Lighter-Than-Air Systems
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Lecture - 62
Envelope Materials – Part II

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Now, the envelope materials have come over the years by a large amount of R & D in textiles for airships. So, we call them as technical textiles, textiles which are not used for shirting or wearing but they are used for technical applications. So, one could look at natural textiles or synthetic textiles. Then, one could look at laminates which means you take two materials, each of them meets some requirement better but it is poor in the other requirement, now you join them together.

Either we join them by adhesives or you fuse them together as one member, we call this laminates. So, we have two ply laminates where there are two materials for example Tedlar and Mylar. DuPont company has come up with these two proprietary products and a Tedlar Mylar laminate very popular in LTA systems. These laminates normally have two components that is one component which is the load bearing component.

And the other component is for the gas retention because leakage of the LTA gas is a very important requirement for the envelopes. There could also be another layer for the weather resistance. So, one could have Nylon 66 as the central material which is reasonably good in load carrying and lightweight. You can coat on top of that with a polyurethane coating to provide the resistance to the ultraviolet radiation and you may coat inside with polyvinyl or PV coating to provide gas retention.

So, it is very common to see as a load bearing member coated on both sides or laminated by other components. But while doing this, we should be very careful about two things. One is the delamination which can happen by exposure to atmosphere, exposure to moisture, temperature or it can happen because of the weathering with time. Sometimes some materials are prone to delamination when you subject them to folding and unfolding.

So, a lot of testing has to be done to ensure that the material works in the operating conditions. Then in between the gas retention and load bearing component and the other two components, we need to have some adhesive or bonding compound. Now let us see the properties of the materials. When you want to classify the property from a technical sense you have to come up with some numerical values, you have to come up with some numbers.

So one very standard number are the stress strain properties. Then we also look at the biaxal loading that means we load the fabric along the warp and along the weft and see the point at which it fails. Then one will look at shear because at any point on the fabric there actually is going to be lateral shear loading. Permeability as I mentioned is a very important requirement and then tear strength. So for all these parameters, you have numerical values available.

It is one thing to say that the fabric should have good permeability characteristics, but how do you quantify? You quantify by saying so many liters per square meter per day. It is good to say that it will be strong but strong means what? So, the strength of a typical fabric is measured in the load required for failure on a strip of 5 centimeter width. So we get the numbers as kilonewtons or Newtons divided by 5 cm.

So understand that it means the strip is not 1 cm because it is very difficult to hold a strip of 1 cm. So 5 centimeter width strip this is the industry standard. So you create laminates, you create pieces of some length and 5 centimeter width, grip it into a machine and then apply the load and calculate at which it fails.

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So let us see permeability, degradation, stress-strain properties, tear resistance, flexural properties these are the properties which have to be considered.

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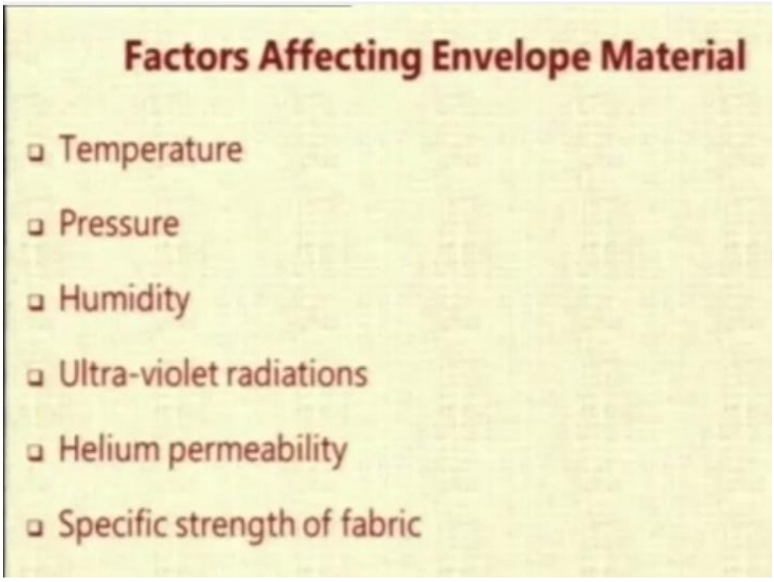

Let us have a look at what are the various factors that affect the properties of the material. It is obvious that temperature to which this particular item is subjected will play a major role. It could be positive temperature, it could be negative temperature, but more important will be the temperature variation. If you are going to subject this fabric to only a small positive range or even a small negative range, it is easy.

But if you say that the night temperature can fall to -15 degrees and it can be + 30 in the day, then the diurnal temperature range becomes very large and that can really affect the properties of the fabric. The second property of the fabric is the pressure. Now, when I say pressure, I actually do not mean the ambient pressure, I basically mean the pressure difference, the pressure inside and pressure outside the difference between these two.

