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

Lecture – 44
Control: δe Required

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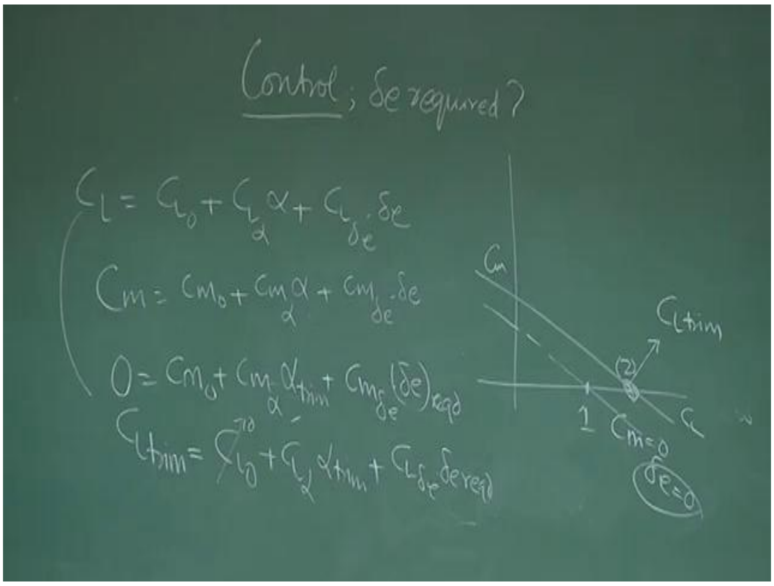

You are now ready for answering the question after all this warm-up. Because, C L is equal to C L naught plus C L alpha into alpha plus C L delta e into delta e. Similarly, C m you know C m naught plus C m alpha into alpha plus C m delta e into delta e. Now, think of if I am trying to go to a trim, some point here. What is the condition here? Condition is this point corresponds to C L trim and also this point where C m equal to 0.

I am asking, suppose the airplane initially was flying here at this point, I am ask a question I want to fly at point 2, how much elevator deflection I will give and which direction, let say this was the initial point where delta requirement was 0. So, everything C m naught came because of the airplane design, so that is the question we are asking now from one C L to, I am going to a C L corresponding to point 2, then what is the elevator deflection I should give.

Final question is, is it at all flying or not. So, since I know second point or one first point, it has to be in trim that is, C m has to be 0. So, I writes 0 is equal to C m naught plus C m alpha into alpha trim plus C m delta e into delta e required. I had if is it C L, the C L will become now C L trim, this equal to C L naught plus C L alpha into alpha trim plus C L delta e into delta e required. For simplicity, let us assume that this value is 0, you can always view this value and write the expression, that is not a big problem.

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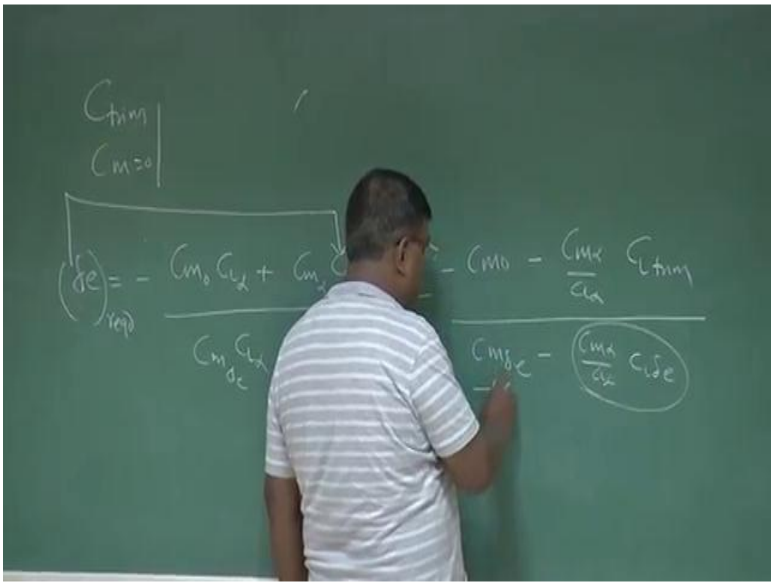

So, using the C L trim equation and C m equal to 0, I can write delta e equal to minus C m naught C L alpha plus C m alpha C L trim divided by C m delta e C L alpha minus C m alpha C L delta e. This is what? Do not forget, this is delta e required, for what, delta e required for a particular C L trim. What is the information required? I need to know C m naught of the airplane, I need to know C L alpha of the airplane, C m delta of the airplane and C L delta of the airplane.

