Aircraft Stability and Control
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Lecture- 18
Maneuvering Point: Stick Fixed

Yeah dear friends, we were trying to develop an expression for Maneuvering Point. You know that we took two examples, one was steady coordinated term, another was pull up and doing that. We found out expression for pull up.

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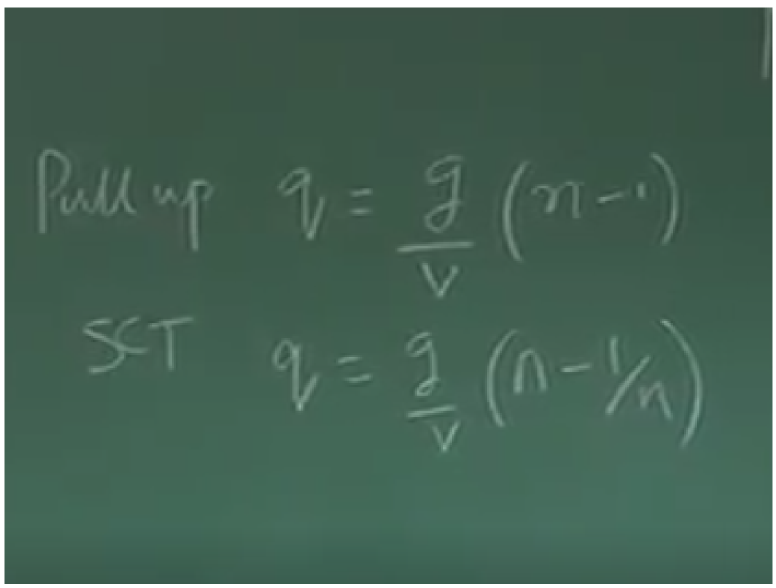

Pitch rate Q is called G by V into N - 1 and for study coordinated turn, Q was = G by V N - 1 by N, what is N? N is the load factor, and you could see that, if I want to have a pull up with a given load factor N, at a given velocity V then this expression tells you how much pitch rate you need to generate okay. And how to generate the picture it? You generate through elevator movement okay and how this pull up Maneuver is done?

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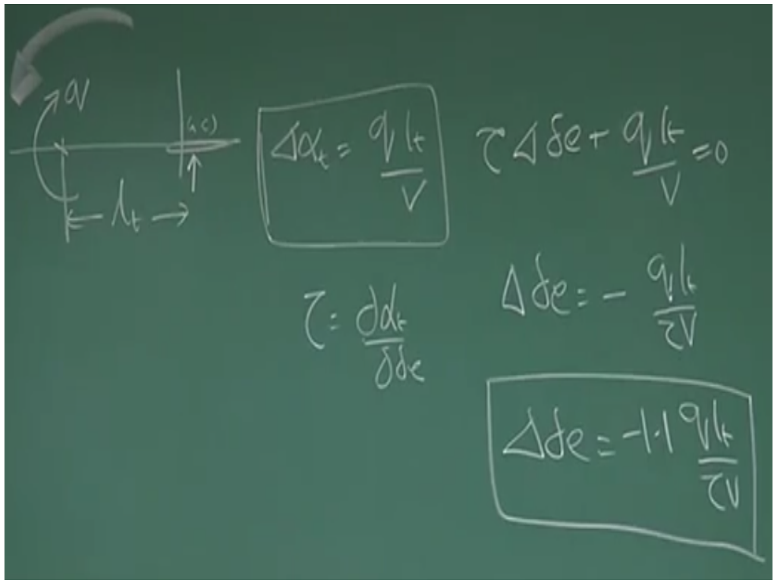

You know that I am going as a cruise, then I pull up I go for given elevator deflection, and I go in a radius and depending upon the value of N I need amount of Q through this expressing for a given speed V, right. Same story true for study coordinated term. The question was how much elevator, I should in addition put to get these Maneuvers. And what we realized was, suppose the airplane was going in a cruise, so further there is some Delta E required for trim which I know how to find out through Delta E = Delta E 0 + D Delta E by DCL into CL.

Now he has to give a additional input, elevator input to go for a pull up, and this pull up what we have realized is, if I see the tail then as it is going for a Q pull up then there is a additional relative air velocity this tail will see and that induces angle of attack that is roughly you can write QLT by V.

We have our LT as a distance between CG and AC of the tail. We have already done that and then we asked the question how much the Delta E I need to give in addition to whatever Delta E is given for cruise. So, that this additional angle Delta Alpha D which will generate a additional moment pitch down moment that does not happen to have to neutralize that, to neutralize that how much Delta E is required we derive it like this, Delta Alpha T which is QLT by V this = 0.

Because I know tow is nothing but D Alpha T by D Delta E so this tells me per unit deflection of elevator how much change in the tail angle happens. But from there I found Delta Delta E require is, - QLT by V into tow, and we also said that we need to take care of the fuselage portion of ahead of the wing and roughly it is not bad approximation if I just add 10% to whatever Delta, Delta E I am getting to this approximation so this is basically Delta, Delta E required.

To go for the Maneuver, please remember it is in addition to whatever Delta E, was given for trimming the aero plane for a cruise okay. So what happens now if I try to find out what is the Delta E is required? we showed that and that was given by.

