Indian Institute of Technology Kanpur

National Programme on Technology Enhanced Learning (NPTEL)

Course Title
Introduction to Experiments in Flight

Lecture-14
Static: Directional Stability Test

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Good morning, so today we will be discussing the physics behind and the experiment which is titled as static lateral and directional stability tests.

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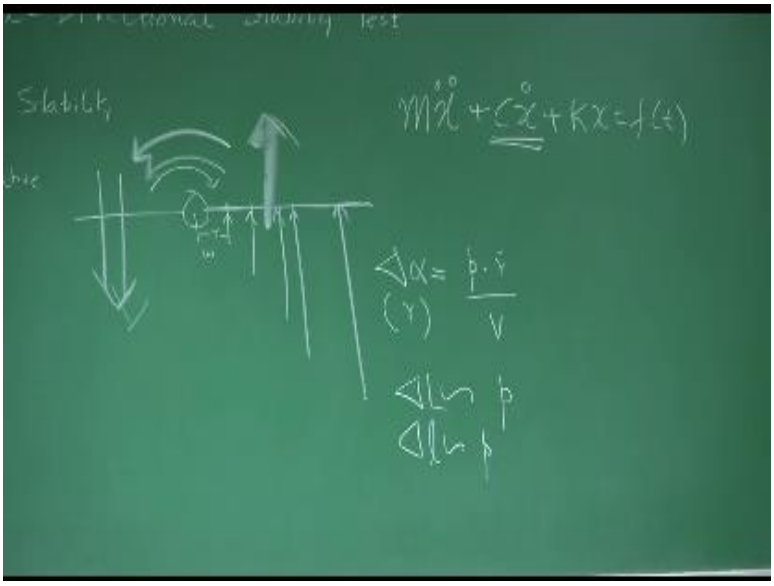

Static now I am not talking about dynamic, static the important thing is lateral directional stability test. If you see the key terms when I talk about static stability you all understand static stability means if a body is in equilibrium if we have, if there is a disturbance about the

equilibrium and if we have that tendency to come back to the initial equilibrium or initial tendency is the particular word right.

Then you say statically it is stabled right, so we can have it for a longitudinal case, suppose that is going at a angle of about 2º because of some upward test the angle becomes 3º that is it. So it should be able to automatically generate initial tendency or initial pitching moment which we will try to come back to that 2º.

If it has we say it is statically stable that is longitudinal case. For lateral case what is the lateral motion, if we are moving the aeroplane like this which one is atomic motion role right. So what is the understanding, when I talk about statics stability in lateral direction that means if there is a disturbance which changes the bank angle it should automatically generate a initial moment which we will try to bring it back.

Then only it is statically stable in lateral mode right, but how does it generate possibly this for longitudinal case if there is disturbance there is a original here which gives the moment right, but for lateral case we do not have any such which will be giving you that moment, so what is the mechanism what happens just watch it appropriately.

If the aeroplane is going like this and you guys are bang, the moment there is a bang disturbance what the aeroplane will do so it start slipping right. As it side slips since there is a vertical tail, vertical tail will experience the force in this direction, so that will give you a rolling moment. So for a positive beta it should generate a negative rolling moment so we say C and beta should be less than 0 for lateral static stability is this part clear.

So it is a CL beta should be less than 0 for lateral static stability okay. Now how does the active control on the role for example the airplane is going like this you actually want to role the airplane like this so you always say when light way going down that rolling moment is convection by it is positive right wing going down is positive left wing going down is negative right so suppose I indeed I want to change the back angle of the airplane from 0 to 5 degree so which control surface is should deflect is the one right.

So next position will come how much far you need defection of air around will produce a rolling movement right and that derivative is known as CL δa it is called aikran control derivative right okay now you can imagine the airplane is like this and it is rolling like this so what is happening if it roles like this the right wing watch out the right wing the right wing is going down that means right wing is seeing relatively air speed perpendicular to that as it moves like that is if draw it here if this airplane.

This wing goes down that mean at each point you could see there what will be the velocity at a distance r from the center if we rotating at ω let us say it will be ω r so that individual velocity it will see and that velocity component will go on increasing because r is increasing got it so there is a additional vertical velocity of where that we will see it means the right wing will see additional positive angle of attack got it so here right wing or whatever wing is going down here.

So it will experience a force in this direction got it simpler to it will happen in the opposite direction here so it will experience a in this direction what this will do this will try to counter whatever way you wanted to rotate it low assures now if you see here this whatever angle of attack is being induced at a distance r will be what will be whatever angular rate.

Let us say it is rotating with angular rate of ICP then into R/V whatever for odds do we as the approximately that will be the angle of attacks seen by the wing at a distance of correct so I could see that this force that delta L will be proportional to P correct, so the moment also will be rolling moment L will also be proportional to P.

