Flight Dynamic II (Stability).

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Module No. # 07

Lateral Directional Static Stability and Control

Lecture No. # 20

Dihedral Effects, Various Contributions

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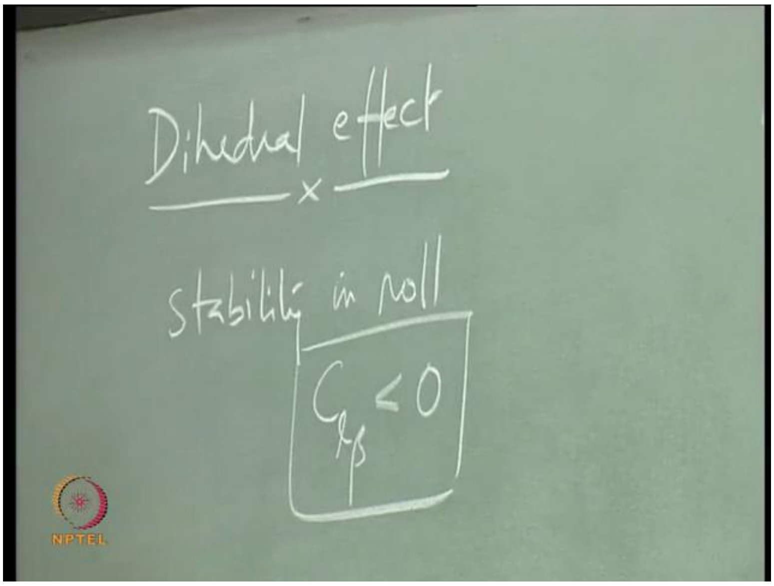

So, we are discussing dihedral effect or the stability in roll, right, and it is given by this parameter Cl beta. So, change in rolling moment coefficient, with respect to a change in small side slip angle and that we said must be less than 0, right, for stability in roll.

There are two things actually, you can visualize it in, in, two manners. One thing, one way I told you yesterday, where you have a beta and you want to see if the aircraft can kill that beta through roll, is it not? That we discussed. Now, I will tell you another interpretation and that will be, see if it makes sense. So, you have this aircraft which is flying straight and level, right. So, it is going straight, only one velocity, forward velocity, bank angle is 0, no side slip.

Now, let us say there is a roll upset, right. So, there is there is a velocity, which upsets the roll, you know, somehow and then it banks.

What will happen if when it banks? It is a small bank. So, it will start side slipping. When it starts side slipping, I want to see if the aircraft has the capability to come back to this wing level condition on its own or not, and that side slip is giving me a velocity from the y axis. Is this clear? And that should be negative. So, if the, if it is having a positive side slip, I am saying that it should roll back in the negative direction to level the wings. So, that is why we are talking about this C l beta less than 0 for roll stability. This is another interpretation.

Student: (( )).

No that is a wanted turn.

Student: (( ))

You are executing it this is not.

Student: (( ))

This is not really a turn. What I am saying, this is a roll upset from the level flying condition.

Student: (( ))

Yeah. So, there, there will be, there will be, some motion like this. It will also fall because there will be a component of the, lift which will be reduced as compared to the weight. So, it will be like this, something like this.

Student: (( ))

Yeah.

Student: (( ))

When it rolls, why will it move in the…

Student: (( ))

Yes, we can resolve the lift force now in two directions. You know lift component in the vertical direction is balancing the weight. There will be another component of lift which will act sideways. So, that is why you will move in the sideways direction. Think about what, or what happens in a, a turn. So, there is a roll upset from wings level flying conditions and there is a sideslip because of that and you want to see if the aircraft is going to come back to its wings level condition or not. That is my trim condition about which we are checking the stability.

So, that was another interpretation of why this C l beta should be less than 0 for roll stability. And we are discussing what all components on aircraft can contribute to this C l beta. So, we will discuss mainly the wing contribution in this class and see if the other effect which is also prominent and worth discussing. We will look at how wing position on the aircraft can give you this C l beta.

