Aircraft Design

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Lecture - 28
Take off: Vstall and High Life Devices

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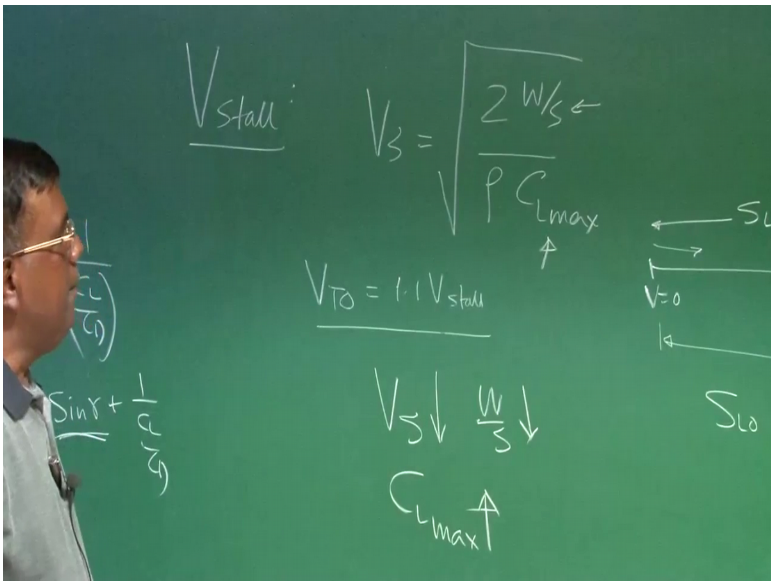

Good morning friends. We will be talking about V stall little more explicitly because if you see the last lecture, it was an attempt to understand how do I decide how an engineer will decide or a designer will decide what should be the wing loading for take off or wing loading for landing, right. If you see V stall is given by 2 W by S rho C l max and as per the regulations, V take off be around 1.1 V stall. Please understand these specifications maybe slightly different for air military aircraft or civil aircraft. When you are designing an aircraft, you have to follow some regulations and you have to follow strictly those as specifications. Part of this lecture is to give you the understanding what we should do.

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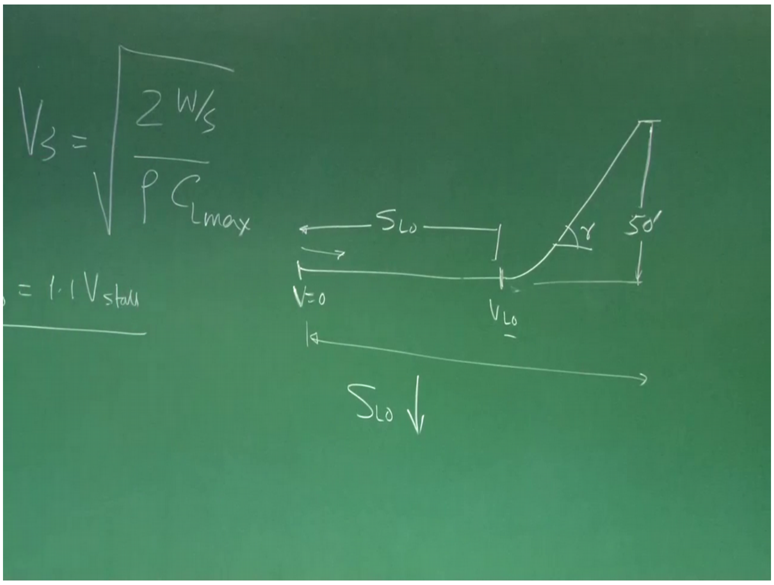

Now, it is very important why we are spending so much time on V take off. If we carefully see what is basically a takeoff, the air frame starts warming up on the tarmac, the pilot could truckle, appropriate truckle and you start gaining speed at a speed which we call V lift off. The pilot will turn the nose and set an angle of attack and it will have a transient flight here and then from here, it will claim and it should by regulation clear 50 feet height or 35 feet height depending upon military or civil aircraft. Once it satisfies its complete condition that distance is strictly speaking take off distance right, but this is a challenge for the designer. You will try to see that this distance from here to here which we can call it S lift off, you will try to reduce it as far as possible and what is then the requirement if you want to reduce this S lift off, this distance from here to here, I should accelerate the aeroplane faster.

So, that from zero quickly it comes to V left off. It roles the aero plane and claims. So, there is a demand for large T by W if you on the reduce S lift off. So, the problem is the moment you want to change or put a higher engine, higher power engine, the weight penalty is there, maintenance penalty is there, cause penalty is there. So, why not we also try to find alternative way of meeting this requirement through wing loading or through Cl max.

