Seakeeping and Manoeuvring

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Lecture No. # 15

Ship Motion in Irregular Waves – II

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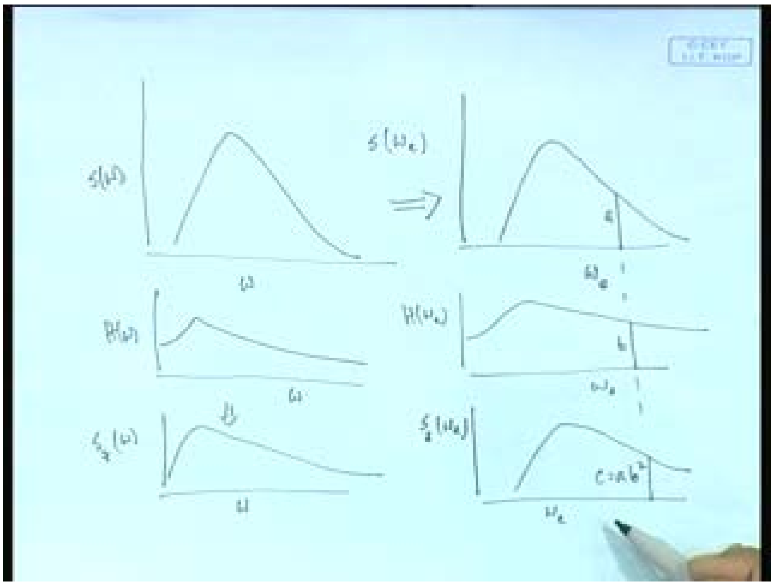

We will continue our talk on ship motions in irregular waves. See, we just spoke about this transformation, that is how do I get encounters spectrum. Now the procedure is straight for us, excuse me simple because what we have to do. See, earlier we had on that for a zero speed H omega against omega and I obtain this response. Say, I call it… but now I have to do the same thing here. I obviously, have to write this H omega e, which also look something like that. And I multiply the corresponding a with corresponding b square, I end up getting procedure is very straight forward. See, earlier I went this way for zero speed case, when there was no speed because this remains same as I viewed and obviously, response also is a function of omega because you would have calculate the responses assuming that there is no motion.

Here, earlier I went in this way now I have to go just this way. So, the procedure remains as simple, just I have added one line here to here and this I have seen that there is a formula. That formula is very simple, that you know omega into omega e, if I have to draw one table then there is a first line omega, next line omega e, third line S omega, fourth line S omega e. So, it is very very straight forward, you do that and end up getting this. So, So, therefore, we what we find out that this procedure is very simple, this is what we call response spectrum. Then what? So, I will now (( )), now I know the procedure, how to get from here to there.

Now we will talk about this little bit. See, if you tale an ship yard or some yard (( )) the response the ship you show me a plot, with some kinds of numbers here. Now, what is going to be impressed, nobody likes it, they want a number. They will tell you, tell me how much it is rolling or heaving. So, you have to crystallize that or quantify that in some number. Now, remember that is why I will discuss this and how do we really represent that.

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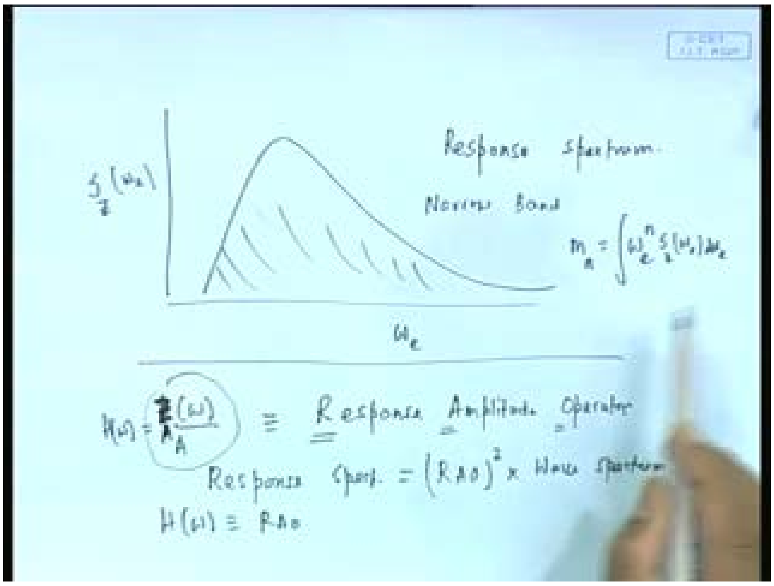

So, let us look back at the response spectrum. So, I again I am calling it heave, but it can be any response which will come to in a minute. Let us take this forward speed case only. So, this is my response spectrum we call, but before that let me tell one small thing that I keep missing. See, I call this H omega and what did I say? I say that S, well let me look at this one z omega e H omega e square into S omega e. This is what we have been saying. See this term H omega e square, this H omega e square, look at that. In our subject this is called as R A O, Response Amplitude Operator. So, you see, I just write down this. So that, see, the procedure is like that, the response spectrum is R A O square into wave spectrum. Actually, here I want to tell you one thing you know, before coming to this part, lets lets keep it aside. Some people call this square that is this square is itself R A O. So, there is some kind of an ambiguity in some some time. See, technically I would prefer personally transfer function to be a better word because in other literature other subjects they used the word transfer function, but historically in marine literature it has come to known as R A O. So, we need to know this, everybody will say R A O. Yeah yeah this this this part.

Now, here actually some people, some books refers square of that is R A O. That means, square of this as R A O. So, that response spectrum becomes R A O into wave spectrum. Whereas, some other book will call this as R A O itself. So, that response spectrum is R A O square into wave spectrum. So, you know that definition of R A O, there is some ambiguity means, what I call R A O by person x another person may call square of that as R A O.

We are going to call here this as R A O, not the square because this well this is a better in my personal opinion because it is a transfer function output by input, no square, no cube no operation involve. And why the ward also meaningful know R A O because you are operating this on the wave spectrum to get response spectrum. This is from there here the ward has come. See, you operate on the wave spectrum, this operator square of this operator to get response spectrum. So, we call R A O. What is R A O therefore? Well, R A O is nothing but, this graph. Go back, what is R A O? It is nothing but, response in regular waves, R A O is just a time. So, when I say find R A O which means I am telling you find out how the body behaves in regular waves.

