Textile Product Design and Development
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Lecture – 17
Estimation of Design Parameters

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Design of a coated swimming pool liner

Product Specification given

S. No.	Characteristics	Value
1	Warp tensile strength	98.2 Kg f/cm (minimum)
2	Weft tensile strength	98.2 Kg f/cm (minimum
3	Weight	0.27 kg/m^2 (Nominal)
		0.24 kg/m^2 (minimum acceptable)
		0.31 kg/m^2 (maximum acceptable)
4	Environment	Acidic, Ph = 6.0
5	Structural restriction	Nil
6	Thickness	0.05 cm = 0.5mm

We will discuss the estimation of design parameters. An example is used to understand how to calculate design parameters when product specifications, particularly performance specifications, are provided. For example, consider a case where the product specification includes a warp tensile strength of 98.2 kgf/cm. Additionally, there is a specified minimum strain requirement.

The weft tensile strength is also specified as 98.2 kgf/cm, indicating that the warp and weft directions require similar strength, with 98.2 being the minimum acceptable value. Exceeding this strength is also acceptable. The nominal areal density should be around 0.27 kg/m^2, with a minimum acceptable value of 0.24 kg/m^2 and a maximum of 0.31 kg/m^2, meaning the average target is 0.27 kg/m^2. The environmental condition is acidic, with a pH of 6.0. There are no restrictions on the type of weave.

The weave type could be plain, twill, or any other construction, as there are no restrictions. The ends and pick density are also not specified and can be decided based on design needs.

However, the fabric thickness is required to be 0.05 cm or 0.5 mm. These are some of the fundamental requirements provided for the design.

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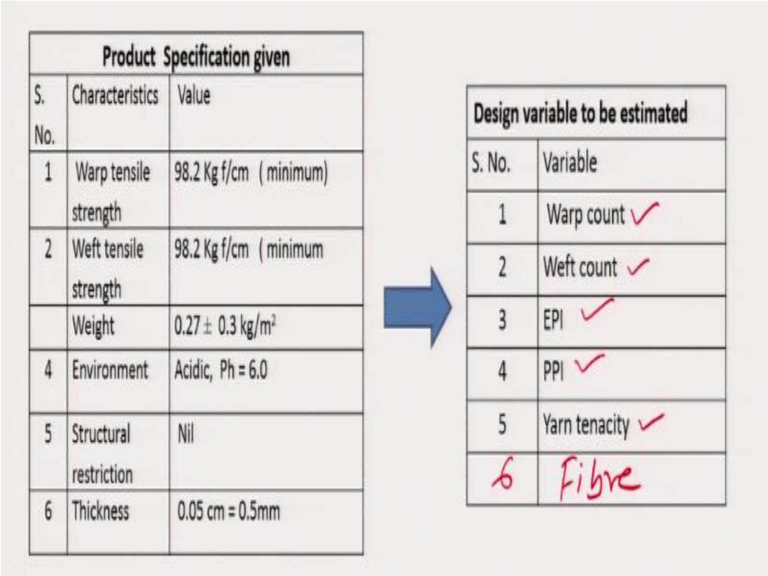

The relevant design parameters or design variables need to be identified, which is represented in the slide. The variables that need to be identified are warp count, weft count, EPI, PPI and yarn tenacity. These values must be calculated from the information about the product specification, represented in the table on the left-hand side. This includes determining the appropriate design variables and the type of fibre that has to be selected to meet these requirements.

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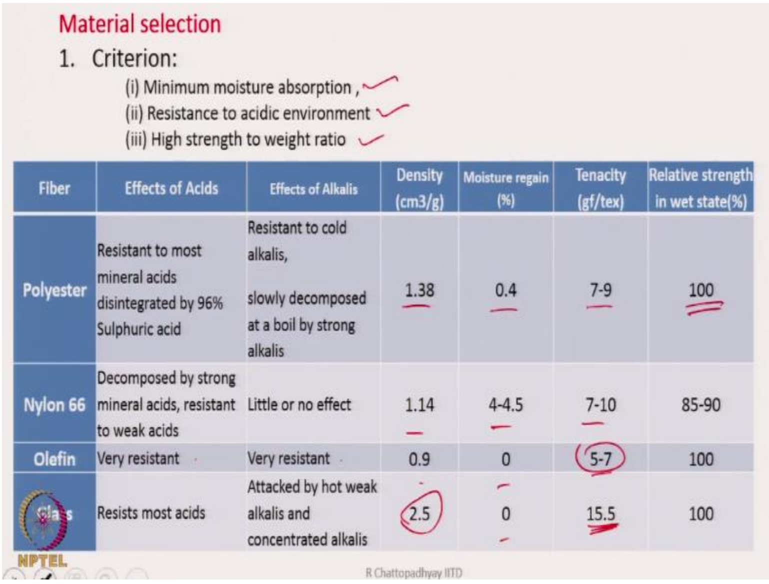

For material selection, a designer has to consider some of the suitable fibres based on the minimum information provided. In this case, there is a list of fibres, including polyester, nylon, olefin, and glass fibres, as well as certain relevant properties. Detailed information about the fibres has to be gathered, which helps determine which material is suitable for meeting the requirements.

Polyester is preferred because it is an acidic medium; it must considered how polyester reacts to acids and alkalis. Polyester is resistant to most mineral acids but can be damaged by concentrated acids like 96% sulfuric acid. It also resists cold alkalis but gradually decomposes when exposed to strong alkalis at boiling temperatures. On the other hand, nylon decomposes when exposed to strong mineral acids but is resistant to weak acids.

With respect to alkalis, olefin fibres, such as polypropylene, exhibit high resistance to both acids and alkalis. Hence, they are suitable from a damage point of view. Glass fibres are resistant to most acids but can be attacked by hot, weak alkalis and concentrated alkalis. Their relevant properties, such as density and moisture regain values, are also provided. Some tenacity values and relative strength in the wet state are also provided, which are important since the fabric will be used in a swimming pool environment.

Therefore, it is essential to know that fabric strength does not significantly decline when wet. Although the fabric will be coated with chemicals for protection, there may still be instances where water penetrates, and it can then weaken the fibres and fabric, resulting in reduced tenacity.

Thus, understanding the relative strength in the wet state is important. Based on this information, the most appropriate fibre has to be selected. The criteria for selecting fibres should be minimum moisture absorption, resistance to an acidic environment, and a high strength-to-weight ratio. A high strength-to-weight ratio is particularly important, as it helps keep the overall weight of the fabric to a minimum. When considering the high strength-to-weight ratio, glass fibre has a high density of 2.5, making it quite heavy despite its high tenacity.

Therefore, glass fabric is unsuitable for this application and should be discarded. On the other hand, while olefin fibre has zero moisture regain and maintains its strength when wet, its tenacity is on the lower side, leading to its exclusion as well. The two viable options are polyester and nylon, which are good in some respects.

