**Aircraft Design**
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**Lecture – 32**
**Wing Loading: Designer's Approach**

Good morning friends. Let us have a relook on the example were we are calculating wing loading.

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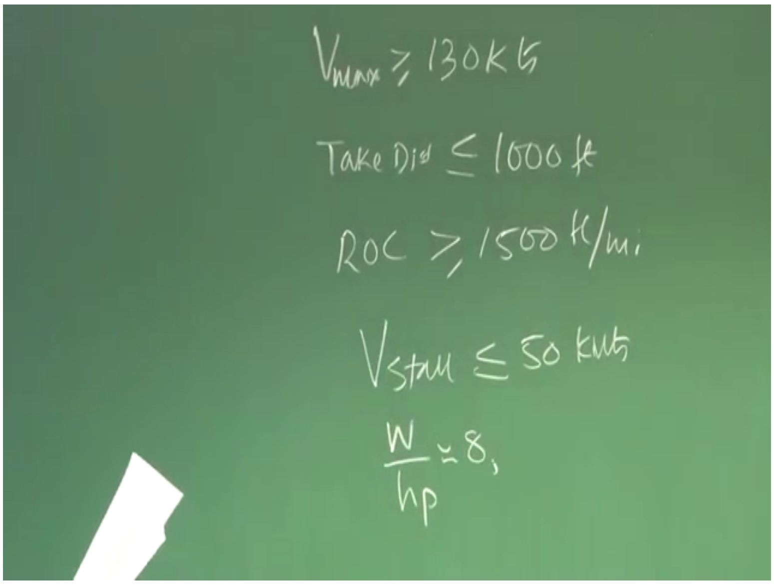


And if you recall a mission requirements were V max greater than equal to one thirty knots then take off distance less than equal to 1000 feet. Then rate of climb greater than 1500 feet per minute. And of course, V stall less than equal to 50 knots. And we have selected the engine based on the baseline aeroplane the power loaded W by h p was around 8.

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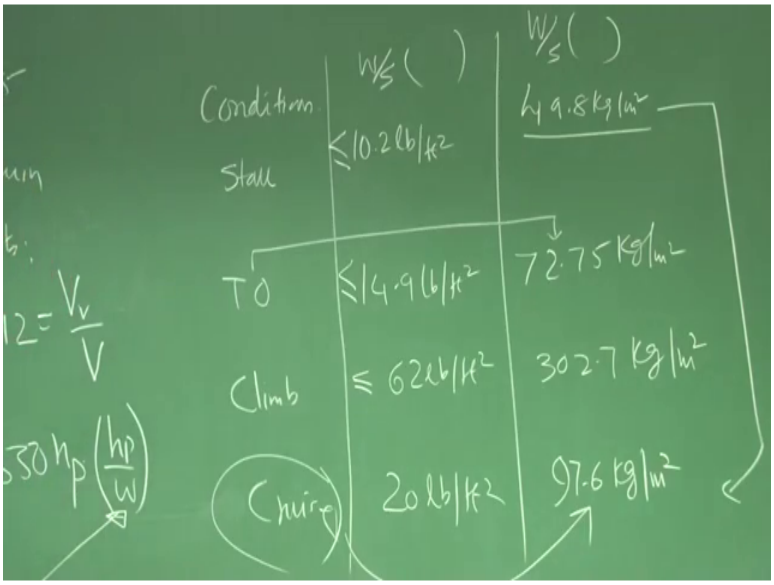


And if you see when you calculated wing loading for different conditions we got conditions if write here was stall one condition, take off was another, climb, and then cruise, these four parameters we have considered just for an example to see how all I use it. And we got W by S for this is 10.2 pound per feet square; and this is 14.9 pound per feet square, climb it was 62 pound per feet square and this was 20 pound per feet square. Af course, this is less than equal to less than equal to less than equal to this. And in kg per meter square if I convert, I get this around 49.8 kg per meter square please see the conversion was the correct or not, 72.75 kg per meter square, and this is 302.7 kg per meter square and this was on 97.6 kg per meter square.

