Introduction to Helicopter Aerodynamics and Dynamics

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Lecture No. # 17

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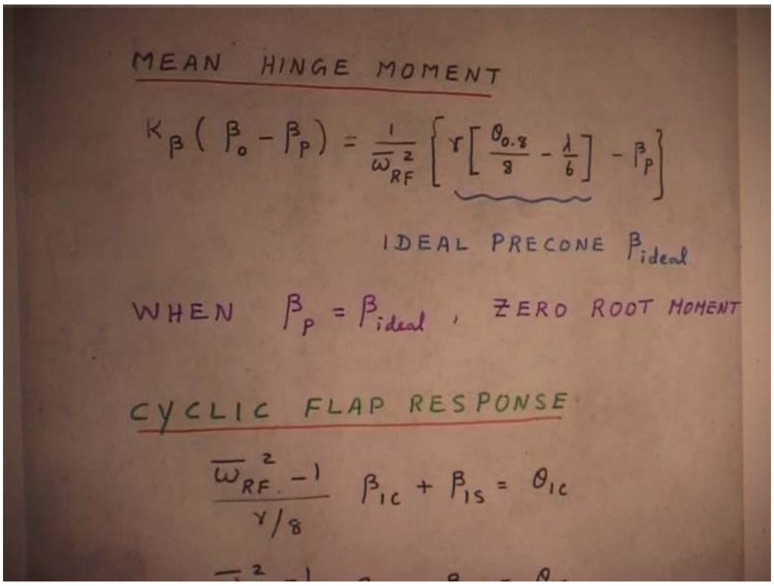

So, I will keep this we saw the ideal precone, that was what we were discussineg in last class. That is essentially, the root moment is K beta beta naught minus beta p this is the ideal precone. If the precone value is this is ideal precone then, we have already kept it at that then there one be any root moment, because root moment will be zero value. That is the idea of a natural design, what they do is they will keep a little bit of precone angle. So, that you really in the design, structural design it is purely from a structural design point of view, you reduce the moment that comes at that blade root.

Because these are all design features plus they also have certain influence on the stability, because if you remember last clas,s because I am just going back.

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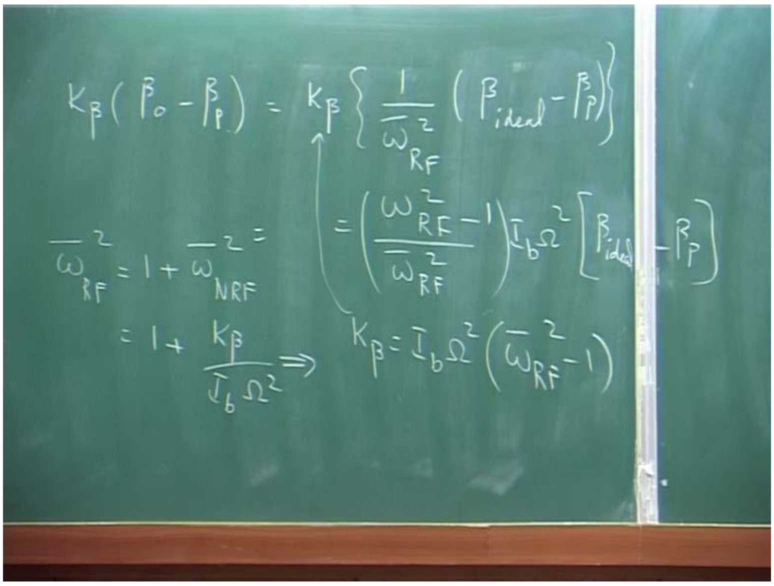

We wrote K beta into we substituted for beta naught and we got this equation 1 by that this, we wrote last time beta ideal minus beta p. And you can replace that K beta directly, because that is again written in terms of been, we know omega bar r flap square is 1 plus omega bar non rotating flap square which is I b omega square. So, what you were doing is you now subtract from here this will be I b omega square into omega bar R F minus 1. So, you substitute this here. Now, everything will be in terms of over sorry minus 1 and I b omega square beta ideal minus beta p.

So, you see automatically, whenever the flap frequency rotating flap frequency is equal to 1 root moment is 0, you would not get any hub moment. Whereas, the moment you have a rotating flap frequency, greater than one then you get a hub moment, but beta ideal is not equal to beta p. Now, you may have any frequency, but if ideal is equal to beta p, then you will not get any root moment, but it is not that you do not want to get any root moment, see it is a very conflicting requirements. If you want to maneuver you need to have root moment, because you want to generate moments, other you will generate. Later we will show you will generate only the moment on the vehicle only by thrust vector that will have some value.

But if you want to have highly agile, you need to generate more moment, then you need to have hub moments from the rotor blades. But at the same time, you do not want to blade to have lot of root moment from a structural design point of view, on one hand you want highly agile, but on the other hand you do not want the structure to be very big. So, this is a trade off finally, you that is why the design of rotating flap frequency to have a particular number is a very very interesting. And very important in the helicopter design, what flap frequency you will keep for your helicopter.

Next we will look at the, if you have the rotating flap frequency other than one, what will happen to the phase difference between control input and the output. Because earlier when the centrally hinged blade, we said that the phase is 90 degree. Now, what will happen is if this frequency is more than one, that phase difference will reduce it will not be 90 it will be less than 90.

