**Textile Product Design and Development**
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**Lecture – 12**
**Relationship Between Fabric Properties and Fibre, Fabric and Finishing Parameters**

This lecture will discuss the relationship between fabric properties and various parameters, including fibre, fabric, and finishing aspects. We will explore how fabric properties are influenced by fibre characteristics, fabric construction parameters, and the finishing treatments applied.

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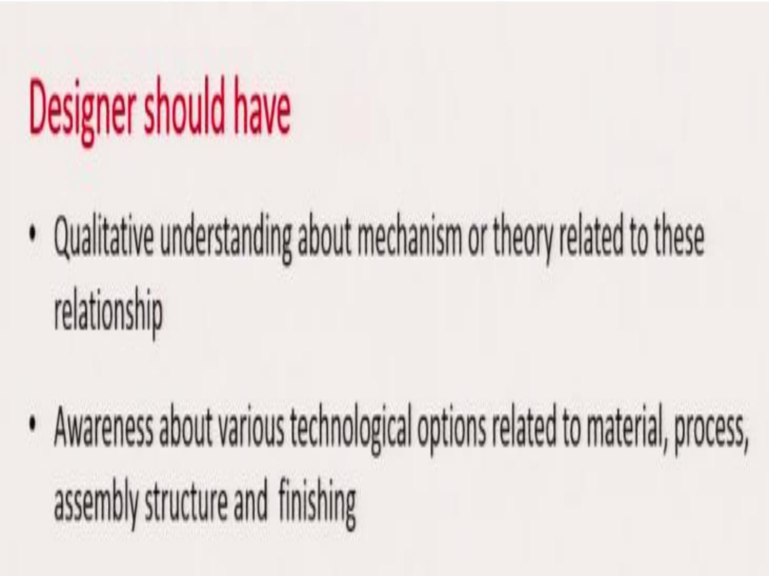


A designer must have a qualitative understanding of the mechanisms or theories that explain the relationships between fabric properties and their influencing factors. Additionally, they must be aware of the various technological options available, including material selection, processing methods, assembly structures, and finishing techniques. This awareness is crucial for making informed design decisions.

In many situations, a designer has several options regarding material selection, processing methods, fabric structure, assembly techniques, or finishing processes. The decision on which option to exercise should be based on several key considerations, such as cost, ease of implementation and availability of technology.

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The relationship between fibre properties and the finished product is highly complex. This is because the fibre first undergoes conversion into yarn; the yarn is then transformed into fabric, which may be subjected to chemical or mechanical processes. Additionally, the fabric may be incorporated into other structures during product assembly.

The relationship between fibre properties and the finished product is extremely complex due to the numerous variations and factors involved. Each stage in the production chain can be seen as a series of input-output relationships, with each stage influencing the product properties. From raw materials to the finished product, many processes take place.

The fibre, the fundamental building block, undergoes numerous operations throughout production. As a result, its properties can change at multiple stages. Moreover, when the fibre is assembled into yarn, fabric, or a finished product, the properties of the assembled material may differ.

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The factors affecting the properties of the end product include several key elements. First is the raw material. The type of fibre used, such as cotton, polyester, or nylon, plays a crucial role in determining the properties of the product. It also depends on the type of yarn. The various types of yarn are available commercially in the market. The other factor is the type of fabric. Fabrics can be produced in different ways, and many manufacturing techniques are available. In addition to the type of fabric, other factors such as finishing and after treatments play a crucial role. Another key factor is the makeup stage, where the fabric is converted into a finished product. There are numerous factors which affect the end property of the fabric.

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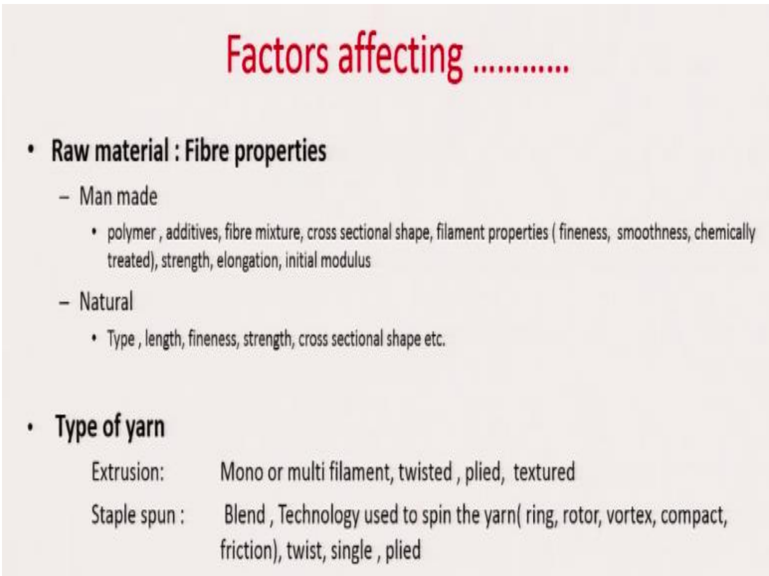

When discussing raw materials, we can categorize them into manmade fibres and natural fibres. There are various parameters of both manmade and natural fibres which affect the properties of the final products. In manmade fibres, the type of polymers used, additives, fibre mixture, cross-sectional shape, filament fineness, filament smoothness, chemical treatment of filaments, etc., have an effect. Strength, elongation and initial modulus are also the parameters for manmade fibres.