This graph or this graph, R A O or transfer function is a representation of regular wave response response in regular waves or supposing I did found out a ships rest behavior, how much it behaves in say 50 meter long wave, 100 meter long wave, 200 meter long wave, over a range of lengths. I will plot them against some parameter here which can be length or omega and this side output per unit amplitude, that is R A O. So, R A O is always that I mean we are calling it, now having said that I should have because see, as you know in every subject there are certain typical term. I mean I have said that that we use the word resistance. Whereas, most of the people use drag in mechanical engineering or in air space aircraft, you will not hear the word aircraft resistance or you will hear missile resistance or you will hear missile drag, but we call ship resistance. So, there is a question of you know like nomenclature. So, similarly, we use R A O. You go to electrical engineering everybody used to answer function. Any experiment you do you have output by input voltage. You call transfer function or you call calibration constant whatever, but we call it here R A O. So, let us keep in mind that.

Now you see, now this, now if I integrate. So, what is happen its turns out, if I have to assume that to be again a narrow band and this is what people say that the R A O, we multi, see this is narrow band spectrum you say, we multiply with that. So, what would happen multiplying with that, getting that it, the presumption is that it does not change too much the ship as far as the statistical quantities go. So, let us presume that this also is fairly good represented by narrow band random spectrum. Although, you have seen that if I see this following way things look very different, but that we will come to that again. So, if I have this then what happen? I let me look at this area under that. So, or let me call this m n as n, what? Yeah absolutely yeah, h yeah he is very very true, I am sorry. This z a omega (( )) right right right. Actually, H omega is R A O for us, that is right, absolutely true. Thank you. This is not H (( )), yeah what I mean that output by input that part which of course is you know, which I called H omega is basically R A O for in our case.

So, now see, with that clarification let look back at that, let us take an nth moment of this graph, this will look like that m n is omega e power of n S z S z omega e d omega e. Now it is turns out, since it is a narrow band spectrum, all properties of statistical importance again is connected to this various m's, m zero, well m zero is going to be area. And in fact, most people are here interested in absolute value amplitude not in the time period. How much it is rolling etcetera etcetera.

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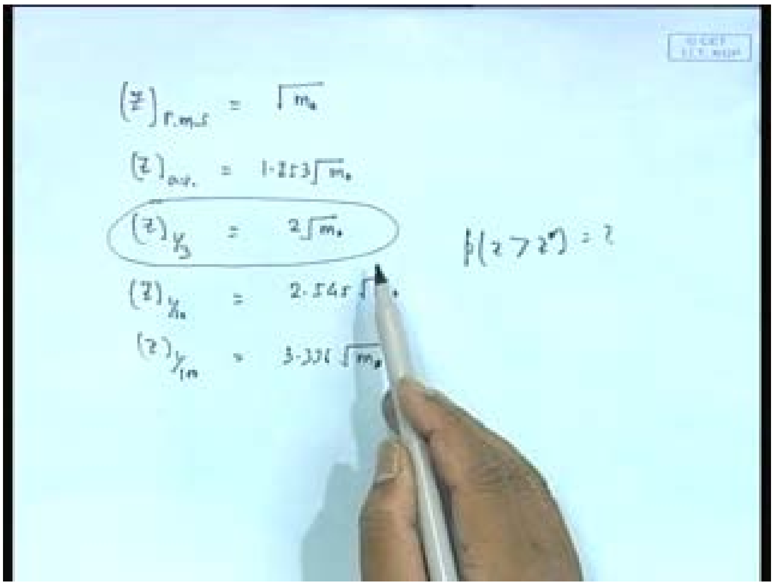

So, what is happening, now formula theories will tell me that average value say Z, in this case response is z, z r m s these are formulas available, like that. See, what I am saying therefore, telling it that, what happen is? You can find out formula for all quantities of interest in terms of area. Remember, that h one third was 4 root m zero. Of course, it was four because it was height, amplitude would have been (( )) same formula, all the ratios was same as in wave. Not only that not only that because it is narrow band spectrum, you can also find out what is the probability of z exceeding for example, z star. What is the probability of z remaining in this bound? What is the highest wave z you would encounter in 100 cycles or 1000 cycles? What is the chance of h becoming more than 0.1 percent? I mean any quantity of interest is available because same formulas will apply. Obviously, people do not go for all of them, mostly what happen we will tell this supposing it was roll motion.

Now look at this area also, we will we will come to that, but normally when you want to quantify, you quantify that or some in some case or some responses you will quantify in term of occurrence. See foe example, there are response like slamming, we will come to that afterwards. One would like to know, in one hour how many times certain value will exceed from value. For example, let say sea sickness it turns out that if your acceleration is some value with a certain period, you tend to vomit then will define some parameter and then we say what is the chance of this parameters occurring. You can find out from the spectrum. So, all this becomes possible.

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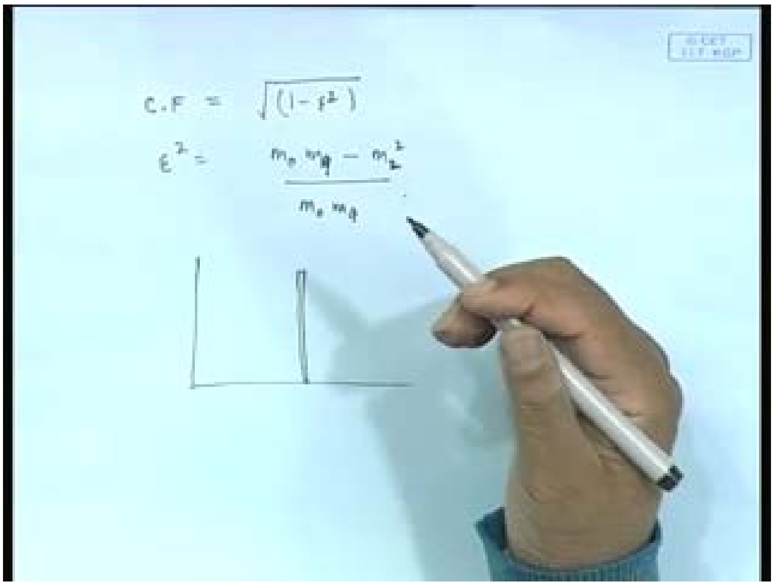

So, it becomes really useful only one thing that I need to say because sometimes this spectrum do not look like a narrow band (( )). So, there is a sometimes a correction factor is introduced, like you multiply all this, all of this, you can multiply with the correction factor, you know you can multiply all of the way with a correction factor. And this correction factor it just introduced sometime, in order to like account for the fact that the response spectrum sometimes is not so closely as narrow band (( )) spectrum. So, this is given something like you know like one minus epsilon theoretically only given where epsilon square, you will find out you know, that frankly you will find out that if the spectrum was absolutely narrow like that then this term turn out to be basically zero and correction value is 1. Because m 0, m 4 and m 2 square become same. You you will find out I am leaving it to you, it will stick like that, m 4 is going to be omega 4 into this this value m 0. So, you know this will become 0, no m 0 m 4 minus m 2 square by m 0.

