Indian Institute of Technology Kanpur

National Programme on Technology Enhanced Learning (NPTEL)

Course Title
Introduction to Experimental in Flight

Lecture – 12
Estimation of Stick-Fixed Neutral Point

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Good morning friends in the experiment we had on cruise climb right okay so how the experiment to get the data how many of you feel sick for vomiting tendency and all non sure so what was the speed at which you where curse in how much okay 100 naught surround there what is the takeoff speed for this airplane anybody as noted so went to 18 or so this is roughly 40 meter per second okay that is a good observation.

So yesterday whatever briefly we had on curse climb that is primary to check what is the drag puller of the airplane essentially we try to find CT naught and K right and also from rate of climb experiment we try to find out what is the speed at which the rate of climb is minimum right what was the basic assumption on those theory what we wrote the expression for rate of climb or for curse the trust equal to drag light equal to weight.

What is the basic assumption was the aircraft is statically stable dynamically stable otherwise we cannot write those equations right so what is the meaning of static stability when is say an aircraft is statically stable what is the meaning what do you understand by that so let us first see their okay what is the meaning of static stability.

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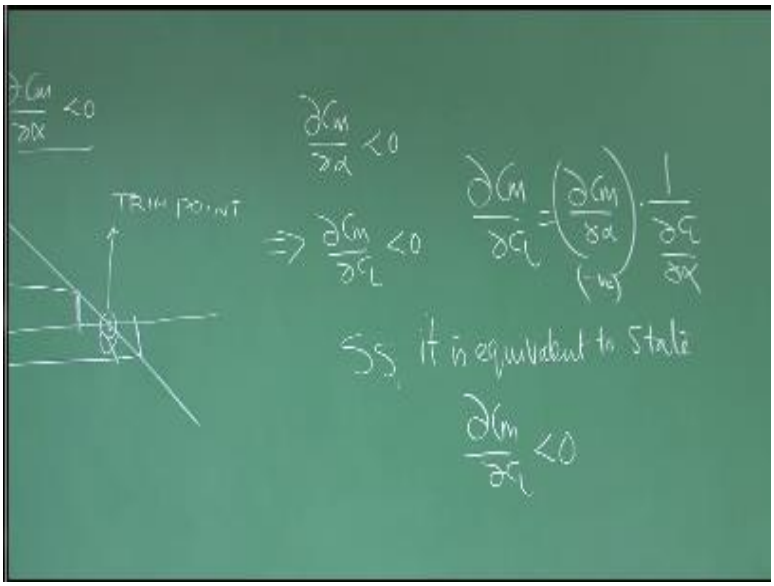

Just I will go through quickly because these things are already available when you talk about static stability mean is the aircraft in equilibrium if it is distributed by some external agency or internal agency and once the disturbance withdraw if it has a initial tendency to come back to the equilibrium we say statically stable the catch word is initial tendency to come to equilibrium right and what is the meaning of dynamic stability it should not only have initial tendency but in finite time it should come to the equilibrium so in dynamic stability we were taking in terms of time response.

Right in static it is only the initial tendency there should be very clear right and if you recall in your stability and control course we always use this sort of graph say cm verses α right the slop should be for static stability this slop should be negative right how we will appreciate this let us say this point we will call at time point means add this point net cm is 0 that means all the movements because of engine because either any forces all net summation is 0 about the center of gravity.

Correct so this is trim point and now I want to check whether the aircraft is statically stable or not how do I check I say suppose for some reason α as increased because of let us say up word

guest as come right so the movement this up gust comes here what the apparent does aplenty 0 raise and negative movement when the angle of attack is increased so the negative movement it will try to have a initial tendency to give roles on movement so initial tendency tom come to the equilibrium.

Similarly for a satiation suppose α gets reduced because of some disturbances so what this will do the movement α is reduced from this graphic to see it will generate a positive cm right which will try to take the lows of that is initial tendency to take it back to the equilibrium so once we cm verse α or say DCM / DCL or DM/ D α is less than 0 we say they are privilege statically stabile now to extend it further we know if DCM / D α less than 0 it will remains DCM / DCL is less than 0.

