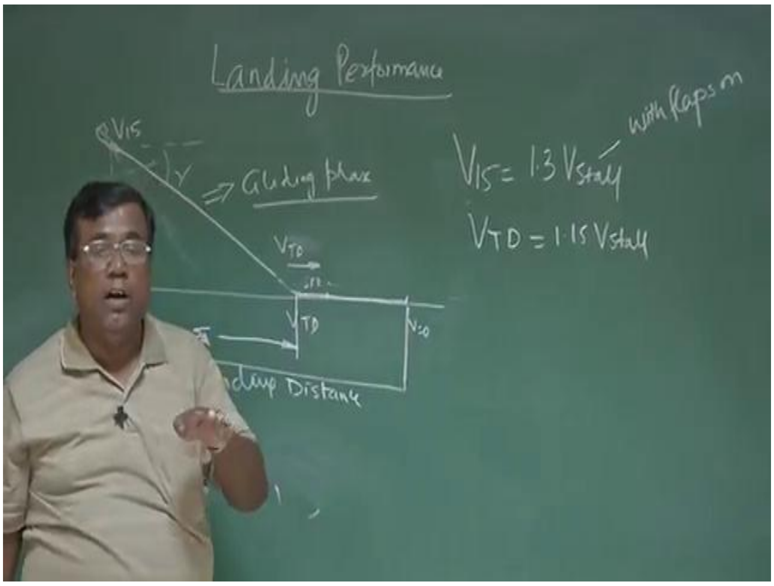
NOC: Introduction to Airplane Performance
Prof. A. K. Ghosh
Department of Aerospace Engineering
Indian Institute of Technology, Kanpur

Lecture - 32
Landing Performance

Welcome back students, today we will be discussing about landing performance. So far we have completed take off cruise, endurance. Now, today we will be discussing another important phase of flight; that is called landing of an aeroplane. And before I am going to the board, if I try to demonstrate a landing, if you see this is the airplane ((Refer Time: 00:35)) and this is the airstrip here.

So, airplane will align some landmark, maybe the center line of the airstrip and basically, it will be coming like this and as it comes near the ground, it actually flares up, what is that, it is called flares up. So, it is actually putting the nose up and ensures that the rear wheel touches the ground and then, starts moving, but same time, we apply the brake, brake could be of different, type, we will discuss about that.

(Refer Slide Time: 01:12)



That whole exercise completes a landing performance or landing manoeuvre. But, as per regulation, we have to give a specific numbers with specific guidelines for the pilot and as per the guideline it is, we start talking about lending performance. When the pilot has ensured that, the airplane is in the approach at a height of 15 metre comes like this. This phrase is basically we will understand the gliding phase, you will be putting the thrust to their minimum.

Almost, you can say ideally it should be 0, but for safety reasons, he may keeps some 10 to 20 percent on using the clutch. So, it comes like this a glide like this, come here now, it flaps up, flares, as it flares, then it touches the, the rear will touches the ground and then, apply the brake and matter is over. ((Refer Time: 02:17)) What is our aim? Our aim is to find out this distance, which is the landing distance.

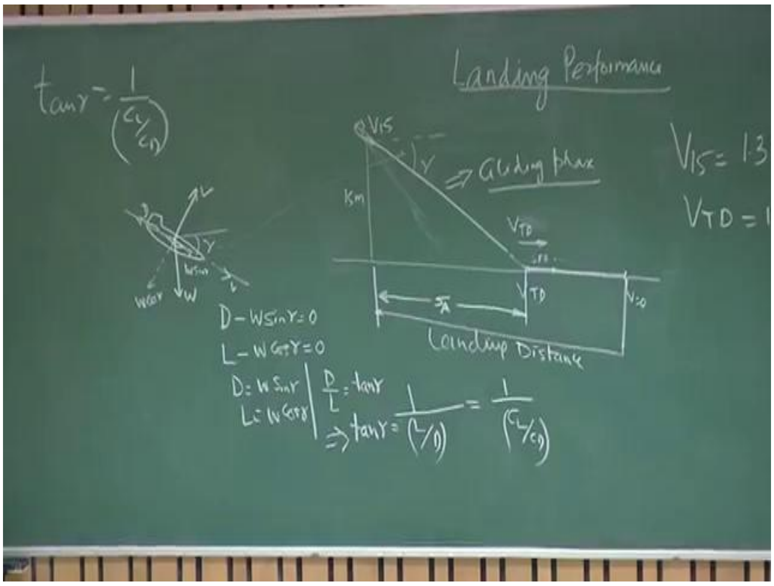
As per the regulation, the V 15 is taken as 1.3 times V stall and V touchdown has 1.15 V stall. What is this V stall? Remember V stall is the minimum speed with which I can balance lift equal to weight. But, in this case when I am talking about V stall, please understand, this is with flaps on; that is highly devices are operative now. The flag is deflected by 10 degrees, let us say 30 degrees.

