Lighter-Than-Air Systems
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Lecture – 23
Ballasting, Weigh-off And Fuel Weight Recovery

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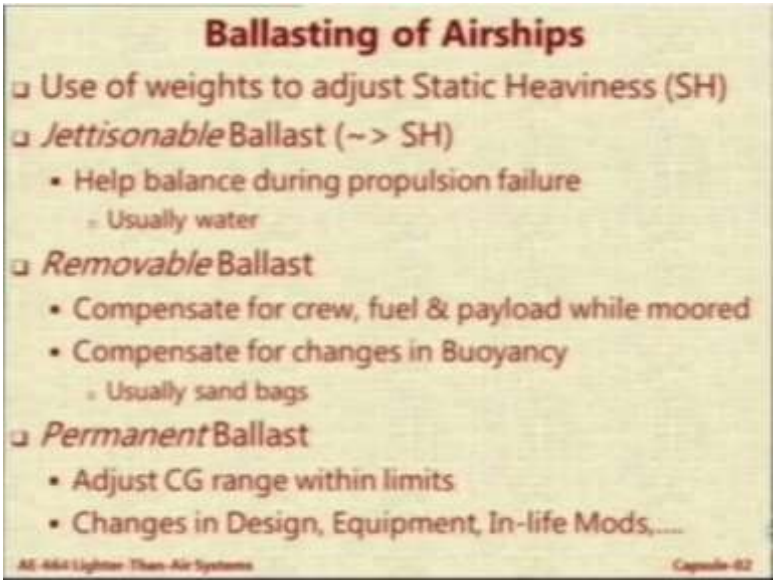

So to take care of static equilibrium, especially to make an airship statically heavy or you want to make it statically buoyant, we resolve to what is called as ballasting okay. Ballasting, basically Ballasting is nothing but use of weights to adjust the static heaviness and this is summarized as SH from now on. So, static heaviness will be called as SH from now on. So, there are 3 types of ballast which is normally available on airships.

One ballast is called as the ballast which can be discarded, jettisonable ballast okay. This is something that helps balance during the propulsion failure, but you do not throw it when you have propulsion failure. If you throw it becomes light, then it would not come down, you have no propulsion system. So, this jettisonable ballast is there to ensure that you are heavier than air.

But in case everything is fine and now you are coming to land or you are coming into land, let us say the flight is getting over and the pilot is coming into land, at that time it is better to have static heaviness. Okay, so common sense says during takeoff I would like to be statically light, during landing I want to statically heavy. During cruise it is best to be statically neutral, right.

So now the airship is coming into land, if I do not reduce the weight, now how do I increase the weight okay. so how do you increase the weight? We will see. Let us see. We will see. There are many methods. Usually we use water because if something has to be thrown, it cannot be stones or it cannot be anything heavy which can hit people. So therefore, the jettisonable balast is always water.

Then we have ballast which can be removed, this is adjustable. This is basically used to compensate for the people who will be in the airship, but when you park it they are not there. For example during flight, the airship will have a pilot, copilot. Generally there is an air traffic regulation that beyond a particular capacity 9 passengers to be precise, you need to have 2 pilots in the cockpit, a pilot and a copilot.

So any airship with more than 9 seats will have pilot and copilot. They may also have a flight crew if it is a passenger airship. There might might be a flight attendant or a flight crew member. Plus when you actually travel in an airship, you carry fuel, you carry payload, etc. But when you park the airship on the ground, you do not carry, you do not put, you do not ask the pilots to stay there.

You do not get out because it will become neutrally you know less buyont, so please stay in this cockpit you cannot do that. So, what you do is as the pilot is going away as the material on the airship is going away, you replace that with some weights. So, these weights they compensate for change in the buoyancy because something has been removed. So, equivalent amount has to be put up. Now what should be the design requirements for these weights?