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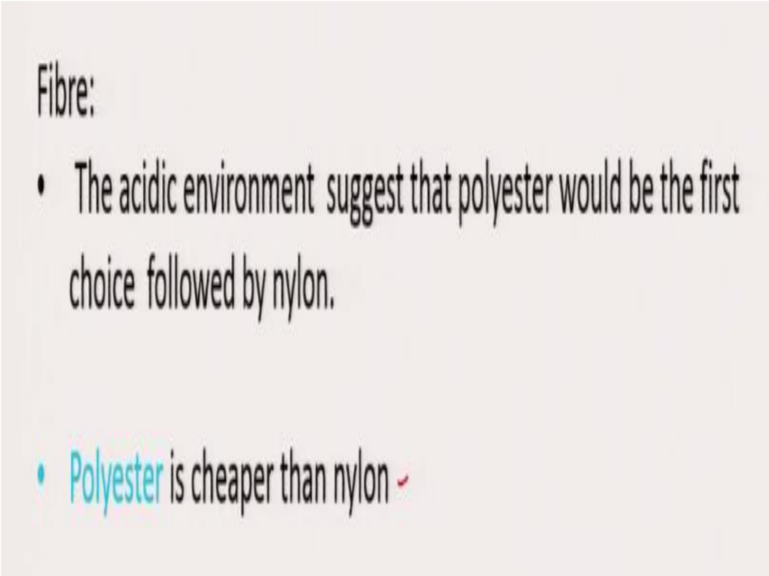

Considering resistance to the acidic environment, polyester is the best choice, followed by nylon. While both fibres are suitable, polyester is preferred due to its lower cost compared to nylon. Therefore, polyester fibre is chosen as the primary material for this application.

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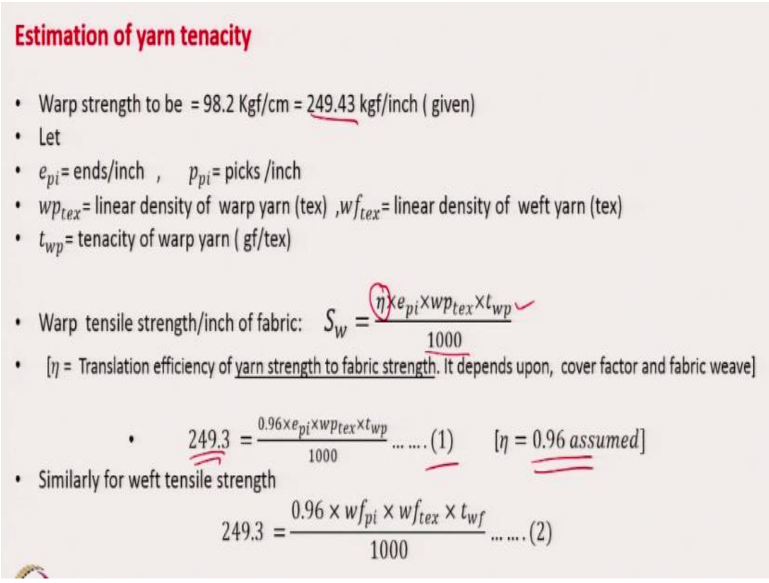

The other parameters that need to be determined are yarn tenacity, yarn count, ends per inch (EPI), and picks per inch (PPI). The strength is specified in terms of kgf/cm, i.e., 98.2 kgf/cm, which is equivalent to 249.43 kgf/inch, which is almost 250 kgf/inch. This is the required strength value given to meet this requirement. The parameters are, ‘e_{pi}’ stands for ends per inch, and ‘p_{pi}’ stands for picks per inch. The term ‘wp_{tex}’ refers to the linear density of the warp yarn, while ‘wf_{tex}’ is the linear density of the weft yarn. Similarly, ‘t_{wp}’ represents the tenacity of the warp yarn.

To calculate the tensile strength of the fabric, the tensile strength per inch of the fabric in the warp direction is given by

$$s_w = \frac{\eta \times \ e_{pi} \ \times \ wp_{tex} \times \ t_{wp}}{1000}$$

Dividing by 1000 converts tensile strength to kg. The factor ‘η’ represents the translation efficiency of yarn strength to fabric strength. This value depends upon the cover factor and fabric weave.

In this case, it is assumed to be 0.96. The value of ‘η’ typically needs to be determined based on research, literature, or consulting reference books. When parameters are not provided, assumptions have to be made. While making some assumptions, it should not be completely arbitrary in nature. It is essential to consult relevant research papers, textbooks, or other sources to identify values that have been reported by others.

Based on these references, a typical value has to be assumed to make initial estimations of the parameters. This forms the basis of the first iteration in the design process. In this case, the translational efficiency of 0.96 is assumed, which is represented in the below equation

$$s_w = \frac{0.96 \ \times \ e_{pi} \ \times \ wp_{tex} \times \ t_{wp}}{1000}$$

Since the strength must be the same in both the warp and weft directions, both equations follow the same structure.

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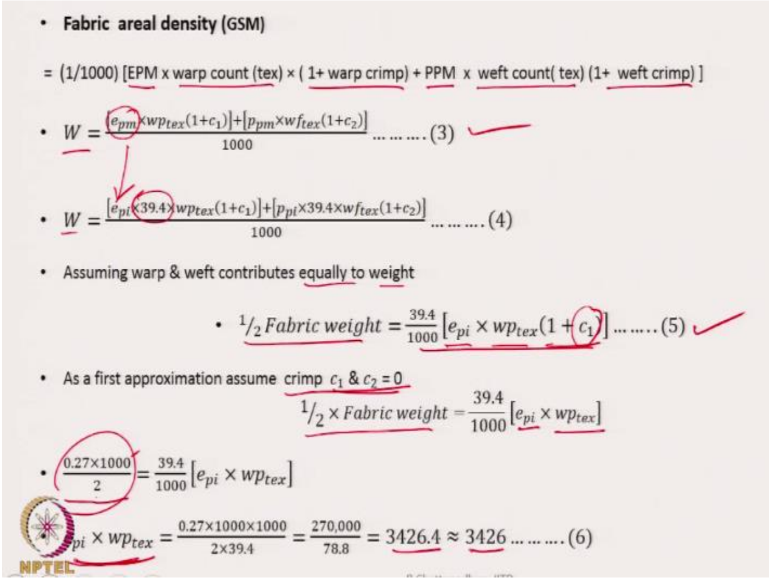

We have two equations with three unknown values. There is no way to find the values for these parameters since there is no sufficient information. The other information that has been provided is the areal density of the fabric. The areal density of the fabric is written as

$$GSM = \frac{1}{1000}[EPM \times warp\ count(tex) \times (1 + warp\ crimp) + PPM \times weft\ count(tex) \times (1 + weft\ crimp)]$$

This standard equation can be found in many textbooks. By changing the units from ends per metre to ends per inch, a constant of '39.4' appears in the equation due to the conversion factor between inches and meters. Other than that, the equation remains the same.

The warp and weft are assumed to contribute equally to the fabric's weight. This implies that the fabric has the same warp and weft densities made from the same yarn. Therefore, half of the fabric's weight is given by

$$\frac{39.4}{1000}[e_{pi} \times wp_{tex}(1 + C_1)]$$

This is the contribution made by the warp, and it is the same for the weft. This is a balanced fabric in which both the warp and weft count and the ends and pick densities are the same.

Hence, half of the fabric weight is equal to this equation. Another important assumption arises regarding the crimp value, denoted as 'C_1'. While crimp is always present in any woven fabric, accurately predicting its value in advance is challenging. Crimp can be measured after the fabric is produced, allowing us to determine the crimp values for the warp and weft. Initially, it is assumed that there is no crimp, meaning the crimp is zero on both sides.

Under this assumption, half of the fabric weight is calculated as

$$\frac{39.4}{1000}\left[e_{pi} \times wp_{tex}\right]$$

The first assumption is the translation efficiency, and the second assumption is zero crimp. The resultant fabric weight is around 0.27 kg/m^2. Converting this to grams and dividing by two gives the weight contributed by the warp yarns. Hence, the equation can be written as

$$\frac{0.27 \times 1000}{2} = \frac{39.4}{1000}\left[e_{pi} \times wp_{tex}\right]$$

From this, it is found that '$e_{pi} \times wp_{tex} = 3426$'.