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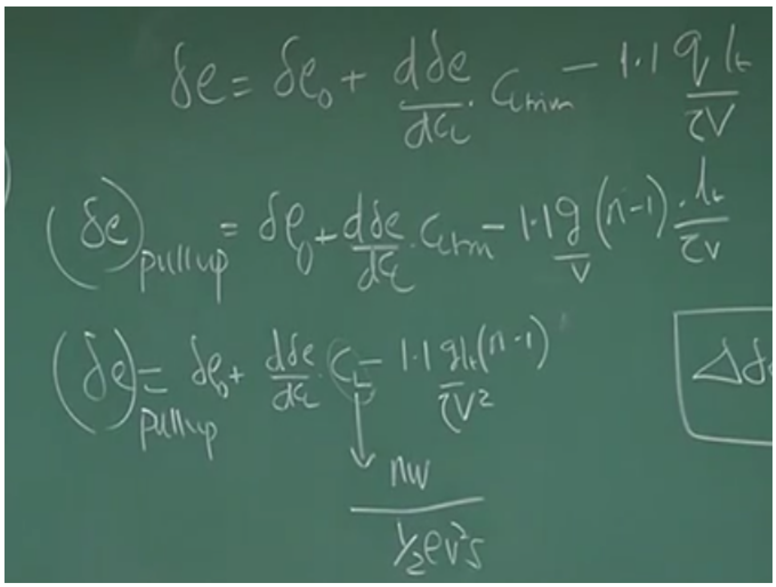

Next we continueDelta E you know that Delta E E0, + D Delta E by DCL trim into CL trim, this is required for the cruise, then because I am doing this maneuver. so this additional Delta, Delta E will come, this is - 1.1 QLT by V so I know that Delta E required for a pull up, I have to go like this Delta E0 + D Delta E by DCL into CL trim – 1.1 in place of Q.

I should put the expression for Q pull up, which is here tow will come, which is G by V N - 1 into LT by tow V. So if I write this expression I will get Delta pull up = Delta E0 + D Delta E by DCL into CL – 1.1 G by V, V square in this tow, this is N - 1 into LT. So LT I can put it here. This we have done last time, and we also realized what is this CL trim now because I am going for a pull up so lift is = NW so CL = NW by half row V square S so that is the CL value here which is NW by half row V square S.

You could see from here this is Delta E pull up you could see here if I am going from a cruise, at N = 1 so, this term vanishes and N is 1, so this is the typical CL for N = 1. It is a level flight okay. So, this is the expression correct which we have done last class.

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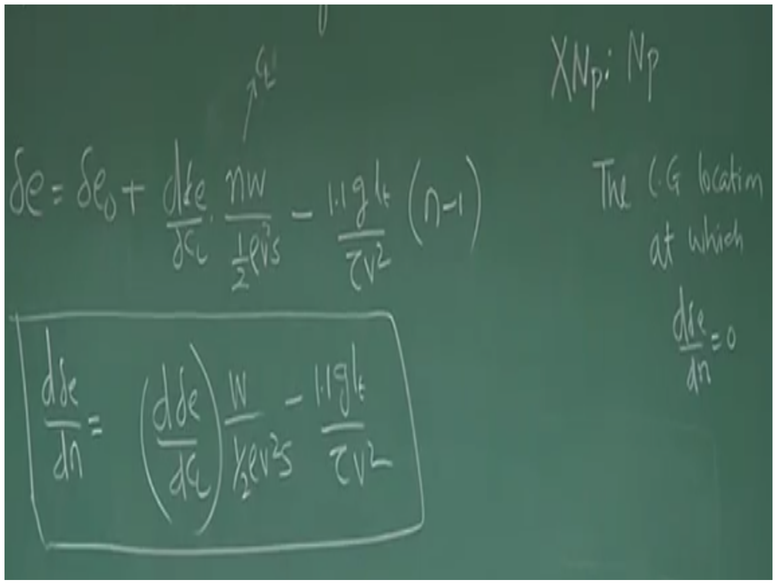

Let me continue will pull up, let me write this expression. Delta E = Delta E0 + D Delta E by DCL into for CL I write NW by half row V square S this is nothing but CL equal, this is CL expression right or lift is = NW, which you have been expert now so – 1.1 GLT by tow V square N - 1.

This is typically Delta E is required for a pull up, with a load factor of N right. Now let us see what D Delta E by DL that will be what that this man goes, so this will be D Delta E by DCL into W by half row V square S, - 1.1 GLT by tow V square, D Delta by DN so, this N so one is here and this N vanishes and this is like this. Now let us focus here.

We define stick fixed neutral point that is XNP as, or sometime NP this is as the CG location, at which D Delta E by DN is = 0, what was stick fix neutral point? It was CG location at which DCM by DCL is 0. What is Maneuvering point will define as CG location at which D Delta E by DN is = 0 right. So you can easily find from here the value because the CG location is somewhere sitting here remember D Delta E by DCL is what? That is XCG - N0, so it will be there, we will not we are simple algebraic manipulation.

And find out what is location for maneuvering point right. And I say we are now discussing about, maneuvering point is stick fixed, when I say stick fixed you all understand by now, that we are not allowing the elevator to float, that is give deflection and hold it okay. There is no floating tendency. So, whatever angle I have given for an elevator it is fixed there. Generally, since elevators are mounted through a hinge, there is a floating tendency of the elevator, which will come from the next class, next or one or two classes.