Similarly, in natural fibres, different types of yarn are used, whether monofilament yarn or multi-filament yarn, twisted or plied yarn, textured yarn or untextured yarn. In the case of staple spun yarn, whether it is a blended yarn or not, various technologies are used to spin the yarn, such as ring yarn, rotor yarn, vortex yarn and compact yarn, amount of twist in the yarn, single or plied yarn. So, there are various varieties available in the yarn, and there will be some differences in their properties. So, the type of yarn also affects the properties of the final product.

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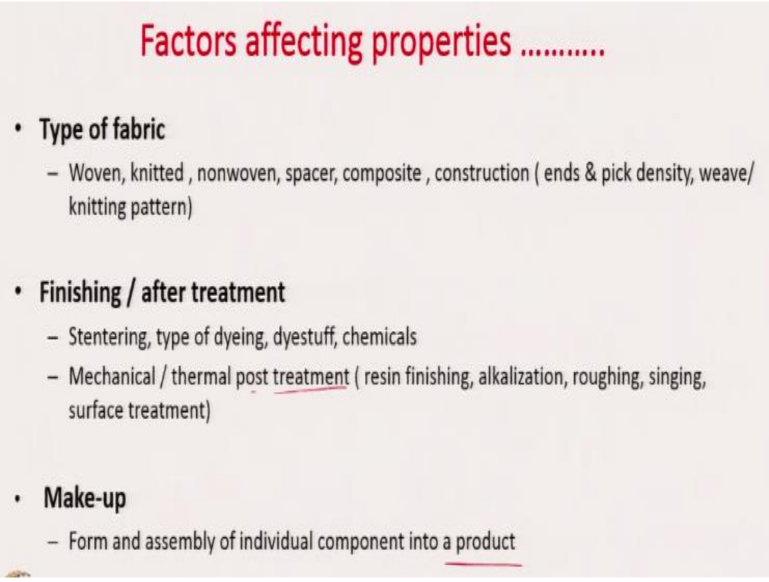


There are various types of fabric, including woven, knitted, nonwoven, spacer, or composite. Its construction parameters are ends and picks density, type of weave and kind of knitting pattern. Finishing treatments include processes like stentering and various types of dyeing, such as the use of different dyestuffs, chemicals, and mechanical or thermal post-treatment. These processes include resin finishing, alkalization, roughening, singeing and surface treatment.

Each of these finishing methods introduces significant variety, and all these finishing processes change the characteristics of the fabric. Hence, associating the properties of the fibre with the final fabric is a highly complex task because of these numerous finishing processes. Additionally, makeup is another form in which individual components are assembled into the final product. How pieces of fabric are joined and assembled influences the overall performance and characteristics of the product.

The makeup process involves several decisions, such as whether to use a single fabric or compound fabrics and the method of joining the fabrics. The sewing techniques or other joining methods can significantly influence the final product's performance. Additionally, the shape and structure of the product play a crucial role in its functionality. Therefore, predicting the performance of the product based on the basic properties of the fibre is a complex task.

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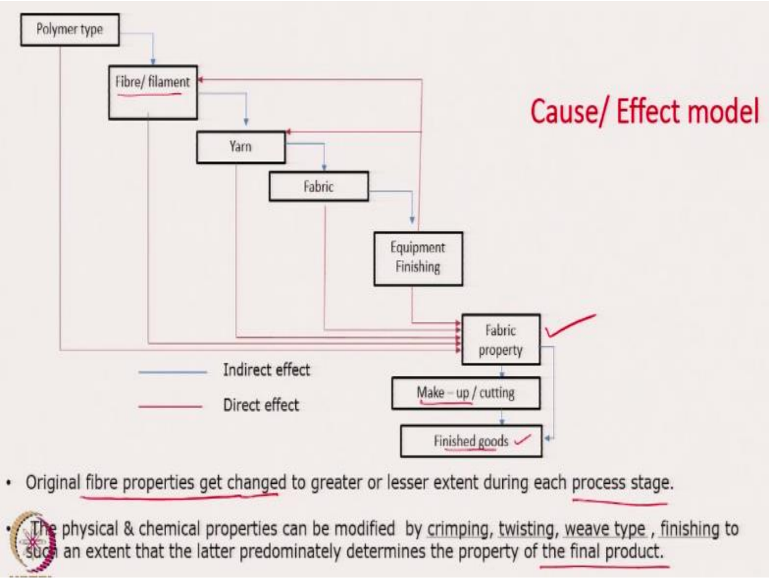


The cause-and-effect model diagram illustrates the step-by-step transformation from the raw material to the finished product. The arrows between the boxes signify the relationship between each process, highlighting how each step builds upon the previous one, ultimately affecting the properties of the finished goods. The first is the polymer type, followed by fibre or filament, fabric, and finishing equipment.

The blue lines/arrow indicate the indirect effect, and the orange line/arrow indicates the direct effect. The property of the fabric is directly affected by the type of polymer used, i.e., fibre fineness, fibre strength, modulus, elongation, and cross-sectional shape, which directly influences fabric property. Similarly, the case of yarn, yarn twist, yarn fineness, etc., directly influences the fabric property. There could be an indirect influence because polymer type influences the fibre or filament property. Filament property, in turn, influences the yarn property, i.e., filament fineness, filament modulus and cross-sectional shape.

