Textile Product Design and Development

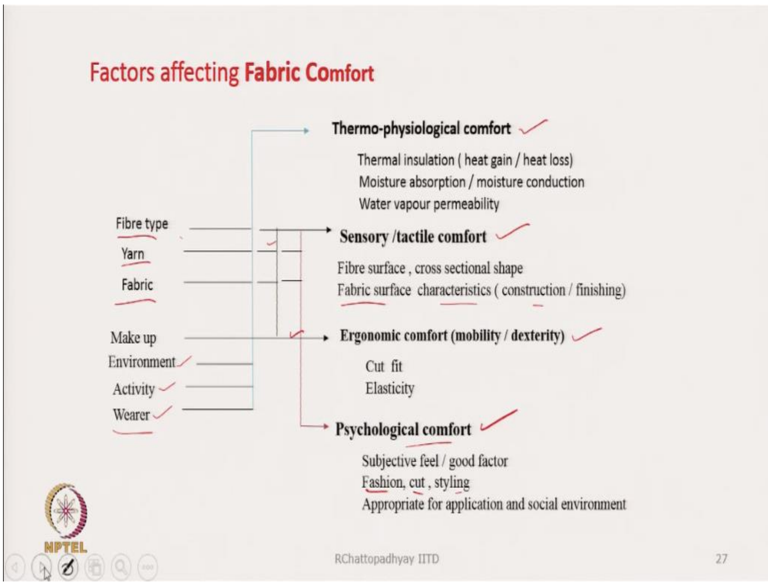
Prof. R. Chattopadhyay
Department of Textile and Fibre Engineering
Indian Institute of Technology - Delhi

Lecture - 13
Relationship between Fabric Properties and Fibre, Fabric and Finishing Parameters (contd.)

(Refer Slide Time: 00:17)

We will discuss another aspect, i.e., thermo-physiological comfort properties.

(Refer Slide Time: 00:21)



The association of fabric comfort aspects in relation to fibre, yarn, fabric, makeup, environment, activity and the wearer is represented on the slide. There are four different aspects of comfort. They are thermo-physiological comfort, sensory comfort, ergonomic comfort (including mobility and dexterity) and physiological comfort.

Focusing on thermo-physiological comfort, comfort is connected to fibre type, yarn, fabric, and make-up. It also depends on the environment, the person's activity level, and the wearer. This plays a role in insulation, moisture absorption and water vapour permeability. The activity level of a person is crucial as it significantly affects heat generation. The amount of heat produced during physical work, known as metabolic heat generation, varies based on the activity level and the individual wearing the garment.

Additionally, environmental factors can influence the rate at which heat flows from the body to the surroundings per unit of time. Each factor plays a role in thermo-physiological comfort. Sensory comfort, which is related to the feel and touch of the fabric, depends on several factors, such as fibre surface, cross-sectional shape, and fabric surface characteristics. These aspects are primarily influenced by the type of fibre, but fabric and yarn construction can also impact sensory behaviour or tactile comfort levels.

The comfort aspects are influenced by factors such as fibre, yarn, fabric, and construction. For example, sensory effects, such as the feel and touch of a fabric, are independent of the wearer's activity level. There is no connection between sensory comfort and the level of physical activity or the type of person wearing the fabric. Additionally, sensory comfort is not affected by the surrounding environment. Factors like activity level or environment do not influence sensory comfort. Instead, it depends on the type of fibre, yarn, fabric, and potentially the finishing techniques used, although finishing is not listed here.

The ergonomics aspect, on the other hand, is mainly related to the cut, fit, and elasticity of the fabric. It is influenced by the fibre type and how the fabric has been tailored or converted into a specific garment, such as a uniform or dress, as indicated by the arrow. Psychological comfort, often related to the feel-good factor, is subjective in nature and influenced by how someone feels while wearing a garment. This can be affected by factors like fashion, cut, and styling. These elements, in turn, are dependent on the type of fibre, yarn, and fabric used.

The orange arrow connects to fibre type, yarn, and fabric, indicating that these elements influence the psychological comfort of a person wearing a garment. This provides an overview of the four different types of comfort: thermo-physiological, sensory, ergonomic, and psychological, each affected by specific parameters like fibre, yarn, fabric, and garment construction.

