NOC: Introduction to Airplane Performance
Prof. A. K. Ghosh
Department of Aerospace Engineering
Indian Institute of Technology, Kanpur

Lecture - 41
Contribution of Wing and Tail: Stability.

In continuation with the stability and control aspects, we will be now discussing about aircraft.

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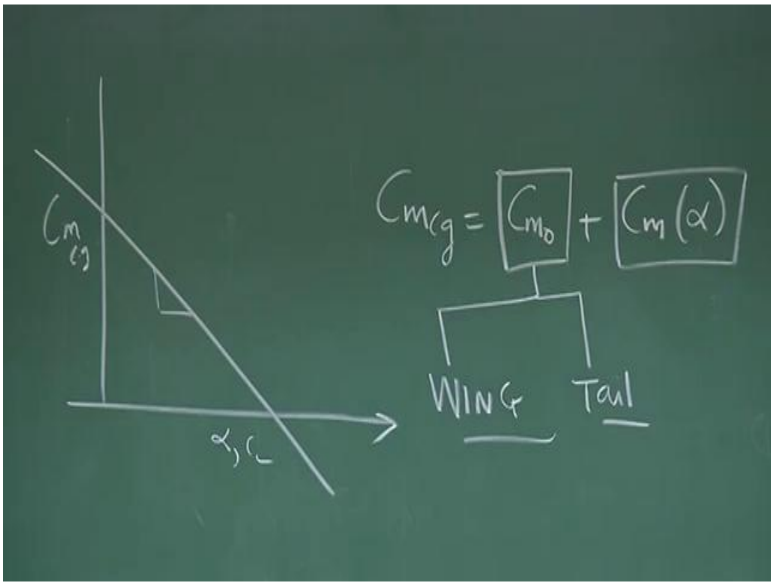

By now, you understand C m c g versus of alpha or versus C L, they are not really different question of changing the scale here. So, if this is my aim I put it C L here, let us say also whatever we interpret. Basic question is, if I want the airplane by itself generate C L naught and it should be self generate, the slope to the requisite manner. What is that amount, I will let you know, then let us first find out who are the contributor; then we will talk about numbers.

So, I can write C m of the whole aircraft C m c g as C m naught, one contribution come from C m naught another C m comes from angle of attack alpha. You see here, y equal to m x plus c same, who are the contributor to C m naught. One I can write wing, one I can write tail, so we will talk about C m naught first, then we will come to this slope.

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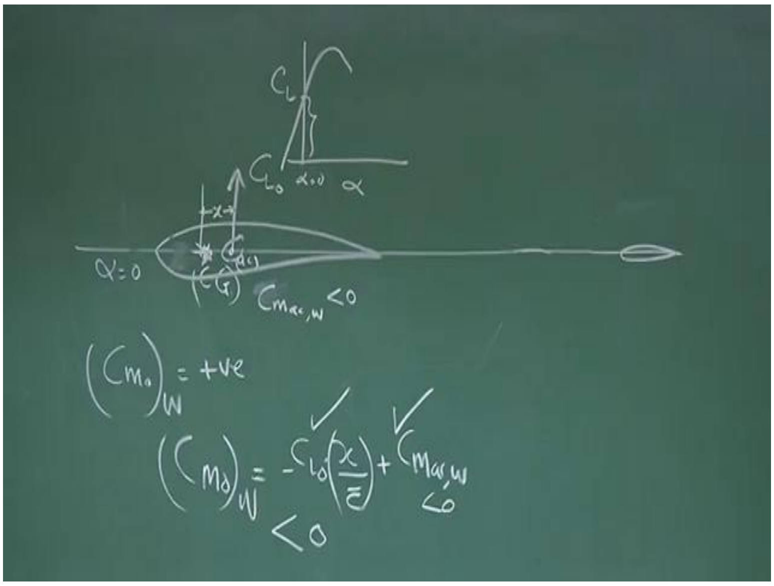

Let us see closely the wing, let say this is the C G of the whole airplane. This is in general cambered aerofoil and let say, far distance there is a tail, tail is always symmetrical in this. Now here, if suppose tail was not there, to make this statically stable, you know the aerodynamic center should be behind C G. To make it statically stable, you know that the, a c should be behind center of gravity, which is flying wing.

