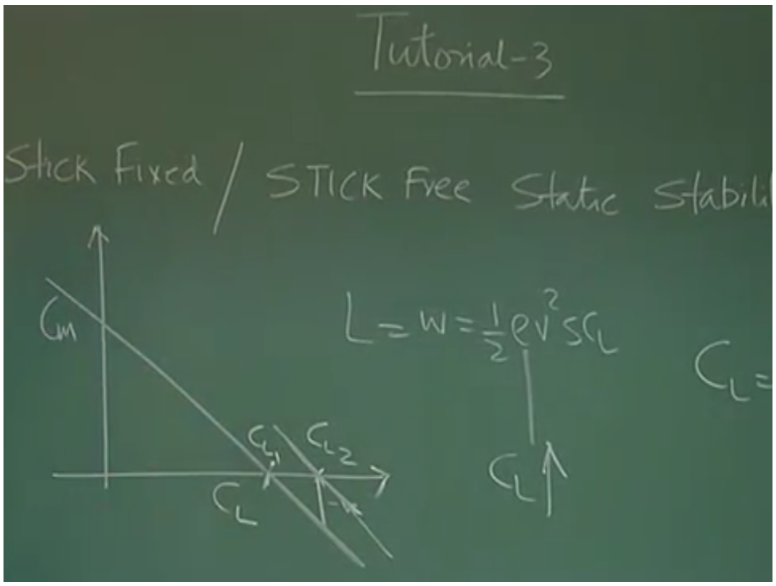
Aircraft Stability and Control
Prof. A.K. Ghosh
Department of Aerospace Engineering
Indian Institute of Technology-Kanpur

Lecture – 58
Tutorial – 3

Friends, let us come to tutorial 3.

(Refer Slide Time: 00:20)



In this tutorial as we discuss we will be revisiting the few concept the final points. One of the observation which I have after seeing the fore arm questions that is on stick fixed and stick free stability stick free static stability. Lot of confusion is there in fact lot of confusion was there when I was start this concept as the tech level so nothing surprising. So I will try to revisit this so that this confusion is removed for all time ok.

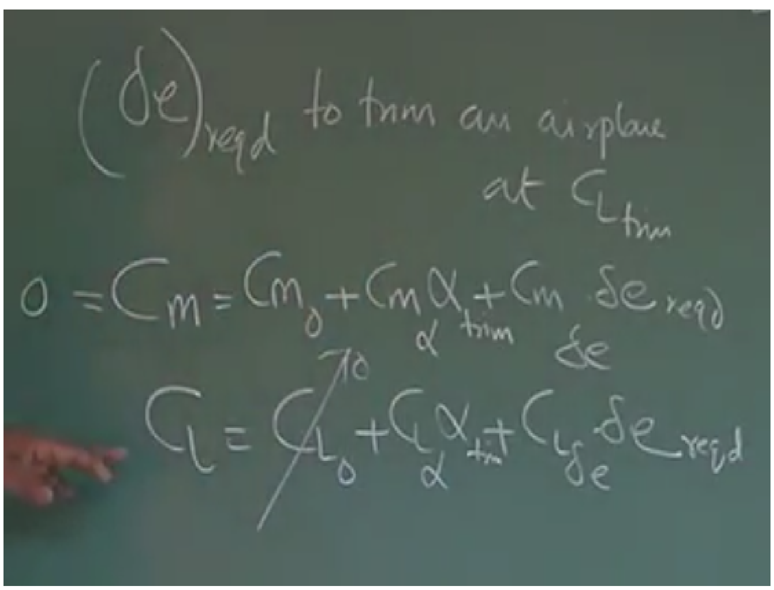
Please understand one thing, we are very clear about one point that this is c m versus c l and I am flying at c l and I have to fly another c l 2 let say. Then, if have to go to this c l 2. The airplane because this is statically stable it will generate the negative moment. Why? Because if I have to increase the c l from here, c l 1 to c l 2 that means I am keeping the speed same what does it mean.

It means have to change the angle of attack ok right. But when I try to also think this way at this point lift is equal to weight at this point so I was lift equal to weight I am not changing the altitude that means, see lift is equal to weight half rho v square s cl if I am not changing the altitude that is rho remaining same.

