Aircraft Stability and Control

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Lecture- 14
Contribution of Engine Towards Stability

Good Morning Everybody. We have talking so much of Neutral point Delta E required, writing so many equations so many expressions, there is every possibility that we get lost into all those expressions, and we may start losing the interest in this subject. So best way to revitalize our self is let us revisit and make a summary to all understanding what so far you have understood. If you recall how we started we understood that if an aircraft is statically stable, and it can be trimmed

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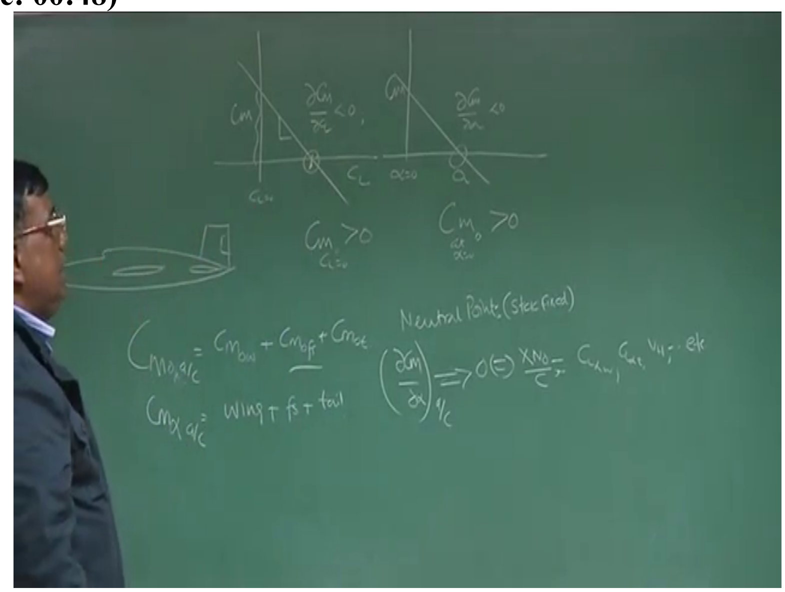

At a positive CL or positive Alpha, then I need to ensure DCM by DCL less than 0, and just to make things more elaborate. If I am plotting CL VS Alpha then this condition is DCM by D Alpha is less than 0 and to ensure that I can have a positive activated positive CL or Alpha accordingly, we need to have CM at CL = 0, which is CM0 is greater than 0 and here CM at Alpha = 0 which is CM0 it will be greater than 0 right this is the understanding.

You also understood 1 thing, that if I have an aircraft then this airplane will contribute towards CM0 which is this CM at CL = 0 in this case, or CM at Alpha = 0 in this case This contributions CM0 of the whole airplane will come from CM0 wing + CM0 fuselage + CM0 because of tail.

Although, we haven't explicitly derive any expression for CM0 fuselage or DCM by DCL or DCM by D Alpha for fuselage which will doing in our assignment.

Also you know that CM Alpha of the aircraft will have also component from wing from fuselage and from tail okay. And So far whatever we discussed was when we derived this expression we have not put any engine here, okay remember this right, from this that for this expression we try to find out what is neutral point? Neutral point we call it stick fixed neutral point how did you do that?

We derived an expression DCM by D Alpha of the whole air plane and then we equated that to 0, and then from there we got expression for XNO by C or NO by C that neutral point stick fixed, at the in terms of CL Alpha of the wing and CL Alpha of the tail, VH etcetera, you can check your formulation.

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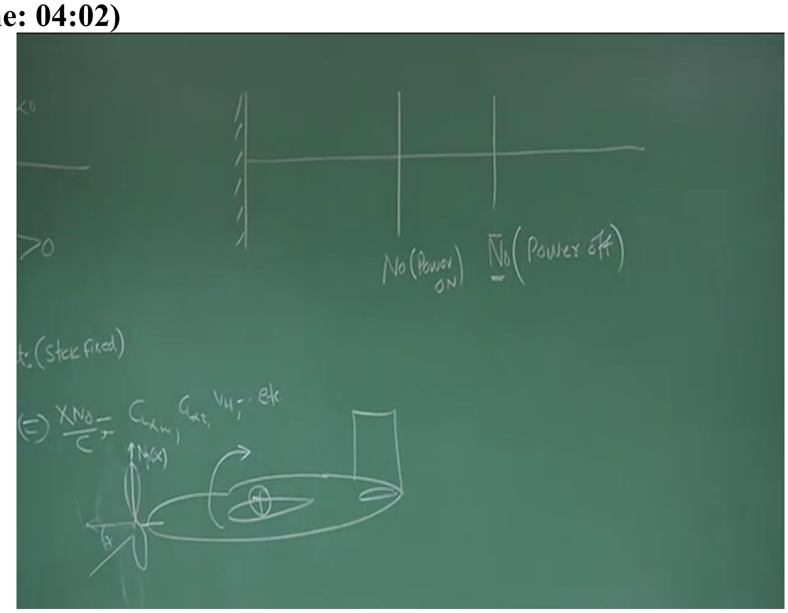