As a result, it ended up with an equation with two unknowns and only one given value. Theoretically, there could be numerous combinations of 'e_{pi}' and 'wp_{tex}' that yield this value of 3426, but not all combinations possible will be viable because this must also meet other requirements.

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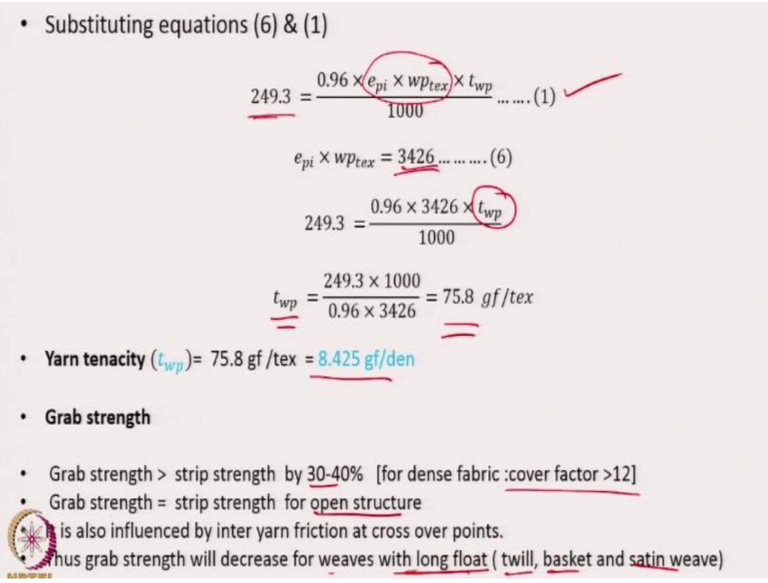

From the strength equation (1), as mentioned previously, it has been determined that

$$e_{pi} \times wp_{tex} = 3426$$

By applying this value in equation 1, it becomes

$$249.3 = \frac{0.96 \times 3426 \times t_{wp}}{100}$$

From this equation, the tenacity of the warp yarn is determined, which gives a value of 75.8 gf/tex. When converted to denier, this equals 8.425 gf/den. Therefore, it is found that this is the required tenacity of the yarn in order to achieve a warp strength of 249.3 kgf/inch.

It has been observed that grab strength is typically 30 - 40 % greater than strip strength, according to some researchers. Generally, grab strength is more than strip strength by 30 - 40% for a cover factor greater than 12. In contrast, for very open structures, grab strength and strip strength are nearly equal. Since grab strength is sometimes specified, it is necessary to convert grab strength to strip strength in order to estimate the parameters accurately. Grab strength is also influenced by inter yarn friction at crossover points. As a result, grab strength tends to decrease for weaves with long floats, such as twill, basket, and satin weaves. This information provides a general understanding of the factors affecting grab strength.

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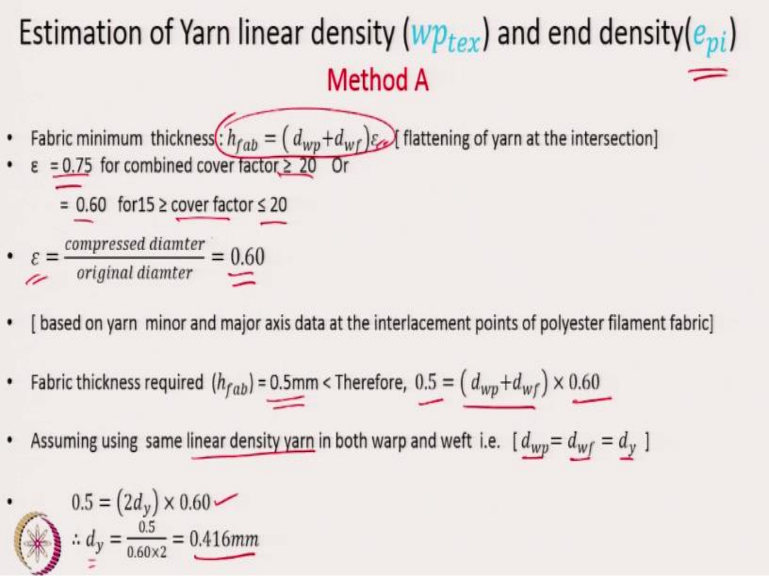

Next, the yarn linear density and the ends per inch can be estimated, but these have not yet been determined. There is a minimum fabric thickness, which is given by the equation,

$$h_{fab} = (d_{wp} + d_{wf})\varepsilon$$

where 'ε' is 0.75 for a combined cover factor greater than 20, and 0.60 for a cover factor between 15 and 20. This equation is suitable for filament yarns, where the twist is very low. It has been stated that these equations can be utilized to predict the yarn count and end density for low-twisted filament yarns. The symbol 'ε' is the ratio of the compressed yarn diameter to the original yarn diameter, which should equal 0.6 for these yarns.

It is stated that the required fabric thickness is 0.5 mm. Therefore, it can be written as '$0.5 = (d_{wp} + d_{wf}) \times 0.6$'. Assuming that the yarns have the same linear density and that the same count of yarn is used for both the warp and weft, the diameter of the warp yarn and the diameter of the weft yarn are the same, i.e., '$d_{wp} = d_{wf}$' and denoted by common diameter as 'd_y'.

Hence, the equation can be written as '$0.5 = 2\,d_y \times 60$' and the diameter of the yarn 'd_y' is determined as 0.416 mm. This calculation helps to find the diameter of the yarn based on the given fabric thickness and the relationship that the fabric thickness is equal to the sum of the diameters of the warp and weft multiplied by a factor of either 0.6 or 0.75. As a result, an estimate for the yarn diameter is obtained.

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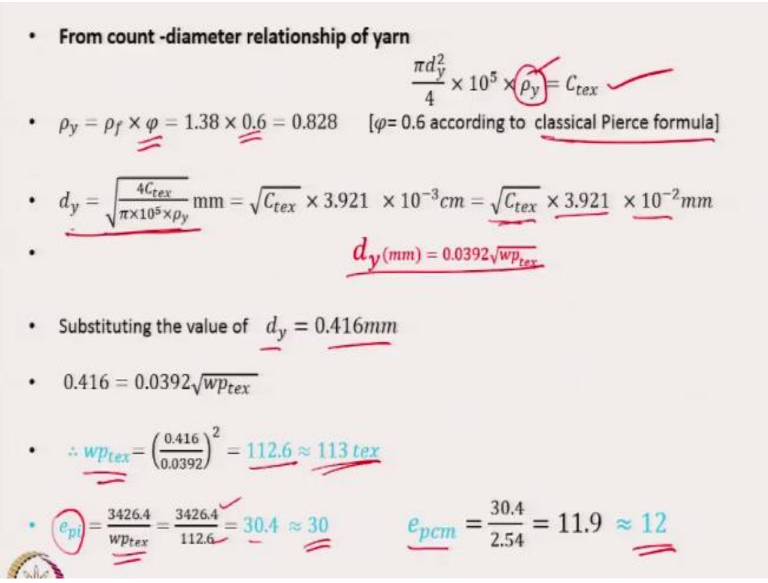

If the estimate of the diameter of the yarn is known, there is an established relationship between yarn diameter and yarn count, which is commonly found in standard textbooks. The only unknown at this point is yarn density. The density of the yarn depends on the fibre packing arrangement, which can be expressed as '$\rho_y = \rho_f \times \varphi$' where '$\rho_y$' the density of the yarn, 'ρ_f' is the fibre density and 'φ' represents the packing factor.

