Seakeeping and Manoeuvring

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Lecture No. # 07

Uncoupled Heave, Pitch and Roll – III.

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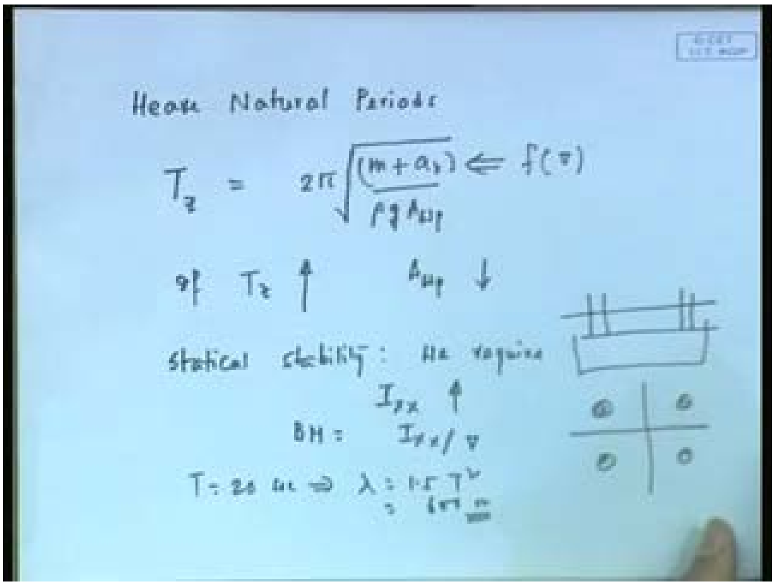

Let us continue a little bit more on the heave natural period of practical of shore and ship structures, like in last lecture we just ended by estimating the natural period, heave natural period for a semi submersible and I was telling you the reason why the structure evolve the way it is, see we had this formula know this T z 2 pi root over of mass plus added mass this keep coming, let me write it directly here rho g AWP which is my c.

So, as we mentioned if I want T z has to be higher, my AWP has to be lower assuming that mass and added mass are more or less constant. Really speaking mass and added mass are basically function of you can say underwater volume and this you cannot control too much in a practical design. So, what happens therefore is that, if I want T z higher, then I need to lower AWP. On the other hand, see from statically stability point of view we require large moment of inertia water plane area.

Because you know that meta centric height equal to I xx by v, when I xx is of course, the water plane areas moment of inertia about the relevant axis. So, how do you do that; obviously, as I said to do this two contradictory things what we have to do is to simply separate out those water plane area boxes, which is exactly what was done in case of semi submersible we we actually separate it out the a w p.

So, my gives me large i x and small AWP and we found out yesterday that you know we could do that practically period of twenty second or so. Twenty second means what is the wavelength T of 20 second, this is actually wavelength of lambda equal to around 1.5T square is around 600 400 meter or so, which is fairly outside the regular wave range 1.5 g.

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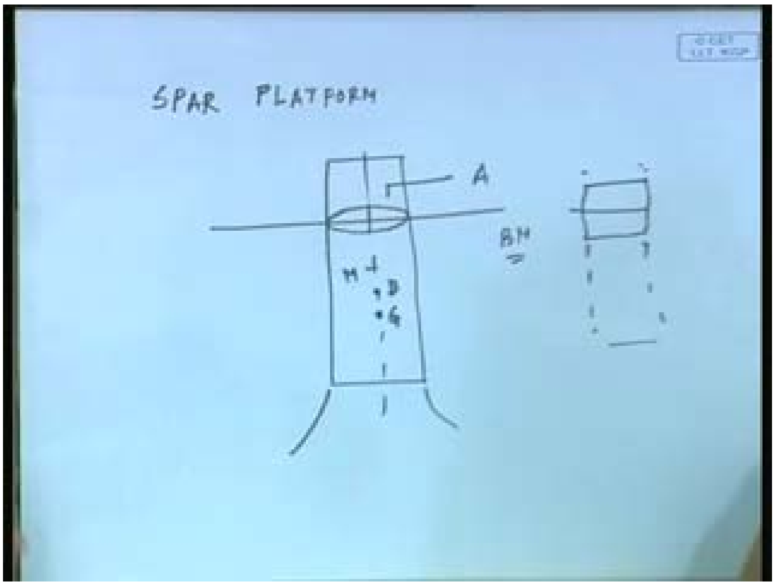

Now, this was we we discuss that let us continue this little bit more, stretch it little bit more on other configuration. Let us take spar platform this is a new concept that came you know what they do, it simply nothing, but a floating cylinder that is it the spar platform is nothing, but a floating cylinder how do I get that? here you see here; obviously, here the question comes its only one cylinder. So, and is of course, reasonably small, but here what happen see my question of meta centric height, this we address by lowering the C G. Suppose, you have A C G lower than I do not have to have an BN higher, because if C G is here B is here see C G is here b is here m will be here, if you get the stability.

So, again you see these two questions maintain stability, but increase period by reducing water plane area satisfied here also. So, this is how it evolves again the starting point is that you cannot have for example, very small a spar buoy like that it just do not want it has to be much deeper and you will find out that typical example this may be 20, 30 meter diameter, this may be 80 90 meter. Now a days they will have gone to even even 100 meter. Now, another important thing shape wise swath hull, why did it evolve?

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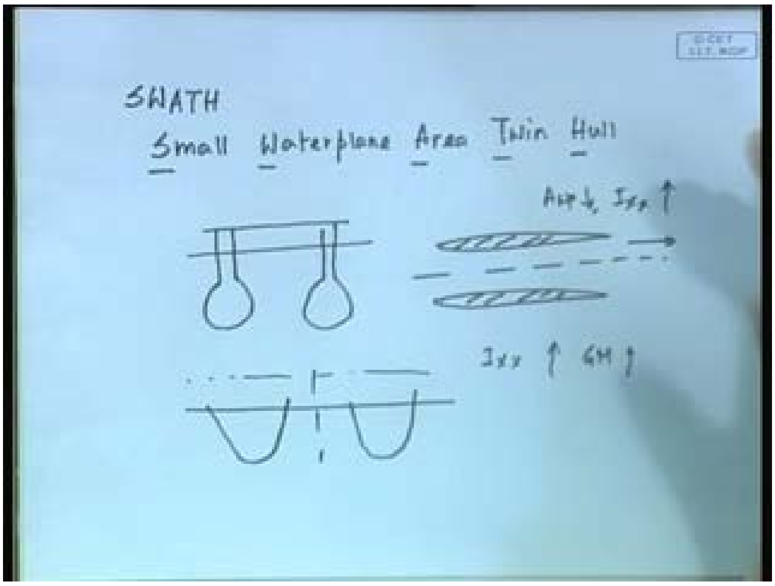