What is important here is that we have not incorporated any effect of engine right. So, now what we find is if I draw a line like this and if this is my reference we say N 0 some time I write XN0 or N 0 they are same when I put N 0 bar means N 0 non-dimensionalised with chord with mean aerodynamic chord right. Once we have calculated N 0 we some time I write it as XN0 or N0 bar bar means by now you that it is non-dimensionalized with mean aerodynamic chord.

So, with this configuration if this is N0 bar which is typically, I said power off why power off because all this computation, whatever you have done so far remember initially wing contribution, tail contribution, fuselage contribution this expression there we have not consider the thrust initially. Now then second case, what we did was we try to understand, if this is the airplane of I put a nose mount at engine.

And CG is somewhere here let say, then we have realize qualitatively, that this thrust whatever been developed will give a destabilizing effect why we also argued, if there is a disturbance Alpha some momentum exchange will be here normal force, which will be function of Alpha in general, and this about CG will give a nose up moment, and you know for a positive Alpha any component.

which gives nose up moment that adds to make the aircraft unstable or it has an destabilizing effect so, what is the message if the engine was off that is power off, if the neutral point is here stick fixed neutral point is here, the moment I switch on the engine, what will happen this aircraft engine being at the nose, ahead of CG and it has a destabilizing effect we have agreed so, the overall stability of the airplane will reduce right, so the N 0 with power on will come forward. So this will be N 0 power on because now the aircraft will be less stable.

So when the power was off N 0 was here that means, I can bring the CG after this point, here only it will become neutrally stable, and if CG is here it will become statically unstable but when, the power On then the limit is reduced because, with this sort of engine configuration at the nose, this will add to destability or it will stabilize the airplane, so the neutral point will come forward that means.

Now, you cannot take XCG up to this point the XCG as soon as is crossed this limit, it will become statically unstable because, now the aircraft is less stable compared to power off as simple as that okay. So these are the two things we need to very understand clearly and then another point comes to our mind, which I would like discuss let us see how realistic are these, suppose I am cruising, then which N 0 should I consider.

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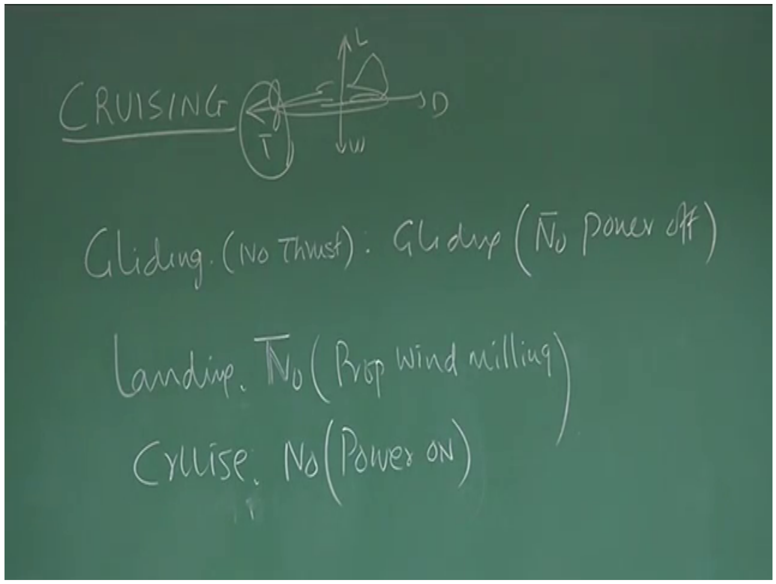

N 0 power nn or N 0 power off that means, what limit I should be very careful that CG should not cross N 0 power on or N 0 power off to ensure that it is stable. For cruise is cruising means which condition cruising you know its thrust = drag lift = weight, and if it is a thrust is there so what is the understanding, if the airplane having a nose mounted engine and it is cruising that means power on case then for me I should consider this N 0 for wherever it is required for estimating different parameters because, I know now it is power on case.

