Lighter-Than-Air Systems
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Lecture – 103
Initial Sizing of Stratospheric Airships

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These are the challenges. Now, we will move to the sizing optimization of these type of systems, initial sizing basically and conceptually stage. So, because challenges is there you have to take care of all the different aspects of the affecting parameters simultaneously. So, there is a design methodology requirement. So, requirements should be such that whenever we feed the operational parameter or design parameter like wind speed because wind speed at that height will be different.

And even it will be different for the different lat-long. At the same height say about 20 kilometers the wind speed at Mumbai will be different from Delhi. So, we should consider that. Solar irradiance will be different at the different location whenever we talk about altitude, latitude and longitude. So, each location at that height will be different. Power availability will be different that will affect our whole systems.

Because if power available is high you will need lesser solar cells, you will need lesser power storing device. Geometric coverage ratio; what is geometric coverage ratio? Can anybody tell? Geometric coverage ratio. Any guess? No guess. It is simply a ratio of something. Coverage must be an area. So the ratio of two areas which are that, simple that basically two areas we have to consider, envelope area another thing is solar cell area.

So, because the envelope area will effect our structural mass and solar area will affect the power output. So, it is basically a ratio of solar area divided by the envelope area that is called a geometric coverage ratio. Discharging time is the time when the direct power from sun is not available and you have to supply power from the battery that is the discharging time which will be larger in winter and it will be smaller in summer.

And it will vary around the globe due to the latitude and longitude, okay no? Off standard temperature because temperature at that height will affect the buoyancy as well as the power output. Purity of LTA gas to affect the buoyancy. And efficiency of cells that is another major research area as general because the highly efficient solar cells will result very low system weight. So, how much maximum efficiency is nowadays we get from solar cells?

Any guess, maximum efficiency of the solar cells, 20%, it is 8 to 10%. People are researching and they have claimed that 40-45%. So it will be a big research output. You know the significance of efficiency? Solar cell efficiency. Light up a single bulb you will need a larger solar area because larger solar area it will accumulate and 8% of that will be converted and it will light up.

So if the efficiency is high, say it is about 100% and output is how much 500 watt per meter square. So if we place a 1 meter we will get 500 watt, but the 8% of that actually a problem. So a big solar plate is required to light up the small lantern at the night. So, the methdology requirement is this and it should be such that at the end while we give the payload requirement as well as the power requirement, it should give the size of airship.

What is the required size to overcome that payload as well as to power. Methodology design should be able to give most feasible shape. For different requirement the shape will be different, it will vary. As I said earlier if the power output is more and more important then it might be ends with some another shape maybe 3D. Because when you consider only power requirement, what type of shape you will propose?

"Professor – student conversation starts." Any guess. Suppose we have to bother only about power, how we can maximize that power output? Maximum area. Maximum area, but maximum area with a different orientation will not result a maximum output. **"Professor – student conversation ends."** So, it should be such that over the day the vector of the normal area vector of the profile should be with the 0 degree angle, ideally with the solar radiation angle, you got the point?

So, it should be such that at each time it should be at 0 degree, then you will get maximum output. Otherwise, cos theta is involved and it will bring down. Larger the cos theta, minimum will be the output irradiance at least input. But there is another problem as well, drag. So we have to take care of drag as well. We have to take care of payload as well. So, what will be the optimum shape which will maximize the output as well as payload output.

Available payload as well as the minimum drag the shape should be like that. And what will be the different mass compared to the mass of the different component like propulsion systems mass and structural weight and storing energy due to battery weight it should be able to give. Design methodology should be such type.