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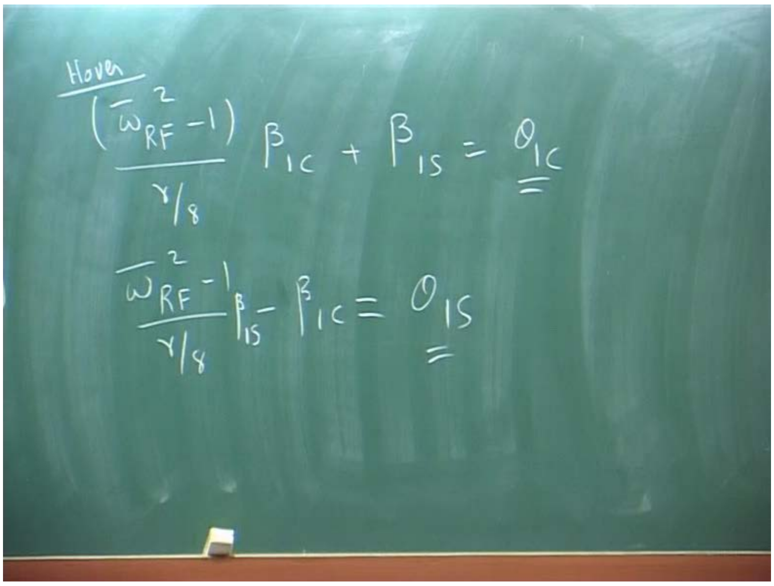

That means, we will see what that values, we will derive only for the hover case, but you will find that, if you restrict your case to hover. The relationship between this is I am writing it from the nodes which I wrote last time. And then R F square minus 1 divided by gamma over 8 minus beta 1 c sorry beta 1 s equals theta 1 s. This is the relation which you reduced from last time, I wrote the long expression from there if you put mu 0, you will get this expression particularly in hover case.

We are looking at hover first, you can solve for beta 1 c and beta 1 s from these 2 equations, because your control input is this and this. Now, if you write that I will just briefly see from these two equations you see that there is a coupling, coupling between longitudinal and lateral. In the sense, if I give theta 1 c I am having these two, if omega R F rotating flap frequency is other than one. If it is one you got this directly, because this we got earlier, if it is not you are introducing coupling between longitudinal and lateral motion of the rotor disk.

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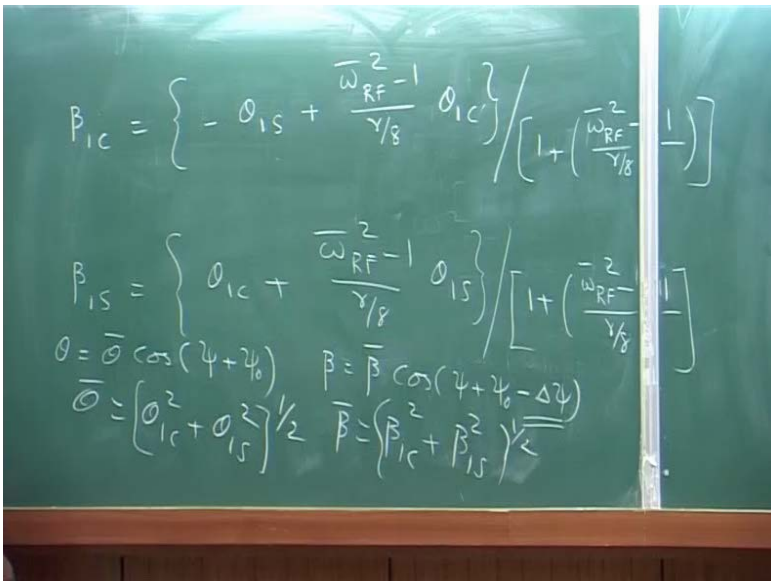

And if I you can solve this, I am just writing this result that is theta 1 c becomes minus theta 1 s plus minus 1 over gamma over 8 theta 1 c divided by 1 plus omega bar R F square minus 1 over gamma over 8. And similarly, beta 1 s equals theta 1 c plus omega bar R F square minus 1 over the denominator is same minus 1 over gamma over 8. Now, this is my the moment in hover itself, I am changing my flap frequency other than one. So, I am coupling now whereas, when the flap frequency is one, you know that theta 1 c gives you beta 1 s theta 1 s will give me beta 1 c that is all.

But most of the rotors have flap frequency other than one, that is actually, more than one. Now, usineg these relations you can find out, what is the phase difference between input output. And that I leave it to you as an exercise, because if my input is theta equal to theta bar cosinee psi plus psi naught and my output I call it beta beta bar cosinee psi plus psi naught minus delta psi. So, this is my input, because you know theta naught is different we are looked the cyclic inputs affect my rotor tilt, but how much it affects it is like this, if you pilot gives an input in the longitudinal direction, thinking that he is tilting the rotor disk like this, he wants to go forward what he will do is he will also start rolling, not only into pitch you will start rolling. You will start moving left or right depending on the coupling.

So, that means, the two axis are not independent, they are coupled which is difficult to fly. When you really want to go in forward direction, you will start going in some other direction, if you want to give pitch you will roll. But you will also pitch it is not that, you do not pitch you will roll. And particularly, in when we I hope whether, there will be some time for analyzing the flight dynamics. The inertia of the vehicle is different, in pitch direction and roll direction pitch is it larger roll it is less. Now, if the inertia is less what will happen is if pilot gives an input for pitching down, actually he will roll much more than what he intends to do in pitch itself.

That is because of the less inertia in the roll direction. Now, this coupling is very difficult for the pilot to fly. So, what do they do, because one input gives me two outputs basically, one intended another one unintended, that means, I have to go either compensate for that, this is where the flying requires skill. Now, you can have automatic flight control system, etcetera etcetera many things, but that will aid the pilot to in assist him slightly. This is one of the key, outside the difference between an aircraft and the helicopter, one of the key in flying the machine. Now, you see if the input is I can write theta 1 c is what theta 1 s.

Similarly, beta this is the phase, usineg this equations you solve I will just write the answer, because that is a algebra. So, which you can try yourself, that is the input theta bar is actually the magnitude of input, that is under root and beta bar is beta 1 c square plus beta 1 s square half it is basically, the amplitude of your input. Because you can see, if you expand this theta bar cosinee psi cosinee psi naught cosinee psi is time varying that theta bar cosinee psi naught is basically theta 1 c that psi naught is some number.