But, you know by now I can make a cambered aerofoil based wing statically stable, but it cannot be retrieved that a positive angle of attack, fair enough. Now, what is the problem? What is our aim? Our aim is I want C m naught, because of wing to be a positive value. Then, only I will get this intercept which is positive, but now, what is happening here you see. C m naught is the, at alpha equal to 0, what will happen? At alpha equal to 0, there will be C L naught.

You recall C L versus alpha, for a cambered aerofoil at alpha equal to 0, there is a lift. So, C L naught will act like this also, because it is the cambered aerofoil, you know it will have m or I write C m a c wing as negative, that I have explained in the earlier lecture. So, if I now try to find out, what is the C m naught contribution by wing, cambered wing where a c is kept behind C G.

This will be what? This will be C L naught into, let see this distance is x between the a c of the wing and C G of the plane. So, x I am just making a non dimensional by divide it by new aerodynamic chord and this will be a negative moment, this will give a nose down moment. Similarly, it already has C m a c wing which is also less than 0, so see the problem. We wanted wing to contribute towards making some positive contribution, so that the intercept is positive.

But, we have used a cambered aerofoil, thinking it is leaved by it is advantages and we put a c behind the C G. We thought it will be helping the static stability, it will help static stability, no more we doubt. But, what is the problem? Problem is, we wanted that C m naught should become positive to have trim at positive alpha or C L, what is happening. This man is negative, this man is negative, so whole wing contribution towards C m naught instead of positivity is becoming negative.

So, which the designer will not like; that means, your wing is trying to contribute something like this here. So, negative value, but our aim was you should contribute towards positive, at least 50 percent, 60 percent, 70 percent. So, what is the problem? Problem is, we have try to use wing to gives stability. But, you know in the beginning I have discussed some point, the role of wing is not to give stability. Role of wing is to give lift, role of stability is gives the tail. So now, let us say we are also looking towards the tail that is, tail wing combination. What I do?

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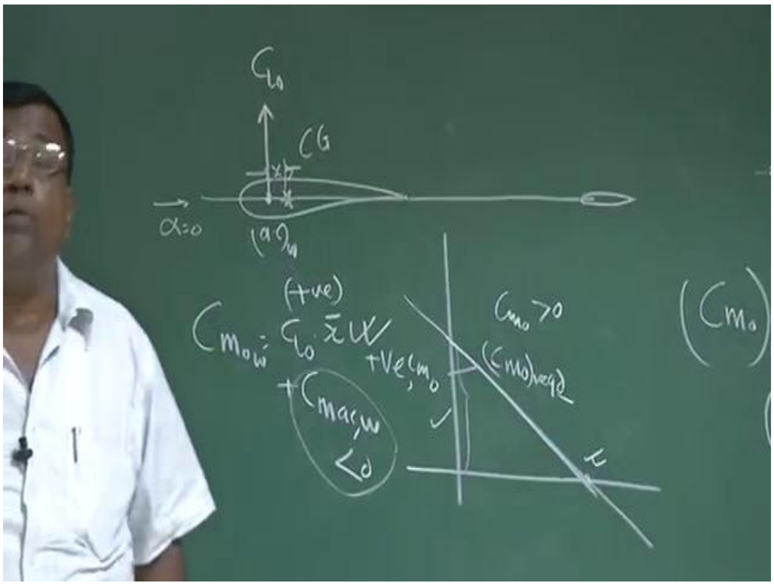

I still use this wing, let tail is sitting somewhere here and this is my cambered wing. What I you do? I put a c of the wing ahead of C G of the airplane. ((Refer Time: 06:06)) we will be at home man, this will become unstable. How does it matter? Remember, wing does not have any responsibility to give stability that is tail that what tail will take care. We are only looking towards after, is there any way I can get some C m naught positive from the wing contribution. What does happened now?

The moment I have put a c of the wing ahead of C G, check with alpha equal to 0, here this is C L naught and I call as earlier this is x, the distance. So, now, the C m naught wing will be C L naught into x bar, which is x by c plus C m a c wing, which is less than 0 negative, this is negative, but this is positive.

