THE WOOLMARK COMPANY

WOOL SCIENCE, TECHNOLOGY AND DESIGN EDUCATION PROGRAM

FACILITATOR GUIDE

WORSTED AND WOOLLEN SPINNING

CONTENTS

THE WOOLMARK COMPANY | AUSTRALIAN WOOL INNOVATION

The Woolmark Company (TWC) is a subsidiary of Australian Wool Innovation (AWI) and is the global authority on Merino wool. With a network that spans the entire global wool supply chain, The Woolmark Company builds awareness and promotes the unique traits of nature's finest fibre.

Australian Wool Innovation (AWI) is the research, development and marketing body for the Australian wool industry. More than 60,000 Australian woolgrowers co-invest with the Australian government to support the activities carried out by AWI and TWC along the global wool supply chain.

The Woolmark Company supports and connects global supply chain participants through initiatives such as The Wool Lab and Wool Lab Sport. These internationally renowned wool-sourcing tools provide designers, retailers and brands with the latest trends in wool yarns, fabrics and technologies, while promoting Australian Merino wool as the ultimate fibre of choice for apparel.

Marketing activities focus on education and awareness raising to ensure consumers, manufacturers and designers are aware of Australian wool's benefits and qualities, can capitalise on wool's inherent properties, and can successfully integrate wool into their product lines.

THE WOOL SCIENCE, TECHNOLOGY AND DESIGN EDUCATION PROGRAM OVERVIEW

The *Wool Science, Technology and Design Education Program* combines a series of introductory and advanced courses of study developed to meet the needs of tertiary-level participants studying within the fields of: textile science and engineering, fashion and textile design and/or textile manufacturing. Individual courses within the series may also be of interest to participants studying sheep and wool science, and those working in the wool production, raw wool processing, textile manufacturing and textile sales and marketing industries.

Introductory level courses are suitable for participants studying at first or second-year tertiary levels, while the advanced courses are aimed at participants in their more senior years of study. The extension courses can be used for specific course requirements.

INTRODUCTORY COURSES

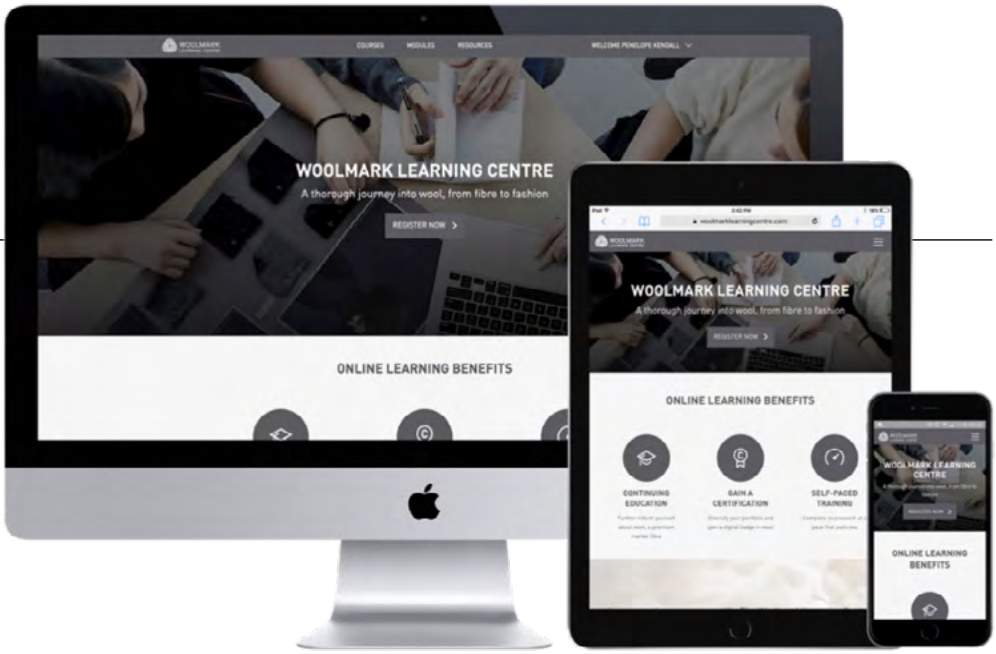
- Wool fibre science
- Introduction to wool processing

ADVANCED COURSES

- Raw wool scouring
- Worsted top-making
- **Worsted and woollen spinning**
- The dyeing of wool
- Wool fabric finishing

EXTENSION COURSES (IN DEVELOPMENT)

- Finishing of wool knitwear
- Wastewater management
- Wool product quality
- Methods of wool fabric formation



THE WOOLMARK LEARNING CENTRE

The *Woolmark Learning Centre* is a freely accessible, online learning platform, which supports The Woolmark Company's commitment to education and awareness raising with regard to wool, wool processing and product innovation.

Make sure you have completed the *Wool Appreciation Course* online before delivering any courses of the *Wool Science, Technology and Design Education Program* to familiarise yourself with The Woolmark Company's approach and core messages about wool production and the wool supply chain.

It is also important to encourage all participants to explore the online *Woolmark Learning Centre* to reinforce and build on the knowledge they have gained by attending this advanced level course.

The W*oolmark Learning Centre* can be accessed at:
https://www.woolmarklearningcentre.com/

INTRODUCTION TO THIS FACILITATOR GUIDE

This Facilitator Guide covers the *Worsted and woollen spinning* course of the *Wool Science, Technology and Design Education Program*.

The information in this Guide will support you to:

- deliver the technical content across a series of face-to-face lectures in an engaging and easy-to-follow way
- carry out a range of practical demonstrations and interactive discussions to support participant learning.

This Facilitator Guide provides:

- an overview of the *Wool Science, Technology and Design Education Program* courses
- the target audience for the *Worsted and woollen spinning* course
- the pre-requisites for the course
- an overview and learning objectives for *Worsted and woollen spinning*
- a suggested agenda for delivering *Worsted and woollen spinning*
- an overview and the learning objectives for each module within *Worsted and woollen spinning*
- course materials and resources required to deliver *Worsted and woollen spinning*
- administrative requirements and institutional responsibilities when delivering *Worsted and woollen spinning*
- guidelines and processes regarding participant recognition upon completing *Worsted and woollen spinning*
- links to participant and facilitator feedback and evaluation questionnaires
- a facilitator checklist to enable successful planning and preparation leading up to, during and following delivery
- recommended room layout for small venues or groups
- a guideline for the effective and engaging delivery of the course content.

INTRODUCTION TO THIS COURSE

Worsted and woollen spinning is an advanced-level course, which commences with a review of the worsted and woollen production systems.

It provides participants with an understanding of:

- the preparation of top for worsted spinning
- worsted ring spinning
- variations and alternatives for worsted ring spinning
- preparation for woollen spinning
- woollen spinning
- post-spinning operations
- quality assurance in worsted and woollen spinning toperations.

The course structure and module plan contained in this Facilitator Guide indicate the technical content to be addressed, however it's important to adapt the focus of your training in line with participants' existing understanding and specific target audience requirements.

TARGET AUDIENCE

The *Worsted and woollen spinning* course is primarily aimed at senior-level tertiary participants studying textile science and engineering, and staff and managers from wool processing companies.

The course is designed to be delivered face to face, in groups of 6 – 50 people, although the ideal number of participants who can attend course lectures depends on the resources available to support the delivery.

COURSE PREREQUISITES

As an advanced course, *Worsted and woollen spinning* is suitable for participants with sound knowledge of wool or the wool industry, or participants who have undertaken the introductory courses of the *Wool Science, Technology and Design Education Program* (e.g. *Wool fibre science* and *Introduction to wool processing*).

If this is the first *Wool Science, Technology and Design Education Program* course being delivered to these participants, start the initial lecture with an *Introduction to The Woolmark Company*.

This presentation is included in the *Worsted and woollen spinning* facilitator slides as an optional introductory module.

COURSE LEARNING OBJECTIVES

By the end of the *Worsted and woollen spinning* course, participants are expected to be able to:

- describe the operations required to prepare top for worsted spinning
- describe the aims of spinning and the operation of the worsted ring spinning frame
- outline alternative spinning technologies that can be used for to improve the quality of ring-spun worsted yarn
- describe the operation of a woollen card and the preparation of the slubbing for woollen spinning - describe the preparation of sliver for, and the process of, semi-worsted ring spinning
- understand the key limitations and relevance of factors influencing the operation of the spinning machine - describe alternative spinning technologies that can be used to spin yarns
- describe post-spinning operations
- outline the role of and techniques in quality assurance programs for woollen and worsted spinning and post-spinning operations.

COURSE AGENDA

The *Worsted and woollen spinning* course consists of ten lectures, of approximately one hour each, supported by a set of PowerPoint slides, videos and recommended demonstrations, as outlined in the table below.

NOTE: Indicated slide numbers for Module 1 take into account the introductory Woolmark Company slides as outlined in the following facilitator notes.

MODULE | SLIDE NUMBER	VIDEOS AND PRACTICAL DEMONSTRATIONS
Module 1: Review of the woollen and worsted production systems | 26 slides	Slide 21: Carbonised and scoured wool (handout)
Module 2: Preparation of tops for spinning | 17 slides	Slide 11: Worsted roving sample (handout) Slide 12: Roving (video)
Module 3: Worsted ring spinning | 23 slides	Slide 4: Spinning (video)
Module 4: Variations on worsted ring spinning | 16 slides	Slide 7: SiroSPUN breakout device (reference) Slide 10: False twist (demonstration) Slide 8: Solospun roller (reference)
Module 5: Preparation for woollen spinning | 44 slides	Slide 6: Woollen quality check (video) Slide 8: Woollen opening (video) Slide 18: Woollen carding (video) Slide 18: Slubbing rubbing (demonstration) Slide 33: Slubbing twist (handout)
Module 6: Woollen ring spinning | 18 slides	Slide 5: Woollen spinning (video) Slide 7: False and real twist (demonstration)
Module 7: Semi-worsted spinning | 12 slides	No videos or recommended demonstrations
Module 8: Alternatives to ring spinning | 16 slides	No videos or recommended demonstrations
Module 9: Post spinning operations | 20 slides	Slide 2: Twist liveliness (demonstration) Slide 3: Steaming (video) Slide 7: Winding and clearing (video) Slide 13: Assembly winding (video) Slide 16: 2 for 1 twisting (video) Slide 17: 2 for 1 twisting (modern) (video)
Module 10: Quality assurance in spinning | 14 slides	No videos or recommended demonstrations

MODULE OVERVIEW AND LEARNING OBJECTIVES

Module 1 — Review of the woollen and worsted production systems starts off this 10-module course by reviewing the differences between worsted versus woollen yarn production, the early operations prior to spinning and their aims. It also covers the differences between woollen and worsted processing systems and products.

By the end of this module participants are expected to be able to describe the similarities and differences in the woollen and worsted systems of production, differentiate the sources of wool used in woollen and worsted spinning systems and outline the unique features of lamb's wool and strong wools.

Module 2 — Preparation of tops for spinning covers the methods used to prepare tops for worsted yarn spinning. While the detail of processes used may vary between processors three main processes are used, re-combing gilling (also called drawing) and roving. Each process will be covered.

By the end of this module participants are expected to be able to describe the operations used to prepare wool top for spinning, describe a roving machine, outline the practical considerations associated with roving and some of the issues impacting the quality of the final yarn.

Module 3 — Worsted ring spinning covers the production of worsted spun yarns by the use of ring spinning.

At the end of this module participants are expected to be able to describe the aims of spinning and the operation of the ring spinning machine. They will also be able to outline the key issues affecting the operation of the ring frame and define yarn count and twist factor. Participants will also understand the key limitations and relevance of factors influencing the operation of the spinning machine and understand the key limitations for spinning wool and relevance of fibre-related and machine-related factors.

Module 4 — Variations and alternatives to worsted ring spinning investigates the developments aimed at increasing productivity in worsted spinning and will be discussed in this module.

At the end of this module participants are expected to be able to describe alternative methods of spinning worsted yarns using ring frames. They will also be able to outline the limitations, advantages and disadvantages of these alternative methods and describe the potential areas of application for yarn spun using variations on ring frames.

Module 5 — Preparation for woollen spinning covers the key components of carding wool specification, the aims of carbonising, opening and carding and the key differences between woollen and worsted carding.

It also explains the major sections of a woollen card:

- controlled hopper feeder
- the forepart of the carding machine
- the cross-lapper
- the finishing section of the card
- the condenser.

At the end of this module, participants are expected to be able to describe the operations used to prepare wool for woollen spinning and explain the aims, machinery and procedures used. They should also be able to explain the action of the woollen card and its purpose in terms of final web and yarn quality, explain the differences between woollen and worsted carding and describe the contribution various components of the woollen card make to the properties of the web and spun yarn. In addition, they will be able to explain some of the key issues during carding, their impact and solutions.

Module 6 — Woollen ring spinning provides an overview of woollen spinning and covers machine mechanics in woollen spinning, woollen yarn production and characteristics and spinning issues for felt-resist-treated woollen-spun knitting yarns. It also investigates the limits of the woollen spinning system.

At the end of this module, participants should be able to identify the mechanics of the machines used in woollen spinning and describe the special needs of fibre control in woollen spinning and compare those with worsted systems. They should also be able to explain the reasons behind the differences in woollen spinning, compared with worsted spinning.

Module 7 — Semi-worsted spinning provides an overview of the semi-worsted spinning process and explores the machine mechanics used to create semi-worsted yarns. The characteristics of these yarns are discussed, along with the limitations of the semi-worsted system.

By the end of this module, participants will be able to outline the production methods for semi-worsted yarns and clarify the difference between semi-worsted yarns and those used for woollen and worsted yarn production. They will also be able to identify the mechanics of the machines used in semi-worsted spinning and describe the special needs of fibre control in semi-worsted spinning and compare those with worsted system requirements. They should also be able to explain the reasons behind the differences between semi-worsted and worsted spinning, compare the characteristics of semi-worsted yarns with those of woollen and worsted yarns and list some of the key products produced using semi-worsted yarns.

Module 8 — Alternatives to ring spinning provides an overview of several alternatives to ring spinning, aimed at increasing productivity and/or improving yarn quality.

At the end of this module, participants should be able to describe alternative spinning technologies and outline the limitations, advantages and disadvantages of these alternative spinning technologies. They should also be able to describe the potential areas of application for yarn spun using alternative spinning technologies and recall the processes used to create felted and bonded yarns.

Module 9 — Post-spinning operations covers each of the following operations:

- yarn relaxation
- winding and clearing
- splicing and knotting
- assembly winding
- twisting/folding

By the end of the module participants will be able to describe the aims of each operation and outline the impact of each operation on final yarn quality.They will also be able to describe the quality issues associated with each operation.

Module 10 — Quality assurance in spinning provides an overview of quality assurance in spinning and post-spinning operations and will cover:yarn relaxation

- the importance of yarn quality
- methods of measuring:
- yarn count
- variations in linear density and fault analysis
- tensile properties
- hairiness
- yarn-metal friction
- extractable materials
- colour
- general versus rogue spindles
- standard operating procedures (SOP) manuals.

At the end of this module, participants should be able to describe the key attributes of worsted and woollen yarn to determine its quality and the issues associated with optimising quality and understand the methods used to measure the key properties of yarn related to quality.

THE WORSTED AND WOOLLEN SPINNING DEMONSTRATION KIT

A range of practical demonstrations, group activities, handouts and samples is recommended to be used throughout this course to support participant learning and complement the content delivered in the lectures.

Recommended resources are listed at the start of each module in the *Worsted and woollen spinning* Facilitator Guide.

The following samples and resources for demonstrations are provided in the *Worsted and woollen spinning* Demonstration kit (resources not supplied in the kit will need to be supplied by the facilitator):

Module 1:
- sample of worsted top
- sample of worsted roving
- sample of woollen slubbing
- worsted and woollen yarns
- samples of worsted and woollen fabrics
- sample of carbonised wool
- sample of scoured wool

NOTE: These samples will be accessed throughout the course, not just in Module 1

Module 2:
- sample of worsted roving

Module 4:
- two x 1m length of top (different colours)

Module 5:
- sample of woollen slubbing

Module 6:
- length of woollen top (2m)

Module 9:
- twist lively yarn
- steamed yarn
- knotted yarn
- spliced yarn

ADMINISTRATIVE DETAILS

ORGANISATIONAL RESPONSIBILITIES

Institutions delivering the *Wool Science, Technology and Design Education Program* course *Worsted and woollen spinning* will be responsible for:

- ensuring all facilitators have completed the online Wool Appreciation Course prior to delivering their first course
- providing the venue and equipment required to support the program (i.e. lecture theatre, data projector, data screen, flip chart, whiteboard and markers)
- enrolling the participants in the course
- ensuring all participants have undertaken the prerequisite courses of study or have sufficient industry knowledge to complete this advanced course of study
- administrative paperwork (i.e. participant sign-in sheets, name tags etc.)
- providing administrative support for communication between the facilitator and the participants
- ensuring both the participants and the facilitator have the required access to external sites required to support participant learning
- providing supporting services, as required. (e.g. interpreter, transport to or from external sites)
- providing The Woolmark Company with participant numbers, and participant and facilitator feedback and course evaluation post delivery.

The Woolmark Company will be responsible for providing:

- Facilitator Guide (PDF provided via DropBox link)
- Facilitator slides (PowerPoint files for each module provided via DropBox link)
- Participant sign-on sheet (Word template provided via DropBox link)
- Participant Guide (PDF provided via DropBox link)
- Demonstration kit
- Certificates of Participation (printed copies will be provided by the local TWC office upon request).

NOTE: Course materials are provided in English. If translation to the local language is required, this is the responsibility of the delivering institution.

PARTICIPANT RECOGNITION

At the conclusion of the eight *Worsted and woollen spinning* lectures, each participant who has attended all lectures is eligible to receive a Woolmark Company-endorsed Certificate of Participation.

PROGRAM EVALUATION

Feedback from those attending the *Worsted and woollen spinning* course must be collected by way of an online survey link. This feedback will be used to adapt the course on an annual basis, if and where necessary, to ensure it achieves the desired objectives in the most effective way.

Feedback from those delivering the *Worsted and woollen spinning* course also must be submitted at the completion of the course.

Facilitator survey:
www.woolmarklearningcentre.com/wstd-surveyfacilitator

Participant survey:
www.woolmarklearningcentre.com/wstd-surveyparticipant

FACILITATOR CHECKLIST

The following list outlines the actions required before, during and after delivery of the *Worsted and woollen spinning* course.

One month before:

- ☐ Fully familiarise yourself with the course materials.
- ☐ Check you have all the materials required to deliver the course (including the facilitator materials and the wool demonstration kit).
- ☐ If you are an external facilitator, obtain contact details for your key point of contact at the host institution. Make contact, introduce yourself and arrange regular meetings leading up to the delivery dates.
- ☐ Confirm the number of participants attending, along with the year level and any previous studies relevant to the course.
- ☐ Confirm any specific needs for the target audience in consultation with the institution.
- ☐ Familiarise yourself with the venue and facilities that will be available for the lectures including room size and potential room layout options (see following notes regarding room layout). This may be via site maps or discussions with your key contact.
- ☐ Confirm equipment available at the venue (e.g. data projector, screen, speakers, laboratory equipment).
- ☐ Adapt the program (if required) to meet the needs of the participants and venue facilities.
- ☐ Check the availability of participant materials in sufficient quantity.
- ☐ Ensure you have reviewed the delivery material and have checked videos for the upcoming lectures work on the available equipment.

One week before:

- ☐ Confirm shipping details of the course materials and equipment (If required)
- ☐ Confirm transport between the institution and any external site visits. (if required).
- ☐ Confirm names of the participants attending the course.
- ☐ Ensure you have ordered a sufficient number of the 'Certificates of Participation' to be distributed to the appropriate participants following the completion of the final lecture.
- ☐ Ensure your wardrobe contains various wool garments. In order to demonstrate the benefits and versatility of wool and wool products, facilitators are encouraged to wear as much wool as possible, across a range of garment types. For example:
    - wool trousers or skirt
    - wool t-shirt or undershirt, long-sleeved shirt, sweater or jacket
    - wool socks.

One day before:

- ☐ Arrange to meet your key institution contacts face to face and any key contacts at external sites (if required).
- ☐ Familiarise yourself with the venue's emergency procedures.
- ☐ Tour the facility. Visit the rooms you will be using.
- ☐ Check the equipment you need is available in working order and you know how to use it (including lighting, heating and cooling).
- ☐ Ensure you have reviewed the delivery material and have checked any videos for the upcoming lectures will work on the available equipment (e.g. speakers).
- ☐ Familiarise yourself with the rest rooms available at the venue.
- ☐ Take note of any challenges associated with each room (e.g. noise, heat, lighting). Identify strategies to minimise these challenges.
- ☐ Prepare the participant materials you will need to distribute at the first lecture (e.g. participant name tags and sign-in sheets).
- ☐ Check you have all the materials you need to deliver the course (including the Participant Guides).
- ☐ Distribute the PDF (soft copy) of the Participant Guide to participants prior to the first lecture if possible, to allow them to become familiar with the course materials and content.

Prior to each lecture:

- ☐ Ensure you are wearing a variety of wool garments that reflect the benefits and versatility of wool and wool products
- ☐ Arrive 30 minutes before each lecture to check the equipment is available and working.

At commencement of the first lecture:

- ☐ Distribute the hard copy of the Participant Guide to each participant.
- ☐ Distribute name tags to each participant.
- ☐ Record those who are present.

After each lecture:

- ☐ Stay to answer any questions the participants may have about the course content.

Prior to the final lecture:

- ☐ Ensure you have received a sufficient number of the 'Certificates of Participation' to be distributed to the appropriate participants following the completion of the final lecture.

At the completion of the course:

- ☐ Provide participants with the online feedback and evaluation survey link.
- ☐ Complete and submit your own online evaluation survey.
- ☐ Provide feedback to the institution regarding the successful completion of the course.
- ☐ Explore future delivery opportunities and liaise with The Woolmark Company regional office.

Post-course survey links:

Facilitator survey:
www.woolmarklearningcentre.com/wstd-surveyfacilitator

Participant survey:
www.woolmarklearningcentre.com/wstd-surveyparticipant

ROOM LAYOUT

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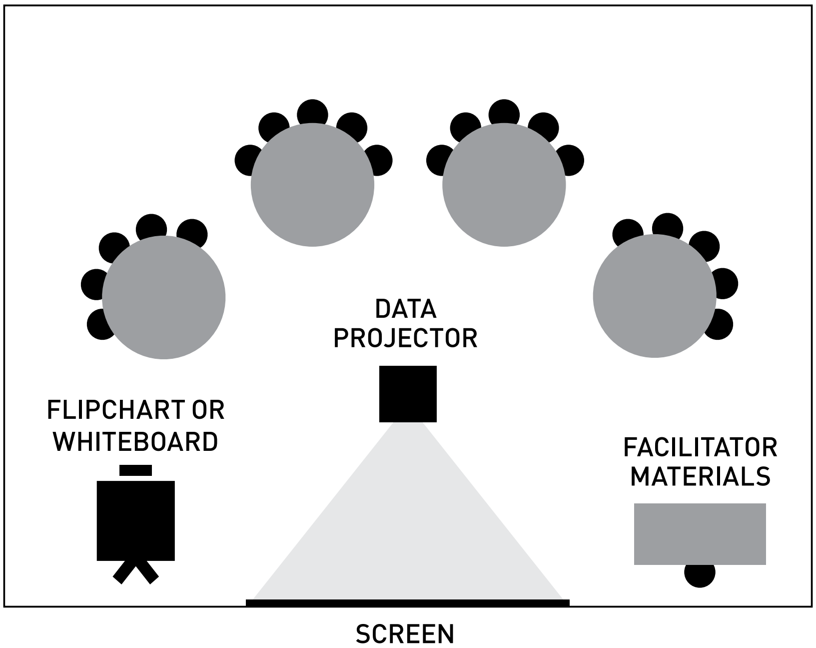
The *Worsted and woollen spinning* course is designed to be delivered face-to-face, in groups of 6 – 50 people. In many cases this will mean delivery occurs in a large lecture theatre and there will not be an opportunity to influence the physical learning environment.

In smaller groups and settings where the learning environment can be influenced:

- arrange tables in a cabaret style (see diagram below) facing a flipchart or whiteboard and a data projector/screen
- allow for small group discussion in groups of three or four.



A GUIDELINE FOR THE EFFECTIVE AND ENGAGING DELIVERY OF THE COURSE CONTENT.

The course materials are designed to achieve a Gunning Fog Index of 8–10, with the exclusion of technical terms specific to the course.

The Gunning Fog Index formula implies short sentences written in plain English achieve a better score than long sentences written in complicated language.

Materials with a Gunning Fog Index of 8 have a readability equivalent to a Grade 8 reading level for English speaking students. It is considered the ideal score for readability. Anything above 12 is too hard for most people to read[1].

Information is provided in Appendix A for facilitators who wish to enhance their skills in facilitation by acknowledging the different learning styles of participants.

Research has shown each person has a preferred way of learning[2]. As adults, we tend to adopt the learning style with which we are most comfortable and ignore learning styles with which we are unfamiliar or uncomfortable. This means learning is most effective when a student can process information and solve problems in a way that is meets their preferred learning style.

When you know a person's learning style, you can present information to them so they can grasp it quickly and easily. If information is presented in a way that is at odds with their preferred learning style, the student will find it more difficult to learn. Sometimes this means, as a facilitator, you may have to present information to a student in a way that will engage them, although that may not be your preferred method. If you do not accommodate the students preferred learning style, you make it harder to get the message across, which may lead to frustration on your part, as well as a lack of commitment from the student.

Honey & Mumford have developed a questionnaire, included in Appendix A, which helps you identify your students' preferred learning styles.

For those who are interested, you could provide this questionnaire to your student one month out from delivery. Using the results from this survey you can cater to your students' preferred learning styles more effectively.

1 http://www.usingenglish.com/glossary/fog-index.html, http://juicystudio.com/services/readability.php
2 Kolb D. A. (1984). Experiential Learning experience as a source of learning and development, New Jersey: Prentice Hall.

APPENDIX A: LEARNING STYLES QUESTIONNAIRE

NAME: ____________________________

This questionnaire is designed to find out your preferred learning style(s). Over the years you have probably developed learning "habits" that help you benefit more from some experiences than from others. Since you are probably unaware of this, this questionnaire will help you pinpoint your learning preferences so that you are in a better position to select learning experiences that suit your style and having a greater understanding of those that suit the style of others.

This is an internationally proven tool designed by Peter Honey and Alan Mumford.

There is no time limit to this questionnaire. It will probably take you 10-15 minutes. The accuracy of the results depends on how honest you can be. There are no right or wrong answers.

If you agree more than you disagree with a statement put a tick by it.

If you disagree more than you agree put a cross by it.

Be sure to mark each item with either a tick or cross.

- ☐ 1. I have strong beliefs about what is right and wrong, good and bad
- ☐ 2. I often act without considering the possible consequences
- ☐ 3. I tend to solve problems using a step-by-step approach
- ☐ 4. I believe that formal procedures and policies restrict people
- ☐ 5. I have a reputation for saying what I think, simply and directly
- ☐ 6. I often find that actions based on feelings are as sound as those based on careful thought and analysis
- ☐ 7. I like the sort of work where I have time for thorough preparation and implementation
- ☐ 8. I regularly question people about their basic assumptions
- ☐ 9. What matters most is whether something works in practice
- ☐ 10. I actively seek out new experiences
- ☐ 11. When I hear about a new idea or approach I immediately start working out how to apply it in practice
- ☐ 12. I am keen on self discipline such as watching my diet, taking regular exercise, sticking to a fixed routine, etc
- ☐ 13. I take pride in doing a thorough job
- ☐ 14. I get on best with logical, analytical people and less well with spontaneous, 'irrational' people
- ☐ 15. I take care over the interpretation of data available to me and avoid jumping to conclusions
- ☐ 16. I like to reach a decision carefully after weighing up many alternatives
- ☐ 17. I'm attracted more to novel, unusual ideas than to practical ones
- ☐ 18. I don't like disorganised things and prefer to fit things into a coherent pattern
- ☐ 19. I accept and stick to laid down procedures and policies so long as I regard them as an efficient way of getting the job done
- ☐ 20. I like to relate my actions to a general principle
- ☐ 21. In discussions I like to get straight to the point
- ☐ 22. I tend to have distant, rather formal relationships with people at work
- ☐ 23. I thrive on the challenge of tackling something new and different
- ☐ 24. I enjoy fun-loving, spontaneous people
- ☐ 25. I pay meticulous attention to detail before coming to a conclusion
- ☐ 26. I find it difficult to produce ideas on impulse
- ☐ 27. I believe in coming to the point immediately
- ☐ 28. I am careful not to jump to conclusions too quickly
- ☐ 29. I prefer to have as many resources of information as possible – the more data to think over the better
- ☐ 30. Flippant people who don't take things seriously enough usually irritate me
- ☐ 31. I listen to other people's points of view before putting my own forward
- ☐ 32. I tend to be open about how I'm feeling
- ☐ 33. In discussions I enjoy watching the manoeuvrings of the other participants
- ☐ 34. I prefer to respond to events on a spontaneous, flexible basis rather than plan things out in advance

- ☐ 35. I tend to be attracted to techniques such as network analysis, flow charts, branching programs, contingency planning, etc
- ☐ 36. It worries me if I have to rush out a piece of work to meet a tight deadline
- ☐ 37. I tend to judge people's ideas on their practical merits
- ☐ 38. Quiet, thoughtful people tend to make me feel uneasy
- ☐ 39. I often get irritated by people who want to rush things
- ☐ 40. It is more important to enjoy the present moment than to think about the past or future
- ☐ 41. I think that decisions based on a thorough analysis of all the information are sounder than those based on intuition
- ☐ 42. I tend to be a perfectionist
- ☐ 43. In discussions I usually produce lots of spontaneous ideas
- ☐ 44. In meetings I put forward practical realistic ideas
- ☐ 45. More often than not, rules are there to be broken
- ☐ 46. I prefer to stand back from a situation
- ☐ 47. I can often see inconsistencies and weaknesses in other people's arguments
- ☐ 48. On balance I talk more than I listen
- ☐ 49. I can often see better, more practical ways to get things done
- ☐ 50. I think written reports should be short and to the point
- ☐ 51. I believe that rational, logical thinking should win the day
- ☐ 52. I tend to discuss specific things with people rather than engaging in social discussion
- ☐ 53. I like people who approach things realistically rather than theoretically
- ☐ 54. In discussions I get impatient with irrelevancies and digressions
- ☐ 55. If I have a report to write I tend to produce lots of drafts before settling on the final version
- ☐ 56. I am keen to try things out to see if they work in practice
- ☐ 57. I am keen to reach answers via a logical approach
- ☐ 58. I enjoy being the one that talks a lot
- ☐ 59. In discussions I often find I am the realist, keeping people to the point and avoiding wild speculations
- ☐ 60. I like to ponder many alternatives before making up my mind
- ☐ 61. In discussions with people I often find I am the most dispassionate and objective
- ☐ 62. In discussions I'm more likely to adopt a "low profile" than to take the lead and do most of the talking
- ☐ 63. I like to be able to relate current actions to a longer term bigger picture
- ☐ 64. When things go wrong I am happy to shrug it off and "put it down to experience"
- ☐ 65. I tend to reject wild, spontaneous ideas as being impractical
- ☐ 66. It's best to think carefully before taking action
- ☐ 67. On balance I do the listening rather than the talking
- ☐ 68. I tend to be tough on people who find it difficult to adopt a logical approach
- ☐ 69. Most times I believe the end justifies the means
- ☐ 70. I don't mind hurting people's feelings so long as the job gets done
- ☐ 71. I find the formality of having specific objectives and plans stifling
- ☐ 72. I'm usually one of the people who puts life into a party
- ☐ 73. I do whatever is expedient to get the job done
- ☐ 74. I quickly get bored with methodical, detailed work
- ☐ 75. I am keen on exploring the basic assumptions, principles and theories underpinning things and events
- ☐ 76. I'm always interested to find out what people think
- ☐ 77. I like meetings to be run on methodical lines, sticking to laid down agenda, etc.
- ☐ 78. I steer clear of subjective or ambiguous topics
- ☐ 79. I enjoy the drama and excitement of a crisis situation
- ☐ 80. People often find me insensitive to their feelings

SCORING AND INTERPRETING THE LEARNING STYLES QUESTIONNAIRE

The Questionnaire is scored by awarding one point for each ticked item. There are no points for crossed items. Simply indicate on the lists below which items were ticked by circling the appropriate question number.

	2	7	1	5
	4	13	3	9
	6	15	8	11
	10	16	12	19
	17	25	14	21
	23	28	18	27
	24	29	20	35
	32	31	22	37
	34	33	26	44
	38	36	30	49
	40	39	42	50
	43	41	47	53
	45	46	51	54
	48	52	57	56
	58	55	61	59
	64	60	63	65
	71	62	68	69
	72	66	75	70
	74	67	77	73
	79	76	78	80
TOTALS	________	________	________	________
	Activist	**Reflector**	**Theorist**	**Pragmatist**

LEARNING STYLES QUESTIONNAIRE PROFILE BASED ON GENERAL NORMS FOR 1302 PEOPLE

ACTIVIST	REFLECTOR	THEORIST	PRAGMATIST	
20	20	20	20	Very strong preference
19				
18		19	19	
17				
16		18		
15		17	18	
14				
13	18	16	17	
12	17	15	16	Strong preference
	16			
11	15	14	15	
10	14	13	14	Moderate
9	13	12	13	
8				
7	12	11	12	
6	11	10	11	Low preference
5	10	9	10	
4	9	8	9	
3	8	7	8	Very low preference
	7	6	7	
	6	5	6	
2	5	4	4	
	4	3	3	
	3			
1	2	2	2	
	1	1	1	
0	0	0	0	

LEARNING STYLES – GENERAL DESCRIPTIONS

Activists

Activists involve themselves fully and without bias in new experiences. They enjoy the here and now and are happy to be dominated by immediate experiences. They are open-minded, not sceptical, and this tends to make them enthusiastic about anything new. Their philosophy is: "I'll try anything once". They tend to act first and consider the consequences afterwards. Their days are filled with activity. They tackle problems by brainstorming. As soon as the excitement from one activity has died down they are busy looking for the next. They tend to thrive on the challenge of new experiences but are bored with implementation and longer-term consolidation. They are gregarious people constantly involving themselves with others but in doing so they seek to centre all activities on themselves.

Reflectors

Reflectors like to stand back to ponder experiences and observe them from many different perspectives. They collect data, both first hand and from others, and prefer to think about it thoroughly before coming to any conclusion. The thorough collection and analysis of data about experiences and events is what counts so they tend to postpone reaching definitive conclusions for as long as possible. Their philosophy is to be cautious. They are thoughtful people who like to consider all possible angles and implications before making a move. They prefer to take a back seat in meetings and discussions. They enjoy observing other people in action. They listen to others and get the drift of the discussion before making their own points. They tend to adopt a low profile and have a slightly distant, tolerant unruffled air about them. When they act it is part of a wide picture which includes the past as well as the present and others' observations as well as their own.

Theorists

Theorists adapt and integrate observations into complex but logically sound theories. They think problems through in a vertical, step-by-step logical way. They assimilate disparate facts into coherent theories. They tend to be perfectionists who won't rest easy until things are tidy and fit into a rational scheme. They like to analyse and synthesise. They are keen on basic assumptions, principles, theories models and systems thinking. Their philosophy prizes rationality and logic. "If it's logical it's good". Questions they frequently ask are: "Does it make sense?" "How does this fit with that?" "What are the basic assumptions?" They tend to be detached, analytical and dedicated to rational objectivity rather than anything subjective or ambiguous. Their approach to problems is consistently logical. This is their "mental set" and they rigidly reject anything that doesn't fit with it. They prefer to maximise certainty and feel uncomfortable with subjective judgments, lateral thinking and anything flippant.

Pragmatists

Pragmatists are keen on trying out ideas, theories and techniques to see if they work in practice. They positively search out new ideas and take the first opportunity to experiment with applications. They are the sorts of people who return from management courses brimming with new ideas that they want to try out in practice. They like to get on with things and act quickly and confidently on ideas that attract them. They tend to be impatient with ruminating and open-ended discussions. They are essentially practical, down to earth people who like making practical decisions and solving problems. They respond to problems and opportunities "as a challenge". Their philosophy is: "There is always a better way" and "if it works it's good".

In descending order of likelihood, the most common combinations are:

1st Reflector/Theorist
2nd Theorist/Pragmatist
3rd Reflector/Pragmatist
4th Activist/Pragmatist

LEARNING STYLES – A FURTHER PERSPECTIVE

ACTIVISTS:

Activists *learn best from activities where:*

- There are new experiences/problems/opportunities from which to learn.
- They can engross themselves in short "here and now" activities such as business games, competitive teamwork tasks, role-playing exercises.
- There is excitement/drama/crisis and things chop and change with a range of diverse activities to tackle
- They have a lot of the limelight/high visibility, i.e. they can "chair" meetings, lead discussions, and give presentations.
- They are allowed to generate ideas without constraints of policy or structure or feasibility.
- They are thrown in at the deep end with a task they think is difficult, i.e. when set a challenge with inadequate resources and adverse conditions.
- They are involved with other people, i.e. bouncing ideas off them, solving problems as part of a team.
- It is appropriate to "have a go".

Activists *learn least from, and may react against, activities where:*

- Learning involves a passive role, i.e. listening to lectures, monologues, explanations, statements of how things should be done, reading, watching.
- They are asked to stand back and not be involved.
- They are required to assimilate, analyse and interpret lots of "messy" data.
- They are required to engage in solitary work, i.e. reading, writing, thinking on their own.
- They are asked to assess beforehand what they will learn, and to appraise afterwards what they have learned.
- They are offered statements they see as "theoretical", i.e. explanation of cause or background
- They are asked to repeat essentially the same activity over and over again, i.e. when practicing.
- They have precise instructions to follow with little room for manoeuvre.
- They are asked to do a thorough job, i.e. attend to detail, tie up loose ends, dot the i's, cross t's.

Summary of strengths

- Flexible and open minded.
- Happy to have a go.
- Happy to be exposed to new situations.
- Optimistic about anything new and therefore unlikely to resist change.

Summary of weaknesses:

- Tendency to take the immediately obvious action without thinking.
- Often take unnecessary risks.
- Tendency to do too much themselves and hog the limelight.
- Rush into action without sufficient preparation.
- Get bored with implementation/consolidation.
- Key questions for activists:
- Shall I learn something new, i.e. that I didn't know/couldn't do before?
- Will there be a wide variety of different activities? (I don't want to sit and listen for more than an hour at a stretch!)
- Will it be OK to have a go/let my hair down/make mistakes/have fun?
- Shall I encounter some tough problems and challenges?
- Will there be other like-minded people to mix with?

REFLECTORS:

Reflectors *learn best from activities where:*

- They are allowed or encouraged to watch/think/chew over activities.
- They are able to stand back from events and listen/observe, i.e. observing a group at work, taking a back seat in a meeting, watching a film or video.
- They are allowed to think before acting, to assimilate before commencing, i.e. time to prepare, a chance to read in advance a brief giving background data.
- They can carry out some painstaking research, i.e. investigate, assemble information, and probe to get to the bottom of things.
- They have the opportunity to review what has happened, what they have learned.
- They are asked to produce carefully considered analyses and reports.

- They are helped to exchange views with other people without danger, i.e. by prior agreement, within a structured learning experience.
- They can reach a decision in their own time without pressure and tight deadlines.

Reflectors *learn least from, and may react against, activities where:*

- They are "forced" into the limelight, i.e. to act as leader/chairman, to role-play in front of on-lookers.
- They are involved in situations which require action without planning.
- They are pitched into doing something without warning, i.e. to produce an instant reaction, to produce an off-the-top-of-the-head idea.
- They are given insufficient data on which to base a conclusion.
- They are given cut and dried instructions of how things should be done.
- They are worried by time pressures or rushed from one activity to another.
- In the interests of expediency they have to make short cuts or do a superficial job.

Summary of strengths:

- Careful.
- Thorough and methodical
- Thoughtful
- Good at listening to others and assimilating information.
- Rarely jump to conclusions.

Summary of weaknesses:

- Tendency to hold back from direct participation.
- Slow to make up their minds and reach a decision.
- Tendency to be too cautious and not take enough risks.
- Not assertive - they aren't particularly forthcoming and have no "small talk".

Key questions for reflectors:

- Shall I be given adequate time to consider, assimilate and prepare?
- Will there be opportunities/facilities to assemble relevant information?
- Will there be opportunities to listen to other people's points of view – preferably a wide cross section of people with a variety of views?
- Shall I be under pressure to be slapdash or to extemporise?

THEORISTS:

Theorists *learn best from activities where:*

- What is being offered is part of a system, model, concept, or theory.
- The have time to explore methodically the associations and inter-relationships between ideas, events and situations.
- They have the chance to question and probe the basic methodology, assumptions or logic behind something, i.e. by taking part in a question and answer session, by checking a paper for inconsistencies.
- They are intellectually stretched, i.e. by analysing a complex situation, being tested in a tutorial session, by teaching high calibre people who ask searching questions.
- They are in structured situations with a clear purpose.
- They can listen to or read about ideas and concepts that emphasise rationality or logic and are well argued/elegant/watertight.
- They can analyse and then generalise the reasons for success or failure.
- They are offered interesting ideas and concepts even though they are not immediately relevant.
- They are required to understand and participate in complex situations.

Theorists *learn least from, and may react against, activities where:*

- They are pitch-forked into doing something without a context or apparent purpose.
- They have to participate in situations emphasising emotions and feelings.
- They are involved in unstructured activities where ambiguity and uncertainty are high, i.e. with open¬ended problems, on sensitivity training.
- They are asked to act or decide without a basis in policy, principle or concept.
- They are faced with a hotchpotch of alternative/contradictory techniques/methods without exploring any in depth, i.e. as on a "once over lightly" course.
- They find the subject matter platitudinous, shallow or gimmicky.
- They feel themselves out of tune with other participants, i.e. when with lots of Activists or people of lower intellectual calibre.

Summary of strengths:

- Logical "vertical" thinkers.
- Rational and objective.
- Good at asking probing questions.
- Disciplined approach.

Summary of weaknesses:

- Restricted in lateral thinking.
- low tolerance for uncertainty, disorder and ambiguity
- Intolerant of anything subjective or intuitive.
- Full of "shoulds, oughts and musts".

Key questions for theorists:

- Will there be lots of opportunities to question?
- Do the objectives and program of events indicate a clear structure and purpose?
- Shall I encounter complex ideas and concepts that are likely to stretch me?
- Are the approaches to be used and concepts to be explored "respectable", i.e. sound and valid?
- Shall I be with people of similar calibre to myself?

PRAGMATIST:

Pragmatists *learn best from activities where:*

- There is an obvious link between the subject matter and a problem or opportunity on the job.
- They are shown techniques for doing things with obvious practical advantages, i.e. how to save time, how to make a good first impression, how to deal with awkward people.
- They have the chance to try out and practice techniques with coaching/feedback from a credible expert, i.e. someone who is successful and can do the techniques themselves.
- They are exposed to a model they can emulate, i.e. a respected boss, a demonstration from someone with a proven track record, lots of examples/anecdotes, and a film showing how it's done.
- They are given techniques currently applicable to their own job.
- They are given immediate opportunities to implement what they have learned.
- There is a high face validity in the learning activity, i.e. a good simulation, "real" problems.
- They can concentrate on practical issues, i.e. drawing up action plans with an obvious end product, suggesting short cuts, giving tips.

Pragmatists *learn least from, and may react against, activities where:*

- The learning is not related to an immediate need they recognise/they cannot see, an immediate relevance/practical benefit.
- Organisers of the learning, or the event itself, seems distant from reality, i.e. "ivory towered", all theory and general principles, pure "chalk and talk".
- There is no practice or clear guidelines on how to do it.
- They feel that people are going round in circles and not getting anywhere fast enough.
- There are political, managerial or personal obstacles to implementation.
- There is no apparent reward from the learning activity, i.e. more sales, shorter meetings, higher bonus, promotion.

Summary of strengths:

- Keen to test things out in practice.
- Practical, down to earth, realistic.
- Businesslike – gets straight to the point.
- Technique oriented.

Summary of weaknesses:

- Tendency to reject anything without an obvious application.
- Not very interested in theory or basic principles.
- Tendency to seize on the first expedient solution to a problem.
- Impatient with waffle.
- On balance, task oriented not people oriented.

Key questions for pragmatists:

- Will there be ample opportunities to practice and experiment?
- Will there be lots of practical tips and techniques?
- Shall we be addressing real problems and will it result in action plans to tackle some of my current problems?
- Shall we be exposed to experts who know how to/can do it themselves?

GLOSSARY

ACRONYMS, ABBREVIATIONS AND UNITS OF MEASUREMENT

EDMSH	Ends down per thousand spindle hours, the number of end breaks in spinning.
ITMA	International Textile Machinery Exhibition
ktex	The weight in kilograms of one kilometre of top.
Nm	Metric count of yarn: the number of kilometres of yarn which weigh one kilogram.
Nw	Worsted count of yarn: the number is the number of hanks of yarn (each 560 yards in length) required to weigh one English pound (454g): A traditional method of defining yarn count but now rarely used.
RC	Resistance to compression; indicates the softness of the fleece.
RH	Relative humidity of air usually expressed as a percentage.
rpm	Revolutions per minute.
tpm	The number of turns per metre, refers to yarn twist.
U%	Uster measurement of yarn evenness or irregularity.

GLOSSARY

Term	Definition
cockling	An irregular surface effect in knitwear caused by loop distortion.
core-spun yarns	Yarns which incorporate a filament in the centre of a staple fibre yarn
doff	The process of replacing full bobbins with empty ones on the spindle.
ecru	Scoured but untreated and uncoloured wool.
fasciated	The term applied to yarns in which the fibres are deliberately entangled in addition to twisting to create additional strength.
friction tester	Measures friction between the yarn and a metal guide by recording the force required to pull the yarn over a metal roller
hairiness meter	Measures yarn hairiness by running the yarn through an optical head which measures the amount of light blocked by the yarn.
kempy	Describes coarse fibre that is brittle and relatively weak, sometimes found in the fleece of broad wool sheep.
lapping	A process in which fibres (or the whole roving) wind around rollers rather than continuing their path through the draft zone.
mule spinning	An old (~1885) form of spinning developed to replicate and mechanise the operations of hand spinning.
Nu-torque	Yarn spinning method to produce torque-balanced singles ring yarns by incorporating a false twister.
open-end spinning	A direct sliver-to-yarn spinning system, in which the sliver is fed to an opening roller where individual, or small aggregates of fibre are drawn from the sliver and, with the aid of an air stream, the fibres are delivered to an inner groove of a rotor rotating at high speed.
rag-pulling	Also known as the mungo trade, recycled wool fibre is recovered from wool garments at the end of their life and used in woollen spinning.
roving	The process to reduce the linear density of the drawn top even further by drafting a single strand. Also used to describe the product of this process.
S-twist	Clockwise twist in yarn.
Shetland	Protective style of knitwear made from strong wools, generally has a thick feel and appearance.

Term	Definition
slubbing	The fine strands of fibre formed by the woollen card and used to feed the woollen spinning frame.
spirality	The variation away from the vertical of the direction of the wales in the knitted structure due to residual torque in the yarn.
splicing	The joining of two ends of yarns by untwisting of the fibre at the two yarn ends to be joined, then bringing the two yarn ends together and inserting twist into the join.
stretch-broken top	Fibre made using a 'stretch-breaking' machine, which extends the previously combed fibres until they break.
top breaking	Longer wool in top form is broken to reduce it to the required fibre length.
twist alpha	See 'twist factor'.
twist factor	A single index, also known as the 'twist alpha', that allows comparison of twist levels across different yarn counts. Both yarn count and twist are combined into a single index.
twist-lively	Describes a yarn prone to twisting when freely hanging, as a result of residual strains in the fibres from spinning.
yarn evenness	A measure of the variability of the weight/unit length of yarn; also known as yarn irregularity (measured using a Uster instrument).
yarn tenacity	A measure of the breaking strength of a yarn divided by its count in tex.
yarn twist	Refers to the number of turns inserted in a yarn over a specific length.
Z-twist	Anti-clockwise twist in yarn.

THE
WOOLMARK
COMPANY

WORSTED AND WOOLLEN SPINNING

WELCOME participants as they arrive, ensuring they collect their pre-prepared name tags or ask them to write their name on a tag as they arrive.

ENSURE each participant takes a copy of the Participant Guide and records their attendance.

INTRODUCE yourself and provide a brief (maximum three-minute) overview of your role, experience and broad objectives in delivering this series of lectures.

After introducing yourself, if you have a group of 20 participants or less, ask each participant to provide a brief introduction (name, role and organisation, or area of study) and share three things they wish to achieve by attending this series of lectures.

NOTE: If you have 20 participants and they each take about 30 seconds to introduce themselves and their objectives, this exercise will require 10 minutes.

Keep it brief. You may need to modify your approach, based on the number of participants in the room. For example, in a large group (20+ participants select a small sample of participants to introduce themselves and share their expectations).

RECORD AND group participants' responses regarding their own learning objectives on the flipchart or whiteboard.

This introduction will expand upon your understanding of each participant's needs and attitude towards their participation in the program and will give them the opportunity to build rapport with you as the facilitator and other participants in the group.

EXPLAIN TO participants you will revisit these objectives throughout the course to ensure each objective has been covered or participants are directed to additional resources that will help them meet their own learning objectives.

Endeavour to draw on these participant objectives as you progress through the course.

ENCOURAGE participants to ask questions by reassuring them that all questions are valuable.

1

SPEND a few moments exploring participants current understanding of wool. Establishing how much individuals, or the group as a whole, already know about wool will allow you to acknowledge and leverage the experience of those in the room and tailor the content and delivery of the course appropriately to either dispel misperceptions or build on current understanding.

ALLOW about 5–10 minutes for a group discussion prompted by a questioning approach outlined below.

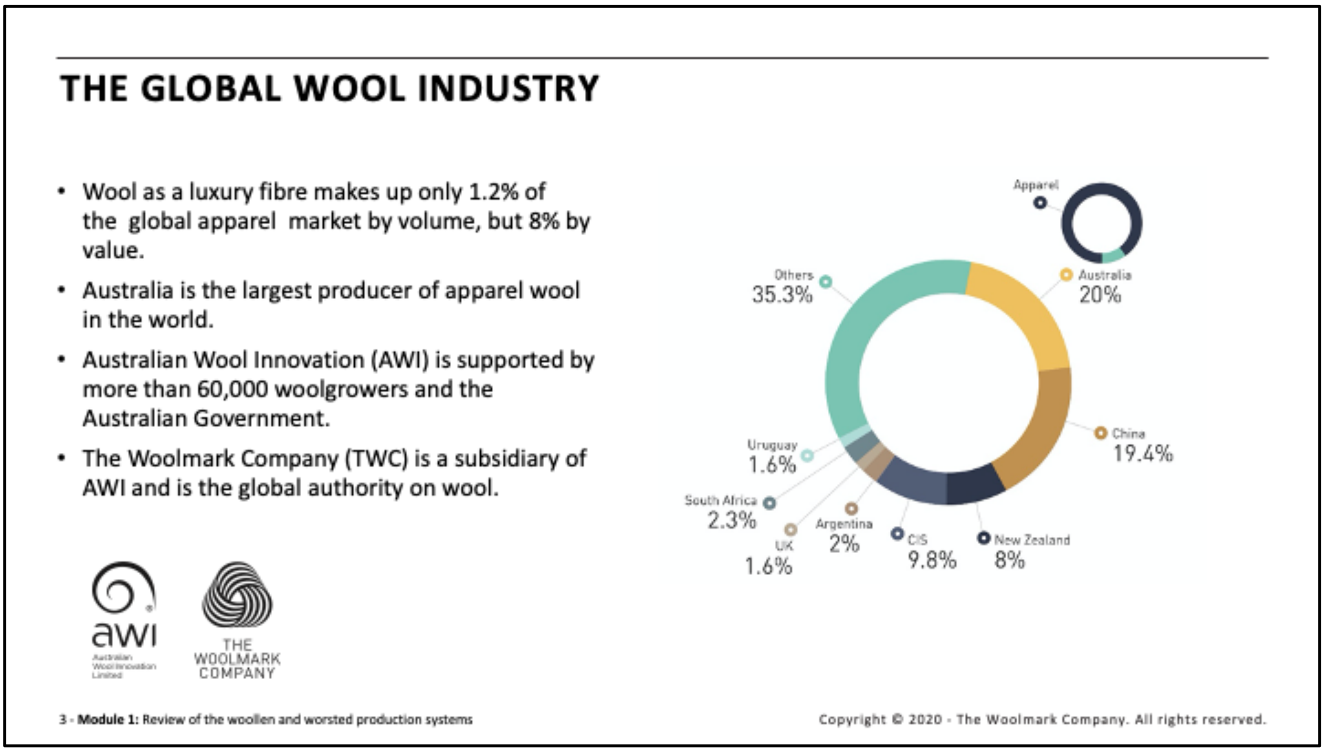
***ASK** participants to share what they already know about wool.*

Examples of questions you might ask to encourage participation include:

- *What is wool top?*
- *What are some key properties of top?*
- *What are the key processes wool has undergone during top-making?*

***RECORD** responses to the above questions on a flipchart or whiteboard and explain that you will re-visit the responses at the end of this module and the course to reflect upon what participants may have learnt during the course.*

***NOTE:** If participants have not already been introduced to Australian Wool Innovation (AWI) and The Woolmark Company (TWC) insert this short presentation here, before continuing with* Module 1 — Review of the worsted and woollen spinning system.



REFER TO the slide as you indicate that Australian woolgrowers produce 90% of the world's fine apparel wool as part of Australia's $2.5 billion wool export industry*.

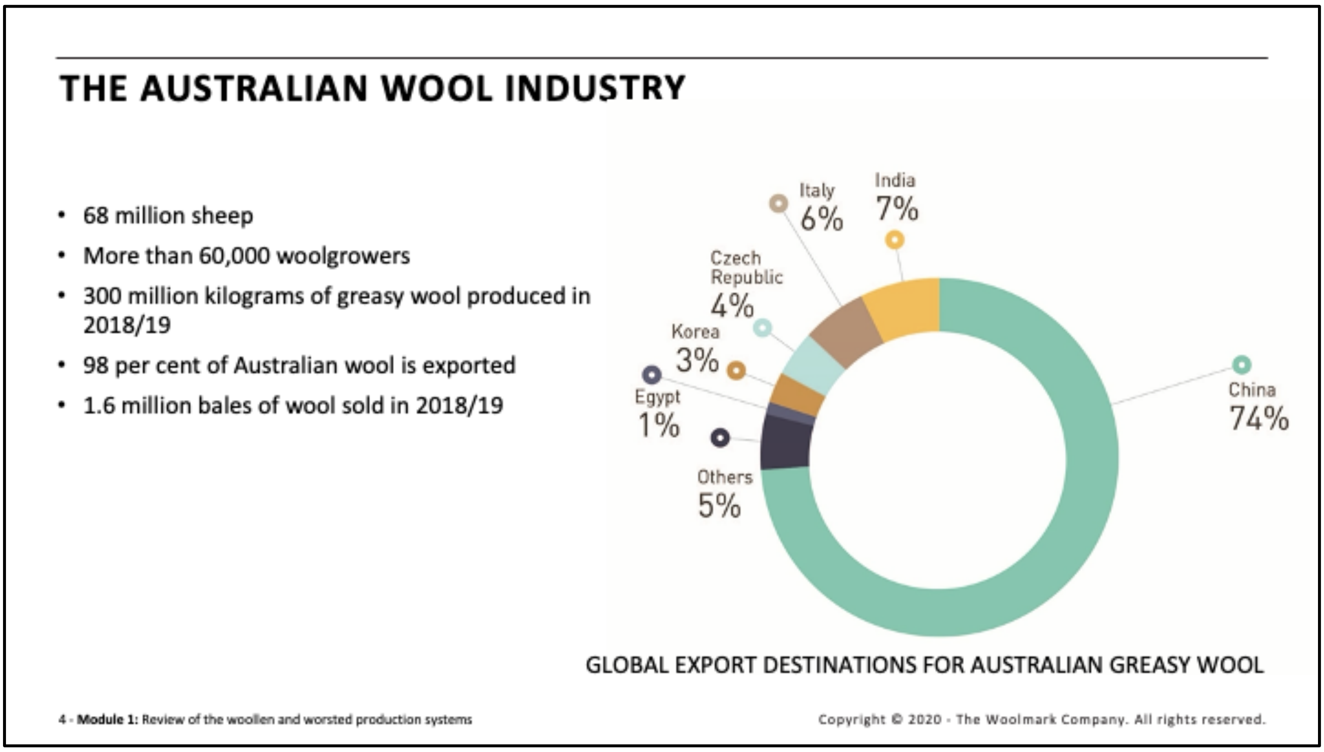
**Source ABARES Agricultural Commodities, March 2020 quarter.*

EXPLAIN THAT Australian Wool Innovation (AWI) is the research, development and marketing body for the Australian wool industry, supported by more than 60,000 Australian woolgrowers, who co-invest with the Australian government to support the activities carried out by AWI and TWC along the global wool supply chain.

EXPLAIN THAT The Woolmark Company is a subsidiary of Australian Wool Innovation and is a global authority on Merino wool. With a network that spans the entire global wool supply chain The Woolmark Company builds awareness and promotes the unique traits of nature's finest fibre.

REINFORCE THAT The Woolmark Company collaborates with global experts on all aspects of wool science, technology and design to develop and deliver educational materials, such as the course you are about to deliver.

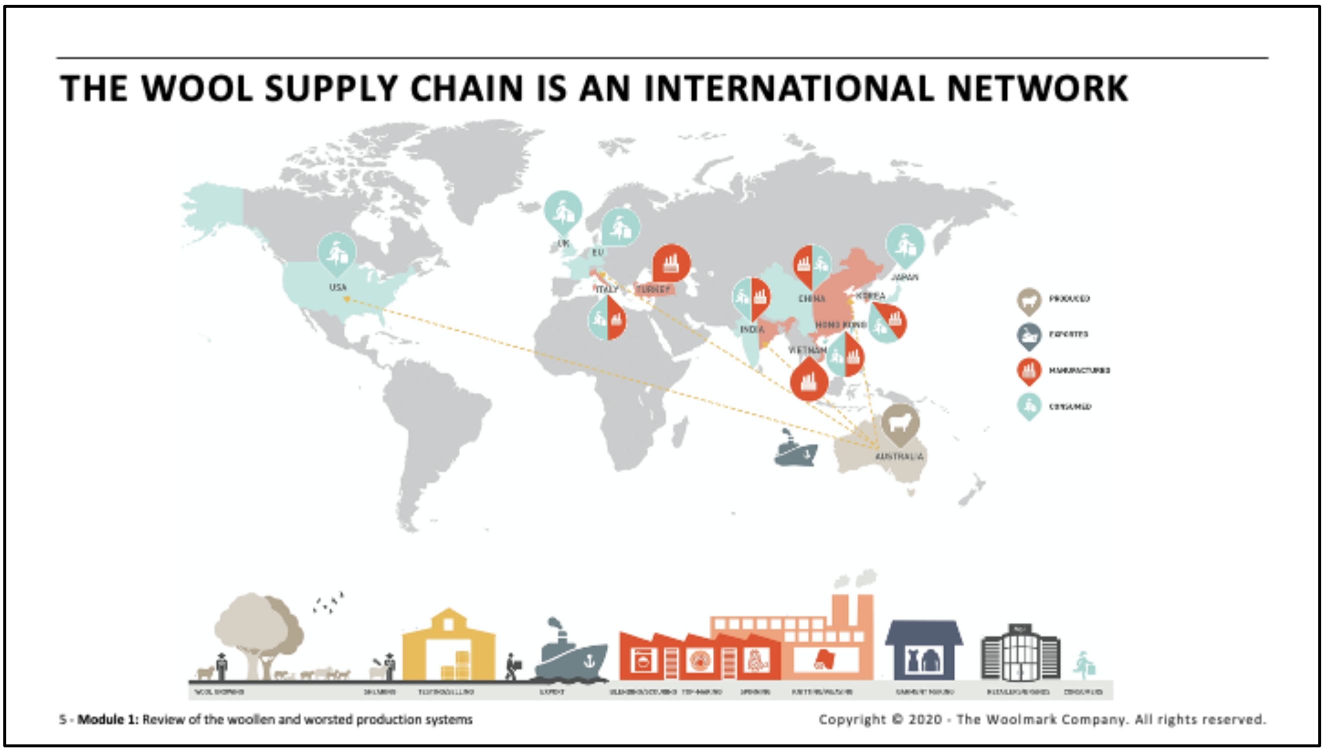
NOTE THAT you will provide a brief overview of the Australian wool industry and global supply chain, and elaborate on the role of The Woolmark Company in the global context before commencing the technical components of the course



EXPLAIN THAT there are more than 68 million sheep in Australia, carefully managed by more than 60,000 woolgrowers.

INDICATE THAT in 2018/19 Australia's woolgrowers produced 300 million kilograms of greasy wool and sold 1.6 million bales of wool.

POINT OUT that 98 per cent of Australia's wool is exported to other countries for further processing into a diverse range of products.



REFER TO the slide as you explain that it offers a snapshot of the global dynamics of the Australian wool industry, illustrating where the key export markets are for Australian wool, where most wool is processed from its raw state into yarn and fabrics and where the fashion and trend influencers and wool consumers are located.

NOTE THAT countries such as China, India and Italy are major manufacturers and consumers of wool products.

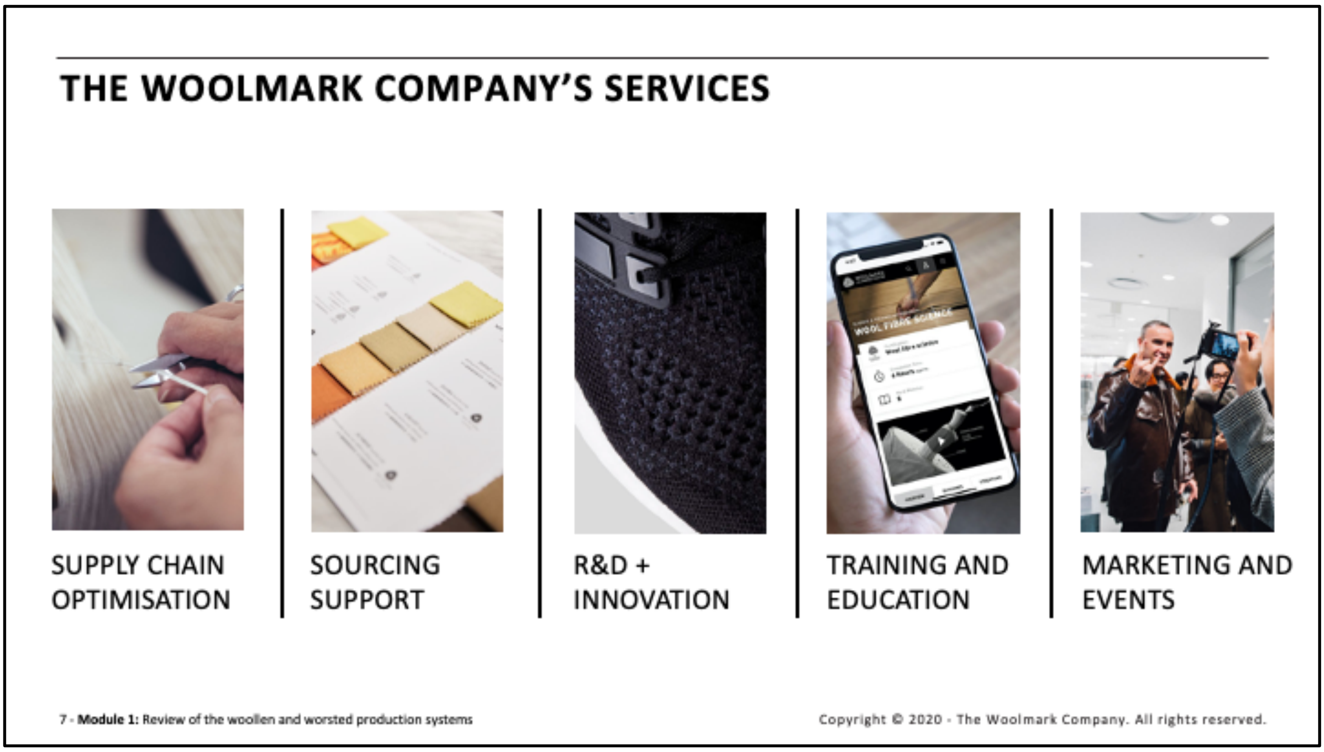
EXPLAIN THAT in line with these global dynamics, The Woolmark Company head office in Sydney, Australia is supported by a growing number of regional offices globally. Through this support The Woolmark Company invests in innovation along the global wool supply chain.

REINFORCE THAT The Woolmark Company works on behalf of Australia's 60,000+ woolgrowers, who are responsible for producing 90 per cent of the world's fine apparel wool.

EXPLAIN THAT The Woolmark Company's parent body — Australian Wool Innovation — invests in on-farm research and development to deliver new knowledge to woolgrowers to increase the profitability and sustainability of the growing wool business.

NOTE THAT The Woolmark Company strives to deliver tangible solutions across the global wool textile industry through process and product research and development.

EXPLAIN THAT the Woolmark Company builds industry confidence through communication, collaboration and a range of educational programs across the industry.



EXPLAIN THAT The Woolmark Company partners with designers, brands and retailers worldwide, offering support with quality assurance, product innovation and supply chain assistance.

INDICATE THAT The Woolmark Company provides sourcing support through direct access to the global wool manufacturing industry through The Wool Lab. A seasonal guide to the latest innovations in wool, fabrics are sourced from the world's best spinners and weavers in the global supply network.

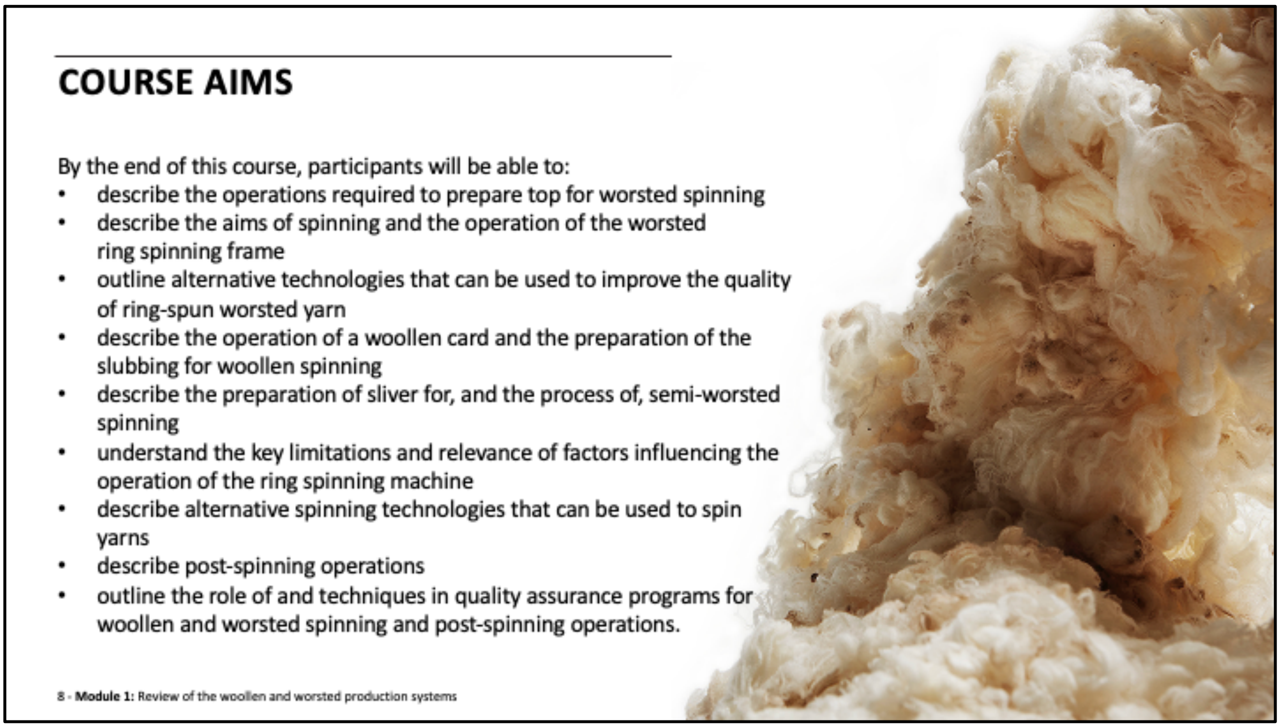
REINFORCE THAT The Woolmark Company takes secures funding and delivers research to improve wool production and processing through fibre science, traceability and fibre advocacy.

EXPLAIN THAT The Woolmark Company offers a range of online and face-to-face training programs to educate the industry. During 2019, The Woolmark Company launched the Woolmark Learning Centre, an online educational hub for industry professionals.

POINT OUT that The Woolmark Company markets the performance and environmental benefits of the fibre to ensure industry and consumers are informed and inspired to make better purchasing choices.

