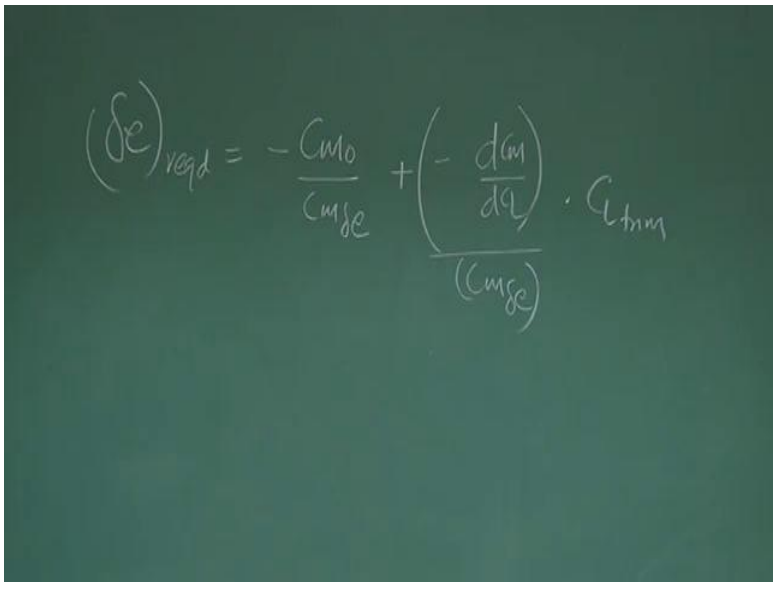
NOC: Introduction to Airplane Performance
Prof. A. K. Ghosh
Department of Aerospace Engineering
Indian Institute of Technology, Kanpur

Lecture - 45
Control: Delta e required continued

I have been getting some message, that we are using lot many mathematician into it, but dear friends honestly speaking, I am trying to see that, not too much of maths, etcetera is used. More importantly I am trying to see, how physically we can understand, what is happening or what is a physical interpretation, so that we get the holistic view of whole airplane performance.

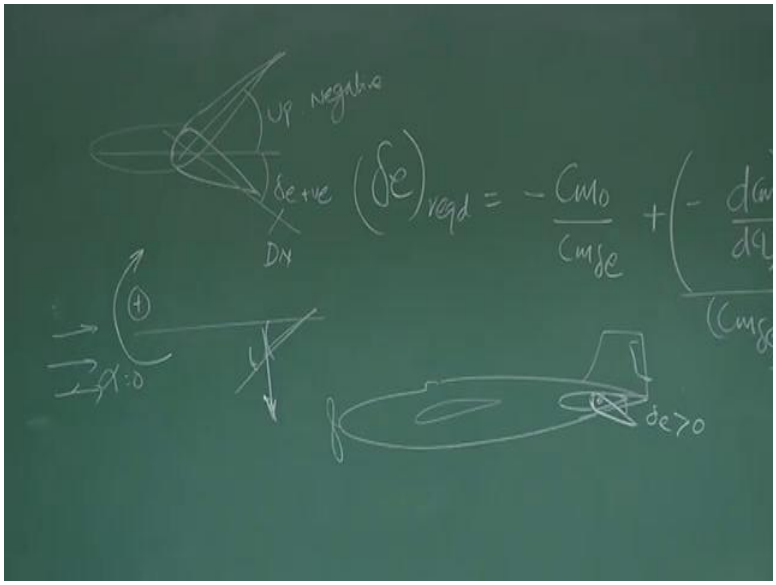
And that is why, whenever I am writing some expression, we will find I will be repeating those expression, you will find, I will be repeating those expression, try to add more physical insight into this, once you understand that mass is not that difficult and you can correlate.

(Refer Slide Time: 00:59)