Now, this means small plane area I will compare immediately with another another you know like vessel that is catamaran hull in a minute, which is also a twin hull see here this is a small water plane area twin hull it is a twin hull, but it is small water plane area, how does it look like if you see this you know section view it will look something like that if you see its water plane area it will look like that, which means this this is kind of how the vessel looks like, if you take a picture you you will see that it has got two demy hulls supported by very thin straps. Water plane area is very small and of course, stop the frequency.

This is to be contrasted with the catamaran hull, this I will do in a second same idea get the buoyancy from this semi submersible, the word semi submersible can because of that it is semi submerged water plane area is small. So, what happen same idea this boat is moving this side you see this particular we achieve the same thing by reducing AWP increasing i x x. So, I have the stability I have lower period. In fact, the right why we we do that what is the primary advantage swath hull they are known to be extremely comfortable in waves, they simply have very less motion why because? the periods are very high they do not get excited.

In fact, I have read an analogy that riding on a swath hull is like riding a Mercedes car compare to a very small car. The comfort level is so high the full purpose of swath hull therefore, is basically motion control. Now, if you look at from other point of view resistance etcetera, you will find it is not that good because, you know if water plane area is waited hull is larger. So, this is supposed to be excusing me good for keeping station.

So, in the special purposes, where you want to make sure that you are making from measurement you on a stable platform this is used. Now, in the other twin hull catamaran hull typical catamaran hull, you know catamaran hull, which is very common now it is also a twin hull. In this catamaran hull, though you do not have very small water plane area, remember as a result catamaran hull do not have very high natural period. So, they are more as comfortable as that at all.

Essentially, catamaran hull type strength lies in stability, you know you are getting actually large i x x. So, you are getting large meta centric height, but consequently there is no equivalent reduction in AWP, which was happening in swath hull. In swath hull I had adduction of AWP along with I x x increase, but here I have only I xx increased because, most people want to be on the top and all. So, this will allow you to have a higher k g, you know like pleasure craft various boats and that.

So, catamaran hull between hull and it is not small water plane area to in hull. So, it is not that comfortable I just wanted to make this point because the word twin hulls, one makes an impression that all mean hull are suppose to be comfortable now the water plane area must be small. So, this is about this kind of a you know like heave motion now we worked it out yesterday periods a typical shape. In fact, a burg and all that or other let me put it this way.

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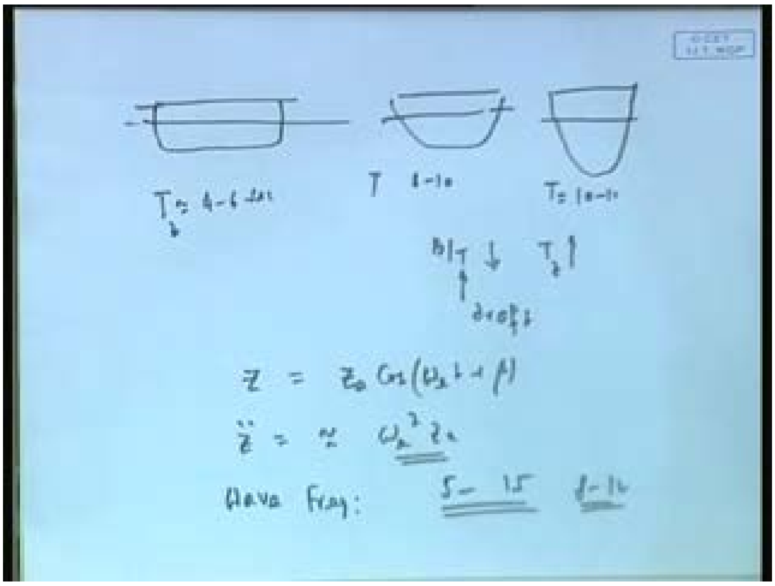

You take a cross section of a burg type typically very large beam, very large depth, then take an ocean going vessel, then probably take a ship with a you know like this if you see progressively, you will find out that most of the boats, which are for country you know riverine vessels for example, the kind of boats that are used to cross Ganges you have much larger breath, much larger draft why because? primary thing is stability, but then they are operating in river small sphere, where the waves are very less and this thing we will end up finding T to be may be just 4 to 6 second the natural heave period, this may be slightly more may be may be 8 to 10 second, this may be also 10 11 second right.

So, what we find out; obviously, the dipper it is the draft is higher compare to basically b by T is lower this gives rise to T higher, the T means here draft you know this this is here draft let me put this way and this is the reason why? you will find out that riding a small boat is usually more uncomfortable, always more uncomfortable remember another thing of interesting suppose heave motion is z a well cos of course, this is of course, oscillation, but let me I think I will not put it in this way see if the oscillation frequency is higher than period acceleration is proportional to omega square z a.

So, you have much larger acceleration you are subjected to much larger acceleration and; obviously, it is not good this makes sense because if you take four seconds to make one cycle then you know that the speed at which you are going rate is much higher. So, if period is low low, frequency is high acceleration becomes since proportional to square of frequency is very high and if it is very high you do not like it because, it is very uncomfortable, one of the reasons why small boats are always uncomfortable is that you know compare to a larger boat in terms of comfort usually.

So, these are all kind of practical values we will get that to this afterwards, but typically our aim would be to be you know like around this range. The other point here having said that what I said yesterday, once again I will repeat it that these all are lying between by practical wave range, what is known as everyday wave wave frequency range, which is between say approximately say 5 to say 15 seconds or so. I mean if you go to open ocean in fact, one can narrow it down to more like eight to twelve second.

