Lighter-Than-Air Systems
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Lecture - 63
Envelope Materials – Part III

(Refer Slide Time: 00:15)

Alright, let us look at some common type of inflatable fabrics. Very easily you will see single ply fabrics. One can have a single ply, single ply means a single material, a uniform material. It can have coating on both sides or it can have coating on one side and an adhesive film on the other side and this adhesive film is applied and then heat sealed. So, there is a company in Nasik called as Entremonde Polycoaters. So, we have visited that company once.

They showed us all these processes. So, at some point of time if we get an opportunity, we might have a class trip to this company. If they open the factory to us, we will like to go and visit and see how they do the coating of various fabrics and how they test them. So, they are the ones who supply the fabric to the airship and aerostat operators globally as well as to the DRDO laboratories in India, they are using their services for coating of fabric.

So, let us see if we can arrange a trip where we can see these fabrics. There is another company in Mumbai which develops the basic fabric. They do not have any coating facility, but they develop basic fabric. So, maybe we can invite them once to give a talk on this special topic. I

do not know where their factory is, I have not visited their factory, but it will be interesting to go and see how these things are done.

I will welcome all of you to visit LTA lab and you can see the fabrics that we have already worked with. We have already done experimentation with around 6 different types of fabrics. I will be showcasing to you very soon some of our fabrics. So, you could have single ply fabrics with coating on both sides or you could have coating only on one side or we may have coating on one side and film on the other side.

Then you could also have laminates of coated fabric. So, there are two fabrics which are joined together. Then we can have laminates of films and strength bearing fabric, so 3 types. So central ember, one film on top, one film one bottom. Now, what is the difference between a film and a lamina or a film and a fabric? Essentially film is a very very thin fabric. It is the same thing, but when the thickness is very less we call it as a film rather than a fabric. You could have 2 ply fabric woven and non-woven with coating on both sides.

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Here is an example. This slide is only meant to give you some kind of a mental picture of the weights. How much does it weigh? So, a typical load bearing member would be around 100 grams per square meter 100 GSM. You coat it on outside and inside. There will be a difference in the coating required. The coating that is required for providing the environmental protection weighs more than the coating that is required for gas retention.

So, around 92 GSM or almost double the weight is created by the coating from outside and nearly half the weight is added by coating from inside. So, the typical weight will come to around 234 grams per square meter with a plus minus 20% variation. And you can notice that the load bearing member is nearly half 43%, outside is 40%, inside is 20%**.** This is a typical distribution of a double coated single ply fabric.

These numbers have come from actual data. I am not able to reveal the details of the material, but I can tell you that this is a standard data for a fabric that is available.

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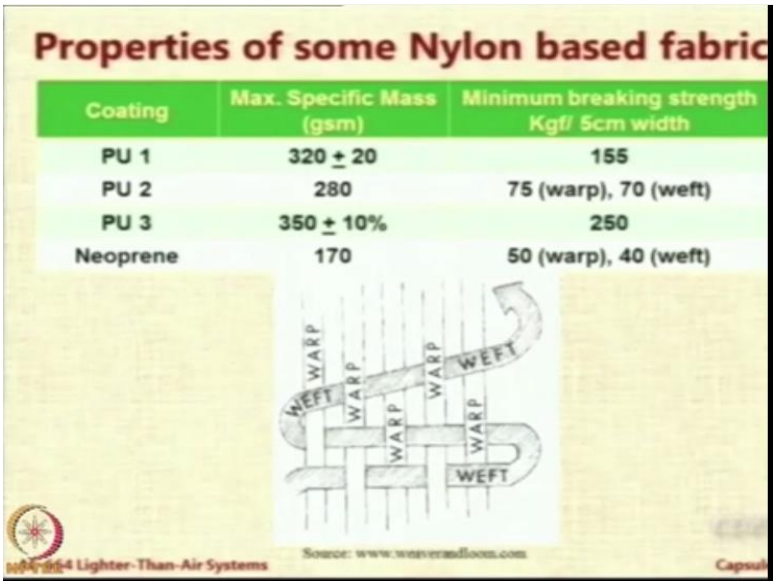

Now, here is a picture which explains to you what is meant by the warp direction and what it meant by the weft direction. In a typical woven fabric we use long longitudinal fabrics and then you weave them with lateral fabrics and the lateral fabrics normally are continuous which go along the width. So they are called as the weft which are used by the weavers and the warp is along the length.