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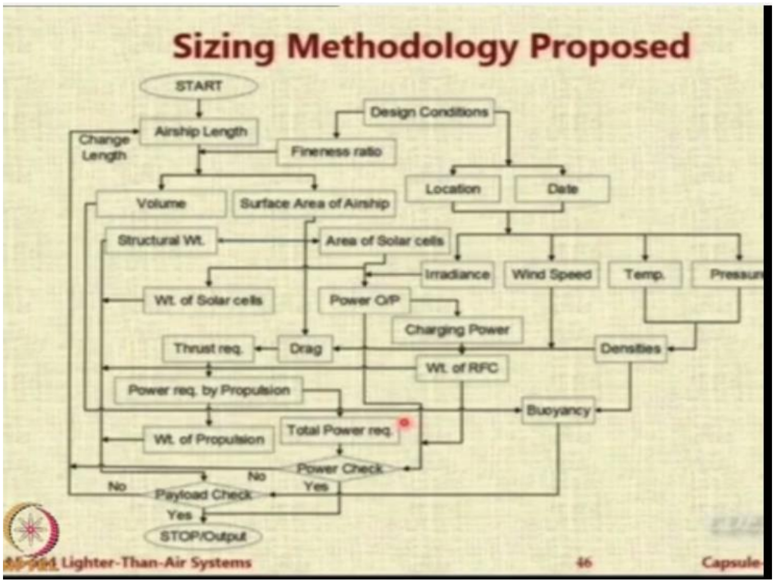

So basically a sizing methodology proposed can see it start from here and give some for the given payload and power requirement give some random length and calculate with a given parameter because the location you know and at that location you know that at the particular time as well. Because over the time over the date, it will vary. Suppose today is what date 8 of

April. Thus energy available at that height in Mumbai it will be different when we consider at some other date.

So, for a given location and date the wind speed is available, irradiance available, temperature, pressure and from that we have to calculate all these systems, volumes. And volume will write the payload and then surface area with the size and surface area of airship will lead to the drag as well as system's weight. And we have to finally check whether the power requirement is met or not.

And if it is not, then you have to go back and change the length. And payload and power check both should be fulfilled. Otherwise, you have to go and change the length. Do the iteration and if all the power requirement or payload are met then end with the calculation that is a for initial sizing. It is not in optimum sizing.

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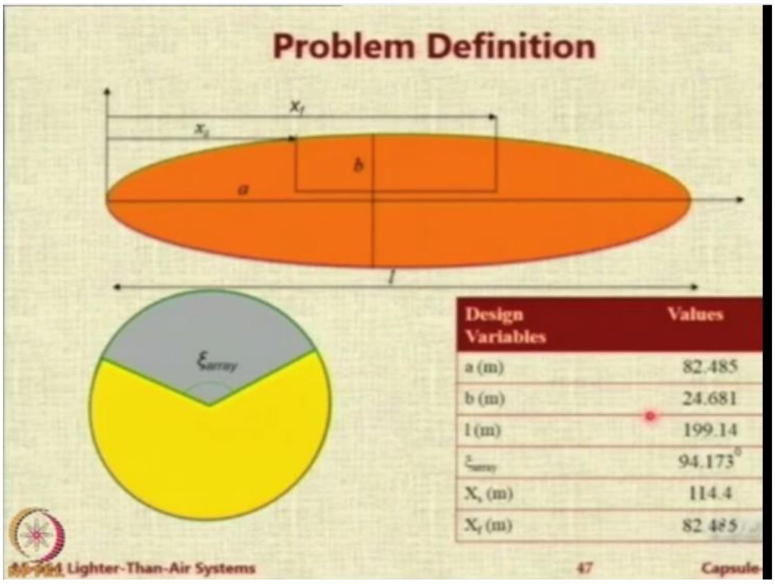

So, for simplicity we can look at this problem. So suppose it is, this is actually an NPL shape driven by the two parabola. You know NPL shape? **"Professor – student conversation starts."** How NPL shape is defined? You say some shapes of the airship. You know different shapes of the airship. Its standard shape, profile. There are some standard profile of the airship, no?

