Aircraft Stability and Control
Prof. A.K.Ghosh
Department of Aerospace Engineering
Indian Institute of Technology-Kanpur

Lecture-01
Introduction

Wish you all very, very happy New Year. We are on the tarmac of flight laboratory airship, and you could see that I am surrounded by so many aircraft, a similar aircraft you might have seen when you did the performance course, but it's a customary that I introduce all the aircraft to you because I do not know really how many students have done this course, first course, which is the prerequisite for second course that is on stability and control.

So, let me explain you whatever aircraft we have with the specific impetus on the components, which would be used for, very, very useful for stability and control understanding. This is Cessna 206 airplane. Here you could see the wing is again a high wing configuration and these are the struts to support the wing and in performance course you know what is this propeller is meant for, the propeller has a unique role to give power, extract power from the brake, but in performance also we decided that we understood that we were precise that wing is meant for giving lift, it has nothing to do with stability because you assumed that in performance analysis that aircraft is most statically and dynamically stable, okay.

So, in performance course, we are more bothered about what is the lift generated by the wing, what is the drag generated by all the components and we primarily aiming towards an L by D which is maximum right. Now but in this course, we will be talking about stability and control. So, our focus will suddenly go towards this portion, which is called horizontal tail. This is complete horizontal tail and this horizontal tail will be seen and we will understand now that this is primary responsible to give the longitudinal stability okay.

And we could see the part of this horizontal tail can move up and down and this is called elevator. It also has a trimmer which goes up and down in the opposite direction, and we will discuss about what is the trim tabs we will be doing.

Most important thing to understand is, this total area both side together is responsible to give both static and dynamic stability in the longitudinal plane and part of it which is called elevator is responsible to give the longitudinal control that is if I want to move the airplane up and down, I will be using this elevator okay.

Similarly, it has a trim tab, you see here I do not know whether it's visible to you or not, a small portion which is required to use at the end so that pilot can fly hands off, we will talk about that okay. Similarly, if you see here, there is a vertical tail which gives you stability in terms of directional and lateral motion, a part of this is called rudder, which can be moved either way to turn the airplane this way or that way. So, that is a rudder control. So, we have now elevator control, rudder control, and now we will go for the aileron.

So, what is the role of elevator? If I want to pitch like up and down like this I will be using elevator, so it is a elevator control. If we want to move the airplane, in this direction then this is the rudder okay, so rudder control. If we want to roll the airplane or bang the airplane like this, then this control is called aileron. So, if I move it down like this you could see as it goes forward, force will be acting upward and it will give a the left wing will go down. Similarly, if I put it like this other thing it will bang like this, so this is called aileron, we will be hang up on that side. So, you can move it together you can move it differentially, so this is called aileron or aileron control.

So, we have now three primary control, one is elevator for longitudinal control, rudder for directional control and aileron for roll control or lateral control. These are the primary three controls surfaces we will be using and when you define everything about stability, we will also try to see, how this control forces or moment generated gives the response vis-à-vis the stability characteristics of the airplane, okay. That will be the total part of this one of the module of this course, and I will be flying this Cessna 206 with my pilot and also give you live demonstration of what is the meaning of static stability or dynamic stability in flight.

This is our Hansa 3 aircraft, I will be walking down to Hansa 3 aircraft, which is our nation's flight, one of the finest light weight aircraft. You could see that if I compare Cessna 206 and Hansa 3 you could see this wing is a low wing a high wing configuration. So, from stability

control point of view, this thing will have implication, that is why I am stressing you please keep back of your mind Cessna 206, which I showed you just now as a high wing configuration, and this is a low wing configuration, okay.

Similarly, we have this is Sinus manufactured by Pipistrel, this is called motor glider. Motor glider because conventionally gliders were launched by cable winch combination, right, it is like flying a kite, but nowadays we find the gliders, gliders means high glide ratio, right so that they can later or longer duration, but need to take off. So, instead of cable what has been done, a small engine has been put.

So, that is used for takeoff, once you go to a particular altitude, you switch on the engine, there are gliders where the whole propeller will go inside, so that you have very good L by D configuration, and you fly and then when you find that it has come down to a lower altitude, you will start the engine and go to another altitude and fly. So, you have a very large endurance from that perspective.