So, this diagrammatic representation provides insights into the numerous causes that can affect the fabric's properties and the fabric property is translated into finished good properties through the makeup process. The fabric's properties are carried over into the final product's characteristics by altering the fabric and shaping it during this process. Thus, the fabric's attributes are transferred to the finished goods through this transformation. Therefore, the properties of the finished goods are linked to those of the polymer, fibre, yarn, fabric, and processing parameters.

The original fibre properties change to a greater or lesser extent during each process stage. As the fibre goes through different processes, it undergoes significant changes as it is subjected to stresses, strains, and chemical treatments. The basic property of the fibre is changed when converting it to fabric because of this kind of treatment. Additionally, physical and chemical properties can be significantly altered through processes like crimping, twisting, weave type, and finishing to the extent that these modifications primarily determine the final product's characteristics. This means that actions like crimping or twisting can significantly change the property.

Twist is a key parameter of yarn that can significantly alter its characteristics. Adjusting the twist can make yarn softer or harder, allowing for many possibilities. Similarly, the type of weave and the ends and pick density used during weaving play a crucial role in woven fabrics. The type of loops formed also has a major influence on knitted fabrics. These factors can sometimes have a more dominant impact on the final product than other properties.

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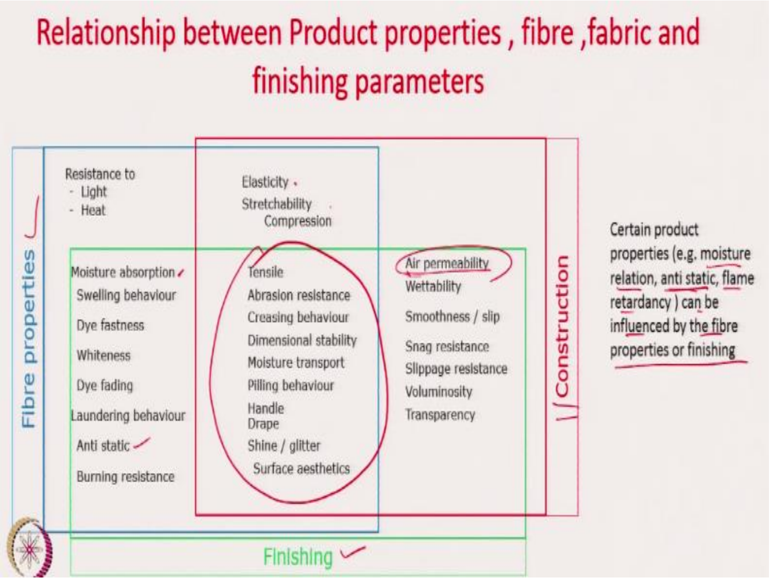


This diagrammatic representation shows the relationship between product properties, fibre, fabric, and finishing parameters. It is similar to a venn diagram, and the text shown in the diagram outlines the properties of the final product, illustrating how fibre, fabric, and finishing parameters overlap and contribute to the overall characteristics of the finished item. Resistance to light and heat, moisture absorption, swelling behaviour, dye fastness, whiteness, elasticity, stretchability, tensile strain, and abrasion resistance are all properties of the product, or, more specifically, the fabric, listed here.

These properties have been grouped systematically, which is influenced by the fibre properties inside the blue rectangle. On the other hand, the properties contained within the green rectangle are influenced by the finishing process. The properties within the red rectangle are influenced by the construction parameters of the fabric, such as ends and picks per inch in the case of woven materials or wales and courses per inch in the case of knitted materials. For example, air permeability can be significantly affected by these construction parameters. The construction parameters of the fabric can influence air permeability.

In woven fabrics, if the ends and picks per inch are higher, the yarn interlacements will be closer together. This results in smaller inter-yarn spaces, which reduces air permeability. The closer the yarns are woven, the less air can pass through the fabric, decreasing air permeability. While construction parameters play a significant role in determining air permeability, finishing techniques represented within the green rectangle also have an impact. For example, mechanical finishing techniques that raise the fibres to the surface of the fabric can affect properties like air permeability, wettability, and smoothness.

Thus, the fabric surface is covered with protruding fibres, which significantly alters the permeability behaviour of the fabric. Air permeability can be modified through finishing techniques as well as construction parameters. Some properties, represented within the overlapping red, blue, and green rectangles, can be influenced by adjusting the fibres, finishing techniques, or construction parameters.

Such a diagram is extremely useful for designers as it helps identify which specific properties can be influenced by fibre characteristics, construction parameters, or finishing techniques. When a designer aims to enhance a fabric's performance in a particular area, this diagram guides them in determining which aspects of the fabric they should focus on to achieve the desired result. The designer can then determine how to manipulate a specific property, either through fibre selection, finishing techniques, or construction parameters.

Product properties such as moisture management, antistatic behaviour, or flame retardancy can be influenced by fibre properties or finishing processes. An example provided includes moisture absorption and antistatic properties, which can be achieved by selecting appropriate fibres or applying specific finishes. For example, antistatic behaviour depends largely on the type of fibre used. Polyesters and acrylic fibres are prone to static, whereas fibres like viscose rayon, cotton, and linen are not.