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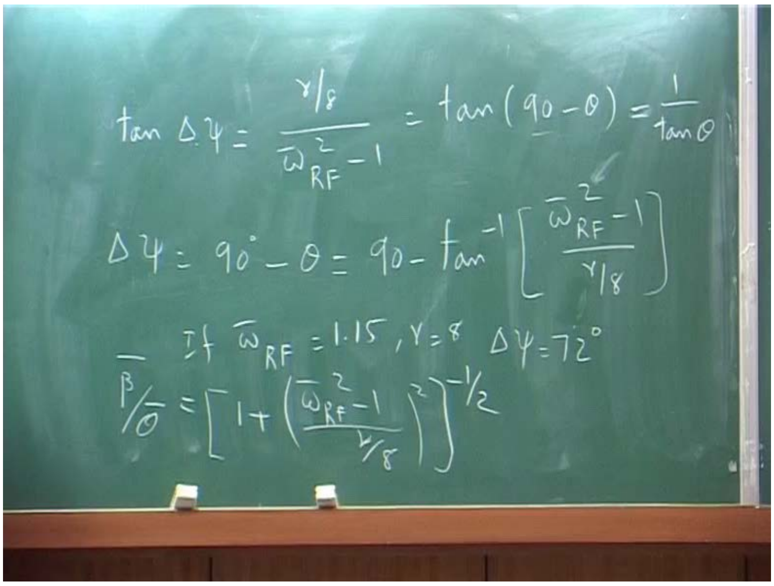

Now, the phase is actually tan delta psi is gamma over 8 minus 1 and this can also be written as delta psi is 90 degrees minus theta which is 90 minus tan inverse minus 1 over gamma. Because you just put 90 minus that way that ratio gets changed, because you can write this itself as tan 90 minus theta, just then you know this will be 1 over tan theta right; that means, tan theta is omega bar R F square minus 1 over gamma 8. So, that is how you just because normally, you write the face is 90 degree when this is one. Now, you see two parameters are controlling, one is the flap frequency another one is the lap number, lap number you know that it is a ratio of aerodynamics over inertia of the blade.

So, both of them influence the coupling now just for some number, if omega bar R F is 1.15 and gamma is 8 then delta psi will be 72 degrees. And our beta bar by theta bar that is is the magnitude of the input to the tilt. This actually, is 1 plus omega bar R F square minus 1 over gamma over 8 whole square power minus half. Usually, you will find this reduction is not a lot, that is the magnitude of the flap and the input is there is slight change of 5 percent, because if you take it as 1 minus 1 0. So, beta bar is theta bar. But if it is 1.15 you take a square you subtract 1 gamma 8, you take again square and then bring it it will be about 5 percent 6 percent change whereas, here this change is substantial. So, what happens, if pilot gives a longitudinal he will roll. Now, what will they do, because the pilot how this is done is there is some control rigging, they call it control rigging that means, pilot will still move stick forward. But the input that goes to the blade is adjusted.

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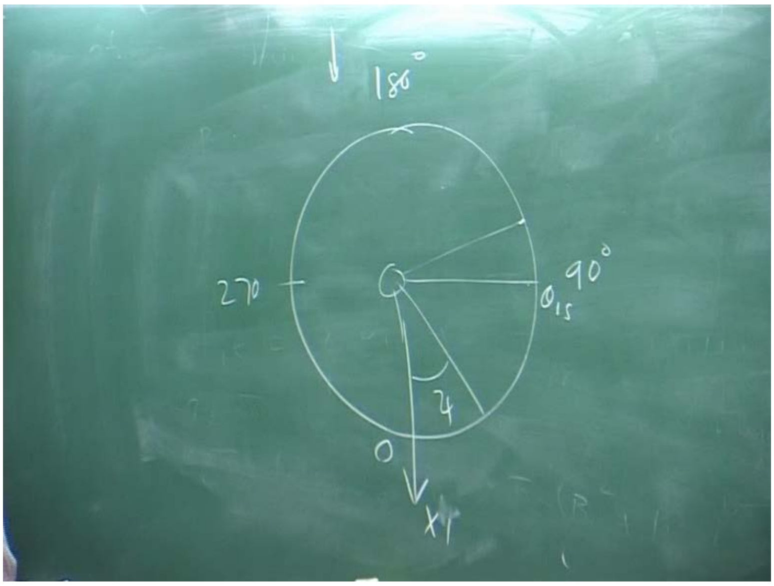

Such that, if you have the rotor disk, if this is x sorry x this is psi, this is a 0 degree 90 degree 180 and 270. And you are flying forward velocity is coming just I am saying, because forward flight also will change, we are doing just hover case. If we here theta 1 s what it will do, it will go and tilt here this will go like this. So, what normally done is when a pilot gives, he will give a input somewhere here. So, that this rotor disk tilts so he will go forward. So, try to reduce the coupling, that rigging is done in the mechanical arrangement of your control rods. Now, you imagine that design, the layout depends on what is your flap frequency.

So, it is everything is linked, even your design, layout many of this things link to flap, otherwise you are increasineg the load of the pilot, because he still has to do lot of control. Now, this phase angle is it constant that 72 degrees is it whatever, we got for this is it fixed, no it may vary with forward speed.But control rigging is done for one, that variation is not for very large, that is why it is done at one value. And then just leave it after that pilot has to fly, if there is a coupling in some other forward speed then he has to adjust. So, the flying he goes through a training. So, the key aspect is coupling between longitudinal and lateral.

So, when now you imagine, if you want to do you have done in aircraft and if you have gone through the first level course, longitudinal dynamics separately. You do lateral dynamics you do separately, but in the case of helicopter, because most of the people who are trained is aircraft first. Even here, let me analyze their longitudinal dynamics of the helicopters, even though it is not right. You have to analyze the full air full helicopter. So, industry for ease of understanding, you can do a little boy of the decoupling, but otherwise it is not possible to decouple, the full longitudinal lateral degrees of freedom. So, you have to solve the full 6 degrees of freedom all coupled in the flight dynamics.

