Aircraft Dynamic Stability & Design of Stability Augmentation System
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Module 6
Lecture No 34
SAS for Lateral, Directional Dynamics

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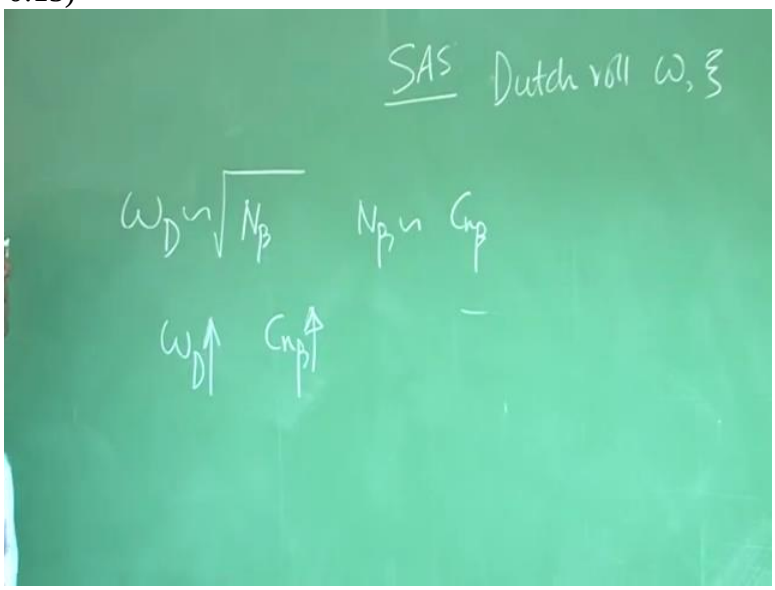

So we will not talk about SAS where we try to augment Dutch roll Omega and Zeta. Okay? We have seen that Omega D from 1st our 1D analysis, it is directly proportional to N beta one-dimensional, right? And N beta has CN beta into this because N beta is half Omega V square S means CN beta by IZZ. So if I want to increase Omega Dutch roll, that means I have to increase CN beta. Remember, for longitudinal natural frequency, we have to increase this CM alpha. What should be the logic here?

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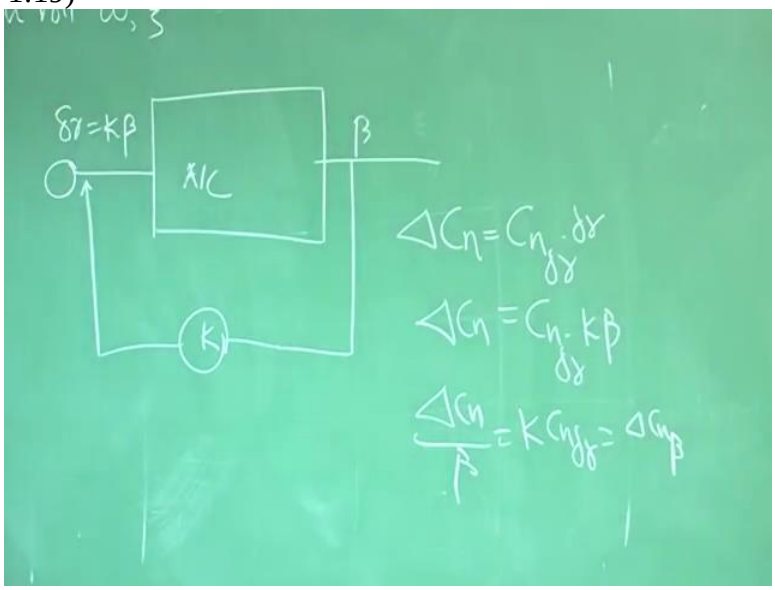

We have the air plane and all this yawing motion we are attributing authority to the rudder. So let us say this is I am tapping beta, again I am multiplying and deflecting Delta R proportional to beta. Okay? What is happening by doing this? I am adding Delta CN yawing moment that will be CN Delta R into Delta R. That will be equal to CN Delta R into K beta.

So that is Delta CN additional. So additional CN beta will be how much? That is Delta CN by beta. That is K CN Delta R. So that is Delta CN beta. So let us come back again here.

