Erasmus+

Engineering Skills

Contents

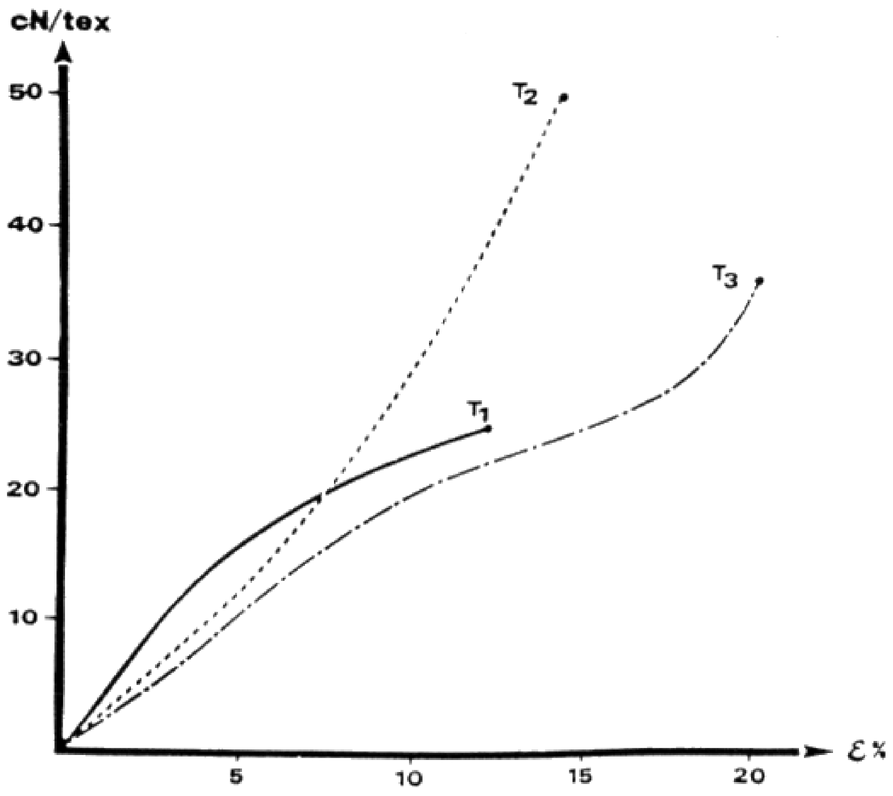
Engineering skills, product development and problem shooting

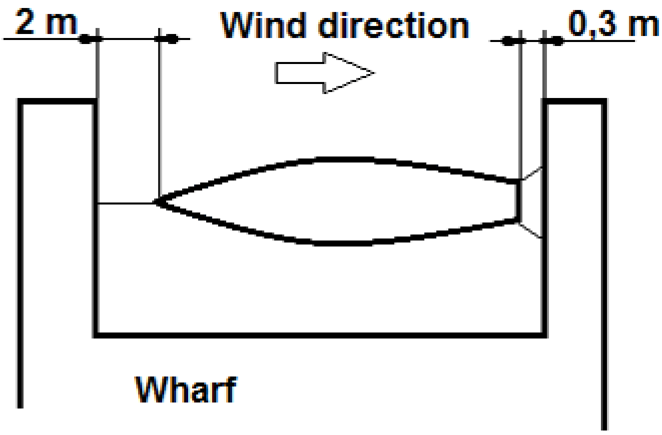
Engineering is the application of skills in math, physics and science along with knowledge about society and applications in order to improve life for society. It means solving problems and both gradually and incrementally improving performance or developing new technologies. For a textile engineer there are numerous branches where a graduate may work and utilise her/his abilities. This session offers a few simplified examples of engineering tasks/exercises.

The following four examples are intended as illustrations of the kind of trouble shooting and analytical skills and methodological abilities that will make life easy for you at our Master's programme.

Rope selection

A boat is anchored at a wharf in accordance with the figure below. Which of the following three hawser (rope) selections will make the boat endure a storm that generates a 50 kN tensile load to the prow hawser.




2 m
Wind direction
0,3 m
Wharf

Consider the following three options:

T1 = 160 ktex, **T2** = 120 ktex, **T3** = 190 ktex, with tensile curves as:

Condition 1: the boat must not hit the rear wharf, i.e. the prow hawser must not elongate more than 0.3 m, which is equivalent to 0.3 m/ 2 m = 15 % strain.