Now, control becomes more complex, because usually when you decouple all this things, you try to understand each subset. And then make some design modifications, such that the vehicle is good. Here, if you do something in one it is going to affect another thing. So, that is the coupling plays a dominant role in the helicopters, how do you reduce it, but of you reduce it, become you say that why you want to have make it this is one that is wonderful, but then the problem is. Now, what we are going to discuss, what happens to the hub moment, because till now, we have studied thrust side force, longitudinal force and the torque, I said we keep the hub moments for a later thing. Now, let us look at the hub moment, which arises due to flapping aerodynamics flapping motion, I will call it flapping motion, because you have to take the inertia also. Now, how do you get the hub moment.

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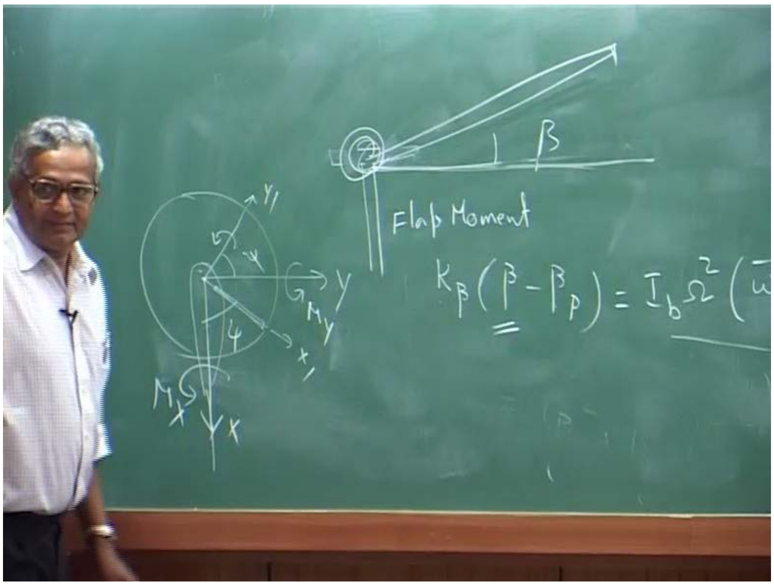

So, this is the we have our model is centrally hinged, blade with a spring this is beta, one way is you calculate like we did the inertia force, aerodynamic course integrate and get that. Another way is what is the deformation of the spring, deformation of the spring is we said K beta into beta p this is the moment due to the deformation and that is acting at the hub. Now, you see there are two ways of calculating the hub moment, even shear also this, if you do vibration you will learn later. I can get the aerodynamic load, inertia load integrate the whole thing come to the root, give that as a moment that is one way, another way is I look at what is the root deformation.

I just take that multiple by those spring concerned in this case, it is much easier. Suppose, if it is a flexible structure, I want to know the root bending moment, root shear force how do you get, I am just throwing it to you to think about it. But here we take only this, because there are two ways of theory like this, I am just giving you I am deviating a little bit.

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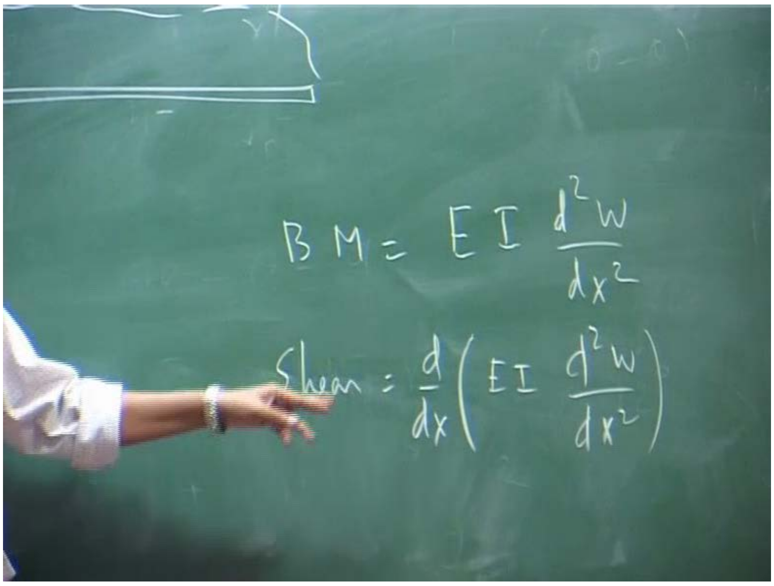

You take this as a cantilever beam; you have learned some loading, I want to know what is the bending moment and shear at the root. May be shear force some bending moment, how do you do, you integrate you will get that you put it, that is one way that means, you are integrating the loads. But you also know bending moment is E I, what this is also and the sheer force you have another d over d x of maybe E I is a shear force simple. Now, if you know w, we can get this also at any location, you take the slope you take the moment whatever.

So, this is the another way that means, you solve for w, you solve the deformation after that put it, one is take the applied load, please understand. Now, you apply the load, you integrate the load and you get the bending moment and shear at some section. Another one is you solve for deformation and then take whatever the standard, in aero-elastic problem what happens, if the load is a function of deformation, please understand the load what applied load, what I put it is a function of deformation. How much it deforms that means, what you have to do, you have to solve for deformation to get the load, but you need to know the load to get the deformation. So, this is an iterative process.

So, usually we do not go and calculate bending moment and shear by this approach, because of the simple reason you are taking second derivative all approximate you are doing numerically. Whenever, you do differentiation you may have error. So, when you want to get the loads, you simply integrate the aerodynamic and inertia, but if you want to get the deformation. Because you also need to know the deformation, then you have to solve the full problem. So, it is like here what we are doing is we are not integrating the loads like, what we did for thrust and other things, we simply say what is the deformation at the root it is easy for me.

But only thing is I must know beta exactly, here I know that I am just assuming that beta is known. So, I take it I take this is the flap moment acting at the hub at any time because, beta is a function of psi. So, now I want to get this is my rotor disk, this is my helicopter and this is my y axis this is my x axis the flap moment, when the blade is here the flap moment is about this axis right, about the this is x 1 this is y 1 this is flap moment, which is this. So, I must take component of that flap moment, along y and x direction that is the body hub hub direction. And then I must add the values due to all the blades and take the mean value that way I get a hub moment, what we did was we get all the forces on one blade. Then we added all the blades assuming that the same the blade behave the same way, here also it is a same thing.