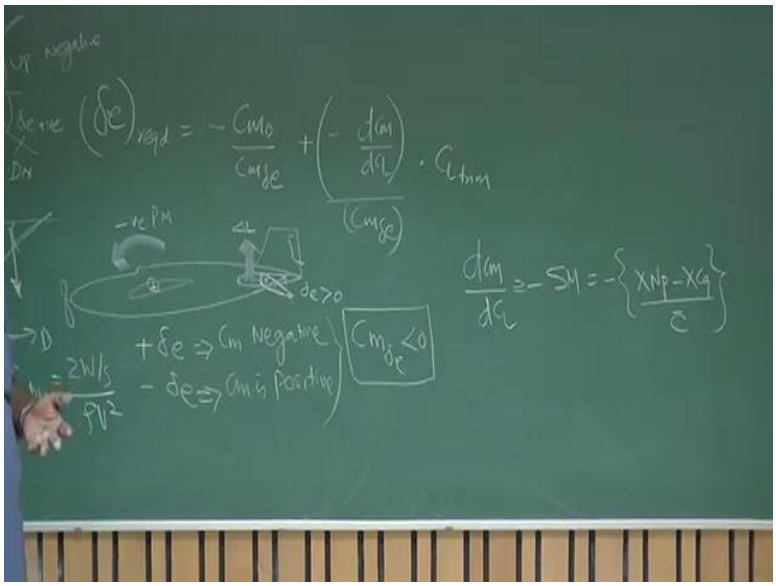
If you see my last lecture, we have derived relationship delta e required equal to minus C M naught by C M delta e plus minus d C M by d C L by C M delta e into C L trim. Try to understand this expression. What was C M naught? C M naught was pitching moment at alpha equal to 0. And, who are the contributor for C M naught?

(Refer Slide Time: 02:05)



You know primary contributor were tail, if I said the tail at a negative angle setting angle, it will give a positive C M naught that is, if I put the tail like this some setting angle I call I T. So, as flow is coming like this at alpha equal to 0, this will have force generated downward direction and suppose C g, somewhere here of the aircraft. So, this will give a positive pitching moment, which is C M naught. What was the C M delta e? Try to physically understand this.

(Refer Slide Time: 02:37)



Suppose this is airplane and this is the horizontal tail and this is the elevator, let us say there are wing, whatever it is. What is delta e? Delta e is the elevator deflection and how do you define delta e, sign convention wise this is the delta e positive and delta e up, this

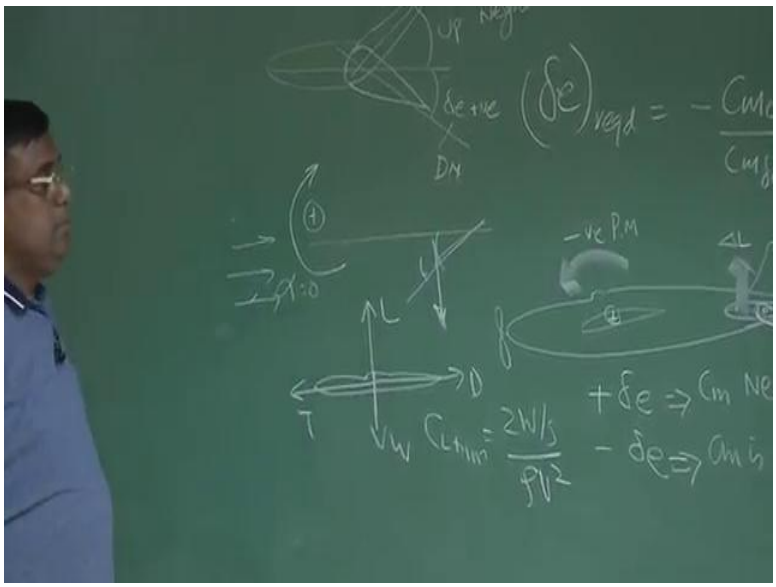
is up this is negative, this is the convention and this is generally we will see it is also denoted as down D N down.

So, now, tell me if this is the horizontal tail, which is here, if I have deflected this downward. So, I know delta e is positive by sign convention, what this delta you will do, this will change the camber of the horizontal tail. So, there will be additional lift, because of this at alpha equal to 0 and this lift will give moment about C g, you know it is a nose down manner that is it will go pitch down.

So, what is the sign of this moment? You know nose up is positive and nose down is negative, so this will generate negative pitching moment, so we say for positive delta e C M is negative. Similarly, for negative delta e, which is up C M is positive and we combine this and we say the sign of C M delta e is less than 0. What is the meaning of C M delta e, that change in pitching moment coefficient per unit elevator deflection only, everything other remaining same. Is it clear?