If I have to fly at the higher c l if c l is higher that means to maintain lift equal to weight I need to fly at the lower speed then only it is possible right. If I am balancing lift is equal to weight at c l 2 where c l 2 is more than c l 1 that means the velocity the speed here less than velocity here. There is no confusion and then next question comes how do you increase c l and do you know c l is nothing but c l not plus c l alpha into alpha that means if you want to change c l and want to increase angle of attack.

The moment I try to change c l from c l 1 to c l 2 this c m versus c l graph tells you that there will negative moment briskly generated because they air craft is statically stable but you want to fly at this c l so you have to deflect the elevator such that this negative moment is neutralized right.

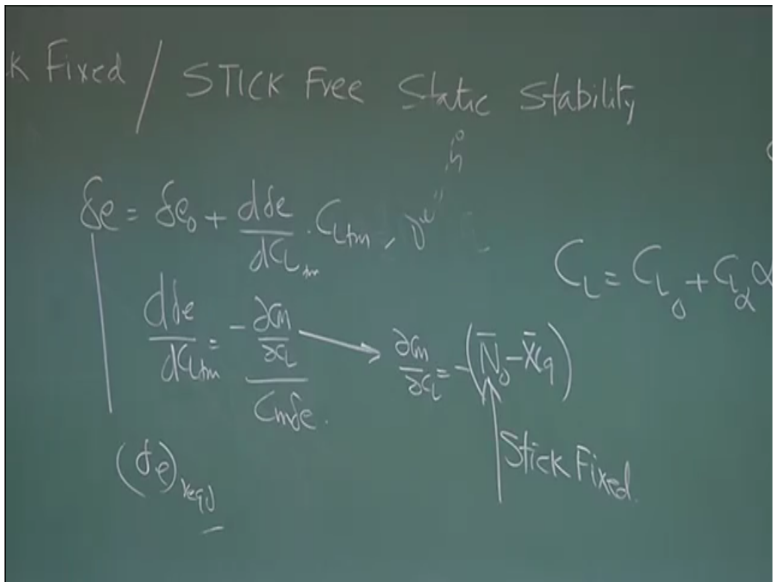
(Refer Slide Time: 03:40)



We under that understanding we try to address the question what is the delta e required to trim an airplane at c l trim. What was the approach? Approach was c m we write c m equal to c m not plus c m alpha into alpha plus c m delta e into delta e and we know c l equal to c l not plus c l alpha into alpha plus c l delta e into delta e in the class we have taken the c l not is zero which is not really zero. But for simply sake we have taken it for zero you can add those expressions but what you have realized.

If I want to fly at particular c l and that to be a trim point that means at that point this c m is equal to zero so what we did we put c m equal to zero and this alpha we said this is alpha trim and delta e is delta e required and here alpha trim an delta e required right.

(Refer Slide Time: 05:07)



Now what we did is we solve this equation and we derive an expressions delta e equal to delta e not plus d delta e by d c l trim by c l trim right and you also know approximately d delta e by d c l trim is equal to minus d c m by d c l by c m delta e. So with this understanding it is very clear if I want to fly at particular c l if I know its stability characteristic if I know its neutral point and c g location why I am saying that, because after all d c m by d c l is approximately minus of neutral point minus x c g and this neutral point we talk about stick fixed.

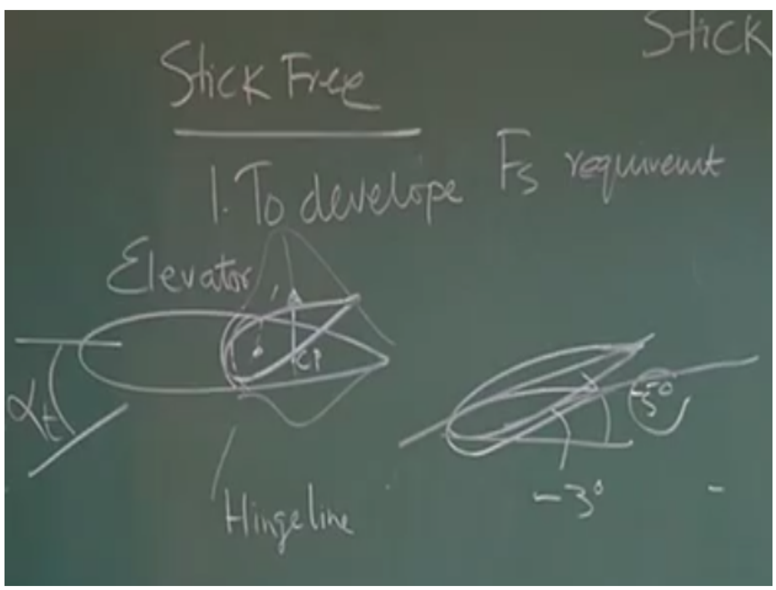
So what is the message, message is if we want to fly at the particular c l trim once you this values you know what is the delta e required and here we use the concept of stick fixed neutral point right. Why is the stick fixed neutral point because we are assuming that although this elevator at any angle of attack because it is hinged here it can start floating we are not allowing that. We are saying that we will not allowing it to float so fixed.