What I am trying to say that, this is some kind of correction factor that introduced for the fact that the spectrum that you have may not be necessarily narrow band. And what I was trying to tell you is that, if you take a theoretically a completely narrowband spectrum, which means a stick, something like that, you will find out that this quantity becomes equal to 0 means C F is equal to 1. Which tells you that strictly absolutely narrowband spectrum there is no correction. The further it goes from that there is a correction. Sometime people use sometime people do not use, the value of them will lie between

0.9, 0.85 etcetera etcetera, typically for a spectrum. Sometime you may want to use it that is all. So, with that you can get this number.

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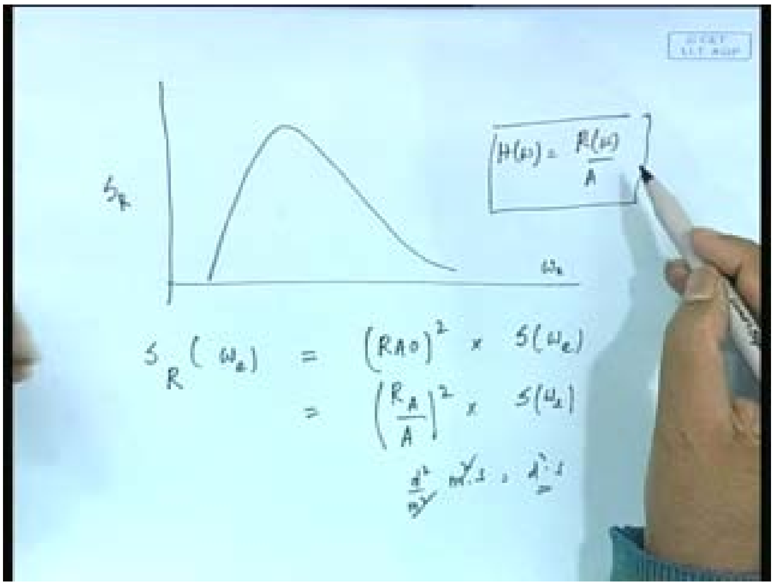

So, what is happening you are getting all this number that you want, in terms of area. See, now I want to look at some of this some of this you know units just. So, that we do not have any confusion on the units. See here, this side is what this side, let us look at this again. Now now let me call this, a response any response, let me now let me now generalize it instead of z let me call it R, R representing any response. So, that is going to be R A O for the response, of that response square into S omega e or I am going to call this as response amplitude by wave amplitude square into S omega e.

So, this we know this here R A is amplitude of the response and this omega e. I am just generalizing it. Now let us say, when this is heave, what is the unit? It is meter; meter by meter square gives a meter square. What is the unit of this? Meter square second. What is the unit of this? Meter square Second. What is the unit of the area? Meter square. So, square root that meter.

Take roll degree, what is the unit of this? Degree square by meter square. So, degree square by meter say here degree square by meter square into meter square second, gives you degree square into second multiplied by one by second give you degree square. So, you get degree. So, what is happening, you see, you will find out here, this meter square meter square second will leave unit of the response square into second and one by second give you square of the unit. Why I am saying this because people are confused, I could have this R A as pressure at a point. What is the unit of pressure? Kilonewton per meter square. You do that, you will find out the unit is going to be here kilonewton by meter square. You know square of that into meter square second, if you do that the whatever you need comes out.

So, there is no ambiguity with respect to units, there is. So, this procedure of breaking down applies to any response, which behaves linearly with waves. Important thing is that it must be H omega must be equal to R omega by A, this must be true which, what does it mean? It means that response is linear with respect to A because R A by omega is constant for a given omega. When I say R by A is constant for a given omega, I am saying basically that response that R is a linear function of A for that omega. So, whichever responses depend linearly on A, this procedure remains valid and there is no ambiguity on that. And this procedure, we will work out some of the problems at the later part of that or something like that.

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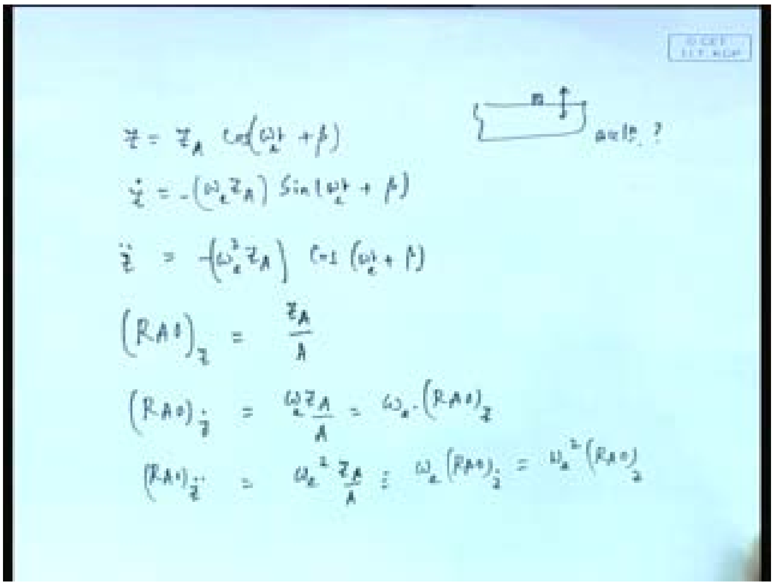

But Let me look at the interesting part of R A O of acceleration. Sometime you know, you want to find out acceleration here, you do not want to find out the motion, but acceleration, physically important because suppose there is a gun mound here, the load is going to be mass into acceleration. So, you are interested in acceleration. So, now, how do I found R A O for acceleration? My z, let say heave heave case, it was z A into how much is z dot velocity. Let us say a minus sign will come, this is okay? How much is z dot dot. So, what is now R A O, I am writing this is as R A O for z, is amplitude by A. What is my R A O for z dot? How much is amplitude of that? Is omega z A. So, it is omega z A by A, well of course we should probably put omega e here. Agree?

