NOC: Introduction to Airplane Performance
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Lecture - 22
Gliding Flight

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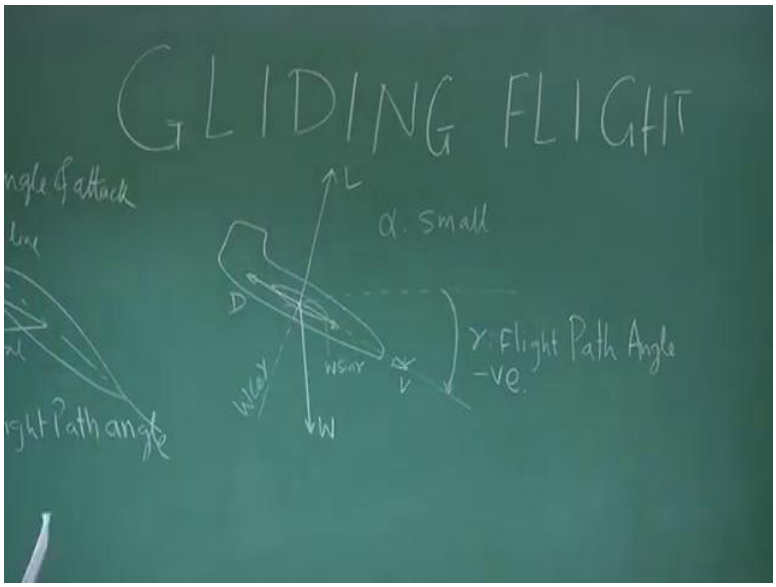

Welcome back, we will be discussing about Gliding Flight. We know, we have sinus123 glider, sinus123 glider with us. In fact, this is a motor glider.

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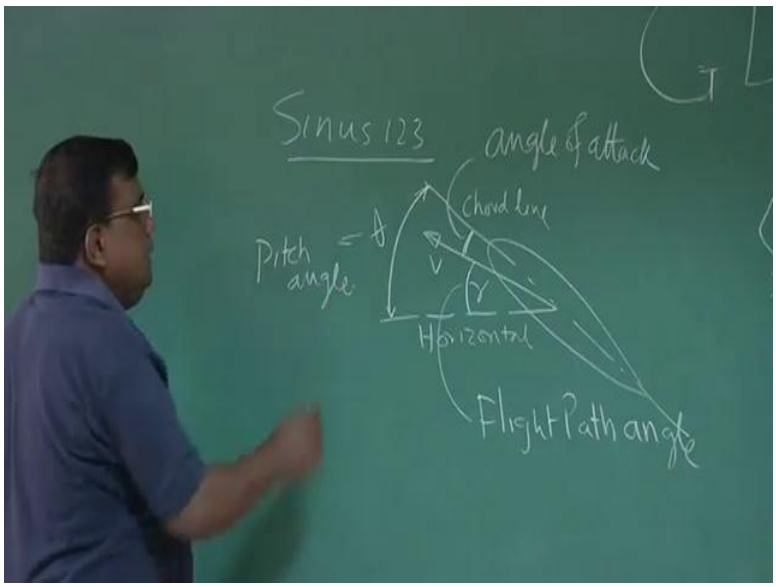

Conventionally gliders did not have any engine, they will be launched by cables and there was a winch and the winch will wind the cable and the glider will attain height. At a particulate height, the pilot will realise the cable and then, he will be doing the gliding flight, that is in the gliding flight there is absolutely know thrust, no engine install. But, nowadays there is a new concept has come, where we talk about motor glider that is, we install small engine on the glider and instead of launching through a cable, we use that engine to take it to a height and then switch off the engine.

And if required there are provisions, where the engine can be folded inside the fuse large also. So, that now you can fly like a glider and when you lose the height and you want to go for further height now, then you take out the engine, switch on the engine, again go to a height and take it. Take the engine back into the fuse large and start gliding that with the endurance of the glider has been increased.

The problem with winch launch or cable launch was that once we reach your height, you will be constantly losing the altitude. Unless, you get some thermal, which all the time you may not get. So, we will be talking about glider via gliding flight. Please remember, when I am talking about gliding flight I am telling there is no engine, there is no thrust. Ideally speaking, when an aircraft will come for a landing, we also try to set the thrust to the lowest minimum.

