Aircraft Design

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Lecture - 38
Elevator Effectiveness

Good afternoon friends. In the last class, we have seen that how to get fill for few numbers, so that it can help you to design a conceptual sketch of an aero plane and the understanding was I have a mission requirement.

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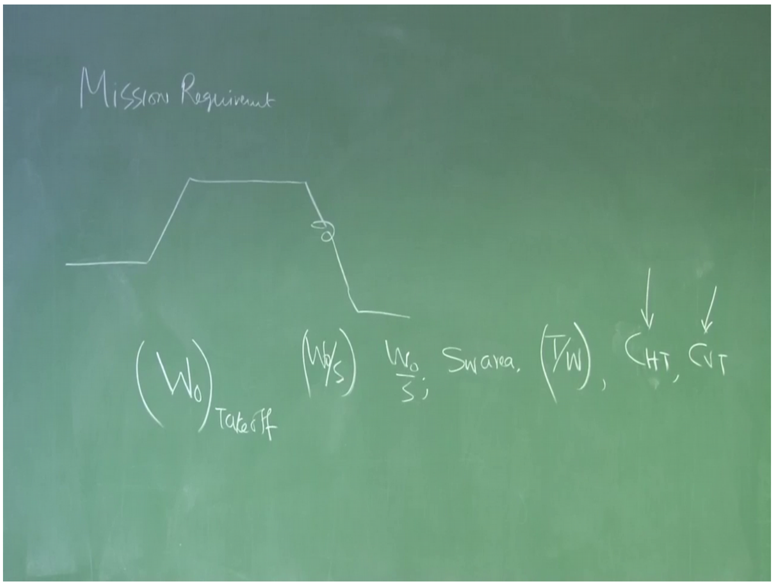

From mission requirement could be something like this. We calculated what is the W naught that is take off. Then, we try to find out wing loading W naught by S. Once we selected W naught by S, we now know what the wing area is. They have also what the idea about what T by W or thrust loading required for the conceptual aero plane is and after that we try to understand how much tail volume ratio is required, how much notation you might have written. CHT and CVT is tail volume ratio for horizontal tail and tail volume ratio of vertical tail.

Then, we also talked about roughly how much will be the elementary size, then some topic, some discussion on aileronflaps. This will help you in just drawing a sketch (Refer Time: 02:00) because after that we will do the analysis, right.

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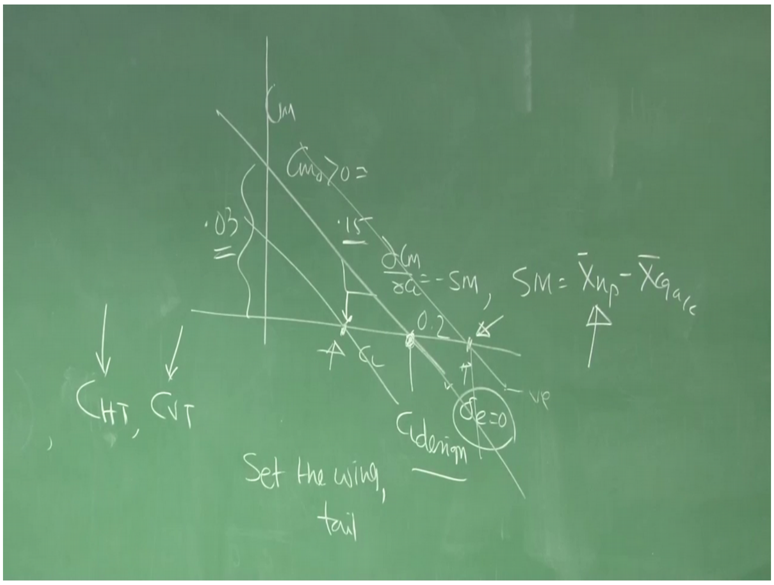

A designer do the analysis, but do not forget one thing. We are all designing this aero plane when it is Cm versus Cl where designing for a particular Cl design the Cl design, we are getting another example which will meet perhaps the cruise condition if it is the transport aero plane and also, we have decided we will design this aero plane for a particular static margin may be 15 percent, 10 percent, 5 percent depending upon how you mature in terms of technology and calculation.