Suppose I am gliding, gliding means no thrust, then which N 0 I should use for further estimation of some other relevant parameters easily understand soon, if it is gliding there no thrust that means for me now this is power off case, this is for gliding, so these are the two extreme case one is cruising the thrust on, and one is gliding when the thrust is not there right typically glider flight.

However, you will realize there is another condition of flight when I am coming for landing, when I am coming for landing the thrust is not fully on right, Ideally there should be a air loss is possible or we say the propeller is doing wind milling right, its deriving energy from the atmosphere and rotating and developing the some sort of a thrust very low. So that is a call propeller wind milling so, you could understand propeller wind milling will be more stable or less stable.

Compared to power off. Power off is the most stable case the moment it is wind milling for nose mounted engine, it will be less than power off so it will be somewhere here I said N 0 propeller wind milling, however it will not be less than N 0 because, this if the full thrust is there or appreciable thrust is there, here it is only wind milling right okay. So this is the limit for N 0 propeller wind milling, and when that has to be used.

So, now you know if it is landing then wherever I want use stick fixed neutral point I will be using N 0 propeller wind milling. Going back here this is for Gliding and for that means, this is your N 0 power off and then for cruise which we have already realized should be a N 0 is better to put in N 0 bar it is power on. This point is clear okay. Now we will see how this things to be used okay.

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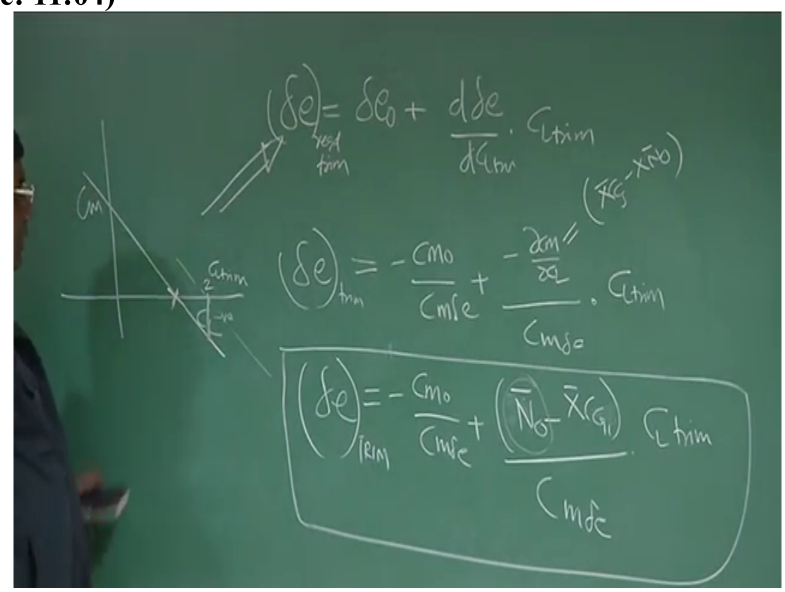

That is more important second case we did was, Delta E = Delta E0 + D Delta E by DCL trim into CL trim, this was what we recall that, if this is CM and this is CL and the airplane is trimmed here I want to fly the airplane at difference CL here that's CL2 because statically stable it will generate negative pitching moment so I need to nullify that, so that this line will becomes like this to neutralize the negative pitching moment have to generate positive pitching moment, and further I have to put elevator up right.

So how much elevator up is required for this CL trim, we calculate from here using this. So this I always say is Delta E required or you can write Delta E trim what does it mean? if I know the

Delta E 0 value if I know this gradient for a given CL trim, I know how much the elevator have to deflect clear, that we have done it. If I see this clearly I see this is CM0 by CM Delta E this is -DCM by DCL divided by CM Delta E into CL trim I recall again that when we derive this expression we have met some approximation on relative magnitude of few derivative but this is a good enough approximation. This further I can write as - CM0 by CL Delta E + this is DCM by DCL is nothing but XCG bar - XN 0 bar right.

