**Lecture- 33**
Numericals: Stick Free Continued

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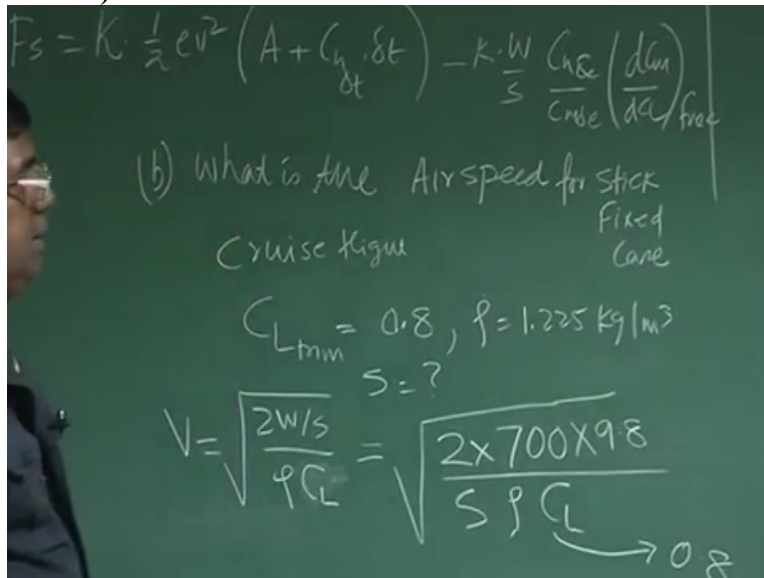
Second question is what is the air speed? We call it indicated in air speed, and you know indicator air speed is as a meaning but, basically equivalent airspeed, basically relative airspeed and this is the airplane speed related to the medium. What is the airspeed? For stick fixed case. That means I have to see this graph right. These are all graphs CM versus CL. For a cruise lines, Trim is that CL = 0.8 first I identify it is a cruise flight right, And CL Trim is how much?

CL trim is given by for a stick fixed case is trimming at 0.8 CL this = 0.8. Now this has been conducted test has been conducted in the wing tunnel, so, I can take Row as 1.225 KG, per meter cube S. S will be required to find out S, why I am doing all this thing? I have to calculate airspeed.
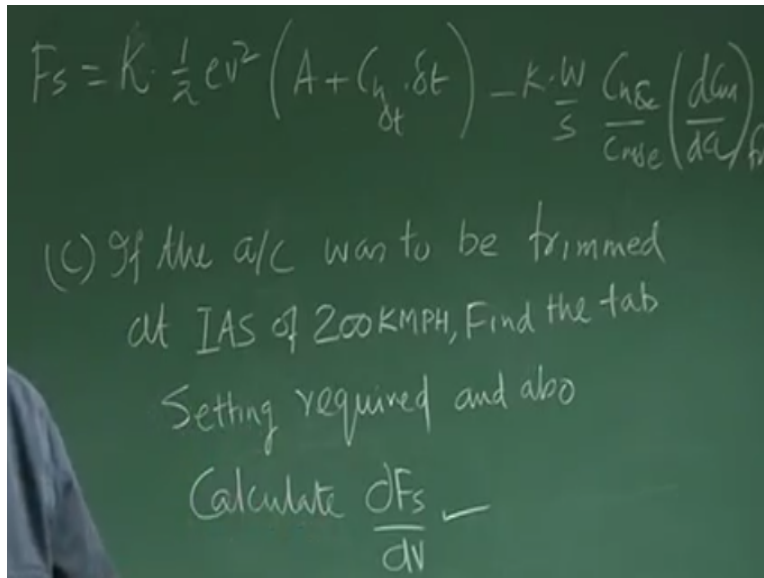
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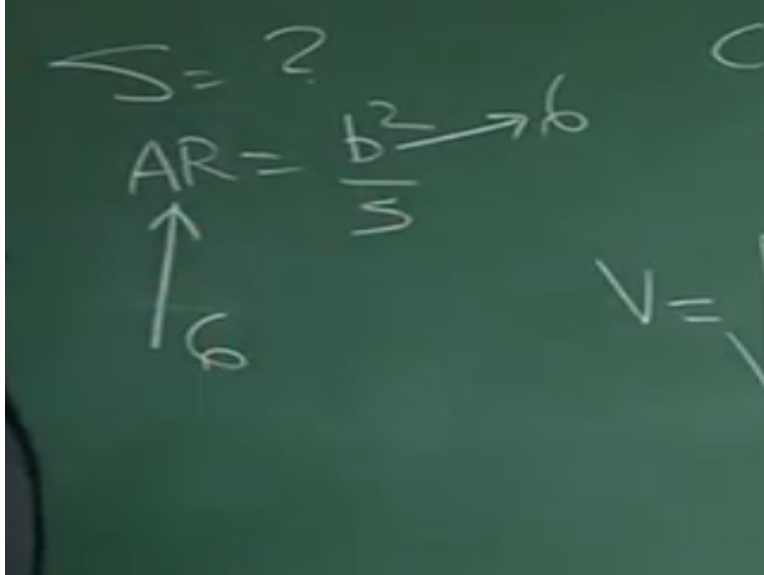
I know for a cruise V is = 2 W by S by Row V square, W is given? Yes W is given 700 KG so, I will write this = 2 and 700 Am I correct. Or I have to do something else? If I put 700 my problem will okay, No because this is in KG yare to put in Newton, you have to multiply by 9 0.8. Then divide by S divide by Row oh sorry V will be = this by CL sorry, V = 2 WS V = under root 2 W by S Row CL okay. So, S is there Row is here, and CL CL I know 00.8 how do I find.

