Aircraft Stability and Control
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Lecture- 15
Revision

Yeah dear friends today I will be discussing on stability of an aircraft right, and remember we have already discussed this at length, and today this session where will revise revisit and try to understand what is the meaning of a stability of an aircraft, and as you recall when we talk about stability.

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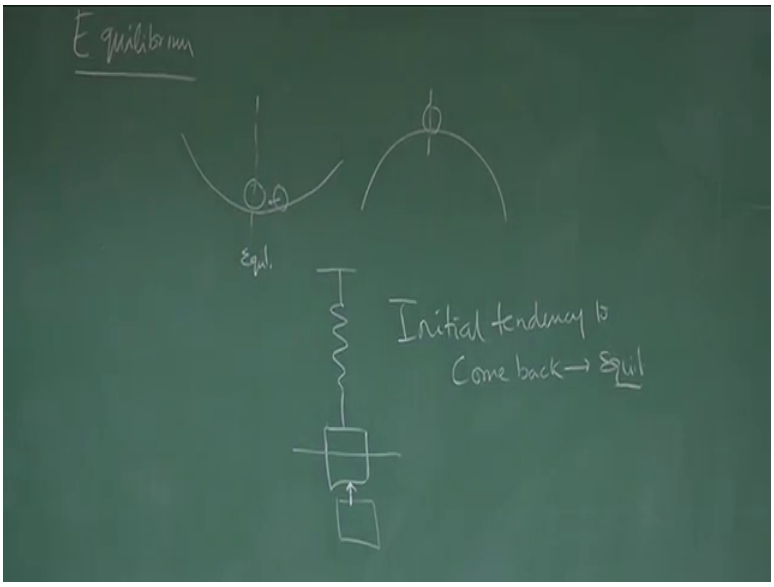

What comes to your mind, yes, can you tell me any student what comes to your mind when you think of stability go to class 10th, 11th standard **"Professor - student conversation starts"** when everything is balanced, standard everything is executed, all the force and movement are equilibrium. See when all the forces and moments are balanced, we say that is equilibrium that not really we talk about stability. Lowest energy state. Pardon, Lowest energy state. Yes that is another yes that again its equilibrium, when you talk about energy state right. and if you. Whether the object can the rebuke into (()) (01:30).

Yes so as I was telling if you think of your school days example, remember this is sort of diagram. "**Professor - student conversation ends"**

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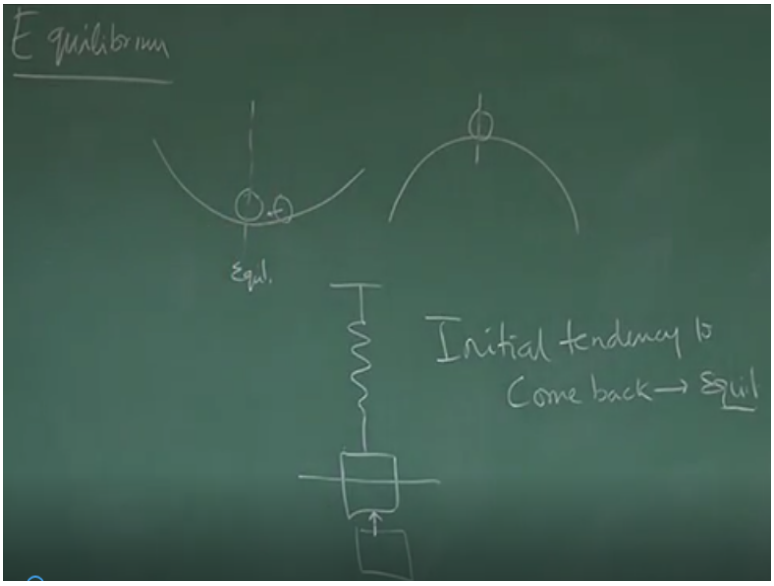

See if I displaced this body from its equilibrium, this is the equilibrium okay. Why you are telling all the forces and moment are balanced, if I disturb this from this equilibrium and if it has initial tendency to come back to equilibrium, we say as statically stable correct okay. For example if again we revise, if there is a mass spring system and if I stretch it, and release it the moment I stretch it there is a force trying to disturb, it has a initial tendency. The key word is initial tendency to come back to equilibrium okay.

