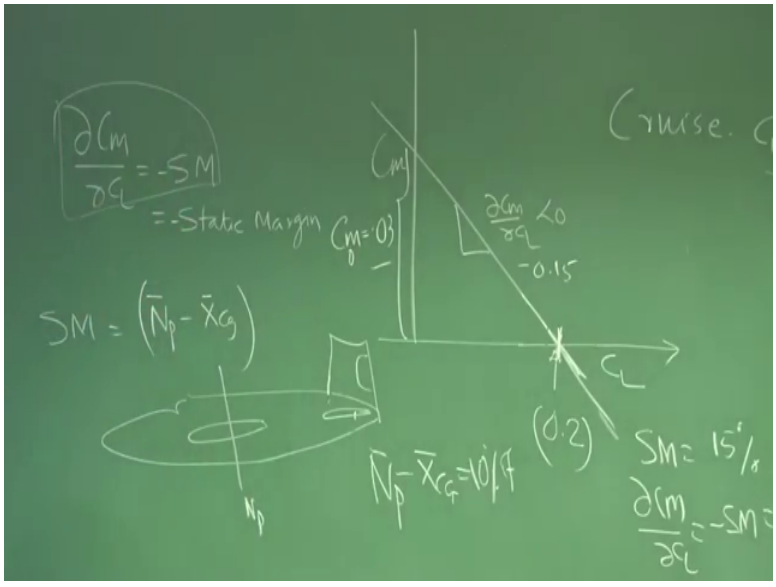
Aircraft Design
Prof. A.K Ghosh
Department of Aerospace Engineering
Indian Institute of Technology, Kanpur

Lecture – 34
Static Stability Basics

Good morning friends, the last lecture we are discussing on effect revising few understanding about static stability of an aeroplane and also very critical point critical understanding about trim and what we record.

(Refer Slide Time: 00:38)



Was if the Cm pitching moment coefficient versus alpha, I will prefer my variation of Cm versus alpha to be like this so, that I have brought in alpha positive sufficient enough for a given dynamic pressure so, that it can produce enough left to balance the weight.

For a designer as I have told you we use those information and try to visualize this basic understanding troughs some simplistic formulation, which can directly tell me what I should do as per as designing the various components of aeroplane which your amount into stability and trim right. For example, from here we are seen for static stability d Cm by ds alpha should be less than 0 and to have a positive trim Cm naught should be greater than 0 and we have also seen that d Cm by d CL is nothing, but d Cm by d alpha as simply (Refer Time: 01:57) to be linear and divided by 1 by d CL by d alpha see this gentlemen is always positive which is lift cup slope. So, I say d Cm by d alpha, less than

0 is a condition for static stability I also invariantly say d Cm by d CL lees than 0 conditions called static stability.

Now, what we do is pretty simple (Refer Time: 02:27) plot I design a will prefer to have Cm versus CL graph like this, and the slope is d Cm by d CL we should be less than 0 at trim that is important. When I am talking about stability I am talking about stability about a trim point, whenever talking about stability I have talking about a slope about the equilibrium about the trim here right.

Now you also recall that approximately you could write d Cm by d CL recovered to static margin right and what was static margin? Static margin was defined as the distances between neutral point and Cg non dimensional right. So, if I have an aeroplane and somewhere here is neutral point and the definition of neutral point was neutral point is that Cg location at which d Cm by d CL become 0 or more classically neutral point is that Cg location at which the aircraft become mutually stable right. This is an approximate expression, but very very useful expression, and see how the designer will exploit these understanding.

