Aircraft Design

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Lecture – 15
Wing Design: t/c, Camber and Leading Edge Radius

Good morning friends. We have been discussing about aerofoil, for the purpose that finally, at the end of the day the lift generation is to be through a proper wing. When you talk about lift drag ratio to make our airplane efficient aerodynamically. Again wing plays very important role. When I want to balance the aircraft you see that they are also selection of a airfoil plays an important role, why important perhaps the most settle role unless you handle it correctly finally, you find the design is not a good design. If I just do a summary of whatever you are discussing, typically in my lectures I call this session as right, I go back I check the videos I find out at this point I have just gone very fast, or perhaps I have given too many informations give me too many information is not the right way of sharing knowledge right. That is why I always create a one session where I cover it under.

But basically we do revision, and try to make things clearer for my mistake, which I have done during my recording whether in terms of writing something wrong or going fast on a particular concept where I should have been little more slower and I would have should have you in a more stress. So, I have just given the thought in the night.

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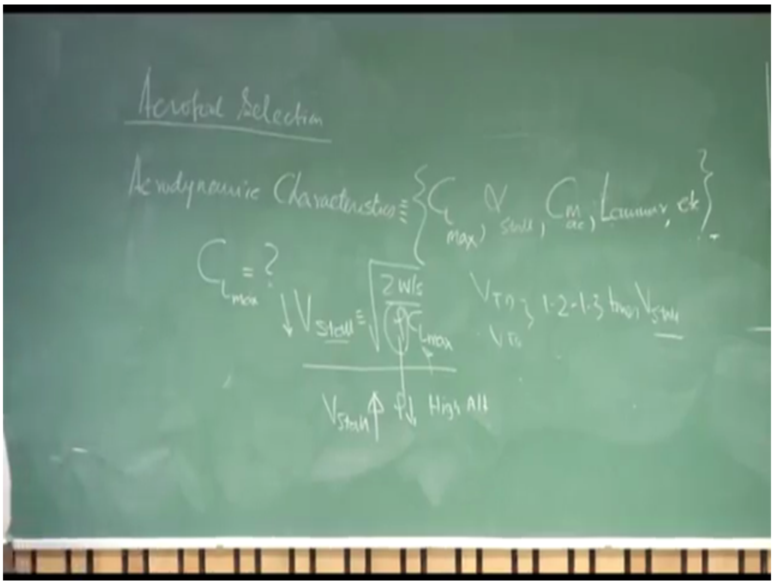

And let us summarize what we are doing is airfoil or aerofoil selections, and we are preparing ourselves whether we know at core level, what is an aerofoil what are it is characteristics what are it is parameters will decides the desired characteristics. And we have seen that specially the aerodynamic characteristics, mostly can be covered through knowing what is the C L max, what is alpha stall what is Cmac whether a slow is slow is laminar you want over most of the part of the wing etcetera right.

If I take this C L max, we know that most of the time when the airplane will be flying it will not be flying axial max, but why were give you so much stress on C L max? For simple reason at V stall which we understand is the minimum speed at which the airplane can maintain a level un accelerated flight it is given by, 2 W by S rho C L max. So, if C L max is higher then your V stall is lower. A V stall lower has lot of advantages that your engine power requirement reduces and also you know we touchdown or V take off they are almost like 1.2 to 1.3 times V stall.

So, if V stall is less then V take off a V touch down is also less. So, you have direct implication on the engine power selection right, is a another think for designer. If you see if you are taking off from a high altitude maybe (Refer Time: 04:52) some someplace like that then the density of air will be lesser compared to sea level density of air. So, there also you see that because of high altitude because rho goes down at high altitude your V stall had a tendency to be more than V stall required at sea level.

So, how do I compensate that because anyway you have to take off from lay. So, if I have a larger C L max, then I can manage that much of V stall which my engine power can deliver right. So, this is one way of looking why do you want C L max. Please understand for in aircraft takeoff and landing is very crucial, mostly when you are flying at C L max.

