Seakeeping and Manoeuvring
Prof. Dr. DebabrataSen
Department of Ocean Engineering and Naval Architecture
Indian Institute of Technology, Kharagpur

Lecture No. # 06
Uncoupled Heave, Pitch and Roll – II

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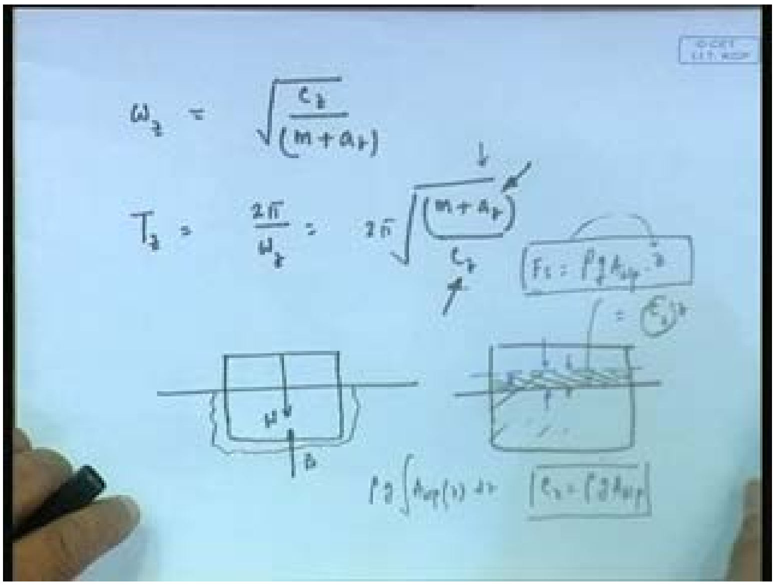

Let us continue our discussion on uncoupled heave motion. In last class, we were discussing about the natural period and the restoring coefficients. See the natural period here was written as c z by m plus a z, and of course the natural period would be 2 pi by omega z is simply. Now, natural period is a extremely important property for a oscillating system. To estimate this, I need to know as I can see a restoring force and I of course also wanted added mass.

So, I was thinking of talking about this, but I think in order to get to this estimate, we need to discuss both restoring force added mass, and see we discussed added mass, we need to discuss damping. Now, let us look at restoring force. You see suppose, I have the floating body here, it is at this location. So, at this point what happens, mass is balancing buoyancy, weight and buoyancy are fully in balance. Now, whatever the weight, w and buoyancy is fully balanced.

What is buoyancy? Buoyancy is nothing but the hydrostatic pressure integration over this wetted surface. Now, what has happened? This is got displaced. I will draw another line.

Let us say it has got displaced by an amount z. How much is my total buoyancy force? Total buoyancy force is now the weight of the displaced water of this entire thing, but of these this mean part is balanced by the weight. So, the unbalanced force that acts the unbalanced part of the static force is of course, the weight of this mass. Now, how much is this? This is of course, rho g A w p, it is like parallel sinkage into z, assuming of course A z A w p is constant, but strictly it should have been rho g A w p z dz integration over that part.

But if z is very small this distance, then A w p can be assumed to be constant over that, this is exactly what we keep on doing in our parallel (( )) calculation, you know TPCTPI calculation and remember, the entire theory of this equation of motion that we got is on the assumption of linearity, which means that we have already said that all the displacements are small in comparison to the body dimension, which means this part is small compared to the draft. So, it is very logical to assume it is constant. In such a case, my restoring force F s is this, but F s I I am writing as c z into z. First of all, you notice that this is actually proportional to z if I of course, assume A w p is constant. So, restoring force F s becomes proportional to the displacement and the constant of proportionality is rho g A w p, which is my c z. So, I end up getting here that c z equal to rho g A w p.

What is important here to notice is that, it is directly in proportion to water plane area. So, here you can see from this, that if water plane area was to reduce, my t z goes up and converse; if water plane area is very large, my t z is small. So, one can see that; however, I cannot still come to an estimate if I do not have a discussion A z. So now, what we will do, before we go to t estimates, we will let us discuss this added mass and damping and it is an extremely important concept because this added mass and damping very many students, actually or many people have a wrong wrong conception on. People have very misconception on added mass.

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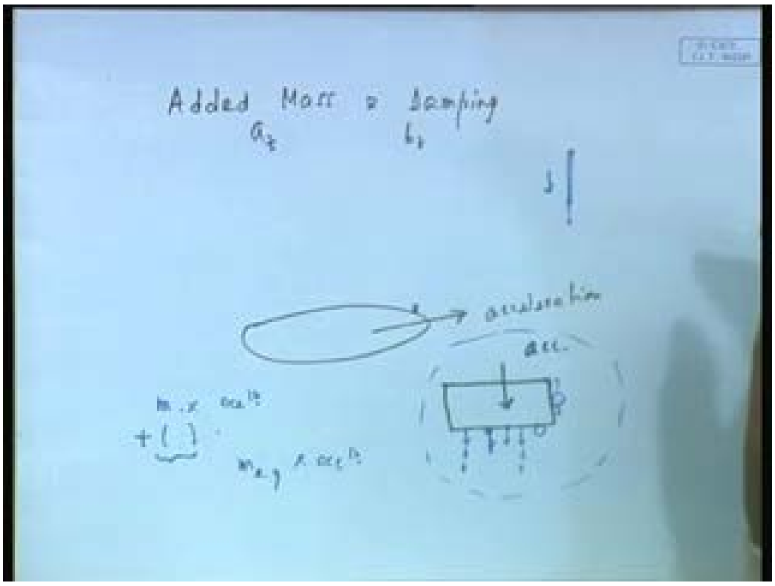

So, therefore, I would expect that we discuss this slowly. Basically, we are looking at here a z and b z, from the heave point of view it can be any name, but we will talk generally what is added mass and damping. Now, you see let me start this from a case of a accelerating body. This is the body here, somebody the full page is fluid, there is no free surface as on now. Now, I begin to oscillate. Basically, oscillation involves acceleration, you know if you oscillate you are always having acceleration, it is not a constant motion like a ship.

So, suppose Let me say some acceleration. I am accelerating in this direction by some value say a acceleration. Now, what happens? See. Now, you consider a fluid particle somewhere here, pen blue or may be a better diagram would be to take let me let me put another diagram, instead of that. Let us take the heave value, let me take a body like that and let me let me say that I am accelerating this side, see acceleration if it deep water. Right. Now, take a particle here, what happens? The particle also gets pushed out because it cannot penetrate; it gets accelerated. Now, what happens to this particle next particle? It also get pushed out, but to a lower extent.

So, what would happen, there is going to be an acceleration generated in certain amount of surrounding fluid. In fact, the acceleration cannot be theoretically said where it ends, there is no boundary, because if suppose I accelerate this body at say 1 meter per second square and it is a flat plate. This particle will move at 1 meter per second square, but the next one will be may be 0.9 meter per second square.

So, it will gradually decay, keep on decaying. So, there will be general acceleration induced on the fluid. Now, what happen? Let us look at the force, what is the force? It is mass of the rigid body, mass into acceleration, but now as I accelerate the body, I am also accelerating part of fluid mass. So, my total force has become this plus some additional part. We do not know how much the additional part. Now, what is happening? I can assume the additional part, this additional part of the force to be some equivalent mass into the same acceleration. Remember, this is very important, it is an equivalent concept.