What is R A O for z double dot it is going to be omega e square and of course actually let me write two steps, it is omega e R A O. So, you see that the R A O for velocity is omega times R A O of displacement. R A O of acceleration is omega times R A O of velocity is equal to omega square R A O displacement.

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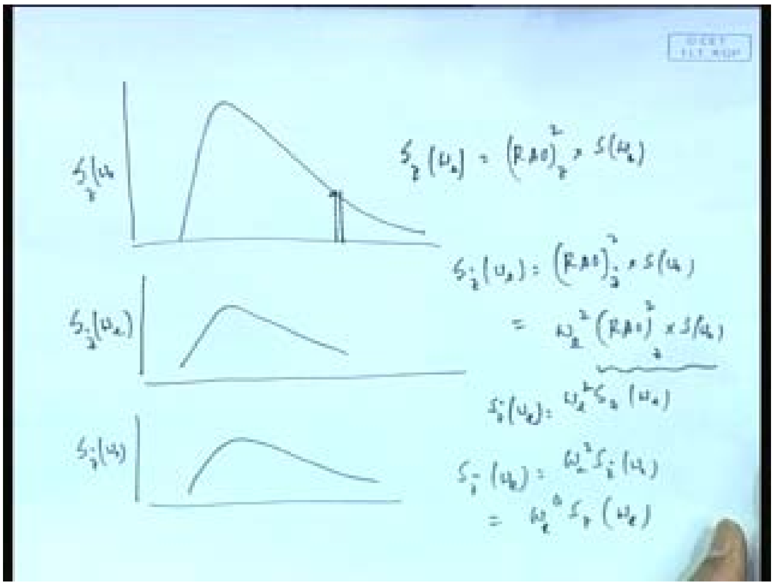

Now, see how do I can get from one to other spectrum. So, I have this spectrum here S z omega e. Now I want to find out velocity spectrum, how much I am going to have that. See remember, this value is what this value S z omega e is essentially R A O of z square into S omega e. Now this value S z dot omega e is suppose to be R A O z dot square into S omega e that is equal to omega e square R A O z square into S omega e. This is equal to S z omega e.

So, in other words all I have to do is to multiply this omega e square to get the value. See this is interesting, therefore, velocity spectrum is obtained from this simply by taking each ordinate into omega e square corresponding value. Now if you see this acceleration spectrum similarly, exactly, is going to be [velo]city this into velocity spectrum equal to this into acceleration spectrum. Now, you see you end up getting this right? Now look at the area if you look at the area under that remember that omega e square z A omega e area under this is actually m 2 for the velocity spectrum displacement spectrum. So, m 2 of displacement spectrum is same as m 0 of velocity spectrum. We will come to that.

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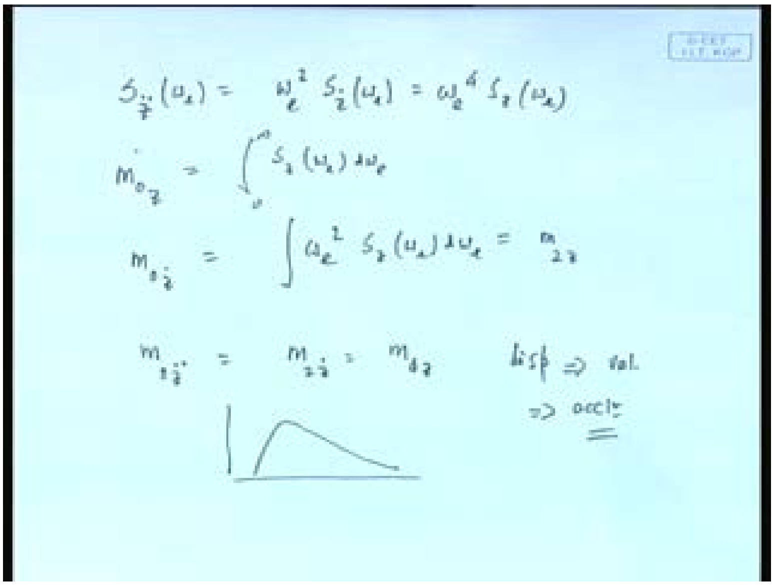

Now, now we we we we we we understood this right? This part. That is let me here put it down in a this way S z dot dot omega e. This equal to omega e square S z dot omega e equal to omega e 4 and similarly, well let me write that, now m 0, let me call it z, that is m 0 z means area under the velocity spectrum, with this we know of course, this is equal to integration of S z omega e.

Now, m zero z dot area under the velocity spectrum, no this is z dot that is why is equal to absolutely its m 2 of z. Now that he wanted to know this thing. So, this is omega e square z A, this is usually because this this this area of this, what it this? This is nothing but, m 2 of z similarly; you will find that m 0 of z double dot is equal to m 2 of z dot equal to m 4 of z. So, what it therefore, means is that see this other two spectrum are once I know displacement I can get velocity, I can get acceleration. In fact, sometime I do not have to plot it because you know for correction factor in the same table, I am calculating the second moment and the fourth moment. If I want to do that those columns will give me my velocity in acceleration.

We will probably work a problem out, you know something like or show you little more detail. So, the question is that displacement to velocity to acceleration absolutely no problem, just multiply its constant. So, the procedure is you know this entire spectral procedure is very simple, this is the reason why you should not make mistakes and it is important. See, I like to tell this that one should not confuse in any subject importance with easiness. I mean hydrostatic is extremely important, if you have you cannot make a ship float, never mind whether what is its resistance because it is sank anyhow.

But then subject wise g m and all very simple, but very important you just not leave without it. So, this is also in a similar way, very simple procedurally, absolutely algebra. We will see, in fact, a people call this post processing in any software it is 99 percent finding out R A O. Having found R A O, you have to just add a few line of code to get this and people do not even call the procedure they may call it post processing sometime of data. You know, it because there is really speaking, there is no no hydrodynamics involved, it is an algebra. Take this column multiply etcetera etcetera.

So, but if you did not do that and at the end tell the person that my, you know that one third or significant role is so and so, then he is not convinced about the motion. So, this is why like yesterday I was telling was long term statistics, same statistics will come from here. See, each one I know the percentage occurrence, then from there I have the spectrum, from the spectrum I know the percentage occurrence.

