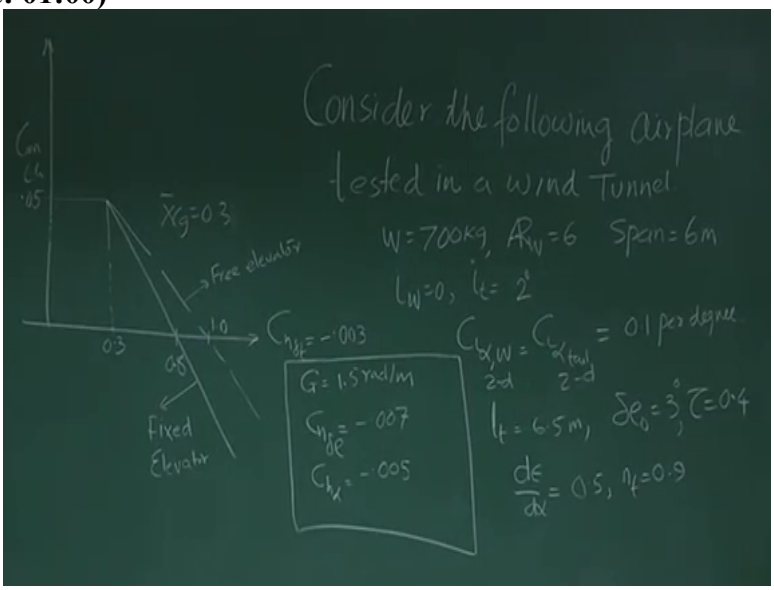
Aircraft Stability and Control
Prof. A. K. Ghosh
Department of Aerospace Engineering
Indian Institute of Technology-Kanpur

Lecture- 32
Numericals: Stick Free

Good afternoon everybody, today will be solving 1 problem related to stick free, I to be particular is stick force, we have seen so many expression in stick force and then every possible reason to get disinterested this expression do not look at best way to handle this sort of the situation is solving problems right, so will be a solving problem randomly on stick force, before we come to stick force it as device few things so that we can conveniently use some problem numbers and get something useful okay.

(Refer Slide Time: 01:00)

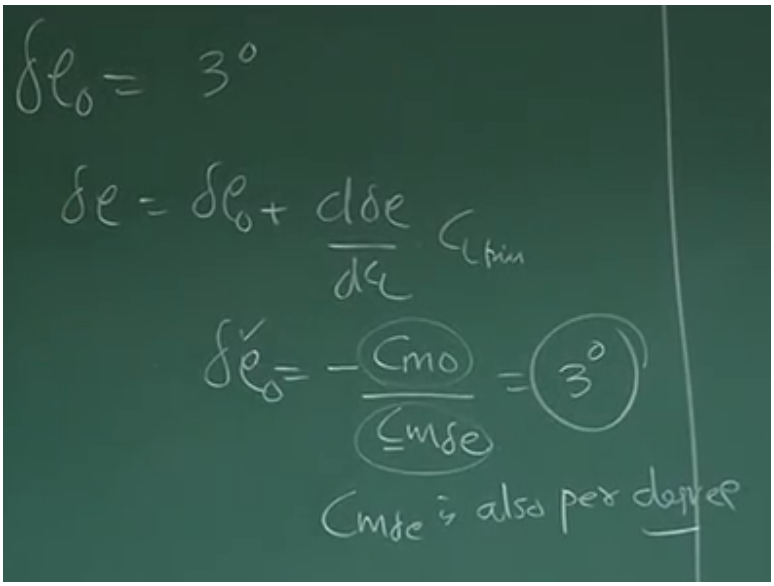


If you could see this problem is given. Let me read the problem first we consider the following airplane tested in a wind tunnel, what is given is weight of the airplane is 700 kg, then aspect ratio of the wing is 6 span of the wing is 6 meter, wing setting angle IW 0, IT is 2 degree tail setting angle is + 2 degree right, note this, Then also some aero dynamic characteristic that is CL Alpha of the wing 2 dimensional 2 D and CL Alpha tail is 2 D is 0.1 per degree.

Please understand this is 2 D so you have to convert this into 3 D okay? Then tail moment have LT is given as 60.5 meter what was LT, LT was a distance between AC of the tail and CG of the

air plane. And this Delta E0 is 3 degree tow is 0.4, and D Epsilon by D Alpha is 0.5 LT is 0.9 what was Delta E0?

