Lighter Than Air Systems
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Lecture - 33
Net Static Lift of Non-Rigid Airships

So now this I have done last time but I want to revisit once again because these are very important expressions and very soon you are going to do an assignment in which you will need these equations.

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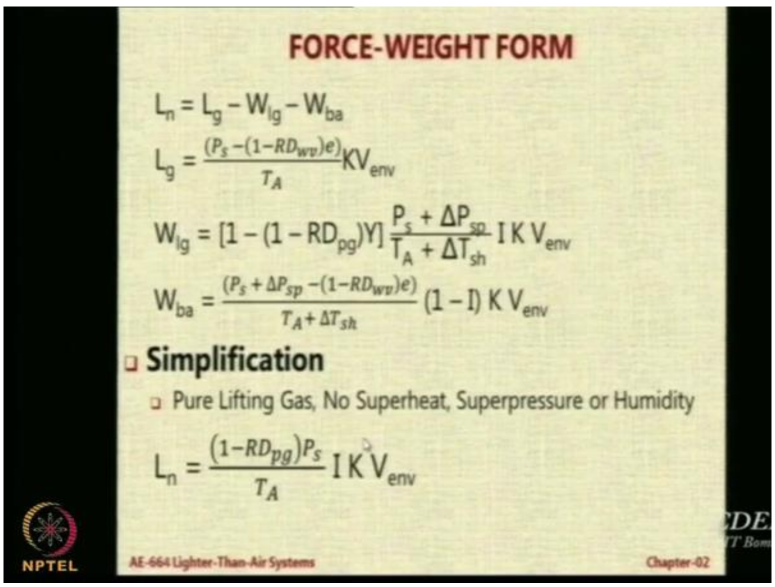

So, there is something called as force weight form which focuses only on the forces acting and the weights of the various system components. So as per this formulation the net lift is equal to the gross lift, which is equal to weight of the displaced air minus weight of the lifting gas minus weight of the air in the ballonet. This is very straight forward so nothing to discuss here. Similarly, the gross lift that we have seen the expression in the last page is going to be obtainable.

So therefore, now if you look at the weight of the listing gas because of looking at the force weight form, we will now bring in the infraction fraction Y sorry we will bring the purity fraction Y. So, in the previous calculations we have actually not look at the purity issues. So, if you want to bring in the purity then the weight of the lifting gas will be equal to the density of the lifting gas into the volume occupied by the lifting gas.

The volume occupied by the lifting gas will be equal to the amount that is there in the envelope minus the ballonet that is why we have to use the infraction fraction I. So, weight of the ballonet will be using that equation derived last time for the same expression I have just copied here. Now we can go for some simplification. So, what you do say let us neglect the value of Y, we say Y is equal to 100% or 1.

Again, get rid of ΔP_{SP} get rid of ΔT_{SH} also get rid of e so with that you got much simpler expression which says that the net static list is equal to

$$L_N = \frac{\left(1 - RD_{pg}\right)P_s}{T_A} IKV_{env}$$

So, V_{env} is the envelope volume which is the total volume. Inside that there are 2 volumes, the value of the air in the ballonet and volume of the lifting gas. K is the constant which we have already seen. P_s is the pressure acting outside $\left(1 - RD_{pg}\right)$ takes care of the fact that not the entire air inside is equal to the lifting gas there is some ambient air? So, RD_{pg} is the relative density of the pure gas T_A is the ambient temperature.