This is obvious because you know DMC / DCL I can write as DCM / D α into 1/ DCL / DR that is DCM / DCL I can write as DCM / D α INTO 1/ DCL / D α right in linear understanding if everything is linear I am very happy those two things are equal mathematically and since you know first static stability this man as to be negative and what is the sign of DLC / D α is always positive so if DCM / D α is less than 0 it automatically means DCM / DCL is also less than 0 so for static stability we can also say that it is equivalent to state DCM/ DCL less than 0 right there now let us go 1 step deep into it.

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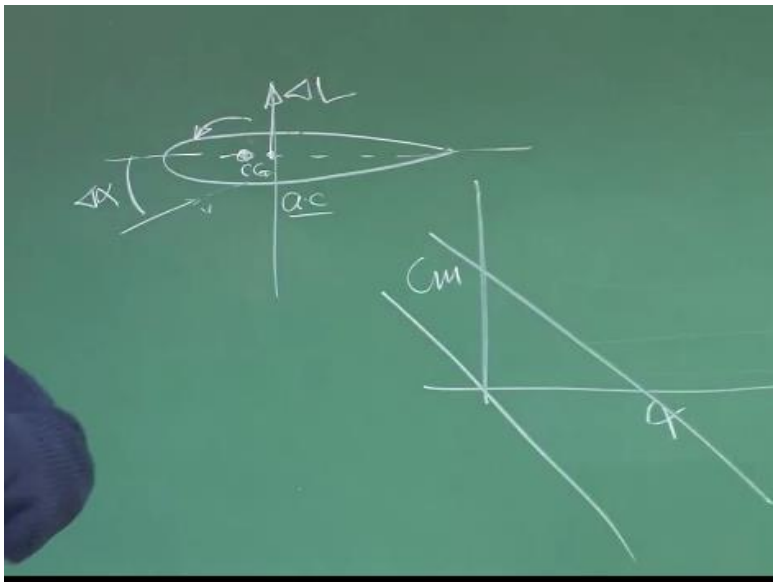

If I take a wing let us say wing is here and let us say CG is somewhere here and if I want to ensure that these wing is also in flight it also is statically stable then where do I put the aero dynamic center, where the aero dynamic centre should be, VISSA verse the CG will the aero dynamic centre be behind CG or ahead of CG, behind CG right? Or if I put indirectly because I know aero dynamic centre of an wing which is based on the aero fall cross section.

Is for a low speed is almost fixed at a quarter a quad point so my statement should be correct to saying that why do I put the CG to ensure that the aircraft is which is a wing is statically stable the answer would be make sure the CG is ahead of the aero dynamic center of the wing right, so CG should be ahead of aero dynamic center of the wing let us say this is the aero dynamic center.

You all know what is aero dynamic center right now let us check whether it follows this trends CM verses alpha the slope should be negative okay we want to check that so what we can see here if I give a disturbance delta alpha in flight what it will happen I will lead to a lift force delta L which I am drive perpendicular because if alpha is small I really this sleep should be perpendicular to velocity vector.

But since angle is small I am taking liberty to draw it like this, so the moment because of delta alpha there is delta L since AC is behind CG now we see that delta L is acting behind CG which will give a nose down moment so DCM/D alpha < 0 so it is statically stable, this concept we all know and is clear now right.

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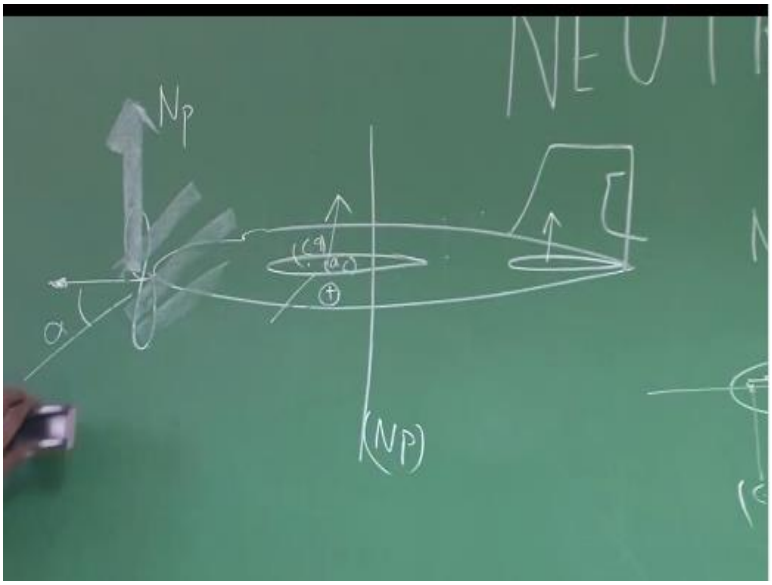