However you, remember we are allowing anything happens we say stick is fixed. So, now what happens if I put D Delta E by DN = 0, D Delta E by DN = 0, we get an expression, 0 = D Delta E by DCL into W by half row V square S – 1.1 GLT by tow V square. So from here you could see D Delta E by DCL is nothing but XCG - XN0 by CL Delta E or if you are not able to comprehend remember D Delta E by DCL was - DCM by DCL by CM Delta E and DCM by DCL was minus static margin.

So I write this static margin means, XN0 neutral point - XCG this is divided by CM Delta E. So this is D Delta E by DCL, so which I have written taken the sign appropriate to it is like that okay. And of course these are all non-dimensional with chord, so I put it like this bar, always I put the bar and understanding this is a non-dimensionalized with chord.

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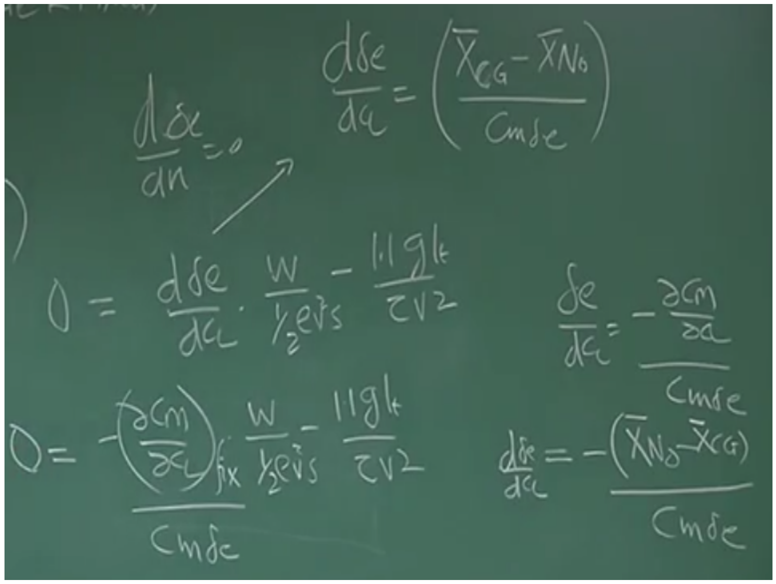

So Now what happens I put it here, so I get an expression 0 = DCM by DCL fixed right, into W by half row V square S – 1.1 GLT by tow V square of course here this is a CM Delta E because I know D Delta E by DCL is - DCM by DCL CM Delta E. So - DCM by DCL fixed by CM Delta E, into W by half row V square S – 1.1 GLT by tow V square, this is = 0 means.

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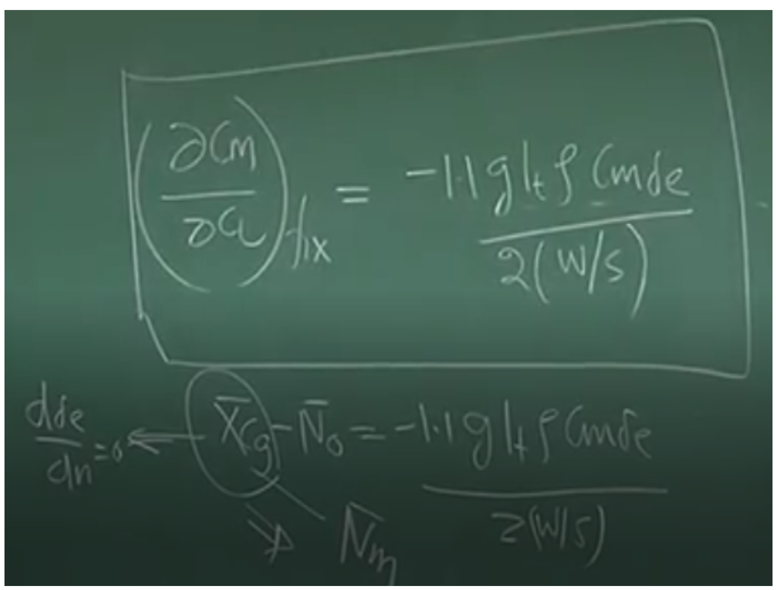

You may straight forward you could see DCM by DCL fixed = from here you could see this =, you could see this = let me, write the expression because, naturally we are wasting time GLT row CM Delta E by 2W by S. Once you solve this equation, you can easily show that DCM by DCL fix is - 1 GLT row CM Delta E by 2W by S.

I will advise you to do yourself these things otherwise you lose insight. What is our aim? Our aim is to find the maneuvering point and what was maneuvering point it is that XCG location at which D Delta E by DN is 0 and we have put the D Delta E by DN is = 0 from the regard this relationship. And now what is DCM by DCL shift? is XCG - N0 = - 1.1, GLT row CM Delta E by 2W by S.

Can you tell me how to get the maneuvering point expression from here, I repeat maneuvering point is that CG location, at which the D Delta E by DN is = 0, by putting it 0 by doing some algebraic manipulation, we have come to this stage DCM by DCL fixed = - 1.1 GLT row CM Delta E divide 2W by S. So now I get expression XCG N0 is = this. What is this XCG? This XCG is corresponding to the case where D Delta E by DN is = 0.

That is how I got this expression, because this is zero so from here I got this expression this XCG corresponds to case where D Delta E by DN = 0. That is how we derived, hence this XCG becomes of the maneuvering point NM stick fixed. Sometime I am missing this bar, please understand that whenever I am putting the dimension they are non-dimensional with chord, so please be careful okay. So what we have got from here? We got a very interesting relationship that.

