NOC: Introduction to Airplane Performance
Prof. A. K. Ghosh
Department of Aerospace Engineering
Indian Institute of Technology, Kanpur

Lecture - 33
Landing Performance: Continued

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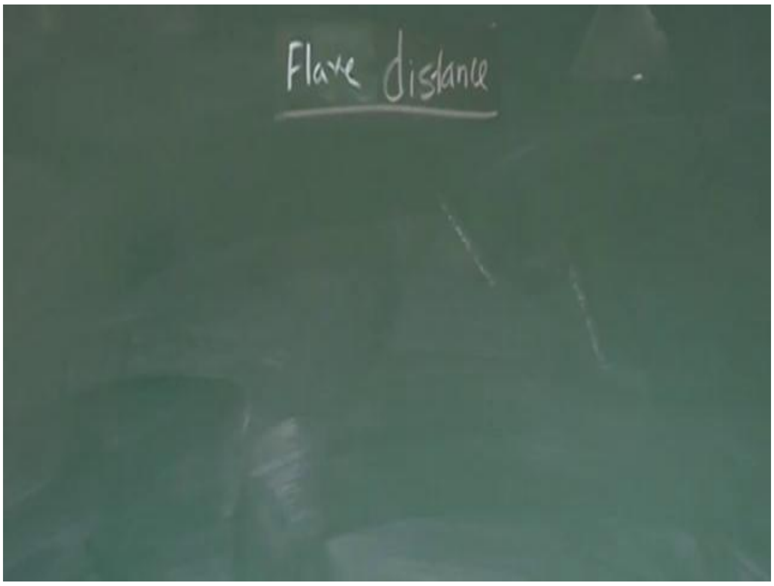

Welcome back students, now our next step will be to calculate the flare distance.

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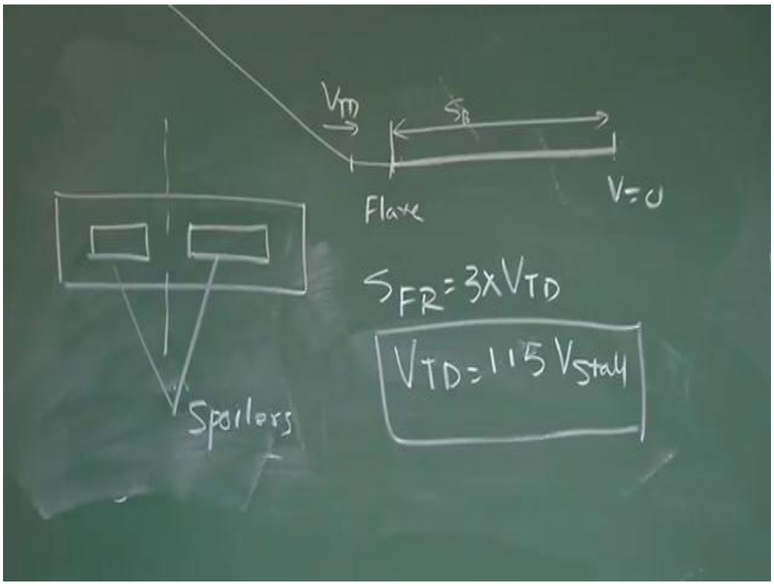

If we draw diagram the again which is something like this, this is the V touchdown and this is the flare. Flare means the airplane is coming like this ((Refer Time: 00:25)), let us see this is the air stream as the airplane is coming like this. So, near the air stream, it will flare out, so that it touches the landing gear. So, that it touches the real landing gear first and then, nose landing gear.

It has to flare out and this operation takes 3 seconds, maximum 3 seconds and it happens at a touchdown speed. So, this S flare F R will be 3 into V touchdown, V touchdown is what, V touchdown you know, it is 1.15 V stall. So, S F R is also calculated. What is remaining now? That is now from here, I will be applying break. What set of break is there? Anywhere they are resting on wing, so normal will break has to be there with, I get cylinder and pneumatic hydraulic system.

