Aircraft Design
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Lecture - 39
Elevator Effectiveness Contd.

Good morning friends. We are continuing our lecture on elevator design. At a conceptual stage what we have realized that, if I have got a horizontal tail like this elevator roughly I can take 40 to 50 percent of the chord as the elevator chord that is not a bad choice to start with.

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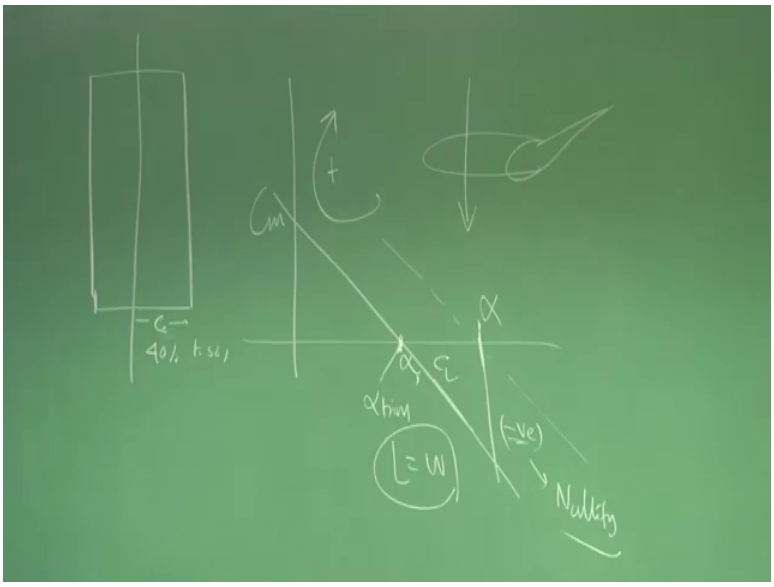

But let us not forget why do you need elevator. Elevator is the part of a control, it is a longitudinal control. Meaning thereby you want to fly the machine at different C l and if you go back because we are designing statically stable aero plane. So, if it is C m versus alpha like this, we know that this is the alpha trim at which, if I provide enough dynamic pressure or if I fly at a correct altitude, and speed relative at a speed, I should be able to produce lift we should balance weight, if I am aiming for a cruise flight. If I want leaved for over then that should be lift should be enough to produce that acceleration and you know that lift equal to NWN is a load factor.

But the question is if I am flying at these alpha or corresponding C l, and if you want to fly at this alpha let us say, or a corresponding C l a maintaining a level flight. Then the

aircraft being statically stable it will automatically opposite, it will generate negative pitching moment. So, if you want to increase alpha it will automatically generate negative pitching moment, but if you want to really fly here, trim their plane here. So, somehow you have to nullify this right. Nullify this movement, how can I do that? I do it by using elevator I will deflect the elevator up because then they will be force downward and C g some over here. So, it will produce a knows up moment and that should be equal to the negative moment generated inherently by the aero plane being statically stable this much we understand.

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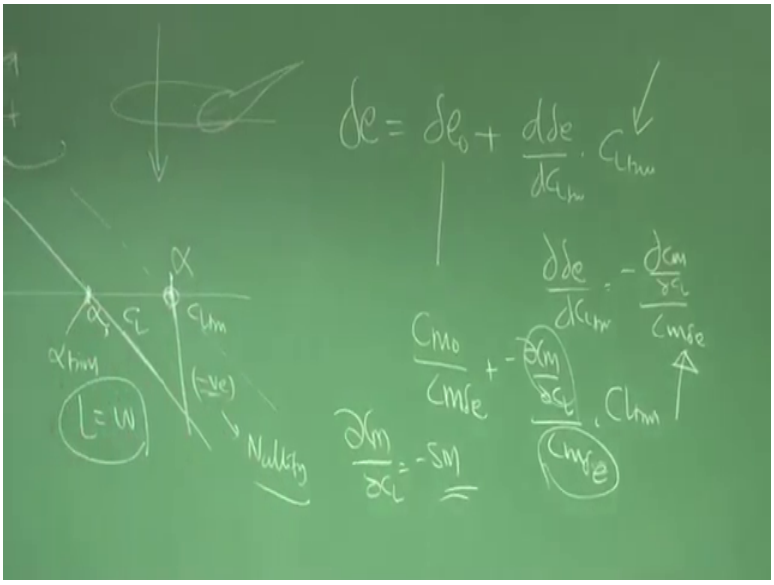