Typical open ocean waves are approximately 100 to 300 meter long typical ship length are also of that length periods heave period correspond to that wavelength. So, there is really no escape for ships and it is somewhat very close by, but for off shore stricture by design you are doing it away and the reason I mentioned yesterday that ships I have a I have a provision to get away from resonance by lowering speed and by changing heading, which I do not have in off shore structure.

Secondly, I do not have the limiting operation as in off shore structure for heave. In there I have to stop operation if my heave is excessive down time is very high etcetera. So, In fact, the full research is going on recently also in our conference about the paper, which was called ultra low motion semi submersible you do not talk of ultra low motion ships normally because, it is not that critical, but here it is important not for comfort for operation point of view.

So, this is about we will get back to this combined thing again now, what I will do I am going to switch to the next motion pitch see heave pitch roll specially heave and pitch they are all similar, just that the equation form will look different, but the solution remains similar

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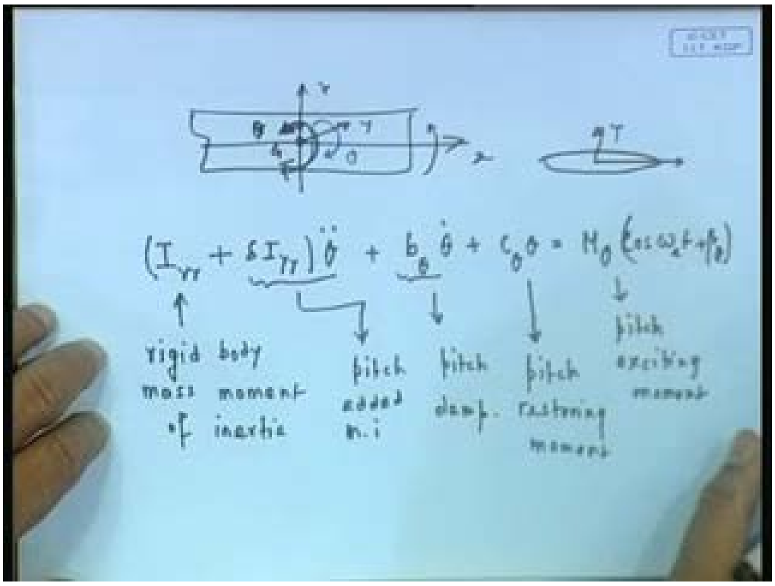

If I now go back to sit back to pitch motion of course, you know this is my x my y this is z and pitch is going to be this motion the theta.

Remember it is always good to use the consistent axis system. So, if I have y to be port side here you can see that is then bow up is going to be my positive pitch according to this diagram right no sorry let me see how it is. So, no sorry sorry I think it is the just the opposite right positive will be this way positive is bow down sorry this theta positive must correct it here if y is here my my positive theta is bow down, but it does not matter for my you know like what I am going to tell purpose.

You see this is a right hand system. So, bow down is going to be positive pitch now, what is the equation of motion for that single degree equation of motion just like heave I am going to have here I moment of inertia of rigid body about which axis y y because we are going through the central gravity because this is my origin that we have defined now, we have defined the motion with respect to coordinate at c g. So, I y y let me write it down plus there is going to be let me write in this way this is added it does not matter how we I calling it.

So, we can call it this is cos may be plus here some beta theta see what I wrote here is exactly same for all equation of motion this is just like m x dot dot for rotational motion you have what do we have, we have rigid body moment of inertia about the relevant axis y y. So, this is please understand rigid body a moment of inertia, it is not to be confused with I x x or I y y that you use in hydrostatics for water plane area it is mass moment of inertia.

Lots of students normally make this mistake may be for symbol or. So, because in hydrostatics we use I x x I y y as moment of inertia water plane area this is rigid body mass moment of inertia not to be confused what so ever. This exactly the same thing added mass basically these two just like what we had earlier added moment of inertia and damping moment why we are calling moment because it is moments now not forces basically this part is that added moment force. So, this is you can say added pitch added mass in pitch and this is damping for pitch pitch damping.

So, this is like pitch we we can call it this way pitch added moment of inertia mass we can call it moment of inertia and this is pitch damping and this of course, is pitch restoring moment hydrostatic restoring moments and this is of course, the pitch exciting moment exactly the same form is same everything is same the solution also will be same of course, this m theta is the amplitude and this is of course, the time. So, the full thing is the moment of inertia.

So, you see if you look at that. In fact, if I did not call it the solution is just same as what we have done before exactly same there is no only the terms changed this is actually m plus a z z dot dot b z z dot b z z etcetera.

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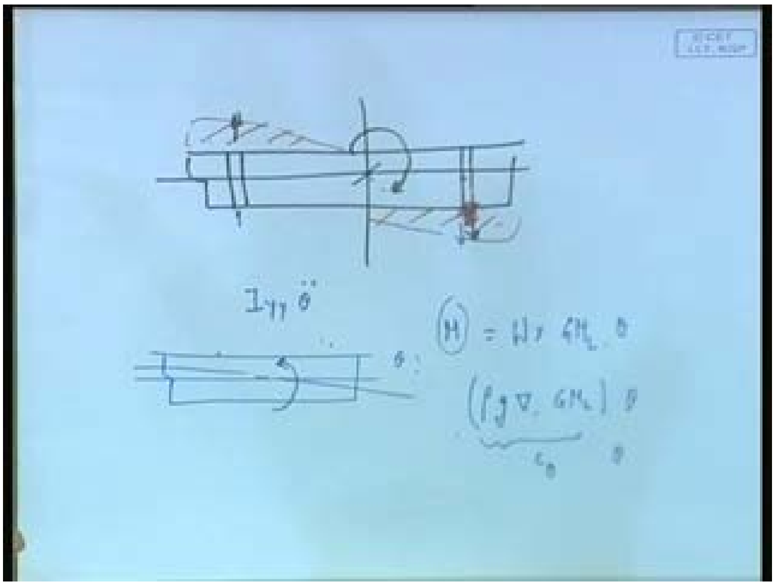

So, solution is exactly same it will look similarly like this like this like this etcetera there is going to be natural period you know like this this is going to be this omega e equal to omega theta omega theta is natural period. So, natural period natural frequency rather pitch frequency is going to be square root of c theta by I y y plus in my here delta I y y etcetera etcetera So, you know the natural periods it T theta is going to be two pi square root of I y y plus delta I y y by c theta exactly same as before. So, there is really not much talk about the nature what we need to talk is what are these terms how much are these terms therefore, what is the estimate of T theta and how do I lower it as far as the formula is concerned you may even think that as the numbers go this is like mass this is like the added mass increase this is like the force which pitch that it is the word you can just cut the word heave and use the word pitch that is all.