So, for example, I have spectrum number one occurring 20 percent time. I find that in that my thetas chance was exceeding 5 degree is x percent. So, 0.2 into x percent, point you know whatever into like that I get the final probability. That is exactly how I am doing it or we are doing it. So, this part is all very well you know like taken care of.

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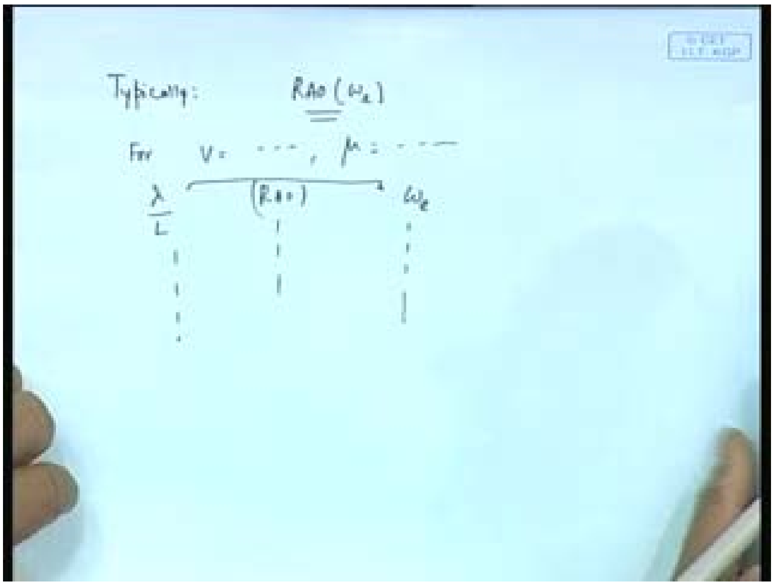

Let us look at some of this way that we can we can do for example, problem or you know like work out. Let us let us look at this this field. See, instead of problem, supposing what will happen typically typically, you will have regular wave response; that means, you will know R A O omega e. Now this R A O omega e can be given in any forms, many times you can be given in terms of not omega e, but in terms of another parameter for example, somebody may say this that for V equal to so and so, mu equal to so and so, lambda by L verses R A O.

In fact, many many people like to write in this form. What you have to first do therefore, is that transform that to omega e, remember, omega e; you can of course do that because see lambda, you can get lambda to omega and then omega for this V and mu omega e. So, you have to first transform this two this thing to omega e and you will end up getting omega e verses R A O. Now, remember one thing that this omega in R A O is going to be not for all the same points.

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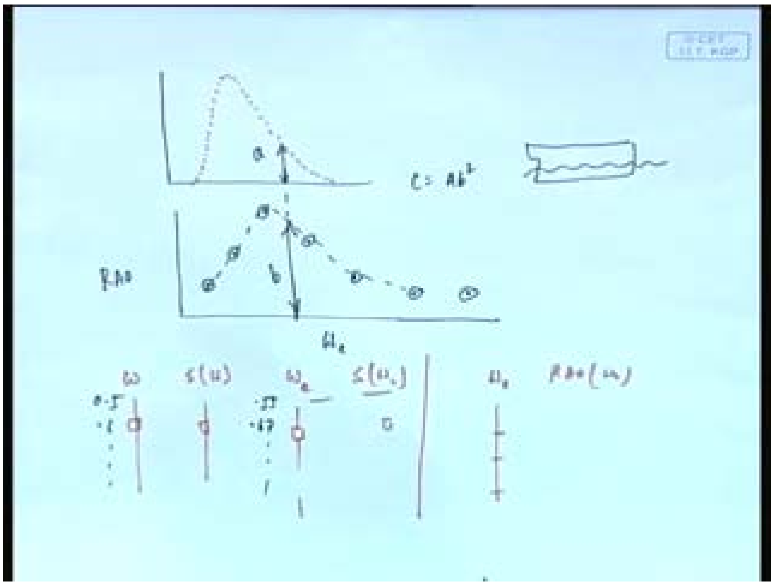

For example, what would happen, let me also draw this spectrum and this thing. So, the let me first draw the R A O then, you are going to get R A O. A point here, point here, point here, point here, point here, point here. Because you are going to do remember only a discrete points, you are going to calculate that at some discrete values, you know not all; obviously, you know how many you might be normally what happen? You would like to calculate this part as I said this is the most combustion part, over a range where the ship response fairly well. You know if you take a ship, if you take waves which are very small, you ever go to port and all you will see, small ripples the ship does move in up and down at all. So, if the wave length is much smaller than the ship length may be one fourth or so, no response at all typically. If you go to a very long wave, you will find out that it actually moves up and down with this, like you know simply goes up and down with the long wave. We have actually done that goes to one that heave motion.

What? Where it response most? That is we we discuss this part know, this part the inertial response and the static response is where lengths are comparable wave lengths are comparable to ship length. This you you will always see that in your strength calculation, you choose, how much do you choose for wavelength as a trochoidal wavelength, you have done some calculation right? See, you have done wave bending on calculation, you assuming wave profile to be static.

No, L by 20 is the height. What was the length you have taken? Why? Why not more length? Why not less length? So, therefore, the maximum dynamics are involved around. Actually, is not strictly true though that truth is that maximum length occurs nowadays found little more than 1, that is about 1.05, 1.06 type, but never mind around 1. So, you see, L by lambda lambda by L 1, which means may be 0.25 to say 4, this range is what is most important. So, you calculate at some discrete values R A O because each one of the you are spending very long time. I will tell you that, you know like commercial codes for zero speed like (( )) that we have, R A O calculation, you know, we take twenty, twenty five lacks rupees for getting a second order. So, you can always think back that the cost is proportional to the investment that went in writing a code.

Hydrostatic code you can buy for, I will give it for two hundred rupees and something like that. My point is that it is always proportional. So, that tells you the effort that goes in. So, obviously, you have you have only few points. Now the the question why I am saying is that this spectrum is of course you have a choice. So, what we do you have that assignment when you do you will see, you will be having number of points a given spectrum. You have you have made this chart number of points against well, you would have actually first order no choice, you would have had omega verses this omega then depending on V this thing you end up getting a particular number.