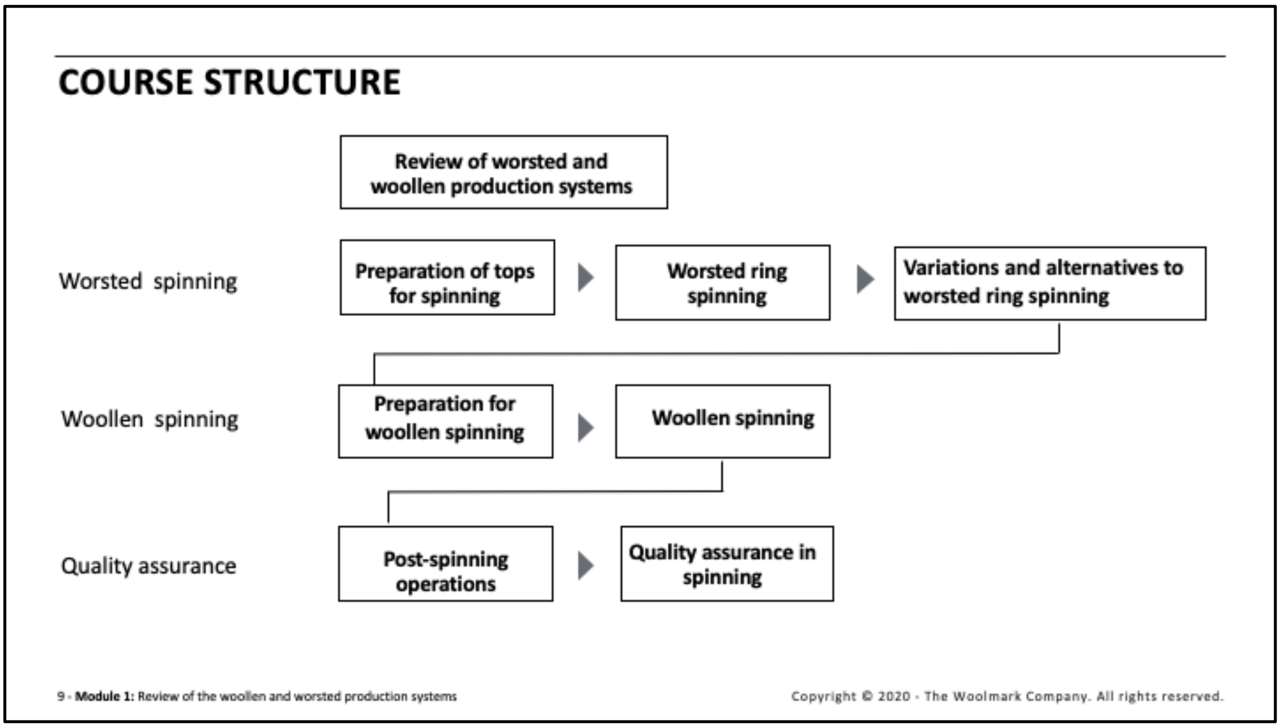
ASK PARTICIPANTS if they have any questions about the Woolmark Company before you proceed with the course aims.

7



INFORM participants that by the end of this course, they will be able to:

- describe the operations required to prepare top for spinning
    - finisher gilling
    - roving
- describe the aims of spinning and the operation of the ring spinning frame
- outline alternative spinning technologies that can be used for worsted spinning of wool
- describe the operation of a woollen card and the preparation of the slubbing for spinning
- understand the key limitations and relevance of factors influencing the operation of the spinning machine
- describe post-spinning operations
- outline the role of and techniques in quality assurance programs for woollen and worsted spinning and post-spinning operations.



NOTE: The sequence of the following information may differ from the actual presentation to allow for differences in venue and participant prior knowledge and experience.

EXPLAIN THAT this course takes an in-depth look at the worsted and woollen spinning and post-spinning operations.

INDICATE THAT this course reviews the worsted and woollen production systems before covering the:

- the preparation of top for worsted spinning
- worsted ring spinning
- variations and alternatives for worsted ring spinning
- preparation for woollen spinning
- woollen spinning
- post-spinning operations
- quality assurance in worsted and woollen spinning operations.

MODULE 1

THE WOOLMARK COMPANY

REVIEW OF THE WOOLLEN AND WORSTED PRODUCTION SYSTEMS

RESOURCES — MODULE 1: REVIEW OF THE WOOLLEN AND WORSTED PRODUCTION SYSTEMS

Contained in the *Worsted and woollen spinning* Demonstration kit you will find the following resources for use as you deliver **Module 1: Review of the woollen and worsted production systems**:

- sample of worsted top
- sample of worsted roving
- sample of woollen slubbing
- worsted and woollen yarns
- samples of worsted and woollen fabrics
- sample of carbonised wool
- sample of scoured wool

NOTE: These samples will be accessed throughout the course, not just in Module 1.

THE WOOLMARK COMPANY

WORSTED AND WOOLLEN SPINNING

MODULE 1: Review of the woollen and worsted production systems

EXPLAIN THAT this first module is a review of the woollen and worsted production systems.

It will review:

- the differences between worsted versus woollen yarn production
- the early operations prior to spinning and their aims
- the differences between woollen and worsted processing systems and products.

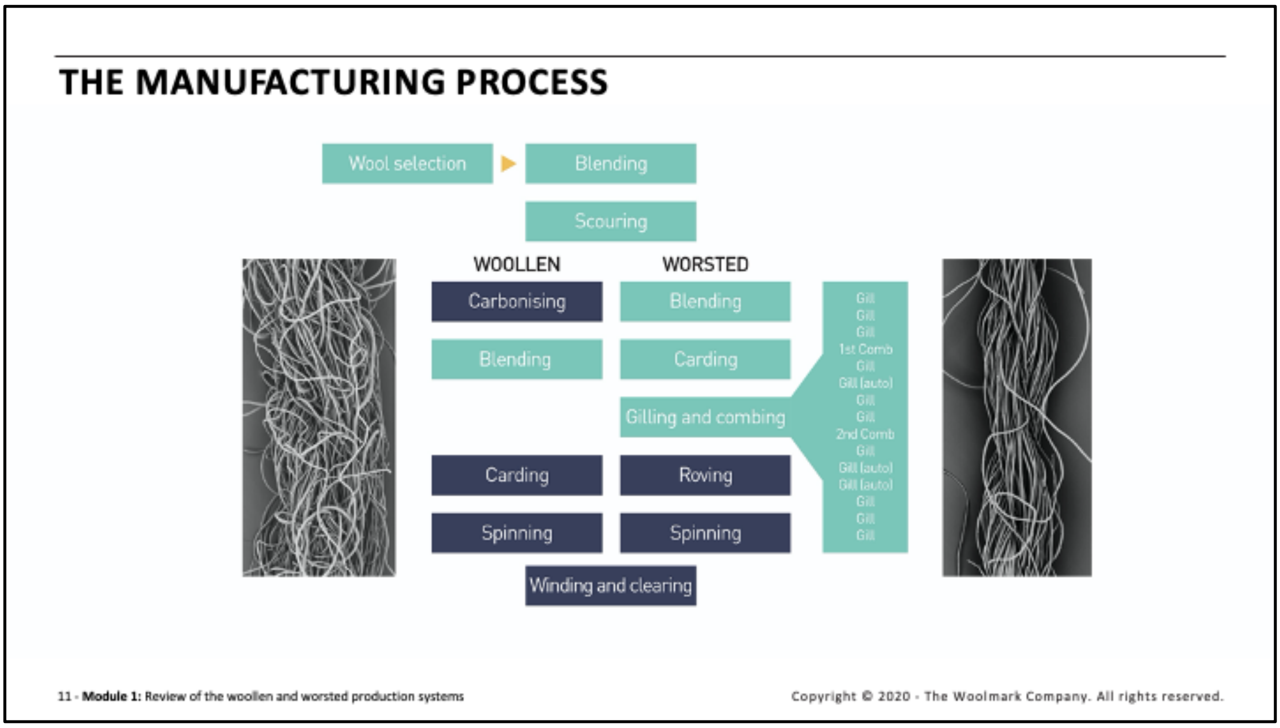
INFORM participants that by the end of this module they will be able to:

- describe the similarities and differences in the woollen and worsted systems of production
- differentiate the sources of wool used in woollen and worsted spinning systems
- outline the unique features of lamb's wool and strong wools.

RESOURCES REQUIRED FOR THIS MODULE:

- *worsted and woollen fibre inputs*
    - *worsted top and roving*
    - *woollen slubbing*
- *worsted and woollen yarns*
- *worsted and woollen fabrics*
- *carbonised wool sample*
- *scoured wool sample*

***NOTE TO FACILITATOR**: The samples are placed at a convenient location in the room and participants are invited to inspect these samples and compare woollen and worsted stages at an appropriate time during the lecture.*



EXPLAIN THAT the process for manufacturing worsted yarns is long and involves many gilling operations and often two combing operations. The process for manufacturing woollen yarn is different from the process used to manufacture worsted yarn. The result is also different.

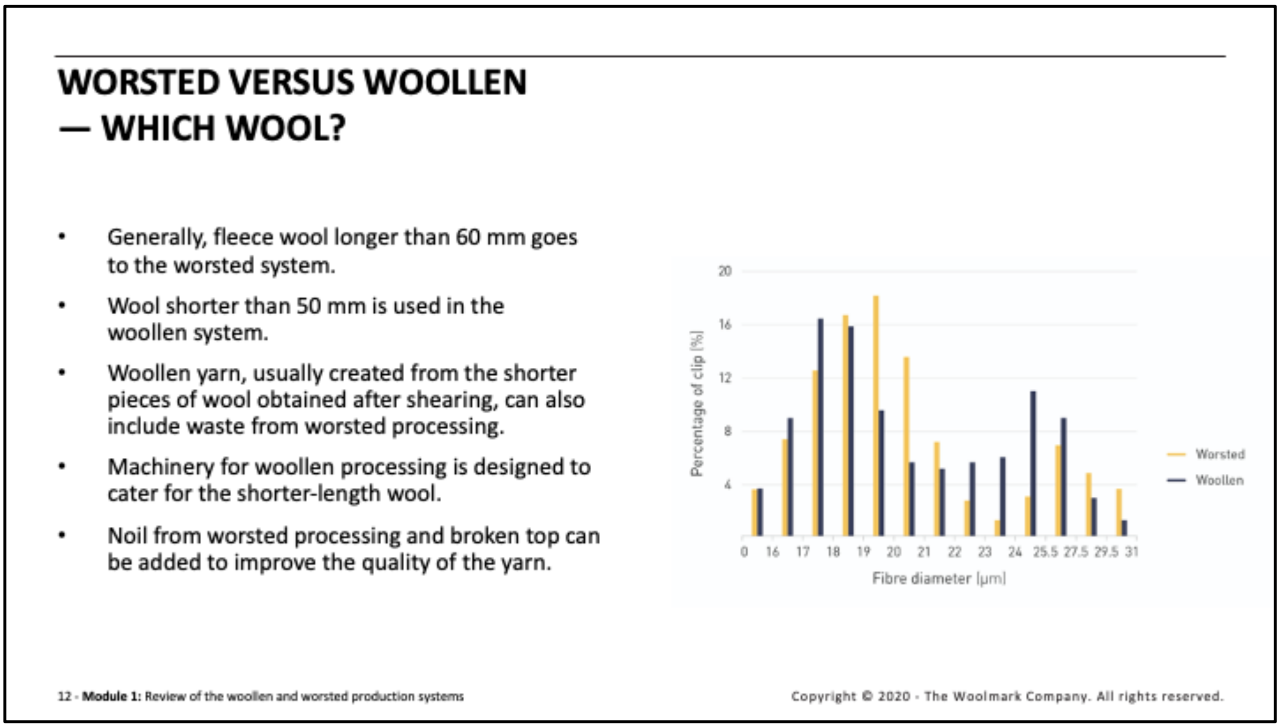
INDICATE THAT the process for manufacturing woollen-spun yarn is the shorter of the two routes. The process for manufacturing woollen yarn is shorter, mainly because it doesn't require top-making (which involves the repeated steps of gilling and combing). The number of gilling operations before and after combing depends on the quality of the wool, the designed yarn count and local practice.

EXPLAIN THAT the woollen system is a flexible method of making yarns and can be used to manufacture coarse carpet yarns from broad wool fibres through to relatively fine yarns for apparel.

NOTE THAT this course will concentrate on the highlighted processes:

- the preparation of top for worsted spinning
- preparation of slubbing for woollen spinning
- the spinning of worsted yarn
- the spinning of woollen yarn
- winding and clearing (a single operation)
- assembly winding
- twisting

NOTE: The final two operations are not listed the slide.



INDICATE THAT longer, more uniform fleece wools are used to produce worsted yarn. As a general guide, fleece wool with staples longer than 60 mm goes to the worsted system. Wool for the worsted system is often called 'combing wool'.

EXPLAIN THAT shorter fibres obtained from other parts of the sheep (e.g. pieces and bellies) are processed in the woollen system. Wool for the woollen system is often called 'carding wool'. Carding wool fibres are shorter, more variable in length and are often more contaminated and discoloured than combing wools. Wool shorter than 50 mm in staple length is used in the woollen system.

MENTION THAT although fine and broad wools are used in both processing systems, the woollen system uses a greater proportion of broader wool than the worsted system.

POINT OUT that the distribution of fibre diameter in combing (worsted) and carding (woollen) wools in the Australian clip is shown on the slide. Both have bi-modal distributions but the woollen system uses a bigger proportion of the mid-micron wools (>23–30 µm).

NOTE THAT by-products of the worsted system, including combing noil and card waste, are used as additional feedstock to the woollen system.

Top breaking

For Australian wool types, machinery for woollen processing is designed to cater for the shorter length wool.

For some woollen yarn, longer wool is broken to reduce it to the required fibre length.

EXPLAIN THAT the worsted top destined for woollen spinning will have its fibre length specially selected or reduced mechanically (by breaking the fibres) to suit the needs of the woollen machinery, and all vegetable matter will have been removed in combing.

TYPES OF WOOL USED IN THE WOOLLEN SYSTEM

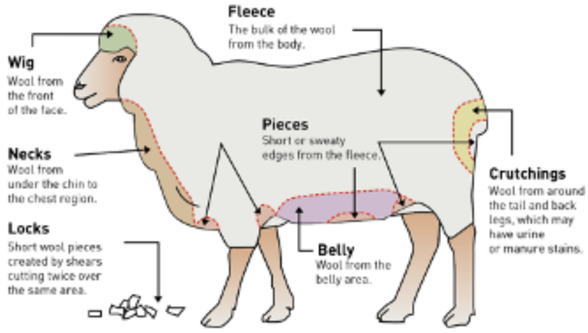
Types of wool:

- fleece wool shorter than 50 mm
- skirtings
- locks
- bellies
- short lamb's wool

Wools should be as fine as is commercially tolerable.

Wools should also have sufficient length.

Recycled wool can also be included in blends for woollen spinning.



Source: Adapted from The Story of Wool, Kondinin Group

13 - **Module 1:** Review of the woollen and worsted production systems

NOTE THAT as illustrated on the slide, wool from a single sheep is categorised, depending on the source and quality:

- fleece
- crutchings
- pieces (skirtings)
- bellies
- locks (second cuts).

EXPLAIN THAT wool from lambs (usually shorter than that of adult sheep) is also categorised separately as lamb's wool.
The following wool types are typically used in the woollen system:

- fleece wool shorter than 50 mm
- skirtings
- locks
- bellies with clumpy vegetable matter
- short lamb's wool.

INDICATE THAT these wool sources frequently contain high levels of contamination, such as vegetable matter and unscourable stain.

In general, the wools destined for the woollen system are selected for the targeted end use and price — this aspect of industry practice will be discussed at several points later in this course.

It is best practice to select a wool with as fine a diameter as is commercially tolerable. This will increase the number of fibres in the yarn cross-section. This in turn should allow improved yarn regularity, increase strength and elongation and give improved processing.

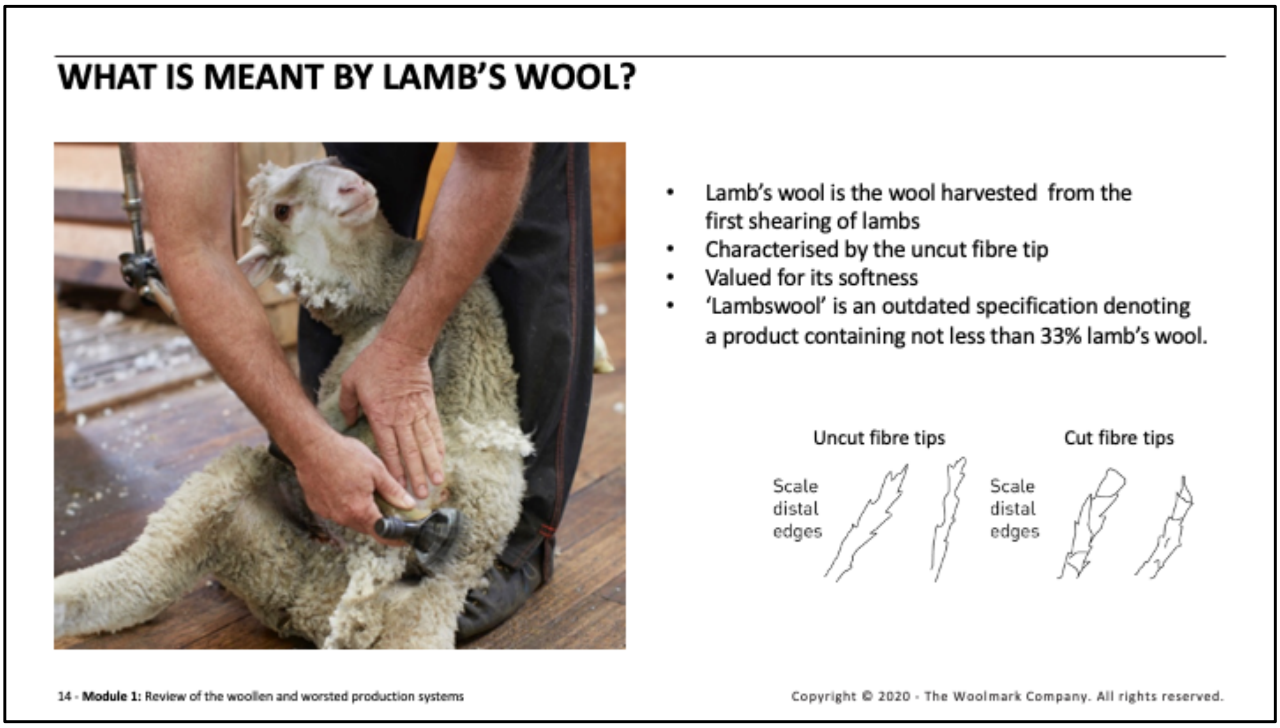
EXPLAIN THAT wools, although short, should also have sufficient length. . Longer wool gives improved yarn regularity, increased strength and elongation and improved processing. Longer wool fibres 'anchor' in the yarn itself and thereby have a reduced propensity to pill during wear. Conversely the fibres must not be so long as to create processing problems during carding.

Recycled wool, recovered from wool garments at the end of their life is also used in woollen spinning. This form of wool has been available for more than a century from the 'rag-pulling' or 'mungo trade'. Such wool is normally blended (up to around 50%) with new wool in the creation of woollen-spun products.

The issue of recycling wool was addressed in the Wool Science, Technology and Design Education Program course *Introduction to wool processing.*

***ASK** participants to explain what the term 'lambswool' covers.*

***ACKNOWLEDGE** responses before advancing to the next slide.*



Lamb's wool vs 'lambswool'

EXPLAIN THAT lamb's wool is defined as wool harvested during the first shearing of lambs.

POINT OUT that the wool from this first shearing contains fine fibres as well as the usual variety of normal wool fibres for the breed. Fine fibres (or sections of fibre) enhance the softness of the fleece due to their lower resistance to compression (RC) and gives lamb's wool its softness. The softness of fine Merino lamb's wool is also due to the fine tip of fibre. The tips of the lamb's wool fibre tend to be rounded rather than cut (given they have not previously been shorn).

Most lamb's wool is shorter than normal fleece wool. Lamb's wool is often spun on the woollen system producing hairier, but softer, yarns and end products. However, it can also be spun on the worsted system if the fibre length is sufficient.

NOTE THAT few garments labelled 'lambswool' are 100% lamb's wool, but are blends of lamb's wool and wool from adult sheep often blended with other fine fibres, such as cashmere and Angora (goat).

EXPLAIN THAT the former Woolmark specification for 'lambswool' required that 33% of the component fibre must be lamb's wool. This specification was withdrawn and the Woolmark Company no longer offer this sub-brand for labelling. The specification required the product to meet the following conditions:

- 33% lamb's wool — based on declarations from the suppliers of the wool and yarn
- mean fibre diameter of <22um
- comfort factor (fibres less than 30µm) > 95%.

The Woolmark Company used the same definition for lamb's wool as the Textile Terms and Definitions.

EXPLAIN THAT the objective measurement of the amount of lamb's wool used a microscope to examine fibre ends to determine the percentage of fibre ends with the characteristic shape of an uncut fibre.

ASK *participants to describe what is meant by the term 'strong wool.'*

ACKNOWLEDGE *responses before advancing to the next slide.*

WHAT IS MEANT BY 'STRONG WOOLS'?

Suffolk (meat breed)

Shetland sweater

https://www.terapeak.com/worth/vtg-chunky-scottish-shetland-wool-sweater-blue-yellow-handknit-mens-l-1/151144153522/

- 'Strong wool' is the term usually applied to wool produced from meat breeds of sheep
- The mean fibre diameter of strong wool is typically greater than 25 – 30µm
- Traditionally characterised by their crisp handle and slightly kempy appearance
- Knitwear from such wools can vary considerably depending upon:
  - customer requirements
  - the fibre type used
  - yarn formation
  - knit structure
  - finishing procedure.

15 - **Module 1:** Review of the woollen and worsted production systems

EXPLAIN THAT 'strong wool' is the term usually applied to wool produced from breeds of sheep used predominantly for meat production.

Breeds that tend to be used mostly for meat production include: Suffolk, White Suffolk and Dorper.

MENTION THAT the mean fibre diameter of strong wool from these breeds of sheep is typically greater than 25–30µm.

EXPLAIN THAT yarns from strong wools are traditionally characterised by their crisp handle and slightly 'kempy' appearance. Kemp describes coarse fibre that is brittle and relatively weak, sometimes found in the fleece of broad wool sheep. Kemp gives yarns and subsequent garments a hairy, 'coarse' look.

The wools used to produce woollen-spun yarns have a typical yarn count range of 2/9 Nm to 2/13 Nm. Knitwear from such yarns can vary considerably in appearance and handle, depending upon customer requirements, and, in turn, the fibre type used, yarn formation, knit structure and finishing procedure.

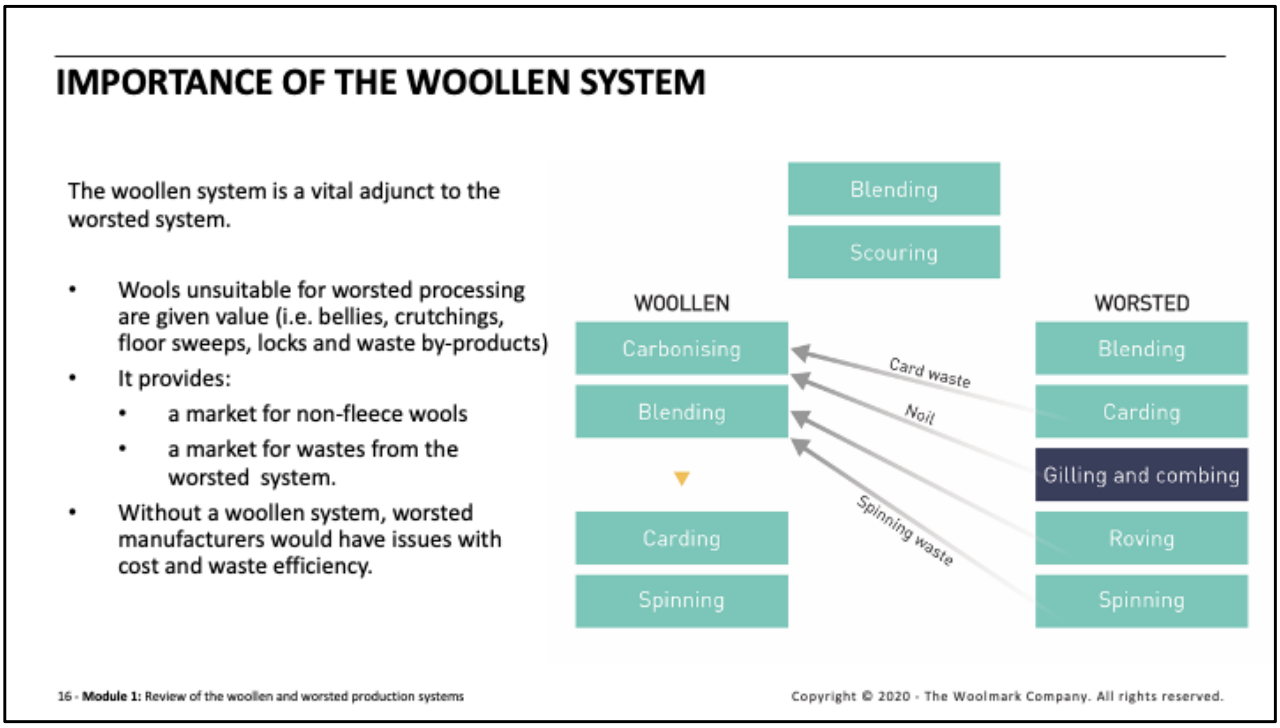
POINT OUT that typically, heavier knitwear from strong wool is knitted on much coarser gauge machines than woollen-spun lamb's wool.

NOTE THAT a type of woollen knitwear widely recognised for its particular characteristics is 'Shetland', which was originally made from a particular wool style from the Shetland Isles. The style now uses a number of strong wool types.

Shetland knitwear generally has a thick feel and appearance and garments are much heavier than their lambs' wool counterparts.

Shetland knitwear is heavy and protective. Lambs' wool knitwear is light and soft.

MENTION THAT the final choice of wools largely depends on the final yarn count and garment type.



MENTION THAT from an Australian perspective, the woollen system is a vital adjunct to the worsted system.

It provides a market for non-fleece wools and a value-add market for the waste components of the the worsted system.

EXPLAIN THAT wools not deemed suitable for worsted processing also have value as feedstock for the woollen sector (i.e. wool types such as bellies, crutchings, floor sweeps, locks, second cuts and waste by-products in the greasy wool harvesting process).

Often these wool components:

- have vegetable matter content higher than the fleece wool from which they are generated
- require processing (carbonising) to remove the vegetable contamination.

EXPLAIN THAT by-products of the worsted system, in combing noil and card wastes, are used as additional feedstock to the woollen system, and all will be carbonised.

NOTE THAT:

- Woollen and worsted processes are complementary in their differences, not competitive.
- It is vital both systems are promoted and preserved.
- If the woollen system disappears, worsted manufacturers have issues with cost and waste efficiency.

ASK *participants if they can explain why roving and spinning wastes can go directly to blending without carbonising.*

ALLOW *participants sufficient time to respond.*

IF NECESSARY *explain that vegetable matter is removed in worsted carding and combing so there is a high concentration in waste. Vegetable matter in roving and spinning waste is low.*

PRINCIPAL BLENDS

WORSTED-SPUN

WOOL BLEND	COMMON USE
Wool/silk	Knitted next-to-skin apparel
Wool/noble fibre	High-quality suitings/jackets
Wool/polyester	Woven apparel
Wool/acrylic	Worsted-spun knitwear
Wool/elastane	Stretch products

WOOLLEN SPUN

WOOL BLEND	COMMON USES
Wool/polyamide	Woollen woven and knitted apparel, carpets, etc.
Wool/acrylic	Woollen knitwear

WOOL RICH BLEND

WOOL BLEND PERFORMANCE

17 - **Module 1:** Review of the woollen and worsted production systems

INDICATE THAT wool fibres are commonly blended with other natural and synthetic fibres in both worsted-spun and woollen-spun yarns to deliver specific performance attributes.

POINT OUT blends of wool with the following fibres are widely used in worsted-spun yarns:

- Silk brings luxurious handle and suppleness to the blend.
- Noble fibres (cashmere, Mohair) bring softness and/or surface interest to the blend.
- Polyester reduces the cost of the products and imparts some functional properties.
- Polyamide (nylon) improves abrasion resistance and strength of yarn and fabric.
- Acrylic brings softness and reduces cost.
- Three-fibre blends, such as wool/polyester/elastane or wool/polyamide/viscose — are used in fashion worsted-spun apparel.

The use of cotton in two-fibre blends is generally confined to the short-staple spinning sector.

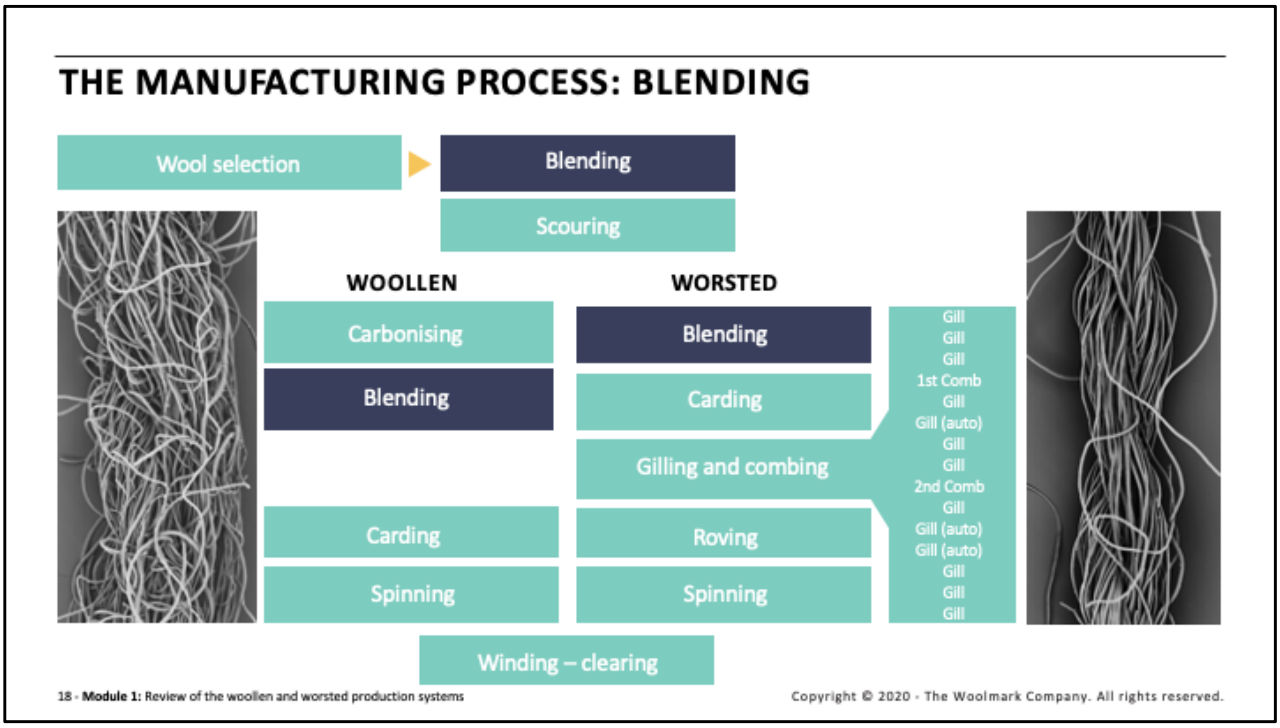
The woollen system is also often used in the manufacture of wool/synthetic blends.

EXPLAIN THAT normally, only blends of wool with polyamide (nylon) or acrylic are used in two-fibre woollen-spun yarns.

- Polyamide (nylon) improves abrasion resistance and strength of yarn and fabric.
- Acrylic brings softness and reduces cost.
- Three-fibre blends, such as wool/polyamide/acrylic or wool/polyamide/viscose, are also used in fashion woollen-spun apparel.

NOTE THAT the Woolmark trademarks for wool blends apply to both worsted and woollen products.

POINT OUT that generally wool/synthetic blends are seen as having a lower quality than pure wool products.



EXPLAIN THAT the next few slides will review the processes leading up to spinning.

Blending

The process of mixing wools of different fibre diameters, lengths, strengths, colours and amount of vegetable matter to produce a uniform batch that will make the best-quality yarn for the lowest price, and meet the spinner's specifications.

NOTE THAT blending operations can occur at a number of points in the processing line but commonly occur before and after scouring.

During processing, the output of several machines may be used to feed the successive machine, resulting in additional blending.

INDICATE THAT the aim of blending is to:

- ensure the production batch is consistent in composition and colour and meets a given price and specification.

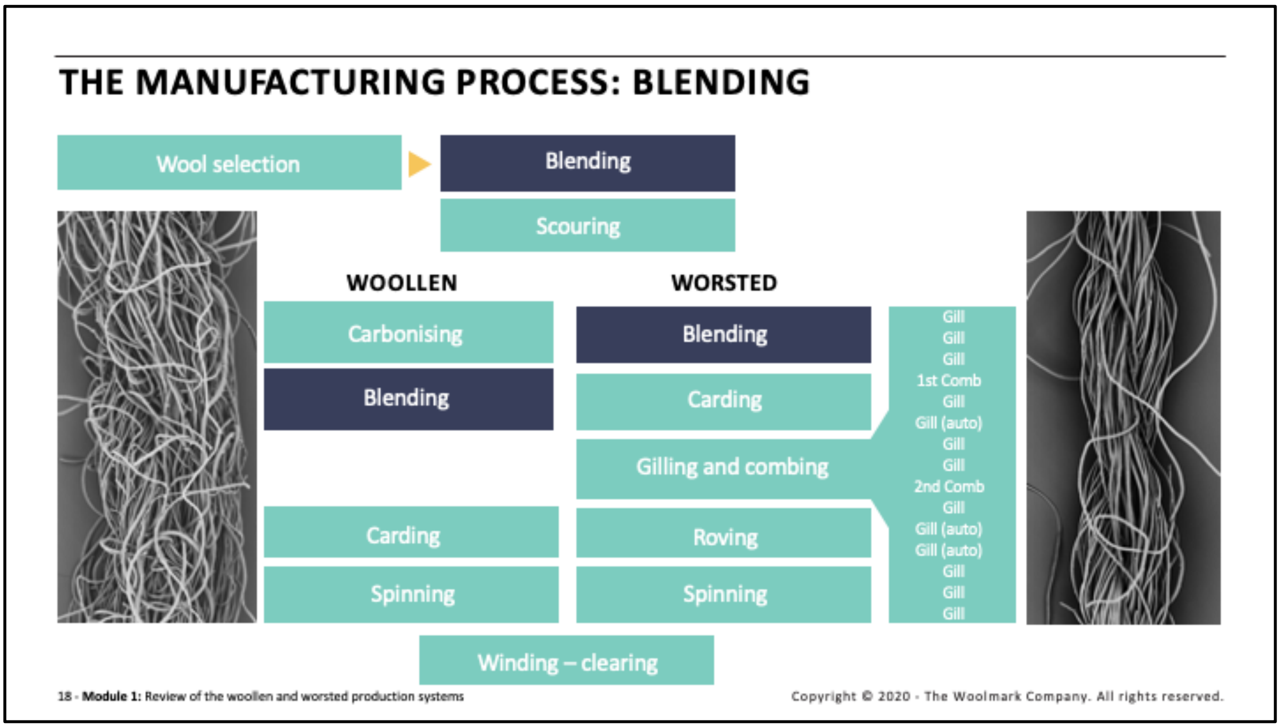
EXPLAIN THAT the components of a woollen blend are generally more diverse than the blends used for worsted processing. Usually there is a bigger variation in fibre length and the amount of vegetable matter between components. It follows that more rigorous blending of the lots making up a batch is required in woollen processing.

ASK *participants which other processes also blend the wool.*

ALLOW *participants sufficient time to respond.*

IF NECESSARY *reiterate that all processes blend wool, except roving, spinning and winding (i.e. roving and subsequent processes), which process a single strand of wool.*

NOTE: *If participants argue twist also is a form of blending – concede.*



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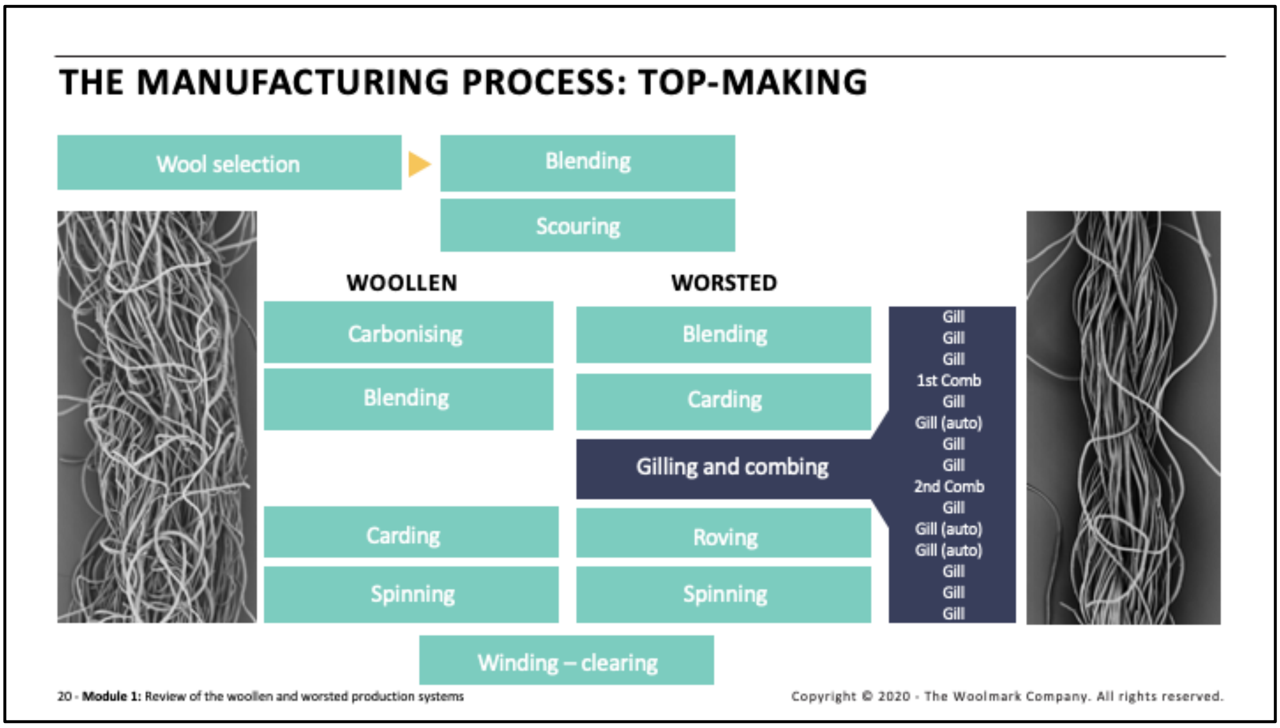


INDICATE THAT wool destined for the worsted spinning system is carded and goes through a series of gilling and combing operations.

These are covered in detail in the Wool Science, Technology and Design Education Program course *Worsted top-making.*

REVIEW briefly, the aims of the various processes in top-making are:

Carding

- to open the scoured wool and individualise the fibres
- to form a sliver in which the fibres are partially aligned
- to remove vegetable matter, especially burrs, from the wool.

Gilling

- to continue the fibre alignment process
- to continue the blending process.

Combing

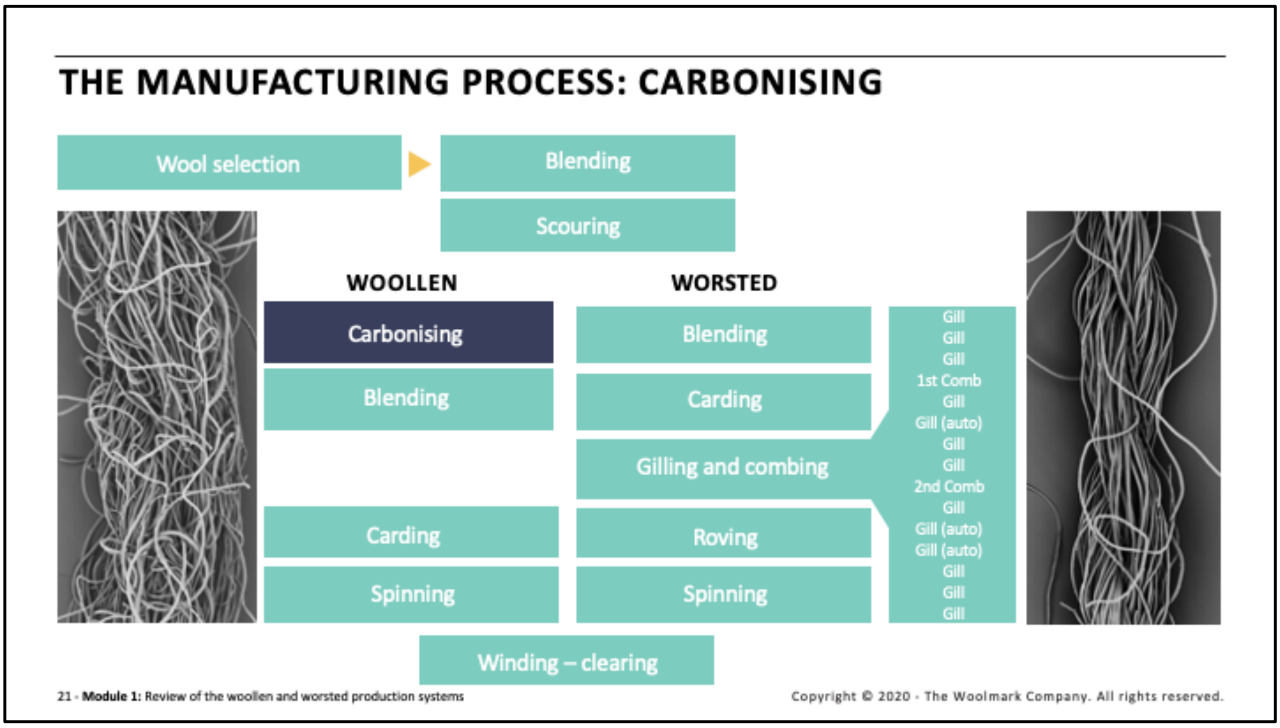
- to remove short fibre, any remaining vegetable matter and neps (fibre entanglements)
- to complete the fibre alignment.

Post-comb gilling

- to re-blend the combed top
- to even out the short-term variations in top weight (per course length) created during combing.

NOTE THAT:

- Between raw wool scouring and woollen spinning there are three operations.
- Between raw wool scouring and worsted spinning there are up to 18 operations.



EXPLAIN THAT wool for the woollen system is often, but not always, carbonised after scouring to remove vegetable matter. The requirement for carbonising depends on the vegetable matter content of the wool.

Carbonising uses an acid (normally sulphuric acid) to remove vegetable matter. Other acids have been used, but sulphuric acid is the choice of the vast majority of carbonising plants.

INDICATE THAT carbonising is normally used on wool where the amount of vegetable matter exceeds 5% of the weight of wool. It is often required for pieces, bellies and other parts of the wool in contact with the ground when on the sheep.

POINT OUT that some of this vegetable matter can be removed through the process of scouring and carding. However:

- carbonising is more effective than either scouring or carding
- combing, which also effectively removes vegetable matter, is not used in woollen processing.

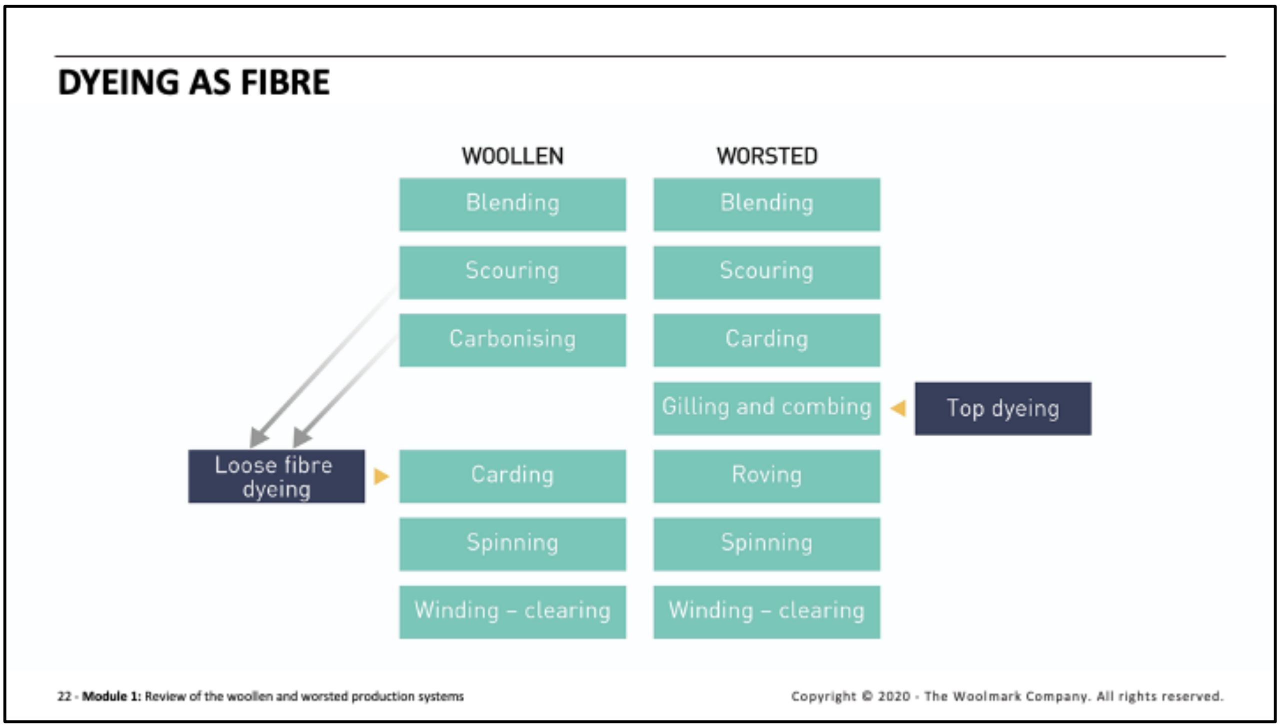
EXPLAIN THAT carbonising can be avoided for some relatively-clean carding wools, in which case the process goes from scouring to blending or opening and then to carding.

NOTE THAT carbonising will be discussed in more detail in subsequent lectures dealing with woollen spinning.

***HAND OUT** samples of scoured wool and carbonised wool to participants.*

***ALLOW** participants sufficient time to observe differences between the two samples.*

***ENCOURAGE** participants to share their observations.*



POINT OUT that during woollen processing, wool is often dyed after scouring or after scouring and carbonising.

During worsted processing, fibre dyeing is normally performed on top.

The dyeing of wool is covered in the Wool Science, Technology and Design Education Program course *The dyeing of wool.*

REASONS FOR DYEING IN FIBRE FORM

The reasons for dyeing in fibre form are to:

- achieve large lots of uniform shade
- achieve multi colour effects or mélange shades
- achieve maximum wet colour fastness with good shade uniformity
- minimise dyeing costs
- allow separate dyeing of the fibres in blends, particularly when the cross staining with different dye types is possible.

Disadvantages of dyeing in fibre form:

- Lower tensile properties — reduced processing efficiencies
- Dyes used must be fast to any wet process (such as scouring, milling, etc.)
- Shade and quantity to be dyed must be selected at an early stage of processing
- Possibility of colour contamination
- Likelihood of waste

23 - **Module 1:** Review of the woollen and worsted production systems

EXPLAIN THAT the vast majority of wool used in the worsted and woollen system is dyed or bleached in fibre form:

- as scoured loose wool in the woollen system before carding
- as top in the worsted system.

NOTE THAT the reasons for dyeing in fibre form are to:

- achieve large lots of uniform shade. Slight unevenness can be eliminated in subsequent blending that takes place in carding or gilling and combing
- achieve multi-colour effects or mélange shades
- create mixture shades that can only be achieved by combining different colours at the blending stage. This feature is important for developing a wide range of colour effects for fashion and interior textiles, which is not practical with yarn and fabric dyeing
- achieve maximum wet colour fastness with good shade uniformity
- minimise dyeing costs
- allow separate dyeing of the fibres in blends, particularly when the cross-staining with different dye types is possible.

POINT OUT that there are some disadvantages related to fibre dyeing that are relevant to dyeing and subsequent processing. These are:

- Dyed wool fibres always have lower tensile properties than undyed and therefore will process less efficiently.
- Dyes used must be fast to any wet process to which the fibre will subsequently be subjected, such as scouring and milling.
- The shade and quantity of fibre to be dyed must be selected at an early stage of processing, typically at least six months before retail.
- There is the possibility of colour contamination during processing.
- Because the quantity of fibre dyed to meet specific orders is often slightly more than necessary, unless the excess can be reused, it is waste.

SUMMARY — MODULE 1

- There are two main systems used to process Australian wool into yarn and fabric: worsted and woollen.
- As a general guide:
  - fleece wool longer than 60 mm goes to the worsted system
  - wool shorter than 50 mm is used in the woollen system.
- Lamb's wool is wool harvested during the first shearing of lambs and often spun on the woollen system to produce a hairier, but softer, yarns and end products.
- 'Strong wool' is the term usually applied to wool produced from breeds of sheep used predominantly for meat production.
  - The mean fibre diameter of strong wool from these breeds of sheep is typically greater than 25–30mm.

24 - **Module 1:** Review of the woollen and worsted production systems

REMIND participants that there are two main systems used to process wool into yarn and fabric: worsted and woollen.

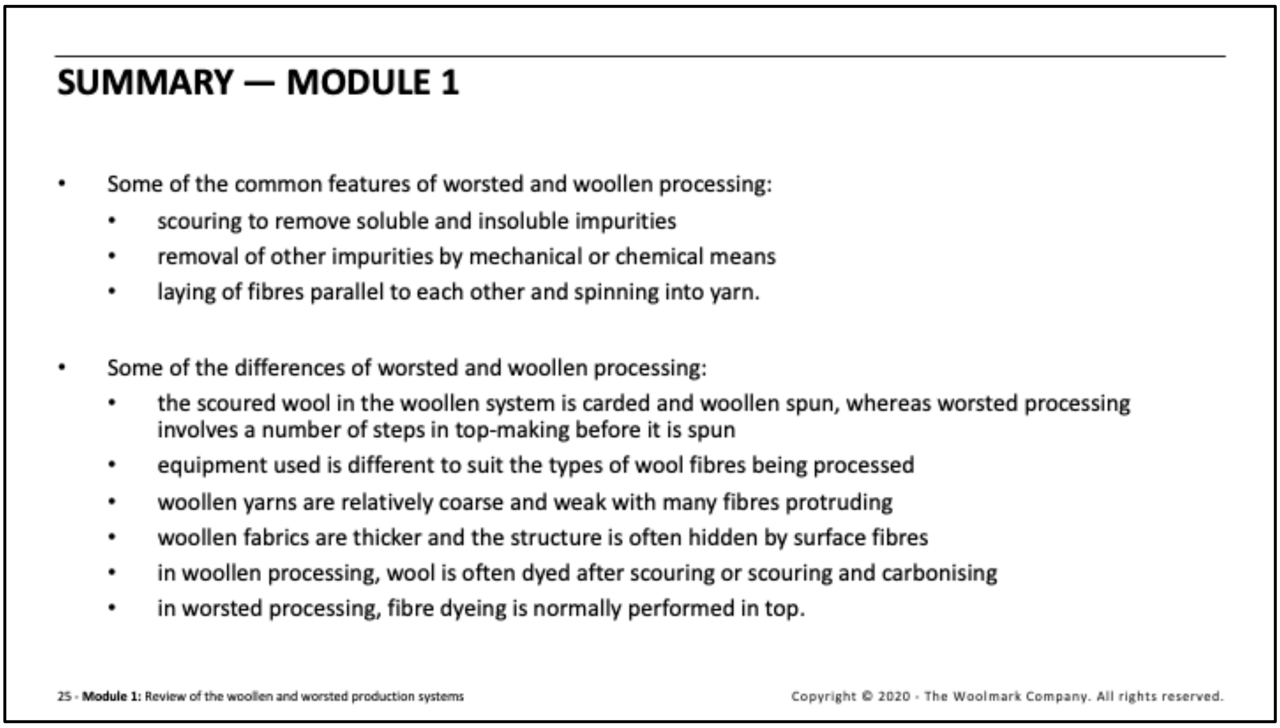
SUMMARISE THAT wool used in the woollen system is generally shorter and often coarser than wool used in the worsted system. As a general guide:

- fleece wool longer than 60 mm goes to the worsted system
- wool shorter than 50 mm is used in the woollen system.

REITERATE THAT lamb's wool is defined as wool harvested during the first shearing of lambs. Lamb's wool is often spun on the woollen system producing a hairier, but softer, yarns and end products.

REMIND participants that 'strong wool' is the term usually applied to wool produced from breeds of sheep used predominantly for meat production. The mean fibre diameter of strong wool from these breeds of sheep is typically greater than 25–30mm.

REVIEW the fact that the woollen system is a vital adjunct to the worsted system as it provides a value-add to the components of the wool-growing sector that are not suitable for worsted yarns.



REVIEW some of the common features of worsted and woollen processing are:

- scouring to remove soluble and insoluble impurities
- removal of other impurities by mechanical or chemical means
- laying of fibres parallel to each other and spinning into yarn
- binding yarns into a fabric or product.

REMIND participants that the differences between the woollen and worsted systems include:

- The scoured wool in the woollen system is carded and woollen spun, whereas worsted processing involves a number of steps in top-making before it is spun.
- The equipment used is different to suit the types of wool fibres being processed.
- Woollen yarns are relatively coarse and weak with many fibres protruding.
- Woollen fabrics are thicker and the structure is often hidden by surface fibres.
- In woollen processing, wool is often dyed after scouring or scouring and carbonising.
- In worsted processing, fibre dyeing is normally performed in top.

REITERATE THAT there are advantages and disadvantages to dyeing wool at the fibre stage.

ASK *participants if they have any questions about the content covered in this module.*

ALLOW *time for questions and discussion before proceeding to the final slide and closing the lecture.*

INFORM participants of the time and location for the next lecture — *Module 2 Preparation for worsted spinning*— and encourage them to read through the relevant notes in their Participant Guides before attending the lecture.

ENCOURAGE participants to explore the Woolmark Learning Centre to reinforce and build on what they have covered in today's lecture.

Participants can register with and explore the Woolmark Learning Centre here: www.woolmarklearningcentre.com

BEFORE participants leave ensure you have collected all materials distributed during the lecture.

MODULE 2

THE WOOLMARK COMPANY

PREPARATION OF TOPS FOR SPINNING

RESOURCES — MODULE 2: PREPARATION OF TOPS FOR SPINNING

Contained in the *Worsted and woollen spinning* Demonstration kit you will find the following resources for use as you deliver **Module 2: Preparation of tops for spinning**:

- sample of worsted roving

WELCOME participants to Module 2 of the Woolmark Wool Science, Technology and Design Education Program — *Worsted and woollen spinning —Preparation of tops for spinning*.

EXPLAIN THAT this module covers the methods used to prepare tops for worsted yarn spinning. While the detail of processes used may vary between processors three main processes are used,

- re-combing
- gilling — also called drawing
- roving.

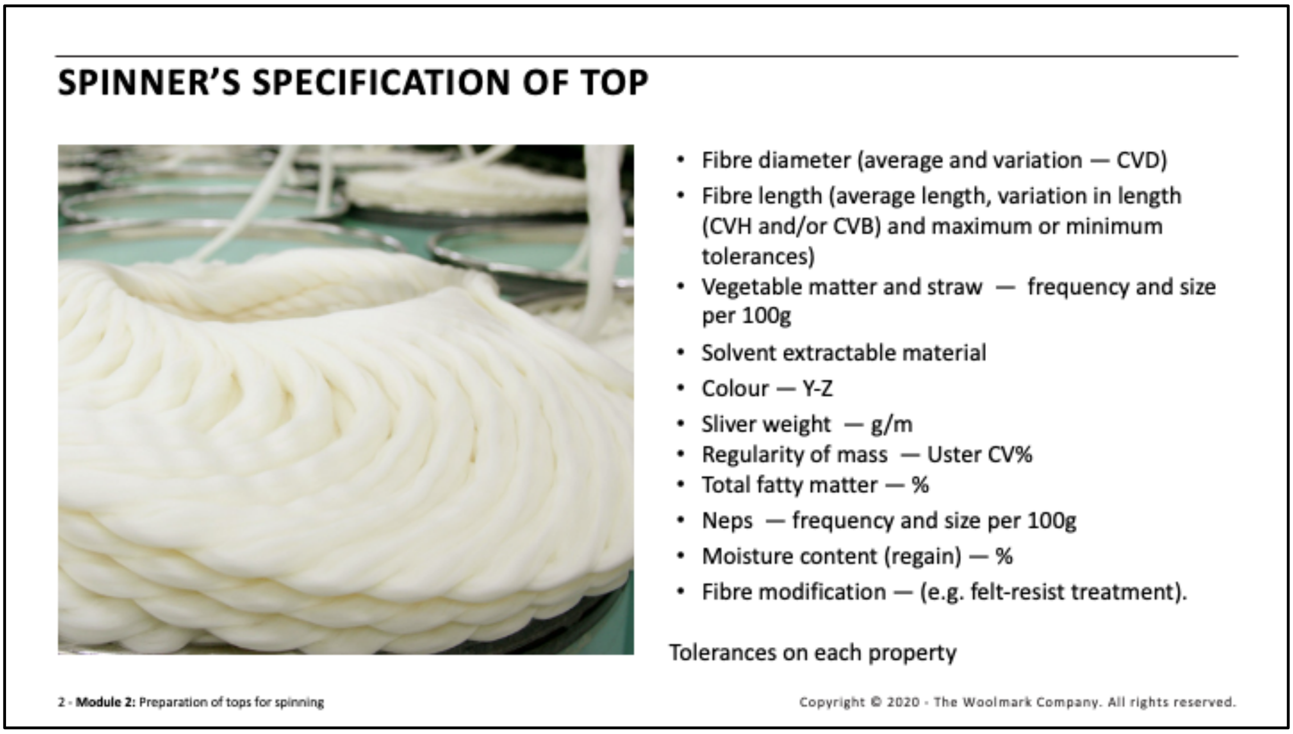
Each process will be covered.

INFORM participants that by the end of this module they will be able to:

- describe the operations used to prepare wool top for spinning
- describe a roving machine
- outline the practical considerations associated with roving
- outline some of the issues impacting the quality of the final yarn.

RESOURCES REQUIRED FOR THIS MODULE:

- *sample of worsted roving*



EXPLAIN THAT wool tops are traded commercially and purchased by spinners as the raw material for producing yarn.

To confirm the reliability of the delivery, the spinner generally tests the tops on arrival at the mill for the properties listed on the slide. Measurement is central to the trading relationship between combing plant and spinner.

POINT OUT that the properties specified, the average value and the tolerance specific to each property need to be agreed to between the two parties.

EXPLAIN THAT typically, the following properties are considered as part of the specification for the top:

- mean fibre diameter — both average fibre diameter and variation in fibre diameter (CVD)
- mean fibre length — this includes hauteur and barbe and variation in length (CVH and/or CVB)
- vegetable matter and straw — frequency and size per 100g
- solvent extractable material
- colour — Y-Z
- sliver weight — measured in grams per metre (g/m)
- regularity of mass — the variation of weight along the sliver (Uster CV%)
- total fatty matter — measured as a percentage (%)
- neps — frequency and size per 100g
- moisture content (regain) — measured as a percentage (%)
- fibre modification — for example felt-resist treatment.

MENTION THAT the top-maker is responsible for delivering a top that meets the specifications set out by the spinner, which greatly affects their choice of raw wool.

NOTE THAT tolerances (maximum and/or minimum) are often imposed on the above properties which will vary with the spinner. The tolerances placed on these values by the spinner depends on the module characteristics and the customer's requirements. In some cases only upper (or lower) limits are placed in the property. For example, only an upper tolerance is placed in fibre diameter since provision, by the top-maker, of finer wool with a lower mean fibre diameter in no way inconveniences the spinner.

***ASK** participants how one or two (depending on time) of these measurements are made:*

- *fibre diameter*
- *total fatty matter*
- *sliver weight*
- *neps*

***ACKNOWLEDGE** participant responses before proceeding.*

SPECIFICATION OF TOP – 18.5 MICRON

PROPERTY	SPECIFIED AVERAGE	TOLERANCE
Average fibre diameter (µm)	18.5	< +0.2
CVD (%)	21.0	< + 1.0
Hauteur (mm)	64.0	+/-2
CVH (%)	48.0	Max +1
% fibres < 30mm	13.0	Max: 13.0
Total fatty matter (%)	0.8	Max
Regain (%)	18.25	
Sliver weight (g/m)	20–25	+/- 2
Uster CV (%)	3.5	Max
Neps (large/100g)	2	Max
VM and straw (large/100g)	2	Max
Coloured fibre	For pastel shades zero	
Fibre curvature to be reasonably high at >85 in greasy wool.		
Hand wash/machine wash/tumble as required		

3 - **Module 2:** Preparation of tops for spinning

REFER participants to the table on the slide showing a typical spinner's requirement and tolerances for a worsted top.

EXPLAIN THAT the fibre curvature depends on the type of fabric being made — high curvature assists with improved bulk/ fabric appearance and with reducing pilling. Low curvature is used in woven products.

NOTE THAT if the product is required to be machine washed or tumble dried the top must be Chlorine Hercosett treated.

RE-COMBING WORSTED TOP FOR SPINNING

Re-combing objectives:
- remove remaining short fibres
- re-alignment (very high)
- final filter for neps and vegetable matter.

Re-combing outcomes
- Improved process efficiency in spinning,
- reduction of yarn faults
- appearance of final yarn all significantly improved

4 - **Module 2:** Preparation of tops for spinning

EXPLAIN THAT the spinner uses a number of steps to prepare combed worsted top for spinning. These steps depend on whether the wool is ecru (uncoloured and untreated) or treated in some way (dyed, felt-resist etc.) The process also depends on the level of preparation of the top by the top-maker.

Re-combing

The recombing of all tops (ecru or treated) by spinners is widespread. In vertical operations re-combing may be carried out in the top-making plant

INDICATE THAT the objectives of re-combing are to:
- remove any remaining short fibre
- straighten and individualise the fibres, the comb being the most effective equipment in worsted processing for straightening the fibres
- remove any residual short fibres, vegetable matter and neps still remaining in the sliver. The long fibres ultimately become the feed to the spinning plant, the short fibres go to waste or noil.

The outcomes of the re-combing process are:
- improved process efficiency during spinning
- reduction of yarn faults
- appearance of final yarn significantly improved.

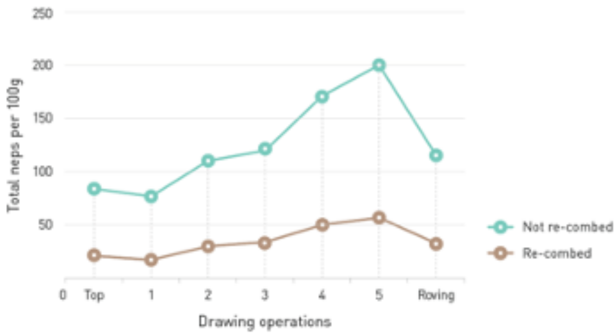
EXPLAIN THAT the downstream advantages of including this additional combing operation in terms of product quality and efficiency of processing, far outweigh the extra cost of the operation. A CSIRO study in 1996 revealed occurrence of neps in finished knit fabrics decreased by as much as 70–90% due to the introduction of re-combing.

NOTE THAT neps are an accurate predictor of yarn faults that may end up as a garment fault:

Top = 1nep/100g → Fabric = 3 neps/m

RE-COMBING AND RE-GILLING

PARAMETER	NOT RE-COMBED	RE-COMBED
Top (21µm)	85	20
First drawing	77	18
Second drawing	112	31
Third drawing	120	33
Fourth drawing	170	48
Fifth drawing	202	56
Roving	116	32



The impact of re-combing on nep content

Data from CSIRO

5 - **Module 2:** Preparation of tops for spinning

EXPLAIN THAT after the top has been re-combed, it must be re-gilled or drawn (called drawing operations in the slide). This is necessary to again even out the weight of the top (improving regularity).

INDICATE THAT the slide presents some hard data to support the claims made for re-combing wool after top-making and before spinning to reduce neps.

- Re-combing is shown to reduce neps by about 70%
- Re-gilling increases nep content, but there are far fewer neps with re-combed wool (red line) than in the top that was not re-combed (blue line).

NOTE: The reduction in neps during the roving stage has two causes discussed later.

IMPACT OF RE-COMBING

PARAMETER	NOT RE-COMBED	RE-COMBED
Total neps in roving (per 100g)	245	90
Total Uster thick and nep faults in yarn (per km)	66	15
Loepfe short thick yarn faults (per 100 km)	381	78
Total winding cuts for faults (per 100 km)	252	93
Estimated winding efficiency (%)	85	95

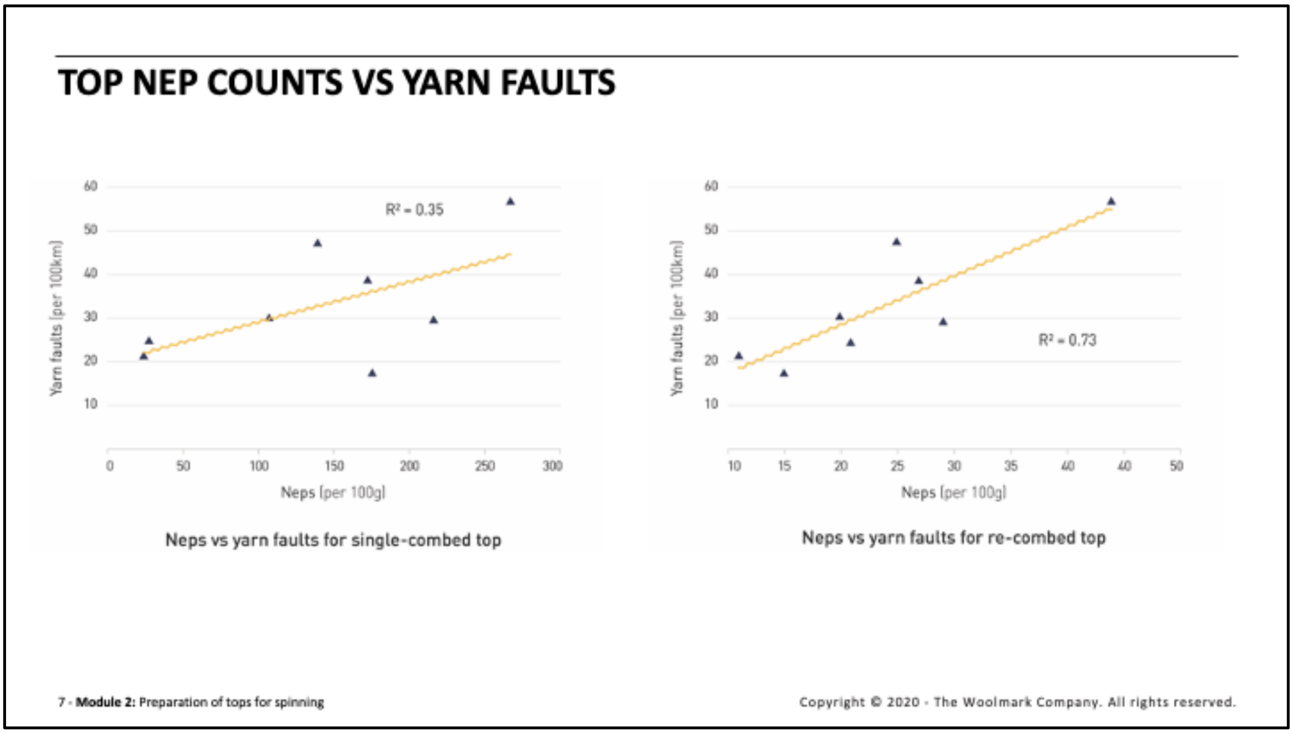
6 - **Module 2:** Preparation of tops for spinning

INDICATE THAT this table presents some hard data to support the claims made for re-combing wool on the quality of yarn.

EXPLAIN THAT re-combing is shown to reduce neps during roving and, in turn, faults in yarn. As illustrated in the table, this reduction in neps improves the winding efficiency from about 85% for non-recombed yarn to about 95% for the re-combed top.

Assuming each fault in winding costs about 2 cents, the resultant savings in winding for the recombed wool in this example was about 65 cents/kg of yarn.

MENTION THAT faults in mending times in woven fabrics were reduced by up to 80%.



A question often asked by industry is: "What correlation exists between the neps counted in tops, and subsequent yarn and fabric faults?".

EXPLAIN THAT there is little reliable information available since it is difficult to relate what is measured subjectively (i.e. neps in top) to what is measured objectively (i.e. yarn faults).

Some preliminary investigations carried out by CSIRO have been made to relate neps and yarn faults.

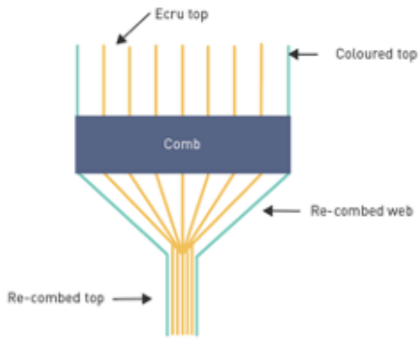
MENTION THAT eight different wools were processed through to top then re-combed and converted to yarn (i.e. all the yarns were spun from the re-combed tops). Nep measurements were made on the single combed tops and on the re-combed tops and the yarn faults were measured by the Loepfe Yarn Master system fitted to a Schlafhorst 238 winder.

POINT OUT the relationship between the single combed top nep results and yarn faults are presented in the diagram on the left of the slide . The correlation between neps and faults was poor. In re-combed top shown in the figure on the right-hand side the relationship was much clearer.

NOTE also the difference in the levels of neps (X-axis) in the single and re-combed tops.

FAULTS FROM RE-COMBING

COMB LOADING (g/m)	COMB SPEED (cycles/min)	EDGE FAULTS (%)	
		EXPECTED	MEASURED
240	175	16.7	50.0
240	210	16.7	58.8
480	175	8.3	15.9
480	210	8.3	28.6



8 - **Module 2:** Preparation of tops for spinning

POINT OUT further evidence of how steps during the earlier stages of processing can directly influence the fault levels in the subsequent yarns as illustrated on the slide.