Now, you could see that so many values of wing loading, we need to have to satisfy the mission requirements which are in terms of stall which cannot be more than 50 knots, take off which cannot be more than 100 feet, climb minimum 1500 feet per minute and when I do a cruise we are taking around 130 knots. Cruise in speed we max could be more than that. If this is the condition now we have different values of wing loading we are having which one I should pick that is why I was telling first of all we should know indeed we know what type of aircraft we are designing. If it is an aircraft which has range to be the most predominant thing then I will look for I will give more weightage to the cruise conditions.

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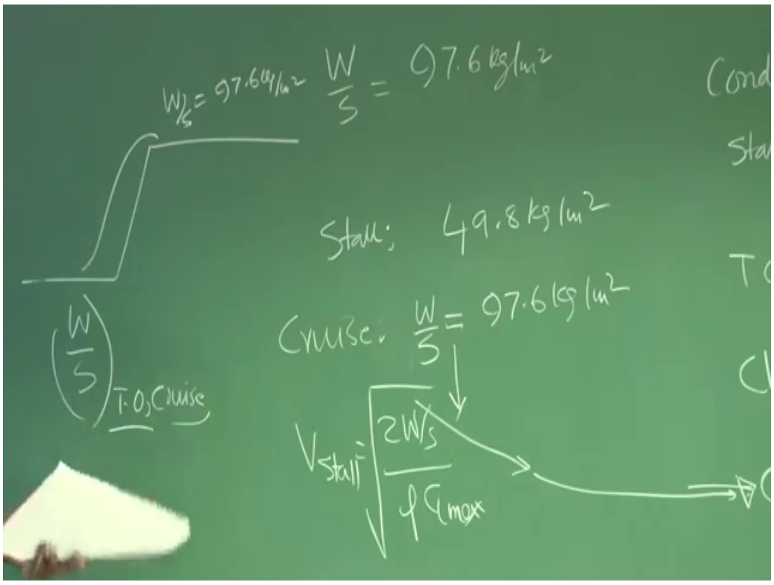


Let us see I give weightage to cruise condition it tells me that W by S should be around 97.6 kg per meter square. And it goes without saying what we are meanings there by that that is W by S here is 97.6 kg per meters meter square or twenty pound per feet square which actually means you know how to covert it back to W by S take off right. You know how much fuel is consumed here to here and here to here divide by their fraction and you get W by S take off requirement for cruise mission, this is we know it.

Today we discuss of that different. When W by cruise is this if I want to see whether my stall conditions are matting or not then I find for stall which is limitation of 50 knots cannot be more than 50 knots. It tells me these are all 49.8 kg per meter square if I select W by S based on cruise it tells me I will have W by S as 97.6 kg per meter square and which one I convert back to the take off from here it will be little more than this right. It may be become 120 kg per meters square.

The point here is very simple, if I take W by S as let say 110 or 120 kg per meter square then problem is how it is going to affect your stall. See as far as stall is concerned V stall is 2 W by S by row C L max. W by S we have picked the value from cruise which is appropriately correct it for takeoff. V stall, I want or on 50 knots. See if I take W by S as 97.6 kg per meter square, we naturally V stall will be more because it where is W by S. To maintain the V stall W by is required was 49.8 or less than that, but we are selecting 97.6 which is more than as dictated by stall condition which actually amounts to that the

V stall will increase, keeping everything constant, but that is a condition you cannot valid. So, what is to be done that is the question.