So, what I am saying therefore, I have got in one hand table one omega verses S omega. This you have done, what you calculate from there omega e verses S omega e. So, you see this value has become this value, this value has become this value etcetera. You have no choice on that, this is my graph 1, graph 2 I have got again, this I see it you made it omega e, omega e verses R A O. Remember that, these values the one that you chose, this values are not corresponding to this values.

So, you have to make sure that you do proper interpolation. Because what you have to do, you have to choose the, see, if here I draw this graph, I have to choose this, I have to choose this value as b, this value was a, to get c equal to a b square. So, I require an interpolation in some sense, I cannot take simply because you see this a equal to b square is for that given omega e.

So, what happen I can choose some discrete values here and at that for those omega is I find out what is my this and at that what is my this. So, this operation must be at the same omega e and typically in any problem any calculation you do, you are not going to have this, see for example, this is going to be, let me just give an example, something like 0.5, 0.6 like that it goes. So, this will probably become because I have no control on this transformation. It might have become 0.55, 0.67 like that. Whereas, this I would have given at something like 0.4, 0.6, 0.8 like that. So, you see they do not correspond. So, you will have to use interpolation, proper interpolation that is 0.1. You will be doing it as part of assignment, I will given to you, but you need to do that. That is point number one.

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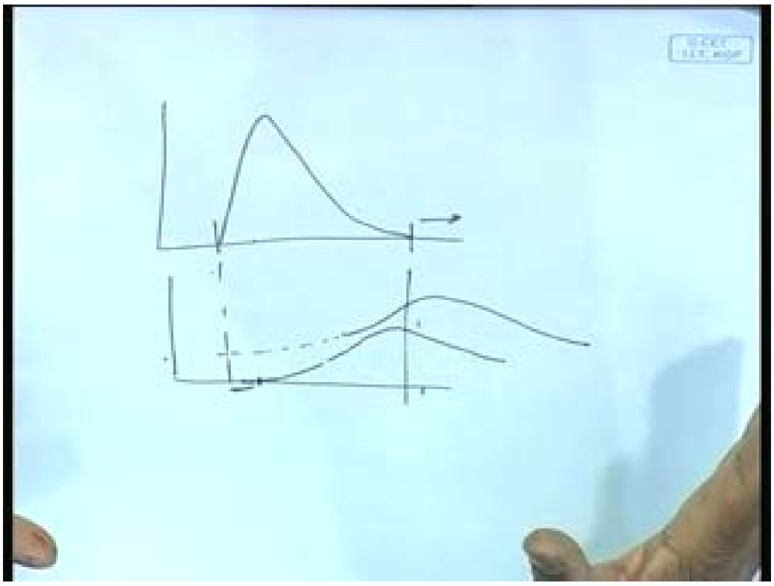

Other thing, this this interesting part also you must see. Suppose, I have a spectrum, the spectrum is after transformation, let say zero speed case only here. Now I have all the R A O points calculated, what is the point, you have to make sure that my R A O that I calculate covers the existing waves. You see my sea consist of certain wave lengths, when I break it down. So, I must find out at least within the wave length, those wavelengths R A O. Beyond that, see there is no waves here, what is the point of my having the ship responding very badly here. It does not because what would happen because here my a is 0, b is there, c is going to be 0. This side the same thing happened b is 0, similar thing will happen when the response is small. For example, in another case for example, then is a response going like that and the response is like that, then this side of response 0, I have no point. So, in other words what is happening? Obviously, typically of course, remember I have no control on this and when you do yesterday's assignment of spectrum of various H one third and T you will be knowing, what is the typical range of this. You will get a feel, you understand that they are lying between something like 50 meter to say, you know like 500, 600 meter with the pick around 200 meter long equivalent wave.

Now, the main point is I should find out the responses at those range, at least. There is no point of finding out response for waves that do not exist. There is no point they are not matching because you it you might say it my response is very badly in a small boat, response very badly in a ten meter long wave, but then there are no typical long wave and the reverse is also true. So, there is a matching part that is important, when you do the calculation you must make this sure, but this brings us a very interesting point about response of ship and now I will take tell this few minutes briefly on that part.

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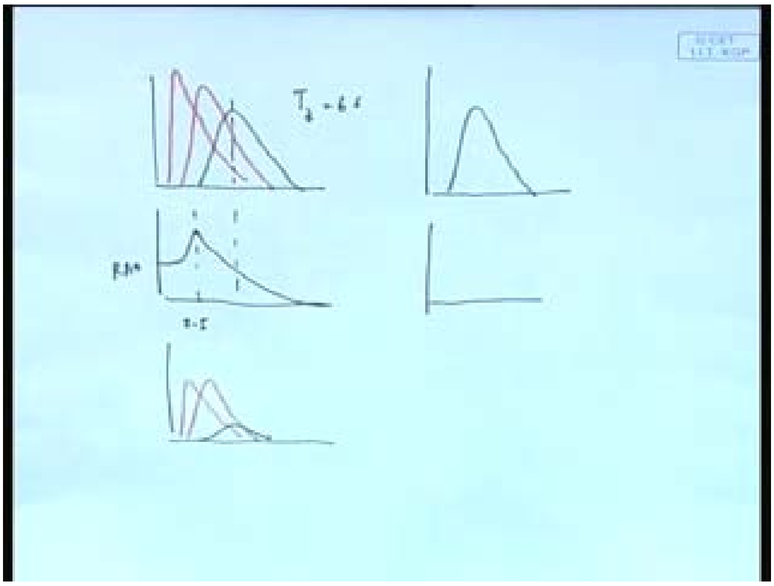

Why it is that not all ships are bad or good necessarily and why is it that? There is a question of tuning there. You see typically let us took this example, this example is interesting example, take a spectrum it is like that, this is at 6 second, pick period is 6 second. Let us say, this is at smaller wave say T z at six second and certain H one third is there, my R A O does not change, remember R A O is something like this diagram. It is peaking here, this this my pick response, which is probably equivalent to as per as this is concern here as 0.5 means 2 pie by 0.5 means about 12 second. Around that, let us say see remember, remember this, omega e, this is actually, let us say for an optional structure zero speed case, let us not complicate things. I just wanted to show you that tuning part, that why is it that, it is not necessarily true that all bodies behaves badly as the wave becomes bad. You know, what is the correlation? The the main point is that, the frequencies at which, your ship behaves worst should be the kind of waves existing most in the wave, then only it will be very bad. Now in this particular case this is my R A O, which does not change of course. Because R A O, this particular boat it has a peak, it has a resonance at 0.5 omega, which means 2 pi by 0.5 gives you about 12 second or so.

