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

Lecture - 35
Introduction to Static stability

Good morning dear friends, you must be tired by now, we have completed take off, climb, cruise, landing. We have also discussed something about twin engine take off, twin engine landing. These are the primary things which we discussed in the performance course. Of course, it includes manoeuvre, we have also covered manoeuvre. However, you will appreciate during our discussion, we have assumed one thing very implicitly and that is, the aircraft is stable in flight.

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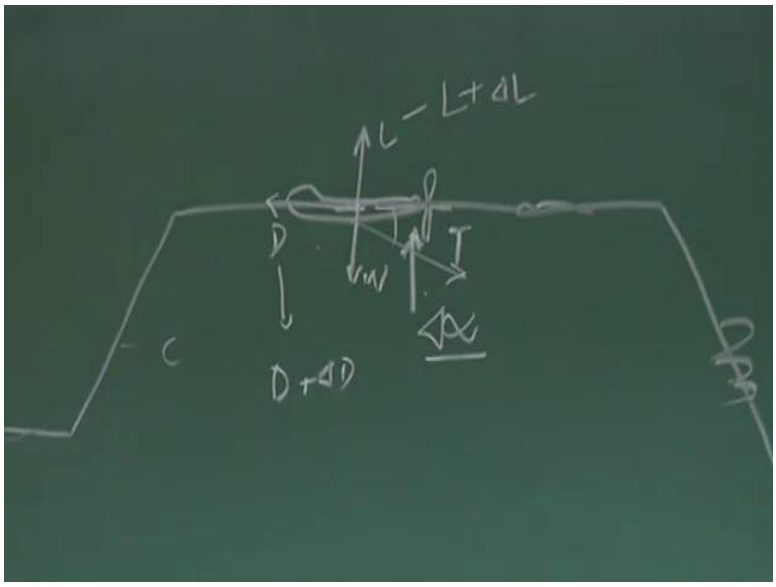

And when I say aircraft is stable, what do you mean by that, what do we mean by saying that aircraft is stable, when if I try to again post this problem, we have distinct phases of flight. By now, you know, this is takeoff; this is climb, cruise, landing, then manoeuvre. Now, let us take a case, when here I am cruising, where lift equal to weight and drag is balanced by thrust. We have been always telling that, this is unaccelerated flight, unaccelerated rectilinear flight.

One thing why net force is, a net force is 0, the summation of all the forces aerodynamic force, gravity force and thrust, they are balanced. So, say net acceleration is 0, also we

assume implicitly, net moment acting on it is 0. Now, in this part of our extended lecture, we will ask a question, suppose an airplane is flying like this and if there is a disturbance, disturbance means suppose it is going like this and there is a upward gust. What is upward gust will do? It will induce an angle of attack.

And the question now is, whether this airplane will be stable; that is whether the airplane will try to manage this disturbance, counter the disturbance or it will just become unstable and take off. So, we are basically trying to focus on the question, suppose it is going like this and there is an upward gust of wind, let me draw little more. So, that there is a clarity upward gust and this will naturally induce angle of attack, it will change in vertical component.

So, it will, it is going like this upward gust, so there is an additional angle of attack, but I want to fly on the particular angle of attack, which where decided by the condition lift equal to weight. So, we like to know, whether it possesses a stability or not; that is, once it is disturbed, whether it has initial tendency to come back to the equilibrium or not; that is come back to the condition of lift equal to weight, thrust equal to drag or not.

So, we will be asking two questions in very specific manner, one is initial tendency and second is within a finite time, whether it is coming back to equilibrium or not. So, what are the two questions will be asking, one is whether it has initial tendency to come back to the equilibrium or not. Second is in finite time, whether it is indeed coming back to the equilibrium or not, having tendency does not guarantee; that it will come back to the equilibrium.

What actually happens? You see that, the moment there is an upward gust, there is a disturbance, I will write delta alpha, small alpha. You are now talking about small angular disturbance. The moment is a small alpha, you will understand this lift will get modified to, lift will become L plus delta L; drag will become drag plus delta D. So, if it has the initial tendency to come back to equilibrium, then it has to do something to ensure that, there is an initial tendency to reduce or to make this delta L into 0. So, that is comeback to the lift and initial tendency to make delta D 0. So, it comes back to the equilibrium condition, where lift equal to weight, thrust equal to drag.