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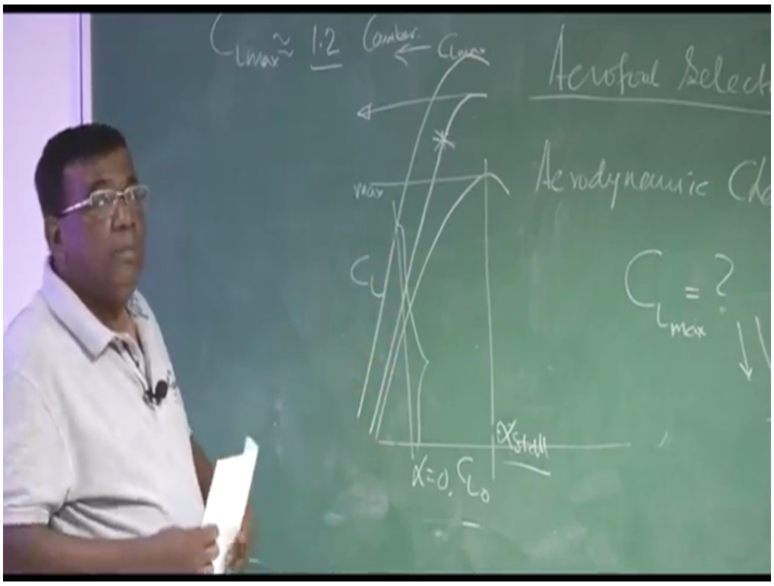

Let us say I am flying at C L max which is theoretically you have close to alpha stall. So, imagine I am coming for landing and because of some ground effect or ground upward wind the local angle of attack suddenly increases then you are actually falling here. So, that is very bad way of operation you do not operate at this point. Why you are operating at this point because we want high C L max with C L. So, instead if you have something the C L max is higher, because of aerofoil because of other considerations you can (Refer Time: 06:33) fly here during takeoff and landing. So, you are safe. So, there is a reason why you want to operate at high C L max.

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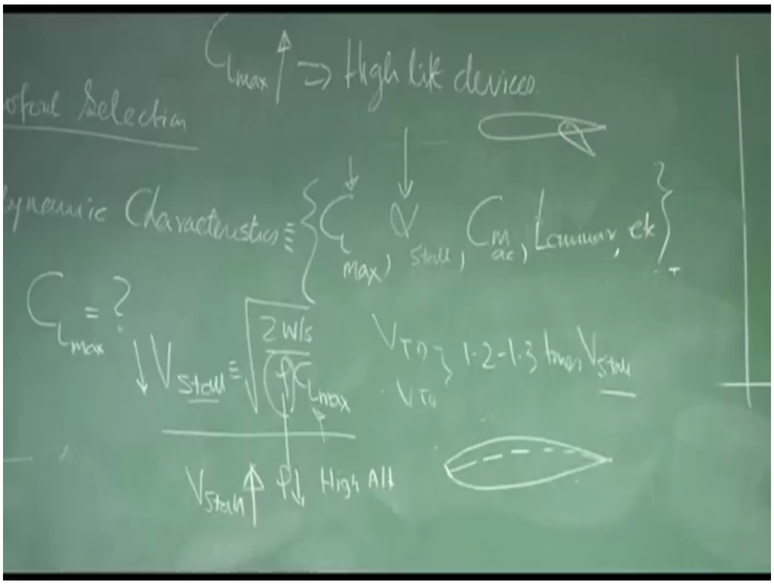

So, what we do by selecting an aerofoil, we try to see what is that aerofoil shape for which I will get C L max higher. Typically, you will find for conventional aerofoil symmetry canal, the C L max is almost saturated at 1.2. Then what we do we say introduce camber were introducing camber. So, there is a camber line by introducing chamber, you are actually increasing further your C L max. That is where the camber part came. So, we introduced camber twin k C L max, but note one thing the moment I am introducing camber, this portion that is at alpha equal to 0 you are also getting C L naught.