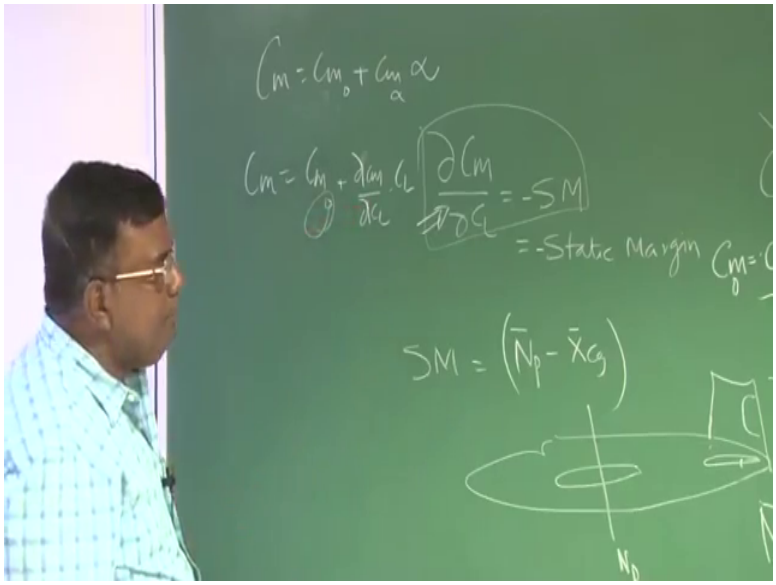
For example, if I am designing an aircraft for a cruise and let us say cruise I need CL equal to 0.2. How do I get that CL equal to 0.2? Yes where talk about a cruise I know if I am flying for best range or trust required minimum, let say your (Refer Time: 04:36) trust required minimum then I know CL should be equal to CD naught by K. So, no in the value approximate value or CD naught and K, I know what CL I am going to fly. It is could also possible that you are not able to maintain trust required equal to minimum condition there is no CL as 2 w by s rho V cruise square.

So, whatever you the condition you know the value of CL to maintain at that altitude for a given speed and if I am designing for a cruise, I know that I have to maintain lift equal to wait for a given dynamic pressure. So, I have to have a particular value of CL and let us say that CL is 0.2. So, if it is cruising your CL 0.2 means a d is a trim point where there is no Cm, C m is 0 that is equilibrium. So, this point becomes 0.2. Now the question is if this becomes 0.2 what should be the slope I should design here at the trim and you know that this slope d Cm by d CL is nothing, but minus of static margin sorry this is you have a correction here this is minus of starting margin and let me put minus here.

And then next question come is what is the starting margin, how much you want. Is typically this static margin N P bar minus X Cg, X C gs for the aircraft is typically it could be 10 percent of called or its 10 percent based on called 15 percent, but if you are doing the final thing and here going all the derivatives everything is perfect you may try to plan it for around 5 to 8 percent right, but that is a design a choice, but and a conceptual stage I will say you start with static margin of let us say 15 percent say for because now everything is very very you know inaccurate it is an all some estimates all those parameters which we are taking. So, I will play safe. So, static margin 15 percent means the d Cm by d CL which is going to minus static margin which is minus 0.15.

So, this slope is minus 0.15 and I know I am going to trim their plane at CL equal to 0.2. So, automatically I know what is the value required Cm naught which is Cm at CL equal to 0 that will be 0.15. So, it is 0.03. So, message for designer is I need to put the wing on the fuse large in such a way.

(Refer Slide Time: 07:48)