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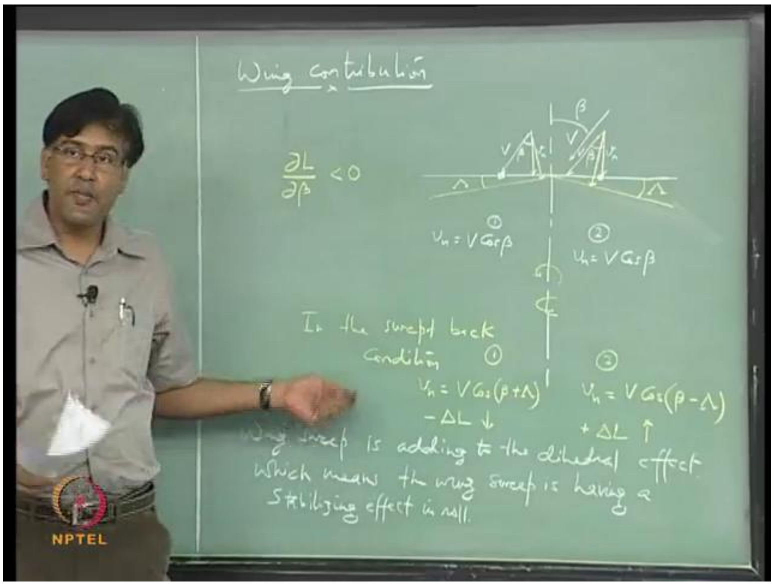

So, mainly wing contribution to C l beta is what we are seeing here. So, yesterday we started with looking at one configuration when the wing was swept-back, right, and let us see if that gives me this C l beta which is, which should be less than 0. So, some velocity coming at beta. This beta is not a trim condition, you have to remember that. I am repeating this term. This beta is caused by a disturbance. If you want, you may call this as delta beta. So, let us look at section of the wing on both the sides at equal distance from the center line. Only the normal component of this velocity is going to be used for computing the lift. So, we are looking at this section and an equidistant section on this side, call this 1 and 2, and so, let us say I am drawing this velocity again.

So, V 1, V n at station 1 is V cos beta, and station 2, is also V cos beta, right. So, we do not expect any roll because of this situation, right, if the wing is a rectangular straight wing. It is not a wing with a sweep. Let us now look at one situation when you have wing sweptback. And the angle of sweep is this .... Now, let us again look at these two sections, airfoil sections on the wing equidistant from the center line; this is the center line.

Now, I have to find a, let us say this has moved here or you have to find a normal, you know, so, location, which is normal ..... So, component of this velocity which is normal to the wing at this section is now slightly changed, right, because of this angle, and that, so, in the swept back condition.

Now, we are looking at two airfoil sections which are equidistant from the center line on the two sides of the wing, right. So, station 1 will see V n, which is V cos beta minus a sweep angle, right, ... and this will see an increased angle, because the normal is going to be somewhere here. You can actually, if you want, you can move this velocity vector. You know all I am interested in is finding out the normal component of velocity at two sections which are equidistant from this center line.

So, V n in this case for this part of the wing is .... this. Which one is higher? This one is higher. What does that mean? The lift on this wing will be higher. So, delta L that we see on this part because of the sideslip, and the wing sweep, is upward, or a positive delta L. On this side, because this is smaller, so, you will see a negative delta L. When it was flying straight, then the lift on the two parts of the wing was same. There was no side slip; then lift on the two parts of the wing was same, right, but because of this sideslip, now it has changed, right. And this is going to give me a roll which is, that roll is negative, right. So, you are getting a roll which is like this. So, Z is moving towards Y. If Y was moving towards Z, then it is a positive roll.

Now, the Z is moving towards, Z axis is moving towards the Y axis, so, it is a negative roll. So, this arrangement is actually giving me a negative roll for positive beta, right. So, if I want to write this, this should be negative, for this particular case. So, wing sweep is actually adding to the dihedral effect. That is what we say. .... What it means is, wing sweep is having stabilizing effect, right. For the same reason, when you have wing swept forward, the effect is going to be destabilizing, and that you should that, that is the homework. So, you should try that at home and figure that out yourself! So, wing swept forward is going to have a destabilizing effect on those. Let us look at another wing effect.