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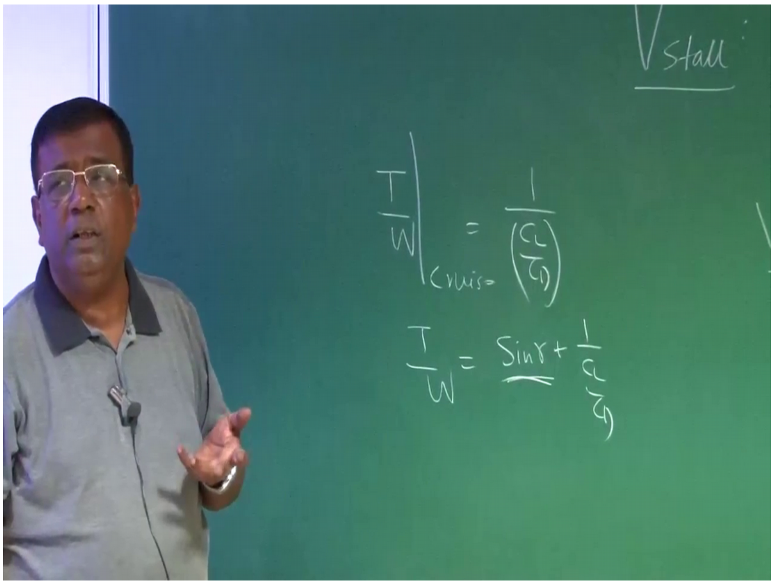

You know very well T by W required for cruise more governed by aerodynamic efficiency C i by Cd and Cl by Cd. Typically it will be 15. So, T by W required to in cruise will be 1 by 15. So, less than 0.1 right, but for a claim, it will be more for claim. You know T by W will be sin gamma plus 1 by Cl by Cd and gamma effect is 10 degree.

So, you consider 0.2 or 0.25 unless you want to accelerate first. So, that additional component you will get added. So, meaning there by T by W is more governed for dictated by the cruise, by claim, by turn rate, by different accelerations. So, why do you unnecessary tax the engine primarily for reducing S lift off if there are other options available, right. So, a designer we will always look for if I want to reduce V stall. I will see that W by S, S is lower or Cl max i increase because if I can locally increase C l max during takeoff, then I will be able to handle this issue knowing very well that if I keep higher Cl max, there will be higher induced drag, right but during cruise, I do not require that much of C l max because that time C l max c l requirements are not that high. It may be 0.2-0.3. The whole attention goes when you talk in terms of V take off which is some percentage of V stall, it goes towards Cl max. How can I increase Cl max?

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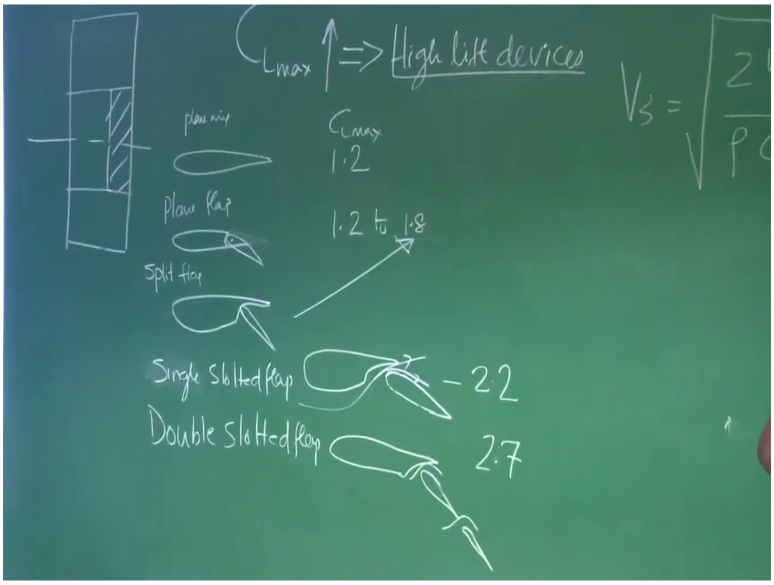

You are aware we can increase Cl max by using high lift devices. Loosely we have introduced flaps for example, if I take a plane wing say plane wing it Cl max, I can say not too bad. So, let say if it is 1.2, mostly airfoil will have Cl max 1.2 by contouring the aerofoil you can have, but seeing that you can change from 1.2 to 1.5 around that, ok.