So, that is a normal break we have, then also there are provisions, you can reverse the thrust of the engine that is called thrust reversal. You can have option of putting parachute, inflator parachute which is done generally fine in this, in fighter airplane. If the land lord is or landing distance of the air stream is not large enough, to reduce it they will be putting some parachute also. So, these are the basic items which are used.

Also you see, in many airplanes especially glider you see, there are if see the glider wing or earlier plane also, it give a central line, there are surface is called spoilers. So, as I land, as I land ((Refer Time: 02:31)) this spoilers will become like this. So, they will also give lot of drag, not only it will give drag, it will also spoil the lift over the wing, where is on the around. Is it clear? So, that will also help in reducing this distance. All these things you have doing to reduce this distance as V, this is the understanding. Now, let us see how can I calculate S B that is our next exercise.

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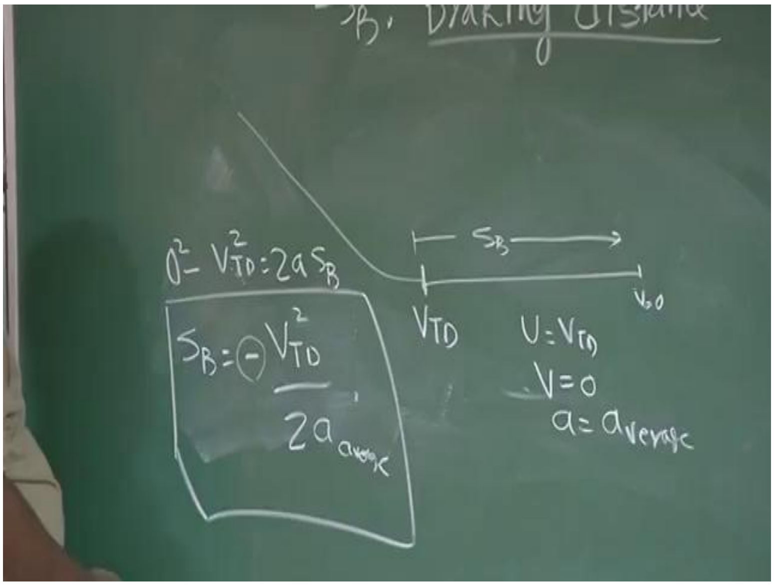

So, S B which is termed as braking distance, so just come like this, flare like this and from here, which is V touchdown to V equal to 0. I have to find out, what is the distance be, go back to class 6th or 7th. How would I solve this problem? Immediately, I will see final velocity is 0, initial velocity is V touchdown, so I will write U equal to V touchdown, final velocity V is 0. I will assume average acceleration a, which can be present as if a is constant.

Then, what should I do? Then, I will write final velocity is 0, so 0 square minus U means V touchdown square equal to 2 a S B. So, S B is minus V touchdown square by 2 a, which is average. I do not require any B.Tech, M.Tech or P.hd to write this equation. My knowledge at 6th, 7th, 8th was good enough and we will be doing the extension of this thing in defining a average.

You could see there is a minus sign, so do not think S B has become negative, this minus sign is here, because a average is not a acceleration now, it is a declaration, because there is reduction in this speed, so that is negative. So, negative and negative get cancelled, it gives a positive number. So, what is our aim now? Our aim is to find out, what is that a average?

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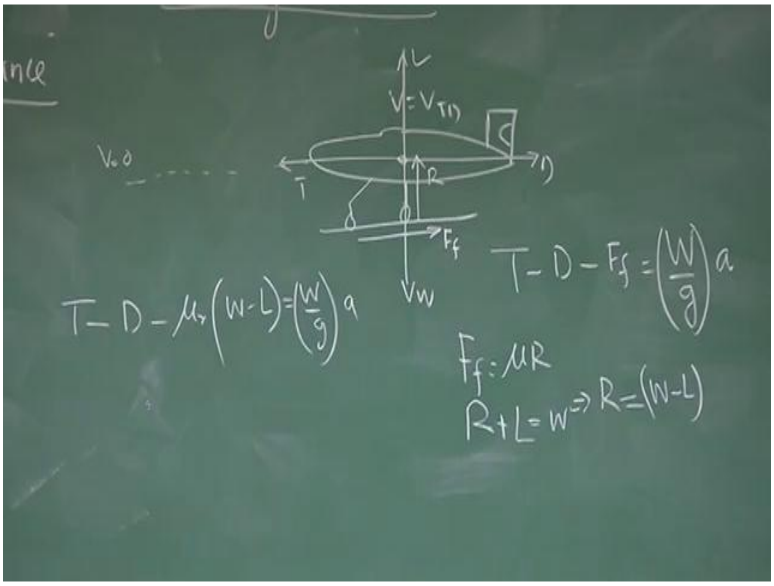

