NOC: Introduction to Airplane Performance

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Lecture - 26
V stall: Cruise and Manoeuvre

Welcome students to flight laboratory, so far we have discussed thrust required, power required for a cruise. We have also discussed range, endurance, very important thing that takeoff and landing. So, today this is a warm up lecture for take off and landing.

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Please draw your attention to this part, which is the landing gear and you could see, this type of configurations are called tricycle landing gear, one nose wheel and two rear wheels. When we are going for a takeoff ((Refer Time: 00:52)), at an appropriate speed the nose will be just high like this and it will continue and lift off and then, it will do like this for a cruise.

So, once I am going like this, I have started the engine, got a particular speed through acceleration and then, I will pull the elevator and the elevator will go up, that will make the aircraft works slightly like this. And then, continues flying climbing and after that again I make the neutral position of the elevator or to a desired elevator position. Basically, I am now reducing the elevator angle and I maintain a cruise.

Why all these things? Why I try to lift the nose up, because I want to get lift. Because, for takeoff I need to have lift little more than the weight or this lift equal to weight. Now, for getting that lift I need angle between the airplane and the velocity vector that is, why I have to roll this airplane for a tricycle landing gear configuration, this is one part. I have been mentioning at a particular speed, it will roll the airplane and how do the pilot know about the speed, for that we have got a initial briefing about airspeed indicator and pitot's tube. We will have more discussion on aircraft instrument in a detailed manner, maybe two lectures will be dedicated on that.

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Just for completion, you could see here it is the pitot's tube and you could see, there is a hole here. Here, this in all the air goes inside and pressure total goes to the airspeed indicator. You could see this static point here; from here the static pressure input goes to the airspeed indicator. And you know, there is a diaphragm and the differential of total pressure which is inletted through this point and the static pressure from here, it goes to a diaphragm and because of difference in pressure, the diaphragm will contract.

And do like this, accordingly this motion is translated through a level and you get the readings, you need some calibration. But, important thing is before you are going for a flying, because we need to know, what is the speed. For a pilot, speed is extremely important. So, one has to be with doubly sure that the pitot's tube is working, that is sometime what happens, some insects may lie inside this pitot tube and actually you may be getting a wrong value, so very very dangerous situation.

So, any pilot before he takes off, he will ensure despite the engineers guidance. He will check the pitot tube is working or not in addition to other control surfaces, but this is extremely important, please understand that is why I am over stressing. So, for a takeoff, I need to have correct speed and correct orientation that is the main thing. Now, let us see another type of landing gear which I will be showing there.

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We were showing tricycle type landing gear, but if say this is an airplane, this Piper Super Cub, one of the very powerful airplane we have been using it for long, for more than 40 years. Now, this is grounded and we are using it for static demonstration. You could see here, this is not a tricycle type landing gear. This is basically a tail dragger, there is a tail wheel landing gear there and two here. What is the difference between this configuration and the tricycle configuration?

You could see even at this position, this wing is making an angle of attack with the velocity vector, if it is going straight there is an angle of attack. So, now when we are going for a takeoff, already it has got a high angle of attack, but the moment I try to start the engine and try to do taxiing, this will produce lot of drag. So, what is done? See, when the pilot is taxiing this airplane, at some speed he will use the elevator and take the tail portion up.

So, it will become almost horizontal like this, so nose wheel touching the ground and the tail wheel will be little up and then, at an appropriate speed when he reaches then he again he pulls up and goes. Because, advantage is this, this wing is having already some angle of attacks with respect to the horizontal.

But, why all these things, please understand finally, to takeoff I want to takeoff at a lowest possible speed and that you know by now, that is possible when the C L max is large; that means, when a pilot theoretically speaking, he will try to fly at an angle during takeoff, which corresponds to near alpha stall that is near C L max, which generally may not be really realistic. So, what is done? You try to fly at a high angle of attack, in a sense compared 2, 3 degrees you try to come 8, 9 degrees and have sufficient speed and you go for a takeoff.

Before I end, I want to stress another point for as per the landing gear is concerned. Remember, for all this tricycle landing gear, we have to understand why the c g should be little ahead of landing gear; otherwise this tail will hit the ground. But, for a tail dragger, the c g is behind this landing gear part. So, that is why if you ask many pilots, they already enjoyed flying this machine, but they also have very reservation about crosswind performance, this especially on landing.

You know, it is something like driving a car with an engine at the back you know, ((Refer Time: 06:39)) you have to fly like this. Barring that, it was a very popular configuration and many, many years this configuration was in existence. I am sure, there are many pilots who love this configuration, I personally love this airplane.

Thank you.