So, when I am calculating V stall, I should take the C L max value with flaps on. Also, must understand that, V touchdown should be as low as possible, to ensure that the impact on the structure is less. With this understanding, let us try to find out first this distance, which we call S A. S A means a notation only tells you that, it is a air. So, airplane was air, till it touches here, till it starts faring on.

This another question comes to our mind, when I am calculating V stall, what should be the weight, because for takeoff distance we have taken the W takeoff; that is full, airplane with passenger with fuel, complete fuel. But, when you are coming down, landing after operation, please remember that, actual the weight of the airplane has reduced. It has reduced by the amount equal to the fuel consumed.

So, in touchdown estimation when you are doing, you have to see, what is the weight during the time, it is now going for a touchdown, which is definitely not equal to the takeoff speed, if everything is normal. And also, there is during this some C L is prescribed that also will be talking about. But, before I do this computation, please also understand, I am saying this phase is a gliding phase, almost a gliding phase.

(Refer Slide Time: 05:38)



What does that mean? You remember, we have studies the gliding flight and I repeatedly mentioned gliding flight does not mean, it is meant for gladder only. This concept will be using even for aircraft, because aircraft during landing, it has a phase almost like a gladly, where thrust is put to very nominal value. And if this is V, you know lift is here, weight is here and drag this side, we are now expert. And this angle is gamma flight path angle, which is negative, which is nothing but, you see here, try to draw the similarity.

In this case, what we learnt? I want to come along this line with a constant speed, because I am landing at a constant speed. So, in both the axis there should not be any net force. So, what does it mean? It means D minus W, the component of W, so I have you here, W cos gamma and I here W sin gamma. So, D minus W sin gamma equal to 0 and l minus W cos gamma equal to 0.

So, this means D equal to W sin gamma, L equal to W cos gamma, you know this, if I combine this, what I get D by L equal to tan gamma or I write tan gamma equal to 1 by L by D. So, D by L is tan gamma, so I write tan gamma equal to 1 by L by D, this is equivalent writing 1 by C L by C D. And you are familiar with these expressions; tan gamma is equal to 1 by C L by C D.

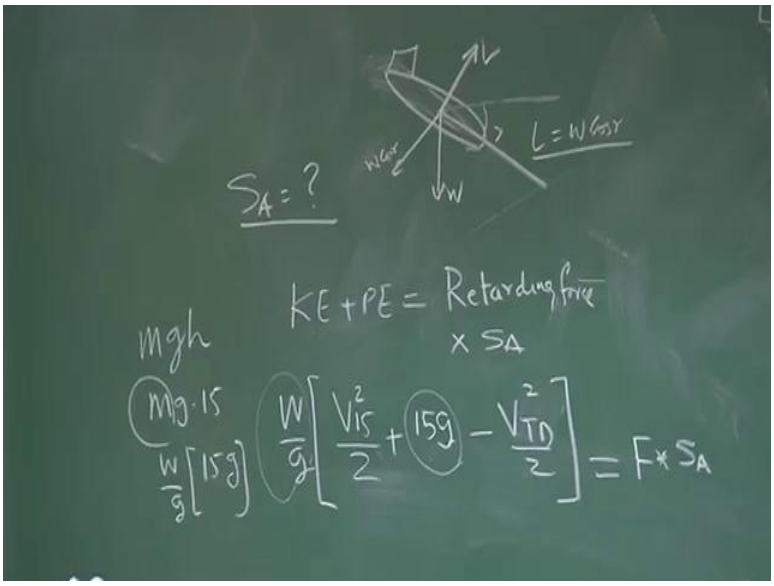
And if you recall for a gliding ((Refer Time: 08:00)) maximum range, we want to fly at gamma minimum and that is only possible, if I am flying at C L by C D maximum; that is C L equal to C D naught by K under root. So, nothing new we are doing, we are using those concept. But, when you landing, it is not feasible for you to fly at C L by C D maximum, you will be flying at a C L by C D such that, depending upon the distance and all, such this angle is within 3 to 5 degrees, this is also called glide path angle.