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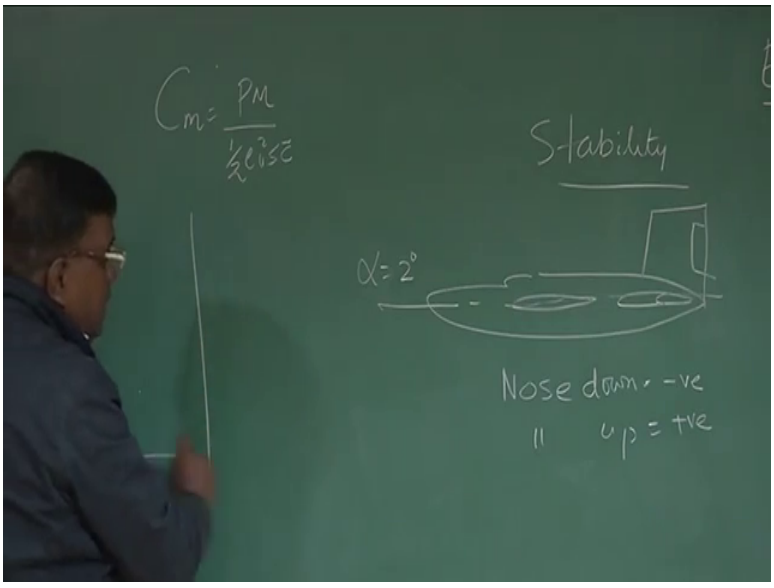

For aircraft this the aircraft we will say this as aircraft is flying at the Alpha = 2 degrees what do you mean by static stability? Suppose it is flying by at an angle two degrees, and because of some upward gust angle of attack increased, so if it is statically stable it should generate nose down moment so that net angle is still remain two degrees. So as static stability we only check whether it has got a tendency to come back to two degree or not, if its tendency if has we say statically stable and this nose down moment we all know its sign is negative.

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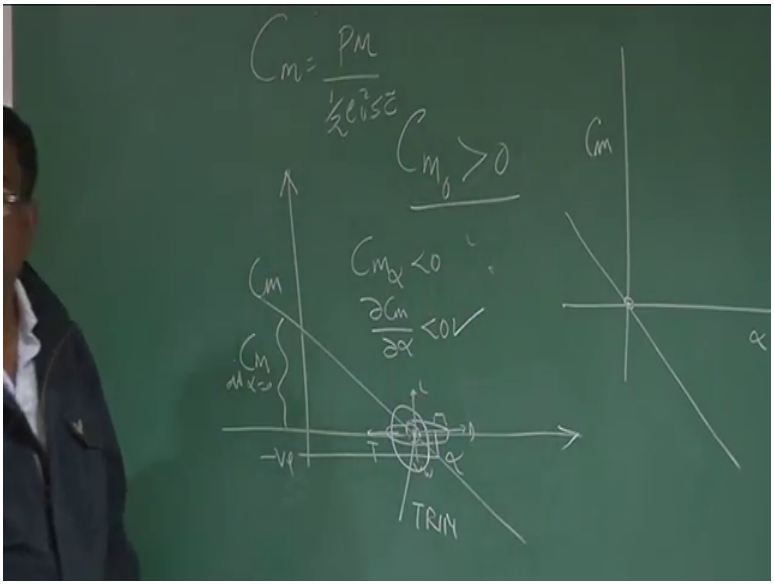

And nose up moment sign is positive, and you are also aware of this term CM which is pitching moment, half row V square SC bar, so what do you say is if this is CM, and this is Alpha the variation of CM with Alpha should be like this. Where is the equilibrium point here? Equilibrium point is here because here CM is 0, and net force is also balanced. It is typically like your airplane is cruising okay, where thrust = drag, lift = weight. Now if you want to check whether it is statically stable or not what you should do?