So, far we were demonstrating you the landing gear, their orientation, we talked about tricycle landing gear, we talked about a tail dragger and we have realized that, we need to generate sufficient lift preferably more than the weight to leave the ground. Now, the question comes when I try to think of takeoff distance…

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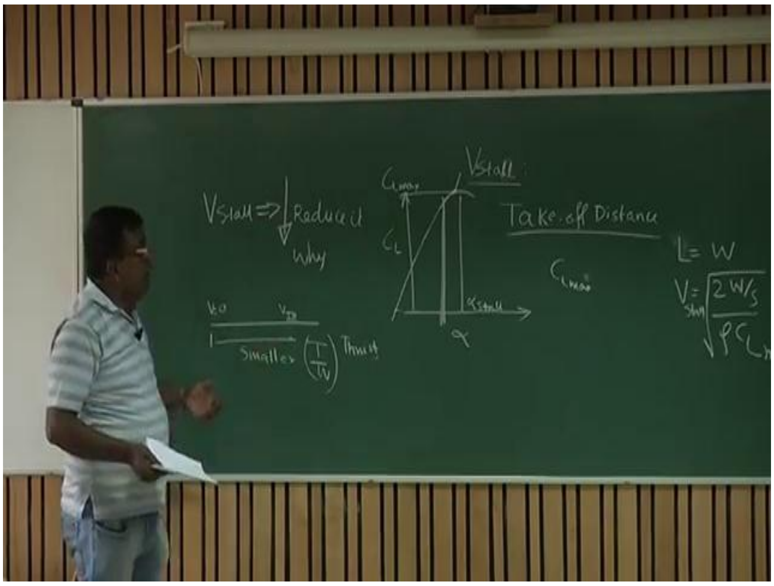

Let us say, we are talking about takeoff distance, what should be our aim. Our aim should be that I should be able to design an airplane; we should not take much of takeoff distance. If you say the distance is too large, then who is going to give you the land, land is so costly. So, one extreme is Vertical Takeoff or Vertical Landing, the VTOL, but we are talking about fixed ring. So, far that we have been successful in ensuring that, this takeoff distance is as low as possible depending upon the technology available. How it is done, that exactly I will be discussing.

If I recall this C L versus alpha and you know this was marked as C L max and this was alpha stall, loosely what is the meaning is, if you are flying at alpha stall you are likely to get maximum lift, but slight disturbance, slight more than the alpha stall. You are going into a stall and you do not want to fly in stall, because lift reduces drag increases other complicated thing happens. So, mostly you try to fly somewhere here, so that is the maximum value you can really get.

And theoretically speaking, we say C L max which is this point, where the maximum C L we are getting here. If I could somehow theoretically get C L max very large, then the V stall will be less. Why? Because, we know lift equal to weight, so V equal to 2 W by S rho C L under root. If C L is C L max, then this is V stall. What is the message here? Message is very loud and clear, this is the minimum speed with which the airplane can fly for a given wing loading and given density, that is given altitude.

Because, this is the, you have maximize the contribution of lift coefficient C L max, but I repeat again. Pilot will not like to fly at that C L max, because if there are slight disturbance, he may dip into a stall. So, he will be flying little less, maybe 20 percent less than C L max, which is practical. So, if I want to reduce V stall, if we want to reduce it… Why I should reduce? Because, we are talking about takeoff, that is I am starting from v equal to 0 to v takeoff.

We will let you know, what is this takeoff. It is between 10 to 20 percent more than the V stall and it goes up. If I want this distance to be smaller, what are the options I have got, I have got put an engine which is having very high thrust to weight ratio. Because, this is responsible for acceleration, this is T thrust, loose we say high power engine. Then, if it accelerates very fast, then it takes smaller distance to get to v takeoff. If it is a lowly powered, then it will take longer distance.

So, one way you increase the T by W as high as possible, but then there is a problem. The moment you want to put a high thrust, high power or powerful engine, the weight maybe a penalty, but there is a limit for engine. So, what is the approach? Yes, whatever best one could do for T by W, we will do in realistic manner. However, from whole aerodynamics point of view or more precisely by taking the advantage of aerodynamics, we can still reduce this distance. How that will be reduced?

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That will be reduced, if I reduce V stall that is, minimum a speed, the airplane can fly and to reduce this stall, I have to increase C L max. The message is clear. If we want short takeoff distance, then reduce this V stall. To reduce V stall, what I could do for a given wing loading and altitude, I have option of increasing C L max. So, that normally a question comes, how can I decrease V stall that is the question.

So, to decrease V stall one thing we have realise, I have to increase C L max. Second thing, if I want to decrease V stall, this is another very important parameter sitting here is wing loading. So, if we want to decrease V stall, what I have to do with wing loading, I have to reduce wing loading and reduction of wing loading is what. If you want to reduce this like C L max, if you reduce V stall further, I have to reduce the wing loading.