So, for that understanding, I have again revisited here and also to ((Refer Time: 08:44)) this point during this phase, I have deploy the flap. So, C L and C D, they have changed. So, I have to very, very careful during estimation that I should take correct value of C L and C D. This is one, second thing, in takeoff analysis, we have taken W takeoff complete weight, fuel all the airplane passengers, but when I am landing in a normal flight, I should also check, how much fuel is consumed. So, that time the weight is not the W takeoff which is the weight minus the fuel at least.

So, this final points is should know, now as per the regulation is concerned, the landing distance is define like this, once this airplane is at 15 metre above the horizontal in classically notation wise, we will find the regulation use 50 feet. So, from 15 metre, it come here, flares, applies brake, whatever place it comes to halt; that is the landing distance. And there are specified speed limits that V 15; that the V at 15 meter should be 1.3 times V stall, V at touchdown should be 1.15 V stall, this is we maintained.

Now, will calculate S A and other distance, to calculate the whole landing distance, but you could see that conceptually, nothing new you are doing, this part we know gladding phase, this part is a flare for 3 seconds. It will be going at speed equal to V touchdown, which we know is 1.15 V stall. This also I can calculate we have done it for takeoff also similar way and here we applied brake. In the takeoff, we found acceleration, took average acceleration, per landing will take deceleration will take average deceleration. So, that we can easily use V square minus V square equal to 2 S and find the S.

(Refer Slide Time: 11:14)



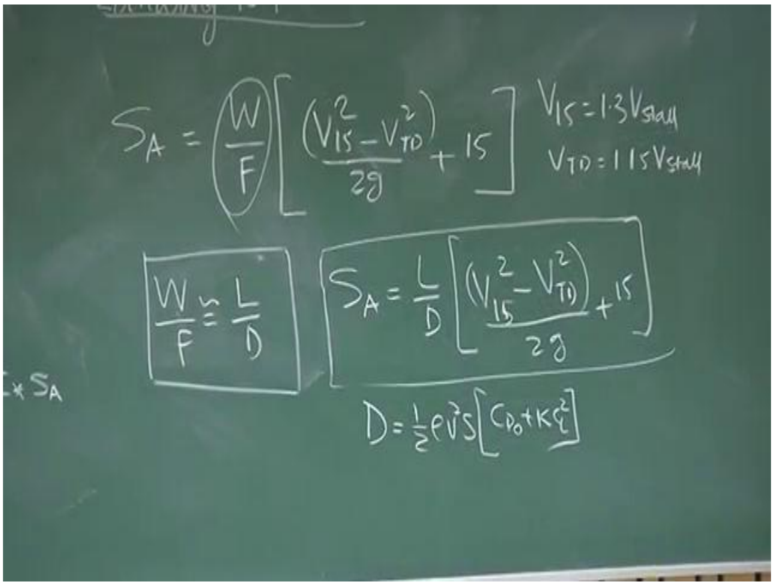
Now, how to find this distance S A is the course; that is a question here, as I told you in estimating or calculating these things, we have to really apply your common sense to make things simpler and get a quick estimate. That is the most important part. What is done in if see any book, they are made in a time to find out different, different ways, I will be presenting or simple way and it really works well and the principal is very simple.

The kinetic energy plus potential energy, total energy retarding force into distance S M very approximation, but it works. What that approximation, because you can immediately question, what is this, you are assuming the whole energy is going into this, whole energy use by the retarding force, yes, it is exactly not, lot of other sources are there, energy getting dissipated, but measure part this.

So, now, if I use this equation, what I get, I get kinetic energy half and V square. So, it is I say W by g is m, V square means here, V 15 square half m V square, I put by 2, this airplane is also having potential energy here; that is m g h, m is outside. So, I have to write 15 g h, this is nothing but, this term will be m g h. So, it is m g into 15, what is m, m is W by g. So, W by g into 15 g; that is exactly W by g into 15 g, so if the potential energy minus the kinetic energy here potential here just become 0, so minus V touchdown square by 2.

