Seakeeping and Manoeuvring

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Lecture No. # 21

Derived Responses and Dynamic Effects – III

See today, we are going to continue the discussion on added resistance in waves.

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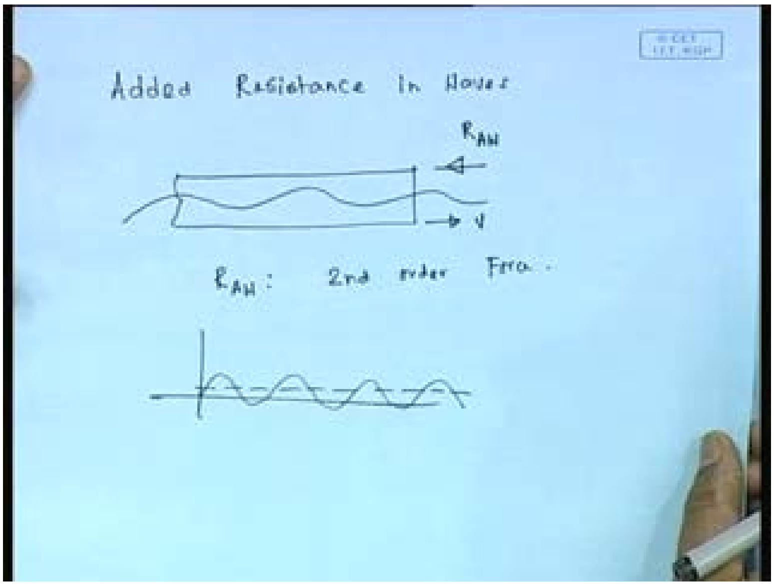

What I mentioned the end of last class is that, when you have a ship travelling in waves, there is a additional resistance you can call it... That comes when the ship is moving forward. See, I was mentioning that this added resistance hydro dynamically arises mainly, because of the fact that the ship under goes heave and pitch motions, and it creates wave, but that not the only thing; I was also mentioning that this is actually hydro dynamically a second order force.

In fact, if you were to think and imagine the force time history is additional force time history, you would expect it to be an oscillatory. The only thing that happens is that is oscillation, if you average over time would have a mean value, this mean value is what is our mean added resistance (Refer Slide Time: 01:30).

What I meant is just imagine the ship is undergoing oscillation, obviously we mention this that in a oscillatory body, when the input itself the incident wave itself is oscillatory; every response is oscillatory, even the force that you measure would be oscillatory. The only thing that happens is that, if I were to take a time average over a long time, this oscillation is not having a zero mean, but has a steady mean and this is what we are call mean drift force, mean second order force, which is same as mean added resistance for a forward ship.

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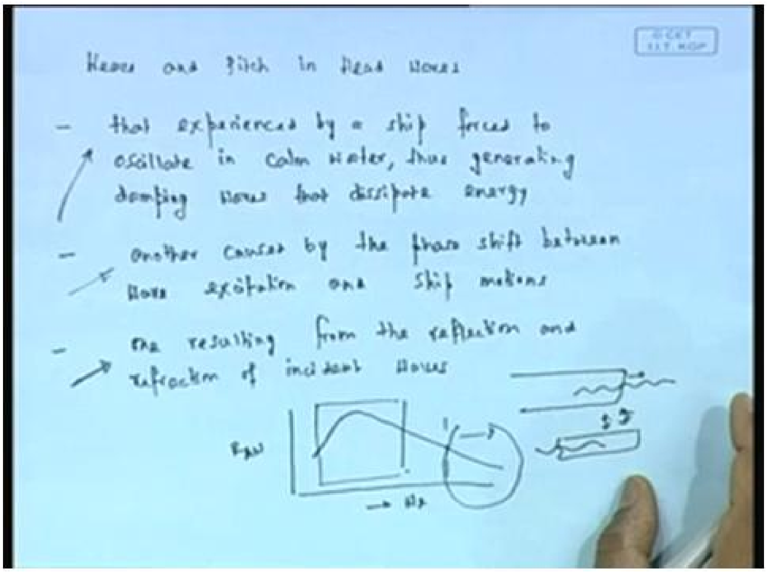

Now, having said that, I will just dwell little bit on the reasons behind that it turns out that, if the ship is subjected to large heave and pitch (No audio from 02:57 to 03:05). In mostly head waves you would expect, the added resistance effects can be broken down two, three different effects. One of them would be, let me write it then we can discuss it more, experience by the ship force to oscillate in calm water (No audio from 03:36 to 03:52). Thus see, it is important the reason I am writing is because remember, what is our objective? Our objective would be to determine, estimate, says whatever find out this quantity.

