Lighter-Than-Air Systems
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Lecture - 76
Design Constants in Airship Design Methodology

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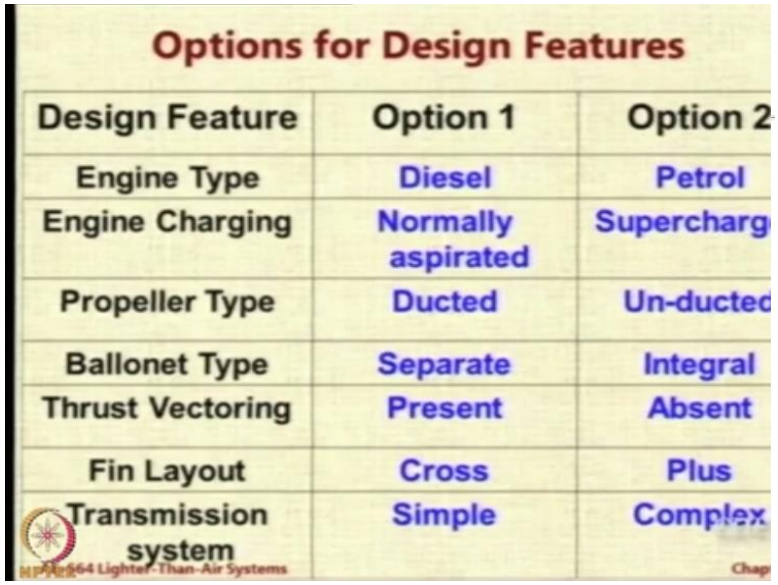

The next important thing is what kind of options or consideration features a designer would like to study. Because the user does not tell you all this. The user will say I want an airship which does this. But based on your own knowledge and experience, you decide should I use a diesel engine or a petrol engine? How would you choose this between diesel and petrol engine? How will you decide?

"Professor – student conversation starts." Size of the egnine. Size and weight of the engine. Size of the engine, weight of the engine. So what I would do is I would say let us try to do the analysis for diesel engine first. Get the engine weight and hence the airship weight. Repeat for petrol engine. And here you might like to use some data from real life and then decide. But given a choice which engine will you use for an airship?

Deisel or petrol? Why petrol? Lighter. Generally lighter. Yes. Generally lighter. **"Professor – student conversation ends."** But then diesel is cheaper. Although it is artificial, it is cheaper. And you might take an assessment and it will remain cheaper for the next few years because of the fact that it is used by farmers in the fields and the government will intentionally keep its

price artificially low. So, this is why many people who are rich may buy diesel car, right because they say diesel is cheaper in the market.

Diesel cars have their own issues. They have higher maintenance cost after a particular mileage or after a particular usage. They have generally more vibrations. They have problem in starting during cold weather. We know all this, but still you see in the market so many diesel cars. So that is why we said who knows the user might tomorrow say I want to try a diesel engine. This will increase the reach of the airship. So, let us try both of them. Now, the engine can be either normally aspirated or supercharged. **"Professor – student conversation starts."** Can somebody explain to me the difference between these two? What is meant by a supercharged engine or a normally aspirated engine? Supercharged engine has a turbine in which density pumps air from outside the air intake. So, a supercharged engine has a small turbine or some device or a pump which delivers compressed air to the intake,why? Because it takes the energy from exhaust gas which actually pumps in. No, but what is the need to do all these? Why should you send in compressed air to the engine in the intake? No, no, it is not that. **"Professor – student conversation ends."** Basically what happens is if you have a normally aspirated engine, which means if you have a normal engine which is having an intake to the ambient air, with the altitude increase the density of the air coming in will reduce. With that your performance will reduce.

So, there is a linear reduction, almost linear reduction in power available with altitude for a typical piston engine. And we were designing the airstrip for high altitude operations keep that in mind, we were looking at lower Himalayas. So, we were concerned that if we use a conventional engine, the power requirement at 12,000 feet may make the engine very large because it will be highly inefficient.

So, does it make sense to use a supercharged engine which is costlier which is slightly heavier, but it has got a constant power output with altitude up to some altitude or should we go for simple, lighter, cheaper, normally aspirated engine, we already give that option. Propeller type; it could be ducted or unducted. So, what is mean by a ducted propeller? **"Professor – student converstaion starts."** There is a Nacelle around.

There is a Nacelle or a duct around it. Why do we do that? We get the performance increased. Why will the performance increase by putting a duct? For separation. Not for separation.

