Lighter-Than-Air Systems
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Lecture - 75
Inputs to Airship Design Methodology – Part 2

The second feature is number of engines. Now number of engines, who will decide the number of engines on the airship? No, I am not talking of the type of the engine, I am talking about the number of engines. Whether you will have 1 engine or 2 engines or 10 engines, who will decide that? No, if you leave a designer of choice he will always say one engine that the regulatory bodies might come into picture.

Like they come into picture for your aircraft design and they might say sorry more than so many passengers you must have two, minimum two. So, typically passenger carrying airships have at least 2 engines for reliability point of view. If one fails there is second one available. It will be disastrous to have a passenger carrying airship with single engine and for some reason the engine fails then it will be very difficult to bring them down, it will be unsafe.

So, minimum 2, but then somebody might say now why 2, why not 3, 4, 5, 6. So, what decides that? So more than two is what regulatory bodies tell you, but they do not say you should have 7 or 6 or 5. So, what would you do as a designer? If they say not less than two, will you limit it to two or will you go for three?
“Professor – student conversation starts.” Correct if I can manage to meet all requirements within two, I will not put a third one. **“Professor – student conversation ends.”**

But suppose my requirements are so stringent and so large that I am not able to get the required cruise speed with only two engines you may have to have a third engine, this does not normally happen in airships because they are not supposed to fly very fast. The power consumption increases rapidly with the size and with velocity it is v cube effect. So, if someone gives you a requirement of a Mach 0.9 airship, then the requirement is broad.

If you put a very big engine or a more powerful engine, it will also requier more drag, you will not be able to overcome. So, in airship design generally we never see a third engine except when that third engine is meant for something else. What could that be?

“Professor – student conversation starts.” For someone said powered lift, what is that? There are motors of hybrid of motors of an engine where you have motor supported through.

Yeah, but look I will have a separate discussion on hybrid airships. Right now, this methodology is only and only for conventional airships. So please do not bring in complicated airship geometries right now. Right now it is simple conventional airship, single envelope, axisymmetric body. So, therefore we will not look at those considerations. So then why would there be a third engine if at all? Augmenting.

For augmenting the yaw power and providing additional yaw control? How will third engine help? Where will you put it? If you have three engines, where will you put it the third one I mean? In the rear part. In the rear part, why in the rear part? Why not the front part? Drag will be more. **“Professor – student conversation ends.”**

There might be more moment arm in putting in the front you do not know that depends on where the other things are located.

So you can put it in the bow or in the stem, both options have been tried by people. But if you put in the front the problem is then where do you attach the mast? The front of the airship is kind of reserved for ground attachment, a kind of, but there have been experiments with engine in the front to give direct side force. Also, an engine in the front might also spoil the aerodynamics of the airship because it will be a large draggy body attached to the front portion.

Most airships have an third engine at the rear because there is this fin available to mount it. In some cases, the fins are not load carrying, they are not that load carrying, they are flimsy. So directly on the envelope. So one very good experiment that was done is, I can remember two of them. One was done by a German airship made by researchers and students called as Lotte in which there was a third engine mounted on the back directly on the envelope.

Similarly, we have seen in our videos the Zeppelin NT airship which has got a third engine on the back, which can also swivel. So in normal takeoff and landing mode, I think in a normal takeoff mode, it is actually giving thrust. But when you want to counter side winds or other forces, it can give you side force also by tilting it. So, it is important everyone should study about the third engine on Zeppelin NT and explain to us how it works on the Moodle page. So this is the second Moodle request.

I can only say request because it is up to you to put it or not. Some of you will do it because there are 10% marks for it. Some of you will do it because you are enjoying the course and you want us and yourself to learn more. Remember when you put something on Moodle everybody learns, I also learn, right. So number of engines could be 2 or 3, never more than that. There are some airships which are having 4 engines because they want to get rid of the fin.

So we are also making one such airship in Brazil or in association with people in Brazil, where there will be 2 in the front, 2 in the back on the gondola. So, on the gondola we are putting 2 horizontal rods and mounted 4 engines. And then we are saying by controlling these 4 engines and their thrust vectoring we can fly the airship without the fins. So they are finless airships.

Now one researcher from Canada McGill University there is one professor Nahum, he has supervised a student for making a finless airship with 4 engines. So I will upload on Moodle page the paper written by the student about the finless airship. The next important parameter which the designer has to decide not the user is the envelope l/d ratio, length to diameter ratio. Not lift by drag ratio, but length to diameter ratio.

So, now let us see from basic aerodynamic principles do we have any information on what should be a good length to diameter ratio for a subsonic body of revolution? How much would be the l/d. Around 10 is true for low speed aircraft. That is what we use in fuselage design 10, 11, 12. But if you make an inflatable body revolution with l/d equal to 10, the first problem you will encounter is for a given volume you will have large surface area.

What is the problem with that? Weight of the envelope will go up. Yes more surface area means more possibilty of leakage agreed because there will be more joints, longer joint lengths. More fabric, therefore more leakage. Then there will be higher drag. Remember we are going at low speeds, you will have skin friction drag and that will become large if you have larger skin. So, in airships it has been shown that the best l/d is of the order of 4 and a half to 5.

So, never we see airships with l/d far far more than this number. There are exceptions. For example, there are some airships like Zeppelin NT, which has got a very large l/d ratio that is driven by requirements like see a Zeppelin NT is a semi-rigid airship. So there the weight of the structure inside is more important than the fabric. Fabric there is basically meant for only giving a covering to the structure and to the gas bags inside.