Reduce the wing loading means what, I have to increase the wing area. So, keep this in mind, this is important and we will use this concept, it is very important. Let us not loose insight, please understand again. We want to reduce the takeoff distance. To reduce takeoff distance, we have understood the V stall or the speed at which lift equal to weight should be low.

To ensure that V stall is low, I have two option, one is I should increase C L max or I should decrease W by S or I do both the thing, that is increase C L max and decrease W by S. If I could do that, I will be able to reduce V stall and immediately, you will see that the takeoff distance will reduce.

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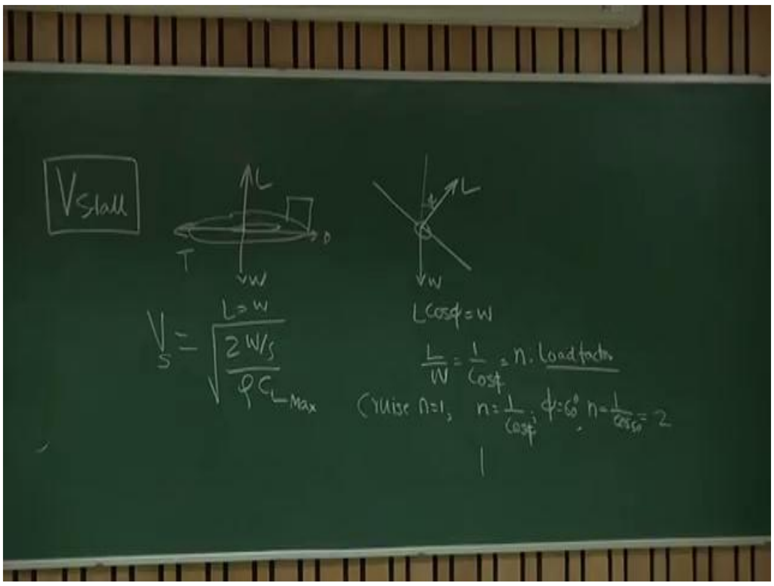

Let me also further stress on V stall, classically when we were talking about V stall, we are talking about… You know the situation where this lift equal to weight and off course, thrust equal to drag, that is how we write V is equal to or you write L equal to W. So, V equal to 2 W by S rho C L and for V stall, we write it here, this is C L max. No issues, this is classical definition of V stall. But, in practice what happened, it is not that pilot is always doing cruise.

He does manoeuvre, that is he will be let us say, he is taking a turn, this is a lift and this is a weight and this is phi. You know that L cos phi and is equal to W that is, he is trying to take a bank turn without losing the altitude. He is not doing this, he is doing this, so this is a turn manoeuvre, here I see L by W is 1 by cos phi. By now, you know this is n called the load factor.

For lift equal to weight or for a typical cruise, n was equal to 1 and for a manoeuvre, this n is 1 by cos phi that is, suppose bank angle is 60 degree, then n is around 2 that is 1 by cos 60, cos 60 is half. So, this is equal to 2, you understand the meaning of load factor 2. Now, you see if this load factor is 2 and if I ask you a question, what is that minimum speed with which I should fly the airplane, so that I can manage this turn manoeuvre.

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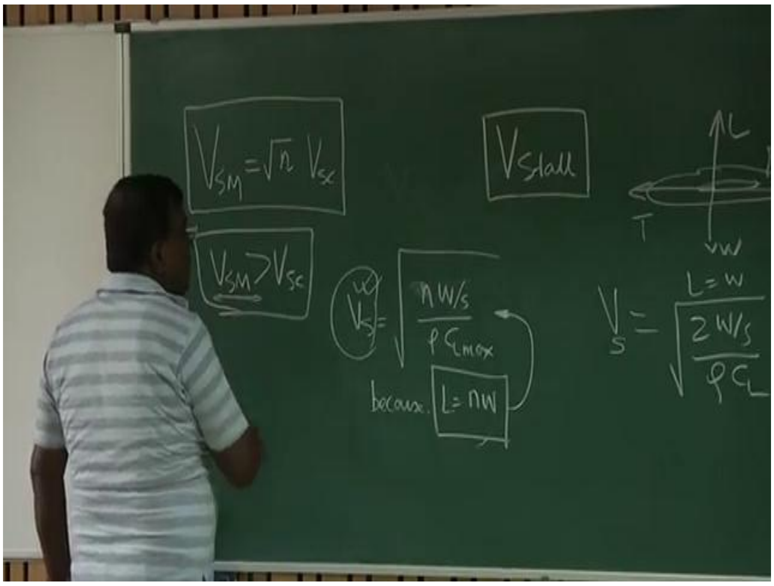

Then, your practical definition can be upgraded and we see, it is n W by S by rho C L max that is, because lift equal to n W now, Are you clear about it? If we are doing a turn manoeuvre, then lift is no more equal to weight, lift is n W. And if use the relationship, I can find the minimum speed and I will call it stall speed for manoeuvre is n W by S by rho C L max. And now, I could see that V stall manoeuvre s m is root of n V stall cruise, let us try to understand this physically.