If I look for an air craft you see that there are components like origin there tail wing then these are few large the ranging right all will contribute towards the pitching movement for example if you see wing whatever forces acting on the wing depending upon where is wing out of dynamic center what is behind CG of the plane or not that will decide sign of the pitching moment because of wing tail half tail you know it will be in variably behind the centre of gravity of the airplane.

So you know half scale will always give a negative pitching movement for a positive angle of attack, for from the thrush point of view if you see ideally thrush is like this but if there is a angle of attack that means the air it is pushing the air like this so there will be a normal component of thrust also here we denote it by NP this part is clear, so this will give a positive CM about CG, right.

So if I recapitulate if the engine is at the nose this will always give dis-stimulating effect because for a positive alpha I where negative movement but engine if it is like this but positive alpha it will give a positive movement so this will be dis-stimulating, right. Wing depending upon whether the AC of the wing is ahead of CG or behind CG it will decide whether it is stabilizing or it is stabilizing.

But one thing is for granted that the tail will always give stabilizing contribution right, so for the whole year plane equivalent to aero dynamic center we define something call neutral void okay because neutral; point and how do I define neutral point let us understand that, sif it was just a weaving with aero foil like nothing like fuse large or a tail then if this is the aero dynamic centre of the wing which you know for a low speed it will be at quarter quad point right, C/4.

So this is the AC now I start putting CG here so will the aircraft be stable statically stable or not, stable now I push it backward I put it here CG then aircraft stable or not statically stable if I out this CG here exactly on the AC line statically stable or not a neutrally stable very good and if the CG comes here then it will be unstable so now allow me to define neutral point, neutral point is that CG location at which the aircraft becomes.

So neutrally stable right or stability become neutral so for a wing type configuration what is a neutral point, it is a atomic centre now for an air well like this the neutral point you decide by how effective with the horizontal tail because this is giving you stabilizing so for an aircraft we have got a sudden point depending upon the size and sero dynamics of whatever surface you are using there is a CG location.

At which the DCM/DCL or DCM/ D alpha of the airplane will become 0 so that is the neutral point that is if the CG is put behind the neutral point the aircraft will become statically unstable is this part clear or not, you have all done this right, okay. Now we have to do an experiment by flying an airplane and using the data how you want to find out what is the neutral point of the airplane.

Definitely we are all going to fly with the configuration where CG and neutral pointer coincident we will not fly at a neutral stable conditions when we flying in a stable condition but from data through establish and we will try to find out what is the neutral point is this clear, right. How do I do that, if you recall you have?

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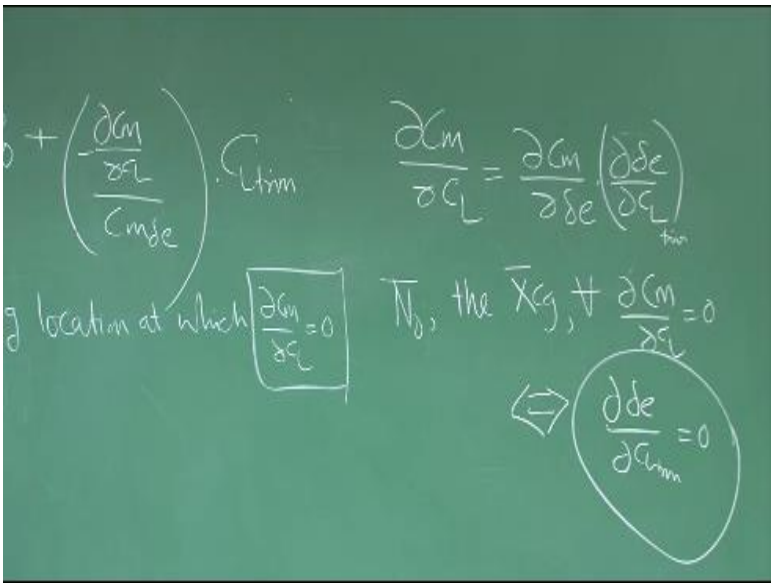