So this tells you this expression tells you delta e required is minus 5 degree. We will take this elevator minus 5 degree which is this and that's all. And the stick is locked the elevator cannot move up and down and when I am talking about stick fixed this also means at when I am starting the refresh from where I am going to measure the elevator in that it is assumed that given at this condition elevator is not allowed to float elevator is here only from here.

So what is the final message if I have to flight at particular. Trim whatever delta e required as I said minus 5 degree so you have to from this reference we will push the elevator here and lock it. So here also stick fixed in the sense we are not giving it permission to float. So whenever we are flying in the air craft how much elevator required to trim an air craft for the given c l is decided by this neutral point stick fixed that is no floating of the elevator allowed.

So that is the number right. But why there is need for the stick free stability. Please understand the stick free stability we define for simple reason that we wanted to model. How much stick force pilot will apply to get the elevator that's the minus 5 degree for this case.

(Refer Slide Time: 08:32)



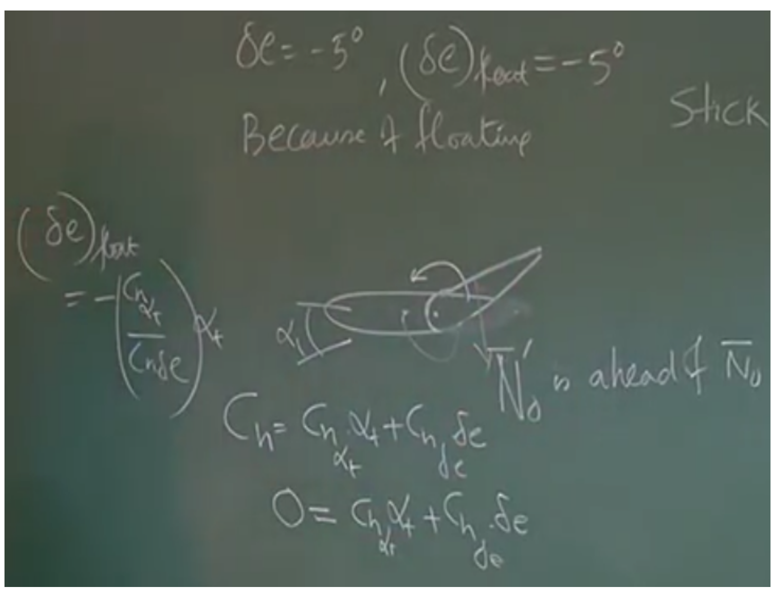
So for stick free concept was used for one is to develop the stick force requirement to deflect it to decide angle but how much angle that is always decided by the stick fixed case ok. How much force is required in that analysis we will be using stick free concept this should be very clear ok.

Now let us see what happens if we recall this is the elevator and this we write elevator and you know for the given alpha tail because there will be pressure distribution above the elevator and mostly the center pressure at the whole distribution over and over and below of the elevator will result in the center pressure wing behind the hinge line this is the hinge line normal it is like that.

So what is that at alpha t if we leave it free if we leave it not fixed then this will give the moment and by its own nature of the hinge moment characteristics it will float to equilibrium some angle right and that will depend upon alpha t for define alpha t will go on changing. So, let us say if I have to take it to minus 5 degree let us say by inherit nature it will automatically go to 3 degrees minus 3 degrees and basically pilot has to put the effort to take it to another 2 degrees that is above it require for 5 degrees and who decided the 5 degree through stick fixed neutral point say minus 5 degrees.