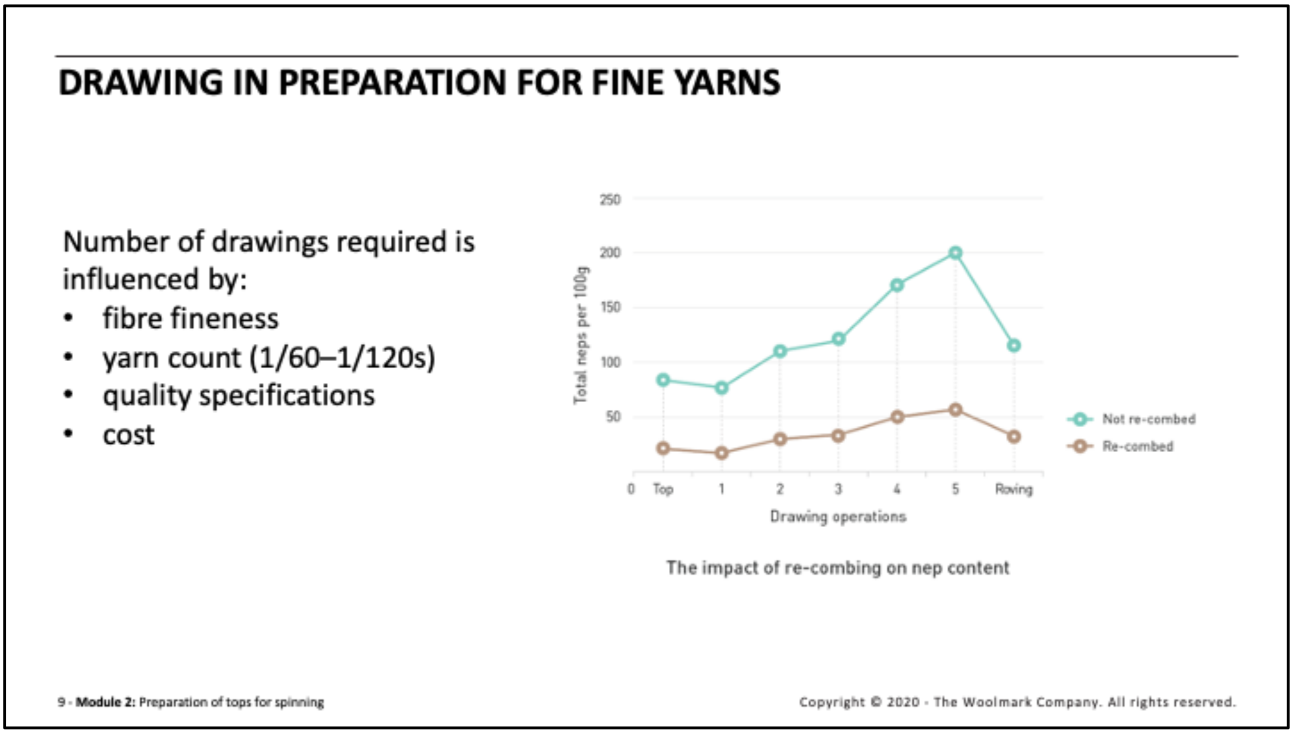
EXPLAIN THAT the edges of the combed web during re-combing are susceptible to disruption under some input loading and comb speed regimes. This was observed using a single-coloured top on the two edges of the ecru tops in the comb feed as shown in the diagram on the slide.

The ecru and dyed tops were also reversed to ensure the problem was not a result of dyeing the top.

The edge disturbances were shown to significantly influence the level of faults in the subsequent yarns.

INDICATE THAT the table on the slide illustrates:

- lighter feeds/webs led to higher levels of faults
- higher speeds slightly increased the amount of faults in the yarns at both feed loads.



EXPLAIN THAT the number of drawings required after combing depends on:

- fibre diameter
- desired yarn count. Limit spinning (with the minimum numbers of fibre in the cross-section) requires more drawing operations to achieve the high levels of top regularity required
- quality requirements of the yarn
- cost balance in the spinning mills (i.e. cost benefits of re-drawing)

INDICATE THAT the graph (shown earlier) confirms the improved regularity of re-combed top resulting from additional re-gilling must be balanced against the increased nep formation.

CONSIDERATIONS WHEN PREPARING ROVING

- Condition of material:
  - moisture content
  - chemical treatment
- Relative humidity and temperature
- of spinning room
- Quality control test data
- Mass irregularity
- Waste — long fibre/nep/noil level

10 - **Module 2:** Preparation of tops for spinning

EXPLAIN THAT depending on whether the feed top is purchased from a supplier, or comes from within the company, it is vital to review the condition of the material being fed to the spinning plant.

This review involves:

- subjective inspection of the condition and appearance of all the individual tops
- technical testing of the top, such a count, mass irregularity, contaminant levels, moisture content etc.
- decisions about the amount of waste extracted which, in turn, depends on:
  - the properties of the feed wool tops
  - the style and technical needs of the yarn to be manufactured.

INDICATE THAT to ensure effective combing and separation of fibre at the combing head, it is essential the wool has sufficient moisture content. This is especially true of dyed tops and felt-resist treated wool, which have recently experienced a drying operation. Measuring the moisture content is essential to ensure efficient processing during gilling, combing, drawing, roving and spinning.

Likewise, if the wool has been chemically treated as top (e.g. felt-resist treatment) a spinning lubricant may have be re-applied before spinning.

ROVING

Designed to reduce the linear density of the top to a level that can be fed into the spinning frame.

A single strand of drawn top is drafted.

Roving requires consolidation to:

- allow handling of the material in the feed to the spinning machine
- eliminate the risk of false drafts.

Options to control fibres:

- real twist
- rubbing.

STAGE	DRAFT	DOUBLING	FIBRES IN CROSS-SECTION	WEIGHT (g/km)
Top			37,800	18,900
Drawing 1	5	6	37,800	18,900
Drawing 2	5	5	37,800	18,900
Drawing 3	5	5	37,800	18,900
Drawing 4	6	5	31,500	15,750
Drawing 5	6	4	21,000	10,500
Drawing 6	7	4	12,000	6000
Roving	15	1	800	400
Yarn	20	1	40	20

11 - **Module 2:** Preparation of tops for spinning

EXPLAIN THAT roving is the next step in the process, following drawing. Roving aims to reduce the linear density of the sliver even further by drafting a single strand of the drawn top (as illustrated in the table).

HAND OUT *a sample of roving to participants.*

NOTE *the ease with which it can be 'drafted' or broken.*

INDICATE THAT the roving is now so fine it requires some form of consolidation to allow handling of the material in the feed to the spinning frame and eliminate the risk of false drafts. The amount of consolidation must balance adequate strength of the roving for handling and high cohesion with the impact on smooth drafting of the fibres.

POINT OUT that while real twist was once widely used for this purpose, and is still used in some limited applications, in 1959 Schlumberger introduced the 'rubbing frame'. The rubbing frame overcame the delivery speed limitations associated with real twist insertion during roving and opened up the path to higher productivity.
Also incorporated in the rubbing frame machine, which was revolutionary at the time of its introduction, was:

- double apron drafting — replacing porcupine and tumbler drafting
- higher draft levels allowing heavier feed tops, and in turn, increased productivity.

EXPLAIN THAT the reduction in neps during the roving stage shown in the previous slides has two causes:

- There are no pins in the draft zone of the roving machines. The entry and exit of the pins in the gilling machines used to control the fibres causes some nep formation.
- The draft in roving (~15) is higher than in gilling (~6) and this breaks some neps or tightens the neps so they appear smaller and are not counted (neps less than 2mm are not normally counted in top).

INTRODUCE the following video, produced by The Woolmark Company (TWC), which offers a brief overview of the roving process.

PLAY *video (about 36:00 seconds)*

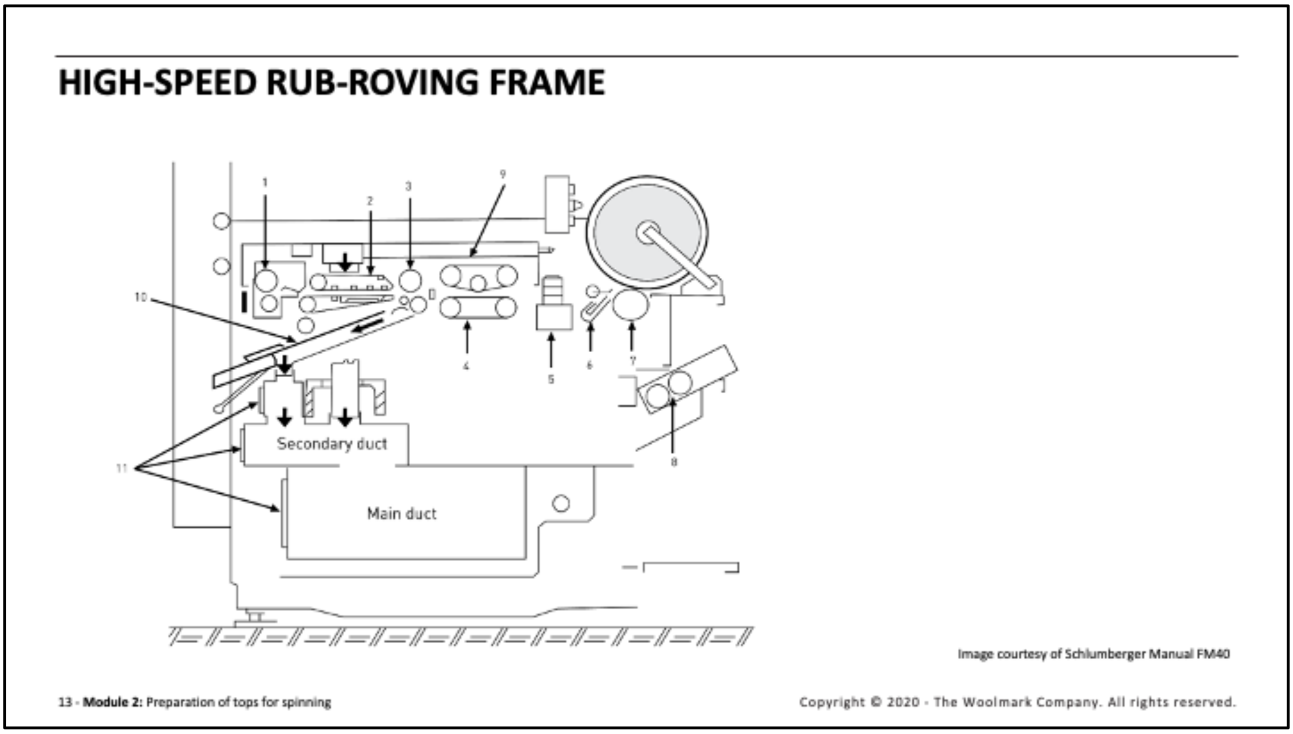
AS THE *video plays note that the roving machine:*

- *stretches or drafts the top reducing its weight per unit length. (16:00 seconds)*
- *rubs the top to give it added strength. (24:00 seconds)*
- *winds the roving onto a package. (27:00 seconds).*

ASK *participants to explain why the rovings are rubbed before they are wound up on packages.*

ALLOW *sufficient time for participants to respond.*

IF NECESSARY *explain that the rovings are rubbed to impart sufficient cohesion and strength for handling in the next process (spinning).*



EXPLAIN THAT in 1979, Schlumberger introduced the FMV10, a vertical drafting and rubbing frame. Further developments since time have been introduced regularly. The modern vertical rubbing frame can:

- deliver at speeds up to 250m/min
- use higher in feed loads
- uses automatic doffing of full packages.

REFER participants to the construction of a typical rubbing frame as shown on the slide:

1. feed cylinder
2. drafting system aprons
3. draft cylinder
4. rubbing aprons
5. stop motion
6. winding guide
7. winder
8. tubes magazine

Suction:

9. upper sucker
10. lower sucker
11. observation windows.

NOTE THAT at the delivery of the rub-rover the slivers are rubbed in pairs between oscillating rubber aprons to impart sufficient cohesion for handling during the next process.

RUB ROVER – RUBBING DEVICE

Image courtesy of NSC Schlumberger

- Number of rubs/m = Frequency (cycles/min) / Delivery Speed (m/min)
- Roving uses negative tension at the delivery
- Most evenness problems in roving are due to incorrect delivery tensions.
- To obtain the best mass regularity, drafts between 15 and 20 are recommended.

14 - **Module 2:** Preparation of tops for spinning

EXPLAIN THAT consolidation of the low-weight roving, to give it adequate stability for handling and processing, is achieved by a continuous forward motion and alternate transverse motion, by a device placed between the final drafting roll and the winding-up system in the rub-roving frame.

The intensity of rubbing is determined by the number of rubs and the length of the traverse motion.

The number of rubs/metre is the ratio between the frequency (cycles/min) and the delivery speed:

$$\text{Number of rubs/m} = \frac{\text{frequency (cycles/min)}}{\text{delivery speed (m/min)}}$$

NOTE THAT to improve productivity and downstream handling, two strands of the roving are brought together to form the so-called 'double-mesh' assembly as the roving is wound onto cylindrical packages ready for spinning.

Issues in roving

Roving manufacture is the only passage that uses negative tension at the delivery.

EXPLAIN THAT the package take-up speed is 1 to 5% less than the forward apron delivery speed. This is a necessity to accommodate the side-to side winding motion of the roving strands.

POINT OUT that setting of the package take-up speed is critical and needs attention with each batch to avoid any tension-related irregularities (false drafts). To obtain the best mass regularity, drafts of between 15 and 20 are recommended.

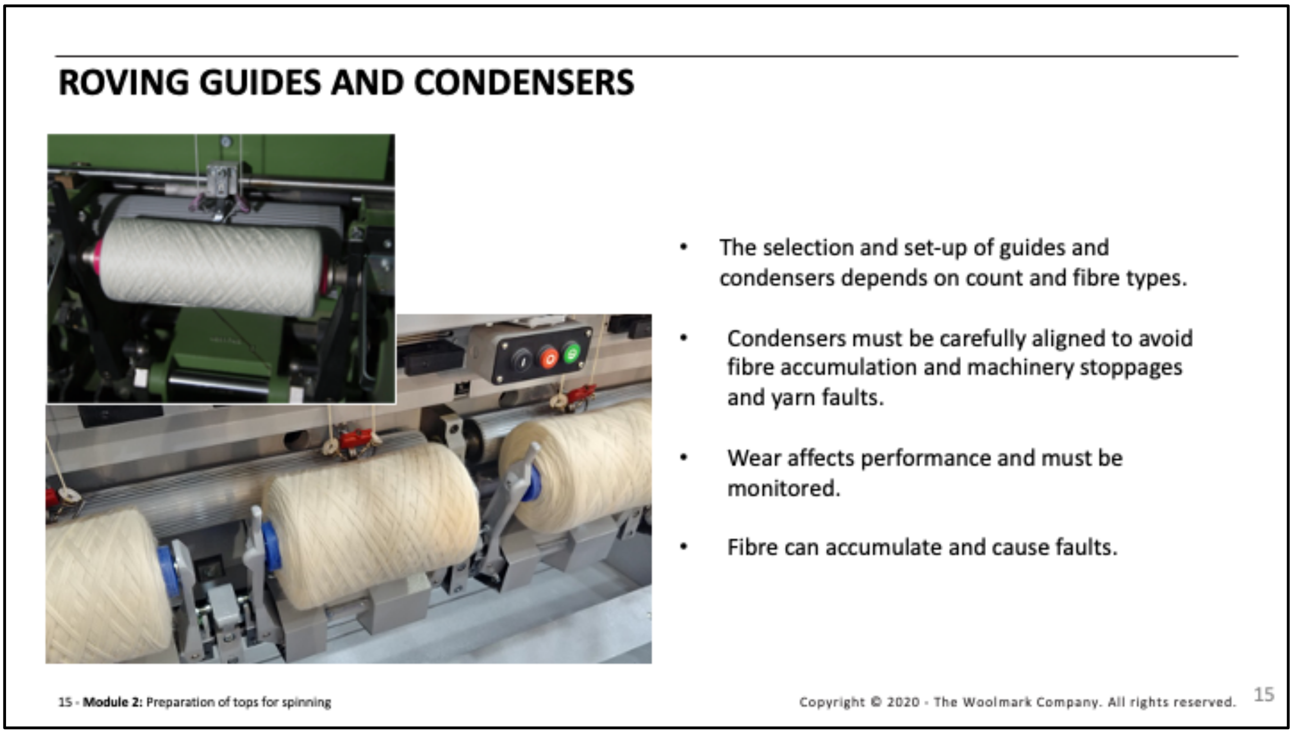
NOTE THAT the hardness of drafting rollers needs to be carefully managed; grinding is critical to match diameters and the surface of the drafting rollers.

Most evenness problems encountered with roving are considered to be attributed to incorrect delivery tension settings.

Monitoring with Uster mass irregularity analysers is critical to ensure settings are appropriate.

EXPLAIN THAT rubbing amplitude and strokes per minute need to be linked to the material, taking into account:

- the fibre diameter,
- crimp characteristics
- fibre length and its distribution.



EXPLAIN THAT the selection of roving guides depends on the specified yarn count and fibre properties. Generally a three-wrap spiral is suitable for most fine wools and fine roving counts. A two-wrap spiral may be considered for broader wools.

Wear of these devices needs to be monitored regularly.

MENTION THAT at the feed, intermediate, and delivery sections of the machine, condensers are used to direct the roving. It is important all the condensers are accurately aligned to prevent distortions of the fibre flow. If the alignment of condensers is poor, serious accumulation of fibres can occur, which when released causes faults in the yarn or machine stoppages.

NOTE THAT alignment needs to be checked across all winding heads before starting a new batch.

Selection of the condenser size must be matched to the fibre and yarn count of the roving being produced.

POINT OUT the condition of the operating surfaces of these condensers needs to be regularly checked for damage.

SUMMARY — MODULE 2

- Described the operations used to prepare wool top for spinning.
- Outlined some of the issues in re-combing impacting the quality of the final yarn.
- Gilling then roving reduces linear density of top from typically 20g/m to 500 g/km.
- Described the functions of a roving machine
  - drafting zone using apron control
  - rubbing mechanisms.
- Outlined the practical considerations associated with making a quality roving.

16 - **Module 2:** Preparation of tops for spinning

SUMMARISE THAT the operations used to prepare wool top for spinning include:

- re-combing
- finisher gilling
- roving.

REMIND participants that to convert the top to roving, depending on the yarn count to be spun, the sliver weight is reduced typically from around 20g/m to around 500gm/km — a factor of 40.

The total drafting generally is achieved by:

- gilling
- roving.

REITERATE THAT as the wool slivers become finer, fibre control is more effective using a pair of rubber aprons that compress the sliver under a controlled load.

The roving machine:

- reduces the weight of a single top
- inserts some means of control of fibres in the light-weight material produced by rubbing or twisting.

REVIEW the practical considerations associated with making a quality roving

- rubbing frequency
- condenser and guide maintenance.

The major issue in re-combing and drawing impacting the quality of the final yarn is the formation of neps; reduced neps give fewer yarn faults.

ASK *participants if they have any questions about the content covered in this module.*

ALLOW *time for questions and discussion before proceeding to the final slide and closing the lecture.*

INFORM participants of the time and location for the next lecture — *Module 3 Worsted ring spinning*— and encourage them to read through the relevant notes in their Participant Guides before attending the lecture.

ENCOURAGE participants to explore the Woolmark Learning Centre to reinforce and build on what they have covered in today's lecture.

Participants can register with and explore the Woolmark Learning Centre here: www.woolmarklearningcentre.com

BEFORE participants leave ensure you have collected all materials distributed during the lecture.

MODULE 3

THE WOOLMARK COMPANY

WORSTED RING SPINNING

RESOURCES — MODULE 3: WORSTED RING SPINNING

No additional resources are required to deliver **Module 3: Worsted ring spinning**.

WELCOME participants to Module 3 of the Woolmark Wool Science, Technology and Design Education Program — *Worsted and woollen spinning —Worsted ring spinning*.

EXPLAIN THAT this module covers the production of worsted spun yarns by the use of ring spinning.

INFORM participants that by the end of this module they will be able to:

- describe the aims of spinning and the operation of the ring spinning machine
- outline the key issues affecting the operation of the ring frame
- define yarn count and twist factor
- understand the key limitations and relevance of factors influencing the operation of the spinning machine
- understand the key limitations for spinning wool and relevance of fibre-related and machine-related factors.

NO RESOURCES REQUIRED FOR THIS MODULE

PRODUCTION OF YARN

The aims of spinning are to produce yarn with:

- the correct count (mass/course length)
- the correct twist
- minimum variation in count and twist
- adequate strength and extensibility
- good appearance (appropriate hairiness)
- fitness for purpose

Requirements of a yarn:

- long-term consistency of count
  - The mass per course length needs to be reasonably constant kilometre to kilometre.
- robustness
- functionality — performs well in fabric manufacture
- visual appeal.

In one kilometre of a typical fabric of 200gsm, there will be 8,000,000m of yarn.

INDICATE THAT the actions of the spinning machine are to:

- draft the roving to the desired yarn count. Consistent yarn is made from proper setting of the drafting elements and associated settings
- twist the drafted material, providing strength to the yarn
- wind the yarn onto a bobbin for ease of handling during the next operation.

EXPLAIN THAT the resultant yarn must have:

- the right count (weight per course length)
- the correct twist
- minimum variation in count and twist
- adequate strength and extensibility with minimum weak places, to minimise ends down in weaving and yarn breaks in knitting
- good appearance — worsted yarns are smooth and not hairy, whereas woollen yarns are full and often hairy.

POINT OUT the yarn must also:

- have good long-term count stability
- be robust (resist abrasion during weaving and knitting)
- perform well in all subsequent operations and in the final product.
- have a good visual appeal (a combination of evenness and hairiness).

EXPLAIN THAT in making hundreds, if not thousands of metres, of a particular fabric, it is imperative the properties designed into the fabric must not:

- vary outside agreed tolerances
- vary with irregularity throughout the fabric length and therefore in the final garments.

It is vitally important therefore the yarn retains its specified properties for kilometre after kilometre along its length. For example, in one kilometre of a typical fabric of 200gsm there will be 8000 km of yarn.

NOTE THAT the demand for such quantities of yarn to effectively and efficiently retain their properties for such massive lengths is a strenuous exercise in control engineering.

***ASK** participants to explain why twist is inserted to the yarn.*

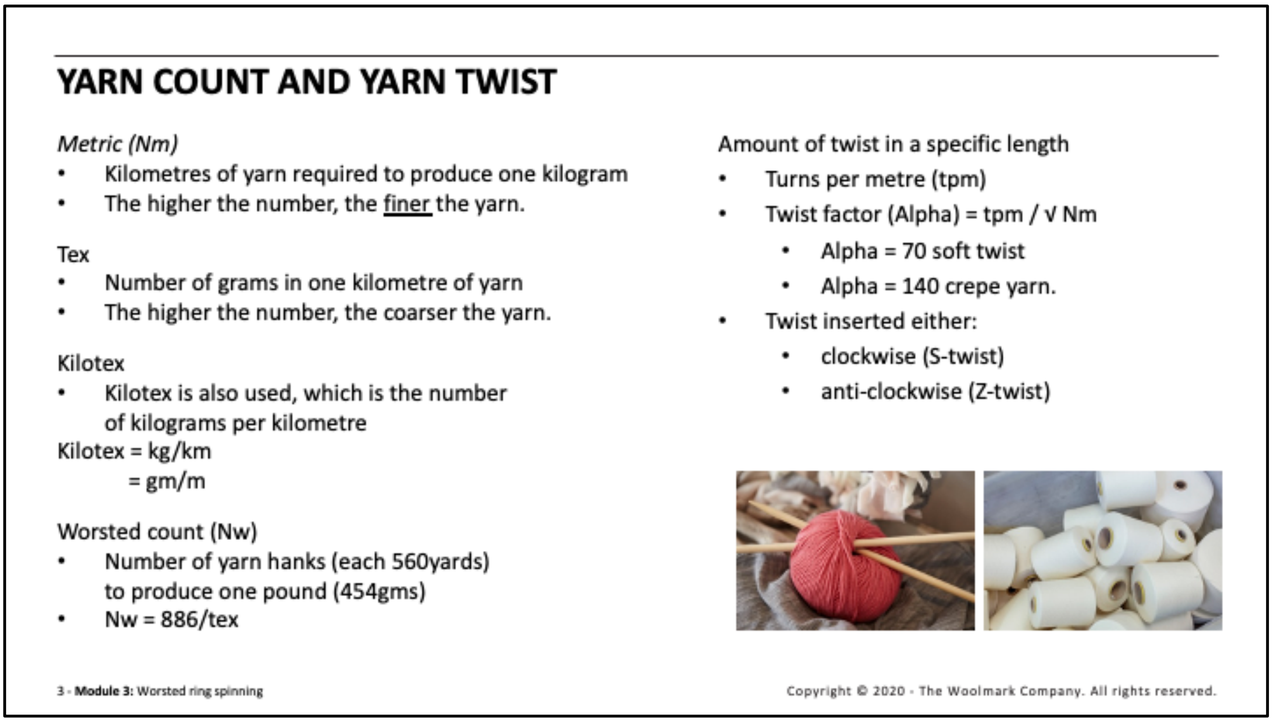
***ALLOW** participants sufficient time to respond.*

***IF NECESSARY** confirm twist is inserted to give the yarn strength.*

***ASK** participants to explain how twisting gives the yarn strength.*

***ALLOW** participants sufficient time to respond.*

***IF NECESSARY** confirm twisting the yarn increases cohesion and friction between adjacent fibres.*



POINT OUT that this slide provides a quick revision of the concepts of yarn count and yarn twist.

Yarn count
Yarn count is the linear density of the yarn. This may be expressed as
- mass/course length (direct system)
- length/course mass (indirect system).

NOTE THAT there have been many different systems developed and used to define yarn count over the years. Two or three important systems have been adopted in the worsted yarn trade.

The most common is **the metric system (Nm)**.
- Nm = the number of kilometres of yarn which weigh one kilogram.
- The higher the number; the finer the yarn.
- Examples: Nm 8 is relatively coarse yarn, while Nm 80 is relatively fine yarn.

A second system is the ISO-recommended **tex system.**
- Tex is the weight in grams of one kilometre of yarn.
- The higher the number; the coarser or heavier the yarn or sliver.
- Examples: 80 tex is a coarse yarn, while 8 tex is a very fine yarn.

The course kilotex (ktex) is also used
- kilotex= kg/km = gm/metre

Worsted count system (Nw), is the traditional method which is now little used, but is used frequently enough to sometimes cause confusion.
- Nw is the number is the number of hanks of yarn (each 560 yards in length) required to weigh one English pound (454g). The higher the number; the finer the yarn.

Conversions
- Nm = 1000/tex
- Nw = 886/tex.

Yarn twist
Yarn twist refers to the number of turns inserted in a textile strand over a specific length. Most often, the number of turns per metre (tpm) is used.

POINT OUT that if turns turns per metre are used to describe yarn in isolation of yarn count, it becomes confusing to communicate if different counts of the yarn are softer or harder due to twist as the yarn count changes.

INDICATE THAT to allow sensible comparison across different yarn counts, both yarn count and twist are combined into a single index. This index is referred to as the **twist factor** or **twist alpha**.
- Alpha = tpm / √ Nm
- Alpha = tpm x √ tex.

Typically ranges for the metric spinning alpha are from 75 for soft knits to 125 for singles weaving.

EXPLAIN THAT the twist can be inserted in either the clockwise (S-twist) or anti-clockwise (Z-twist) direction. The direction of the twist is of significance for the appearance of the finished product.

INTRODUCE the following video, produced by The Woolmark Company (TWC), offers a brief overview of the ring spinning process.

PLAY *video (43:00 seconds)*

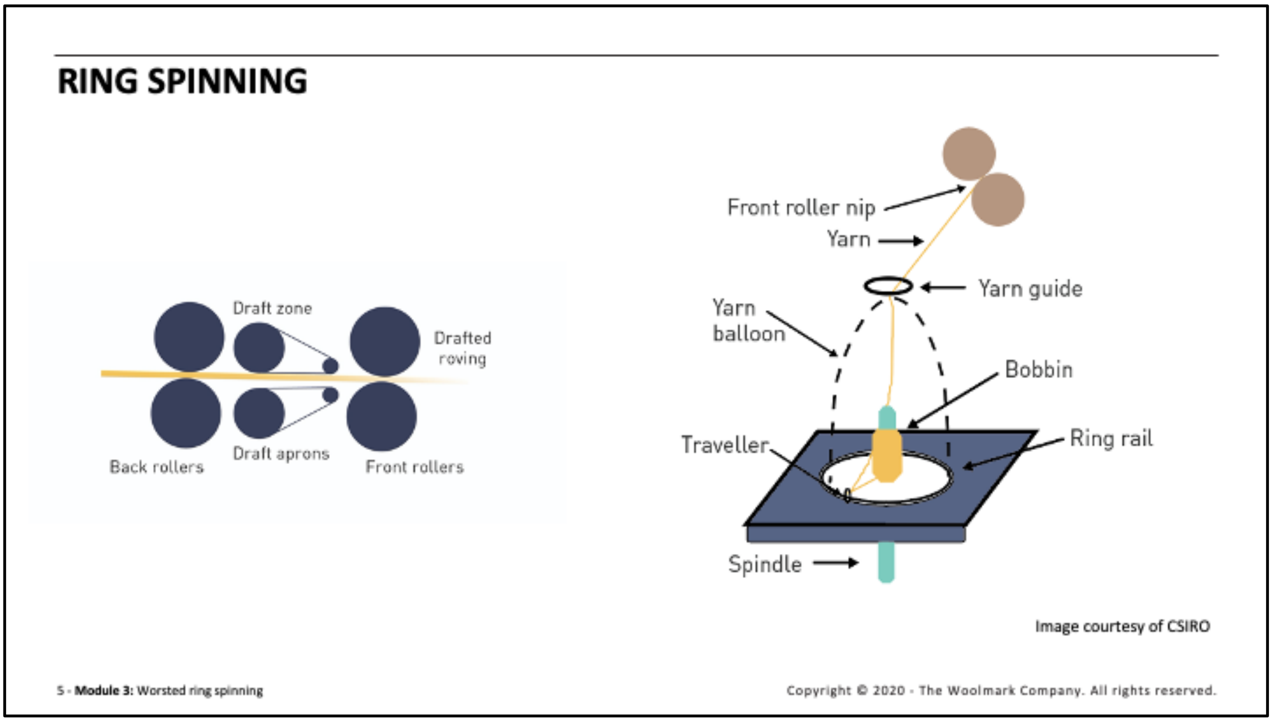
AS THE *video plays note:*

- *the large number of spindles on each frame. (2:00 seconds)*
- *the machine drafts or stretches the roving and aprons are used to achieve fibre control (8:63 seconds)*
- *the machine twists the fibre strand (19:35 seconds) and winds the yarn onto a bobbin. (30:00 seconds)*
- *the bobbins are removed automatically or manually (34:00 seconds).*

ASK *participants to indicate who has studied ring spinning as part of their textile program.*

CALL *for volunteers to explain the action of the ring frame.*

ALLOW *sufficient time for participants to respond.*



EXPLAIN THAT many principles have been employed to spin wool including:

- flyer spinning
- cap spinning
- mule spinning
- ring spinning
- modified ring spinning
- alternative techniques.

NOTE THAT flyer and cap spinning are no longer used in commercial operations and will not be discussed

Ring spinning

Ring spinning is the most common spinning method in use today to manufacture wool yarns and will be the focus of this module.

EXPLAIN THAT in beginning this process, a twin roving is pulled off the freely-suspended packages in the feed zone of the spinning machine. These strands are separated, and enter the drafting zone at adjacent spindle positions.

Drafting

The drafting zone consists of input and output rollers running at the required speed differential. The linear density of the roving is reduced as it passes through the drafting zone to that of the desired yarn.

Drafts around 20 are typical (i.e. the roving is stretched to 20 times its original length and the weight is reduced by a factor of 20).

Fibres are controlled by two synthetic aprons driven by rollers that are recessed so a light pressure is exerted on the drafting strand.

Imparting twist

Upon emerging from the output drafting rollers, twist is inserted.

EXPLAIN THAT the fibre strand is attached to a spindle positioned inside a ring and running at high rotational speeds (as depicted in the diagram on the slide). There is one spindle for each strand of fibres being processed.

POINT OUT that from the drafting zone, the yarn is threaded through a yarn guide then a clip (called a traveller), which is free to move around the ring rail and rotates with the spinning spindle inserting the twist to the yarn.

Winding onto the bobbin

The traveller also winds the spun yarn onto the bobbin or a cardboard tube placed on the spindle

The ring and traveller move up and down relative to the spindle, distributing yarn regularly on the cardboard tube.

MENTION THAT sufficient twist is inserted in the fragile fibre strand to impart enough strength to:

- allow the strand to pass efficiently through the next stages of fabric manufacture
- meet the requirements of the final product.

WORSTED RING SPINNING

6 - **Module 3:** Worsted ring spinning

NOTE THAT a worsted ring spinning machine typically will have anywhere from 100 to 500 spindles on each side of the machine.

INDICATE THAT drives to the machine can be common to both sides but more usually, each side is driven independently.

Depending on the fineness of the yarn and the amount of twist needed, spindle speeds are commonly 7000 to 12,000 rpm.

EXPLAIN THAT A Z-twist is usually inserted at the worsted spinning frame and twist levels vary from about 300 to 1000 tpm. If the twist required is 500tpm, and the spindles are turning at 10,000rpm, then the delivery speed of the machine is 20 m per minute.

NOTE THAT due to this relatively low production per spindle, many spindles are required for a reasonable productivity.

Typically, ring diameters are 44 to 60 mm.

SETTINGS IN RING SPINNING

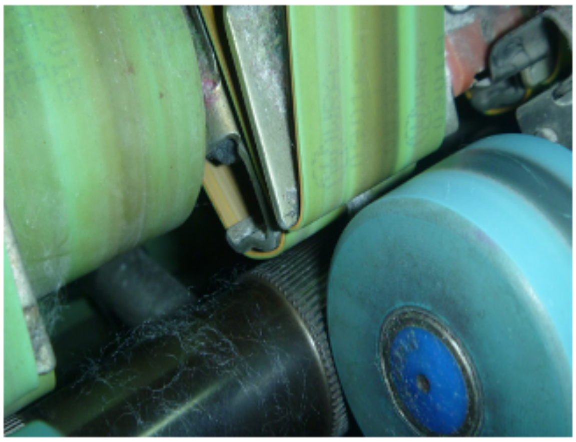


Image courtesy of CSIRO

- Draft aprons to front roll nip
- Tensor or gap setting
- Condensers
- Drafting roll condition

7 - **Module 3:** Worsted ring spinning

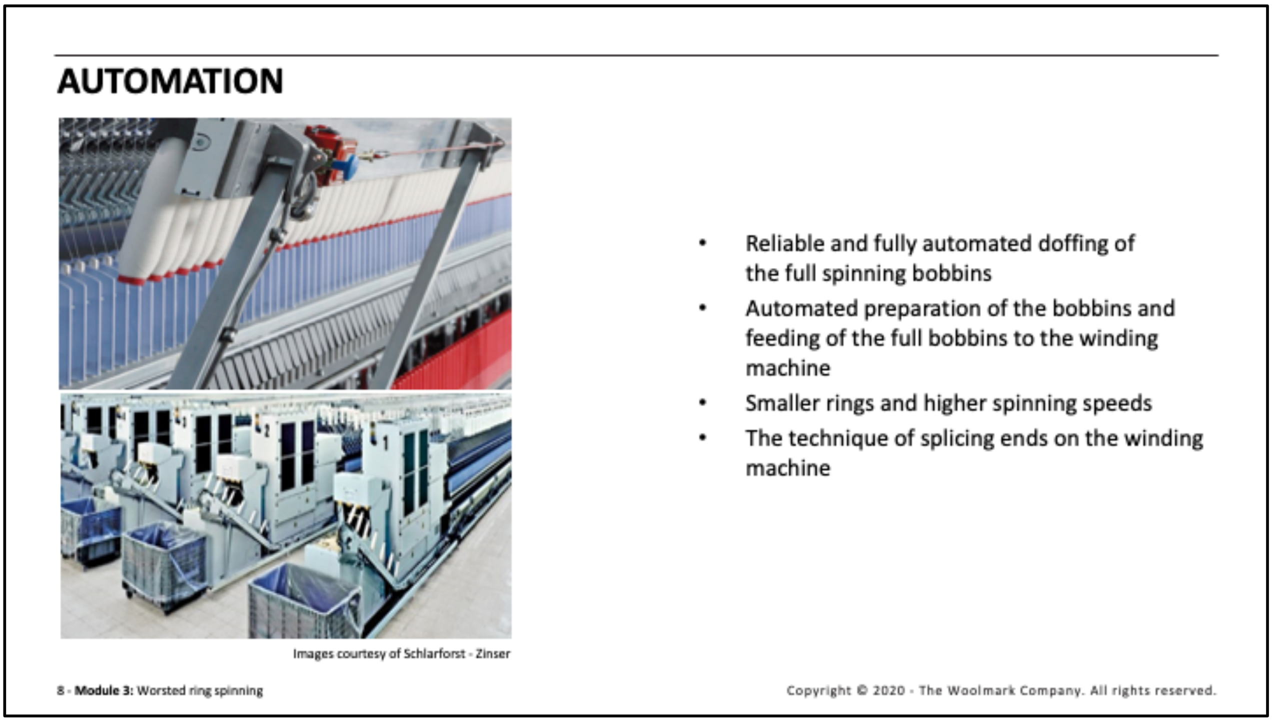
INDICATE THAT in practice, there are only a few setting points on ring spinning machines that have a significant effect on yarn quality and subsequent processing.

EXPLAIN THAT on most spinning machines, the distance between the draft aprons and the position of the front roll nip to these draft aprons is usually adjustable. The recommendations of the machine maker should be observed. A general rule of thumb is to adjust these settings as close as is practical, taking into account the fibre and yarn specifications required.

EXPLAIN THAT the distance between the deflection edges of the top apron cradle and guide bridge is known as the tensor setting or gap. This setting determines how firmly the top and bottom aprons are pressed against each other. It is important for the yarn and roving counts to be matched and then this gap setting be selected accordingly.

NOTE THAT manufacturers provide different guide plates or clips — the coarser the yarn count, the wider the clip. This clip should always be selected as tight as is practical.

EMPHASISE THAT the drafting rollers and the condensers must be well maintained.



EMPHASISE THAT in the finest-quality textiles, worsted ring spinning remains the method of choice.

INDICATE THAT to meet the demands due to increasing costs of production, especially in Western Europe during the 1990s, manufacturers of ring spinning machines responded to their customers by:

- raising the degree of automation within these machines
- linking this machine to the feed and delivery needs of the machine.

EXPLAIN THAT automatic doffing of full spinning bobbins has become standard, where the full bobbins are removed from the spindles and replaced by empty bobbins.

Empty bobbins are presented to the spinning frame on a conveyor and the full bobbins are taken away by the same conveyor. Using this conveyor system, the spinning frames can be directly linked to winders.

POINT OUT that automation has allowed the use of smaller rings and bobbins, which were formerly avoided to reduce the number of 'dofts' required. Smaller rings have allowed higher spinning speeds, which are limited by the traveller speed on the ring.

Smaller bobbins and rings also means more joining of yarns in winding but again this has been overcome by the use of automated splicing (discussed later in this course)

POINT OUT one problem, which has had to be overcome in worsted spinning, is that wool singles yarns are normally steamed before winding to reduce twist liveliness.

Several companies have introduced in-line steamers where the bobbins are transported from the spinning frame through the in-line steamer on a conveyor before being presented to the winder.

EXPLAIN THAT at the same time, winder manufacturers have also improved their machines to allow winding of twist-lively yarns by maintaining the yarn ends under tension.

NOTE THAT it is becoming increasingly difficult for spinning mills to find reliable staff. As a result, the automation trend is gaining greater momentum worldwide. Automation also increases and assures yarn quality.

LIMITS: FIBRE DIAMETER

	WOOL		COTTON
Fibre diameter(µm)	18	22	12
Yarn count (Nm (@ 40 fibres)	78	52	114
Yarn count (Nm (@ 35 fibres)	90	60	130
Minimum fabric weight (gsm) (based on 40 fibre yarns) • Plain weave • Gabardine	160 190	205 240	75 90

Source CSIRO

9 - **Module 3:** Worsted ring spinning

EXPLAIN THAT because of the random positioning of fibres along the yarn inherent to the spinning process, it is impractical to spin yarns with much less than 40 fibres on average in the yarn cross-section.

INDICATE THAT this limits the finest yarn that can be spun and the minimum weight of the subsequent fabric. In some situations fibres in the cross-section can be reduced to 35, but generally at the expense of more ends down during spinning and lower quality yarn

EXPLAIN THAT worsted spinning is principally a balance between:

- the cost of the wool with the maximum mean fibre diameter that can be used to spin a yarn of a designated count
- satisfactory spinning performance and yarn and product quality.

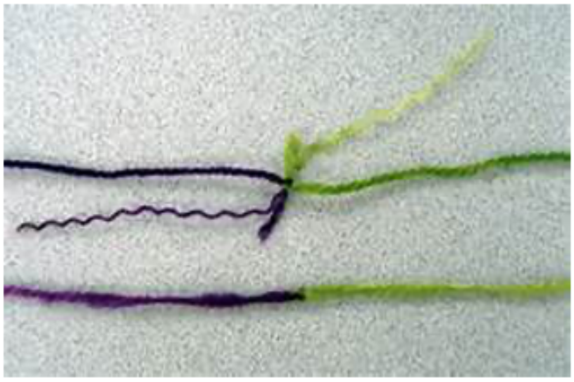
POINT OUT that beyond this, the next most important fibre and top properties in order of importance in determining the limits of spinning are:

- hauteur — longer fibres have lower spinning limits (finer yarns)
- fibre strength — stronger fibres have lower spinning limits
- CV of diameter — wool with lower CV has have lower spinning limits
- crimp (in some instances) — limited studies on the impact of this property have been inconclusive. No clear answer to this question has been developed for modern spinning

NOTE THAT the limits for the yarn that can be spun for a particular fibre diameter need to be considered when developing the specification for the top.

REFER participants to the table showing the finest yarn counts that can be spun on wool and cotton. As cotton has a smaller fibre diameter than wool, cotton yarns can be finer than those from wool. This allows the weaving of lighter-weight fabrics. Typical minimum weights of a plain weave and gabardine are shown.

SPINNING BREAKS (ENDS DOWN)



EDMSH — ends down per thousand spindle hours

For wool spinning at limit condition:

- <20 EDMSH is excellent
- 20 – 50 EDMSH is acceptable
- >70 EDMSH unacceptable.

10 - **Module 3:** Worsted ring spinning

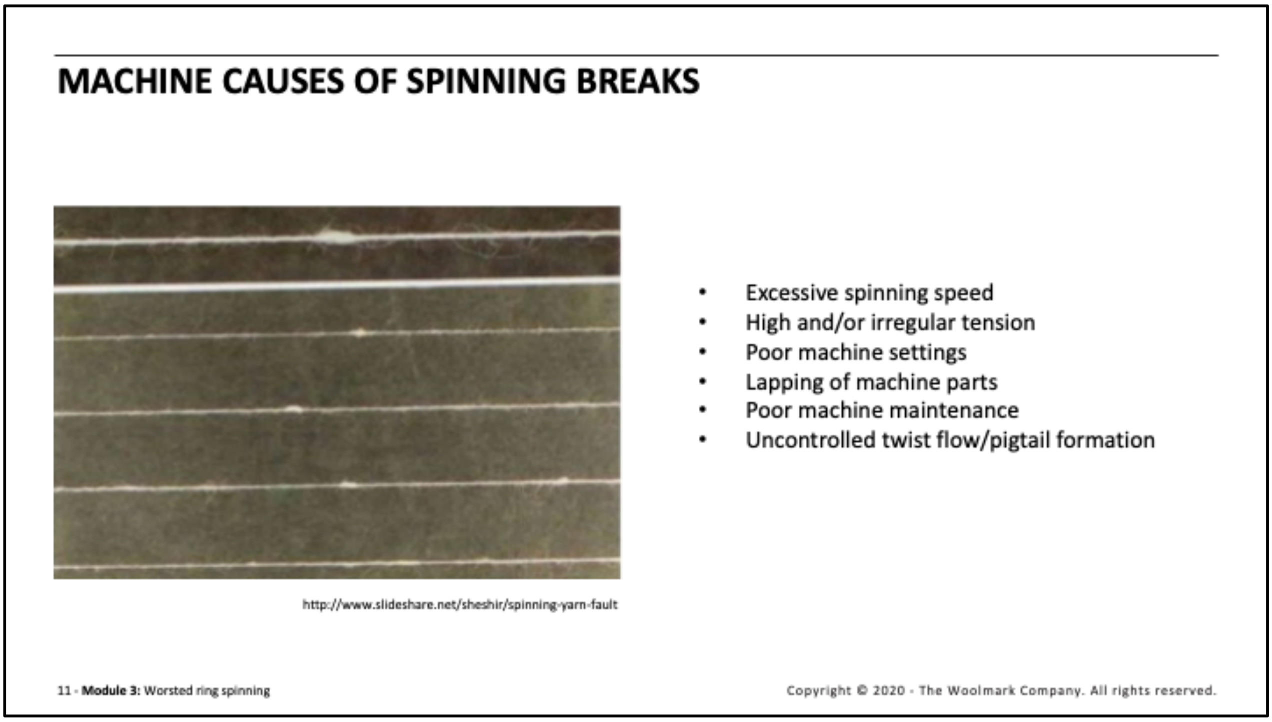
INDICATE THAT in practice, the number of end breaks in spinning determine the success of the spinning operation. The ends down are usually measured as ends down per thousand spindle hours (EDMSH).

POINT OUT that ends down in spinning cause:

- loss of production = impacts negatively on profit margin
- reduced yarn quality (more splicing or knots)
- problems in subsequent processing
    - warp breaks in weaving
    - yarn breaks in knitting.

EXPLAIN THAT the goals are usually applied to wool spinning at limit condition (i.e. the finest yarn that can be spun with a given wool type 35 — 40 fibres in the cross-section)

- <20 EDMSH is excellent
- 20 to 50 EDMSH is acceptable
- >70 EDMSH is unacceptable and will probably indicate stoppages are likely to occur in fabric manufacture.

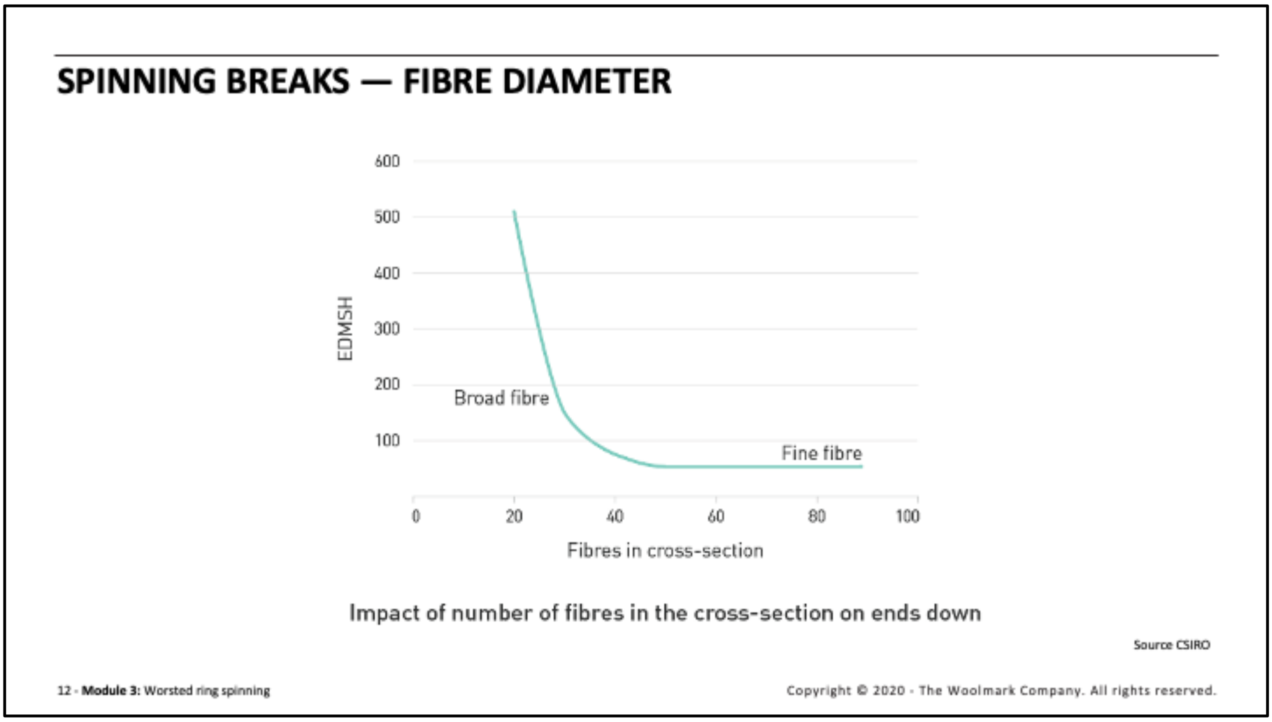


EXPLAIN THAT there are many machine factors that lead to spinning breaks, including:

- excessive spinning speed. Suspected inferior yarn quality and excessive ends-down can be compensated for by slowing the spinning speed and possibly increasing the twist.
- high and/or irregular tension in the fibre stream
- inappropriate machine settings (wrong apron spacer, wrong back-draft etc.)
- lapping of the rollers and other machine parts. Lapping describes the situation where fibres (or the whole roving) wind around rollers rather than continuing their path through the draft zone and onto the spinning bobbin. Lapping of rollers can arise if
    - the wool is too dry or there are wet patches
    - there is insufficient lubrication or anti-static treatment
    - there are excessive residuals on the wool after scouring
    - the rollers have become dirty or degraded.
- poor machine maintenance (worn rollers, rings, pig-tails or aprons, eccentric spindles, slipping drives, misaligned components, missing ring lubrication etc.)
- uncontrolled twist flow/pigtail formation

INDICATE THAT establishing the actual cause of underperformance can take considerable time, but firstly requires the ability to measure yarn and fibre properties under standard conditions.

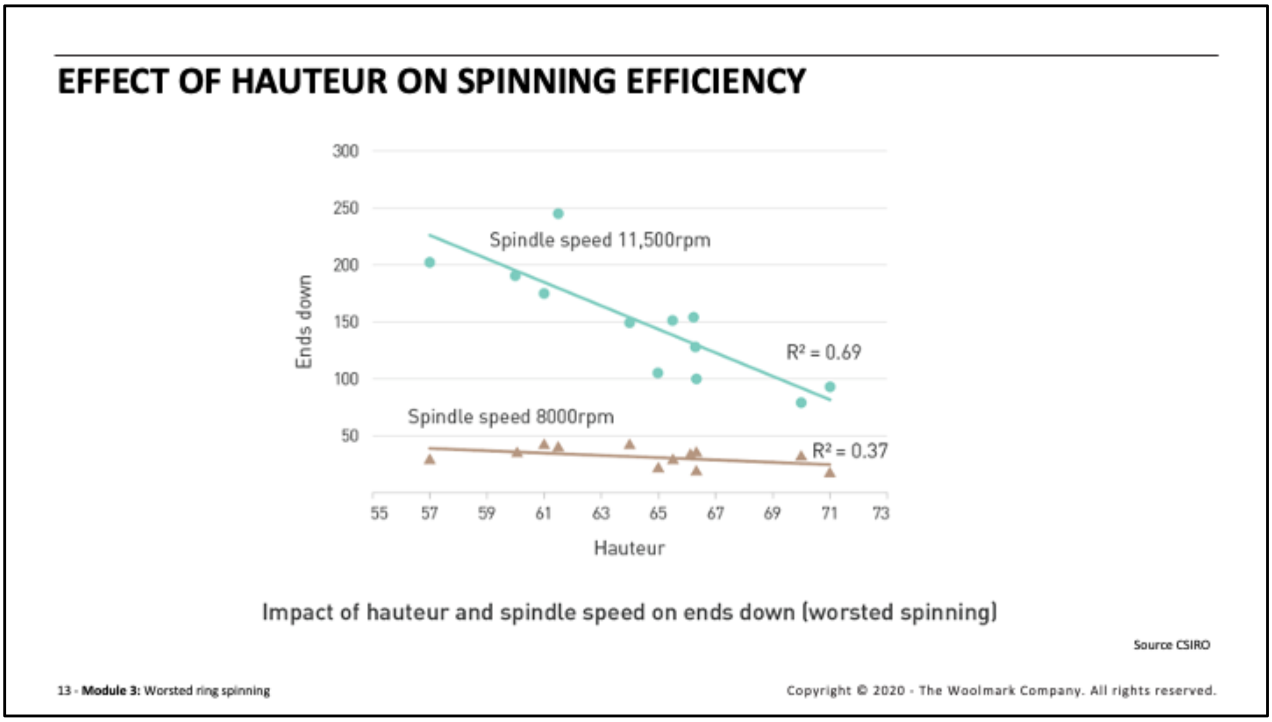
NOTE THAT problems can also become apparent in downstream processing, but most should be picked up early if sliver and yarn properties are monitored.



EXPLAIN THAT the number of end breaks during spinning also depends on the number of fibres in the cross-section.

A range of 35-40 fibres in the cross-section is considered the spinning limit for most wool yarns. Below this limit there is a rapid increase in the end breaks and a reduction in the regularity of the yarn as illustrated on the slide.

NOTE THAT ends down is also affected by fibre length and strength characteristics as well as the conditions of spinning, such as twist and traveller speed and the condition of the spinning machine as mentioned.



To determine the impact of fibre properties on spinning, 1/44Nm yarns were spun with 45 fibres in the cross section, at both 8000 and 10,000rpm.

POINT OUT as shown in the diagram, at low spindle speeds, hauteur has little effect on end breaks. However, under the higher stress encountered at the elevated spindle speed, longer fibres spin with fewer end breaks.

NOTE THAT in the same study, no reliable relationship was found between staple strength and position of break (POB) with spinning breaks, apart from a weak indication that rovings produced from batches of the lowest strength wools may give a poorer performance.

EXPLAIN THAT under the higher stress encountered at the elevated spindle speed, poorest spinning efficiency was evident for the lowest staple strength wools (results not shown). In most cases those batches of wool with a position of break (POB) in the middle of the staple have produced more ends down than those with a POB near the tip or base.

NOTE THAT in view of the wide range of hauteur and short fibre contents of the wools used in this study, it is perhaps surprising to find no consistent relationship between breaks in subsequent winding, Classimatt faults, or faults detected in subsequent clearing and staple strength and POB. Tensile properties were similarly of little relation to greasy wool properties.

These processes will be discussed again in later modules.

Faulty input materials have a big impact on spinning performance.

EXPLAIN THAT yarn properties and spinning performance are quite sensitive to small changes in fibre properties, such as:

- fibre damaged during dyeing, irregular roving, slubs, bad joining etc.
- low fibre moisture content (due to low relative humidity in the spinning room).

LIMITS ON SPINNING PRODUCTION (M/MIN)

	SPINDLE SPEED (RPM)	
	12,000	30,000
	PRODUCTION RATE	
Wool (700 tpm)	14.3	Excessive end breaks
Cotton (840 tpm)	11.6	35.4

Source CSIRO

14 - **Module 3:** Worsted ring spinning

EXPLAIN THAT there is a limit to the speed with which a worsted yarn can be spun using wool. Wool fibres are relatively weak, but quite extensible. Wool needs to be processed at somewhat lower spinning speeds than its competitors.

POINT OUT that as outlined on the slide, cotton can be spun at 30,000 rpm, whereas wool is limited to around 10,000 rpm.

Cotton spinning is aided by the natural waxes on the fibre which assist greatly in:

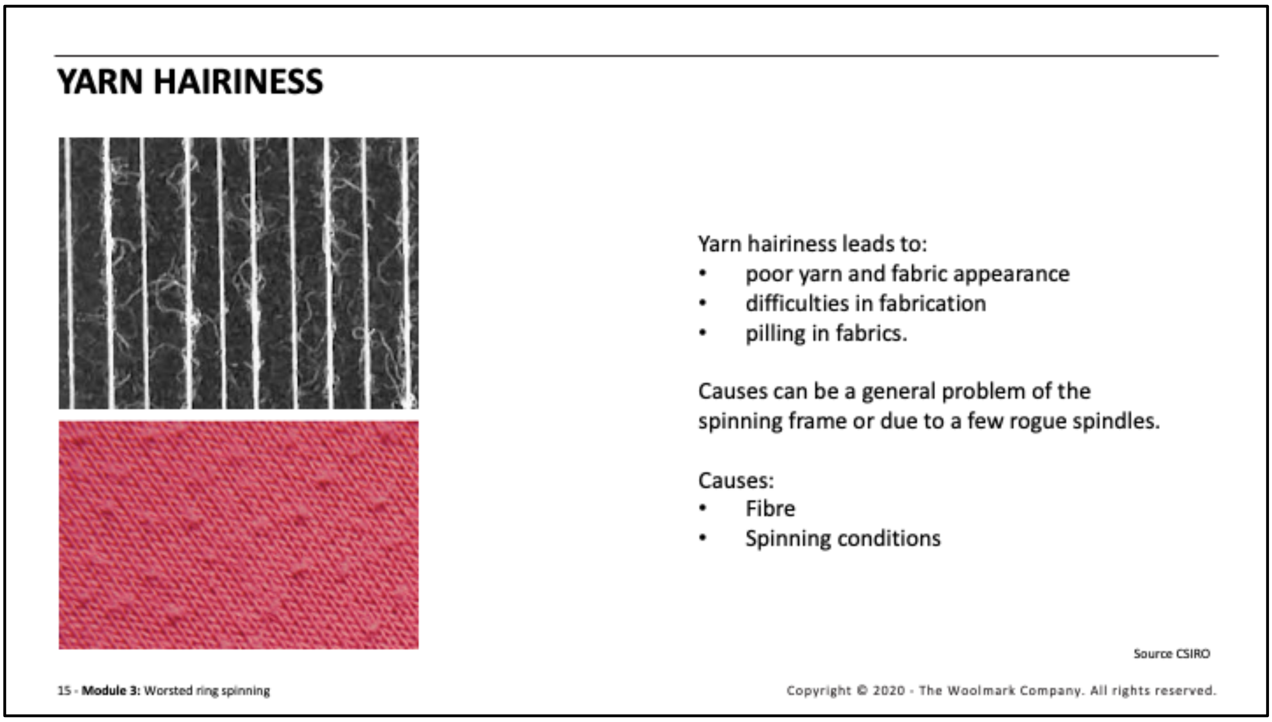
- providing lubricants at the ring/traveller interface to reduce metal-to-metal friction
- reducing frictional drag on the yarn in the spinning balloon.

As wool is relatively dry fibre, a lubricant must be added into the ring/traveller interface. This improves spinning performance, however the lubricants are not as effective as the natural waxes derived from the cotton fibre.

NOTE THAT the high strength of synthetic fibres allows even higher spinning speeds.

The ring and the traveller are the elements of the spinning machine that determine the working conditions in spinning.

EXPLAIN THAT in practice, the mechanically-possible speeds are rarely reached because of the limit set by the maximum linear speeds of the traveller. This in turn limits the application of the maximum potential speed of the spindles.



POINT OUT that unacceptable levels of hairiness in yarns leads to:

- poor weaving and knitting performance in fabrication
- poor appearance in the resulting fabric
- easier loosening of hairs from rubbing during wear, which leads to:
    - poor abrasion resistance
    - excessive pilling.

NOTE THAT the slide shows examples of yarn hairiness and fabric pilling.

EXPLAIN THAT hairiness in yarns can be a general problem with the spinning department or related to a particular batch of fibre, caused by a few or several individual rogue spindles.

If left uncontrolled, these few bobbins of yarn are then spread randomly through the fabric leading to downgrading or rejection.

NOTE THAT some of the more frequent fibre-related causes of yarn hairiness arising from the fibre used are given on the slide.

Material

- Finer fibres tend to give hairier yarns.
- Fibres with lower regain (moisture content) tend to give hairier yarns.
- Rubbing of synthetic fibres raises hairs more than natural fibres like wool. Nylon tends to be more difficult than polyester.

Fibre length

- Longer fibres tend to have fewer fibre ends in the yarn reducing hairiness.

Crimp

- Low-crimp fibres are less bound into the yarn structure, increasing hairiness.

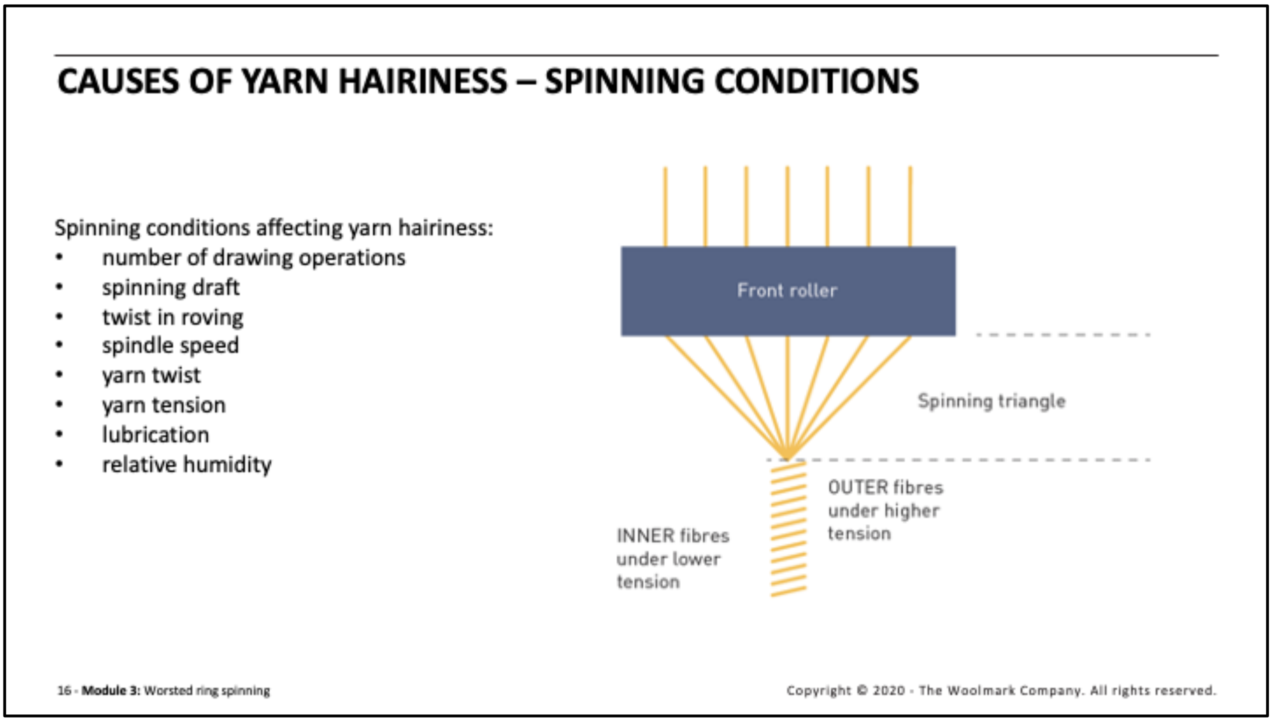
The spinning conditions are shown on the next slide.

ASK *participants to explain under what circumstances is hairiness in yarns considered a disadvantage and when it is considered an advantage.*

ALLOW *participants sufficient time to respond.*

IF NECESSARY *confirm that:*

- *hairy yarns can be more difficult to weave and knit*
- *for some woollen products hairy texture may be desirable.*



POINT OUT that spinning conditions can also affect yarn hairiness.

Number of drawing operations
Provided associated care is maintained in the spinning system, then increased numbers of drawings can slightly reduce hairiness.

Spinning draft
According to the fibre material, high drafts assist with keeping the fibrous strand narrow in the drafting system and in turn in the spinning triangle reducing hairiness.

Twist in roving
While only having a small effect, false twist imparted by the rub-rover is better at reducing hairiness than real twist. Higher twist levels help reduce hairiness.

Spindle speed
Increased spindle speeds increases hairiness.

Yarn twist
Higher twist reduces hairiness.

Yarn tension
Hairs are determined by the length and width of the spinning triangle. A useful level of tension:

- minimises yarn contact with machine elements,
- ensures free flow of twist to the delivery rollers
- both narrows the triangle, while reducing its length.

A front zone condenser will improve hairiness if properly set and maintained.

Lubrication

- Insufficient lubricant increases hairiness.
- Special care is needed after dyeing of fibre or yarn.
- Lubricant needs to be considered along with regain (moisture content).

Relative humidity (RH)

- Hairiness increases if the fibres are too dry.
- Adequate moisture should be available to the fibre.
- If possible, the roving should be rested in a high RH room.
- Spraying water onto the fibre surface can make hairiness worse.
- The moisture needs to be within the fibre (not on the surface).

EXPLAIN THAT as illustrated on the slide, within the spinning triangle, the fibres on the edge are under higher tension than those in the middle. When the trailing edge of these outer fibres comes out of the front roller of the draft zone it can move outwards and create a hair on the surface of the yarn. These hairs are then rubbed up by the traveller in spinning or in yarn guides in winding.

CAUSES OF YARN HAIRINESS – SPINNING MACHINERY

Machinery impacts:
- Roller assembly (setting, condenser)
- Thread guides
- Traveller/ring
- Yarn tube length
- Yarn tube diameter
- Winding

17 - **Module 3:** Worsted ring spinning

EXPLAIN THAT the processing machinery can impact on hairiness.

Roller assembly (setting, condenser)
- Close settings are preferred, especially those between the double apron course and the front delivery rollers.

Thread guides
- Friction between yarn and guide should be minimal.
- Surface damage to the thread guides should be minimal.

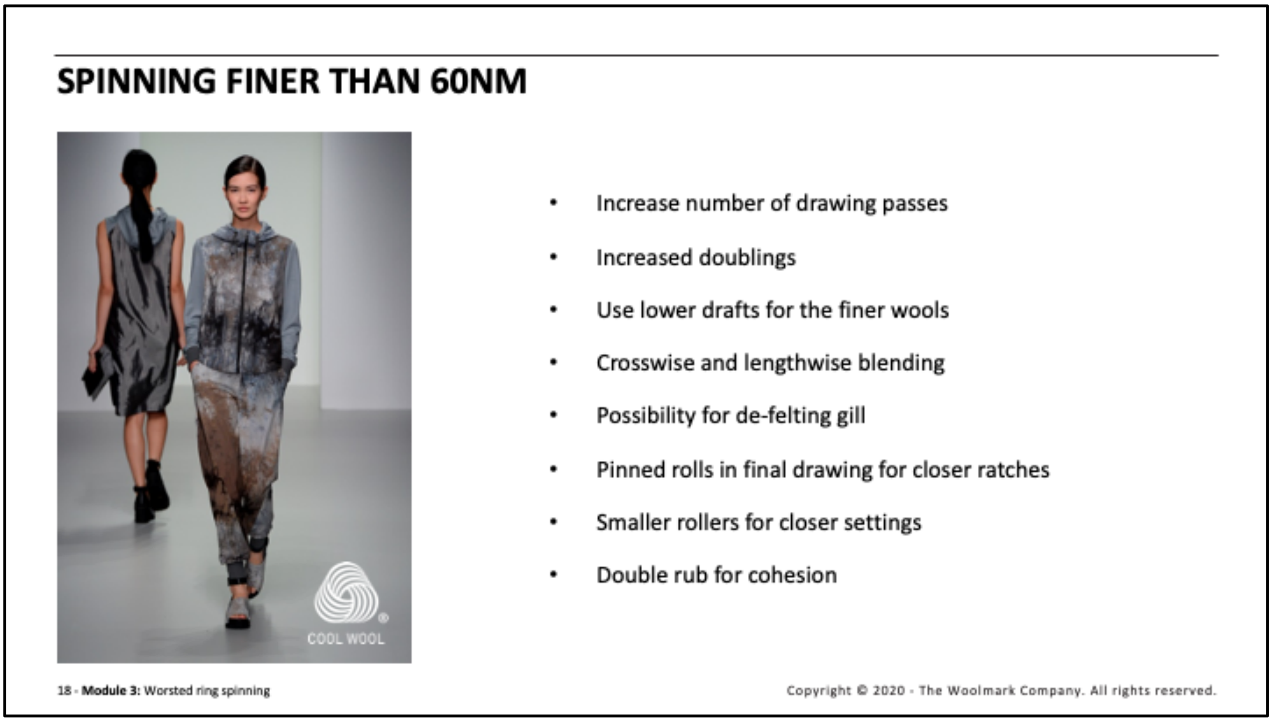
Traveller/ring
- Friction between ring and traveller should be minimised.
- The best profile traveller for the yarn count and fibre material should used. Nylon travellers tend to produce more hairy yarns.

Yarn tube length
- Longer lengths can increase hairiness.

Yarn tube diameter
- Optimal diameter should be used.

Winding
- Winding the yarn from bobbin to cone can significantly increase hairiness.
- There should be minimum contact with machine parts on the winding frame and these elements should be smooth where contact is unavoidable.
- Adequate tension on the yarn assists with minimising yarn/metal contacts and resulting hairness.

EXPLAIN THAT combinations of low regain with other faults (e.g. poor surface condition) can be disastrous in their effect on hairiness.



INDICATE THAT during the past two decades, there has been a trend toward lighter fabric weights. This demands finer and finer yarns. Due to the spinning limit of around 35 to 40 fibres in the yarn cross-section, wool with finer fibre diameters must be selected to meet the demands of this trend.