By choosing the right fibre or creating a blend of static-prone and static-resistant fibres, we can reduce the static propensity of a product. If changing the fibre is not an option, finishing techniques can be employed as an alternative means to manage static properties. Applying an antistatic finish reduces the static charge generation. This illustrates how both finishing techniques and fibre properties can influence antistatic properties.

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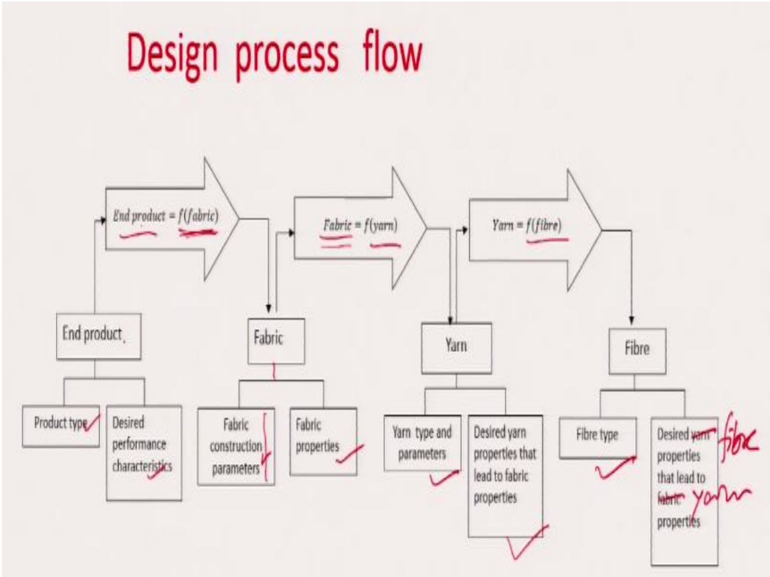


This diagram illustrates the design process flow. Starting from the left-hand side, the process moves toward the right. Typically, designers start with the finished product in mind when they begin the design process. The desired property attributes of the finished product are usually provided, specifying the required performance. Therefore, the first step is for the designer to clearly understand the requirements regarding the product’s properties.

Once the designer understands the product requirements, they work backwards, starting from the product and moving toward the fabric. When the product type and desired performance characteristics are known, this becomes a function of fabric, as the final product's performance largely depends on the fabric. This process is illustrated in a simplified diagram. The properties of the end product are a function of the fabric properties, which, in turn, are influenced by both fabric construction parameters and fabric properties.

The fabric’s properties, in turn, depend on the yarn, which has two key aspects: the type of yarn and its parameters. The desired yarn properties directly contribute to the overall fabric properties, and the designer must work through these details to achieve the intended product performance. The designer determines the required fabric properties based on the desired end product properties. This involves identifying the appropriate fabric construction parameters and the target fabric characteristics needed to meet the product's performance.

To achieve the desired fabric properties, the designer must decide what type of yarn to use and understand its parameters. The designer must determine the type of yarn and its design properties to achieve the desired fabric properties. This involves deciding on the fineness of the yarn, whether to use filament or spun yarn or if a blend is necessary. Additionally, the designer must select the appropriate yarn technology, whether ring spun, carded or combed yarn, to ensure the fabric meets the performance goals. Since yarn properties depend on the fibre, the designer must carefully select the fibre type and its desired properties.

The chosen fibre properties will directly influence the yarn's characteristics, affecting the fabric's performance. Hence, the process flows from the product to the fabric, from the fabric to the yarn, and finally, from the yarn to the fibre. As we move from left to right in this process, the entire design process gradually takes shape. By the end, the designer clearly understands the various technical parameters required for the fibre, yarn, and fabric to achieve the desired product properties.

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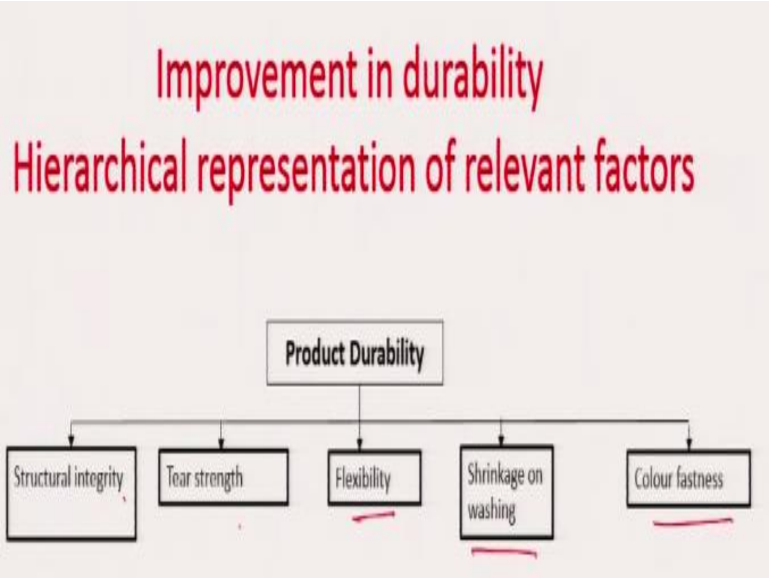


Let's consider an example where durability needs to be improved in a fabric or product. In this case, the designer must first identify the relevant factors that influence durability. These factors can be represented hierarchically to guide the design process. Product durability includes several key aspects, such as structural integrity, tear strength, flexibility, shrinkage during washing, and colour fastness.