So, this also increases and you have to be careful about what is the effect of this in terms of balancing the in aircraft, we will talking about. Those first all and C L max goes together and let us say you have an aerofoil where maximum by doing this optimization that if I increase camber C L max increases, but stall also reduces. So, you say at the most I can get C L max around 1.4 or 1.5, but from V stall requirement did not take off a landing you will be happier if C L max is around 2 or 2.5 or 3. Then what you do then the point C L max, I increase not only through aerofoil which is already basically present an already design. So, I use highly devices. We will talk about highly devices in detail this. Essentially means that some portion of this is put down 10 degree 15 degree. So, effectively change in camber locally at that point and you have what a higher C L max.

I wrote a here Cmac, the moment there is a camber as we introduced camber and you know that if this is camber, I am introduced in the lower portion resultant force will be in this direction upper one in direction they do not pass on the same point.

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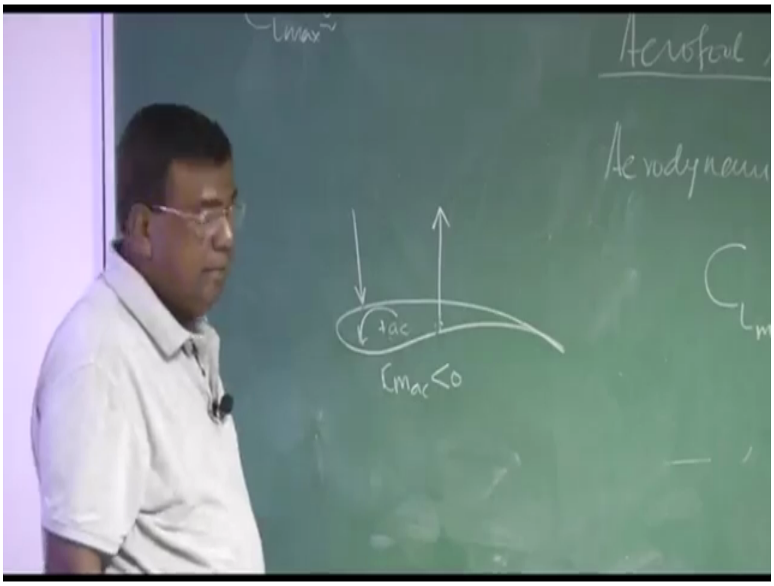

So, about the aerodynamic center when you want to shift this force is to aerodynamic center, it will have Cmac negative. That is one challenge you to handle Cmac negative. More and more camber you are giving Cmac will become more and more negative. What is the issue of Cmac being more negative, let us see that?

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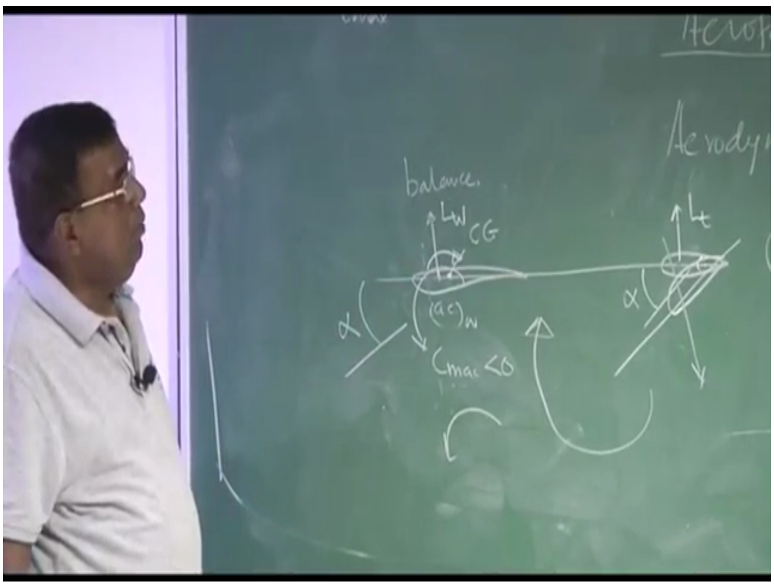