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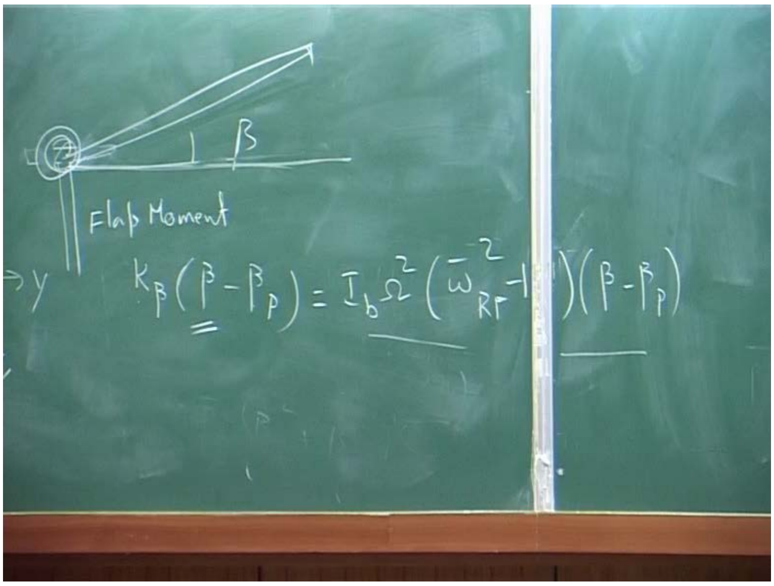

Now, let us write this quantity that is the moment, flap moment. I will write it flap moment I b omega square omega bar R F square minus 1 into beta minus beta p. So, I am converting, the spring stiffness directly in terms of flap frequency, rotating flap frequency. This is a modification just because you know that what is K beta. Now, usineg this, I will go get my moment, because this is my psi. So, this angle is also psi I take along x and y what is the moment.

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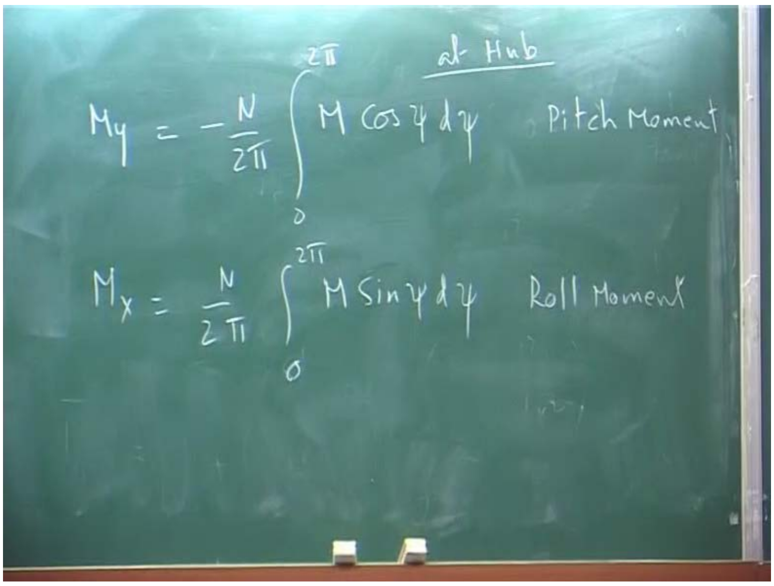

So, I will have, M y will be my moment here pitch moment. And m x will be my roll moment; this is M x this is M y in the hub system. So, my M y becomes, please understand I am now doing a M which is the flap moment into. This is pitch, pitch moment and similarly, roll moment M x N over 2 pi integral 0 2 pi M this is roll. Please understand these are at hub, because you know that a flap moment how much the spring is deforming, what is the force this is very similar simple problem. You also you know that, if you have a spring match whatever, force excreta, everything acting here f m k. If you know what is the force that acts, it is just k x that is all same way, here is the force here it is the moment. So, k beta times the deformation and k beta is replace by this.

Now, you put it here and you know beta is beta naught 1 c cosine psi plus 1 s sine psi, because we are truncating rest of the quantities, we are not considering only first harmonic. Now, you substitute here and then integrate the whole thing, you will find beta naught cosine psi beta naught is a constant, it will go to 0 and then beta 1 as sine psi cosine psi that is again sine two psi integral that is also 0. What you will have is only beta 1 c that M is this expression; you are substituting for beta this expression. You will find only beta 1 c will remain for pitch moment. And for roll moment only beta 1 s that expression is I will write it here, because is now the non dimensionalize it may be I erase here.

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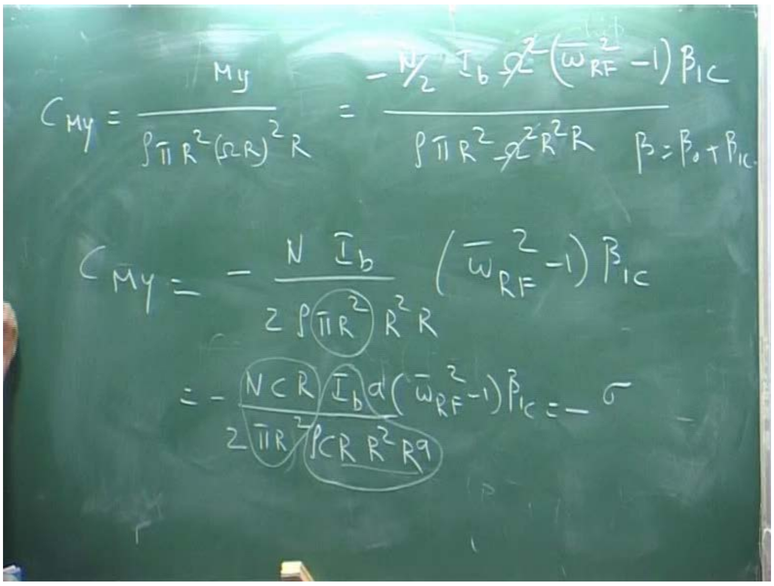

You non-dimensionalize your moments, that is C M y like c t we will put M y over rho phi R square omega R and M y, you will get what that is minus N over 2 I b omega square, because here I am just substituting this quantity and integrating. You will have omega bar R F square minus 1 beta 1 c over rho pi R square omega square R square R. Now, this quantity is you knock out this terms and here N by 2. What is that, what you have there will be minus N I b over what is that 2 rho pi R square R square R into omega bar R F square minus 1 beta 1 c what you do is you pi R square you put N C multiplied by R C R in the numerator denominator you multiply by again C R.