You could see here instead of N 0 bar I am writing XN0 bar, so they are the same so this will become X or let me write N 0 bar you will get confuse unnecessarily - XCG bar divided by CM Delta E into CL trim and this is Delta E, trim what Delta E required concentrate here okay.

Now see here suppose I am doing a cruise at CL = 0.2, and let say neutral point okay. CL equal, suppose just repeat again, here suppose you want to cruise at CL = 0.2 for a given XCG location right? XCG is fixed some location right? Now when I want to know how much they will Delta trim I should have, for CL = point 2 while cruising while cruising this important, how do I use this formula this is known.

This is known for the aero plane question will be what N 0 should I take? Should I take N 0 power on N 0 power off or N 0 propeller wind milling, you know very well now because it is cruising so I should take N 0 power on this value will take right because cruising thrust is on correct.

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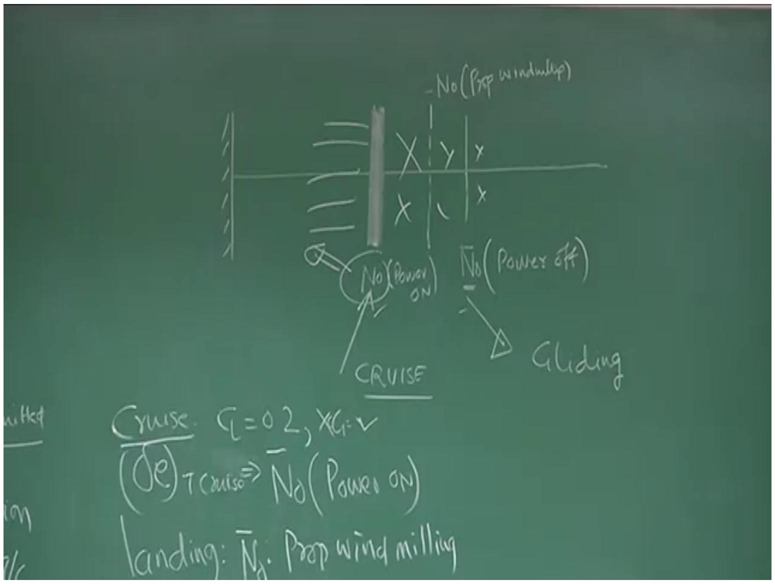

Now similar so for Delta E = Delta E trim for cruise, I will use N 0 power on right.

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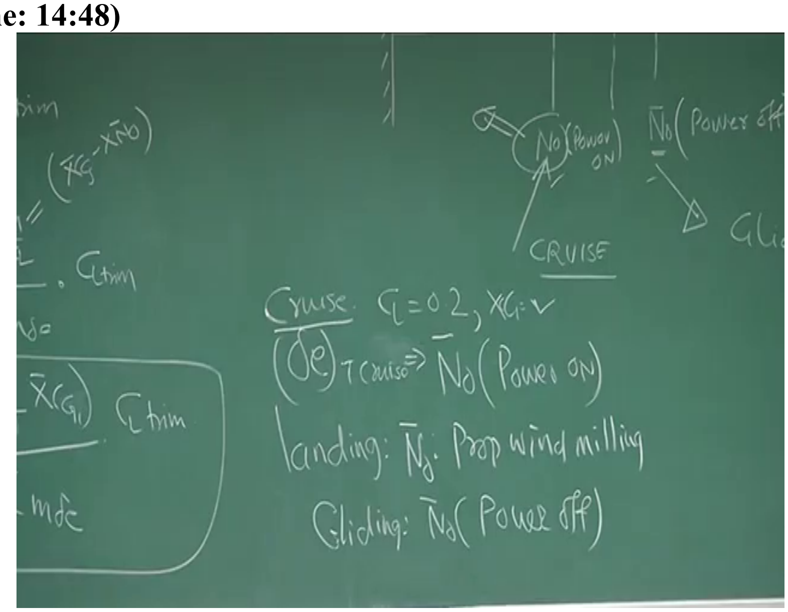

Now let us say suppose it is coming for landing that is what is the case of landing? Propeller wind milling right N 0 should I use I should use N 0 propeller wind milling so it will be N 0 should be corresponding to propeller wind milling okay. Suppose we are coming for gliding, right we want to glide switch off the engine, and we are not allowing propeller wind milling are you simplified case suppose I am doing a gliding flight with the glider.