Now, you can see that if I put a wing having a cambered aerofoil and ensure that a c of the wing is ahead of C G, then this term will give positive C m naught. And, theoretically I can go on changing x that is, I can go on increasing this difference and value will become, so large that it will not only negate this negative value, but it will come down to a value, which is required to fly at this C L, but that will be too much. So, what is done? If, this is the C m naught required, we try to get partly from the wing and partly from the tail. So, what we have done here? Now, we have change this configuration, we have now becomes smarter.

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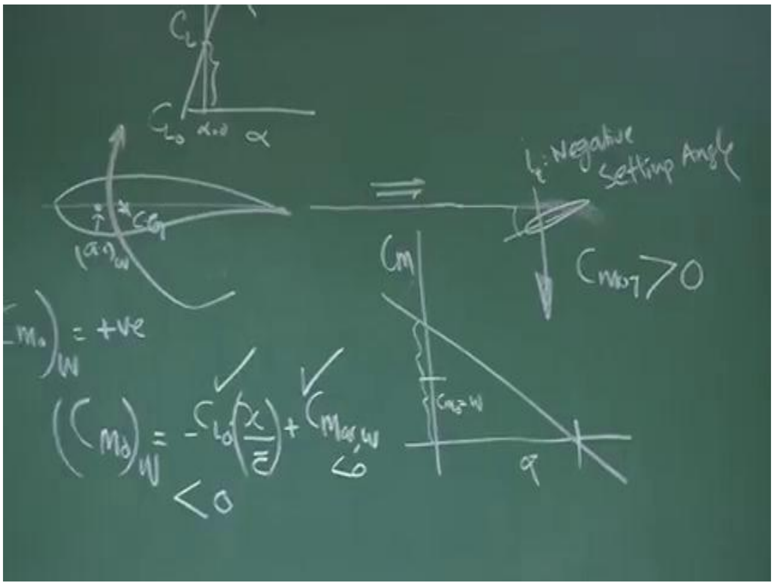

We will still use this cambered wing, but we will put a c of the wing ahead of C G of the airplane, this is very important. So, some part of C m naught will get, because of C L naught into x bar and let us say we are aiming at full C m naught. We have not got full C m naught, we have got this much contribution from wing. So, rest I can take it from the tail, what I have to do in that tail? Instead of housing this tail like this, I will house the tail like, I will give negative setting angle, we call it i t that is negative setting angle.

What will happen? If I set it negative like this at alpha equal to 0, this will generate a force, which will give a positive moment about C G. So, this tail you will also contribute towards C m naught tail also will contribute towards positive. So, what is the message? If I want this C m naught for a given static margin or I do not say static margin, for a given C m naught for a given static stability if I want to treat the airplane in a particular C L, I can generate that C L naught by putting a c of the wing ahead of C G of the airplane and giving some setting angle at the tail.

So, as a designer I have to take this parameter and see that it decrease it C m naught I am getting, as simple as that. C m naught what is over and next question comes, how do I get this slope? How much slope? This is another big question. How much static stability? Because, you know if you make it very high instability, then to manoeuvre it will be difficult, so let us adjust that.

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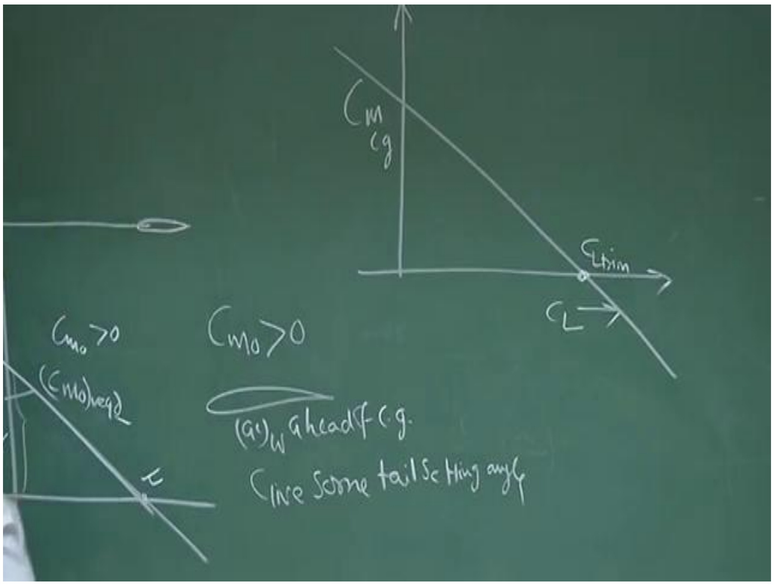