Durability is a very general term. Durability is a function of these characteristics, including abrasion resistance. Depending on the application, abrasion resistance might become a critical factor; in such cases, it can also be considered a durability component. In this case, product durability can be seen as a function of five key fabric properties influencing its overall durability.

For example, even if the mechanical strength of the fabric remains intact, a product might be rejected due to poor colour retention. If the colour fades too quickly, the customer may stop using or even reject the product despite it being structurally strong. This highlights how factors like colour fastness and other properties play a crucial role in the durability of a product.

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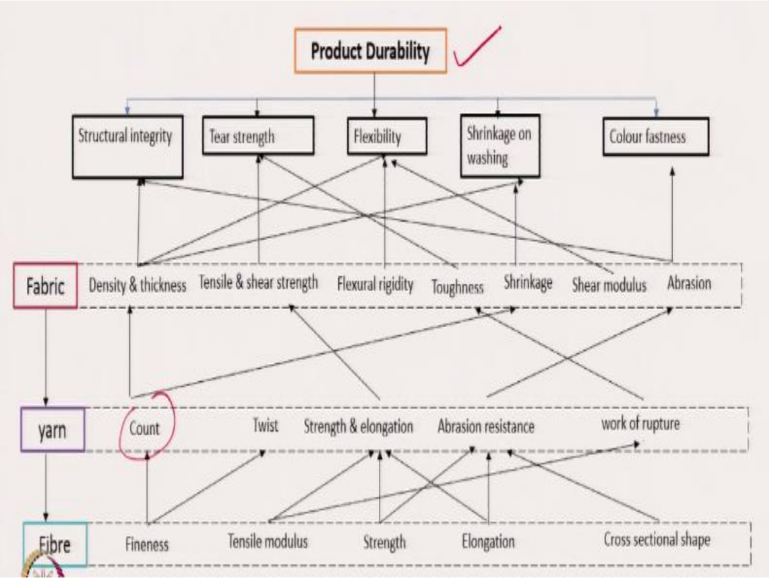


Identifying the parameters that influence key durability aspects, such as structural integrity, tear strength, flexibility, shrinkage, and colour fastness. We focus on the relevant fabric properties from a durability perspective to address these aspects. We have selected specific parameters or properties that influence structural integrity, tear strength, flexibility, shrinkage, and colour fastness. The arrows in the diagram indicate how each parameter or property affects these attributes.

For example, the density and thickness of the fabric are key factors. The density and thickness of the fabric impact its structural integrity, as indicated by the arrow pointing to structural integrity. A fabric’s flexibility is affected by how tightly it is constructed and its overall thickness. As such, both structural integrity and flexibility are impacted by these factors. Additionally, the density and thickness of the fabric play a role in determining how much the fabric will shrink during washing.

The three durability-related parameters or properties, structural integrity, flexibility, and shrinkage, are affected by fabric density. Similarly, colour fastness is affected by factors such as the fabric’s abrasion resistance and the quality of the dye used. The colour will fade more quickly if the fabric has poor abrasion resistance. Thus, the fabric's abrasion resistance and the dye's quality significantly determine colour fastness.

Sometimes, the colour fades because the fibres move away from the surface of the yarns with time. The fabric properties are influenced by yarn properties. Key yarn parameters include count, twist, strength, abrasion resistance, and work of rupture. Additionally, yarn twist affects the tensile strength of the fabric, as it contributes to the overall structural integrity and performance of the fabric. The yarn count influences both the density and thickness of the fabric, as well as its shrinkage properties, which is indicated by two arrows from yarn count.

By mapping these connections, one can visualize how various yarn parameters affect fabric properties relevant to product durability. In this process, the product level moves down to the fabric, followed by yarn, and finally to fibre. A list of fibre properties that affect the yarn properties is mentioned in the diagram. Yarn count and yarn twist are influenced by fibre fineness.

The tensile modulus of fibre influences yarn strength, elongation and work of rupture. By establishing these associations between fibre, yarn, and fabric parameters, how each material level affects overall product durability can be understood. Such a structured method makes the design process more efficient, making it much more systematic in nature.

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| Yarn Property | Formulae |
|---|---|
| Tensile modulus($E_y$) ( Filament yarn) | $E_y = E_f \times Cos^2\alpha$ $E_f$ = fibre tensile modulus and $\alpha$ = twist angle |
| Yarn tenacity ($F_{ys}$) ( Filament yarn) | $F_{ys} = E_f \times e_y \times Cos^2\alpha$ $e_y$ = yarn breaking strain |
| Yarn strength ($S_y$) ( spun yarn) | $S_y = S_f \times Cos^2\alpha(1 - k\ Cosec\alpha)$ $S_f$ = fibre strength<br>Factor $k$: decreases with increase in fibre length, fineness , friction and migration. |
| Yarn tensile modulus ($E_y$) ( spun yarn) | $E_y = E_f \times Cos^2\alpha[(1-k)Cosec\alpha]$ $k$ = constant |
| Fibre strain in yarn($e_f$) | $F_y = C_y \times E_f \times e_y \times Cos^2\alpha$ $C_y$ = yarn count( tex), |
| Yarn Stress at a given strain ($F_y$) | $F_y = N_y \times E_f \times e_y \times Cos^2\alpha$ $N_y$ = yarn count( tex), |
| Yarn bending rigidity ($B_y$) | $B_y = n_f B_f = n_f \frac{E_f d_f^4}{64}$ [Lower estimate] $B_y = n_f^2 B_f = n_f^2 \frac{E_f d_f^4}{64}$ [upper estimate]<br>[$E_f$ = fibre modulus , $d_f$ = fibre diameter, $n_f$ = number of fibres in yarn cross section |

These diagrammatic representations illustrate the relationships between different properties, but quantitative relationships can also be explored. Literature and textbooks often contain equations that detail these quantitative relationships between fibre and yarn and between yarn and fabric properties. From various textbooks and research, we find numerous quantitative relationships that are crucial for designing fabrics and estimating design parameters.