So, I would require to come up with some formula, just like in resistance to do that I need to know, what the components that might consist are, that might compose of this force; and then I can have an estimate for the various components and add it up whatever (No audio from 04:24 to 04:41). This is of course, what we have told earlier I will come back to this let me first complete writing (No audio from 04:50 to 05:03), phase shift between (No audio from 05:05 to 05:36) reflection and (No audio from 05:40 to 05:53) let me now I mean that finished writing.

Now, see first one suppose suppose I were to plot in some means, by some means added resistance against frequency obviously, frequency is wave parameter is it not, like RAO it will basically may look something like, (()) will have some variation now what happens see now, we will just look at that. If you are looking at very low frequency, let us look at the other way round high frequency, somewhere this side what does high frequency mean? High frequency means waves are short.

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So, suppose I take a very large tanker, waves that have they are very short you know, the not this short but, some short what would happen? You will expect in this that the ship does not even have an motion, very less motion; rather this walls of this hull will reflect act as if they are just like a wall, and the incident wave comes and hits and gets reflected back. See, it is if you take a very large ship in a very short waves, small waves the entire hull would not even undergo motion, but the waves would come and mostly you know that in water line part, the hull is vertical it will act as a wall and get reflect it.

But, it will also create a mean steady force, then what we are looking at is force in this region that is given by this effect, that is resulting from reflection refraction of incident waves (Refer Slide Time: 07:28). Now, mostly of course, is this range where the ship is undergoing motions heave and pitch, which of course gives rise to radiated waves; and remember damping, the word damping term actually represent the radiation wave energy.

So, essentially just like in our wave wave resistance, this energy of this waves that are getting dissipated has to be coming out as resistance which is what I mentioned yesterday, so this part is given by this (Refer Slide Time: 08:04). And there is of course, one more reason this is difficult to explain, but this also arises, so having said that see we will have to come with certain empirical formulas, this is a second order problem as I mention this force is a second order mean problem, it is not very easy to solve, but it is very important.

Because, everybody wants to know how much is the additional resistance that is coming, which would cause the ship to slow down you need to know that, you need to estimate that it is a primary quantity of interest for a ship design. Because, after all you have to know since, you are when you are going from a top be you are always going in certain sea state; and therefore, you are not making that 20 knots or whatever you design for calm water, how much you are going to lose or what is the extra energy you need power.

We will come to that, but there is another few points I want to say that certain observations on added resistance characteristic, before we go back to this formulas (No audio from 09:15 to 09:26) we normally consider head see, because it is the head see that you expect maximum heave and pitch, and maximum average. In fact, infact this is very interesting because, you see the vertical plane motion are maximum in head sea, and you know we mention earlier about spectrum, in head see the transformation of spectrum absolute to encounter there is no problem.

The problem that arise always all the singularity in following waves, but it turns out in reality at least this is one good thing of sea keeping that it the head sea, which is more important I do not have this problem of you know that following the singularity in S w and all that (()) you know, negative frequency 0 frequency and all this stuff. Anyhow the having said that this is of some of the observation, R A w it turns out is fairly independent of still water resistance (No audio from 10:28 to 10:36) (Refer Slide Time: 10:21) say this of course, good or bad news we do not know because, had it when a percentage it is different.

But, it is not a percentage which means in some cases it can slow down very much, because it does not really have, suppose there is a ship design for a low speed with a low still water resistance, R A w may be a very large percentage. It is proportional to A square this is of course, we know that it is proportional to A square regardless of ship motion, regardless of reflection is an energy (No audio from 11:22 to 11:44) (Refer Slide Time: 11:28), it turns out that pitch motion is very significant even more than heave motion, as far as (No audio from 11:51 to 12:28) actually this reflection that I said is relatively small, that is this high frequency part.