Suppose, pilot is going like this ((Refer Time: 17:48)) and there is some necessity for him to turn like this, go this way. So, what he does, he banks and then he turns like this. Now, as per this relationship that the minimum speed should be V s which is more than the classical V stall speed by, how much? By root of n, so this gentleman V s m is greater than V s cruise; that means, when I am trying to bank and turn, my stall speed to maintain that manoeuvre.

My minimum speed to maintain that manoeuvre will be more and my engine master have enough power or if I am not utilizing the engine power or I have already at the threshold of the engine power, then I should have enough lift to produce that load factor. And in that process, in a confusion what can happen, the pilot may go on increasing the angle of attack and he may go into a stall, unless the aircraft is properly designed that is, why the V s m stall speed for manoeuvre is so important.

A designer must ensure that within the flight envelope for different n, he the pilot in command should be able to generate this much of load factor without going into stall. This is extremely important, many accidents happen because of this confusion.

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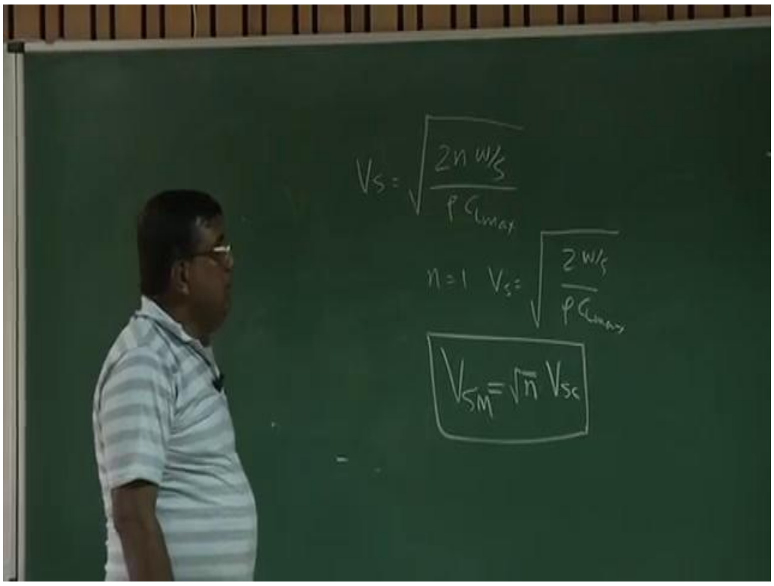

So, if I summarise what we have seen V stall is to n W by S by rho C L max, where for n equal to n is our classical V stall, which is 2 W by S by rho C L max. Also we have seen V s or manoeuvre is root of n into V stall cruise, based on the cruise.

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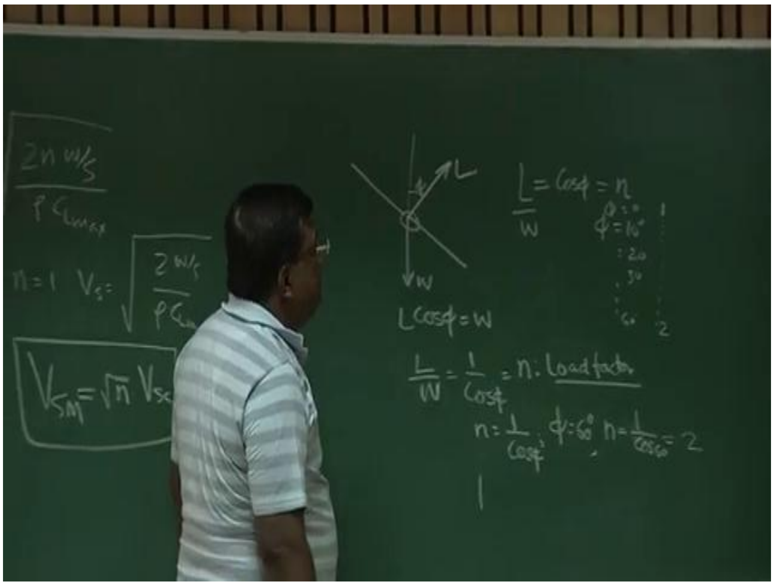

Now, here also you have seen that L by W is cos phi, just to give you a feel. You can check yourself, if it is 10 degree, 20 degree, 30 degree up to 60 degree, you could see from and 5 equal to 0 degree from 1 to 2, this is load factor changes and that is a appreciable changes. And one has to be fairly, fairly cautious, the designer has to be fairly, fairly sincere and systematic to ensure that, pilot has this bandwidth. He can do a bank and he gets enough power, enough C L without going into all those troubled area.

Thank you.