And; that means, if I designing an aircraft you need to have some sort of, some benchmark gliding capability which is essential for approach on landing. So, gliding flight does not may save when we need not flying with glider. So, gliding flight is one of those flight manoeuvres, which in normal aircraft needs to do or the designers must ensure that he have enough capability to do recursive gliding flight. So, now, let us see, how do we explain a gliding flight. Look at this diagram, this is a aircraft or to more specific now we call it a glider, which is descending. This is the velocity vector and this angle gamma is called flight path angle.

And if you recall, we define three angles, if this is the velocity vector and this is the chord line or refer this line and this is the horizontal. Then, this angle is gamma, which is called flight path angel. This angle that is chord line and velocity vector in the vertical plane is called angle of attack and this angle, from chord line to horizontal notation is

theta, it is called pitch angle. Now, climb angle you understand, the velocity vector tells how it is going and gaining the altitude.

Pitch angle tells, what is the attitude of the airplane and angle of attack tells you the angle between the chord line and the velocity vector. Because, that angle of attack is responsible for giving the lift forces and as say side effect, you also get drag correct. But, if I try to see this diagram ((Refer Time: 04:26)), I ask a question, where is the angle of attack here? This velocity vector is a line to the chord line, this is a simplified diagram, this assumption that we are flying at a very low angle of attack.

So, actually there is an angle of attack, but since we are assuming alpha small we are drawing it like this. Once we agree and understand this drawing with a clarity that this gamma is a flight path angle and which is negative ((Refer Time: 04:54)). This is the conversion of gamma positive that is, when you are climbing, the flight path angle is positive. When I am descending, the flight path angle is negative. If this diagram is clear, now let us see.

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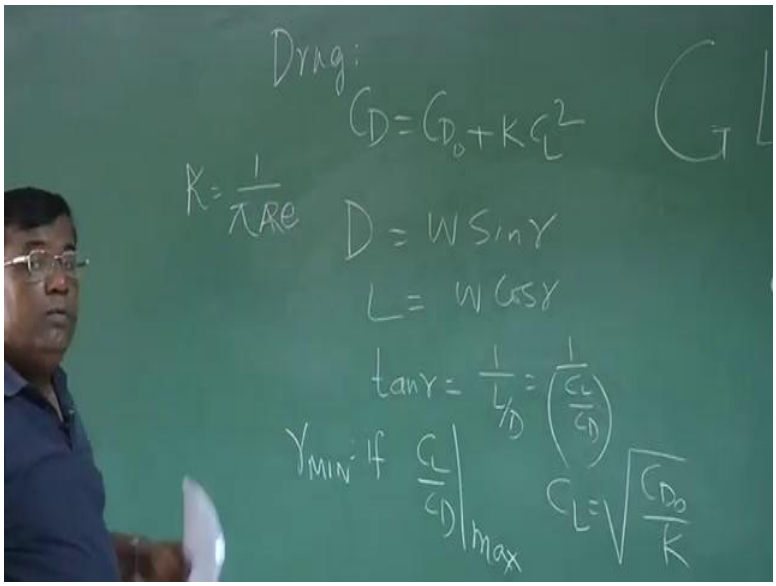

Let me write this, I am assuming that I am coming such that forces are balanced. So, this is the lift and the w cos gamma is this component of weight, which is balanced by lift and drag, there is a w cos gamma w sin gamma here, so they are balanced. So, if I write these two equations, I could easily show that tan gamma is equal to 1 by L by D or 1 by C L by C D, correct. What is gamma? Gamma was this angle, flight path angle.

Now, think of if I want to have a maximum range that is, I want to go to larger distance, then what should be the gamma for range max. I should ensure that gamma should be as low as possible. I go like this ((Refer Time: 06:14)) for the range; that means, gamma minimum means, from here gamma will be minimum. If that is gamma minimum, if C L by C D is maximum, from this relationship and this condition is not unknown to us, we are very familiar.

C L by C D max means what? It means I should fly, such that C L equal to C D naught by K. And why from I get C D naught and K? Remember, drag polar every airplane is bench mark with the drag polar, that is C D equal to C D naught plus K C L square, where K is nothing but, 1 by pi aspect ratio e. So, once you buy an airplane, the manufacture will give you the drag polar, but drag polar will be evaluated through an experiment, through flight test, through analytical method. All collaborated together and finally, validate through flight test and then, that is a bench mark drag polar for an airplane.

