**NOC: Introduction to Airplane Performance**
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**Lecture - 29**
**Take off Performance**

Welcome friends, you must be seeing that we are really very seriously warming up for taking a takeoff analysis. Reason is very simple, as I told you there is to be lot of accidents during takeoff and landing and it is our prime goal to ensure that. We understand everything about takeoff and landing and make sure that, our honourable pilot is made fully aware of the real situation, so that he can fly the airplane with full safe.

And, in talking about takeoff I have requested our chief engineer to discuss with you about airspeed indicator, altimeter little more than what we did in the first phrase. Easily simple, when a pilot is flying please understand, for him he is totally depending on airspeed indicator, altimeter and few other gauges to infer, whether he is in appropriate conditions for takeoff, landing or cruise or anything.

So, we have to be very, very sure in understand, what is an airspeed indicator, what are the instruments, how do they measure, what are the sources of error. So, for that I have requested him and there is a module dedicated for that. And before we analyse this, we will see that you will have to go through that very clearly and your mind should be very, very clear.

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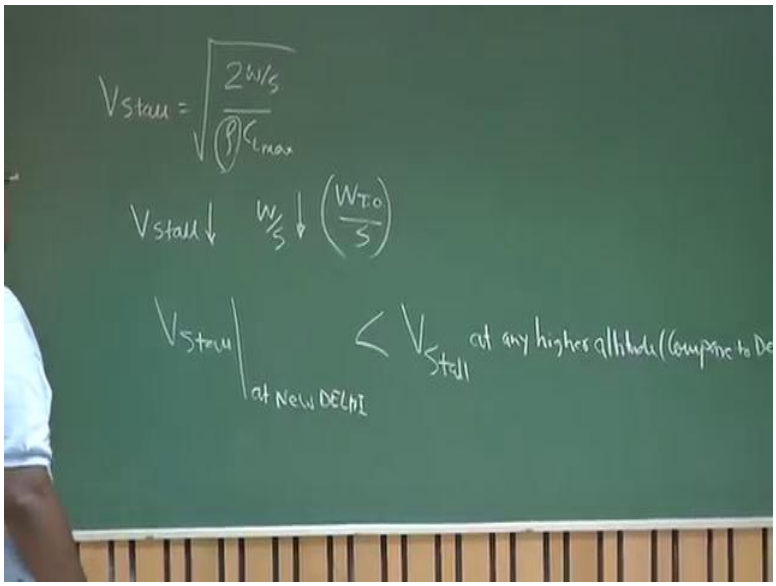


Now today at this point, we are discussing about takeoff, before takeoff we revisit V stall and we have seen for one G V stall means, when I define V stall for cruise, we have seen this is 2 W by S rho C L max. Please also understand, when you talk about V stall you should not think, we are in stall. No, the correct interpretation of V stall is this is the minimum speed with, which you can fly an airplane.

Any speed less than that as far as air is concerned, this is not to be considered or assume that is not available, because that will not help in flying the machine. So, there is a boundary that is why V stall is called the minimum speed, it does not mean you are in stall please understand that. Let us see here, if I see V stall if I want to reduce V stall I want yes V stall should be low. Why I want V stall should be low? Because, I know if V stall is low, then the runway length for takeoff will be less.

But, how can I make V stall low? One thing comes to my mind from here, that I should make W by S also low that is true; that means, the wing should have large area, then only W by S will go down, larger area wing has another problem that is it will have lot of drag. So, you would not be able to have a better performance in terms of high speed that is, why you will find for a high speed airplane W by S is not that low, it is in the higher side.

We will be discussing this in the 7th or 8th week, when you will be cruising towards design, but at this point keep this in mind. However, you should also notice here, this W

by S is basically W takeoff by S and suppose for some reason I want to takeoff at a shorter distance, then being prescribed. So, I my myself as a pilot can locally change the wing loading that is W takeoff by S. How? Suppose, it is 10 passengers I will not take 10 passengers I will take 6 passengers, I will not take full tank of fuel I will take less fuel.