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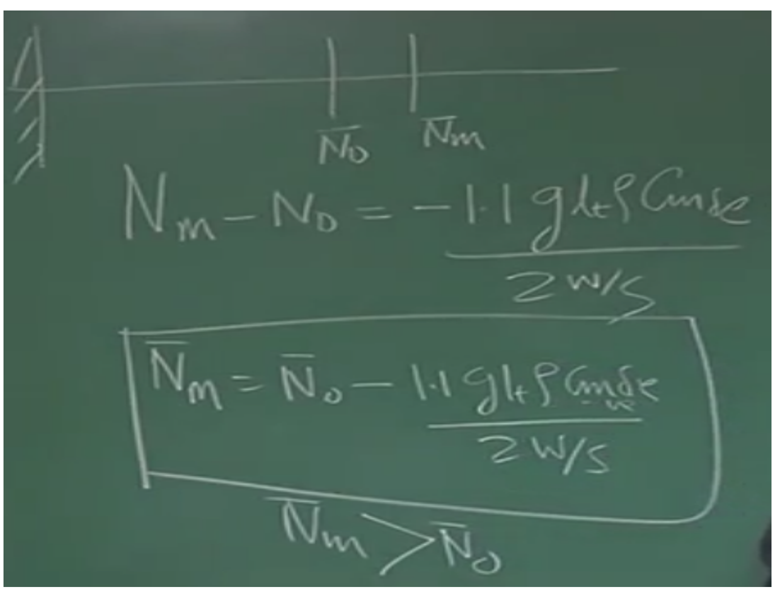

NM - N0, NM - N0 = - 1.1 GLT CM Delta E, and also a row divided by 2W by S, or I can write NM is = N0- 1.1 GLT row CM Delta E by 2W by S. What is the message you are getting now, you know that CM Delta E is negative so this term with - N, become positive therefore if this was N0 stick fixed okay then NM is greater than N0 because, this is - so - - +. So NM is greater than N0, that means NM will be aft of N0 which is correct or not? NM should be behind N0 means this is the more stable case, and we know as its goes for a pull up there is a Delta Alpha D which tries to give a nose down movement.

So apparently it becomes more stable right that is they indeed this expression, make sense because apparently more stable means the neutral point, the maneuvering point should be AFT of stick fixed neutral point, that is if I bring the CG close to N0 it becomes statically unstable but as for maneuver is concerned I can draw the CG up to this point were D Delta E by DN will be zero.

That is why this is maneuvering point, and this is stick fixed neutral point, this is stick fixed maneuvering point. This is a wonderful expression and generally we do experiment and I try to find out this, through some experiments. I will tell you how to do that okay only my worried to all of you that so many expression we write it should not loose insight please every time ask yourself why am writing all this expression, what I am going to find out, this is whole lecture.

We are trying to find out the maneuvering point, what is the maneuvering point? It is that the XCG locations at which D Delta E by DN become 0. So let us do little bit of more algebraic manipulation, it may help us to give some insight.

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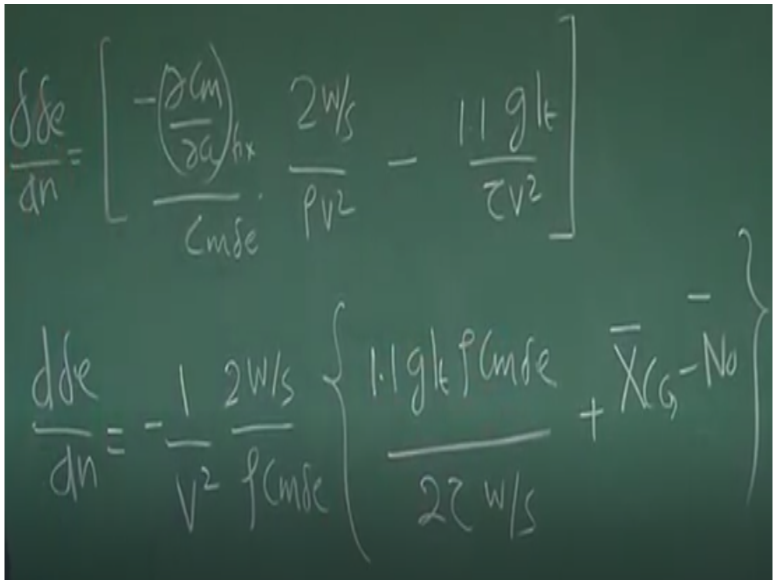

We started with D Delta E by DN = - DCM by DCL fixed by CM Delta E into 2 W by S row V square – 1.1 GLT by tow V square. This again I can write little differently D Delta E by DN we can write as - 1 by V square 2 W by S by row CM Delta E to 1.1 GLT row CM Delta E by 2 TOW W by S + XCG bar - N 0 bar nothing great we have done anything we have just taken.

This common, so since in the first this term W by S was not there, so I put W by S. So I get XCG by N0. So what I will do we know from this expression N0 = NM + this term, where from we got this expression by putting D Delta E by DN = 0. So this was the maneuvering point. So now there is a N0 lying there, so I will replace N0 by NM + 1.1 G. So this will further I will write as.