Now because of floating tendency it has one and half two let us say minus 3 degrees so how much effort pilot should put effort to take the aircraft to this but there what happens the moment it comes here again it can have a floating tendency so the pilot has to keep on holding the elevator in normal case right. So that is why we put trim tab extra. The point here is please understood when we talking about stick free concept.

(Refer Slide Time: 11:13)



We are assuming that at the given alpha t the elevator has already floated like this and that why c l alpha of the tail reduces and that why neutral point is stick free is ahead of neutral point stick fixed because it float at the particular equilibrium so the c l alpha tail is reduced ok. That is why neutral point stick free is ahead of neutral point stick fixed and this condition is taken as first equilibrium point from here we take to the next one.

For example let us see suppose delta e required is minus 5 degree as given by this relationship where n not stick fixed is used and that is only to be used right. But we have seen suppose because of floating and if I recall what is floating and is c l is equal to c h alpha t into alpha t plus c h delta e into delta e remember c h alpha t means if there is alpha t tail there will be nose down movement because of alpha t same time they will restoring moment because of c h delta e.

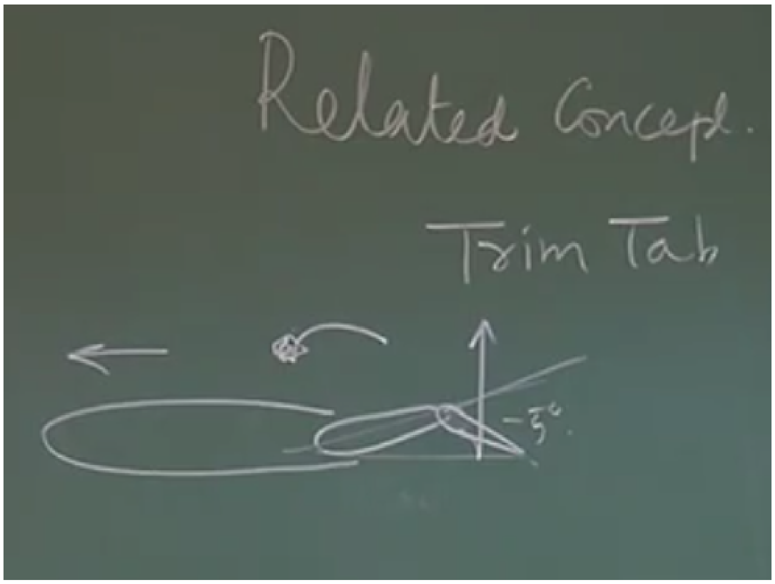
So as it goes up delta e so it comes down and delta will restore it. So there will be equilibrium at equilibrium the contribution will cancel each other so c h will become zero. So c h zero that will be c h alpha t into alpha t plus c h delta e into delta e or delta e float required to minus c h alpha t by c h delta e into alpha t this we know.

So why I am talking about floating tendency? Suppose you have designed c h alpha there c h delta t here such a way that because of floating this delta e float at that alpha t also becomes minus 5 degree. I repeat this question suppose I want delta e minus 5 degree to trim the airplane at given c l trim and we are clear that this should be evaluated by stick fixed. What we found we allow it to float by itself it floats up to minus 5 degree.

So naturally if this happens for the particular alpha t pilot need not apply any force it will automatically go to minus 5 degree we will get the trimmed at whatever trim is required right. So the understanding is how much c l trim is required is decided by stick fixed neutral point. That is when we are analyzing neutral point we have not allowed the elevator to float so it is there fixed right. So that c l alpha of the tail remains c l alpha tail without any deflection of elevator ok at the tail. This distinction has to be very clear.

And also you know stick free case is valid realistic when we are talking about reversible control that is if I move the elevator the stick also move, if I move the stick elevator also move. But from modern aircraft reversibility is not there that is irreversible for that this stick free concept looses its significance as well as finding the stick force is concerned right. So this should be very very clear.