Then we will also revise that the delta e equal to delta e naught because d delta e by d C l trim into C l trim, and where we know the d delta e by d C l trim is minus d C m by d C l by C m delta e and where C m delta is the elevator control power; that means, how much moment per unit deflection of this elevator we will generate. That is what is we relate to C m delta e that is d C m by d delta e, how much pitching moment it will generate per unit deflection of elevator right. This relationship is important because it tells you, if I want to fly at this C l trim that is suppose, I want to fly at this C l trim then how much the elevator deflection is required to nullify this made in moment is given by this relationship. Where I need to know what is C m naught then what is C m delta e and then minus d C m by d C l by C m delta e into C l trim.

And you know d C m by d C l is minus static margin and as a designer you have decide at the a priory that you will be design the aero plane for a particular static margin may be 10 percent 15 percent. That is your choice as I repeatedly say I start with 15 percent and I know that by Murphy law there will be C g limitation will come and I will approach towards 10 percent.

Now, the question is what is C m delta e, how this C m delta e gets linked with the elevator sizing here, that is important. Although we have taken 40 to 50 percent as a initial conceptual stage. To understand this we will have slight revision of one of the problems which you have done in our stability classes, in the earlier courses.

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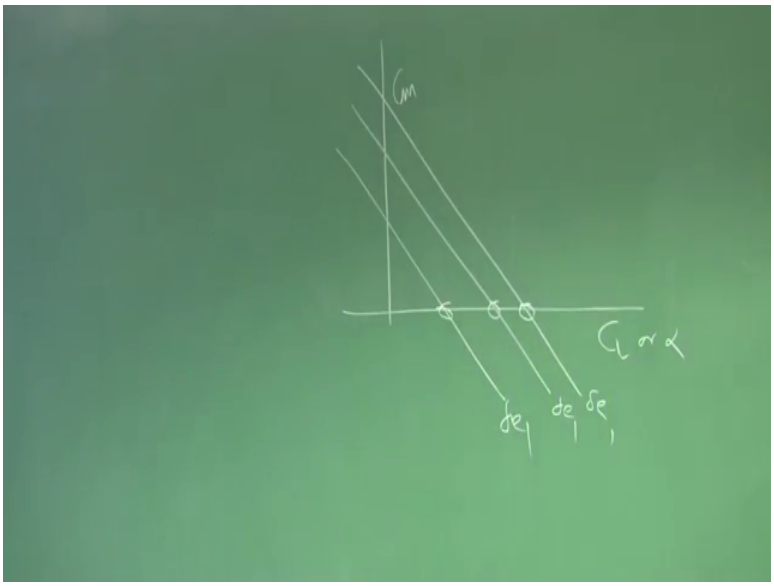

And before that it has summarized what we are talking, but I can trim the aero plane at different C l or alpha and for different delta e different delta requirement will be there, if you want to trim at here or here and the question is, is my elevator enough powerful to generate or to trim the aero plane? That is the question right.

Let us solved an example and then we will see that yes does not. Make sense or not please understand the elevator maximum deflection we will be required if there during landing, if that is a low speed all during takeoff which is also almost v stall speed equal to v stall 10 percent more than v stall. So, if you want to trim the aero plane the delta you max will be near take off all landing conditions. And also you know that during landing because of ground effect I must give some extra delta available, extra delta up available

right. Let us say I have got an aero plane to C m about C g is minus 0.20 minus 0.35 alpha.

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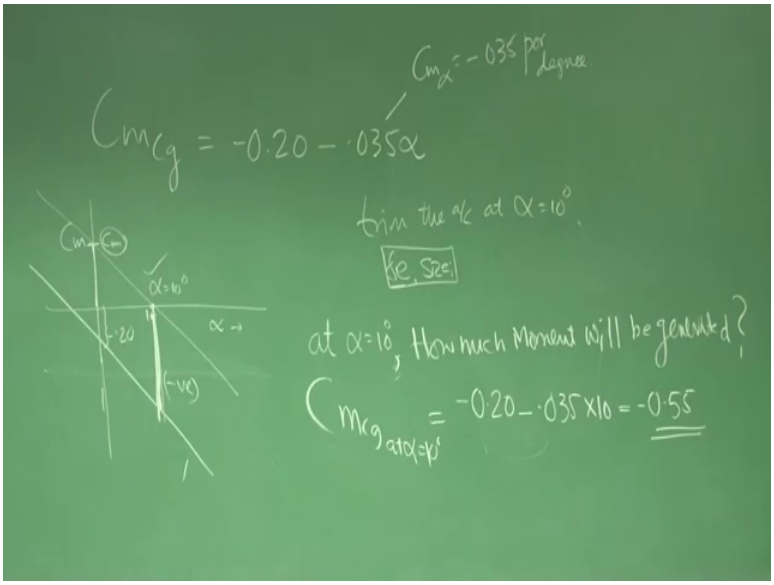