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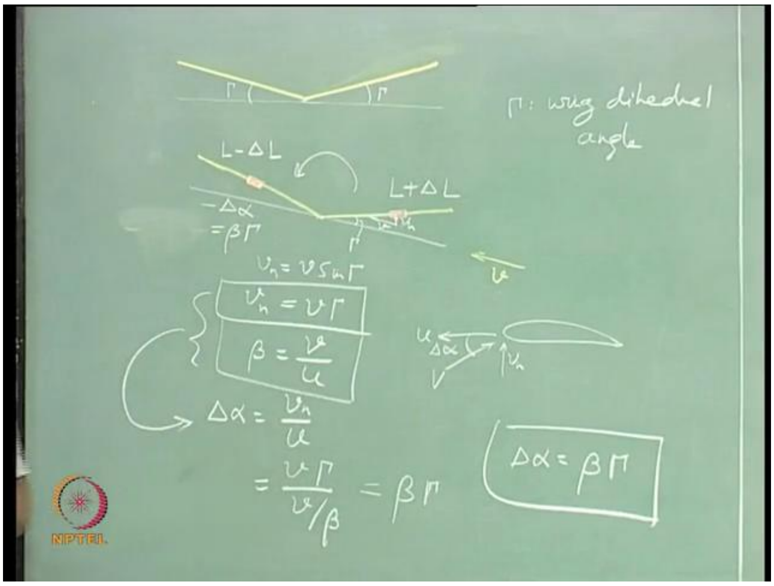

So, you have now wing which is, ... Let us look at the effect of this wing dihedral angle on the roll stability. So, as the name itself suggests, it should have a, we are talking about dihedral effect, and dihedral effect means C l beta should be less than 0. So, wing dihedral angle should give me stabilizing effect in roll, but how does that happen? Let us try to understand that.

19:05

Again, let us look at this situation when this aircraft is flying level. This lift looks like having a little dihedral, only small dihedral perhaps. So, you are flying level and let us say there is a roll upset. So, roll upset means this, let us say, and then, the aircraft is starts side slipping. You have a positive sideslip angle. Now I want to see if this particular arrangement is going to bring the aircraft back to its level flying condition or not.

So, let us see what happens when this, this plane is rotated. So, there is a roll upset which rotates the airplane. So, this rotation is the positive rotation. That is what is going to give me a positive side slip. So, there is a velocity v coming from side, right, and I am looking at two sections - one is this .... I want to find out this normal component of velocity. What is that going to give me? If you look at this airfoil section, you know, this component of v is acting from downward, and that is going to give me a change in angle of attack at this section. So, if you are looking at this particular section, this component is going to give me this velocity, right; it is Vn. And the aircraft is moving with the velocity, which is u in the forward direction, is it clear? What is this component Vn? So, let us say this is, this is, your v which is this. What is V n? What is V n?

Student: (( ))

No, because of this dihedral angle, because of this angle.

V sin

V n is v .... right.

Let us say this angle is small. I am going to remove that sign also from there. So, I am only going to keep ....., is that all right?

Student: (( ))

Is this all right? How do you define the sideslip angle beta? Beta is small, this v over u; u is the forward velocity and this small v is the side velocity. So, this is how you will define this small angle beta; beta is small here. And I want to find out what is the corresponding change in angle of attack and that change in angle of attack will be given by, V n by u, again small angle. Are these expressions clear to you? How many of you understand this, this? So, the majority, then I can move forward. Is this all right? In, in, approximation, when I am saying this dihedral angle is small; you can write this .... beta is defined like this.

So, side velocity and, ratio of the side velocity and the forward velocity, you know, and here also I have assumed, the, this beta to be small. So, this is also clear I believe. Delta alpha is, now this is your relative velocity. Now, what the airfoil section is seeing? So, it has a forward component and a vertical component, is not it? And I am going to measure this delta alpha. So, you have a relative wind coming from down that will change the angle of attack in a positive manner, is not it?

So, this delta alpha is going to be positive and see what this is. V n is .... and u is this small v over beta. I am using these two expressions, is this clear? So, delta alpha that we see is .... on the side of the wing which is going down. Now, for the same reason, the wind that you see on this section because of sideslip is going to introduce a change in angle of attack which is negative. So, minus delta alpha here, which is again .... this. So, change in angle of attack on this side is negative, and because of that, there is going to be a reduction in lift. So, L minus delta L on this side. So, this L is when you are flying level condition, this delta L is coming because of this effect. And that is going to give me a moment which is negative. So, a positive sideslip has given me a negative rolling moment only when I have wing dihedral and this dihedral is for positive dihedral. For negative dihedral, we use word called - anhedral, anhedral.