Now, what we do is, we know that if somehow I can change the camber of the wing locally, it will help in increasing Cl max. So, that is where this concept of flap came during takeoff. You just deflect the flaps. Flaps are you will see now aircraft also, there are flap plane. These are plane flaps which can be deflected downward and in the process what we have done, we have changed camber of the wing. We should be careful that by deflecting this flap, only some portion of the wing aerofoil I have been made given additional camber and not all the portion, right.

That is one of the important observation you must have and if you do that, you can enhance this from 1.2 to 1.8. These are some tentative number, right. Now, this is called plane flap. Now, there are another interesting design you must appreciate this. This is called the split flap. What is done in the split flap that not only give a deflation here, you can also give it a motional like this, right. So, if you see it open up like this and it can also go forward. So, what it is doing is not only changing the camber, it is also increasing the area. So, you have double advantage.

So, this is one of the fantastic third process innovation and you will find may aerofoil and flap combinations are based on this silently, right. There are values added to that, but this is one of the fantastic observation. In fact, you will find this 1.8 when you try to reach 1.8 or mostly common aerofoil, it is the split aerofoil that we will help you. We selected a split aerofoil flaps. Now, the question is the moment I split it like this, I deflect it like this, there is the possibility of flow getting separated from the top, right. If it is something different like these foils coming from here, they may separate. So, you may not get that efficiency that sort of Cl max.

So, where do handle it if something is getting separated from here. I want to delay it. Delay means how can I do a delay by pumping energy to it, right. So, what is done suppose if I create a slot here, let air flow come here and they go because this is a small area. So, lot of speed in instrument will be there. So, that will impact kinetic energy to the fluid and the separation will be delayed and a process you get Cl max. So, this concept is used for single slotted flap. The concept is simple. As we have just discussed this is the aerofoil and now, once you deflect the flap, ensure that there is a gap, right. So, the air will come and they will go through this and that should help in delaying the separation.

So, I can deflect it further right, but be careful as a designer I should contour this portion in such a way that the flow really goes like this. If you have done a contouring here wrongly, the flow may go like this, right. So, the lot of CFD studies, lot of wintal studies goes on and you actually design this slot, right. So, this is covered under single slotted flap, right the moment do a single slotted flaps. So, there was also demand for the idea got extended double slotted flap. Now, you know that it should not be difficult for you to visualize what is a double slotted flap. It is one like this; another like this, right.

Suppose by giving 65 degrees, this we will separate. You do not give 65 to it. Give another 15 degree to this. Now, everywhere there is a hole. So, now, you can have a more efficient enhancement in Cl max. This is clear, but what I am saying suppose if you deflect this and there is a slot by say 50 degrees and near, even if I am having a slot, then this may separate, right. So, do not do this. What you say this, you give it to gradually you increase it for this. You may make it to 30 degree and this can be 20 degree because you know flow is also coming from here. So, overall effectiveness you can increase and if you see the typical numbers for a single slotted, it will be around 2.2. These are just typical order of magnitude. We have to see charge to get the exact value or if you go for a tunnel testing.

The story does not end here. Once this concept is understood that if I put a slot, I can delay the separation. So, I can increase the deflections.

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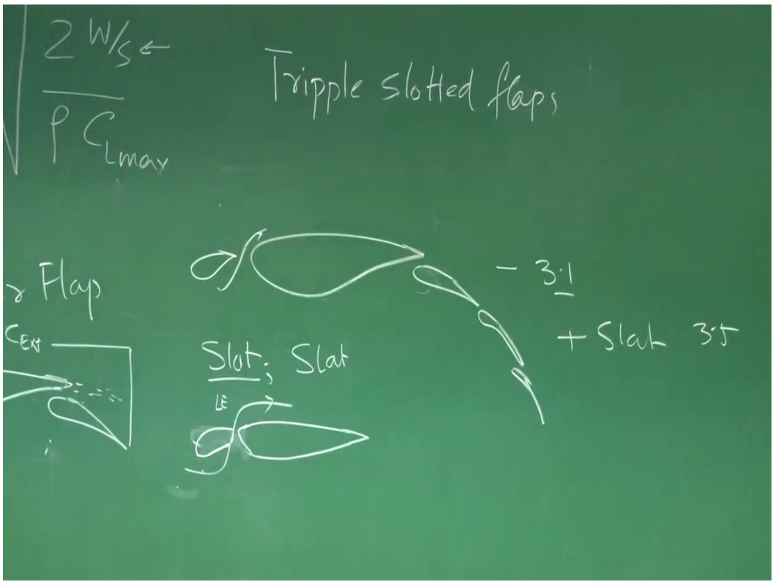