(Refer Slide Time: 05:44)

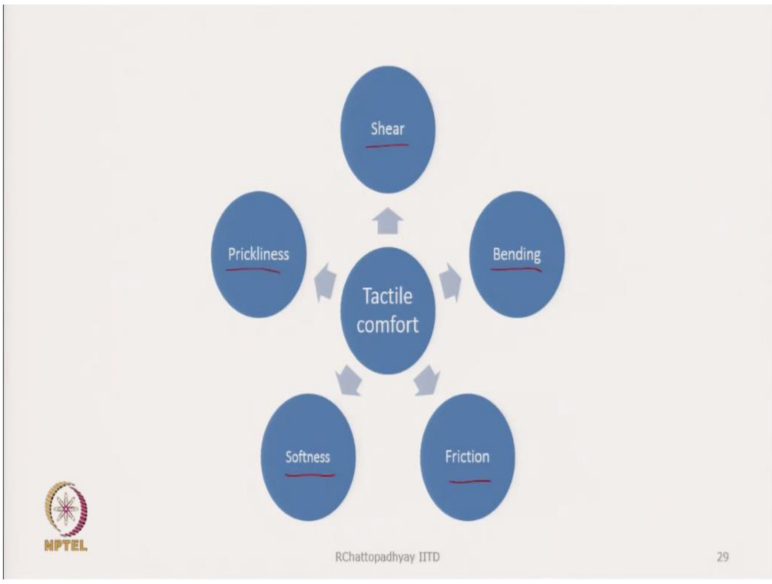
Factors	Fibre parameters	Yarn parameters	Fabric parameters	Finish	Make up
Stretchiness	Fibre type, fibre combination, Extensibility, recovery behaviour, fineness	Type of yarn(spun, filament, textured), Twist, fibre orientation,	Crimp, loop size, type of woven or knitted structure	NIL	-
Lightness	Density, cross sectional shape	Twist, compactness, count	Cover factor	NIL	-
Slip-ability	Type of fibre (staple, filament)	Type of yarn (spun or filament yarn)	Type of weave	Smooth finish	Design, Fit, openings
Reduction in clinging	Surface smoothness, fineness	Count	Type of weave	Smooth finish	

When focusing on wearing comfort, which is primarily related to mobility and ergonomics, key factors come into play. Wearing comfort depends on the stretchiness of the garment, its lightweight, its slip-ability (how easily the fabric moves against the skin), and the reduction of clinging to the skin. These factors contribute to the wearer's overall ease and comfort in movement. Prickliness can also be included as a factor in wearing comfort, though it could be part of tactile or sensory comfort due to its sensation-related nature.

However, wearing comfort primarily focuses on mobility, so factors like stretchiness, lightweight feel, slip-ability, and reduction of fabric clinging are more relevant. These aspects are influenced by fibre, yarn, fabric parameters, finishing processes, and the garment's construction (makeup). A list must be created where each aspect must be evaluated regarding its connection to fibre, yarn, fabric, finishing, and makeup parameters. When considering stretchiness, consideration must be given to whether stretchiness is connected to fibre parameters.

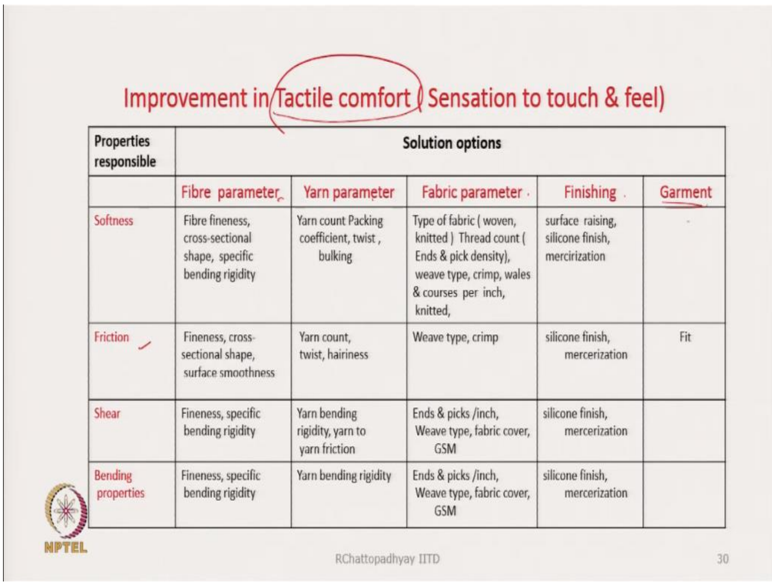
If fibre parameters influence, then what specific fibre characteristics affect stretchiness must be known. Additionally, the influence of yarn, fabric, and finishing parameters must be considered. Stretchiness is not influenced by finishing techniques or makeup, so those categories are marked as nil or nothing. The primary influence on stretchiness comes from fibre parameters and, to some extent, yarn and fabric. Thus, for any particular performance aspect of a fabric that needs to be enhanced, one has to consider the relevant properties for that particular performance aspect and how that property will be affected by fibre, yarn, fabric, finishing techniques or makeup.