In fact, that is what happens in fact, this high frequency part this graph typically comes down, so you know like the values larger value of added resistance occur, because of the motion. Now, this is another important the maximum (No audio from 13:04 to 14:05) see this is actually just another observation that if you have understand that, if motion is larger you of course, expect more resistance right. Now, in pitch resonance period, you are going to have a very large pitch, heave resonance period you are going to have very large heave that is of course, one of the reason in the design you do not want to make you do not want the natural, heave and natural pitch period to be same.

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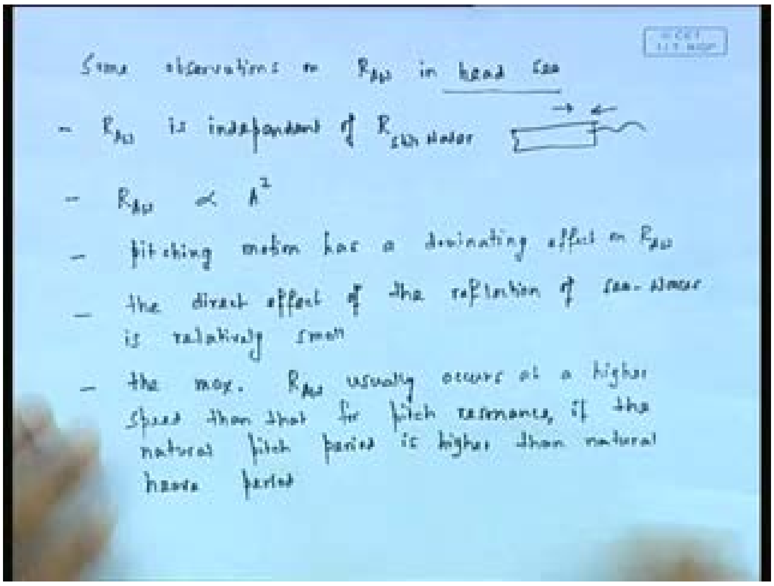

If it is same you have a very very bad motion and very high added resistance sometime, but this only says remember that the encounter period changes depending on the speed. So, suppose that a given speed I have a pitch resonance, normally what would happen maximum R A w will occur at a higher speed than that, that is what it says it is a general observation; any how these are just general observation. Now, let us come to certain formula for that, now we can understand that there is no general formula that caters for added resistance over the entire range.

Because, what we have seen, at higher frequency which means if lambda by l wavelength per unit ship length is much smaller may be half or less, then there is much more reflection and it is dominated by this (()) phenomena reflection, but we have also seen that this is actually small value (Refer Slide Time: 15:08). So, most of the formula that have actually been proposed or used is for this region that is for the motion part of the regions that is connecting.

And therefore, all this empirical formula, you would expect will be related to number one heave damping, pitch damping, heave motion, pitch motion, basically heave and pitch phenomena, which would be in terms of exciting force, radiation force etcetera.

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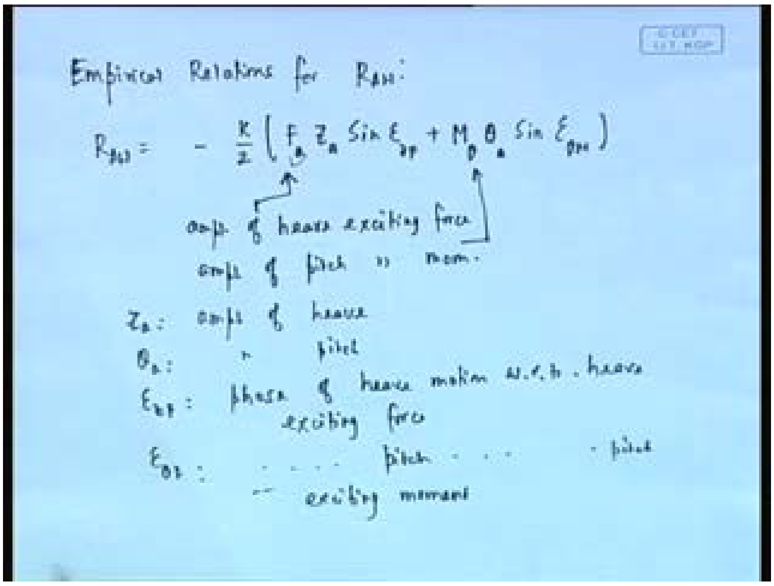

So, let us look at some of the old formulas and you know progressively newer formula, one the older formula (No audio from : 16:02 to 16:15), one of the old one, most very old one it is, it shows like this. I just want to say little bit of that (No audio from 16:24 to 16:42) (Refer Slide Time: 16:24), and unfortunately none of them are very you know validly good, see here this is exciting force in heave, amplitude of the exciting force in (No audio from 17:00 to 17:09) obviously, this is going to be amplitude of pitch exiting moment (No audio from 17:16 to 17:25).

