Lighter Than Air Systems

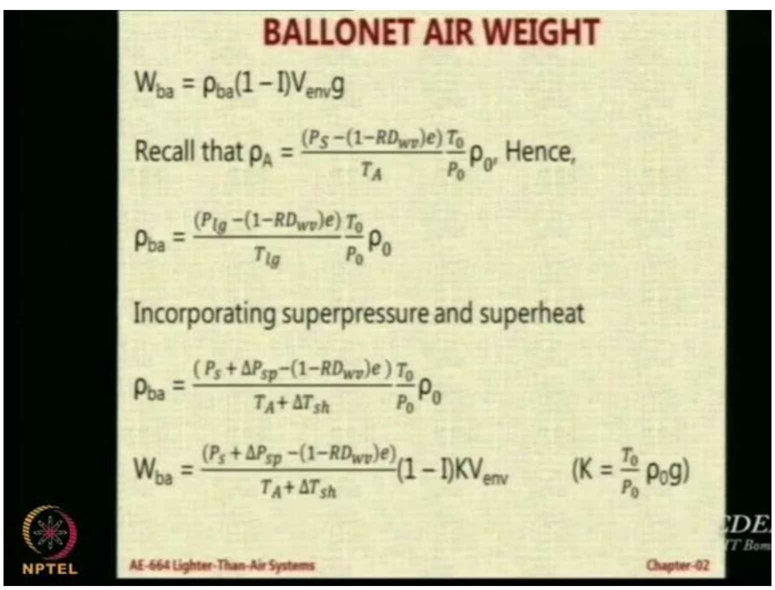
Prof. Rajkumar S. Pant
Department of Aerospace Engineering
Indian Institute of Technology - Bombay

Lecture - 32
Ballonet Air Weight Estimation

So today we continue from the last class. Today's class will be a kind of revision of what we did and also, we will look at some important aspects related to specific LTA systems. So, if you recall what we have done last time is looked at various methods to estimate the static lift. We spend a lot of time trying to understand the effect of humidity and to figure out how the static lift changes in the presence of humidity.

We also had a look at 2 additional or 3 additional terms one was the impurity of the lifting gas. So, we used the term Y to take care of the lifting gas impurity. We also took care of two other aspects one was the super pressure that is pressure inside the envelope more than the ambient and also the effect of super heat that is exposure to ambient air temperature due to which the gas inside gets heated.

(Refer Slide Time: 01:27)



Now let us look at now what happens because of all these factors to the weight of the air in the ballonet. So, recall that weight of the air in the ballonet can be given by the expression ρ_{ba} that is the density of the air in the ballonet times (1- I) where I is the infraction fraction. Infraction fraction just to recall your memory is the ratio of the lighter than air gas upon the total volume of envelope. In case you do not have any ballonet then I will be equal to 1.

And in case the whole envelope is filled by ballonet then I will be zero. So, weight of the ballonet air

$$W_{ba} = \rho_{ba}(1 - I)V_{env}g$$

$(1 - I)V_{env}$ is the volume available for the ballonet because V_{env} is a total volume and $(1 - I)V_{env}$ is the volume occupied by the ballonet at instance and g is the classical acceleration due to gravity which takes care of the units in this case because we are to be sure that the units are coming in Newtons.

So, also recall that the density of the ambient air ρ_A

$$\rho_A = \frac{(P_s - (1 - RD_{wv})e)}{T_A}\frac{T_0}{P_0}\rho_0$$

If you recall we got this $\frac{T_0}{P_0}\rho_0$ using the standard gas equation.

So, this term in numerator in bracket is essentially the pressure which was going to be less by the magnitude $(1 - RD_{wv})e$ because of the humidity. Because of the density I am sorry because of the relative density sorry not humidity. This is because of the density of LTA gas is lower than that of the air. Now the density of the air in the ballonet that will be ρ_{da}, if you assume that pressure inside the envelope is P_{lg} pressure of lifting gas and the same pressure is transmitted to the ballonet.

We are assuming that equalize the pressure between ballonet and envelope and if you also assume that the temperature inside the envelope of the lifting gas is T_{lg} the same temperature ultimately convert to the air in the ballonet. Then the density of the air in the ballonet also will be like the same expression except that instead of P_s which is the ambient air pressure under standard conditions instead that we will use P_{lg} pressure of the system inside the envelope.

And for T_A which is the ambient air temperature we will use T_{lg}. So, by the same expression one can get the density of the air inside the ballonet. Recall that the density of the air in the ballonet can be equated to density of the air outside it all depends on the temperatures. Depends on whether P_A and T_A, T_{lg} and P_s and T_{lg} and T_A if they are matching then it will be the same value. Now in this we need to incorporate the effect of super pressure and super heat.