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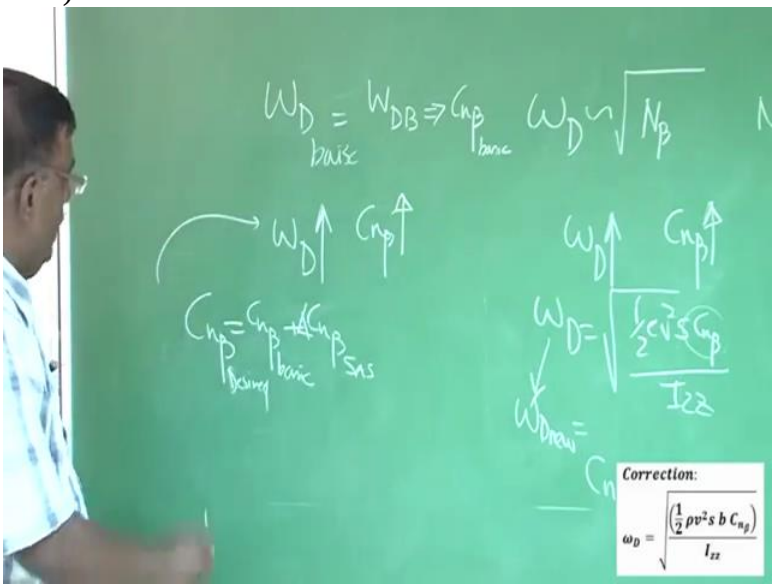

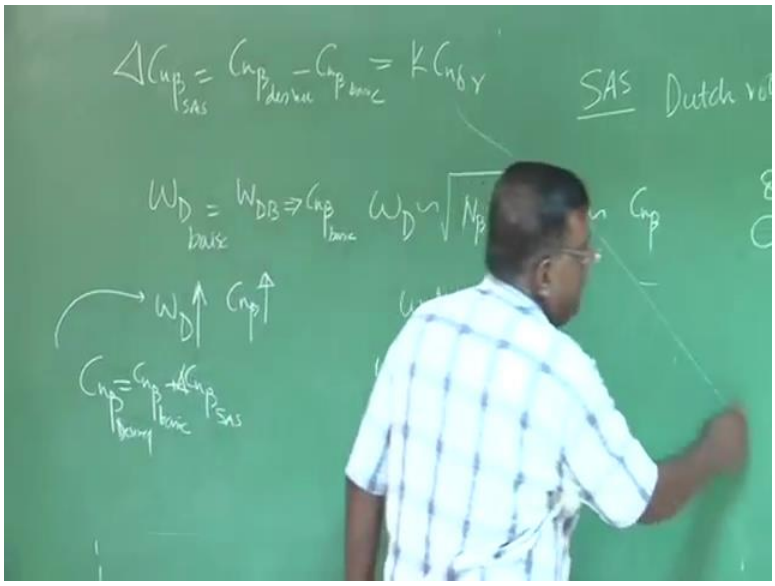

Suppose I have got Dutch roll frequency basic. I have let us say WDB, I will say basic. Now with this basic whatever the air plane has, we found the corresponding CN beta for CN beta basic. Now we want to increase the Dutch roll frequency. Hence CN beta has to be increased. How much it has to be increased? For that, for approximate value, I can use the expression for Omega D. Omega D is equal to under root of half Rho V square S CN beta by IZZ. So all these values I know. From here, whatever Dutch roll new is required, that I put on the left-hand side and for a Rho, V and Z, S and IZZ I know what is the CN beta new required.

So I have got CN beta is CN beta basic + CN beta which would come from SAS. That is the additional. And this is the required. Or desired or required whatever you say. Who decides this CN beta desired? That is linked to whatever Omega D required which we got approximately from here. So now I know that Delta CN beta SAS would be equal to CN beta desired - CN beta basic and this is equal to K CN Delta R.

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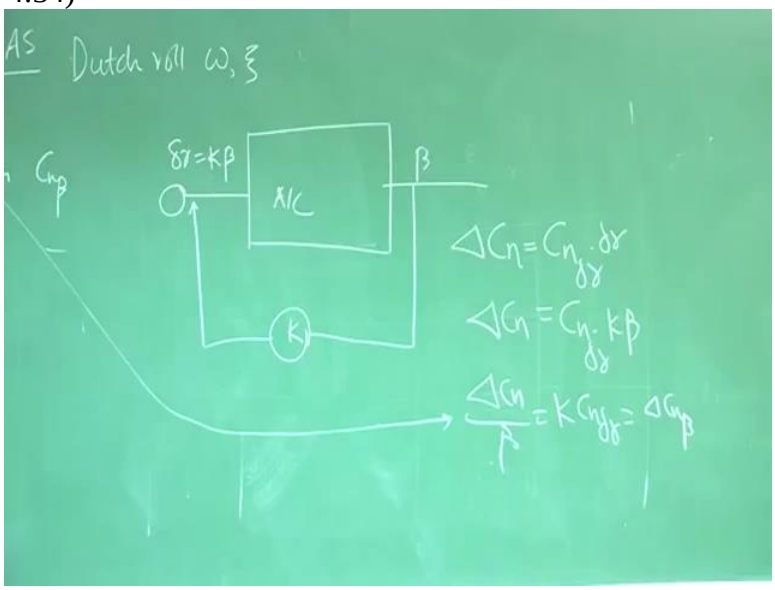