This I will write this, this is also if you recall from your stability and control close if I want to find out how δ you require to trim an aircraft at a particular CL for a given CG location so I can easily find out suppose if I had a trim at this point at the CL what is the δ required will be given by this, right which is express approximately like this, right could you recall this, okay. Now what DCM/DCL here is the static margin, right so and now you could see that if I am interested to find what is that CG location at which DCM/DCL=0 how do I conduct that experiment that is the question.

This is a very innovative way of thinking into this is DCM/DCL I can write as DCM/DδE into DδE if I assume everything trim, if I assume things to be linear then I can always I did like this through CG rule, right. So we are talking about neutral point $\bar{N}_0$ that is a bar when I say bar means it is not domination like width mean be record of the aero plane, so if you under look N_0

that is the CG location I say $\bar{X}CG$ for which dcm.dcl is 0 so equivalently I can say from this expression that DCM/DCL IS DCM/DδE.DδE/DCL trim what is DCM/DδE control power that cannot be 0.

So it means if dcm/dcl is 0 is equivalently says that DδE/DCL trim is 0, correct it is that okay, now the point is when I am doing experiment if you want to find out that CG location what the measurement I need to have, I need to measure what is the eliminated deflection when I am trimming the aero plane and what is the CL trim, Cl trim how will you find out, CL trim I will find out from left equal to width left equal to width at trim.

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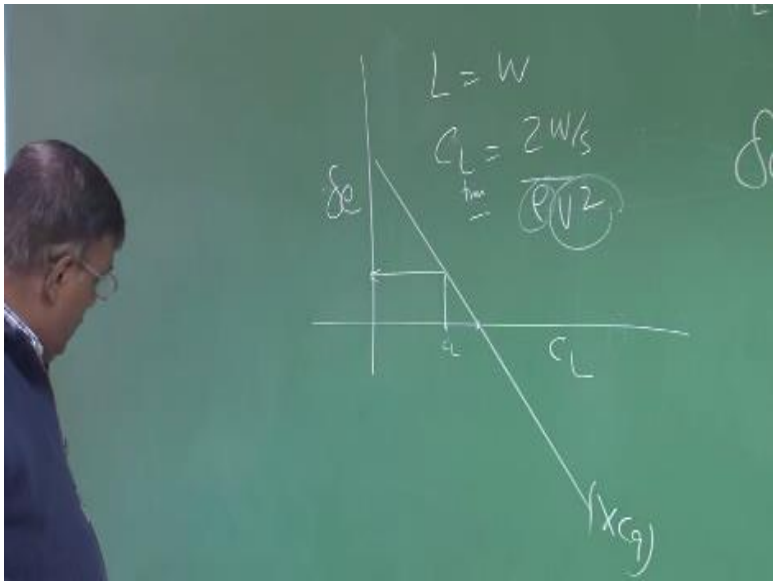

Let us say at this point lift is equal to width so I know CL will be equal to $2w/s/\rho v^2$ and all these things you know how to measure ρ you know to measure through how they estimate through temperature and standard stable and v you know from air spray indicator and you can all do corrections so this is a known to you so CL trim you know, only thing for that CL trim what is the δ you required that you have to measure, right and to just give a better understanding for this you can sue this graph for understanding.

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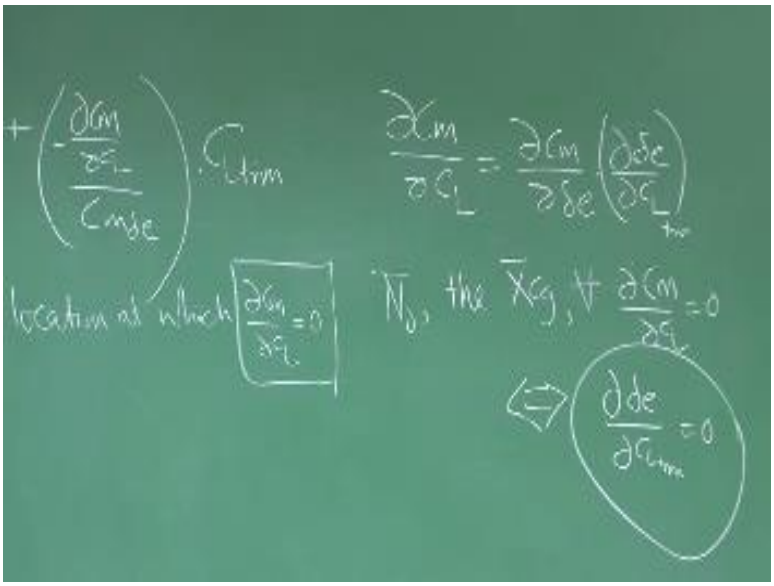