“Professor – student conversation ends.” Basically what will happen is that if you look at a conventional propeller or a conventional propeller for an engine unducted, if you use an unducted propeller, the efficiency is lower because there is spillage beyond the diameter that if you contain it the efficiency improves.

Plus understand one more thing this is an airship, which is going to operate with passengers and most likely we are looking at nonrigid airship. Most likely the propeller will be mounted or the engine will be mounted on the gondola. So, there will be people walking past it and from a passenger safety point of view if it is ducted it is safer because when a propeller moves at high rpm it becomes almost invisible.

And therefore there is a real-life situation possible in which people will probably walk in the propeller or get hurt, it has happened so many times. So, from ground based operational safety, it will be safer to duct the propeller. Not only does it increase the efficiency, it also makes it safer to operate, but it increases the cost and the weight. So you must take a call. So when we make small remotely controlled airships, we never duct the propeller.

Because the weight problems are far more than the benefits and there we say be careful, propeller is rotating, do not go near so with that warning. Sometimes what we will do is make a small cage around the propeller just in the front, in the back, connect them and you know it is visible. But that is also very tough because there is any vibration or disturbance this cage can hit the propeller.

So there will be weight penalty anyway and the improvement in the thrust may not be that substantial for a very small propeller. But for a large propeller there might be. So we said let us have a feature. Then ballonet type separate or integral? What is meant by a separate ballonet and an integral ballonet?

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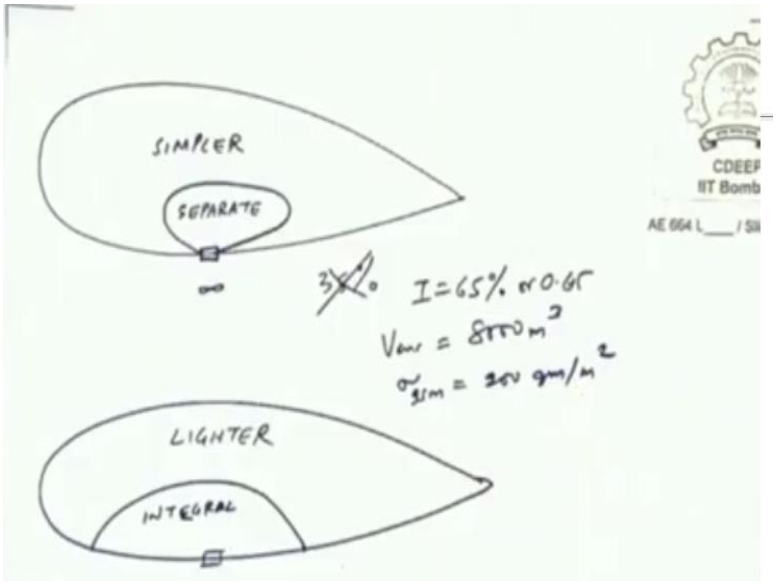

So let me show you a figure of the two types and then you will probably appreciate. This is a very small thing actually. It is not something very great, but it can make a difference in some cases. So this is an airship envelope and in this envelope, I will show you the single ballonet. In this airship envelope, I make a small cut here and then I put another small bag inside and here I put this double-sided fan which can either expel air or which can suck air.

This is called as a separate ballonet because it is a small envelope inside the big envelope. So, this is the separate ballonet. The other option I can have for the same requirement is there is this thing and I have only a hemispherical only a hemispherical bag which is attached. This is called an integral ballonet. What is your main repercussion of choosing integral or separate? Let us say which one will you choose?

Will you make a separate ballonet or an integral ballonet for a passenger carrying large airship, what will you choose? We will choose separate ballonet okay. **"Professor – student conversaion starts."** What is your logic? Because the attachment is easier in separate ballonet. Correct. The attachment of a separate ballonet is very easy. You can actually make it separately, push it through this small hole, stick it to a very small area, seal it and put this double-sided fan.

If that is the case then why people go for integral and are there any benefits for integral compared to separate? Less fabric. Less fabric required. **"Professor – student conversation ends."** So this is lighter and this is simpler. Now you might say fabric, but in a large airship if

the ballonet is 35% you can see in one case you will have a sphere of that much volume and the other case you will have a hemisphere of that much volume roughly.

So, it will be really normally it will be half the surface area and suppose half surface area of a ballonet is not a small number. Just assume, you can do the simple calculation. Take an airship of 8000 meter cube envelope volume and tell me on Moodle page for the same GSM of 200 grams per square meter what is the difference in the weight of an internal versus separate ballonet? It will be half but will it be 2 kgs or 20 kgs.