So, you will have to pi R square, you will have C R and then what that rho C right, no there is a when R square R right am I right, sorry right. Now, what you do is sorry, I will put the rho this sigma. So, you any way, you will have this term, you will have minus sigma rho C R power 4 right. That is I yeah sorry, rho C R to the power 4, you multiplied by left curve slope a and divide by a, then this factor is rho a C R to the power 4 over I b this is gamma. So, you will have minus sigma a over 2 gamma sigma a is the this is gamma and 2 into you will have omega bar R F square minus 1 beta 1 c. Let me simplify and write it.

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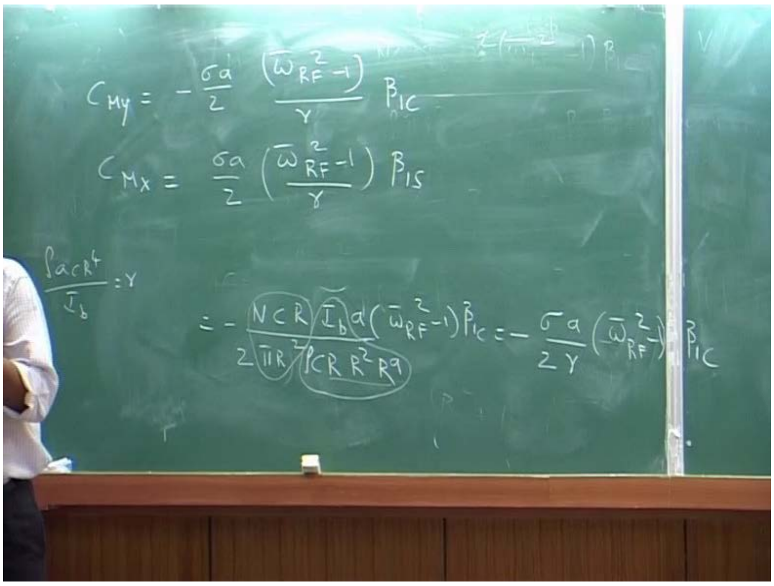

So, your C M y becomes minus sigma a over 2 omega bar R F square minus 1 divided by gamma over 8 beta 1 c that is all sorry sorry not 8 I am sorry gamma. Similarly, you can write for M x here what will happen is beta sine psi. So, you will kind only 1 s will come. So, that I you will just write the expression. So, your beta C M x becomes sigma a over 2 omega bar R F square minus 1 over gamma beta 1 s, these are my hub moments. Now, there is a little thing further to this, we got the hub load all the 6 components this is what I gave in my notes that two page.

If you know the value of these are all rotor configuration, omega bar R F square flap frequency is a rotor characteristic, gamma is the rotor only thing is depending on your beta 1 c or beta 1 s how much movement, you are generating at the rotor hub due to the rotor. Now, how much you generate at the fuselage c g, because fuselage c z you will get the hub forces, they will also get transformed into the fuselage c g hub moment. Also will get directly, transformed what is the relative order. If you look at that particular part there is a slight derivation. Because that is again highly approximated please understand, because you know the c t, you know c h, you know c y, assuming that wherever is the c g in your fuselage very very simplified form I will show that diagram.

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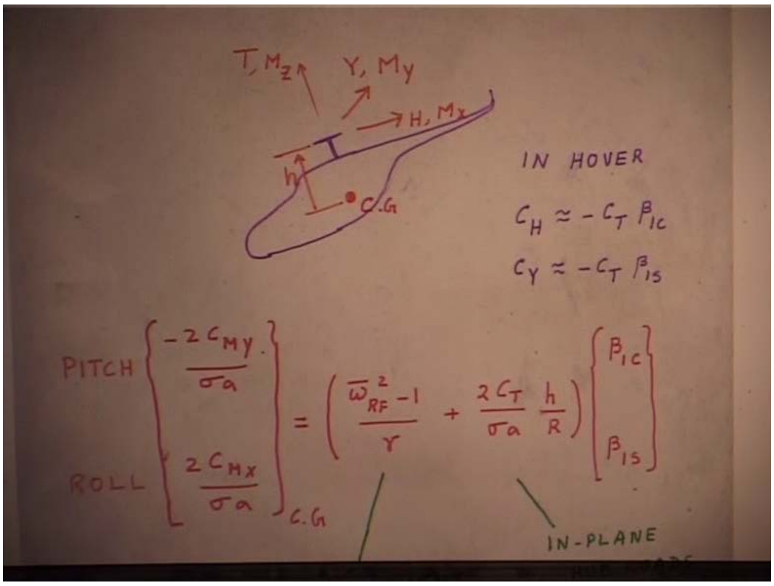

Moment about the hub center, because these are all for controls, flying, you need to know that value. You assume that the C G is here rotor hub is at a height h just I am putting it right on shaft, it need not be straight on shaft, it can be anywhere a little displaced those things, will come when you do the actual problem. Now, you have a hub H longitudinal force M x which is the roll moment. Similarly, you have y which is the side force, which is the M y which is the pitch moment. And thrust and the torque, these are the hub loads, hub loads due to the blade operating condition.

But what happens to this, if you look at this because I have written some form to come to this. See if you want to know the pitch moment, the thrust is what directly, passing through the C G, because I am saying C G is right on the shaft. And thrust is always I defined on the perpendicular, through the plane of the hub. And it is through it is not going to give me any moment. But what will give me moment is the H and the Y side force and the longitudinal side force, capital H into this height, that will give me a pitching moment. Similarly, the y force and to this height will give me a roll moment.