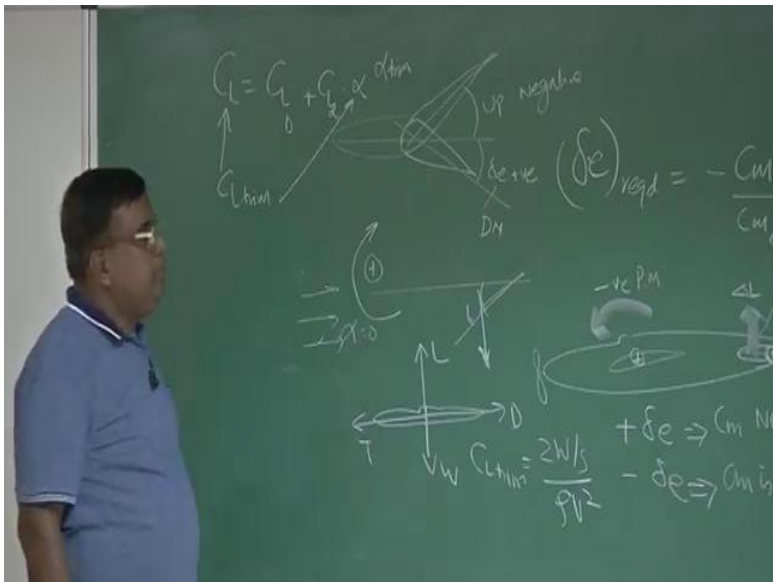
So, that is the meaning of C M delta e, what was d C M by d C L, we now export by, now d C M, d C L is nothing but, approximately we have seen it is minus of static margin. And, what was static margin? We know static margin is minus of X neutral point minus X C g of the aircraft with non dimensionalized with C g, clear.

(Refer Slide Time: 05:46)



So, this term is also known whatever C L trim, how do I physically understand, what is C L trim, I told you if the airplane is flying with lift equal to weight, thrust equal to drag. Because, we have taken cruise as an equilibrium, all these examples are assuming that cruise is our equilibrium. So, lift equal to weight, thrust equal to drag, then C L trim will be 2 W by S by rho V square, clear. This is very well understood and the alpha corresponding to C L trim.

(Refer Slide Time: 06:20)

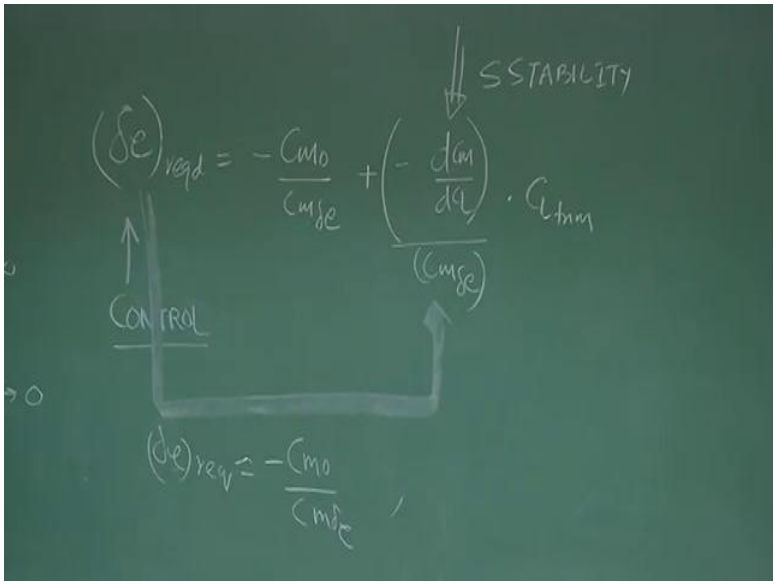


Because, C L we know C L of the aircraft I can write as C L naught plus C L alpha of the aircraft into alpha, so if this is C L trim, then corresponding alpha with as far as alpha trim, every term is clear. So, what is the understanding? If I want to fly at a particular C L trim, if my question is, how much elevator I should deflect, what I need to know, what is the static stability margin of the airplane 10 percent, 15 percent by put that value 0.1 or 0.15 same delta value this are aerodynamic derivatives, which are known once a configuration is there, you can evaluate you can get from tunnel.

But assume that, this values are known C M naught also is known, so see everything is known here, so you can easily calculate what is delta required. But, understand one more important thing this is an expression, you go on putting C L 2, it will go on giving delta required, but there is a limit, if I go on deflecting the elevator like this there is an angle beyond, which the flow is get separated.

So, it will not generate lift at all a very small lift more drag which elevator get separated, so that is the point, where say elevator is not effective. So, we need to know we need to constraint this, you say no dear friends I have a limitation, so I can only control it to my best friend. So, it cannot be any trim it has to be a limited C L trim this is a one question, second thing is very important please understand this carefully.