The packing factor chosen here is approximately 0.6, which is also a typical packing factor based on Pierce's classical formula. The formula for yarn diameter is given as

$$d_y = \sqrt{\frac{4C_{tex}}{\Pi \times 10^5 \times \rho_y}}$$

From there, it gets simplified to

$$d_y = \sqrt{c_{tex}} \times 3.921 \times 10^{-2} mm$$

This gives the value of '$d_y = 0.0392 \times \sqrt{wp_{tex}}$'.

Substituting the previously calculated yarn diameter value of '$d_y = 0.416mm$' in this equation, yarn count can be determined. This calculation gives a yarn count value of approximately 112.6 tex. With this yarn count value, the ends per inch are calculated as follows

$$e_{p_i} = \frac{3426.4}{wp_{tex}}$$

Substituting yarn count values in this equation yields a value of around 30 ends per inch or 12 ends per cm. Therefore, the values of both the count of the warp yarn and the ends per centimetre are estimated.

These estimates are based on certain assumptions, and while they provide a good starting point, they are initial estimates and not final values. With these initial estimates, one can proceed to create a fabric sample. The next step is to assess whether the fabric meets the desired requirements for strength and areal density (g/m^2). These parameters must be modified if the fabric does not meet the requirements. This methodology provides a systematic approach for initial estimation.

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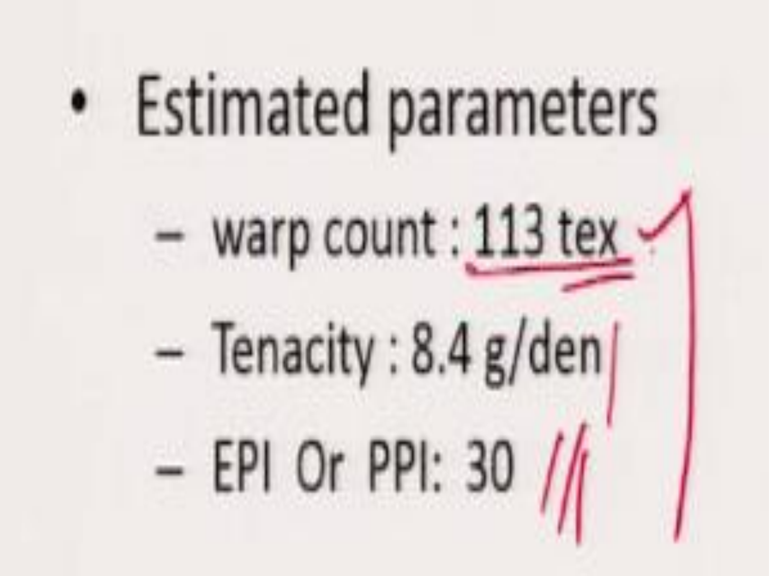

The estimated parameters are: warp count is approximately 113 tex, the same as the weft count; yarn tenacity is 8.4 g/den; EPI and PPI are around 30. It is necessary to determine if a yarn with this exact tex count is available. If a yarn with 113 tex is not commercially available, yarn with a tex count that is as close as possible to this value has to be chosen. In practical situations, if the exact yarn count of 113 tex is not available and the closest available options are, for example, 115 tex, 98 tex, or 100 tex, the adjustments have to be made accordingly. Once the yarn is chosen, the parameters are recalculated and checked to determine whether the fabric will still meet the original strength, areal density (g/m^2), and thickness requirements.

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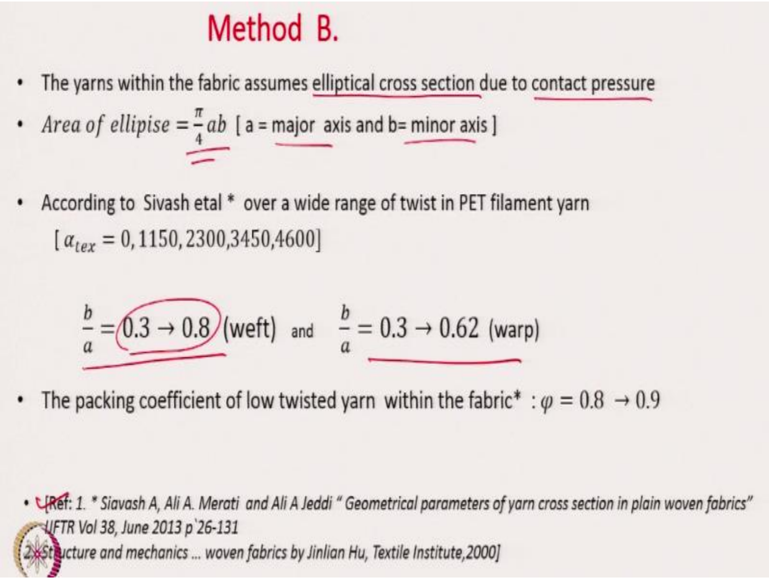

The alternate method of finding the yarn count is stated. In this method, the yarn within the fabric is assumed to take on an elliptical cross-sectional shape due to the contact pressures during weaving. The area of an ellipse is calculated using the formula

$$\frac{\pi}{4}ab$$

where 'a' is the major axis, and 'b' is the minor axis. One important paper which mentions that the ellipticity, defined as the ratio of the minor axis to the major axis ($\frac{b}{a}$), ranges from 0.3 to 0.8 for weft yarns and 0.3 to 0.62 for warp yarns.

In this study, the researchers used filament yarns, twisted them to varying degrees, woven them with the same ends and picks per inch, cut cross-sections of the fabric, and measured both the minor and major axes. Based on this information, it is observed that the ellipticity of weft yarns varies between 0.3 and 0.8, depending on the twist in the weft yarn and the corresponding twist in the warp yarn. This is due to the interaction between the warp and weft at every interlacement point, which creates pressure.

Under this pressure, the yarns flatten and take on an elliptical shape. If the yarn maintains a perfectly round shape within the fabric, the ‘$\frac{b}{a}$’ ratio is 1, indicating no change in shape. This means the yarn remains circular. The ratio of ‘1’ signifies round yarns, while lower values indicate that the yarns have become more elliptical in shape. The smaller the ‘$\frac{b}{a}$’ ratio value, the more elliptical the yarns are.

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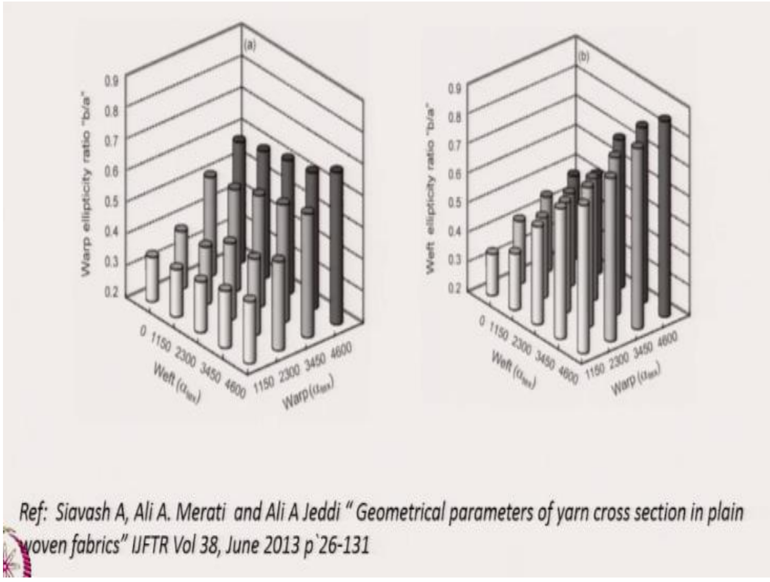

So, this is the range in which the ‘$\frac{b}{a}$’ values lie, representing the ellipticity ratios presented by the same authors. It is shown for both warp and weft directions. The vertical chimneys represent the ellipticity of the warp and weft. The ellipticity of weft yarns can go as high as 0.8, while the maximum ellipticity of warp yarns reaches up to 0.6.