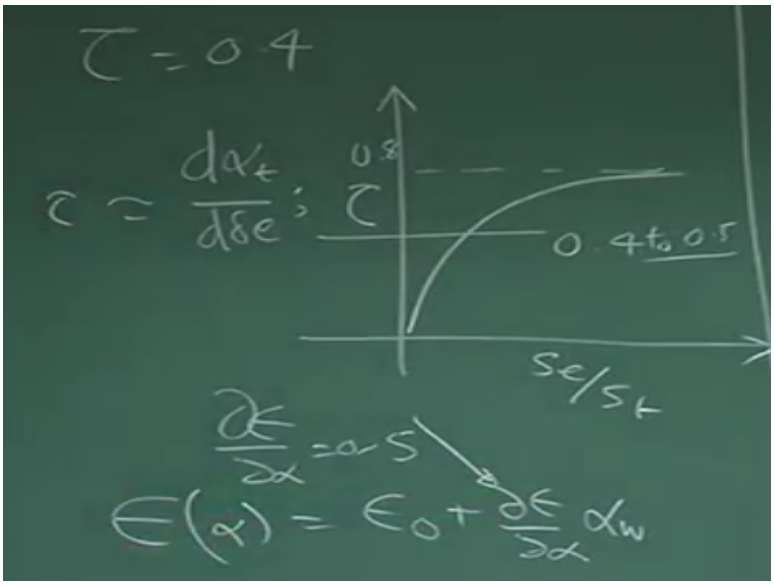
(Refer Slide Time: 02:03)



Please remember when this right side Delta E0 is 3 degree and Delta E = Delta E0 + D Delta E by DCL into CL trim and you know Delta E0 was given as - CL0 by CL Delta E. Right and if I know the value of CM Delta E. If I know the value of CM0 I know what is the value of the Delta E0, In this problem Delta E0 is given as 3 degree you could see that sign will be positive because CM Delta E is negative, CM0 is positive so positive negative, negative positive, negative negative positive.

So this is 3 degree This also tells you that CM Delta E is also per degree, not per radiant, per degree that is why 3 degree here, this I must understand okay.

(Refer Slide Time: 03:09)

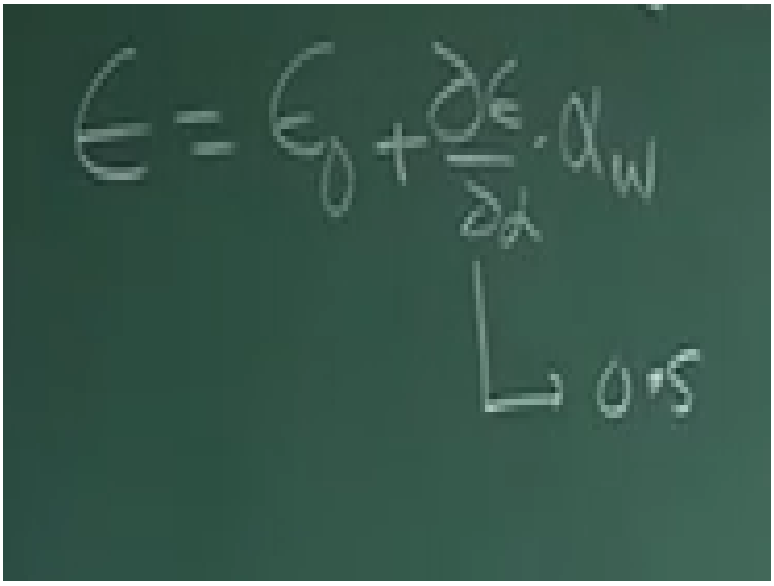


So, that is on Delta E0 and tow is 0.4, you understand what was tow, if I write tow is 0.4 I understand tow means D Alpha T by D Delta E what is the meaning of this D Alpha T by D Delta E which is nothing but tow we interrupt this line, or you need to deflection or elevator how much the tail angle is changing right and you know this can be evaluated or estimated by empirically this is tow.