So obviously larger the difference in the pressure larger is going to be stress imposed onto the fabric. Humidity is a very big factor. We sometimes ignore this factor, but as we have seen although the numerical value of effect of humidity onto the lift generation is only 2-3% , so it might be okay for a first cut estimate to ignore it. But the effect of humidity on the strength of the fabric is extremely large and one has to quantify this number by doing experiments.

UV radiation are another killers which can grossly lower the strength of the fabric after sustained exposure. Permeability we have already seen and we already seen specific strength.

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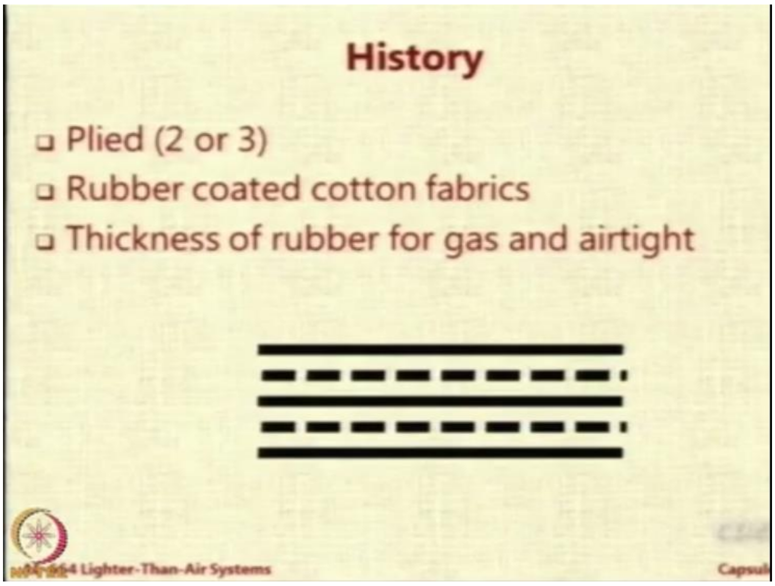

Now let us look at a little bit of historical factors. When we started using these LTA systems in early years 1920s and 1930s, at that time we did not have the benefit of material technology that we have today. So many of these special fabrics which we see today like Kevlar for example were not there at that time. So, what was used by people was things like naturally occurring compounds, either cotton or rubber.

Why is that people used to stitch those fabric and then dope it with some kind of liquid to allow it to have permeability below extracted limits. So, there are instances in history of rubber coated fabrics. First there was the basic was done by people using cotton because cotton was the only fabric available in large quantities, but cotton is permeable. Cotton can take some strength, but it is permeable. So you have to coat it with something.

This coating of cotton or any other base fabric to give it some desirable properties is called a doping. So doped fabrics were used, Hindenburg for example was doped with the aluminum oxide and that was a dangerous thing they did because aluminum oxide as you know now is very highly combustible. So, if you dope a fabric with aluminum oxide, it gives it a good metallic sheen and it also gives better permeability.

But any exposure to spark will cause a disastrous effect of ignition. So rubber coated cotton fabrics were very popular in the beginning of LTA history and they said that if we cannot do anything if we cannot dope it or if we cannot provide anything on top the best thing is to use thick rubber. So the thicker the rubber, the less will be the permeability, but unfortunately the higher also will be the weight.

So, you will see many LTA systems which are made up of rubber, but it is thick rubber. So there was one student from our civil engineering department who wants to use an aerostat for weather monitoring. So he has imported one small balloon and that balloon is nothing but isopropyl rubber. It expands to around 5.5 feet diameter give around 650 grams of lift, net lift. So he wants to mount the camera below it and other things on the tether.

But the material is rubber and they say that the maximum life of this particular balloon for this purpose is 4 or 5 inflations. If you inflate it and deflate it, after 4 or 5 inflation deflation cycle they say that we cannot guarantee it will hold the gas. So it is kind of a disposable material and it is quiet heavy but this is one way in which people can even some students sitting in this class are looking at a nanoblimp they also use rubber that is fine.

There the purpose of using rubber for containing the gas is that it is a quick and disposable material, you do not have to fabricate the envelope, it is easily available and there is a design challenge to make a very small airship which can operate. But rubber has its own benefits, it is waterproof, it can also give good permeability to some extent, but you know it is not at all able to take any external pointed loads.

It starts developing leaks very soon, it can get punctured very easily. Then some people came up with using paraffin for coating the inner fabric for gas retention. So people experimented with various fabrics for what you see. The sketch that you see here is that of three fabrics for different applications, which are joined together by adhesive.