If I try to see this graph, now please notice I am writing C m versus C L graph, let us say this is a C L trim, you want to fly at this C L. Once C m naught issue is understood, we realise C m naught I can make positive by putting a c of the wing ahead of C G and give some tail setting angle. Of course, we have taken a generic cambered airfoil wing, next part is how much static stability.

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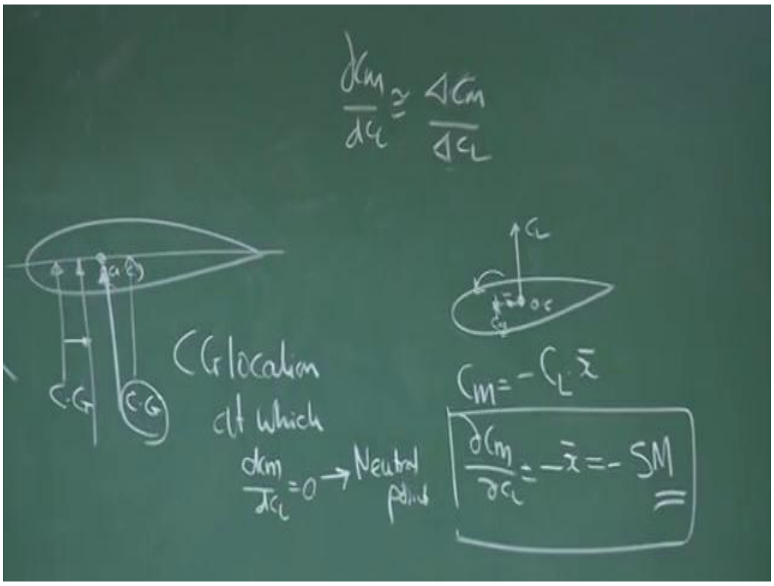

Before I answer that, let me see what is the meaning of this d c m by d C L or for us, I will try to interpret this. What is a slope of C m versus C L? Let us go back to simple case. Suppose this is aerodynamic center and this is C G, so C L is this, C m will be about C G. So, if I write C m, C m will be minus here nose down is negative, C L into x bar, x bar is the distance between a c and C G. So, from here I try to interpret d C m by d C L, that will be minus x bar.

What is minus x bar? If I try to give a physical interpretation, which will be useful for analysing aircraft that is my aim. We want to understand, what is this x bar and try to give an interpretation, which will be useful in analysing static stability performance of an airplane, that is the purpose. And, I repeat again I am avoiding all the equations, because that generate a part of our second course, but here with whatever we understood, we will try to put our understanding in a synthesis form and that you see whether, we can develop a field for this numbers or not.

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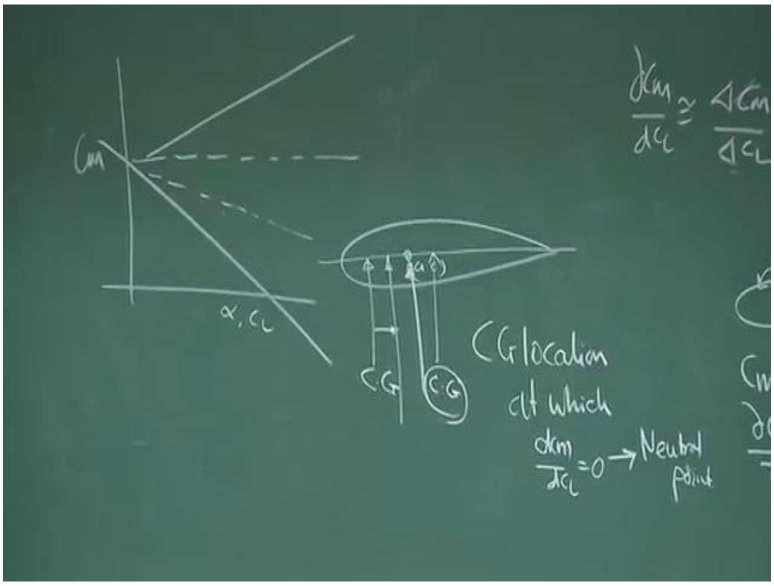