Which does not have an engine let's say then if I want to trim the glider for different CL which N 0 should I take? I know for gliding I should take N 0 bar with no engine to power off, this is the understanding

I hope now you get the clarity, what is the importance of neutral point for power on, power off propeller wind milling and how they are going to affect Delta E trim. Please understand the different value N 0 means you are having a different static margin, different degree of stability for a given CG location, as N 0 changes for different cases so, static margin or stability margin will change.

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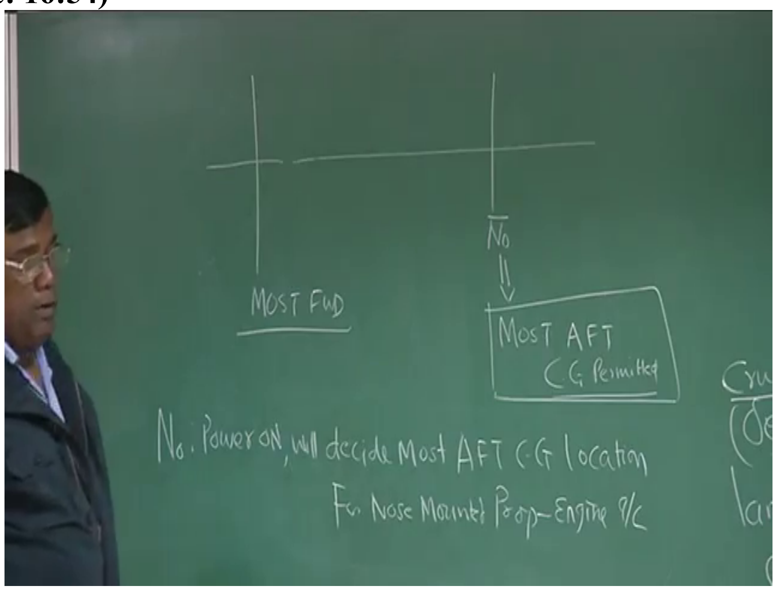

So accordingly Delta E also will change nothing new we are doing, so this should be kept in your mind while solving a problem and we should not lose the insight of what we are doing okay. one thing we should also understand and keep on telling ourselves when we are talking about N 0 what is the definition of neutral point? It is a point when the aircraft if I put the CG at that point aircraft will become neutrally stable, or if I put the CG beyond that.

The aircraft will become statically unstable right? That is the definition of N 0 okay But now see one more thing in a way N 0 is telling us what is the most aft CG permitted am I correct isn't it? Because you know, if the CG goes beyond N 0 it will become statically unstable, so it is telling oh man the CG cannot go beyond this point, beyond this neutral point. Now think of you have N 0 power on, N 0 gliding or power off and this is wind milling, from designer point of view

What should you put restriction as a most aft restriction for the central gravity of the airplane up to this CG can be taken up to this definitely not because we still like that then during power on case it will become statically unstable right. So your most aft CG permitted will be governed by N 0 power on so this should be very clear that N 0 power on okay will decide most aft CG location for nose mounted propeller engine aircraft this should be very, very clear.

I repeat here again you know that N 0 means the CG is beyond N 0, the aircraft becomes statically unstable, So now you have got N 0 power on, N 0 power off, N 0 propeller wind milling so as for design is concerned you should ensure that because power on. Cruising and that is the lowest, that means my CG should lie somewhere in this domain, it should not lie here, here, here or here.

This is 1 landing right? And of course we are talking about an aircraft which has a nose mounted engine, you could understand that if the engine is put behind the CG, this discussion will become different, but mostly engines are inside the nose mount are ahead of CG so we are focusing on this right. This is one so most aft CG we know how to draw this specification it should not cross beyond that, because N 0 power on we will compute based.

On the wing characteristics, tail characteristics, fuselage characteristics and the engine thrust characteristics that is how the engine thrust is changing with Alpha etcetera, etcetera. it has nothing to do with CG right. So this is done most aft.

The question comes, how do I decide most forward. And who will decide, what is the philosophy of most forward? if the CG is ahead of the neutral point, it is going to be stable, from stability point of view there is absolute no issues, as the CG goes, take the CG forward, forward forward and forward it will become more and more stable, statically stable but is there any restriction.