You should give a disturbance about this stream point, so let's say the airplane suddenly its angle of attack is increased so what this diagram is showing you? If the angle of the attack is increased immediately it will generate a negative pitching moment. So it has initial tendency to come back to this angle correct. So we say this is statically stable and mathematically we say CM Alpha less than 0, or if I write more explicitly DCM by D Alpha less than 0 correct.

Now also we checked this issue that upon to the slope, there is a important point, suppose I draw it like this and this is CM and this is Alpha, this is the trim point CM is 0, here also the slope is negative so which one you will prefer? This one or this one. **"Professor - student conversation starts"** First one. Why first one yes, very good, I would express this like this, finally when I'm going to fly a machine I want angle of attack should be positive. So that there is a lift as well as, it should fly like this it should not go on doing this like this. "**Professor - student conversation ends"**

So CM should be 0, should fly like this so, I am trying to see that not only should to be a stable, where not only CM by D Alpha should be less than 0 but also it should this is called trim okay trim at positive Alpha correct, to ensure that trim at positive Alpha, the graph should look like this or what you're telling CM at Alpha = 0, that is I write as CM0 should be greater than 0 correct.

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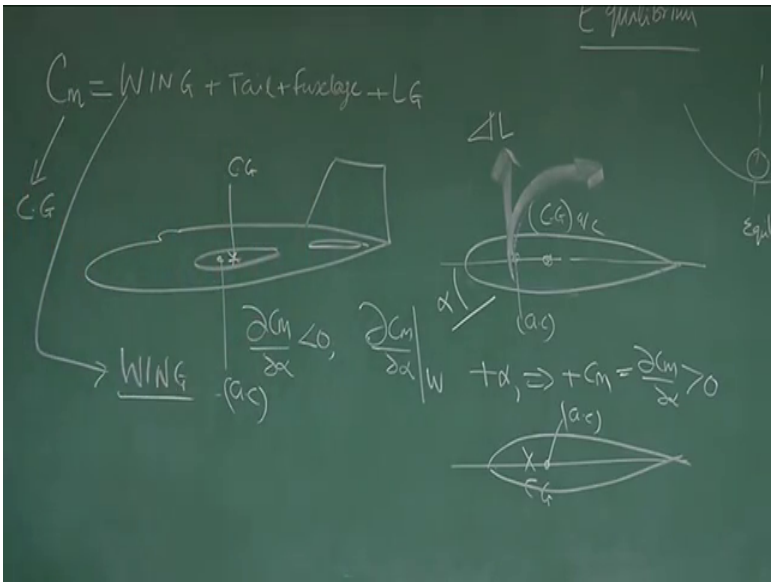

If you satisfy these two things then you can fly a machine which is stable, statically stable right. We also know this CM, whatever the pitching moment is coming this contribution will come from wing, it could come from tail it could come from fuselage it could come from landing gear right because all will generate forces and that will be a moment, and this CM you should remember this is about center of gravity.

Because, the body in free space you rotate about an axis passing through central gravity right. So all these CM or the moments are about center of gravity of the airplane. Now see this is very important if I see the wing part okay, what is my aim? My aim is DCM by D Alpha should be less than zero of the whole airplane. I like to check what is DCM by D Alpha contribution because of wing, correct. Now If I see an wing and there is a aero dynamic center.

You know what is an aerodynamic center? It is the fictitious point about which the pitching moment is independent of angle of attack, and let's say CG of the airplane is somewhere here. So if I draw explicitly this is the wing, and this is the typically this is a quarter chord, and this is CG of the whole airplane because we are talking about CM about CG of the whole airplane right. Now do you think this will give you DCM by D Alpha negative?

Check yourself, if there is a disturbance say Alpha, then I will represent the force acting through AC. So AC is here and CG is here this force, are Delta lift will give what type of moment, it will give positive moment about CG that means for positive Alpha, you have got positive moment so this is telling DCM by D Alpha is greater than zero, so this is a destabilizing contribution clear.