So, the material is 200 grams per square meter and then airship envelope is 8000 meter cube and the inflation fraction is 35%. So, I just make a note here 35% inflation or I will be equal to 65. So, actually I = 65% or 0.65, V envelope is 8000 meter cube and the GSM is 200 grams per meter square. This is the weight of the ballonet fabric. So, for these three things work out the difference in the weight of the integral and separate ballonet.

The next thing that we wanted to study. **"Professor – student conversation starts."** Yes. Should we consider how the dynamics change when the ballonet you know when air is pushed inside the ballonet or when it is pushed out of it do we consider how the dynamics change? Dynamics actually will not change too much because if you have volume available in the spherical or hemispherical ballonet, the same pump is sucking and throwing air.

So, it would not change too much. That is fine, but if you have a separate ballonet and you have a big sphere inside and it occupies a considerable volume right like in this case it comprises of about 35% of the entire volume. In that case, do not you think when you pump out all the air, the dynamics of the entire airship will change? When you pump out all the air from a spherical ballonet or hemispherical ballonet, the only difference will be that this is heavier than that.

The empty weight will be more. What is the other difference you see in dynamics? What is seen in terms of new movements that will be introduced because your balances will be different because all the air from the ballonet is out. In both cases all the air will be out. Yeah, but the concentration of mass is different, right. Because in case of the integral ballonet the mass was widely distributed, but it is not in the case of this case.

No, that is not true. Even in the case of separate ballonet the mass of air sucked in will again go into a spherical fashion at almost the same location. So, will there be too much difference? Because once inflated, you are right in a way that in one case it will be spread to a larger area and lesser height, in the other it will be a smaller, smaller dia, I mean smaller width and larger height. Yes, so that can affect also. That can also affect.

It can also affect, it can create some difference. But right now we are not considering that, we are considering only and only the effect of weight. **"Professor – student conversation ends."** Then thrust vectoring. Thrust vectoring is something that helps in the performance of the airship. You know that it can take off easily if there is thrust vectoring and I mean thrust vectoring will support in vertical takeoff, but then is going to create weight and complexity.

Similarly transmission system. Fin cross and plus already we have seen. Transmission system; this was just a small point that how do you transmit the thrust vectoring mechanism onto the gondola. So, we just wanted to put one factor there as either a simple system or a complex system.

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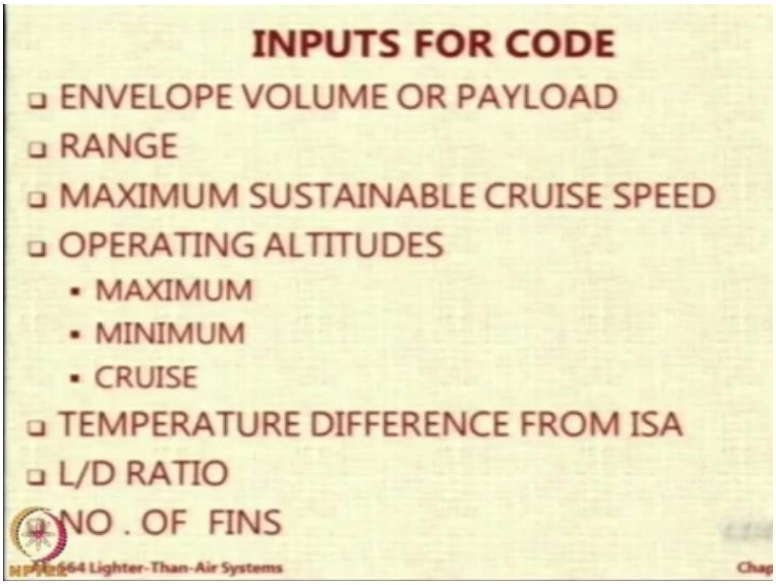

Inputs for the code, I call it a code because ultimately we made it into a Fortran programme and we also have a spreadsheet I think. So, the first input will be the envelope volume or payload depending on whether you are using it in the analysis mode or in the design mode. Then the range. Then the maximum sustainable cruise speed to get you the maximum thrust required and hence engine sizing.

And then operating altitudes maximum for pressure altitude, minimum and cruise for the ballonet sizing. And then whether we are operating in ISA or other than ISA conditions and what is the length diameter ratio. And the number of fins, basically 4.