Please understand before you do some formulation we can conceptualize that if an airplane become highly stable, then it is very difficult to change or trim the airplane at a particular CL, because I may not have that much of elevator control power, we have seen that. So now based on that philosophy we will see what is the, how best we should understand how do I locate, how do I specify, the most forward CG location right.

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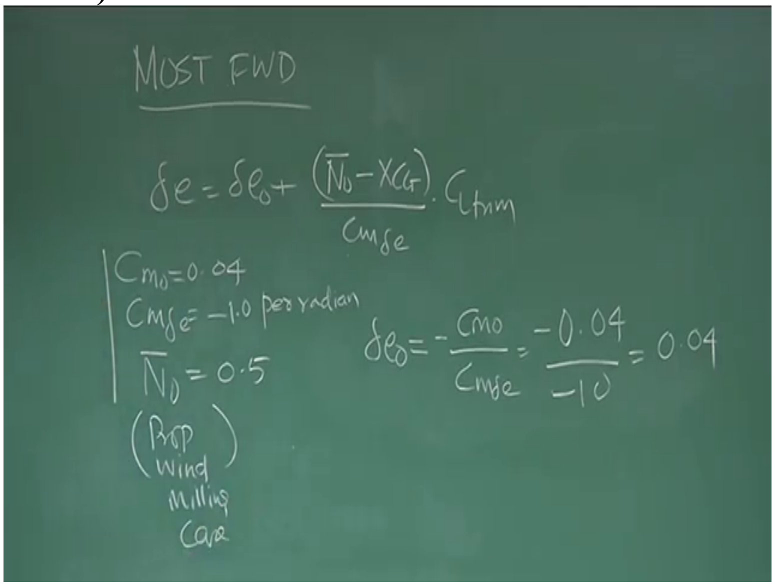

Before discussing on most forward, let me take a simple example right let's say Delta E = Delta E0 + D Delta E by DCL is nothing but - so it will be N 0 - XCG by CM Delta E into CL trim right? Let us take some values let's say I take CM 0 this numbers have taken just to give some illustration of a concept okay. So allow me to these values CM Delta E is – 1.0 per radian, please note down that this is per radian okay.

And let's assume N 0 bar is 0.5, with these three numbers I can easily find out what is Delta E0, what is Delta E0? It is - CM0 by CM Delta E so this is – 0.0 4 by – 1.0, so this is 0.04 so that is the value of Delta E0 correct.

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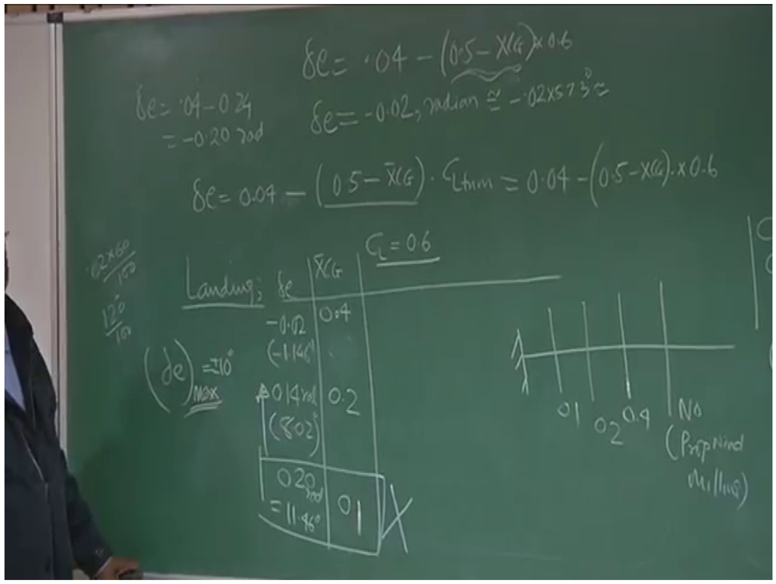

And, if I now simplify what do I get? So I get Delta E = 0.0 4 then, + N 0 is 0 point 5 - XCG bar divided by - 1, so CM Delta is -1, so I put it here a minus sign into CL trim right. Now see this case think of landing, so when I put N 0 = point 5 because, I am studying a case landing that means I am clear that this is propeller wind milling case okay. Let's see this point 5, now let us do a tabulation, I want to see what is the effect of moving CG forward for Delta E required.