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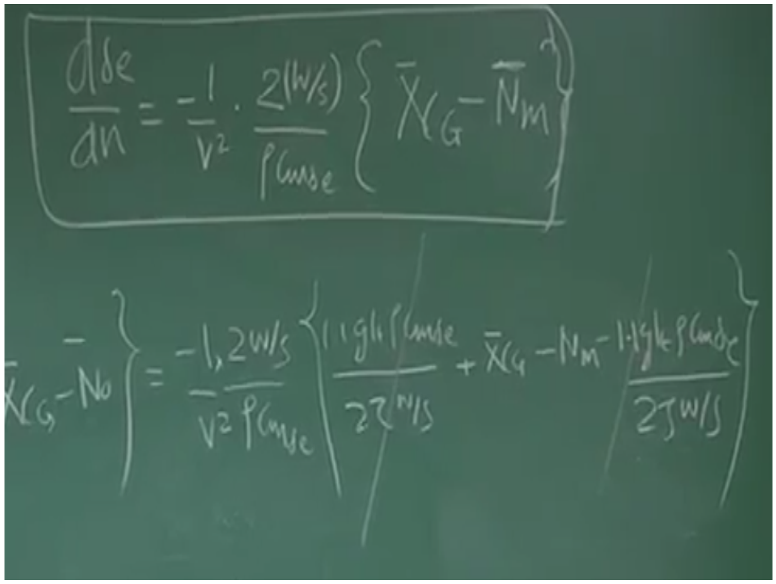

- 1 by V square 2 W by S 0, CM Delta E and then 1.1 GLT row CM Delta E, you please do yourself two tow W by S, then XCG bar for N 0 I am writing NM + this term right. Since this is - sign, - N0 so it will be - NM and – 1.1 GLT row CM Delta E by 2 tow W by S. Nothing great I have done.

Please I repeat, N0 I have replaced by this expression, N0 is = NM + 1.1 G LT row CM Delta E by 2W by S and what was happened by doing this, this gentleman, this gentleman get cancelled, and you get an expression D Delta E by DN = - 1 by V square 2 W by S by by row CM by Delta E into XCG bar - NM. This is very interesting expression, these expression we could derive, because we have assume that neutral point is a location at which DCM by DCL is zero, and here we assume that maneuvering point is at location at which is that CG location at V D Delta E by DN = 0.

Based on that by doing some sort of manipulation, we have come to this expression, and it can be verified that if XCG is at maneuvering point then D Delta E by DN indeed become 0. It also tells as D Delta E by DN, largely depend upon wing loading, and inversely in the control power and inversely in the V square. This is very very important from pilot feel point out view okay? Let us summarize what are the things we have learnt. See we know.

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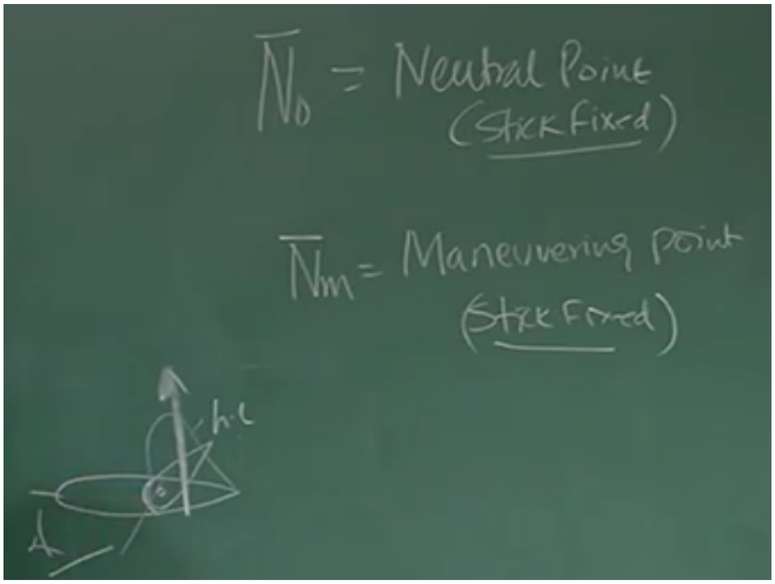

Now the definition of N0 sometime I have written it as XN0 this is called neutral point. Neutral point is stick fixed, then you have understood what is NM. It is maneuvering point stick fixed is the one what I am every time saying, stick fixed just for initial introduction and let me tell you that, if this is the elevator here because, this is the hinge line with any Alpha, it will have a tendency to float.

Because there will be a pressure distribution, and if this resultant is behind the hinge line in natural tendency to float this way or that way depending upon where is the location because if this fiction is too less. But when you say stick fixed, I am not allowing this to happen that's the meaning of stick fixed. The stick is fixed as I know how much floating is allowed, we will see actually it floats then what is the how to model the problem, that is the different issue. When I say stick fixed is stick is fixed nothing, no floating is allowed. Now the question comes how can I determine.