At T z 6 second is this peak period for a spectrum. So, if I multiply this two, I end up getting a response spectrum, which is actually a small area. Because where the maximum wave is occur, my response is small. Where the response is highest, my this is small, but now I make this bigger . So, I shift it up here. So, what would happen is that I am making this at 8 second; obviously, that or rather I can put it. In fact, I can put in this graph only. Now, more winds. So, this ship this side, now this and this are matching. So, I end up getting larger area. Now further, but here it is not that bad, may be may be larger, but not necessary that bad. So, what it means is that, it is not that necessarily true that as the wave height increases, you will end up getting much worse and worse kind of responses. Now I will also want to tell that this is why we talked about this natural pair so importantly. You see this natural period, this peak is a natural period, this is the peak at which my response is maximum.

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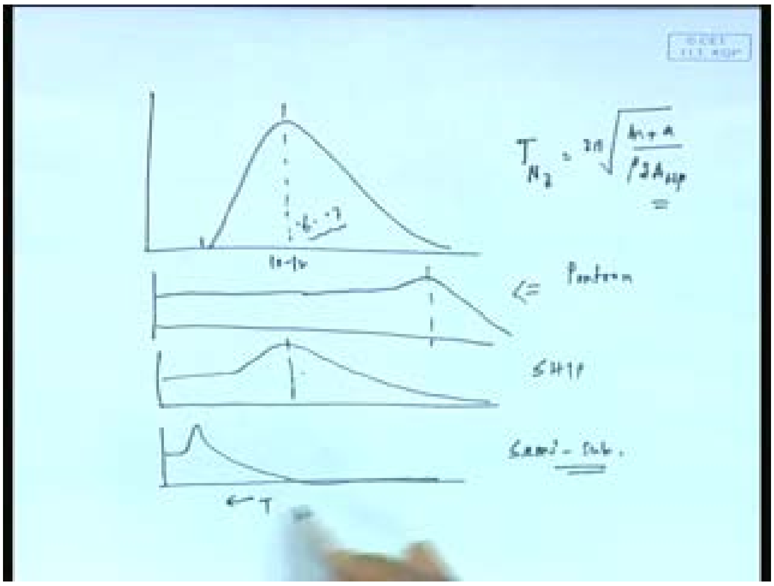

Now, if I have a wave at which my response is maximum then I am going to have a very bad motion. All right, how much it should be? Now you see, if you take a budge, very long budge, we discussed this at one time. Or rather let me put it in this way, pontoon (( )) spectrum, this is also interesting about the response part.

See, there is a typical spectrum and I will see and I will take that three different cases. Now if you take a particular pontoon type of thing, big thing. What would happen? It has got a very high natural period, sorry sorry, small natural period, high natural frequency. Because you see, T natural in heave is what is the formula 2 pi root over of, no, omega was m plus a divided by rho g a w p. Now if a w was very high like a pontoon, my T z is very low it can be 4, 5 seconds. So, I took a typical wave, which looks like that. Typical wave everyday wave of say sea state four etcetera will have about 10 second period, means omega equal to 2 pi by 10, would give you about may be 2 pi by 10, gives you how much? 0.6, 0.7 like that. In that region say 0.6, 0.7 type of somewhere here or or it is basically equal to say 10 second or say 10 to 12 second, but my remember this is low wave. So, this will look something like that, go like that because this natural period is much higher.

Now, this is typical pontoon, take a typical ship. What is the typical ship? Typical ship has, we have seen it unfortunately has some where here. A typical ship has its natural period about we have seen that know 8, 10, 12 second, we have done it earlier. As I was telling you that we have the unfortunate consequence that they are around, not unfortunate, but it so happens that is around that range. If you take any typical values 10, 11, 12 seconds. So, it is somewhere here, take an offshore structure, you design an offshore structure to make sure that hits peak is here. So, it is something like that. Now multiply this with this. What will you get? Fairly large response, but not that bad, but still quite large response more all less same as this. You will get response one type in this particular wave, this you are going to get much worse. Because here this higher and this height more or less close by, this you are going to get practically no response, this is the reason why we design this. Why you design this? Because you cannot, you see here, there is there is a reason, there is a ship, this is semi-submersible.

Obviously, from I have mentioned this also earlier, from a operation point of view a semi-submersible, which is producing oil is not able to change location. That is point 1. Point 2 is that its operation demands that it has low motion, otherwise if it is heaving then you cannot operate. Where is the ship it may not be so, as such. So, therefore, you have to ensure by design that it has very low response and that is exactly why you have of course lower this a w p to make sure T n z is actually about 20, 25 seconds and if you did yesterdays, you know calculation you will find out that around that all even at a very high cease state, there is practically no energy. Even if you do high, this side is actually you know like lower than 20 second of as so. So, if I have a structure 22 second, 25 second natural period, this peak I am going to have very low response. This is idea, full idea is that. Now so so, what we find that, we have tuning, I can I call it tuning a ship would response badly if its R A O, this part gets tuned with the wave. Much lower a w p. Absolutely, this is omega. That is the period, no, this is omega. That is what I am saying, time period is 20 second and above. So, what I was saying is that, if you did those actual values of spectrum formula with H one third even up to 8 meter, you will find out that there is a spectrum, you will end up getting a ship like that it is shifting. Even though its shifts, you will find out that the event for the highest wave, there is practically no waves beyond above twenty second.

In fact, only if you do this program and write equivalent T, you will get a physical feel about what are the kind of waves you find in the ocean. We call this offshore, people call this every day wave. You know somebody can say, well is there no tsunami or long wave? They are very rare, the wind generate wave given by the spectrum is like that.