So, therefore, as far as the solution is concerned of the equation of motion there is nothing extra that is why I spent so much time on the heave part, because single degree of freedom equation solution nature will be looking exactly same now, all right now good question let us discuss the physics of where did this added moment of inertia come in this case very relevant question see now, I am rotating it what happen to this section is try to come down what happen to this section is try to go up.

So, what happen to this fluid particle here gets pushed down what happen to this fluid particle here some disturbance is there. So, what happen there is a general mass of fluid particle again getting disturbed now you see when I rotate it about this axis I have I yy theta dot dot as moment of inertia for any rigid body if I take a rigid body moment of inertia now here same thing along with that some mass of water is also have to be rotated.

You see here when I am pushing it down this water gets pushed down. So, it is like again. So, much of water if I were to show a picture in a with a rate as if. So, much of water is attached to it and getting rotated this is the origin because whenever I am like accelerating there is some amount of water that is also getting accelerated. In this case, this comes down this goes up therefore, as if the mass of the section becomes heavier with this amount of mass. So, if I take a moment of inertia it is this mass plus this mass this is the origin same thing see any modes of motion whether rotation or whether linear we are necessarily pushing water an accelerating surrounding water. So, the surrounding water acts as if it is part of this mass the difference being here is that I had to take moment of inertia of that mass for rotational modes of motion.

As I said if I were to take a small piece of mass here see this red piece of mass this fluid particle, this particle is also getting accelerated down. So, therefore, what is my moment of inertia mass of this section distance square plus mass of this particle distance square? So, if I integrate that I end up getting a contribution from the mass of the fluid particles this is what is added moment of inertia. So, added will also come in any accelerating motion.

Remember this is an acceleration motion because I am just accelerating it. So, moment I do that there is an acceleration if steadily keeping like a trim there is no added moment of inertia like when I shifted a weight it trim there is no concept of added moment of inertia or other this force does not apply all right. So, we will get back to this c theta part this is from here only I can tell tell me ask this question if I were to trim the ship by an angle theta what is my restoring moment what is the moment that is trying to bring it back what is the. So, called pitch you know what I should say in case of trim the trimming moment.

See it is given by weight into g z in longitudinal direction or I can say g m l into theta actually because in in pitch axis theta is always small. So, we always write that way in reality and you have seen the trim cannot be more than two three degrees because if it was so the bow would have come up. So, trim is always very small. So, it is w into weight into g m l into theta this is my trimming moment m right that is what we have done always you know if we shift a weight here what happen w into d equal to w g m l theta and this g m l you write as you know T p c etcetera etcetera not T p c sorry m c T moment we change trim.

So, but our case it is like that. So, what is w it is I always prefer to use this in a s i unit s i unit mean its force into distance force meaning mass into acceleration. So, therefore, what I do is I will write now mass sometime you know people write trimming moment as confusion be always have tan meter actually it is TransForce meter. So, it is always good not use consistent s i unit. So, I prefer to write this as rho g v because there is no ambiguity if you write this as rho g into sometime you know people do not take g etcetera.

So, if you use that this becomes fully consistent mu tan rho no confusion it is mass by length cube g no confusion this no confusion. So, this into g m l into theta this is my c theta what it means is that if I were to just like in heave if I were to trim it or pitch it by theta degree there is a moment trying to restore that of this amount if I once again if I trim a hull like this if trim a hull like this the moment comes in trying to restore it back and that is given by this into theta larger linear with respect to theta and therefore, this is my.

As you know very well for estimate purpose for ship sometime I can use g m l equal to b m l you know approximately, but that is for ship we do not have to do it, but this is my best formula.

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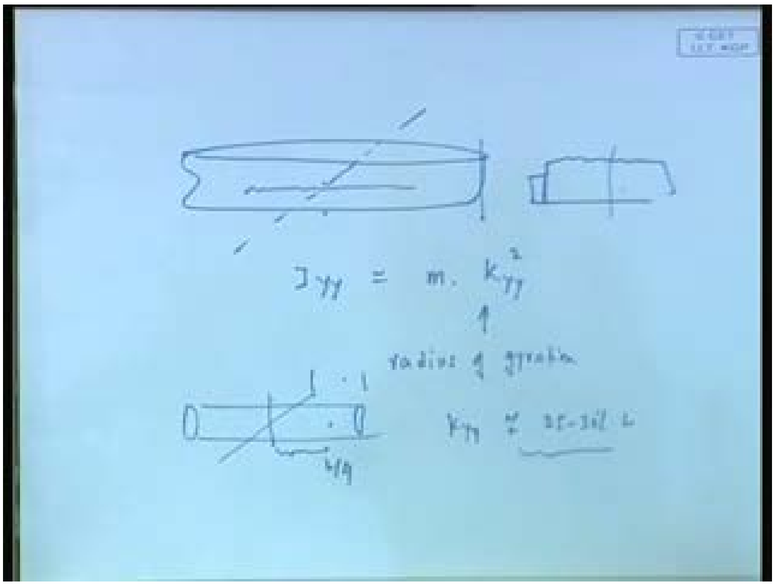

So, this g m l is known now we will get back to again this this part lets again have an estimate I x x I y y etcetera first of all let’s look at I y y you see here this is my ship this is my axis what i am doing i want to find I y y how i can write I y y it is actually mass into you can say k y y square when k y y is radius of gyration about the y axis this the relevant radius gyration.

Now, tell me from this from estimate these masses are more or less distributed going lower etcetera see suppose you take a cylinder uniformly distributed mass you can find out k y y you know that it will be somewhere here around here well it I do not recall, but we it will be something like something by root twelve etcetera what I mean is that if I these are difficult to estimate how do I estimate I have to we have go to weight curve I actually have to go to the weight weight distribution curve then take sectional weight then take square of that etcetera etcetera, but quite often getting weight curve of a shape is one of the most not difficult, but uncertain things because lot of weight come here and there all the time. So, for our purpose we can make a reasonably good estimate.