This is SE by ST and it depending like this maximum line only pointed to 1, just a practically 0.8 and typical value lies between 0.4 to 0.5 or 0.6 sometimes, so that 1 can find out empirically if I know what is the elevator area and what is the tail area For this problem this all exercise has been done and you are, you are given tow as 0.4.

and now comes the Epsilon by D Alpha when you say D Epsilon by D Alpha 0.5 you know that Epsilon downwash a tail because of wing right, can be expressed as Epsilon 0 + D Epsilon by D Alpha into Alpha wing and this D Epsilon by D Alpha would this 0.5 if this value which is pretty high right? You also see that D Epsilon by D Alpha is given as 0.5 and we know by now were this wing because of the wing there is a downwash at tail that is important

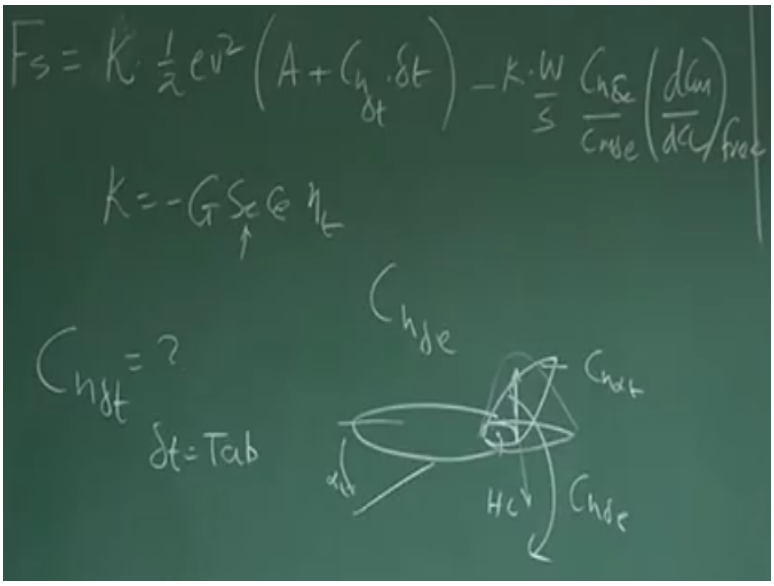
(Refer Slide Time: 04:51)



And that can be expressed as Epsilon = Epsilon 0 + D Epsilon by D Alpha into Alpha wing because this is the downwash of tail who as crossed this downwash because of the wing where from it has come because wing because of the pressure differentiation lift and those vertices are cause the downward at tail and this D Epsilon by D Alpha is 0.5.

You know I want Epsilon 0 if it is cambered aero foil wing the Epsilon 0 will be non 0, for symmetric it will be 0 okay, this things we understand you also would like to know what are the other information given so that with get the correct feel of the problem. Like way I come here you could see that the G so I am talking about I am coming towards the domain of stick force G was here is constant and if you recall the expression of stick force which is given as if I difficult to remember if see a stick force.

(Refer Slide Time: 05:54)



We derive this question as K into half row V square A + CN Delta T into Delta T - K into W by S CH Delta E by CM Delta E into DCM by DCL free, Please do not get bothered if I by mistake I written some wrong expression somewhere error you are supposed to correct it, okay.

I will I am just telling how to handle and how to understand a problem okay, expressions already have and you should cross check, Now see what was G here, G means. Where in this expression if I remember the K was given as - G SE CE Neeta T what was G, G is the gearing constant and that is exactly the G we talking about 1 0.5 radiant per meter, radiant per meter okay, so that is G, what was SE, SE is the elevator area, what is CE, is the elevator chord and Neeta T you know the ratio of handling pressure handling at tail to a free stick dynamic pressure.

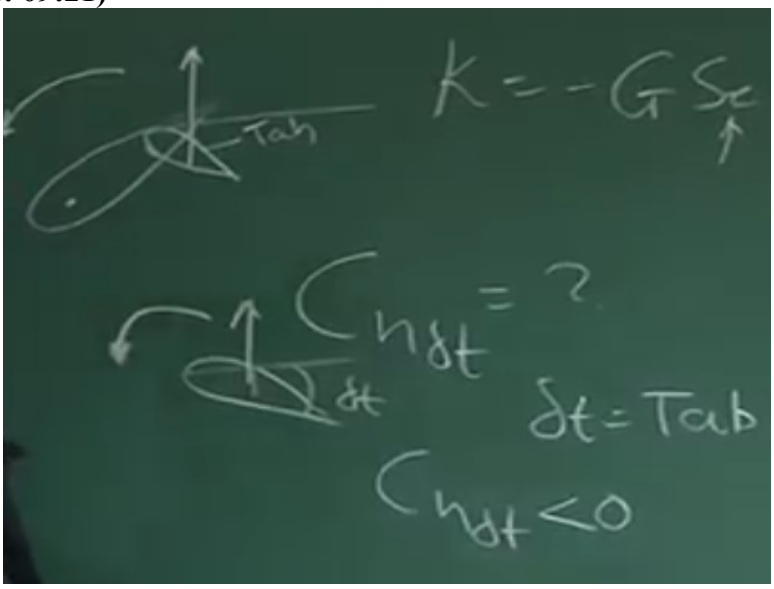
So, we understand what is G, what is CL Delta E and CH Alpha, CH Delta E if I recall that you know we are assuming that the elevator is free to rotate because of Alpha T, this is Alpha T and if this is the hinge line then there will be a pressure with extinction over the elevator and if center of pressure is behind the hinge line then this will try to float the elevator up that is the effect of CH Alpha T right.