(Refer Slide Time: 15:27)

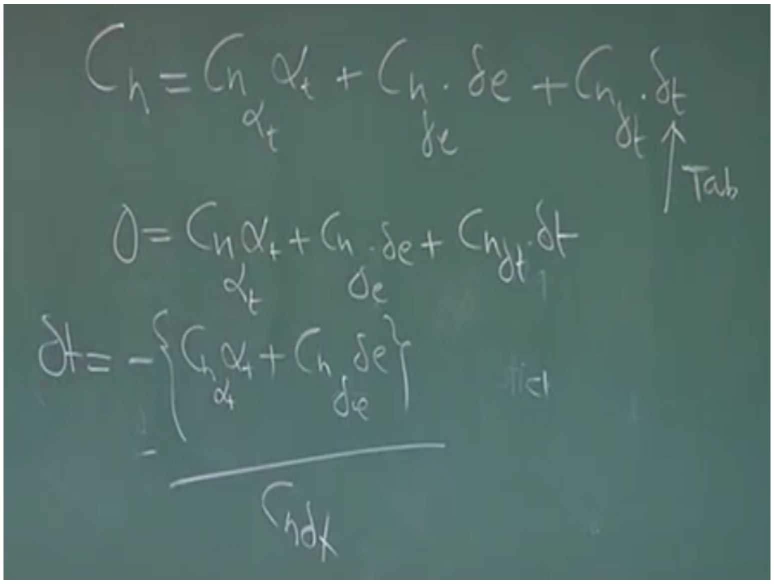


So related concept to stick free is trim tab if you now realize that this is the tail so this is the elevator and put it trim tab like this, what happens suppose you do not put the trim tab here if I have to fly at minus 5 degree elevator. Please understand where the elevator minus 5 degree is required. So what the pilot will do.

Pilot will try to pull the stick in a sense it will try to reduce the speed and increase the angle of attack so c l is more and maintain lift is equal to weight. But imagine the pilot has to keep on holding the stick but at the moment he relieves because of reversible the elevator will go down or it may not be able to maintain this positions so pilot will get tired and how this maintain minus 5 degree major contribution is the force applied on the stick so in the stick there is the moment.

What is done to give relieve to the pilot we put it trim tab the trim tab should deflect like this and as you are moving like this you could see that trim tab will generate the force in this direction and that will give the moment like this which will keep on holding the elevator at the particular decide angle. Now once the pilot sets the trim tab the pilot can leave the stick what we say we say that hands off flying. That is the beauty of trim tab.

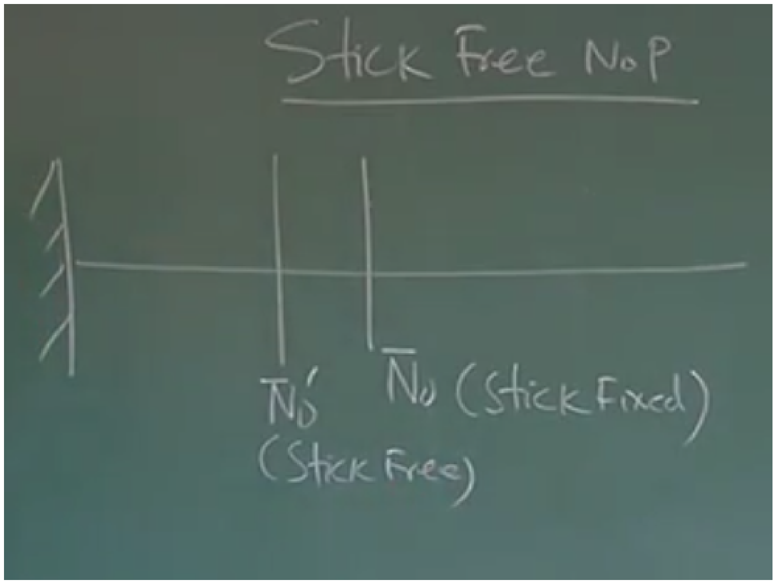
(Refer Slide Time: 17:22)



Mathematically what we have shown c h is equal to c h alpha t into alpha t plus c h delta e into delta e plus c h delta t into delta t where this is the deflection trim tab deflection right. So when its hands off this is equal to zero equal to c h alpha t into alpha t plus c h delta e into delta e plus c h delta t into delta t. So I can easily find out what is the delta t required that will be minus c h alpha t into alpha t plua c h delta e into delta e divided by c h delta t.