How do you make the same wing having stabilizing contribution, you have to ensure that I lay the wing in such a way, than if this is the CG of the airplane if I put the wing in such a way that AC is behind the CG of the airplane, it will give stabilizing contribution. So what is the lesson learned if I want from wing if I want DCM by D Alpha negative then AC of the wing should be behind CG of the aircraft correct.

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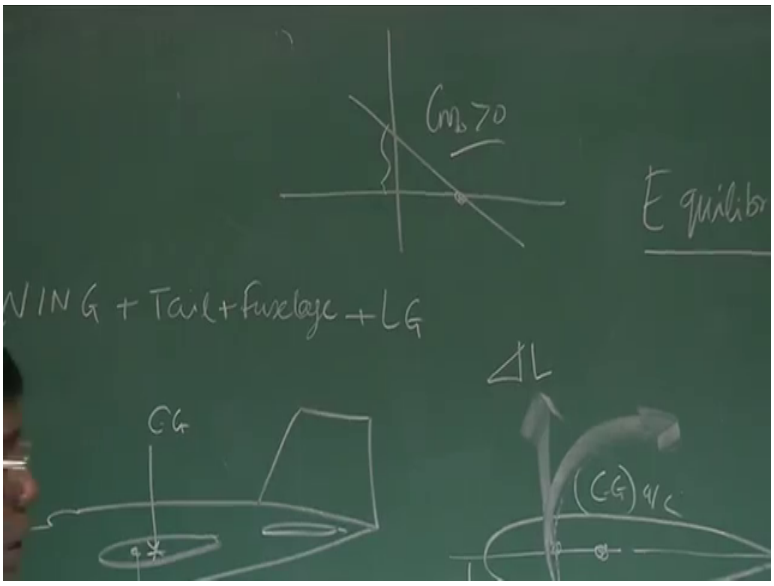

But we know very well it is not only we are looking for slope here, this is DCM by D Alpha we also looking for this gentleman, CM0 should be positive, and let us see if I put the wing the way we realize to get stability for the CM0 contribution is positive or negative.

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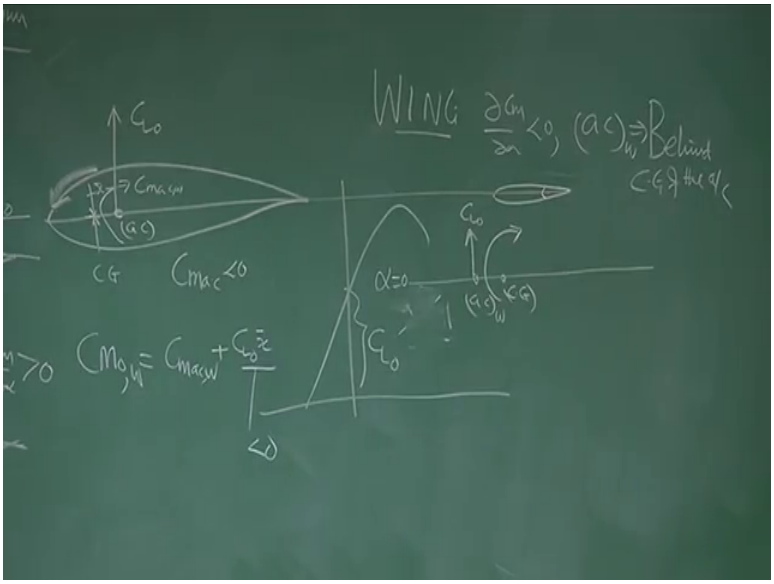

If this is the wing, if cambered wing, if this is the AC of the wing and this is the CG of the wing, you know why we have cambered wing aerofoil we have got CMAC of wing which is less than 0 right, typically - point 0 2 - point 1 it will be there because, we are transferring the forces and there will be momentum, but if you want to calculate CM0 because of wing what will happen at Alpha = 0, there will be a force CL0 act or non dimensional CL, CL0 is acting at AC, this is okay or not?

Because you know for a cambered aerofoil something like this, the CL0 right at Alpha = 0 what this CL0 will do? at Alpha = 0 this CL0 will give what type of moment about CG nose down, negative moment, so what will happen you have already have the CMAC of the wing, now you will have CL0 into X bar which is also negative, let say this is X bar. So overall CM0 because of the wing is becoming what? Negative, this is negative.