This indicates that the weft yarns become more deformed in this example than the warp yarns. This is because warp yarns are always under more stress and tension, which reduces their potential for deformation, making the weft yarns more likely to flatten.

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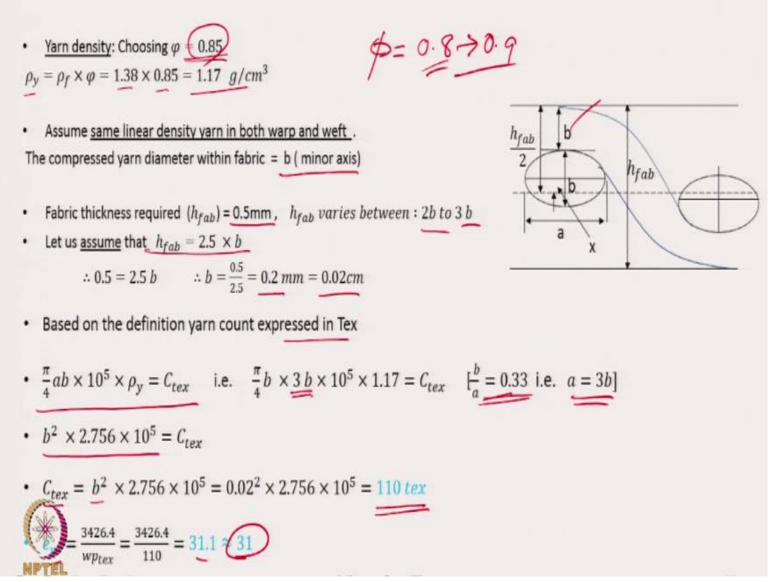

To determine the yarn density value from the data provided by the previous authors by taking the minor and major axis values of the filament yarns from their cross-sectional measurements, the packing density of the yarn within the fabric was found to vary between 0.8-0.9. This range is based on the data they have suggested. The packing coefficient (φ) values vary between 0.8 and 0.9. The maximum value, 0.9, represents a closed-pack geometry of circular fibres, while 0.8 is the typical value.

It is important to remember that these values are within the fabric. Within the fabric, the yarns are tightly locked into position and subjected to pressure, resulting in a highly compact structure. This high packing coefficient is observed specifically for filament yarns. For spun yarns, the packing coefficient cannot reach 0.8; it will be much lower. In this case, the value is chosen as 0.85. using this packing coefficient, the yarn density can be calculated as '$\rho_y = 1.38 \times 0.85$' which gives a value of 1.17g/cm^3.

Given this yarn density, the compressed yarn diameter within the fabric corresponds to the minor axis 'b' in the diagram, which represents the compressed yarn diameter. The compressed yarn diameter is key in determining the overall fabric thickness. Given that the fabric thickness is 0.5 mm and the relationship 'h_{fab}' varies between '$2b$' and '$3b$', '$2.5b$' is chosen for this case.

Here, the deformed shape of the yarn is taken into account, where the minor axis of the ellipse 'b' is treated as the yarn diameter. From this, the value of 'b' is calculated, which comes out to be 0.2 mm or 0.02 cm. Based on the definition of yarn count expressed in tex, the formula for the elliptical cross-section of the yarn within the fabric is used. Since the yarn is deformed into an ellipse, the yarn count in tex can be written as

$$C_{tex} = \frac{\pi}{4} ab \times 10^5 \times \rho_y$$

In this case, it is chosen that '$a = 3b$' because the ratio '$\frac{b}{a}$' for very low twisted yarns is typically 0.33, meaning the major axis 'a' is three times the minor axis 'b' indicating significant deformation. Looking at the ellipticity values, it is observed that when the yarn twist is at its lowest or zero, the yarn undergoes maximum deformation. Therefore 'a' is replaced by '$3b$'. In this case, because a swimming pool liner is formed from filament yarn, which is hardly twisted or has no twist. With such a lower twist, yarn deformation takes place.

With this calculation, the relationship becomes

$$C_{tex} = b^2 \times 2.756 \times 10^5$$

From this, the tex value of the yarn comes out to be approximately 110 tex. Given this yarn count, the yarn ends per inch is calculated to be 31. When comparing this result to a previous method, the yarn count, tex value, and ends per inch are very close. This shows that regardless of which method is followed, it ends up with a yarn count that is quite similar. This holds true for fabrics made from filament yarns, particularly those with low-twisted filament yarns.

In such cases, significant deformation occurs within the fabric, especially in the fabrics that are to be coated. After the fabric is produced, it is coated to enhance protection from sunlight exposure, abrasion, and other environmental factors. There are several reasons for applying a coating to fabric surfaces. For coating the fabric surface, the fabric surface has to be very smooth. The irregularities or unevenness on the fabric surface are not suitable for coating.

To achieve a smooth surface while maintaining a stable construction, low-twisted filament yarns combined with a plain weave structure are suitable. Because low-twisted yarns deform easily, allowing the fabric surface to become smoother. The thickness of the fabric will also be relatively low because both the warp and weft yarns undergo compression and spread out within the fabric. This spreading reduces the inter-yarn distances, minimizing visible gaps between the yarns as they take on an elliptical shape. Both warp and weft yarns adopt this deformation. This is why low-twisted filament yarns are typically preferred in such applications.

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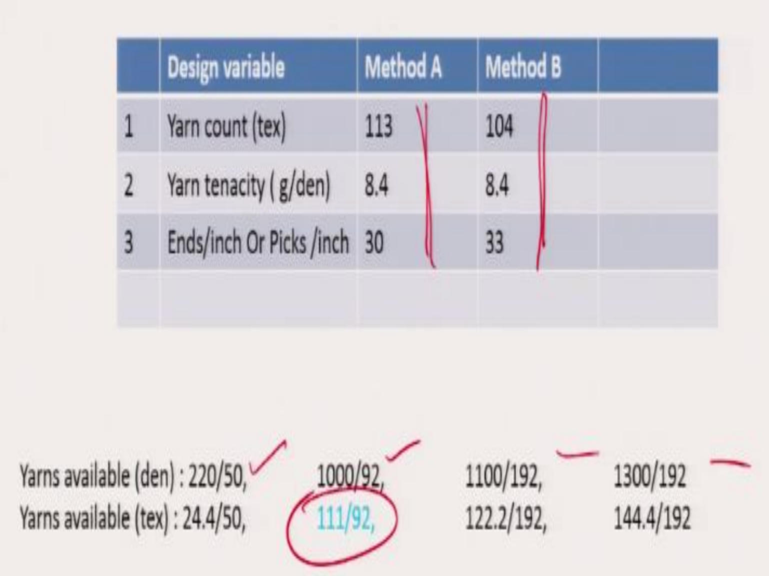

This comparison shows that 'Method A' provides certain values, while 'Method B' yields closely matching results. Suppose these yarns are available denier wise in an inventory, as shown in the slide. For example, a yarn with a tex count of 111 is in close agreement with the calculated values. These yarns can be selected based on their tex count. It is essential to determine the corresponding tenacity of the yarns because this selected yarn must meet the minimum tenacity requirement of at least 8.4. If the tenacity exceeds 8.4, that is acceptable, but yarns whose tenacity is less than 8.4 cannot be chosen.