So, they came triple slotted flap. How should it look like? This is 1, this is 2 and this is 3, right. You can go on doing it and for a triple slotted flap, you can aim up to 3.1, but whenever you are adding those flaps, please understand it we will also drag component. It will also have a maintenance issues, right. That is why the aerodynamics they work on what are those combination, especially what should be the aerofoil, what should be this short of a slot dimension. So, that is C l by C d is not compromised, right. Lot of work goes on designing multi aerofoil high lift devices.

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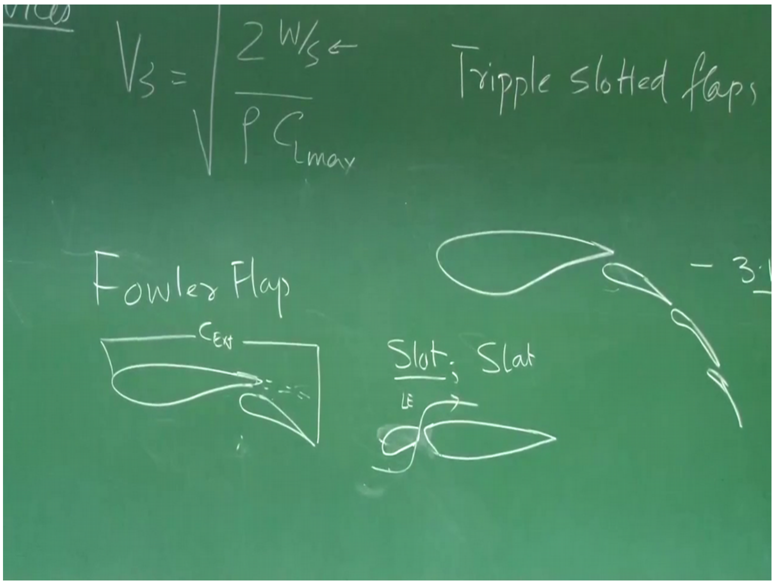

This is another popular high lift devices Fowler Flap which is typically in spite by the concept of slit flap and that is, it can go down, also move, but with a split flap with a slot, roughly you can assume that there is a Fowler Flap. So, what is being done one is using the split flap concept, the cord is extended, the camber is extend and also you have putting a slot. So, flow separation will be delayed. It is simple. No high maintenance is required. Now, there will be always to have it as long as he is within a particular weight class, right. If it is a huge aero plane in, naturally you need to enhance Cl max up to 4 or 5.

So, you have to go for all this complicated flaps, right. Another thing you must understood we are talking about slot with something called slat. That is leading a slat. You put something like this in the leading edge, right or if I draw it correctly maintaining in the contour. So, at the leading edge it is there so, from the leading edge, there will be flow bowing to energy. The flow behind that we will also delay the stall.

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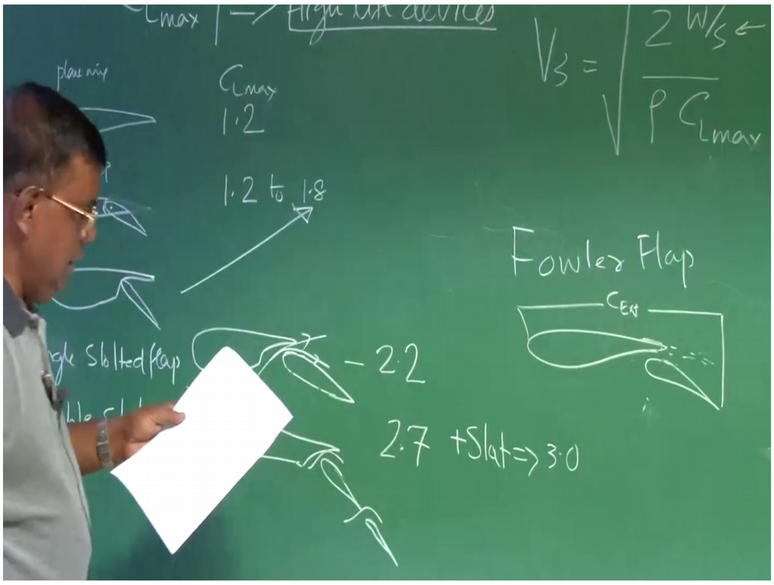

So, immediately you will see that if I have a double slotted flap is 2.7 I could achieve, but if I add with slat also, I can go up to 3. Then, this triple slot if I put a slat here, that is I put something here, then I can go up to 3.5.