If I know, then immediately this expression will tell me if I want to fly at C L trim 0.6, what is the delta e required, that is what is our aim. But, now I am trying to give some designer field to this expression, so we will do some manipulation, some approximation. Let us see what we do, we divide numerator and denominator by C L alpha, then what will have, we will have minus C m naught minus C m alpha by C L alpha into C L trim divided by C m delta e minus C m alpha by C L alpha into C L delta e.

We do further approximation, that this term you see actually when you put number, this term is less than this. This is typically C m delta will be of order of minus 1, C m alpha by C L alpha is order of 6, 5 or 6, the C L delta are 0.6, 0.7 to indeed this will be less or compare to C m delta e. This is not a bad idea to neglect this to get a designer perspective. So, if I neglect this term you compare to C m delta e, then I get a neater term which a designer can get a better feel.

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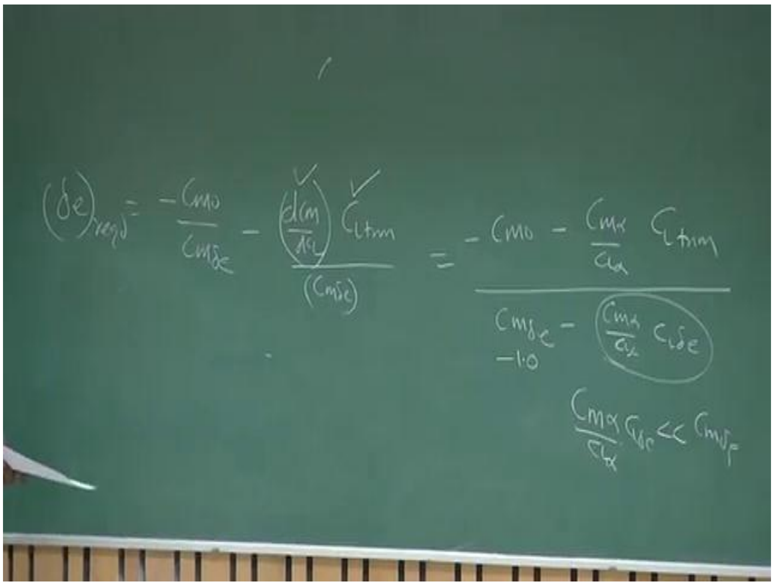

So, I have delta e required equal to minus C m naught by C m delta e minus d C m by d C L C m alpha by C L alpha, if you are expert now. Is it clear? This is C m naught. What you have done? This C m alpha by C L alpha into C L delta e lesser than, less than C m delta e, so this has gone, so minus C m naught by C m delta e is here, then C m alpha by C L alpha d C m by d C L this is here, C L trim is here C m delta is here. What is the meaning? The meaning is tell me what C L you want to trim, then initially this will give delta required. But, then you know if delta required is coming 50 degrees, 45 degrees, you say sorry mam I cannot. Trim your aircraft like that C L we got delta is coming very, very high, so there is a limit that will be set by this.

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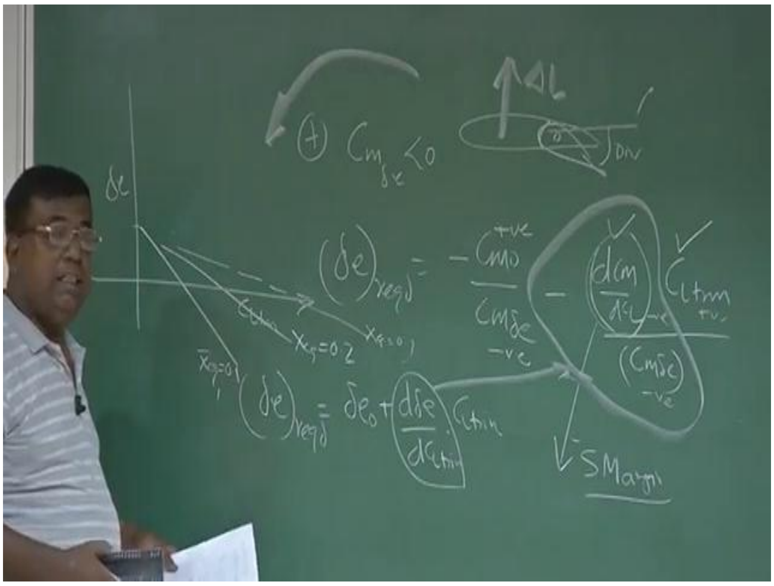

For, what is this d C m by d C L? This is nothing but, static margin, remember and say this is negative, this d C m by d C L is what, this is minus static margin. So, this is negative and C m naught is positive, let understand this C m naught is positive, C m delta is negative. Now, this is a tail, this is a elevator, c g somehow here and delta if positive we have defined as down which act as a node, this delta down will give additional lift here, which will give nose down moment about c g.