It has come from here.

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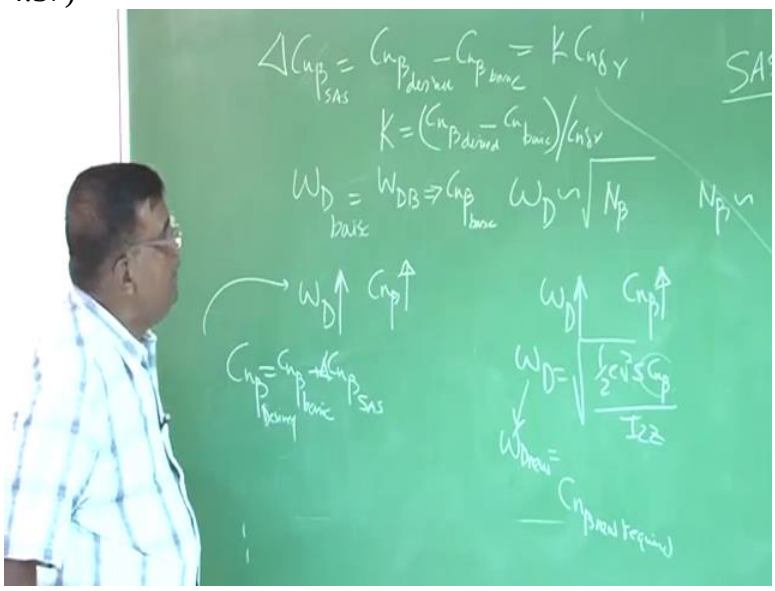

So I can easily find out that K is CN beta desired or required - CN beta basic divided by CN Delta R. So I know what value of K is required. But always remember, K is too high, it may make the system unstable. So that is why we always say, whatever value comes, then again you have to go back to theAS4 + BS cube + CS square + DS + E equal to 0 and see where are the roots lying.

Right? Specially those who would be working on control, you will find this is done routinely. Although there are shortcut ways of getting some 1st information.

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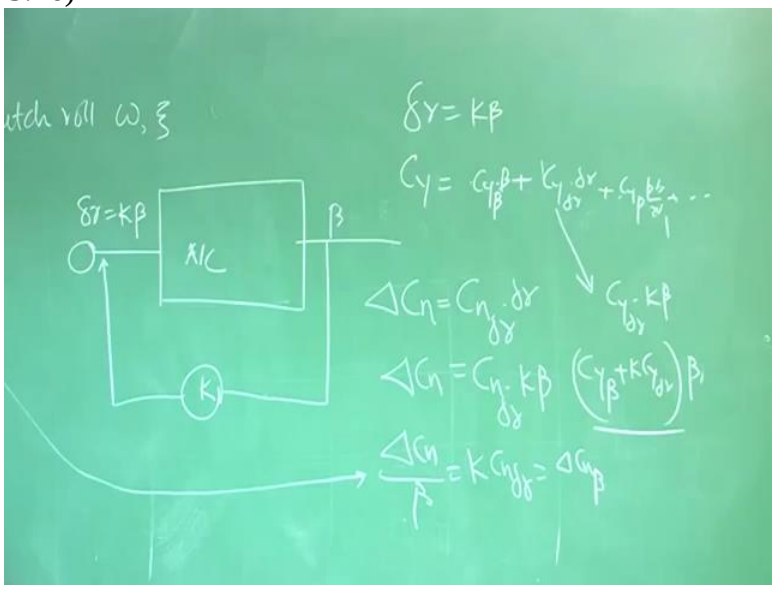

So now the next question comes, if I am deflecting Delta R as K beta, then what happens is that, is there any other derivative that gets affected? See that in CY, we have one term called CY Delta R into Delta R. So this we will now get additional effects, CY Delta into K beta. Okay? So here, we have CY we try to beta. There are maybe CY P into PB by 2G or 2U1. So like this blah blah.