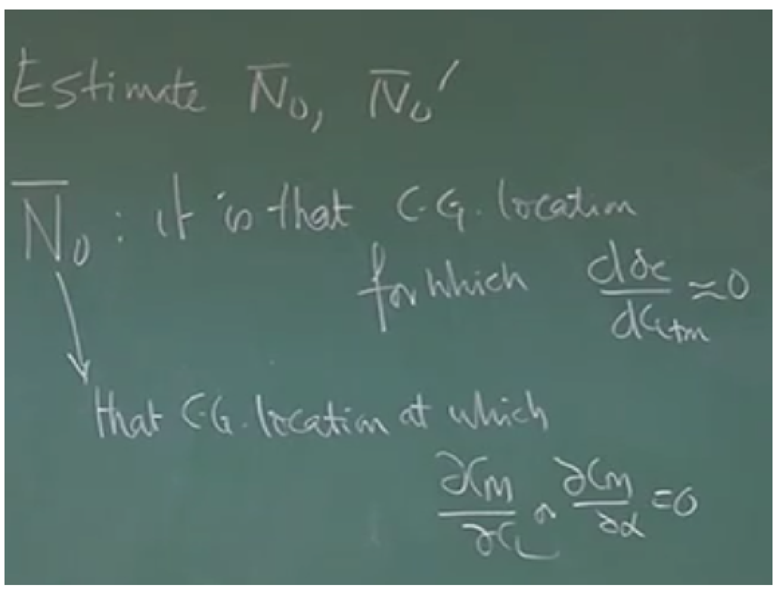
So if it is derived properly for even alpha t given delta e which I need to keep it I can easily find out how much trim tab deflection is required so I can easily calibrate this deflection is done this understanding ok. Final correction will done by the pilot through the lever. This is very important as well as flying quality of the airplane is concerned right.

(Refer Slide Time: 18:46)



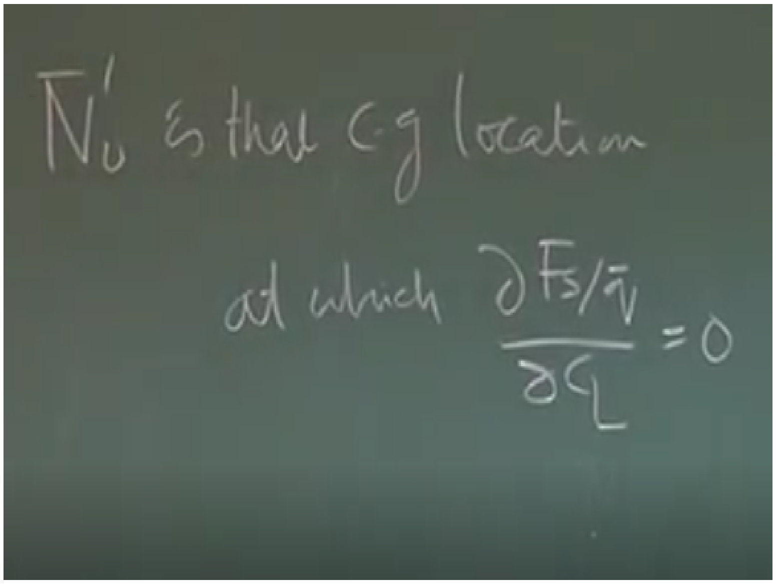
When we are talking about stick free neutral point we realize that if this is the reference line and measuring from here and this is n not bar is stick fixed then n not bar prime stick free will be ahead of stick fixed neutral point right. And if you also recall when we are talking about how to estimate neutral point stick fixed neutral points stick free in that problem formulation.

(Refer Slide Time: 19:29)