This glider if you see also has high wing configuration from stability and control point of view, you please note down that there is a there must be some requirement to have high wing configuration, sometime low wing configuration and primarily from stability and control point of view sometime it could be because of maintenance point of view also. So, we will be talking about those things in detail, okay.

And since I am talking about the gliders, I have talked about Hansa 3, the speeds are less than around less than 0.3 Mach. You could see this is these are the aileron which by now you know and these are used to give a bang to the airplane and airplane can be rotated like this through this aileron, and this is also one of the control, like we have elevator, we have rudder and we have aileron, okay.

These are extremely important to understand because please understand in this course, we are not going to talk in terms of performance, we are going to talk in terms of stability and control. So, we will be really bother about how much moment each component gives what center of gravity

and whether that contributes to static stability or not, that is very important right. For example if we see this airplane, right and if you assume that let's we assume that CG somewhere here let's say here okay.

Let's say hypothetically. So, if this wing sees some angle of attack, its lift force I can represent at the quarter chord point, so this force will give a nose up moment, okay. As the angle of attack will increase this will give nose up moment that means with the increase of angle of attack, this wing will contribute towards the stability. It will further take the aircraft up. But if you see the tail since CG is there, if there is the change in angle of attack, then this will have a force in this direction, that will give a nose down moment. So, this will try to reduce the angle of attack if there is at all given through a distance, right.

So, this we will be talking it has a some sort of stabilizing effect, all those things we will be discussing and in general we find that any component which is located ahead of center of gravity will give destabilizing effect, any component, which is behind center of gravity will give stabilizing effect. So, this is in general we need to understand in an airplane and then we will be talking in detail and formulated and try to see how can I understand this characteristics and configure an airplane with adequate, well planned and designed stability characteristics right, that is the basic purpose of this course.

So, we are talking about subsonic or low speed aircraft. Now in this course as far as stability and control are concerned, we will not be restricting ourselves to low speeds, we will also go for high speeds. So, let me introduce one of our, another pride aircraft, I have the model for that aircraft and you all must be knowing this is Tejas, this is delta wing configuration. This is one of our pride, Tejas subsonic aircraft, and because it has delta wing, lot of sweep, okay.

And you could see control surfaces are led in a different than, different manner than what is in a conventional aircraft and performance when you're talking about sweep, we are talking in terms of critical Mach number primary to reduce the drag, however once the sweep for such high speed airplane is there, we need to discuss about what is the effect of speed on the stability, what is the

effect of variation of parameters with speed in terms of dynamic stability, then what is the sweep is going to do as far as stability and control consideration are there.

So, that is why this Tejas, which I am purposely showing you, I always love to show our own aircraft, unfortunately out of so many aircraft, only two are our own aircraft, I would like this sort of a course should held by youngsters that after 10, 15 years this tarmac is full of aircraft designed and manufactured by India only, okay.

With that aspirations, with that wishes in the New Year, I again say Happy New Year to all of you and let's start learning this course with a clear cut ambition in next 10, 15 years, this tarmac will be full of aircraft manufactured, built, designed by we, we the Indians. Thank you very much.

We are back again and Kanpur is a – it's basically a pleasant part of the winter session, you will find during this time people are wearing fancy dresses, warm clothes, lots of fog around, lots of disruption in flight, but there is tacid freshness among all the individual. With that freshness, we will start this course title Flight Stability and Control. And I will underline two words, one is stability and control.

In my first course on airplane performance, at the end we have discussed about these two terms, stability and control. In this course, will start from there but now we will be unfolding few salient things in an exhaustive manner to understand the true meaning of stability and control and how a designer will ensure the stability and control aspects of airplane.

So, that finally the pilot will fly, he is flying at ease do not forget whatever you decide with the flied vehicle, if it is a man flied vehicle we need to be bothered about the human being, the pilot, the passengers, if we are very, very careful about their comfort, if they are not comfortable then the vehicle is not well designed. To ensure that we take care of these issues, we need to know more detail about stability and control. Now the question come, how I am going to take this course forward?

See in introduction to airplane performance, we were talking about mostly response of the airplane in terms of translatory motion. So, you assume that yes we apply Newtonians law that is

force equal to M into acceleration of central mass. So, we simplify the whole description to a point mass approximation or point mass model, but in this course since we are talking about stability and control, we will be talking about totally how the airplane is going in a translatory motion.