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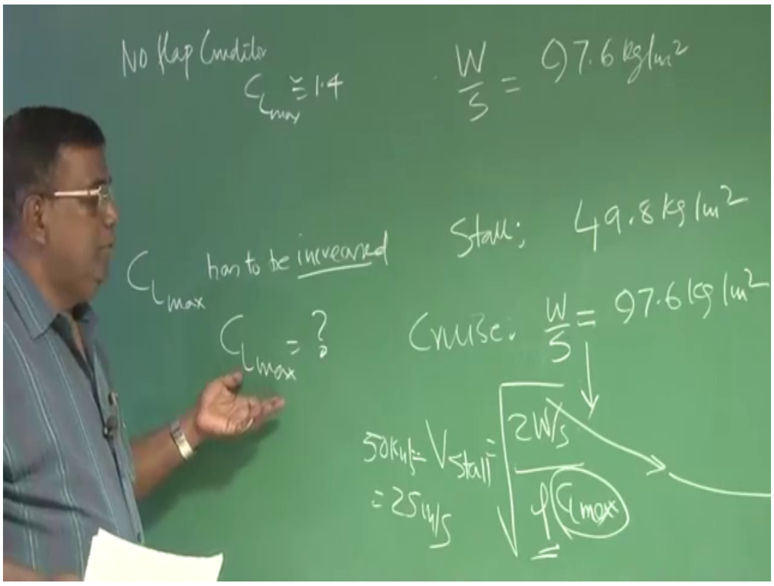


If you see in the example of rammer, they have used no flap conditions work. And they have taken C L max as 1.4 around that, but in this example I have already assumed that there is a plane flap because I understand that normally air foil C L max of 1.2 is a good initial number to start your job right. And once you use the plane flap, if you give a deflection by 10 degrees flap deflection, you can easily touch 1.4 C L max. But then coming back here, if W by S increase, but still you want to keep 50 knots or around 25 meter per second and keeping in W by S as 97.6 kg per meter square density remain same, same place you are taking off which will amount to how much C L max is required. So, that C L max will definitely not the C L max use here.

So, in this case if you to maintain this C L max has to be increased. Then you check how much C L max is required, how much and see whether that enhance when the C L max I can get by further deflect in the flap or not or using a little higher order of flap or not. So, this sort of a debate will go on. And if it is making life miserable in terms of effecting every other parameter then you have to take a look whether I can play around with this or not. We will solve an example which is just to show you what sort of issues are coming. So, if I could immediately see a conflict maintaining stall condition and cruise condition right. Next, you see what happens before it a climb conditions.

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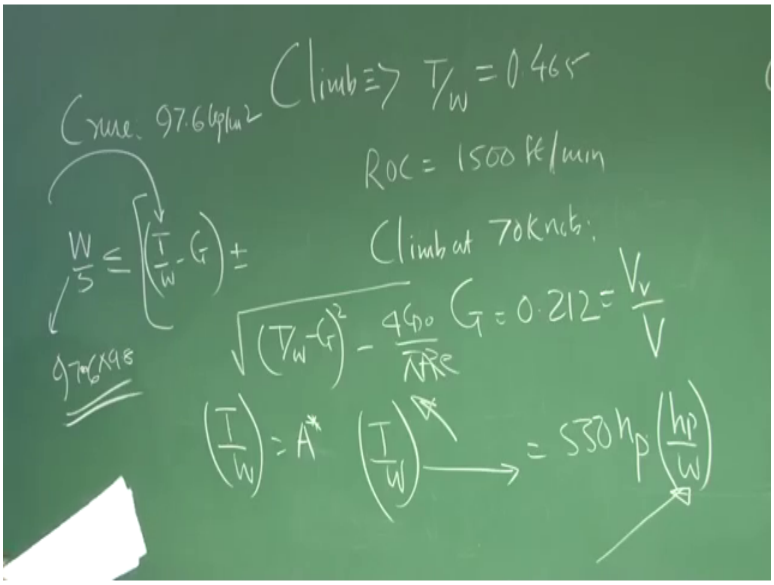

If we have to maintain the climb 1500 feet per minute, it tells me two things that T by W should be around if you check your notes T by W here on 0.465 yes by 0.465 because as per the climb rate is rate of climb is concerned which was 1500 feet per minute. And we plan to climb at 70 knots which is 35 meter per second we got G as 0.212 which was ratio of vertical velocity with the climb velocity roughly.