So, as you can see the strength along the warp direction is generally slightly higher than the strength along the weft direction. So if you use different types of coatings, you can see look at the first fabric which has got the PU 1 coating. The GSM is very high, it is 320 plus minus 20, but the strength is 155. So, 155 kilogram will be required by a 5 centimeter strip to create strain such that the fabric starts elongating.

It may not break, but it may just keep elongating endlessly and then there will be a neck formation and then it will tear. So, a lighter fabric PU 2 it has got 280 and the strength is almost

half in both directions. Then you could have PU 3, it is heavier fabric and hence the strength is also larger. If you look at neoprene which is basically a lightweight compound, it weighs half, but the strength is also much lower.

So, generally there is a trade off between the strength that you can get and the weight. So, you have to design it very carefully. When you select a fabric, you have to look at both depth dimensions. So, what we do normally is we first calculate how much strength is needed, I mean what are the loads coming on the fabric. Then we get a factor of safety and then we look at the load carrying capacity of the fabric.

And we assume that this capacity will be reduced slightly further because of imperfections or some other issues. So, either you can inflate the factor of safety or you can put another extra mile is the same thing. So, the factor of safety normally 5, typically we use factor of safety of 5 in fabrics because of degradation with atmosphere changes. The degradation because of the fabrication imperfections is quite large.

So, in an aircraft aluminum structure because the behavior is predictable to some extent, we use lower factor of safety. Whenever you have a less predictability, you have higher factor of safety is between 4 to 5 for the fabrics of a LTA system

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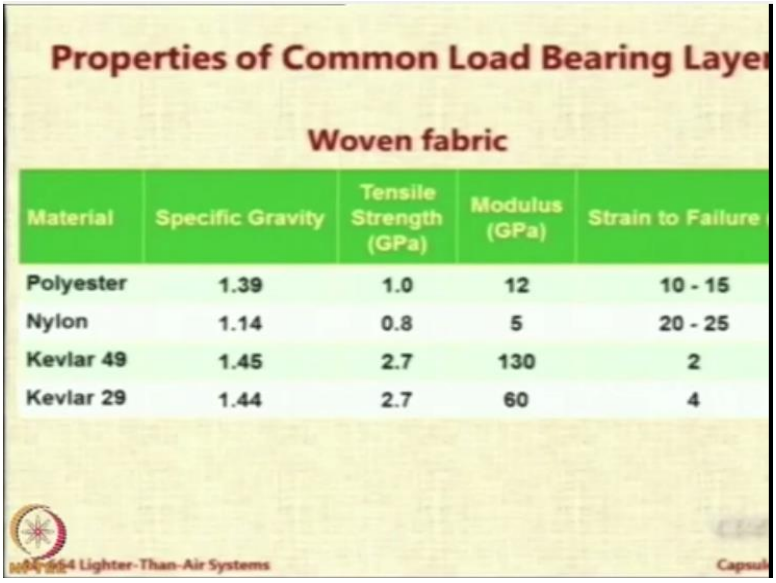

If you can look at the load bearing layer, these are 4 candidates for the load bearing layer. Polyester fabric is very commonly used including for shirting and suiting. The same fabric can also be used for base load carrying member of the fabric. So, you can see that it has a tensile

strength of 1 Giga Pascal. And if you use nylon, nylon has got a lower specific gravity. That means it is lesser in weight, it will weigh less, but the strength also will reduce.

Kevlar is a very interesting fabric. Although it is a bit heavier from 1.39 to 1.45, but tensile strength is more than two and a half to three times. So that is why tensile modulus is very high. So therefore Kevlar is one very commonly available fabric. However, Kevlar is very expensive because it is a proprietary fabric. So if you want to make an airship with Kevlar, then you have to have deep pockets, it is going to be expensive. So in academic institutes we cannot afford it unless some donor uses kevlar fabric, we cannot afford it.