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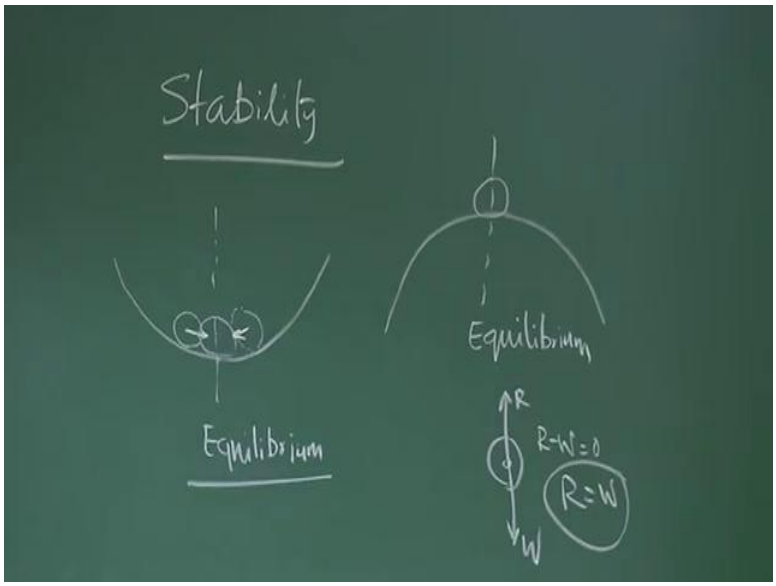

If I now take you back to class 11, 12, when you are talking about or learning the beginning about stability, which diagram comes to your mind, you close your eyes, I am sure all of you will be able to recall a very popular diagram. What does this diagram reminds you about or what really comes to your mind, if I see the dotted line, what is this dotted line, I say, this is the equilibrium line.

You could see here, net force acting on the body is 0, because one is weight of the body and then, there is a reaction from the surface, so they balance to each other. So, there is no acceleration along this vertical line, so we say it is at equilibrium. Similar situation is here, this is also at equilibrium. And if I again try to make it more explicit, this is the W weight and this is a reaction for a surface and R minus W equal to 0, R equal to W and that is, what is the consequence of it being in equilibrium.

And similarly, there are no forces in any other direction, which is unbalanced. But, now please understand, we want to know about stability. So, we want to see it is behaviour, we saw this, a disturbance. You may be having so many friends, few will be your special friends, among yourself we must be discussing, this man is very sensitive, this man becomes very violent, he or she encounters slight disturbance, don't you think so.

You might have seen one of your friends could be reacting very violently for small jokes and few of them will be, whatever you do, they do not react, they remain in their state of calm. So, those friends, who have this character of not getting disturbed or even, there is

a disturbance, they know how to manage their original state of mind still remain calm. We say there is a stable person, but there are person, you may slightly you can joke about them and they will just become violent, they may start fighting.

See, now our language, you say that man is unstable. Now, if I try to correlate this to this diagram to see whether this body is stable about this equilibrium or not, what I should do I should give some disturbance. So, if we give a disturbance like this, that is another displaced in bodies here and leave it, what will happen, immediately you see this body has initial tendency to come back to this equilibrium, because of this weight component and then, it over shoot.

Again, the moment is over shoot the equilibrium, immediately there is an initial tendency to come back to the equilibrium. To all the time, it has initial density to come back to the equilibrium as soon as it is disturbed from the equilibrium. So, any system which when disturbed from the equilibrium state, if it has a initial tendency to come back to the equilibrium, the catch what is initial tendency, then we say that system has static stability. Is this clear?

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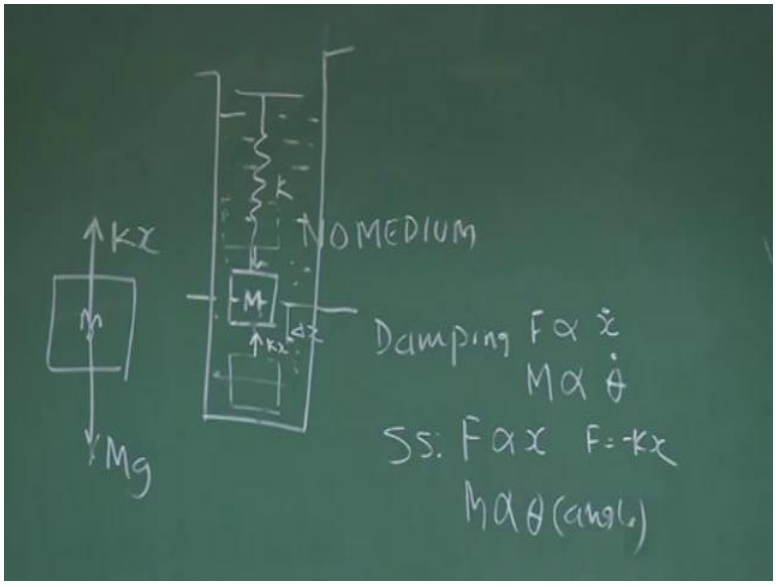

That is, think of another situation, which will be more illustrative, this is also from your daily life and you have seen from your text book, which is a mass spring system. And you know, if I hang it, there will be a slight extension and at this point, whatever force out of weight of this mass is balanced by the spring force in the opposite direction. So, if

I draw it, it will be, this is the mass, this is the M g acting like here and spring force, K into x, x is the displacement.