We also like to talk about is rotational motion right, and the moment something rotation comes, your point mass approximation or point mass simplification will not work, because you know in rotation, it is not the total mass, it is the mass distribution or we say it is the moment of inertia that plays a role, okay.

At the same time, we will be also bothered about what is the moment coming on the airplane at a given flight conditions. Since these things we have touched upon in last lecture, so you will find that few of the last lectures will be repeated, so that there is a continuity.

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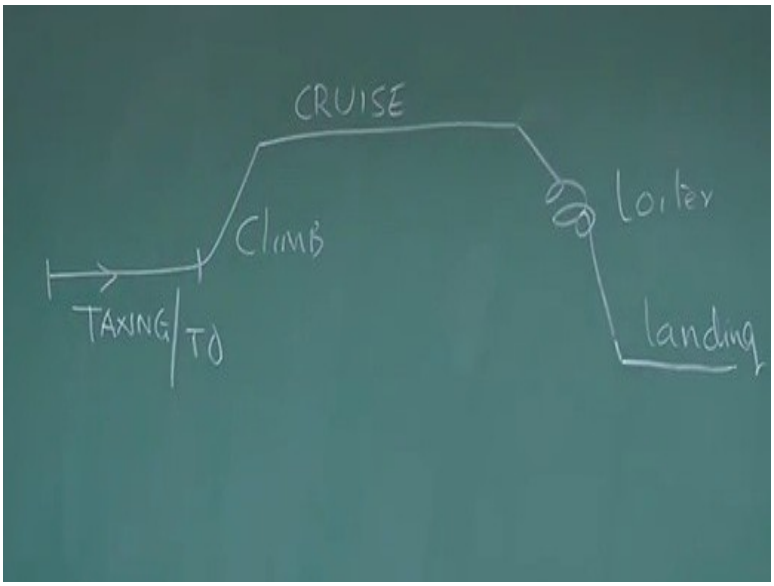

Why that is important please understand after all we have learned by now some important phases of airplane motion and this part was taxing and takeoff.

This was climb, this was cruise or it could be accelerated flight, this is loiter, here it is landing. The question we ask to our self is if I want to climb, I need to generate particular amount of lift and once I generate particular amount of lift how do I generate that, that is what are the control surface I deflect and that part is taken care in the topic of control.

And the next question comes to our mind, if I deflect the control, it's a elevator whether the airplane is going to be stable or not or to be more precise, more correct, how this control deflection will generate response to an aircraft which is stable. Same control input will have a different type of response if the aircraft is not stable right. So, we need to build a relationship between stability and control in a very tacit manner and we should understand exactly what it means, what this relation is going to give us.

For example, so far we have assumed that for a cruise, we have to give some elevator deflection, but question is if I give a elevator deflection does the airplane immediately comes to the angle of attack or there are transience, and if you want to really design an airplane better you should know clearly about the transience response.

So, that is the part of a stability which is we referred to as dynamic stability, okay. So, in stability we have static and dynamic, both, okay. And by control here we will be primarily meaning this elevator control, the aileron, it could be rudder, there could be canard like this. So, we will try to understand each of this and try to see how stability and control are connected, how they are connected and why we are interested in how they are connected, because finally we know through their relationship what is the handling qualities of the airplane, because we are more bothered about the pilot and the passenger, okay.

So, that will be the whole direction road map for this course and we will be taking back to our earlier lectures may be around eight to 10 where we will start the introduction the way we used in that time, so that there is continuity, okay.

I will use Mann Ki Baat too frequently in the first 15 lectures, so as to make ensure that we are seamlessly going into direction where the continuity is there, okay. Let us go back to this term stability and we agreed that we will try to study it through static and dynamic stability, okay. What is static stability?

You recall, you are clear by now through our first course that every system, which is in equilibrium or any system which is in equilibrium and if it is disturbed above the equilibrium and if it has initial tendency to come back to that equilibrium we say the body is in static equilibrium or the body is statically stable, we will say the body is statically stable that is precisely more correct, appropriate. Just to recall remember, we have given this example.