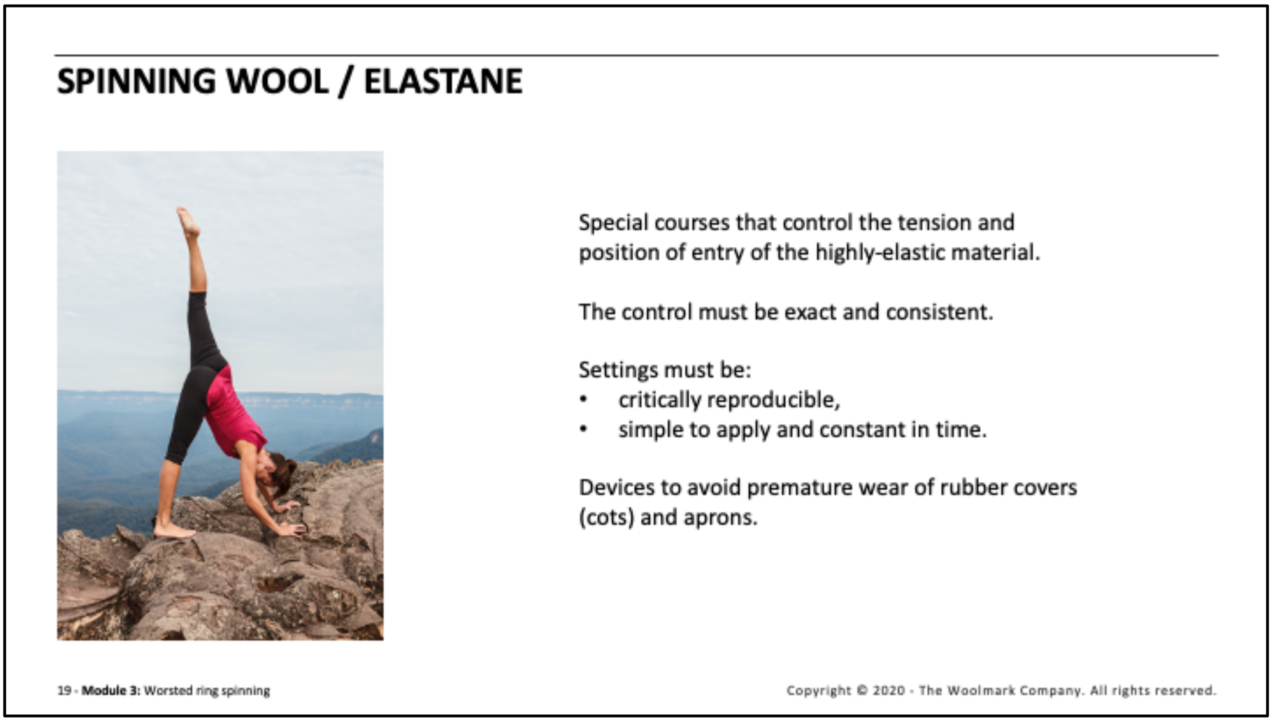
POINT OUT that machinery manufacturers have developed specialist sets of machines to meet the stringent requirements of producing a high-quality yarn with so few fibres in the yarn.

EXPLAIN THAT these developments also include an increase in the number of processes between top and finisher gill ensuring a high-quality roving. For a 60 to 100Nm yarn up to 10 operations are recommended compared with the five normally employed for yarn counts of 50Nm or less.

Additionally, new designs in the drafting processes and machinery were required to control the generally shorter wools associated with finer wool fibres.

EXPLAIN THAT these developments, which normally involve improvements to the quality of the roving, include:

- an increase in the number of passes (referred to above)
- an associated increase in the total number of doublings
- an ability to reduce the total draft needed when drafting finer shorter wool styles
- introduction of a special blending frame used before combing to blend both lengthwise and crosswise directions
- fitting machines with a de-felting course to break the cohesion in dyed and/or shrink-resist treated wool
- the use of special pinned rollers in the final drawing to allow better fibre control via closer-set ratches.
- smaller diameter rollers in the drafting zone of the finisher to allow closer ratches to 25mm
- a double rubbing system that provides the necessary cohesion in these finer count roving while still allowing working speeds of 2200 rubs/min.



POINT OUT that during the past 10 years stretch has become an integral part of the fashion industry, especially sports fashion.

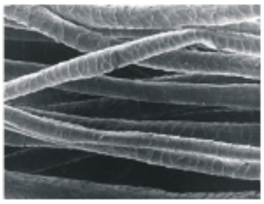
NOTE THAT a popular method of producing stretch wool garments is the use of wool/elastane blend yarns (e.g. wool + Lycra combinations). To spin such yarns effectively, special courses that control the tension and position of entry of the highly-elastic filament into the region on the spinning machine in which the wool is running are required.

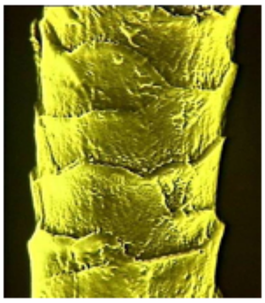
INDICATE THAT the control must be exact and consistent on each and every spindle. Settings must be:

- critically reproducible
- simple to apply and constant in time.

NOTE THAT dedicated devices to avoid premature wear of rubber covers and aprons are also a vital design aspect of these courses.

SPINNING FELT-RESIST TREATED WOOL





- Change in friction
- Change in moisture absorption
- Risks of spot felting — 0.1% untreated wool can cause noticeable 'spot felting' to occur during washing.
- Risk of contamination

EXPLAIN THAT the spinning characteristics of felt-resist treated wool top and roving differ in some respects to those of untreated fibre. It is essential to follow specific guidelines for selecting fibre lubricants to assist in mechanical processing.

NOTE THAT wool that has been treated to minimise felting during domestic washing has significantly different properties to untreated wool.

INDICATE THAT a change in frictional properties of the fibres is inevitable due to:
- the alteration of the fibre surface
- the application of a polymer resin to the fibre surface. The barrier of polymer alters the dynamics of the movement of the fibre in the top.

EXPLAIN THAT a change in the moisture content of the fibres occurs as the drying to cure the polymer reduces the moisture equilibrium of the fibre mass so the steady state moisture content of the wool is lower. If not carefully monitored, the drier felt-resist treated wool can lead to difficult problems during processing.

NOTE THAT the felt-resist process must be 100% effective, as even levels of 0.1% untreated wool can cause noticeable 'spot felting' to occur during washing.

EMPHASISE THAT during manufacture there is a risk of contamination of a treated wool lot by that of untreated wool.

COSTINGS

COSTINGS

YARN COUNT FIBRE DIAMETER	YARN PRICE (AUD$/kg)	ESTIMATED CONVERSION COST (AUD$/kg)
24^{s} Nm 22 micron	17.00	6.00
56^{s} Nm 18.5 micron	23.50	11.5
72^{s} Nm 18.5 micron	27.70	16.70

Compares with combed cotton ring spun conversion cost of $3.50/kg for 1/60Nm (i.e. ratio of 3.3)

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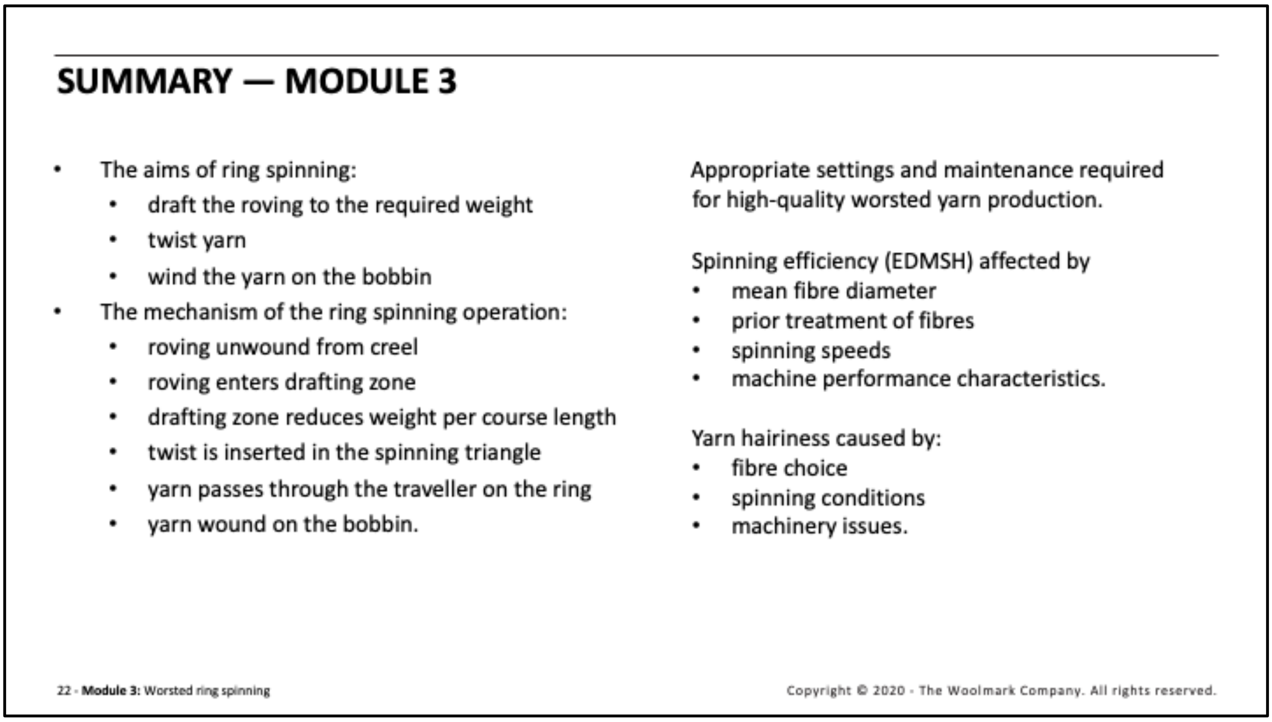
POINT OUT that finer yarns are more expensive than coarser yarns. This is a result of the increased price of the finer wool required to make a fine yarn and an increase in spinning costs as finer yarn is spun

The conversion cost of wool yarns increases with finer counts varying from about AUD$6.00 to AUD$16.70 as shown on the slide.

NOTE THAT at similar yarn counts, the conversion cost for wool processing is approximately 3.3 times that of combed cotton spinning.



REITERATE the aims of ring spinning are as follows:

- to draft the roving to the required weight
- to twist the drafted roving to form yarn.
- to wind the yarn on the bobbin.

REMIND participants the mechanism of the ring spinning operation is as follows:

- The rovings on the creel are unwound.
- The feed rollers take the roving into the drafting zone.
- Rovings are extended in the drafting zone to the correct weight/course length.
- The drafted roving enters the spinning triangle as is passes through the front (exit) rollers where the twist is inserted.
- The yarn passes through the traveller on the ring
- The yarn is then wound onto the bobbin.

REVIEW the fact that control of settings and maintenance issues is required for high-quality worsted yarn production.

Yarn counts are limited by the mean diameter of the fibre used.

REMIND participants that spinning efficiency (EDMSH) is affected by

- prior treatment of fibres
- spinning speeds
- machine performance characteristics.

EMPHASISE yarn hairiness is affected by:

- fibre choice
- spinning conditions
- machinery issues.

INFORM participants of the time and location for the next lecture — *Module 4 Variations on worsted ring spinning* — and encourage them to read through the relevant notes in their Participant Guides before attending the lecture.

ENCOURAGE participants to explore the Woolmark Learning Centre to reinforce and build on what they have covered in today's lecture.

Participants can register with and explore the Woolmark Learning Centre here: www.woolmarklearningcentre.com

THE WOOLMARK COMPANY

VARIATIONS AND ALTERNATIVES TO WORSTED RING SPINNING

RESOURCES — MODULE 4: VARIATIONS AND ALTERNATIVES TO WORSTED RING SPINNING

Contained in the *Worsted and woollen spinning* Demonstration kit you will find the following resources for use as you deliver **Module 4: Variations and alternatives to worsted ring spinning**.

– two x 1m length of top (different colours)

Additional resources to be sourced by the facilitator include:

– SiroSPUN breakout device
– Solospun roller

WELCOME participants to Module 4 of the Woolmark Wool Science, Technology and Design Education Program — *Worsted and woollen spinning — Variations on worsted ring spinning*.

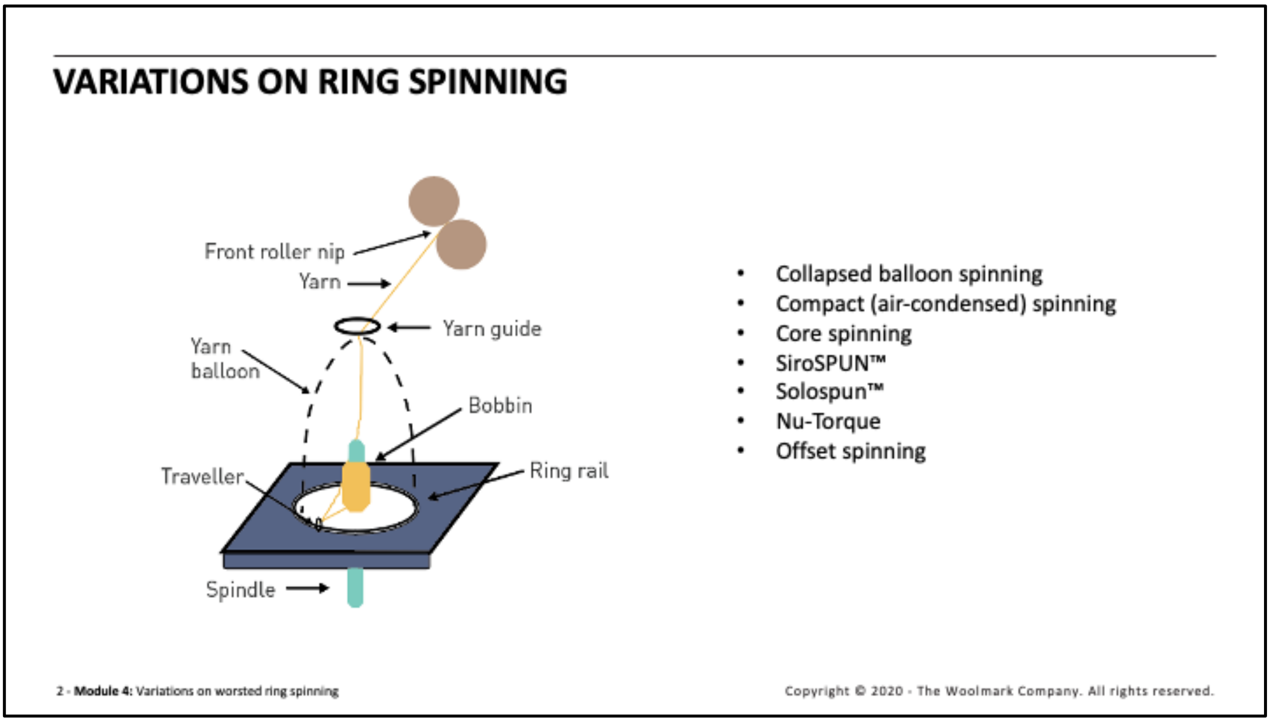
EXPLAIN THAT during the past three to four decades there has been pressure to increase the productivity of spinning technologies for all fibres. Many of these improvements have been applicable to worsted yarn spinning. Several of the developments aimed at increasing productivity in worsted spinning will be discussed in this module.

INFORM participants that by the end of this module they will be able to:

- describe alternative methods of spinning worsted yarns using ring frames
- outline the limitations, advantages and disadvantages of the alternative methods
- describe the potential areas of application for yarn spun using variations on ring frames.

RESOURCES REQUIRED FOR THIS MODULE:

- *SiroSPUN breakout device (facilitator to provide if available)*
- *Solospun roller (facilitator to provide if available)*
- *two x 1m length of top (different colours preferred)*



EXPLAIN THAT in conventional ring spinning, twist is inserted into a fibre stream to form a yarn through the action of a rotating spindle. As twist is being inserted in the yarn, it rotates around the spindle before it passes through a traveller, which is rotating around, and in frictional contact with, a stationary ring rail (often called the ring). After passing through the traveller, the yarn is wound onto a bobbin.

As the yarn rotates around the spindle, it balloons out. The yarn balloon is subject to air resistance as it is being rotated. This resistance puts strain on the yarn and is one of the limiting factors in production speed.

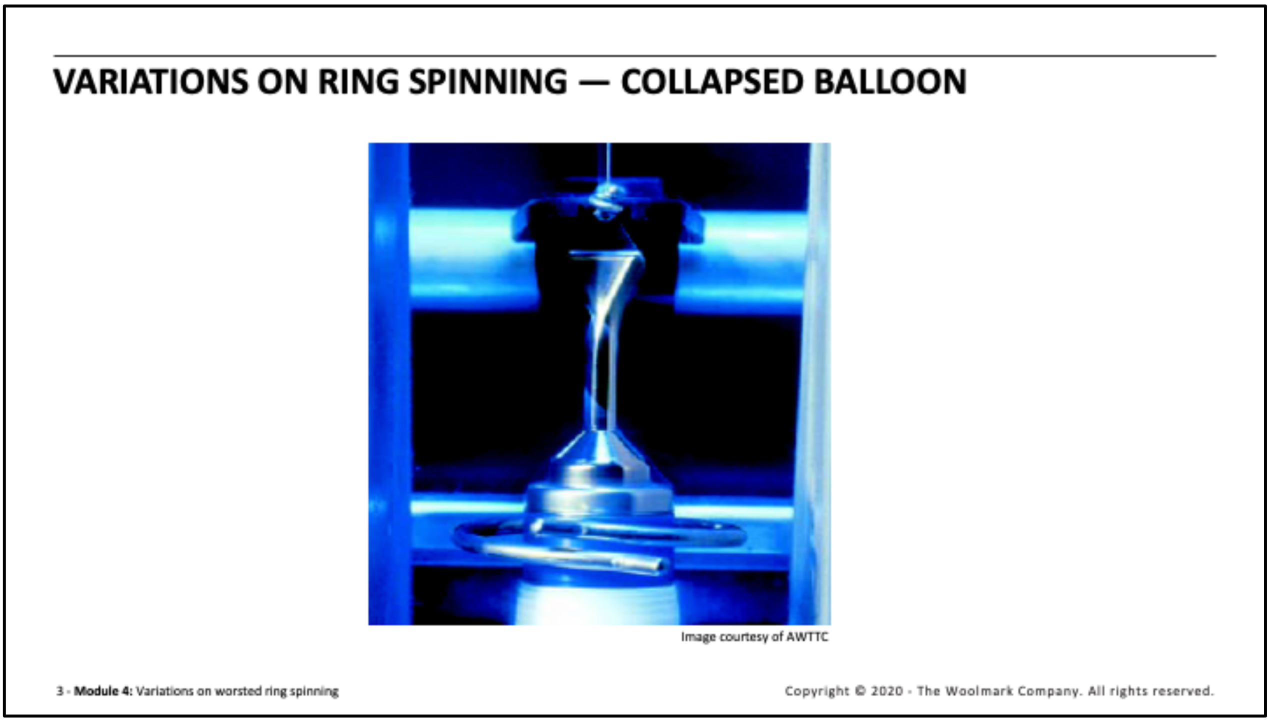
NOTE THAT friction between the ring rail and traveller is another productivity-limiting factor.

POINT OUT that during the past three or four decades, several attempts have been made to:

- reduce the strain, or tension, on the yarn during ring spinning
- better control the fibres emerging from the drafting zone in the spinning triangle.

EMPHASISE THAT several variations on ring spinning have been developed to achieve these aims and are discussed in this module, including:

- collapsed balloon spinning
- compact (air-condensed) spinning
- SiroSPUN™
- Solospun™
- Nu-Torque
- offset spinning
- core spinning.



EXPLAIN THAT one of the systems adopted recently to reduce the strain on the yarn balloon during ring spinning is known as the collapsed balloon system. This system has actually been adapted from the woollen spinning sector where a similar system has been in use for some time.

The collapsing of the 'yarn balloon' is achieved by passing the yarn around a spindle finger attached to the top of the spindle – see diagram.

The forming yarn is looped once or twice around the slightly bent spindle finger.

INDICATE THAT this prevents the yarn balloon from forming such that the yarn path spirals around in contact with the bobbin (or the yarn that has already been wound onto the bobbin) before passing through the traveller and also being wound onto the bobbin.

Reducing or eliminating the yarn balloon significantly reduces tension in the yarn.

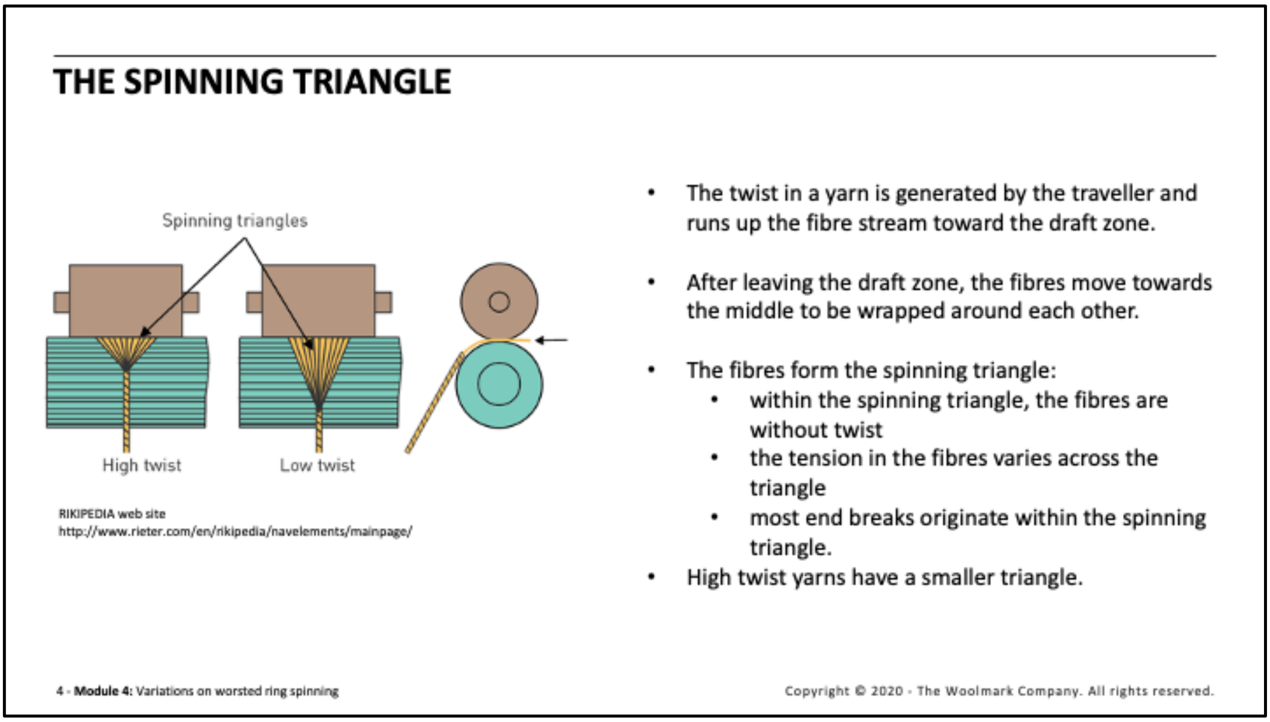
NOTE THAT tension measurements have shown that the mean yarn tension above the spindle finger is about 10–20% of the equivalent yarn spun without a spindle finger.

EXPLAIN THAT the decrease in yarn tension can be used to:

- increase the spindle speed and hence increase yarn production
- decrease the twist inserted, also resulting in an increase in production
- spin yarns with fewer fibres in the cross-section, resulting in finer yarns
- substitute finer fibres with fewer coarser fibres (end product parameters permitting) to produce yarns of the same weight per course length.

POINT OUT that one consequence of the increased yarn-to-metal contact during spinning, resulting from the contact with the spindle finger, is the teasing out of fibre ends from the yarn surface. This results in an increase in fibre ends protruding from the yarn surface and an increase in yarn hairiness.

The collapsed balloon principle is available on Zinser, Cognetex/Finlane and Guadino spinning frames.



ASK *participants if they have heard the term 'spinning triangle' and can explain it to the group.*

ALLOW *participants sufficient time to respond.*

ACKNOWLEDGE *responses before continuing.*

NOTE THAT many improvements in ring spinning have resulted from greater control of the fibres in the spinning triangle.

EXPLAIN THAT the turns of twist in a yarn are generated at the traveller and move up the yarn towards the drafting rollers as the yarn moves towards the traveller. The twist runs back as far as possible toward the nip of the final draft roller.

INDICATE THAT when the fibres emerge from the final roller, the twisting action causes the fibres to wrap around each other. To do this the fibres on the outer edge of the emerging fibre stream must move towards the centre of the stream. This creates the 'spinning triangle', which is illustrated on the slide.

Within the triangle
The tension on individual fibres varies according to their position within the triangle. Fibres within the triangle have no twist, so there is a weak point in the fibre stream.

Most yarn breaks result from disturbances within the spinning triangle.

Text and images derived from http://www.rieter.com/en/rikipedia/articles/ring-spinning/

VARIATIONS ON RING SPINNING
COMPACT OR AIR–CONDENSED SPINNING

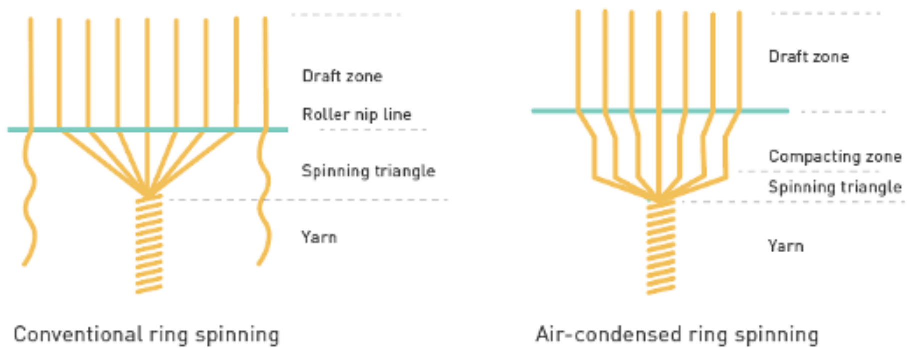


Image courtesy of NPTEL (India)

5 - **Module 4:** Variations on worsted ring spinning

EXPLAIN THAT the compact or air-condensed spinning system is an extra fibre-stream-control zone (the compacting zone) added to a spinning frame after the main drafting zone, before the twisting zone.

INDICATE THAT the compacting zone uses air to reduce the width of the drafted, but untwisted, fibre stream to almost the same diameter as the yarn.

NOTE THAT in conventional ring spinning, the drafted fibre stream has a width of a few millimetres. Twist is inserted in this fibre stream as it emerges from the front rollers of the drafting zone. The action of inserting twist results in a consolidation of the fibres, but not necessarily all fibres, into the yarn.

POINT OUT that as illustrated on the slide, the air-condensed spinning systems reduce the width and length of the spinning triangle. This improves the control of fibre ends, resulting in fewer fibre ends poking out of the yarn (i.e. the yarns are less hairy). Reducing, or condensing, the width of the fibre stream after drafting is achieved by using a controlled stream of air to draw the fibre closer together.

EXPLAIN THAT in comparison to equivalent conventionally-spun yarns, the condensing system significantly reduces yarn hairiness, improves yarn tenacity and results in more even yarns.

INDICATE THAT condensed spun yarns are stronger and more even, it would be possible to spin them at higher production rates than equivalent conventionally spun yarns. This would reduce the cost of spinning.

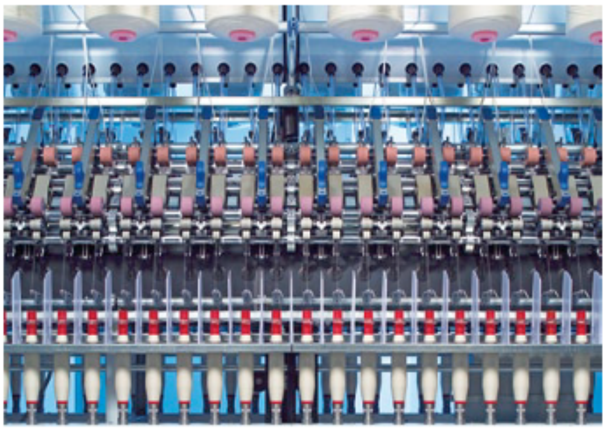
POINT OUT that air condensed yarns are finding wide application in fine worsted yarn spinning for both weaving and knitting and in medium count knitting yarns to assist with pilling reduction and fabric appearance.

NOTE: This spinning system is now very popular.

The image courtesy of NPTEL (India)

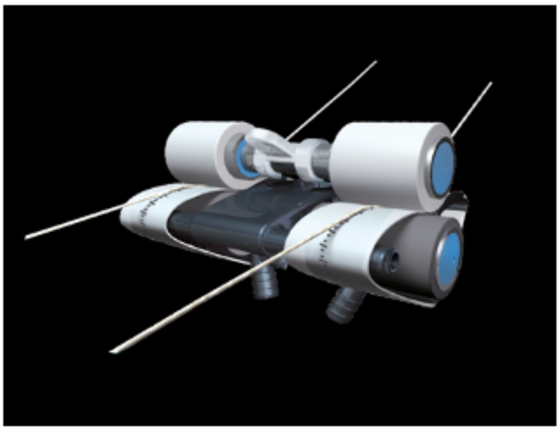
- Faculty: Textile Engineering
- Course: Yarn manufacture
- Lecture: Other spinning systems

COMPACT SPINNING MACHINERY



A compact spinning frame

Image courtesy of the Saurer Group



http://schlafhorst.saurer.com/fileadmin/Schlafhorst/pdf/Ring/Zinser_451_Impact FX_140505_EN.pdf

6 - **Module 4:** Variations on worsted ring spinning

INDICATE THAT a number of variants (manufactured by different spinning machine manufacturers) are used in the short-staple (cotton) spinning sector.

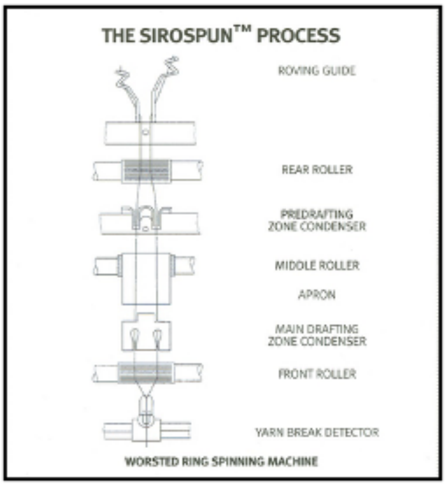
EXPLAIN THAT three variants of the air-condensed or compact spinning system have been adapted for wool worsted spinning.

An apron system.
Air is drawn through a central line of small holes to consolidate the fibre stream. The apron can be either above or below the fibre stream; this is the CSM system released at ITMA, 1995 in Milan.

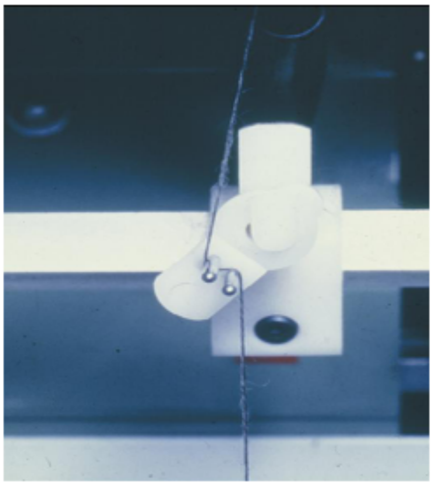
A large diameter, perforated roller system.
The perforations are situated in a central line around the circumference of the large diameter roller.

An air-permeable mesh apron system.
The air-permeable mesh apron runs over an elliptical suction tube containing a slot, or slots, which may either be parallel to the fibre stream, or offset at a small angle to the fibre stream to effect consolidation of the fibres.

VARIATIONS ON RING SPINNING — SIROSPUN™ PROCESS



Images courtesy of CSIRO



Break-out device

7 - **Module 4:** Variations on worsted ring spinning

EXPLAIN THAT traditionally for weaving, two singles ring-spun yarns are twisted together to form two-fold yarns. Conventional singles yarns cannot resist the abrasion inherent in the weaving process and must be treated in some way before they can be used.

INDICATE THAT twisting singles yarns together to produce the two-fold yarns binds the surface fibres of the singles yarns into the twisted structure so it is smoother and more resistant to abrasion during weaving.

NOTE THAT the process of spinning, steaming, winding, clearing, assembly winding and twisting necessary to created a two-fold yarn adds considerable cost to the final yarn.

Siro spinning
The SiroSPUN™ system is the combination of spinning and two-folding in a single step on the spinning machine.

EXPLAIN THAT as illustrated on the slide, two rovings are drafted and the emerging streams of fibre are spun onto the same spindle. SiroSPUN uses the torque/friction forces involved to bind two drafted roving strands together initially, and then applies twist to the two-fold structure in the conventional ring-spinning manner.

NOTE THAT a device to break out the remaining strand if one of the strands should be accidentally broken is required (see above). This device acts as a twist block when pulled off centre by the remaining strand; breaking it.

EXPLAIN THAT the SiroSPUN system has two major advantages:

- the cost of two-folding is eliminated
- the productivity per spindle on the spinning frame is effectively doubled.

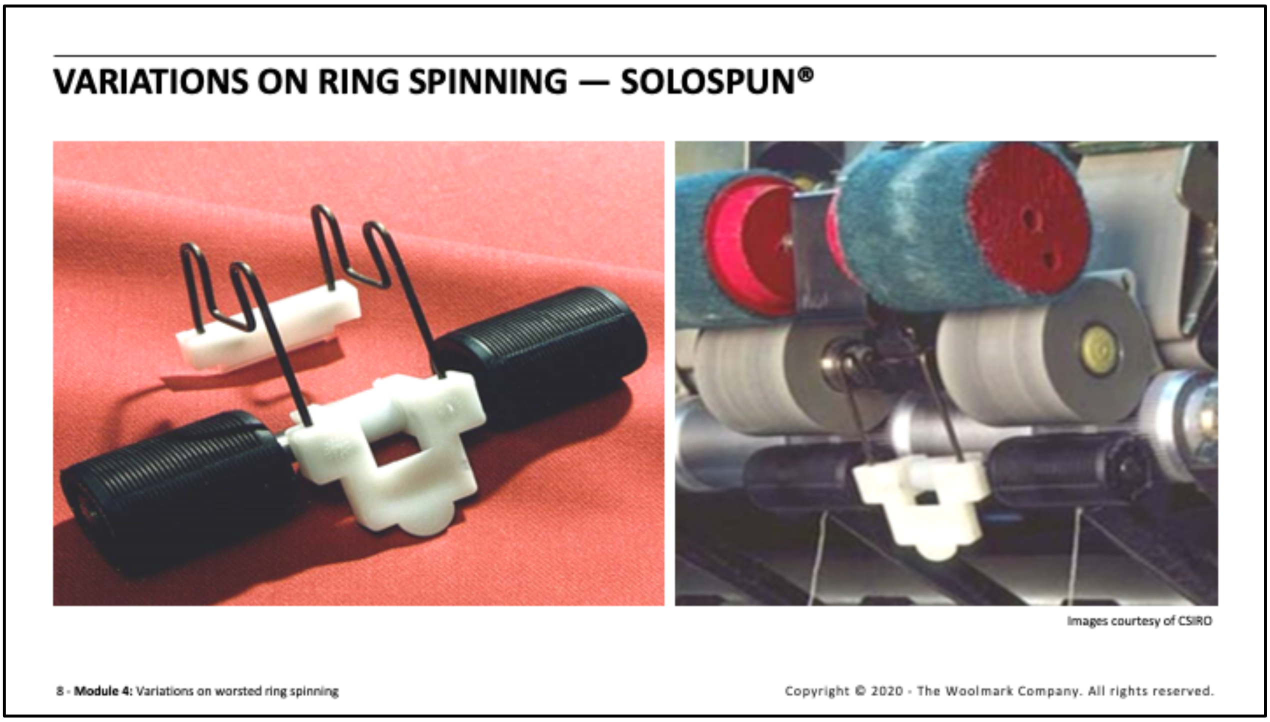
SiroSPUN is especially suited to the production of fine yarns suitable for light-weight, trans-seasonal 'cool wool' fabrics and was promoted-by The Woolmark Company for this purpose.

SiroSPUN also allows spinning of finer yarns — 20µm fibre can be spun to 2/72Nm compared with 2/60Nm from conventional ring spinning.

***SHOW** participants the SiroSPUN breakout device.*

***ENSURE** all participants can observe device closely.*

Duospun
Duospun is an alternative worsted spinning system, similar to SiroSPUN, which has a different method of controlling ends down.



EXPLAIN THAT Solospun® is a spinning technology that produces a 'weavable singles' yarn in one step from a single roving. The technology was the result of a joint development between CSIRO Textile and Fibre Technology, the Woolmark Company and the Wool Research Organisation of New Zealand (WRONZ). It was commercially released in 1998 and is now successfully operating in worsted mills worldwide.

The Solospun™ technology is a simple, inexpensive, clip-on attachment to standard long-staple (worsted) spinning frames.

INDICATE THAT the hardware consists of a bracket that holds a friction pad and a pair of Solospun rollers . The bracket clips on to the shaft of each pair of top front draft rollers of the spinning frame, with each Solospun roller being positioned just below and parallel to, but not in contact with, its corresponding top front draft roller.

The Solospun rollers are rotated by being in contact with the bottom front draft rollers.

Solospun differs from air-condensed, or compact, spinning in both application and principle.

EXPLAIN THAT it achieves fibre security through the actions of localised twist in sub-strands and fibre migration.

POINT OUT that condensed-spun yarns, on the other hand, may still require two-folding or sizing to be suitable as warp yarns.

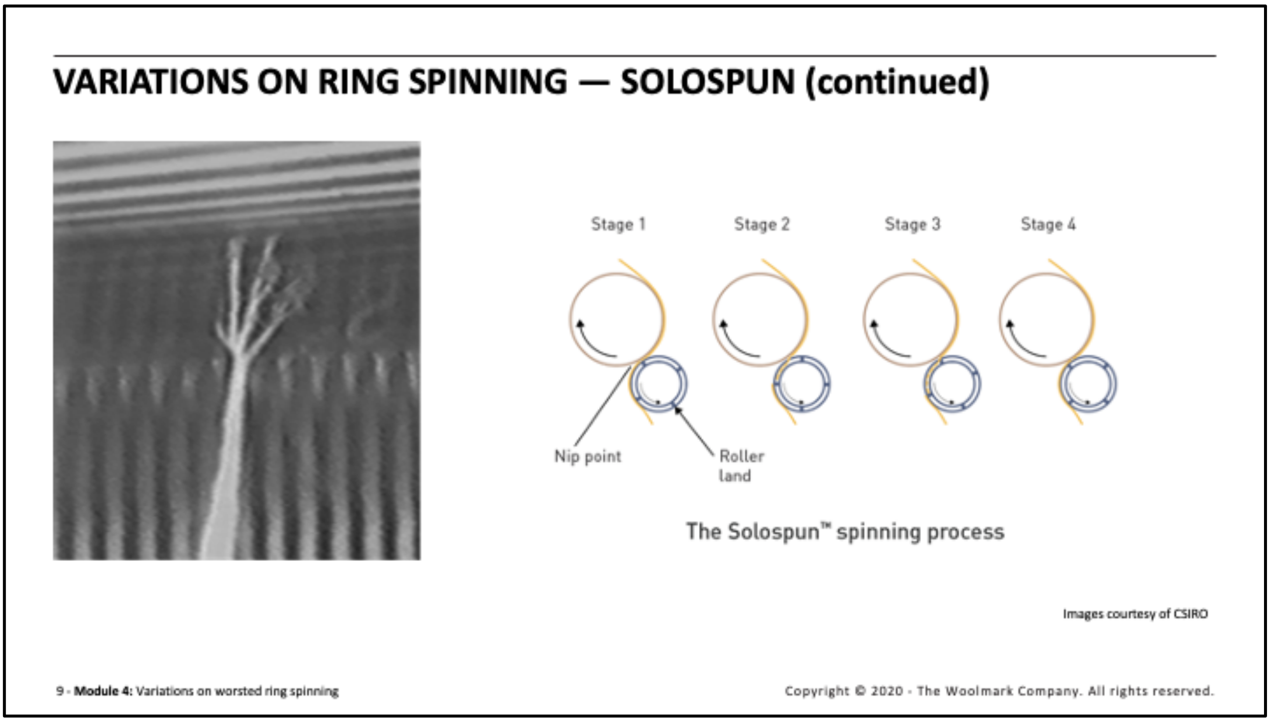
Less twist is required in Solospun yarns, which reduces fabric streakiness.

EXPLAIN THAT higher spinning speeds are possible with much better spinning performance than can be achieved when spinning the singles yarns needed for a similar resultant two-fold yarn.

NOTE THAT the overall result is a significant reduction in yarn production time and costs.

SHOW *participants the Solospun breakout device.*

ENSURE *all participants can observe device closely.*



INDICATE THAT the Solospun rollers' operation is to interrupt the path of the drafted fibre strand, nipping it against the bottom front draft roller.

EXPLAIN THAT the surface of the Solospun rollers is made up of four segments.

- A 'land', which is flush with the roller surface and runs parallel to the roller axis, separating each segment.
- Between each land is a series of slots, which are offset in each adjacent segment.

The Solospun rollers act as intermittent twist blocks, preventing twist from reaching the fibres emerging from the front draft roller nip.

NOTE THAT the slots in the Solospun rollers divide the drafted fibre strand into a number of sub-strands as shown on the slide, which, through the intermittent twist-blocking action of the roller lands, converge at varied angles and rates to achieve a subtly entangled structure with locally-differing twist levels.

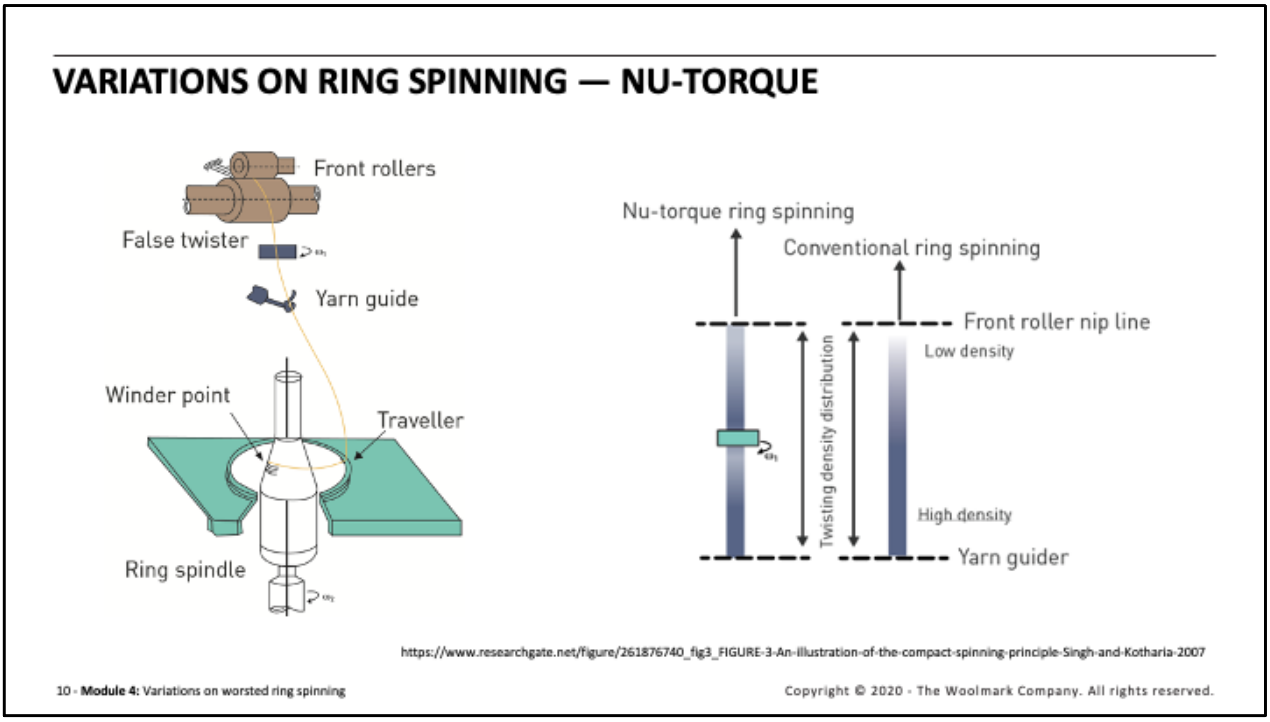
INDICATE THAT the varied angles and rates are achieved in a one-quarter turn of the roller. Following the sequence on the slide from left to right, new sub-strands are formed after the main, drafted fibre strand has been nipped by one of the roller lands.

As the land rotates away from the nip point, the

The continuing changes in these angles result in increased fibre migration and fibre trapping.

EXPLAIN THAT when the next land reaches the nipping point, a new set of sub-strands is formed in the offset slots of the following quarter segment.

This process is repeated every quarter turn, so that, depending on their length, fibres may undergo many changes in sub-strand position during twisting into the yarn.



EXPLAIN THAT Nu-Torque is a physical manufacturing method to produce torque-balanced singles ring yarns in one step. The system was developed at Hong Kong Polytechnic University and allows production of weavable singles yarn.

INDICATE THAT a false-twister is inserted between the draft zone output rollers and the yarn guide above the spindle. The false twist inserted improves control of the fibres in the spinning triangle and wraps fibre ends more securely in the yarn

NOTE THAT the greater strength and lower hairiness of the yarn allows:

- spinning of knitting yarns at low twist factors (i.e. softer handle)
- reduced pilling of the final knitted product.

The Nu-Torque spinning system has been adopted in parts of the cotton industry but is yet to be widely adopted for wool spinning.

DEMONSTRATION: FALSE TWIST

Resources required:

- *two lengths of top (1m each and preferably different colours)*

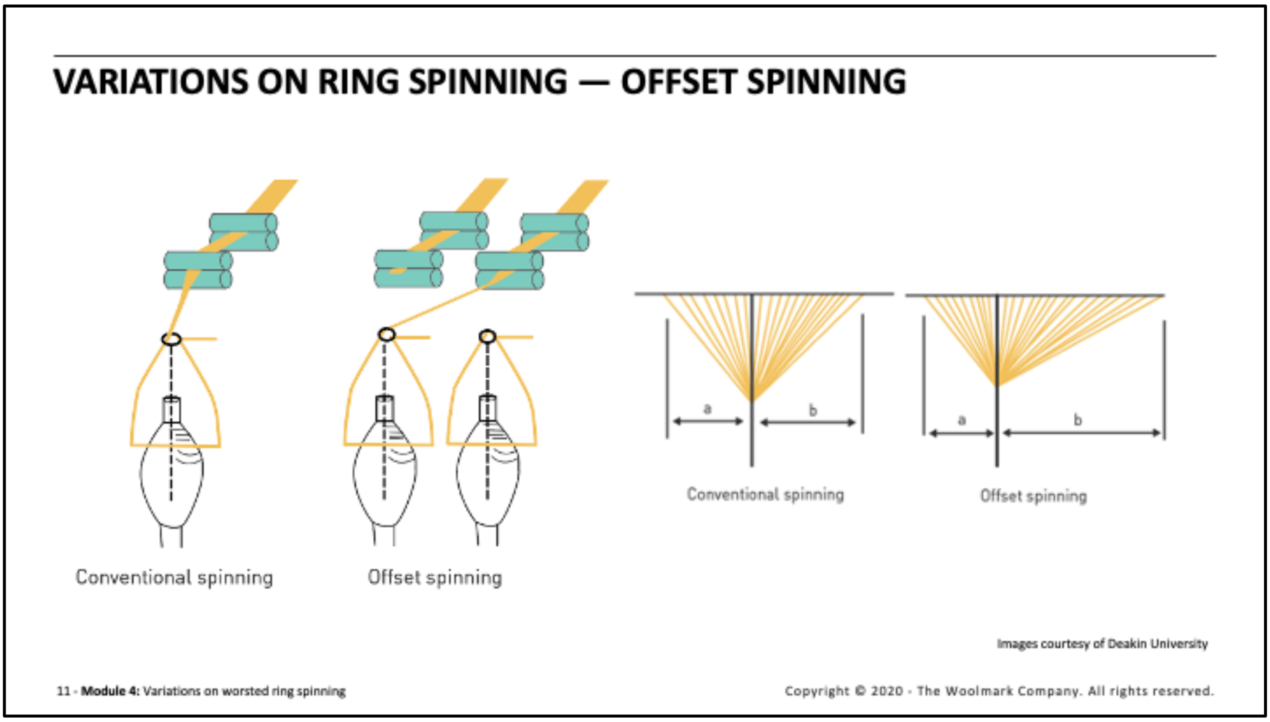
Ask two volunteers to face each other at a distance of about one metre and hold the opposing ends of the lengths of top in their right hands.

Using their left hands ask the volunteers to twist the mid-section of the yarn bundle to impart twist.

Ask the volunteers to then release the twisted yarn.

***NOTE THAT** the twist disappears — demonstrating the concept of false twist.*

***EMPHASISE THAT** the Nu-Torque spinning method uses false twist to augment real twist.*



EXPLAIN THAT under normal circumstances, the drafting zone of a conventional ring spinning frame feeds the traveller and spindle directly below it. The spinning triangle at the output of the drafting zone is fairly symmetrical.

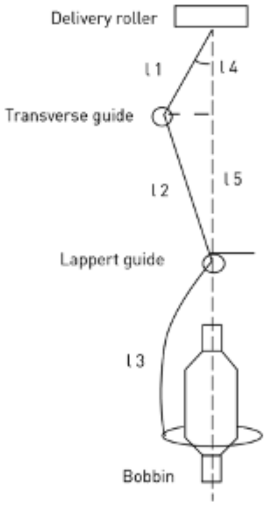
NOTE THAT in offset spinning, the fibre stream emerging from the drafting zone is fed to the adjacent spindle as shown on the slide. Conventional spinning is shown in the left hand image. Offset spinning modifies the spinning triangle and as a result, the properties of the yarns. Yarns are claimed to be less hairy and stronger than those produced on conventional ring spinning machines.

POINT OUT the reduction in hairiness is due to the fact that one side of the spinning triangle gets more tension than the other and the outer fibres get bound inside the yarn (see images on the right side of the slide).

EXPLAIN THAT the extent of the change in yarn properties depends on:

- the direction of the offset
- the direction of the twist.

ALTERNATIVE OFFSET SPINNING

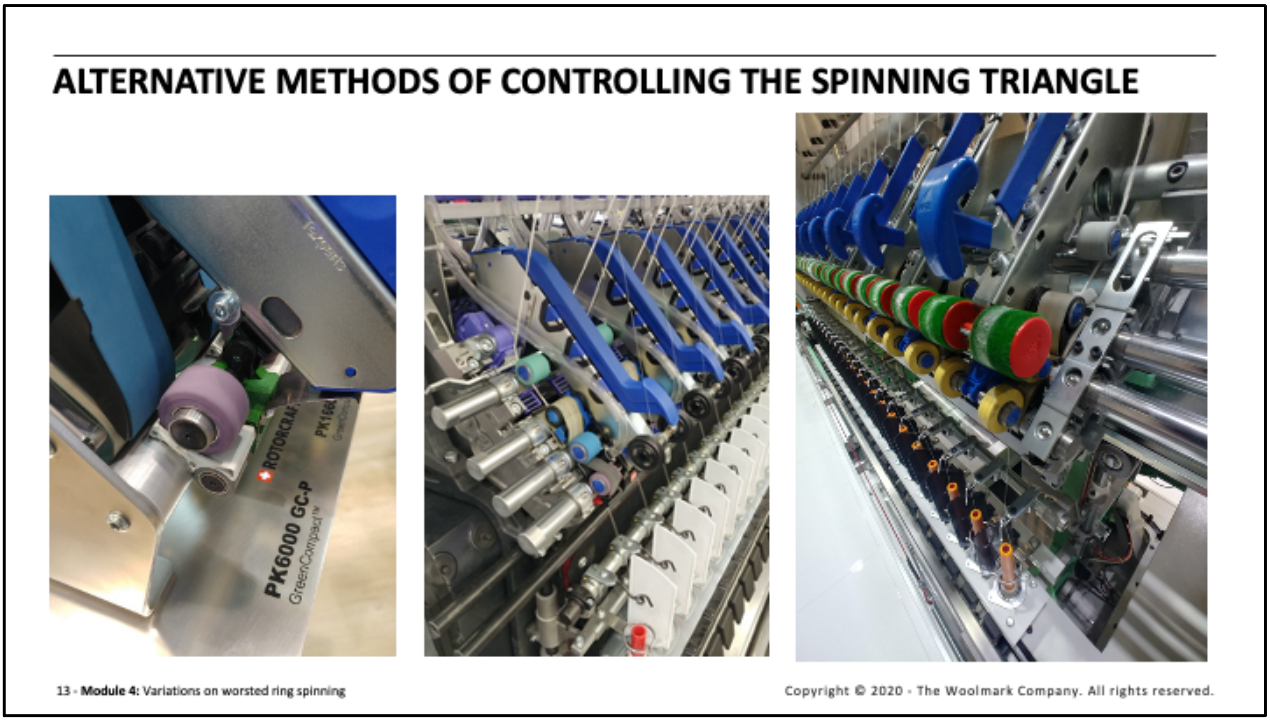


YARN TYPE	3 – 9mm HAIRINESS	TENACITY (cN/tex)	TENACITY CV (%)	ELONGATION (%)	ELONGATION CV (%)	UNEVENNESS (CVm%)
0	121.1	18.0	5.0	7.3	4.5	9.89
R6	101.1	17.3	4.9	7.2	4.0	10.26
R12	69.5	17.8	4.2	7.4	3.2	10.15
R18	73.3	18.0	3.9	7.4	3.2	10.15
L6	127.5	16.9	4.6	7.1	4.1	9.37
L12	173.2	17.5	3.2	7.3	3.4	10.03
L18	171.0	17.4	3.4	7.2	4.1	10.17

12 - **Module 4:** Variations on worsted ring spinning

INDICATE THAT a variation on offset spinning has been devised where the emerging fibres are deflected, changing the shape of the spinning triangle, but the rollers still feed the spindle directly.

POINT OUT the impacts of the system on yarn properties are shown in the table.

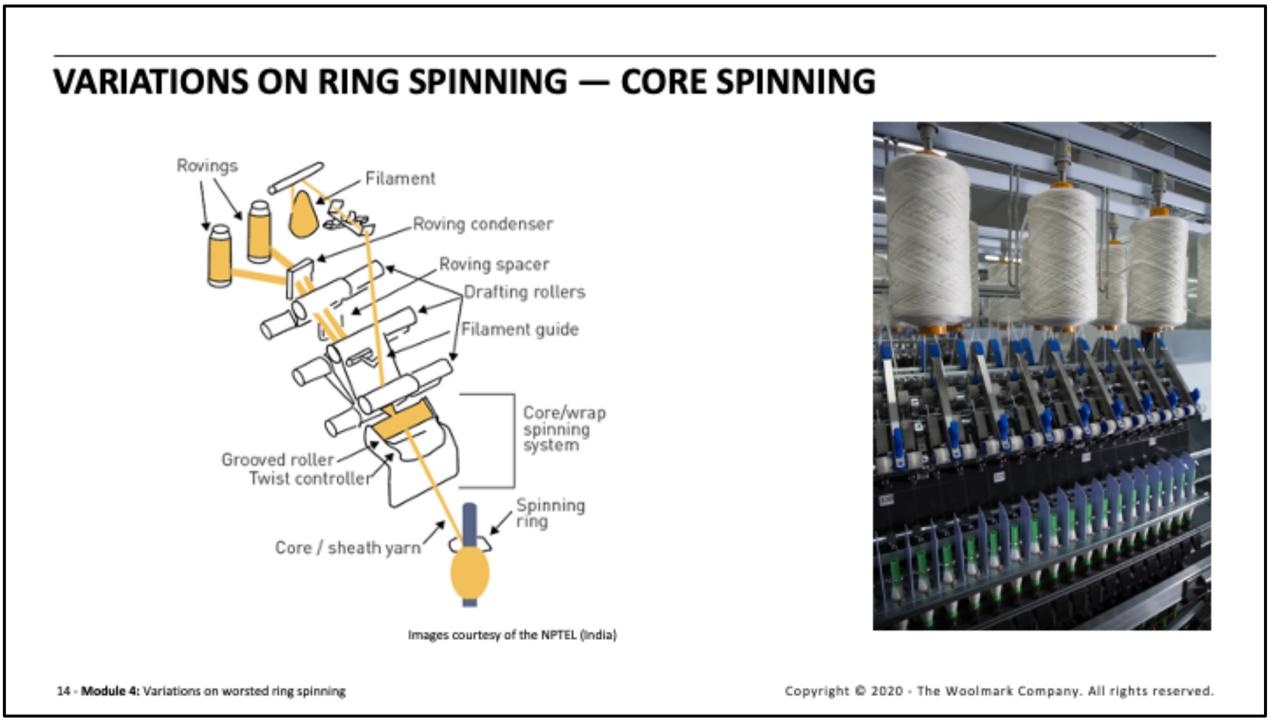


EXPLAIN THAT the images on the slide show some of the methods currently used to achieve better control of the spinning triangle. This technology was exhibited at the International Textile Machinery Exhibition (ITMA) in Barcelona during 2019.

Note the:

- additional fitting on the draft roller (left image)
- the extended draft apron (centre image)
- additional roller between the draft roller and the twist zone (right image).

REINFORCE THAT each system is designed to control the fibres in the spinning triangle to create more even yarns.



EXPLAIN THAT core-spun yarns incorporate a filament in the centre of a staple fibre yarn. The staple fibres are wrapped around a central filament. The filaments can be single or multiple filaments of synthetic materials such as polyester, nylon or elastane.
The filaments are typically introduced to the staple fibre stream behind the nip of the front draft rollers.

NOTE THAT guides and tension devices are required to align and control the introduction of the filaments.

INDICATE THAT the main problem associated with this yarn type is 'strip back' or exposure of the core filament. This can be a problem with these yarns in subsequent winding, knitting and weaving operations and is difficult to correct in worsted yarns. Solutions are found in setting yarn clearers in winding to detect the 'thinning' when the staple fibres are missing.

POINT OUT that core-spinning finds application in blended knit fabrics and in the manufacture of stretch wool fabrics; in this case the filament is an elastane.

Images courtesy of NPTEL (India)

- Faculty: Textile Engineering
- Course: Yarn manufacture

SUMMARY — MODULE 4

Alternative uses of the ring frame:

- Collapsed balloon spinning
- Air-condensed (compact) spinning
- Core spinning
- SiroSPUN™
- Solospun®
- Nu-torque spinning
- Offset spinning.

15 - **Module 4:** Variations on worsted ring spinning

REITERATE THAT worsted wool yarns can be spun using alternative forms of ring spinning.

Alternative uses of the ring frame include:

- collapsed balloon spinning
- air-condensed (compact) spinning
- SiroSPUN
- Solospun
- Nu-torque
- offset spinning
- core spinning.

REINFORCE THAT the cost and yarn quality outcomes of the various spinning options vary.

NOTE THAT new technology has been developed to achieve greater control of the spinning triangle, creating more even yarns.

ASK *participants if they have any questions about the content covered in this module.*

ALLOW *time for questions and discussion before proceeding to the final slide and closing the lecture.*

INFORM participants of the time and location for the next lecture — *Module 5 Preparation for woollen spinning*— and encourage them to read through the relevant notes in their Participant Guides before attending the lecture.

ENCOURAGE participants to explore the Woolmark Learning Centre to reinforce and build on what they have covered in today's lecture.

Participants can register with and explore the Woolmark Learning Centre here: www.woolmarklearningcentre.com

BEFORE participants leave ensure you have collected all materials distributed during the lecture.

MODULE 5

THE WOOLMARK COMPANY

PREPARATION FOR WOOLLEN SPINNING

RESOURCES — MODULE 5: PREPARATION FOR WOOLLEN SPINNING

Contained in the *Worsted and woollen spinning* Demonstration kit you will find the following resources for use as you deliver **Module 5: Preparation for woollen spinning**:

- sample of woollen slubbing

THE WOOLMARK COMPANY

WORSTED AND WOOLLEN SPINNING

MODULE 5: Preparation for woollen spinning

WELCOME participants to Module 5 of the Woolmark Wool Science, Technology and Design Education Program — *Worsted and woollen spinning — Preparation for woollen spinning*.

EXPLAIN THAT this module covers:

- key components of carding wool specification
- the aims of carbonising, opening and carding
- the key differences between woollen and worsted carding
- the major sections of a woollen card:
    - controlled hopper feeder
    - the forepart of the carding machine
    - the cross-lapper
    - the finishing section of the card
    - the condenser.

INFORM participants that by the end of this module they will be able to:

- describe the operations used to prepare wool for woollen spinning
- explain the aims, machinery and procedures used
- explain the action of the woollen card and its purpose in terms of final web and yarn quality
- explain the differences between woollen and worsted carding
- describe the contribution various components of the woollen card make to the properties of the web and spun yarn
- explain some of the key issues during carding, their impact and solutions.

RESOURCES REQUIRED FOR THIS MODULE:

- *sample of woollen slubbing*

***ASK** participants to explain the major difference between a 'combing wool' and a 'carding wool'.*

***IF NECESSARY** reiterate that carding wools are shorter than combing wools.*

***NOTE:** If the participants have forgotten the use of the terms 'carding' and 'combing' wools, do a quick revision of these terms.*

- *Carding wools consist of short fibres and are used in the woollen system.*
- *Combing wools consist of longer fibres and are used in the worsted system.*

SPECIFYING CARDING WOOLS

Specification of carding wool is much less precise than for combing wools.

Sampling is a major issue — batches can be highly variable.

Measurement limited:
- fibre diameter characteristics
- staple length
- length after carding
- bundle strength

Limited use to predict spinning performance.

2 - **Module 5:** Preparation for woollen spinning

EXPLAIN THAT specification of wools used in the woollen system is much less precise than for wool processed through the worsted system.

INDICATE THAT the so called 'carding wools' destined for the woollen system are commonly much less homogeneous than the worsted 'combing' wools, making sampling of sale lots a poor indicator of overall wool quality due to variability. Processing lots are often blends of a wide range of wool types, as explained on the next few slides.

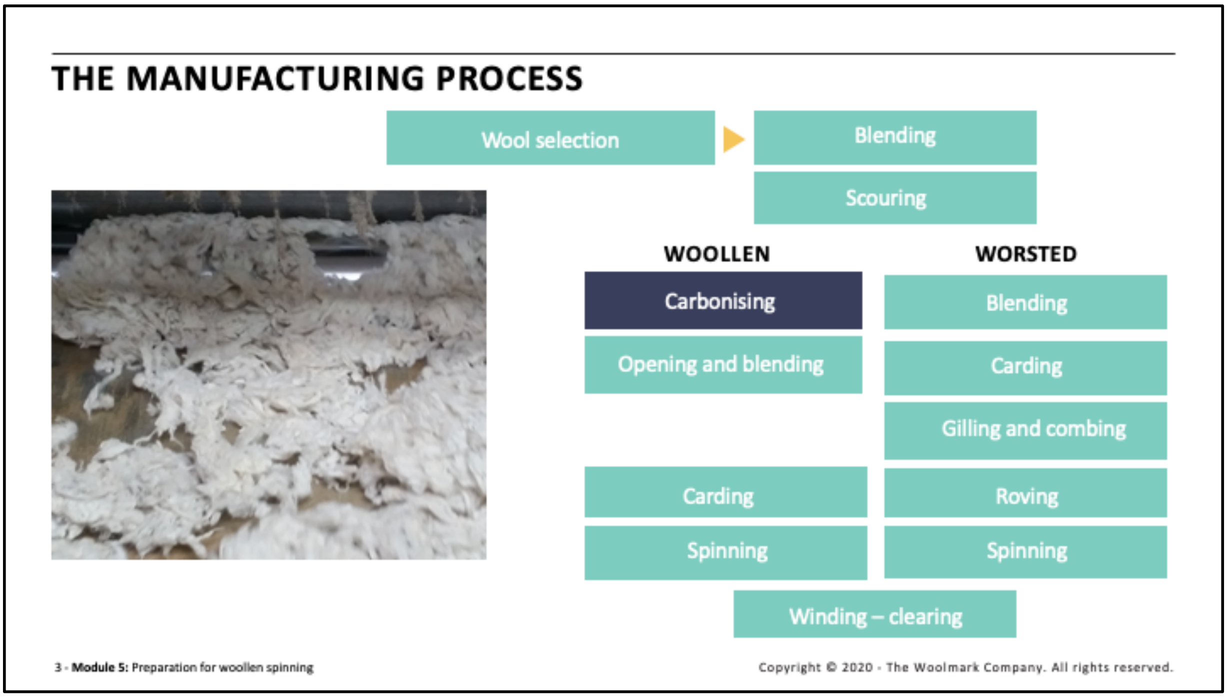
NOTE THAT the number of measurements made on the raw carding wool is less than for worsted (combing) wools.

Mean fibre diameter of the processing batch and the individual lots that make up the processing batch remains a key feature of the wool specification for carding wools.

POINT OUT that staple length is also important, although the range and values of the batch components will often vary considerably more than in worsted processing batches.

EXPLAIN THAT length after carding and bundle strength are sometimes used as a predictor of performance, but their predictive value is limited. The skill for the processor is in buying wool that will meet the final yarn specifications. The skill of the processor (usually the spinner) in choosing and blending sale lots of carding wools will often determine the financial viability of the operation.

2



NOTE THAT wool used in the woollen system normally has considerably more vegetable matter (VM) than that used in the worsted system.

Where necessary, carbonising is carried out after scouring. The process is normally used on wool where the amount of vegetable matter exceeds 2% of the weight of wool.

EXPLAIN THAT some vegetable matter can be removed through the processes of scouring and carding. However, because combing is not used in woollen processing, unless the scoured wool is carbonised, much vegetable matter can remain in the yarn as a potential source of yarn fault.

INDICATE THAT carbonisation is often required for pieces, bellies and other parts of the wool in contact with the ground when on the sheep. The wool shorn from the underbody and around the legs of the sheep often has a high degree of vegetable matter, in the form of burrs, seeds and grass, picked up while the sheep were grazing. If this vegetable matter is not removed, it would be impossible to produce a high-quality yarn during subsequent processing.

NOTE THAT carbonising is a continuous chemical process that removes vegetable matter (which is composed primarily of cellulose) using acid.

EXPLAIN THAT carbonising can be also carried out in fabric form during the finishing process, but carbonising of scoured loose wool is the most common method.

Carbonised wool (sometimes called carbo wools) are used extensively in the woollen system.

NOTE THAT for some carding wools, or relatively clean noil, carbonising may not be required. In this case the wool goes from scouring to opening and blending and then to carding.

3

STAGES IN THE CARBONISING PLANT LINE

Carbonising:

- is a continuous chemical process
- uses an acid to dehydrate vegetable matter
- reduces vegetable to dust, which is removed by beating and shaking the fibre clumps.

The stages in carbonising are

1. Acidising
2. Squeeze rollers
3. Drying
4. Charring by baking
5. Burr crushing
6. De-dusting
7. Washing and neutralisation
8. Final drying

4 - **Module 5:** Preparation for woollen spinning

EXPLAIN THAT the stages of a typical carbonising line include:

Acidising
The scoured wool, still damp after the rinsing bowls in the scouring line, moves into the acidising bath. A large long bowl containing a solution of 6–7% (w/v) of sulphuric acid (H_2SO_4) is used to increase the residence time. 1–2 g/l of a non-ionic wetting agent assists the penetration of acid into the burrs, and protects the properties of the wool fibre.

Squeeze rollers
Before entering the drier, as much moisture as possible is removed from the wool by means of double squeezing or passage through a continuous centrifuge.

Drying
The wool is passed through a heated chamber in a continuous dryer to a regain (moisture content) of about 10% at a temperature of between 60°C and 80°C.

Charring by baking
The wool passes through another dryer at a temperature of 95–120°C to bake the wool and turn the vegetable matter into carbon. During this stage, a large portion of the moisture is removed, leaving residual moisture and concentrated H_2SO_4 on the fibre and burrs to chemically react with vegetable matter as well as the wool. This moisture removal is the most critical phase of the entire carbonising process.

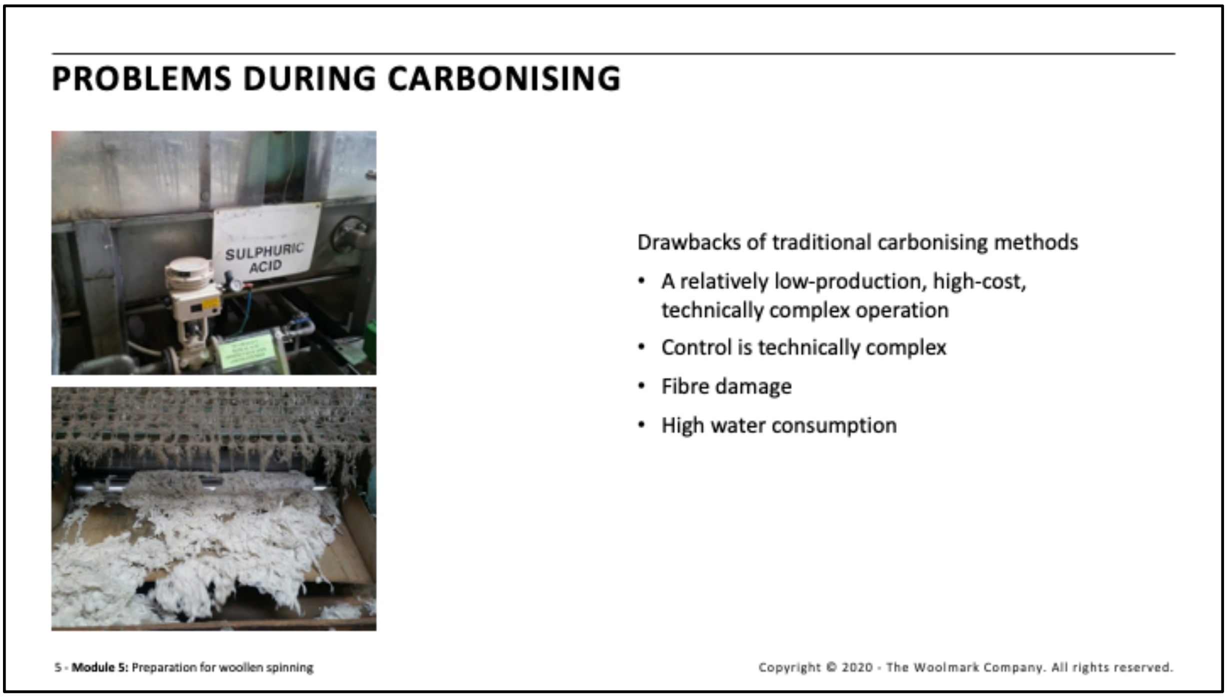
Burr crushing
The wool passes through a series of heavy metal fluted squeeze rollers where the carbonised vegetable matter is turned into dust.