So, total weight of the airplane will reduce off course, it will amount to range not that, what we otherwise get from the normal aircraft. But, as a takeoff is concerned it is a routine practice that, not all the time you are going full of full load that is and if generally, when we are doing experiments here. Sometime we take full load, we have a capacity of 5 passengers, but depending upon wind conditions we may be flying at a lower W by S wing loading by taking only 3 students.

So, that is small correction of wing loading locally, so the pilot has that option. Why I am saying pilot? Because, remember once the plane is given to the pilot, pilot is the pilot in command, he is the boss. So anything, now you want to do it has to be under the cognizance of the pilot. He has to say, yes. Why I am talking about this V stall etcetera, etcetera? You will appreciate; see here the density part rho.

Even for a same wing loading if rho decreases the V stall increases, V stall increases means we need larger takeoff length. Because, anyway V takeoff is some percentage more than the V stall, you want just lift to be more than the weight. So, as I am going higher and higher for takeoff means, let say the airport in Delhi, airport in Leh Ladakh. So, naturally that is a higher I am talking about takeoff please understand.

At the higher altitude, so there density is less, density is less means the V stall at New Delhi will be lower than V stall at any higher altitude that is compared to Delhi. Let us say Leh Ladakh Kashmir that is simply, because this rho is less at high altitude; that means, in Delhi if it was taking 200 metres runway length, same airplane under same condition at Kashmir or at Leh Ladakh will take more than 100 metres.

So, sometime it may happen, for a specific purpose the pilot may reduce some load that is he may not take the full passenger; he may take less fuel and takeoff from that high altitude and come down to some other place. So, these are the operational thing based on this understanding.

So, what is to be understood is, even if wing loading is same, even if C L max is same depending upon, what altitude is your runway the V stall will change, so pilot will be aware of this, fine. So, once we are very clear about V stall, we have also seen that I can reduce this V stall by using flaps, because by flaps we are actually increasing C L max value locally.

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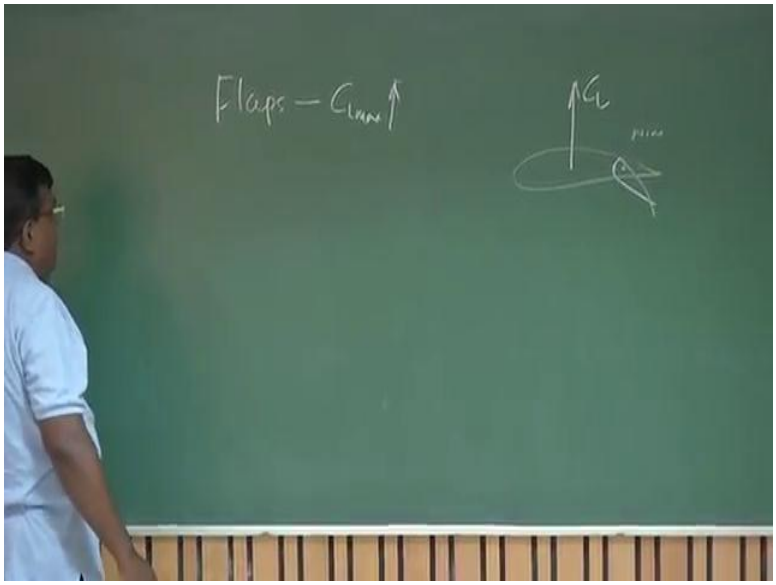


So, by flaps we are increasing C L max locally. Why I am saying locally? Because, the moment I put the flap, yes C l max has increased, because cambered has changed. But, what is the problem? Problem is, it has now contributed more towards drag. For example, induced drag K C L square will increase even C D naught will increase, because geometry has changed.

But, for short duration I will engine the aircraft in such a way that it takes that power overcomes that sort of a extra drag, but that cannot be done for all so. Although, flap is giving us more C L max, which we use locally for takeoff, but in actual flying we are planning to fly at a condition, where C l by C D is max. So, you are not flying really with any flaps down for most of the flight, unless for some manoeuvre you may use.