Normal airship. GNVR. GNVR and double ellipsoid. Double ellipsoid is actually NPL shape. **"Professor – student conversation ends."** It is a combination of two half ellipsoid with the same minor axis and different major axes. So, this is different from this length, same major axis and it basically a ratio of root 2. So, we consider that and this is the area required suppose, the X_f is the final position of the solar cells and X_s is the start position.

So, the length will be X_f minus X_s and angular coverage is zeta array, zeta or psi what you say? So, whatever it is. So, complete area you can calculate. So, let us, these are the design variable a, b; b is the radius of the airship at maximum diameter, a is the semi major axis. And when you will multiply with $a\sqrt{2}$, it will give the other side area, length and so 1, 2, 3, 4 and when you add $a + a\sqrt{2}$, it will lead to the l, total length of the airship and the psi.

So, basically 5 design parameters a, b, zeta array, X_s and X_f. So, these are the initial values we get from initial design. Now we have to optimize. Because the location we will put X_s and X_f will affect the output, we have to maximize that and how much coverage will be required to fulfill the power. So, for initial sizing what you have said in a design, these are the our parameters for initial sizing.

To fulfill the power requirement and payload requirement you will need a length of around two 200 meters and with this angle starting and ending total length of the solar cells.

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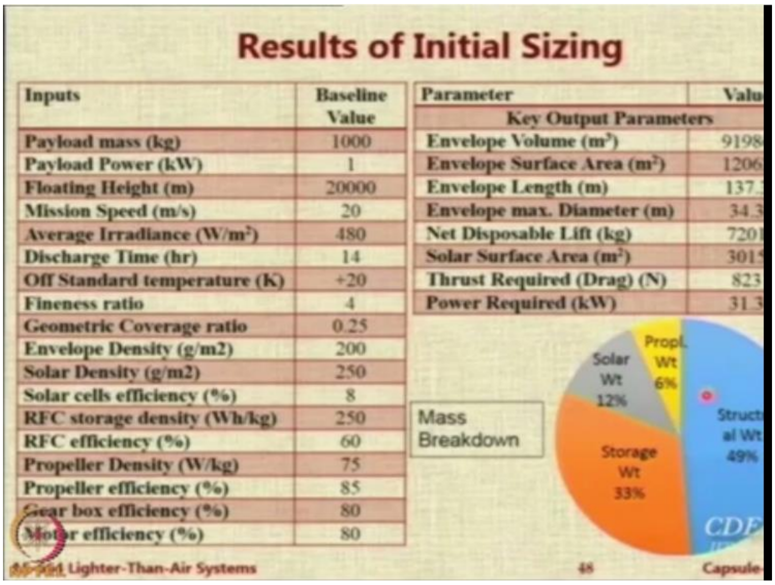

And other output parameters for initial sizing you can see for these are the input parameters, these are the output parameter. So, payload mass of 1000 kg and payload power of 1 kilowatt. These calculations are made and what we are getting is you can see the size of to produce such payload and power you will need around 137 or 138 meter length of the airship. And the power required to overcome the thrust will be 31 kilowatt.

And the mass breakdown as I said methodology should be able to give the mass breakdown of the systems. So, you can see around 50% of the weight of the systems is due to its structure that is why the problem. Whenever we will decrease the gsm keeping the same strength, it will give a better good output. And a storage weight is about one-third of the total system. So, it is another problem.

When will we maximize the storing capacity of the RFC or lithium-ion battery, it will lower the system's weight and we will get a higher payload.