So, all these things, all this high lift devices is going to affect C l max and you could understand from 1.2 or 1.5, we are going to 3 how much enhancement is there right because the V stall goes down. So, V take out goes down the lift of distance goes down and that is very very important.

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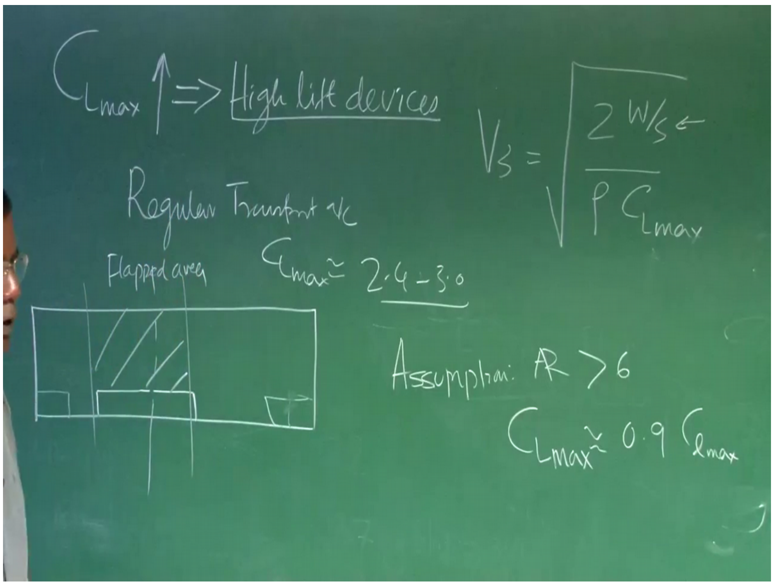

Just to give you a feel for number is regular transport aircraft the C l max, it could order of around 2.4 to 3 around this. So, if you are designing a regular transport aircraft, I will recommend you assume C l max to be around 2.2 or 2.3, right and then start calculation.

Once we are talking about Cl max, we are focused towards wing. So, this is our flap, the aerodynamic will be someone here. So, when I am deflecting these flaps, I need to know what should be the C l. As a designer I know roughly how much C l max it will really generate because once I reflect this, only this portion which is the flapped area there camber will change right, but here the camber remain same. So, how do I get a rough value of Cl max? Once I have reflected these flaps, the assumption is if the aspect ratio is more than 6, then 3 d C l max will be roughly equal to 0.9 of the aerofoil Cl max.

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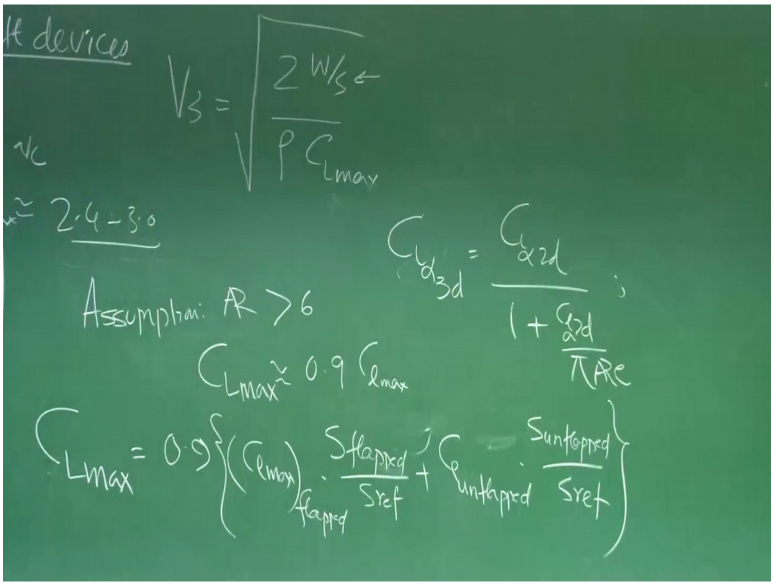

You know the relationship Cl alpha 3 d is C l alpha 2 d by 1 plus c l alpha 2 d by pi aspect ratio e. So, typically 90 percent these good estimate and then, for C l max of this wing, you can use this as good initial estimate because 90 percent of 0.9 if C l max, this is flapped into S flapped by S reference which is A wing area plus C l unflapped into S, unflapped by S reference.