(Refer Slide Time: 08:27)



Tactile comfort is influenced by several key factors, such as the shear properties of the fabric, bending rigidity, friction, softness, and prickliness. All these characteristics collectively contribute to how a fabric feels against the skin, impacting the overall tactile comfort of the garment.

(Refer Slide Time: 08:54)



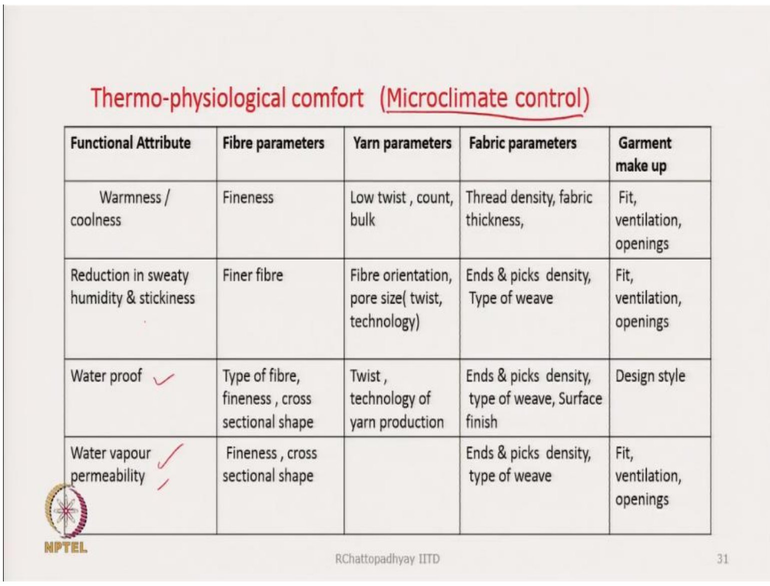
Improvement in Tactile comfort (Sensation to touch & feel)

Properties responsible	Solution options				
	Fibre parameter	Yarn parameter	Fabric parameter	Finishing	Garment
Softness	Fibre fineness, cross-sectional shape, specific bending rigidity	Yarn count Packing coefficient, twist, bulking	Type of fabric (woven, knitted) Thread count (Ends & pick density), weave type, crimp, wales & courses per inch, knitted,	surface raising, silicone finish, mercirization	-
Friction	Fineness, cross-sectional shape, surface smoothness	Yarn count, twist, hairiness	Weave type, crimp	silicone finish, mercerization	Fit
Shear	Fineness, specific bending rigidity	Yarn bending rigidity, yarn to yarn friction	Ends & picks /inch, Weave type, fabric cover, GSM	silicone finish, mercerization	
Bending properties	Fineness, specific bending rigidity	Yarn bending rigidity	Ends & picks /inch, Weave type, fabric cover, GSM	silicone finish, mercerization	

This table outlines how softness, friction, shear, and bending rigidity are connected to fibre parameters, yarn properties, fabric structure, finishing techniques, and garment construction (makeup). If a designer needs to enhance or modify tactile comfort based on customer demands, they can use this table to explore different options. The designer must first identify the root cause of dissatisfaction with the tactile comfort. If customers are not happy with the feel of the fabric, the issue could be caused by various factors that must be identified.

The key is determining whether the discomfort arises from friction, shear, or bending properties. Once the issue is identified, for example, if friction is the cause of discomfort, the next step is to analyse how the friction properties can be modified. It is because of whether the friction is too high or too low. Based on that, one must understand how fibre type, yarn construction, fabric structure, or finishing techniques can influence friction. These are the options available, and by playing with these options to improve the tactile comfort.