Suppose this is a wing, and this is the horizontal tail, I want to balance this airplane, that is balance this airplane in air for like this an, let us say this is the a C and somewhere you have kept let us say C g is here, of all simplification let me put C g summer here. That is I am writing a case where a C of the wing is ahead of C g. Now what will happen you see, as I give angle of attack alpha, there will be a dynamic force I can represent roughly I am just dry perpendicular to this, which is strictly it has a perpendicular to this because the angle of attack small I am drawing it like this. So, there will be a lift generated here. This will give a nose down moment at C g, equivalent alpha which may not be equal to this alpha as you know this alpha tail will be lesser than this because of downwash.

So, this will generate a force here lift tail and I have to ensure that the moment balance is there that this lift giving moment about C d nose up this gives nose down. So, I have to ensure the lift as well as the distances. So, that there is a moment balance, but the problem is once you have a camber wing you already have another Cmac, which is less than 0 this moment is also there. You have to correct the moment about C g because of lift on the wing, which is balanced by lift on the tail plus you have to balance the knows down moment which is coming because of Cmac. So, though if I just throw the wing it will come like this. So, if you have to ensure that through tail I balance the Cmac also, but unfortunately what is happening the Cmac is less than 0, nose down.

So, any alpha here it also gives the nose down. So, this will not be able to handle Cmac negative, but you have ways of doing it, you know will see that we put the tail in a tail negative setting angle, which tries to give force in this direction which gives the nose of moment. So, all this things you have done in stability and control. What I am telling the moment you are using a cambered aerofoil, please be careful about Cmac you should not allow Cmac it to be very large negative then you have to pay penalty all you have to do little ingenious way of handling how to do that right.

This is what I thought I must share which is nothing new for you have done these things of course, you know laminar etcetera flow if to maintain typical Reynolds number on the wing a major part of the wing. So, that it is able to generate laminar flow at the same time you know if you want to make a laminar wing manufacturing is demanding as well as keeping that wing clean is also demanding because small particles may locally turn the flow into a turbulent flow right.

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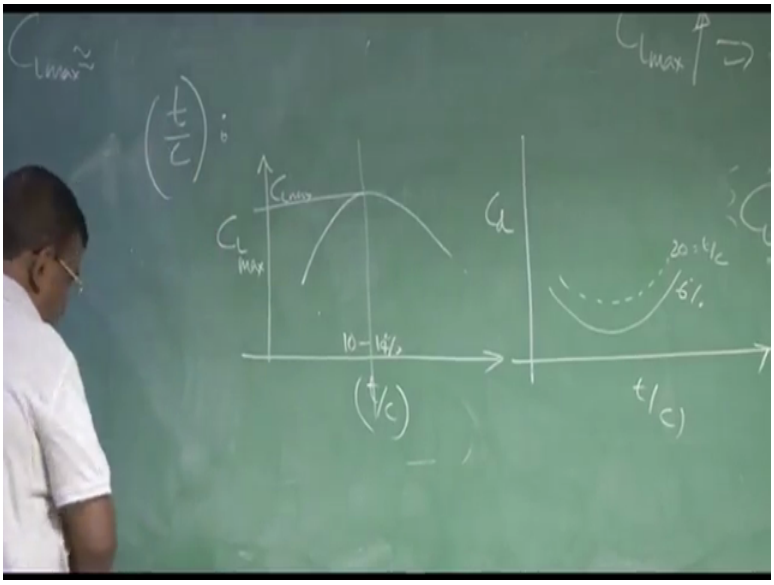

These another topic as talking discussing was T by C the stickiness to cord ratio right. And you should know from the discussion what came out was if I lost C L max by T by C the strained will be something like this. The particular T by C generally it is between 10 to 14 percent these are design number typical numbers right. You get maximum C L max as far as effect of T by C is concerned. So, more. So, design low subsonic will find there be operating around this. The moment you will high speed this Mach number effect also comes right, because you need to have a smaller T by C. So, that you reduce the drag in turn increase C L by C B.