I presume as if there is a some kind of identified mass accelerating at the same acceleration, reality wise it is not happening so. Please understand. The fluid part there is no identified mass, remember. So, it is not a mass concept, it is a force concept. Basically, I have a force and if I divide the force by acceleration, I end up getting a unit which is mass and I am telling that mass, it is it is as if that much of mass is attached to the body, the word as if is very important. So, there is no identified mass.

So, people think that yes, when I oscillate there is a mass identified. No, there is simply a force. So, added mass therefore is a concept of force, added mass force is equal to some mass into acceleration and that some mass is what we call is added mass. This is very important. Now, another thing let us remember, suppose I take a fluid particle here or let us say I take this particle here, now I am accelerating. Now, you see this is a in viscid flow theory, added mass concept is for in viscid flow theory. Now, if it was a viscous fluid, then this could have got stuck and also accelerated for boundary layer, but; however, here we are not talking of that. Here we are developing that added mass concept presuming fluid is not viscous. Therefore, this this can slide fast.

So, it is only in the normal direction, that it is accelerated that we get. For example, therefore, if I take a plate here and if I accelerate this side, what happen? There can be some boundary layer attached to that, but that has nothing to do the added mass. Added mass is the one that is getting pushed in the normal direction and in theoretically, this plate has no mass if it is a straight line plate. So, added mass in this direction is going to be 0.

So, why therefore, it is important remember, that we sometime ask the question. In my ship resistance, but it is also moving, but there is no added mass, we have never introduced, why? Because the ship was moving at a steady forward speed, not accelerating. Therefore, there is no acceleration force of the fluid.

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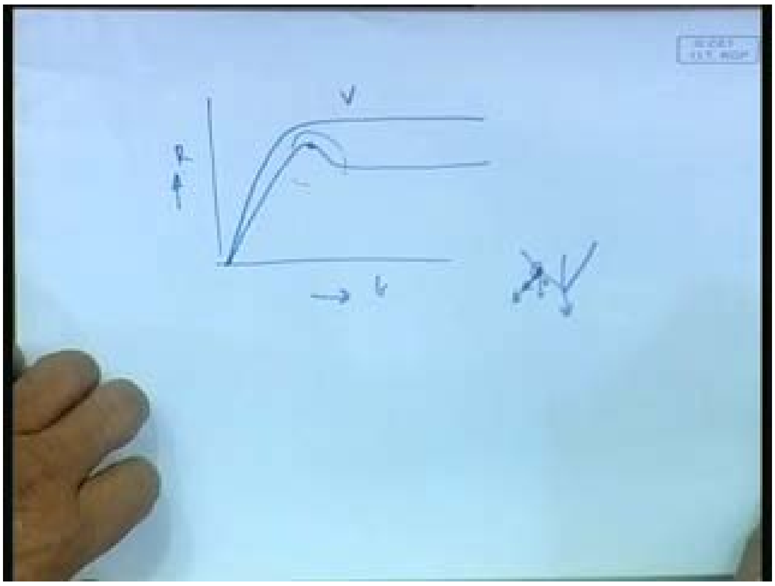

So, there is no added mass force. This is what we have explained to you and one of the reasons, why in say ship resistance, in a if you were to plot here resistance from 0 speed say speed goes like that, this is v, resistance you will find out going like that and going like that. Why this hump is there, because remember at this point it is accelerating, before it reaches steady state and because it accelerates the net force becomes slightly more, which of course will diminish when you reach a steady state. This is a say force or resistance whatever, with respect to time.

So, added mass force therefore, well added mass therefore, is a concept of force, not a mass. Lot of people thinks it is a mass attached to the body. No, there is no mass attached to the body, it is not sticking. First of all, it is based on potential theory. So, it cannot stick, it is only getting pushed in the normal direction, if I have a body here and I push it here, this water particle will get pushed this direction, not in this direction. Because it will have a velocity, this this it can allow you can allow it to slide, but you cannot allow this side; obviously, you cannot allow because if allowed to this side that would amount to the fluid entering the fluid body you know. So, the normal relative velocity has to be 0.

So, this is the idea of added mass. Now, what I said is this here in a deep water. Now, we will now do a little, we go to the next level.

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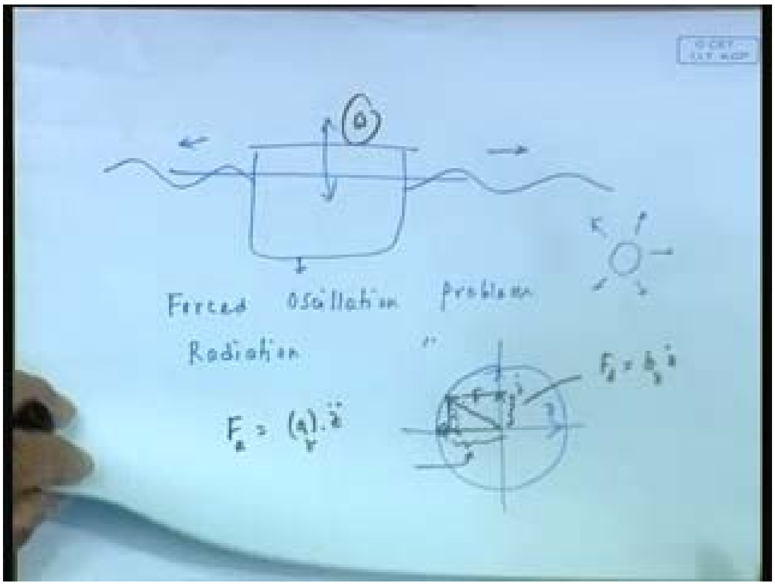

Now, I have this water here, I am oscillating. Now, if you oscillate, what happen you will of course, find out. Now, what we said, this problem of oscillating by force in a calm water, in fact it is known to be a forced oscillation problem. Sometime, we also call it a radiation problem. I am just introducing this word, why because as you oscillate, you always create waves and these waves will always radiate out from the body. In other words, in a planned view if you oscillate, waves are going to go outward. You know, if you oscillate it, waves are going to go outward, these are called radiated waves. Now, what is the force there?

Now, we look at the force part of it, what happen; obviously, when I oscillate it, you see there is a particle, which are also getting induced. Now, in the case of deep water, the force was just the additional mass force, but here what is happen, if I was to take a vector view and if I call this to be displacement, say z and this to be z dot, these all of you know I will guess that, there is a phase gap between in a oscillating system displacement velocity at this thing, what happen the force vector turns out here happens to be somewhere like this not in in phase with acceleration, but slightly behind, not in phase with acceleration. If it is deep water, it is always in phase in acceleration, but here because of the wave creation, as you give this highest force acceleration that is not the time when the highest force comes.

So, there is a phase gap. Then what we say, this is my force; this is my F, radiation force and I this is what I want to find out in my right hand side. Now, it turns out that by definition this part of the force that is the part that is in phase with acceleration, this part we are calling added mass force and we are calling it is added mass into acceleration and this part of the force, I am calling it damping force.