So, let us now as we did for takeoff case, we try to draw the free body diagram, aircraft is a on the ground. So, and it is V equal to V touchdown and it is coming down to V equal to 0. We want of find the a at average, this deceleration average. We know that this is the thrust direction T, this is the drag, lift, weight and there is a friction F f and of course, we write R as the reaction from the earth, the airplane.

Now, once I write the equation, I get T minus D minus F f is equal to m a W by g into a, but as I understand now that drag is proportional to speed square. So, I did not speaking a will change, a will not remain constant, also I see that F f, I can write as mu into R and R, I can find out R plus L is equal to W. So, r is nothing but, W minus L, so this equation becomes T minus D mu R. It is a coefficient of friction for rolling into R that is, W minus L equal to W by g into a.

Now, can you tell me, how can I apply my common sense here to further simplify this. Remember this is equation, now we have land it and we want to reduce the braking distance. So, what should I do? Should I put this thrust here? Now, no requirement of thrust in fact, if possible I will put a reverse thrust by the jet engine, the mass flow being changed in the other direction or by changing the pitch of the propeller.

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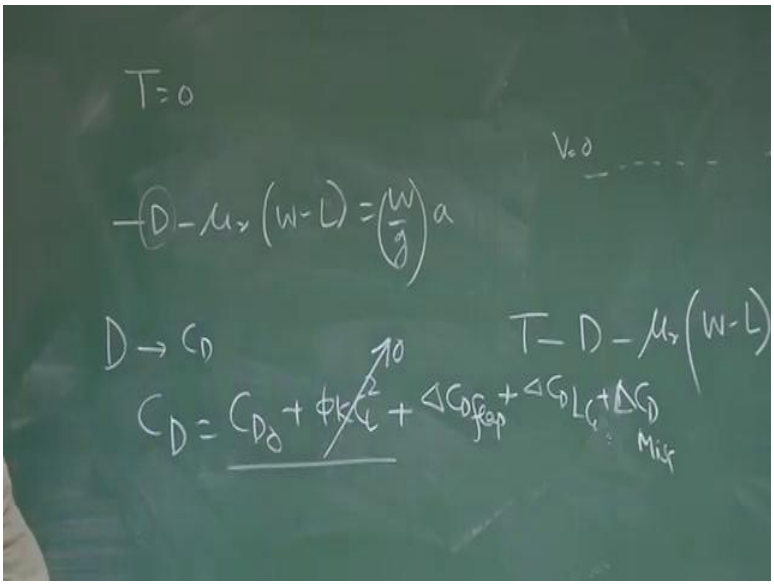

So, for first case I am putting thrust equal to 0, which is obvious. Once I have landed, why should I keep thrust? So, then I have an equation like minus D minus mu R W minus L equal to W by g into a. Please understand here another certain point, once we have to model this drag through C D, I will write mechanically C D equal to C D naught plus 5 K C L square, because of round effect plus delta C D flap plus delta C D landing gear and plus miscellaneous.

As I was telling you I can put a parachute, so that will also have a drag, but concentrate here. As I have landed on the ground, I want this component should be 0. Why should I have need a lift? So, naturally that component goes, I ensure that there are no lift on the aircraft, so then the C D gets modified like this. So, I am not really bothered about ground effect while going for a braking, this you must understand. Now, after this, what we do? We have to find a average in fact, I need not complete this U S and we will be able to do this in one shot.