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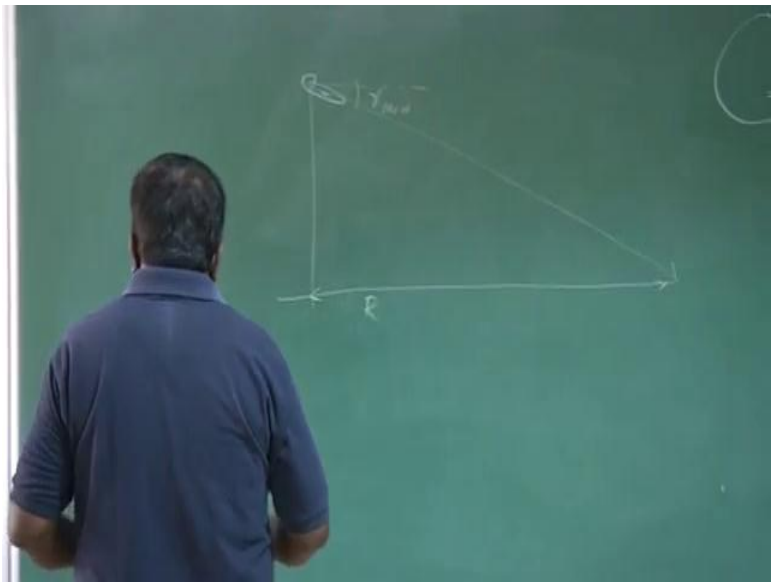

So, we have seen if this is a glider here coming down like this, for maximum range or to be a maximum from here, this gamma should be minimum as low as possible. But, the next question comes to my mind, if I decide to stay for a long in the air that is, I want to have larger time air bone that is I want to stay for long, longer duration that explicitly

gives me a message. If that is possible, if the rate of distant is minimum, you are familiar with rate of climb ((Refer Time: 08:20)).

Now, I am taking about rate of descent, if this is minimum, then I can stay for longer hours. So, let us find out what is that condition for a gliding flight. Why I am saying gliding flight? Please understand, gliding flight means there is no thrust. Gliding flight does not mean, it is only refer to gliders, even an airplane should have a gliding flight characteristics.

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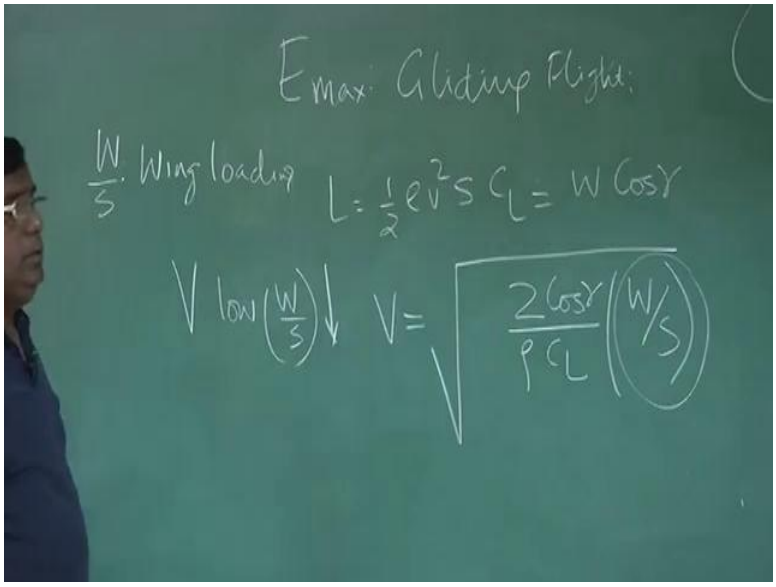

So, if I am talking about larger time or endurance max for a gliding flight, how do I model it? How do I try to understand? You know, lift equal to half rho v square S C L that is equal to W cos gamma. We have seen from here ((Refer Time: 09:23)), lift equal to W cos gamma, this angle is also gamma and that clearly gives me an expression V equal to 2 cos gamma by rho C L into W by S. What is W by S? W by S was what? Very important parameter is called wing loading that is if W by S is low; that means, for a given weight it has larger wing area. Larger area wing means it is very lift effective, lift upon the area. So, I could see that if I want this V to be low, then W by S should also be low, also it tells me that as I go higher and higher, as I gain altitude this V required to balance lift equal to weight.

In the since, lift equal to W cos gamma that also increases; that means, because rho goes on decreasing as like higher and higher, so naturally V also goes on increasing. So, minimum velocity you get at C level for a given C L and wing loading.