So, there T by C requirement will be more decided by the Mach number effect. So, where T by C with drag as T by C increases drag also will increase. So, let us say this is for 6 percent T by C would have spread this is for 20 percent T by C. Typically there will be increment based on different of aerofoil, but you should know that there is going to be a penalty, you are paying as you are increasing the T by C as far as drag is concerned write or C d drag coefficient is concerned.

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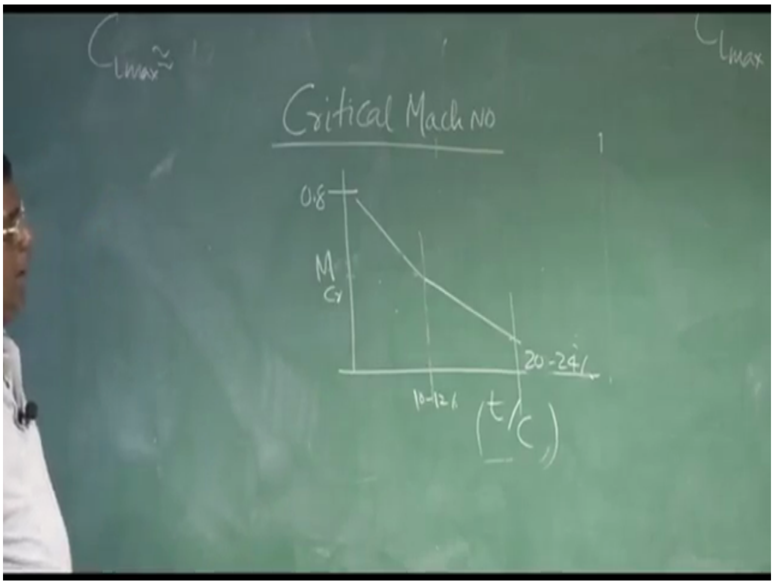

Then another thing we discussed which was free a lot of time we spend the critical Mach number, that is that free stream Mach number at which for the first time some part of the or some point on the aerofoil attains Mach one right. And if I C T by C versus Mach number this critical Mach number M C r if I 0.8 and all little typically it will be something like this. And this region is around 10 to 12 percent. Typically, M critical changes with T by C this sort of the variation you will find and this may be around 14 to or not 14 may be around 20 to 24 percent T by C. This is a last drop in critical Mach number as you are going beyond 10 to 12 percent T by C that is very important right.

So, when you are try to go for a high subsonic airplane and you for some reason you want to go for a T by C higher you know what sort of energy are going to plain right. Where you if a no other option if I saw the extreme you have to go for higher T by C, one understanding can help you try to give a sweep, but as of you sweep you understand you are losing lift as well. So, these are all sort of optimization goes on right. You have to (Refer Time: 16:44) with all these conflicts.

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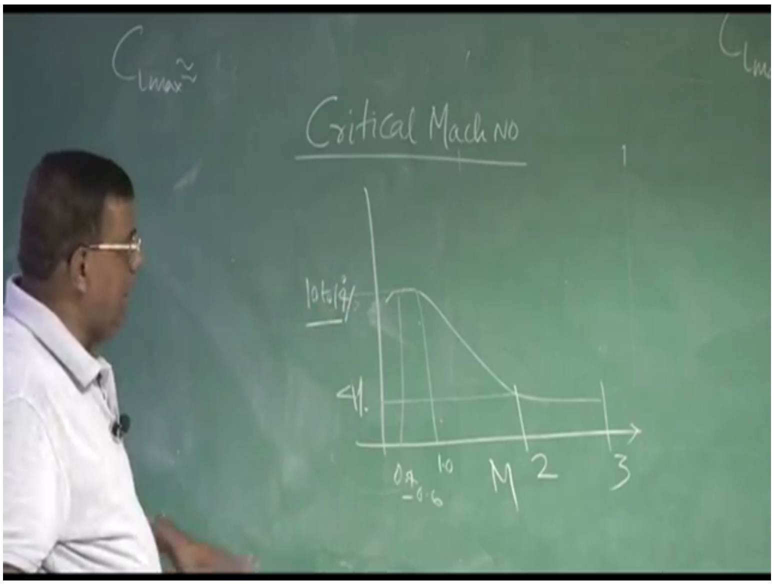