So, when we look at conventional non-rigid airships, I must clarify that this methodology is also limited to only non-rigid airships. So for conventional non-rigid airships, l/d max, length diameter max is 5**,** to four and a half. Then ballonet volume for trim. I hope you will recall we had a discussion on this also and we also had a question in your examination about how the ballonet can be used for providing trim?

What is trim? Yes what is trim? When is an airship or an aircraft said to be in a trimmed condition? When the net moment acting on it is zero, correct. So it maintains his position and flies, right. Because if there is unbalanced moment it will respond to that moment and change its orientation correct. So, lt us say the airship is now trimmed at an angle of 3 degrees, angle of attack of 3 degrees, flying up 3 degree of attack.

For some reason, maybe I feel that at 3 degree angle of attack there is going to be very high drag, it is a high speed flight. Airships do not fly very fast, but when they fly at near their maximum speed they are actually flying at their fastest, almost the fastest. So at that speed, you will have large amount of drag. So let us say the pilot wants to fly in such a way that the airship is trimmed at 1 degree, not 3 and a half or 4 degrees. So, what can the pilot do?

How will you change the angle at which the airship gets trimmed? Yeah, one of them is CG control that is tough. That is very tough because having a facility to move the mass, yeah inside you might say the gondola has got two fuel tanks, one in the front and one in the back or there are two tanks carrying ballast of water and you dump, but it is complicated. **"Professor – student conversation starts."** Any other simpler way?

Taken each ballonet completely flush. Correct, you have 2 ballonet and see you want a particular amount of air in the ballonet to take care of operating conditions. But you could get that from only the rear ballonet, only the front ballnet or a mixture of both, so by adjusting. Now the question is that in a way the ballonet volume that you carry is like subtracting from the volume available for the envelope.

So, what factor or what operating requirement directly decides the ballonet volume with respect to the envelope volume or the inflation fraction? ΔH, not H, very important, it is ΔH. From which height you want to go to which height that is important. So, if you are given some ΔH for oeprating requirements, you will have to have let us say 30% ballonet you have to take because ΔH requires it.

Now, you will want to put additional ballonet for trim control because 30% will be consumed in maintaining ΔH requirement. But let us say at the maximum altitude or the pressure altitude when ballonet is flush, now you cannot use it for any trimming. So, I would like to have some margin in the ballonet for pure trimming purposes. So, should that be 10%, 2%, 5% how will you find it?

So, this question was in front of us that fine, we can calculate the ballonet volume required or the inflation fraction needed from operating requirements by using the aerostatic formula, but how much extra to give so that we can have sufficient reserves ballonet volume for trimming purposes How would you go ahead if you are given this problem? So how much is sufficient? Is it 5%, is it 10%, is it 1%?

So Praseed what would you do if you are designing an airship and you are facing this problem? Let me put the problem in some other way. Every month a student in IIT Bombay incur some expenditure in accommodation, food, mobile, travel, blah, blah. There is some number. But you have to keep slightly more than that for some emergency. How do you decide this number?

Let us say we have landed up in IIT Bombay and you want to know what should be the monthly amount of money in my bank account so that I can take care of my expenses. So, somebody will say no problem I mean accommodation is some rupees per month, mess bill is roughly so much, this is a fee so much, etc and then what do you do? Tell me what you do exactly? Ask the PG students how much they. So, you ask the senior right. **"Professor – student conversation ends."**

You ask the hostel mates. How much do you spend in canteen? Typically so much. How much on mobile? Do not worry network is available here and there, once in a while you need on the phone, so you can take a 1 GB pack like that somebody will advise you. Similarly, we did the same thing we looked at the data of existing airships how much trim volume are they keeping? And we said first thing is we should know how much they are keeping so that we do not keep less than that.

And secondly we said let us see if you keep more than that what is the effect? So that we know we cannot go more than what we keep because it affects a lot. This is what is empirical, nothing wrong in this. Many people have a wrong notion that empirical means non-technical, empirical means all good hedgehog type things. It is not true. In fact doing analytical calculations are very easy.

No brainer because somebody gives you a method and we just punch the numbers and get some answer that is very easy that I think many people can do. The most challenging thing is to be able to get this kind of fuel of real-life situation in design by learning from other people's experience levels of what has been done, not blindly following it. Suppose SFC of a typical engine is so much, I do not say SFC is so much.

I would say today's number is so much, 10 years later intelligently I have to find a way of predicting what will be the reduction in the SFC. We all do it right, all of you, I mean Sandip has designed an aircraft and flown it. He never knew in the beginning what it would be. But he knew that typically UAV are of this weight class. So, now when he talks about it to other junior students, you can make out that experience has come.

You should do this, you should not do this, no one taught him unless he did it. Similarly, the designer who learn about things they learn only by experience, only by doing the calculations. So, ballonet volume for trim we decided this number as I said based on data of existing airships and a sensitivity analysis using equations on how much is the payload loss because of providing larger ballonet trim. The next point is internal overpressure.

We all know that the pressure inside has to be kept more than the pressure outside, otherwise it will cave inside, but how much more? So that depends on many things. It depends actually on 3 things. It depends on how much dynamic pressure you are expected to encounter during flight. So, if you are told at this speed at this altitude just calculate half rho v square that will be acting on it and it should be present on side should be atmospheric plus more than that that much more than that where it does not cave inside.

But then there are other things in a very large airship even the pressure will be different at the bottom of the envelope and top of the envelope because of the weight of the gas acting on the bottom. So, when we look at stress analysis that will be a chapter in one of our studies, we will look at these 3 factors. What we did is we are starting the design, we do not have all these data.

So we took an internal over pressure based on the information available about other airships. So, the configurational parameters are some things that the designer assumes either based on experience or based on we will try cross fin and then see plus fin and then take the best of the two. The performance requirements are given by the user and also the operation parameters.