But, keep this back of a mind, these flaps are primarily used for takeoff and you will see flaps are primarily used for landing, not for cruise or any other place. So, this is one, so called side effects of flap that it generates drag. Also, you will see as I put the flaps down, the C L of the wing will increase. Suppose, this is the wing and here is the flap, if

I put the flap down, now the C L will increase for same angle of attack that is how C L max has been increased.

So, it will also cause some moment, so you have to also take care of that moment through elevator. So, these are in my language I called side effects of flap, but they are really wonderful creation. It has saved us from reducing the requirement of airstrip length that is very, very important for an aircraft.

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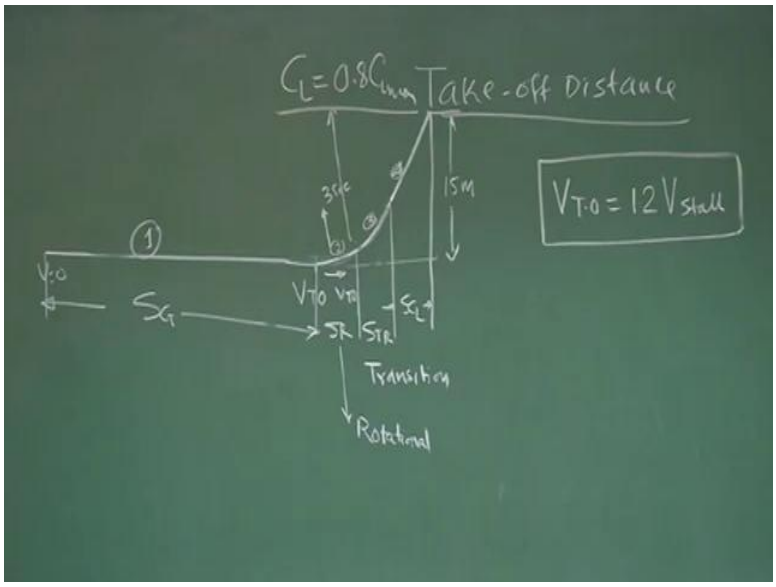


Now, let us see by regulation what is the takeoff distance, why I am using the word regulation, as I as you understand this airplane to be flowed in a safe mode, the regulatory bodies have given some boundaries to ensure that, even by mistake there are no accidents. Let me draw, what is as per regulation the definition of takeoff distance, see I start from here V equal to 0, go to a point or more precisely accelerate to a point, where I have achieved V takeoff I will explain, what is that V takeoff speed.

Then, I pull a nose wheel little up, we call it roll the airplane for approximately 3 seconds. Approximately 3 seconds, I roll and in actually, in aeronautical language I will not say roll I will say I will rotate the airplane to an angle 1 or 2 degrees, but within 3 seconds of time. Then, there is a transition, some sort of a curve like a pull up and then, climb what climb up to a point, when you have climbed 15 metre of height and this is also called screen height ((Refer Time: 12:16)).

So, what are the regions you could see very carefully? One is S G, I will call it ground distance and what happens during ground distance, the airplane is here after doing warm up etcetera, etcetera. The pilot accelerates the airplane, attain a speed of V takeoff, then slightly rotate the airplane. So, this time now your nose wheel has left the ground and still it moves like this, then there is a transition. It is like a curved path like a pull up and then, he during like he manages, controls the climb and goes for a climb.

So, there are distinct region, this I will call S R that is rotational distance, this is I will call it S T R that is transition distance, this is rotational, that is during this time the pilot has rotated the airplane and the nose wheel is no more touching the ground, but its moving like this and this is this time it is now taking in little pull up and trying to stabilize the airplane for a climb.

So, this is that is why I call a transition distance S T R clear, so these are the 1 2 3 and 4, 4 segments this is classically everywhere you will find with new books you may find mostly they are talking about S G as takeoff distance, but we will talk, what is by regulation and we follow that nomenclature.