Remember again, here we are calling it potential damping or radiation damping because we do not have discussed it yet in the fluid. So, this I am calling b z into z dot. In fact, the negative sign, etcetera comes in, but this is the idea. What is happening in free surface therefore? If there is a free surface because of the wave creation, you remember wave creation means energy is getting dissipated; no, certain energy is being taken away by the waves. So, what happen? this act as retardation on the force and as a result, the phase gap develops and that is why, by in fluid mechanics always a force in proportion to velocity is known as damping force because what happen, it tends to lower the motion displacement solution wise.

So, it starts to retard it. So, you call it damping force, some kind of holding back. So, here also that part of the force in proportion to the displacement is called sorry velocity is called damping force and this is called added mass force. What happen? If you go deep water down, this vector actually becomes like that because there is no damping in deep water, no no wave creation. As you go up, more and more wave it actually goes up down and one can see that of course, there is a some changes there. see These forces are all depends on this oscillation frequency and there is a very nice and simple proof for that. You see just an intuitive proof; you take this why should be so? Like you know.

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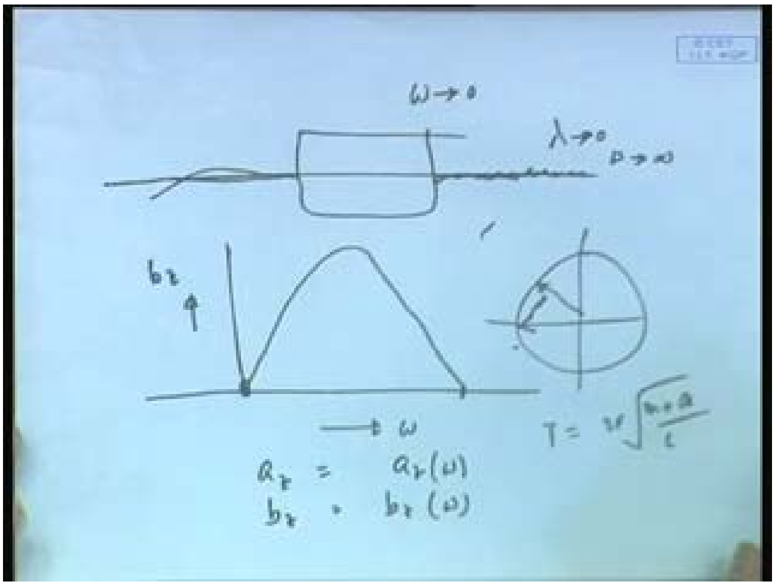

Now, let me just also call damping force here in terms of omega. Some damping force, say I am calling (( )). Now, suppose I oscillate this at a very low, means I am taking all my time to oscillate. What would happen to this wave? Practically no wave will get created. You see that by physics. So, the that the damping force is going to be 0.

Now, if you do also because see this, damping force is connected to the energy of the waves. Now, if you that do not have any waves, as in deep water case there is no damping force. Now, if you take limit of omega tends to 0 that is t equal to infinity, which means you are actually oscillating at a very, very slow rate. You can take experiment yourself, take your hand or somebody and oscillate, take all your time you will not find any waves created. Then you will expect this to be very small, actually theoretically 0. Now, you take the other extreme of extremely high, you will find out if you do extremely high, there will be kind of ripples, but the energy of that is going to be also 0 because lambda tends to 0. You see the wave that is get created, the lambda of the wave tends to 0 at omega of the wave tends to infinity.

Now, energy is always over square area. So, you know it is like half rho g A square lambda, that is what you are dividing by. So, if lambda tends to 0, you actually end up having practically no energy. This is a reason why, yesterday I mentioned that a large ship in a port when there are ripples, they just does not move there is no energy of the waves. So, this is also going to be 0, but in between that it makes wave. So, therefore, that this damping has to go something like that, which obviously, tells me that damping is depending on frequency, which basically means this graph of the force graph. It actually swings to this side, swings back this side. So, it depends on frequency.

So, what happen? If damping is depending on frequency; obviously, added mass is also depending on frequency because added mass and damping are two part of the same force. So, what happens in free surface phenomena radiation force, which is added mass and damping, becomes frequency dependant, in this also; that means, in what it means is that a z is a z omega; b z is b z omega. There is nothing like, there is the statement that added mass of this ship is so and so, is incorrect statement as for as heave or modes of motions are concerned, you have to tell at what frequency. Normally what has happen? You see I told you that at high frequency it is making ripple, practically no energy.

So, it is high frequency limit one can show tends to be like same as deep water. Now, if you have studied vibration, you know then you will find out that in vibration of hull, when we consider the added mass we always considered the deep water limit because vibration frequencies are very high frequency 1 second, 2 seconds like that. So, in their practically one takes the high frequency limit of the added masses. That is why in vibration and in a loosely, people talk that oh the ship has so much added mass, but this statement is incorrect as far as free surface is concerned because it depends on frequency, at what frequency. So, therefore, if I were to find out for example, natural period also t, which is actually having these 2 pi this m plus a; obviously, this has to be for that t or for that omega what you take, but we will not go through all the detail. We will simply try to make estimates of that a, a and b. So, you see having said that therefore, one of the big problems for us becomes how do I estimate, how do I compute added mass damping.

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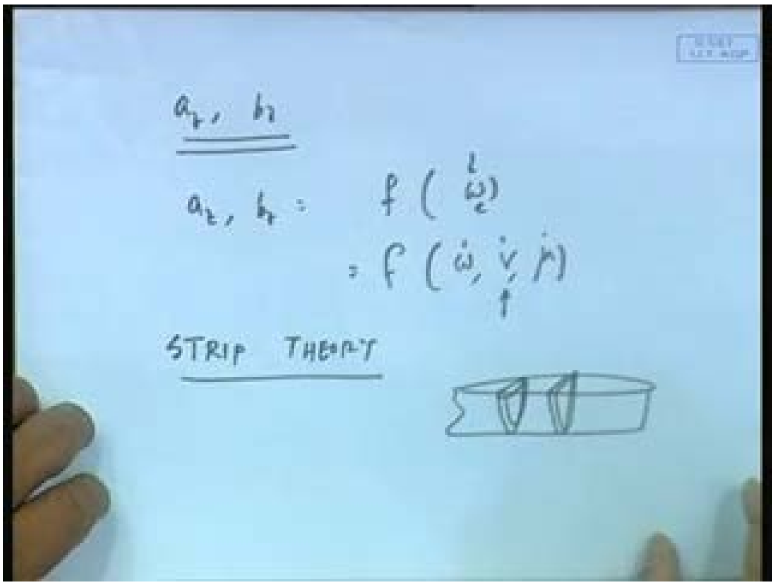

Now, this a z and b z. This has been a matter of research for very, very, very long time, because of its historical importance and there are numerous methods and today, we have got very sophisticated three dimensional methods etcetera, but before I do that again, see remember a z, b z is function of omega, but omega is a function of see is a function of actually omega e because essentially omega e is the oscillation frequency, but omega e is a function of omega v and nu. So therefore, for getting nu you see it is speed dependant. It is not also only omega dependant, but speed dependant. In the in earlier classes, we have seen that there are situation where two similar omega e, a same value omega e can occur for different combination of these two or these three. We have seen that in following waves.