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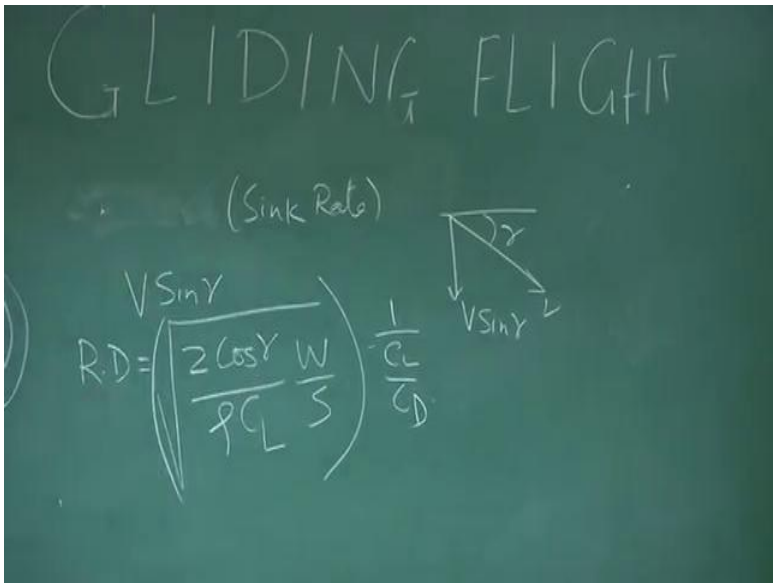

We are taking about rate of descent or this is called sink rate. Better, what is sink rate? Let me erase this, in your text book you will see that rate of descent or sink rate, climb rate or sink rate. What is the rate of descent is nothing but, V sin gamma. From the diagram you could see that, this is V, this is gamma, so this velocity component is V sin gamma and that is the rate of descend or sink rate.

So, if V is this and V sin gamma is rate of descent, so I can write rate of descent equal to V is 2 cos gamma by rho C L, W by S this is V. And what is sin gamma? Remember, we have seen tan gamma is equal to 1 by C L by C D. For a small climb angle or small angle of descent, if gamma is small, then I can write tan gamma is approximately equal to sin gamma, no objection.

So, now, what I will do? Rate of decent was V sin gamma V, if this expression for sin gamma, I will take this expression of tan gamma which is 1 by C L by C D, so 1 C L by C D. So, whatever you seeing here, see the rate of different expression very carefully.

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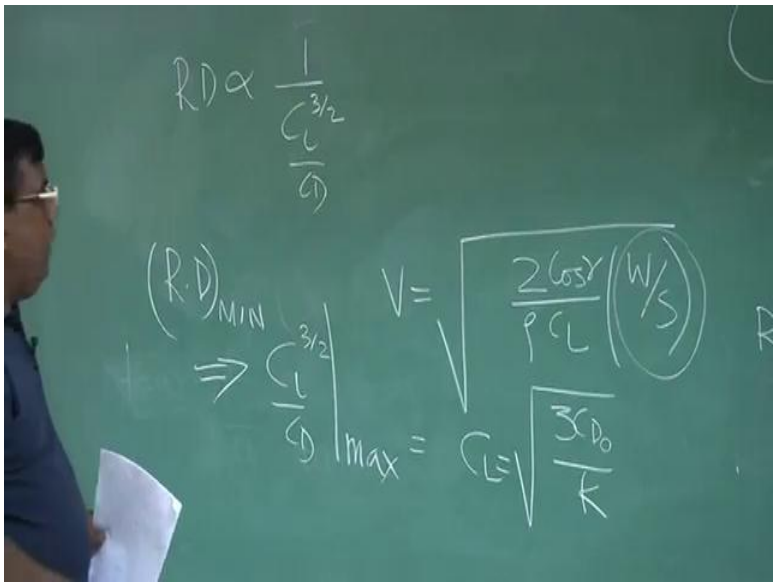

If I see now this rate of descent, I could easily see that it is proportional to C L 3 by 2 by C D. This C L is here ((Refer Time: 13:07)), C L half is here, so C L 3 by 2, this C D goes in the numerator, C L 3 by 2 by C D. So, if I want rate of descent or sink rate to be minimum, what does it mean. It means other C D is constant, C L 3 by 2 by C D should be maximum. You are also familiar with this condition. What these conditions give us? It simply means that I should fly at a C L which is equal to 3 C D naught by K, clear. So, what is I have learnt now?