This is also negative, but what we are looking for, we are looking for positive. So we are happy about it right, So what is the done in most of the aircraft wewill see that AC of the wing is actually kept ahead of CG. So the wing is destabilizing number one however it gives relatively positive CM0 if you see here Alpha = 0 there is a CL0 here, that will give a nose up moment correct you can check in the aircraft, which have cambered aerofoil then the debate comes what is the use of that wing which will be destabilizing the airplane.

The answer is stability is that the role of the wing, role of the primary roll of the wing is what lift. Stability is somebody else will take care. who is that gentleman who take care of stability? This is a stabilizer not the control surface it is the horizontal stabilizer, control surface takes care of the control, that is I'm flying at a particular CL I want to go to another CL so that is the control, that is not stability.,

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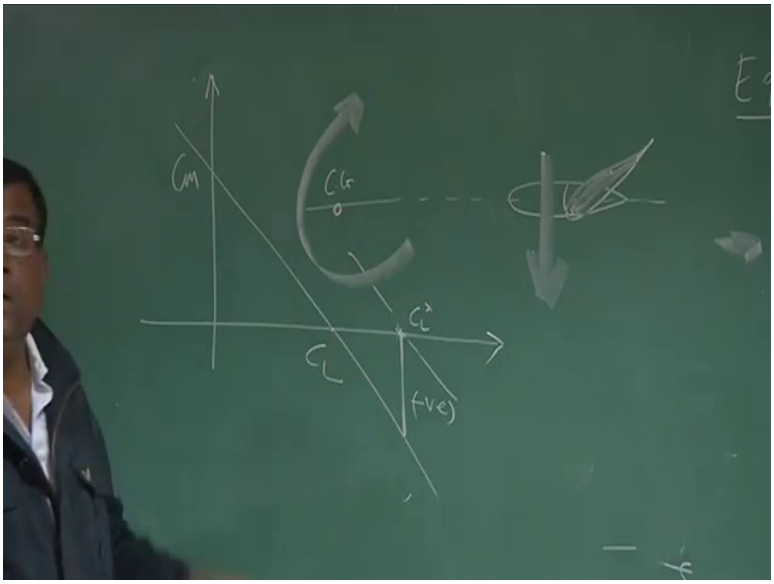

This a distinction should be there very clearly and then we need to know what is the elevator deflection for a particular CL we again come back here. So this CM versus CL we agreed that here CM is 0, which is a trim I am flying at this CL and slope is negative so statically stable. But suppose I want to fly at this CL say CL star if I try to fly at this CL what will happen? See that initially the airplane will generate negative pitching moment.

So it will not allow to go to that CL that means if I want to increase CL I have to bring the angle of attack up using elevator, but because it is statically stable, it will generate the negative moment so, if you want to fly at this CL, what you have to do, you have to ensure that this negative moment is nullified, and who does it there is a, that is the control moment that is done by the elevator.

This your tail okay this is the elevator, this is CG, now suppose you want to fly to have the CL , CL star of the trim, the airplane generates negative pitching moment so, the airplane tries to come back like this. But you want to hold it like this, so what do you do, you put the elevator up okay, as the elevator up net force here acts downward right and this will give a positive moment, and it should carefully deflect the elevator up, such that this magnitude of negative moment is nullified. Then you are flying at different CL