That is I have to use aspect ratio and span, if you see now I am trying to find out S S is what? I have given aspect ratio in aspect ratio is B square by S, aspect ratio is given 6 span is given how much. Span is given 6, so I can easily find out S okay, So, S is known Row I know wing tunnel at C level 1.225, so I can easily calculate this is the V trim or what is the airspeed for stick fixed case is this much whatever value comes here.

In my calculation, this value comes out to be around 48.33 meter per second, but you please check right. This is I have done in the hurry, my job is not to spoon feed you, you should able to calculate this, I repeat again this S I calculate like this from aspect ratio and span row I have taken 1.225 because the wing tunnel testing was d1 in a at C level conditions, span of assumption and CL is 0.8 because stick fixed case this right? Okay so second question is over.

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$$F_s = K \cdot \frac{1}{2} \rho v^2 \left(A + C_{h_t} \cdot \delta t \right) - K \cdot \frac{W}{S} \frac{C_{h\delta e}}{C_{m\delta e}} \left(\frac{dC_m}{d\alpha} \right)_{fr}$$

(c) If the a/c was to be trimmed at IAS of 200 KMPH, Find the tab Setting required and also Calculate $\frac{dF_s}{dV}$
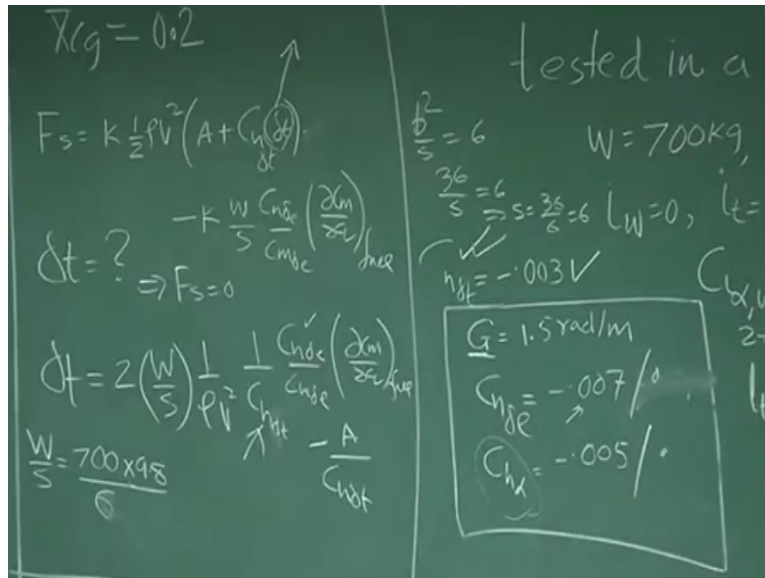
Now let us go to third question this question, these questions are designed to see that not only understand whatever we are talking about, you should understand the relationship between stick fixed and stick free. So what is the third question? Third question is, if the airplane or the aircraft was to be trimmed at indicated airspeed IAS, you know of 200 kilometer per hour find the tab setting, find the tab setting required and also calculate DFS by DV too important question I have asked okay.