(Refer Slide Time: 10:56)

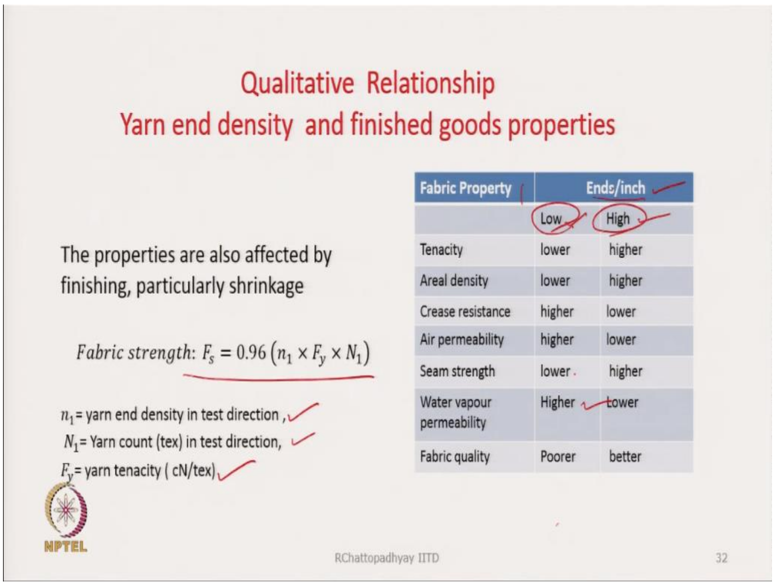

Thermo-physiological comfort (Microclimate control)

Functional Attribute	Fibre parameters	Yarn parameters	Fabric parameters	Garment make up
Warmness / coolness	Fineness	Low twist , count, bulk	Thread density, fabric thickness,	Fit, ventilation, openings
Reduction in sweaty humidity & stickiness	Finer fibre	Fibre orientation, pore size(twist, technology)	Ends & picks density, Type of weave	Fit, ventilation, openings
Water proof	Type of fibre, fineness , cross sectional shape	Twist , technology of yarn production	Ends & picks density, type of weave, Surface finish	Design style
Water vapour permeability	Fineness , cross sectional shape		Ends & picks density, type of weave	Fit, ventilation, openings

Let us consider another example related to thermo-physiological comfort, specifically focusing on microclimatic control. Microclimatic control involves regulating warmth, reducing sweat humidity, ensuring waterproofness, and allowing water vapour permeability. This table shows how these functional attributes are connected to fibre, yarn, fabric, and garment makeup parameters.

This requires a domain knowledge. When dealing with these aspects, a deep understanding or knowledge is essential. The knowledge is about manufacturing and relating a performance property with fibre, yarn, fabric, finishing techniques, or garment make-up. Hence, a thorough understanding of the relationship is desired and will be handy for the designers.

(Refer Slide Time: 13:09)



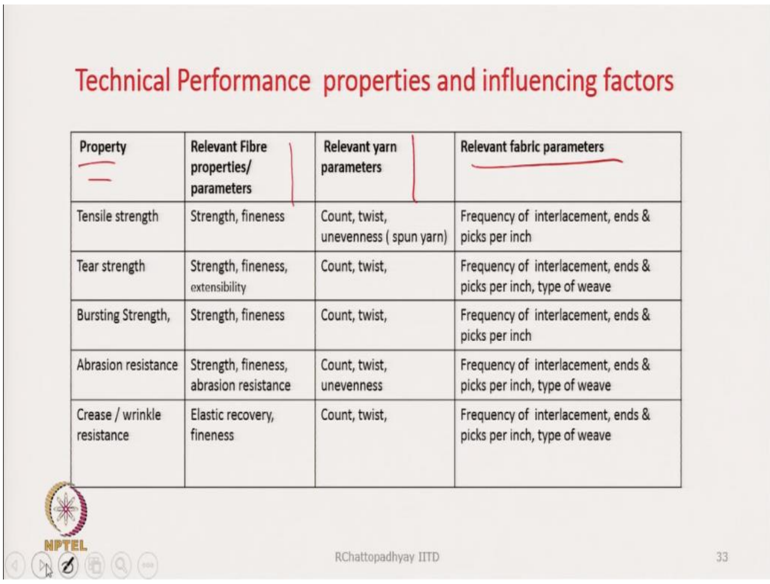
Next is the qualitative relationship between yarn end density and the properties of finished goods. For instance, certain fabric characteristics, such as tenacity, areal density, and crease resistance, can be linked to the number of ends per inch. It is important to note that fabric construction parameters, specifically ends per inch and picks per inch, are prominent factors in this relationship.