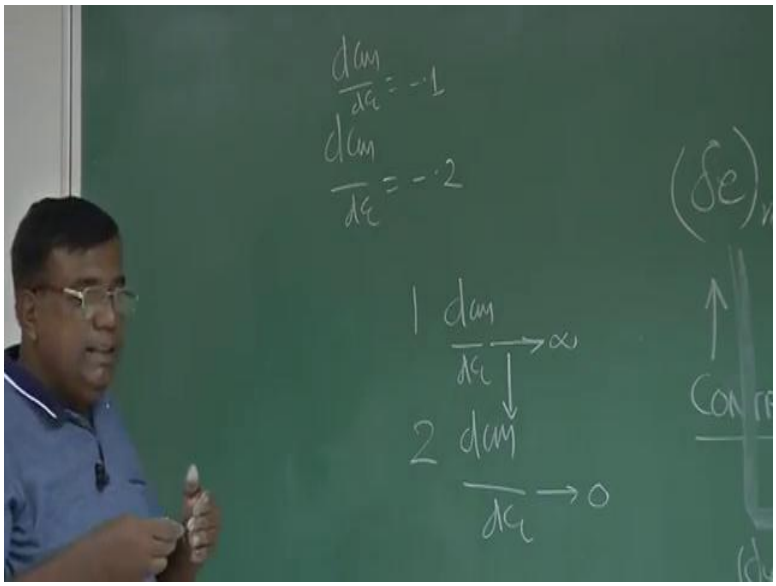
(Refer Slide Time: 08:26)



Now, try to visualise the connection between control and static stability, so if I ask you, which part is over control part here, but here naturally control is the elevator. So, this is our control part is a elevator control part to be more precise, which is the stability part here, stability means, what I am talking about static stability and you know d C M by d C L is static stability parameter, so this is the static stability parameter.

We want to build up a relationship between this and this, which we have done it. By now, we want to add value to it and try to physically understand, what is this gentleman doing think of a situation, suppose d C M by d C L is infinite.

(Refer Slide Time: 09:20)



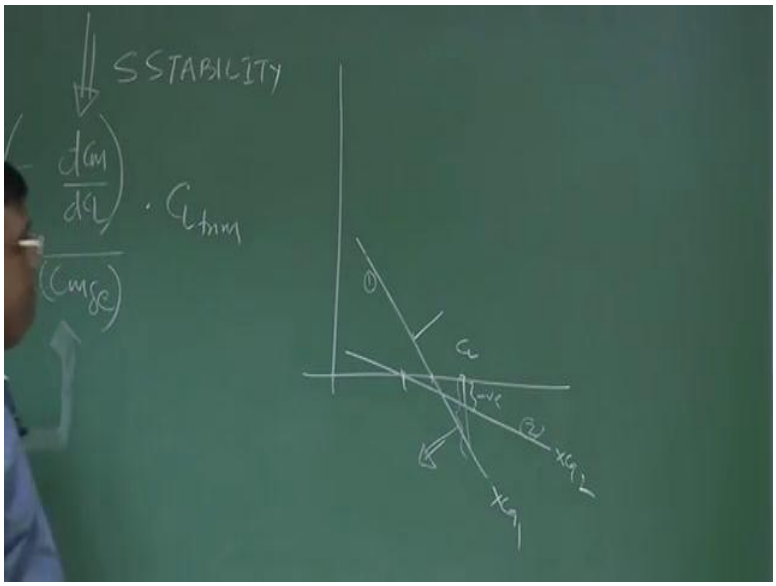
Suppose first case, d C M by d C L goes infinity means it is very, very highly statically stable one infinite list stable, what is the meaning then, how much delta require you require, if this part becomes infinity, but delta you also become infinity; that means, you also require in finite elevator deflection. So, what is a physics you getting out of it, that if I increase static stability delta requirement also will increase.

Similarly, in the reverse way you see, if d C M by d C L goes to 0, you know what is this case d C M by d C L goes to the means it is neutrally stable, that is X C G is just on the neutral point of the airplane. So, it does not have restoring moment, but then what happened and it says delta a required just minus C M naught by C M delta e, it does not depend upon C L trim at all, which is typically of neutral stability characteristic.

But, if I take two extreme, which are physically not realistic, but it gives as a message, it clearly says as I reduce d C M by d C L as I make it less and less negative in a say in an absolute sense, what I am saying is d C M by d C L if it is minus 0.2 in one case d C M by d C L is minus is 0.1.