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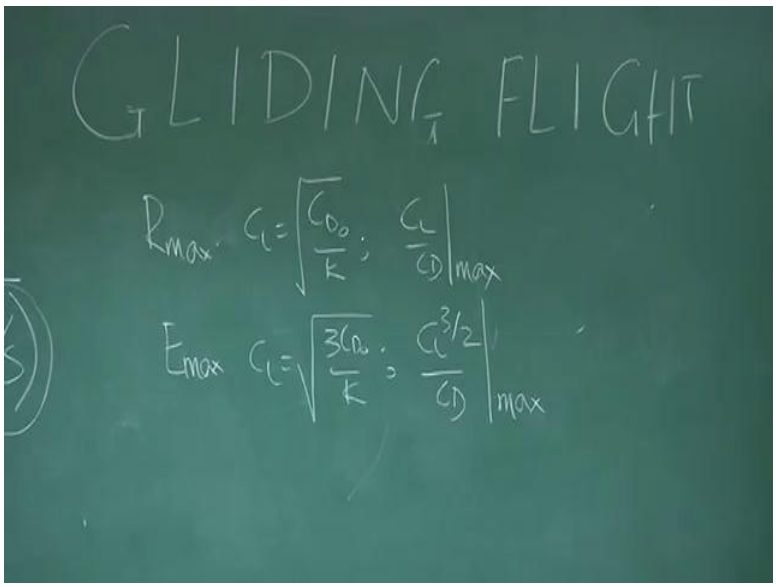

One thing, if I want the range maximum, then I must write C L equal to C D naught by K, because I am trying to fly such that C L by C D is maximum. And for endurance maximum, I must fly at C L is equal to 3 C D naught by K, because I am flying at a condition C L 3 by 2 by C D maximum. No issues, everything is clear. Now, let us go closer to a pilot, we are telling, requesting pilot please glide at a constant speed, it does not have a thrust.

So, it is very serious expectation we are having from glider pilot. This is very easy on black board, you say it is coming forces balance, but here what are the controls he has got to balance the forces. Nothing, except alligator we will try to manage altitude or try to see C L and how we can manages that. Again we are telling, you fly such that C L equal to C D naught by K to get range maximum, let us see what is the implication of this on a pilot.

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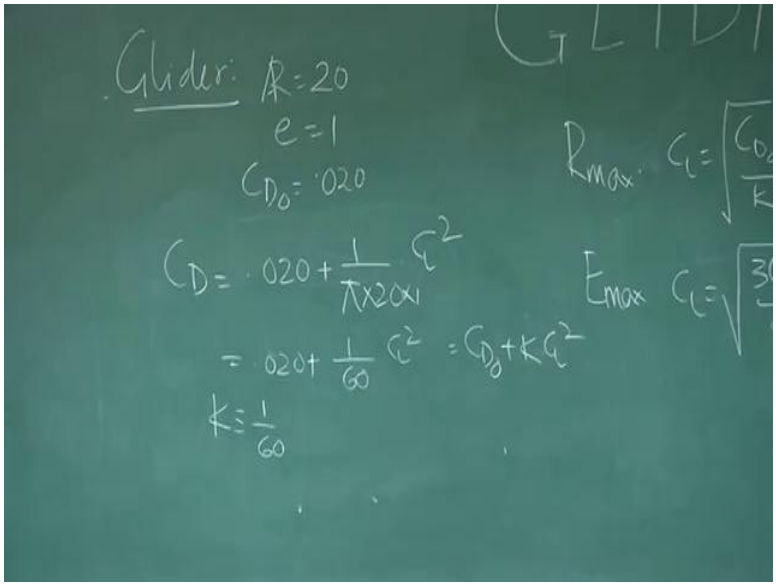

Let us take a typical example, let us say you are talking about the glider, take a case of a glider. You know the aspect ratio is around 20, let us say e is 1 or say BCD and let us say C D naught for the glider is 0.020. So, if I write the drag polar, it is 0.020 plus 1 by pi, aspect ratio is 20 into e C L square and this value is roughly 0.020 plus 1 by roughly 60 C L square, C will have the value. See 1 by 3.1416 into 24 1 by 60. So, what is the value of K? K is 1 by 60, because approximate value. Because, C D naught plus K C L square. Now, what we have suggested the pilot from our analysis?