I draw this line, this is a ball. Now what happens, it's must, excite your mind to go back to your class 10^{th}, 11^{th} where these diagrams were frequently used, let's say this body is in equilibrium, this dotted line show the equilibrium position. What is the meaning of the equilibrium, the net force and its moments are zero, right. The similar case if I come through aircraft….

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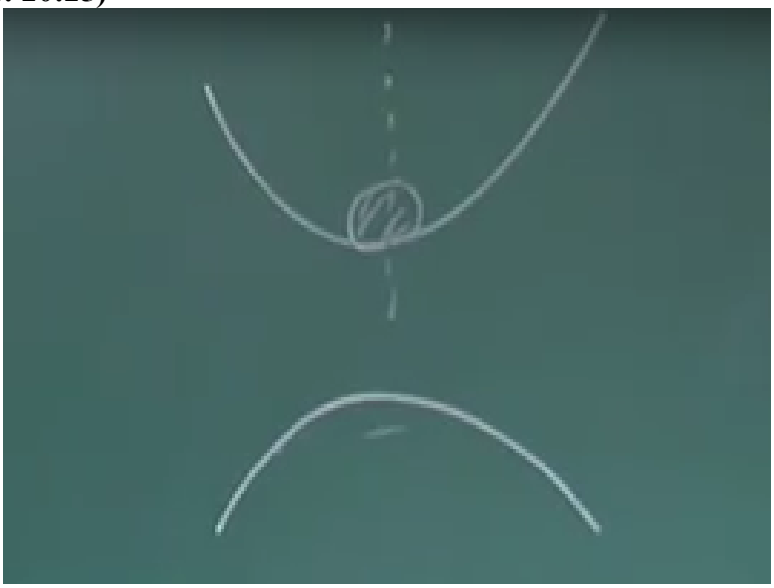

…one of the equilibrium state is on the airplane is in cruise okay, where lift = weight, thrust = drag, net force is 0, net moment is 0, so cruise is also in equilibrium state. Now what is the question you are going to address, you are going to address whether this body at this equilibrium is statically stable or not, meaning thereby if I come again from here to here, if I have the same question.

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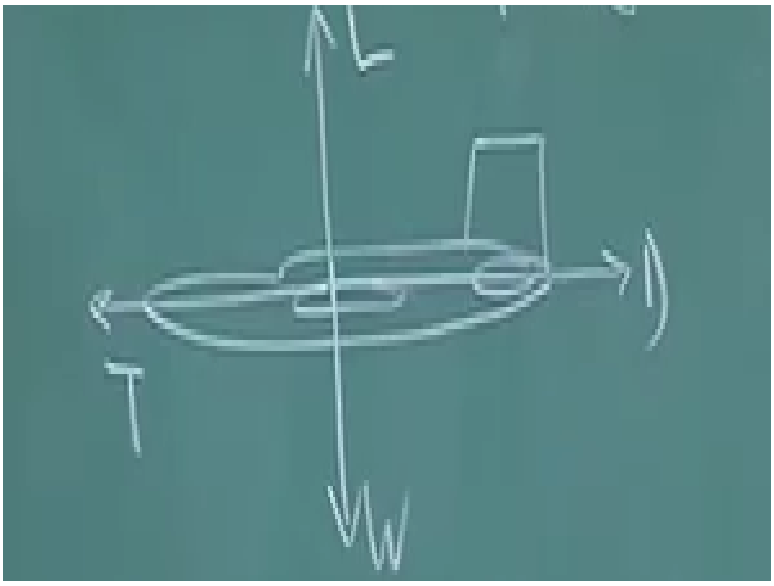

Yes this body is in equilibrium here because net force is 0, whether this body is in body statically stable or not, how do I check? I say I give a small disturbance. The moment I disturb it from the equilibrium state, you see there is a component of weight will be there which would try to take it back to the equilibrium state. So, it has initial tendency to take the body toward the equilibrium state, the catch word is initial tendency. So, we say this body is statically stable more or statically stable condition.