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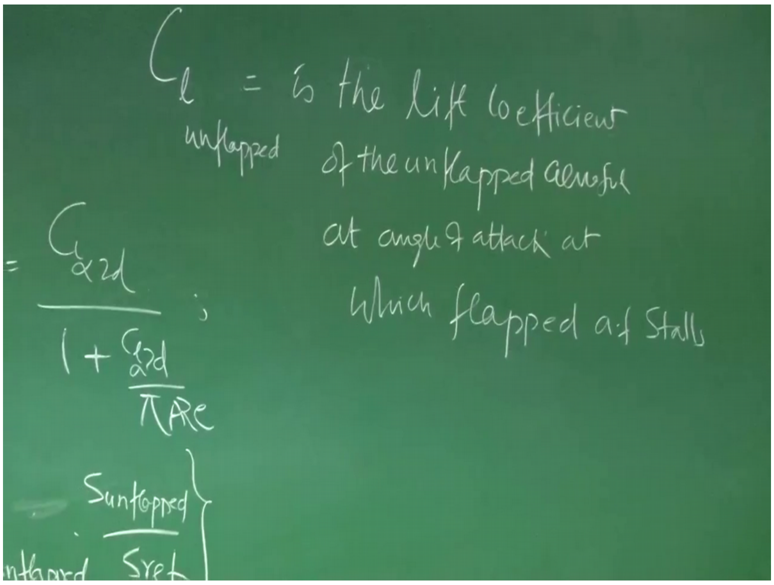

Please note that what Cl is unflapped. This is very important. It is the lift coefficient of the unflapped aerofoil at angle of attack at which flapped aerofoil stalls.

This statement is important. Please understand this we are asking a question what will be the Cl un flapped. See the moment you have flapping, once you have putting this flaps down is stall angle. We will reduce because the camber has increased remember.

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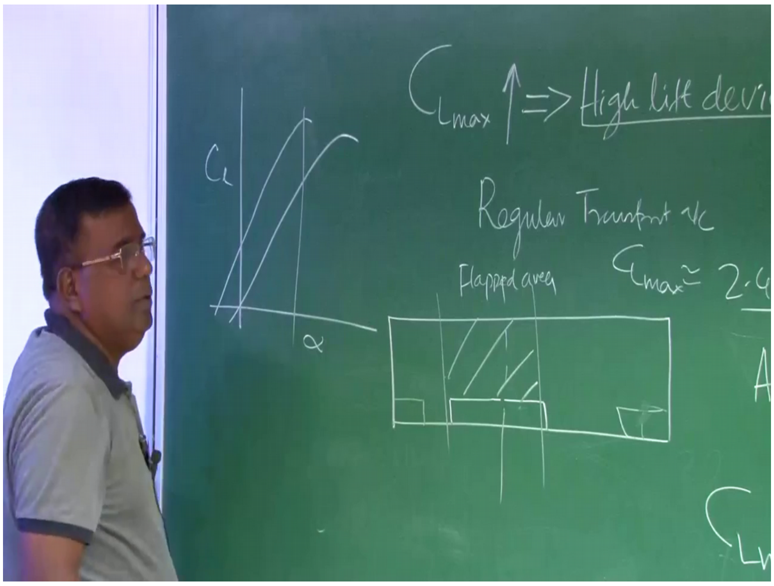

If this is Cl versus alpha, if this is symmetric for camber Cl max enhancement is there, but stall angle we will reduce, right. So, how much C l this portion will generate will depend upon the situation that these gentlemen should not stall. So, let us say its stall angle is 10 degrees, then we will calculate Cl of this portion corresponding to alpha equal to 10 degree. Is it clear?

So, this is a very important statement. All these expressions are to develop feel for the numbers, but you will see that there are historical charts which will give you different values of C l max for different types of flaps and we will add that also in this lecture or in the assignments. Now, we are coming back to what will be the wing loading required to maintain V stall. As I told you we have to go back to the regulatory bodies recommendation for different class of aircraft.