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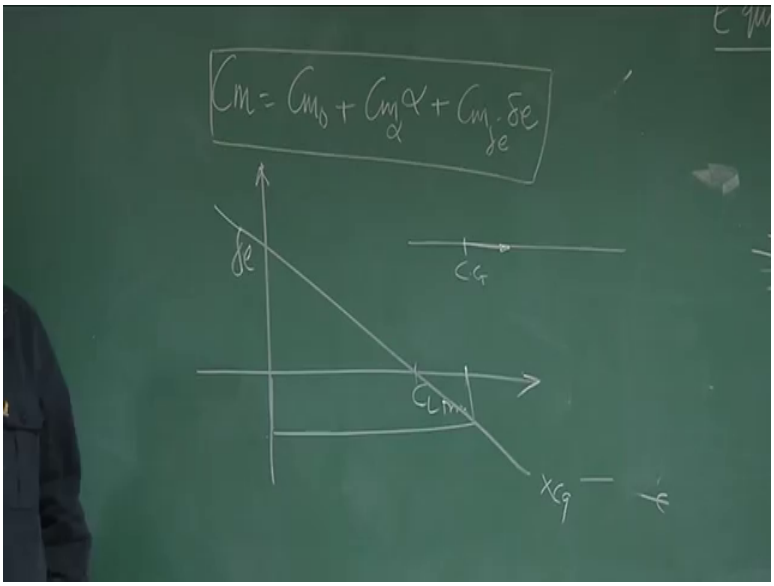

And this is the control part, this comes through the elevator okay, and how to approach this problem that is given by what is the CM, you know CM is CM0 + CM because of CM Alpha into Alpha because angle of attack, and CM Delta E into Delta E these are all, this is coming from stability right. this is coming from control, if I got a aircraft but CM Delta E is very strong, then I should be able to easily control the airplane, okay.

This is one and multiplying this if I try to plot Delta E required for different, different CL trim,Variation is like this, here again you could see that if I am flying at this CL trim if I want to fly at this CL trim, this variation will tell you how much Delta E negative we have to put, so this directly give the feed to the pilot, before he goes for a flying he will check what are the elevator deflections, and that's why he trains himself. Now imagine if I go on taking of the CG on the airplane backward.

What will happen, see from you know If I take this CG backward there will be time when and CG and AC will coincide, so it will become a neutrally stable. So there is a neutral point concept of the whole airplane, if there is a location at which if I put the CG, the airplane become neutrally stable beyond that if we take the CG it becomes statically unstable. Let us come back to stability, suppose I have an airplane, where the wing is high wing okay.

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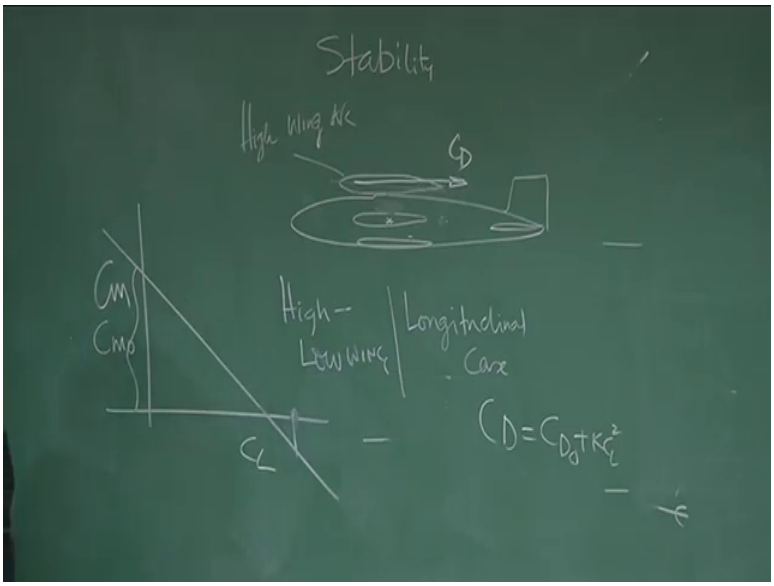

And tail could be somewhere here. This is typically configuration of which avatar airplane is high wing airplane in flight left, 6 0 2 0 6 if you have right, my question is we are very much clear about, CM versus CL we want this slope should be negative at trim, and we need to know about CM0 at Alpha = 0.

Suppose the wing is high wing another case, the wing is mid wing another case let say wing is a low wing okay, and CG is somewhere here is or somewhere here is or to make problem simpler I said CG is somewhere here. Now check from stability point of view high wing versus low wing in longitudinal case, that is what we are discussing which one is more stable, that is the general confusion high wing is more stable in lateral directional mode.