Once I do that, then we were looking for how do I set the wing and tail, so that these two conditions are met, that is one is Cm naught greater than 0 which is particular number. If this is 0.2 and this slope is 0.15, that is 15 percent static margin, then this value because 0.03 when the question we addressed was how do I looked at wing and tail. What is tail setting angle and how do I find it, so that Cm naught is satisfied and d Cm by d Cl is satisfied. Remember for static martin let say this is neutral point minus x c g of aero plane and we have expression for how to find neutral point which largely depends on tail volume ratio. All these things we have done, right.

The next question is suppose this is Cl at which we have design, but it is not all the time we will be flying at this Cl. So, I need to fly at sometime and this Cl sometime perhaps at this Cl right, but at a higher speed, at a lower speed, how do I do that because when I am designing the basic configuration which is here, this is that time I will ensure that the elevator requirement is 0. So, that time drag is 0, but where to go from here to here. If you see that, immediately it will generate negative pitching moment. So, I have to counter that. So, I have to give elevator up. So, how much elevator I need to give up. So, there my next Cl is what I desire here or how much elevator deflection when I want to fly at this Cl and that is typically the control problem and when I talk about control problem, what I must look for is the control power of ma of the elevator.

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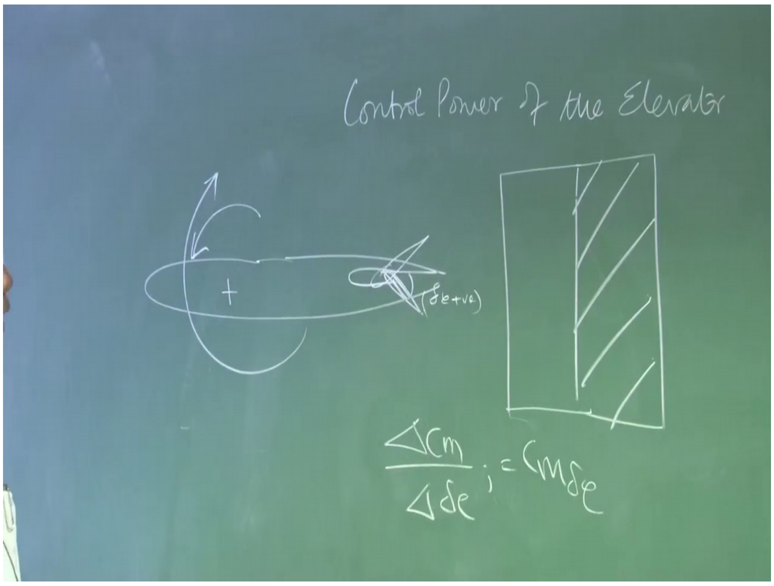

You see this is the elevator. You see this is complete in the horizontal tail and this cord is elevator. Then, how much delta Cm that is how much Cm it will produce if I slow it like this? This is the tail and this is the elevator and this is delta is positive. You know all these things the elevator control part is defined as delta Cm by delta which is Cm delta e which essentially tells you how much Cm it will generate per unit elevator deflection. It goes without saying if elevator is deflected down, it will give nose down movement. If elevator is up, it will give a nose up movement. If I connect this from here to here, my question would be if I flying at Cl 0.2, where elevator deflection is 0, if i now want to fly here Cl 0.3, how much elevator up is required that I should know as a designer and I should spread the elevator deflection within the maximum and minimum value or plus and minus value of the elementary deflection.