What will be a good estimate a good estimate will be that if it is around l by 4 moment of inertia k y y around that not necessary may be may be around 25 percent to 30 percent you see what happen is lets lets take a logical guess if the mass was uniformly distributed like a cylinder moment of inertia is going to lie between somewhere here because you see masses which are further contribute more. So, if you see. In fact, m x square and integrate you will find here. So, if there is uniformly distribution of mass; that means, if mass was uniformly distributed it is something like 35 percent or. So, I think 33 35 percent of that.

But in the ship case what happen you understand that masses are more in the central region sections are bigger as you go to h typically you have smaller section smaller mass on the other hand they contribute more. So, it's very logical number one it can never be at 0.5 because 0.5 would mean as if all the mass is here it cannot be at a center. So, it appears from any practical point and it has been born out from large number of measurements it is around 25 percent 25 26 27 28 29 30 something like that.

So, you can more or less say k y y is approximately you know like 25 to say 30 percent of L this is a guess though one can always say why 25 why not 22 yes, but for you will find out the difference will not be. So, much in the prediction number one number two really you cannot hit the exact number whichever way you do it is an estimate. So, this is ok now comes to. So, what I am trying to get at this that I we want to make an estimate for real structure this value again it is at what period I have an excessive pitch.

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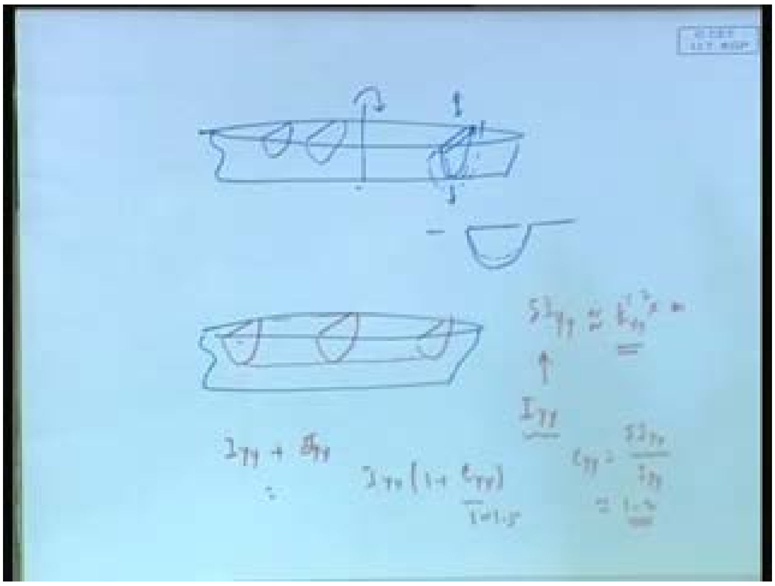

So, I need to estimate this and this for a real ship now let us look at I y y part the delta I y y part that added moment of inertia now once again here we we will look at this way. So, if I have this ship here take this section now if this section is this section now when this section is undergoing like the body is undergoing rotation this is try to come down the question is what is the kind of mass attach to it approximately if I take the same acceleration remember that that is a sectional added mass in heave that is the mass you would expect to be attached to this going down sectional added mass in this direction is what is the added mass of this contribution.

So, if I take that m square the distance then add it up then I end up getting. So, called the added moment of inertia approximately once again now again you find out that that we have discussed last class a good estimate of that is that it is mass of the water of this surrounding semi circle. So, what it means is that this becomes again approximately the added moment of inertia of water mass having this you know like semi circular body just like the mass would be heave added mass would be mass of that pitch moment of inertia would be moment of inertia of that.

In other words something like this if I were to draw in a different color as if this was the ship here and as if there is there is a another geometry you know like a kind of a geometry which is semi circular in look, but top is actually same breath mass of that becomes a approximately the added mass in heave moment of inertia of that becomes approximately the moment of inertia for pitch so; obviously, if you look at these again, you will end up finding that your delta I y y is, which I also can write k dash y y square into mass I can write in this fashion if want.

This turns out to be all most equal to 0.25 in other words this is very comparable to I y y just like the other case we have found. So, therefore, if I were to write this you know I yy plus delta I y y delta what did I write delta I y y. So, I can write this as I y y into one plus some factor say some c y y so this I can always call c y y to be you know like added moment of inertia divide by rigid body moment of inertia. So, this turns out to be again around 11.5 like that the factor just like what we have done before. So, this added moment of inertia plus moment of inertia which can be called virtual moment of inertia may be around two and half times rigid body moment of inertia approximately.

So, you see the c y y of course, by definition is coefficient that is delta y y by I y y. So, this is around one to two may be lower may be higher in the order exactly same as what happen for heave added mass. So, we will take this as bench mark for our estimates for you know like do it certain estimates now now let us go back to the estimates all right.

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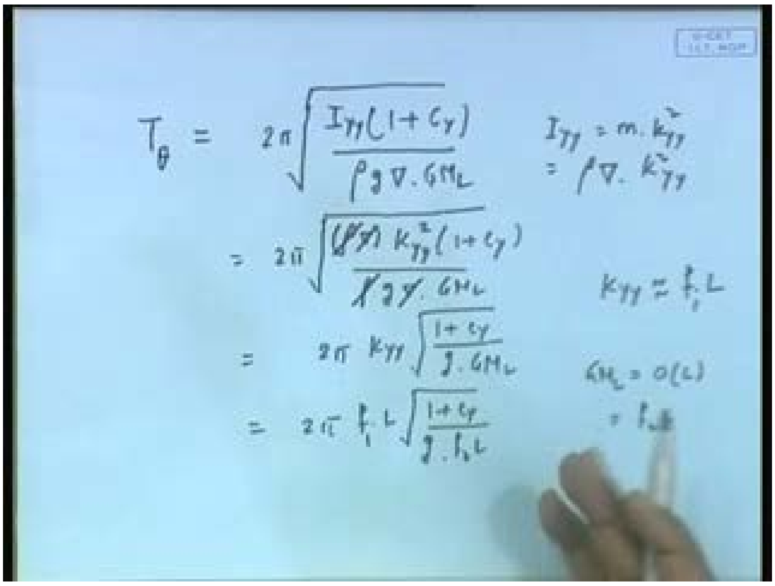

So, let me write this again then T theta then it what was that 2 pi I am you know spending long time in the natural period estimate because remember when you do a design you do not have a control on the environment, but we have a control on the geometry and the mass distribution which decide natural period.