Again, I take this example suppose this is the aerodynamic center and let us say I have initially I kept C G here at this point C G. So, it is statically stable, no issues. If I plot C m versus alpha or C L statically stable means the slope will be negative and it is in general aerofoil have taken, so I have taken some C m naught. It as well pass from here which is symmetry that is not the point, the point is on the slope.

Now, if I move this C G towards this towards right, let us say I have come down to a point here I kept the C G here. What will happen? This slope will reduce, because now restoring moment has reduced. So, when the C G just is below the a c, what happens, the slope become what, slope become zero or it is this line become parallel to the x axis. And this is the condition, where we say the airplane at this configuration is neutrally stable, because below this it was statically stable.

The moment C G goes behind a c, it will become unstable, the slope will become positive. So, this is the point or the C G location at which the d C m by d C L is zero, we call it as a neutral point. So, that C G location at which d C m by d C L is zero you say that C G location is called neutral point. So, for a designer you always find out the neutral point, because neutral point depends on the configuration, how the size of the wings or what is the aspect ratio, what is the trim ratio, what is the airfoil use.

So, we ensure, if you wants to design a wing, wing around airplane I want to makes statically stable. You will ensure that C G behind that C G or C G never crossing the neutral point, because for this case a c and neutral point are same.

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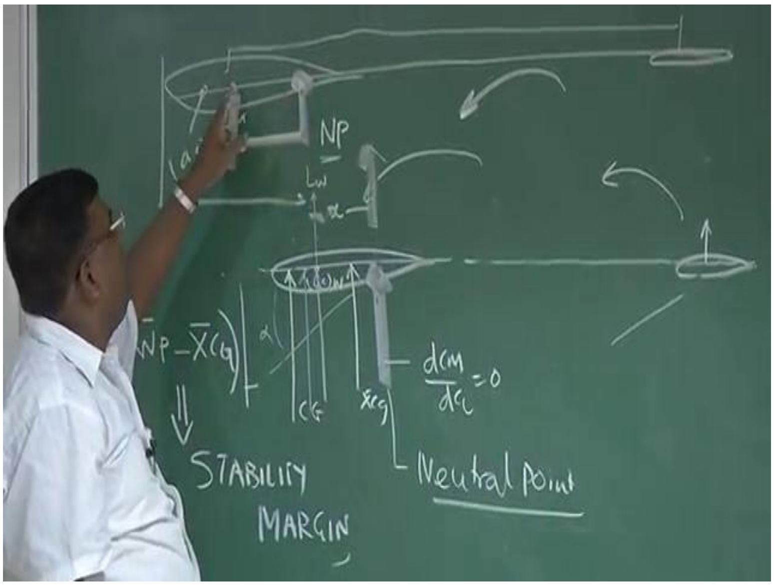

But, suppose same configuration I take same configuration, now I put a tail, let us see this is a c. Now, again I do same excise I put x C G are C G here, you know that there are two lifting surfaces both under any disturbance alpha both will give initial restoring tendencies about C G that is C G term somewhere here. I further take it I know put the C G just below the a c of the wings this is a c of the wing.

Do you think it will become neutrally stable? See suppose C G is just below the a c of the wing and if there is an alpha disturbance here there will be lift, because of wing. And since, C G and a c are at same point it will not be very disturbing moment; however, this tail is here it will give restoring moment.

So, it will not become neutrally stable still this slope will be negative that is tail for a positive alpha there will be negative C m you take it further somewhere here x C G. Then, any alpha disturbance if you give now the lift on the wing will give destabilising moment and leaved from the tail will give stabilising moment that is lift on the tail will try to discourage this angle of tag increase; however lift on that wing will try to encourage it.