CH Alpha T, but what CH Delta E will do as it goes up, It generate the force towards down it tries to resist so CH Delta is restoring hinge moment CH Alpha T is the floating is try to float floating heeling moment of try to float the elevator so those values are negative because hinge

line is a head of the resultant of pressure so CH Alpha T and CH Delta E values are – 0.007 per degree, this is – 0.005 per degree , suppose this is given and also of course.

I think somewhere CH Delta T is also given, this is the TAB what is CH Delta T, that is also understand CH Delta T, it is also a good idea whenever the problem is given during the training period every parameter number in see you ask what is this okay. What should be sign, what should be its magnitude? Why and what are the influence it could cause? Or how it can influence the whole airplane? If you start doing like this will develop the field for this number and you will do justice to this subject.

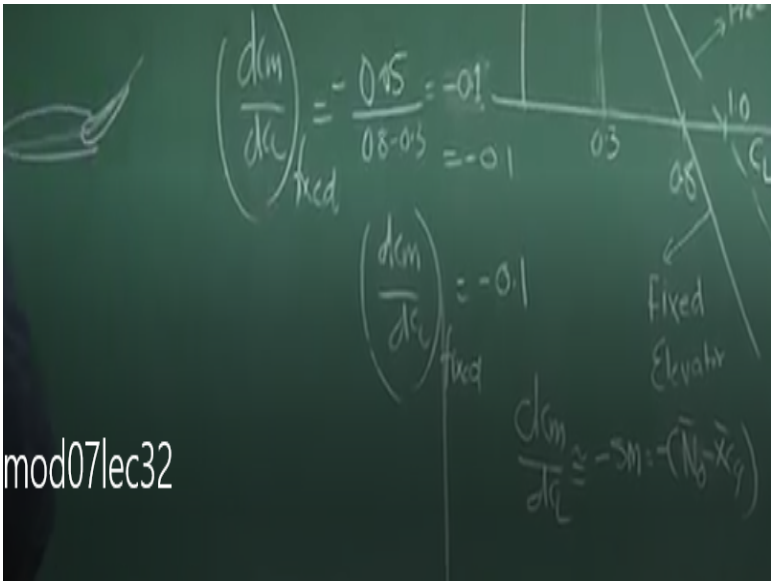
(Refer Slide Time: 09:21)



So let us see what CH Delta T, what is Delta T, Delta T is the tab, it's a trim tab longitudinal case so what is the trim tab? We learn last class itself remember if this man elevator as to deflected like this then if the pilot as to pull the stick and hold it so that will wait timing so there is another portion is goes down and goes up and this is the tab you can set this tab and this will the moment to hold this whole elevator at this angle so that a stick force applied by the pilot will be 0 and that is in a stick free case we say neutrally stable okay.

So, we understand CH Delta T you also understand what should be sign we define Delta T positive like elevator this is Delta T positive so Delta T positive will give A force in this direction why the slope has changed?

(Refer Slide Time: 11:13)



That will give a nose down moment so it sign CH Delta T signs will also negative because whether positive Delta T it is given nose down moment so CH Delta T sign should be less down 0 anything left here to understand okay, number wise is okay. Now come back to this diagram this is also part of the problem Okay? We keep this since we will be using so what is given in this diagram, it is writ10 in CM and CG y axis.

Why CM and CG you all understand the pitching moment is all calculated above the center of gravity because the airplane in free space will locate about an axis passing through center of gravity since this is the longitudinal motion. So this is CM about the CG of the airplane and what is here this is the CL, to the CL now what up to this 2 things 2 lines 1 is fixed elevator that is stick fixed case this line and there is free elevator.

Why does the slope as change you know that the nose of the air plane the elevator will float like this right? So, in a way the at equilibrium the shape is like this of hood of the camber so the reduction in the tail left so CM Alpha or Stability added by the tail will reduce hence DCM by DCL for a free elevator the slope will be less compare to stick fixed case.