De-dusting
The wool passes through a rotating shaker, known as a de-dusting course. The dust of charred vegetable matter is separated from the wool by mechanical action.

Washing and neutralising
To neutralise or remove the acid, the wool is treated with a solution of a mild alkali, such as soda ash, followed by rinsing and squeezing.

Final drying
The wool is finally dried in a continuous drier. The final moisture content should be appropriate for the next stage of processing. The moisture content should be even throughout the fibre mass.

4



INDICATE THAT several problems are associated with carbonising:

- At only 300 to 600 kg/h the carbonising process suffers from relatively low productivity, using specialised machinery with high capital costs.
- Machinery operating costs are also reasonably high.
- Various aspects of the carbonising process are technically difficult to control. Small changes in acid content, moisture content, drying and baking temperatures cause severe loss in tensile properties of the fibre. These losses are transferred to yarn and fabric. Loss of fibre tensile strength can be of the order of 15–60% depending on the properties of the wool and the amount of vegetable matter in the wool batch.
- Overall, water consumption used during scouring, rinsing and neutralising is high. Environmental treatment of waste waters is a heavy cost burden.

NOTE THAT frequently the carbonising is undertaken by specialist carbonising companies and so only a few highly-skilled companies are used commercially.

EXPLAIN THAT this video shows the process of separating stained and unsuitable pieces of wool from a batch of quality lamb's wool.

In some operations the carbonised wool is manually inspected to remove:

- pieces of heavily-stained (yellow) wool. This is important when the wool is to be dyed a light shade as coloured fibres will show on the final product
- residual vegetable matter that resists the carbonising process. Some types of vegetable material are more resistant to carbonising than others
- any non-wool contaminants.

This procedure is normally adopted on high-quality carding wools used in high-quality woollen-spun knitwear.

Poorer quality wools will not be inspected and sorted in this way as it is a labour-intensive and expensive process.

***PLAY** video (31:00 seconds)*

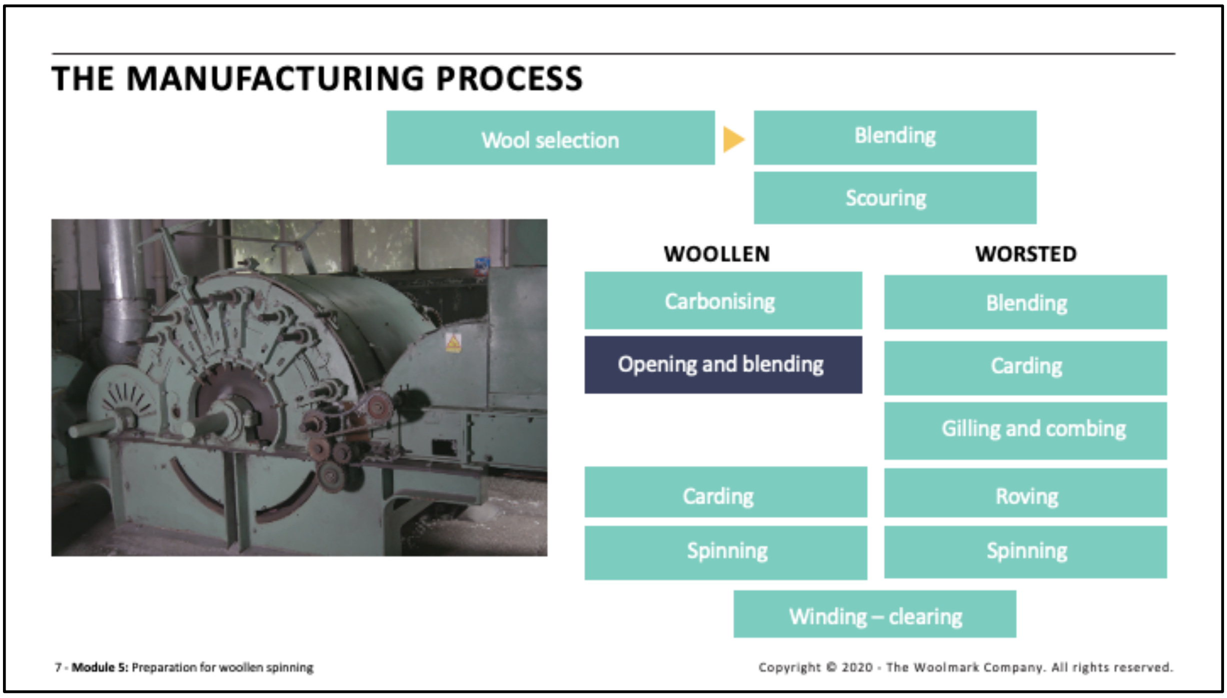
***AS THE** video plays note:*

- *the quality of wool is often checked manually with operators sorting out the damaged or stained fibres*
- *the stained samples placed in the basket are used in poorer quality products. (22:50 seconds).*

***ASK** participants if they have any questions or comments regarding the video content.*

***ALLOW** sufficient time for participants to respond before proceeding.*

6



NOTE THAT after carbonising the wool is put through an opener to break up all the clumps of wool.

EXPLAIN THAT many different machines are designed for this purpose. These machines are described in the the Wool Science, Technology and Design Education Program course *Raw wool scouring*. Refer to the notes on opening machines used before and after raw wool scouring.

A considerable amount of blending also occurs in the opener machine.

INDICATE THAT at this point, other short wool (e.g. noil and broken top) may be blended with carbonised wool.

EXPLAIN THAT this video shows one of the machines used to open short wools before woollen carding.

TO REITERATE — the aim of opening is to open the clumps of wool in preparation for carding.

- The concept is similar to the method used to open worsted wool before scouring.
- The effect is often achieved using a beating action.

***PLAY** video (25:00 seconds)*

***AS THE** video plays, note:*

- *the opening of the wool is very important especially if it is dyed before carding*
- *the machine shown has a strong opening action.*

***ASK** participants if they have any questions or comments regarding the video content.*

***ALLOW** sufficient time for participants to respond before responding.*

8

BLENDING

Image courtesy of Temafa Machines
http://www.temafa.com/Fiber_Blending_System_Bin_System.html

Blending occurs
- during opening
- before carding.

Broken top may be added during blending:
- usually lamb's wool
- carded and combed by top-maker then broken
- low vegetable matter and good length
- expensive.

Stretch-broken top
- low short and long fibre content
- free of vegetable matter
- very expensive

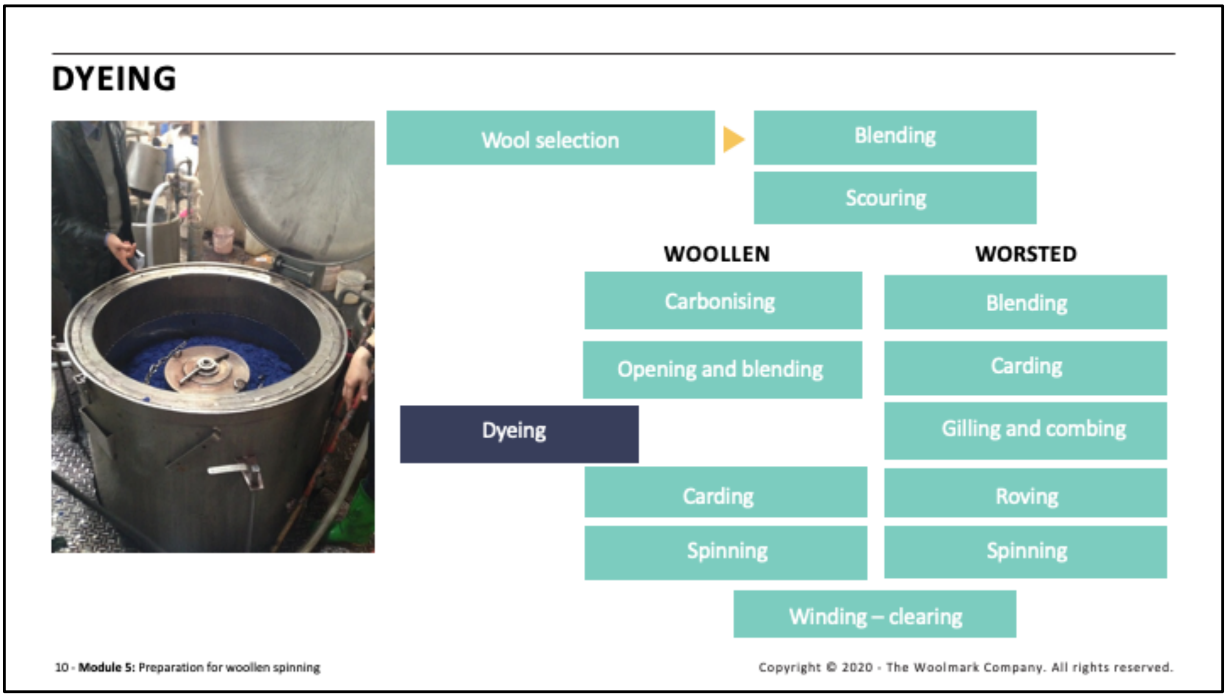
9 - **Module 5:** Preparation for woollen spinning

NOTE THAT blending occurs:
- during opening
- before carding.

EXPLAIN THAT broken top from worsted processing may be added during the blending process — often to lamb's wool. This wool is carded and combed by the top-maker (using worsted processing equipment) then broken (normally using a 'stretch-breaking' machine, which extends the previously-combed fibres until they break). The fibre is often called 'stretch-broken top'.

INDICATE THAT this form of wool has very low (or none) vegetable matter and good length, but is expensive.

EXPLAIN THAT stretch-broken top is characterised by :
- low content of very short and overly long fibres
- being free of vegetable matter
- a high cost.



EXPLAIN THAT loose wool (fibre) dyeing is widely used during woollen processing. It allows the processor to:

- achieve large lots of uniform shade. Slight unlevelness or differences between batches can be eliminated in the blending that takes place during subsequent blending and carding operations.
- achieve maximum wet colour fastness with good shade uniformity
- achieve mélange shades or multi-coloured woollen yarns
- minimise dyeing costs
- produce blends with other fibre types. Where different dyes and methods must be used for the differing fibres or when the cross staining with different dye types is possible, carding wools are often dyed as loose fibre before blending.

INDICATE THAT there are some disadvantages to dyeing wool at the loose fibre stage:

- Dyed wool fibres always have lower tensile properties than undyed and therefore will process less efficiently.
- Dyes must be used that are fast to any wet process to which the fibre will subsequently be subjected (scouring, milling, crabbing).
- Colour contamination during processing is possible.
- The quantity of fibre dyed to meet specific orders is often slightly more than necessary, to allow for extra 'waste' in processing. Unless the excess can be reused, it is of low value.

Dyeing is covered in more detail in the Wool Science, Technology and Design Education Program course *Wool dyeing*.

10

FIBRE LUBRICATION PROCESSES IN THE WOOLLEN SYSTEM

Lubricant solution is added to the fibre during blending:

- Accuracy of application is of vital importance.
- Leave the application of the lubricant as late as possible during the blending sequence.
- Up to 10% oil may be used.
- Allow the blended material to stand for at least 24 hours before carding commences.

11 - **Module 5:** Preparation for woollen spinning

NOTE THAT lubrication is a particularly important subject as far as woollen processing is concerned.

EXPLAIN THAT fibre processing aids (lubricants) are normally added to scoured (or scoured and dyed) wool during blending to reduce fibre-to-metal friction and static in ensuing processes. It also improves fibre-to-fibre cohesion, which should be sufficiently high in order to minimise waste during carding and also to aid web separation during condensing.

INDICATE THAT the outcomes of fibre lubrication include:
- reduced fibre breakage
- increased yields
- improved mass regularity of slubbing/yarn.

The lubrication process
The lubricant solution is added to the fibre during the blending operations. This can be done manually for small batches or in-line (within blending machines) for larger batches.

EXPLAIN THAT the importance of using an efficient oil applicator, capable of metering controlled amounts of lubricants on to the wool fibres, cannot be over-emphasised.

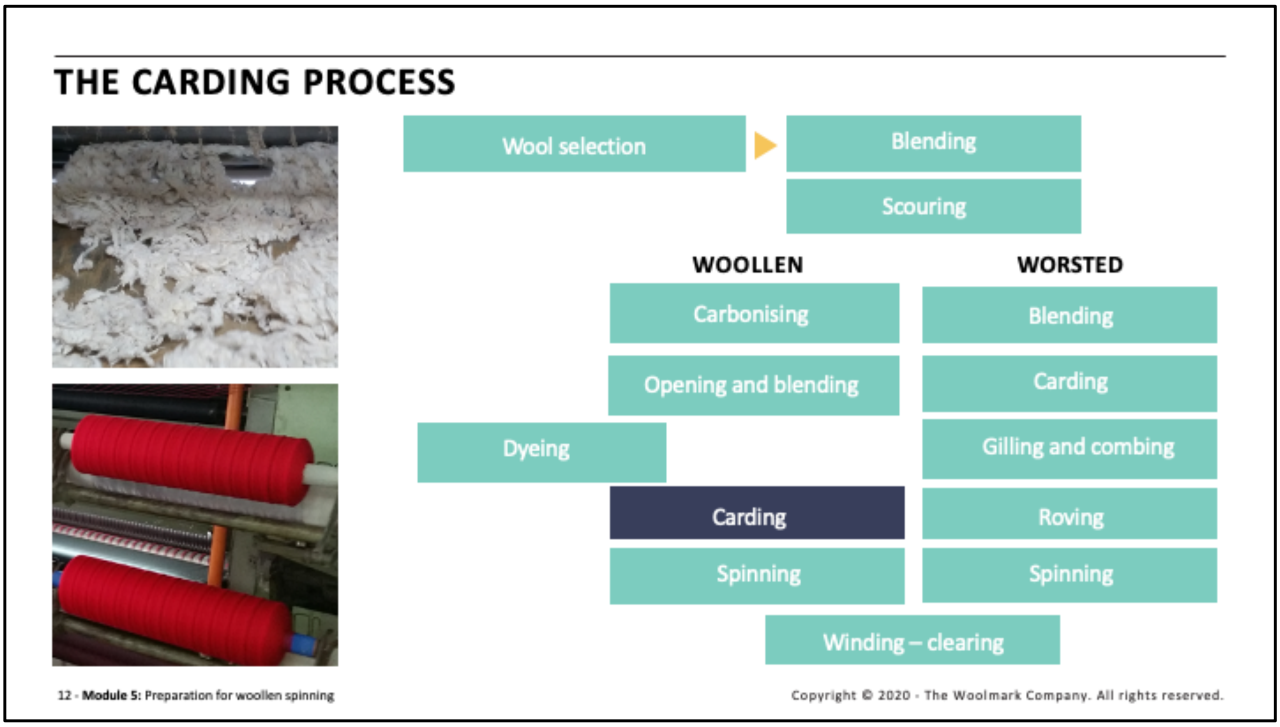
POINT OUT that the ratio of lubricant to water needs to be considered. To optimise this decision, a knowledge of the moisture content of the input wool is invaluable.

NOTE THAT many modern lubricants have excellent migration properties, but accuracy of application is still vital in order to avoid long-term variations in lubricant distribution. Application of the lubricant (up to 10%) should be left as late as possible during the blending sequence when the fibres are more open and allow more even distribution of the oil.

EXPLAIN THAT the blended and lubricated material should be allowed to stand for at least 24 hours before carding to allow sufficient time for the blend to ‘condition’, although circumstances may often limit this.

Types of carding lubricants are discussed in detail in the Wool Science, Technology and Design Education Program course *Worsted top-making* and include:

- blended fatty oil
- vegetable-based oils
- emulsifiable mineral wool oils
- synthetic lubricants (water and and/or grease miscible).



EXPLAIN THAT woollen carding is the single process in the woollen system that takes the fibre clumps after scouring, carbonising and dyeing and prepares them ready for spinning.

NOTE THAT the major objective of carding is to separate and individualise the fibres and obtain a formation of a homogenous web in terms of weight per course area, then split that web into 'slubbings' ready for spinning.

INDICATE THAT a slubbing in woollen spinning is the equivalent of the roving in worsted spinning.

THE AIMS OF WOOLLEN CARDING

The purpose and objectives of carding is to:

- disentangle and separate clumps of fibre
- align the fibres
- blend fibres
- remove vegetable matter
- orientate the fibres
- produce a uniform web
- split the web into narrow widths
- consolidate sections of web into slubbings.

Compared with a worsted card, the woollen card:

- is significantly longer
- is required to do more opening, mixing and blending
- provides a uniform web rather than a sliver
- provides a more uniform web both across and along the web.

13 - **Module 5:** Preparation for woollen spinning

NOTE THAT although one of the aims during the scouring process is to minimise the degree of fibre entanglement, a certain degree of entanglement invariably occurs. This entanglement is compounded by any carbonising and dyeing processes that may be carried out.

INDICATE THAT the result is the loose wool tends to be presented as clumps or flocks of entangled fibre. After carbonising and dyeing, these clumps become even more dense, with considerable entanglement. The level of entanglement in the wool used for the woollen system is considerably greater than scoured wool in the worsted system.

Consequently the woollen card is considerably longer and has many more working points than a worsted card.

EXPLAIN THAT the purpose of carding is to:

- disentangle the entangled clumps of fibre by separating them into individual fibres
- align the fibres so they are more parallel to each other
- further blend the fibres by intermixing
- remove vegetable matter if the wool has not been carbonised
- orientate the fibres in the machine direction to assist the drafting during subsequent spinning. As will be explained, this orientation occurs relatively late in the carding process
- produce a uniform web
- split the web into narrow widths — the width of the split sections is directly linked to the linear density of the desired yarn
- compact these narrow webs into fine strands, called slubbings. The compaction process is required to give the strands sufficient strength to enable them to be handled during subsequent operations.

POINT OUT that compared with the worsted card, the woollen card:

- is significantly longer with many more sections
- is required to do more opening, mixing and blending
- provides a more uniform web, both across and along the web
- divides the web into slubbings rather than creating a single sliver.

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POINT OUT that as illustrated on the slide, woollen cards are significantly longer than worsted cards with more sections. The later sections of the woollen card use flexible card clothing rather than the rigid metallic wire common in worsted carding. Woollen cards need to produce a more uniform web across and along the web to ensure yarn uniformity is maintained.

INDICATE THAT as with worsted carding, friction between the fibres and the card clothing must be closely controlled. Typically, the amount of residual grease remaining on scoured wool is about 0.3% to 0.5% by weight; this is positive because wool grease in itself is an effective processing lubricant.

NOTE THAT significantly more lubricant is used during woollen carding than worsted carding to:

- preserve fibre length through the long card
- reduce static electricity
- help with condensing the narrow fibre strand by the rubbers.

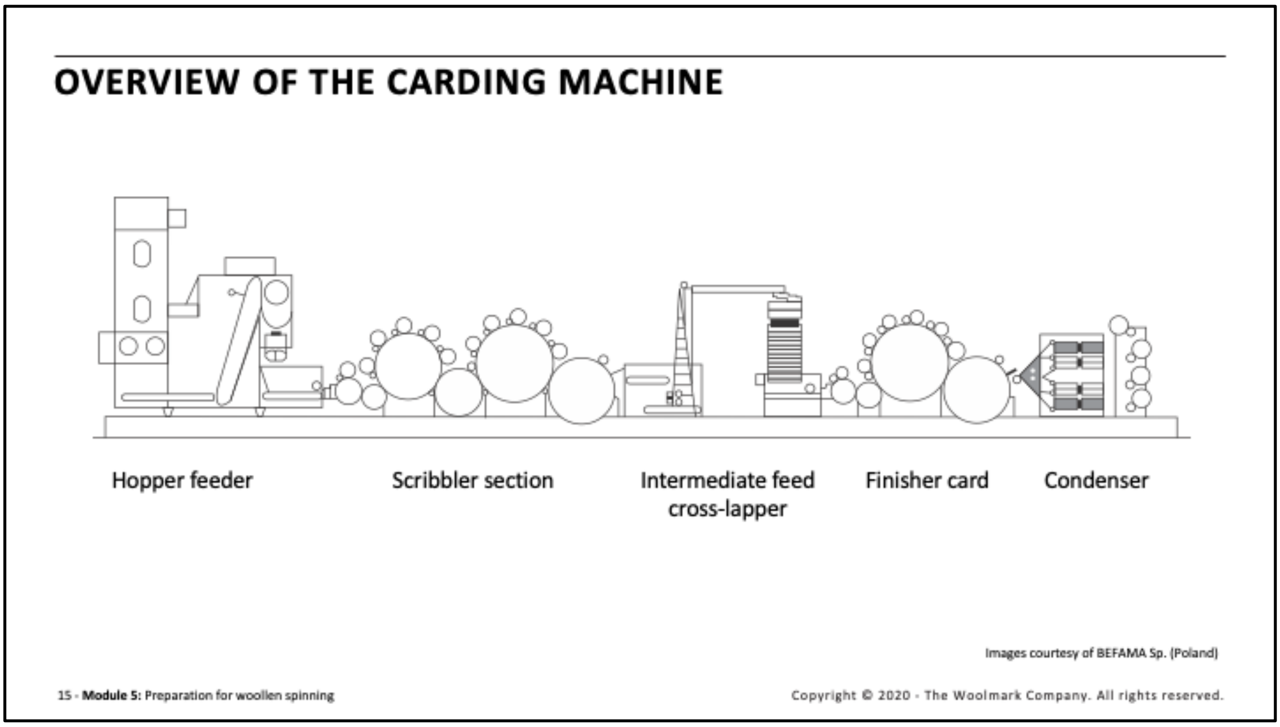
EXPLAIN THAT this can range between 4% and 10% depending upon the actual components of the wool blend. For example, lamb's wool blends (4% to 5%) and for Shetland (8% to 10%).

MENTION THAT the purpose of adding higher quantities of processing lubricant is to reduce wastage by minimising the number of short fibres that fall out during the carding process and accumulate under the machine.

ASK *participants to explain which rollers do the major separation of the staples into individual fibres.*

ALLOW *participants sufficient time to respond.*

IF NECESSARY *explain that swift, worker and stripper rollers carry out the major separation of the staples.*



INDICATE THAT the card, or carding machine, comprises a series of horizontally-aligned rotating rollers or cylinders covered in pins or teeth of differing configurations.

As in worsted carding and as will be shown in subsequent slides, some of the rollers or cylinders rotate in different directions (clockwise and counter-clockwise), while others rotate in the same direction.

NOTE THAT some rollers or cylinders rotate at the same surface speeds (metres per minute), while others rotate at different speeds. Some are the same size in terms of diameter, while others vary.

The teeth on some rollers are the same in terms of density, length and orientation, while on others they vary.

These different configurations enable differing types of mechanical actions to be exerted on the wool as it passes through the carding machine.

EXPLAIN THAT these differing mechanical actions, in order as the wool passes through the machine, include:

- a combing action as the wool enters the machine, to assist in orientating the fibres and removing dirt and very short fibres
- a carding action to disentangle the clumps of fibres and thoroughly inter-mix the fibres to form a homogenous blend
- a stripping action, which works in conjunction with the carding action, assisting in further blending and contaminant removal
- a doffing action to produce a homogenous web of fibres of uniform mass
- a blending action: while not using rollers covered in teeth, there is a cross-lapping action to further blend the wool and minimise any side-to-side variation

NOTE THAT without using rollers covered in teeth, there is a splitting and condensing action that separates the web longitudinally into narrow strips a few centimetres in width, and then by a rubbing action compacts these strips of web into continuous lengths of slubbing ready for spinning.

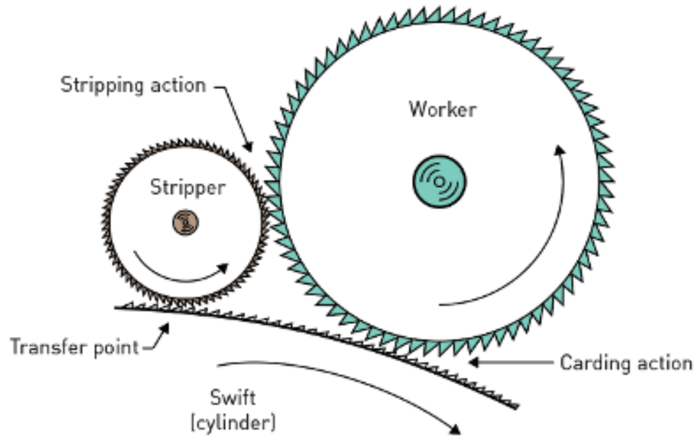
CARDING ACTIONS

Carding (working) action
— disentangles fibres

- Wire points of the two surfaces must have opposite inclination.
- The movement of the surfaces should be in either opposite or the same direction with a relative speed differential.

Stripping action — transfer of fibres

- Wire points of the two surfaces must have the same inclination.
- the surface charged with material should move.



16 - **Module 5:** Preparation for woollen spinning

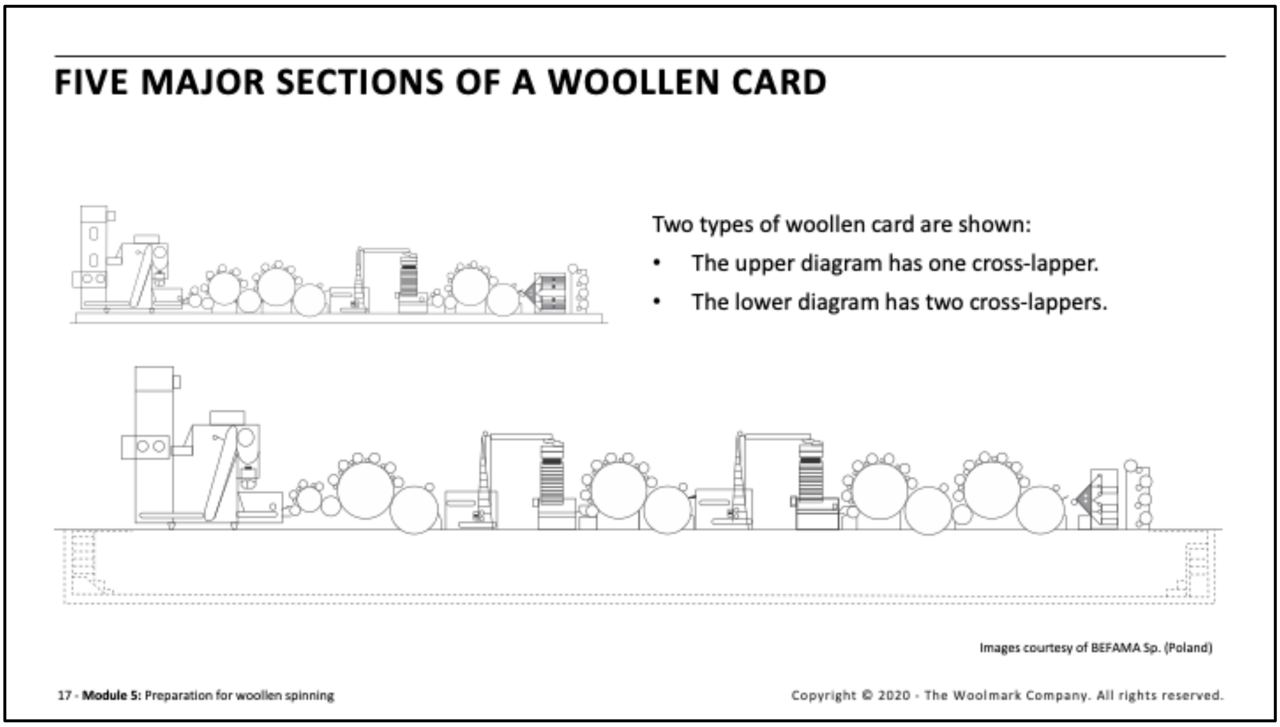
TO RE-CAP — the basic principles of the carding process lie in the working and stripping action (as outlined on the slide).

EXPLAIN THAT the disentangling of fibres is done by the working (or carding) action. In order to realise the working action between two surfaces, the wire points of the two surfaces must have opposite inclination (point to point). For the working action, the movement of the surfaces should be in the same direction with a relative speed differential. Between the cylinder and the working roller, the surface speed ratio is in the vicinity of 40–60 to 1.

NOTE THAT the transfer of fibres is done by the stripping action. In order to realise the stripping action between two surfaces, the wire points of the two surfaces must have the same inclination (point to back). When in the same direction, the surface charged with material should move faster in the direction of inclination of its wire points.

INDICATE THAT the actions in the card fall into two categories:

- point to point — a fraction of fibres being retained by both surfaces
- point to back — all fibres removed from one surface to another.

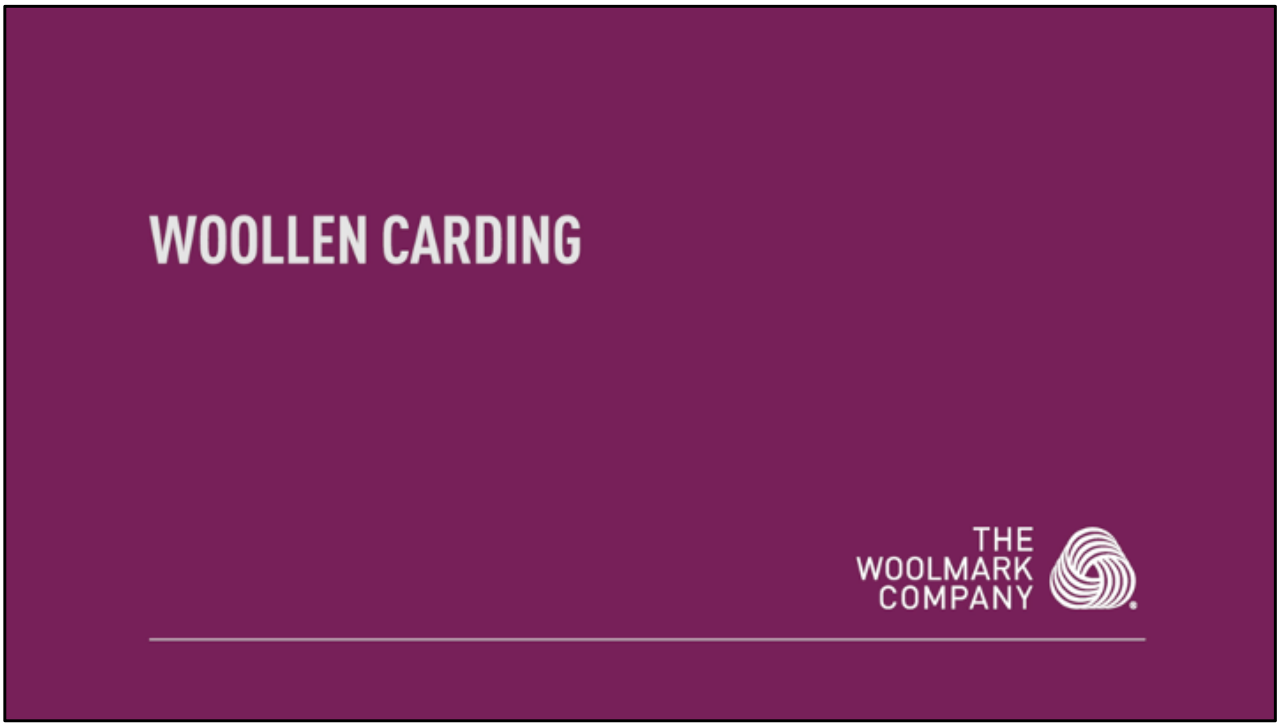


EXPLAIN THAT a woollen card usually comprises five major sections:

- controlled hopper feeder
- breaker card or forepart
- intermediate feed using cross-lapping
- the finisher card
- the condenser.

As shown in the diagram, cards are also designed with more than one than one component of each part (e.g. cross-lappers).

INDICATE THAT each of these will now be examined in more detail.



EXPLAIN THAT this video, produced by The Woolmark Company (TWC) shows the operation of a woollen card.

PLAY *video (3:22 minutes)*

AS THE *video plays, note that:*

- *in the woollen system the scoured wool is carded and the wool is often dyed first*
- *the wool is well opened before carding. (9:00 seconds)*
- *the weigh belt ensures even feeding of the machine. (25:00 seconds)*
- *the fibre tufts are separated into fibres by workers and strippers like the worsted system. (37:62 seconds)*
- *the emerging web is folded rather than drawn into a sliver (48:00 seconds)*
- *the folded web is transferred to the next part pf the card. (1:07 minutes)*
- *the folded web is laid across the card (1:46 minutes)*
- *the carding continues. (2:15 minutes)*
- *tapes are used to split the final web into 'slubbings'. (2:31 minutes)*
- *the slubbings are rolled onto packages. There are many packages coming from the card. (2:46 minutes)*
- *the slubbings are rubbed to give them additional strength (2:53 minutes).*

DEMONSTRATION: SLUBBING RUBBING

Required resources:

- *sample of woollen slubbing*

DEMONSTRATE *the concept of rubbing by rubbing the slubbing back and forth vigorously between two hands.*

ASK *participants if they have any questions or comments regarding the video content.*

ALLOW *sufficient time for participants to respond before proceeding.*

OVERVIEW OF THE CONTROLLED HOPPER FEEDER

- Weighing-hopper feeder used to control input:
  - Secondary adjustments can be made
- Control of moisture content
  - Moisture variations add to the feed variations to the card.
  - A high level of control is required for fine yarn spinners.
  - Sophisticated devices are available to control moisture content.

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EXPLAIN THAT input to the woollen card is usually via a weighing-hopper feeder. As any variation to density at input will generally appear uncorrected in the yarn, modern woollen cards use accurate weighing systems (e.g. weigh pans, roller-weigh systems or weigh-plate systems).

NOTE THAT some hoppers also use secondary corrective systems, such as Servolap, which adjust the feed rate according to a nuclear or X-ray measurement of the feed layer into the card.

The measurement (weigh-system or X-ray) then controls the feed roller speed, providing a constant average feed rate of fibre.

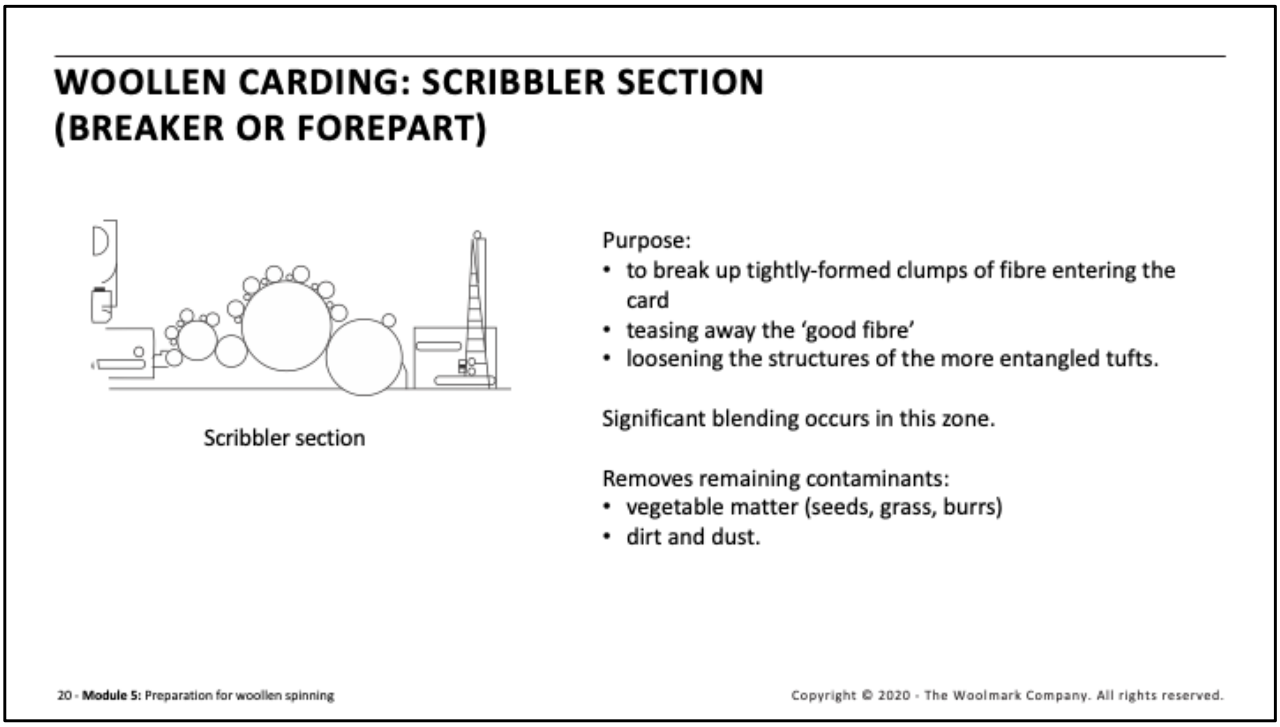
INDICATE THAT even in cards without this sophistication, it is vital the feed is set optimally for the type of fibre being processed, as the aim of the carding process is the formation of a homogenous web in terms of weight per course area.

EXPLAIN THAT because moisture variations behave similarly to variations in the mass of fibre being fed to the card, it is best practice for spinners of fine- count yarns to monitor the amount and variation in moisture entering the card.

POINT OUT that there are several instruments available, but one of the proven systems is the Drycom moisture analyser and meter system. These precision instruments use a unique adaptation of the conductivity principle, which allows the system to be engineered to provide the best solution for each application.

INDICATE THAT the advantages claimed for the Drycom systems are:

- immediate, continuous and accurate moisture measurement
- sensors that measure the entire thickness of the product, not just the surface
- readings that are not affected by surface presentation, colour, temperature, normal variations in thickness or density of the product under test.



EXPLAIN THAT the first section in the carding zone is the forepart or breaker card. Its purpose is to break up the tightly-formed clumps of fibre entering the card, teasing away the good fibre and loosening the structures of the more entangled tufts so the finer wires in the latter sections of the card can better tease and open the wool layer into a more uniform bed of well-opened fibres.

Significant blending also begins in this section of the card.

INDICATE THAT this card should also remove the bulk of any remaining contaminants, such as vegetable matter (seeds, grass, burrs), dirt and dust. Some cards incorporate a 'Hamel roller', which crushes the vegetable matter under high pressure so it breaks up and falls out of the fibre stream.

WOOLLEN CARDING:
INTERMEDIATE FEED OR CROSS-LAPPER

Cross-lapping device, or 'Scotch-feed':

- links 'forepart' and 'finisher' sections of the card
- takes the web produced by the forepart and:
  - condenses it
  - lays it across the input of the finisher section.
- corrects cross-wise density variations at the feed.
- Eliminates side-to-side variation

Correct operation of the cross-lapping device is crucial to subsequent yarn quality.

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INDICATE THAT the 'forepart' and 'finisher' sections of the card are linked with a cross-lapping device, or 'Scotch-feed'.

Weight control systems and the smoothing action of the card cannot correct cross-wise density variations at the feed.

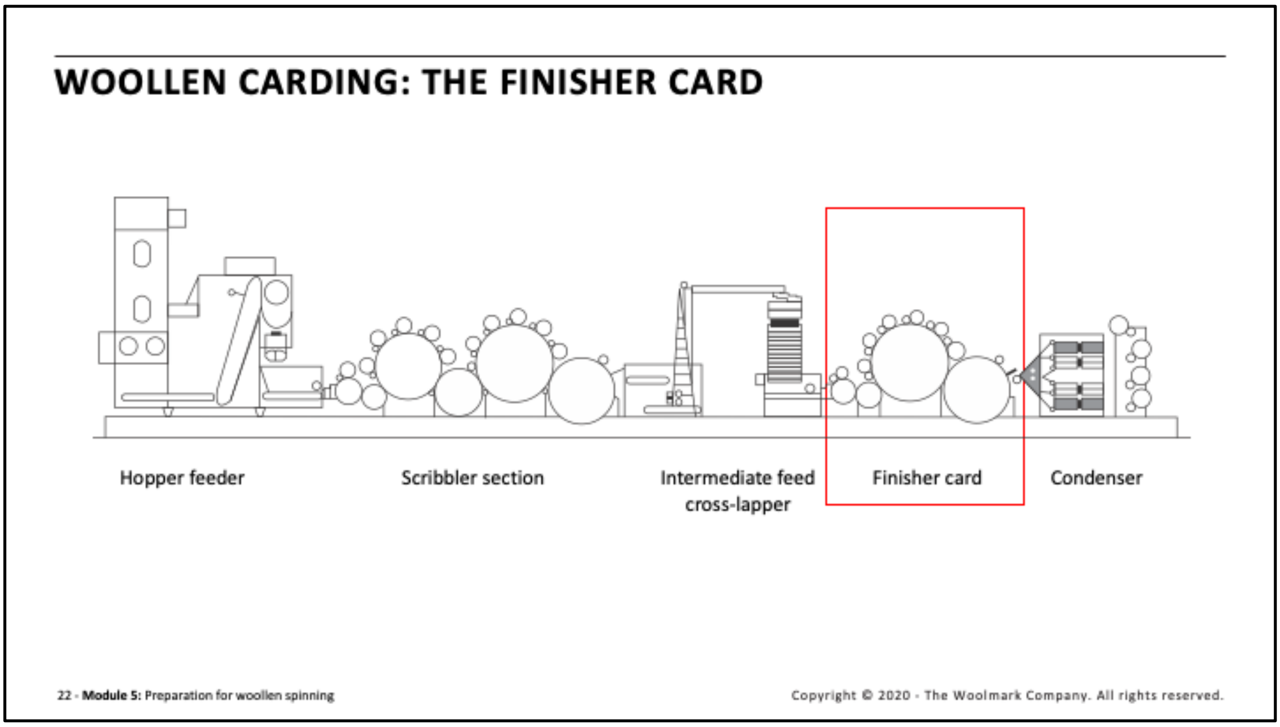
NOTE THAT the card is therefore split into 'forepart' and 'finisher' sections, linked with the cross-lapping device, which takes the web produced by the forepart, condenses it and lays it across the input of the finisher section.

EXPLAIN THAT the purpose of the cross-lapping device is to take the carded web, turn it and lay it at an angle of 90 degrees, before feeding it into the second section of the card.

This allows for more adequate blending of the wool and eliminates side-to-side variations (from one side or edge of the carding machine to the other).

EXPLAIN THAT this process ensures mixing across the card and improves blending of the different fibre types introduced as tufts at the feed section. It also provides smoothing of cross-wise density variations occurring at the input to the card.

NOTE THAT the correct operation of the cross-lapping device is crucial to the evenness of the web produced and subsequent yarn quality. Any fluctuations occurring at the cross-lapper due to poor overlaying of the condensed lap will only be partially smoothed out by the finisher section.



EXPLAIN THAT the finisher card is clothed in finer wire than the scribbler section. It has less distance between the rollers (and these distances progressively become smaller) and requires more careful selection of relative speeds.

INDICATE THAT these differences are all targeted at:

- any mass variations, separating fibres as much as possible
- orientating the fibres along the machine axis
- minimising neps along with remaining vegetable matter and dust
- evening out the flow of wool through the card

The aim of the finisher card is to produce the best web possible for manufacturing high-quality yarns.

EXPLAIN THAT the finisher card operates by separating fibres and fibre tufts between rotating rollers covered in card clothing. The clothing or wire has many fine points, like a wire brush, that catch the fibres.
The teeth of the wires covering the swift cylinder face forward while the teeth of the worker wires face backwards. The speed difference and opposing wire directions means the swift and worker rollers work point-to-point. Fibre on the swift is separated at the worker-swift interface: some fibre passes to the worker and some fibre stays on the swift.

NOTE THAT the fibre on the worker moves relatively slowly towards the stripper. The stripper returns the fibre to the swift and the fibre is split again at the worker.

The process is repeated with a time delay determined by the worker speed and size. In this way the fibres are separated and blended.

POINT OUT that the effect is also to smooth out density fluctuations.

WOOLLEN CARDING: THE FINISHER CARD (CONTINUED)

The finisher card is designed to

- Complete the separation of the fibres
    - clothed in finer wire
    - less distance between rollers
    - requires careful selection of relative speeds.
- Orient the fibres along the machine axis
- Minimising neps, vegetable matter and dust
- The operation also smooths out density fluctuations.

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EXPLAIN THAT if all the workers run at exactly the same speed (because the swift is running much faster than them), then they would always return the same fibre to the swift at almost the same time. This would mean a coloured tuft or a fibre density fluctuation would be reinforced by the worker action laying the fault back onto itself repeatedly.

NOTE THAT for this reason, workers are usually driven by sprockets of diminishing size so they operate at different speeds.

The doffer

A similar separation occurs at the doffers, where some fibre is transferred to the output and the rest is recycled around the swift cylinder. Most of the fibre is remixed many times in the machine direction before leaving each carding section.

EXPLAIN THAT the ‘fancy’ roller is positioned just before the doffer and runs in the same direction. It is slightly faster than the swift (known as the “fancy lead”) and lifts the fibre embedded in the swift closer to the surface.

INDICATE THAT this increases the efficiency of fibre transfer to the doffer and reduces recycling. It also helps reduce or limit the amount of fibre that becomes permanently embedded in the swift that has to be periodically removed by fettling. The fancy is clothed with long flexible wire that is set to slightly penetrate the swift wire.

SPECIFICATION OF CARD CLOTHING

CARD SECTION	COUNT/CROWN/WIRE NO.	POINTS/cm²	COUNT/CROWN/WIRE NO. 40	POINTS/cm²
	Forepart		Finisher card	
Swift	70/7/24	77	140/13/34	286
Doffer	75/7/24	83	140/13/34	286
Workers	75/7/24	83	140/13/34	286
Strippers	40/4/22	25	90/9/32	127
Fancy	40/4/24			66

Source CSIRO

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INDICATE THAT there are two main types of card clothing available:

- metallic
- flexible wire (or fillet).

Metallic card clothing

Metallic card clothing has largely superseded flexible clothing in the cotton and worsted spinning industries and is gaining in popularity in the strong-wool woollen spinning sector.

EXPLAIN THAT the main advantage of metallic card clothing is the improved fibre transfer between cylinder and doffer. This reduces cylinder loading, allowing increased throughput and hence increased productivity.

The main disadvantage of metallic card clothing is the loss of fibre mixing.

Flexible card clothing

Since most of the intimate fibre-to-fibre mixing is achieved during finisher carding and is related to the openness of the fibres and the amount of fibre transferred between cylinder and doffer, improving this fibre transfer will reduce the mixing powers of the card.

EXPLAIN THAT this is the reason flexible card clothing is still the dominant type used for wool suitable for fashion apparel and where colour mixing of the delivered material is a high priority.

POINT OUT that it is common to use metallic card clothing on the breast part of the finisher card, utilising its resilient and hard-wearing properties on a part of the machine that has to deal with the tightest tufts and survive the odd number of foreign objects that tend to be fed into the card with the wool. It is common to use the flexible card clothing on the swift, workers, strippers, fancy and doffer.

INDICATE THAT selection of the types and geometry of wire to apply in carding is directly related to the type of wool and to the final yarn quality required. A typical specification is shown on the slide.

- Finer wool diameters and finer yarns benefit from the use of wires with higher point density.
- The ability of the card to disentangle neps and other fibre faults improves with the use of wire with a higher density of teeth.
- The detrimental effect of using coarser wires cannot be remedied by carding on finer wires at a later stage.
- Using fine high-density wire with broader wool, or higher web densities, can lead to increased fibre damage.

TYPICAL SURFACE SPEEDS IN WOOLLEN CARDING

ROLLER	DIAMETER (mm)	SPEED OF ROTATION (rpm)	SURFACE SPEED (m/min)
Feed roller	72	3	0.7
First worker	210	5	3.3
Condenser surface drum	200	17	10-7
Doffer	900	4	10-9
Worker stripper	710	300	104
Swift	1300	90	368
Fancy	400	380	478

$$\text{Surface speed (m/min)} = \frac{3{\cdot}142 \times \text{diameter} \times \text{rpm}}{1000}$$

Note: Diameter is measured over the wire in millimetres.

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EXPLAIN THAT a critical element of successful carding is that the actions of carding described so far are optimised when the relative speeds of the working elements are selected correctly. It is an important aspect of carding, therefore, to consider the absolute and relative speeds of the carding elements and to consider altering the ratios for different types of fibre being processed.

INDICATE THAT a simple calculation for determining the surface speed of a carding cylinder is shown on the slide. An example of the different surface speeds in a card are shown in the table.

NOTE: It is important to recognise these figures vary greatly depending upon the type of carding machine, the type of material being processed and the desired end product.

The fancy roller on the woollen card is designed to lift the fibres before doffing to improve the evenness of the web.

NOTE THAT fancy roller lead on the carding machine (the excess in surface speed of the fancy roller over the swift cylinder) is usually expressed as the percentage fancy lead.

$$\text{Percentage fancy lead} = 100 * \frac{[(\text{fancy rpm x diameter}) - (\text{swift rpm x diameter})]}{(\text{swift rpm x diameter})}$$

Both diameters are measured over the wire.

GAUGING OF CARD ROLLER SETTINGS

GAUGE	THICKNESS (mm)	THICKNESS (inches)
14	2.03	0.080
16	1.63	0.064
18	1.22	0.048
20	0.91	0.036
22	0.71	0.028
24	0.56	0.022
26	0.46	0.018
28	0.38	0.0148
30	0.32	0.0124
32	0.27	0.0108
34	0.23	0.0092
36	0.19	0.0076

Source CSIRO

INDICATE THAT the gap between working rollers is critical and varies throughout the card, being wider at the start of the carding process and gradually becoming closer until at the end of the finisher card, the closest settings are used.

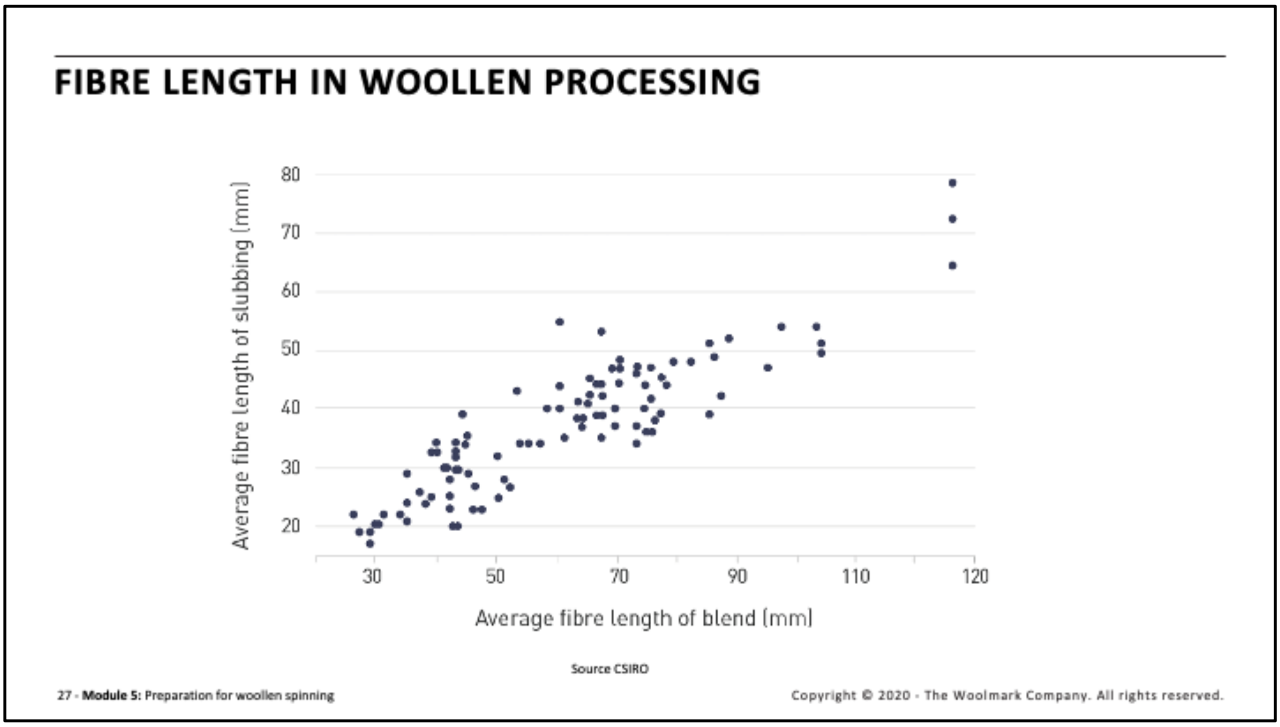
EXPLAIN THAT this ensures the fibrous material is gradually opened, rather than trying to open fibre more quickly, with a view to reducing time and costs of production.

NOTE THAT if the gap is set too wide for the particular material, the material will tend to be rolled between the surfaces and become extremely difficult to open during later stages of processing, leading to an increase in fibre faults.

If the gap between the worker rollers is set too close, fibres will be broken, and in the extreme the card can jam and grind to a halt.

MENTION THAT in the UK, the spacing between carding rollers is traditionally set with gauges marked in' Imperial Standard' wire gauge numbers.

REFER participants to the table on the slide, which lists the gauge sizes normally encountered and gives their equivalent in millimetres and in inches.



EXPLAIN THAT in the woollen processing route, fibres are presented to the card in locks or tufts, which have to be opened finally to the single fibre state, and, if possible, the individual fibres should be mixed together. This can be expected to produce fibre breakage.

NOTE THAT all methods of separating fibres produce fibre breakage, as is shown by the results of a small experiment conducted by CSIRO, which measured the average fibre length of a sample of wool opened by hand cards and by a carding machine.

POINT OUT that the average fibre length of the feedstock was 73 mm. After hand carding the length reduced to 65 mm. When machine carded the result was 63 mm.

This experiment suggests most fibre breakage depends more on the state of the feed material and less on the carding action.

Nevertheless, due to the large magnitude of fibre breakage, it is imperative to find techniques to minimise the outcome.

MENTION THAT to obtain some basic information on the fibre length of woollen blends at various stages of processing, a survey was carried out some years ago in across 50 mills in Great Britain. The survey covered blends consisting wholly or partly of wool, cashmere and man-made fibres.

Yarns produced from these fibres ranged from knitting and weaving to carpet-pile yarns.

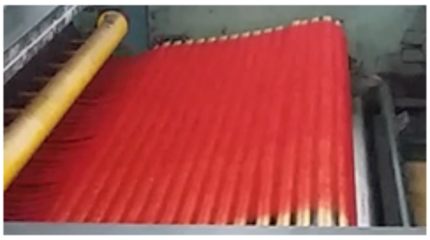
For the blends covered in the survey, the average fibre length ranged from 25 to 125 mm with 80% of the values between 30 and 80 mm.

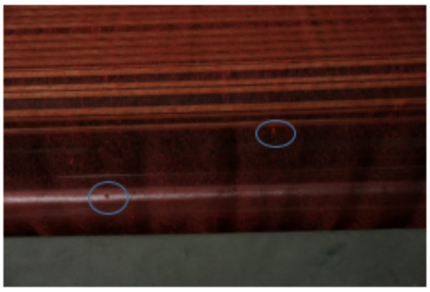
EXPLAIN THAT as would be expected, and as shown in the accompanying slide, the average lengths of the fibres in the slubbings were less than those in the corresponding feed blends. The suggestion from the data is that longer wools break more often than shorter wools.

***ASK** participants to explain what a nep is.*

***COLLECT** responses from around the room and use the content to support the discussion before moving on to next slide.*

NEP FORMATION IN WOOLLEN CARDING





- Neps result in yarn faults
- No mechanism is available to remove neps in woollen processing.
- Understanding the reasons for nep formation aids in reducing their frequency.
  - Finer fibres are more prone to neps.
  - Dyed fibres tend to result in more neps.
  - Carding conditions affect nep frequency.

28 - **Module 5:** Preparation for woollen spinning

REINFORCE THAT a nep is any entanglement of fibres that cannot be separated by needles during examination. Neps are a major problem in the carding of staple fibres, such as wool, and are common to both natural and man-made fibres. Neps in the web on the cross-lapper can be seen in the bottom photo.

EXPLAIN THAT neps are a serious defect in both worsted and woollen manufacture. In the latter, they detract from the appearance of the yarn and fabric as they tend to rise to the surface of the yarn during spinning. They limit the spin count and increase end breaks in spinning.

POINT OUT that unlike the comb in the worsted sector, there is no machine to remove neps during woollen yarn manufacture, so understanding the reasons why neps form and how to minimise them is vital to quality woollen-spun yarn production.

NOTE: Nep content is often a function of fibre diameter: the finer the fibre, the greater the number of neps.

NOTE THAT increased entanglement caused by the wet operation of scouring, carbonising and of fibre dyeing also increases nep levels.

INDICATE THAT carding conditions, such as overproduction of the card (where the mill to put more wool through the card than the optimum production rate) causes an increase in neps, as does poor adjustment of settings, speeds, etc., along with poorly-maintained wire surfaces.

NEP FORMATION: ROLE OF FIBRE DIAMETER

MATERIAL	NEPS/g IN CARD FOREPART	NEPS/g IN FINISHER WEB
24µm lamb's wool	18	4
19.5µm broken tops	59	52
21µm noil	173	113
19.5µm lamb's wool	208	155

29 - **Module 5:** Preparation for woollen spinning

INDICATE THAT there is no doubt fibre diameter plays an important role in the nep content of the card web.

EXPLAIN THAT finer fibres always produce more nep in webs than broader fibres and, as such, demand more rigorous conditions during carding if unacceptable nep is to be avoided.

The state of the material being fed to the card must always be considered.

POINT OUT that fibre diameter effects of 24µm and 19.5µm wools are shown in the table. Broken top has been previously combed and, as a result is more open. Comparison of the outcome using broken top with the 19.5um lamb's wool clearly shows the advantage of minimising entanglement in the feed material.

EXPLAIN THAT the 21µm noil, loaded heavily with nep due to its history (noil includes the waste from worsted combing and contains all the neps removed from the worsted sliver) contains a lot more nep than one would expect from, say, a 21µm lamb's wool or virgin wool.

NEP FORMATION: EFFECTS OF CARD PRODUCTION RATE

CARD PRODUCTION RATE (kg/h)	NEPS/g IN CARD WEB	
	Swift at 80 rpm	Swift at 120 rpm
12	36	14
15	62	13
20	105	19

30 - **Module 5:** Preparation for woollen spinning

EXPLAIN THAT the production of a card may be affected in two ways:

- by altering the throughput (i.e. the thickness or density of the fibre stream passing through the machine)
- by altering the speed at which the stream moves (i.e. the dimensions of the main drive of the machine).

INDICATE THAT the results of an experiment by CSIRO to study the role of production rate on nep frequency indicates that:

- an increase in throughput with constant swift speed will increase nep frequency,
- there will be fewer neps at higher swift speeds with constant throughput, providing the machine is not taxed beyond its capacity.

POINT OUT that these results have a similarity to the results on the effect of speed on the worsted card and quality of carding using fibre density flows, which is discussed in the course of the The Woolmark Wool Science, Technology and Design Education Program course *Worsted top-making.*

PROPERTIES OF TYPICAL WOOLLEN WEBS

PROPERTY	RANGE OF VALUES
Weight per course area of web (g/m^2)	5–50
Width of web (m)	1–3
Thickness of web* (mm)	2–5
Mean diameter of fibre (µm)	15–60
Mean length of fibres (mm)	15–180

*Distance between two planes which include practically all fibres.

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INDICATE THAT as guidance for practical woollen carding, some of the characteristics of typical woollen webs, which may consist of both wool and man-made fibres, are highlighted in the table.

WOOLLEN CARDING: THE CONDENSER

Image courtesy of Blackberry Ridge Woollen Mill (USA)

32 - **Module 5:** Preparation for woollen spinning

INDICATE THAT the final web from the finisher card is fed into the tape condenser. By application of a scissoring action between the tape and a smooth roller (the calendar roll), the tape condenser splits the web into many narrow webs.

EXPLAIN THAT the width and the number of tapes across the card is determined by the yarn count range to be spun. Narrow tapes are used for fine counts and wider tapes for coarser counts. These narrow sections of web are fed to rubbing aprons oscillating at right angles to the direction the web is travelling through the card.

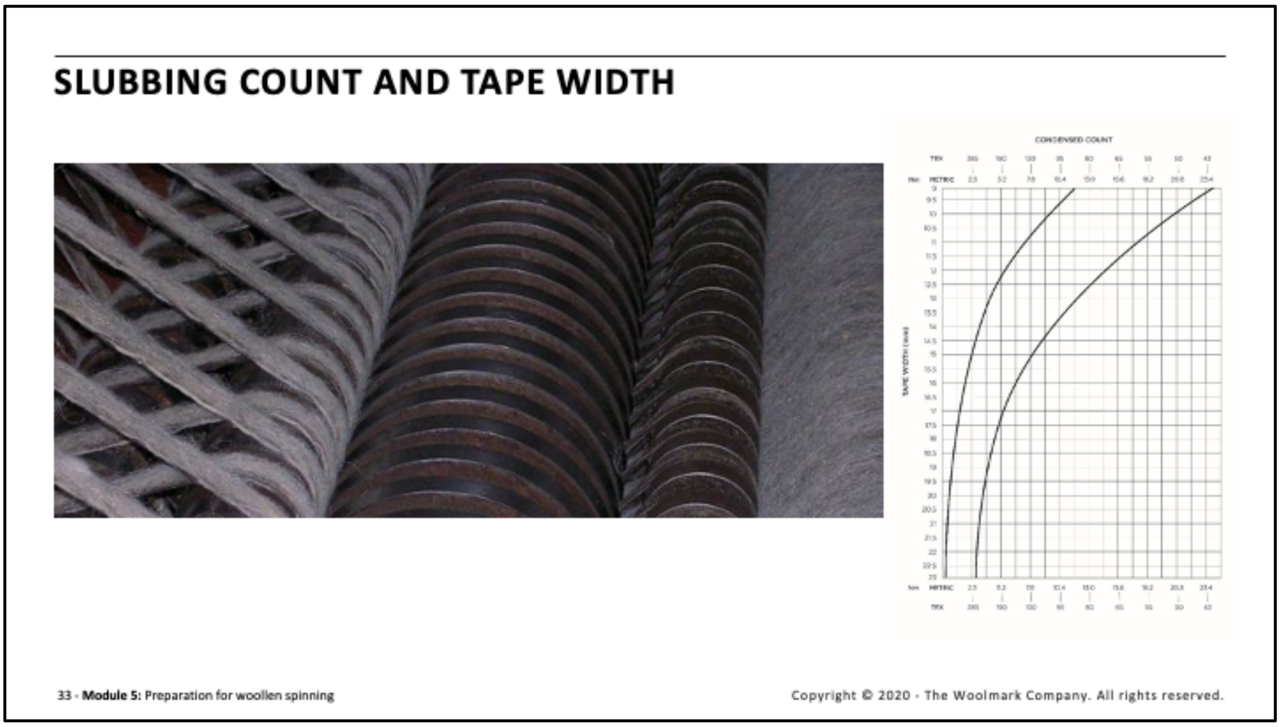
NOTE THAT these rubbed or condensed webs, now possessing some strength for handling later, are fed to take-up rollers, which form them into bobbins. At this stage, the compacted narrow webs, after condensing, are referred to as slubbings.

POINT OUT that tapes for woollen cards are usually of either the series or endless type. Endless tapes are used most in the fine lamb's wool trade because they should, in theory, ensure even tape tension along the width of the card.

The series-type tapes often have uneven tensions between tapes, giving uneven slubbing weights.

EXPLAIN THAT for yarn with twist below about 315 turns/m (8 turns/inch), it has been found the degree of consolidation of fibres in a slubbing affects yarn strength. The more consolidation the greater the yarn strength. This effect is most obvious in low twist yarns.

For a given condenser, the amount of consolidation is usually controlled by the setting of one apron to another, the speed of the eccentric shaft and the stroke (throw) of the rubber.



INDICATE THAT as discussed on the previous slide, the width and number of tapes across the card is determined by the yarn count range to be spun. Narrow tapes are used for fine counts and wider tapes for heavier counts.

NOTE THAT fine count cards have tapes around 10 mm wide and at the extreme spin down to about 40 Nm, while medium counts of 8 Nm would have tapes around 14 mm wide.

Machinery manufacturers provide tables or charts shown on the slide to advise on the choice of tape width.

POINT OUT condenser tape width is a critical carding parameter.

- If the tape is too wide for the count, the card web will tend to be lean and uneven.
- If too narrow, the tape is unable to hold the weight of web per course area and problems will arise when dividing the web up into slubbings.

EXPLAIN THAT in order to increase production rate, double and even triple rubbing sections are sometimes used.

HAND OUT *a sample of woollen slubbing, asking participants to note how weak it is, even though it has been 'rubbed' to increase its cohesion.*

ADVISE *participants that the strength of the strand increases dramatically as the slubbing is twisted during spinning.*

TWIST *a small section to demonstrate this effect.*

SLUBBING PACKAGE

Winding from card

Unwinding on spinning frame

Image courtesy of Blackberry Ridge Woollen Mill (USA)

34 - **Module 5:** Preparation for woollen spinning

INDICATE THAT after rubbing, the slubbings are wound onto packages via a surface drum. The surface drum keeps the winding speed constant whatever size the package has grown to.

The packages are removed or ‘doffed’ when full and the condenser ‘creeled’ with empty packages. The width of the packages is chosen to allow for easy handling should manual handling be required.

EXPLAIN THAT for automatic systems, larger packages can be used. The diameter of packages is limited because the slubbings are soft and cannot be wound tightly.

ASK *participants to explain the differences and similarities between a roving and a slubbing.*

IF NECESSARY, *reinforce that:*

- *a roving is formed on the worsted system from a single top and has long fibres*
- *a slubbing is separated from card web and has short fibres*
- *they are both ‘rubbed’ to improve strength and cohesion before being wound onto a package.*

PRODUCTION RATE PER COURSE WIDTH OF WOOLLEN CARD

BLEND TYPE	SLUBBING COUNT		MACHINE WIDTH	PRODUCTION RATE	
	(Nm)	(YSW)	(mm)	(kg/h)	(kg/h/m)
Carpet yarn	2.5	5	1830	81.6	45
	2.5	5	2440	108.9	45
Hosiery yarn: all wool	6.3	12	2540	72.6	29
Hosiery yarn: medium-quality wool	4.7	9	1525	18.1	12
	5.1	10	1525	15.9	10
	7.4	141	1525	13.6	9
	8.7	17	1525	11.3	7
	10.0	20	1525	9.1	6
Wool/nylon/polyester	6.3	12	1525	15–9	10
Lamb's wool	10.0	12	1525	6–8	4

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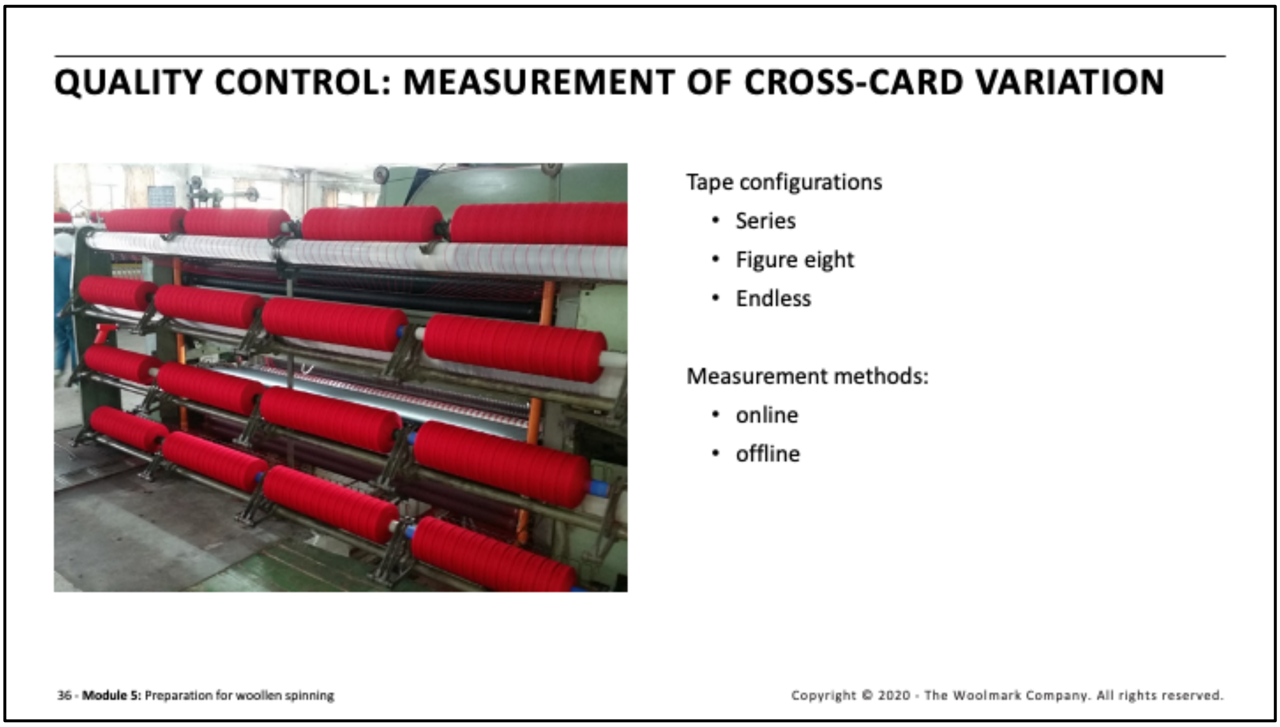
INDICATE THAT to compare production rates of machines of different widths, the production rate per course width (P) is usually calculated.