No objection now this moment will be termed as what, as stiffness or a damping, damping because you are all know that for a second order type of modeling see this is CX^0 this is proportion to the rate and that C is the damping constant right, so you have a damping also in roll and that rolling movement is represented as CLP which you will know all very well, this is Dpb/2u this is P is not the visualized.

Whereby multiplying By B/2u and that you know from other lectures but you are in the other courses you have don, okay so this is a lateral part now if I come to the directional part so let me write this.

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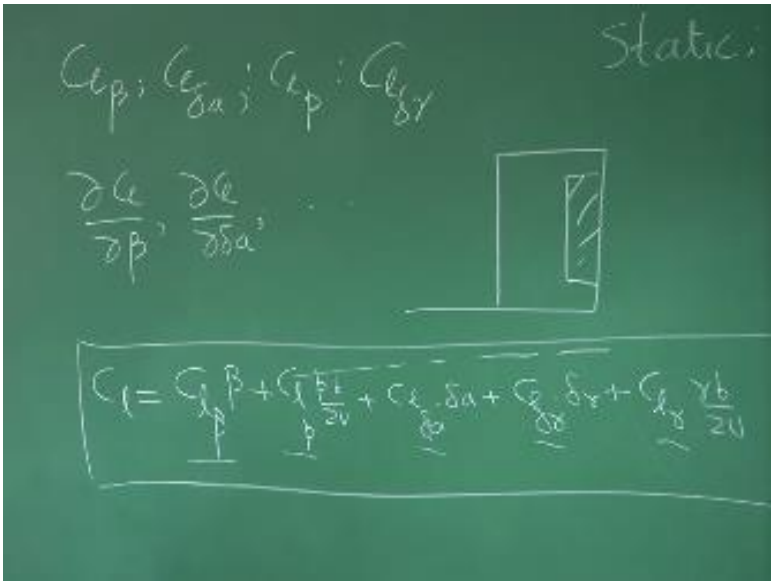

We have anti-filed CL beta provide require CL delta A with identified CLP also before I come to directional you should also understand that if this is the rader here rader here and let us say this is the centered line of the plane so if I defect the rader what it will do, suppose let us say this is the rader over the fuse large right, if I deflect like this what this will do, it will generate a force in this direction is moving in forward direction this force will do what.

One is it will give us UI moment and there is what, because this force is somewhere in center here and this is the distance from the centre line of the fuse line so this will also give a rolling movement so you can use a rader to generate rolling movement will denote this using notation CL delta R so what is the meaning of this derivatives. These are all partial derivative CL beta means DCL/D beta CL delta means these DCL/D delta A.

And that is to know why we are adding it like this because we are assuming that we are walking in a linear domain right and partial derivative means what, what is the meaning of DCL/Dβ what is the change in CL per unit change in β held the other constants that is the partial derivative so I can use this under the linear approximation CL I can expand the CLβ.β+CLp.pb/2u +CLδa.δa+CLδr.δr are you familiar with this expansion, sure.

Somebody may ask there could be rolling moment because of your 8 right, if that is your we considering then you have to write CLr.rb/2v okay, so this is how I expand the CL for mathematical treatment using CLβ, CLp, CLδ, CLδ and CLr and these derivatives are called arrow dynamic derivatives they are called non dimensional arrow dynamic derivatives, right and what is the use of this if I know the values of CLβ, CLp, CLδa all this non dimensional arrow dynamic derivatives then I can postulate the model of CL mathematically and if I know what is the value of β, what is the value of p, δa extra, extra I can estimate how much rolling moment coefficient the aero plane is explicity, right.

Then you can write the equations of motion extra, extra right. So it is important that we should know what are the, it is important to know what are the values of this we estimate this values through analytical method through wind current testing but finally we do flight test and see whether how accurate are those estimates and then we go for further analysis okay so this is the lateral but and we will do something to seer show much you can estimate through the experiment second but when I come for directional.

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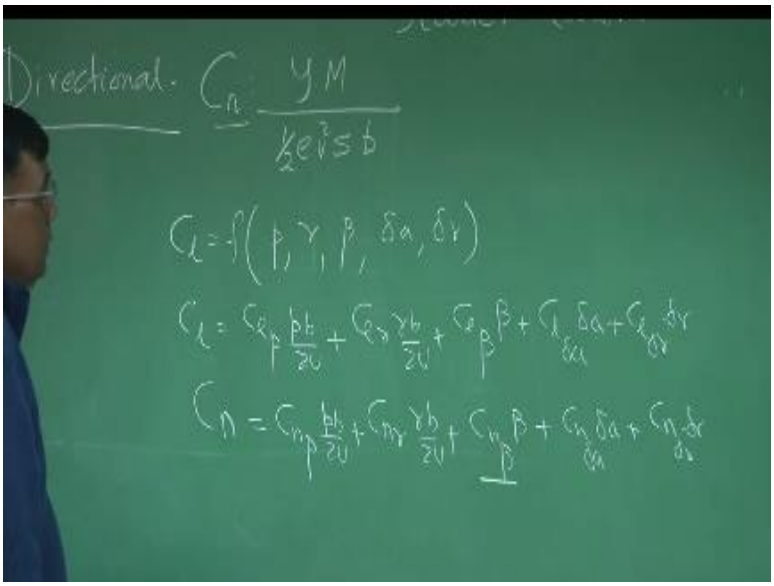