An example of one of the relationships between yarn and fibre is yarn tensile modulus, which is related to fibre tensile modulus by the following equation, '$E_y = E_f\ x\ cos^2\ \alpha$' where '$E_y$' is the yarn tensile modulus, '$E_f$' is the fibre tensile modulus, and '$\alpha$' is the twist angle. So, a list of known formulas is represented in the table, and these formulas should be available to the designer to use in the relationship while estimating the design parameters.

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Yarn structural features can get masked and modified or magnified by finishing treatments. An example is the brushed fabrics, where textural features of the constituent yarn get masked, and enzyme-treated fabrics, where hairiness is reduced, giving a smooth appearance and clear finished fabrics, where textural features of the yarn tend to get emphasized. There is a direct relationship between the fibre and yarn properties, and finishing techniques completely change the surface properties of the yarn and the fabric.

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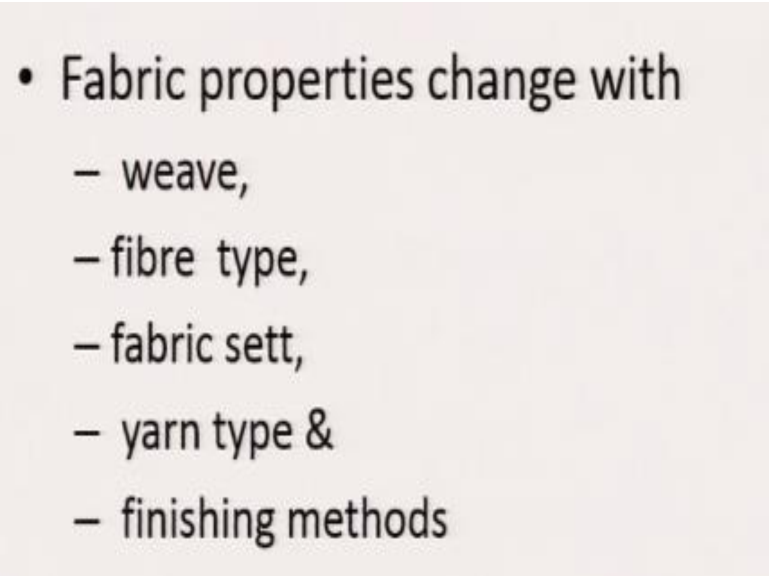


The other quantitative relationship between fabric properties has to be known that fabric properties can change with weave, fibre type, fabric set, yarn type and finishing methods.

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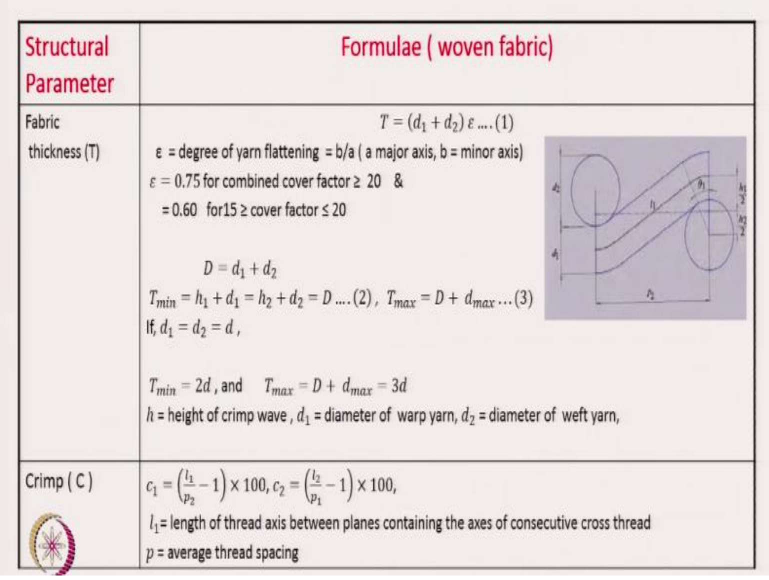

| Structural Parameter | Formulae ( woven fabric) |
|---|---|
| Fabric thickness (T) | $T = (d_1 + d_2)\,\varepsilon \ldots.(1)$<br>$\varepsilon$ = degree of yarn flattening = b/a ( a major axis, b = minor axis)<br>$\varepsilon = 0.75$ for combined cover factor ≥ 20 &<br>= 0.60 for15 ≥ cover factor ≤ 20<br>$D = d_1 + d_2$<br>$T_{min} = h_1 + d_1 = h_2 + d_2 = D \ldots.(2)$, $T_{max} = D + d_{max} \ldots(3)$<br>If, $d_1 = d_2 = d$,<br>$T_{min} = 2d$, and $T_{max} = D + d_{max} = 3d$<br>$h$ = height of crimp wave , $d_1$ = diameter of warp yarn, $d_2$ = diameter of weft yarn, |
| Crimp ( C ) | $c_1 = \left(\frac{l_1}{p_2} - 1\right) \times 100, c_2 = \left(\frac{l_2}{p_1} - 1\right) \times 100,$<br>$l_1$= length of thread axis between planes containing the axes of consecutive cross thread<br>$p$ = average thread spacing |

The different types of formulas are stated here, and they must be used whenever required. These formulas are available in textbooks and can help estimate the various design-related parameters. Here the formulas for thickness and crimp are stated.