As a typical designer if you want to just get fill for numbers you will find, typically this June where your T by C is 10 to 14 percent. Here mostly for Mach number range of 0.4 to 0.6 0.7 around that you will find T by C 10 to 14 percent or 12 to 14 percent will be as you go higher speed to or Mach 3 you will be approached towards T by C or 4 percent which are nearly available, and being tested right this is the order of magnitude right. You could see the difference 10 to 12 or 14 percent to 4 percent maybe 6 percent may be 5 percent right around that. So, this is one observation you must have.

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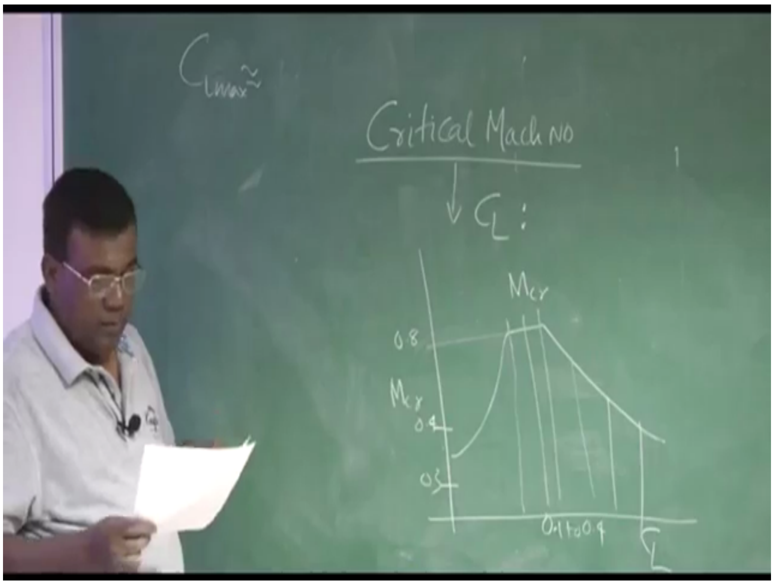

Also please understand this critical Mach number and C L, have some sort of a coordination right. Remember when you are having C L drag the C d will have a unique value for a given C L right. So, as C L Increases C d also increase.

So, let us see how M critical, typically it varies with rough idea, do not get too much from this if this is 0.8. This is M critical this may be around 0.4, 0.3 and this points are this is 0.1 to 0.4 that rential this is. So, you have critical macro by 0.8. As you go to higher C L there is a huge drop in the mock critical mach. So, you understand if you are flying at the higher C L, your critical Mach number is going to reduce, but you are operating between 0.1 to 0.4 critical Mach number will be maximum that time manageable right. Then this another discussion we had on the camber lite.

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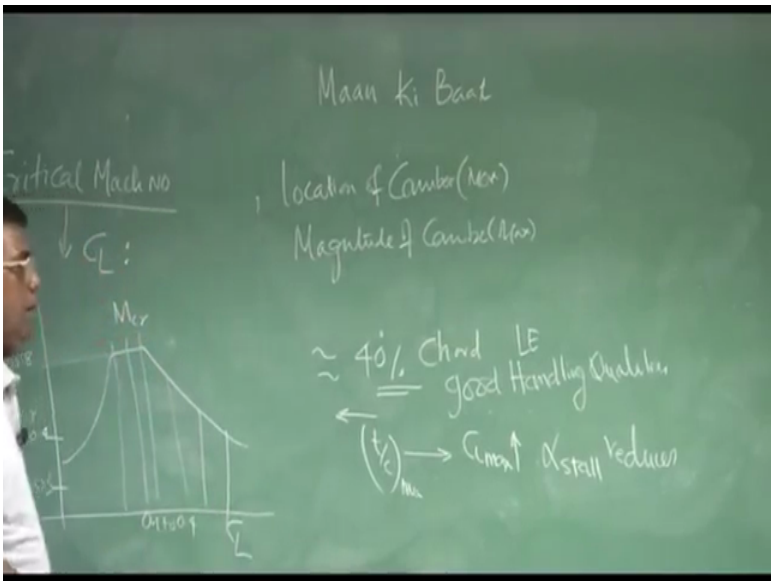