EXPLAIN THAT the values tabulated on the slide indicate typical P values achieved in practice.

POINT OUT factors that can affect the production rate include:

- the type of wool (as seen in the table)
- the number of ends on the condenser
- the degree of consolidation required by different blends for different end uses.



NOTE THAT the measurement of cross-card variation on a woollen card is required as a frequent check in commercial woollen carding to ensure the weight (per course length) is consistent across the card.

INDICATE THAT the methods for comparing slubbing variation and the frequency of testing depend on:

- the type of yarns spun
- the type of condenser in operation
- the frequency of adjustment to the card
- the fibre blend being processed.

EXPLAIN THAT the measurement of slubbing variation is time consuming, therefore each woollen processor must decide on the amount of testing to carry out. A weekly check is recommended for hosiery and fine count yarns. The minimum level of testing frequency for competent woollen yarn production is monthly. In theory, checks should be carried out after each blend change and/or machine adjustment.

The type of tape configuration (i.e. type of condenser) affects the number of ends that should be checked and overall frequency of testing.

NOTE THAT there are basically three types of condenser to consider:

- series — all ends each time representing each tape
- figure eight — two banks of bobbins each time representing each tape
- endless — one bank of bobbins only to check across the card.

EXPLAIN THAT the number of ends tested can be reduced on certain types of creel without affecting the competence of the test; even so, periodically, a test is required on each end.

There are two types of measurement that can be used to measure cross-card variation:

- online measurement
- offline measurement.

MENTION THAT as online testing is expensive, offline techniques are still the most popular test methods employed.

METHOD OF TESTING FOR SLUBBING WEIGHT

- Identify and break the sample of slubbing.
- Tension and cut 10 × 1 m samples.
- Check balance for zero and weigh sample.
- Check against specification.
- Adjust if necessary.
- Build a set of data for the bobbins.

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EXPLAIN THAT the weight of the slubbing is controlled by adjustments to the speed of the card belts and rollers relative to the feed rate of the feed hopper.

INDICATE THAT to allow for efficient operation of the spinning machine, the target carded weight is set approximately 30% higher than the target spun yarn count.

MENTION THAT the weight per course length of the slubbing should be checked at least twice per set of bobbins off the card.

Method:

- Identify, code and break the designated slubbings.
- Run off 10 arm lengths of slubbing and break this end.
- Hang the lengths on a clamp, under light tension, and cut a metre length. Check there are 10 × 1 m lengths on the clamp.
- Check the balance is zeroed and weigh the sample.
- Determine the slubbing weight per course length.
- Record value and check against specification.
- If the value is outside specification, adjust the doffer speed accordingly.
    - If the weight is too heavy, increase the doffer speed.
    - If the weight is too light, slow the doffer speed.
- If adjustments to the weight have been made, wait 1–3 minutes for fresh slubbing to emerge and check again to ensure the desired target weight per course length has been reached.
- Compare weight results against specifications and record data to build a history for quality control purposes.

POINT OUT that operators should keep the feed hopper as full as possible at all times when the machine is operating. Fluctuations in the level of this hopper will result in changes to the bulk density of the wool, which will cause the weight of the slubbing to vary.

QUALITY CONTROL: INTERPRETING DATA

1. Bank-to-bank variation
2. Side-to-side variation
3. Erroneous count variation

38 - **Module 5:** Preparation for woollen spinning

EXPLAIN THAT the results recorded require a number of calculations to interpret the information. The areas that require analysis (linked to tape configuration) are:

- bank-to-bank variation (the slide shows four 'banks', one over the other)
- side-to-side variation
- erroneous count variation (due to individual tape tension).

Bank-to-bank variation

INDICATE THAT the phenomenon of bank-to-bank variation can be due to a number of factors. To determine which of these is causing the irregularity, one must go through a process of elimination.

The areas of fault could be:

- surface drum linear speed differences
- rubbing apron linear speed differences
- tape tension differences.

It will normally be found that tape tension is the problem fault on series and figure eight tape condensers. After the necessary corrections have been made a following cross-card check will confirm the corrections have yielded the desired effects.

Side-to-side variation

MENTION THAT side-to-side variation can be due to a number of machine faults:

Tape roller skew

- The problem of tape roller skew is only a problem on series and figure eight condensers.
- The skew of one tape roller will give opposing high and low readings on one side of the card, but the average of all banks will be equal across the card.

Card roller skew

- The fault of card roller skew is normally notable due to the side-to-side variation in a straight line when taking the average of all banks.
- The fault is normally due to the fancy, but it could also be due to any other roller on the carder parts.

The intermediate feed.

- Variation from the intermediate feed is normally noticed as a progressive tapering-off of the slubbing weight per course area at the edges of the card.
- The fault can be due to either the lay of the sliver being short of the card sides, or there being a difference in overhead feed rate to cross-lapper speed.

Erroneous count variation

EXPLAIN THAT there may be some variation on individual tapes. This is usually due to individual tape tension, with a tight tape taking more fibre and a slack one taking less.

It can also be due to damaged card clothing, a lap on the fancy or fibre trapped between the undergrid and a card roller.

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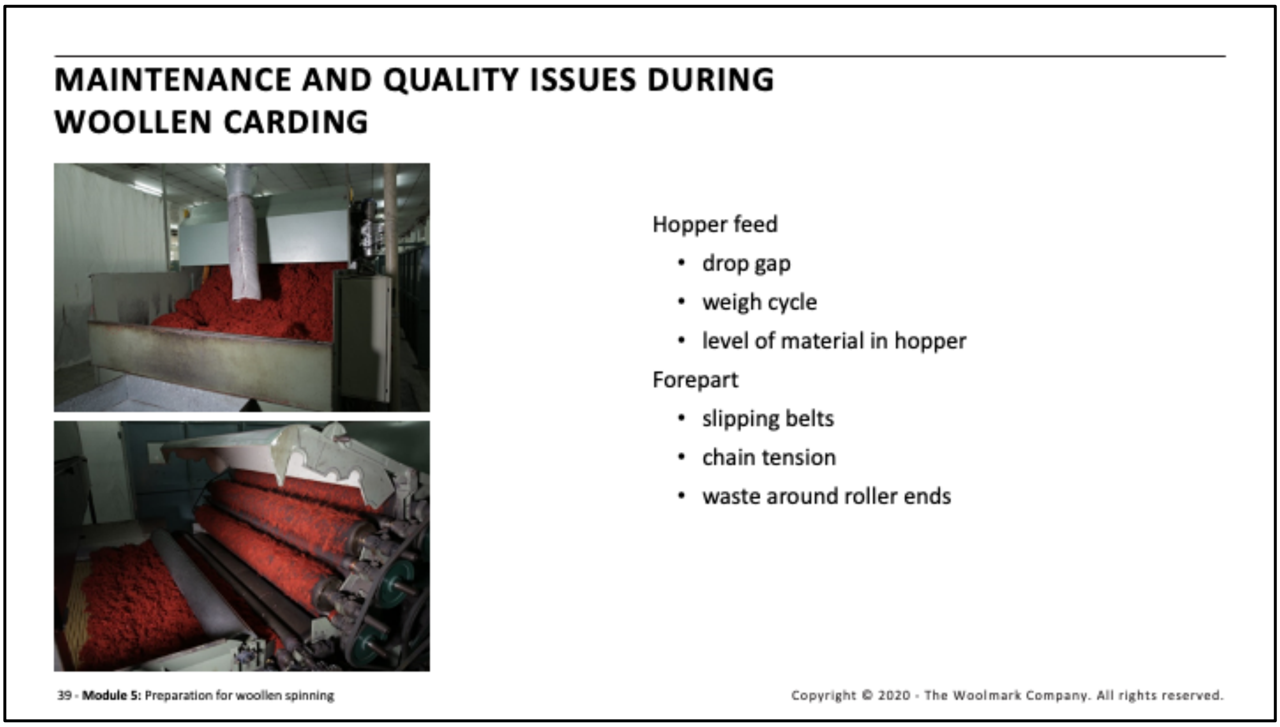


EXPLAIN THAT whenever a new blend is started on the card, the following elements of the card should be checked. If followed, most normal faults on the carding machine can be avoided.

Hopper feed

Drop gap: This should be set so there is no gap between each drop. If there are gaps, the hopper should be reset to eliminate this gap. If the gap is not set correctly (i.e. there is a gap or the material is overlapping) then this causes yarn irregularities.

Weigh cycle: The weigh pan has to achieve all its pre-set weight in good time. If it is filled too quickly, there is a possibility of a large fluctuation of weighs on each drop, resulting in irregular yarn count. If the time required to achieve the correct weigh is too long, the result is missed weights, which causes light and irregular yarn. It has been found that the weigh pan operates at its optimum when the hopper achieves the set weight in the weigh pan at two-thirds its full cycle.

Level of material in hopper: This level should be kept at a constant amount of material in the back of the hopper. When the level alters, this results in an increase or decrease in the amount of in-flight fibre dropping into the pan. Although the electronic hoppers currently on the market compensate for this, it is still best practice to keep this level constant.

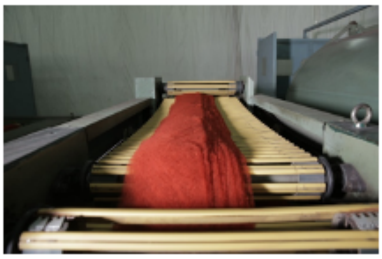
Forepart

Belt slippage: Belts should have the correct tension on them so there is no slippage during running, as this can cause irregularities in the resultant yarn. It is best practice when oiling the machine cycle to check all belts for tension and adjust when necessary.

Chain tension: Chains should have the correct tension on them so there is no slippage during running, since this can cause irregularities in the resultant yarn. Again it is best practice when oiling the machine to check all chains for tension and adjust when necessary.

Waste around roller ends: Any waste build-up at the end of rollers should be removed, since this could cause rollers to stop turning and also it could be a fire risk—the friction on the material is sufficient to create a high temperature, which could ignite spontaneously.

MAINTENANCE AND QUALITY ISSUES DURING WOOLLEN CARDING



Intermediate feed sheet
- Overlap
- Laying to sides
- Sliver tension to overhead
- Sliver tension back to carriage

Condenser
- All tapes
- Waste accumulation
- End slubbing count
- Waste in nip of calendar roller
- Web clarity

Fettling
- Frequency

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Intermediate feed sheet

Overlap: The laying of the material on the feed sheet is critical if an even yarn is to be achieved. Take care when making adjustments: the sliver lying across the feed sheet should be set so there are no gaps between each one, and there is an overlap, which varies according to the type of feed.

Laying to sides: Ensure the sides are not thrown too far out or are too short.

Tension on sliver to overhead: The sliver, if it is not carried by a lattice to the overhead conveyer, should be able to support its own weight to the overhead conveyer, even when the sliver has been damaged to the extent that only 75% of the sliver is intact.

Tension on sliver from overhead to carriage: The tension on the sliver from the front overhead pulley to the carriage rollers should be neutral — the sliver should not overfeed the carriage rollers, nor should it be so tight the sliver pulls away from the edge of the feed sheet (i.e. the sliver follows the carriage as it reverses direction for a short distance).

Condenser

All tapes on calendar rollers: Check to see all the tapes are properly positioned on the calendar roller.

Waste round all tape rollers: Check waste has not lapped round any of the rollers as this can lead to stretching of tapes, resulting in irregular end-to-end counts. This also may cause irregular slubbing, because the lapping tends to slightly rub the stubbing.

Waste in nip of calendar roller: When this happens, it produces irregular and weak slubbings.

End slubbing is correct count: Check the side slubbing on the carding machine regularly, as large count variations often occur (i.e. in excess of ± 25%).

Web clarity: Check the appearance of the web for nep content, fibre distribution and web tension.

NOTE THAT all of these points affect the efficiency of the carding and spinning as well as the quality of the yarn. The nep content and fibre distribution indicate the state of the card clothing and settings of the carding machine.

Fettling

Frequency: Fettling has always to be done before nep increases in the web. The frequency varies greatly between different blends, but for greasy wools can be as little as 500 kg and sometimes as much as 10 tonnes on clean blends.

DIFFERENCES IN THE MANUFACTURING CONDITIONS FOR STRONG WOOLS: BLENDING

- The minimum number of fibres generally regarded as being necessary for adequate processing of woollen yarns from strong wool types is 120.
- **Carding:** The correct degree of openness is also vitally important in order to minimise fibre breakage.
- **Dyeing:** Lamb's wool and Shetland blends are usually dyed in relatively small batches.
  - Multi-colour blends are widely used.

Images courtesy of Australian Wool Exchange

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EXPLAIN THAT for both strong wool and lamb's wool processing, yarn regularity and processing performance is significantly affected when reducing the number of fibres in the yarn cross-section.

INDICATE THAT the minimum number of fibres generally regarded as being necessary for adequate processing of woollen yarns from strong wool is 120.

Blending

In applications using strong wools, it is still important to produce a blend at a given price. In order to achieve price objectives, mills will often combine several different blend components.

EXPLAIN THAT the use of more than one component also allows easy substitution with another type should one wool be unavailable at any time.

POINT OUT that the conditions for opening of strong wools differs from that of finer wools especially lamb's wool. Notwithstanding the degree of opening of strong wools must be properly managed to ensure carding with minimum fibre breakage.

NOTE THAT lamb's wool and blends of strong wools are usually dyed in relatively small batches. It is often necessary to combine more than one dyeing in order to achieve the correct blend weight and also to help ensure the final colour is absolutely right.

SUMMARY — MODULE 5

The aim of the carding process is the formation of a homogenous web.

Compared with a worsted card, the woollen card:

- is significantly longer with more sections
- is required to do more opening that a worsted card
- provides a more uniform web.

A woollen card usually comprises five major sections:

1. controlled hopper feeder
2. breaker card or forepart
3. intermediate feed using cross-lapping
4. the finisher card
5. the condenser.

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SUMMARISE this module by explaining that the aim of the carding process is the formation of a homogenous web in terms of weight per course area.

REMIND participants that compared with a worsted card, the woollen card:

- is significantly longer with many more sections
- is required to do more opening, mixing and blending than a worsted card
- provides a more uniform web both across and along the web.

REITERATE THAT a woollen card usually comprises five major sections:

- controlled hopper feeder
- breaker card or forepart
- intermediate feed using cross-lapping
- the finisher card
- the condenser.

SUMMARY — MODULE 5

- Input to the woollen card is usually by a weighing-hopper feed.
- The first section in the actual carding zone is the forepart or breaker card.
- The card is usually split into forepart and finisher sections, linked with a cross-lapping device.
- The finisher card evens out any mass variations.
- The final web from the finisher card is fed into the tape condenser.

The differing mechanical actions include a:

- combing action
- carding action
- cross-lapping action
- stripping action
- doffing action
- splitting and condensing action.

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REITERATE THAT input to the woollen card is usually by a weighing-hopper feed.
It is vital the feed be set optimally for the type of fibre being processed as the aim of the carding process is the formation of a homogenous web in terms of weight per course area.

REVIEW the first section in the carding zone is the forepart or breaker card. The purpose of this section is to break up the tightly-formed clumps of fibre entering the card.

The card is usually split into 'forepart' and 'finisher' sections, linked with a cross-lapping device. The purpose of the cross-lapping device is to allow for more adequate blending of the wool and to reduce the mass variations in the carded web.

REMIND participants that the finisher card continues the fibre opening, ideally to the individual fibre state, and evens out any mass variations to produce the best web possible for manufacturing high-quality yarns.
The final web from the finisher card is fed into the tape condenser. The tape condenser splits the web into many narrow webs.

The card, or carding machine, comprises a series of horizontally-aligned rotating rollers or cylinders that are covered in pins of differing configurations

REMIND participants that these differing configurations leading to a range of mechanical actions, in order as the wool passes through the machine, include a:

- combing action
- carding action
- cross-lapping action
- stripping action
- doffing action
- splitting and condensing action.

ASK *participants if they have any questions about the content covered in this module.*

ALLOW *time for questions and discussion before proceeding to the final slide and closing the lecture.*

INFORM participants of the time and location for the next lecture — *Module 6 Woollen ring spinning* — and encourage them to read through the relevant notes in their Participant Guides before attending the lecture.

ENCOURAGE participants to explore the Woolmark Learning Centre to reinforce and build on what they have covered in today's lecture.

Participants can register with and explore the Woolmark Learning Centre here: www.woolmarklearningcentre.com

BEFORE participants leave ensure you have collected all materials distributed during the lecture.

MODULE 6

THE WOOLMARK COMPANY

WOOLLEN SPINNING

RESOURCES —
MODULE 6: WOOLLEN RING SPINNING

Contained in the *Worsted and woollen spinning* Demonstration kit you will find the following resources for use as you deliver **Module 6: Woollen spinning**:

- length of woollen top (2m)

WELCOME participants to Module 6 of the Woolmark Wool Science, Technology and Design Education Program — *Worsted and woollen spinning —Woollen ring spinning*.

EXPLAIN THAT this module provides an overview of woollen spinning and covers:

- machine mechanics in woollen spinning
- woollen yarn production and characteristics
- spinning issues for felt-resist-treated woollen-spun knitting yarns
- the limits of the woollen spinning system.

INFORM participants that by the end of this module they will be able to:

- identify the mechanics of the machines used in woollen spinning
- describe the special needs of fibre control in woollen spinning and compare those with worsted systems
- explain the reasons behind the differences in woollen spinning, compared with worsted spinning.

RESOURCES REQUIRED FOR THIS MODULE:

- *length of woollen top (2m)*

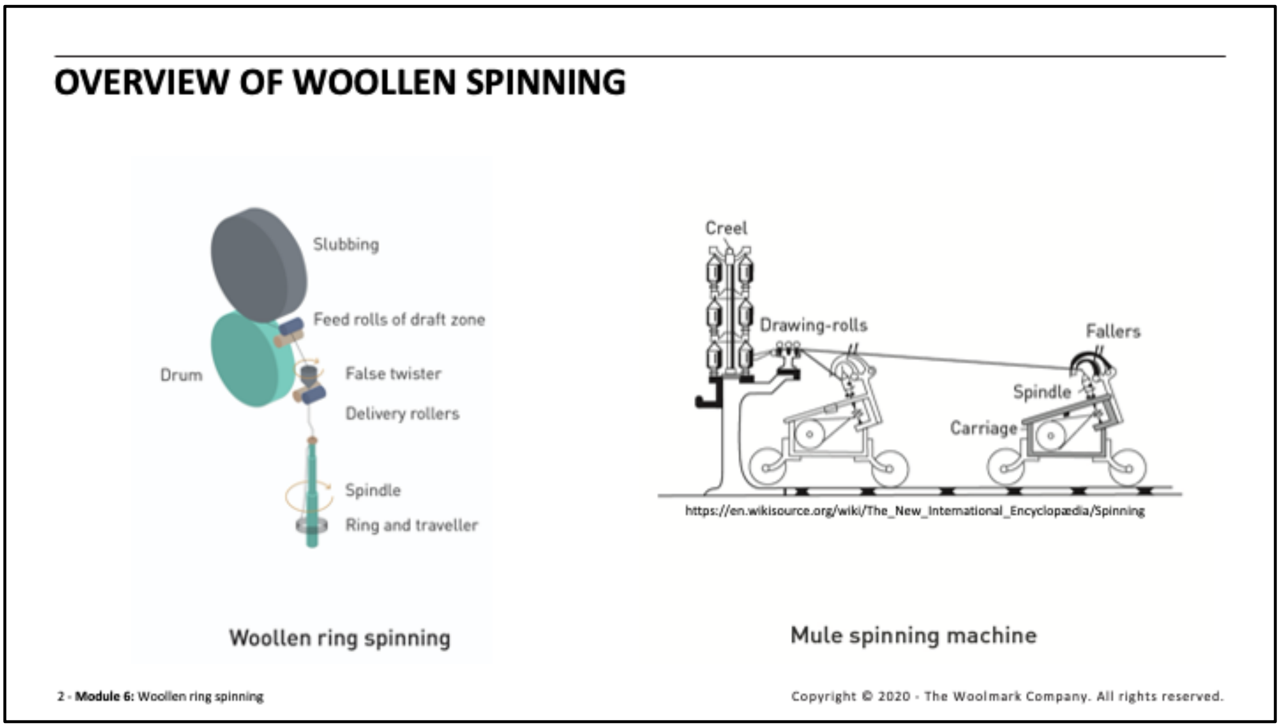
DISCUSSION: WOOLLEN SPINNING

***SPLIT** participants into small groups to discuss the issues in carding that affect the ability to spin.*

***ALLOW** five minutes for discussion before collecting responses from around the room.*

***ENSURE THE** following concepts are covered:*

- *The cohesion of the fibres in the web affects the formation of the slubbings.*
- *The orientation of the fibres to the axis of the slubbing affects the splitting of the web into slubbings.*
- *The regularity of the web density affects the evenness of the slubbings and the subsequent yarns.*
- *Residual vegetable matter in the web affects the evenness of the slubbings and the subsequent yarns.*
- *The number of neps formed in carding affects the quality of the yarn.*



EXPLAIN THAT woollen spinning consists of three main steps:

- drafting
- twist insertion
- winding the formed yarn onto the bobbin.

NOTE THAT there are two major types of spinning machine used in the woollen spinning industry:

- ring spinning
- mule spinning.

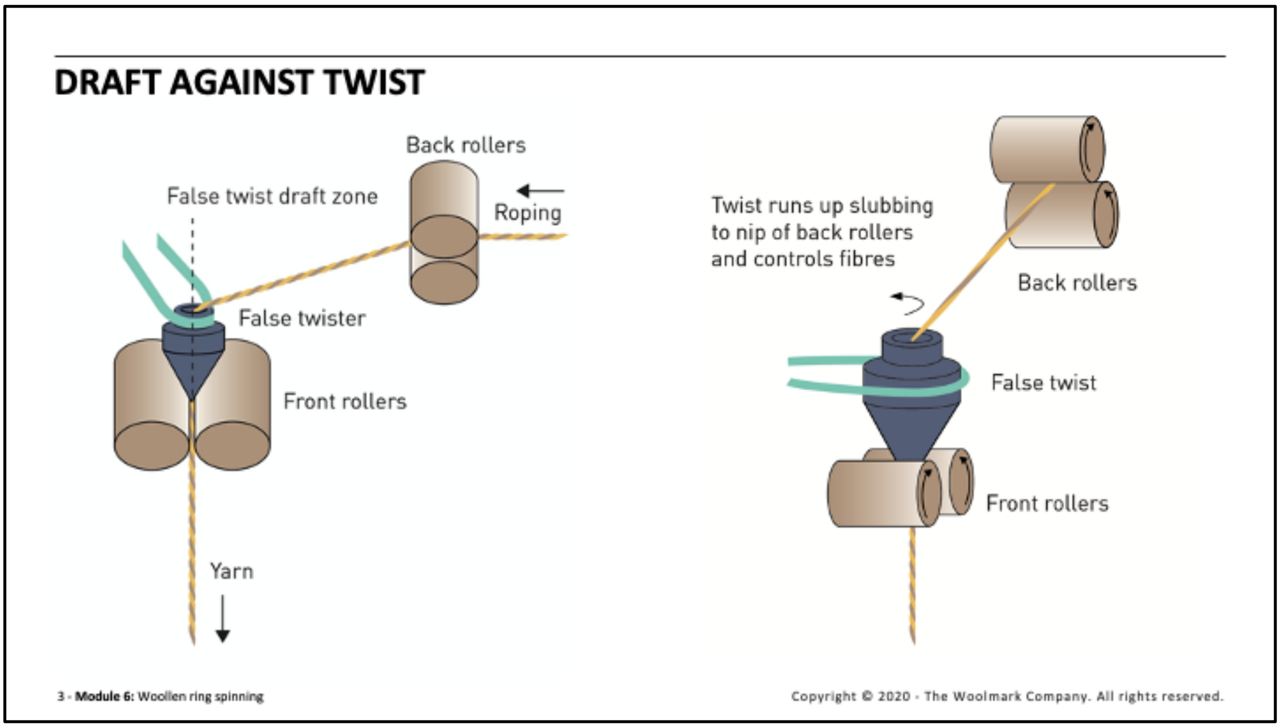
The three main steps are performed differently by each machine.

POINT OUT that the ring spinning machine combines drafting, twisting and winding into a continuous sequence and is more productive than the mule spinning machine.

EXPLAIN THAT during ring spinning, the woollen slubbing continuously enters the drafting zone on the spinning machine. After which a predetermined amount of twist is inserted to produce a singles strand yarn. The amount of twist inserted into a slubbing to make a yarn is determined by the end use to which the yarn will be put.

NOTE THAT in the mule spinning operation, drafting, twisting and winding occur in a discontinuous way: The drafting and twist insertion occur separately from winding onto the bobbin (which is sitting over the spindle and is not shown on the figure).

NOTE: Mule spinning is discussed more fully in *Module 8 Alternatives to ring spinning*.



EXPLAIN THAT drafting serves two purposes. It:

- improves fibre alignment and uniformity of the yarn
- reduces the linear density to the required yarn count.

INDICATE THAT drafting against twist (either false or real twist) offers better control of the fibres in the draft zone. Without twist, there would be a tendency for thin places to draft more than thicker places, causing more unevenness in the yarn, along with frequent slubbing and yarn breaks.

NOTE THAT twist tends to run preferentially to the thinner parts of a slubbing as the thinner sections have lower torsional rigidity. The relatively higher twist increases the strength of the thinner sections of the slubbing and so provides a stabilising mechanism to counteract their relative weakness.

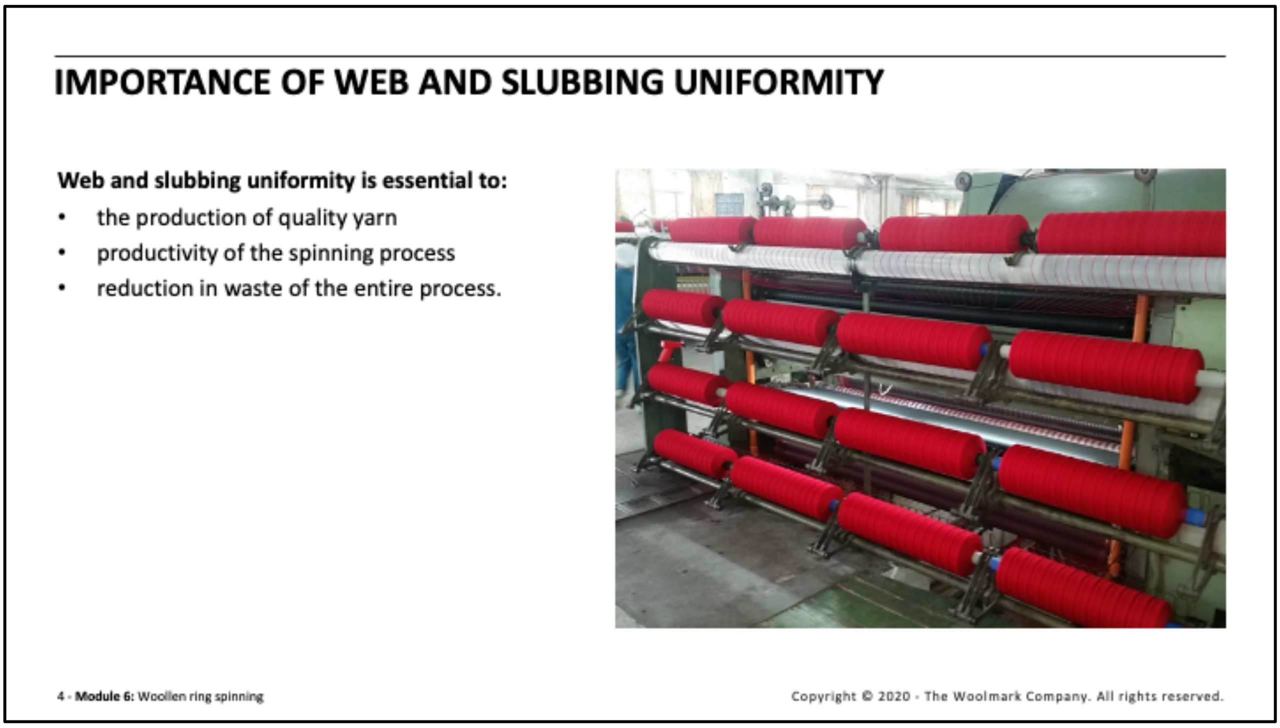
POINT OUT that in theory, the thicker places are preferentially drafted over the thin places. As they become lower in linear density, the twist redistributes to control further drafting. In this way, it is possible for the drafted slubbing or yarn to have better evenness than the parent slubbing.

EXPLAIN THAT in practice, the yarn irregularities are frequently (about 80%) due to the web irregularities already present at the carding stage. The conversion of web to slubbing, and to yarn generally, makes things slightly worse.
The twist level imparted by the false twister during drafting and the draft level itself have a marked effect on the yarn quality.

NOTE THAT the twist level is not always directly proportional to the twister speed relative to the delivery speed.
The twister can slip against the slubbing once twist reaches a certain level and resist further insertion of twist.

EXPLAIN THAT the optimum draft is usually around 30–35%. It depends on fibre length, fibre orientation and slubbing uniformity. The optimum twist level depends on fibre-to-fibre friction and fibre orientation and length.

***ASK** participants to explain why woollen spinning needs a false twister in the draft zone, while worsted spinning does not.*
***IF NECESSARY** explain that the fibres in the worsted roving are longer, giving it better cohesion and strength compared with the woollen slubbing. Note that the drafting zone in worsted spinning is shorter because the roving is more even.*



INDICATE THAT web and slubbing uniformity, both along and across the machine and both short term and long term, is essential to the production of quality yarn and also to the productivity and reduction in waste of the entire process.

POINT OUT that even so, because the fibres are poorly orientated to the yarn axis, and because there is a significant proportion of short fibres in most woollen yarns, not all fibres contribute their share to yarn strength.

4

EXPLAIN THAT this Woolmark company video shows the woollen spinning process.

POINT OUT that ring spinning is the most widely used method of spinning staple fibres such as wool.

In beginning this process, a slubbing is pulled from the packages from the creel into the drafting zone of the spinning machine.

NOTE THAT the drafting zone consists of input and output rollers running at the required speed differential. Within the drafting zone a device imparts **false** twist to the drafting slubbing to give it strength. The linear density of the slubbing is reduced as it passes through the drafting zone to that of the desired yarn count. Drafts around 1.25 to 1.5 are typical.
The fibre strand is attached to a spindle positioned inside a ring and running at high rotational speeds. There is one spindle for each strand of fibres being processed.

EXPLAIN THAT from the drafting zone, the yarn is threaded through a yarn guide then a clip (called a traveller), which is free to move around the ring and rotates with the spinning spindle inserting the **real** twist to the yarn.

The traveller also winds the spun yarn onto the tube placed on the spindle.
The ring and traveller move up and down relative to the spindle, distributing yarn regularly on the tube.

PLAY *video (1:44 minutes)*

AS THE *video plays note that:*

- *woollen spinning is similar to worsted spinning*
- *the slubbings are unrolled from the packages (11:00 seconds)*
- *the draft region is much bigger in woollen spinning (37:17 seconds)*
- *a false twister is used to give the slubbing sufficient strength during drafting (50:13 seconds)*
- *real twist is inserted by the ring and traveller (1:25 minutes).*

ASK *participants if they have any questions or comments regarding the video content.*

ALLOW *sufficient time for participants to respond before proceeding.*

PROPERTIES OF WOOLLEN YARNS

The most important characteristics of woollen yarns are:

- yarn count
- yarn twist
- yarn evenness (index of irregularity)
- yarn tenacity
- hairiness.

INDIRECT YARN COUNT SYSTEMS		COURSE OF YARN COUNT	CONVERSION NUMERATOR*
Metric	Nm	1 km/kg	1000
Worsted	NeW	560 yd/lb	885.8
Woollen Systems			
Alloa	Nal	11 520 yd/24 lb	1033
American cut	Nac	300 yd/lb	1654
American run	Nar	100 yd/oz	310
Cardado Coviha	NPw	1 m/5 g	5000
Dewsbury & Batley	Nd	1 yd/oz	31000
Galashiels	Ng	300 yd/24 oz	2480
Hawick	Nh	300 yd/26 oz	2687
Irish	Niw	1 yd/0.25 oz	7751
West of England	Nwc	320 yd/lb	1550
Yorkshire	Ny	256 yd/lb	1938

DIRECT YARN COUNT SYSTEMS			TEX TO YARN NUMBER	YARN NUMBER TO TEX
Tex	Tex	g/1000 m	1	1
Denier	Td	1 g/9000 m	9	0.111
Woollen (Aberdeen)	Ta	1 lb/14 400 yd	0.02903	34.45
Woollen (American grain)	Tga	1 grain/20 yd	0.2822	3.543
Woollen (Catalonian)	Tcw	1g/504 m	0.504	1.984

6 - **Module 6:** Woollen ring spinning

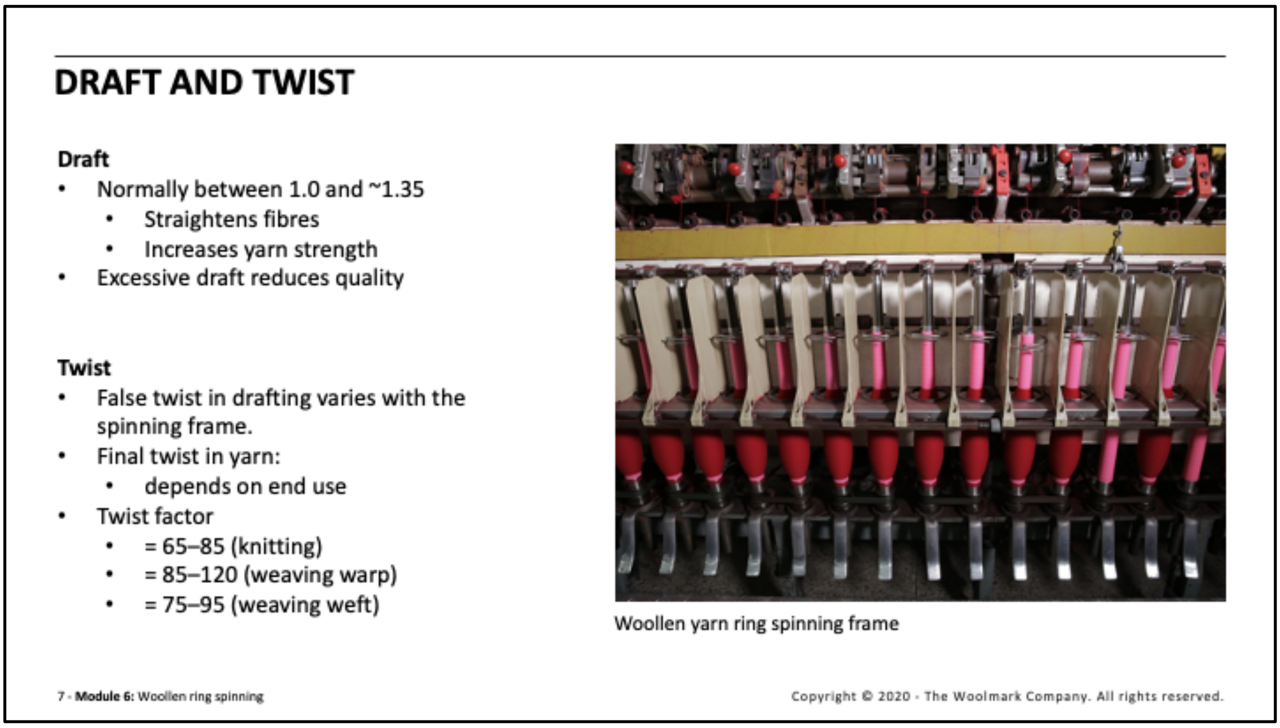
NOTE THAT the most important characteristics of woollen yarns are:

- yarn count
- yarn evenness (index of irregularity)
- yarn twist
- yarn tenacity
- hairiness.

EXPLAIN THAT the quality parameters of a yarn ultimately determine the mechanical, aesthetic, tactile and physiological characteristics of a textile product. The aim of an objective supply strategy is to determine the optimum in terms of price, further processing behaviour and fabric properties.

Yarn count

INDICATE THAT some of the many count systems used in woollen processing are shown in the slide.



EXPLAIN THAT woollen yarns may be plied or twisted together and subsequently knitted or woven in either singles or plied form.

POINT OUT that the slide shows typical figures for a woollen yarn ring spinning frame.

DEMONSTRATION: FALSE AND REAL TWIST

Resources required:

- *length of top (2m)*

ARRANGE *three volunteers side by side in a straight line.*

ASK *the volunteers at each end of the line to each hold an end of the length of top.*

FALSE TWIST:

Ask the volunteer in the middle of the line to hold the middle of the top with both hands (about 30cm apart) and impart twist to the top. This represents FALSE TWIST — when they let go of the top, the twist is released.

REAL TWIST:

Ask the volunteer in the middle of the line to step back from the top as they will not be needed for this part of the demonstration. Ask ONE of the remaining volunteers to twist the top using both hands. This represents REAL TWIST.

ASK *the volunteers to release the twist in preparation for the final demonstration and ask the volunteer in the middle of the line to step forward again.*

FALSE AND REAL TWIST:

Ask the volunteer in the middle to grasp the length of the top in the middle and hold it still.
Ask one of the volunteers at the end of the top to twist the top using both hands (REAL TWIST).
Invite a fourth volunteer to come forward and insert twist (FALSE TWIST) in the untwisted section between the first two participants.
Ask both volunteers in the middle of the top to release their hold — the false twist will fall out and the real twist will remain.

YARN EVENNESS (USTER)

SINGLES YARN		TWO-FOLD YARN	
Count (Nm)	Uster (%)	Count (Nm)	Uster (%)
1/10	8.7–13.5	2/14	7.1
1/14	9.5–14.0	2/16	7.3
1/16	11.3–16.5	2/20	8.6

Source CSIRO

8 - **Module 6:** Woollen ring spinning

EXPLAIN THAT the uniformity (evenness) of woollen yarns for a given number of fibres in the yarn cross-section is not as good as worsted yarns . The result is that commercial woollen yarns rarely have fewer than 100 fibres on average in their cross-section.

INDICATE THAT yarn irregularity or variation in count is critical in avoiding unwanted visual variations in the fabric. Measuring yarn irregularity (Uster — %) provides information regarding:

- the type and extent of mass variations in the yarn
- the number of faults and neps present and likely to affect the visual appearance of the product

POINT OUT that this slide shows typical Uster (evenness) values for commercial woollen-spun yarns measured using a Uster evenness tester.

NOTE:

- the evenness of coarse yarns tends to be lower than that of finer yarns
- the improvement in evenness as a result of two folding (twisting) the singles yarns.

ASK *participants to compare the Uster results shown in the slide for the singles yarns with those for the two-fold yarns.*

ALLOW *sufficient time for participants to respond.*

ACKNOWLEDGE *responses before proceeding.*

INDEX OF IRREGULARITY

$$\text{Index of yarn irregularity} = \frac{11.05 \times U\%}{D(\mu m) \times (Nm)^{1/2}}$$

U%	12.4	12.7
MFD	20	22
Nm	16	16
Index	1.7	1.6

Guidance values:

- Even <1.5
- Average ~2.0
- Uneven >2.6

https://textiles24.wordpress.com/2013/07/03/yarn-unevenness/

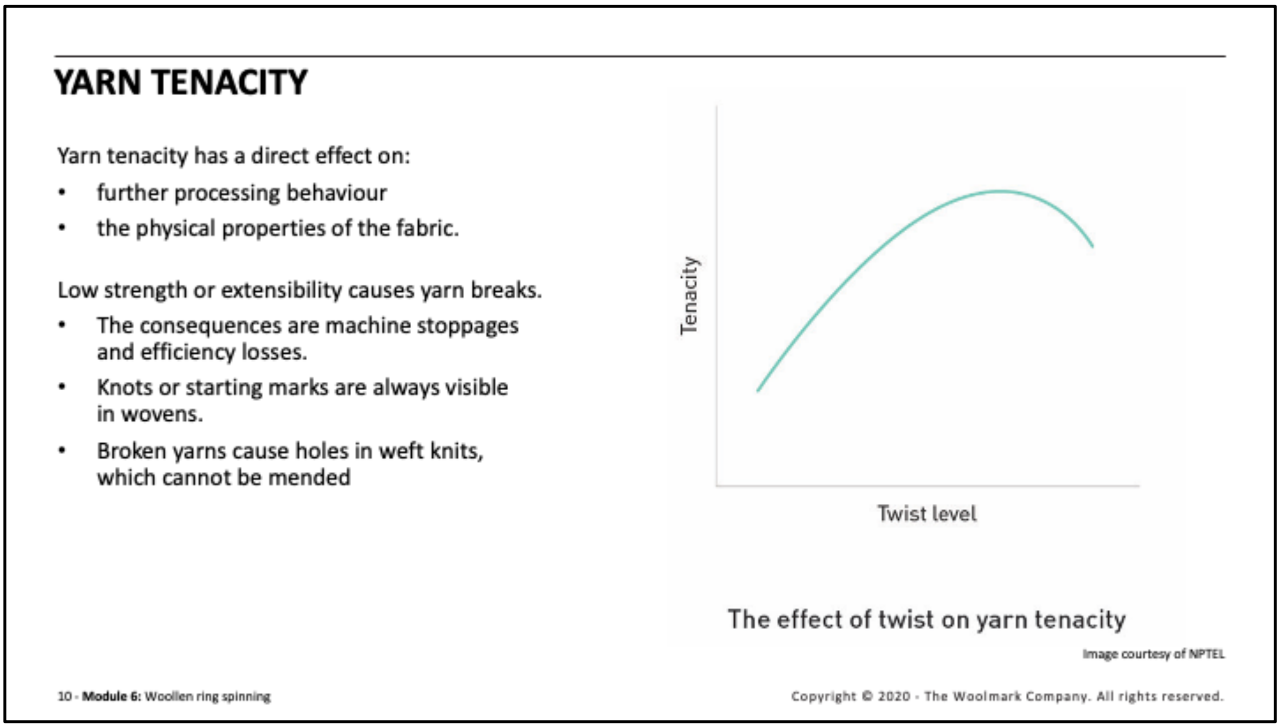
9 - **Module 6:** Woollen ring spinning

INDICATE THAT yarn irregularity (U% or CV%) varies with yarn count. When comparing yarns of different or differing counts for performance or acceptance, the use of the index of irregularity, which factors in the yarn count, is useful.

***NOTE** the formula on the slide.*
For example, if the Uster (U%) results from spinning a 1/16 Nm yarn from a 20µm wool and a 22µm wool are 12.4 and 12.7 respectively, the indices of regularity may be calculated.

EXPLAIN THAT with an index of 1.60, the yarn spun from the 22µm wool is more regular than the same count spun from the 20µm wool even though the Uster (U%) is lower for the 20µm wool. So when spinning the 20µm wool, the spinner is not doing as good a job as when processing the 22µm wool.

NOTE THAT the lower Uster value of 12.4% remains the more even yarn.



EXPLAIN THAT tensile properties of yarns (i.e. tenacity) have a direct effect on further processing behaviour of the yarn and the physical properties of the fabric.

INDICATE THAT yarns whose strength or extension under load is too low can break during later processes. This will result in machine stoppages and a reduction in knitting and weaving efficiency. Knots or starting marks are always visible in wovens, while holes in weft knits cannot be mended and create fabric waste.

NOTE THAT yarn tenacity is a measure used in comparing the breaking loads of two yarns, which differ slightly in count:

$$\text{Yarn tenacity} = \frac{\text{Mean single thread breaking load (g)}}{\text{Count (tex)}}$$

POINT OUT that woollen yarns have a lower tenacity than worsted yarns, and are considerably hairier.

NOTE THAT the effect of twist on yarn tenacity is shown on the slide. The tenacity of yarn increases with twist until a maximum is observed, after which the tenacity of the yarn decreases. The increase with twist (at low twists) reflects the greater contact between fibres. At high twist the load-bearing capacity of the fibres is affected by their increasing angle to the direction of strain along the yarn axis.

***ASK** participants to explain why there is a maximum in the strength/twist curve.*

***ALLOW** sufficient time for participants to respond.*

***IF NECESSARY** explain that fibre interaction reaches a maximum and fibre orientation becomes important.*

EXPLAIN THAT hairiness measurements provide information about the nature of the yarn visual thickness (not weight per course area) and any undue variations that present unwanted changes in the appearance of the product. Excessive yarn hairiness results in a deterioration of some types of knitwear, such as that shown on the slide.

FEATURES OF THE WOOLLEN SYSTEM

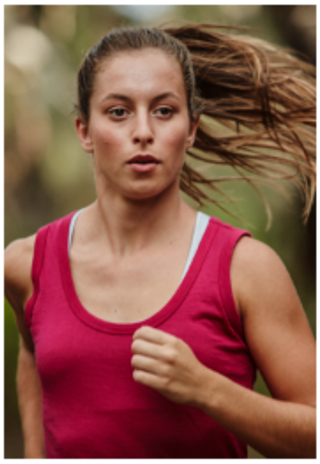
Benefits

- Can process wool types and wastes the worsted system cannot adding considerable value to the processing of wool.

Limitations

- As yarn becomes finer carding speed is limited lowering production rates and rapidly increasing costs.
- More fibres in the yarn cross-section required
  - n = 90
  - fine yarns >20 Nm are impractical.

Woollen-spun



Worsted-spun

12 - **Module 6:** Woollen ring spinning

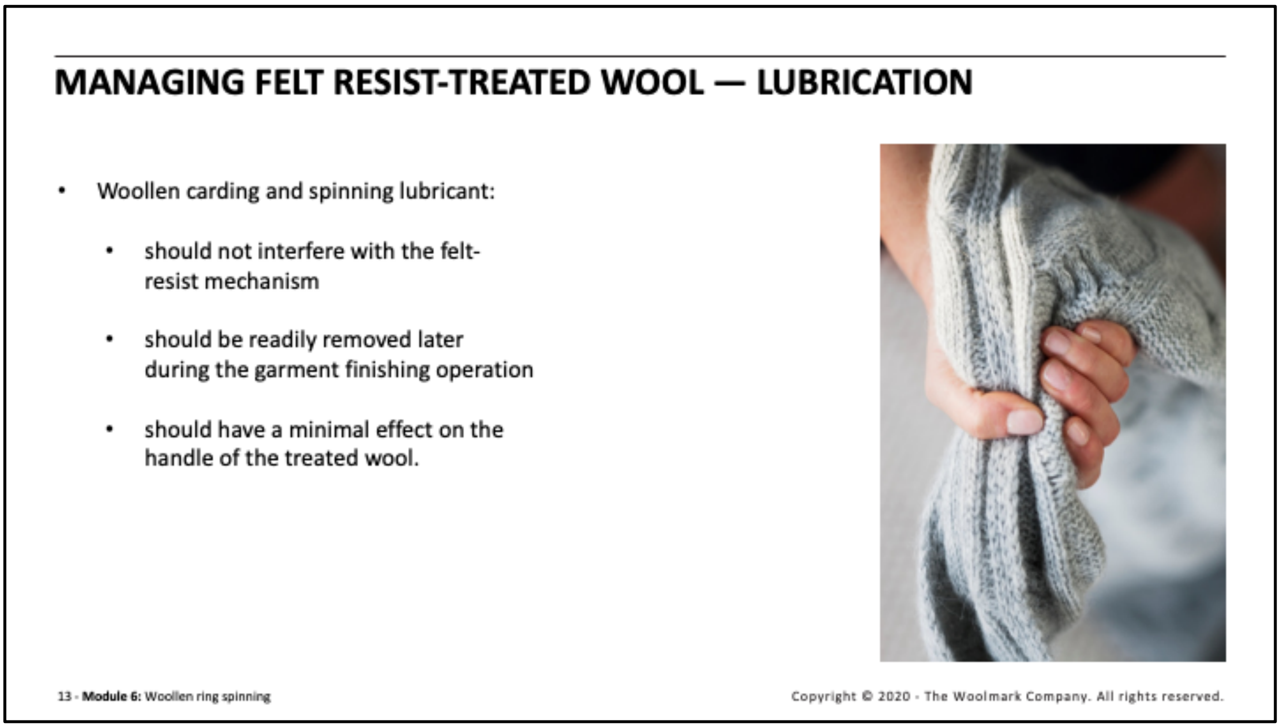
EXPLAIN THAT the woollen system can handle shorter fibres than the worsted system and is highly amenable to processing multiple fibre blends, including large proportions of recycled fibres.

INDICATE THAT the woollen card provides excellent intimate fibre blending, but the speed is limited to produce finer yarns, resulting in lower production rates (kilograms per hour) and rapidly-increasing costs.

NOTE THAT because of the poorly-oriented conformation of the fibres in the woollen yarn, a greater number of fibres in the cross-section is needed compared with worsted yarns to achieve a viable spinning process (not too many ends down).

EXPLAIN THAT the spinning limit (the finest yarn spinnable under commercial conditions) for woollen yarn is about 90 fibres although 120 fibres is probably a more common limit used in commercial practice. In contrast, for worsted yarns the limit is 35 to 40 fibres.

POINT OUT that more fibres in yarn cross-section are required for woollen-spun yarns, so very fine yarns are not practical.



EXPLAIN THAT the spinning of felt-resist-treated wool to manufacture machine-washable wool yarns comes with added complexity. To create a felt-resistant woollen-spun yarn, the wool must be treated in loose stock form. There are a number of suitable processes to impart this treatment, which are covered in detail in the Wool Science, Technology and Design Education Program course *Wool fibre science*.

INDICATE THAT when manufacturing machine-washable woollen-spun knitting yarns there are three main factors to consider:

- lubricating the treated fibre
- avoiding contamination
- potential issues in the carding and spinning operation.

Lubricating the felt-resist treated fibre:
EXPLAIN THAT in selecting a suitable woollen carding and spinning lubricant, it is necessary to select a product that:

- does not interfere with the felt-resist mechanism
- is readily removed later during the garment finishing operation
- has a minimal effect on the handle of the treated wool.

Potential issues in the carding and spinning operation
INDICATE THAT there is usually no need to make special adjustment to the card settings when processing felt-resist-treated wool, in spite of its differing frictional properties to untreated fibre.

NOTE THAT attention should be paid to the density of the slubbing produced on the condenser bobbins during the start of the carding operation.

Yarns of a given count produced from felt-resist-treated wool tend to be slightly leaner than untreated yarns.

POINT OUT that it is advisable when producing machine-washable woollen-spun yarns to spin to a slightly coarser yarn count in order to obtain a yarn with a similar diameter to that of an untreated yarn. For example, in terms of yarn diameter a 2/14 Nm machine-washable lamb's wool yarn is equivalent to a 2/16 Nm lamb's wool yarn produced from untreated wool, and likewise a 2/8 Nm machine-washable Shetland yarn is equivalent to a 2/9 Nm untreated Shetland yarn. With regard to selection of twist levels, consideration should be given to the requirements and the effect on performance of the final product.

MANAGING FELT RESIST-TREATED WOOL — CONTAMINATION

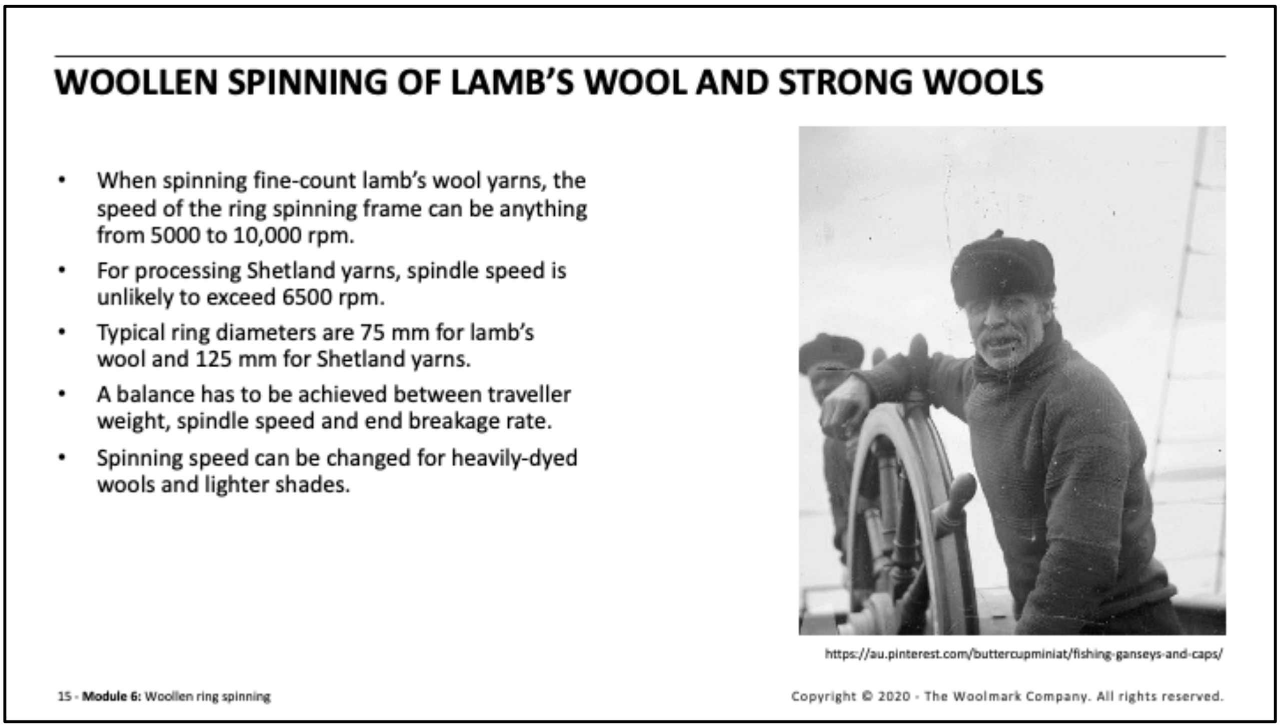
Contamination can cause spot felting on machine washable garments.

Only a small amount of untreated fibre will cause spot felting.

14 - **Module 6:** Woollen ring spinning

EXPLAIN THAT because contamination by only a minute proportion of untreated fibre can destroy the felt-resist effect, resulting in the phenomenon known as spot felting, it is essential:

- the treated wool lot is kept completely separate and is not inadvertently mixed with untreated fibre
- the card is thoroughly cleaned before carding the treated wool lot
- either a small amount of waste-treated wool is run through the card beforehand to remove any remaining untreated fibres not removed by fettling, or the first 10 or so minutes of the carding run should be discarded and re-used elsewhere
- all equipment (e.g. bins, opening machines, hoppers, spinning frames) is thoroughly cleaned
- dedicated machines are used if possible to process treated wool
- treated wool is clearly identified by code letters in the lot numbers (e.g. MW) and different colour lot tickets are used
- for undyed material, fugitive tints (i.e. Durotint range, Stephenson Thompson Ltd) can be used. This is always applied in blending to identify individual blends and qualities
- treated yarn is packed in polythene bags of either a different colour or bags which have been printed or contain printed labels carrying a warning (e.g. 'Machine-washable wool: do not mix with untreated fibre or yarn.')
- all staff involved in handling treated material are advised of the dangers and consequences of contamination.
- all customers are advised by including warnings on tariff sheets, delivery notes, invoices, etc.



Lamb's wool

INDICATE THAT when spinning fine-count lamb's wool yarns, the speed of the ring spinning frame can be anything from 5000 to 10,000 rpm. The speed will depend largely on whether the material is a 'good spin' or not.

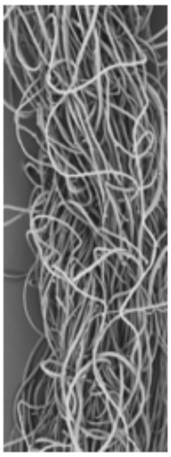
NOTE THAT some mills also have one spinning speed for heavily-dyed blends and one for lighter shades, reflecting the degree of damage incurred during dyeing.

EXPLAIN THAT typical ring diameters are 75 mm for lamb's wool yarns. The false twist speed is generally about 33% of spindle speed but this can vary greatly depending on fibre length. A balance has to be achieved between traveller weight, spindle speed and end breakage rate to optimise the best package weight.

Strong wool

NOTE THAT for processing Shetland yarns, spindle speed is unlikely to exceed 6500 rpm and is more commonly 5000 rpm. Typical ring diameters are 125 mm for Shetland yarns.

WOOLLEN VERSUS WORSTED YARN



PARAMETER	WOOLLEN YARN	WORSTED YARN
Wool type	Short wools — pieces, skirtings, locks etc Waste fibres from worsted processing	Fleece wool
Fibre length	35–55 mm	55–90 mm
Number of fibres in the yarn cross-section	130	35–100
Process route	Shorter	Longer
Count range	Less versatile 2–28 Nm	More versatile 10.0–120 Nm
Average spinning draft	1–1.5	20–30

16 - **Module 6:** Woollen ring spinning

INDICATE THAT to review the topic of spinning:

- The differences between worsted and woollen yarn are compared in the information listed in the table.

- Woollen spinning uses the shorter, more variable wools and requires more fibres in the yarn to make a good yarn. The fibre assembly is drafted much less than in worsted processing.

- Woollen spinning requires more lubricant than worsted spinning to allow for the shorter fibre length.

- Due to the much improved fibre arrangement, and the reduced amount of short fibre, worsted yarns can be spun finer, are more uniform and have a higher lustre.

- Woollen yarns tend to have a distinctive smell as a result of the amount of additives used.

Removal of the additives requires more vigorous scouring during the fabric or garment finishing processes. These processes are described in the Wool Science, Technology and Design Education Program courses *Wool fabric finishing* and *Wool garment finishing*.

SUMMARY— MODULE 6

There are two major types of woollen spinning machine:

- mule spinning
- ring spinning.

Ring spinning:

- is the most common method in both the worsted and woollen sectors
- combines drafting, twist insertion and winding into a continuous process.

The most important characteristics of woollen yarns are:

- yarn count
- yarn twist
- yarn evenness (index of irregularity)
- yarn tenacity
- hairiness.

Features of the woollen system:

- It can process wool types and wastes.
- Carding speed is limited.
- More fibres in yarn cross section are required for woollen-spun yarns.

Three main factors to consider when spinning felt-resist wool to produce machine-washable knitting yarns:

- lubricating the treated fibre
- avoiding contamination
- potential issues in the carding and spinning operation.

17 - **Module 6:** Woollen ring spinning

REVIEW the fact there are two major types of woollen spinning machine:

- mule spinning
- ring spinning.

REMIND participants that ring spinning combines the three steps of spinning — drafting, twist insertion and winding onto the bobbin — in a continuous sequence.

REMIND participants that important characteristics in woollen yarns are:

- yarn count
- yarn twist
- yarn evenness (index of irregularity)
- yarn tenacity
- hairiness.

REVIEW the fact that web and slubbing uniformity is essential to the production of quality yarn and to the productivity and reduction in waste of the entire process.

SUMMARISE THAT while the woollen system can process wool types and wastes the worsted system cannot:

- carding speed is limited, as yarns get finer, lowering production and increasing costs
- more fibres in yarn cross section are required for woollen-spun yarns — fine yarns are not practical.

REMIND participants of the three main factors to consider when spinning felt-resist wool to produce machine-washable knitting yarns:

- lubricating the treated fibre
- avoiding contamination
- potential issues in the carding and spinning operation.

ASK *participants if they have any questions about the content covered in this module.*

ALLOW *time for questions and discussion before proceeding to the final slide and closing the lecture.*

INFORM participants of the time and location for the next lecture — *Module 7 Semi-worsted spinning*— and encourage them to read through the relevant notes in their Participant Guides before attending the lecture.

ENCOURAGE participants to explore the Woolmark Learning Centre to reinforce and build on what they have covered in today's lecture.

Participants can register with and explore the Woolmark Learning Centre here: www.woolmarklearningcentre.com

BEFORE participants leave ensure you have collected all materials distributed during the lecture.

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SEMI-WORSTED SPINNING

RESOURCES — MODULE 7: SEMI-WORSTED SPINNING

Contained in the *Worsted and woollen spinning* Demonstration kit you will find the following resources for use as you deliver **Module 7: Post-spinning operations**:

- 'twist lively' yarn
- steamed yarn
- knotted yarn
- spliced yarn

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WORSTED AND WOOLLEN SPINNING

MODULE 7:
Semi-worsted spinning

WELCOME participants to Module 7 of the Woolmark Wool Science, Technology and Design Education Program — *Worsted and woollen spinning —Semi-worsted spinning*.

EXPLAIN THAT this module provides an overview of the semi-worsted spinning process and explores the machine mechanics used to create semi-worsted yarns. The characteristics of semi-worsted yarns are discussed in this module, along with the limitations of the semi-worsted system.

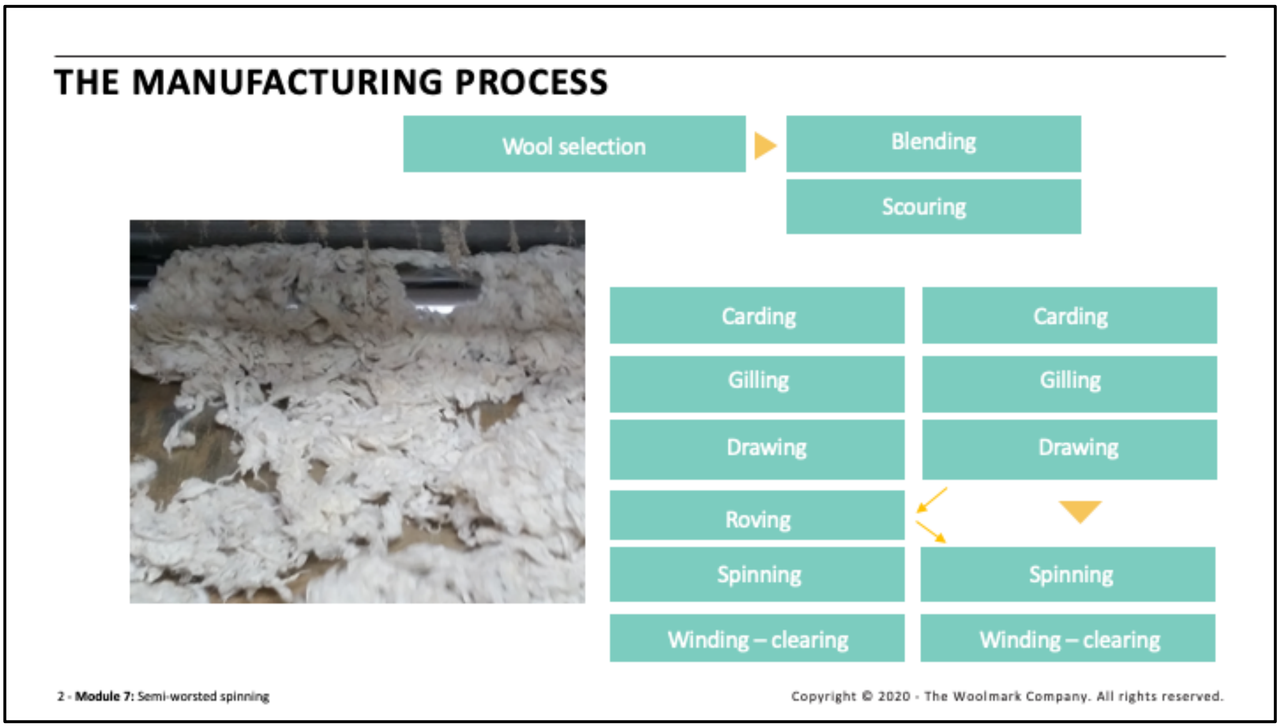
INFORM participants that by the end of this module they will be able to:

- outline the production methods for semi-worsted yarns
- clarify the difference between the wools used for semi-worsted yarns and those used for woollen and worsted yarn production
- identify the mechanics of the machines used in semi-worsted spinning
- describe the special needs of fibre control in semi-worsted spinning and compare those with worsted system requirements
- explain the reasons behind the differences between semi-worsted spinning and worsted spinning
- compare the characteristics of semi-worsted yarns with those of woollen and worsted yarns
- list some of the key products produced using semi-worsted yarns.

Note that much of the text in this module is based on a report on semi-worsted spinning written by Brian Manston for The Woolmark Company.

RESOURCES REQUIRED FOR THIS MODULE:

- *Semi-worsted yarn*



INDICATE THAT the Textile Institute (UK) defines a semi-worsted yarn as: *"one which is spun from sliver produced by carding and gilling, the carded sliver not having been condensed or combed; alternatively a roving produced from such a sliver may be used."*.

NOTE THAT as outlined on the slide, the semi-worsted processing route is initially similar to that of worsted top-making. The wool is scoured, carded and gilled a number of times to align the fibres and enhance blending. The uncombed sliver is then drawn (using gilling machines) to the required sliver weight and spun normally using a ring spinning frame.

EXPLAIN THAT the semi-worsted route is sometimes called 'sliver-to-yarn' spinning.

INDICATE THAT for most medium to heavy semi-worsted yarns, spinning of the drawn sliver takes place directly after the drawing operations. This requires high levels of drafting in the spinning frame.

For fine semi-worsted yarns, rovings may be prepared before the spinning operation.

WOOL FOR SEMI-WORSTED SPINNING

CHARACTERISTIC	WOOLLEN	SEMI-WORSTED	WORSTED
Length (mm)	Shorter wool (<55)	75 – 125	>55
Strength	All types	Sound	Sound
Diameter (µm)	All fibre diameters	Usually 27–35	Usually <30
Vegetable matter	Often carbonised	Low VM required	Removed during combing
Recovered wool	Included in blend	Not used	Not used

3 - **Module 7:** Semi-worsted spinning

EXPLAIN THAT wools used to produce semi-worsted yarn production should:

- have a staple length in the order of 75-125 mm
- be sound (>35N/ktex)
- have low vegetable matter content (<1%).

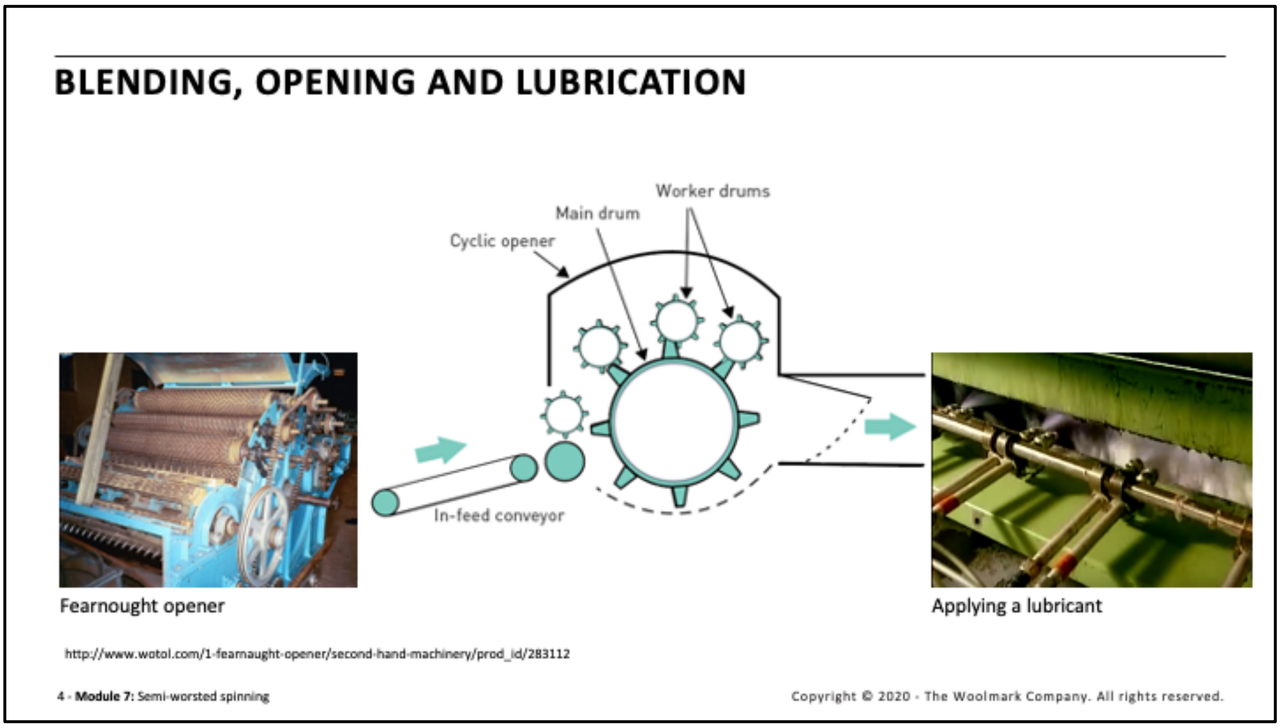
INDICATE THAT semi-worsted yarns are generally manufactured from medium-to-broad micron wools (27–35µm), but provided the wool is sound and of sufficient length, a wide range of wool fibre diameters can be used. Fibre diameter should be carefully selected in accordance with the yarn counts to be spun.

EXPLAIN THAT the semi-worsted processing route is not suitable for short or recycled wools. Drafting is an important feature of the semi-worsted spinning system and short fibres that cannot be controlled during the drafting process should be present in only a small proportion. If a large number of fibres are not controlled during drafting, an uneven yarn can result.

NOTE THAT for medium-to-heavy yarns, the mean fibre length (hauteur) should not be less than 75 mm and the short fibre content (< 30mm) should not exceed 25 per cent.

INDICATE THAT vegetable matter content should less than 1 per cent, since there is no opportunity to comb out any vegetable matter after carding.

EXPLAIN THAT to minimise waste and therefore cost, 'recovered' wool from gilling, combing, drawing and roving in both the semi-worsted (where applicable) and worsted systems is used as feed stock for the woollen system (i.e. are re-introduced at limited quantities into the feed of the woollen card). However, recovered wool is not incorporated into the semi-worsted spinning system.