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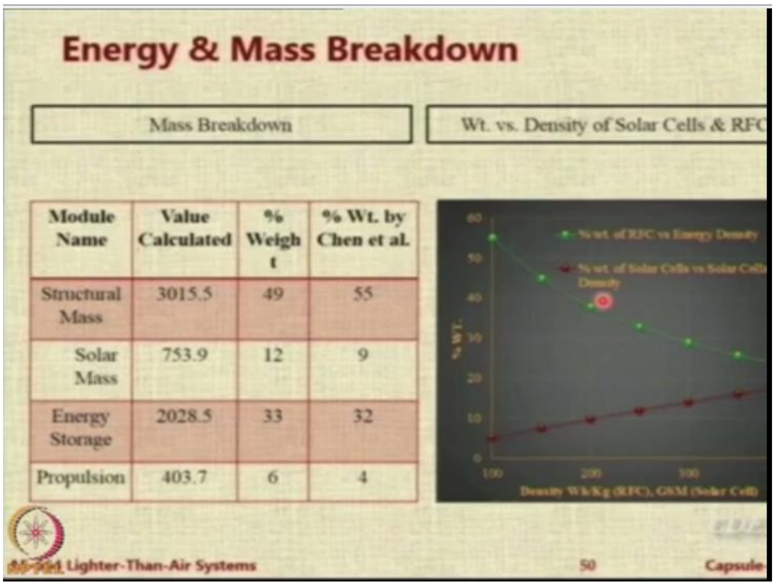

So, these are the sensitivity analysis. How different output parameters will be driven with change of the input parameters that is actually sensitivity of design parameters. So, you can see this is the percentage weight due to the RFC and the solar cells. So, whenever we will increase the energy density of RFC that means it can store same energy with a lower weight itself its weight that is better.

So, whenever we will increase the density capacity of RFC, the percentage weight of the system will go down. These trends you can see. Are you able to see this? No. and another thing is that when efficiency of the solar cell will increase, the system's weight will go down, you get the point? System’s weight will go down.

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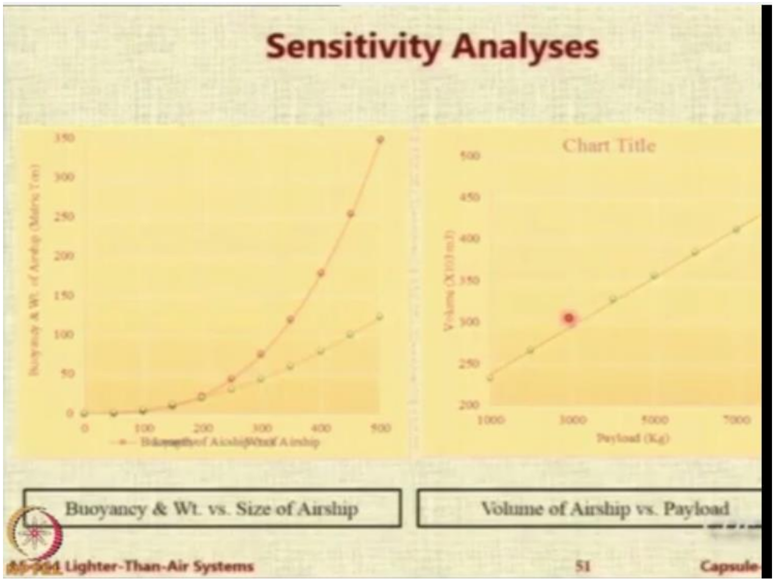

Now, see the variation of buoyancy with the length. This is the length, this is the weight of airship and this is the length variation. Are you able to see? No, I should have designed the light background. So, you can observe one interesting thing is that there is a minimum length of the airship required to overcome its own weight and below that length the system will not even overcome its own weight.

And you have to get extra payload to carry the systems, another systems that is interesting. And another variation is that a simple volume, payload with the volume as the payload is driven by the volume and is a linear relationship between the payload and the volume.