Is this question clear? The third question is if the aircraft was to be trimmed at indicated air speed of 200 kilometer per hour, Find the tab setting required and also calculating DFS by DV, when is a tab setting required the meaning there by is after setting the tab, the pilot should fly hands off pilot should fly hands off means, the question is what is the tab setting required? So that the stick force become 0 both are equivalent question right.

So will do that we have to take help of this big big expressions, that will try to give a better feel I will not erase this part, I will try to solve this problem within this, so that you can see the portion when I am solving.

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On the blackboard (left side):

$$X_{cg} = 0.2$$

$$F_s = k \frac{1}{2}\rho v^2 \left(A + C_H \frac{\delta t}{\delta t}\right)$$

$$-k \frac{W}{S} \frac{C_{h\delta e}}{C_{m\delta e}}\left(\frac{dc_m}{d c_L}\right)_{free}$$

$$\delta t = ? \implies F_s = 0$$

$$\delta t = 2\left(\frac{W}{S}\right)\frac{1}{\rho v^2}\frac{1}{C_{h\delta t}}\frac{C_{h\delta e}}{C_{m\delta e}}\left(\frac{dc_m}{d c_L}\right)_{free} - \frac{A}{C_{h\delta t}}$$

$$\frac{W}{S} = \frac{700 \times 9.8}{6}$$

(right side):

tested in a

$$\frac{b^2}{S} = 6$$

$$\frac{36}{S} = 6 \implies S = \frac{36}{6} = 6 \quad L_w = 0, \quad l_t =$$

$$W = 700 kg$$

$$\eta_{\delta t} = -.003 \, V$$

$$\boxed{\begin{array}{l} G = 1.5 \, rad/m \\ C_{h\delta e} = -.007/^\circ \\ C_{h\alpha} = -.005/^\circ \end{array}}$$

$$C_{L\alpha,w}$$
$$2\delta$$
$$l_t$$

First of all let us understand this 200 kilometer per hour, so we have to convert this V indicated VI is 200 kilometer per hour I convert it into meter per second, And in my calculation it comes around 55.55 meter per second. So this is fifty 5.55 meter per second, VI no problem in the XCG what is the XCG given? And the XCG was given here the problem, this will be extremely important information yeah it has to be given this XCG even is 0.2 see why?

Suddenly I look for XCG because I know when you are especially for a stick force remember, we are we have to generate a moment about the hinge right. And stick force and stability related, like elevator deflection and stability are related right. If the over stable then you have to put lot of stick force turn the elevator for a trim, so I need to know what is the XCG location, which by mistake I missed but the question I found yes it is there, yes XCG is 0.2 whenever we solving a problem, please activate your mind on the physics of the problem okay.

Now what is the FS? FS is let me right this FS is K half row V square, A + CH Delta T into Delta T, - K I write here - K W by S CH Delta E by CM Delta E, which Delta means elevator into DCM by DCL free what is the question? Question is what is the value of Delta T that is, what is the value of tab setting angle? So what is the question, question is what is Delta E so that FS = 0 right? That is question.