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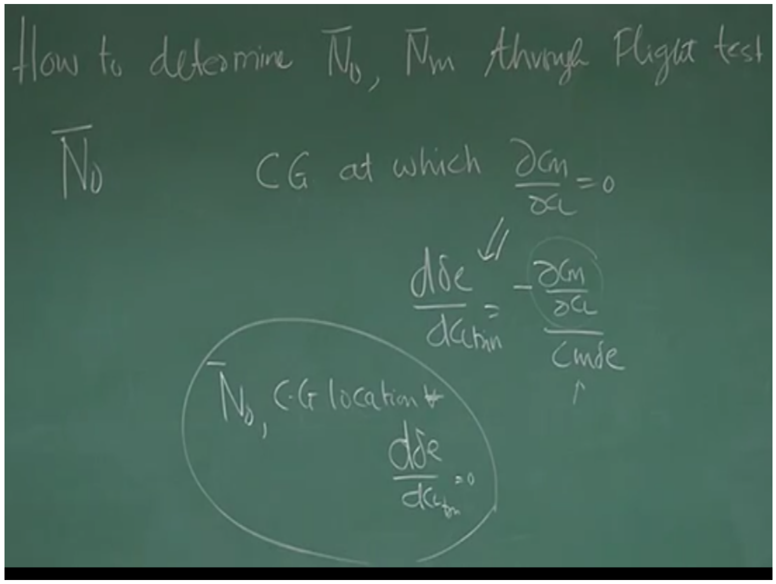

How to determine N0 bar and NM bar through flight test. Let us first talk about N0 bar, which is stick fixed neutral point. How do I define stick fixed neutral point? We will find it is at CG location at which DCM by DCL is 0. Now you also know from equation that D Delta E by DCL trim = - DCM by DCL by CM Delta E.

So if neutral point is at CG location at which DCM by DCL is 0 I can equivalently say because DCM by DCL is here this becomes 0 this is never 0. So I can equivalently define neutral point in that CG location, for which D Delta E by DCL trim 0. This is an approximation is because you know whole this expression is an approximate expression. But from experimental point of view this is good enough right.

Why this is important because, when I do experiment I can easily measure Delta E I can calculate CL trim right? How do I measure Delta E?

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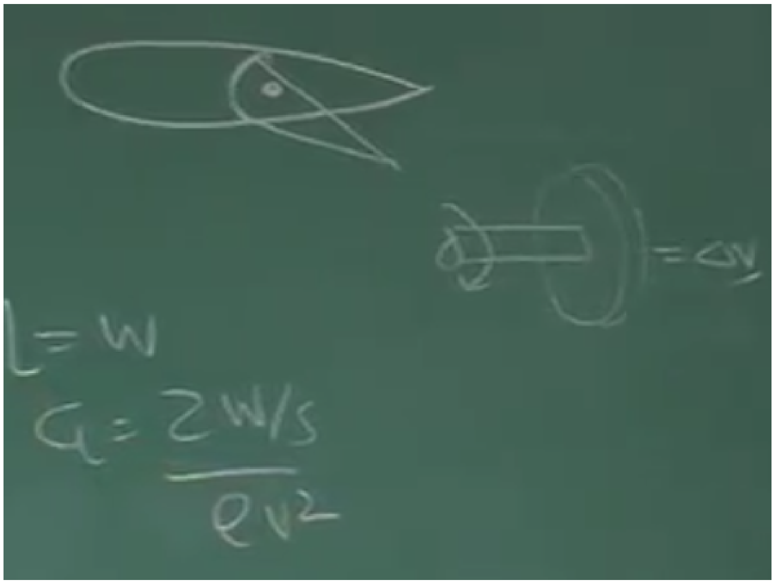

You know if this is an elevator, when the elevator rotates it is connected to a potentiometer shaft rotary potentiometer something like this so as this man rotates the shaft also rotates and then it develop some potential difference of voltage and that voltage I can calibrate and get what is the amount of deflection of the elevator. So it is easy to measure and CL trim always, you know we can do it.

Because lift = weight and CL = 2, W by S by row V square so if I know about altitude I am flying can get the density, if I know what is the speed I am flying I can know this V square and what is the W by S weight of the airplane and the wing area. So this also I can compute easily. So to calculate neutral point to the experiment, I will be using this concept that it is the CG location at which D Delta E by DCL trim is 0. So how do I do this experiment? Let us understand that.

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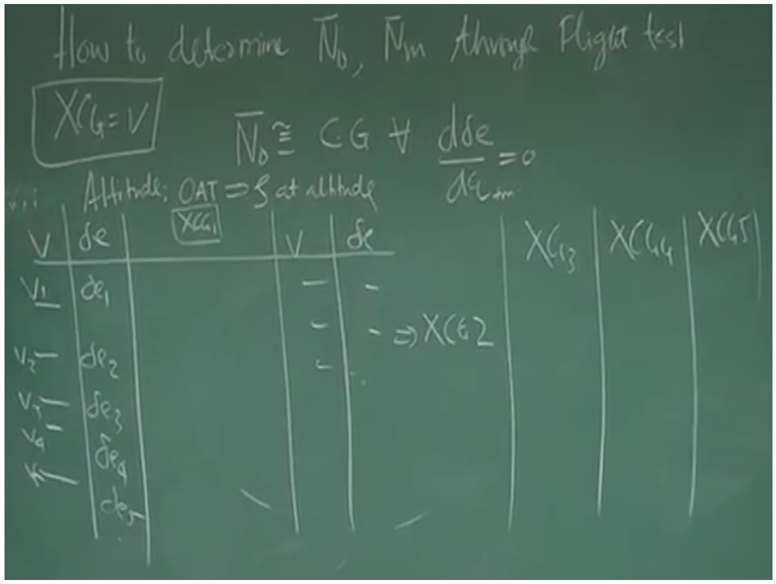

So we are saying it is N0 is that CG location approximately for which E Delta E by DCL trim is 0. So what I do? I go for an altitude let's say altitude, I also note down the outside air temperature because I need these two information to calculate the density of the air at the altitude right? This is required for calculating row at altitude, okay. Now what I do? I cruise I go to the altitude at the cruise at a particular V let's say V1, V2, V3, V4, V5 and then ensure that.