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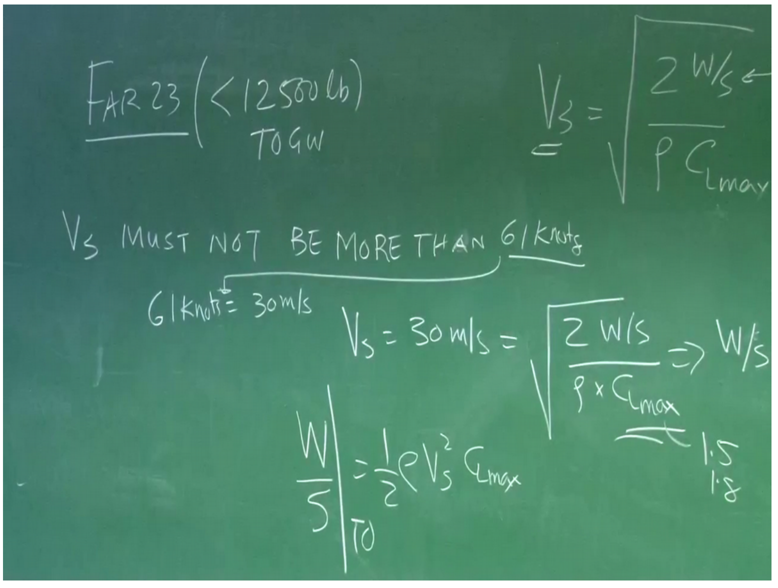

I am just giving one example as for FAR23, it is a very oldest specification. I will be giving you all newer specification which is more standardized one say is for less than 12500 pound. This is takeoff gross weight requirement is the V stall must not be more than 61 knots. This is important this number.

Whatever you do, this weight class it cannot have more than 61 knots V stall. The moment you know 61 knots is let say roughly equal to 30 meter per second, right I am assuming it is almost half of it. So, your V stall is 30 meter per second and then, it is 2 W by S. Select what is the critical altitude at which you will be flying there mostly in Delhi in winter and summer. If it is winter, then you put the density of air during winter with that is will give larger W by S. So, depending upon what is the altitude, you put that number and depending upon what sort of aircraft you are using and what sort of that aircraft is complemented with high lift devices for a generalization. I have plane like say is 206 and all we will find plane flaps.

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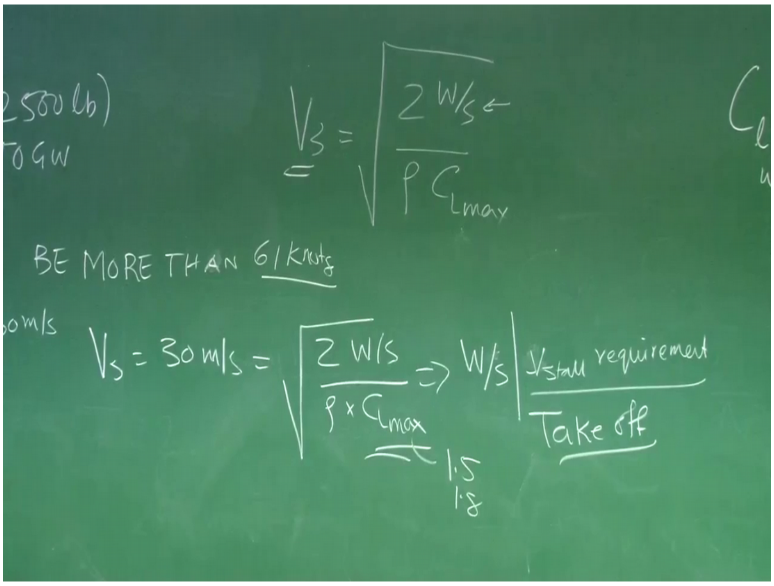

So, you will put a number and if it is a plane flap, it may be 1.5 and if it is a split flap, it may be 1.8. If it has a slot, you will put another number and now, using this you can easily find out W by S from stall or V stall requirement, right. This is from takeoff point of view from takeoff. So, if I write what explicitly W by S for takeoff will be half rho V stall square into C l max if is here, there is a slight error which has come and you need to be careful about it and that is why I will now from here I will come to the observation that we often come error like this, although that is small.