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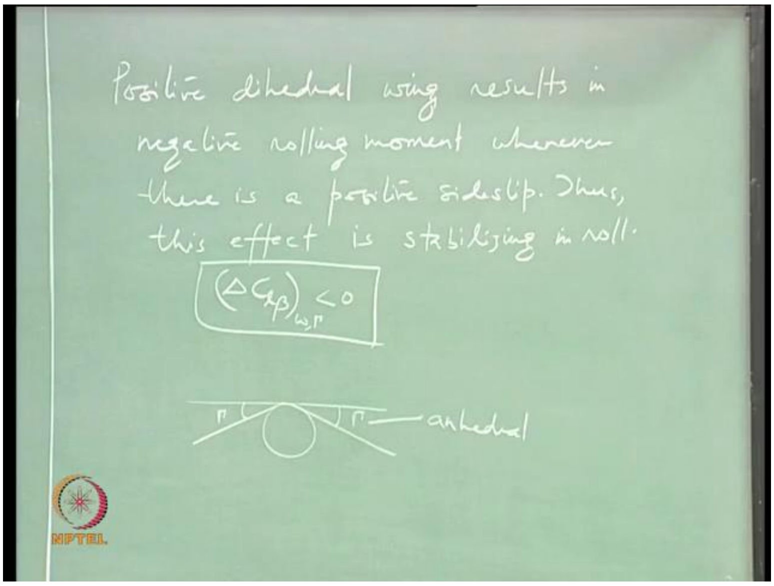

So, now, I do not need to tell you, you should figure this out that when the wing is having anhedral, you know, making an angle with this. So, anhedral is this. So, wings drooping down..... and this is going to have a destabilizing effect. This you should, both of these, you should be able to figure out yourself. What else? Anything else with the wing location on the, the way its mounted or the shape of the wing?

Student: (( )).

Twist is something which is primarily, twist is provided to actually change the angle of attack across the span.

Student: (( ))

I am not sure if that is going to, I mean, the primary function of that is to add to the roll stability. Anything else? How is this wing located on this aircraft?

Low wing

So, low wing is also going to have an effect on roll stability. It can have, right, and because of what? Because of the wing fuselage interference effect. So, flow is going to, you know, if the wing is low, flow is going to move on to this airplane from side in a different fashion as compared to when it is high and, that is, that can also add to this dihedral effect.

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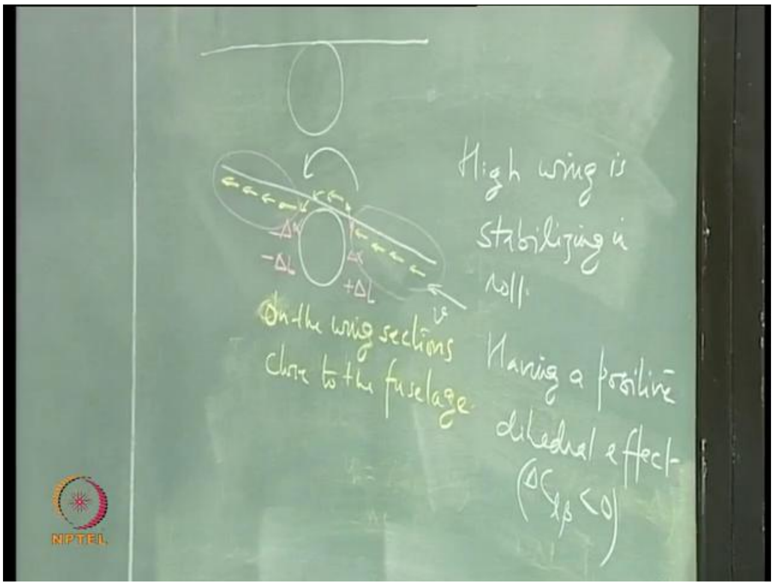

So, let us look at that. So, we, we, can call that as fuselage contribution, not really a wing contribution, but the fuselage contribution. So, I have a high wing here, and so, for you it should be taken like this; my X is into the board, and now, I see a roll upset like this and airplane starts side slipping. This is how you look at, you should look at it, and let us see what happens when there is a roll upset. So, now, ... and there is a velocity, wind coming from the side. Let us see how typically air will move when this is the situation.