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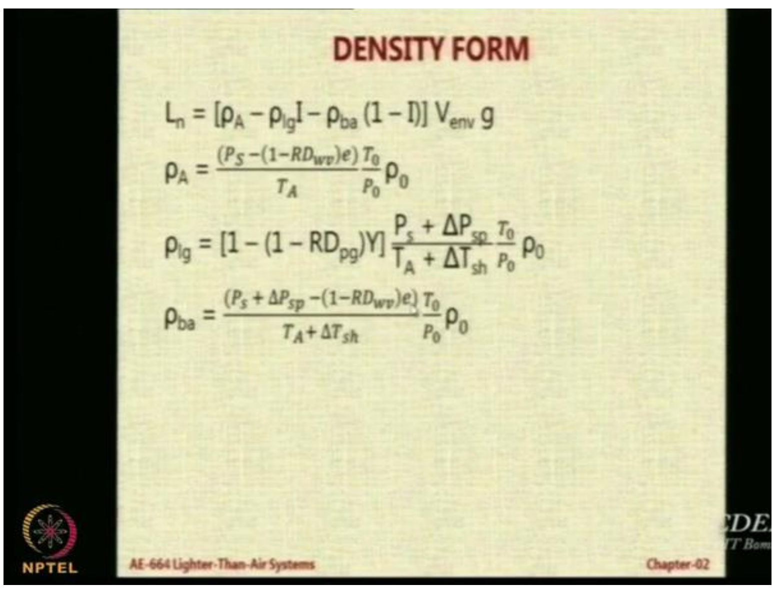

Now same expressions we can also look at from the density point of view keeping in mind that the lift available is equal to the difference of density times the volume. So, what happens in that case is that the net lift will be density of the ambient air minus density of the air of the lifting gas inside the envelope which will be the density of the lifting gas times I where I is the infraction fraction minus density of the ballonet air multiply with (1-I) because that much could be occupied by the ballonet.

So, this is basically the difference of density the classical $\rho_A - \rho_g$ that multiplied by envelope volume into g. This is another way of expressing the net static lift. In this we are now going to insert those equations, those expressions from the various term. So, for density air keeping in mind the effect of humidity. For density of lifting gas keeping in mind the effect of super pressure, super heat and the gas purity fraction.

And for the density of the balloon air keeping in mind super pressure super heat and the presence of humidity. So, all three areas the ambient air, the lifting gas inside and the ballonet the air inside the ballonet all three of them have their own densities and those are obtained by this expression. Now, it is your task because you keep staring at the board and say yes. Your task is now is to insert this expression and get me the expression for net lift.

You will be surprised that it is very small expression because many terms will cancel out so do it and when you finish, please raise your hand. What I need is, I need an expression for L_N, net static lift by replacing the three terms. P_s, s stands for standard. P_s is essentially ambient pressure under standard conditions in the atmosphere at that altitude. T_A is the actual pressure of the ambient air because you may operate in the atmosphere which is not ISA it may be ISA+10.

Look ISA is the standard atmosphere where the sea level temperature is 15 degrees centigrade that is if you go to sea level in Mumbai the temperature from 15 degrees it may be 30 degrees which means we are operating in ISA plus 15. What it means is at every altitude above Mumbai the pressure, temperature, density etcetera pressure and temperature I should say temperature of the ambient air will be equal to temperature at ISA + 15 degrees.

So, when you operate under non-ISA conditions the pressure and density of the air is not standard it is P_A and T_A. Therefore, the density is ρ_A. So, please understand P_s is the standard ambient air pressure at that altitude P_A is the actual ambient air pressure at that altitude. And these two will be same if you are operating on a standard ISA conditions. These 2 will be different in case you are operating on the non-standard.

Now the presence of water vapour can be there at any atmosphere that depends on the value of P. or it shows in terms of e. Does somebody have the expression? All you need to do is, let us try to achieve it here; do it here if you can.

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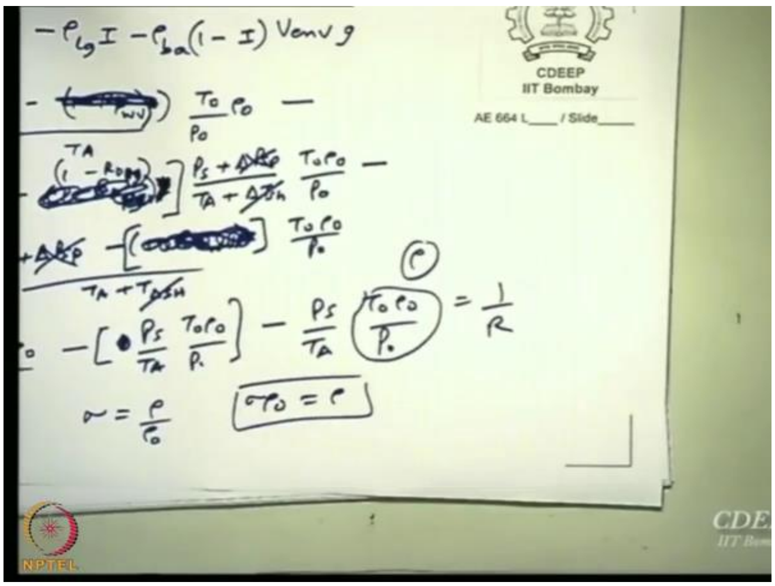