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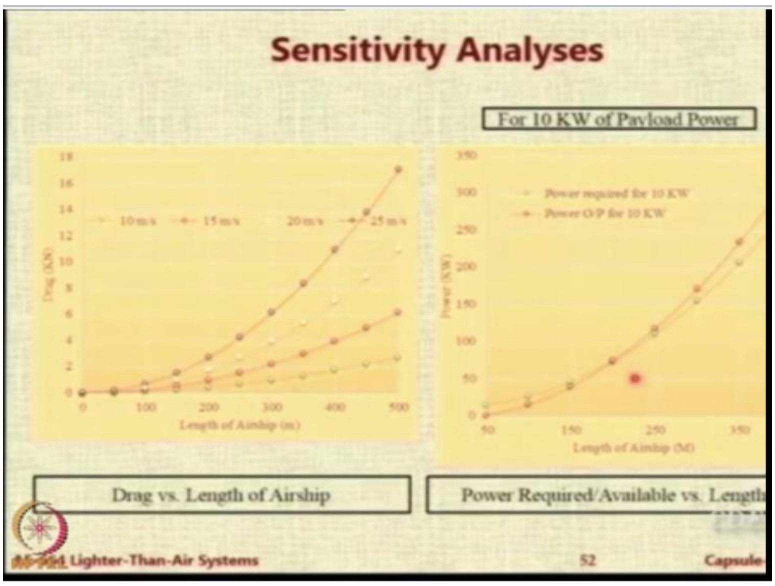

So, move on to the next slide. See the effect of wind speed. How much it affects at that height. It is for 10 to 25 meters per second for the same size of airship say around 500 length and we are getting a very low drag. And when the wind speed will increase to 25 meters per second, the drag is about eight folds that is the significance of wind speed. And because the very big size it is directly the $\frac{1}{2}\rho V^2$, it will go a square with velocity.

To overcome the power because power is required to propel the airship to withstand with the drag and to fulfill the power requirement by the payload. So, there is a minimum requirement of the length or size of the airship which will actually fulfill the power required. And below that length around say around at 175 or at 190 meters, system is underpowered.

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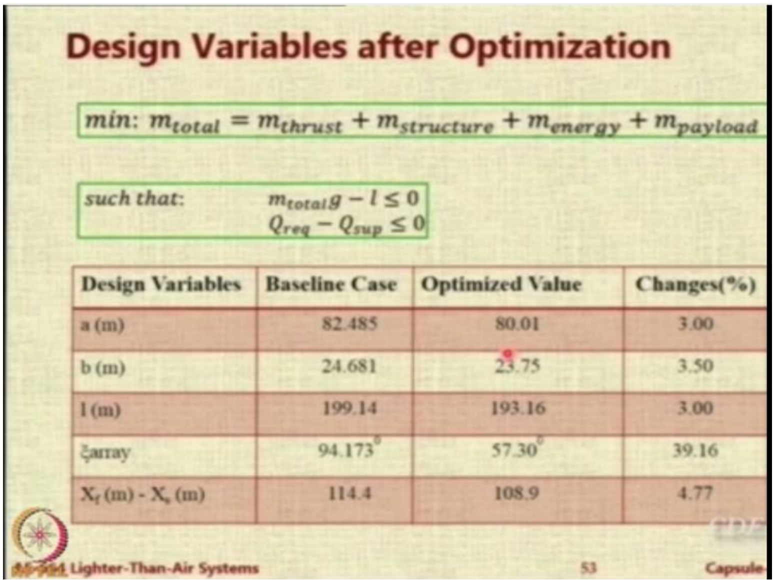

So, now with this earlier it was because for a initial sizing and now we have to optimize, we put the systems methodology and optimization to get the best result. So, the formulation is such that total mass, we have to minimize the total mass of the systems while fulfilling the requirement of payload as well as power required. So for the baseline case, when we have not considered the optimization, the baseline case was these.

For the same power requirement or payload requirement after optimization we are getting this. So, the change we can see actually the purpose of optimization. So, are you getting or I think you are getting bored, not you are not getting a point. So, it is almost.

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So, on the last slide, it is not the least but in last year we have seen in Times of India about the high altitude airships. The researches are going on over the globe and it is a very potential area. So that was all. Thank you.