The influence of ends per inch in various properties, such as tenacity, seam strength, etc., is represented in the table. Specifically, a lower ends per inch results in decreased tenacity and seam strength. Conversely, water vapour permeability increases when ends per inch are lower. When ends per inch are low, larger gaps between the yarns lead to increased vapour permeability. However, this also results in poorer fabric quality. A fabric with significant spacing between the yarns lacks tightness and stability, which ultimately compromises its overall quality.

The properties of fabrics are also influenced by finishing processes, particularly shrinkage in cotton fabrics. We can observe both qualitative and quantitative relationships here. For instance, there is a quantitative relationship between fabric strength and yarn end density, as well as between yarn count and yarn tenacity. Initially, it is essential to understand the qualitative relationship between fabric properties and structural parameters.

One key structural parameter is ends per inch, but others may include picks per inch, total interlacement per unit area, and cover factor. These are some of the key structural parameters to consider. It is important to start with a qualitative understanding followed by a quantitative relationship that may exist and can be used.

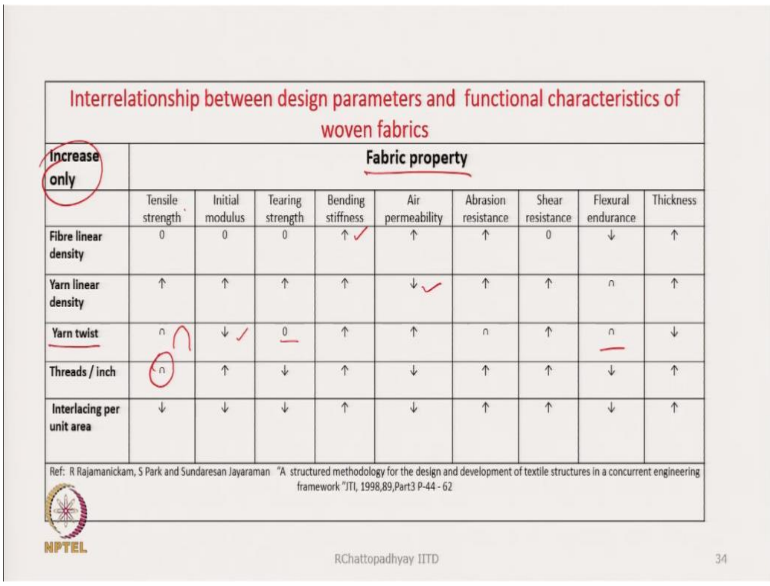
(Refer Slide Time: 16:06)



Property	Relevant Fibre properties/ parameters	Relevant yarn parameters	Relevant fabric parameters
Tensile strength	Strength, fineness	Count, twist, unevenness (spun yarn)	Frequency of interlacement, ends & picks per inch
Tear strength	Strength, fineness, extensibility	Count, twist,	Frequency of interlacement, ends & picks per inch, type of weave
Bursting Strength,	Strength, fineness	Count, twist,	Frequency of interlacement, ends & picks per inch
Abrasion resistance	Strength, fineness, abrasion resistance	Count, twist, unevenness	Frequency of interlacement, ends & picks per inch, type of weave
Crease / wrinkle resistance	Elastic recovery, fineness	Count, twist,	Frequency of interlacement, ends & picks per inch, type of weave

Technical performance properties and their influencing factors are represented in the table. On the left end column of the table, properties such as tensile strength, tear strength, and bursting strength are listed. The adjacent columns specify the relevant fibres, yarns, and fabric parameters associated with each property. This provides a clear overview of the relationships between fabric properties and their influencing factors. This table specifically addresses woven fabrics, but we can also develop analogous tables for knitted fabrics, non-woven fabrics, compound fabrics, and braided materials.