What is the directional case we long which there are less about y axis right and lateral is rolling about x axis and directional is about z axis do what is the convention for direction case right wing going back is possible so the young moment co efficient will be positive your right wing is going back okay so and Cn is the join moment co efficient and you all know how they are defined zy moment non dimensional light weight ½ $\rho v^2 s$ x b, b is the span it is a usual definition.

Now once we know the roll just say Cl where function of p r β δ a δ r since we note Cl = Clp x pb / 2u1 + Cl r x rb/ 2u _ CLβ x β + Cl δ a x δa + Cl δr x δr once we are confident about this now help me how do I explain Cl should be what same this is Cnp x p b / 2u + cn r x rb/ 2u I can write this no issues right, but let us see whether understand in particular this term okay then we take first Cnβ term what is Cnβ term anything you achieve in more the Cn β that is stability longitudinal phase what was the condition the Cn $\alpha < 0$ right.

So what is the condition for direction case to this table practically Cn β should be a greater than 0 right the condition is Cn $\beta > 0$ for directional static system stability, if I require, how do I regulize this, for example again, this is the vertical tail, this is the vertical tail and as we are doing like this, as we go the configuration is β=0, sometime the wind turbine like this, so there is

positive β now, okay. To make the β as 0, how do the turbine has to do, turn into the wind, so what will become β becomes 0, you should have the natural tendency, of the initial tendency to come back to equilibrium, you have that the altitude has to go back, so positive β, Cn should be positive, so Cnβ should be greater than 0.

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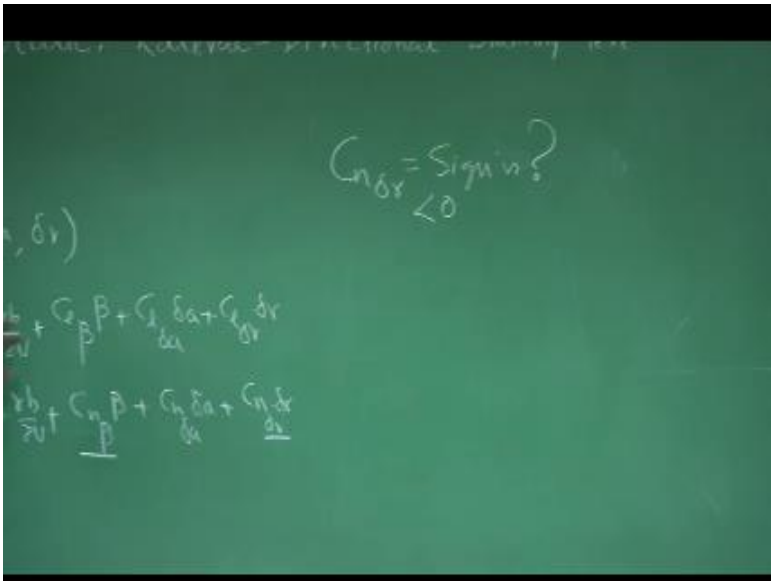

As you recall earlier lecture by plot Cn verses β is equal to something like this, both should be positive, this is δφ/ δβ, for directional case, for longitudinal case, it might be Cn versus α and both should be negative, right. We say Vcn, Vα will be like this, we have understood what we earlier we call it, than we understood earlier that Cnβ should be greater than 0. Now we can say Cn data, okay, what should be the final Cn data?

Okay what is Cn δ Cn δ is coming because of later deflection that is Cn δ is coming because of later deflection. Being non dimensional and again we come back here. Someone can define you can see the conversion looking for the top and will power radar will goes like this that is left is the positive radar reflection. If towards left the is the top it is the positive radar reflection. There are positive radar reflection if there is a positive radar reflection side force on the tail will act in which direction. Will positive will come towards this right.

Yes or no this will give a tale like movement so you in the front so what is the sign of linear turn right okay. So CN δ will be greater than 0. So other signs we will find out or you can refer the with these understanding now you will be conducting experiment to estimate these derivatives also we will try to see true factors what are the derivatives we can find out in the proximate manner or what are the relationship along the social readable.

Which should satisfy or the whatever the six doc module we follow conventionally we are doing it or we are doing right.

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