So now if I put FS = 0 and this manipulate this expression, I will get Delta T expression as 2 W by S 1 by ROW V square 1 by CH Delta T, CH Delta T into CH Delta E by CM Delta E into DCM by DCL free -, A by CH Delta T. Please understand what we have done we have done nothing, we have to calculate Delta T and for Delta T FS has to become 0 so I put 0 here, and then do this algebraic manipulation to get this expression.

Which you can yourself find out, and if there is any mistake should be able to correct it okay, for example now I see a mistake here, this will be 2 W by S 1 by ROW V square into 1 by CH Delta T, CH Delta E by CM Delta E DCM by DCL free - enough apparently there is no mistake, but it should be very careful okay. So, now what is required? Do you know W by S let us see, I will not erase this because you will be requiring this do some trick.

Or you can use here, what is W by S? W by S W you know 700 divided by S yes you can find out aspect ratio is B square by S = 6, and B is 6 that mean thirty 6 by S = 6 this implies S = thirty 6 by 6, so it is 6 meter square okay? So I write W by S = this by 6 it's correct. No it's not correct because W should be a Newton multiply, this by 90.8 do not forgot that okay. So this is W by S that will come here ROW, what is the ROW?

ROW will be 10.225 because, we are talking about C level condition, next CH Delta T CH Delta T is given – 0.003. That value comes here CH Delta E – 0.007 per degree comes here, CM Delta E is CM Delta E given anywhere? And we check if it is not given there we have to find out or this should have been given. So let us see where is in the question with the CM Delta is given or not CM Delta is not given so we cannot solve this problem is it correct. We cannot surrender right?

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$$C_{m\delta_e} = -a_t V_H \eta_t \tau$$

$$C_{L_{\alpha_t}} (3-d)$$

$$C_{L_{\alpha_t}} = \frac{C_{L_{\alpha_{2-d}}}}{1 + \frac{C_{L_{\alpha_{2-d}}}}{\pi AR}} \qquad e = 1$$
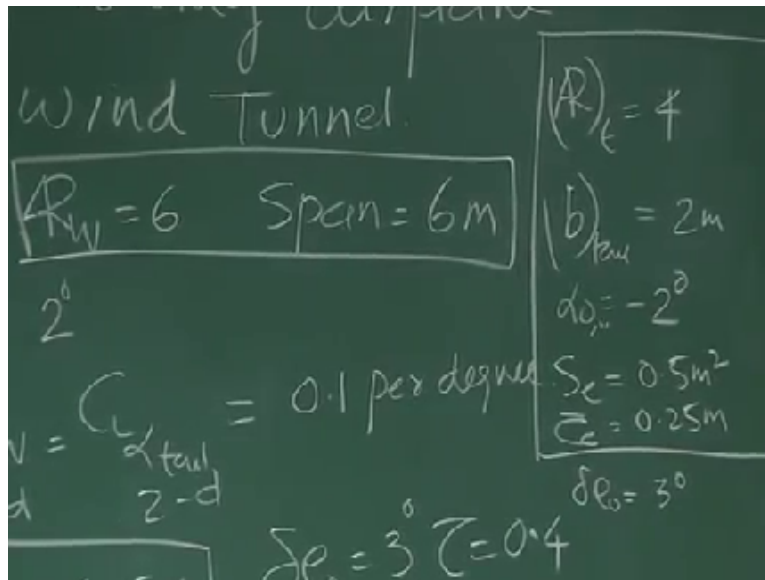
(c) If the a/c was to be trimmed at IAS of 200 KMPH, Find the tab Setting required and also Calculate dFs ___ , $\bar{X}_{(g)} = 0.2$

Let us see how to calculate CM Delta E okay, We need to calculate CM Delta E given that data there, CM Delta E has given as - AT or CL Alpha tail, into VH Neeta T into TOW what was AT? AT was CL Alpha tail; of course we have to have 3 dimensional rights.