So, you know that K x is equal to M g and that is the equilibrium point and there were no other unbalanced or imbalanced forces. So, I called that is the equilibrium. Now, I want to check, whether this system is statically stable or not. So, what is the rule of thumb? You introduce a disturbance and realise it, let us see what happens. So, I introduce a disturbance, I stretch it to some distance, let us say delta x and then, realise it, stretch it, and realise it. What will happen? If you further assume that the spring is a linear spring and there are no medium here, no medium, so what will happen.

See the moment I stretch it from the equilibrium, this mass will be acted upon by an opposing force or the spring force in the opposite direction, so which will have an effect showing initial tendency of this body to again go back to the equilibrium. If my mass spring system is stretched through mass, then you see the moment it crosses the equilibrium, immediately a force will come K x to the opposite direction, which will have a tendency to take this mass to the equilibrium.

So, this system has got initial tendency to come back to equilibrium. So, I said this system is also statically stable like that system. But, what will happen here, if there is no medium, this will have an initial tendency, so this case, this will go and it will somewhere here and it will go on oscillating like this. As it goes there, again the moment crosses the equilibrium, there is a restoring force, it is start apply, the moment it crosses the equilibrium line.

By inertia, it goes to this point, then again it, so it goes on oscillating like this and now, you know that by definition of static stability, the moment is crosses the equilibrium, it has a force which tries to restore the equilibrium. So, this system is statically stable, but no about guarantees that will come back to the equilibrium, I am talking of a case, where there is no medium, so it will go on oscillating like this. So, there will be a conversion of potential energy and kinetic energy.

But, think of a situation, if I put this as a cylinder and put some oil or water, then what will happen. If I stretch it, since it is crossing the equilibrium from here, immediately K x, that is storing force will start acting, it has an initial tendency. So, it will exhibit static stability, try to go to the equilibrium. Now, because oil or water is there, it will start

oscillating in the manner that amplitude will go on reducing, because there is a lot of friction will be there with the water or oil or we will tell that this system will have some sort of damping force.

Damping force means, you know when the force is proportional to the rate of the motion displacement. For this discussion, it is good enough to know that, you need damping were the force to be proportional to displacement, rate of displacement x dot or if it is a movement, this proportional to the angular rate, Mr theta is angular rate. More importantly, damping is proportional to the rate of change of the state of the body, whose reference to the equilibrium.

And what we are talking about static stability, there the force that is for static stability, we are talking about the force proportional to the displacement, because you know F equal to minus K x or movement, if it is proportional to the angel. Theta I am using a notation as angel, theta dot is angular rate, mostly we will be talking about static stability in this part of this course. Let us try to ask ourselves, what we have discussed after this point.

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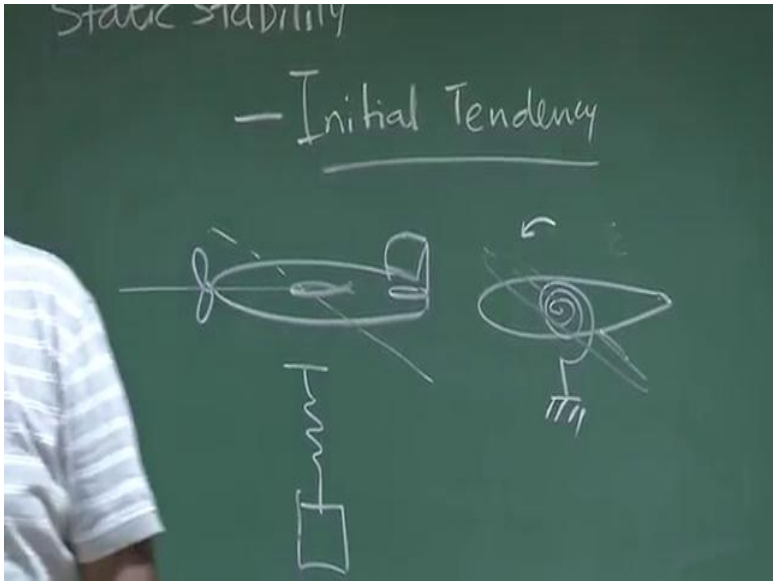

We have talked about static stability and the catch word is initial tendency to come back to equilibrium. Now, coming back to aircraft, when it come to aircraft, we are in this part of the lecture, perhaps in this course will we are focus towards angular stability. That is,

if air aircraft is like this, if the angle is disturbed, whether it has initial tendency to come back to the original angle or not.