Suppose you have let us say this way I will explain differently, suppose I am flying so as that Cm verses CL graph is like this you all agree that DCM/DCL has to be negative it has negative so trim point is here suppose you are flying at a CL trim 1, CL trim 1 means you are flying at the velocity v and densities has that lift equal to width, what a given width right, now you want to fly at this CL so the stability will not change then what we have to do to fly at this CL the moment you want to fly at this CL this aero plane will do what it will be generate negative pitching moment it was no, no I will not allow you because it is statically disturb will but you have to hold it.

So how do you hold it if it is 0 at the negative pitching moment you have to generate a positive pitching moment so how to you do that by putting elevator up, so that is this elevator we are talking about right, okay so we have to this will be corresponding to an elevator up and a along you can measure how much the elevator has been deflected as long you estimate CL I am happy to measurement are made so this is what is required before w go to the next how do process this let us briefly discuss how do you measure elevator deflection okay, then will back to this.

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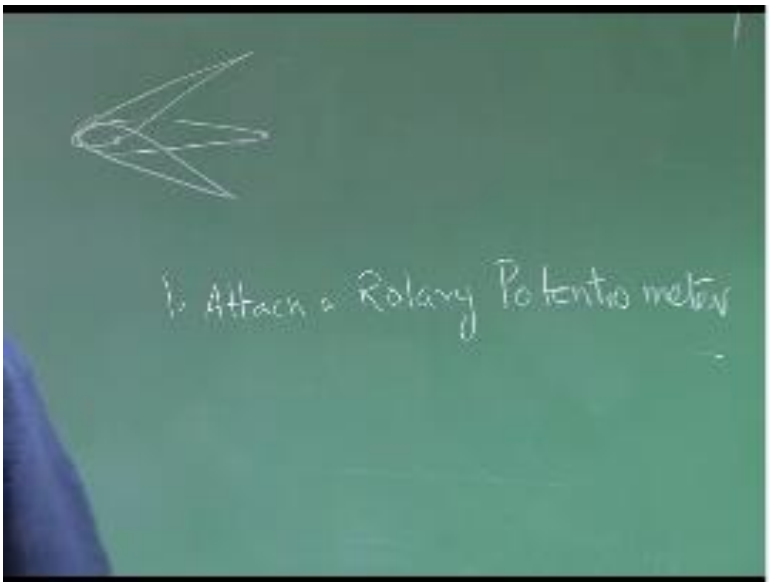

See after all this is your hellions so our hellions elevator whatever it is control surfaces deflection will goes like this or it may like this right going like this so what we do at this point we add attach a rotary potent ion meter you what is rotary potent ion meter all those knobs set of any notation registries will change the voltage will change right so put a rotary potent ion meter here so as the pylori give the deflection there is rotation in the arm of the rotary potential meter so that will give a different voltage and that is recorded through a levied whatever setup we have got which you have a separate.

And if you calibrate that this much voltage means this much deflection on the laptop will find automatically it has recorded okay you have to already use some spectrum initial taping a here and there but the physics is we use a rotary potential meter which is link to the movement of this control surface as it rotate the potent ion meter shaft also rotate as it rotates the register is changing the voltage changing and from the calibration we find it is equivalent to 2^0 3^0 or 4^0. This measurement is done so once we are confident about this let us see how to bill out theory for this we are talking first about.