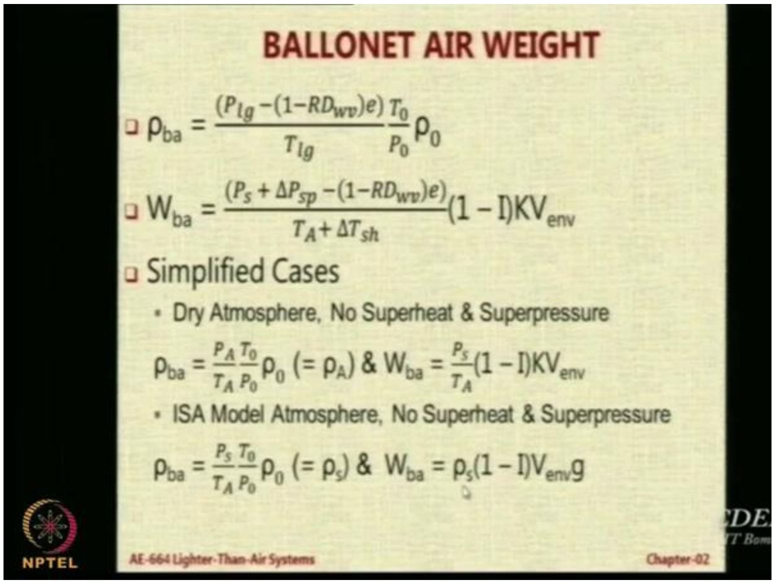
Super pressure if you recall is the additional pressure that is acting why because we are inflating the ballonet to a higher pressure then need it, so this ΔP if you recall intentional. So, what happen is that in the numerator the term P_{lg} will be added by ΔP_{SP} similarly the term in the denominator T_{lg} will be an additional term of the ΔT_{SH} so other things will remain the same and this expression now is expression that takes care of super pressure as well as super heat.

If you have any questions, so this is basically a class to revise and to understand what we have learnt last time in case there are any doubts you are most welcome to interrupt me we can go back and revisit few questions if you feel. Now the weight of the air in the ballonet is the first line in the in the slide is the density of the air in the ballonet times $(1 - I)V_{env}g$. So this ρ_{da} from here if you replace this expression you will get full expression for the weight of the air in the ballonet which is just this term ρ_{ba} inserted here and $(1 - I)KV_{env}$.

Recall that this K is the atmospheric constant which is nothing but the value of T_0, P_0, ρ_0 and g. So, g which you have here as a coupled here and that is K and that is a constant because T_0 is 15 degrees Celsius or 288.16 Kelvin, P_0 is 101325 Newton per meter square that is also constant. ρ_0 is 1.2256 kg per meter cube is also a constant and g is just to take care of the units. And these are the expressions now which will help us determine the total weight of the air in the ballonet and if you need some explication then density of the air inside the ballonet.

These particular equations are basically they are called as a force form equation because they were concerned about the weights.

(Refer Slide Time: 08:04)



Now the same expression is copied and pasted here for continuity again the same expression that we have used before. Now let us look at some simplified cases because not every time will you have issues like super pressure super heat. So, let us see if we can take a simplified case. So, the first simplified case is dry atmosphere no super heat and no super pressure. So now I want someone to help me what will happen to this equation in case we have this kind of situation.

When I say dry atmosphere, I mean that there is no effect of humidity or humidity is absent. So, when humidity is absent what do you get? What will change in the expression? One by one you have to raise your hands that allow me to also exercise some choice. So, who will help me understand what happens if the humidity is neglected or it is absent? So, e will be zero that is right. So when e is zero (1 – RD_{wv}) into this term is going to vanish.

What happens when the super pressure is not there? Then ΔP_{SP} is 0 similarly what happens when super heat is not there ΔT_{SH} not present. So, if we do that the expression becomes very simple and becomes the ρ_{ba} the first one will become the term inside the bracket completely go away. And ρ_{ba} will become

$$\rho_{ba} = \frac{P_A}{T_A} \frac{T_0}{P_0} \rho_0$$

because now with lifting gas will ultimately come to equilibrium with the air outside.

So, P_{lg} will become P_A and T_{lg} will be completely T_A so this will be becoming

$$\rho_{ba} = \frac{P_A}{T_A}\frac{T_0}{P_0}\rho_0$$

And this whole expression, you know is equal to ρ_A that is the density of the ambient air. So, if you have low humidity no super pressure, no super heat. So, density of air inside the ballonet is equal to density of the air outside which is what I just few minutes ago told you that it can happen in certain cases.

Similarly, W_{ba} or the weight of the air in the ballonet will be; this term will again go away. So, these two simple expressions, you can get the values for the condition of dry atmosphere and super heat and super pressure neglected. Let us look at another situation now we are not working in any atmosphere but working under the International standard atmosphere.

So, what will happen in these cases that the rho air will be equal to rho s which is the standard ambient air density. So, the expressions will be similar only thing is it will not be ambient air it will be density of the ambient air under standard conditions and the pressure also. In this case what will happen is that you can also replace this and our K can be brought inside and with that you can get the recover the value of ρ_s.