Let us see we will have an aircrafts which are the wing few large combination and C m C g we are getting like this. That is if I plot C m versus C g this will look like some over here something like this. And this value we will be 0.20 minus. And during landing you want to trim the aero plane trim the aircraft at alpha equal to 10 degrees. Let us say this is C m alpha which is minus 0.35 per degree. If you want to convert C m alpha from per degree to per radian you have to simply multiply by 57.3. Roughly then we will get per radian. So, what is the problem? Problem here is this aircraft has C m versus alpha like this, but I have to fly and trim the aero plane at alpha equal to 10 degree. That means what? If I want to fly at alpha equal to 10 degree this aero plane at 10 it will generate automatically and negative moment.

So, I have to counter the negative moment, in a sense the C m not I have to ensure it is raised to this point right. Then only I can trim it here right here. The cm naught was negative that is why I cannot trim the aero plane at a positive angle of attack. To trim that aero plane the positive angle of attack, I will have to use elevator we will have received this point from here to here. Although if you are if you are configuration is like this, this is not a good design. We always try to see that the C m naught is positive right. It is for

an example it will give you wider understanding of what is being done, the question here is what is the elevator size. So, that I can trim this aero plane here that is the question ok.

Now, let us see at alpha equal to 10 degree how much moment will be generated right? That is only we have to mollify, that is at alpha 10 degree this must moment will be generated negative moment that I have to nullify. So, that here the moment is 0. So, that it become the trim point.

That I can easily find from here C m C g at alpha equal to 10 degree will be minus 0.20 minus 0.35 into 10 because this C m alpha is per degree. And if I do that then I get the value as minus 0.55. So, that much moment I have to nullify right. And that we will decide what is the elevator size.

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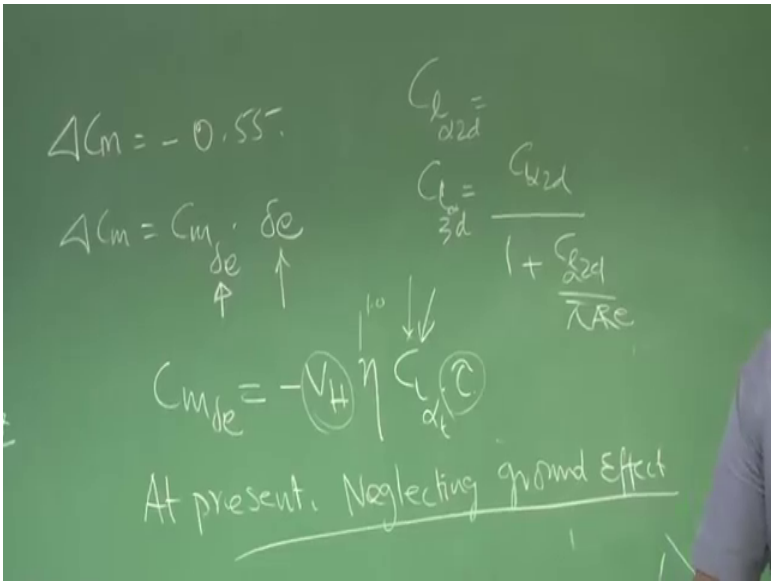

Now, this delta C m which is minus point, 0.55 that should be nullified. So, I write delta C m is equal to C m delta e into delta e. I have to nullify this delta C m by using elevator and it is obvious that elevator should be up. Now the question is, how do I visualize what is delta e what is C m delta e as per as numbers are concerned? We realize this delta C m is minus 0.55 which has to be nullified. So, I am asking a question how much elevator and how much C m delta e value, the aircraft should be able to generate? And let us see what is C m delta e remember C m delta is given as minus V H and eta C l alpha tail into tau. V H we have already assumed and eta I can take 1 and once I have selected a symmetric tail then I know C l alpha C l 2 dimensional alpha of the tail.