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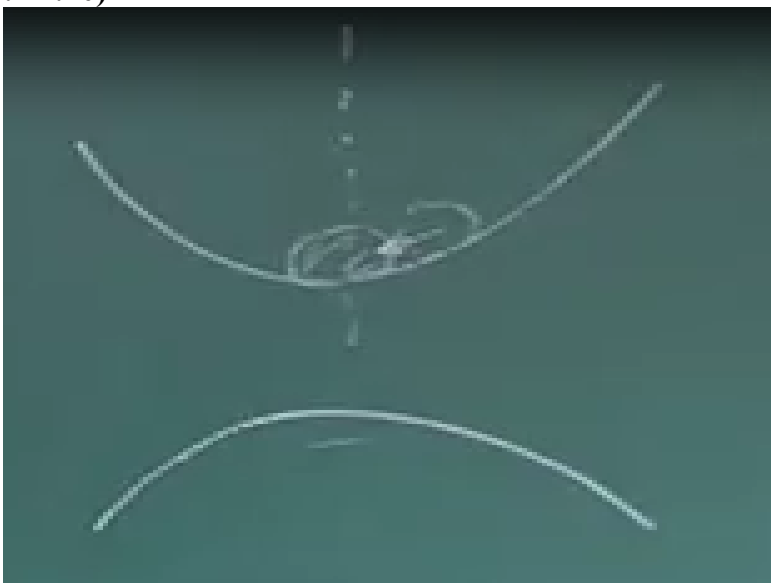

In contrast if you say this body here, if I displace it by small amount now the component of weight will take it away from the equilibrium state, so we say, it does not have any initial tendency to come back to equilibrium. So, this is statically unstable, this is clear. Similarly with

this understanding if I try to know whether this gentleman or friend aircraft is statically stable or not, what we have to do, we have to first see what is the equilibrium state because static stability, we are talking with reference to the equilibrium, a disturbance about the equilibrium.

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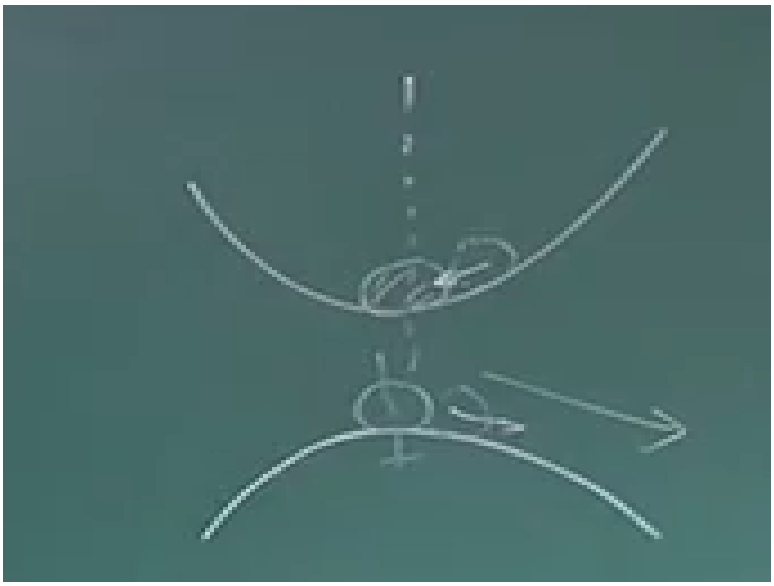

So, first we find out equilibrium state, here I know the cruise where lift = weight, thrust = drag and moments are automatically balanced. This is typically a equilibrium state and now what I, if I want to check whether this is static stability or not satisfying static stability condition or not what I have to do, I have to give it some disturbance, as Delta Alpha, angle of attack, will be an upward gust coming like this and if it immediately generates a moment nose down that is to nullify…

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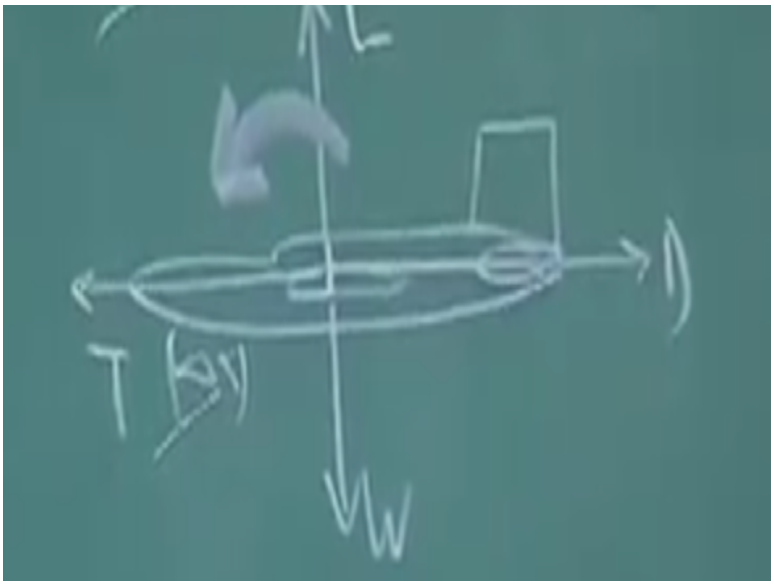