So essentially

$$L_N = \rho_A - \rho_{lg} I - \rho_{ba}(1 - I)V_{env}g$$

this is equal to ρ_A can be replaced. Now let us assume that there is no super heat which means this will go this will go. No RD is the relative density of the pure gas with respect to the air outside there is no water vapour term there. See the water vapour term is taken care in terms e that is the humidity effect, in the case ρ_{ba}, in the case of ρ_{lg}. So, in the case of ρ_{ba} what is Y? Y is the purity of the lifting gas. Now RD_{Pg} is what the relative density of the lifting as with respect to air.

This is the ρ of the lifting gas upon ρ of the ambient air. So, you are saying what should be here? In which expression this expression ρ_{lg}, here sorry I am looking here, you are right. Now, we also remove we also remove the super pressure. That means we need to knock out this item, knock out this term. Then suppose we assume pure lifting gas that means Y is equal to one. And let us also ignore humidity that means this term goes.

This term goes and also this term goes. So, what do you get here?

And basically, if you look at this expression, this expression is basically equal to 1/R. and P/RT is equal to ρ density. So, that is why it will become ρ_A which is the ambient air density and $\sigma = \frac{\rho}{\rho_0}$. So, if I take $\sigma\rho_0 = \rho$. So, it simplifies a lot if you go for assumptions.

Now not every LTA is basically going to be an airship with ballonet. There are many other LTA vehicles. So can you name some other LTA vehicle which will not have just an envelope and ballonet. So, for that it is rigid airships what do you have in rigid airships do you have a ballonet? You do not have a ballonet in rigid airships. What happens in rigid airships is that the gas is stored in individual gas bags many of them.

And these gas bags are inside the structure. There is a structure there is a covering over the structure and inside structure they have independence gas bags. So, therefore the volume occupied by each gas bag will be a partial volume of the total amount of volume and that too because of the presence of the structure the total volume of the outside envelope is not available for the gas. Although the volume of the air displaced is equal to the outer volume of the body.

But the volume occupied by the lifting gas if you added it up it is not going to be same because there are other things inside. So, rigid airships we assume that there is something that is some volume V and each of the ballonet sorry each of these gas bags are going to occupy some volume with its own inflation fraction because the radius of gas bag will be less than the radius of the airship envelope at any point.

So that effect is taken care of by individual I_n and as you go from nose to the tip there is curvature in the envelope shape. Even the infraction fraction will not be the same. You will have for instance less value of I at the front and the back and more value I at the constant diameter or central portions. So, therefore the infraction fraction I can be replaced by summation of individual infraction fraction times individual volumes of the gas bags upon the envelope.

Secondly there are no ballonets is in a rigid airship you no need ballonet in rigid airship because you are not supposed to maintain internal pressure. In a rigid airship there is nothing like a ballonet needed because you have an external envelope which does not deform under the loads coming on the envelope are taken care by the structure. So, it will not allow a ballonet to compress or expand.

And inside a large volume of the envelope is filled with gas bags. And they are individual because one of them leaks it does not need to catastrophic failure or loss of lift. So, we can always bring back the same equation as last time. These equations are seen many times now so I copied and pasted them. How will they be changed when you go for rigid airships? So, what will happen in rigid airships? Please tell me one by one which term will drop off and which terms will change if you have a rigid airship.