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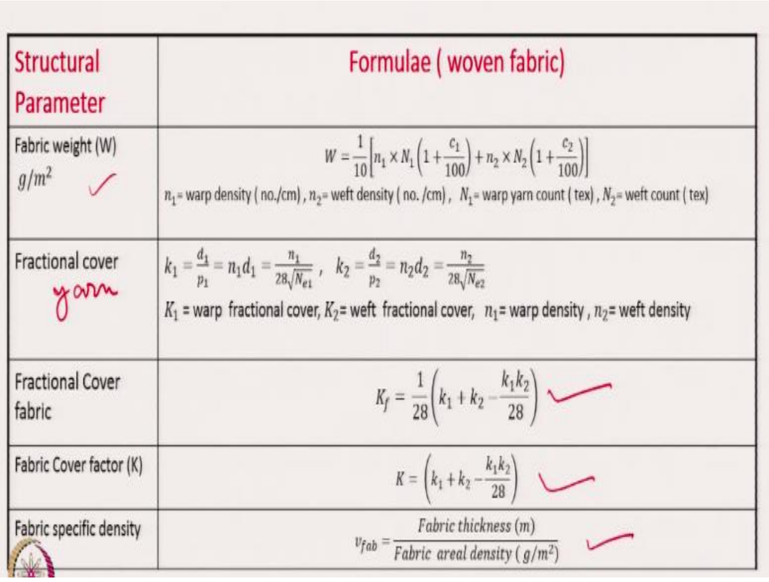

| Structural Parameter | Formulae ( woven fabric) |
|---|---|
| Fabric weight (W) $g/m^2$ | $W = \frac{1}{10}\left[n_1 \times N_1\left(1 + \frac{c_1}{100}\right) + n_2 \times N_2\left(1 + \frac{c_2}{100}\right)\right]$<br>$n_1$= warp density ( no./cm) , $n_2$= weft density ( no. /cm) , $N_1$= warp yarn count ( tex) , $N_2$= weft count ( tex) |
| Fractional cover yarn | $k_1 = \frac{d_1}{p_1} = n_1 d_1 = \frac{n_1}{28\sqrt{N_{e1}}}$, $k_2 = \frac{d_2}{p_2} = n_2 d_2 = \frac{n_2}{28\sqrt{N_{e2}}}$<br>$K_1$ = warp fractional cover, $K_2$= weft fractional cover, $n_1$= warp density , $n_2$= weft density |
| Fractional Cover fabric | $K_f = \frac{1}{28}\left(k_1 + k_2 - \frac{k_1 k_2}{28}\right)$ |
| Fabric Cover factor (K) | $K = \left(k_1 + k_2 - \frac{k_1 k_2}{28}\right)$ |
| Fabric specific density | $v_{fab} = \frac{Fabric\ thickness\ (m)}{Fabric\ areal\ density\ (g/m^2)}$ |

The fabric weight or fabric areal density is expressed in $g/m^2$. The equations for the fractional cover of the yarn, the fractional cover, and fabric specific density are also stated.

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| Property | Formulae ( **woven fabric**) |
|---|---|
| Tensile strength ($F_s$ ) | $F_s = 0.96\left(n_1 \times F_y \times N_1\right)$<br>$n_1$= thread density in test direction , $N_1$= Yarn count in test direction, $F_y$= thread tenacity<br>0.96 = strength translating efficiency (yarn to fabric strength)<br>The efficiency may vary with cover factor, fabric weave |
| Young modulus | $\frac{1}{E_\theta} = \frac{Cos^4\theta}{E_1} + \left(\frac{4}{E_{45}} - \frac{1}{E_1} - \frac{1}{E_2}\right) Cos^2\theta . Sin^2\theta + \frac{Sin^4\theta}{E_2}$<br>$E_1, E_2, E_{45}, E_\theta$ =Young moduli in warp, weft ,45degree and θ directions. |
| Grab strength ($F_{grab}$) | $F_{grab} = 1.3 \; to \; 1.4 \times F_s$ ( in the same direction for fabrics with Cover factor >12)<br>$F_{grab} = F_s$ (for nearly open structure)<br>Grab strength decreases for fabrics with open floats ( 2 × 1 twill, 2×2 basket & satin weave) |

The tensile strength of the fabric is represented by the simple formula '$F_s = 0.96\left(n_1 \times F_y \times N_1\right)$', where 0.96 is the factor called strength translation efficiency from yarn to fabric, '$n_1$' is the thread density in the test direction, '$N_1$' is the yarn count in the test direction, '$F_y$' is the thread tenacity.