I have trimmed the air plane, because I am cruising, so I will measure that Delta E so Delta E1 Delta E2 Delta E3 Delta E4 and Delta E5. I repeat I will go to an altitude, I will fly at a particular speed and note down what is the elevator deflection given for trim similarly for V2 what is Delta E2 like that up to V5 what is Delta E5 I can take 6 7 8 9 10 readings whatever is possible. But before I do this experiment remember what is our aim?

Our aim is to see that what is that CG of which the aircraft becomes neutrally stable or Delta E by DCL trim is zero equivalently. So when I am going for the experiment I should note down, what is the CG configuration of the airplane this is extremely important. So what we do? Suppose we are five passengers are going so we will take the weight and find out the CG location okay. And let's say this reading is for a one combination of XCG 1 then second batch will go we will also generate.

Similar reading VN Delta E right which will be corresponding to XCG 2 location. So different people, different way they can swap here and there, and give try for different CG different location like this XCG3, XCG4, XCG5 various combination of CG we will fly, and we will trim at different V1, V2, V3, V4, V5 okay. Once you have done that, if I take first case for a combination or the combination X, XCG 1, one group so I can plot for the group.

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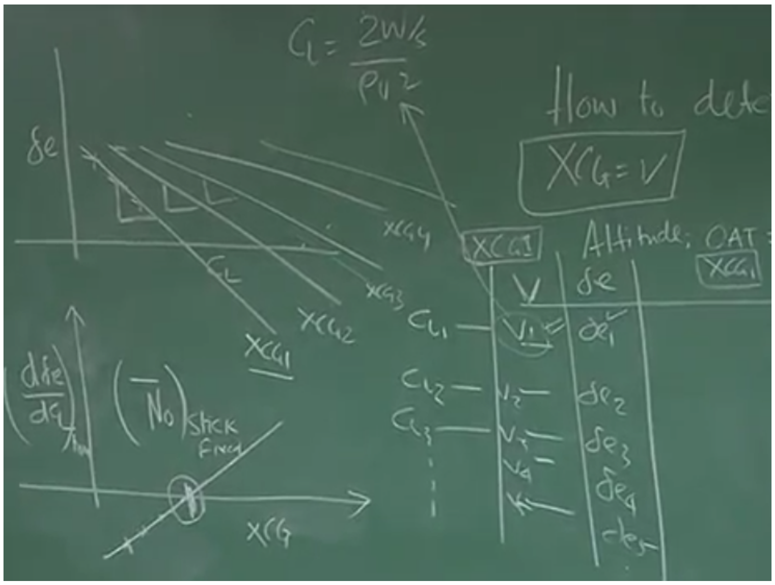

What is Delta E and what is the CL so the question is how do we find the CL? You can answer beyond cruising. We are trying to find out N0 we are cruising and when I cruise that means, CL = 2 W by S by row V square, since we are taking all these measurements you will know what is the value of CL for a corresponding V.

So this is CL1 this is CL2, this is CL3 like this using this relationship. So you have Delta E which you have measured we have CL1, which through V using this relationship, I got CL1 for XCG 1 combination that is for one group of people the total aircraft CG is let's say XCG 1.

So I will be plotting this, and I will get a graph D Delta E by DCL + XCG 1 correct. So similarly I take another case for XCG 2 again I have plot Delta CL so there is a graph is like this, the second maybe like this, and third one maybe like this, fourth one maybe like this depending upon where is XCG to XCG 3 XCG 4 now what I should do?

I will take the slope of this line and the cross plot, D Delta E by DCL and the slope versus XCG clear. So I take the slope, I take the XCG location, so this is the point I take this slope and this is the CG location so this is the point. Like this I will get points I join then and it cuts at the point of X axis.

So this is the point at which this is the CG location, at which D Delta E by DCL trim is 0. So this is the neutral point stick fixed clear? Let me repeat, we want to find out N0 which is the CG location for which D Delta E by DCL trim is 0. Now how do I do that? I know how to make sure elevator deflection, to an instrumentation based on potentiometer rotary potentiometer. So I go for a cruise I note down the altitude.

I note down the outside air temperature because, this will be used to find the density at the altitude, of air at that altitude right? I fly in a configuration let's say four people and we are a fuel in the tank, so you will find out what is the XCG location for that configuration. I call it XCG 1, then I cruise that V and select and check what the Delta E elevator required for trim. Similarly, now only for V2, V3, V4, V5. So I have series of V1 Delta 1 V 2 Delta 2, like the V 5 Delta 5.

Now once I know what is V, at what we say V1, I need to know what is CL1 because I want to find this D Delta E by DCL trim so CL trim I can find because I know I am cruising so CL is given by 2 W by S row V square. So I use this V I use this row then I find what is the CL? And then I plot Delta E versus CL for the XCG 1 configuration.

I draw a straight line so will be found XCG 2, XCG 3, XCG 4, XCG 5, now what I do I take the slope so d Delta E by DCL and this correspond XCG 1 so I mark it here similar here. So all this point when I join extrapolate and where it cuts this is the XCG location at which D Delta E by DCM trim is 0, so this is called the neutral point stick fixed. This is the way to find out experimentally, okay.