For a particular CL trim, let me assume CL trim is = let say point 6 okay. So what is this expression will become? You can yourself do this point 0 4 - point 5 - XCG into 0.6 okay. The CL trim value is point 6. Let us take a case, Delta E for different XCG okay. So let's take XCG as point 4 if XCG bar is point 4, what is the Delta E is required? So now you know that Delta E require is point 0 4 - point 5 - XCG into point 6 right.

So if XCG is point 4. So this value becomes point 1, so point 1 into point 6 becomes point 0 6, so point 0 4 - point 0 6 will be = - 0.02. Let us check again XCG is point 4, so point 5 - point 4 is point 1, point 1 into point 6 is point 0 6 this is - point 0 6 this is + point 0 4, so Delta E required is - point 0 2, what is the unit here? This will be per radian, why radian? Because CM Delta E we have taken per radian and you could see that this CM Delta E if it is in per degree, then it would have been in degree.

Because CM Delta is per radian this Delta E also will become per radian please be very, very clear about this okay. So to get a feel, roughly I can write this = point 0 2, into 57.3 degree so how much it is? So we are seeing that for CL trim point = point 6 for XCG location of point 4 so let's say, let me draw this is a reference let say this is XCG point 4, and this is N 0 you know this is power propeller wind milling, because this propeller wind milling case because we are thinking in terms of landing am I correct yes right okay.

Why we are talking about landing, because we are trying to find out most forward CG, how far this CG can go forward, we have seen for one tentative case, if I take XCG = point 4, then Delta E required is - point 0 2, which is roughly - 1 point, my calculator shows 1.146 degree okay right am I correct.

Now think of a second case, see if I take the CG at point 2, if it is point 2 then what will happen here is Delta E at XCG point 2 will be point 0 4 - point 5 - point 2, this is point 2 is point 3 into point 1 6 is point 1 8, is this correct? Now XCG is point 2 so this value is point 3, point 3 into point 6 is point 1 8. So I will get the value as point 1 8 - point 1 1 8, - point 0 4 is how much? Point 1 8 - so, this will be - 0 point 1 4 radian, correct. So what is point 1 4 radian. Point 1 4 radian.

Let me check, point 1 4 into 57.3 and that will be 8.022 degrees. So this is point 1 4 radian, and that is if I put this CG is here, 0 point 2 and that is = 8 point 0 2 degree. So we have seen that as I am taking CG forward the elevator angle, required to trim is increasing, now if I take XCG at point 1 let say point 1, what will happen?

Again if I calculate by this expression then XCG is point 1, so this difference is point 4, point 4 into point 6 is point 2 4 - point 2 4 + point 0 4, so Delta required will be point 0 4 – 0.24, so this = - 0.20, so what is 0.20 radian. That means that we can calculate that is 0.2 into 57.3 = 11.46. So this is 0.20 radian and = 11.46 degree. So do you see this how this is happening?

That means if I take it further this Delta E will further increase one way, but you have a Delta E limit so Delta E max we will have, right? Suppose Delta E max was 10 degree, suppose Delta E was 10 degree + - generally it is + - 15 or + - 25, suppose Delta E max is 10 degree, then this result shows that, I will not be able to trim the aircraft at CL point 6 for a configuration.

Which is having CG point 1, this is not, I am not able to trim this airplane for this CG location, because to trim this airplane at point 1 location, I need 11.46, but Delta E max is let's say 10 degrees, if this Delta E max is 15 degrees I should be able to do it, okay. Remember, this is for CL equals to point 6 but when you are landing, the CL is around

1 or 1.2 so now let's see what happens if it is 1 or 1.2, we could easily see that if this is 1.2, then the Delta E requirement will further will become very very stringent and you will have to be very very careful that how far I keep my CG of the airplane will be decided by the Delta E max limit, okay. Let's do 1 example suppose we are doing it for CL is = 1.0 during landing, and I am now trying to calculate Delta E, let me write this here CL = 1. 0, so let me erase few things so that you do not get lost.