Just like I said the reasonable ballast should be something that does not hurt people when it is thrown. So water is fairly heavy, but it may not hurt people as we throw them. So for the removal ballast, what would be the design requirements? If you are designing removable ballast system what would you put?

“Professor – student conversation starts.”

Yes Chetan. Sir probably wheels at the bottom. Wheels at the bottom. Sir to load and unload easily.

So that is basically meant for ground motion, ground movement. So are you saying you will attach the wheels and make it heavy? Agree.

"Professor – student conversation ends "

So in some cases you may have, but then you need someone to run behind the airship which is dynamically moving system and you have to run behind airship and there should be a hook somewhere and you have to go and attach this hook, not an easy task.

So, I have not seen people using wheels, etc., to be attached as the removal ballast. This is something you will put inside the cockpit let us say, inside the gondola.

"Professor – student conversation starts"

Yes Amir. I would like to have multiple units of a small unit of it like sandbags or something. So I can one thing is that is more or less you can quickly just throw down and if they are of 1 kg each like say then we can very easily match the exact bigger. This is exactly the case. So usually sandbags are used.

"Professor – student conversation ends."

Usually we use sandbags, heavy sand which occupies less volume for the given weight because if I use a lightweight object it will occupy more space it will be difficult to remove. So, we use sandbags. So depending on the airship sizes, when we fly our small remotely controlled airship we have bags of 100 grams, 50 grams, 200 grams, 500 grams okay.

So, we just use directly, we put bags when the airship is moved and then we balance it, but in passenger carrying airship there could be 100 kilograms sandbag, 200 kilograms sandbag, 50 kilogram, etc. Up to down to 1 kilogram, half kilogram a few of them for the final balance. So, this is another kind of ballast. The third type of ballast is permanent ballast. This is not something that is removed. Now why would you like to have permanent ballast?

Because when you build the airship, the customer may want you to install a particular equipment. So, you install it and you can carefully design such that when this instrument is installed the CG is below the CB, so you would adjust the location. After of some time the customer says I have now one more camera or my camera has changed or there is another equipment of 350 kg which has to be installed and you cannot say hang it on the balloon.

It has to be carried. These are heavy items, you cannot just put them anywhere and from the point of view operational use they may be needed to be at a particular place. So with that your

CG will go for a fix okay. So if you have for instance heavy items added on the backside, you will have airship with nose up. Now you cannot fly with that kind of an airship. Nose up flight is not possible.

There will be very high angle of attack and hence there will be a substantial increase in the drag coefficient. So, what we do is we trim the airship to a desired angle by putting deadweight at particular places called as the ballasting base. Now for the ballast is basically there to cancel the moments. So, the best place to put the ballast is the farthest away from center of gravity, farthest away from the CG would be the nose or the tail.

So, what we do is we always build some kind of pocket or some kind of a container, either at the extreme nose or behind. Now normally our experience has shown that CG normally moves back than desired. So, by and large experience shows that the ballast is to be carried more in the nose side or in the front side. But there could be a situation where the ballast is needed on the rear side. So there should be provision for ballast both in the extreme front and extreme back.

So, ballast which is provided to create or to move the CG to a location that is desirable and need not be moved as never touched unless there is an imbalance that is called as a permanent ballast. The permanent ballast is also used in aircraft. All aircraft have permanent ballast. In fact MiG 27 I remember used to have around 90-95 kg of permanent ballast mounted in the nose because of modifications and changes over the years, it is dead weight.

But if you can use, suppose we are given a requirement to mount the new payload and that matches with or is somewhat comparable to the weight of the ballast needed and so we will put it at that location great. Then you can say fine, my payload capacity is not compromised, but ballast is also the payload. But this is a ideal situation which may not happen okay.