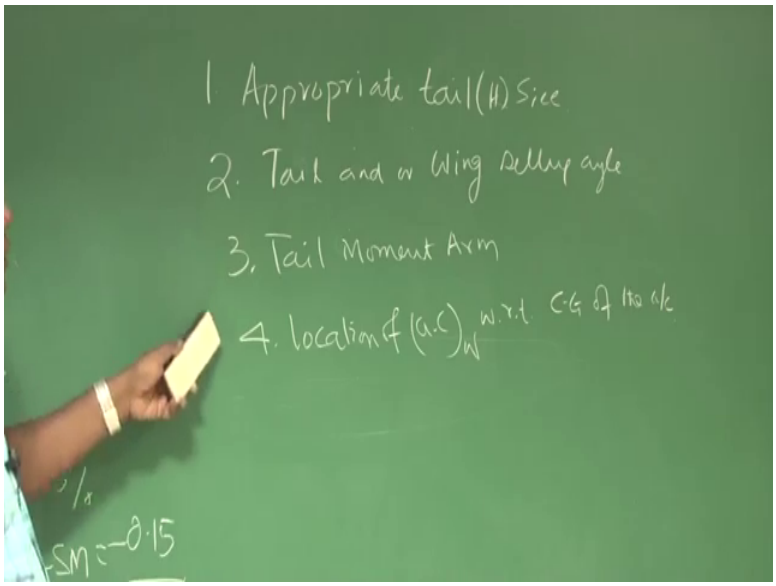


I need to put little bit this is the fuse large which will have design so far. So, I need to put the wing such a way that you should be able to produce that much of lift which is required for a given dynamic pressure at a CL 0.2, at the same time the aircraft should be statically stable. Further the Cm naught that Cm at CL equal to 0 it should be around 0.03 this 3 conditions it has to satisfy.

So, as far as slope is concern to make a negative we use horizontal tail and Cm at CL equal to 0 that is Cm naught if you have a confusion of when I right Cm equal to Cm naught your Cm alpha into alpha, this Cm naught is Cm at alpha equal to 0 because I am expanding with respect to alpha if I am expanding with CL that is Cm naught plus d Cm by d CL into CL if I am using this, which I am doing it now sorry using this formulation then this Cm naught corresponds to Cm at CL equal to 0 right.

But we will see that these are the ways if I understand how to how much I need Cm naught and how much CL I will I need, how much d Cm by d CL I need prior if I know then I can easily manage this through.

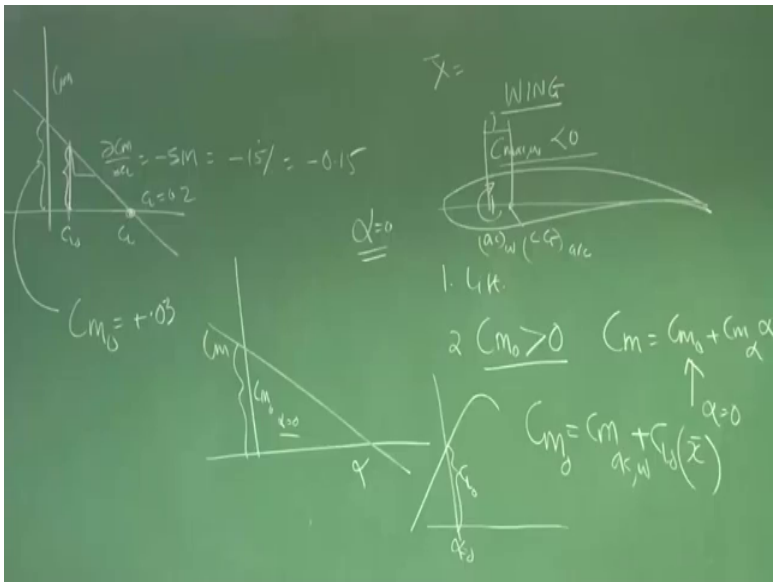
(Refer Slide Time: 09:37).



One appropriate tail that is horizontal tail size, second thing tail and or wing setting angle, third is tail moment arm, and fourth you will find location of a c of the wing with respect to CG of the aircraft.

This is what a designer will look for when is trying to stabilize a aeroplane and you see that.

(Refer Slide Time: 10:49)



As I go for forward how simplistically you can get field for this number one way or life has become simpler, that if I know this is Cm, this is CL, I know what CL I should design for lets a CL 0.2, and I know what is the slope here which is d Cm by d CL which is minus static margin, which is a minus 15 percent. So, this is typically minus 0.15 which tells me what is this value Cm naught equal to minus or plus 0.03.

So, the message is now how do I put the wing and tail in combination. Wing is primarily meant for giving lift right, but we have also seen if I am using it cambered wing what is the primary role of wing a designer will give a priority to the different components. Whenever he thinks of a wing (Refer Time: 11:59) wing is meant for giving lift, but yes it is true it is for lift. Second thing you understand that we have a Cm naught criteria Cm naught should be greater than 0 right.