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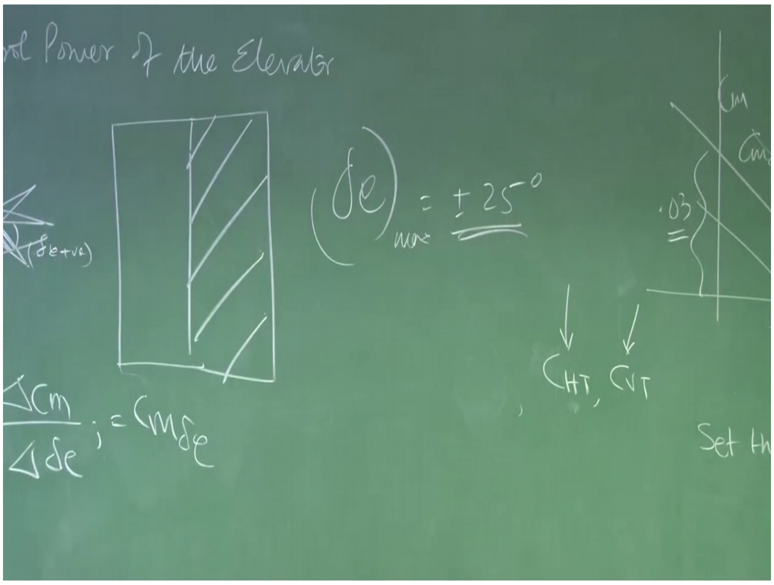

For example, delta e max if it is plus minus 25 degree, then I should spread all the operations within at least plus minus 15 degree because you know that around 7-8 degrees and you need to keep extra for ground effect while landing, right.

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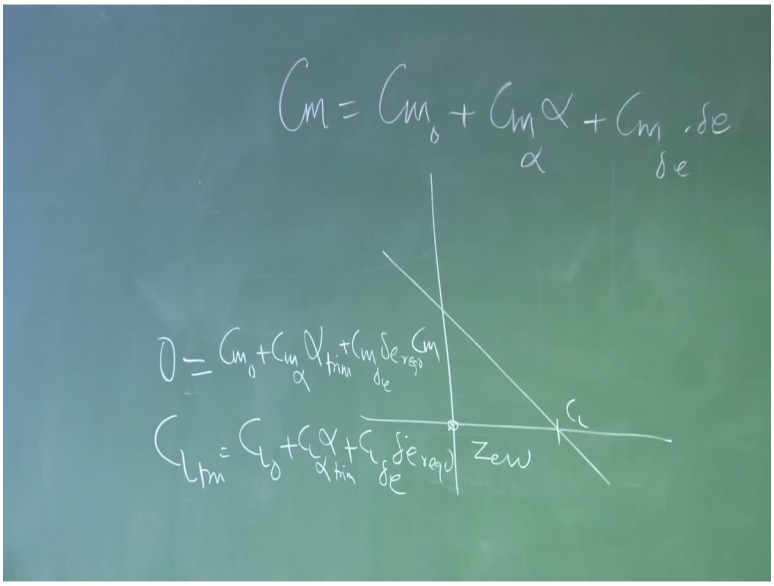

So, how do I get an assessment of how much elevator I should reflect to trim and aircraft a particular Cl. Just a revision for all of us. You have done if instability and control you know that Cm we write it as Cm naught plus Cm alpha into alpha plus Cm delta e into delta e. So, when I am trimming the aero plane at a particular Cl, that means that time Cm is 0.

So, I write 0 equal to Cm naught plus Cm alpha into alpha trim plus Cm delta e into delta I required, right. Alpha trim means this is Cl trim, where alpha corresponding to this Cl is alpha trim and also, I will write Cl trim is equal to Cl naught plus Cl alpha into alpha plus Cl delta e into delta e required in this alpha is alpha trim and you add it and you recall if I use these two equations for an approximate case, where I neglect Cl naught.

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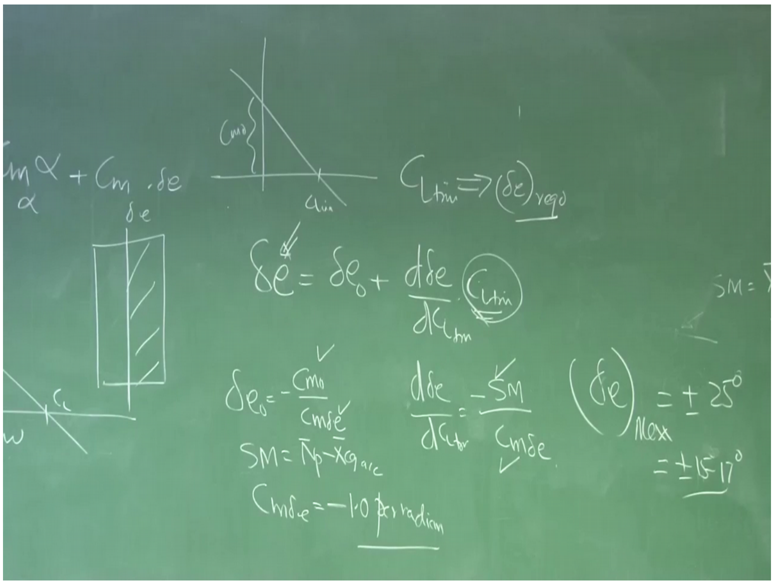