So, it will have a initial tendency to come back to equilibrium here it will not have initial tendency to come back to equilibrium, because now C G is here and a c is here. So, theoretically you can find a point some point if you could find, where this moment is neutralized and that point, where d C m by d C L will become zero that is even this angle of a tag this is disturbance; whatever disturbing moment wing is giving that equally compensated by the restoring moment given by the tail and that net moment that tail is zero, so it is neutrally stable and that point for the aircraft is called neutral point.

For a wing along configuration having an aerofoil neutral point is the aeronautic center that is if I keep C G just come siding aerodynamic center that is a neutral point. To make the aircraft statically stable I must ensure the neutral point is always behind center of gravity. Now, for whole airplane I definitely want it should be statically stable, but there are no dictum one wing to generate initial restoring moment to make it statically stable, because that is not is dictum that responsibilities with the tail.

So, I can say I can always aligned suppose this C G of the airplane I can always a line a c of the wing ahead of C G, if it gives me some other benefit we have seen if I put a c of the wing in front of C G special for camber aerofoil, but this helps in giving positive C m naught; however, this will have stabilising contribution, but we say will appropriately design a tail size and locate it as a particular length to see that overall stability this aircraft become stable that is the neutral point come somewhere here it is simple like there is one force here, now another force is there. So, resultant is come down you can lowly seeing the center of pressure has come here all the 11, 12 students.

Now, the question is once I write neutral point here or in a very restricted casual manner you can say neutral point is that aerodynamic center is the airplane this is a dangerous statement aerodynamic center is define only aerofoil. But, to make one to one standing at this stage I can say the neutral point is that the aerodynamic center of the whole airplane like, neutral point for an wing the aerofoil, what the aerodynamic center.

And, this is the C G this distance that is if I measure from here X N P the distance of neutral point minus X C G distance of central gravity, which are non dimensional zed with cord this is call stability margin, why I came to all this. Because, I want to give a physical interpretation of this C m is equal to minus C L into x as if all the forces is whatever acting here I am thinking it is represented at neutral point, which is for aerofoil aerodynamic center and this distance from, here to the C G is x.

So, C m was minus C L into x d C L by d C m is minus x which is nothing, but now I understand minus S M, S M is the static margin, which is the distance between neutral point and the C G, if I understand this my job is simpler.

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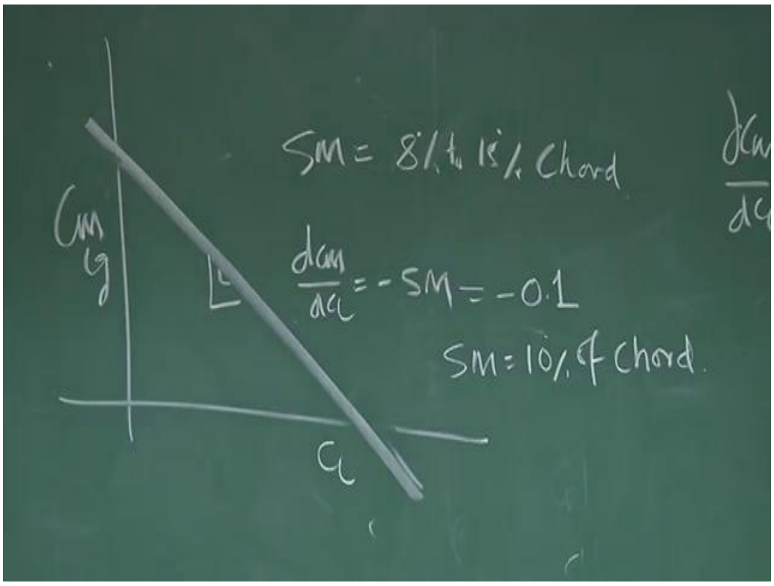

If I now, draw C m C G versus C L I know this lope is nothing, but d C m by d C L, which is minus static margin that is the distance between neutral point and the C G. So, that is the margin if the C G goes and concede with neutral point this value will become zero it will be neutrally stable. Generally, for deigning airplane let me correct this, this should be straight line do not get mixed up.