So, here you see if I put the a c of the wing ahead of Cg there is we have seen even at alpha equal to 0, let us say at alpha equal to 0 if I am trying to see about the Cm about Cm naught plus Cm alpha into alpha, which easier way to visualize which is Cm at alpha equal to 0 that means, I am looking for Cm versus alpha were this is Cm naught let me alpha equal to 0.

There are easier to visualize this you can get same information from here. So, at alpha equal to 0 you see what is the CL? It is a cambered aerofoil right you always see at alpha equal to 0 what is the CL? That is CL naught you pick that CL naught point, CL naught

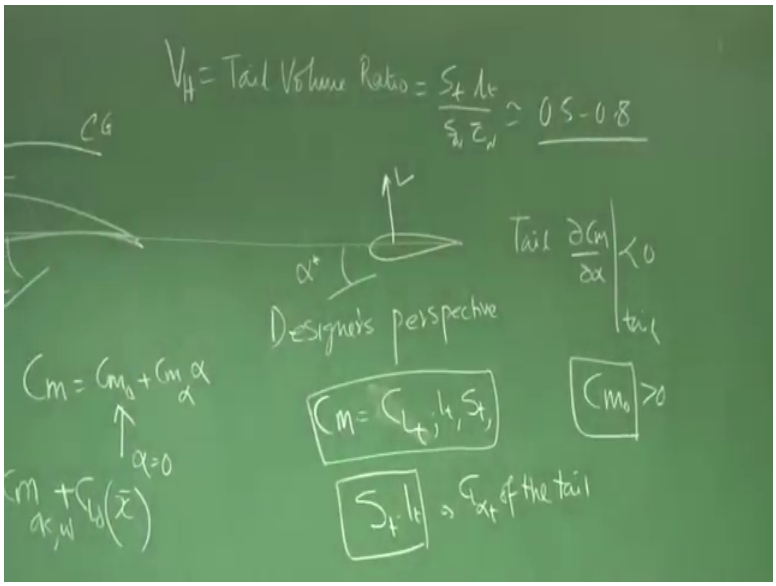
right this is this becomes your Cm at alpha equal to 0 what is the assumption here is the first approximation is all the lift everything is coming from the wing right is the conceptual stage that is why we are doing all these approximation.

So, now you have also seen here the moment I use a cambered wing, there is a Cm a c of the wing which is a concentrated moment which comes because a transpiring the forces which is negative. So, that is going to jeopardize Cm naught to be positive. So, what is done? One way please from please understand we are talking about wing and we agree that wing primary role is to give lift, but I am also telling you can get a secondary (Refer Time: 14:09) from wing by adding some Cm not positive, because this wing is carrying a luggage of Cm is negative and I want Cm naught should be positive.

What is the done is, put the a c of the wing little bit of ahead of Cg of the aircraft and then you know that Cm naught will be Cm a c wing plus CL naught into x bar, which x bar is of course, this distance x bar which is of course, non dimensionalised with called. So, that will give you a positive Cm naught which will try to compensate for the negative Cm exhibits it is carrying. So, what is the message? Yes it is indeed true worried think about wing with primarily thing in terms of lift, but there is in way out by putting the a c of the wing little ahead of Cg of the aircraft, you can also contribute towards Cm naught being positive or your positive contribution.

But same time you should understand the moment I put a c of the wing ahead of Cg of the aircraft, is wing become destabilizing right. So, if you want to make it sable you are definitely you are using a tail which is a horizontal tail in this case.

(Refer Slide Time: 15:35)



So, you put a horizontal tail somewhere here, now what this horizontal tail will do let us see. Again I am talking from designers perspective I will do more methodical with formulation in the next class and this is a warmer class, designers perspective will be. If there is an angle of a tack alpha seen by the aeroplane and it will also see some angle alpha star which will be less than the angle of a tack you know because a down version all, those details will come later, but message is this will generate a force lift right and the lift will give moment about Cg right ok.

So, any positive angle which is coming (Refer Time: 16:41) stabilize this aircraft, this tail will give a restoring moment. So, we know the tail as per tail is concerned d Cm by d alpha will always be less than 0 that is f tail is always stabilizing (Refer Time: 16:57) find out how to assess how powerful will be the tail in terms of stabilizing effect, I know that yes this Cm will be dependent on the lift on the tail. So, I say since I am talking about non dimensional to CL of the tail, and also this moment all right the this force into this length will give me the moment. So, it is also l t then tail area.