What is happening? I have just drawn one stream line, right. Similarly you can draw other stream lines. What is happening here? Over this part, it is the same velocity, right, and there is, there is, no anhedral, it is a straight wing. There is no dihedral angle here, it is a straight wing, and now, it sees a side component of wind. So, over this part actually noting is happening; ... over this part, there is nothing happening. There will be a no imbalance of lift because of this part and this part what, what, is happening, yeah.

Student: (( ))

Now, if you look at the normal component of this velocity, parallel to this, its parallel to the wing.

Student: (( ))

Cutting across

Student: (( ))

Ahead of the wing.

Sir yes sir

Look at what is happening close to fuselage.

Student: (( ))

That will have a symmetric effect. So, that, that, will not give me actually a change in lift on both the sides. I am talking about how that does that give me a change in or a differential lift which will cause the roll. That is what we are discussing. We are not talking about what will happen to the flow which is going below the fuselage. I am only looking at what is happening close to the wing and the fuselage.

We are looking at flow asymmetry, right, on the two sides so that we get the differential left. So, this part and this part is not going to contribute, but close to the fuselage, there is a small change in angle of attack; you know, flow is turning here. So, it is, it is, having an a upward component which is adding to the angle of attack of the wing due to the fuselage, very close to the fuselage, is not it?

So, there is a delta alpha change, positive change in angle of attack very close to the fuselage and this positive change in angle of attack at, is at the wing, and that is going to give me a rise in lift, overall lift of the wing. For the same reason here, there is a negative change in angle of attack because flow is going downward. So, you get moment, which is, negative. So, a high wing configuration is a stabilizing configuration, stabilizing in roll. Whenever I get C l beta less than 0, I say it is a positive dihedral effect. So, let us also look at what happens when it is a low wing.

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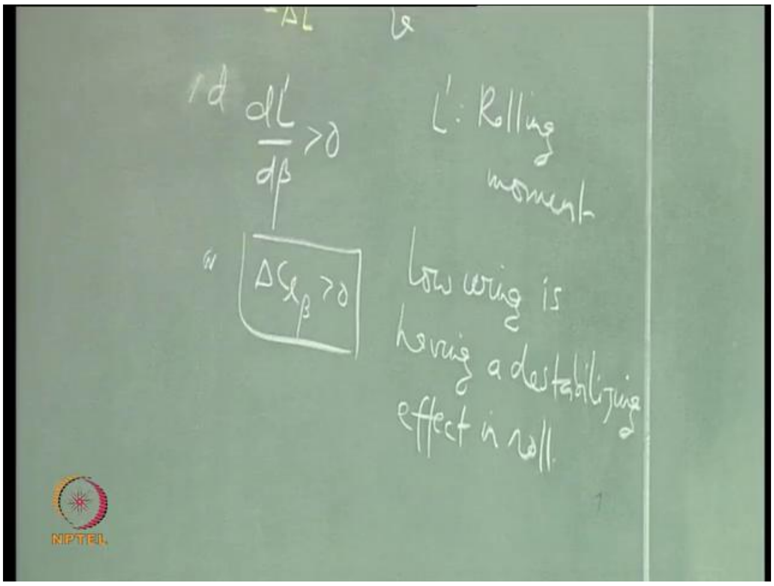

Same reason again now, right, here there is a decrease in angle of attack on this side, very close to the fuselage .... and the moment, is a positive roll moment because of this. So, it is going to roll further, right. .... If you look at a modern combat aircraft, you will see that wing is not only swept back, it is also drooping down, right. So, it is having anhedral angle. So, anhedral means you are having less C l beta, less or destabilizing dihedral effect and wing swept back and high wing. There are three combinations actually. Many combat aircraft you see, recent ones, you will see that, it is high wing configuration with a wing swept back and wing drooping down like this. So, it is a combination, so all three effects are there, and what did you expect actually? A fighter aircraft what should it have?

Student: (( )).

It should have less of stability in roll or in any other motion, right, and the stability there is provided by the control systems and those control systems are really strong, you know, very advanced control systems on modern combat aircraft. Is this clear? So, we can stop now. If you have any question, we can answer that.