Condition 2: the prow hawser must not break, meaning that the normal stress of the prow hawser must not exceed its tenacity, which are the ultimate stress of the individual graphs.

Analyse each one of the three options.

T1

According to the graph the strain at break of T1 is below the 15%. Hence, it will not elongate to the extent that the rear hits the wharf. C1 – check! Will T1 endure the 50 kN? The graph tells that T1 has a tenacity of 25 cN/tex and the linear density of T1 is 160 ktex meaning that its ultimate load is $25 \cdot 10^{2} \cdot 160 \cdot 10^{3}$ N = 40 kN, which is below the force generated by the storm. Thus, T1 will break. C2 – not fulfilled!

T2

According to the graph the strain at break of T2 is close to 15%. There is a risk that it may elongate too much. How about the strength? The graph tells that a 50 cN/tex tenacity and its 120 ktex linear density gives it an ultimate load of 60 kN which is higher than the 50 kN from the storm. Hence, once it faces the 50 kN it will not reach its ultimate strain and both C1 & C2 are fulfilled.

T3

According to the graph it is much tougher than the 15% and has a tenacity of about 37 cN/tex, which gives an ultimate load of $37 \cdot 10^{2} \cdot 190 \cdot 10^{3}$ N = 70.3 kN. The hawser will not break but how long will it elongate at 50 kN load? The graph suggests that 15% strain generates a 25 cN/tex stress in T3, which is equivalent to $25 \cdot 10^{2} \cdot 190 \cdot 10^{3}$ N = 47.5 kN. Thus the hawser will elongate more than 0.3 m once applied to 50 kN.

[See answers at the end of resource]

The rope bridge

A bridge made out of two parallel, high tenacity polyester ropes connected by wooden boards spans a 12m wide canyon.

1. What thickness (linear density) of rope is needed to accept a maximum 0.3 m deflection at a total 250 kg weight (bridge included)?
2. What will the safety factor for the bridge be?

High tenacity polyester material parameters	
Specific Modulus	700 - 800 cN/tex
Specific Tenacity	78 - 80 cN/tex
Density	1.39 g/cm3
Extension to break	13 - 16%
Tensile Modulus	9 - 11 GPa
Shrinkage @ 100oC	1.5 - 6%
Tensile Strength	0.9 - 1.1 GPa

[See answers at the end of resource]

Product development

You are given the task to develop clothes to be used in a surgical theatre by staff who will be in direct contact with patients.

1. Define the product, or if you so wish; set of products. What is the intended use? What tasks should they fulfil?
2. What requirements should the product/set of products fulfil to fit with the product definition? Make sure your requirements are quantitative and verifiable. What test methods are suitable for verification?
3. Come up with a draft for a prototype design that is in line with steps 1 and 2.

[See answers at the end of resource]

Concept design

You are tasked with designing a concept antistatic woven polyester car seat fabric. Feel free to use any technology as long as it is not potentially harmful to users. The product should also provide at least 20 years of service time. What do you recommend? Appropriate considerations should be made.

[See answers at the end of resource]

Answers

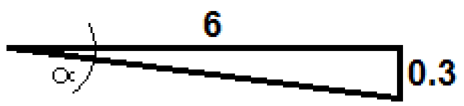
Rope selection

It is only **T2** that will endure the predicted 50 kN load without excessive elongation while T1 will break and T3 will elongate so much that the rear of the boat will hit the wharf.

The rope bridge

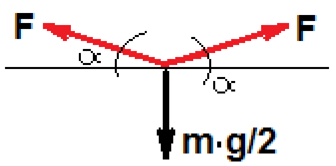
We consider the material as linear elastic. The 0.3 m deflection is connected to a rope elongation that is determined by the Specific modulus and the cross-sectional area of the rope. We have to use the less favourable values of the table. Hence, a Specific Modulus of 700 cN/tex = 7 N/tex.

What will the strain be at 0.3 m deflection?   Consider the triangle:



The hypotenuse compared to the half-length of the bridge, using Pythagoras, gives a 0.125% strain and $\tan \alpha = 0.3/6$ and since α is small $\tan \alpha = \alpha \Leftrightarrow \alpha = 0.05$ rad.