This is a primary things as far non dimensional is concerned, and there you will see that S t into l t will play an important role for a given CL alpha tail of the horizontal tail. Once we have chosen an aerofoil which is generally symmetrical aerofoil there, how much effective will be will strongly depend upon what is the area and what is the moment arm right and if it is called once you are do thing in terms one dimensional term.

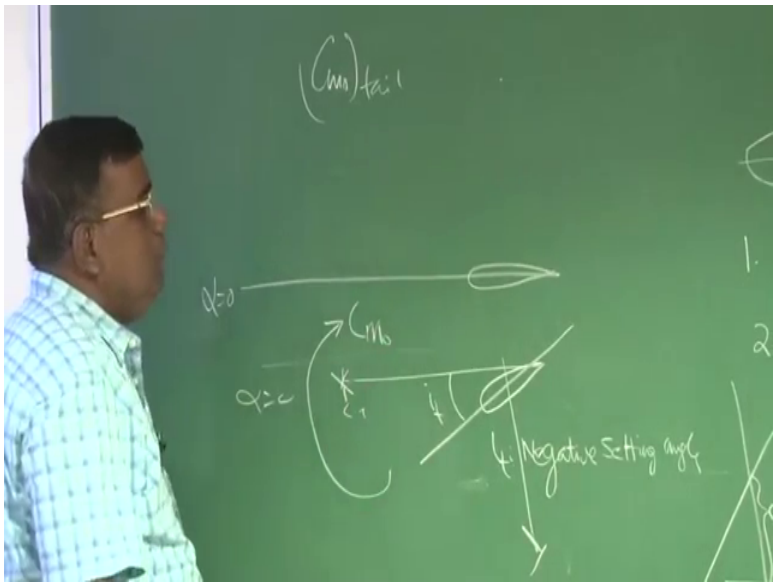
So, we define something called V H tail volume ratio which is S t l t by S wing c bar of the wing.

So, this tail volume ratio is regressly used to conceptualize an aeroplane initial stage from the stability point of view and typically we will find the as a initial stage from 0.5 to 0.7 or 0.8 if you take you are fairly safe right you can do final tuning after words. So, we will also see how to design a tail from tail volume perspective right.

So, this tail volume primarily it will talk about static stability, it will contribute toward d Cm by d CL. Please understand if I put the ac of the wing ahead of Cg, it is a destabilizing d Cm by d CL of the wing is positive. So, this gentleman of (Refer Time: 19:38) tail as if primary role of providing longitudinal stability. It is role is not providing lift the primary role for providing lift is wing. So, the jobs are divided and we should also thing separately.

Now, once tails primary job of giving stabilities over, we have to also thing how to extract contribution of tail in making Cm naught positive that is also important. So, what is done you will see I will not talk much this is I am just warming you up because by subsequent lecture will develop whatever you have done and then you will try to synthesize, but this is a designer would think like this. So, once I give you the all those expressions you should be able to think in this term or you should be able to extract only those information, which is designer need designer does not required too many equations right, but you need to have those too many equation understood correctly so that you can get those thus juice of the whole discussion right.

(Refer Slide Time: 20:51)



So, Cm naught from the tail if this is my tail. So, at alpha equal to 0 I want to Cm which is Cm naught, what I should do? I simply we set this tail at a negative setting angle i t. So, i t is a negative because down setting angle you can very well see that at alpha equal to 0, tail force in this direction and Cg somewhere here. So, it will give us positive moment and this is Cm naught. So, there what is the role of this I and a tail to provide major contribution towards d Cm by d alpha less than 0 making their crust radical is stable, and also to contribute towards Cm naught making it positive as desired right. What is the role of wing? It is lift and partial it small contribution towards Cm naught of the whole aircraft tending to become 0 or nullifies Cm is a negative right. If you understand this things in the next lecture we will build it up from first principle.

Thank you.