(Refer Slide Time: 16:59)


Interrelationship between design parameters and functional characteristics of woven fabrics

Increase only	Fabric property								
	Tensile strength	Initial modulus	Tearing strength	Bending stiffness	Air permeability	Abrasion resistance	Shear resistance	Flexural endurance	Thickness
Fibre linear density	0	0	0	↑	↑	↑	0	↓	↑
Yarn linear density	↑	↑	↑	↑	↓	↑	↑	∩	↑
Yarn twist	∩	↓	0	↑	↑	∩	↑	∩	↓
Threads / inch	∩	↑	↓	↑	↓	↑	↑	↓	↑
Interlacing per unit area	↓	↓	↓	↑	↓	↑	↑	↓	↑

Ref: R Rajamanickam, S Park and Sundaresan Jayaraman "A structured methodology for the design and development of textile structures in a concurrent engineering framework "JTI, 1998,89,Part3 P-44 - 62

NPTEL RChattopadhyay IITD 34

Tables can be created for various fabric types, including technical fabrics. For example, the relevant properties of technical fabrics include initial modulus, tearing strength, bending stiffness, air permeability, abrasion resistance, shear strength, and flexural strength. In this representation, the parameters such as fibre type, yarn type, yarn twist, threads per inch, and interlacing per unit area are on the left-hand column. For each parameter, how increasing its value affects the corresponding fabric properties is indicated.

In this representation, a '0' indicates no change, while an upward arrow means the property increases and a downward arrow means it decreases. This method relates fabric properties to relevant parameters and shows the effect of changes in those parameters. These arrows allow one to quickly understand whether a fabric property improves or declines when a specific parameter is increased. The symbol '∩' indicates that a property will increase initially and then decrease.

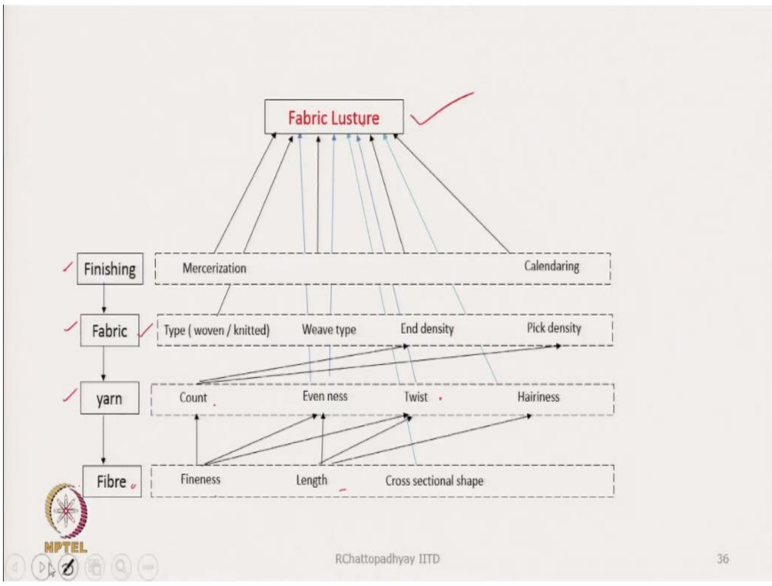
For example, if increasing the yarn twist, the tensile strength of the fabric initially rises, but after a certain point, it starts to decrease. Hence, the symbol '∩' shows that the property increases initially and then decreases as the parameter continues to increase. In this representation, the modulus decreases as the twist increases, so a downward arrow is used. There is no effect for tearing strength, indicated by '0'. Bending stiffness increases as the fabric becomes stiffer, as shown by an upward arrow.

This method visually represents relationships using symbols instead of text, i.e., upward arrows for increases, downward arrows for decreases, ‘0’ for no change, and ‘∩’ show properties that rise and then fall, or vice versa. While there may not be examples with a regular ‘∪’ shape in this context, the symbol ‘∩’ is prevalent, indicating that properties will first increase and then decrease. Such tables have been utilized by researchers and are quite useful for summarizing these relationships effectively.

(Refer Slide Time: 20:34)

When considering fabric aesthetics, several important aspects come into play, including clean appearance, attractive colour, the presence of faults, and lustre. All of these elements contribute significantly to the overall aesthetic appeal of the fabric.