In case the mass m = 250 kg works in the middle of the bridge, the following free body diagram for one of the ropes can be drawn:



Vertical force equilibrium tells that $2F \sin \alpha - mg/2 = 0 \Leftrightarrow F = mg/4\alpha$

Using the definition of normal stress put into Hooke's law tells that the linear density of the rope should be $F/E\varepsilon = mg/4\alpha E\varepsilon = 1.4$ Mtex//

The second part of the question - to check the safety factor means that we should look at the ratio of the bridge's ultimate strength minus the actual stress divided by the actual stress. The actual stress is given by Hooke's law; i.e. $\sigma_{250\ kg} = E\varepsilon = 7 \cdot 0.00125 = 0.875$ cN/tex.

Hence the safety factor becomes (78-0.875)/0.875 = 88 times// That sure is comforting!!

Product development

1. Surgical garments should provide the surgical staff shelter, comfort (thermal, smoothness and mobility), they should be an efficient barrier to contaminants without transferring microbiological species, releasing wear debris or other particles to the patient. The garments are not intended for patients.
2. In order to give shelter, the garments should be thick and dense enough to be non-transparent – this may be tested. Also the barrier properties as well as the smoothness and mobility are linked to the thickness, denseness and pliability. The garments should come in a range of sizes to fit staff.

   Comfort properties may be tested by a Kawabata system or experienced by a test panel – potentially a combination of the two.

   Wear and debris generation can be assessed by Martindale testing – ISO 12945-2:2000.

   To avoid disease transfer from fabric to patient the garments must stand at least 70°C with a shrinking limit – e.g. ISO 3759:2011 is applicable.

   The garments should have neutral colours with good colour fastness where stains become visible but not extra obvious – applicable colour fastness standard method.

   Eventually, when investigated further the requirements should materialize into a requirement specification where each requirement has a testing method and release limits.
3. Pairs of trousers and shirts in a range of sizes to fit all staff and genders.

They are both based on polyester/Lyocell staple fibre yarn twill weaves of about 200 g/m2 area weight.

Trousers should have drawstring round the waist and cuffs at the leg endings to accommodate skin, hair and other organic debris.

The shirts should have short sleeves both to facilitate individual fit, to minimize wear between the lower arm and sleeve and to enable disinfection of the lower arms. It should be collarless, round neck and long enough to overlap the waist drawstring with a good margin.

Neither trousers nor shirts should have pockets where potentially contaminated or other hazardous objects such as cell phones or keys can be kept.

Garments should be turquois or similar light blue colour since it the most popular colour that signals freshness and cleanness.

Concept design

In order to make the fabric antistatic its electrical conductivity needs improvement. This can be accomplished in many different ways. The ready-made upholstery may be treated with an antistatic finishing treatment. However, it may be difficult to accomplish good adhesion between the fabric and finishing agent that ensures high durability. A finishing treatment may also reduce wicking and permeability of the fabric that compromises comfort properties.

Another way is to incorporate electrically conducting yarns in the weaves by i) ready-made conducting yarns or ii) spinning blended polyester and conducting staple fibre yarns or iii) by adding a conducting monofilament or multifilament in the core of the polyester yarn or iv) winding a conducting mono- or multifilament around a polyester yarn.

These four options offer pros and cons. In all cases tensile behaviour mismatch has to be assessed and if it is considerable it needs to be managed.

It is particularly sensitive if a stiff mono- or multifilament is put in the core of the yarn since it will make it much stiffer than the pure polyester staple fibre yarn. Hence the weave will be much less flexible than the reference weave. It is also difficult for the core filaments to form a conducting grid since the sheath staple fibres isolate them from one another. These considerations more or less disqualify option iii).

Option i) with electrically conducting yarn is challenging in terms of stiffness matching and weave design to accomplish a fabric that resembles the reference weave.

When it comes to option ii) the fibre diameters need matching to get a smooth yarn and the fraction of conducting fibres can probably be around 20% to reach the percolation threshold where both the yarn and the fabric reaches conductivity. Here modest stiffness mismatch should not be a big issue since the yarn twist will mitigate its effects.

For option iv) the big issue is probably whether the winded outer conductor can be visibly hidden and if there is a risk for it to be grabbed by or hooked up on objects that may injure it and reduce the conductivity of the upholstery.

In summary, I would make demonstrators of concepts ii) and iv) since they have the best chance of creating weaves that resemble the reference upholstery. The most durable option is concept ii) where the conducting fibres are embedded and thereby also well protected. If I could find conducting staple fibres of relevant titer, made conducting e.g. by incorporation of TiO_2 during compounding, this would be my first option.