But we are talking about longitudinal so you can, do you understand what is the catch see here, if there is a increase in CL because of the disturbance here, CL has suddenly increased that means. Suddenly angle of the attack has increased, because of gust or because of anything. Then what will happen? This CL of this wing will increase CL means you know drag polar CD = + K CL square, so what will happen if CL increases CD increases the CD will act in this direction right so this will give what type of moment about CG. So this will contribute to, so this is destabilizing. Please remember for longitudinal case the high wing, is destabilizing for lateral case.

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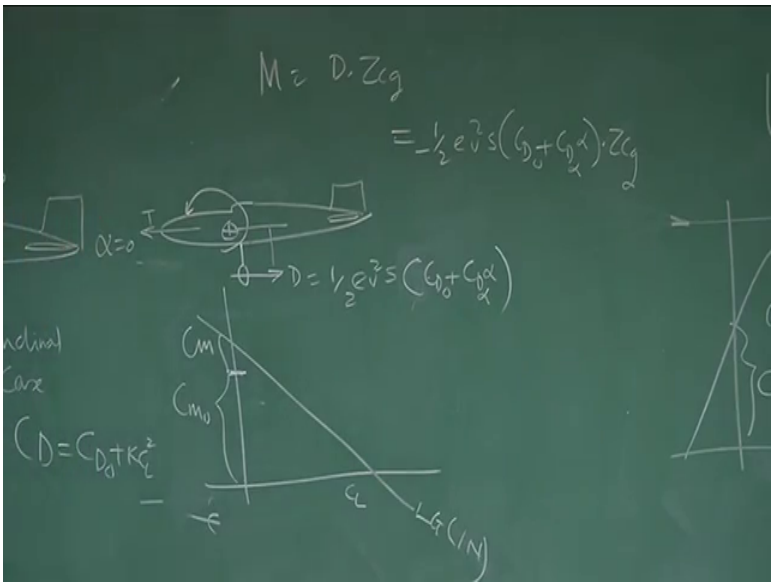

It is stabilizing, similar thing you can check here, if there is a increase in Alpha as here, the drag will be additional drag will come here, this will give what type of moment about CG nose down, so low wing will be providing static stability longitudinal case is this part clear so let us check another case, if this is the airplane and let us say landing gear is out okay, flying like this, if I draw CM versus CL where landing, gear was in that is inside the fuselage, now you have ejected the landing gear out.

How this graph is going to change predominantly. CL is okay, CL remains same, you should think like this what is happening to this CM0? So what is CM0, CM0 at = 0. So if Alpha = 0 and this will experience the drag, what we are trying to compare is suppose the airplane is flying with landing gear in and then landing gear out, simply landing gear out will be during landing okay.

And we are saying when the landing was In CM versus CL was like this, when the landing gear is out, how this CM versus CL as a designer should think we going to change, so best way to think is first check what will happen to CM0, see at Alpha = 0, this landing gear will experience the drag this drag will produce a nose down moment negative moment so CM0 will decrease, Is this clear everybody. So now CM0 will come somewhere here, and as for as stability is concern you know drag means what it is half row V square S CD for CD I will write CD0 + K CL square can I write this.

No, I cannot write this because, this drag polar is for wing, right. This is not this whatever form is there, this is for wing lifting body. So I will not write, commit this mistake of writing like this, however, I will know 1 thing this CD, I can write it as instead of CD some CD 0 + CD Alpha into Alpha, always there will change in CD because of Alpha that much I can approximate.

So you could see since the Alpha is there, whatever moment this drag is giving nose down, will have a Alpha component so that slope of moment because of drag also will be negative now. Whatever moment is what? Moment will be D into whatever length okay, ZCG correct and D is half row V square S CD0 + CD Alpha into Alpha into ZCG but I have to ensure that I put a minus sign, because I know with Alpha 0, Alpha = 0 this will give a nose down moment.

So if I find DM by D Alpha, so this Alpha is here I will get a negative sign so this will make the airplane little more stable.