So now, my life is simple one once I understand d C m by d C L static margin if I am plot C G and C L this slope is minus static margin a static margin is the distance between neutral and the C G. Generally, when you design a transport airplane you keep static margin anywhere between 8 percent to of 15 percent of chord.

So, when I say static margin is minus this is, when I say d C m by d C L is minus 0.1 or d C m by d C L the slope of this C m verses C L is minus 0.1, what I actually mean is static margin is 10 percent of chord, which is aerodynamic chord or the separation between C G and neutral point is 10 percent of the chord. So, if you design a airplane let us say you want to design an airplane, how will you start how will you make the beginning question is this, first you will ask what is airplane is it is a simple transport airplane.

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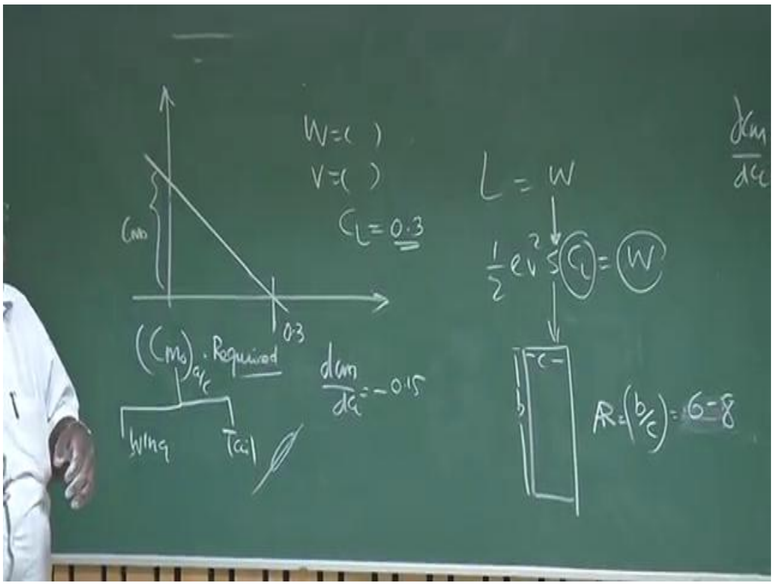

So, you start like this as a designer you first see what is the work of airplane will note down this is the weight will note down from the history of data first similar type of aircraft what is a cruise what is the cruise altitude. If I know this, then I get a rough assessments of the C L requirement, let us say C L is 0.3 anyway for all practical propose at the optimum altitude that you used that drag bucket, where operate C L point within C L 0.3,0.4 an normal case 0.2 to 0.4.

So, we know this is the C L let us say 0.3 I am going to design the airplane accordingly I got enough cruise that a given altitude. Since it is a transporter airplane I know what is the static margin I will be keeping as a initial estimate I can let us say 15 percent. So, I know d C m by d C L is minus 0.5, so I draw a slope of that and extend it and see what is the C m naught C m naught of the aircraft required.

Once, I know this C m is not required then I try to distribute some part two wing some part to tail through tail setting angle that is I will try to put a c of the wing little ahead of C G from there I will get positive C m naught I will give some tail setting to the tail horizontal tail to get some positive C m naught, and ensure that this two when gets added I get this is the value.

So, this understanding at least tells you gives you guideline how do I locate the wing in a fuse large, where do I put the a c of the wing, where do I put C G of the airplane now this are few tips, which will help you in getting a line to actual process of design this gives initials field.

If, somebody ask you how do I get there? How do I decide wing area. Natural question comes what is this wing area required for this for lift is equal to width. So, you know how rho v square S C L equal to width. So, you can easily calculate how much is required depending upon what speed you have flying what altitude of flying, what is your C L design and what is a width is going to its width.

So, once you get a you then try to lay out the wing what should be the aspect ratio that is b by c suppose rectangular wing will distribute this as appropriately rectangular initially and try to see the aspect ratio depending upon it is a glider configuration or a normal airplane if a normal airplane between 6 to 8 you try to keep the aspect ratio and find out, what is a span what is the chord like this iteration go on. So, in my next lecture, when I am starting something on the design initial preliminaries this understanding will help.

Thank you.