I can write delta e equal to delta e naught plus d delta e by d Cl trim into Cl trim, where d delta e by d Cl trim is nothing, but minus static margin by Cm delta e. This is a linear graph with an assumption which are well known. You must refer my class on air craft stability and control, but this linear variation is quite good in terms of getting hang of initial numbers. See here what is delta e naught delta e naught is minus Cm naught by Cm delta e and static margin. You know what you have design for nuetral point minus C g of the aircraft and Cm delta e, you can always find out if you know what percentage of the horizontal tail is elevator and typical value for this for normal aero plane will be order of minus 1.0 per radian. I am giving this number because we are at a conceptual stage and you know very well how to find out Cm delta e 1. The geometry is given Cm naught. You know from Cl trim and Cm naught, this is also known to you. The designer stage you put that number, put Cm delta e static margin you know Cm delta. So, you will get for a given Cl trim what will be the delta you required, what we as a designer has to ensure that if you are delta e max which is true for a conventional aero plane p is equal to plus minus 25 degree.

So, as a designer you use only plus minus 15 degrees, 15 to 17 degrees, not more than that. Keep that 8-9 degrees for handling the ground effect because you know as I come close to the ground, but downwards value almost becomes half. So, naturally there is a another pitch down movement comes, so you have to put the elevator off. So, you need to keep that much of elevator of free for you, otherwise the elevator still missed all. So, once I know this, I can easily find out if I want to trim the aero plane for a particular Cl trim. What is the elevator required and what is within this plus minus 25 degree or not?

So, this is also very important while you are designing the aero plane at the initial stage, right and you can very well see that is delta i requirement and we will change with respect to the static margin. That means, as I am making it less and less stable say from 15 percent if I make it to 10 percent, the delta requirement we will go down naturally. Less stable means less effort. If I am increasing the static margin that is I am taking Cg forward and forward, then delta I required to will become pretty high. So, we have to see this whether I have got that much of bandwidth in elevator or not, this Cg travel because you know that the aircraft as different level of static margin when it is taking off, when it is having no win will condition where disclosing depending upon where the engine locations are there.

So, all these are part of analysis, but at a conceptual stage if you take 50 percent or 40 percent of the horizontal tail as your elevator, as we discussed earlier you will find fairly good beginning, right. Once you make this layout, then we need to address one by one. Now, I was debating after this, we should go for aerodynamics or not. That is once I know all these geometric parameters, should I go for refinement of the weight and the weight is the aerodynamic drag coefficient estimation or I should go for landing here.

I have taken a decision that from here we will go to different types of landing here and once at a system level you complete, then you will come to analysis. So, after this keep a hault. I will be talking about landing here configurations, I will be talking about how do mound the engine, I will talk about fuel tanks, where to locate fuel tanks, all this system level thinks and one this system level thinks are over, I will come back to the analysis and in the mean time, I have seen lot of demand on designing unmanned aerial vehicle, especially electric motor power.

So, we will have kept one session for examples were given. We will be given add it, they have kept one session where examples will be given which will help you in designing unmanned aerial vehicle which are electric driven, power driven, the battery power driven and also throughout example you will also understand how to set the wing setting, angle tail setting, the angle etcetera, but how were the data will be for unmanned aerial vehicle. This way you will get a broader prospective and you will really appreciate this course more because small unmanned vehicle you can make yourself and check for yourself.

Thank you very much.