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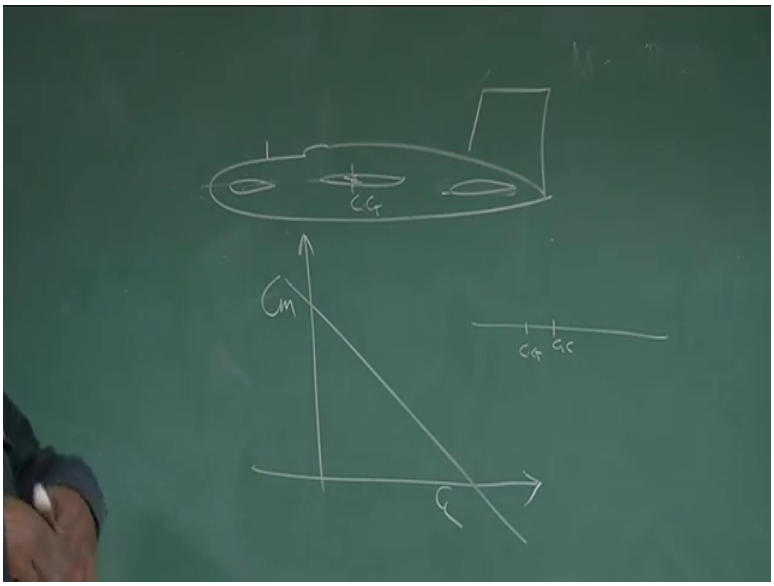

So will find that this slope at this point will be more than the slope here so, basically landing gear is changing the CM0, however marginally it may increase the static stability correct. Again if I see this is the airplane let say CM versus CL is like this, and If I put another surface here that is I put that canard here how this graph is going to change, if I assume that CG as not altered, how this will change? It will become more stable or less stable.

This is the best way to check is always if this is CG any component which is ahead of CG will be destabilizing, You have to check that too, if AC is here and CG is here then only it is statically stable. If AC is behind CG but this is AC of this component is ahead of CG so this will make it less stable, and that is why when you want have a maneuvering aircraft, we will find lot of canard surfaces are used so stability is reduced so I can turn faster way.

We were discussing about stability for long and we were very emphatic that, wing primary role is for left, but we will see in a secondary manner, wing also supports stability or it may contribute to static stability.

This is sinus 9 1 2 this is also high wing aircraft, and now when we are talking about static stability suppose this airplane was flying at a angle 1 or 2 degrees, and there is a upward gust, additional angle of the attack is coming like this, as a disturbance the moment there is a additional angle of a attack, there will be additional drag because, it comes from through the drag polar, and additional drag, which will be acting towards this, towards the tail that direction this will give nose up moment about center of gravity, so high wing is not preferred as far as longitudinal stability is concerned, you see high wings are in demand for lateral directional stability.

And that is why you will find why there is a high wing, why there is a dihedral, but theoretically fundamentally you should know, although high wing is adding towards lateral or directional stability, which will be coming later, but high wing in particular adds to instability of the airplane okay because this drag through drag it operates and if you now come to that engine side here how you are thinking or discussing, which we already have discussed in the class room.

What happens what is the contribution of this propeller, on the longitudinal stability of the airplane specially static stability, and you know if there is angle of attack disturbance coming here, then the there will be thrust will have a direction like in this way, and there will be normal component of thrust which will be function of angle of the attack, in a loose way and this will give a nose up moment about CG, so such nose mounted engine.

Where there is propeller driven, or whether it is jet engine or duck based, they all if they are ahead of CG all such engines if they are located ahead of CG will contribute to in stability of the airplane as far as static stability concern okay, same engine if I put behind CG like a pusher, than they will contribute towards stability static stability.

So wing this is the propeller , horizontal tail you already know landing gear, we have discussed and that makes the whole understanding of static stability, that also makes us understand who contribute what. To conclude we see that horizontal tail will primarily contributes to our longitudinal stability and wing as the marginal effect high wing will contribute towards in stability in terms of static configuration concern, and if you see.

This wing which is a low wing configuration so, this will actually act to static stability okay, in terms of longitudinal stability, we will discuss their effect on lateral or directional stability in lectures coming ahead okay. Thank you very much.