…that Delta Alpha because initially the equilibrium state was let's say Alpha 2 degree and because of the disturbance let's say angle of attack became 3 degrees, so static stability demands that it should automatically here it is nose down moment, so that it has initial tendency to come back to 2 degree of Alpha, is it clear? Okay. If it has, it is statically stable, if it is does not have, it is statically unstable. At this point please understand it is not that we cannot control statically unstable airplane.

The catch statement is unstable does not mean uncontrollable, you can do an experiment, you can take a stick on your finger. Imagine a stick is there that's statically unstable, but you can control it, okay. In fact your most of our fighter airplane they are marginally stable or marginally unstable in terms of static stability sense. That is why they are highly maneuverable, okay. Once you do that static stability we will be spending lot of time on dynamic stability, that is okay, fine.

We understand that suppose I take a mass spring system right and assume that this whole mass spring system is isolated from the environment, and the spring is linear, there is no air, completely vacuum you know very well here some point this is the equilibrium. That is here if I draw the free body diagram I will find MG acting here and here the force because of extension case and they are balanced so it is at equilibrium.

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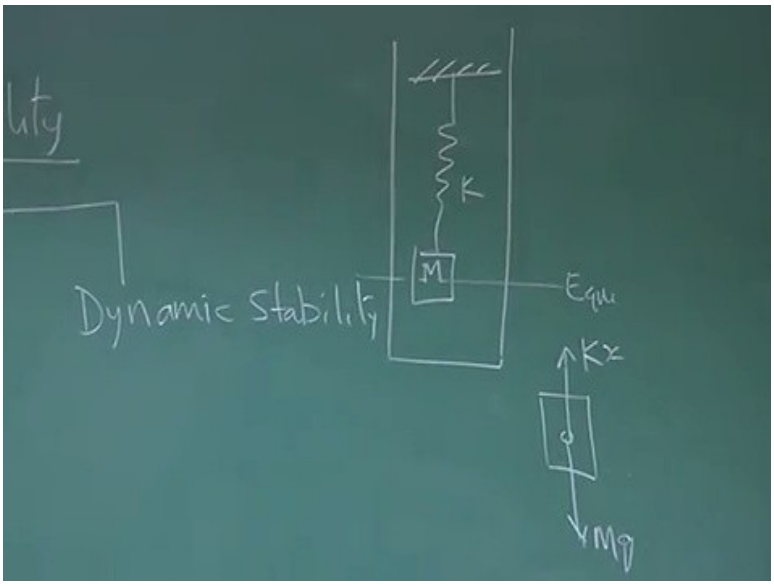

Now if I want to check whether this body is statically stable or not, what I have to do, let's say I stretch it, I stretch it here to some length and then release it. So, what will happen the moment I release it because there will be a force KX acting opposite so it will start moving towards the equilibrium, it will overshoot. Again as it overshoots, the force will be acting downward, so it will again take it like this. So, it will go on oscillating like this and since there are no air no medium a spring is linear it will keep on oscillating like this.

So, do you call it statically stable or not, let us check from the equilibrium, where I deflected the body, it has tendency to come back to the equilibrium, so it has initial tendency to come back to equilibrium but because of inertia it goes up and again as it goes away from the equilibrium, it has the tendency to come back to this, so it goes on doing like this.

So, it does have static stability but does that mean it has dynamic stability, if you want to know what is dynamic stability, we have to put another condition there, not only the initial tendency to come back to equilibrium but also its amplitude should became fine air time that is it should go on doing like this and finally it should come here to equilibrium. So, this will not happen here, this is the case where it is statically stable but dynamically not stable.