You have to say this aircraft is statically more stable compare to this aircraft, but with algebra you say minus 0.1 is greater than minus 0.2 I am not using that. So, you please understand this if this is more negative by I say this is statically more stable from that point of view. So, coming back here, what you say that, if I go on reducing that static that I go on taking the X C g of the aircraft closer to neutral point.

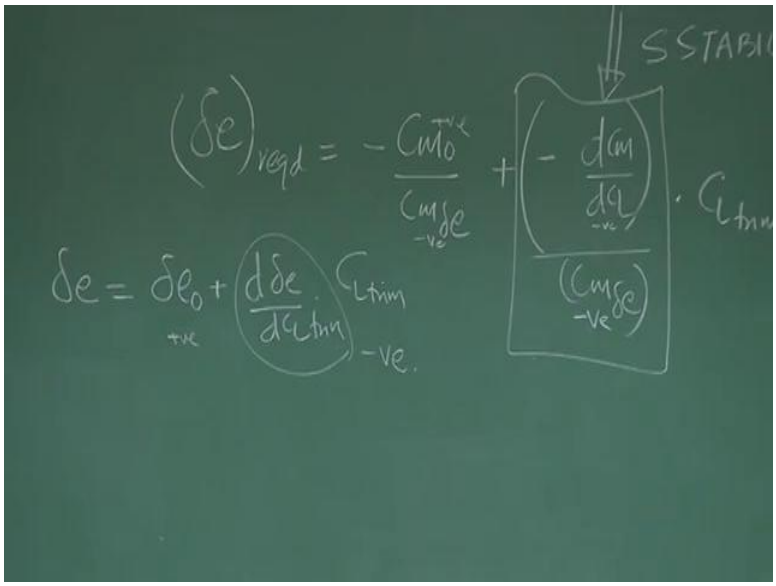
(Refer Slide Time: 11:42)



Then, the requirement for delta e also will reduce, which we have seen just few minute back, we did that suppose there is a aircraft X C g 1 and this the aircraft X C g 2, which is statically more stable, definitely I call it one and call it two, which is having more negative slope at the trim at this point.

If really, this one has more slop more negative, so you could see that, if I want to trim anything here, at this point this configuration require elevator deflection to neutralize this much of negative moment pitching moment, but if I am using aircraft with the configuration at that static stability, so high. Then, it requires elevator deflection larger, because this negative moment to be neutralized is larger, because it is statically more stable. So, whatever we understood this expression tells us exactly the same thing is it clear

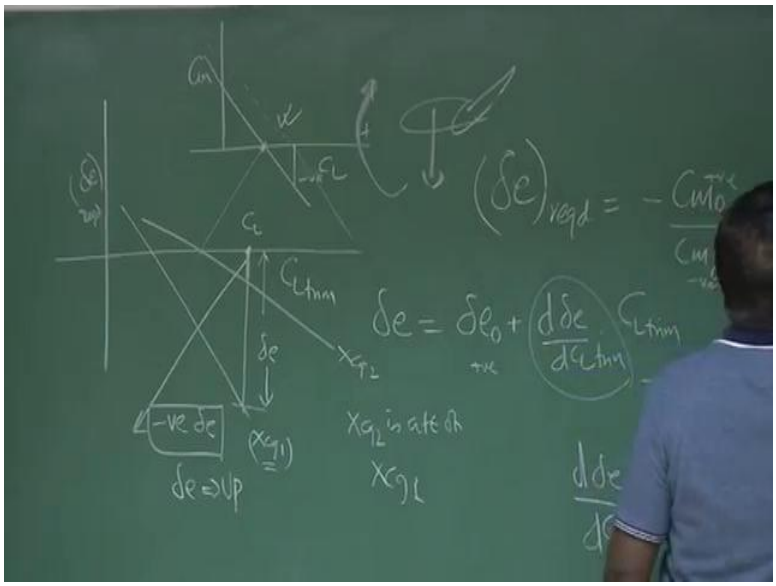
(Refer Slide Time: 12:55)



Now, in text book will find this is represented as delta e naught plus d delta e by d C L trim into C L trim, you could easily see that this delta by d C L trim is nothing but, this term. And, before I go to this, let us see this sign C M delta, you have seen the sign is negative d C M by d C L for a statically stable it is negative, so this is negative, negative positive and this negative sign sitting here.

