Lighter-Than-Air Systems
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Lecture – 94
Inputs for Aerostat Design Methodology

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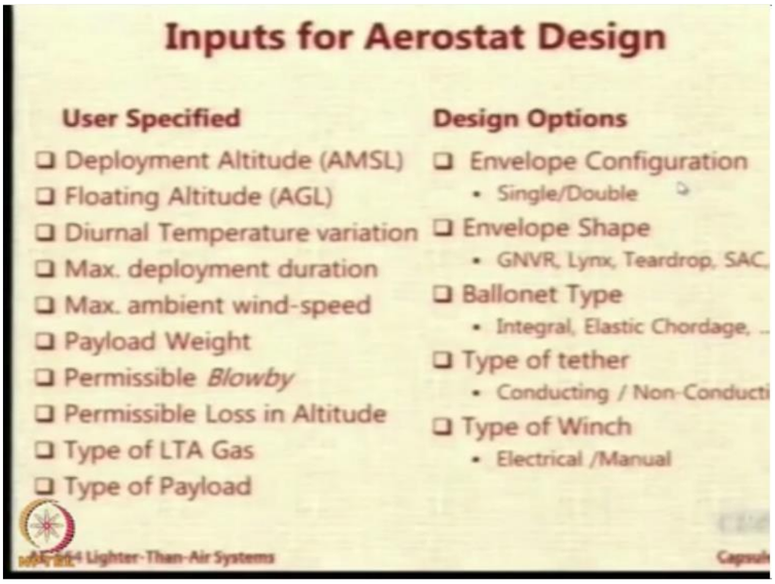

So, what we have done is we have developed a methodology which is now being used all over the world by many people to design aerostats which looks at these important parameters, which either the user will give you based on the operating scenario or you have to assume based on your experience or based on what you think will be needed. Let us look one by one. Deployment altitude above mean sea level, this is the altitude at the ground of the location at which you will deploy.

Are you deploying it in Leh or in Mumbai or Manali that decides the altitude at the ground because the temperature, the pressures will depend on that and the ΔH. The next one is called as the floating altitude or the altitude at which you want the aerostat to float. This is above the ground level. Then the next important thing is called as the diurnal temperature variation. The word diurnal means day and night.

At any location, you know that there is some maximum daytime temperature and some minimum nighttime temperature. This difference +15 in the day and –5 in the night that means 20 degrees is the temperature difference which this envelope will encounter. And it should not lose buoyancy so much with this temperature change or it should not gain so much superpressure because of this heating that it starts creating a tension.

So, this delta T also decides the size of the ballonet. So it is important to know that. Obviously in places where we have very high ΔT, you will need a larger ballonet system and hence a bigger envelope for the same payload. And places where temperature remains almost constant let us say night temperature is minimum +5, daytime use maximum +10, then you only 5 degree ΔT, so the ballonet will be small.

The ballonet required will be small at that location. Maximum deployment duration helps you to determine how much extra volume to keep to take care of leakages. Ambient wind-speed will decide the two things. The tether profile will be affected very badly with that very heavily with that and also the load coming on the aerostat because under heavy wind conditions, you will have heavy loads and your tether should be able to withstand that load.

So, while selecting the tether, you will be able to estimate the tension coming in hence you might say I cannot use this, I have to use that, that will be heavier than this one. So this will play a role here. Payload weight obviously this is what we have to carry. Permissible blowby, so what is meant by blowby? Blowby is a technical term in aerostat technology which is basically the horizontal displacement of the aerostat because of winds.

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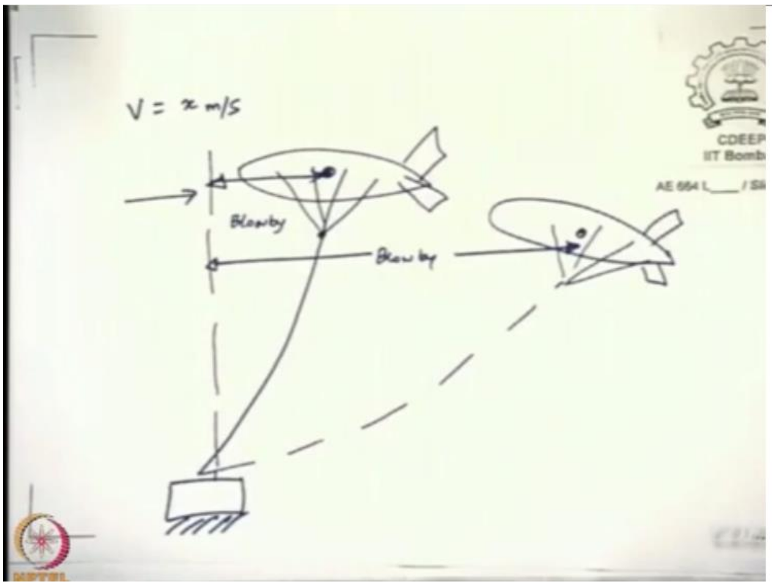

So for example if I can just sketch a smaller aerostat and show you let us say this is our aerostat system. So let us say this is our aerostat system during some wind condition. Let us say V = x meters per second ambient wind. So, from the vertical take any reference point, let us say we take the CG for example, then this distance is called as blowby. Now as the wind speed increases and suppose the tether length is kept fixed, what will happen?