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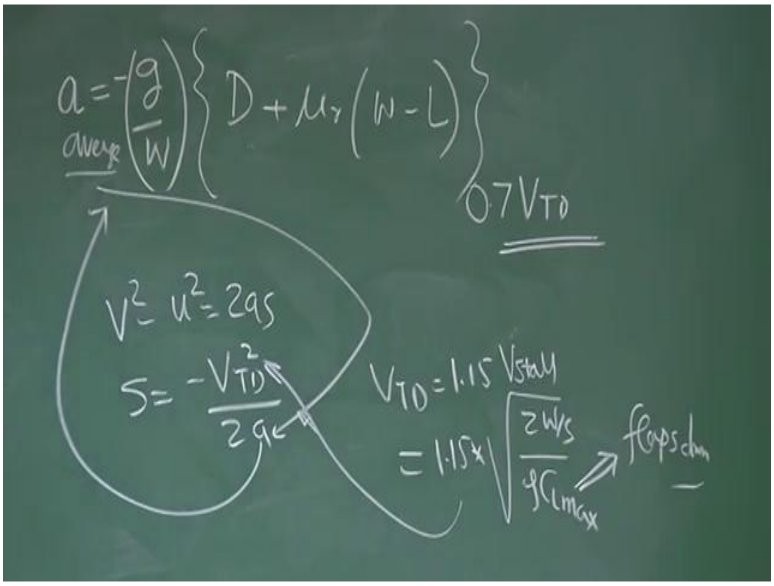

We have expression for a, a will be g by W, I put a minus sign here, D plus mu R W minus L. And as you have done for a takeoff case to calculate a average, this accelerated average which will represent the overall effect to compensate for the complexities of this relation being varying in nature. If I calculate a at same as 0.7 times V touchdown, please understand V touchdown. If I calculate this drag lift I am list bother, lift almost it will be going to be zero, because I do not required a lift.

So, this will give me an expression for a average. Now, since I know that v square minus u square, remember this equation earlier you know. So, s will be equal to minus V touchdown square by 2 a. So, I will be substituting the value of a here and I will substitute V touchdown as 1.15 V stall which is nothing but, 1.15 into... The V stall is 2 W by S by rho C L max, you know this deals with flaps down.

Please understand, when I am calculating V touchdown 1.15 times V stall by 2 W by S rho C L max, that does not mean in the aircraft. On the ground, we having a C L max configuration, this is for calculation, you have calculated. To understand that, that is the speed with which will actually the initial speed for the airplanes that is all. Well, you start touching the ground, then the speed goes on decreasing. Now, if I substitute all these things into this equation, what I get. I leave it to you to just find out the final expression, which is as simple as just substitute in this here and a, from here.

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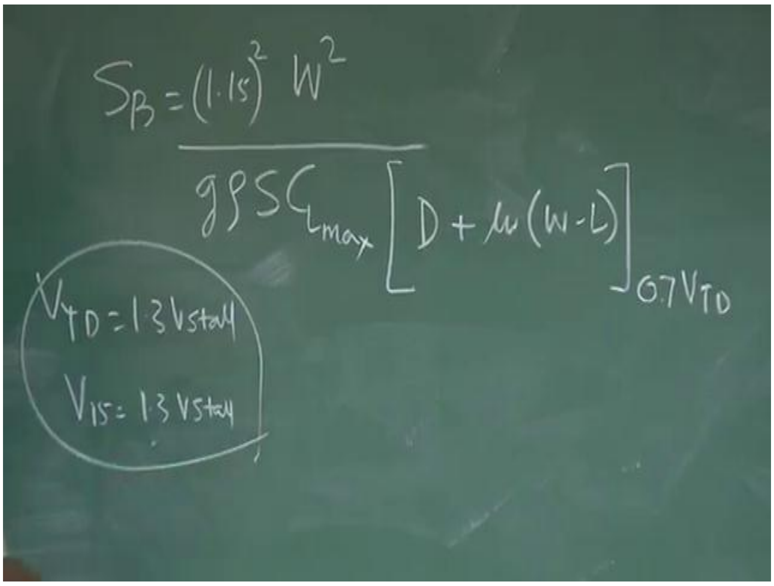

So, you will get an expression like S B is 1.15 square W square by g rho S C L max D plus mu R W minus L at 0.7 V touchdown. If you say book, many books where they take V touchdown as 1.3 times V stall, I have seen even, many book I have seen. V touchdown they have taken as 1.3 times V stall, but we have taken V at 15, 1.3 times V stall, note this change. So, if you read some book, you may find that this value is around 1.69 that is, they have taken V touchdown as 1.3 V stall.