So, at the fuselage C G, I generate moment due to two sources, one direct moment another one is due to the forces, but this particular thing which I have written here. In hover see it is very interesting, in hover we can reduce it, but we make again assumptions. That is what I am telling lot of assumptions are made, in hover if you look at what is my longitudinal force coefficient C H, because we got that expression last and that long one, which I gave you that sheet. You can say approximately, that is thrust into beta 1 c approximate, because you have to replace theta 1 c is beta 1 s that kind of a regulation you have to use it to get that approximation. It is again I am telling this is obtained from your that page, which I gave you in that printout.

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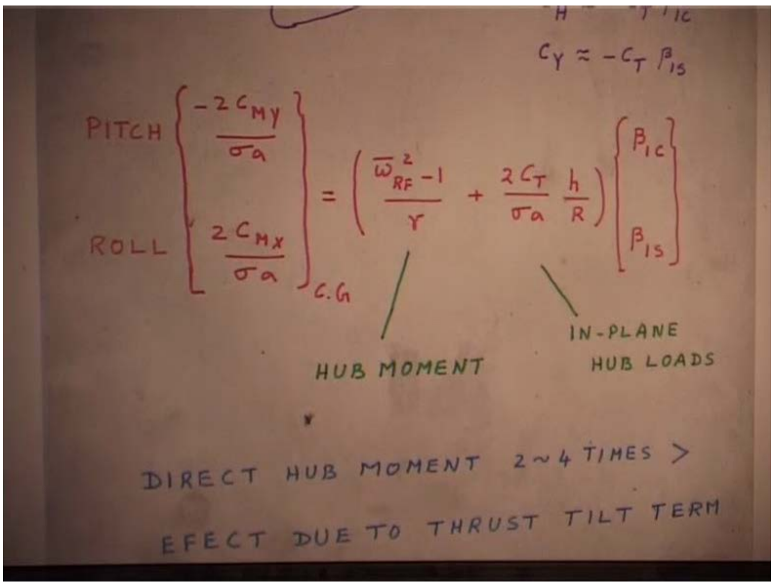

Now, if you use these expressions and then calculate net moment at the C G, please understand net moment at C G. One is hub moment another one is due to thrust, because you see it is converted that H and Y are converted in terms of (( )). This is the in-plane hub loads. Now, if you use the omega R F is 1.1 or 1.05 whatever or 1.15 is a just slightly higher value. You will find this value is much higher than this value, if you use. So, this is direct hub moment this is through tilt of the thrust. So, you have two sources due to tilt of the thrust vector, the moment you get is some, but direct hub moment is some sometime two to four times greater than the effect due to tilt. Because C T value, you can substitute sigma, you will substitute a you substitute H over R you take you will find.

Now, you see if pilot wants to do a good maneuver, which moment is good. Suppose, if you make my flap frequency is equal to 1 that means, this term is done, I do not get any hub moment. He has to fly only with this C T only by thrust tilt that is why in helicopter, you do not go to 0 thrust condition. That is the inverted loop when you go 0 G, 0 G means 0 thrust that means, he cannot generate any moment that means, he will lose control over the vehicle. That is why helicopters particularly, they are two bladed where it centrally hinged; you do not have any moment. You would do not fly low G, because you do not have the moment, that is why they try to put some spring. So, that increase this the control. But then, if you keep on increasing the flap frequency it will become highly sensitive, because any small change immediately it will start rolling.

Now, this is the trade off, what you would like to have whether, you want a sluggish, but stable vehicle or you want highly sensitive, but highly sensitive means again it is subjective. So, when they go through the flight they always have the pilot. So, pilot's opinion plays a major role in then actually, drew some diagrams in which all the pilots, different pilot then they come oh this is convenient. This is I can handle it, but then experienced pilot will be able to his opinion will be different from a new pilot.Once as you gain experience, it is a I can handle it, but new pilot will say it is very difficult. So, these are all the tradeoffs, which one has the finally, they will says all right. Let us decide on some combination of in the sense the flap frequency gamma how do we play.

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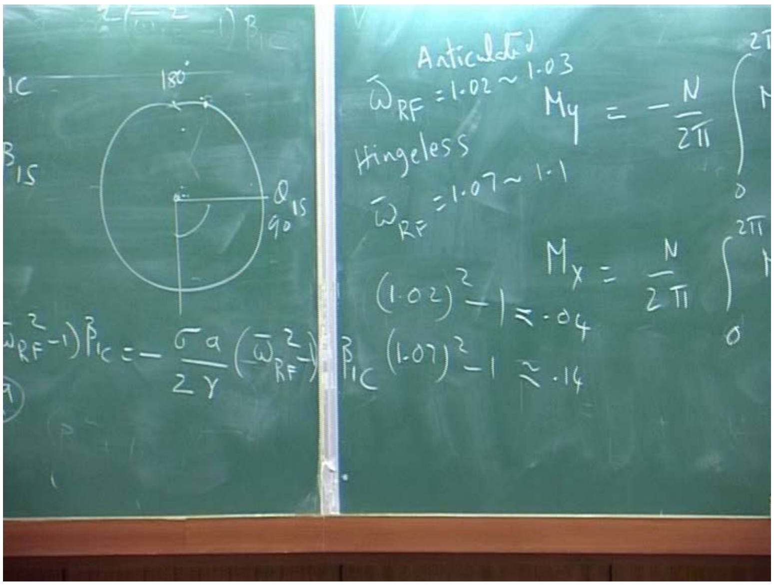

Flap frequency is most dominant, usually it is kept you will be surprised omega bar R F for articulated, articulated rotors it maybe 1.02 to 1.03 somewhere around there 0 2 0 3 maybe 0 4 is a slightly higher, for hinge less omega bar R F is 1.07 to 1.1 somewhere around them. Now, you see articulated rotor, because you have a hinge, but you do not have a spring. So, the model is little different that we that part, when we do the next section we will learn. You see the flap frequency difference this is the high flap frequency, that is why I am saying I have written of two two decimal points, industry will calculate. You will be surprised; they will want to go to at least three decimals two to three decimals in flap frequency.