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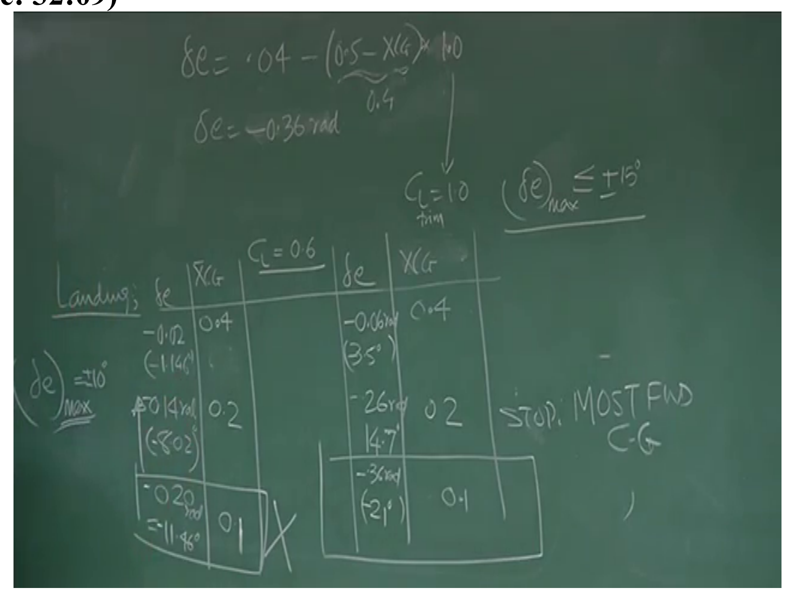

Let's say now I am doing for CL = 1.0, typically this CL are for landing, landing and takeoff right and I am talking about landing and this is XCG. Now see for CL 1.0 I have landing like this, if I now want to see what is happening for point 4, when I go back here, XCG is point 4, so point 5 - point 4 is point 1, and this is no more point 6, this is 1.0, right? CL trim I write CL trim, so how much it is? For XCG equals to point 4 this is point 5 - point 4 is point 1, point 1 into 1 is point 1 - point 1, so Delta E becomes - 0.06 radian am I correct?

This difference is point 1, point 1 into 1 is point 1 so - point 1, and + point 0 4 is - point 0 6, so this is – 0.06 radian, what is this in degree? Let me check, this will be point 0 6 into 57.3 = 3.5

degree approximately, notice here from 1.1 it has become 3.5 degree, and when I say negative, negative means what elevator up, negative means elevator up correct. Now if I come to point 2. How much it becomes the C point 2 means point 5 - point 2 is point 3, point 3 into 1.3 - point 3 so Delta E will become in this case will be point 3 - point 3 + 0 4 so - 0 point 2 6 correct. You see here this difference if XCG is point 2, this difference is point 3 so can see point 3 into 1 is the CL trim here.

So point 3 - point 3 + point 0 4 is - point 2 6 again this is a radian and point 2 6 radian means, there I check point 2 6 into 57.3 = 14.8 degrees. So this is - point 2 6 radiant and this is 14.7 degrees. What is the message instead of 8 degrees, now it is become 14 degrees because you are not try to land XCL, = 1.0 and let us assume that Delta E max is less than = + - fifteen degrees, let us see for point 1 then come back here.

This will become point 5 - point 1 so point 4 into 1, this is because point 4 into 1 is point 4 - point 4 this Delta become now – 0.36 radian, so what is - point 6 is radiant we just calculate point 3 6 into 57.3 = 20.6 degrees so, this gives me - point 3 6 radian and that means how much 20.6 degrees around 21 degrees all are minus right, whenever I am writing this is minus please understand this also minus this is also minus. All minus sign means I am correcting it here.

Coming back here is for CL = 1 that CL trim = 1 typical value, for landing I see that If my CG is at point 1 C, then the requirement Delta E is 21 degree, but limit is 15 degree + - elevator so, I restrict my forward CG by the elevator deflection limitation, so I will not go beyond point 2 I stop it here so this will be my most forward CG as far as this examples are concerned is it clear? So you could see that for CL = 1 my most forward CG of the airplane will be restricted.

By this CG most forward CG location point 2 if it is CG is going ahead of point 2 is point 1 most forward then this limitation that Delta E max is effective only have to + 15 will not be able to trim it so, my most forward CG be restricted by the elevator deflection limitation clear. For one so only for point 6 we have seen this.

Typically for landing this is the number you look towards, next class you will during landing there is some else happens that also restricts, your elevator availability for trimming and that has a effect on most forward CG location who will do that okay. Thank you.