Typically, V takeoff is 1 point 2 times V stall let 20 percent more than the V stall add that altitude, where from you are flying, because the V stall will change based on the airport altitude as I told V stall will be different, when you are taking off from Delhi compared to, when you are taking off from Leh Ladakh for the same airplane, that should be kept in your mind.

So, now, what is our job, our job to find out this distance1 2 3 4, so I name it 1 I name it 2 I name it 3 I name it 4, but remember one thing during the rotation it is going like the like this accelerated to V takeoff then nose wheel up is still it is going with V takeoff here also this is V takeoff speed now.

Let us, try to find out the distance S G S R S G R and then and S C L this will be this I will be S C l means distance during climb to clear the obstacle of fifteen metre, which is also known as screen height, if this is understood. Now, I will also try to address one question, here that what is that C L max generally, when it is going for rotation how much he should rotate the airplane.

Typically, I can tell you that should be around 80 percent of the C l max should rotate the airplane how much angle, then you can take this will be around 0.8 of C L max that is that much angle, which will bring 80 percent C L max for the airplane and then he goes and takes off. But, these are tentative numbers pilot will not see any gauge to see 0.8, 80 percent or 70 percent that is a beauty of design, the design should make pilot, so much adaptive that he should that is all with 2 or 3 iteration he will understand by feel you have to give the feel to the pilot that is, why I am again and again telling that this instruments are important pilot gets the feel from these instruments and from the stick through that stick force for a conventional airplane.

And please also understand with all this sophistications coming, where everything becoming electronic through display systems multifunctional display system, which I by now you must be knowing that the feel for the pilot has to be given very careful weight age, because autopilot's are being used actuators are used. So, how a pilot will get the feel that is also a biggest challenge, and there are ways of ensuring that still pilot are under the feel rather than seeing only the gauges, so we are not going to that now.

We were assuming, it is a simple plane, where I can pull the stick I can pull the rudder pedal and from the forces and I should be able to make out, what is happening along with screen doors gauges I know where, I am and what should I do, how much should I go, how much should I climb, how much should I turn all this thing I get for the instruments these are extremely important.

So we now, want to again come back to this estimation of ground distance, let us go back to class 9th 10th even, why 9th 7th 8 or 8 class 6 7 8, I remember at the personally there are three formula in physics become the lifeline.

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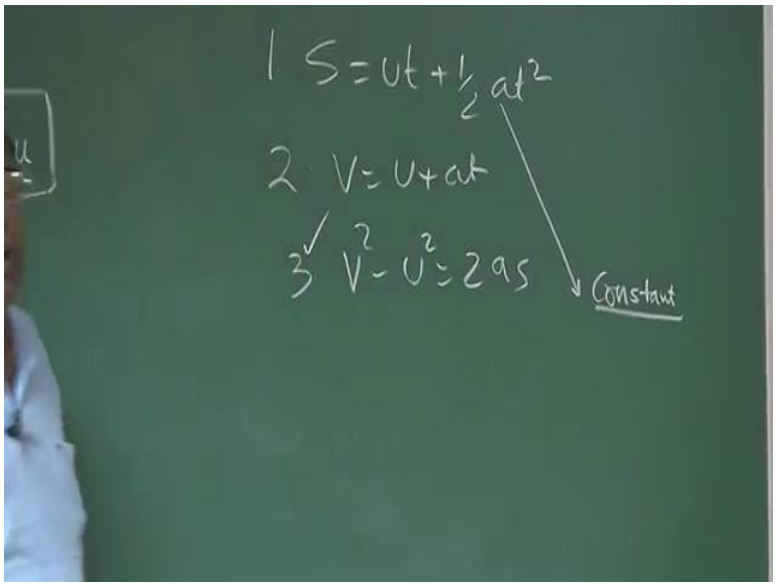


One was S equal to U t plus half a t square and there was V equal to U plus a t and third one was V square minus U square equal to 2 a S, am I not correct. Whenever, my teacher is to give me a problem in physics on mechanics on specially on motion rectilinear motion I will eat the problem and see, what are the things given, if, final velocity is given and distance is given, then I know I have to use this formula.