What is given here CL Alpha wing and CL Alpha tail 2 D is given, that is 0.1 per degree but this formula want CL Alpha 2 tail at 3 dimensional, so what I have to do CL Alpha tail 3 dimensional can easily calculated, but CL Alpha 2 D tail by 1 + CL Alpha 2 D by PI aspect ratio, I am taking E = 1, as simple as that just mechanical job, u put that 2 D value here put the aspect ratio value PI here you get CL Alpha 3 D.

What is VH? What is VH? VH is ST LT by S C bar, then let see ST is given or not, LT is given 6.5 meter so, ST was missed so ST is that it let me write the value of ST, so there are other information also given which are required. So let us see I am writing here for example.

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Wind Tunnel.

$(AR)_W = 6$ Span $= 6m$

$(AR)_t = 4$

$(b)_{tail} = 2m$

$\alpha_{0_w} = -2^0$

2^0

$S_e = 0.5m^2$

$\bar{c}_e = 0.25m$

$V = \dfrac{C_L}{\alpha_{tail}} = 0.1$ per degree

$\delta e_0 = 3^0$

$\dfrac{d}{2-d}$

$\delta e = 3^0$ $\tau = 0.4$

What is given is aspect ratio of the tail, as 4 tail span B of tail has 2 meter, Alpha 0 = - 2 degree of the wing, this is of course of the wing right. And also things are given like elevator area, S elevator as point 5 meter square and LT is already 6 point at elevator chord, that is CE chord is 0.25 meter and Delta E 0 is given somewhere or not? Delta E 0 let us also write here Delta E 0 is given as 3 degree and other values are given of course.

So is not a problem as you solve the problem you understand this data are required and they need to looks for those data right. So what we are looking for was what is the trim tab setting required for FS = 0, and we are calculating at a speed V because, we are trimming at that speed V so, we are trying to calculate this is 2 W by S W need a precaution 700 the way to 90.8, and S whatever S of the wing is there.

ROW value you know V value you know CH Delta you know CH Delta you know CM Delta you know DCM by DCL free. Where from you get from that graph which we have given, is – 0.0 7 - A by CH Delta T what is A? What is A?

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$$A = C_{h_0} + C_{h_\alpha}\left(\alpha_0 - i_W + i_t\right)$$
$$+ C_{h_\delta} \delta e_0 =$$

If you check your notes A is nothing but, A is nothing but CH 0 + CH Alpha into Alpha 0 - IW + IT okay? + CH Delta into Delta E 0 and all this given hope values are given, trivial thing you have to check the data side and put those values but from you are solving is his somebody ask you what is the trim tab setting required.

To trim at speed V so, that FS is 0 you need to ask for all this information so this exercise is d1, you give a that feel but we have to look for all this information small small information, what remember this are not straight forward information, how to get CH Alpha tail how to get CH 0 this are herculean task, you need to do exhaustive internet testing, specially hinge moment coefficients or hinge moment derivatives.

All those black board looks very simple to solve a problem, but to generate this data this herculean task and a good airplane is design provided this data's sets are relevant okay? Now second problem we want to calculate DFS by DV at XCG = 0.2, so let as erase this all so we get some space,

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$$\frac{dF_s}{dV} \text{ at } \bar{X}_{cg} = 0.2$$

$$F_s = K \frac{W}{S} \frac{C_{h\delta}}{C_{m\delta e}} \left(\frac{dc_m}{dc_L}\right)_{free} \left(\frac{V^2}{V_{trim}^2} - 1\right)$$