So therefore, just to make it a guess omega e really will not tell the correct story because the same omega e would have arise in because of different physical phenomenon, different actually wave systems. So, this is a function of omega e, that is one part, but then one has to have simple solution methods because you cannot keep waiting for that. So, what has happen? People have been waiting working for that for a long time and I will mention a practical way of estimating that now, which is called synthesis based on strip theory. See what happens? You know Always a two dimensional, these are mathematical problems a two dimensional solution is simpler than a three dimensional solution.

Now, if I take a three dimensional ship. If I were to take this entire thing, even if I did not go forward speed, at 0 speed move forward up and down, I end up having difficulty of solving the problem; difficulty means this becomes much more complex, complexity level is higher, but ships are always long and slender, typically. So, what we can do? We can presume this ship to be something like two dimensional section ships. Now, this I will I need to discuss at more length here, perhaps. Now, you see to get bigger diagram.

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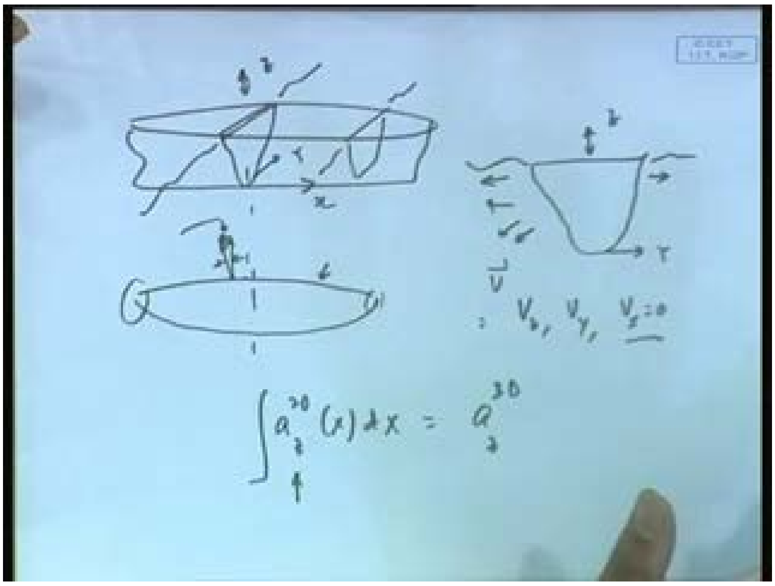

So, let me take a section. Now, I am oscillating in the heave direction. Take this section here, it is making wave. Let me take the water plane also. Now, you see if I this section. Now, this slope slope of this hull water line is very small. Now, what happen? This particular part when I oscillate, it is supposed to be actually moving this direction. See if I oscillate which ever direction it will be normal to the surface, but what happen is that see that because this slope is very small, this component this component is much smaller compared to this component, this component is much smaller. So, what happen because it is long and slender, I can presume it to be locally two dimensional with what it means is that, when I oscillate a section I can presume that the flow is contained in this plane, the 2 D plane or rather. If I were to plot this this thing see, if I were to make this x, z and y. So, this is my z and this is my y.

What we presume is therefore, that at a given section if I oscillate, as if the flow is all in z y plane, which means that if I take a velocity vector of fluid, it is like that. In other words, if I take a v here of fluid, v will have only a z component and a y component and x component is assumed to be 0, because it is very small. See if this is allowed, then what happen; the ship can be assumed to be composed of locally 2 D sections, each one is oscillating, each one is creating a wave in its own plane and therefore, I can find the four added masses for each sections two dimensional sections and add them over the length. So, if I were calling added masses of 2 D section as, say a 2D z at a certain x. If we integrate that over d x, I can get a 3 D z.

This approximation, that is getting a 3 D value by considering the problem to be a set of 2 D problems, sections and adding them, is what is called strip theory synthesis, because you are assuming the ship to be composed of strips. See you are making a presumption that the ship is composed of strips and that is not illogical, practically also because ships are long and slender. Because if you do oscillate, you do expect; not much of excepting of the edges, from edges some problem may come. Excepting for the edges, you would expect largely it is in the two dimensional plane.

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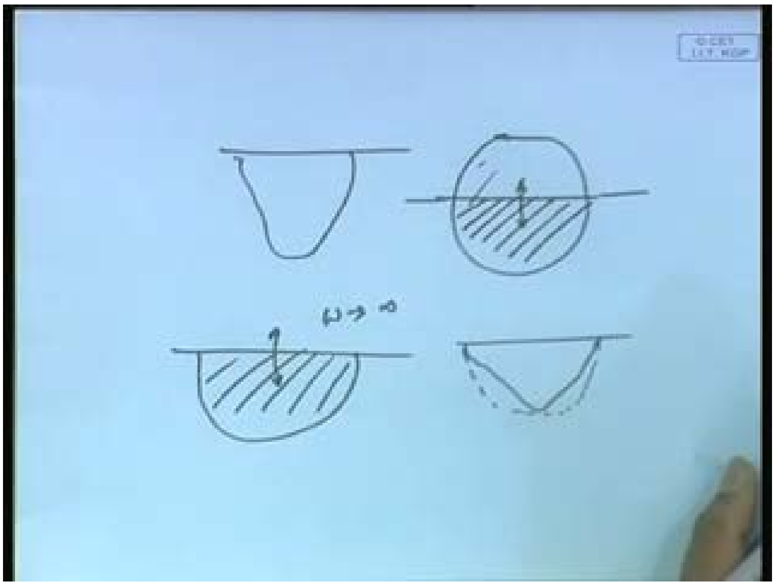

So now, this thing is more easy to compute for 0 speed to, because what is happening? Now, lot of researches gone in, where oscillation of a 2 D section where done. Now, in fluid mechanics or hydrodynamics you might have learned that if I were to take a circle and find out oscillate this side, what is the added mass? Most I, this is supposed to be a pre requisite to your course. In marine hydrodynamics, you would have done the added mass of that becomes exactly same as mass of the displaced water and in fact, at high frequency limit one can show that it becomes equal to mass of this.

You know if there is a free surface here if I what I mean if I take a semi circle, if I oscillate this side at a very high frequency, then it turns out added mass is equal to this. This is a theoretical solution obtained. In fact, if you take any cross section, a good approximation of added mass becomes the mass of that circumscribed semi circle. That is a good approximation, when you have no knowledge you can always use that. Of course, this is only one value and this is valid strictly speaking close to deep water, deep water meaning infinite fluid at high frequency like that. There is a whole lot of discussion on that, we probably cannot go through.

So, what happen? There have been now charts available, where people have worked out. The added mass of various sections based on certain sectional parameters. You see here.

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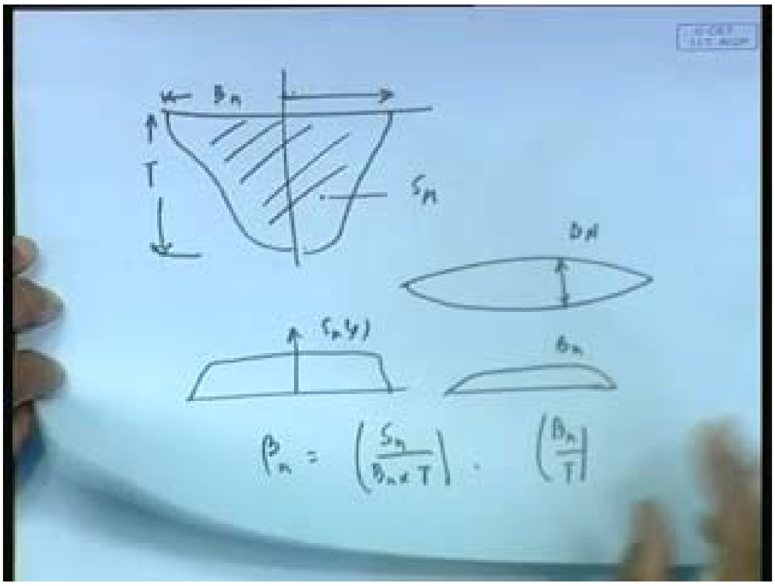

Now, we will talk of ships little bit. If you take a typical ship, in design you would have understood. It would have a sectional areas S n, say n th section I am talking of. It has got here it is breadth b n and of course, draft does not change, draft remains t more or less for all sections, if you taken (( )).