Now they have given some number also if I we want to know what is DCM by DCL fixed from this diagram, Fixed means elevator fixed or stick fixed all are same thing, So this is CM given, this is CL given this is the fixed elevator case, this 1 are originally called stick fixed in DCM by

DCL will be a slope this is Y, Y by X that is 0.05 by - here I put 0.8 - 0.3 so there will be - 0.1 this slope of this line right.

This is physically 0.5 and this is 0.05 by 0.5 with - sign because more than it is the slope of the line is negative so this is - 0.1 so I get DCM by DCL fixed elevator fixed or stick fixed is - 0.1 so what is the interpretation for this. That means it as its static stability margin of 10% because I know DCM by DCL I can approximately write as - static margin or - of neutral point - XCG correct.

So DCM by DCL fixed is - 0.1 is DCM is DCL is nothing but - static margin so static margin is 10%, 10% of what 10% of the chord that means the distance between stick fixed neutral point and CG is 10% of the mean aero dynamic chord as simple as that. Now if you are do same exercise so DCM by DCL free so I want to find out and what is the value?

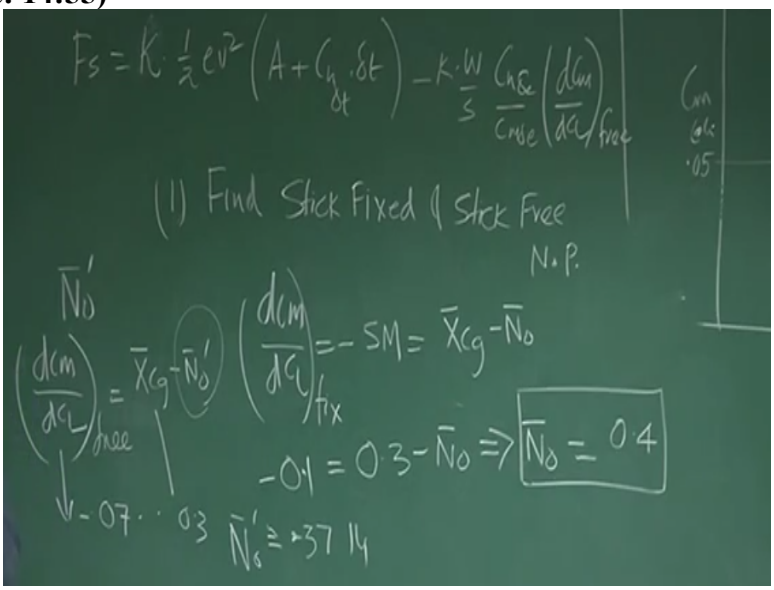
(Refer Slide Time: 13:42)

So, DCM by DCL free so which graph I should see this is fixed this is free so again you have to see the distance is 0.3 and 1 so it is 0.7 and this is 0.05 so this is - 0.05 by 0.7 and this value is typically – 0.0714. Please you yourself should do this calculation do not assume that I am doing it correct I will be telling you the process correctly numerical things that you have to do yourself so that you get correct number now if I compare DCM by DCL free and DCM by DCL fixed I

find yes DCM by DCL fixed has a larger negative slope and that is why we say naturally DCM by DCL fixed should be more stable configuration than DCM by DCL free why?.

Because in DCM by DCL free calculation reveal out the elevated to float and that become the equilibrium okay? Correct? So these are the interpretation of these numbers now will do the problem next.

(Refer Slide Time: 14:55)



Will star problem 1 by 1 and then calculate first question find stick fixed and stick free neutral point. You see after studying the problem getting the interpretation of number how simple is this problem you know that DCM by DCL is nothing but - static margin which is nothing but XCG bar - N0 bar because static moment mean N0 bar - XCG bar so - sign we absorbed by like this what was DCM by DCL fixed we just now calculated it was - 0 0.1.

This = XCG is how much given yeah, XCG as to be given so XCG is given as this problem you take XCG = 0.3 or XCG bar = 0.3 so this is 0.3 so I write 0 0.3 - N0 bar so this tells me stick fixed neutral point is = 0 0.4 as simple as that. Now if I ask you what is N0 prime how will you find out as simple as that you know DCM by DCL free will be = XCG bar - N0 prime this is the stick free neutral point this value you know as – 0.07.

Something you just now did it XCG you know 0.3 so N0 prime will be simply solving this and you have supposed to get N0 prime if I have not done. Any mistake and I should tell you that

repeatedly please do not blame be so I will write something approximately point 37 0.4 something like this you should yourself do it okay. So, this is the first question we solved on stick fixed and stick free.