So, then from there I convert to 3 d C l alpha tail as C l alpha 2 d, by 1 plus C l alpha 2 d by pi aspect ratio e we can take e as point it. So, you have a value of C l alpha 3 d which value is here just for tail. I do not know what is the tau, although when I have assume 50 percent of the horizontal stabilizer radio as elevator I can easily do it like this.

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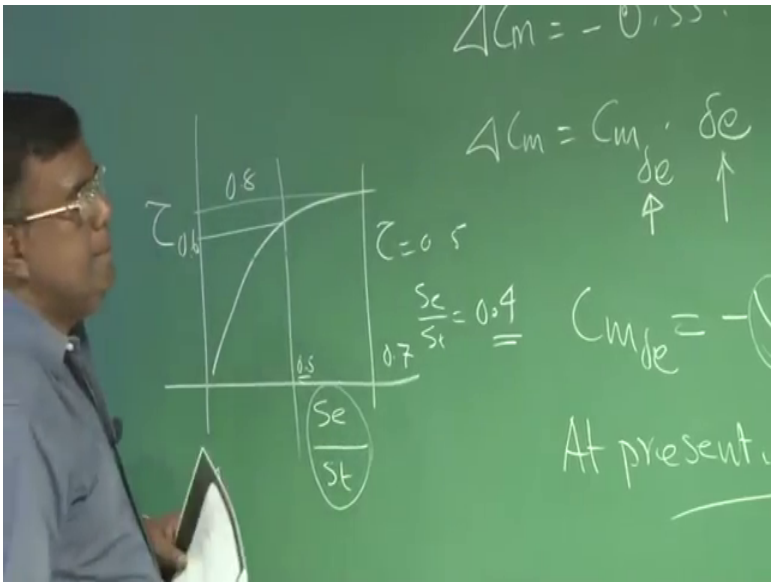

I have a chart very popular chart S e by S tail and this go something like this and this value is roughly is 0.8, and this corresponds to a ratio of 0.7 and typically at 0.5, you will find this value we will come and 1.6 if this is 0.5.

This is one way to find out what is the value of tau. So, since you have already taken 50 percent or 40 percent called elevator. So, you can easily find out S e by S t, and then find out the value of tau, but what we will be doing here a little different. Since I know I have to trim this aero plane at alpha equal to 10 degrees. And at present I am neglecting ground effect right. Just for case of and demonstration, let us say I am neglecting ground effect; that means, either I have extra elevator taken care when I have said elevator is minus 25 and plus 25, I have already ensure that my elevator is effective up to minus 35 right. That may be little bit to higher side, but yes the question is, you need to keep that margin right?

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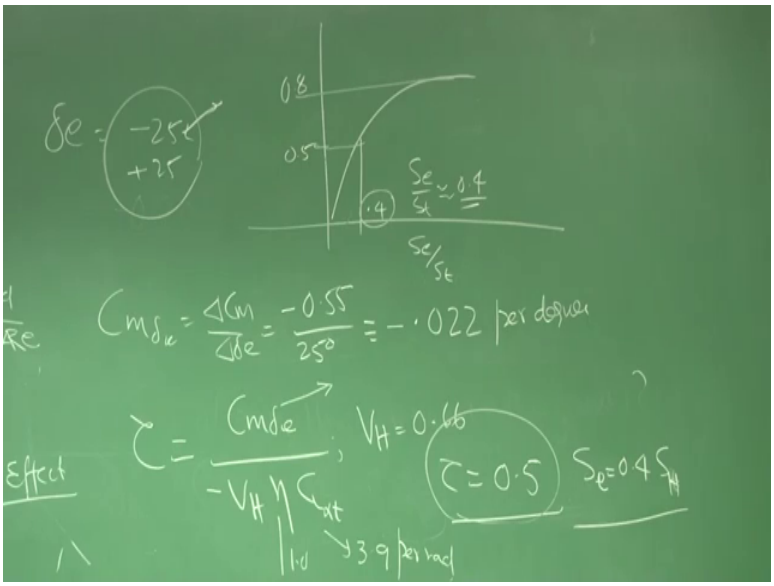