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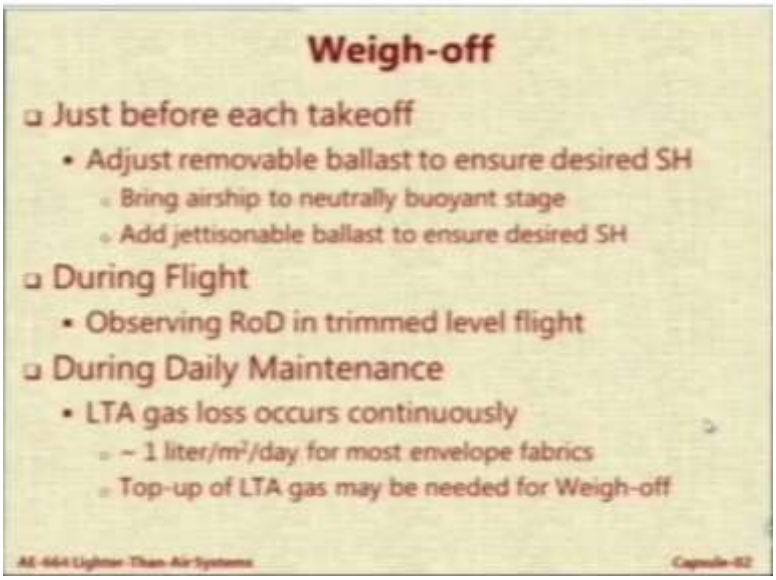

Now, there is a term called as weigh-off which is very important as far as LTA systems is concerned. Weigh-off basically means what you do to trim the vehicle to the condition at which you want to operate. So, just before each takeoff and remember this is each takeoff what we have to do is we have to adjust the ballast for maintaining the required static heaviness. So, first you make it neutrally buoyant by adjusting the removable ballast.

Now, the airship is neutrally buoyant. After that you add the jettisonable ballast, usually water tanks are filled up to provide the required static heaviness okay. So, when you fly the airship there is a permissible static heaviness or a recommended static heaviness which the manufacturer tells you. So, in some airship it is 500 kilograms. So, an airship with 13, 14 passengers would have a static heaviness of maybe even more than 500 kilograms.

So, that much weight you carry in the form of jettisonable ballast. Now, during flight what you do during flight is the pilots during level flight because remember airship flights are normally for very long endurance. They do not normally have short flights. So, flights of 10 hours, 15 hours, 17 hours are routine or normal in airships and the consumption of fuel also is low, not as rapid as that in large transport aircraft.

So, you have to keep on looking at the rate of descent during the flight and you have to keep on see if I trim the aircraft that means if I balance out all the moments and as I start flying the aircraft or the airship does it start descending slowly, so one has to maintain that okay. Secondly, during daily maintenance, this is a dynamically changing or equal, no envelope material is perfectly gas proof.

Especially if you look at hydrogen, it is such a nasty gas smallest molecule. So, there are stories of people saying that it has escaped from steel containers okay. You think steel is a very safe way to store things, the gas can go out from steel containers because the molecue is very small. So, what about this LTA fabric? So LTA fabric can only contain the gas to some extent in real life.

Now, we will have a special lecture on airship envelope materials where we will discuss the properties of materials. Basically, the rough ballpark value of leakage of LTA gas from a good airship is around 1 liter per square meter per day. So, over so many days there will be some gas loss and that will affect the lifting capacity. So if you want to make it statically light, it will not happen because the gas has gone out.

So then we will have to go for topup if you want to weigh-off, weigh-off means balancing. If you want to achieve neutral buoyancy for an airship, which has been flying for let us say 6 months, you may have to topup the gas. You may have to push in more gas and then acquire the required weigh-in features. So these are different things compared to aircraft. In aircraft you do not have these problems, in airships you have these very strange situations.