So, we say C m delta e is less than 0 it is negative, for a positive delta e it is the negative C m. So, this is negative, this is positive, so this is whole term is positive, d C m by d C L is negative for a statically stable airplane. So, I write negative, this is also negative, this is positive, for this part is negative. So, I write it like this, I write delta e required equal to delta e naught plus d delta e by d C L trim into C L trim and what is d delta e by d C L trim this is nothing but, whole of this expression including minus sign that is, minus d C m by d C L by C m delta e.

For now, if I plot delta e versus C L trim what type of graph I will get, I will get some delta e naught and the slope will be negative, d delta e by d C L trim you could see is nothing but, minus d C m by d C L by C m delta e, C m delta e is negative, this is negative, then it will be positive, this minus sign is there. So, this whole this term which is d delta e by d C L trim is negative. So, I will get some line like this and that will be corresponding to a particular c g location.

Why, because d C m by d C L is here, which will change with c g location, but d C m by d C L is minus, static margin and as c g goes aft the static margin reduces. So, this becomes lesser and lesser negative. So, as I am going back I am taking c g let say earlier it was 0.1 edge 0.1, now 0.2 which I am taking it back. So, this c g equal to 0.3. What is the message you are getting? That, if I am trying to trim an aircraft at different C L, delta requirement will go on increasing as static stabilities increase, let us understand this point.

Good morning friends, we are at a very important junction now, we have understood a little bit about statist stability. You have understood what is the trim point, we have understood what is static margin and we have also understood what is the effect of c g in terms of stability, I would affect stability and more importantly you have also understood, how do I get the neutral point of the airplane.

Now, the question is as repeatedly I am in telling if an aircraft is highly statically stable, then you need to put lot of effort to take it from one trim to another trim that is, if it is flying at a particular angle of a tack or particular C L, if I want to change the C L that is say, I want to increase the C L and lower the velocity, so that still lift equal to weight. If I want to increase the C L, I will have to increase the angle of attack and I have to give a nose of moment and that could be done through elevator by putting the elevator up.

And we are trying to find out how much elevator up I have to give to change C L from one C L trim to another C L trim and it goes without saying you understand, if an aircrafts is highly stable, then we have to put lot of effort to change it is equilibrium from one trim to another trim. That means, you have to give more effort, more effort means it has to come through the elevator. So, we will try to establish this and extract whatever a designer should have in this mind, where he is designing an aircraft. So, if I simply revise few important things which you need to understand clearly before I try to synthesis all these concepts.

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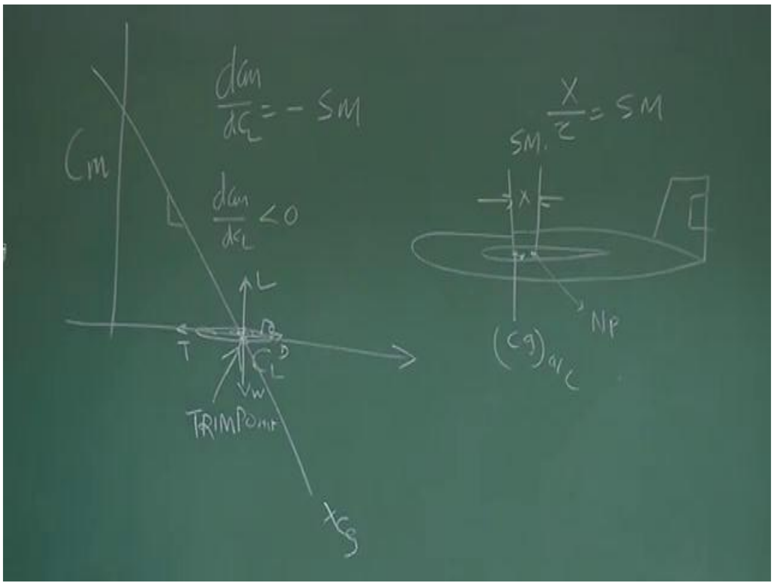

One is, I have written and drawing this graph C m and this C m is pitching moment coefficient about center of gravity of the airplane, this is C L. And we know by now, that C L alpha is a question of a scale factor and if I say the aircraft is statically stable; that means, then d C m by d C L this slope is negative about the equilibrium point or the dream point. You will try to visualize, it actually means the aircraft is let say cruse is our equilibrium point, this aircraft is here, where lift is equal to weight, thrust is equal to drag.