(Refer Slide Time: 20:56)

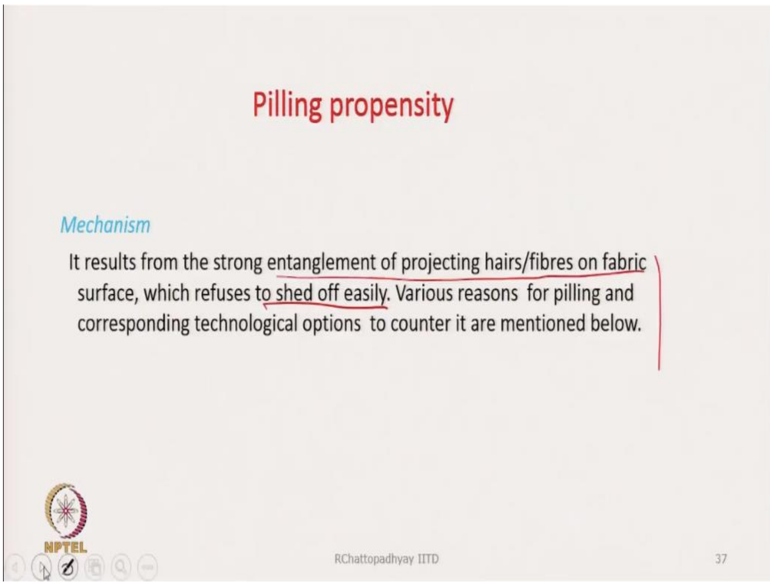


Focusing on the fabric lustre, if a company has concerns about lustre and tasks a designer to enhance it, the designer should create a diagram as illustrated. Start with finishing at the top, followed by fabric, yarn, and fibre. In the finishing section, list the processes that can affect fabric lustre.

The fabric properties or parameters that influence fabric lustre are also stated. Moving down the hierarchy to yarn and fibre, it specifies the properties that affect the lustre. This visual representation effectively highlights the stages and relevant parameters that play a role in determining the lustre of the fabric.

With this knowledge, the designer will be better equipped to choose the right solutions for enhancing fabric lustre. Since multiple options are available, ranging from adjustments in fibre, yarn, fabric, or finishing techniques, the designer can make decisions based on factors such as cost considerations and the availability of technology. This enables to select the most appropriate approach for the specific circumstances.

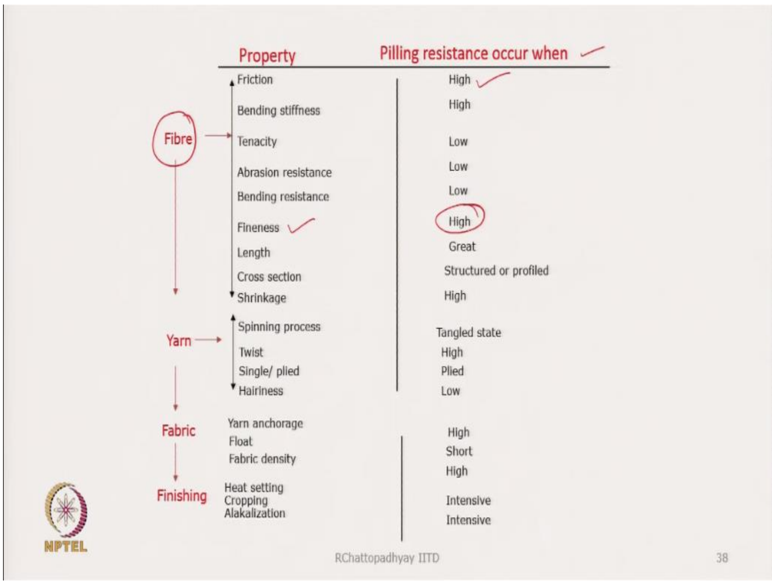
(Refer Slide Time: 22:52)



Pilling propensity is another common issue, with excessive pilling leads to rejection of many fabrics. This is a typical problem faced in fabric production. To tackle this, thorough research and analysis are required, often conducted by the designer or the design team. To address pilling, one can refer to numerous research articles that provide valuable insights into the issue. This forms the foundation of design research, where investigations are conducted to enhance specific performance characteristics.