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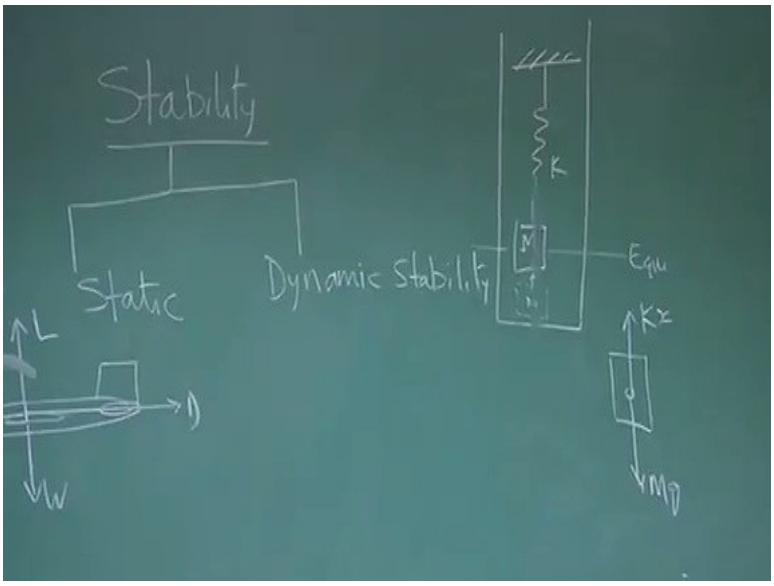

Now think of a situation, if I put some water or oil in to this, what will happen? It will have this and amplitude will come down, so there is a damping. And for dynamic stability not only the initial tendency, it should also its amplitude also should become fine air time, so there will be concept of stiffness, there will be a concept of damping when you are talking about dynamic stability, right.

And this damping decides the passenger comfort or the handling qualities of the pilot. So, we see how they get connected, okay. So, we will be talking more and more on the dynamic stability in this course. Two part of static stability I have covered in the last course.

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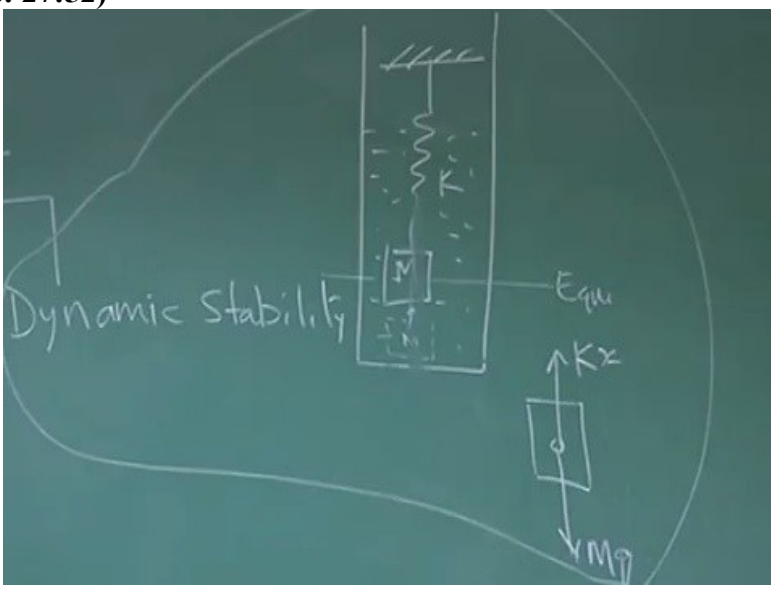

Because there will be there will be many students who will be joining these course who may not have the first course exposure, even if they have if anybody want time so it's my duty to see we revisit again the important point and we will make you prepared ready to cruise or accelerate into the stability aspects including dynamic stability aspects. This is one thing. Second would be the response. That is if we see, let me erase this part. Suppose this is the airplane and this is the tail and this is the elevator, the wing and there is the rudder and there is an engine.

Let's say it's flying at some speed. We have seen whether it is statically stable or not, dynamically stable or not once we have done that, then we will try to know if I give unit deflection of elevator, how the angle of attack is building, right. Whether it is building something like this or building something like this or building something like this.