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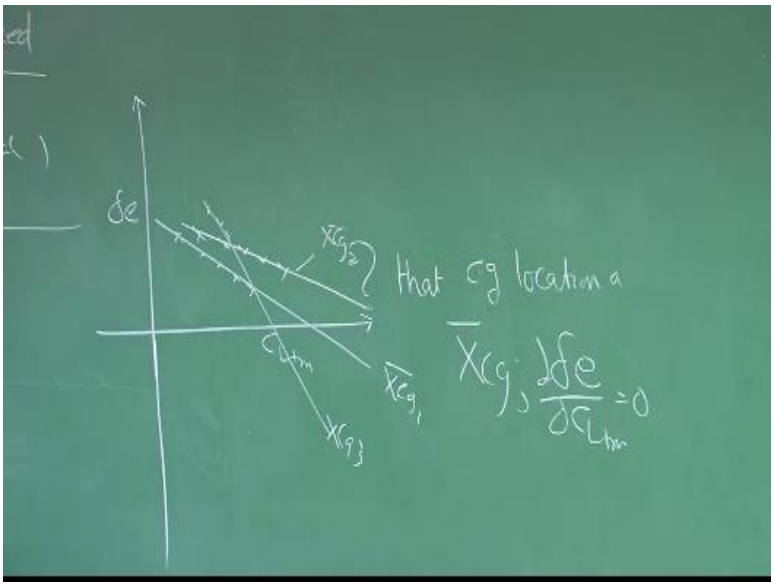

You should go and generally we say stick fixed what we have seen mutual one is stick fixed is that CG location at which DCM/DCL is 0 which equivalently I say mutual point stick fix is that CG location at with detailed de/ dcl extreme is 0 correct so what are you look I will go again as I told you go and note down what is the altitude and what is the outside here temperature this we must note down.

Now the pilot will be setting his aero plane in trim that means he will be trim cruse okay, so he will be doing a cruse at speed v1and he note down through a laptop arrangement what is the δe for that configuration right suppose we are cursing at 60 nodes δe will be record on the laptop say 2 degree or 3 degree plus so that you are noting down. Similarly he will again curse that v2 δe2, v3 δe3 like that so you will have for a particular configuration the value of v1 δe1, v2 δe2, v3 δe3 like different combination. So what he will do as you have this experiment you have noted down what is the speed and what is the and you know very well I am trying to find out what is the XCG location for which dδe/DCL trim is 0, so 1 is δe and CL trim CL trim we know how to find out δe you are measuring you have to measure XCG also.

So what is the solution, before you go for experiment you take the aero plane will be using answer 3 take the aero plane to the balance and pilot will be there either he will sitting or a person who has equivalent weight of he will be sitting and person who will be doing the experiment will be sitting in the co-pilot seat then the other phrase will take the reaction so that offline you can find out what whether the CG configuration you are flying it is clear. So if different students are sitting at a different flight the CG will change CG will also change because fuel will be different so we are generating the data for different, different CG location is it clear.

So you are generating data that the data means for this speed or for this CL what is the elevator deflection require because generating for different CG location means different static margin values, clear okay. So you have δe and CL trim let us say this is some point here or you may get value something like this, so 5 point you have taken, this is for, Xcg 1, that is one group has done this experiment, that one group, one member from the group will be flying with answer.

Now the next group does the same thing, again takes what is altitude, what is outside temperate, what is the speed, what is ΔE, for different, different speed domain, will note it down through laptop arrangements, so he does that and then he generates something like this, so this corresponds to Xcg2 location and another party you does something like this, may be Xcg3, like this Xcg4, Xcg5 combination.

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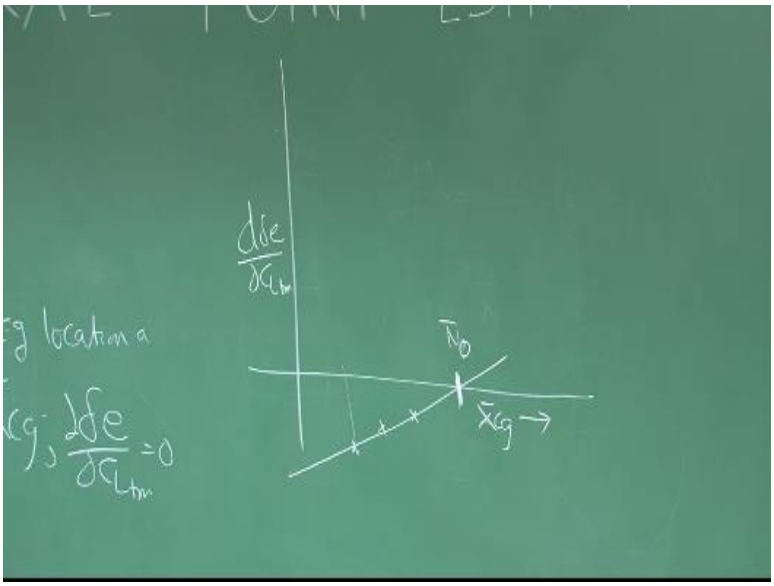