So, let me write here one was location of camber that is maximum camber right. And magnitude of camber maximum camber. After all, why you introduced camber? The purpose was to get C L max higher right. As well location or maximum camber is concerned understanding is if it is located 40 percent of the chard measured from leading edge the typical numbers. Then gel filling is that it gives good handling qualities right. What happens if you move this location of T by C max followers to other leading it. Yes, it indeed increases your C L max partially s; however, you are stalling alpha stall reduces very fast. And so if you are really taking T by C maximum forward and forward you will find that there is a tendency of the wing to stall abruptly right.

So, that is where you will find with all those data set and the designer roughly 40 percent of the chard from leading edge if you are locating the T by C maximum you can start from the conceptual stage that it we likely to give good handling qualities right. These experiences is I am sharing these are not numbers which you can challenge in the code write 40 could be 35 could be 37, but is not 10 percent that way.

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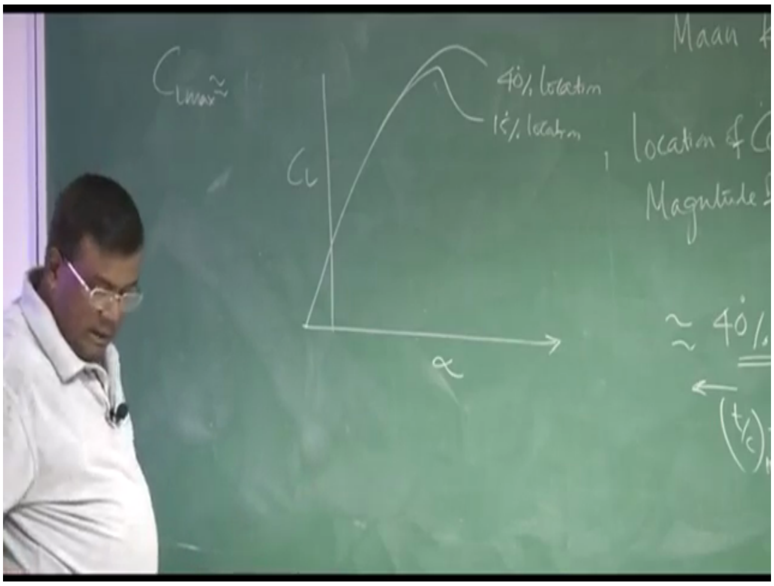

Others knowledge I have to share with you, it is if you see C L versus alpha and if I am plotting this is for 40 percent locations for the maximum T by C maximum is at 40 percent of chard measure for leading edge. Another if I draw this is 15 percent location. It could easily see that since from a test data, which follows the logic right. If T by C maximum is forward the flow will accelerate very fast right. So, naturally it will stall also very fast to see 50 percent location is stalling much earlier and it abrupt also this is important not like this we abrupt which is not good as far as handling qualities are concerned and if somebody asked me I just checking data set.