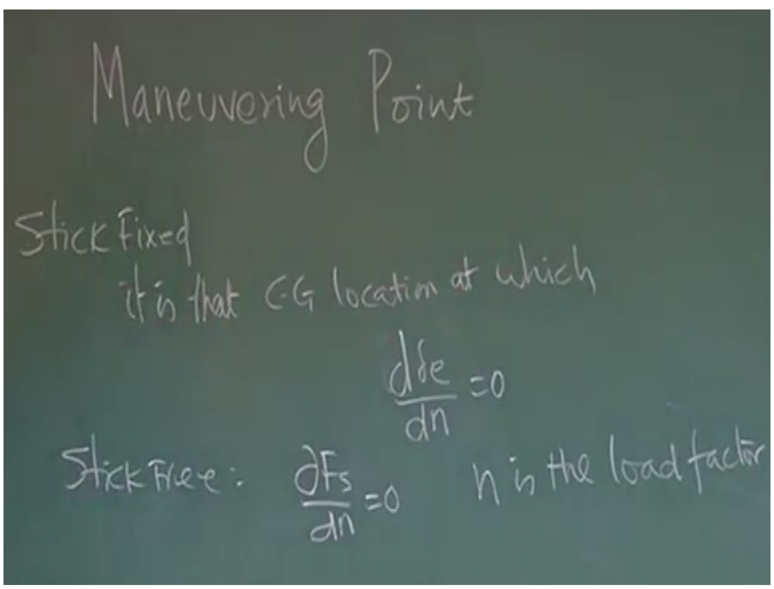
What we said for n not it is that c g location for which effectively d delta e by d c l trim is equal to zero little bit approximation although you know neutral point stick fixed with that c g location exact definition is it is that c g location at which d c m by d c l or d c m by d alpha is equal to zero it is neutral stability but why did not you find stick free neutral point what did you say through the formulation.

(Refer Slide Time: 20:13)



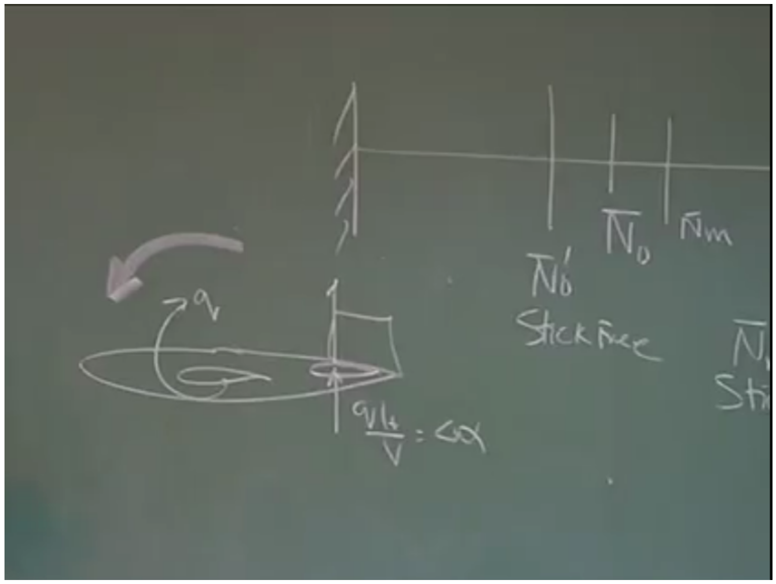
It is said that n not prime is that c g location at which d f s stick force by dynamic pressure by d c l is equal to zero so this distinction should be there in your mind.

(Refer Slide Time: 21:24)



Similar concept is used when we are talking about maneuvering point. How did you find maneuvering point for stick fixed? It is that c g location at which d delta e by d n is equal to zero and for stick free we define manuvering point stick free d f s by d n equal to zero but f is the stick force n is the load factor ok.

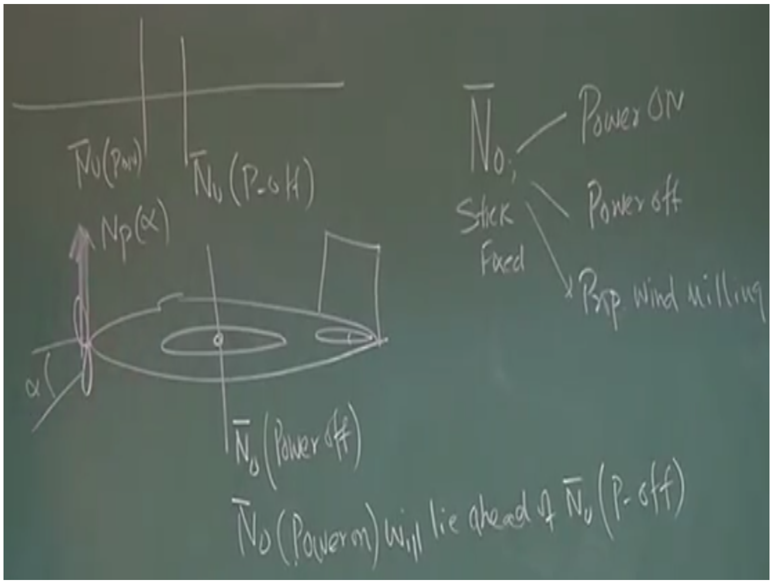
(Refer Slide Time: 22:31)