INDICATE THAT as occurs during worsted and woollen yarn production, the process of blending for semi-worsted yarns is primarily concerned with the efficient mixing of various component lots to make a suitable blend for a yarn of specified quality. It is imperative the different components are mixed as intimately as commercially possible.

NOTE THAT secondary objectives of blending include:

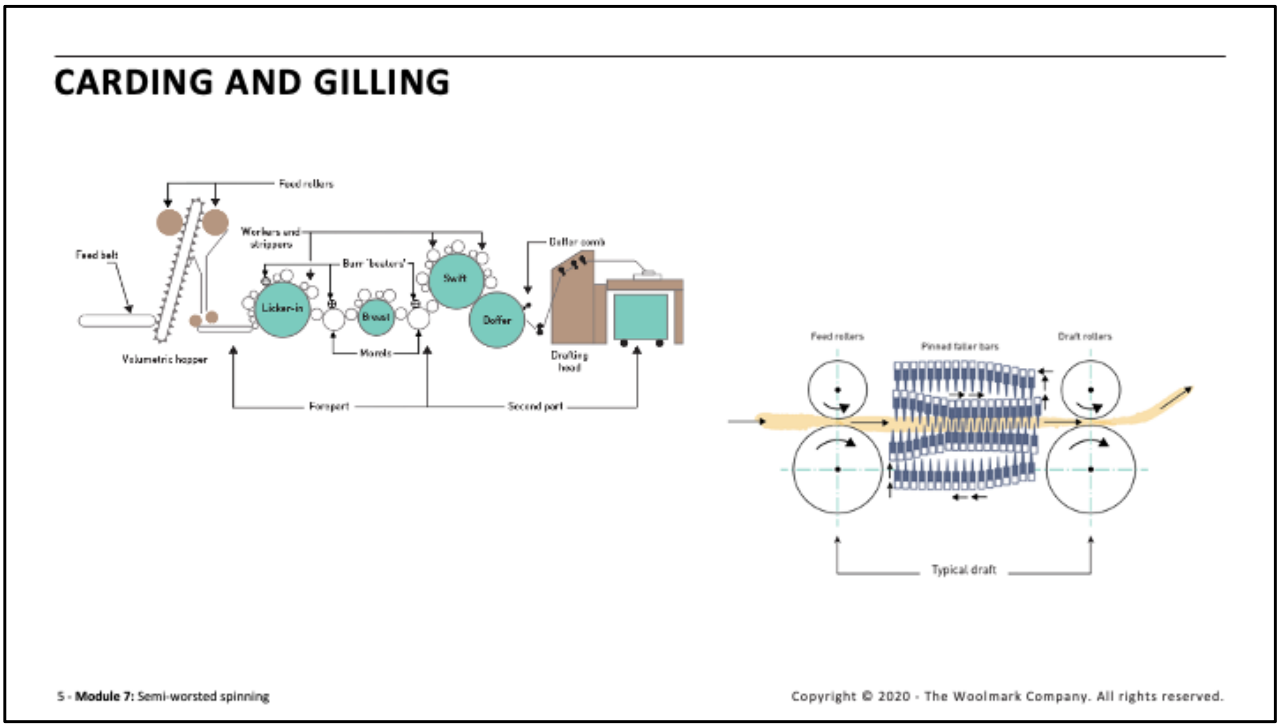
- removing loose contaminants (e.g. dust)
- partially opening the fibre
- applying a fibre processing aid (lubricant) to reduce fibre-to-fibre friction and minimise fibre breakage during carding.

EXPLAIN THAT the assembled components of the blend are presented to a opener by one or two pairs of feed rollers.

This machine opens the wool tufts and mixes the components, which are then cleared from the opener pneumatically. The opener in semi-worsted processing is a simpler machine than the Fearnought opener shown on the slide, which is used in woollen processing and has a gentler action. An in-line shaker or similar cleaning machine is often used to remove dust and vegetable matter.

INDICATE THAT many fibre processing aids (lubricants) can be used in a semi-worsted system. As in woollen and worsted processing, selecting a fibre processing aid is quite a complex issue, involving the consideration of a number of factors, which are explained in earlier modules. The high speeds associated with semi-worsted carding require the wool to be optimally lubricated. Studies of the effects of total fatty matter (wool grease plus fibre processing aid) on drawing waste, laps and breaks at spinning, yarn strength, slubs and yarn regularity indicate that the optimum total fatty matter content for semi-worsted spinning is 0.6–0.9 per cent.

NOTE THAT wool grease is not a effective fibre processing aid; if the raw wool scouring process has been completed correctly, the clean wool should have an extractable matter of approximately 0.3–0.4 per cent (called 'residual wax'). If the residual wax exceeds 0.5 per cent it will cause problems during subsequent processing. This supports the 0.3–0.5% application levels of fibre processing aid as being appropriate.



EXPLAIN THAT the different types of semi-worsted carding machines in use around the world operate on the same basic principles. The number and configuration of the various rollers (e.g. swifts, workers, strippers) may vary and the vegetable matter removal systems differ in design, but the objectives of carding machines remain the same.

NOTE THAT the objectives of semi-worsted carding are similar to that of worsted carding; to:

- disentangle the scoured wool and separate the fibres from one another
- intimately mix the individual fibres
- reduce the percentage of vegetable matter remaining in the wool after scouring
- form the carded fibres into an endless sliver, in more or less parallel formation, and package this sliver for the next processing operation.

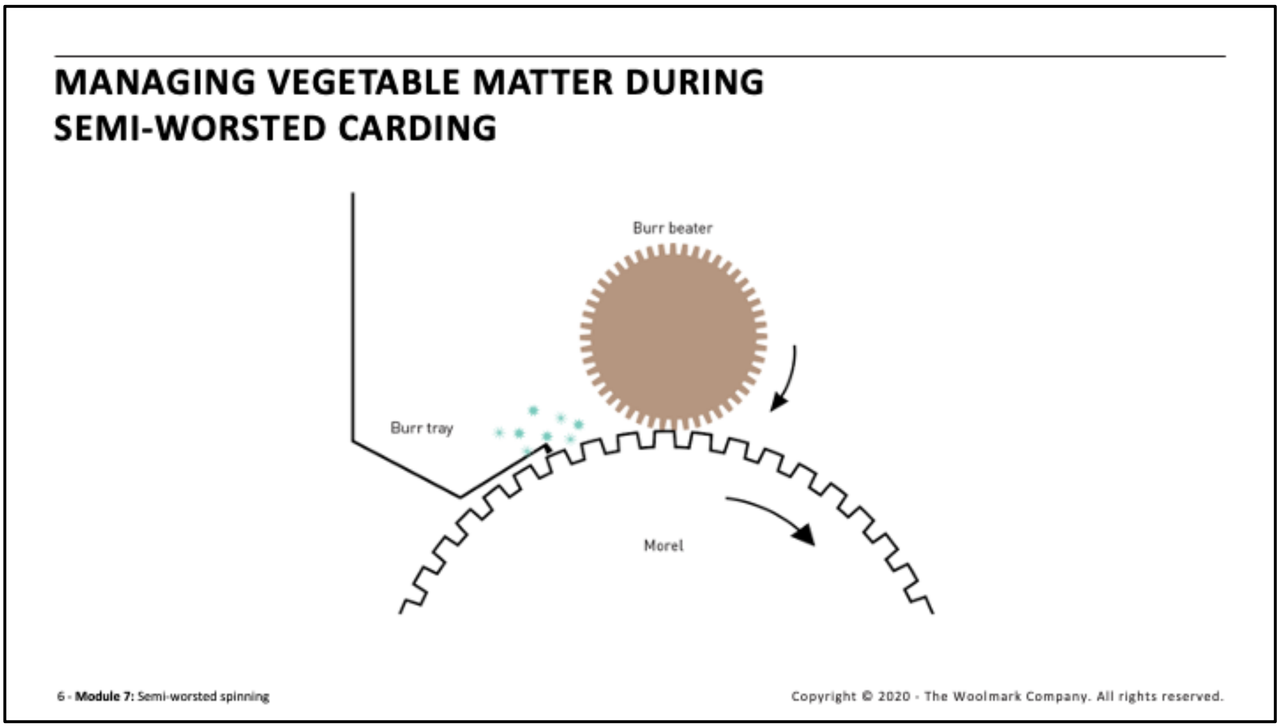
INDICATE THAT compared with the woollen carding process, there is less mixing of the wool in a semi-worsted card, so blending before carding requires greater controls.

NOTE THAT in former times, a 'fancy' roller was used just before the doffer during semi-worsted carding. The fancy roller has a raising action, which occurs when the backs of the card clothing teeth on a faster-moving roller brush against the backs of the card clothing teeth on a slower-moving roller. Fibres that become embedded in the card clothing teeth of the swift by several worker–swift actions are subsequently raised to the surface of the card clothing, ready for removal by the working action of the swift–doffer relationship. The use of metallic card clothing has reduced the need for these 'fancy' rollers.

EXPLAIN THAT carding in woollen processing is critical because it sets the yarn count and is the final opportunity for blending. Carding in semi-worsted and worsted processing is less critical because of substantial blending and drafting opportunities during subsequent steps.

INDICATE THAT as in the worsted system, drawing before spinning serves a number of purposes, as discussed in the earlier modules.

NOTE THAT In the preparation for semi-worsted spinning, auto-levelling devices must be used on one or more of the gill boxes used during the drawing process. The auto-leveller is an automated device fitted to machines to improve the evenness of the output material. On intersector gill boxes it is usually an optional device sited between the creel and the back rollers of the intersector head.



INDICATE THAT the selection of wools for the semi-worsted yarn manufacturing process requires the wool to have little or no vegetable matter. Apart from the semi-worsted card, the processing route has no operations (e.g. combing) capable of removing small pieces of vegetable matter within the blend being processed.

EXPLAIN THAT three traditional methods of vegetable matter removal are used during semi-worsted carding:

- burr beater,
- fly tray (or fly sheet),
- Harmel crush roller.

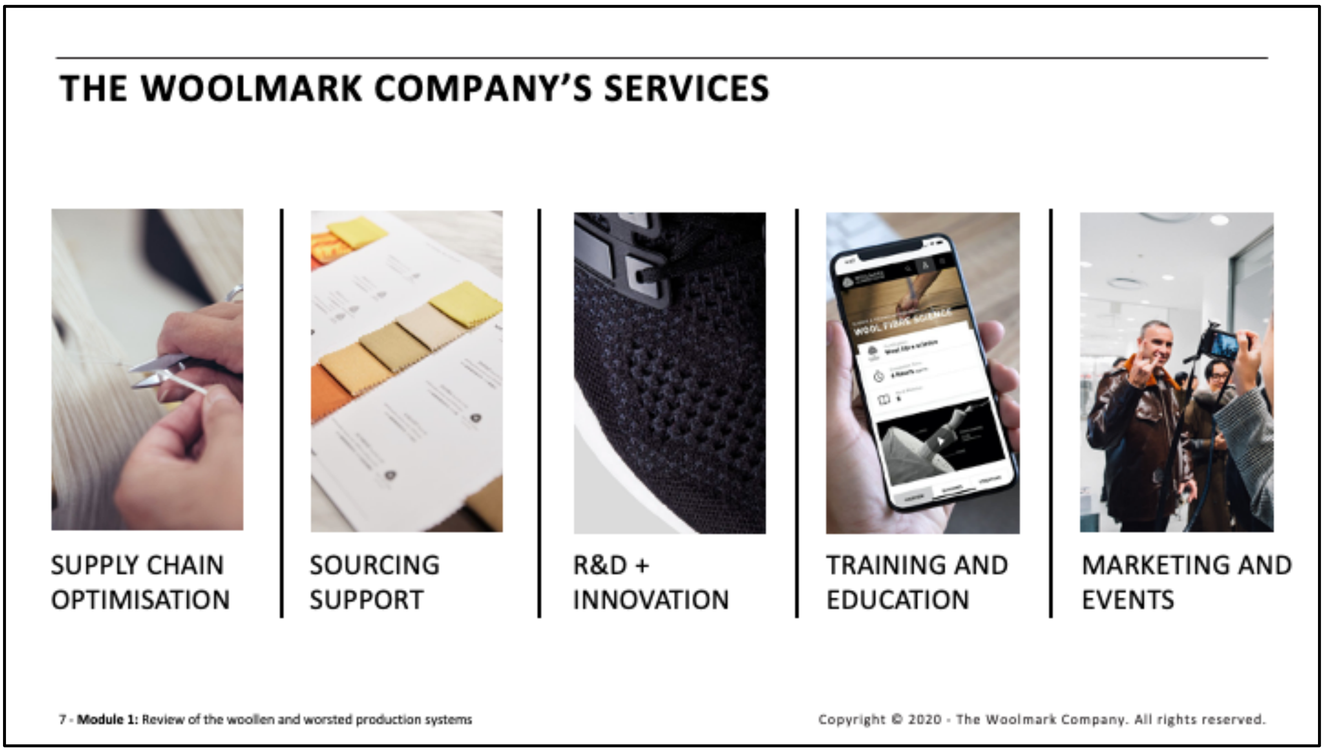
Although these mechanisms can remove large pieces of vegetable matter, such as burrs, none is particularly effective at removing small pieces or fibre-like vegetable matter.

INDICATE THAT the principal points for removing vegetable matter during semi-worsted carding are the same as those for worsted carding; the burr beaters on the morel rollers. The flat-topped profile of the wire teeth used on the morel rollers, combined with the spaces between the teeth, allow wool fibres to be carried underneath the beater. The exposed vegetable matter particles are subject to the impacts of the beater blades.

Fly trays present an edge near the first stripper on the main swift of the card. As much as 20 per cent of the shive types of vegetable matter missed by the morels can be separated by this edge. The vegetable matter falls into the tray and is swept away as waste. While the fly tray seems to be a worthwhile addition to the carding machine, there is a trend to remove them as fibre waste can accumulate and cause the tray to be pulled into the stripper, causing mechanical damage.

The Harmel roller was a device fitted to the card following a doffer, since it was designed to operate on a web. Its purpose was to crush burr seed and shive, or perhaps to bend it into a shape that rendered its removal more likely at a subsequent burr beater or fly tray. This device is only suitable for double-swift cards.

REINFORCE THAT semi-worsted processing is particularly sensitive to shive and straw contaminants, which are difficult to remove in a card.



EXPLAIN THAT The Woolmark Company partners with designers, brands and retailers worldwide, offering support with quality assurance, product innovation and supply chain assistance.

INDICATE THAT The Woolmark Company provides sourcing support through direct access to the global wool manufacturing industry through The Wool Lab. A seasonal guide to the latest innovations in wool, fabrics are sourced from the world's best spinners and weavers in the global supply network.

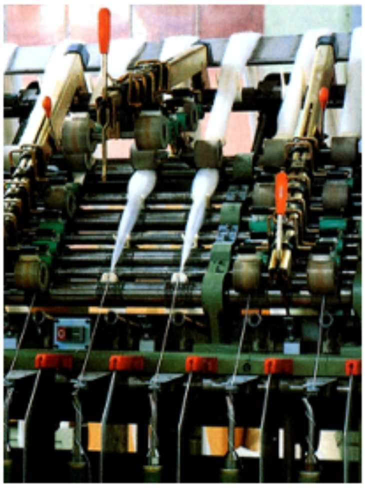
REINFORCE THAT The Woolmark Company takes secures funding and delivers research to improve wool production and processing through fibre science, traceability and fibre advocacy.

EXPLAIN THAT The Woolmark Company offers a range of online and face-to-face training programs to educate the industry. During 2019, The Woolmark Company launched the Woolmark Learning Centre, an online educational hub for industry professionals.

POINT OUT that The Woolmark Company markets the performance and environmental benefits of the fibre to ensure industry and consumers are informed and inspired to make better purchasing choices.

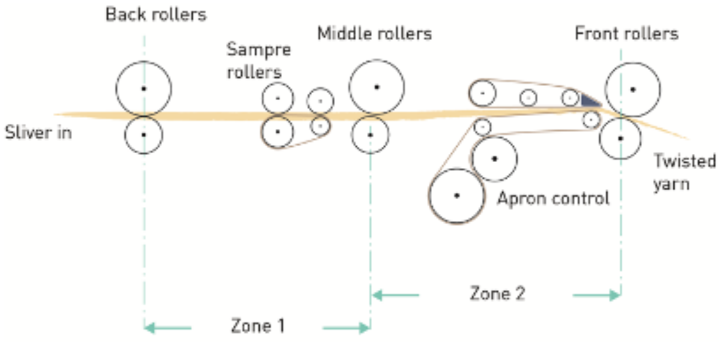
ASK PARTICIPANTS if they have any questions about the Woolmark Company before you proceed with the course aims.

SEMI-WORSTED SPINNING



High-draft zones

Image courtesy of Woolwise



Semi-worsted spinning

Source: GA Robinson

7 - **Module 7:** Semi-worsted spinning

EXPLAIN THAT for fine yarns, a finer feed to the spinning frame than can be produced on a gillbox must be used. In such cases the sliver is drawn and a roving produced. The roving is then spun in the normal way.

INDICATE THAT when yarns are spun directly from drawn sliver, finer counts of yarn (usually for weaving and knitting) are produced on machines with double-zone drafting systems, commonly called 'high draft' or 'sliver-to-yarn' spinning systems. The advantage of double-zone drafting, which can have total draft of up to 200, over single-zone drafting is that to spin yarn in the range of 7.0–30.0Nm sliver weights of 6–9ktex can be fed into the machine compared with around 3.5ktex for single zone drafting. This reduces the amount of drafting that must be achieved in preparation for spinning.

NOTE THAT a four-roller system is set up with progressively increasing surface speeds, perhaps with a short apron followed by a conventional double-apron drafting system.

INDICATE THAT in some machines rollers are used in the first drafting zone and aprons in the second. As shown in the diagram, soft Sampre rollers, which apply only light pressure to the sliver can be used in the first zone.

EXPLAIN THAT in either drafting system, it is common practice to operate the card and drafting at standard settings. Thereafter, to get the correct count in the yarn the spinner can adjust the draft of the spinning frame.

When the desired sliver or roving has been drafted, twist is inserted by a conventional ring spinning system.

INDICATE THAT for heavy-count yarns, larger packages are used to minimise the proportion of time allocated for doffing (changing of full take-up packages). For fine counts, small packages are used to maximise spindle speeds and the number of spindles per frame. Ring diameters range from 75 mm to 180 mm.

NOTE THAT wrap spinning (described in the next module) is popular in this sector of the industry, but is used much less extensively than ring spinning.

SPINNING SYSTEM COMPARISON

CHARACTERISTIC	WOOLLEN	SEMI-WORSTED	WORSTED
Level of complexity	Shortest route to yarn	Intermediate	Longest and most complex route to yarn
Management of vegetable matter	Little removal of vegetable matter	Little removal of vegetable matter	Vegetable matter removed
Management of short fibres	Short fibres incorporated into yarn	Short fibres not removed	Short fibres removed
Input to spinning	Slubbing	Sliver or roving	Roving
Quality of fibre alignment	Poor	Medium	High
Number of fibres in the cross-section	>90	>90	>35
Draft	1.0 – 1.5	80 – 120 Two-zone drafting	15 – 30
Spinning speed (rpm)	2500 – 4000	3000 – 6000	7000 – 17,000
Yarn count range (Nm)	2 – 28	1 – 30	10 – 120

8 - **Module 7:** Semi-worsted spinning

EXPLAIN THAT when comparing the characteristics of the various spinning systems (as outlined in the table on the slide), the woollen system offers the shortest route with the fewest steps, although, as previously described, the large woollen card has a low production rate.

POINT OUT that semi-worsted processing offers a compact, high-production system, but has more steps than woollen processing.

NOTE THAT the worsted processing route is the most complex route, with the most steps. The production rate of worsted yarn is limited by the speed of combing, which is not a constraint in semi-worsted yarn production.

INDICATE THAT the semi-worsted card removes some vegetable matter (VM) but as discussed earlier, it cannot be used to process wool with high VM levels, as it has limited ability to remove this material.

EXPLAIN THAT unlike the worsted system, in which the comb removes short fibres from the sliver, semi-worsted yarns still contain the short fibres.

NOTE THAT there is a reasonable degree of fibre alignment in the yarns although less than in an equivalent worsted yarn.

INDICATE THAT a commercially acceptable semi-worsted yarn requires at least 90 fibres in yarn cross-section, which is considerably more than worsted yarns (>35 fibres). This means the count of semi-worsted yarn produced from a wool of a given fibre diameter (fineness) is considerably coarser than the equivalent worsted yarn.

EXPLAIN THAT semi-worsted spinning systems use much higher levels of draft than worsted or woollen spinning systems.

NOTE THAT spinning speeds (rotational speeds) in semi-worsted spinning systems are lower than those used in worsted spinning. However, production rates (m/min) may be higher, reflecting differences in count and twist level typically used in the two systems.

COMPARISON OF YARN PROPERTIES

PROPERTY	WOOLLEN	SEMI-WORSTED	WORSTED
Appearance	Hairy	In between woollen and worsted in appearance	Smooth
Bulk	High (soft)	Intermediate	Low
Tenacity (cN/tex)	3 – 5	5 – 7	7 – 9

9 - **Module 7:** Semi-worsted spinning

INDICATE THAT a comparison between the properties of semi-worsted, woollen and worsted yarns is shown in the table on the slide.

There are fewer fibre ends and loops protruding from surface of semi-worsted yarns compared with woollen yarns so these yarns are less hairy. However, both woollen and semi-worsted yarns are hairier than equivalent count worsted yarns.

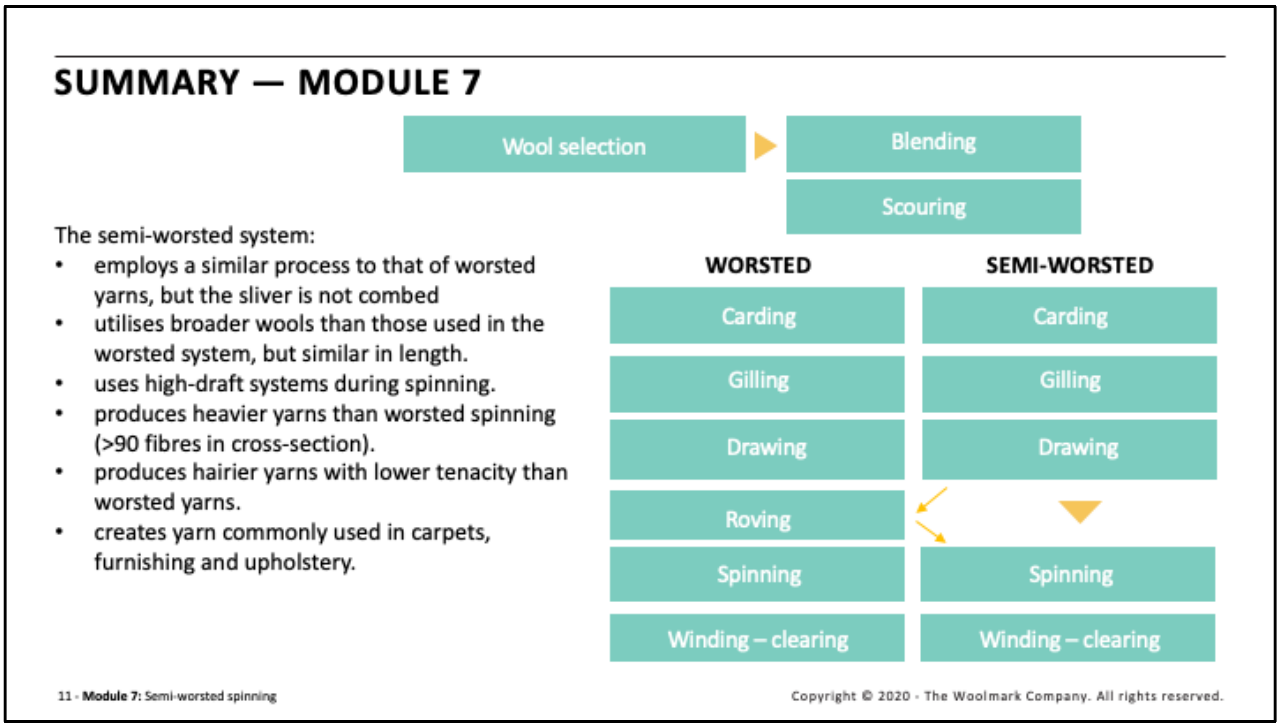
NOTE THAT the bulk and resilience of semi-worsted yarns lies somewhere between the equivalent count woollen and worsted yarns.

POINT OUT that the typical breaking tenacity of semi-worsted yarns is 5–7 cN/tex, which is higher than woollen yarns but lower than worsted yarns.

INDICATE THAT carpets are a major end-use for semi-worsted yarns. Carpets typically are woven or tufted from broad wools (>29µm) grown in New Zealand, China and many other countries.

Furnishing fabrics (curtains, upholstery and blankets) also utilise semi-worsted yarns.

Semi-worsted and worsted yarns can be combined in specialist knitwear to give the appearance of a 'hairy' woollen-spun fabric, but with the improved durability of a worsted-spun fabric.



SUMMARISE THIS module by reiterating that semi-worsted yarns:

- are produced by machinery and procedures similar to that of worsted yarns, except the gilled sliver is not combed.
- utilise broader wools than those used in the worsted system, but are similar in length to combing wools
- are spun from sliver, or from an intermediate roving, using high-draft systems
- require at least 90 fibres in the cross-section so are significantly heavier than would be produced by a worsted process
- are hairier than, and not as strong as, worsted yarns made from comparable wool
- are commonly used for carpets, furnishing and upholstery.

***ASK** participants if they have any questions about the content covered in this module.*

***ALLOW** time for questions and discussion before proceeding to the final slide and closing the lecture.*

INFORM participants of the time and location for the next lecture — *Module 8 Alternatives to ring spinning*— and encourage them to read through the relevant notes in their Participant Guides before attending the lecture.

ENCOURAGE participants to explore the Woolmark Learning Centre to reinforce and build on what they have covered in today's lecture.

Participants can register with and explore the Woolmark Learning Centre here: www.woolmarklearningcentre.com

THE WOOLMARK COMPANY

ALTERNATIVES TO RING SPINNING

RESOURCES — MODULE 8: ALTERNATIVES TO RING SPINNING

Contained in the *Worsted and woollen spinning* Demonstration kit you will find the following resources for use as you deliver **Module 8: Alternatives to ring spinning**

- Two two-metre lengths of top

WELCOME participants to Module 8 of the Woolmark Wool Science, Technology and Design Education Program — *Worsted and woollen spinning —Alternatives to ring spinning*.

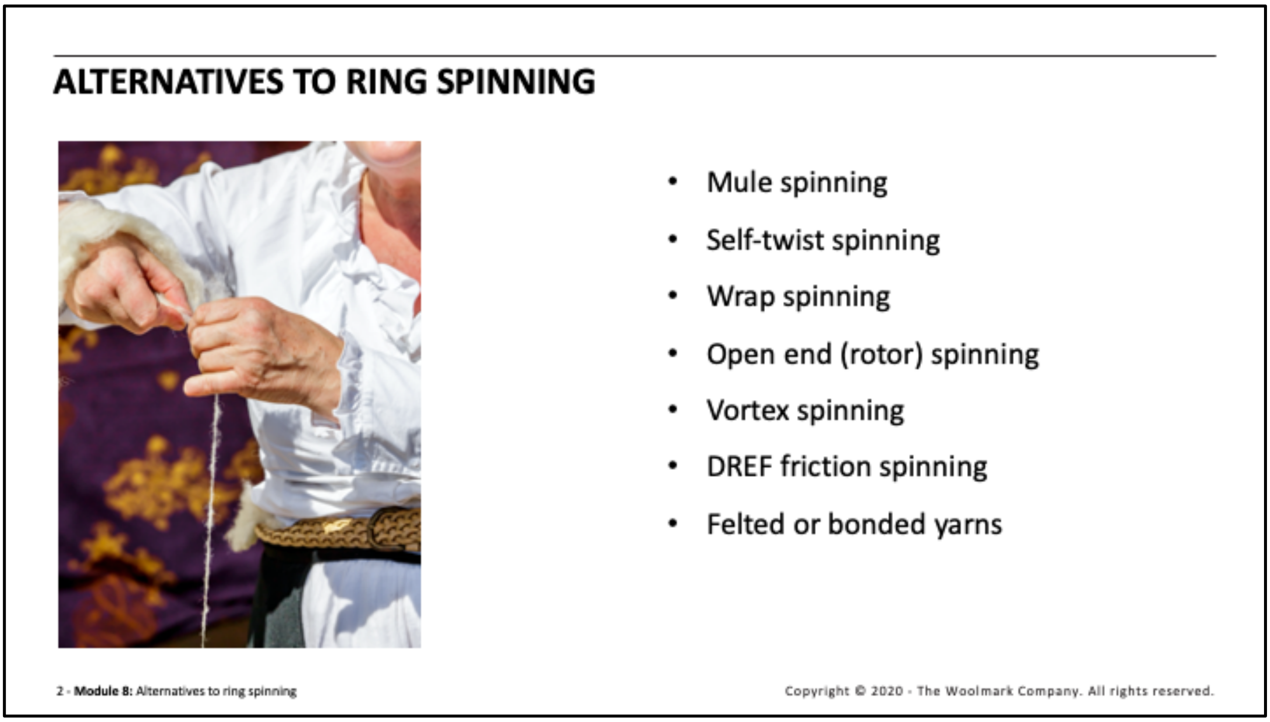
EXPLAIN THAT this module provides an overview of several alternatives to ring spinning, aimed at increasing productivity and/or improving yarn quality.

INFORM participants that by the end of this module they will be able to:

- describe alternative spinning technologies
- outline the limitations, advantages and disadvantages of these alternative spinning technologies
- describe the potential areas of application for yarn spun using alternative spinning technologies
- recall the processes used to create felted and bonded yarns.

RESOURCES REQUIRED FOR THIS MODULE:

- *Two two-metre lengths of top*



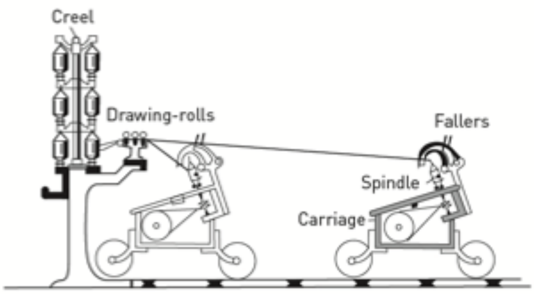
EXPLAIN THAT a number of alternative spinning techniques are available, which can (in theory) be used to spin worsted yarns, including:

- mule spinning
- self-twist spinning
- wrap spinning
- open end (rotor) spinning
- vortex spinning
- DREF friction spinning
- felted or bonded yarns.

INDICATE THAT the spinning systems have been evaluated as alternatives for spinning worsted wool yarns, but none has been widely used commercially.

MULE SPINNING

https://commons.wikimedia.org/wiki/File:Spinning_Mule_1897_-_Mueller_Woollen_Cloth_Mill.ogg



https://en.wikisource.org/wiki/The_New_International_Encyclopædia/Spinning

3 - **Module 8:** Alternatives to ring spinning

EXPLAIN THAT mule spinning is an old (~1885) form of spinning developed to replicate and mechanise the operations of hand spinning.

The rovings are held on a creel and the spindles are held on a carriage that travels backwards and forwards towards the creel.

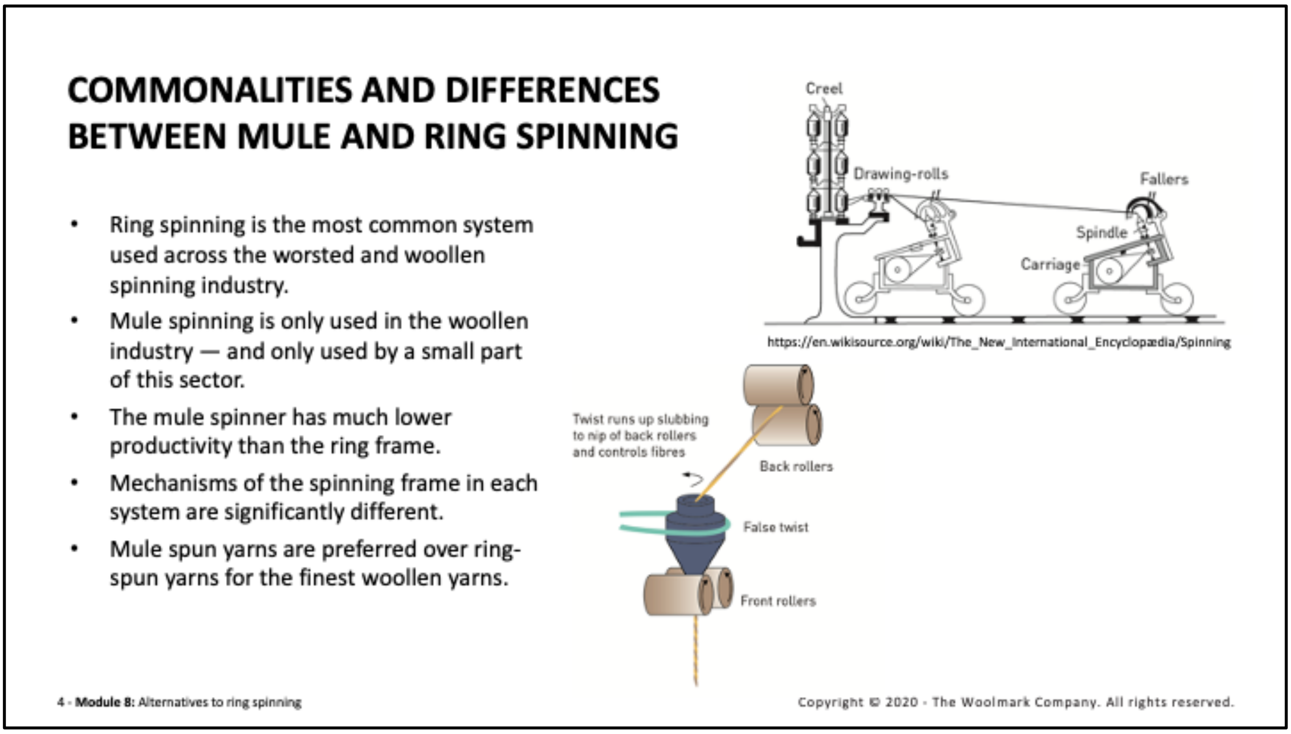
On the outward traverse (a distance around 1.5 m), the fibre stream is drafted and twisted by the rotating spindles.

The containers of roving are driven by rollers to release the precise amount of roving required for the draft imparted in the operation.

The spindles remain at the far position until the twisting operation is complete.

On the return trip, the carriage moves back to its original position winding the newly-spun yarn onto the spindle.

INDICATE THAT mule spinning is no longer used for worsted spinning, except in rare craft industries, as it lacks the production and automation of other forms of spinning. It is still used in short-staple spinning and is used to produce woollen-spun yarns.



EXPLAIN THAT ring spinning is the most common method for the worsted and woollen spinning industry. Mule spinning is used only for the woollen industry.

NOTE THAT the mule spinner has much lower productivity than the ring frame due to its discontinuous action. For this reason, this technology now has limited use within commercial spinning mills.

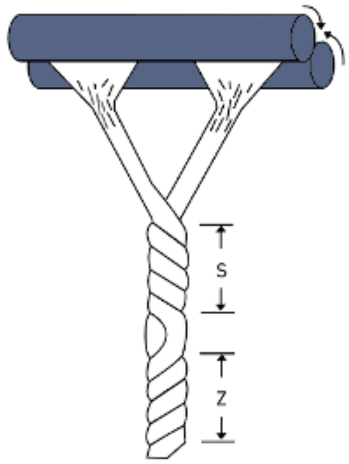
INDICATE THAT the mechanisms of the spinning frame in each system are significantly different:

- mule spinning drafts a partially-twisted slubbing
- ring spinning drafts a false-twisted slubbing.

POINT OUT that many manufacturers believe the mule spinner produces a more even yarn and as such it is still preferred by some sectors of the woollen industry manufacturing finer count yarns.

NOTE THAT in addition to conventional woollen spinning methods, short-staple spinning systems, such as those used for cotton (e.g. open-end spinning), are also used to spin short wool types suitable for the woollen system.

SELF-TWIST SPINNING (REPCO)



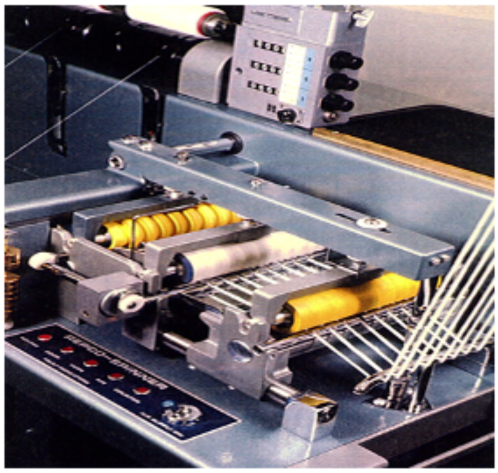


Image courtesy of the Rieter Rikipedia website

EXPLAIN THAT self-twist yarn is produced by inserting alternating twist into each of two drafted strands of fibre and immediately bringing them together so that in trying to untwist, they twist about each other.
This spinning system was developed in 1971 by CSIRO.

INDICATE THAT the most convenient way of spinning staple fibres into such a yarn involves the use of a pair of rubber-covered rollers, which both rotate and axially reciprocate in opposition.

EXPLAIN THAT in this procedure, two strands of wool rovings are drafted and passed between the reciprocating rollers so that short sections of each drafted roving are twisted in one direction, and the next short section is twisted in the opposite direction, and so on.

As the strands emerge from the reciprocating rollers they are immediately brought together, each strand then becomes twisted about the other to form a stable two-ply yarn.

EXPLAIN THAT the action of the reciprocating rollers results in a short length of each strand having a twist reversal zone. To avoid the twist reversal zones being aligned when the two strands are brought together, the path lengths of each strand pair differs, resulting in the twist reversal zones being off-set.

NOTE THAT this form of spinning is also called ‘Repco spinning’.

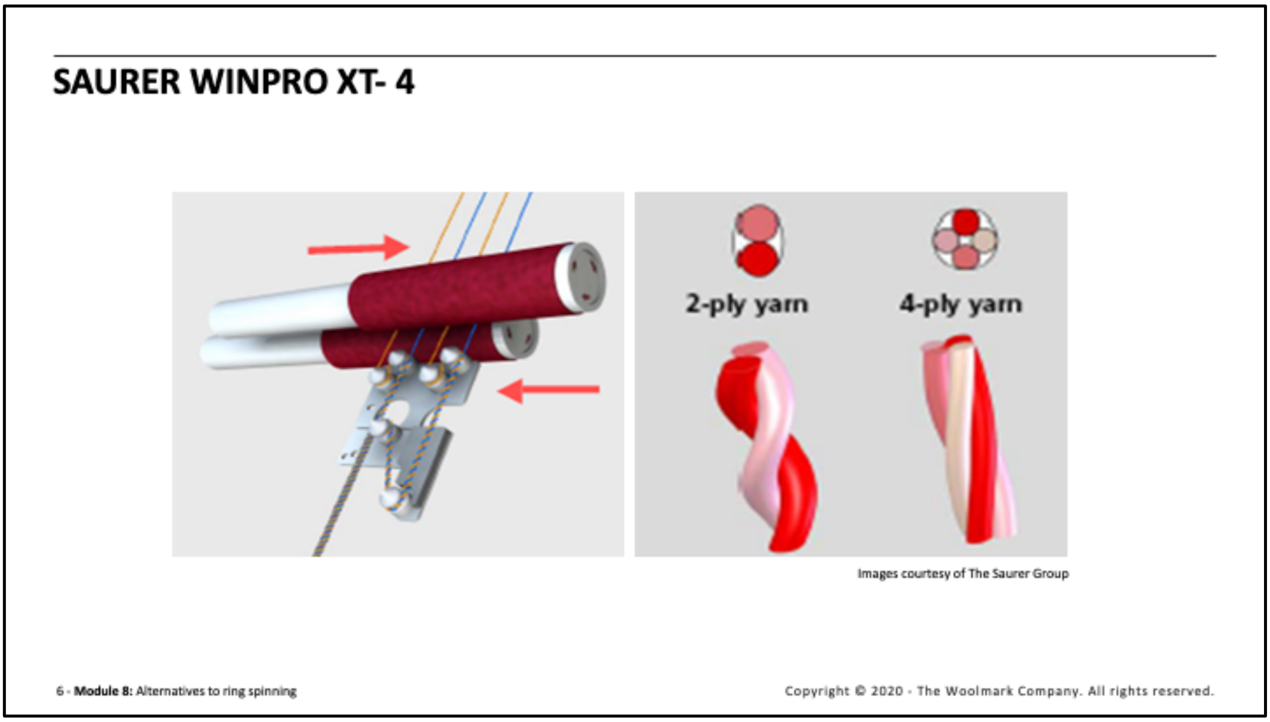
Use of self-twist yarn
As produced by the self-twist spinning machine, the yarns are suitable for knitting.

EXPLAIN THAT in the commercial implementation of the process to produce weaving yarns, the wool self-twist yarn still requires a further twisting operation.

INDICATE THAT production speeds for self-twist yarns are up to 200 m/min. A typical four-package machine is therefore equivalent to more than 50 spindles of a conventional ring spinning machine, which results in significant savings in floor space and energy.

NOTE THAT recently Macart Spinning Systems (UK) incorporated the self-twist spinning in their knitting yarn production system. In a continuous operation, this system manufactures yarn directly from slivers where the self-twist yarns are steam relaxed to introduce bulk in the yarn through fibre relaxation before being wound onto yarn packages. Production speeds up to 400 m/min are claimed.

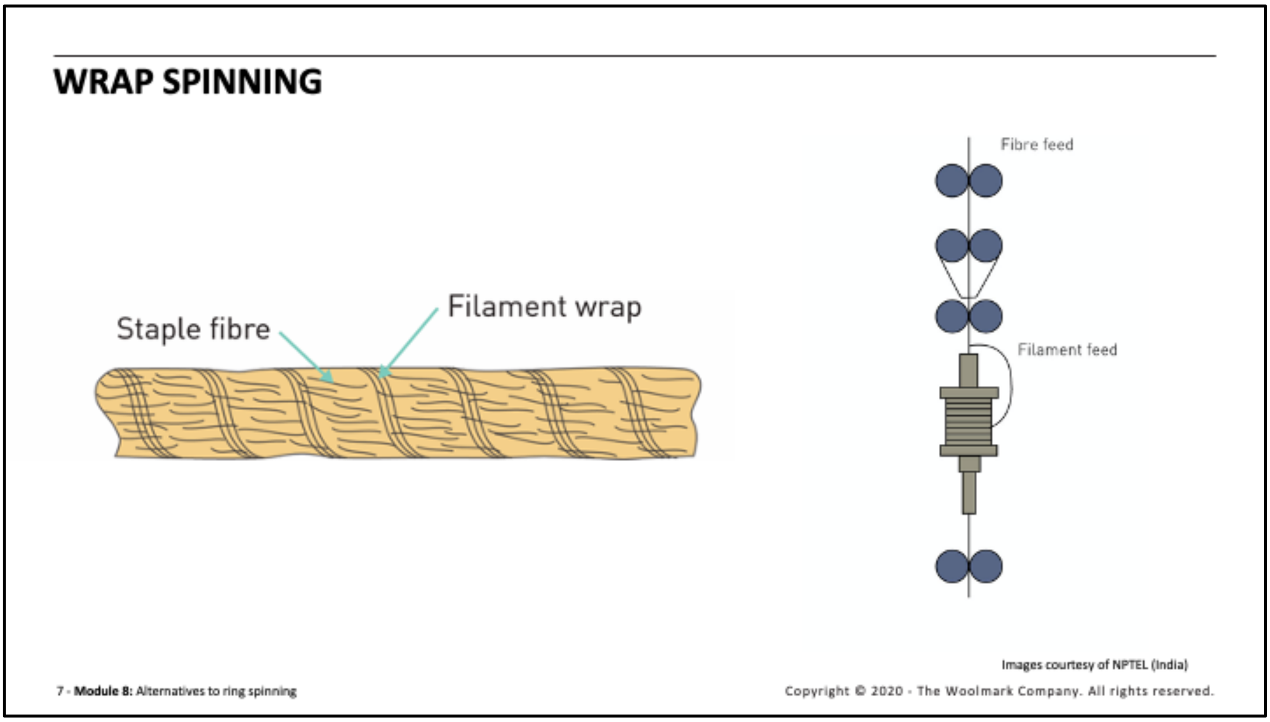
EXPLAIN THAT the variation in twist can cause irregularities in the surface appearance of some woven fabrics so the use of the technology is limited.



EXPLAIN THAT Winpro™ is another system similar to self-twist spinning to produce as two-fold (2-ply) and four-fold (4-ply) yarns in a single operation. It is claimed that Winpro spinning achieves:

- counts from 3Nm and 120Nm yarn fineness
- high speeds of up to 250 m/min
- 50% lower production costs
- a high degree of production flexibility
- 80% less waste
- faster throughput time and less material in production
- fewer splicing positions
- large packages.

NOTE THAT as with yarns from self-twist spinning, Winpro yarns are suitable for knitting and weaving. Visual effects from the areas reversing twist can affect the appearance of some fabrics.



EXPLAIN THAT wrap spinning involves the wrapping of filaments around a stream of staple fibres.
The filaments may be wrapped around:

- a twisted stream of staple fibres (i.e. a yarn)
- an untwisted, parallel stream of staple fibres.

INDICATE THAT wrap-spun technologies gained popularity during the 1970s, however, today they are confined to niche markets. Generally, fancy twisters are required to produce wrap-spun yarns.

EXPLAIN THAT a more recent development to produce wrap-spun is the Sirofil system. This system is based on SiroSPUN spinning technology.

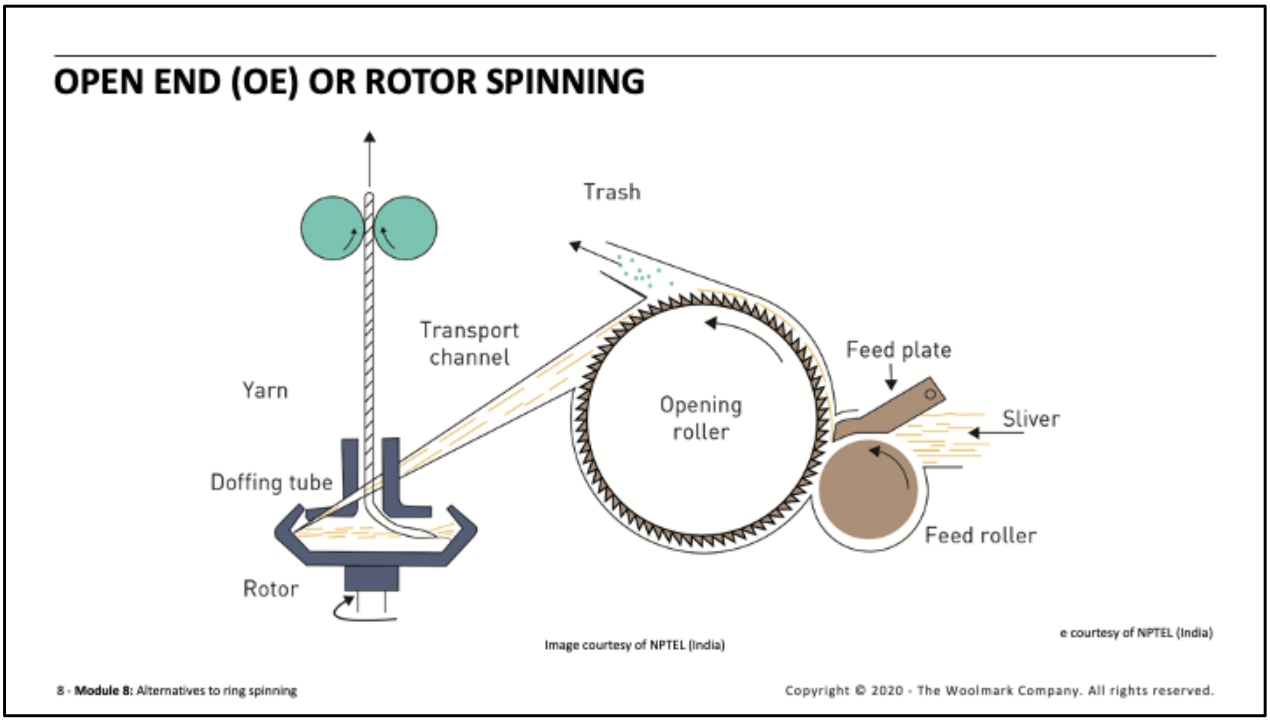
Instead of two wool fibre strands being spun, one of the strands is wool and the other is a filament, or a strand of multi-filaments.

As the wool and filaments (spaced about 15 mm apart) emerge from the front draft rollers, they are twisted together, resulting in the filament(s) being wrapped around the wool.

EXPLAIN THAT the SiroSPUN break-out devices, which ensure both strands are broken if one fails for some reason, are modified to be able to stop the filament from being spun into the yarn in the event the wool strand fails.

Text derived from and Image courtesy of NPTEL (India)

- Faculty: Textile Engineering
- Course: Yarn manufacture
- Lecture: Other spinning system



EXPLAIN THAT open end (or rotor) spinning was initially developed for the short-staple (e.g. cotton) sector, where it currently has a significant market share in yarn production.

INDICATE THAT open end spinning is a direct sliver-to-yarn system, where the sliver is fed to an opening roller where individual, or small aggregates of fibre are drawn from the sliver, and with the aid of an air stream, the fibres are delivered to an inner groove of a rotor rotating at high speed.

NOTE THAT production rate is governed by the speed of the rotor and the speed of the rotor is governed by its diameter.

REINFORCE THAT wool typically is coarser and longer than cotton and the wool fibre also has varying degrees of crimp. Fibre length governs the diameter of the rotor and therefore wool typically used in the worsted sector requires large diameter rotors or the conversion of wool to a fibre length suited to the cotton system. Both approaches have found limited commercial application.

EXPLAIN THAT a number of modifications are required in order to spin wool yarns with the open end method.

- Large diameter rotors are used at slow production speeds, hence the economic benefits for long staple wool has not been realised.
- Additionally, due to the structure of open-end-spun yarns, greater numbers of fibres are needed in the cross-section in comparison to ring-spun yarns; approximately 150 to 200 wool fibres are required for open end yarns compared with 35-40 for limit spinning in ring-spun yarns.
- Both the greater fibre diameter of wool and its crimp result in greater difficulties in compacting sufficient fibre numbers in the rotor groove to produce a uniform yarn.
- To some extent, the problems have been overcome by using short (32 to 45 mm) fine lamb's wool (19.5–21.5µm), which has allowed the use of smaller rotor diameters, typically 46 mm, offering higher production rates.

NOTE THAT production rates are not as high as for cotton fibres; the rotor speed used to produce open-end-spun wool yarns are up to 60,000 rpm, compared with 150,000 rpm for cotton yarn production on 28 mm diameter rotors.

EXPLAIN THAT because of the short, fine wool requirement for open end yarn manufacture, it currently is a niche market and the requirement for wool cleanliness is critical.

Image courtesy of NPTEL (India)

- Faculty: Textile Engineering
- Course: Yarn manufacture
- Lecture: Rotor spinning system

MURATA VORTEX SPINNING SYSTEM

Image courtesy of Murata Machinery Ltd

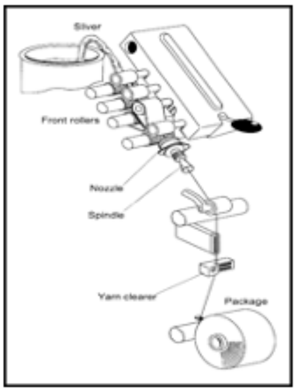


Image courtesy of NPTEL (India)

EXPLAIN THAT the Murata vortex spinning system is now in its third generation. The system draws the yarn from a spinning nozzle, which contains a friction roller or nip roller (in the earlier models).

The system claims spinning speeds up to 500 m/min.

INDICATE THAT work has been done to evaluate the technology for spinning a number of wool types:

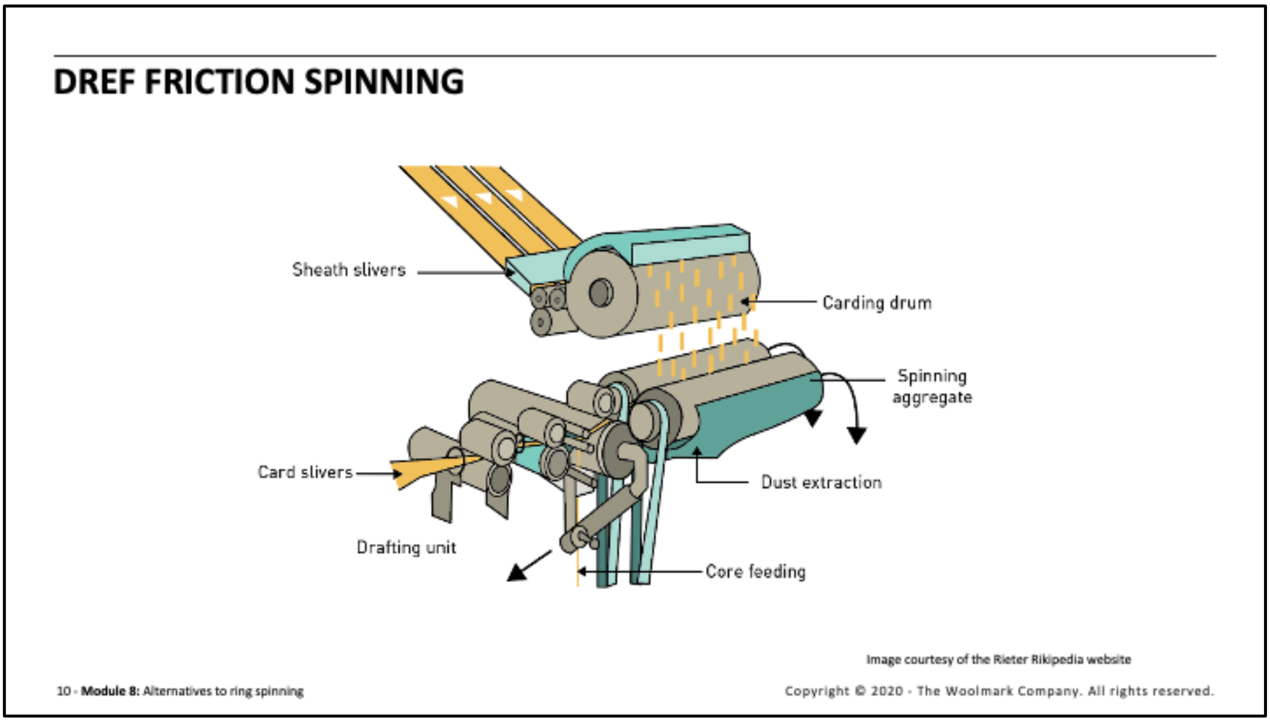
- mid-micron wool for interior textiles
- fine wool for quality knitwear.

EXPLAIN THAT although yarns could be manufactured using short-staple wool (wool suitable for woollen-spun yarns) the uptake of this technology by the wool industry has been limited to short-staple blends (wool-cotton).

EXPLAIN THAT vortex spinning systems create a fasciated yarn. Fasciated yarn is a term applied to yarns in which the fibres are deliberately entangled in addition to twisting to create additional strength. Usually these yarns are not suitable for apparel fabrics but have made considerable penetration into the market for yarns used in industrial fabrics.

Image courtesy of NPTEL (India)

- Faculty: Textile Engineering
- Course: Yarn manufacture
- Lecture: Vortex spinning system



EXPLAIN THAT the DREF friction spinning system was patented in Austria by Dr Ernst Fehrer in 1973.

INDICATE THAT in this system, staple fibre in sliver form is drawn into a carding drum. The carding drum creates a fibre stream, which is delivered to a pair of parallel, rotating, horizontal cylinders. The cylinders are closely spaced and rotate in the same direction. Air is drawn through fine perforations in the cylinder surfaces, drawing and compacting the fibres in the V-groove formed by the close proximity of the cylinder pair. The rotation of the cylinders imparts twist to the surface fibres thus forming a fasciated yarn as it is drawn off axially from the cylinders onto a yarn package.

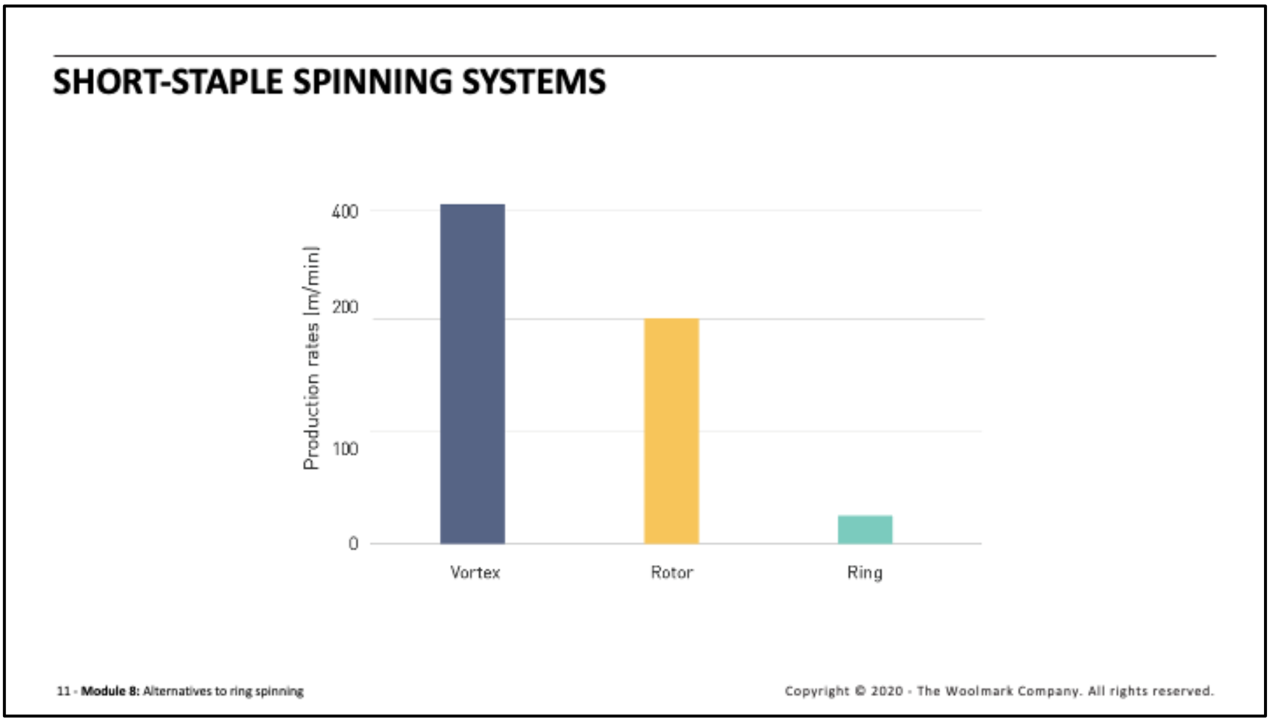
NOTE THAT this system can spin a range of fibre types, including wool.

EXPLAIN THAT the earlier versions of this technology were mainly suited to coarse-count yarns. The latest versions of the DREF spinning technology allow:

- the spinning of relatively finer yarns
- the facility to incorporate other drafted fibre streams, pre-spun yarn and filaments of varying types as cores to the fibre stream, or sheath, introduced by the drafted sliver input.

This allows the manufacture of technical yarns with a range of sheath and core combinations. Production speeds up to 250 m/min are possible.

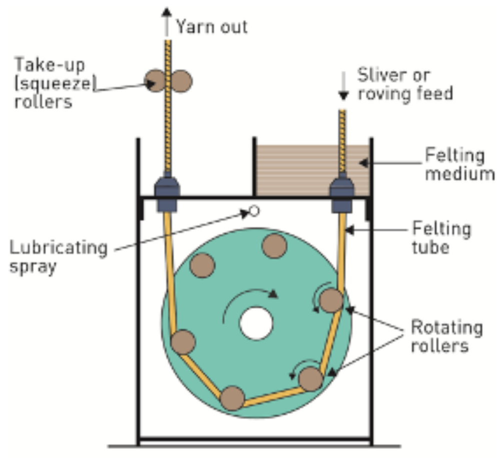
NOTE THAT this technology has found application in spinning coarse yarns for rugs and carpets.



EXPLAIN THAT the speed of production for a selection of the traditional and more recent spinning systems (designed primarily for short staple spinning) is presented in the diagram.

NOTE THAT of particular interest is the vortex system, which is the fastest yarn manufacturing system for staple fibres to be developed to date. To date there have been extensive trials using wool on this system but little commercial uptake of this technology by wool spinners.

FELTED YARN



Source: Anon Wool Science Review, 1949, 3(3)

Felting forms yarn directly from roving or sliver

12 - **Module 8:** Alternatives to ring spinning

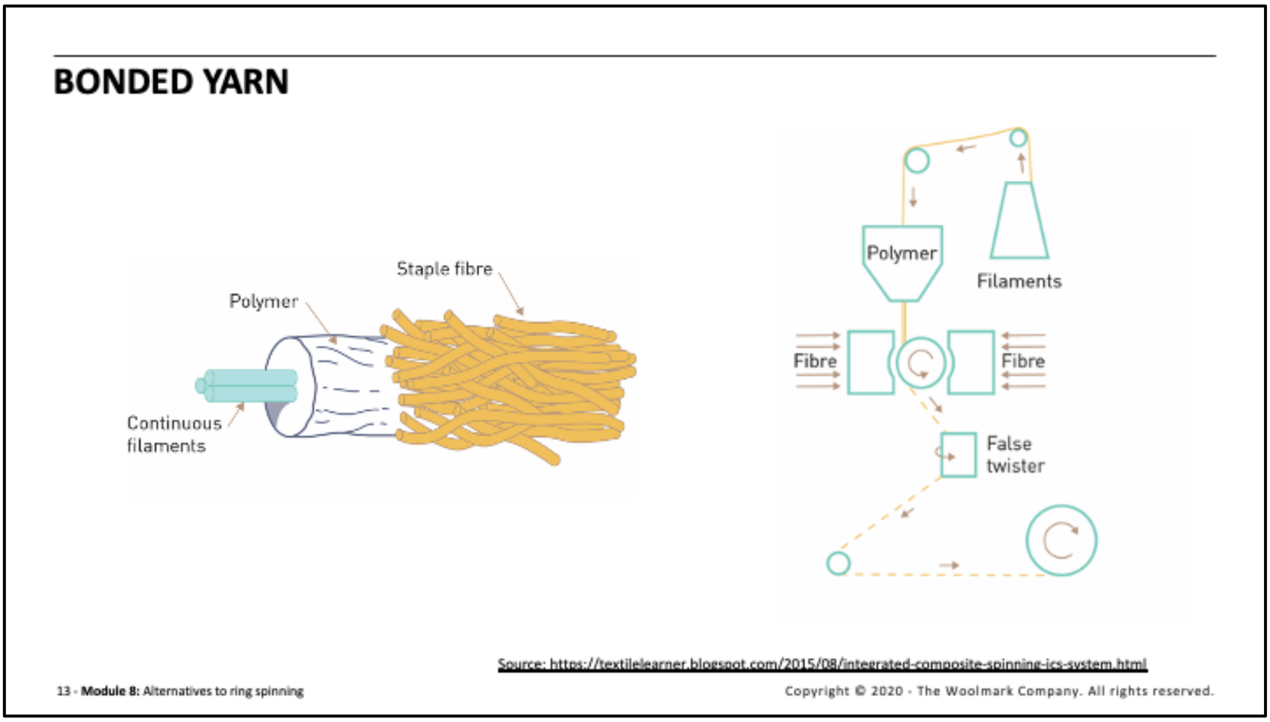
EXPLAIN THAT it is possible to create wool yarns directly, or modify existing yarns, by felting. A felting process (called the Periloc process) can be used to create yarns directly from sliver or roving.

INDICATE THAT this process is most often applied to heavy-count woollen and semi-worsted-spun yarns used in carpets and craft knitting.

EXPLAIN THAT the Periloc process was developed by the International Wool Secretariat (Ilkley, UK). In this process, outlined on the slide, the sliver, roving (or a pre-spun yarn) is wet with water containing a detergent and passed through a plastic tube. The tube is compressed by a series of rollers, which provide the mechanical action required for felting to occur.

For untwisted roving or sliver, a false-twister is used before the fibres enter the tube to give the fibre stream sufficient strength for handling. The roving or sliver enters the tube untwisted and is felted into a coherent, but twistless, yarn.

EXPLAIN THAT two or more yarns may also be co-felted in the plastic tube allowing for unique colouring effects.



EXPLAIN THAT to produce bonded yarn, a glue is applied to the untwisted fibre stream after drafting.

NOTE THAT the methods of applying the glue can vary. One approach, shown on the left of the slide, is to use a synthetic filament in the core of the yarn to provide strength to the fibre as well as carrying the bonding agent. The availability of core-sheath synthetic fibres with a meltable sheath offers a modification of this approach to forming bonded (rather than spun) wool-blend yarns.

EXPLAIN THAT in the Bobtex system, shown on the right of the slide, for making core staple yarns, a false twister is used to enhance the bonding of the fibres by the bonding agent. It also gives strength to the yarn during the bonding operation. The final yarn is, however, twistless.

INDICATE THAT bonding technology is rarely used to create wool blend products, as the approach offers no net advantages over conventional spinning methods.

COMPARISONS OF YARNS FROM DIFFERENT SPINNING SYSTEMS

	CONVENTIONAL RING	COMPACT	VORTEX	SOLOSPUN
Cost	High	High	Attractive	Reduced
Robustness	Average	Average	Acceptable	Reduced
Flexibility	Good	Good	Limited	Limited
Quality	High	High	Reduced	Debatable
Appearance	High	High	Reduced	Debatable
Distribution	High	Small/increasing	Very small	Limited
Market	Reducing	Small/increasing	New (limited)	Stagnant
Fibre needs	Flexible	Long hauteur	Short staple	Long hauteur

14 - **Module 8:** Alternatives to ring spinning

REFER TO the above slide as you indicate that it makes some comparisons between some of the technologies used for spinning wool.

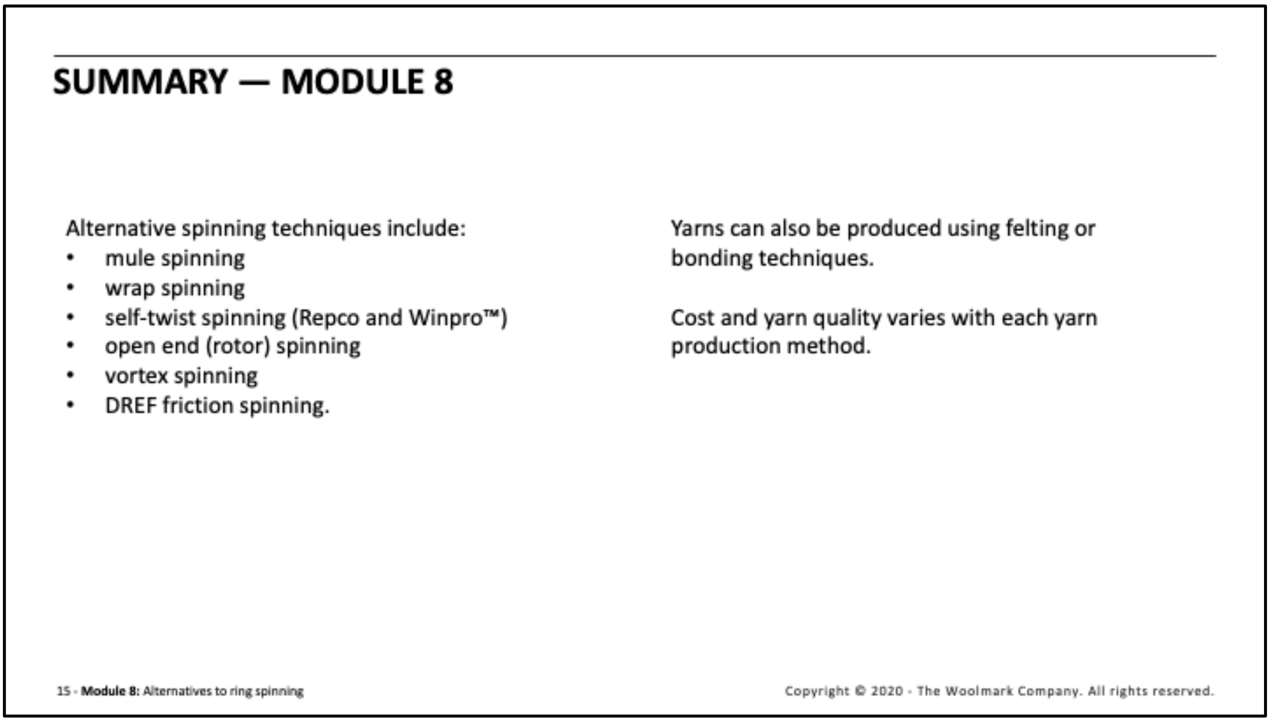
NOTE THAT compact spinning has been shown to improve yarn quality and reduce yarn irregularity and hairiness. This system is finding increased application for both knitting and weaving yarns.

EXPLAIN THAT vortex spinning produces a lower-quality yarn than ring spinning, but at higher speeds and lower cost. The application of this system is limited to short-staple fibres and woollen-spun applications.

NOTE THAT Solospun produces a weavable singles fabric and thus a weaving yarn at a reduced cost. It is most suitable for long wool and there is still debate on the quality of the yarns compared with conventional ring-spun and folded yarns. Like any singles yarn technology it suffers from poorer appearance of the fabric when compared with a two-fold yarn.