So, I need to have an idea what it should be where it is how much it is and can I play around with this what I should change it etcetera etcetera that is why we are playing we that much because our aim is always to ensure that they do not coincide if it coincides how I can get away you know all this stuff. So, this was if i were to take I y y outside let see this one plus c y that is what I wrote here and let see this is rho g v into g m l now I will do one thing as I this I y y as mass this rho into v remember into k i k y y square right see I y y is what mass into k y y square mass is nothing, but rho into volume into k square y y agreed.

So, this into k y y square 1 plus c y y rho g v g m l. So, i have this gone this gone this gone this gone. So, this turns out to be 2 pi k y y y y square comes out this thing here one plus c y by g into g m l something like that. So, this is this is now this k y y outside now you see let me put it this again this 2 pi k y y i told you i can write k y y proportional to let me write it now as a factor let me call it as f l when f of course, I said it was 0.25 or so.

Let us write in terms of like that. So, this say I call it f into l let us call it this this is one plus c y and g is here now g m l remember in for ship typically g m is order if length right its very large number one fifty etcetera we can also call this again. So, well if I call it f 1 l I can call this f 2 l say I call it were I tell you why I wrote that f 2 is typically what value one and half like that around 1 f 1 is around 0.25 now let us put these numbers here this one will get back to this for a typical shape.

This is only valid for a ship, but because I use this l part for a semi submersible may be slightly different because semi submersible g m l really is not order of length it is much much much smaller because for semi submersible g m l g m T are of same order both of which are higher than g m T typical ships, but much lower than g m l we will come to that. So, if I look in other words for semi submersible you really have no reference on x and y axis, but here let us take a ship length of 100 200 meter I mean typical. So, if I have 200 meter here let us go back to the next one.

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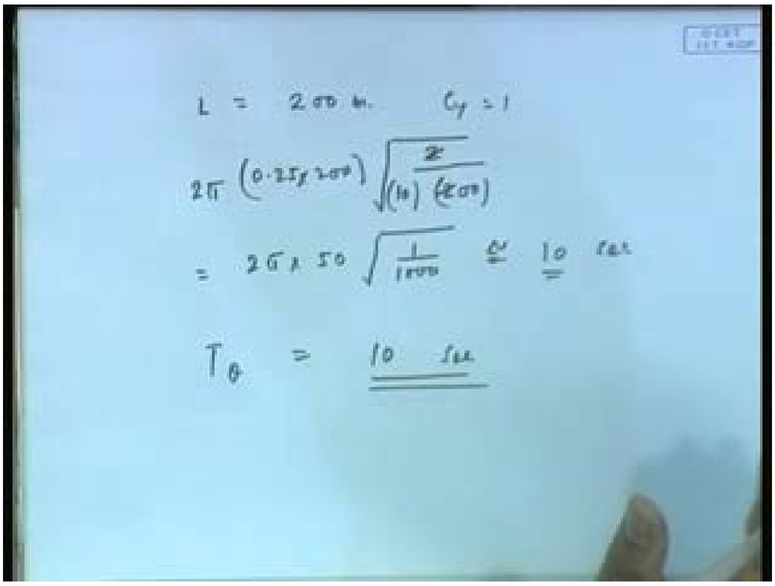

Say L is about two hundred meter say c y I am taking 1 which is quite reasonable now this becomes c I will take f one is 0.25. So, I have got 0.25 into 200 root over of 2 by g is about 10 f 2 is again 200. So, this will turn out to be let us see how much it comes this is 100 this is let me try to find out if this is this is coming to be 100 here one by 2 pi into this is 50 right into square root of 1 by something like that let us see how much this is this is this and 250 into 2 into about 9. Around ten what I got is around 10 second.

So, again you see interestingly once again for a large ship my T theta is ten second. So, once again we are for pitch middle of the wave spectrum for a large ship now I will leave it to you to work out for smaller boats and you will find out it will be also something like seven eight nine seconds. So, again we see we are in a problem of that now let see what we can do typically if I again look back to that see I y y really speaking you cannot change much actually this formula if I go back to that f one as you cannot really change much it is like that always.

F two also sees it depends on f 1 f 2 and c y c y also a geometry typically it will remain around 1 to 2. In fact, two there say the difference is that if it is one it will be root two. So, the factor is 1.4 if it is two root trim is 1.7. So, basically it is default by something like 13 15 means 20 percent 10 would have become may be 12, but it will still be within that range. So, my point is of course, we are not hitting the exact number range 8 to 12 second if I were to stretch both the side for the large ship he also have a into 12 second.

So, we are in trouble a same not in trouble, but we cannot avoid it is just unfortunate consequence of that.

So, we have this ah you know like unfortunate consequence for a ship let's look at some semi submersible now or some spar or something off shore structure because remember we are doing this also as a part of ocean engineering.

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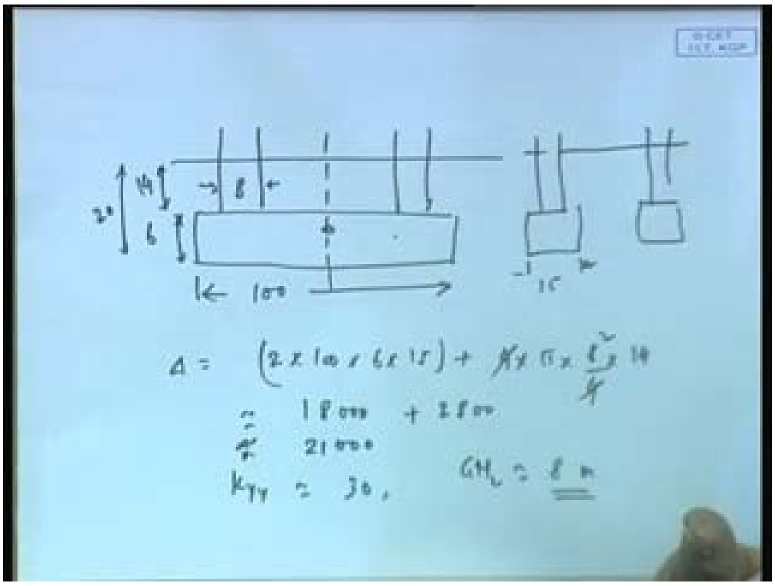

So, you also have to have an idea of floating off shore structures and. In fact, in for floating off shore structure these things is much much more important from design point itself this motion.