So, in this example I am neglecting this ground effects, if you and as a and as a practitioner you must keep their 78 degrees margin; that means, effectively if you elevator is within plus 25 minus 25 we should not operate beyond 17 degree anyway deflections right. Roughly, let us say we are the electric this ground effect now this is C m delta I expressioned, and C m delta if you see is delta C m by delta delta e and we are taking minus 0.55 by delta delta is let us we are using 25 degrees. So, this will become minus 0.022 per degree. You could see that in per radiant we have to simply multiply this number by roughly 57.3. So, it will come around minus 1, around that range minus 1, 1.1 that is typical value of C m delta e.

So, if I know C m delta e then I can easily find out tau is equal to C m delta e divided by V H and eta C will alpha tail. From here and let us say when you have conceptualize I then V H we have taken around 0.66 these are some number which could be 0.5, 0.6, 0.7 let us we have taken 0.6. And these gentleman is one and let us say this is around 3.9 per radian right. And C m delta you also you have to put in per radian. And if you put that you will find tau will come around 0.5 roughly. Now if we say tau 0.5 means if we see this chart which are given in your class, tau 0.5 means tau 0.5 will mean S C by S tail around point 0.4 that is 40 percent ok.

That is how the guidelines are generated let the chord be 40 percent of the horizontal tail or 50 percent. What are the designer you should know that if I take around 40 to 50

percent of the chord, stabilize a chord at as elevator, I will get tau around 0.5 that is a good number. So, once we get tau now. So, once I get tau as 0.5 what I do? I mean cross check I come here, again see this chart which gives around which is 0.8 and this is S e by S t I try to check how much this actually means for 0.5 tau is 0.5 some over here. So, if you see this graph it will come down to again around 0.4, but is S e by S t we will be approximately 0.4.

So, that again comes back to the understanding the 40 percent. So, you can easily write here if I want to trim this I need area as elevator area as 0.4 times horizontal tail area. And you have already V H you have rough idea of what is the horizontal tail area. So, you can easily find out, elevator area of which again tells you that only 40 percent of that area if the rectangular one, just take the 40 percent or chord elevator that will suffice your initial estimates, this is clear? So, what I have tried to mix 2 things, one is we are taking major historical data.

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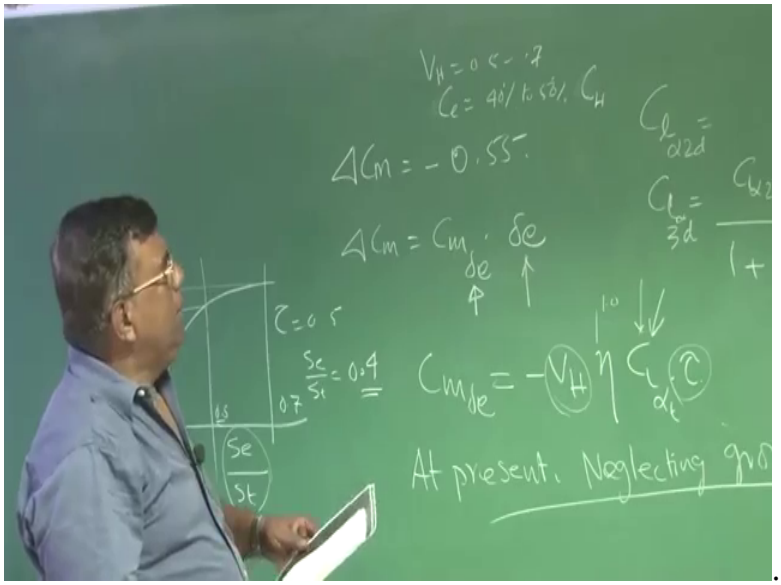

So, V H around 0.5 to 0.8 or 0.7, then elevator chord around 40 percent to 50 percent of horizontal tail chord. And you have demonstrated one example and you see that the numbers classically also comes within this domain.

So, whatever historical data is there, when they have been correlated when they have been converted into database this physics was always there right. So, at a conceptual stage if you use those data or though data sheet you are near the solution point; however,

after doing this you need to do analysis and refine the design right. A good design unless it has a good beginning it can never become excellent right. So, beginning is extremely important, and that is the purpose of this course.

Thank you very much.