$$\boxed{\frac{dF_s}{dV}\Bigg|_{V=VTRIM} = 2K\frac{W}{S}\frac{C_{h\delta e}}{C_{m\delta e}}\left(\frac{dc_m}{dc_L}\right)_{free} \cdot \frac{1}{V_{trim}}}$$
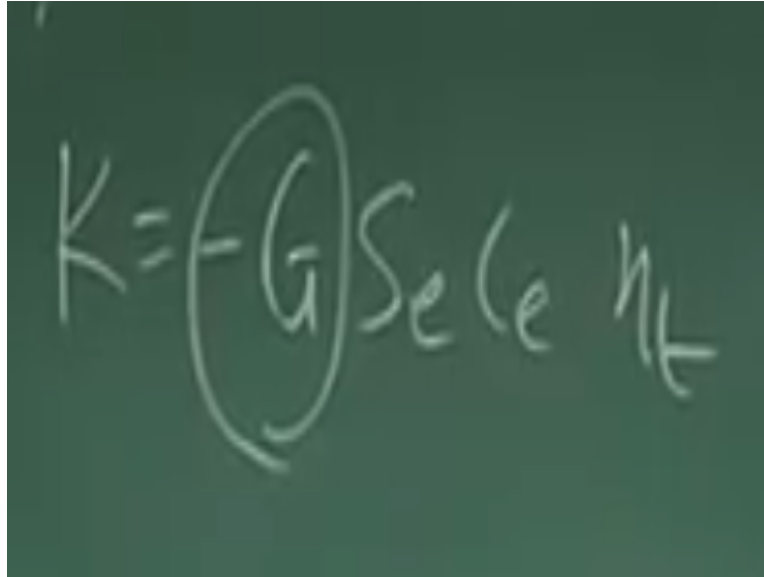
Let we write the problem we want to calculate DFS by DV at XCG = 0.2, please understand it is extremely important if some1 to ask you a question. What is DFS by DV meaningless question, because you know this has to be specific for other conditions also, but CG is extremely important right? If it over stable then DFS by DV will give a large gradient, so how do I calculate that? that is the question is again very mechanical as them when you understand things is just question of putting some number so, what is DFS by DV?

If we see the expression so, let us see DFS by DV and before that if we see my notes will find FS. Given as KW by S CH Delta by CM Delta E into DCM by DCL free into V square by V trim square - 1, and then we took DFS by DV but that derivative was at V = V trim, and that expression was just to take derivative the expression was ,let me write it is 2 K W by S CH Delta by CM Delta E, CH Delta E also same thing DCM by DCL free into 1 by V trim, that if I take the derivative then put V = V trim so, there is only 1 by V trim will remain.

So this is the expression what is so great to calculate this, what I should know I always know, I am expert now, what is W by S and I know that when I put W have to put in Newton, so, I will multiply by 90.8, if the weight is given in H, CH Delta value is known CM Delta value is known, DCM by DCL free is also given, V trim I know what is the V trim because, I am cruising at that point what is remaining only value of K what is K?.

So simple it is a so straight forward, it is that if we will get bored solving that problem, all though expressions are big big and very nasty looking expression, but only once you solve it is very electrician.

So what is K? K is - G SE CE Neeta T that's all, but look for what is the value G? In the if we where bring real aircraft, you have to find out the value of the through experiment AC is the elevator area, CE is the elevator chord NT is the ratio dynamic pressure. At the tails which respect to free stream dynamic pressure, some numbers are given here right.

And this is simply K you know here, you put the value of K so you will get the value of DFS by DV at V trim V = V trim, but understand 1 thing solving this problem is very simple, but when you try to generate let us say value of G you have lot of experiments right. And you get the value equivalent value of G ,similarly when you want to do use the CH Delta E CM Delta E all those derivatives, don't this has just from an look of table you get exact values.

We have to do wind tunnel testing, we have go far flight testing and multiple flight testing, and then finally you get these values accurately. The whole art and sweat lies in generating this number, not applying this numbers for some equation getting some number, So equations gives a feel and you can extend your design correct your design, but validation comes from actual flight test or some part through wind tunnel, and whole task become how do I generate this number.

Which mathematical model expects to simulator real situation, that is the real challenge okay? I hope this example will give you some feel, and you will enjoy doing this problem, and enjoy the subject stability and control. Thank you very much!