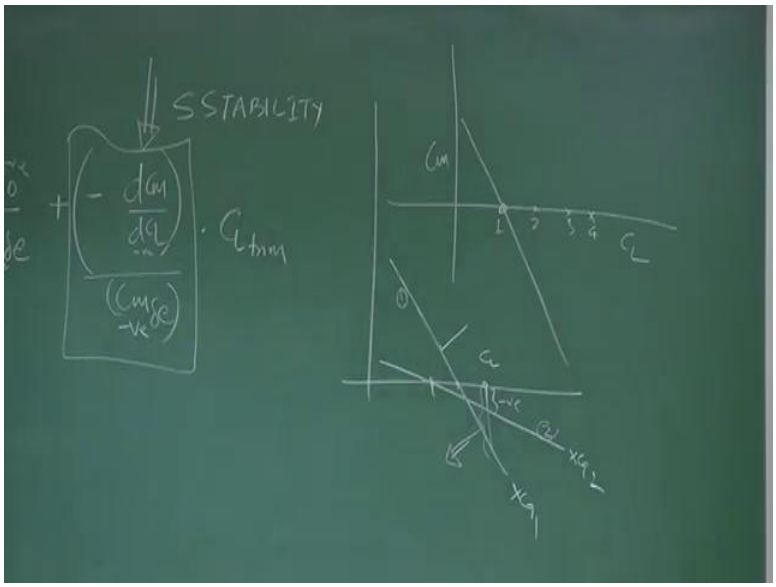
So, sign of this is negative, what is the sign of delta e naught you could see C M delta is negative C M naught is positive, so this is negative, negative positive this sign is positive this is clear. So, let us try to physically understand or develops of feel closer to the pilot, who will be able to understand rather then, going into all these equations, etcetera, etcetera.

(Refer Slide Time: 14:06)



Let us, draw this delta e verses C L trim please understand, we are not plotting delta e versus C L, we are plotting delta e versus C L trim, what is the meaning of that there should be very, very clear your mind.

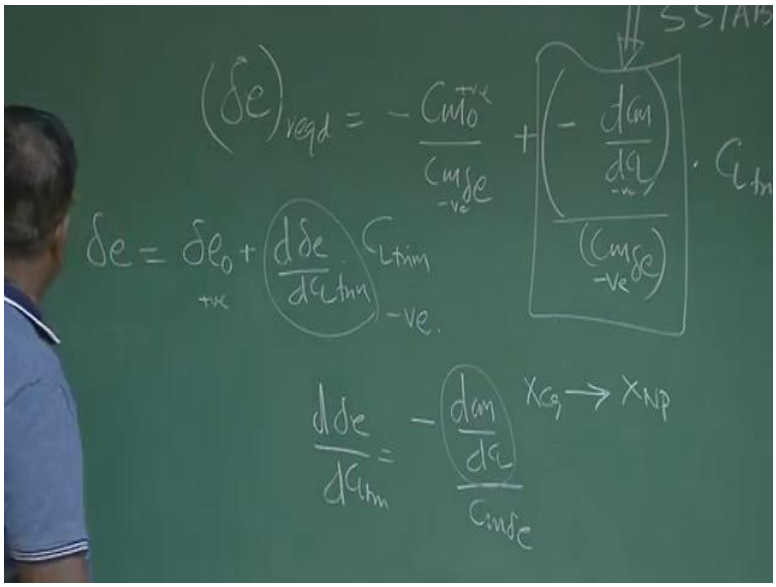
(Refer Slide Time: 14:27)



Suppose, I was flying here, this is C M versus C L graph I was flying here 0.1, 0.2, 0.3, 0.4, what we are trying to tell delta e by d C L trim is, when I am change a trim from 1 to 2, how much is delta e is required, when I am changing trim from 2 to 3, how much delta e is required. So, what is a change in the C L trim not in the C L that should be very, very

clear see if I plot it, let us say this is for C g 1 you could see here, that this values is positive. So, you have positive intercept here for C L trim to be 0 and the slope is negative slop is negative.

(Refer Slide Time: 15:26)



Now, how the slop will change, what is this slope, d delta e by d C L trim is minus d C M by d C L by C M delta e. So, you could see that, if I assume C M delta equal to constant it does not change the C g location, then I can see that as C g is going at, C g going towards neutral point for in statically stable airplane d C M by d C L value will become less negative.