So, this is a difference in total energy here, this is kinetic energy plus potential energy at V 15 minus the kinetic energy here and that is equal to the force regarding force time into S A; that is a work done by the retarding force that the approximation. If I do this, I will get something meaningful and I will get an approximate value, I repeat this is that very accurate, but this is not bad, it works.

(Refer Slide Time: 14:36)



So, from here using this relationship, I can write S A is equal to W by F into V 15 square by 2 g, let me write this, we touchdown square plus 15 no issues. If you could see that, I have taken the g inside, so V 15 square by 2 g; this is minus V touchdown square by 2 g and this g, g cancels. So, this looks pretty good. Now, enjoy the approximation, how this great people have made like so simple and got some relevant numbers.

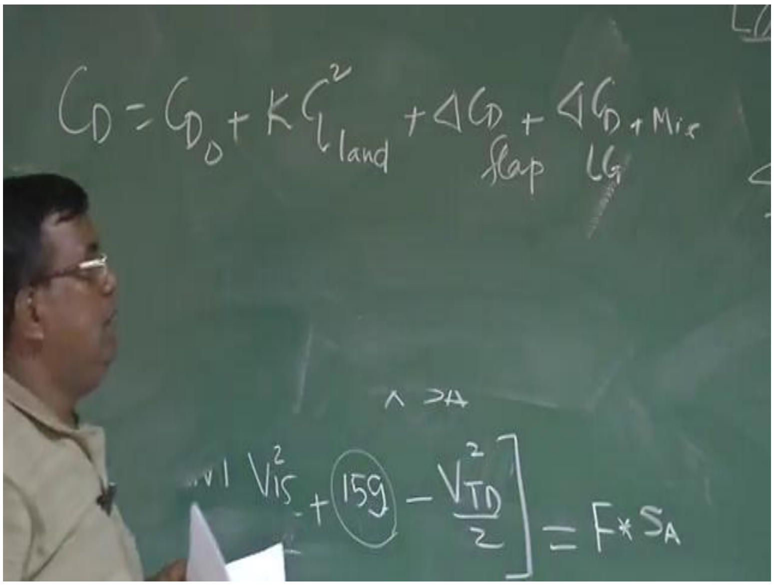
And these do not happen just because of lack of knowledge, this happens because, those who have done this approximation, work in the field, they have experience to really apply the common sense, to apply in a manner with mix life comfortable, without causing much error. In it is lot of experience and please enjoy that, what is being approximate it is, the retarding force is primarily the drag and for all practical purpose lift is equal to wait.

You also understand that lift is not equal to the weight during the gliding, if you see, what we have seen, if this is the gliding, it coming down. So, it is W, it is lift, this is gamma or this is W cos gamma. So, L is actually equal to W cos gamma, but here the W is replaced by lift, why because gamma I was telling you 3 degrees small angel, small flight path angel. So, this is not a bad approximation and if is drag, because in the air, the energies is being dissipated, because of drag.

So, this approximation, although not exactly correct, but not a bad approximation, so now, I substitute here, so I write S A is equal to L by D, V 15 square minus V touchdown square by 2 g plus 15, this will give you meters. So, that is in approximate expression for your S A, which is the initial path, please again revisit, please remember V 15 is to be computed as 1.3 V stall with the flap sound, landing around and V touchdown is 1.15 V stall, which flaps and landing gear out.

What is also more important is you should understand when I talking about drag, then drag means using the air, but it is coming like this drag we know half rho V square S C D naught plus K C L square. But, the moment you are putting the landing gear out, the moment that you are putting a flap down, it is changing C L is fine. But, because of lending gear out, there is a C D naught landing gear, because a flap set down, there will be increase in drag, because of flap down. So, it is a fair enough equation for understanding purpose to write C D as follows.

(Refer Slide Time: 19:00)



So, I can write C D as C D naught plus K C L land is C L with which is coming square plus delta C D flap plus delta C D landing gear plus some miscellaneous, we will understand, what is a miscellaneous soon.

Thank you very much.