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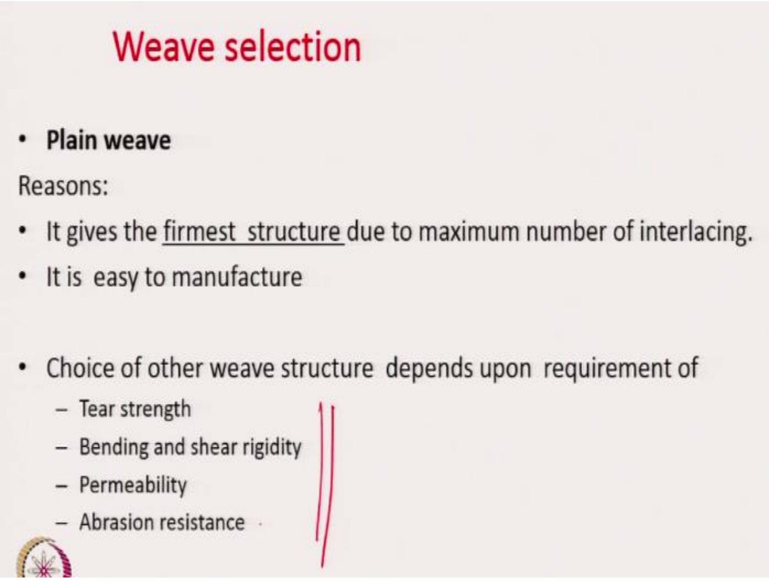

Another important factor to consider is the selection of the weave. As mentioned, plain weave is typically chosen because it provides the firmest structure due to the maximum number of interlacements between warp and weft yarns. This makes it well-suited for applications where a stable, compact fabric is required. Additionally, plain weave is relatively easy to manufacture. The choice of alternative weaves, such as twill or satin, would depend on specific requirements such as tear strength, bending and shear rigidity, permeability, or abrasion resistance.

Different fabric constructions will result in varying properties, such as tear strength, bending, and shear rigidity, even when using the same yarn. Altering the weave design, whether switching from plain to twill or twill to satin or exploring other weave types like basket weave, directly impacts these characteristics. Choosing plain weave to basket weave or plain weave to twill depends on the specific performance requirements for tear strength, bending rigidity, permeability, and abrasion resistance.

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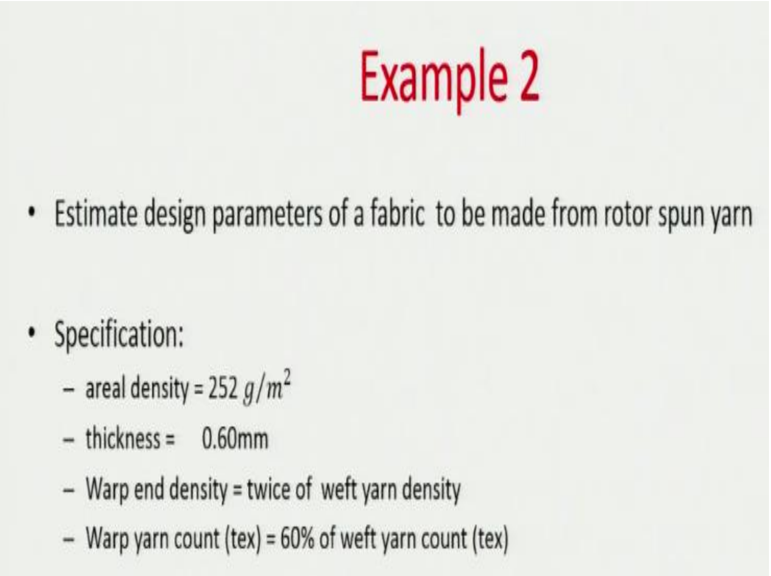

We previously discussed estimating design parameters for technical fabrics, and here, another example is considered for estimating design parameters for a fabric made from rotor-spun yarns. In this case, the yarn type rotor-spun has already been specified, so the designer does not need to make a decision regarding the yarn type, whether ring-spun, combed, or rotor-spun yarns.

The specifications that need to be met are the technical requirements. These specifications are as follows: The areal density should be 252 g/m^2, which is the fabric weight. Another key specification is the thickness, which must be 0.6 mm. Additionally, the warp end density should be twice the weft yarn density or vice versa. If the warp density is 'x', the weft yarn density should be '$\frac{x}{2}$'. The warp yarn count should also be 60% of the weft yarn count. These are the given specifications to estimate the various design parameters so that the weaver can use them to produce the fabric.

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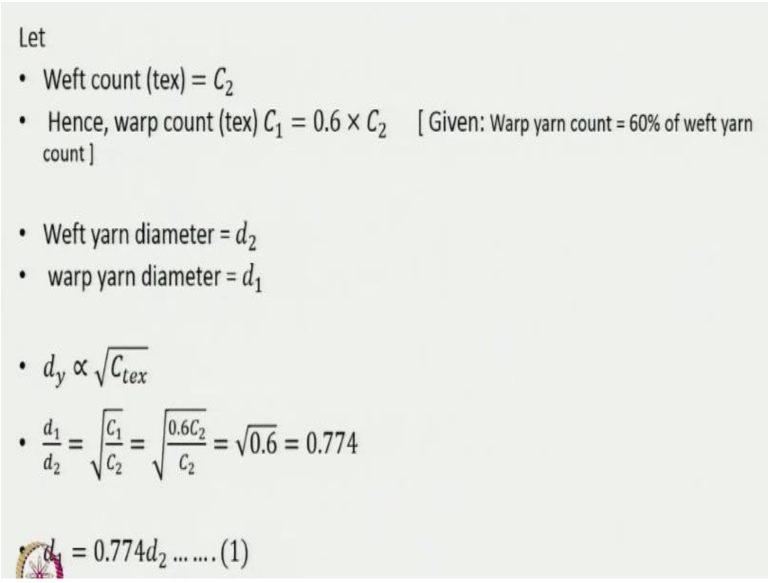

Let the weft yarn count be 'C_2'. Therefore, the warp yarn count is 60% of that, which is represented as '$C_1 = 0.6 \times C_2$'. Similarly, the diameter of weft yarn and warp yarn are 'd_2' and 'd_1'. The diameter and yarn count are unknown here. We know that the yarn diameter is

$$d_y \; \alpha \; \sqrt{C_{tex}}$$

where the count is expressed in tex units. Then, the ratio of '$\frac{d_1}{d_2}$' is proportional to '$\sqrt{\frac{C_1}{C_2}}$' where '$C_1 = 0.6 \times C_2$'.

Therefore, the ratio becomes

$$\frac{d_1}{d_2} = \sqrt{\frac{0.6\, C_2}{C_2}}$$

As a result, the warp yarn diameter '$d_1 = 0.774 \times d_2$'. Thus, the warp yarn diameter is about 0.77 times the weft yarn diameter.