So now CY beta into beta was there. Now CY Delta into Delta. So this is CY Delta into K beta. So finally we find CY beta + K CY Delta R into beta. So your CY beta effectively gets modified. Because CN beta has got modified, so CY beta also gets modified. So we have to see what is the effect of this on the overall stability of the system. This understanding is must.

What is the final thing? You know from the handing quality requirement, how much Omega D we need to have. If it is less, we have to increase. So we have to increase CN beta. If it is more, we have to reduce. So reduce CN beta. So accordingly we would decide what type of beta feeding we will be doing for natural frequency.

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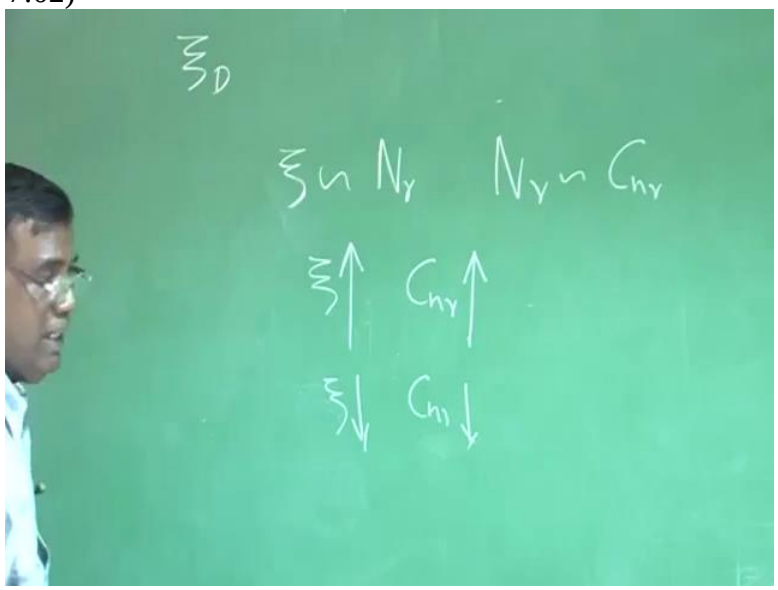

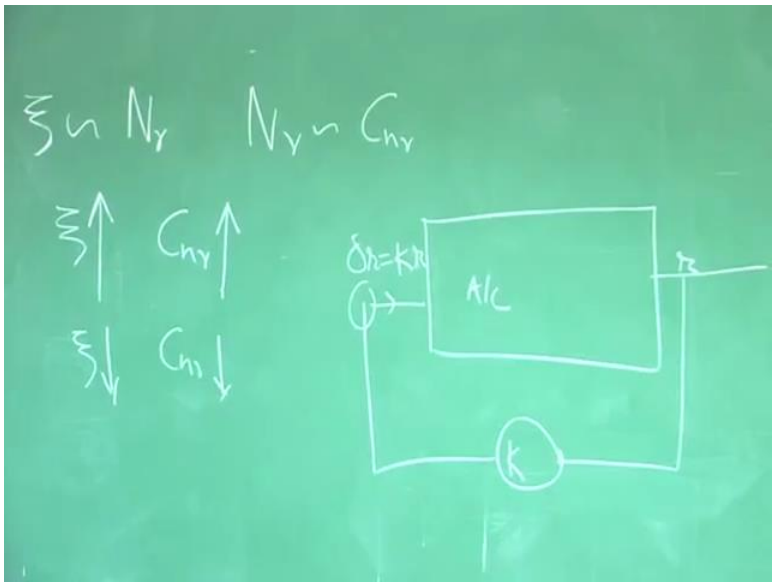

Once that is done, now if we want to change the damping ratio for Dutch roll and you know that damping ratio will be proportional to NR and NR is proportional to CNR. What was CNR? Whatever is CMQ for longitudinal mode, CNR is for directional mode. That is, yaw damping. So I have to ensure that if I want to increase Zeta, I need to increase CNR.

If I want to decrease Zeta, I have to decrease CNR in flight through SAS. So what will be the approach? Again, the approach is same. This is the aircraft. Now we will be tapping R and again we multiply with this and Delta R, we put as KR. Deflect Delta R with one which is proportional to rate and how do you measure rate? You have rate gyro. You can measure this.