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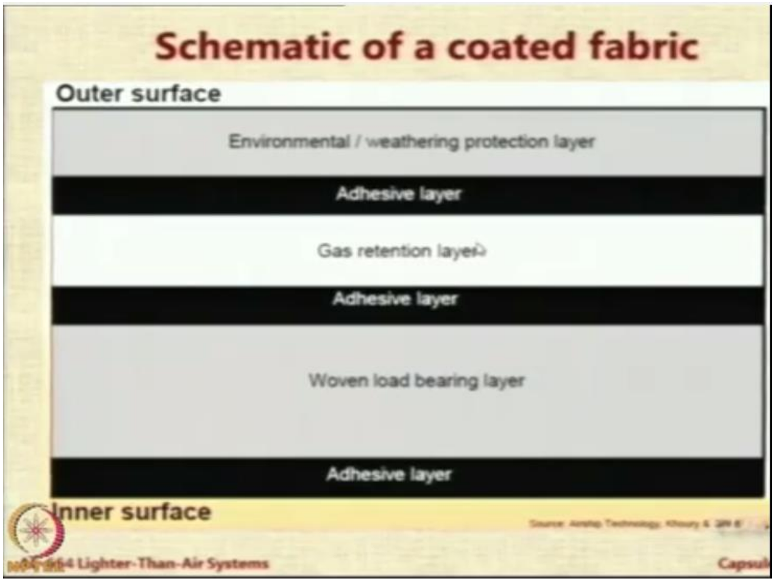

Now, today if you go to the market and look for some standard airship fabric which is used for carrying passenger carrying airships, you will find that the laminate consists of one outer layer for environmental production and weathering, that there is an adhesive, there is a layer for gas retention, then there is an adhesive and then there is a load bearing layer and then there is an adhesive layer.

So, I think this figure is not correct. The adhesive layer should be changed. There has to be adhesive layer between, I think this gas retention layer will actually should come down. The gas retention layer should be inside the fabric. So, this is a mistake which I will correct and I will upload the correct one.

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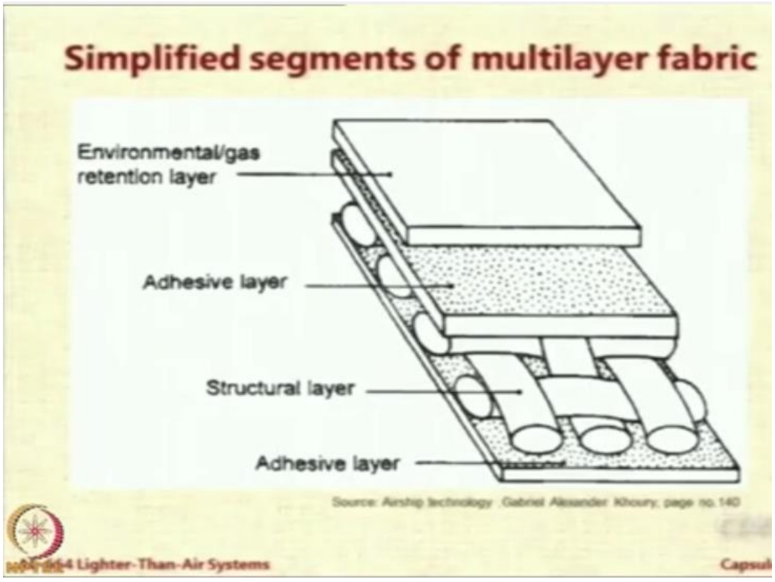

Here is a sketch of the kind of fabric which is typically used nowadays. So, you have a structural layer mostly Nylon 66 which is consisting of woven fabrics. So, because it is woven, the fabric can give you bidirectional strength and these fibers are entwined with each other in such a manner that the load is transmitted along the entire surface.

Above and below you have the adhesive layer and then you attach the environmental or gas retention layer and you can put a layer inside for the other applications. So, this is one example of how fabric structure can be used nowadays.

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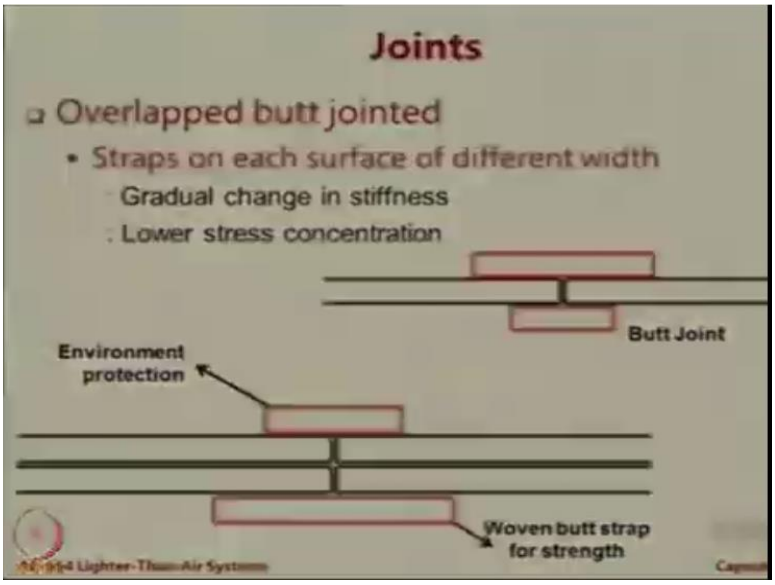