Now what is your aim, your aim is to find neutral point. So how do I use this data to find neutral point of the airplane; that is the question, right? So now let us see if I use this graph, from each cg location, I can plot vΔE/Dcl trim versus Xcg location isn't it? Let us take this Xcg1, take the slope of this line, that becomes the ΔE/Dcl trim, this transfers to this Xcg1, so I take that value and this transforms to this. Similarly for another if this, for another is this, now I joined this and whenever it cuts, what is this point, this is the Xcg location, where dΔE/Dcl trim = 0, and that is our neutral point.

You find neutral point by this method, okay, clear? Everyone is clear? So what you have to do, when you go for a flight, where's the pilot stats trimming, note down the altitude and temperature, speed and ΔE, ΔE will be recording the lector, One of our RA will tell how to use that and then offline will be processed like this, so now after this neutral one is over, we may do something on maneuvering point, you remember what is maneuvering point?

Some of the airplane is statically stable, and when it goes for a maneuver it will become more stable or less stable? See as it moves like this, then the tail plane will see a vertical component of

a, so that will give the angle of the tail, so that will give a nose on moment, it will give more nose on moment.

This more nose moment is where, it amounts to stability being more, right? So that is why, also you know that this has something to do with the damping of the system, p and q terms. So in j, if the airplane is maneuvering like this, because its half still as it move like this, the wind device comes like this that gives additional angle of attack which, gives a nose on moment which helps in material most stubborn, when it becomes more stiff.

We have to find out what is the cg location, I can correlate the, correlate that with maneuvering point, we call it maneuvering point, we do not call it by neutral point. By definition recall your flight dynamics, flight mechanics lecture on stability and control.

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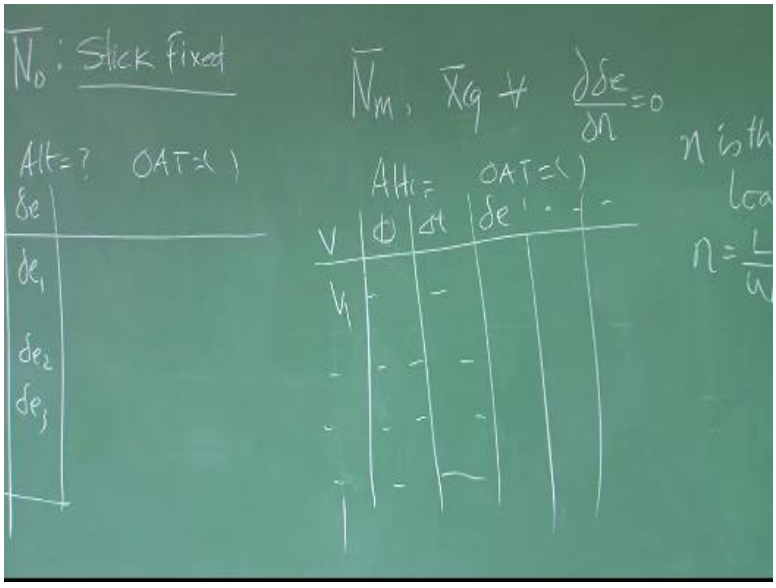

The maneuvering point Nm, non diminitionalised with minor dermis card, is defined as dash cg location for which $d\Delta E/dn = 0$, where n is the load factor, am I correct? How to define load factor, L/w which is nothing but $1/\cos\varphi$ if it is a flight, if your turning like this the load factor becomes $1/\cos\varphi$, so it clear to everybody? So now we will be doing this experiment using a

steady coordinator time or turning flight to find out the maneuvering point for this airplane. What I have to do, I will create moment this first experiment, bilateral now I go for a turn, so note down the altitude, what is the outside temperature.