Let us take an example then only become to this often I tell you a twin something like a twin a typical semi submersible let us say it looks like that you know like the side view plane view there two there this say about 100 meter say this is about 6. So, the width is about 15 I mean I am just telling these are all kind of realistic number this may be about eight these are all kind of you know like realistic kind of number typical values are like that eight to ten meter you can take 10 or what you want 90 to 100 meter this is about 6 to 8 meter width is 15 meter you see the displacement you can work it out equal to how much 2 into 100 into 6 into 15 that is the plus lets also take this this may be the draft may be about 20 meter let say 20; that means, this is about 14 right.

Is all very rough number I am just trying to, but they are realistic number you know we we are doing an engineering course we need to I have always retain that we need to always make guesses which are of light order. So, this is this and this is how much this is 4 just tell me quickly this 4 into pi into well actually 8 square by 4 right this 4 into of course, the height 14.

So, this will come around let me just try to do this 2 into 100 into 6 into 15 this is 18000 plus this becomes 8 square into pinto 14is about 2800 right say around 28 you can of course, see immediately you know that contribution of this is. So, much smaller than this. So, essentially buoyancy comes from this and the water line support come this is why these things are known as columns stabilized semi submersible columns are stabilizing it.

See this what for these are column stabilized semi submersible semi submersible because buoyancy is below columns are stabilizing it anyway this comes to around 20 say around 21000 let me put it this way now you see let put this some number how much do you think for this one the a good value for k y y is going to be now you see this is a more or less box here this is what contribute.

So, 25 percent of this is about 25 meter, but because of this cylinder may be I will make it more let say it make it thirty meter because this cylinder will push something out. So, lets lets call k y y around thirty meter this is quite take good guess because remember this column will push out slightly. So, k dash y y I will make it one for that purpose and another thing is need g m l right now remember here g m l this kind of bodies the g m l is going to be much lower than 100 meter much lower. In fact, if you want to make a guess you can also make guess buoyancy and all that buoyancy will turn out to be something somewhere here k b and if you do b m it will come something like because I is much smaller.

So, this will turn out to be about may be around 5 to 10 meter something like that 8 to 10 let put it 8 meter or. So, it will not be 100 meter because is much smaller much much smaller, but see 8 is quite remember for a ship g m T what is the order of g m T only one meter 2 meter actually the rule says only 14 centimeter is good enough right, but we have 1 or 2 meter g m l is 100 meter, but this case g m l and g m T are same order both are something like 8 meter or. So, 8 10 5 like that.

And remember this is safe enough. So, there is no issue with safety at all. So, let us call it that along 8 meter.

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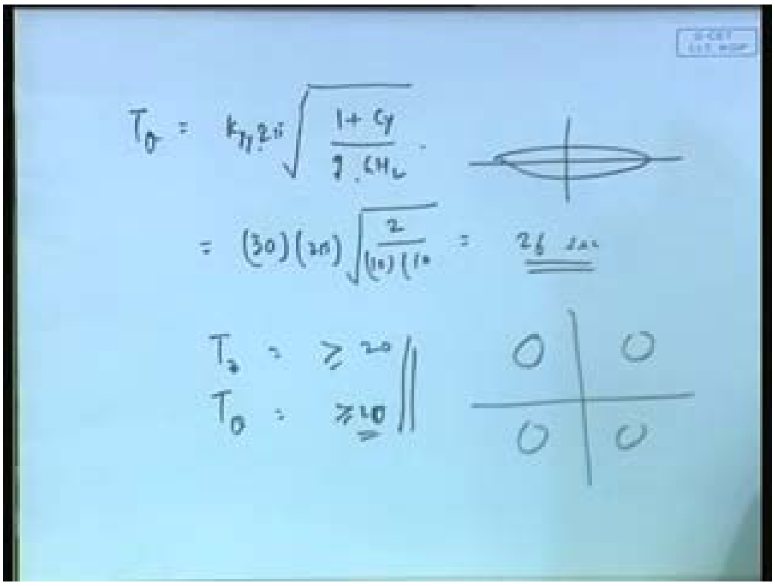

So, now, we will walk back to this formula try to see what is this thing again we will find out that similar path happen say theta equal to two pi we will write it this way here sorry one plus c y by g into g m l into here of course, I have k y y. So, this k y y I say 30 meter is 2 pi root over of say 2 by 10 into say let put it ten 10 only you know g m l instead of let us make it 10 easier to calculate.

How much it comes to let us work it out this 2 divided by 100 right square root of that into 2 into pi into say 30 26 absolutely good see here what we find T pitch again very high see look T heave was around twenty or more than twenty or. So, in that order T pitch is also something like much more than 25 or. So, or 20 or. So, means both of these by design we are far from the everyday wave absolutely good therefore, again if I look that why it is. So, you can easily make out from here see in the ship g m l is much higher if this higher this is, but yes, but whereas, semi submersible this is reasonably much lower something like one tenth time here.

So, one tenth means you know factor of 1 by root 3 1 by 10 square root and one third. So, it’s almost three times more if 8 second is 24 second. So, this is very good very good news because we would do not want any natural period of any motion close by to everyday wave. So, this is again you see very interesting thing happen and that is again a part of a design and how why why did you get is again the same thing why was g m l small because my b m l is small why b m l b m l small because my i was small, but not too small, but small enough because a is small.

Remember my semi submersible water plane area is this whether you take about this axis or that axis more or less similar both are similar ship take this axis much smaller take this axis much larger. So, here I have got equal bayous both sides g m l is much lower and I end up getting this very nice thing that it is like this and of course, you have to design it for that. So, suppose somebody wants to design and you kind of change this value you make it much bigger much smaller etcetera you will end up getting a much lower natural period if you increase this a AWP goes up decrease this mass goes down you will find out suppose you get more volume from the cylinders which would imply this calling from here which would imply you are getting AWP more high more which would imply g m l much higher lower t.