In the case of pilling, understanding the mechanism is crucial. Pilling occurs due to the entanglement of projecting fibres or hairs on the fabric surface that refuse to shed. The mechanism of pilling can be broken down into three key stages. First, fibres must project from the fabric surface. Second, these projecting fibres become entangled due to friction or other forces. Third, these fibres do not shed off easily after entanglement, meaning the entangled fibres are strong enough to remain attached to the fabric surface. This process has been extensively studied; here is a brief overview of the mechanism.

(Refer Slide Time: 24:35)



This process represents the outcome of design research. For any design, the designer or the design team must conduct research, which involves reviewing published articles or textbooks to gather insights. They then create an abstract summarizing key finding. The diagram mentioned acts as a visual abstract of this research, staying in front of the designer for easy reference. It helps the designer visualize how pilling resistance relates to fibre characteristics.

This diagram categorises the relevant properties into fibre, yarn, fabric, and finishing. For example, when the friction property of the fibre is high, pilling resistance improves because the fibre is less likely to move or project from the fabric surface. The diagram lists the fibre properties, yarn properties, fabric properties, and finishing techniques that affect pilling resistance. On the other side, the table specifies whether pilling resistance improves or declines when these properties are high or low.

Pilling resistance improves when the fibre fineness is lower, meaning coarser fibres offer better resistance to pilling. Coarser fibres do not bend as easily, which makes them less prone to entanglement and, therefore, less likely to form pills. On the other hand, finer fibres have lower bending rigidity, making them more flexible and more prone to buckling and bending. This flexibility increases the likelihood of neighbouring fibres entangling, leading to pill formation.

This approach fundamentally shows the essence of design research. A designer systematically identifies how pilling resistance can be improved by altering various fibre, yarn, fabric, and finishing parameters. It is more than just listing these parameters; it also explains how specific changes will increase or decrease pilling resistance. So, it is not only listing but also stating in a way that what will happen if these properties are changed. There are different ways of representation.

(Refer Slide Time: 27:56)

Reasons for pilling	Solution options			
	Fibre	Yarn	Fabric	Finishing
• Presence of projected fibre ends from Fabric surface	Long, reduce short fibre %	use compact yarn, plied yarn		Singing Enzyme treatment
• Ease of entanglement between projected fibre ends	Increase diameter, increase inter fibre friction	low hairy yarn adequate twist		Low friction surface finish
• Ease of plucking of fibre ends from yarn surface	Long fibre	enhance twist	Tighter fabric construction	Plasma treatment, chlorination
• Higher bending and torsional rigidity of fibres	Finer fibre, non circular fibre	-		
• High tenacity and breaking energy of fibres	Low tenacity and low breaking energy	-		

RChattopadhyay IITD 39

The reasons for pilling are stated, including factors such as the presence of projecting fibre ends, ease of entanglement, ease of plucking, high bending and torsional rigidity of fibres, and high tenacity and breaking energy of fibres. The various causes and solution options are also given in the table. The designer can select the most appropriate option based on the situation. Since projecting fibres contribute to entanglement, minimising their presence is essential.

To achieve this, the designer must understand how fibre properties can help reduce projecting ends. This requires domain knowledge and research. For yarn, one effective solution is to use compact yarns. Singeing is another process of reducing projecting fibres. The table can be created, and it helps identify reasons for particular performance-related parameters of the fabric or the design products because similar parameters can be seen in the design products. While pilling is particularly associated with garments, it can also occur in technical textile applications.

By analyzing the causes and solutions through a structured table, designers can effectively apply this knowledge to enhance the performance and durability of various textile applications.

(Refer Slide Time: 30:15)

In this lecture, it is clear that a designer must thoroughly understand various performance parameters and their connections to fabric properties. This includes recognizing how fabric properties relate to yarn and fibre characteristics and other relevant parameters. This understanding is important. One also has to do research related to design because sometimes these answers may not be available directly, and one has to do some background research to understand this.

Wherever mathematical relationships are available, it is important to use them because sometimes manufacturing a product, testing it and then trying to find out whether it suits or not is a trial-and-error approach. Instead, adopting a more objective approach is essential to utilizing scientific methods and tools.

In modern design and engineering processes, software tools like Microsoft Excel and MATLAB greatly simplify calculations and data analysis. This tool enables us to perform calculations easily and visualise results through the graphs. Once the design parameters are thoroughly analyzed and optimized using various tools and methods, the next step is to move into production, create prototypes, and conduct rigorous testing. With this, we conclude this lecture. Thank you.