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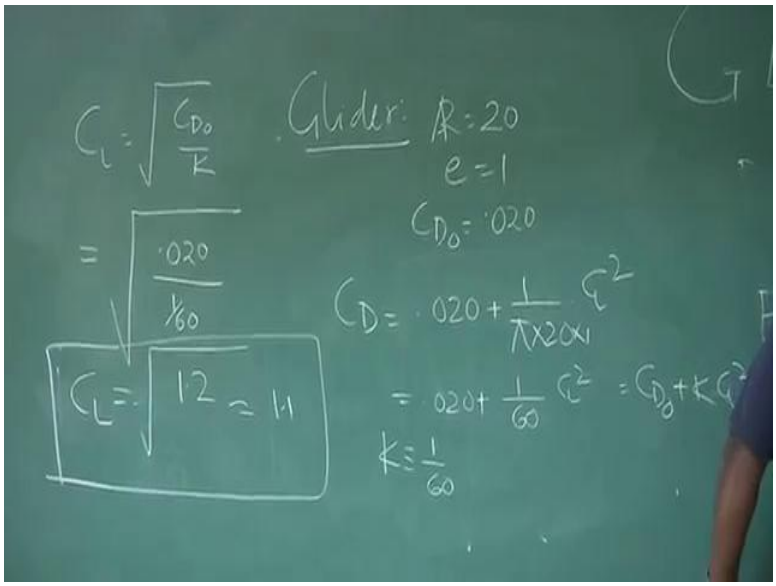

If you want to go for range maximum, sir please fly such that C L equal to C D naught by K; that means, for this glider C L equal to C D naught is how much, 0.020. How much is K? 1 by 60, so what is this value, this value is around 1.2 and typically, this value will be around 1.1. This is an approximate number, just to give you a feel. Is this clear? C D naught by K, K is 1 by 60, so 60 goes up, so this becomes 1.2 and this is around 1.1. So, what are you telling? You are telling pilot, sir we want range maximum, please fly C L as 1.1.

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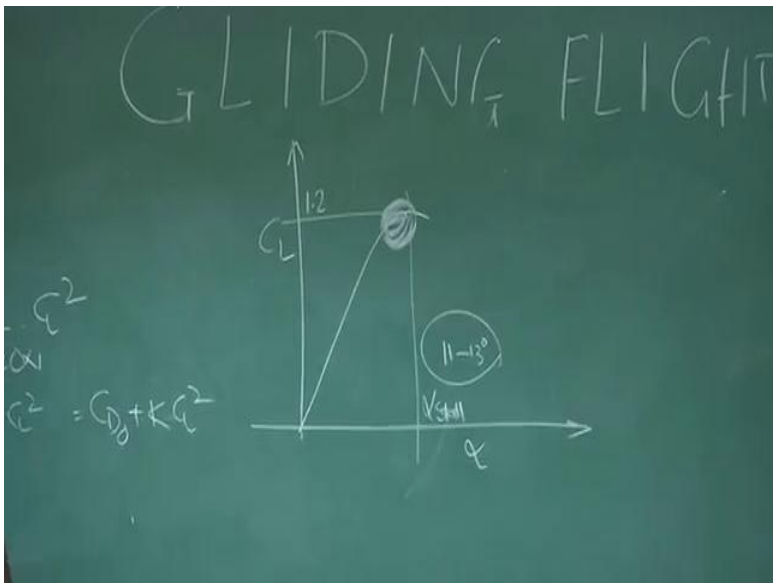

Now, what is happening is here. The moment you say this, what is actually the real situations. You know by now, if I plot C L versus alpha for a airplane, maximum value is around 1.2, if I do not use flaps and etcetera. Normally, it is one point to the realistic value and this angle is called alpha stall, which is also between 11 to 13 degrees around that number. So, essentially what you are telling ((Refer Time: 18:19)) to get maximum range, you fly somehow here.

Are you expecting something irresponsible by giving this statement? Answer is definitely no, because although your C L is coming 1.1, which tells you that your range will be maximum for glider. But, if you try to fly the glider near the stall, slight upward just we take it to stall and lot of disturbance will come to the airplane. When I say the airplane has gone into the stall, please understand that does not mean, we cannot come out of the stall, but avoid going to a stall situations.

So, all these numbers whatever you generated, the designer my request is after this numbers are generated, please think from pilots point of view, that whether you have given enough bandwidth in your design, so that the pilot can fly the machine safely and with good predictability.

We should not go into the origin of answer to written every time and that is what I will be stressing again and again, that any number you put on black board, any number you put on design board for an airplane design, please talk to your pilot in command. Take his input and then finally, write the whole configuration, then only we can understand what truly airplane performance means.

Thank you.