But, I have taken V touchdown as 1.15 V stall. So, that should be clear in your mind, do not get nervous about it. So, let us understand those of details. Understand the physics behind this.

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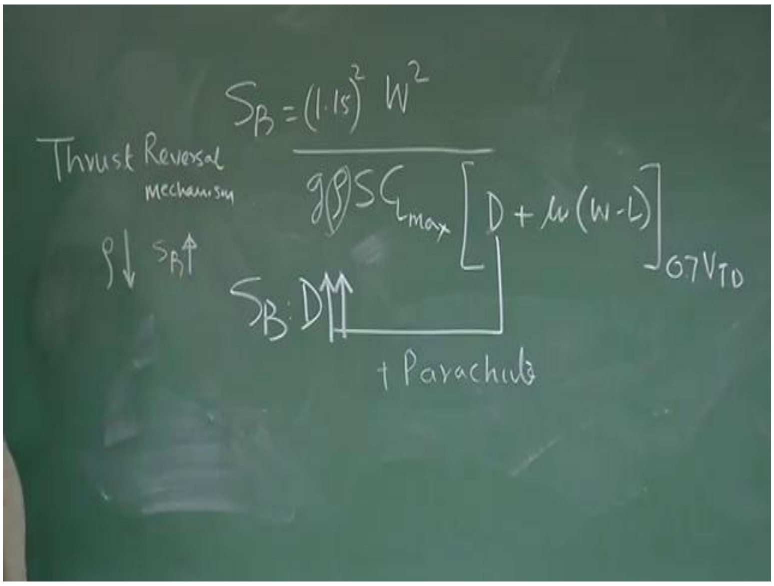

What does this be means, I can reduce S B, if I have drag is very, very high. How can I increase the drag that is a question? What is done is, the flaps will be now put to 40 degrees, which will not go to lift, but it actually gives drag. If it has a spoiler, spoilers will simply stand up like this ((Refer Time: 13:36)), that will give drag. Also you will find, there are airplanes all substitute airplanes in fact, they have got something called thrust reversal channels mechanism.

What is it does? As I have touchdown the ground, earlier thrust was like this, now the thrust will be opposite direction. So, that will also reduce the braking distance. How that could be done? You know it is jet engine, if it is a get engine, then what about mass flow is was first being thrown out in one direction to get a thrust during takeoff, now through mechanism, same mass flow you through in the opposite direction, the thrust direction will change.

Also for a propeller driven engine, the pitch of the propeller you can now reverse. So, that earlier thrust was coming like this, now the thrust will be towards the airplane and it will help in reducing the braking distance. Also I can increase drag by adding parachute, which I was telling we will find most of a fighter airplane, they will be using parachute. The moment they land ((Refer Time: 14:54)), at a certain distance the parachute will be deployed, which will give enough drag and that will again increase this value. So, the S B braking distance will reduce.

So, you understand, so far we were all very annoyed with drag, why drag is there, but now you understand, how important is drag. Please understand that is why, an intelligent person knows how to convert an advantage to a more advantage situation or a disadvantage to a advantages situation and that is the role of a designer. If he is really in true sense, a good designer and to do get to that feel, to get inspired to be a good designer I am stressing all this point again and again.

You can also see, now your expert you can also see that rho. If rho goes down S B goes up; that means, if you are touching down at a high altitude airport, where the density of air is less than density of ait at sea level. So, that airport when you are landing, be careful you will be requiring larger braking distance.

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So, by now you have learnt how to approximately calculate S A, the flare distance S F R and braking distance S B and total landing distance for a single engine. Landing distance will be S A plus S F R plus S B, but it goes without saying, when you are designing an airport or air stream, you will keep lot of margin. How much margin to be kept, we will be discussing in one of our session. But, this is clear now, you know how to calculate approximately the landing for a single engine airplane, maintaining the regulation and the guidelines.

Thank you very much.