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| Structural parameter | Formulae ( **Weft Knitted fabric**) |
|---|---|
| Course constant ($K_c$) | $K_c = c \times l$ , [ cpi = courses / unit length $l$ = loop length] |
| Wales constant ($K_w$) | $K_w = w \times l$ , [ wpi = courses / unit length ] |
| Stich density constant ($K_s$ ) | $K_s = K_w \times K_c = S \times l^2$ [ S= stich density i.e stitch per unit area] |
| Loop shape factor ( R) | $R = \frac{K_c}{K_w} = \frac{c}{w}$ |
| Fabric width or circumference ($F_C$ ) | $F_C = N_w \times \frac{1}{w} = N_w \times \frac{l}{K_w} = \frac{L}{K_w}$<br>[$N_w$= no.of wales line in fabric i.e. number of needles engaged in making loops, L = course length] |
| Fabric length ($F_L$ ) | $F_L = N_c \times \frac{1}{c} = N_c \times \frac{l}{K_c}$ [$N_c$= number of courses ] |
| Fabric weight per unit area ($F_w$) | $F_w = \frac{S \times l \times C_{tex}}{100} = \frac{K_S}{l^2} \times l \times C_{tex}$<br>S=stitch density ( loops/cm2) , $l$= loop length (mm), $C_{tex}$= yarn count ( tex) , $K_s$= in metric system |
| Tightness factor ($TF$ ) | $TF = \frac{\sqrt{C_{tex}}}{l\,(mm)}$ or $\frac{1}{\sqrt{N_e} \times l}$ [$d_y$= yarn diameter, $N_e$= yarn count( English),] |
| Tightness factor ($TF$ ) Warp knitted fabric | $TF = \frac{\sqrt{C_{tex.a}}}{l_f\,(mm)} + \frac{\sqrt{C_{tex.b}}}{l_b\,(mm)}$ [$C_{tex,a}$= yarn count on front guide bar, $C_{tex,b}$= yarn count on back guide bar, $l_f$ and $l_b$ are corresponding stitch length] |

Similarly, quite a few formulae are also stated here for weft-knitted fabrics.

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| Knitting constant of single jersey fabric | | | |
|---|---|---|---|
| Constant | Dry relaxed | wet relaxed | Fully relaxed |
| $K_c$ | 5.0 | 5.3 | 5.5 |
| $K_w$ | 3.8 | 4.1 | 4.2 |
| $K_s$ | 19.0 | 21.6 | 23.1 |
| R | 1.3 | 1.3 | 1.3 |

| Typical TF ( Tightness factor) values of some fabric | |
|---|---|
| Type of fabric | TF |
| Plain knitted fabric | 1.3 – 1.5 |
| 1 × 1 Rib ( flat bed knitting) | 0.3 – 0.6 |
| 1 × 1 Rib ( Circular knitting ) | 0.48 – 0.67 |

There are some typical constants like knitting constants for dry, relaxed, wet, relaxed, and fully relaxed knitted fabrics. Then, typical tightness factors of some of the knitted structures are also stated here.

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| Structural parameter | Formulae ( Non woven fabric) |
|---|---|
| Fabric density ( $\rho_{fab}$ ) | $\rho_{fab} = \frac{G}{t}$ [ G = fabric weight / $area$, $t$ = fabric thickness |
| Fabric bulk ( $B$ ) | $B = \frac{1}{\rho_{fab}} = \frac{t}{G}$ |
| Fibre volume fraction ( $\varphi$% ) | $\varphi = \frac{\rho_{fab}}{\rho_f} \times 100$ [ $\rho_{fab}$ = density of fabric, $\rho_f$ = density of fibre] |
| Porosity ( $\epsilon$% ) | $\varepsilon = (1 - \varphi) \times 100$ |
| Pore size ( r) | $r = \left(0.075737 \sqrt{\frac{c_f}{\rho_{fabric}}}\right) - \frac{d_f}{2}$ [ Wrotnowski's model] [$c_f$ = fibre linear density (tex), $\rho_{fabric}$ = fabric density ( $g/cm^3$, $d_f$ = fibre diameter (m) <br> $r = \frac{d_f}{4(1-\varepsilon)}$ ( Goeminne's model) [ for porosity < 0.9] |
| Largest pore size (2 $r_{max}$ ) | $r_{max} = \frac{d_f}{2(1-\varepsilon)}$ ( Goeminne's model) |

There are formulas related to the non-woven fabrics that are also available and stated. They are fabric density, fabric bulk, fibre volume fraction, porosity, pore size, etc.,

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| Structural parameter | Formulae ( Non woven fabric) |
|---|---|
| Number of fibres / $m^2$ of the medium ($N_f$ ) [ Peart and Ludwig] | $N_f = \frac{4\rho_{fab}}{\pi\rho_f d_f^2 l_f}$ [$M_s$= density of medium ( $g/cm^3$) , $\rho_f$ = density of fibre( $g/cm^3$) , $d_f$= fibre diameter ( m) , $l_f$= fibr length (m) |
| Number of pores / $m^2$ of the medium ($N_p$ ) [ Peart and Ludwig] | $N_p = \frac{16\rho_{fab}^2 l_f}{\pi^3 d_f^4 l_f}$ |

Similarly, formulas for calculating the number of fibres/m$^2$ and number of pores/m$^2$ are also available.