And we have also seen if this is your n not stick fixed and this is n not prime stick free then n m stick fixed manuvering point will be if I am measuring from here it will be some where here n m stick fixed manuvering point because we have seen as airplane goes for the manuver this is the q and there is the q l t by v this much of angle of attack roughly get induced and gives the force here and that gives the nose down movement which try to restore or stabilizing tendency strictly dumping in nature.

So in our side we says that the aircraft tends to have more stability during manuver and that is why n m stick fixed manuvering point is behind stick fixed neutral point ok. Then there was a question that if.

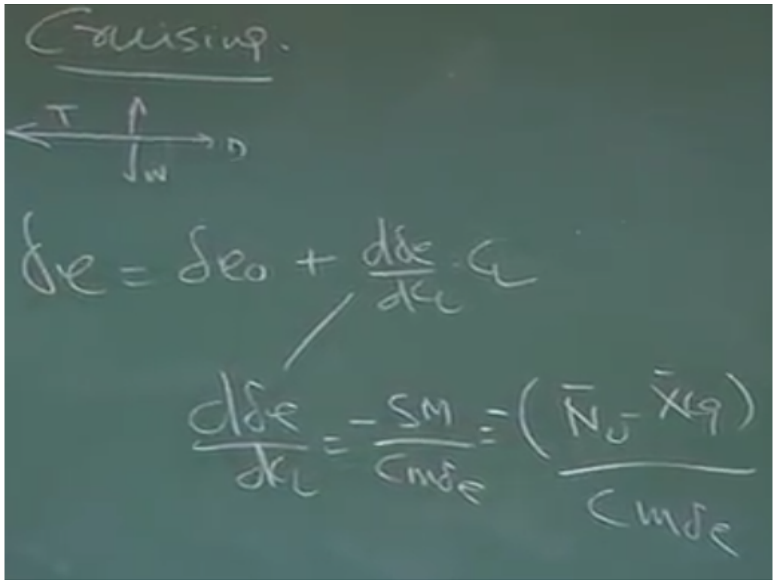
(Refer Slide Time: 23:46)



N not stick fixed whether I should take power on and take power off or propeller wind milling this questions where there right. Physically understand you know this is the airplane suppose you estimate neutral point stick fixed and let say this end point is some where here this is the end point when you compute n not bar let us say that we have not taken the contribution of engine ok right. That is this and we will say that power off typically glide without an engine.

Now suppose the engine is kept somewhere here I see engine piston lever engine properly I will say. The movement of propeller is here ahead of c g we know that angle of attack of an alpha will generate a normal force here at the function of alpha and that will make the aircraft lower stable this stabilizing in nature so n not power on will lie ahead of n not power off clear that is if it is n not bar power off then n not power off will be ahead of n not power on because this is more stable case for the nose mountain engine.

(Refer Slide Time: 26:11)



Now let us see suppose you are cruising that's why you are cruising, for your cruising that means you have a thrust this is drag this is lift this is the weight this is the nose mountain engine configuration now if I have to calculate delta e d delta e by d c l is minus static margin by c m delta e which is minus n not bar minus x c g bar by c m delta e.

So if it is cruising that time this thrust is on I should you power on n not right. But if it is coming for the landing approaching for landing then it what happens theoretically this engine should be short although the engine is on the propeller is not rotating however you will see that it comes down there because of wind mill effect propeller will rotating and generate little bit of thrust although you will find competitive gives 20 percent thrust but what you say wind mill theoretically because of the wind the propeller is rotating and generating some margin of thrust.

So naturally this case I should use how mush delta e is required for landing and all I must use n not corresponding to wind milling I should not use n not corresponding to power on isn't it and if the engine is off if wind milling is not there then I need to use n not power off for calculation of delta e required so that distinction should be there in your mind ok. Thank you.