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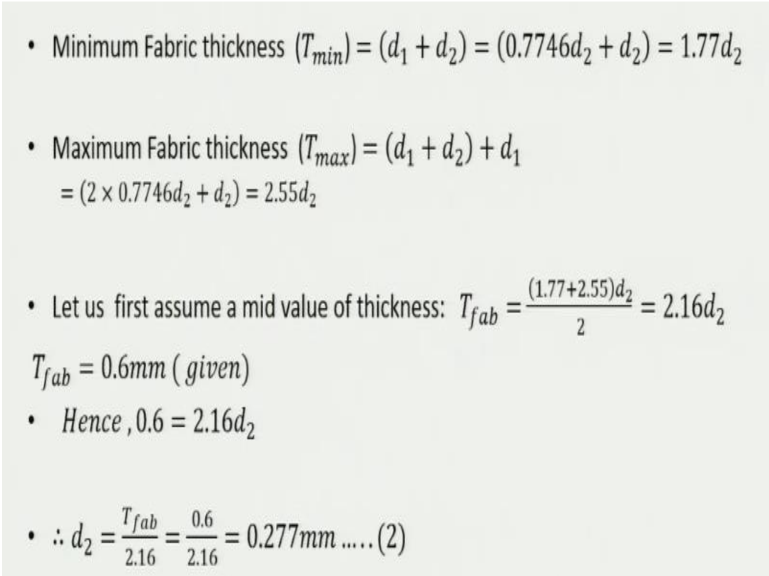

The fabric thickness has been specified, and it must meet this requirement. According to some textbooks, fabric thickness can range between a minimum (T_{min}) and a maximum (T_{max}) value. The minimum thickness is given by '$T_{min} = d_1 + d_2$'. Substituting '$d_1 = 0.774 \times d_2$', it results in '$T_{min} = 0.774\, d_2 + d_2$'. Hence, the minimum fabric thickness is approximately equal to '$1.774 \times d_2$'. The maximum fabric thickness 'T_{max}' is given by

$$T_{max} = (d_1 + d_2) + d_1$$

substituting the value of 'd_1' The maximum fabric thickness is '$T_{max} = 2 \times 0.774\, d_2 + d_2$' which is equal to '$2.55\, d_2$'.

So, the minimum and maximum fabric thicknesses are directly related to the diameters of the warp and weft yarns. This means the fabric thickness will lie between '$1.774d_2$' to '$2.55d_2$'. To proceed, a mid-value of the thickness is assumed as a starting point since the exact degree of compression or the final thickness of the yarns after the fabric is woven is not known. After weaving, the yarns undergo compression and typically take on an elliptical shape, influencing the final fabric thickness.

As the upper and lower limits of fabric thickness are known, an initial estimation of the actual thickness lies between these two limits. By taking the mid-point, the estimated fabric thickness is given by

$$T_f = \frac{(1.7 + 2 \cdot 5)\, d_2}{2}$$

which is equal to '$2.16\, d_2$'. Given that the fabric thickness is $0.6\, mm$, the value of 'd_2' will be $0.277\, mm$. Thus, the diameter of the weft yarn 'd_2' should be approximately $0.277\, mm$ to meet the fabric thickness requirement.

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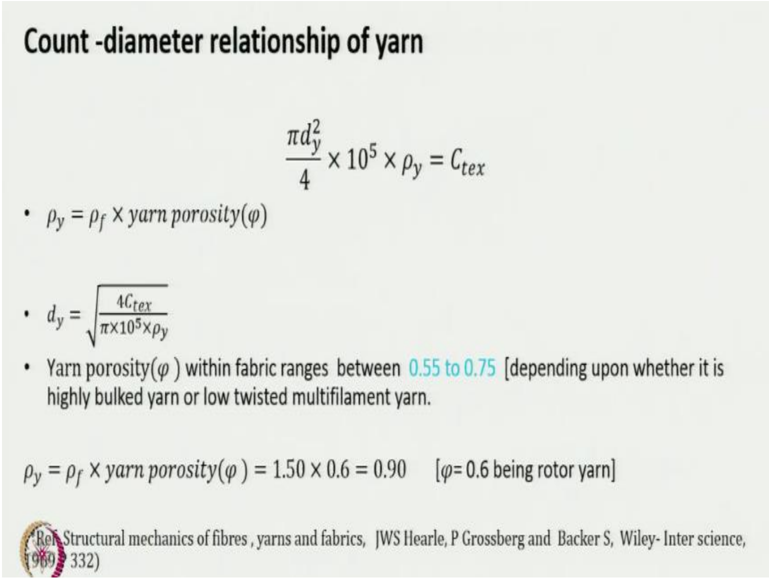

To translate the yarn diameter into the count (tex), we use the typical relationship found in textbooks, which relates the diameter 'd_y' of the yarn to its count 'C_{tex}' in tex units. The formula is given by

$$C_{tex} = \frac{\pi d^2}{4} \times 10^5 \times \rho_y$$

and yarn density is '$\rho_y = \rho_f \times \varphi$'. The diameter of the yarn can be expressed as

$$d_y = \sqrt{\frac{4C_{tex}}{\pi \times 10^5 \times \rho_y}}$$

Yarn porosity within the fabric ranges between 0.55 to 0.75.

This value can typically be found in research articles or literature, depending on the fibre type and fabric structure. If no relevant information is available from literature sources, conducting in-house experiments or research to determine these values may be necessary. Yarn porosity typically varies within the fabric, ranging from 0.55 to 0.75. the yarn density will be 1.50 g/cm^3 if cotton fibre is used. In this case, a typical value of 0.6 has been chosen for the porosity of the rotor yarn. Hence, the density of the yarn is given by '$\rho_y = 1.50 \times 0.6$' which gives the value of 0.90 g/cm^3.

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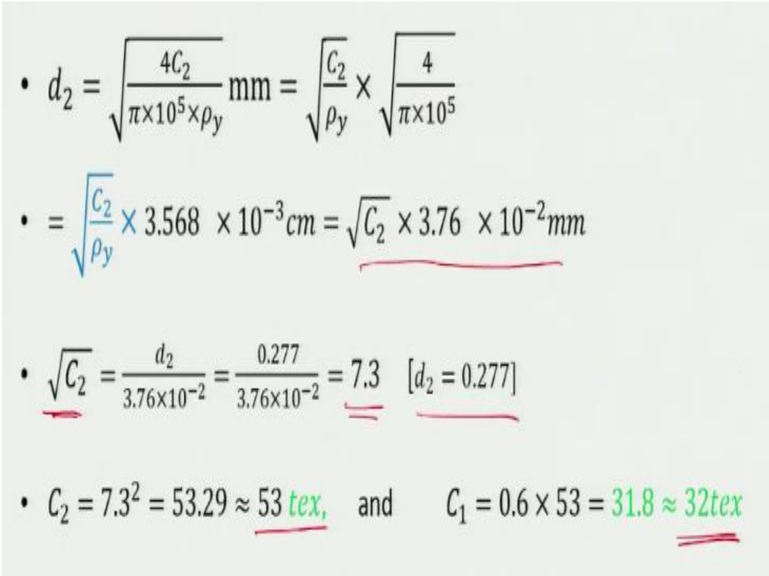

With the assumption of yarn porosity as 0.6, the yarn density is calculated, and to calculate the diameter of the weft yarn, the formula relating to the yarn count can be written as

$$d_2 = \sqrt{\frac{4C_2}{\pi \times 10^5 \times \rho_y}}$$

Substituting all the values in this equation gives

$$d_2 = \sqrt{C_2} \times 3.76 \times 10^{-2}$$

From here, the value of '$\sqrt{C_2}$' is found to be 7.3. Hence, the value of 'C_2' is the square of 7.3, which gives a yarn count of 53.29 tex, which is approximately equal to 53 tex. Since the warp count 'C_1' is defined as 60% of 'C_2', the value of 'C_1' will be close to 32 tex. This approach effectively provides the count values needed for both yarns based on certain assumptions.