So, now the question is if I have chosen cruise W by S 97.6, let say I have chosen cruise at 97.6 kg per meter square, but climb requirement is around 302.7 kg per meter square what is the implication of it. If you see we write W by S less than equal to T by W minus G plus minus under root of T by W minus G square minus 4 C D naught by pi aspect ratio e which W by S of 302.7 kg per meter square we got by taking T by W at 0.465. So, now if I put W by S as 97.6 because that if I am choosing which may be around 100, I told you when I convert back to take off conditions. Then of course, this I have to multiplied by 9.8 to make a due to per meter square to be consistent with the unit. If I do that and I can find out keeping everything same what is the T by W requirement.

And from here if I find T by W is some value A star, but we have seen T by W equal to A star which I am getting by put in the W by S as whatever is prescribed by cruise condition, I put that value here. And I find what is the T by W coming from this expressions from here everything same. This T by W, now I check back with 550 into neta p into hp by W. And see what is the hp by W required or what is the inverse up all loading require, whether I am able to get from that engine or not. So, this sort of hint iteration will go on. And you see when we actually solve an example, this thing will become crystal clear. Similar thing you will find with takeoff distance. If you see if I take the cruise W by S which is around 97 kg per meter square, and for takeoff distance it is around 72.75 kg per meter square, immediately you know I will be able to satisfy take off conditions if I take a cruise condition. So, this does not bothered you much. What bothers you is this one and to some extent is one that is sort of an iteration is a must and we have to do that.

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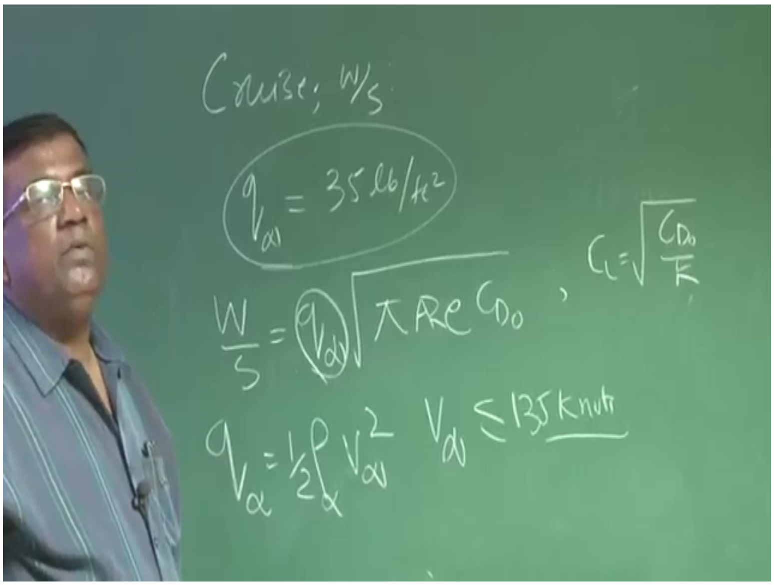

Also understand one more thing when I close list see the cruise data which will help you in making a decision must be careful about what is the cruise W by S we are talking about. How did you calculate cruise W by S? We assumed the dynamic pressure at 35pound per feet square. It amounts to some altitude, which you can find out because you have an idea about what speed I am going to do. But if you see when I calculated W by S for cruise what I have done I have taken q infinity under root pi aspect ratio e C D right. And what is this condition this condition is for maximum range where we are assuming C L equal to under root C D naught by K from that this expression has come. Aspect ratio that conceptual stage we have some number, you have some numbers C D naught – 0.02, and C L is fixed C D naught by K.

Now, I ask a question to myself when I am writing q infinity as 35 pound per feet square with a dynamic pressure. So, q infinity is half rho V infinity square. So, I know through dynamic pressure, what is the combination of rho and V infinity. If I want to tweak this W by S, suppose I want to see that W by S, I want to increase from 100 to 150, so that I can do a compromise. That only way I can do it is I change the dynamic pressure or which in term means ether I come little lower altitude which we not like or you increase the speed. Or then for a speed you know that for speed maximum is 135 knots. And we are try to evaluate cruise at around that speed so that is the problem.