So, I have got essentially local b x, b n and sectional areas. Normally, what happen? Sectional area and the local breadth is a good representation of a ship section, although you may say that there to be many section, but you will find out that when you do design problem, you actually develop the lines plan based on those two parameters. Essentially, you actually you know like find out the sectional area curve, that is S n curve and a half breadth tan curve, that is b B n curve and based on the two you actually try to find out the section.

So, essentially what you do; that means any ship section usually is derived based on these two primary parameters, the ships ship can be many. Now, what is happen; people have worked out, here based on different such two parameter, that is sectional; see I can always use a non dimensional sectional parameter S n by b n into t and of course, this what is B n, beta n becomes non dimensional sectional area coefficient, because you always want to non dimensional thing and if I have another coefficient, that is B n by t n T, this become you can say non dimensional sectional with coefficient.

Now, these two parameters more or less are a good measure of the sectional ship. So, what people have done earlier, what has been done is that based on these two sectional ships, using certain theory the added masses for the 2 D sections have been worked out. This theory etcetera fairly complex for me to explain here, the theory is based on things like we call it certain transformation like Joukowski transformation you would have heard. There are similar transformations, what happen is that theoretically one knows the added mass of the circle. Now, it turns out that you can actually transform a circle to this ship based on the parameter.

So, like that by using transformation one can find out added masses. So, this is certainly done in one case. We call Lewis form, this transformation is also; there are number of transformation one is Lewis form. What it means is that if you take a distance of certain area and certain breadth, you can transform that to something like a ship like section you know ship like sections.

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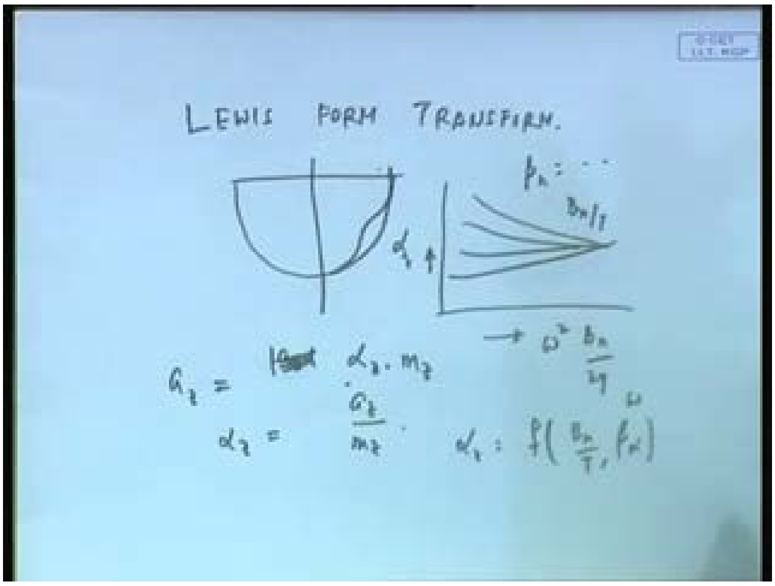

So, what in conversely was done is that, based on the area, based on the local beam one fitted that and then one ended up having this graphs of non dimensional frequency omega square. Typically, it is written like that, versus the coefficient here added mass, typically this is added mass coefficient. Always you write added mass as a coefficient. Well, let me put it this way rather; alpha let me put it alpha z into m z or alpha z equal to a z by n.

In other words, normally added mass you represent as how many times mass it is, rather than just by number. You see it is a relative non dimensional wave; a coefficient; added mass is a unit of mass. So, easiest way to tell how much is added mass is of course, trying to tell how many times of the actual rigid body mass is added mass. So, you have a feel. So, this is how it is. So, alpha z that these plots are available for different value of say say different value of B n by t and this may be for. So, in other words if you see basically alpha z here as function of B n by t and beta n and of course omega. So, this versus this for, it is a three parameter thing. So, there is a family of curve available.

So, one way is that you go to this graph, we can go to those graph; pick up my required values of sectional added mass. So, I will be knowing my sectional added masses, integrate them and get added mass. This is one way of doing thing and same thing exists for damping, exactly the same thing.

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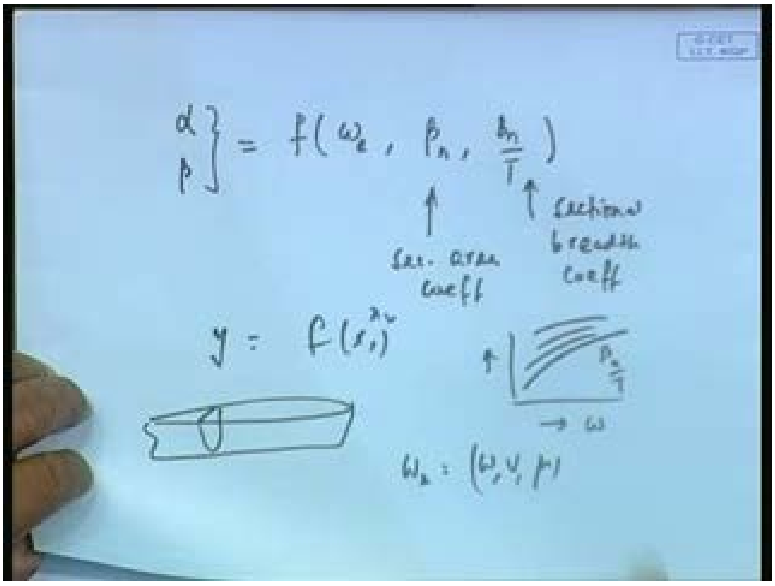

What I am saying therefore is that see, that one way of doing added mass is that go to those charts and tables, where the added mass coefficient alpha and damping coefficient beta; if I call this added mass coefficient and this damping coefficient as a function of; obviously, it is function of omega e, which you of course, work on based on d beta and for the ship part it is based on a sectional area coefficient beta n and B n by t. This is sectional area coefficient, this of course is sectional width, breadth coefficient you can say; these 2 parameter. So, what happen?

Obviously, when I have to plot x, this three parameter; what I will do, I have this versus this for a number of values for one of them for a given value of this. So, basically repeat it, remember there was a statement I heard earlier. That if y was a function of x 1, you need one graph; if it is x 1 and x 2, you have number of graph; if it is x 1, x 2 and x 3, then you have to repeat this number of graph number of times. This very obvious, is not it? See if y is a function of x x 1 just one parameter, one line will suffice to define that; if it is a function of x 1 and x 2, you will have y versus x 1 for different value of x 2; that means, you will end up having number of graph. If it is y is a function of x 1, x 2 and x 3, then these numbers of graph are to be repeated for different value of x 3. So, you end up repeating. There is a statement that if it is 3 you require number of pages and it is 4 you will require a book and 5 you require a library to represent them because it goes one time more.