So, this d d l type or d C L T value will also become less negative as per slop is concern is this part clear. If, this is constant as the C g is as X C g is going towards point that is it is become lesser and lesser statically stable, then this value, will also become lesser in lesser negative number minus 0 point 1 minus 0 point 05 like that.

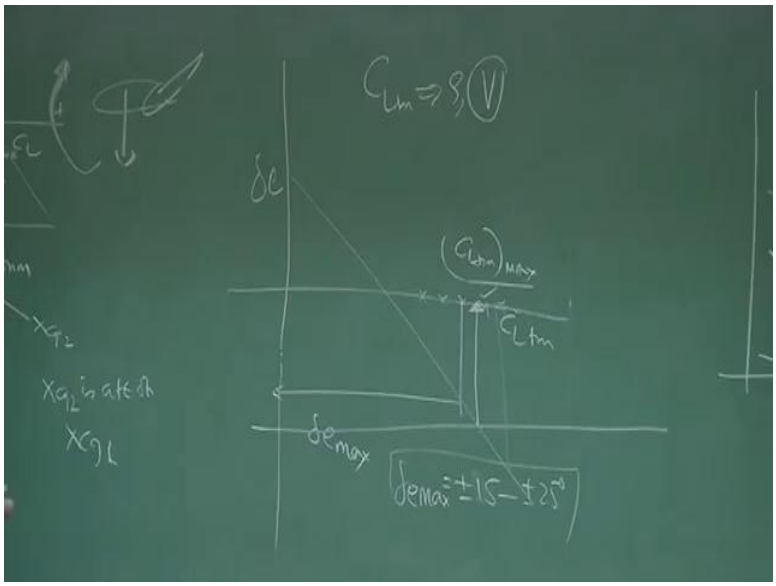
So, your slop of this also will become lesser and lesser negative, so if it is X C g 1,then for this is X C g 2, where I am saying X C g 2 is eft of X C G 1 at when, X C g is behind is closer to retail point. Now, from here you could see, again that if I want to trim this aircraft particular C L and if I got a this configuration, then I have to give this much of elevator deflection directly elevator required this is delta e required.

Now, think yourself, if I am changing C L to another new C L, which is more than the C L value are actually flying in this case; that means, in versus C L graph you have come connect this, then you understand very well C M verses C L graph, which is like this. So, this point is this point now, you want to fly at this point some other point, you want to fly then, what happens this much of negative pitching moment will be generated.

So, to counter that negative moment pitching moment pitching moment you have to give a generative positive pitching moment and how will you generate positive pitching moment by giving elevator how elevator up is not it, elevator up will give us positive pitching moment about C g. So, from here I understand that, if I want to fly from C L to a new C L, which is more than the C L at which, are flying I have to ensure that elevator deflection is positive, because it has to counter this negative C M. And, what I am getting here also I am getting negative delta e and, what is negative delta e negative delta e by convection is delta e up clear.

Now, see, if I want to change C L from a particular C L to this C L for aircraft having X C g 1, which is very highly statically stable, then so much of delta e up I have to give this negative means up. Now, next question come do I have this much of limit, how long or how far I can stretch the delta e deflection, how do I decide that let us see.

(Refer Slide Time: 19:16)



From delta requirement point of view I am only talking, you can generate infinite such numbers of C L trim I can fly please understand, when I say C L trim I can fly; that

means, there is also limit how much speed you can get. So, but I am assuming that lets a that is within the control and I can have this C L trim I can have this C L trim this C L trim, but how much question is this.

So, how it is done you should know, what is the limit of elevator, which can be deflected, because beyond that elevator is loses effectiveness. So, that number let us say delta e max and we draw a line like this, once I draw line like this and once you delta verses C L trim it clearly tells you cannot go beyond this C L trim, so this is a C L trim maximum. Beyond that, if C L trim is here I cannot I cannot manage it with the elevator for this typically delta e max value for convection airplane it is between plus minus 15 to plus minus 25 degrees, but there are the methods to increase this by adding some around system.

So, I hope now the pilot is seeing this graph delta e versus this C L trim and pilot knows I have to him he knows correspondingly further altitude, what is the speed, we have to fly for maintaining lift equal to weight. So, from this C L trim he knows, how much elevator up to maintain to go for the maximum C L trim and this has every intermediate point and this understands by the designers should ensure that the solutions are available. So, pilot by iteration he can find out that solution.

Thank you, very much.