The same balloon will actually come maybe like this, correct. The balloon because the length is being kept fixed, so therefore there will be a loss in the altitude. So, the blowby will increase. Now suppose I do not want to allow any loss in the altitude, what could be the reason? I do not want to allow any loss in the altitude because if I lose altitude my camera will not point at the place where I wanted to point or my payload will not work.

Let us say I want to collect air samples at height of 1 kilometer near a chimney for measuring the pollution levels you cannot say no, there is blowby you can take sample at 500 meters. No, I want at 1 kilometer. So what will you do? So, you will release tether. When you fly a kite you do that right, *dheel* that, you are right. Why do you do? You give it because you want it to go to a longer distance or stay at high altitude but the wind is pulling it, so you release tether.

Same thing will happen here. The difference is in a kite, if you release more rope or thread it is you who is flying it. So you are facing the tension in your hand. Is it not true that when the wind is very heavy, you have to hold it more tightly, sometimes it just pulls you also, sometimes your hands get cut because it is so harsh it is pulling you. So in the case of tether what will happen is that the weight of the tether is going to be carried by the aerostat envelope.

And the weight of the tether will be subtracted from the payload carrying capacity, is not it? Because the balloon has some net buoyant lift. So, if I want to carry 300 kilograms of payload and if the tether itself is 100 grams, I am actually going to carry 400 grams of payload. If I release another 50 meters of tether actually I will not be able to reach that altitude. So, in a scenario when the tether length is fixed and there is blowby or wind increase, blowby causes lower altitude.

If the altitude needs to be maintained, you have to release more tether. This results in reduction in payload carrying capacity because the weight of the additional tether is also going to eat away the lifting force. So, somebody might say that look I am operating this aerostat for aerial photography of the IPL match. Therefore, the blowby I will allow is only 20 meters because after that it will start looking at the hockey match not at the cricket match, it will point somewhere else.

So, the user might say permissible blowby is only so many meters, so then you have to do the calculations to find out how do I ensure. Then the next one is permissible loss in altitude. That means as I said you want to deploy the aerostat at someplace for some work, how much loss in altitude because of temperature variation or because of any other reason because the loss of gas are you permitting?

So in 14 days, it should not lose height more than 10 meters this is what somebody might say. And in these 14 days, the maximum delta T between daytime and night temperature can be 30 degrees. So with that much ΔT, it should not come down below some distance or some altitude that could be a requirement. Type of the LTA gas, somebody might say hydrogen, somebody might say no we cannot use hydrogen it is unsafe, we will use helium.

Somebody might say no, I want to make a low cost aerostat, so can we use steam or some other LTA gas? That will affect the size of the envelope and everything else. And type of payload, here what I mean is this payload is it self contained from all considerations? That means does it have onboard battery which will power it or you want to send the electrical current for it from the ground?

You could send it by an additional cable along with the tether or you could send it inside the tether if you have a special conducting tether. So conducting tethers are available in which you have a central high strength membrane which is inter woven over the optical signal carrying fibers or LAN cables or electrical cables. If you use a conductive tether, then you can do all ocmmunication, etc., from ground. But this is heavy and this is costly.

If you may say no, I am going to use a small camera with onboard battery, then I can use a simple nylon rope or any other high strength or strong enough rope that will be cheaper, it will be lighter. So, type of payload will determine what kind of tether is permitted. Then there are some design options. These are options which are chosen by the designer based on availability of material.

These are not normally given by the user, user does not know these things. For example, are you going to use a single envelope or a double envelope? That means are you going to have envelope inside the envelope or are you going to have a single envelope and gas inside? So, what could be the positives and negatives of both of these choices? So, why would you use double chamber envelope?

“Professor - student conversation starts.” Lesser leakage. Lesser leakage rate. Why because so you are saying instead of one you use two membranes, so the leakage will be through one and then through the other one. That is not that reason, but there is a related reason. Yeah you are right. What you say will happen, but we do not put double chamber because of that. The atmospheric conditions.

Yes, the atmospheric conditions like mainly loss of pressure. So how will double chamber help? It will help in give a protective envelope. So it is you are talking about outer covering as a protective envelope over the aerostat. This could be one reason. **“Professor - student conversation ends.”** Basically, I will tell you the basic reason. The issue is this the requirements from the envelope material are very stringent and very contradictory.