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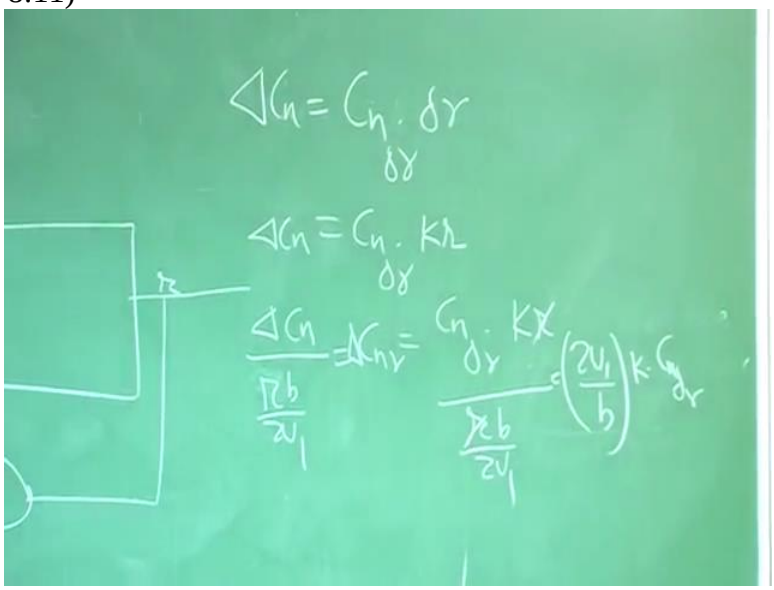

The moment you do this, how much Delta CN this will introduce, that will be CN Delta R into Delta R. And this is equal to CN Delta R into KR. This is Delta CN. So I divide Delta CN by RB by 2U1 to get CNR additional. That is equal to CN Delta R KR divided by RB by 2U1. So this R and R get cancelled. So we have 2U1 by BK into CN Delta R. That is the additional CNR you have to generate through SAS.

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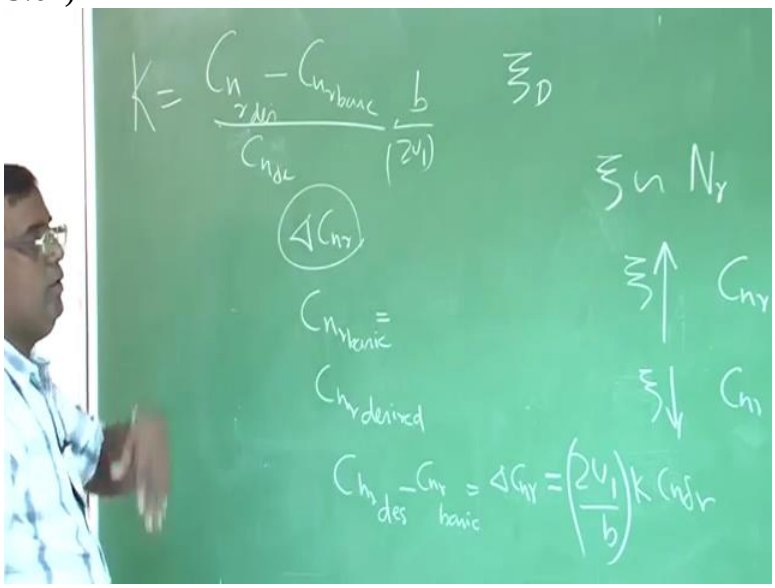

So this is very simple now. How do I find additional Delta CNR? You know CNR basic which was for the aircraft. You know CNR desired so that you have right type of damping ratio which you get approximately using one-dimensional analysis. Delta CNR is nothing but CNR desired -

CNR basic, that is equal to Delta CNR and that is equal to just now we derived, 2U1 B into K CN Delta R.

So we can find that K in this case will be CNR desired - CNR basic divided by CN Delta R into B by 2U1. Am I correct? So K will be equal to into B by 2U1. Please check yourself. And this is CN Delta R. This is K. And again, as you know that I have to feed this back to the dynamic stability exact equation and see how the roots are changing because it will have an effect on the other derivatives as well.

I always say that if this is the value of K which will take care of CNR the new value required, so that we have the correct damping ratio but we should also check that this will have an effect on the other derivatives.