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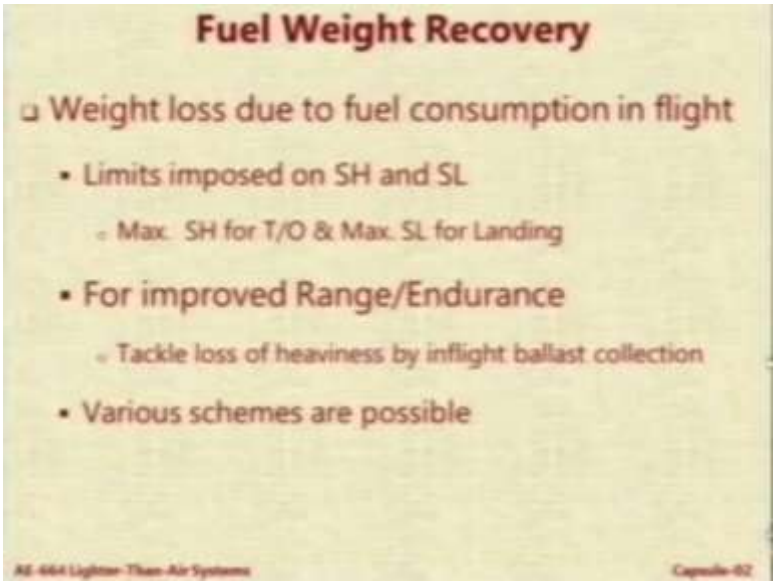

Of course, we know that as the airship flies there will be loss of weight due to fuel.

"Professor – student conversation starts."

Sir as we are flying if we are flying for 15 hours or more because of interior noise we will face a severe loss of the air, Yes, correct. **"Professor – student conversation ends."**

So, now due to many reasons, one because of flying for 15 hours nonstop, the other because we are flying and fuel is getting consumed.

The weight of the system which was statically heavy will become statically neutral or even light okay. So 15 hours ago, you were okay, statically heavy. Beyond 15 hours from the flight now you are statically light, so what do you do? That is what we are going to look at now. We have to have some mechanism of recovery of the weight that we have lost because of the fuel. So this is a very imaginative area and here you will see people have done very interesting things.

So, let us look at what people have done. What are the pluses and minuses of each and then you can suggest some better methods of doing it. So, because of the weight loss during flight, there will be a limit imposed on the statical heaviness and static lightness with which the airship will be allowed to operate. There should never be a situation that during flight you achieve a situation of static lightness and you cannot do anything about it after that.

So therefore you can never come down. In case there is a power plant failure, you are stuck in air. So, one has to avoid that situation. So, basically we define certain maximum static heaviness for takeoff and certain maximum static lightness for landing. So, we need to calculate during the whole flight how much statically light we will become. We cannot allow below a particular number because then it will become unsafe for you to operate.

So, now for improving our engine endurance because suppose you start becoming statically light below the permissible limit, the only option is please go and land and make yourself heavy by collecting something. So, that means you are limiting your range just like we studied in twin engine aircraft operations over the sea. There are the limits on what route you can take because of the one engine inoperative criteria. So, there are limits on operation.

Similarly, in every airship there will be a limit because of the permissible static heaviness and static lightness. What will happen tell me? What will happen if you are more statically heavy than permitted during takeoff? It would not take off. So, how does it take off when it is tactically heavy? Propulsion. So, stactically heavy, you start the engines okay, maybe you start giving it some kind of thrust vectoring if it available.

So you leave the ground and then you start moving forward. As you move forward, there will be a component of the force acting. So, that component will overcome the static heaviness. So you will be able to become neutrally buoyant and then you can fly. What will happen if your airship is less or I should say more statically light compared to maximum permissible? You cannot come down because the thrust produced by the tilting of the engine is not able to overcome the static lightness.

So you are struggling to come down, but you cannot come down because the net vertical force is taking you up. Therefore, there is a limit. So, what we can do is can we do something in flight? We have 15**,** 20**,** 30**,** 40 hours of flight. Can something be done to collect weight during the flight? So that as the fuel is consumed and the airship becomes light, we kind of compensate that by collecting weight while going.

Now obviously you cannot create mass in midair that is against the basic princples of physics. So, we have to do very interesting things.