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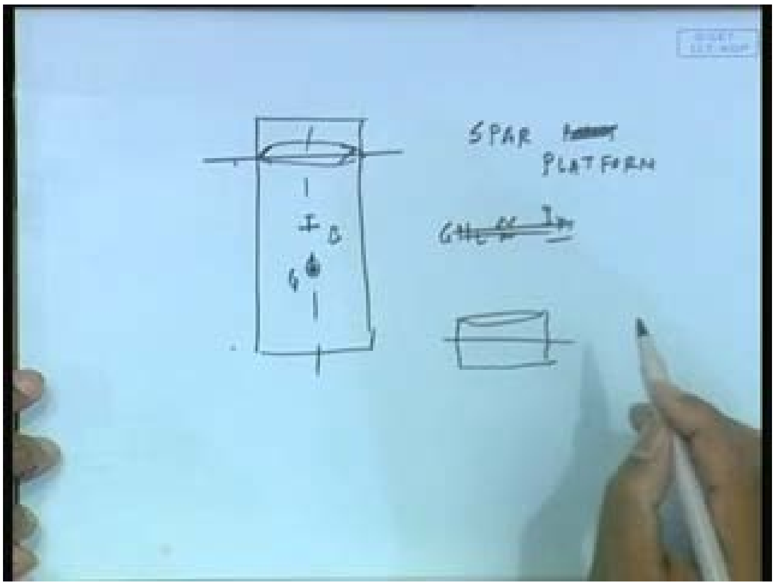

So, there is a balance that is very important now before at the beginning of the class I talk about spar buoy also this is a new concept spar you know everybody wants to simplify it what is the spar just a simply a cylinder vertical circular cylinder that is a spar buoy a new. In fact, this concept spar buoy spar platform when it was proposed a company was formed called spar international you know originally proposed then off shore structures are always evolving see the interesting part of off shore designing is that ships are typical ship like structure long narrow all you play around with a section shape up form etcetera.

But generic change in form that is whether it looks like box type or this type or some type all these are possible only in off shore structure much much wider variety of design, but when you do that you have to remember this thing these are these forms are critical part natural period has to be over 20 18 20 at least. So, here what we are doing again see here this is not a problem because in this case again I g m l which is of course, you know like in a sense proportional to well you can say I of water plane area by actually this thing g m l and g m T are same because circular cylinder both g m l and gm T are the same order what people do of course, play around with center of gravity that is why it is. So, much lower.

So, g can be somewhere here. So, I can always see my b is here I can always and put g in such a way. So, that I get the enough g m l not very high we of course, do not get very high, but not very low either see remember as far as this is concerned there is no difference between g m l and g m T they are same. So, in a ship g m T is much lower g m l is much higher, but in this both are same how do I control it; obviously, I want to have minimum value of g m let me call it g m here in one word because g m l g m T same. So, how do I control it I control it simply by playing with a g.

Normally of course, with all design comes again if you put the numbers here you will find out any book will give you this kind of typical evaluation of spar the kind of this may be 30 40 meter diameter this may be 80 meter 90 meter depth you will end up getting that a part of the design of spar or whatever is to make sure that you end up getting period about again eighteen twenty second or more.

So, 18 20 second or more is basically necessary from design we in other words this is if I were to do a spar thinking though I will just make a spar like that you will see it will not work now this brings a question to our mind about F P S O which is a typical tanker hull type you know flow F P S O.

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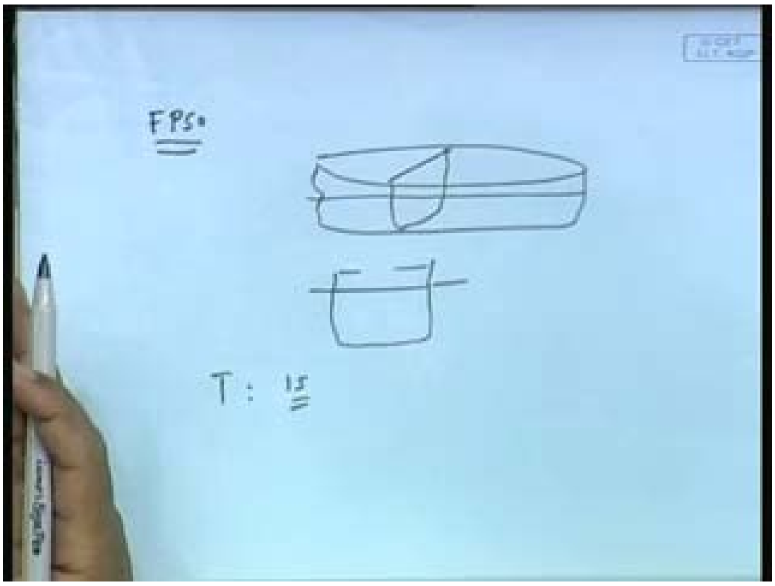

If you see I just want to before end of this this lecture talk about this also because F P S O are nothing, but a tanker hull, but you will find out that typical F P S O tend to have a much deeper draft the section ship tend to be much more like that why you do that deeper because you know if you do deeper draft you end up getting we have seen that in heave natural period and the pitch will be same thing it inverse with proportion with T make a deep or draft your natural period goes up.

So, this is why F P S O typical natural periods are not. So, much as twenty and all it may be around fifteen or so, but at least you try to make it push to 15 16 not keep down to lower that is 8 10 and how do you achieve it basically making it deep or draft remember this is in a one station. So, my requirement regarding free etcetera are less when you convert it anchor you have less choice, but when you design from beforehand you have more choice and you will always find if you take an first design FPSO with a tanker compare it you will find that the F P S O are deeper.

So, you know again why it is. So, because there is a tendency of course, one thing is you have more volume, but volume I can always get by making broader beam, but you do not do that you do that deeper because you necessarily want to push the natural period up this is the logic behind the evolving evolving the structure.

So, I will end to this lecture is our by saying that this natural period heave and pitch we have seen very important when you are doing specially off shore kind of structure you have to keep in mind in your forefront when you are evolving a design without doing that and see in a ship we do post process after the design is done we try to check as a verification or you can say as a post you know like study how much you know what was that period here you cannot do it. So, with that stop this hour, we will go to the next in a minute.