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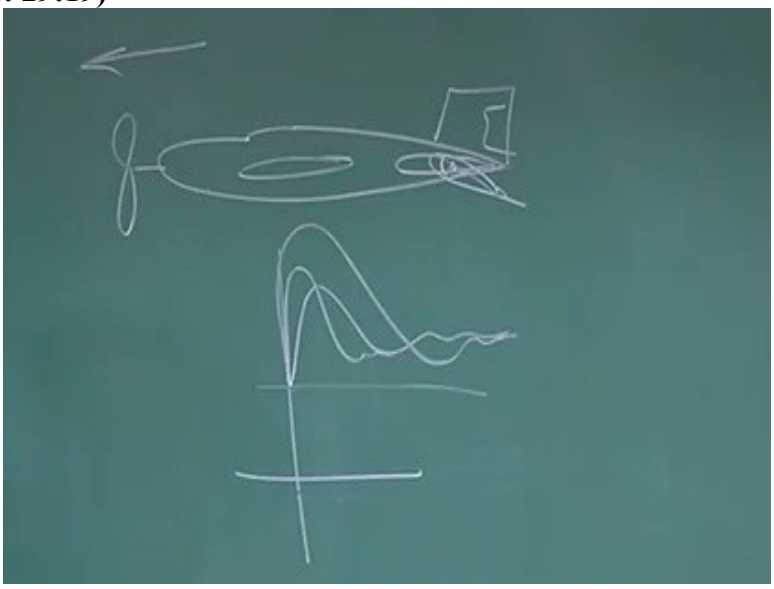

So, in this 3 diagram, I have shown that they are all finally coming to some angle, let's say Alpha star but these 3 graphs also tells you that transience of going to that Alpha star is different. So, we have to clearly see, how do I calculate Alpha star that the response for a deflection of elevator in time domain, right, with time how it is happening. So, this is also extremely important topic that we will be discussing in this course. So, you could see that initial few eight to 10 lectures will be exactly what we have done.

In our last course, in fact some same video clips will be shown to you. I will be coming again after two or three lectures, as a Mann Ki Baat session and try to discuss few things more because

there will be many students who are who might not done airplane performance, even if they have done they have missed few concepts.

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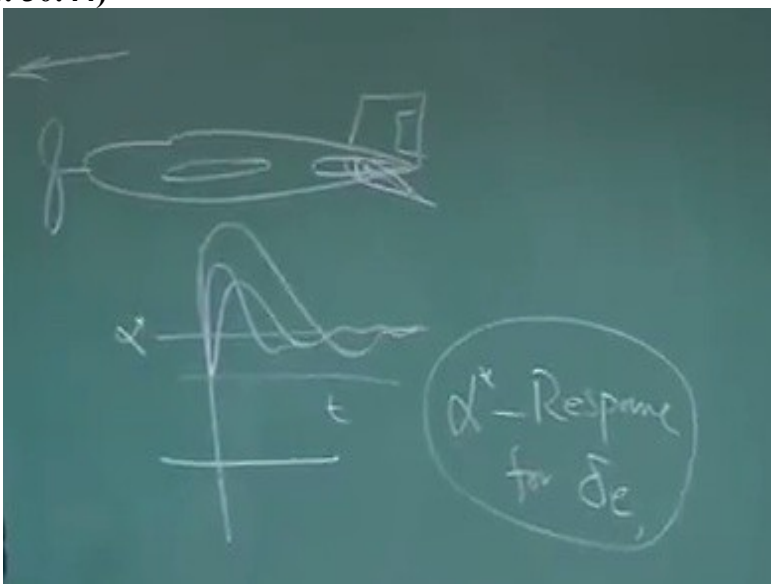

But once we build a solid base, then we go systematically into static stability, what are the control required, dynamic stability part, response and how do I design the handling qualities. So, this will cover the whole course, which is it is a huge course, please understand. It will require little bit of effort from your side, we have to sit with pen and pencil and solve some equations which are again are not more than a first-degree equation may be some time, I will be using Laplace transform which I will explain, don't get panic about all these names. I will ensure and take guarantee that it will be as simple as you are a student of class 12^{th} or the most first year.

So, with that positive note we will take up this course, I hope you will enjoy and this time for a change you will be allowed to interact with me directly on question sessions through my another email ID I will be creating or I would like to interact with you directly along with the TS right, so that helps sometimes there is a lag which I learned from last course. Thank you.