And this is one equilibrium and one have drawn C m versus C L the slope is nothing but, d C m by d C L. The slope is nothing but, minus static margin and static margin you have understood to be the distance between neutral point and center of gravity of the airplane that is, if this is the c g of the airplane and if this is the neutral point, I write N P. Then, this distance is the static margin and which is non dimensionalized with respect to the mean error dynamic chord.

Static margin is expressed in a non dimensional form and you know that, who in one dimensionalize static margin by being error dynamic chord that is, if this distance physically is x, then x by c bar is static margin. What do you also understand that, this static margin is a unique number for a given configuration for a particular c g location. You can understand from here, if this is the c g of the aircraft and the aircraft is same.

But, for c g if I change by distributing the internal components, then as c g moves towards neutral point this separation reduces.

So, their slope of the line also will reduce, it will become more flatter and also physically understand, if the separation reduces, so there is a reduction in the static stability. And other point, very clearly when c g concise with the neutral point it is neutrally stable, so there is no restoring moment, this is you understand. Now, what is the question you are going to ask ourselves. Now, you are focusing on the control.

Meaning thereby, suppose the airplane was flying here, now the airplane wants to fly here, let say point 2. How much elevator deflection should I give to ensure that the airplane is now flying at trim that is, at lift equal to weight and thrust equal to drag.

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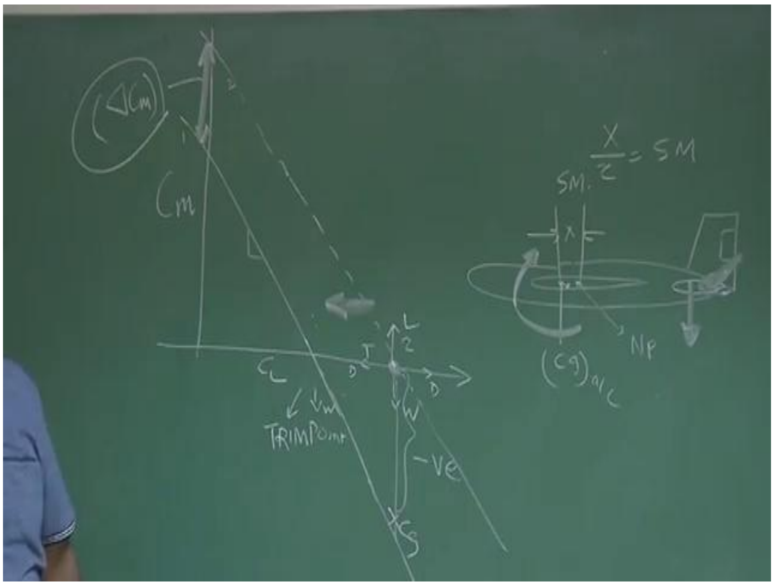

Lift equal to weight, thrust equal to drag, but at different C L that you know. Since this is statically stable airplane, the moment you try to change the equilibrium from here to here, because it is statically stable it will generate a initial tendency to come back to the original equilibrium. And from the graph how do I lead that, if the C L new C L is here, then the airplane will generate negative pitching moment, negative pitching moment means the angle of attack will attain the tendency to come down and that is what you say it has a tendency to come back to the equilibrium.

So, it is the statically stable it is very well known characteristic of a statically stable system. But, what is our aim? Our aim is no, no we will not allow it to come back, we want to hold it here. So, if we want to hold it here, what I have to do, who is trying to take it back, this negative moment. So, if I want to hold this here means, I have to nullify this negative moment. So, how can I nullify this negative moment? So, there is an elevator here.

So, I have to do what, I have to give generate positive pitching moment and how can I generate positive pitching moment, I will deflect the elevator up and because of deflection of elevator there will be a force generated at the Harrogate until. The downward direction and this will give a nose of moment and I should be smart enough to neat appropriate deflection. So, that this moment and the restoring moment they cancel and again it becomes a trim point that is C m is 0.

And since stability of the aircraft I will have not change, you have not change the configuration of the airplane we have cape the c g same, we have not change any shape of the outer surface of the wean, tail, vertical tail of ((Refer Time: 17:01)) the same airplane. So, these two lines will be parallel, because these two lines are present static stability are this two lines represents what is the neutral point and c g same for both the airplane for both the configurations of flight, same airplane I am taking from one C L to another C L.