Why because if I square it 1.07 becomes what 1.14 approximately. You subtract 1 that means, one is gone the leading term is gone. So, what is left is only 0.14 so whether it is 1.15 1.05 1.07 those numbers become that one is not dominant now. So, even if you change your flap frequency little bit, your hub load is change by substantial. So, you will see very interesting, the change in flap frequency here what is the it is almost 5 in 100 right, that is what 5 in 100.5 percent right here. Whereas, if you substitute the square and then get the hub moment, that is one point what 0 2 square minus 1, this factor will be this is what .014 to 0.4 right 0.04 approximately. Whereas here 1.07 square minus 1 this is 0.14 three times they changed whereas, flap frequency changes, you see only new 5 percent, I have changed my flap frequency by one percent two percent, but I changed my hub loads like, three four times this is a very very critical change in the helicopter another goes down. So, you have to integrate from minus r to plus r that is why that stabilizer bar part you have to do that.

This is for each blade is independent; it is not the other blade is dependent on the motion of the one blade, if you do that that equation will slightly change. So, is it clear because you find flap frequency is a very very dominant parameter, really influence. So, industry spends enormous time, because in deciding and then going through the iterative thing, several design. Now, imagine you are actually, making a blade compulsive blade with the hub design. You must know the flap frequency to the third decimal, usually they will say 1.092 and 93 something like that, you may wonder what is the third decimal going you know in the engineering thing, you will say it is all right. Even 1.09 or 1.1 it makes a lot of difference.

So, this is 09 do not round it off to the next decimal, only for flap that is why I am saying in the helicopter, certain things are really critical, then the criticality of each feature gets changed or reduced just for the blade alone. So, the design you will be surprised, they may do the blade frequency calculation almost every day like, you are an engineer you keep doing change, some small stiffness change go read run the whole program and then get the flap frequency. So, everyday your job will be get the flap frequency, flap frequency and on force lead lag keep plotting that is all. Because that is very very important, you may find what is that I am doing everyday same program, I have running change some small number get it, but it has to be done that way.

Finally, they freeze this is the number, but now you see that is a theoretical calculation, then you do experiment of course, experiment what you get you take it, because you cannot do much about it you cannot change anything. So, in the case of of course, a l h it is around 1.093 or 9 1 something like that flap frequency which is high why it is high they said.

Now, you find that when i have my flap frequency high, I get a good control moment, but that the same time that means, I am transferring lot of loads from the rotor to my fuselage. So, I will transfer more vibration also. So, if you have less small flap frequency, the load transfer is less vibration is also may be less and you know, but control is also less agility is less. Now, what is the trade off. This is where the design goes into several iterations and once industry has gained experience, in a particular design they will stick to it, because they know that this a this kind of design, will do this effect and I know the sequence all right. Now, with this I close the fla, simple flap motion next starts the trim.

But I will start that in the next class because, I want to show one small demo, how see you have a blade of course, it is a centrally hinged. How it will respond, because we said if I change some body motion it is rotating. How fast or how slowly it will respond, that is why I thought I will show you a small video clipping, it is not video clip sorry actual model, we have a model and that will be able to see seeing is believing. So, I will remove this, what is it here this is better. Now, you rotate what you can. So, now this is spinning, if I tilt you see it takes slowly, that see this line the rotor disk, see rotor disk is perpendicular to the shaft. If i tilt the shaft it will not immediately come you, see it takes time to come and this particular delay, please understand see if I tilt see this delay takes time.

This does not have any aerodynamic, only two masses and just like a stick, which is spinning this is called the stabilizer bar. Now, you see this is has a inertia it keeps rotating. So, even I tilt my shaft it takes some time for it to come to the other position, this gives a feedback in my now, you have to put the. Now, you put the just a blade you see the response, no only one of them it will be very fast there it takes some time for it to come.

Now, you are actually it is only inertia in that case, now you add aerodynamics that is like you are having the aerofoil, if I tilt you see it will immediately come the time it takes for the rotor to respond. It is very quick, particularly in flap motion that is why even though there is a lot of dynamics involved in this. The pilot will usually, feel that he gives an input, it does not mean that, it takes lot of time to tilt or there is no that sluggishness will not be there, you will feel that it is acting quickly response is very good. It is a very interesting that is why because this is like a gyroscope, please understand right. Now, what we have done is we just spinning it.

Now, what we did was we had put two aerofoil shapes, just they generate lift now you see you rotate it, see if I tilt now see it is very quick whereas, in the other case, it took some time to the aerodynamics alone influences. The response you can actually, write a equation for this type of dynamics, just a rod you are just rotating and it has do this response what is the delay. But if I put to just aerodynamic lifting surface, very simple model whatever, we have done how quickly it response. And the same thing happens in the rotor blade, because it is a rotor blade you give an input it quickly response.

So, it does not take lot of time, pilot gives it will do slowly it will be pretty fast. Now, we were I will just briefly mention about the I think this is enough the trim part. So, I will describe the trim in the next class, what is that procedure it is only the procedure and final results I will show for a general helicopter system, after that the subject can take in different directions. Because it can be only blade dynamics, please understand not flap dynamics blade dynamics, that means, you do flap you do lead lag, you do torsion. And then you do combined coupled, that is a one direction of work.

Another one is you take only the flap, but include fuselage motion that means, coupled blade fuselage dynamics, you follow and that has it is own set of problems, like you have flap motion coupling with the fuselage, lead lag motion coupling with the fuselage, each one has it is own stability problems. And then flight dynamics is rotor and the fuselage. Now, you see you can pursue your course or the lectures in various directions, because everything is going to be complicate, because it is not that I can write an equation. Only for blade isolated flap I can write, isolated torsion I can write, that I will cover after the trim part. Then we will it is pretty much like, what are the various types of problems you face in helicopters, that is all it is mostly descriptive with some mathematics, but you cannot derive the equations, because it is too much for us.