So, here it is three. So, that is what we are doing. You are representing this added mass damping as function of frequency non dimensional for different value of beta B n by n for a given sectional area, repeat that. So, obviously what happens? When I have a actual ship here, I will take sections I will find out it S n, beta n value, sectional area values with values. So, for that I will go to the chart, find out whatever sectional added mass a to z like that, I will do it for different sections, integrate it I will get total added mass.

This is one simple way of doing. Of course, it does not answer the question about how do I get omega e because you know it is not differentiating between same omega e's arising because of different combination of this because it is only a function of one parameter omega e. This is one problem, means there is an approximation. The second thing is that; obviously, here I do not have the ship moving. You imagine this part also that this ship is oscillating at period 10 second.

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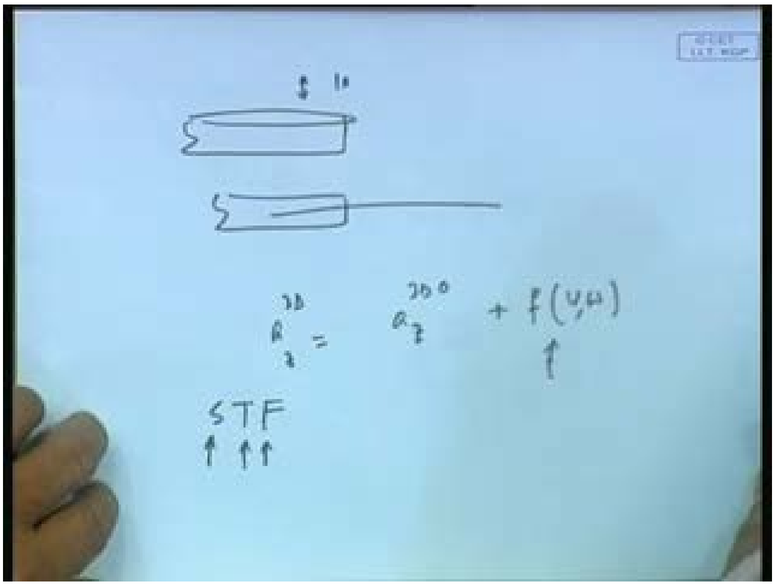

So, it will have some force, but second one is moving and oscillating. So, the second one is the ship is moving and oscillating; first one is just oscillating.

So, even the both are 10 seconds; obviously, you do not expect the physics to be same. So therefore, added mass has to be a function of speed. So, for that there have been many elaborate theories, where a 3 D z becomes a function of a z 3 D at 0 speed plus some correction terms, which is function of v, omega, etcetera.

So, these kinds of things are all full of mathematics. There are many theories that are developed, which have worked out; what is this correction, speed dependant correction we call to get to the speed dependant added masses. This is all beyond the scope of our this class. It is all part of classical hydrodynamic theories from which these are all developed. Whole lot of Maths, whole lot of you know like abstract Maths are necessary in order to get to this and; obviously, there are different versions because there are no close solutions.

For example, one very popular paper, which talks about this expression is I want to mention that, is called classically STF method, Salvation Tuck Faltinson method. It is very why I am saying this because this was historically recognized in our Nevelac society. Salvation was an American, Tuck was an Australian, Faltinson is an Norwegian and people say this is the best example of international collaboration, which actually is used even today. In any shipyard industry, most of the ship motions are based on STF method of strip theory, but we cannot talk about it here, this is more of a part of hydrodynamic course, but I just wanted to mention that you know so that you have an idea.

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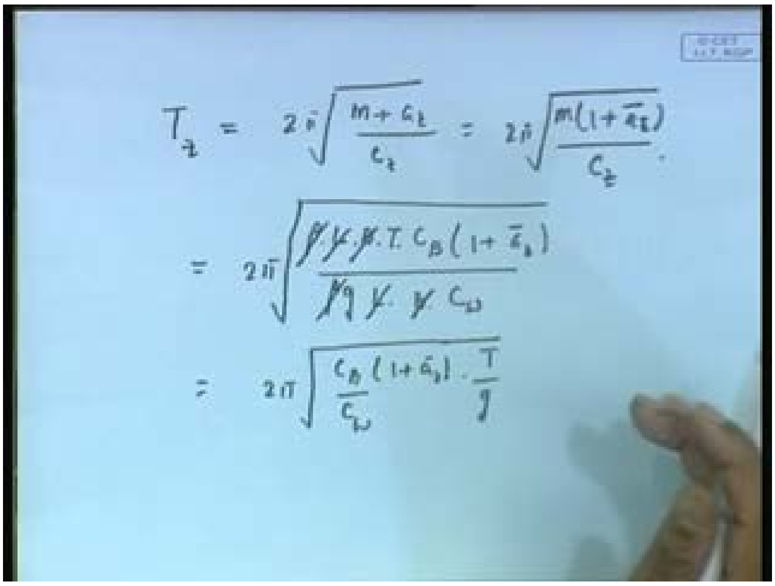

So, I am now going to go back, back to our strip this thing. The natural period discussion T z part, because we need to have an idea, physical idea regarding these values m plus a z by c z and I can write this to be; actually, we can write this to be m 1 plus that coefficient, added mass coefficient; what do I call it? Let me call it a bar z. Remember, a bar z is added mass coefficient, that is mass into a bar z gives you; now, let further work we can work it out for a typical ship; let me work it out for a typical ship. We will work it out for different thing, but let us work it for typical ship. What is my mass? 2 pi, let me write it down basically, it is rho into v; rho into volume. What is volume? l b t into c b.

So, I write l b t into c b. You agree with that no, because volume is length breadth draft into block coefficient 1 plus a z bar. What c z? rho g A w p. What is A w p? l into b into c w, right because c w is (( )) area coefficient. So, l b into c w, for a ship. I am talking for a ship, this one is for a ship does not apply for offshore structure as of now standard. So, now we can see this gets cancelled, this gets cancelled, this gets cancelled. So, what do I get? 2 pi, let me write it down here properly. c B by c w 1 plus a z; T by g, right see t by g stays, c b, c w, 1 plus a z.

So, this is my typical ship formula. Let us say, now I now want to make approximate for that eventually. Now, a z; let us talk about a z, because we need to estimate a z. You know that typical for typical ship a z would be almost like 1, why? I told you that if I want because we are making a rough guess. See we are now trying to figure out and I am discussing, what is the order of T z for a typical ship; which order? Is it 5 second, 10 second or 5 second, 6 second or is it 25 second, 30 second or is it 100 second? I want to have an understanding of which range T z varies. It is very important because if T z was like 1 second there is no waves of 1 second, then I do not have to worry about T z at all or if it is 100 second, which also is very non-existent every day wave I do not have to worry about it.

Remember, I mentioned earlier; waves are mostly 5 second to 15 second or so, mostly. So, I need to have an estimate of that, it need not be very accurate. After all if I make an error of factor of you know like large error in a z also, because of squaring function the error in T z is smaller than that.