That is, if the aircraft is here, flying like this, if I disturbed it, weather there will be a restoring moment, which will ensure that the moment, the aircraft crosses the equilibrium; that is restoring moment will come to ensure tendency to come back to the equilibrium to that part will be talking in terms of static stability for the aircraft. And if I try to model it, I will model it like this, this is the aircraft and I put a coil spring, for mastering jumper system, we model it like that.

Here you say, if I disturbed it, it has an initial tendency to come back to the equilibrium, here disturbance will be, I disturb it like this. The moment I disturb like this, this coiled, this spring will generate a nose down moment, which will ensure that, it has initial tendency to come back to this equilibrium. This is what will be discussing in this part of the lecture may be another 1 or 2 more lectures on that.

But, try to see this carefully, if there were no coil spring, then I will not get any restoring moment, but when aircraft is flying, there no spring like that, this tendency, this initial tendency through a moment has to be generated by interacting with the air and that is where the whole designer will be focusing on to make an aircraft statically stable.

So, he has to identify a part of the airplane, which should be responsible primarily to give that nose down moment, if the angel of a tag is increased or nose up moment, if angel of tag is decreased, to ensure there is a initial tendency. We are trying to search for this answer, what is that component.

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The question 1, where addressing static stability, question number 2, again, let us see this model, so question number 1 is, we are trying to address issue on static stability, finding that component of airplane, which will provide static stability. And question number 2 is very, very important related to controlling the aircraft; that is through this schematic model.

Suppose, there is a spring like which we have represented here, by now, we know that, there would not be any physical spring when they are planes are flying. The spring like action has to be generated by interacting with air and we have to identify which component will do that job, let us see that available. So, that is what is represented here. So, it will resist any change of the altitude of the airplane.

But, now tell me you are flying at a speed V and it has a corresponding C L, so that lift equal to it, now you want to fly at the higher speed still maintained lift equal to width. So, what you have to do, see their speed is higher, now you have to reduce the angle of a tag, because you have to reduce C L. Reverse way, suppose I am flying at a lower speed and C L is say 0.5. So, let us say angel of tag is 4 degrees, now you want to fly at a lower speed, so your C L has to be more, so you have to range the angel of a tag.

So, you have to ensure that depending upon speed, depending upon the altitude, you should be able to change the angel of a tag of the airplane or you can change the attitude of the airplane, but you have made the aircraft statically stable. So, any moment you

want to change it, it will say nothing doing, I will try to come back to the equilibrium, the real problem. So, what we have to do, if you have to really ensure that, the airplane now have a attitude like this and this spring's still there as a model other model. I am try to somewhere to generating the restoring force, because or restoring moment in this case, because this statically stable, it is discouraging any change.

So, if you now want to really fly at this angle, so you have to hold it. So, you have to generate force here, which will give a moment and this moment should be equal to the restoring moment, because of this spring. So, now at this attitude net moment again it will become 0. So, this become your another equilibrium and at this equilibrium, since and at this equilibrium, since this aircraft is stable, if there is a further disturbance, the aircraft will try to maintain this equilibrium.

So, what is the message is something statically stable, if you want to go to another condition. For example, from one angle of a tag to another angel of a tag, I have to ensure a moment, we should overcome the restoring tendency, because this is statically stable and this is what is called control problem. So, not only static stability now second question is, how do I control the aircraft, is the question clear, if something is very highly stable in our language, it is difficult to control.

Because, if it is highly stable, it will not like to change is from is own equilibrium, it will resist to go to another equilibrium, because highly stable. So, you have to apply the huge control moment to really take it up. So, there is a limit, how much stability or static stability want. So, that you can comfortably control the airplane and that is what is the biggest challenge for the designer. Because, finally, you understand this airplane will be shown by pilot to the human being.

Even, if you say nowadays so many actuator are there, control system is there, you have to also think of the actuators, they you should not over tags the actuator. You should not unless over load actuators; that is not a good design. So, will be now explicitly see, what do you mean by static stability, how do we give static stability to an aircraft like a spring back action type for ensuring stability. And also how do we control the aircraft, if these two things we have understand and if you understand their relationship, job is done.

Thank you.