So, these two lines are going to parallel and this is the new trim point were the airplane will be flying at thrust equal to drag, lift equal to width or is a cruise. So, what is happen, what is the chatter of duty for the elevator in terms of some number, you see you nothing as chained between this line one and two, but for the y intersect. So, this much additional C m act C L equal to 0 has to be generated ((Refer Time: 17:58)) C m at or C m 0 to be generated and who generated this, this is generated by the elevator deflecting upward direction.

If I now compare one and two, if I additional delta C m is generated and who are generated this delta C m at C L equal to 0, if it is symmetric airfoil, it is equalizing alpha equal to 0, who was done it, it is by the elevator being tail in up position. So, my elevator should be enough powerful to give be this much of delta C m is suppose the delta C m is very large and whatever you do elevator deflection still it is not able to generate that much of delta C m. So, then you would one be able to trim the airplane for that C L trim, so that is where is the connection and trying to understand that via statist ability.

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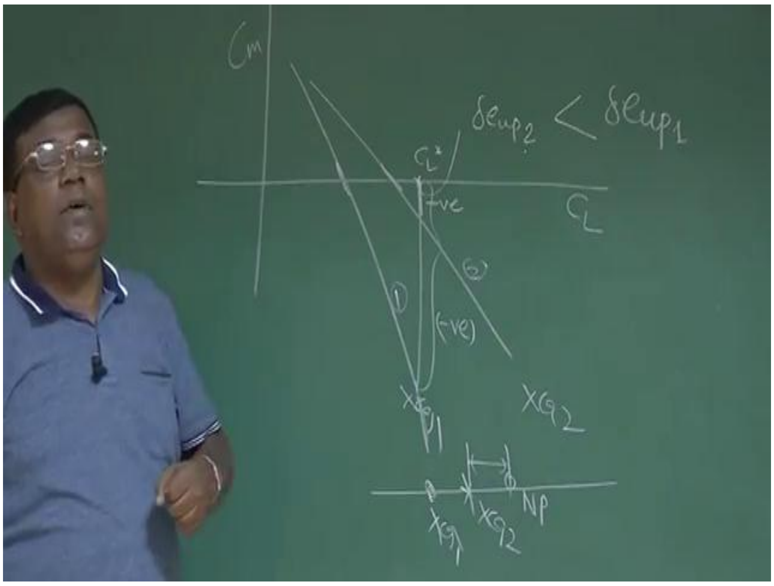

Let us take a simple case this is C m and again C L, this is one graph for the same airplane, this is second one and two for the same airplane. So, what might have change, why this slopes are different, because you win if the configuration is same what we are agreeing that yes, where discussing about a same airplane. So, external configuration is same, but they are d C m by d C L are the statist ability parameter is different that could happen only, because the c g locations are different.

We could very well see, one case one is slope here you see, slope here you see, this slope is more negative come back to slope at two. That means, the airplane in the configuration of x c g 1 is more stable then x c g 2 or I can also say if this is the neutral point of the airplane if x c g 1 is here x c g 2 is somewhere here and so the difference between the x c g 2 and neutral point is lesser compare to difference between x c g 1 and the neutral point. So, I said this airplane is statically more stable then this airplane.

Now, let us statically if I want to trim the airplane at this C L, C L star if I had this airplane that is the airplane with c g as x c g 2 are which is statically less stable then I have two see that this much of negative pitching moment I have to counter by generating positive pitching moment and how will I do that or will deflect the elevator up. So, let us say which is this corresponds to elevator up 1 or ((Refer Time: 21:13)) 2, because as per this convention.

Now, same C L star if I want to get it trim by aircraft one that is if I want aircraft one to fly at this C L star with lift equal to weight and thrust equal to drag, how much negative pitching moment will generative is this much at this I have to deflect elevator much higher compare to this case to nullify the negative pitching moment and that say that is delta again up, but it is 1 and delta up 2 is definitely less than delta is up 1.

If I see from static stability point of view, please understand this concept, this aircraft is more in terms of static stability it has the more static stability compare to this aircraft that is why, because this is having higher static stability I need elevator deflection to change this trim from one equilibrium to another equilibrium. So, which this very obvious and you can understand that any aircraft with highly statically trouble it has an inheritance to come back to retain in the position to restored to have initial tendency to come back the position it will resist in change from the position very strongly as compare to an aircraft which is having static stability less. So, this is very, very clear to us, so this understanding is extremely important and will be using this understanding to define an relationship between elevator required and C L 2.

Thank you very much.