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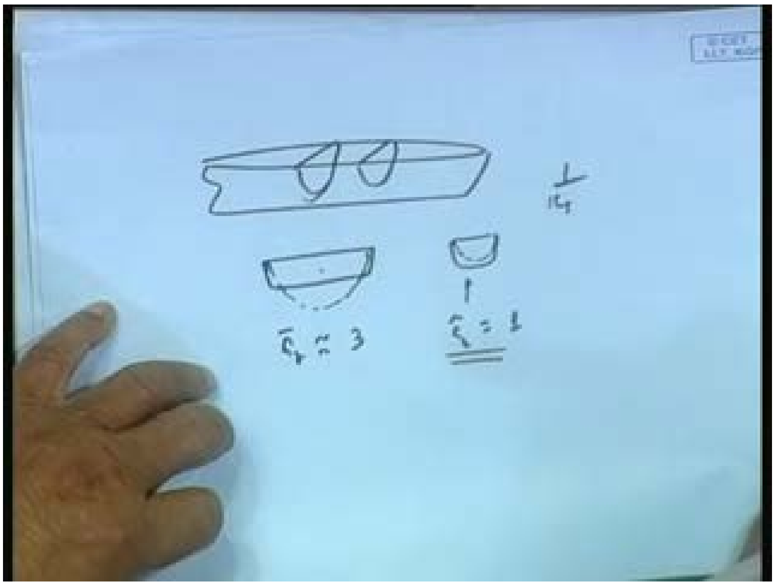

So, we can make an approximation for a z for this purpose. Now, I mention earlier that if nothing is there, you can always take this circle, add them up and if you add it up, you what you will find out; essentially, a quantity which is something somewhat close to the mass of the hull itself. In fact, if the breadth is very high, suppose there is a barge here. If you take a barge with a section like that; obviously, this this is much larger. If you take a smaller boat, this is smaller.

In other words, a flat barge would have a larger added mass, heave heave motion and a narrow a frigate type of ship would have smaller added mass, but if even if you take this, it might be in this case a z bar might be as much as 3; this may actually be may be something like 1. So, it is in this order 1, 2, 3. You can always work it out because you know these things are all; you imagine yourself a kind of a semi circular box, mass of that with respect to the mass of this. It is see what is block coefficient? Mass of the rectangular block. What is prismatic area coefficient? It is area of mass of this kind of this mid ship area throughout.

So, this is something lower than that. You know if you think logically, you will find out it is something slightly lower than your sea prismatic. Now, sea prismatic is something like a sometime you know like no no not lower sorry, the other way round. It is inverse of that, I I am telling opposite like one, it is like one by c prismatic little and lower than that slightly. So, it is around 1.52. So, let us take that we will take example of 1, as well 2, as well as 3, let us say.

Now, we will want to figure out the value of this; go go back to this expression of T z here. So, we will get back to this. Now, see let us take a ship; let us take the kind of ship where t may be 10 meter, this may be 2 or may be; let us take 2.

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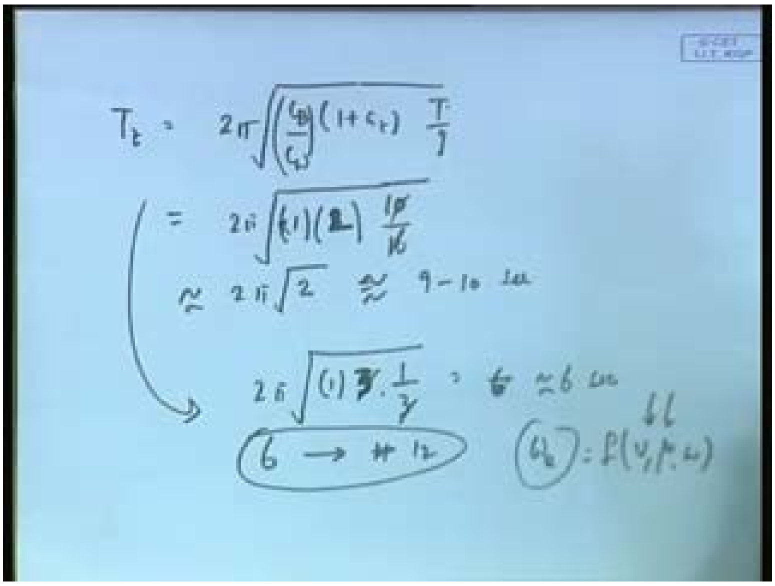

So, if this 10 meter; let us do it in another piece of paper. Now, c b by c w is what order? Very close to 1, we are just making an approximate guess is almost like 1 here, this one this term. right This I am telling say 2 means it becomes 3. Actually, 2 is too high, let me take it 1 only. So, because in real life it become actually let me make it 2 here. T i said in this case 10 meter, right g is also around 10. So, it goes off. So, how much it becomes, 2 pi root 2, around. How much is this? 6 into 1.5, around 9 to 10 second. You see for a large ship, now take a small barge; let me take a very small barge that kind of barge is that you are using to cross a you know the how that part T is very small, may be 3 meter or so; however, a z is much high because of those barges are you know very flat.

So, it may be 3 here. So, that will be more logical thing. So, in that case T z will be now approximately say, say this is still I take 1, I mean it can varying. So, this may be I will take 4 here because normally if you take a very high, it becomes that high. If not 4, let us take it 3; 4 may be too high. So, T by g, T is how much I should take? Let us say 3 meter. So, T by g I can take 1 by 3, you know let me just approximately take that, T is about 3 and half meter g is around 9.8. So, around 1 by 3. So, how much it comes to? It comes to 2 pi around 6 point around around 6 second.

If you take larger t, you may find 11 second. So, what I am finding, typical ships 6 to say 11, 12 seconds, something like that; say 12 second. This is only an estimate; remember actual one will may be 9, whatever. Now, look at this 6 to 10 second. Absolutely, right at the middle of the ocean wave that exist. So, you see what happen? Ships therefore, are absolutely middle of when actual ocean waves exist. So, you; obviously, end up having some waves sometime that will match to these and you are going to have very large heave. You cannot avoid it by design.

Ships, it was accepted. Why it was accepted? Because supposing, you encounter very high motion, which will will talk about some problem afterwards. What you do? You have a choice, I want to change omega e, because suddenly I have hit a wave, where my omega is matched with my omega z, I cannot change omega z because omega z is my property; omega e is of course, what I am encountering, but omega z this is a function of v, mu and omega. So, I can of course, change this or change this to get change of this right. So, I can slow down, well I cannot speed up normally because I do not have the power, that I can slow down, I can change direction.

So, I can do a combination of the two. I can slightly change direction and slow down. So, I have a choice to change my encounter frequency, so that I do not resonate. So therefore, even if it is resonating, I have an option to get away from it you know. So, I need not worry it so much, because I have a choice to if I hit a bad motion, I simply turn my head in different direction, slow down. I will not have as much bad motion. So, there is a question of avoiding excessive motion that is possible for a ship.