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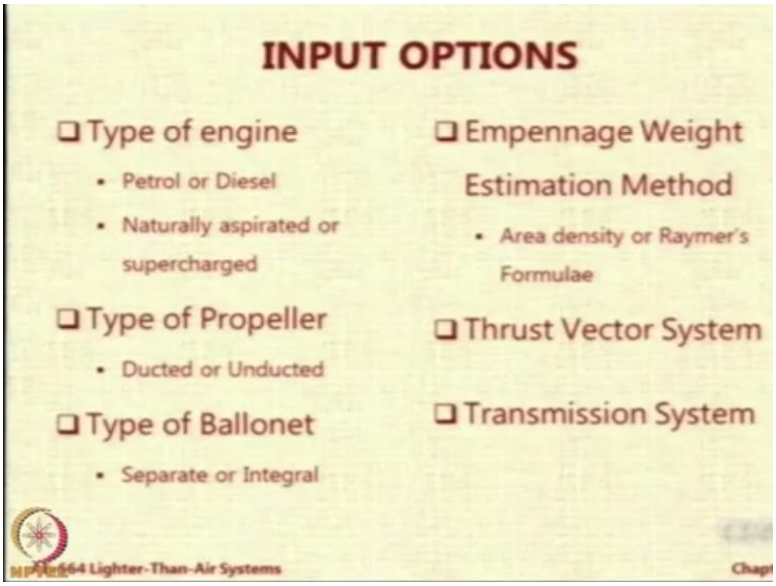

Then the other inputs were type of the engine, already we have discussed it. Type of the propeller. Type of the ballonet, there is one more issue. When you estimate the weight of the fin, you can assume the fins to be either inflatable or solid or rigid. In the case of airships, we normally see fins which are inflatable normally. The reason for that is very simple that the size of the fin is going to be quite large in a big airship and you can use the volume available inside the fins to put LTA gas to get more.

But you will be surprised that most airship manufacturers actually fill the tail fins with air not with LTA gas because the fins tend to fly often separately if you put LTA gas. And secondly it is a very clever way of controlling the center of gravity in case the CG has to be moved slightly behind by putting air in the fins you increase the weight behind. So there are two ways, now in the calculation here we will assume it to be basically built-up structure like a small wing.

So, there are two approaches one where we say okay it will raise too much per square foot or per square meter and we simply use it. This is called as area density method or we said let us look at the textbook given by Raymer which discusses formulae for vertical tail and horizontal tail of small aircraft, which are similar for an airship using that formula. I think we abandoned

Raymer's formula eventually and we used the area density method. Then the TVC, thrust vector system and transmission system.

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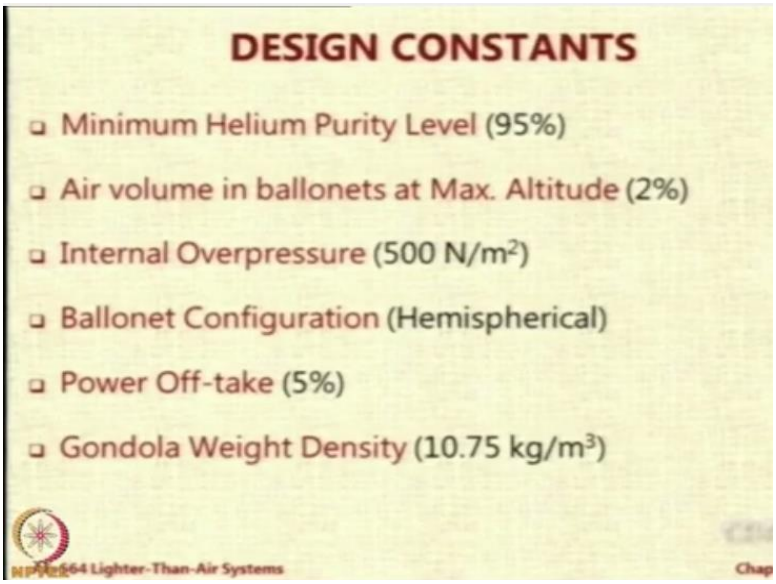

Then constants. So, I will just quickly go through the list. I have already mentioned the parameters. The helium purity level we took 95% as the rock bottom, below this we want the gas to be purified. Air volume in ballonets at maximum altitude for control and trim was 2%. This is based on a study of I will show you that detail. So this is the ballonet volume required for trim. Overpressure was considered to be 500 Newton meter square.

And we went for simple hemispherical ballonet because we were concerned about the weight. We assume that 5% power will be consumed by accessories. And the gondola will be made up of simple standard composite fuselage type structure without pressurization. So we got this number for the typical value of weight per volume of a gondola. And empennage area density, weight of the empennage per square meter. So with this we can get some idea. We are running out of time. So at this point we will stop today's discussion.