And suppose it demands that you have to decrease from 97 to let say 90 the option could be primarily you reduce q infinity or that means, keeping this speed same one option could be go higher altitude. There you reduce, but then if depending upon type of engine, type of navigation available, type of air traffic controller clearances for generic air craft of this time is all much variation in the high end altitude will not be permitted you know which are not go beyond that we will not get. So, all these sort of a conflict will come and finally, we will have to pick one and then which start calculating the mission performances with that.

For example, let say would do you all this compromise let say we fixed W by S as 110 kg per meter square. Generally, we read a book thumb rule advice is always you take the lowest wing loading. Lowest wing loading here is which one stall 49.8 kg per meter square. Why it is recommended, lowest wing loading means larger wing area, so that is, but do you understand larger wing area means larger span because you need to have a larger aspect ratio, a larger wing area means larger drag. So, all those complications come. And then the question is if the lowest wing loading criteria I am selecting I will cross check what is the mission performance it is satisfying it is stall by airplane if the requirement is very stringent on takeoff condition then I may giving loading as a primary importance. As long as I am exhausted with all the C L max or high leave device options. If it is a plane for maximum range and all then why should I give so much weightage to this right, so that is one of a debate will go on.

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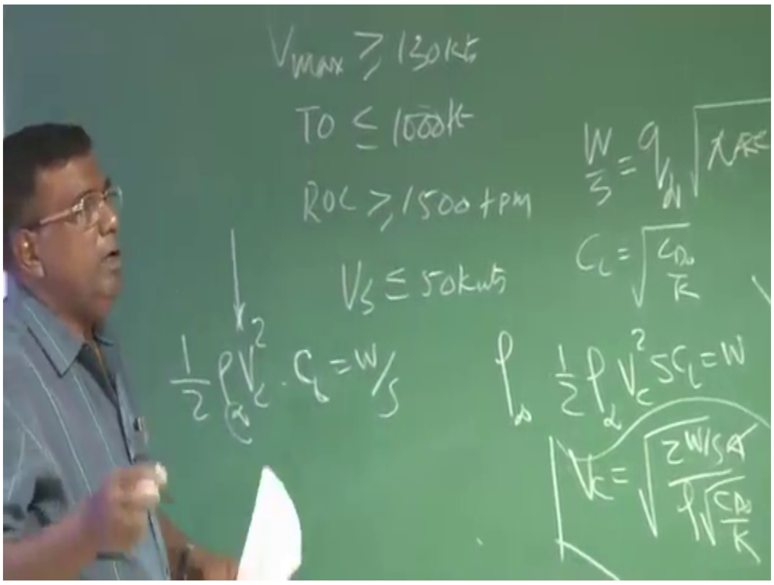


And let say W by S is 110 kg per meter square we have decided then what we have to do, again go back to our question V max 130 knots then take off distance less than 1000 feet rate of climb greater than 1500 feet per minute and V stall less than 50 knots. So, with this new wing loading, we will check whether this mission requirements are meeting or not; few we will find ok, few again you have to see what additionally I can change to make a compromise and near optimized solution I get.

Special in cruise you need to also understand, when I wrote cruise as the expression based on maximum range which was q infinity under root pi aspect ratio e C D naught. This assumes C L equal to under root C D naught by K. So, if we have chosen an altitude where you will be cruising primarily then how rho V cruise square S C L will be equal to weight or V cruise will be 2 W by S by rho C L means C D naught by K. So, you could see that your V cruise get fixed for a given wing loading which is for range to maximum, but you have to check with here the cruise feet is what a customer is looking for, he may save come on this feet is very low or you may find this be feet is very, very high that will have lot of structural implication. Generally, you will finds come low, so then what to do. Then again you try to alter the altitude or you there compromise you say I am sorry I will be getting this W by S by giving more weightage to cruise speed or accordingly I will look for C L, it will not be a really a condition of minimum or maximum range.