Now once neutral point stick fixed, you know how to find experimentally you need to also know how to find maneuvering point stick fixed through experiment.

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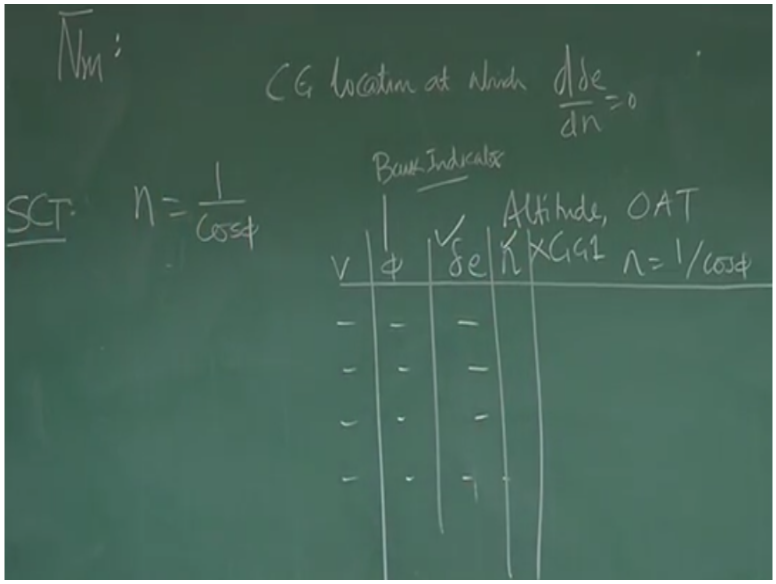

So now we will be discussing how to find out experimentally the maneuvering point okay. What is maneuvering point? It is that CG location at which D Delta E by DN = 0 correct. What is N, N is the load factor, and Delta E is the elevator deflection okay. We can do two maneuver that will be actually doing say for it is a coordinated turn and what is that I go like this and bank the airplane and turn like this without losing the altitude. And you know in this process the nose factor is given by N = 1 by COS. So whatever bank angle I am maintaining I still maintaining the coordinate turn from the bank angle.

I will see for the top feet what is the bank angle, immediately I know what is the load factor because I know N = 1 by COS 5 if the air plane is taking the study coordinated turn, without losing any altitude. So, indirectly I am getting the angle of load factor, through back angle and bank angle, I see from bank angle indicator which is house in the (()) (34:32), okay.

So now how do I plan it? So what I do? Again I go for an altitude right then I will note also the temperature and then I take XCG 1 again one group of people they are going for one experiment so they will go for a steady coordinated turn and they will note down what is the V what is the five, and what is the Delta E right clear?

So how do I get five, five get for the bank indicator, bank indicator is there they cooperate from there you can find bank indicator right. By knowing five immediately you can calculate what is N, because N is = 1 by COS of 5 so know you have Delta E and you have N okay for a given XCG 1 location okay. So again I will do that what I will do.

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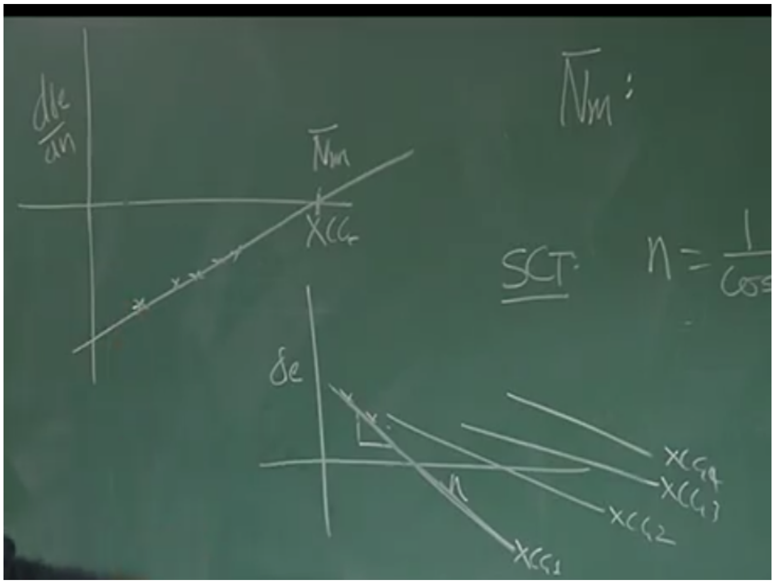

I will plot Delta E versus N I will get some value and this is XCG 1. Second batch will go and do exactly the same, but that will thrust on to a different CG location. Because different people will be sitting different weights sometime what we do initially go five people to get that they will put two people to get there then they will put one student in the front. So that there is the difference in the CG location, with the variants in the CG location, so you can do like that let it be XCG 2, this is XCG 3, and this XCG 4 like that you will get different data points.

Now what we do again you recall maneuvering point is that CG location at which D Delta E by DN = 0. So I will find D Delta E by DN from the slope of this line, it will be straight line approximately so I put D Delta E by DN and this is XCG so again D Delta E by DN 0 for different CG location I will get point if I join them this is my NM.

This is the CG location at which D Delta E by DN = 0 so this becomes my experiment to determined maneuvering point. Is this clear? You could yourself check why D Delta E by DN for a given XCG location be negative, see the expression of D Delta E by DN and put the appropriate sign of the derivatives, you will find the answer okay and I am sure you will be able to do it. I may ask such questions for the assignments. Okay, thank you very much.