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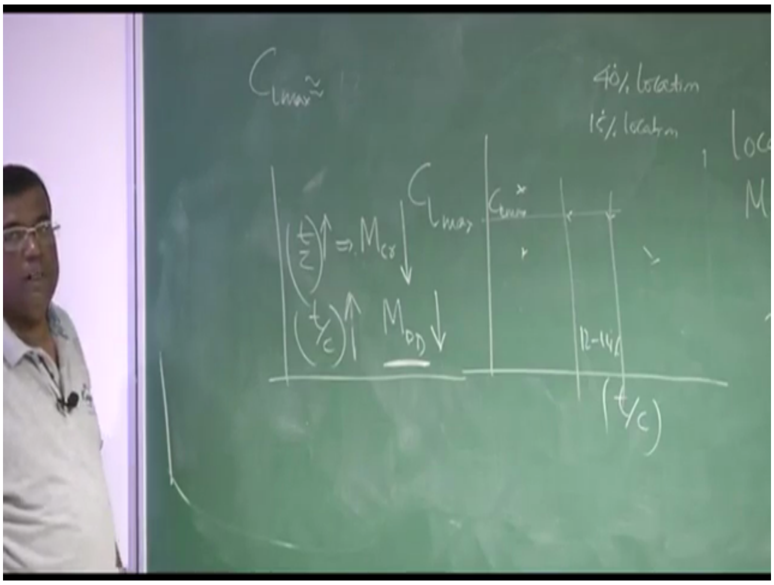

If I want to know C L max versus T by C what sort of T by C, I should take typically you will find around 12 to 14 percent C L max will be maximum, C L max this will be the maximum value generally you get fellow slow speed 12 to 14 percent, because you know at high speed T by C we services C L max is not that important as drag is important they finally, C L by C d is important right.

So, this has sweeper swift in that manner also it would see how important is T by C, if T by C is increased then critical Mach numbers reduces. So, if you are designing a high speed airplane, high subsonic even. So, you know man T by C increasing T by C you may have advantage in C L max, but I have to be penalty critical Mach number will go down. So, you have to find out alternate methods alternate attributes to optimize this right because there may be a comparative indeed want T by C to the higher. And also T by C as it goes down or if T by C as it goes up drag divergence Mach number goes down. This is for high speed this draws maximum swift from the designer, because you know that yesterday we defined drag divergence Mach number the sharp rise in the city. So, whatever T by C advantage we are getting, but if it does not give us satisfaction or drag divergence Mach number for high subsonic airplane, it is thank you very much I will fight some other way.

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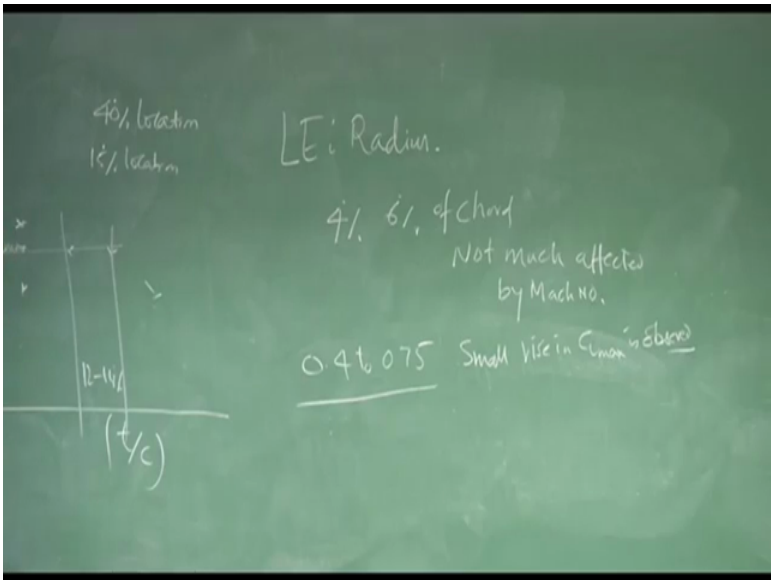

We have also tries upon something or leading it radius, I thought I also mentioned this between radius 4 percent 6 percent of chord, not much affected by Mach number. Just see from 0.4 to 0.75 on that Mach, yes small rise in C L max is observed, but small these are just some observation, when will be actually designing a airplane. We see the datasheet and will try to the recall all what is this meaning is that happening or not right. Today I thought I will only do this much. Please go through my lectures and also take some textbook and read the relevant matters, see the data do googling, that is the best way to learn a design course. Because at the end of the day we are not sitting together to design any configuration that is a limitation here.

Thank you very much.