But ideally one what one will do we try to select what altitude I select I still I fly with this, and my cruise peed is acceptable. You could see that if I reduce rho cruise speed will increase. So, I can always do that sort of iteration that ok, I pick up an altitude where I get higher cruise speed to maintain lift equal to weight flying at C L equal to C D naught by K which satisfy my customer also its not that too slow in aircraft. So, all those implications will come and finally, you take one or two that is why in design you at least have two to three configuration moving parallelly as far as wing loading is concerned. And create a huge data base for example, if I want to create the data base I will create the data base for W by S for different, different dynamic pressure different aspect ratio different C D naught or all those should be available with me. So, whenever crisis is there I can pick up them and use a linier interpolation method to get my configuration.

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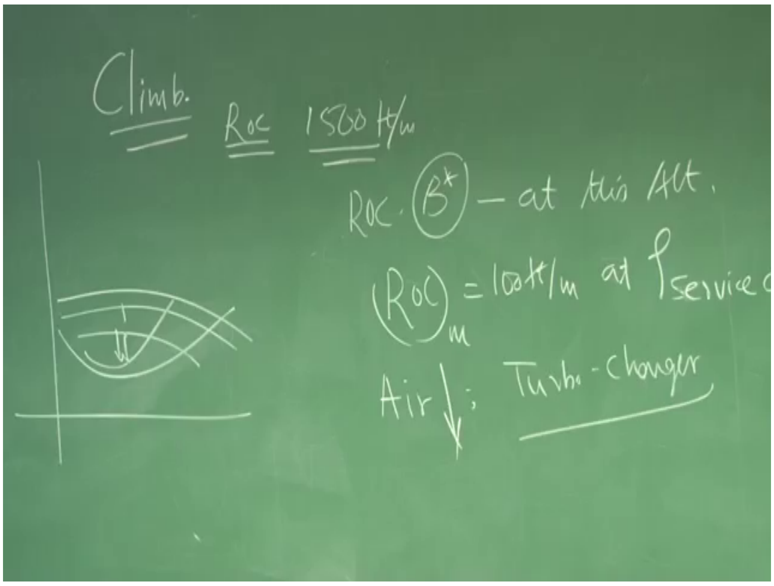


After cruise if I need to discuss something on climb you will find this rate of climb whatever we have prescribed maximum rate of climb to maintain that this is 1500 feet per minute. To maintain that we need an axis power are different, different altitude as we were going higher and higher, this gentlemen comes down and this goes like this. So, here x is fall reduces. So, if you were trying to ensure that S issued have a particular rate of climb, let say rate of climb B star this much rate of climb at this altitude right to be more specific. Suppose I want rate of climb maximum it is 100 feet per minute at rho sea level sorry service ceiling. What is service ceiling? service ceiling is that altitude at with rate of climb is 100 feet per minute that indirectly tells you up to what altitude you can climb because whatever climbed at you have at the sea level as I am going up and up amount of air is reducing. So, your engine will develop or deliver that much of power which was available at the sea level. It will go on reducing and also the power required graph also changes as we have seen that is why excess power reduces right.

So, how do I ensure the rate of climb maximum 100 feet per minute at particular altitude which is service ceiling, we sometime since there is air is going down in particular oxygen is going down. So, you can use some sort of a turbo charger. If you see our (Refer Time: 24:47) airplanes they used this during that altitude it is operational right However, this cost money right efficiency goes down, but yes we have to go to that altitude.

So, there are a provisions of turbo charger, super charger etcetera, etcetera associative with the engine that also not only that helps in getting good service ceiling, but also this creates maintenance issues particular about it. Apart from that beyond and altitude for a non pressurized air planes like Cessna 206 at all you need to ensure that there is a amount of oxygen in the cabin so that pilot and passengers are comfortable right. So, we will find many such altitudes people are flying pilots and copilot combination of flying they carry oxygen cylinder oxygen mask with them.

So, just for a conventional general aviation aircraft which start thinking of altitude, you should not only thing in terms of excess power or should not thing in terms of wing loading, thrust loading or C L max. Please remember as I go higher and higher, the amount of oxygen goes down and that has to be handled pilot, these to have some oxygen or keeping is himself alert. So, that some time decides whether you are going to fly other altitude or not because it adds to cost this is very, very important right.