Another place which is of real concern is joints when you join the fabric together. So, how do you join fabrics together? You could do it by adhesives, you could do it by thermal welding that is by fusing the material together by heat if it is heat joinable. You could also do it by what is called the dielectric heating or radiofrequency heating. So, we have in our laboratory a machine that uses RF sealing Radio Frequency sealing.

So, what this machine does is basically it sends signal of very high frequency through the fabric. So, what you do is you take two fabric pieces to the joined, you put them in an overlap and then there are brass dyes which are matching with the contour of the fabric. You put a brass dye on top and on the bottom so that there is complete dielectric transfer and then you have a very high frequency oscillator through which you send a high frequency input.

So, what happens is that the water molecules present inside the fabric they start vibrating, there is a resonancy, so they start vibrating the resonant frequency that vibration generates heat. And that heat is enough to melt the fabric and fuse it together because we have these dyes from top and bottom it does not allow this melt to come out. So, what happens is that you have a fuse joint and our testing has shown that the joint is stronger than the fabric.

But there are limitations. Number one, it can only be used for those fabric materials which have water molecules inside and not all materials have it. Now PVC or polyvinyl chloride is one such material and hence it can be used for joining sheets of PVC which is what we have done in most of our early airships. We have made them using PVC fabric, but our fabric is not just PVC it has got PVC with some coating.

Now, PVC itself has got a reasonably good gas retention capability. The desirable value of gas retention is less than 1 liters per square meter per day, PVC in our testing has shown 2.75 or 3. So, it is three times more leakage, it is actually bad. So, if I want to use this airship or aerostat outside for a long time, I will not be able to use it, but the advantage is it is easily available.

You can simply go to a market and buy it because you must have seen these flex banners they are all PVC with some netting inside, but they are heavy. A typical flex banner will weigh around 350 to 400 grams per square meter. But if I use simple PVC sheet, I can bring it down to nearly 140 grams per square meter or GSM. Even 140 is not very low, but it is manageable and we were able to.

The first airship that we made the microairship it used a fabric of 140 GSM and with a length of around 5 meters or 15 feet, we were able to get a net lifting capacity of around 1.5 kg, not bad for an experimentation. So, let us look at the joints. Now one of the most commonly ways of joining LTA fabrics is the Butt joint in which the two fabric pieces are brought and they butt against each other, no overlap.

They just butt right and then on top and the bottom you put these strips, give joining strips they could be adhesive strips if you are going for adhesive coating or they could be dielectric material strip for dielectric heating. But what we do is we normally avoid using the same length because if you use the same length of the butt joints, first of all weight will be increased.

You will be surprised to know, you might say what is the problem with the weight, but interestingly even a small reduction in the width of this trip actually leads to a reduction in the envelope weight a lot. Please understand that every petal is going to be joined with this strip. So, typically how do you make an airship? I have not yet shown you, but I will explain that to you in one of our lectures on RC airship fabrication.

You will see that you make it in pieces and then each piece has to be joined with each other. So, you have to ensure that the strap widths are differ, othewise there can be stress concentration. Otherwise the stiffness will change drastically. Suddenly you will have a very stiff portion and what can happen is it can create a wavy structure in the envelope. So, the stiff areas will not deflect or will resist deformation and the weak areas will deform.

So, when I put high pressure in the envelope, you will find there will be bulges and the shape will look very bad plus it will also not be optimal. So, to lower the stress concentration and to ensure that the fabric has roughly similar distribution of stiffness, we go for different width strips on outside and inside. Then you can also have multilaminate fabrics joined internally by heating or adhesives and on top and bottom you have these strips.

Sometimes there are some researchers what they have done is they have said that our basic fabric is not very strong. It is good for permeability but not very strong and we acquire strength through both strips on the joint. So if they are able to fuse it very nicely with the base fabric, they are able to sustain the loads along the strip. So they simply put a woven back strap for strength and that can take the load. But there is still some debate on whether that is a good way of load distribution on the envelope or it is better to distribute it on the envelope surface.