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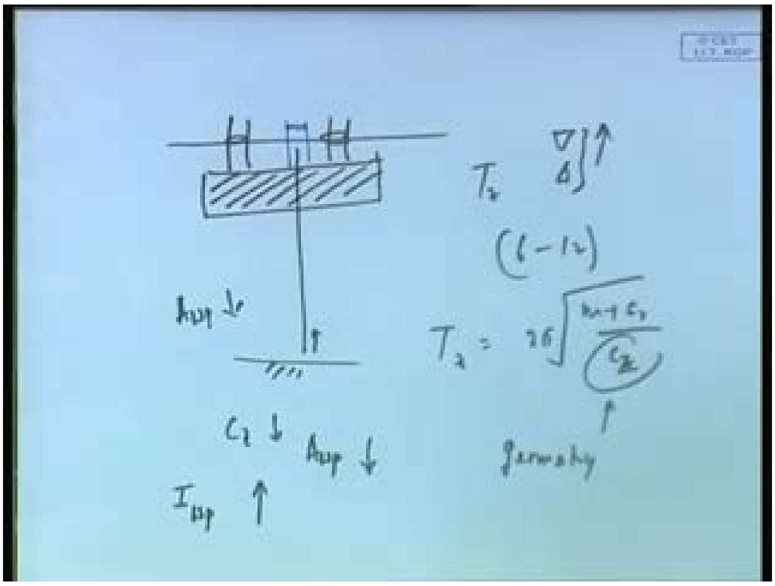

Take an offshore structure, my offshore structure is here. Now, I will we will you will know why offshore structure designs are actually primarily guided by natural period unlike ships, where you are designing by you know by carrying capacity and as a much more fundamental parameter. In your design courses, you will find that natural period of a ship is never occurring at the primary design; you have not even talking about it. After you have done you talk about how much natural period, but you do not use. If you are you are doing another course, you do not even use it as an input important parameter for your design, but in offshore structure you cannot do that absolutely. Why because you see here, this one is staying in one place throughout, while you have to have small heave motion therefore, you cannot afford a situation where some wave will come, which will resonate, because you cannot get away from it.

So, what you do? By design you must choose a natural period T z, which is far away from this 6 to say 12 seconds, far away. Now, if I want to do, we we keep on writing this all the time. Remember, this is geometry, this also is geometry, but this is much more geometry. Actually, it is geometry of water plane area, this one c z A w p. So, what we could do? If I want to make it lower, I have to increase it. So, I become like a barge, but that is not very practical we will find out. What we can do? We can make it much higher. So, if I want to make it much higher what I should do, I should lower this. So, my objective is lower c z means lower A w p.

However, I cannot lower a z, because mass and a z because it is a carrying capacity rather volume. Let me put it this way, the mass cannot be lower, after all mass is the displacement of the water and it is the volume and carrying capacity; I cannot if mass lower means the net available is small. see Let us say, take that I have to store so many million or so much of lakhs of barrels of oil. So, I must have so much space right. So, I must have so much of size. So, I cannot reduce buoyancy or displacement, but I must reduce A w p. How do I do it? This is the way we have been doing it, semi submersible the concept evaluation take the buoyancy carrying units below water. So, this is water. So, I have this high or this high, which which ever way you call it; support it by columns.

So, my A w p is low, but if my A w was low. Suppose, now question is why I do not have only one why I do not have only one. If I have it one, what is my metacentric height? I by v; what is I, moment of inertia of this water plane is very small. So, what I want, for stability point of view I want i of water plane of course, to be high. So, how do I achieve it? Make small A w p, separate it out.

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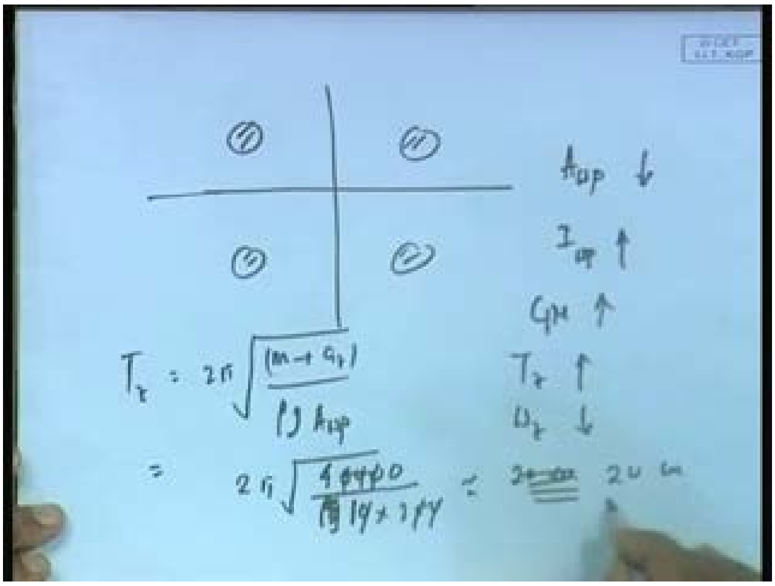

So therefore, take a water plane like that sorry. So, I have low A w p and I have I w p height. So, G m is high, T z is also high, omega z is low. This is precisely what you have to do. Now, we will see even a numbers, how the numbers coming approximately? you know We will just talk about that numbers in a minute. So, this is what we have understood. Now, you see we will put this number like that T z, I have to go to this original formula because here mass plus a let me put it this way only, here rho g A w p. We will just put it here. Now, take a typical semi submersible. If you look around, you will find the mass may be around 20000, 25000 tons.

So, this may be around, but I will take it as one, So 40000; approximately I am telling. If you take you see if you take a pontoon, you can also can figure out typical pontoon you can take any book around 100 meter long may be 10 meter, 10 meter like that. So or 15 meter into 6 meter. So, about 10000 meter square volume of one pontoon, with 2 pontoon 20000 this do not contribute much; say say 20000, let me take as an sample value. You all agree with it 20, around 20000.

So, if I take 20000 (( )) 40000 we have running out of time. So, this is 2 pi into say 40000 rho g; let us put this A w p, rho g say rho g is 10. Now, for just quickly we have to do that A w p is this areas. Now, let us take very quick estimate. So, this diameters are 10 meter. So, what is the area quickly? So, basically pi into 10 square because all the four of them here, pi 10 square means 100 300, so 300 right. Work it out this, this, this, this, this, this 2 pi square root of; actually, this did not come out, this will be a smaller than that.

What I means is that, if you did work out, you will end up seeing that this will be around 20 second and more or rather, well this may be this number may be.

It is a pi d square by 4.

Yeah. So, yeah 4 by 3; no, pi d square by 4 into 4; there are 4 there no; 4 of them there. So, pi d square rho g, this is 40000, sorry sorry I made a mistake here. So, 40000 means 1, 2, 3, 4 40 by 3; 40 by 3 is about 10. If you work it out anyhow, about 40 by 3 is how much about 13 square root is approximately 3 3 or 4, say 4. So, 2 pi into say 2 pi into 3, 6 into 3, 18 see around 20 second. You immediately see that our aim has been to make it 20 second and more, you cannot that is the reason how the shape of this structure evolve as that.

We will discuss that tomorrow’s class little more on the practical side, why spar buoy evolve the way it is? Why other offshore structure evolves the way it is? Why the swath hull evolves the way it is? All of them are connected to making natural heave period, actually pushing it up more than 20 second. So, you want to make lower water plane area, not sacrificing on stability. This is the full principle and if you want to do offshore design, your starting point has to be from natural period. So, with that I will stop and we will continue little bit on this and then, go over to pitch and other motions. Thank you.