If time somehow is given, then I know out of these 2 either 1 or both of them has to be used whether both of them have to be used or not that is to depend upon what is finally, required. But, almost I personally was do doing this sort of a problem mechanically, because my teacher told do not worry about the acceleration assume that the acceleration is constant. We had class sixth or seventh there are no introductions to integration differential etcetera, etcetera, so most of the problems were assumed that acceleration is constant.

Then, there were series of problem, where acceleration were not constant very obvious from the description of the problem. The solution was take the average acceleration it will work, because those type of problem people have seen, if you take average acceleration results would be, now come back to this problem of estimating h g and you will see, how similar is the situation nothing has changed in last, so many years as far as I am concerned.

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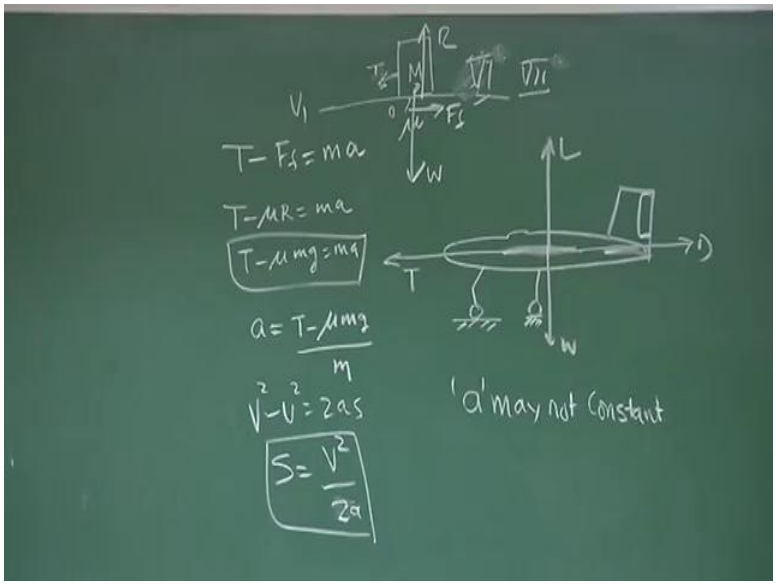


So, let us first draw airplane, we know this is thrust, this is drag, this is lift and here, it is weight and this is nose wheel on the ground and here we will all landing gears on the ground. Similar problem, in class 6th or7th if I try to recall it is, there is a table there is a box or somebody is pulling it with tension T.

And, there is a friction its coefficient of friction for a surface is mu mass is m find the acceleration, find the distance in time T or how much distance it has to travel to get a speed from 0 to say V 1 all these problem. Were solved by either S equal to U T plus half T square or V square minus U square equal to two a s because the basic assumption was the acceleration is constant.

If I try to compare these two problem that is, what I studied in class 6th or 7th I do not see any difference, but for that now I know the acceleration, may not be constant, why that is, so that also we should know that is why, we have made one video recording for you to, what a pilot will be doing for takeoff, how he will operate the engine he will go on increasing the thrust all such things will be a demonstrated and you will see that.

So, this problem was easily solved, because we assume that it is going on a constant acceleration if I assume here the acceleration is constant. I am not doing anything new same problem I am solving, but let us see what actually happens for airplane that is very important.

If I now, write are try to write equation of motion before that, if I try to write here, what would be here, T minus there will be friction force F s T minus F s will be equal to m into a, F equal to m a and I know, because this mass is resting on this. So, there will be reaction r because of weight w, so I will write T equal to T minus mu R equal to m a or T minus mu m g will be equal to m a, I will be solving this equation.

Because, R and W are equal R minus W equal to 0, when there is the acceleration in the vertical direction there is only acceleration in the horizontal direction. So, this would have been in the, where to solve this problem and a equal to, then comes T minus mu m g by m and you apply V square minus U square equal to two a s, so I find s equal to V square by 2 a if a is constant my problem is solved. So, this is very straight forward if I try to solve this problem assume a is constant, which is for all practical purpose it should be constant.