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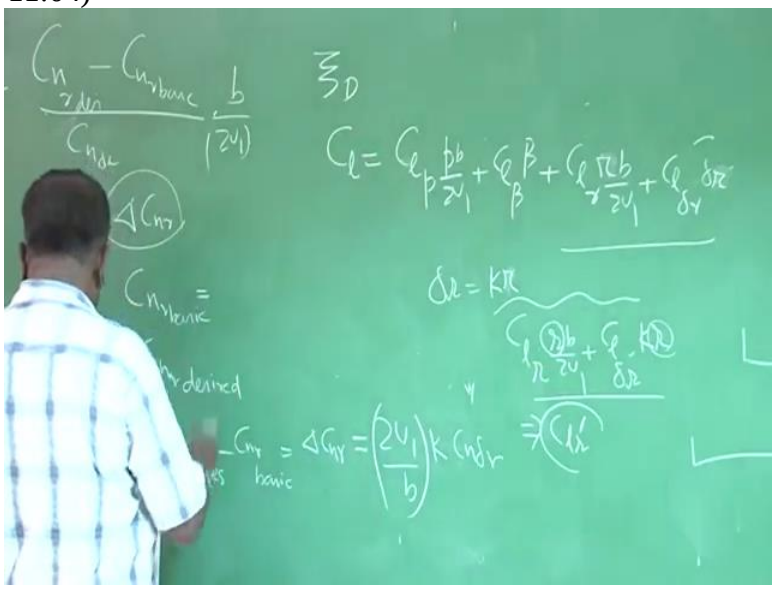

For example if I see rolling moment coefficient, CL is CLP into PB by 2U1 + CL beta into beta + CLR into RB by 2U1 + CL Delta R into Delta R. Now check here. What is happening? We are putting Delta R equal to KR. Same thing, same notation. Do not get confused. This is R.

So then check out here. This is CLR into RB by 2U1 + CL Delta R. For Delta, you write KR. So effectively what is happening? Do you see what is happening now? If I take, this R is lying here, this R is lying here. So now this CLR, effective CLR is getting modified. So this CLR prime will be the sum of these 2 and appropriately you take B by 2U1. So what I do?

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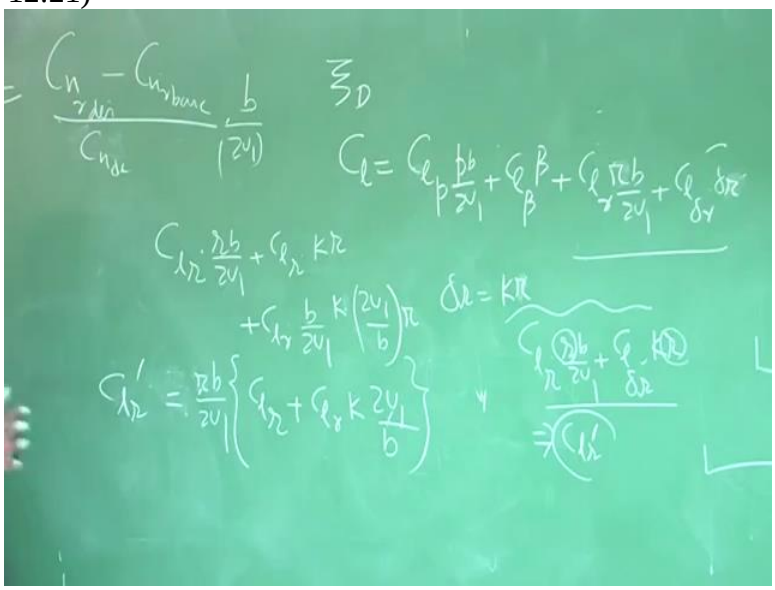

I write this simply as, this is CLR into RB by 2U1 + CLR into KR then, I write this as CLR into B by 2U1 K, I multiply this and, same thing. So I can take CLR into RB by 2U1R. R is here. So if I take RB by 2U1 from here to here, so I have RB by 2U1 common and I say CLR + + CLR K + 2U1 by B because I take RB by 2 yes Couric, you can yourself also do. Please understand this.

So this is the effective CLR now, sum of all this. So what has happened? Although you wanted to increase the Dutch roll frequency by giving a rate such that rudder is different to proportional to the rate. Although Zeta has increased but we have changed the value of CLR. So this is again a cross coupling happening. So we have to be very careful and go back to those exact solutions and see where are the roots lying.

Are we achieving those things which we are looking for or not? But the beginning is here. If this is correct, then rest is just mechanics, just mechanically you can do. So I thought I will give you this insight here on this and I request you, please do it yourself. This you should do yourself. Thank you very much.