It has to be lightweight as well as strong as well as less permeable to gas as well as able to withstand infrared radiation as well as able to withstand scrubbing and rubbing etc., poor handling because you will put hooks and other things on that so people will pull it. So, some people said can we not have two envelopes? One envelope will take care of only a lightweight gas barrier bag a bladder like, football bladder.

The other one will be like a parachute cloth which can take scrubbing, you can put hooks on that, it can be coated to have infrared property, etc. So some people have gone this path saying delink the requirement into two. One for gas retention and shape generation like a football can come without, tyres are there tubeless tyres and tube tyres, Similarly, you can have a tubeless aerostat and tubed aerostat.

If you have the envelope technology such that one material can take care of all the requirements, then a single chamber is always lighter, may not be cheaper, it will be lighter and easy to handle, one less headache. But if you do not have it, it is better to go for two chambers so that you can delink the requirements of the two. So, the conflicting requirements can be handled by putting two.

So many students when they build their first aerostat they will go for a single chamber because only one envelope to build, less work, but their envelope should be able to take care. So both of them are possible. This decision is taken by the designer. So in some applications, we can say okay let us go for double chamber. For example, the people with whom I work in Brazil, they have gone for a double chamber aerostat.

In fact, they have not made it they are buying it. So they use a double chamber aerostat. But all the aerostat that we have built so far are all single chamber because we were able to get a single material meeting most of our requirements. Envelope shapes; what should be the envelope shape? Now, if you look clearly at the requirements of buoyancy and weight, then the best shape is spherical because for a given volume, a spherical shape has the least surface area therefore least self-weight.

But spherical shape has got very high drag. It has a very high drag coefficient plus if you look at the vortex structure behind a spherical shape, it is very disturbing as compared to slender long shapes, so depending on the application. Now when you go on the highway and you see these small balloons which are used to popularize some trade show or some they have a spherical balloon, which just keeps shaking.

They are not doing any great scientific work, they are just cheap low cost system, they make it spherical. But you will be surprised even very serious scientific work is done sometimes by spherical balloons depending on the application. So, in outer space for example you will say let us use spherical. There is no drag because there is no ambient wind. So, depending on the application you can choose. Other than that many shapes have been suggested by people.

There is one shape called as GNVR about which we will see today very briefly, given by Professor GNV Rao of IISc, Bangalore. This shape is used by all aerostats designed by ADRDE in Agra. Have I spoken to you about the shape? So, you will have some idea. This is one standard shape, it is a good shape. Then we have a shape called Lynx, this has come to us from a company in Russia called as RosAeroSystems.

They have an aerostat called Lynx, so I called this as Lynx shape. They have not given any name to it, I just called it as the Lynx shape. Then there is a teardrop shape, which is the name given the shapes made by a company called TCOM in USA. Interestingly, SAC is a shape given by Space Application Center in Ahmedabad. They also made one small aerostat and whatever shape they used is called as a SAC shape.

So, interestingly, many companies which make aerostats they do not share their shape data with you that is a proprietary item. Just like aircraft manufacturers do not give you the airfoil data, they will say use NACA 0012 or NACA 24013. But if you ask them what is your airfoil, many of them do not reveal. They will say modified so and so airfoil. Similarly, whenever I meet aerostat manufacturer and I talked to them and I say look we work in aerospace, what is your shape.

They smile and they say this is proprietary. We have acquired this over so many years, etc. So getting data about standard shapes is easy, getting data about actual shapes is not easy. So what is the layout? Let us say you have an aerostat from TCOM, the only idea is to take pictures and read the coordinates that is what we do, there is no other option. The ballonet type could be of various types.

One could have integral ballonet or one could have an elastic chordage. This is what we have used in all small aerostats. So on the bottom of the aerostat you put elastic like a shoelace and tighten it a little bit. So, when there is superpressure, the envelope wants to expand the elastic takes the load and allows the expansion. When temperature falls and the aerostat wants to contract, elastic allows it to contract.

So, without disturbing the shape too much, it actually allows it to control the buoyancy to some extent. One very interesting chordage I saw in the aerostat developed by TIFR the SAC shape. They put elastic chordage from the nose to the tail inside. So, their idea is that as the aerostat wants to shrink, let us shrink the tail by pulling the tail from the back. And as it wants to expand, the elastic expands and the aerostat becomes fuller along the length.

I already mentioned to you about types of tether; conducting, nonconducting. Winch could be manual or electrical. A manual winch is used for low altitude aerostat 50 feet, 100 feet, why should you put electrical. But you might say no I want to bring it down quickly within half a minute, so then you cannot and then sometimes the load required you know. We are desigining one small aerostat for a college and we came to know that the tension in the tether is 250 kilogram under 25 meter per second wind.

So it will require herculean power to pull that by hand and wind it. So obviously we have to use some kind of pneumatic or electrical winch, but in aerostats which we have made some small airships for colleges able bodied human beings are enough to winch it down.