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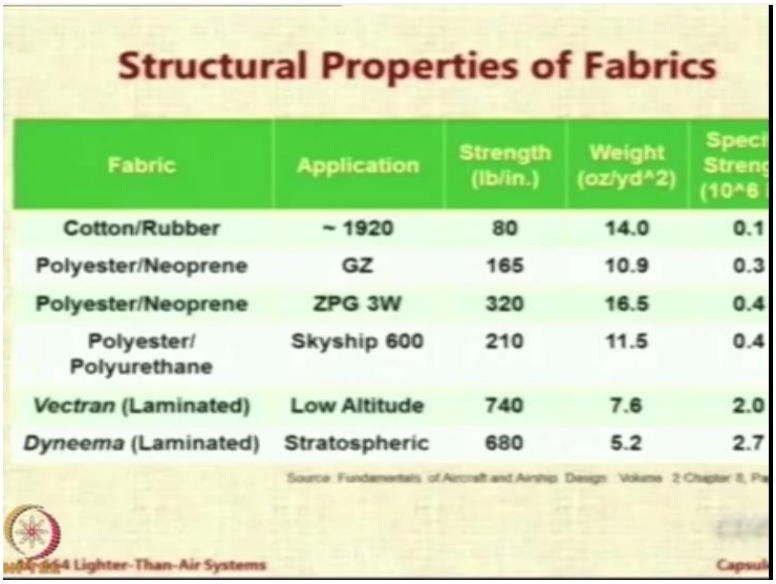

I am coming to that. There are many exotic fabrics Depron, Vectran, Dyneema these are all trade names of fabrics which have been created by companies like DuPont, especially for LTA applications. So, they can be used. But how much coating has to be put on top and bottom depends on the application or the depends on the situation where you are going to use it. For example, if you look at cotton and rubber, it was used in the early 20s for the old airships.

The strength is only 80 pounds per inch. The weight of the fabric, I have kept this intentionally in the non-standard units because when we look at the data in open literature, you will find all kinds of units, grams per square meter is used by us mostly. But if you go to the west in US for example, you will find ounce per square yard as a very commonly used parameter or a unit for measuring the weight of the fabric.

One can easily convert one to the other by adding the conversion factors. So we see in this particular figure that Dyneema, which is a special purpose laminated fabric aimed for stratospheric airships. Stratospheric airships are still being designed. None of them have been deployed for a long time for actual application. The only long term deployment of a test balloon was by a company in Texas, but that was also not like a functional system.

It was just to test that and airship can be taken to a height of around 12,000 feet and kept there for 8 to 10 to 12 hours. So, these are very large sized. The typical lengths are 150 meters, 200 meters in length. So, one of my students is doing a research on design of high altitude airship, so he will be coming and making a presentation on the technology of higher durations. We will discuss it a little bit later.

So, here are some applications. So, GZ or GZ is one airship which was used by the Second World War. It was very popular in Second World War. You can see that it has polyester and neoprene as a combination. And then ZPG 3W are the airships which came almost towards the mid 60s to 70s. They used a slightly better fabric but it is very heavy. Skyship 600 is the airship which revived LTA technology in the modern times and that is a question in the quiz also.

That particular airship you can see the fabric is only 210 GSM. So, it can be easily concluded that the coming back of airships has been mainly possible because of the developments in material technology allowing us low weight better quality fabrics compared to the past. So, from 320 it has come down to 210. And you can see that that can greatly reduce the self weight and hence it will give you even though the skyship 600 has the envelope of nearly 8000 meter cubes.

It can lift around 6 to 7 passengers. And then Vectran, now Vectran is a very strong fabric 740 pounds per square inch. So this is recommended for low altitude applications. And you can see that even though the strength is so large, the self weight is only 7.6 ounce per square yard. And stratospheric airships require very strong fabrics and the weight is further.

And then the Japanese have come up with a new material called PVA and some very long name that has got much better properties than even Dyneema and that is being recommended. So, I will leave it to the student to come and talk about that in more detail.