EXPLAIN THAT SiroSPUN (not listed) produces a weavable pseudo two-fold yarn in a single operation at reduced cost.

NOTE THAT there is still debate on the quality of the yarns spun using these newer technologies compared with conventional ring-spun and folded yarns particularly in critical face-finished products like gabardines.



REINFORCE THAT wool yarns can be spun using alternative spinning methods including:

- mule spinning – sometimes used for woollen yarns
- self-twist spinning (Repco and Winpro technologies)
- wrap spinning
- open end (rotor) spinning
- vortex spinning
- DREF friction spinning.

REITERATE THAT yarns can also be produced without spinning using felting or bonding techniques.

EMPHASISE THAT the cost and yarn quality outcomes of the various spinning options vary.

ASK *participants if they have any questions about the content covered in this module.*

ALLOW *time for questions and discussion before proceeding to the final slide and closing the lecture.*

INFORM participants of the time and location for the next lecture — *Module 9 Post-spinning operations*— and encourage them to read through the relevant notes in their Participant Guides before attending the lecture.

ENCOURAGE participants to explore the Woolmark Learning Centre to reinforce and build on what they have covered in today's lecture.

Participants can register with and explore the Woolmark Learning Centre here: www.woolmarklearningcentre.com

MODULE 9

THE WOOLMARK COMPANY

POST-SPINNING OPERATIONS

RESOURCES — MODULE 9: POST SPINNING OPERATIONS

Contained in the *Worsted and woollen spinning* Demonstration kit you will find the following resources for use as you deliver **Module 9: Post-spinning operations**:

- 'twist lively' yarn
- steamed yarn
- knotted yarn
- spliced yarn

WELCOME participants to Module 9 of the Woolmark Wool Science, Technology and Design Education Program — *Worsted and woollen spinning — Post-spinning operations*.

EXPLAIN THAT this module will cover each of the following operations:

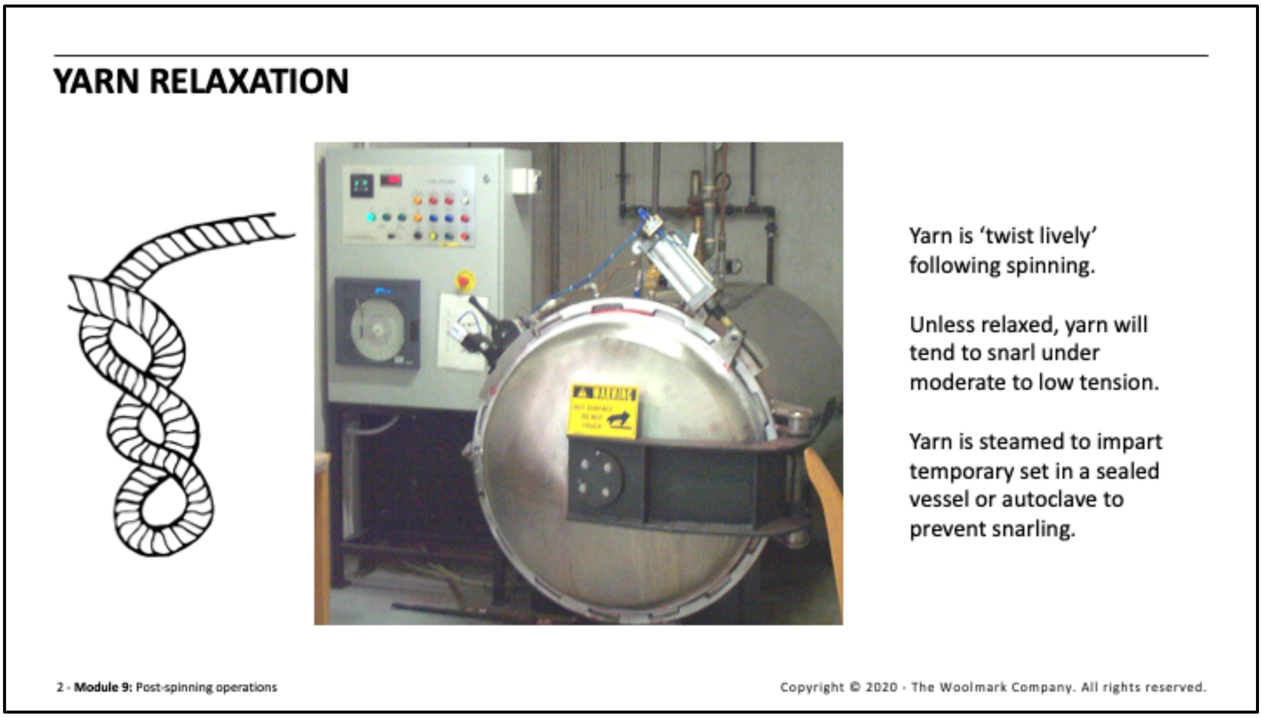
- yarn relaxation
- winding and clearing
- splicing and knotting
- assembly winding
- twisting/folding

INFORM participants that by the end of this module they will be able to:

- describe the aims of each operation
- outline the impact of each operation on final yarn quality
- describe the quality issues associated with each operation.

RESOURCES REQUIRED FOR THIS MODULE:

- *'twist lively' yarn*
- *steamed yarn*
- *knotted yarn*
- *spliced yarn*



EXPLAIN THAT the yarn on the ring spinning bobbin is normally 'twist lively' and must be set in steam (relaxed) before it can be used in weaving or knitting, otherwise, under moderate to low tension, the yarn will tend to snarl.

DEMONSTRATION: TWIST LIVELINESS

Resources required:

- *length of 'twist lively' yarn*

DEMONSTRATE *the concept of 'twist lively' yarn by:*

- ***UNWINDING*** *a section of the 'twist lively' yarn.*
- ***JOINING*** *the ends of the yarn together.*
- ***WATCHING*** *the yarn twist up (as shown in the diagram on the slide).*

INDICATE THAT in order to prevent fibre damage, a temperature of 80°C should be adequate for steaming most worsted-spun yarns. If this is insufficient and some unacceptable snarling remains, longer steaming times, rather than higher temperatures, should be used to avoid yellowing of the fibre.

EXPLAIN THAT a more severe steaming cycle, which aims for the total elimination of snarling, is not necessary at this stage and can make the production of optimum spliced joints in the winding operation more difficult. It can also lead to dyeing problems due to fibre damage arising from unnecessary exposure to high temperatures. Damage caused by steam will change the dyeing behaviour and colour of wool.

ASK *participants the following questions:*

- *What form of set is being applied to the fibre? (* ***ANSWER*** *– Temporary/ cohesive set is being applied.)*
- *Why is 80°C a suitable level for steaming? (***ANSWER*** *It is higher than the glass transition temperature.)*
- *Is the moisture content of wool important, and if so, why? (***ANSWER*** *– It is important as it affects the glass transition temperature.)*
- *Why is there not much permanent set during steaming? (***ANSWER*** *– The steaming temperature is not hot enough)*

NOTE THAT the steam used during the setting process must be dry and consistent. If it is not, condensation of unwanted moisture will occur on the fibres and areas of the fibre with high water content will be damaged.

EXPLAIN THAT this video, produced by The Woolmark Company (TWC), offers an overview of the yarn relaxation process.

PLAY *video (37:00 seconds)*

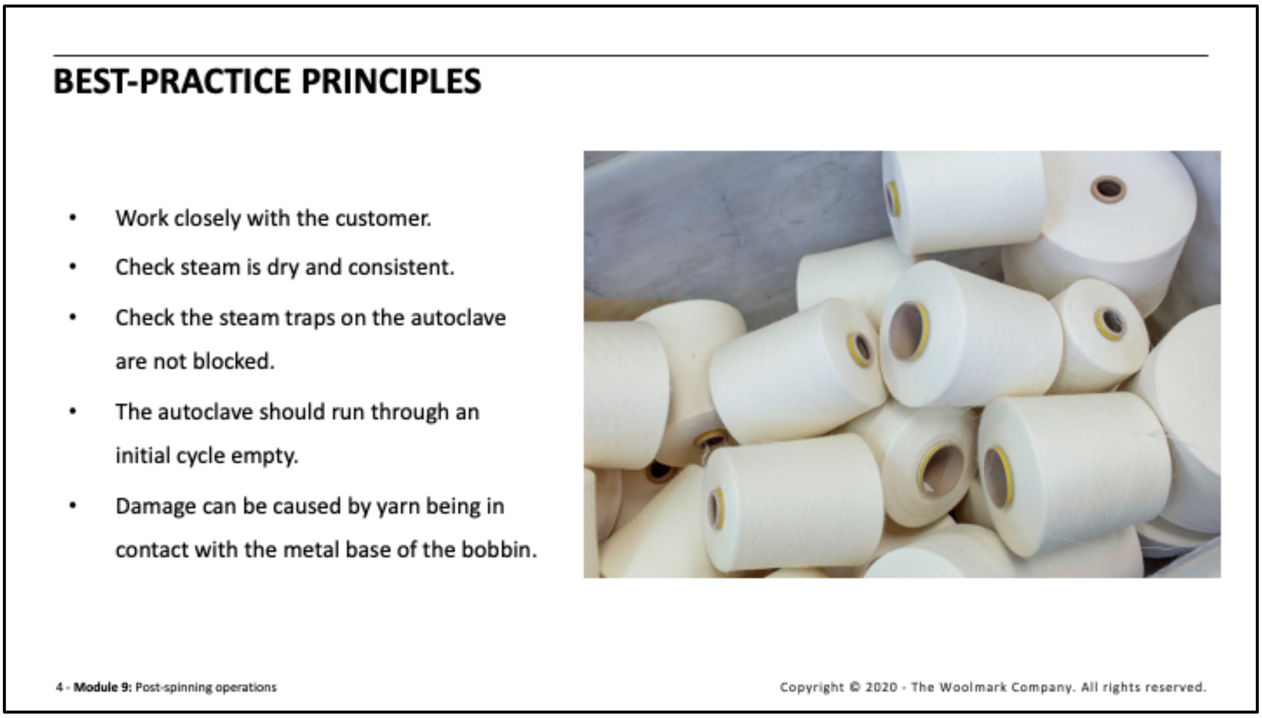
AS THE *video plays note that:*

- *the bobbins or other packages are placed in carts (6:00 seconds) and loaded into the autoclave steamer.(8:00 seconds)*
- *the autoclave is closed (21:00 seconds) .*

INDICATE THAT *although it cannot be seen on the video, a vacuum is created within the autoclave and steam is injected.*

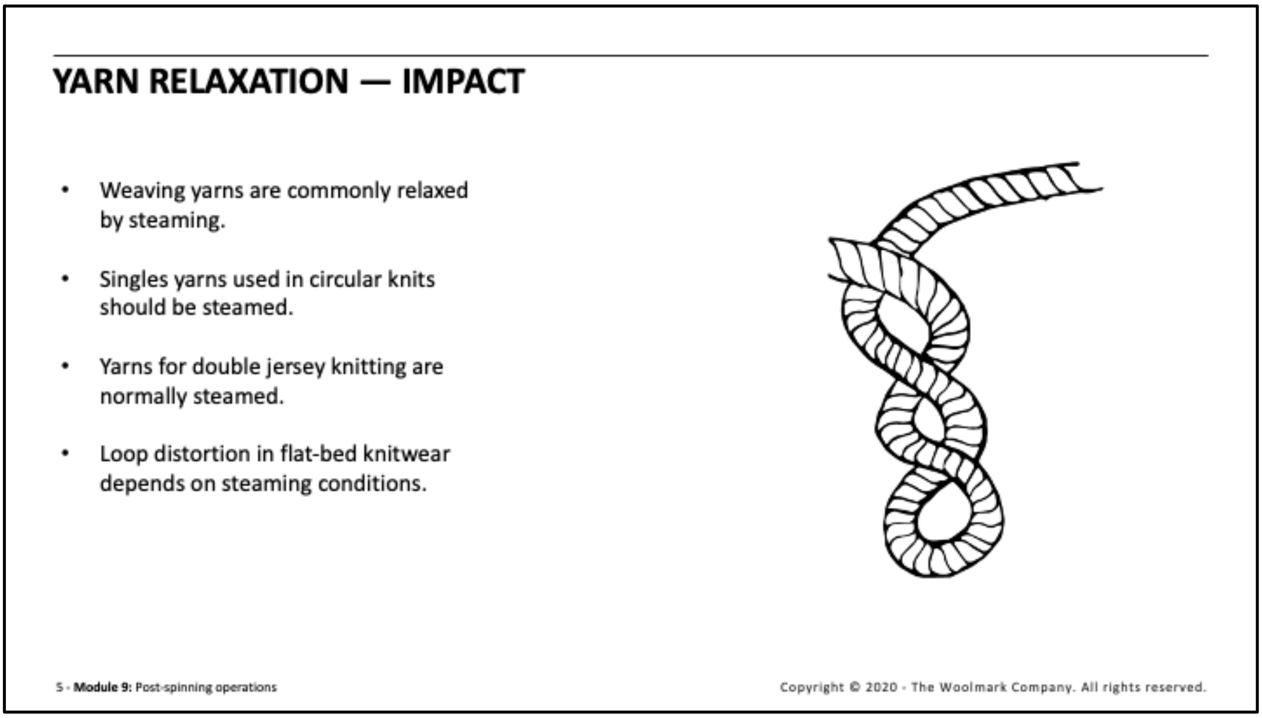
ASK *participants if they have any questions or comments regarding the video content.*

ALLOW *sufficient time for participants to respond before proceeding.*



EXPLAIN THAT the following best-practice guidelines should be followed:

- Work closely with the customer to understand their needs. For example, cockling and spirality in fine gauge knitwear can be minimised with correct yarn relaxation during steaming.
- Check the steam is dry, consistent, and not poor quality or damp.
- Check the steam traps on the autoclave are not blocked. The steam traps separate liquid from steam and if they are blocked some areas of the wool may be more severely damaged.
- The autoclave should run through a whole cycle empty so it can heat up to the desired temperature before steaming commences. Often the first batch of wool for the day is the only damaged batch because the machine had not yet reached the desired temperature. It is also often the case that the damaged fibres are isolated to the bottom of the bobbin where there is a steel ring. Condensation will form around the steel ring and damage the fibres close to it.



EXPLAIN THAT for weaving, both singles and twisted yarns are normally steam relaxed.

INDICATE THAT circular knits where singles yarns are used, are prone to spirality. Spirality is the variation away from the vertical of the direction of the wales in the knitted structure due to residual torque in the yarn. It is necessary therefore to steam relax the singles yarn to minimise this problem.

NOTE THAT yarns for double jersey knitting have a much higher twist than other types of knitting yarns so steaming is common.

POINT OUT that in flat-bed knitwear, distortion in the final garment can occur if the yarn is not appropriately relaxed in steam. Distortions such as cockling (loop distortion) are regularly found using two-fold yarns if the yarns have not been properly relaxed.

NOTE THAT the relationship and technical understanding between the spinner and the knitter is critical.

INDICATE THAT formulae for minimising distortion by achieving balanced twist levels are reasonably well established. However these twist formulae are not necessarily correct for wet-relaxed fabrics so the nature of any subsequent process should be considered by the spinner.

WINDING AND CLEARING

Yarns are wound from bobbins onto a larger packages (cones).

Clearers identify and remove yarn faults to:

- meet customer requirements
- ensure in-house quality improvement.

Packages should be wound with uniform density within and between packages.

6 - **Module 9:** Post-spinning operations

EXPLAIN THAT the amounts of yarn on the spinning bobbin are relatively small. The next operation, winding, accumulates the yarn from several spinning bobbins onto one supply package – a cone. This vastly improves efficiencies in the weaving and knitting processes.

After autoclaving, bobbins are wound at high speed onto these larger packages.

INDICATE THAT winding is carried out on highly-automated and efficient machinery, in conjunction with clearers for removing objectionable yarn faults.

These clearers cut out, or 'clear' thin and thick spots and neps, which are sensed by capacitive or optical sensors set to the required tolerances.

NOTE THAT in mill practice, it is usual to clear different yarn qualities and counts at different clearer settings.

POINT OUT that optical sensors such as Siroclear (licensed by CSIRO to Loepfe) or Uster Classimatt (by Uster Zellweger) can even detect dark or discolored fibre in an ecru yarn.

When the imperfection is 'cleared', the ends of the yarn are re-joined by knotting or splicing.

EXPLAIN THAT this video, produced by The Woolmark Company, offers an overview of the winding and clearing process.

PLAY *video (47:00 seconds)*

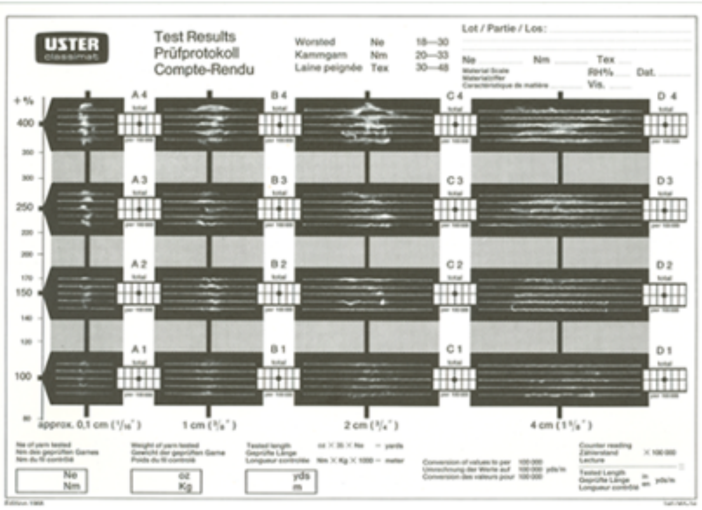
AS THE *video plays note:*

- *the winding machines wind the yarn from the bobbin onto a bigger package.(16:00 seconds)*
- *sensors then check the yarn, and remove faults using a splicer to re-join the broken ends.(22:00 seconds)*
- *the machines wind the inspected and cleared yarn onto a larger package.(33:00 seconds).*

ASK *participants if they have any questions or comments regarding the video content.*

ALLOW *sufficient time for participants to respond before proceeding.*

WHAT IS A YARN FAULT?



Source: Uster Zellweger

8 - **Module 9:** Post-spinning operations

INDICATE THAT Uster Zellweger has in the past provided guides for the yarn faults typically found in yarns.

POINT OUT that an example of the Uster Zellweger yarn fault guide can be seen on the slide. The yarn faults are categorised in terms of the increase in thickness in comparison to the average yarn thickness and the length of the fault.

NOTE THAT depending upon the agreed fault level customers will accept, a spinner can set a clearer so it will detect and remove selected categories of faults.

EXPLAIN THAT the clearer settings may vary depending on the end product. For example, single yarns destined for knitting and weaving without two-folding (such as Sirospun or Solospun yarns) need to be cleared of faults more critically than twisted yarns. Some of the faults may be hidden within the twisted yarn.

YARN FAULT DETECTION AND REMOVAL

Detectable faults include:

- thick spots
- thin spots
- vegetable matter
- dark and medullated fibres
- non-wool coloured fibres.

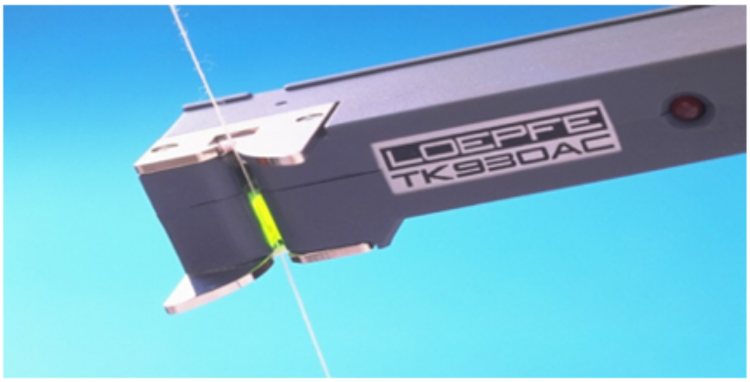


Image courtesy of CSIRO

9 - **Module 9:** Post-spinning operations

EXPLAIN THAT during the winding operation, the opportunity is taken to monitor the yarns for faults. Traditionally, the yarns were monitored for thick and thin faults. It has now also become common practice to monitor ecru yarns for coloured contaminants such as:

- vegetable matter,
- dark and medullated fibres
- non-wool coloured fibres
- grease contamination.

INDICATE THAT Uster Zellweger is a leader in this field, developing the first yarn fault analysers and clearers during the 1960s. These were based on the principle of detection by change in capacitance.

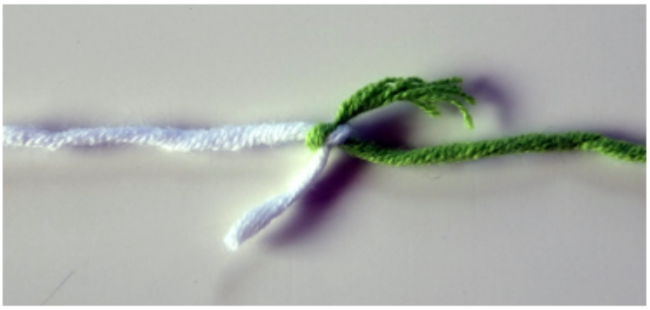
MENTION THAT Siroclear (licensed by CSIRO to Loepfe) is an optical sensor incorporated into the thick and thin fault sensor to monitor the colour of the ecru yarn being wound.

EXPLAIN THAT both Loepfe and Uster incorporated sensing technology for the detection of polypropylene (undyed) in ecru yarn. The Loepfe technology is based on a triboelectric principle. Uster appears to have combined a capacitance detector with an optical detector.

NOTE THAT Keisokki has also introduced an optical foreign fibre detector into their clearer technology.

POINT OUT that any coloured contaminant or foreign fibre that is detected and falls outside pre-set limits is automatically removed and the yarn spliced.

JOINING TWO ENDS OF YARN



Knotting

Splicing

10 - **Module 9:** Post-spinning operations

INDICATE THAT during winding, the faulty sections of yarns are removed and the fault-free yarns are re-joined, either by knotting or splicing. The ultimate solution would be a yarn joint completely indistinguishable form the parent yarn.

Knots

Knots are yarn faults that may fail in subsequent processing. They can cause other faults during processing and require labour for their removal during mending of the final fabric.

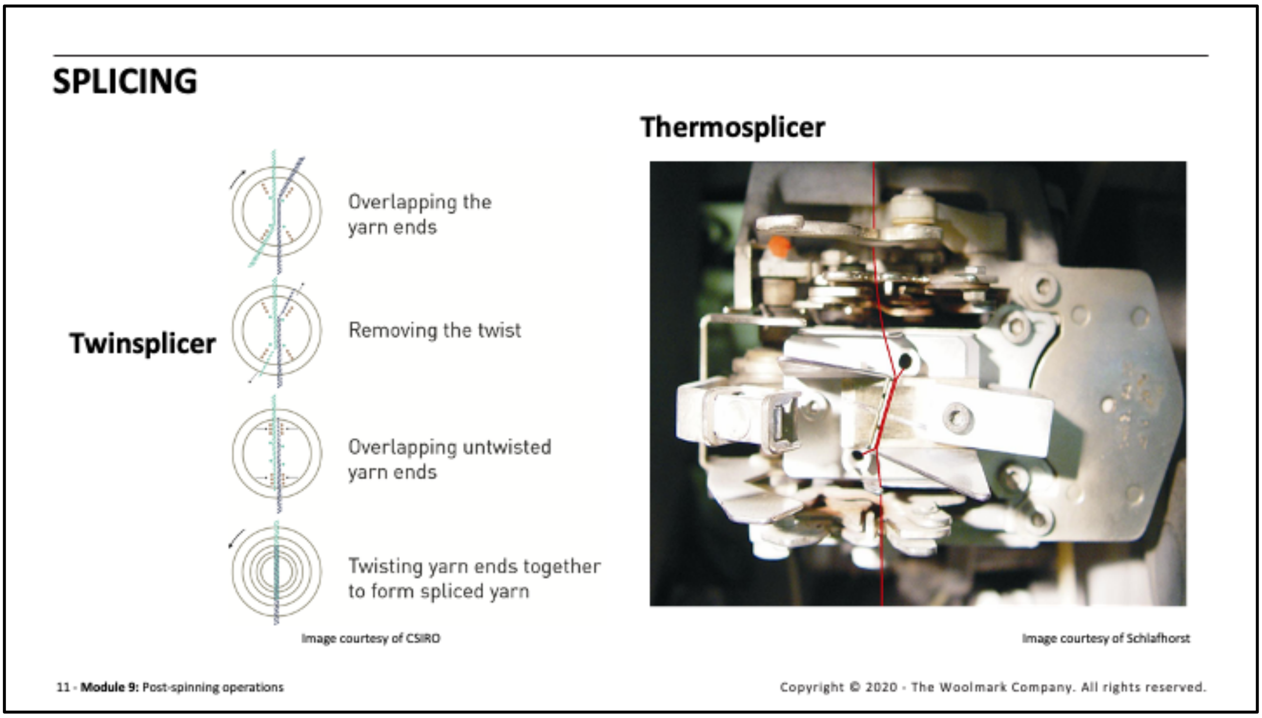
POINT OUT that knotting has been generally superseded by splicing.

Splicing

Splicing involves the untwisting of the fibre at the two yarn ends to be joined, then bringing the two yarn ends together and inserting twist into the join. This method is used after the detection and removal of a yarn fault, and where the start and end of yarns from two spinning bobbins are to be joined. Ideally, the splice must have the same appearance as the parent yarn and have almost the same strength.

NOTE THAT two splicing systems have been developed:

- mechanical - Savio (Italy)
- pneumatic - Schlafhorst (Germany).



Twinsplicer, (shown on slide)

EXPLAIN THAT the yarn ends to be joined are sandwiched between two annular discs, which are geared together in such a way that they rotate in opposite directions around their central axes.

To produce the yarn splice, the discs are first rotated to remove the twist over a short length of the two yarn ends to be joined.

The untwisted ends are then overlapped and twist is inserted into the join by rotation of the discs in the opposite direction.

NOTE THAT the twinsplicer is primarily used for cotton yarns.

The Thermosplicer

INDICATE THAT in this instrument, the ends to be joined are re-entangled together in a stream of hot air. This technology takes advantage of wool's thermoplastic properties. The type of prism, timing and air pressure used by the splicer all need to be considered to obtain acceptable yarn splices for every lot.

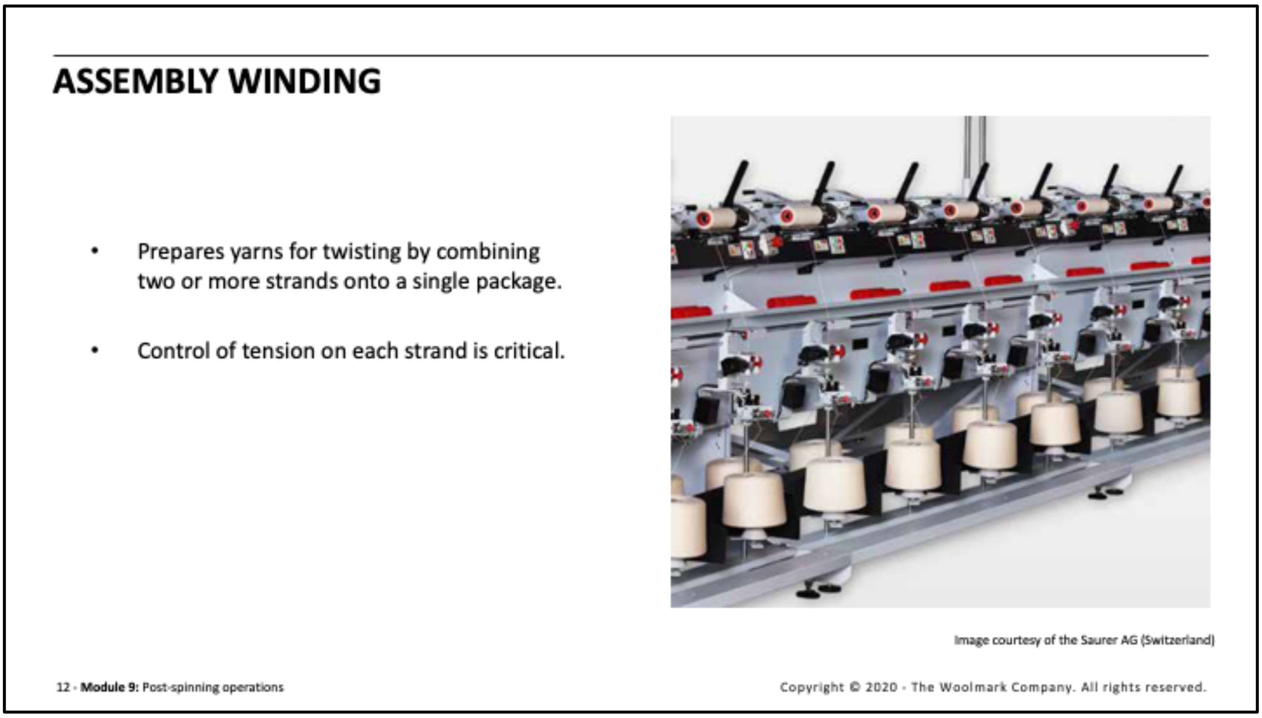
Cold-air splicing is also available.

NOTE: This technology was developed for worsted yarn after the observation that heating wool fibres increased their flexibility.

EXPLAIN THAT the thermosplicer works by rapidly heating the wool fibres above their glass transition temperature during the yarn joining phase of the splicing operation. The fibres become more pliable and consequently are easier to bind into the splice. The result is a stronger, more invisible splice.

NOTE THAT investigation has shown that hot-air splices in wool yarns, irrespective of yarn type or state are far more abrasion resistant than cold-air splices.

- In weaving, cold-air splices recorded the higher failure rate.
- During fabric inspection, hot-air splices were judged to require the least level of mender attention.



EXPLAIN THAT frequently in worsted yarn manufacture, two singles-spun yarns need to be twisted together to meet the final requirements for the yarn, fabric and ultimately the product. This is often called folding (two-folding if there are two yarns), twisting or plying.

INDICATE THAT to bring the two strands of spun yarn together in a yarn package suitable for the efficient twisting of the yarns, an operation known as 'assembly winding' is introduced.

NOTE THAT it is critical in this operation that both ends of yarn are brought together on the final yarn package with equal length. Tension adjustment on each strand is critical and has to be uniform across all positions on the assembly winding machine. If this is not the situation, variations in the final twisted yarns will lead to visible imperfections in the fabric.

POINT OUT that given the apparently simple nature of this process, it often too easy to overlook the routine maintenance and processing procedures, which ensure the two ends are 'assembled' correctly.

EXPLAIN THAT this video, produced by The Woolmark Company (TWC), offers an overview of the assembly winding process.

____

PLAY *video (24:00 seconds)*

AS THE *video plays note that:*

- *two yarns must be wound onto the same package to prepare yarns for twisting or folding*
- *tension control is critical — see the tension control components.(9:00 seconds).*

ASK *participants if they have any questions or comments regarding the video content.*

ALLOW *sufficient time for participants to respond before proceeding.*

____

TWISTING

Twisting confers:

- improved abrasion resistance
- improved appearance
- improved tensile strength and uniformity
- balance yarn for knitwear.

Twist relationships:

- Plying twist is usually in the opposite direction to the singles twist.
    - A singles yarn of Z twist will be plied in the S direction, trapping fibres in the structure and increasing the yarn bulk and rendering fibres in the singles components parallel to yarn direction.
- For knitting yarns, the ply twist (tpm) will be about two-thirds that of the singles twist.

14 - **Module 9:** Post-spinning operations

INDICATE THAT the purpose of twisting (folding or plying) is to :

- create a yarns more resistant to abrasion than a singles yarn of the same count, so they will more easily resist the tension and abrasion during weaving
- significantly improve the mass regularity and therefore the appearance of the yarn
- improve the strength of the yarn
- create a balanced yarn that is not twist lively and will not cause spirality or other distortions in the resulting knitwear.

NOTE THAT the relationship between the singles twist and the folding twist inserted during folding determines many properties of the yarn and final fabric and is an issue of particular relevance in designing a textile fabric.

EXPLAIN THAT yarns for weaving, particularly warp yarns, are usually twisted or two-folded although it is not uncommon to use singles yarns in the weft. Yarns for circular and flat-bed knitting are normally, but not always, folded.

Hand-knitting yarns are often multi-plied (two-ply, four-ply, eight-ply etc).

POINT OUT that folding twist is usually in the opposite direction to the singles twist. A singles yarn of Z twist will be plied in the S direction. This has the effect of trapping fibres in the structure, while increasing the yarn bulk and rendering the fibres in the singles components parallel to the yarn direction.

NOTE THAT for knitting yarns, the ply twist in turns per metre (tpm) will be about two thirds that of the singles twist.
For weaving yarns a number of variants are used between 75 to 110% that of the singles twist. This affects the surface appearance of the woven fabric.

EXPLAIN THAT for some fabrics, even twist-on-twist yarns may be made, where the ply twist is in the same direction as the singles. These are hard, lean yarns of high density and are typically used in woven crepe fabrics.

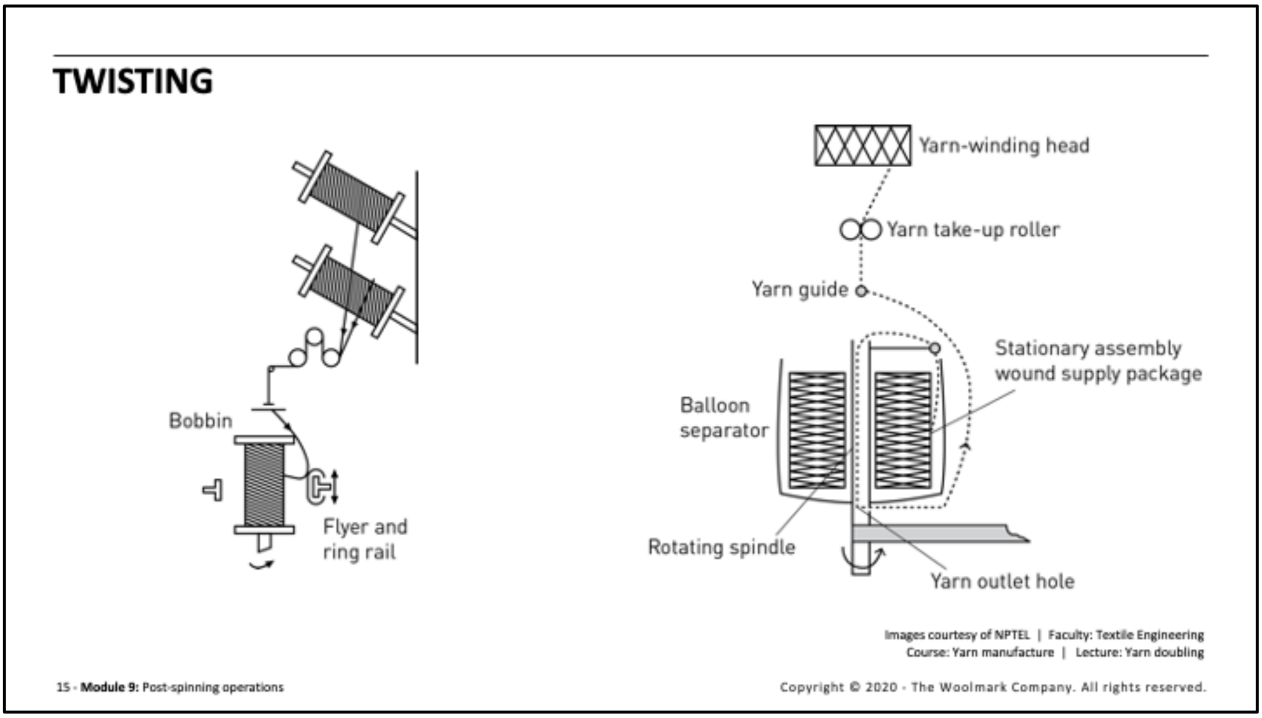
NOTE THAT the two-fold yarns again require steaming to set the new fibre configurations and minimise twist liveliness.

ASK *participants to explain the advantages of a 60/4 yarn over a 30/2 or 15/1 yarn.*

ALLOW *participants sufficient time to respond.*

IF NECESSARY *confirm that:*

- *four-fold yarn is inherently more even than two-fold or singles yarn*
- *finer wool is required to make a 60/4 yarn than a 15/1. More than 40 fibres in the cross-section of the singles yarn means the wool to make a 60s yarn must be finer than that to make a 15s yarn. Finer wool = greater expense.*



INDICATE THAT two types of machines have been used for twisting

- ring twisters
- two-for-one twisting machines.

Ring twisters
These machines operate on the same principle as ring spinning frames. The yarns to be twisted are fed though the ring (without drafting) onto the spinning yarn package. The twisted yarn is wound onto a removable bobbin or spindle. These machines are not as efficient as the alternative and are rarely used.

Two-for-one twisting machines
Two-for-one machines insert twist by continuously looping the pair of yarns around the package thus inserting two turns of twist for each rotation of the loop. These machines use an 'assembly wound' package.

NOTE THAT the major components of the twister are:

- the yarn package
- the spindle
- the balloon separator
- take-up rollers
- yarn winding head.

EXPLAIN THAT the yarn is threaded through the spindle flyer and down the hollow spindle emerging through a hole in the bottom under

The yarn proceeds outside the cylinder containing the yarn, through yarn guides to the take-up rollers and winding head. This inserts the 'second turns of twist'.

POINT OUT that the yarn package remains stationary and the spindle rotates at high speed. The twist inserted is the ratio of the spinning speed of the spindle and the take-off speed.

Images courtesy of NPTEL

- Faculty: Textile Engineering
- Course: Yarn manufacture
- Lecture: Yarn doubling

EXPLAIN THAT this Woolmark Company video offers an overview of the two-for-one twisting process.

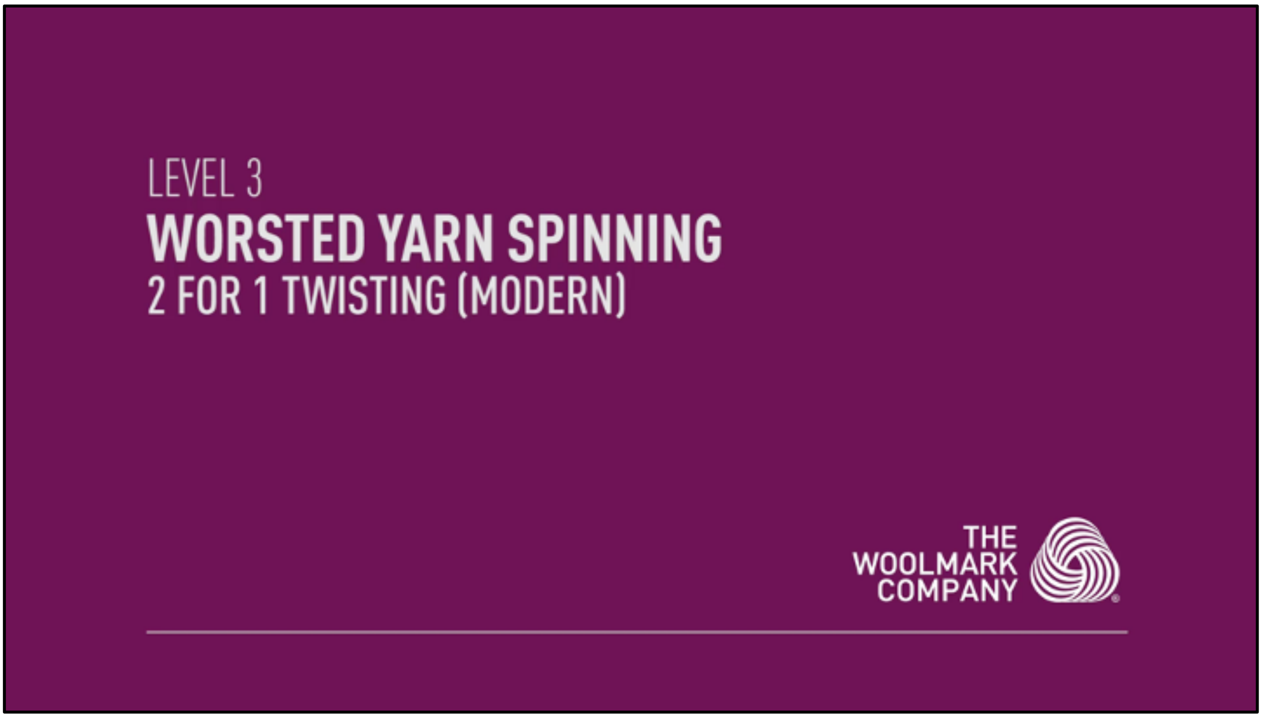
PLAY *video (25 seconds)*

AS THE *video plays note that:*

- *the package with the two yarns spins rapidly while the yarn is drawn off, inserting twist (10:00 seconds)*
- *the yarn is then wound onto a new package (21:00 seconds).*

ASK *participants if they have any questions or comments regarding the video content.*

ALLOW *sufficient time for participants to respond before proceeding.*



INDICATE THAT this Woolmark Company video offers an overview of a more modern two-for-one twisting process.

____

PLAY *video (34:00 seconds)*

AS THE *video plays note that:*

- *this second machine also has a package wound with two yarns that spins rapidly (13:00 seconds)*
- *the yarn tensioning device controls the density of the new package (18:00 seconds)*
- *wax can be applied for knitting yarns (22:00 seconds).*

ASK *participants if they have any questions or comments regarding the video content.*

ALLOW *sufficient time for participants to respond before proceeding.*

____

PRACTICAL CONSIDERATIONS IN TWISTING

Two-for-one twister

- Too much twist in the yarns
- Too little twist in the yarns
- Increased end breaks
- Loss of yarn strength
- Poor take up package build
- Density variation in package
- Pattern formation in package

Image courtesy of Saurer AG

18 - **Module 9:** Post-spinning operations

EXPLAIN THAT the following problems can occur during twisting:

Too much twist in the yarn may be caused by:

- incorrect gears.
- central disc touching the take up roll or not moving freely
- friction roll is loose or damaged
- cradle pressure too low.

Too little twist in the yarn is caused by:

- incorrect gears
- incorrect friction roll speed to spindle speed
- wrap build up on spindle whorls
- spindle brake is blocked or dirty
- pot bearing is defective
- spindle speed too low.

Increased end breaks can be caused by:

- Incorrect yarn reserve adjustment. Check with a stroboscope to see if tension device, unwinding aids and possibly yarn lubrication are at fault.
- The flyer touches the feed package or the yarn balloon during start-up.
- Flyer not moving freely.
- Balloon tension too high. Check the height of the balloon thread guide.
- Take-up tension too high. Increase the wrap angle on the overfeed roll.
- Check for irregular contact of yarn on machine parts

Loss of yarn strength can be due to:

- Low twist (see above)
- The yarn balloon touching the upper edge of the pot. Check the height of the balloon thread guide with a stroboscope.
- Loops in the yarn, which are yarn tension related.
- Irregular yarn balloon. Check yarn reserve with a stroboscope.

Poor take-up package build:

- If the yarn package build is deformed, ensure the correct ratio between pre-take-up pressure and package density has been selected.
- Check action of anti-patterning device and position and eyelet size of the traverse thread guide.

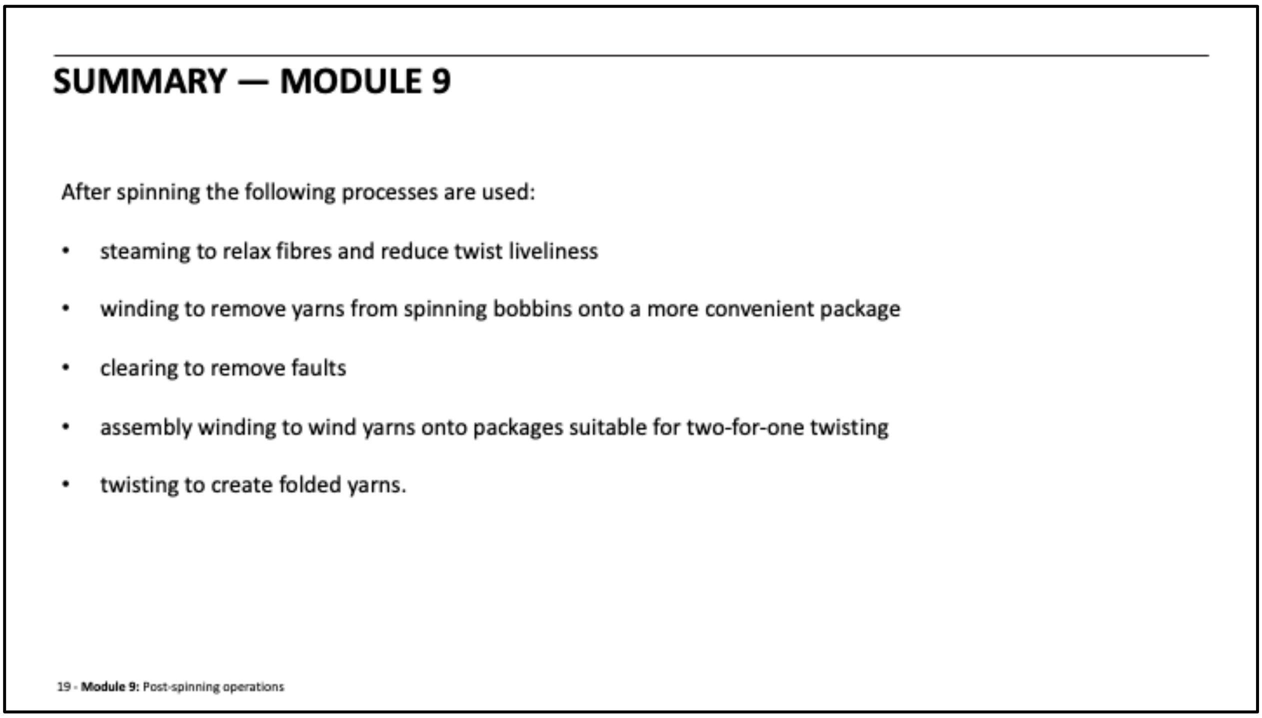
Density of take up package varies:

- Check uniformity of cradle pressure and the wrap angle on the overfeed roll.

The pattern formation has band throw over:

- Check anti-patterning device.

INDICATE THAT operators should check regularly for potential build up of fly around accumulators and in the base of the pot.



SUMMARISE THAT after spinning yarns are treated in a number of operations to prepare them for use including:

- steaming to relax the fibres and reduce twist liveliness
- winding and clearing in a single operation to remove yarns from spinning bobbins onto a more convenient package and remove faults. Pneumatic splicing devices are used to join or splice the ends of broken yarns
- assembly winding — to wind yarns onto packages suitable for two-for-one twisting
- twisting — to create folded yarns improving yarn strength, evenness, appearance and hairiness.

REMIND participants that yarn faults are categorised in terms of the increase in thickness in comparison to the average yarn thickness and the length of the fault.

ASK *participants if they have any questions about the content covered in this module.*

ALLOW *time for questions and discussion before proceeding to the final slide and closing the lecture.*

INFORM participants of the time and location for the next lecture — *Module 10 Quality assurance in spinning* — and encourage them to read through the relevant notes in their Participant Guides before attending the lecture.

ENCOURAGE participants to explore the Woolmark Learning Centre to reinforce and build on what they have covered in today's lecture.

Participants can register with and explore the Woolmark Learning Centre here: www.woolmarklearningcentre.com

BEFORE participants leave ensure you have collected all materials distributed during the lecture.

MODULE 10

THE WOOLMARK COMPANY

QUALITY ASSURANCE

RESOURCES — MODULE 10: QUALITY ASSURANCE IN SPINNING

No additional resources are required to deliver **Module 10: Quality assurance in spinning**

WELCOME participants to Module 10 of the Woolmark Wool Science, Technology and Design Education Program — *Worsted and woollen spinning —Quality assurance in spinning*.

EXPLAIN THAT this module will provide an overview of quality assurance in spinning and post-spinning operations and will cover:

- the importance of yarn quality
- methods of measuring
    - yarn count
    - variations in linear density and fault analysis
    - tensile properties
    - hairiness
    - yarn-to-metal friction
    - extractable materials
    - colour
- general versus rogue spindles
- standard operating procedure (SOP) manuals.

INFORM participants that by the end of this module they will be able to:

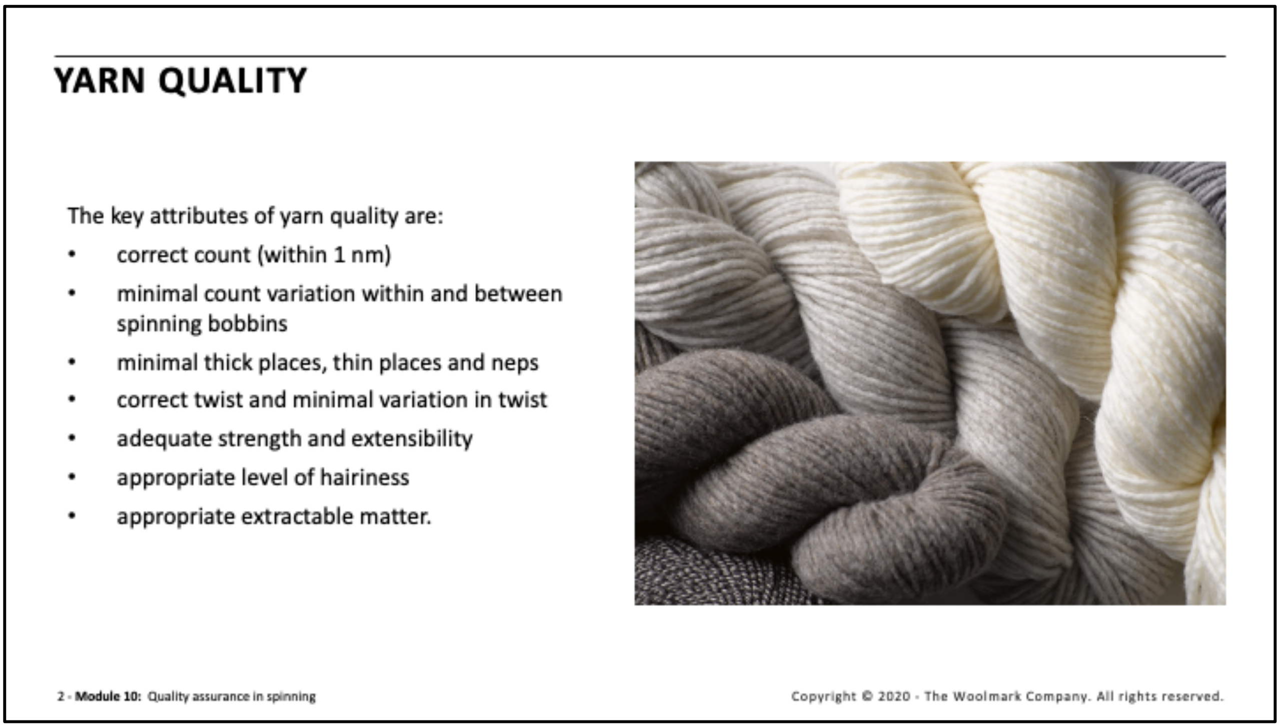
- describe the key attributes of worsted and woollen yarn to determine its quality and the issues associated with optimising quality
- methods used to measure the key properties of yarn related to quality.

ASK *participants to describe the characteristics that are important in determining yarn quality.*

RECORD *responses on whiteboard or flipchart.*

ADVANCE *to next slide to confirm the responses are all covered.*

NO RESOURCES REQUIRED FOR THIS MODULE



CONFIRM THAT the quality parameters of a yarn ultimately determine the mechanical, aesthetic, tactile and physiological characteristics of the final textile product (fabric, garment).

NOTE THAT the list of the key attributes determining yarn quality are shown on the slide.

***REFER** to list of participant suggestions on whiteboard or flipchart and tick off those corresponding with the list on the slide.*

EXPLAIN THAT modern test procedures serve as a valuable source of information for the innovative yarn spinner and form the basis of yarn selection and purchasing decisions.

POINT OUT that in addition the test data allows the simultaneous optimisation of quality, processing behaviour and cost.

YARN QUALITY ASSURANCE PROGRAMS — INFORMATION SOURCES

Yarn sampling and testing
- routine timed samples of singles and folded yarn
- measurement of
  - count and evenness
  - twist
  - strength/extensibility
  - friction
  - hairiness

Output of spinning frames
- ends down per thousand spindle hours.

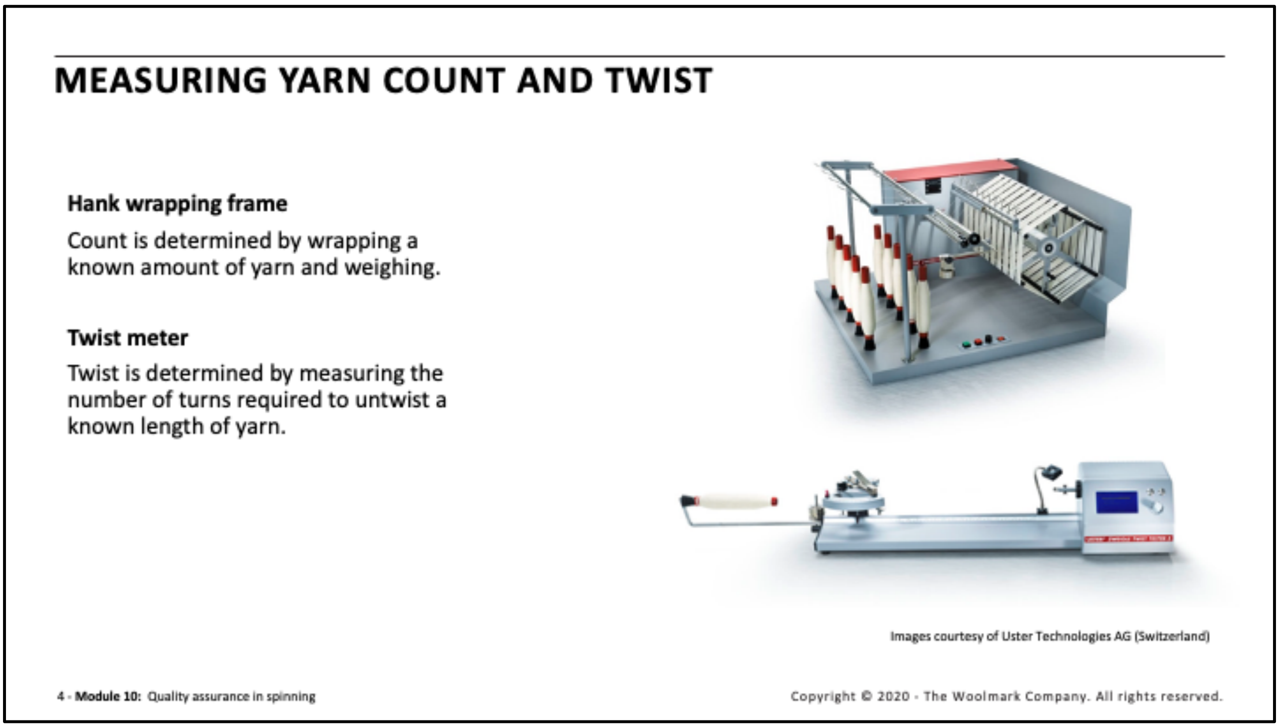
Output of winding frames
- splicings per kilometre of yarn wound.

3 - **Module 10:** Quality assurance in spinning

INDICATE THAT there are several sources of information about yarn quality obtained from processing equipment. These sources include:
- the test data from routine sampling and testing
- the measurements of ends down (EDMSH), which is recorded automatically on modern spinning frames. On older spinning frames EDMSH can be measured manually by operators if necessary
- the measurements made of yarn faults at the winding frame (splicings per kilometre). This is recorded automatically by yarn clearers or can be recorded manually by operators.

EXPLAIN THAT an appropriate quality assurance (QA) program uses the results of regular testing of singles and folded yarn regularly sampled at production.

POINT OUT that all measurements of yarn should be conducted in a laboratory conditioned to 20°C, 65% relative humidity (RH) after the sample has been allowed to condition (reach equilibrium with the surrounding atmosphere).



NOTE THAT the two most important properties measured in a quality assurance program are:

- count — which should be within 1 Nm of the required count in coarse counts and 2Nm of the requirement in fine counts
- twist — singles twist should be within +/– 20 tpm of required level; folding twist should be within +/– 10 tpm of required level.

INDICATE THAT the instruments to measure count and twist are shown on the slide:

- Hank wrapping frame and balance for count
- Twist meter for singles and two-fold twist

ASSESSING YARN EVENNESS

Yarn evenness is measured using the Uster evenness tester (or equivalent):

- U%
- thin places
- thick places
- neps.

The limits depend on the requirements of the customer.

Image courtesy of Uster Technologies AG (Switzerland)

5 - **Module 10:** Quality assurance in spinning

NOTE THAT yarn evenness, or the variation in mass per course length (irregularity), is critical for avoiding unwanted visual variations in the fabric.

POINT OUT that yarn evenness (short, medium, and long-term mass variations) and count variation is measured in a Uster evenness tester and is determined as average variation in weight per course length — U%.

INDICATE THAT the value of U% is specified for a particular end use and must be within certain specified tolerance.

EXPLAIN THAT the method of measuring yarn evenness is as follows:

- The yarn is run through a plate capacitor.
- The capacitance alters depending on the weight of wool between the plates.
- Changes in the measured capacitance are used to measure changes in mass variation of the yarn.
- The instrument measures:
    - variation in mass (U%)
    - thick places
    - thin places
    - neps.

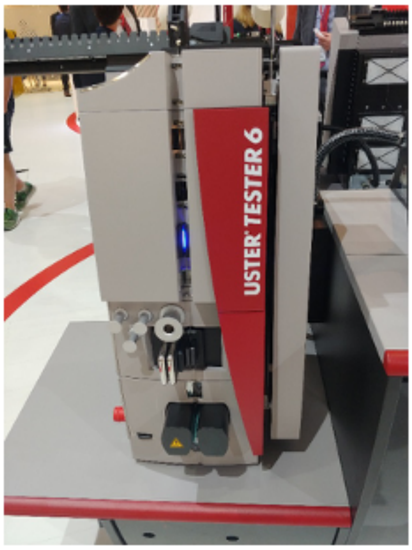
The limits are normally agreed between spinner and customer.

POINT OUT that variations in moisture due to improper conditioning of the sample or variations in lubricant levels can add to the variation in capacitance and hence the final result.

USTER TESTER 6

Measures:
- yarn evenness
- yarn count
- yarn hairiness of staple yarns
- yarn diameter and variation in diameter
- yarn density
- shape of yarn cross-section
- yarn impurities

Predicts
- weaving performance,
- fabric appearance (based on yarn evenness)
- pilling.



6 - **Module 10:** Quality assurance in spinning

INDICATE THAT the recently released Uster Tester 6 is claimed to have new sensors (e.g. optical sensor seen as blue light in the image) to detect faults in yarns in addition to the more traditional capacitive sensors for the measurement of the evenness of yarns, roving, top and sliver (1-12000tex).

NOTE THAT options are available with the instrument that are claimed to measure:
- yarn evenness
- yarn count
- yarn hairiness of staple yarns
- yarn diameter and variation in diameter
- yarn density
- shape of yarn cross-section
- yarn impurities.

EXPLAIN THAT software incorporated into the machine also makes predictions from the results for weaving performance, fabric appearance (based on yarn evenness) and pilling propensity.

TESTING TENSILE PROPERTIES

Tensile properties:

- strength (load at break)
- extension at break.

These properties affect:

- further processing behaviour
- the physical properties of the fabric.

The method of test influences the result.

Image courtesy of Uster Technologies AG (Switzerland)

7 - **Module 10:** Quality assurance in spinning

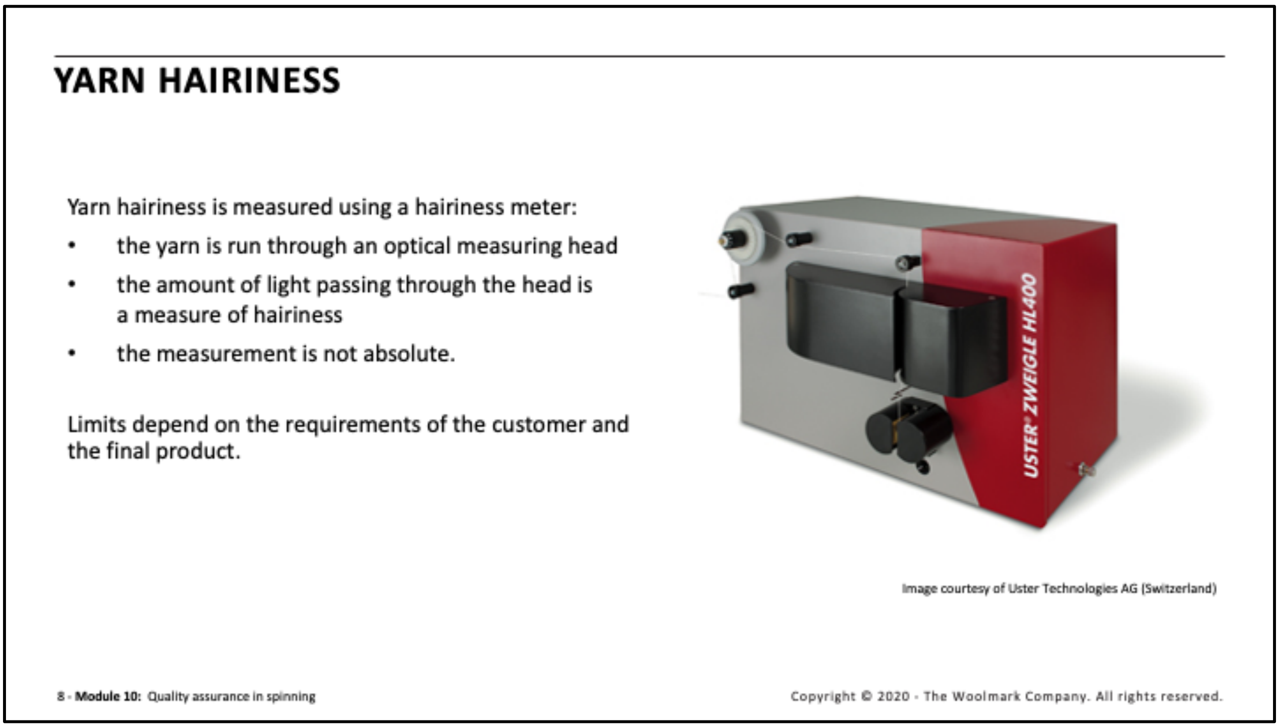
EXPLAIN THAT tensile properties have a direct effect on further processing behaviour and the physical properties of the fabric. Yarns whose maximum strength or extensibility is too low can break in knitting or weaving. The consequences are machine stoppages and efficiency losses.

INDICATE THAT the method used to test tensile strength is as follows**:**

- The yarn is fed into the instrument from a sample bobbin or other package.
- The operator or the instrument draws off a known length of yarn and stretches it to breaking point, measuring:
    - load at break
    - extension at break.
- Another length of yarn (as yet unstretched) is drawn off and the process is repeated until enough measurements have been taken.
- The second sample of yarn is moved into the testing position and the procedure is repeated until enough samples have been measured.

NOTE THAT the details of the method of test (e.g. rate of extension) influences the result and should be quoted in commercial transactions.

EXPLAIN THAT instruments with very high rates of extension are available to imitate the rate of stress in weaving.
Tensile properties should meet customer requirements.



EXPLAIN THAT hairiness measurements provide information about the nature of the yarn surface. Yarn hairiness affects the appearance of the final product and any undue variations in hairiness result in unwanted variations in appearance of the product.

INDICATE THAT yarn hairiness is measured using a hairiness meter. The yarn is run through an optical measuring head. The amount of light passing through the head is a measure of hairiness.

EXPLAIN THAT hairs on the surface of the yarns block the light. Optical meters can classify hairiness into:

- hairs < 3mm
- hairs between 3mm and 10mm
- hairs > 10mm

NOTE THAT the measurement is not absolute, but can compare batches of yarn and locate particular spindles that are operating poorly.

POINT OUT that limits depend on the requirements of the customer and the final product. As a general rule a maximum of 5.5 hairiness courses is recommended for singles yarns.

YARN-TO-METAL FRICTION

Friction between the yarn and metal guide:

- is measured by recording the force required to pull the yarn over a metal roller
- is affected by the construction of the yarn and the presence of lubricants
- predicts behaviour in knitting and weaving.

Variation in friction also important.

9 - **Module 10:** Quality assurance in spinning

MENTION THAT yarn-to-metal friction is measured using a friction tester.

EXPLAIN THAT the friction between the yarn and metal guide is measured by recording the force required to pull the yarn over a metal roller. The absolute value of friction predicts behaviour in knitting and to a lesser extent, weaving.

INDICATE THAT variation in friction is also important as it can cause irregularities in fabric appearance. This variation should meet customer requirements (depending on application).

NOTE THAT the result obtained is affected by:

- construction of the yarn
- presence of lubricants and waxes.

POINT OUT that waxed yarn has frictional coefficients around 0.18 compared with the unwaxed yarn around 0.34. The latter yarn could not be machine knitted successfully.

EXTRACTABLE MATTER AND COLOUR

Substances remaining on the yarn can affect the colour of the yarn and subsequent processing:

- lubricants
- spinning aids.

Determined by Soxhlet extraction with dichloromethane or petroleum ether.

Colour is measured with a spectrophotometer.

Soxhlet apparatus to extract residual contaminants

10 - **Module 10:** Quality assurance in spinning

INDICATE THAT substances can remain on the yarn after processing. These include:

- lubricants from top-making or woollen carding
- spinning aids added during preparation for spinning (gilling and drawing or woollen carding).

EXPLAIN THAT these materials can inhibit subsequent processing (knitting or weaving) or can promote soiling of the yarn by dust and dirt.

NOTE THAT the level of oils on woollen yarns can be particularly high. These oils aid the cohesion of the woollen card web and the slubbings formed.

POINT OUT that the most common method for measuring residuals is Soxhlet extraction with dichloromethane or petroleum ether where the former is banned by law.

The most common method is that used for top (IWTO-10) but other test methods have also been published.

NOTE THAT colour is measured with a spectrophotometer as described in the Wool Science, Technology and Design Education Program course— *The dyeing of wool*.

GENERAL VERSUS ROGUE SPINDLES

Faults in spinning can be analysed to determine their origin:

- use appropriate labelling and testing regimes
- identify if faults are general to the process or can be isolated to one or a few locations
- undertake corrective action and retest.

11 - **Module 10:** Quality assurance in spinning

POINT OUT that in seeking to locate the source and cause of faults in spinning (or any associated process) a useful approach is to:

- use an appropriate labelling and testing regime so all processing heads, spindles, winding heads, etc.) are regularly tested over a given period
- analyse the test results to identify if faults are general to the process or can be isolated to one or a few locations (e.g. a few rogue spindles or winding heads)
- take corrective action and continue the sampling program to ensure the fault has been corrected.

STANDARD OPERATING PROCEDURE MANUALS: EXAMPLE FROM WORSTED COMBING PLANT

STAGE	ACTIVITIES	RESPONSIBILITY	ACCOUNTABILITY	DOCUMENTATION
Raw material	Wool top quality report is received from wool combing department and linked to raw wool tests	QAD technician	Head of QAD	Raw wool register
	Wool combing reports shown to head of production for approval	Head of QAD / head of production	Head of QAD	Wool combing report

12 - **Module 10:** Quality assurance in spinning

EXPLAIN THAT a quality assurance program should include a manual that details all standard operating procedures (SOP) including those for quality control sampling and testing.

All operatives must be fully aware of their duties and responsibilities and to some extent the roles of other personnel in the department.

The reporting functions and responsibilities also need to be fully understood by all employees.

INDICATE THAT the written documents for all staff to access the necessary information are:

- standard operating procedures (SOP)
- job specification sheets.

Verbal communications are also vital.

Workplace health and safety (WHS) specifications and associated notes are also mandatory for all staff.

REFER participants to the slide which shows an example of a standard operating manual procedure.

SUMMARY – MODULE 10

Count (Nm)	+/- 1Nm
Singles twist	+/- 20tpm
Folding twist	+/- 10tpm
Uster (CV%)	Max 18.0
Thin places/km	Max 160
Thick places/km	Max 50
Yarn hairiness	Max 12
Yarn strength (cN)	Max 5.5
Yarn extension (%)	Min 140
Yarn-to-metal friction	Min 12.5
Total extractable matter	Max 0.18
Colour	

13 - **Module 10:** Quality assurance in spinning

REMIND participants that yarn is, after top, the next point at which wool is sold as a commodity. Quality assurance programs are essential to the manufacture of a product with consistent quality

REVIEW the fact that quality of yarns is determined by measurement of the parameters shown on the slide.

Count

- should be within 1Nm of the required count
- measured using:
    - a yarn wrapper to measure the length of yarn
    - a balance to weigh the yarn

Twist

- Singles twist — should be within +/- 20tpm of requirement.
- Folding twist — should be within +/- 10tpm of requirement.
- Measured using a device to determine the number of turns required to remove twist in a standard length of yarn.

Yarn evenness is measured using the Uster evenness tester. The properties measured are

- variation in mass U%
- thin places and thick places
- neps.

Hairiness is measured using a hairiness meter.

Tensile properties are measured using a rapid strength tester.

Multiple measurements of breaking load and extension at break are made and averaged.

Yarn-to-metal friction is measured using a friction tester.

Total extractable matter is measured using Soxhlet extraction with dichloromethane.

Colour is determined using a spectrophotometer.

***ASK** participants if they have any questions about the content covered in this module.*

***ALLOW** time for questions and discussion before proceeding to the final slide and closing the lecture.*

INFORM participants that this module completes the Woolmark Wool Science, Technology and Design Education Program course *Worsted and woollen spinning.*

ENCOURAGE participants to explore the Woolmark Learning Centre to reinforce and build on what they have covered in today's lecture.

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