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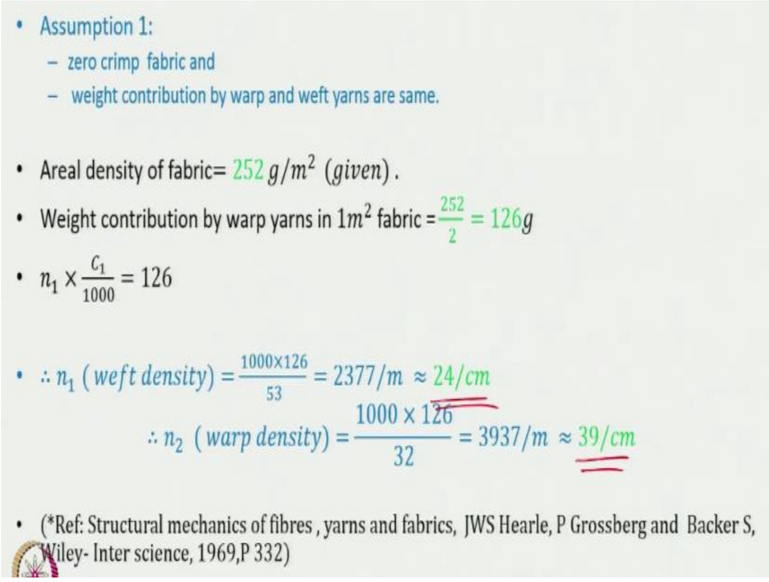

The assumption is not arbitrary; it is based on specific research articles. From there, the yarn count, as well as appropriate ends per inch and picks per inch, has to be determined. The first assumption made is that the fabric has zero crimp, meaning no crimp in the threads. While this is not feasible in practice, start with this assumption as a baseline for the analysis. The weight contribution of the warp and weft will be equal, assuming the yarn counts are the same. Given that the areal density of the fabric is 252 g/m^2. Hence, the weight contribution of warp yarn will be 126 g. Therefore, '$n_1 \times \frac{C_1}{1000} = 126$'. From there, the weft density and warp density are calculated and found to be 24/cm and 39/cm.

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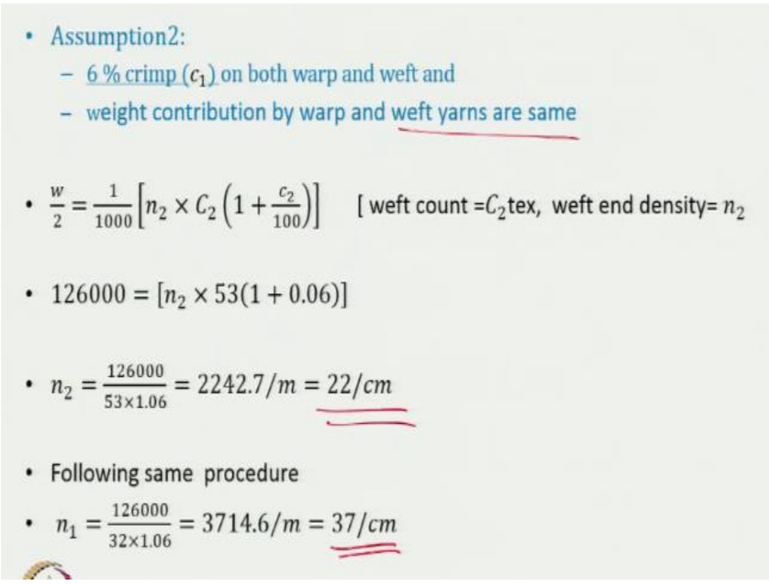

The next assumption is a 6% crimp, which is typical for cotton fabrics. Crimp in both warp and weft can vary significantly, and it is challenging to predict the exact value in advance. However, based on numerous published articles and the available data, a typical crimp value of 6% for both the warp and weft has been estimated. In this case, the weight contribution of the warp and weft remains the same. These are the two assumptions, and based on these, the equation can be expressed as

$$\frac{w}{2} = \frac{1}{1000}\left[n_2 \times C_2 \left(1 + \frac{c_2}{100}\right)\right]$$

where 'c_2' represents the crimp value and 'C_2' is the tex value of the yarn. Using this equation, the value of 'n_2' can be determined, which comes out to be 22 yarns per centimetre. The same procedure is used to calculate the value of 'n_2' which results in 37 yarns per centimetre.

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No.	Fabric	Thickness (mm)	Weight (g/m²)	Fractional cover	Diameter (mm)		Thread Density (per cm)		Linear density (Tex)	
					Warp	Weft	Warp	Weft	Warp	Weft
Actual*	Cotton	0.59	252	0.98	0.21	0.29	44	23	30 (OE)	49 (OE)
Initial Estimates		No crimp			0.214	0.277	39	24	32	53
		6% crimp on both warp and weft			0.214	0.277	37	22	32	53

Estimated values are quite close to actual values

Since crimp is difficult to know in advance assumption has to be made

Ref: Vinay Midha's Ph. D thesis

With these two assumptions, if we proceed further, it is observed that the actual values are provided in the first row of the table. For the cotton fabric, the thickness, weight, fractional cover, and diameters of the warp and weft are all given. The thread densities (warp and weft) and the linear densities of both yarns (warp and weft) are also stated. These are the actual values used in the construction of this fabric.

The calculations we made based on the two assumptions of no crimp and 6% crimp provide the corresponding values for thread density and linear density, which are required for fabric production. We obtained 53, 32, 24, and 39 for the no crimp assumption, where the thread densities for warp and weft are 39 and 24. When we compare these values to the actual ones, the actual thread density values are 44 and 23, and the calculated values are very close. Similarly, the actual values for linear densities are 30 and 49, and the calculated values are 32 and 53, again showing close alignment.

If the 6% crimp assumption is applied, some values change. The linear density values remain the same, but the thread density changes from 23 to 22 (previously calculated as 24) and 39 to 37. Comparing these to the actual values of 44 for one and 23 for the other, it is found that our calculated values of 37 and 22 are reasonably close to the actual ones. This demonstrates that using a procedure like this, based on certain assumptions, allows us to arrive at values that are relatively or quite close, though not exact, to the actual measurements.

So, for every designer, based on these estimates, the next step is to produce and test the fabric, much like creating a prototype. The process starts with a prototype, where you create the fabric based on your initial estimates and then check if it meets the required specifications. If it does not meet the requirements, relative adjustments are made to the parameters. Some parameters will need to be increased, while others may need to be decreased to ensure the fabric meets the required specifications. These initial estimates are just a starting point, not the final values. A similar approach can be followed for other cases, but we must recognize that specific challenges exist, such as the difficulty of accurately estimating crimp.

Based on extensive data collection, a designer can only estimate that a certain typical crimp value can be obtained when using a particular loom with a specific type of yarn. Therefore, designers need to have a comprehensive data bank to make informed and careful choices about parameters rather than selecting them arbitrarily. Thank you.