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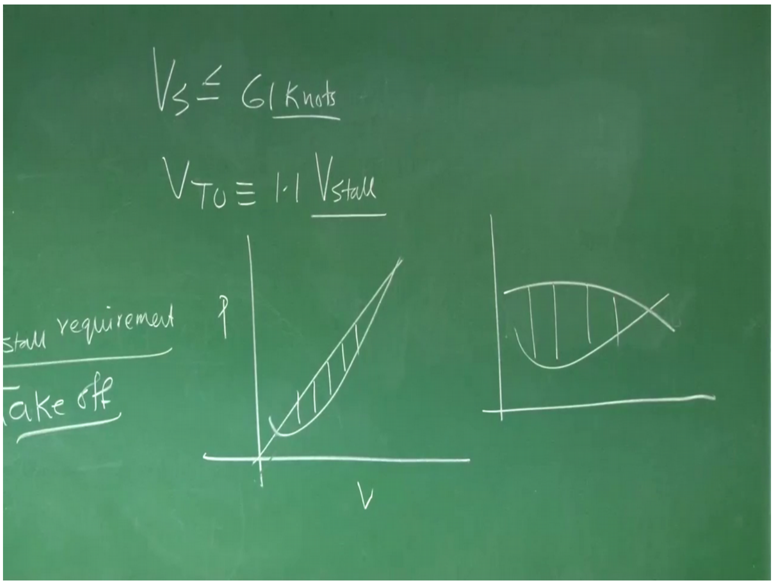

What the specification says is V stall cannot be more than or less than equal to 61 knots, but please understand this is V stall. V take off will be around 1.1 times V stall. So, when we are taking off, you are not flying at C l max condition, right. It is obvious that if you are going to take off, here operating at the alpha stall, the slight change in the angle of attack we will put the diagram V stall. Why should you fly like that? I should not land for a takeoff more than 89 degrees from safety point of view. So, another question may come to your mind when I am taking off, why I am telling that is very critical, here are many accident. Remember there is a human tendency to reduce T by W requirement because T by W enhancement means you have larger engine, larger maintenance cost goes high.

So, we try to reduce it you know in the process what do you do is, you are not left with large excess power and if it is a jet engine, already you know if it is a jet engine, then excess power which actually talks about your rate of claim that bandwidth is very small in comprise into a properly driven aircraft, but a properly driven aircraft you know that if this is the power, this is their huge excess power available.

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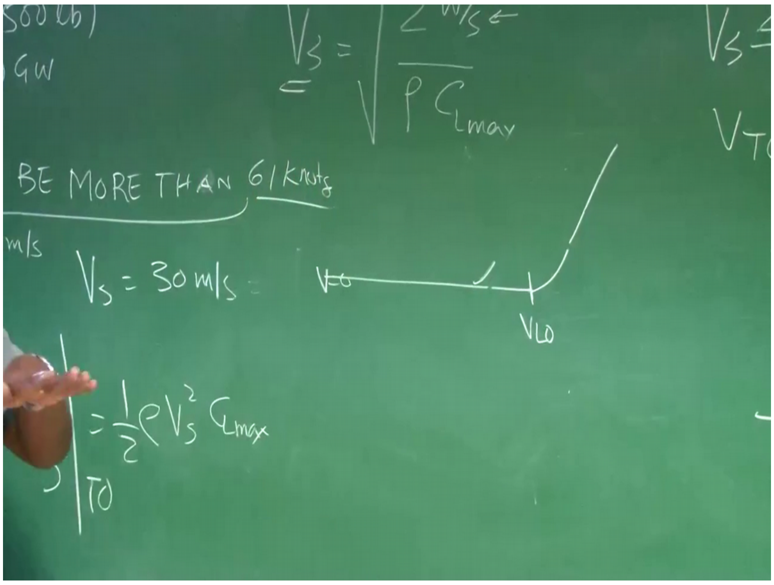

Now, for a jet driven that gap is not that high and how does a pilot goes for a takeoff. Let us also see that it starts with V equal to 0 accelerates and in at time when here is got enough V lift off, it should rotate the aero plane and then claim, but let us say the pilot does a judgment error earlier days and you do not have excess power and he tries to lift off here. What will happen till not get sufficient lift right, but the pilot will again try to pull the stick to get the lift and you go into the stall and pre match your stall, prematch your takeoff any lands like this. You might have seen one of the accidents. We lost one of pilot, right. What he was trying to do, some manure bad luck for all of us that is also we will example of a prematch your take off, but you go and try to turn and takeoff like this and V stall and the wing if all like this and the pilot lost his life.

So, that is why I am spending time on takeoff and you should all understand how important is this, that is wing loading. I am connecting here and we have to be the designer. We have to be very clear, but the problem is if wing loading is lower, that means, wind area is higher. You know drag will increase and such requirement you will increase. Then, it will be more sensitive to wind. So, all those handling qualities problem also we will not be able to accelerate very fast if W by S is slower. So, area is more, so drag will be more. So, you will not be able to accelerate as you need more power. So, all this conflict you will come for a designer, right.

Thank you.