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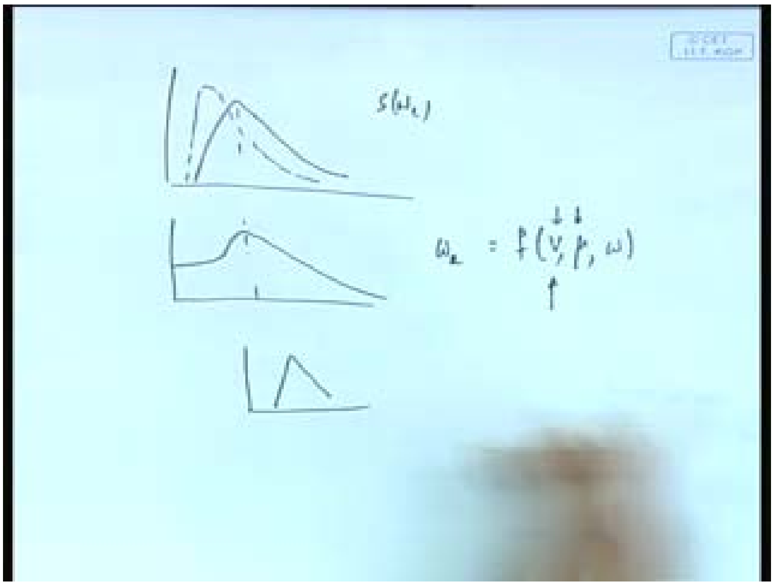

Now coming to the ship part, why we can? So, what happen, since I have no getting a wave of the semi-submersible I have to design by that, but ship is like that, but how we can manage, the interesting part is this. See, remember this is my spectrum, now this is my encounter spectrum, this is my very badly it is moving. What I do? I will shift this. How do I shift it? Well, I slow down. We have a slow down, this is going to become encounter, further shift this side. Remember, so, I can teach detune it, see I am encountering a wave, say I am at a certain sped V equal to 15 knots heading into waves, very high motion. I would think that well my natural period is encountering those waves with the same period. Well, I want to detune myself, I do not want, I want to make sure this and this do not match. Few minutes. So, I want to detune myself, how do I do it? Well I have an option, I can essentially change speed, I can actually change omega e.

Now, omega is a function of V and mu of course of omega, we have no choice on that these two. So, I can change this two. So, typically what I do is basically see I cannot increase V because typically I am running at the full V. So, I can decrease V. I can also change mu marginally, I do not change mu typically very hard because I keep telling if I want to go a to b, I want to end up going to c by changing my heading.

So, what I do of course I make slight change, but primarily I reduce V. This is what is known as voluntary speed reduction, when I enter a very bad waves such. So, this choice I have go the captain has got this choice. So, I can get away with it, as it is I am a mobile. So, if I encounters storm, there is a forecast, there is a storm coming I can get away from that. I (( )) from that path, but offshore structure I cannot do that is the reason why I have this, but what is important. Therefore, you find out that, see encounter spectrum can be shifted?

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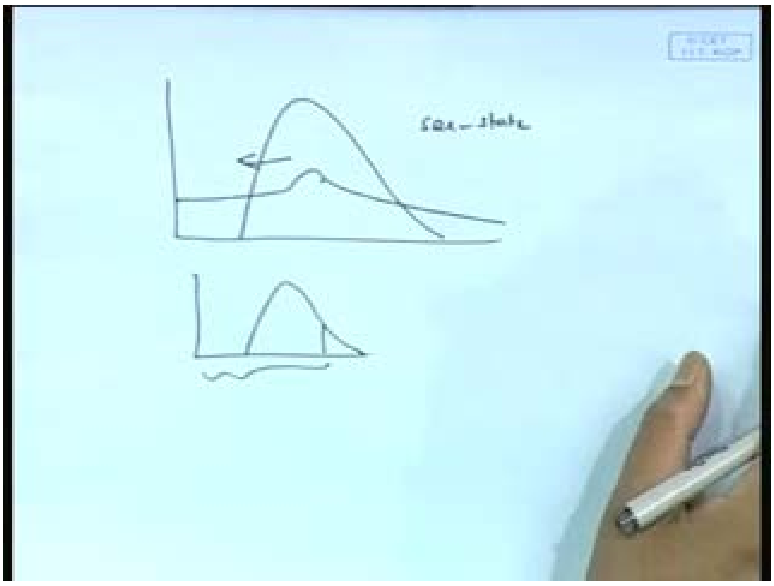

That it is a last slide, I will want to show this, say two things take a spectrum. Now this spectrum, just absolute spectrum. It shifts with respect to sea state. Normally, a low sea straight spectrum would be on the right hand side with the lower energy and the peak height to be at lower, you know like wavelength. Let us say see state 3 would have maximum energy at 100 meter long waves, sea state 6 would have maximum energy for 200 meter long waves. So, there is a factor with this thing.

Now, if I have a particular budge like that this does not change, but sea state shift at this side. So, you see, in fact, this explains why typically small boats respond very badly in low sea state, because low sea state this is at this side and the peaks are may be of 6 7 seconds and small boats because a w b small etcetera, also have a smaller typically natural period. So, it is of this side, but if you shift this side, what would happen small boats would simply ride the wave.

See, suppose you take a small craft of thirty meter long ship and it is going in a sea state 6, where large waves are 200 meter and above 200 is about 6 times more then it will simply ride the wave. But if there is a smaller wave 50 meter long wave maximum sea state 2, something like that, it will behave very badly, but take a large ship big tanker 300 meter long tanker, it is not going to even feel this fifty meter long ships, but it will become much worse if I have sea state 4. Because at that I have mostly 300 meter long wave, where it is behaving badly.

So, there is issue of tuning you know, that is important. This also tells us why small boats are always bad typically, of course you can always see from acceleration. Which is omega square into H there is a square term involve and; obviously, you see what happen if this is here, this displacement spectrum and (( )) is shifted further, amplitude acceleration spectrum is omega each one you are multiplying omega square. So, this is further of it becomes more area.

So, obviously, if I have got larger omega e then I have more acceleration, make sense know its 4 second to have 1 oscillation. So, I have the entire thing coming in 4 second another ship same distance I am travelling in 15 second. So, my acceleration is smaller. So, that is why small boats are always uncomfortable you see.

And next class we will discuss about human comfort level and all you know, if you are subjecting your body at a very high acceleration you are uncomfortable, but some level you are comfortable and above. Anyhow, I am going to stop at this and we will continue this discussion little more and perhaps the problem I was telling we will do next class, but what we understand is the procedure to calculate response in irregular sea is absolutely simple straight forward algebra nothing to it multiply. So, you have for you would have make sure that, you have taking probe. What is important of course is you are studying for that responses eventually, is it good? Is it bad? Is your ship going to behave properly? Etcetera. And this days it is becoming more and more important and then going back you find out the most difficult part in this, still remains getting this R A O.

This is where efforts go, those who are not in this subject practitioners look only the last 1 percent. Those of us who are inside, we are talk about the R A O mostly. So, with that I am going to close today's lecture. We will get back on this again next class. Thank you.