Then note down what is the week, you say I started turning, you are supposed to carry a stopwatch or mobile phone, all you have to see if it taking a 90 degree turn, how much time taking, so you can get a lap point here turn rate, please note these things, that will not record in the laptop.

Now what we do in as is to making a turn it will be banking how will you make a turn, because we are turning flight goes like this bangs and this lift component will be used for turning. So at the same time important thing is we have to adjust the angle of it such that by banking you should not sink according to the turn it cannot lose the altitude.

So it is very important it need to note what is the V at which is turning. It will turn value one person, because it is the one person will take a reading your answer. And then you note down what is the bank angle right. and that also note down what is the time taken for making the turn you may say I will take a turn in 90 degree turn. But check that turns the indicator that is over stop it okay.

These readings we have to take at least four or five whatever he will be giving then offline will be processing is this part clear. Also this δE will automatically go into the laptop, so do not worry about it as far as you are concerned we will note down, we will note down what is the bank angle and δt rest will automatically go you have to press some button. So once you know this now once we understand whenever in point mean that is the low pressure for δ d δ/da=0.

I should now understand how do I process the data before I go for experiment. Understanding must be there whether you can conduct the experiment correctly.

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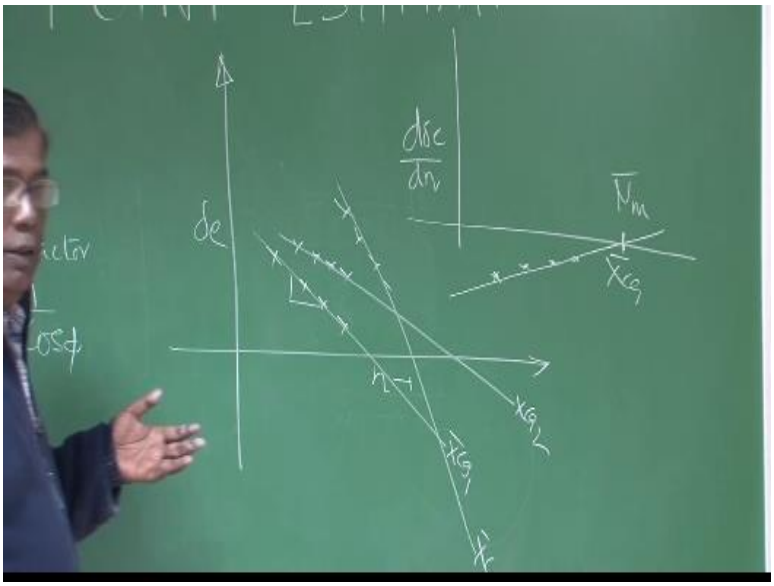

So what you will have, you have here you have a CE location, because you already noted down your weight. So δE and N you can plot for different speed and different bank or even sometime make a turn at a same speed right. So that part you have to check, so you plot δE versus N say this is for a XCG1 location by 1 member of the blow.

Second again he does the other group does same thing and this is corresponded to XCG2 there could be another group with XCG3 so there will be seven groups I suppose there are 30 student means around seven need to be there. So one of this data is collectively plotted, now you have to do about these plot D δE/dn and here XCG1.

Now you plot take the first graph XCG1 see what is the slope here, this slope is d δE/dn corresponding to XCG1 is it clear. So hope we write here XCG1 and this is the point first point, second point, third point, fourth point and then join them extrapolate what are these point, this is the XCG location at which d δE/dn is 0 now this is your manually part, is this part clear right.

So once you do the exercise, once we take the data and process it, then you will get better feel for this, but please understand when you are doing an experiment things are not so smooth right, you

do not expect all the points will be in a state line there will be measurement data, there will be modeling error, so that is why in practice we do lot many experiments and take the best feet.

So that we try to minimize the noise or in accuracies. But this is a part of exposure to this course, so we should know how it is to be done okay. And we are sure that when you apply the and start sticking you have seen all those instruments where is the outside temperature which was as per the indicator, which was used by ton bag indicator etc, that we do not lose time on that right, thank you very much.

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