(Refer Slide Time: 17:30) This is we can make it out Z a amplitude of heave motion, theta a amplitude of pitch, e z f phase of heave with respect to exciting force and same pitch pitch exciting moment. This is one of the old formula, so what I wanted to mention here therefore, see is that suppose I have to estimate it I, if I use this formula what happens I require to find out heave exciting force, pitch exciting moment, heave heave you know in amplitude, motion amplitude, pitch motion amplitude, and the phases which essentially means I am solving this heave and pitch R A o's and all these parts I get.

So, you may wonder here, why in this formula I do not have explicitly heave damping and pitch damping, because after all damping term represents the energy of the dissipative wave. The reason is here actually in hydro dynamically you know, exciting force and radiation force are related to each other, in fact the damping forces is the information of that is embedded in this f A and M theta (Refer Slide Time: 18:52).

This, this, this parts what I am trying to say is that look at the hydrodynamic principle point of view here, I have which added mass and damping force which is call basically radiation force that is, if I took A calm water and oscillate a body, then the wave that gets created, that force connected to that (Refer Slide Time: 19:04). Then I have got an exciting force, if I hold the body fix and incident wave come and gets reflected, theoretically these two are actually related.

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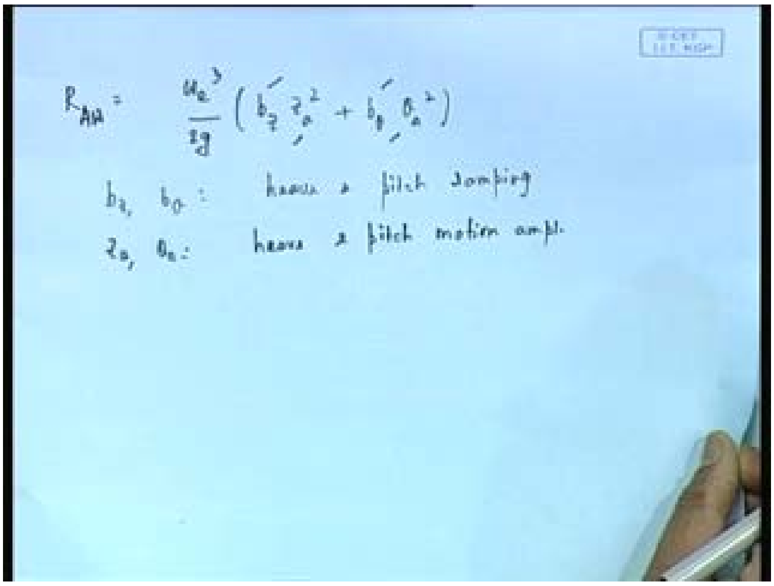

In any case there is no point of going to several theories, another formula this one is better in terms of see this looks like omega e cube by 2 g this is what, these are all simple formulas (No audio from 19:50 to 19:58). Now, here I will not purely right, but b z b theta are heave and pitch damping, z a and theta a are heave and pitch motion amplitudes omega e of course, you know I forgot to mention here, that here this k, this k is basically wavelength parameter or frequency parameter that is you know the wave number (Refer Slide Time: 20:36).

So, omega square is g k, that is this k, omega square is g k means omega square is g k.

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No no, that the omega square is g k, so k is omega square by g essentially what I am trying to say that the information of the frequency is embedded here, and all of them have to be for that particular frequency, see this is what is given given frequency given wave these are all regular waves. See, you know there is single regular wave of frequency omega e or number k for that what is the R A w that is we are talking, we are not yet talking about R A w in irregular waves which we will talk eventually, so this is like that, this formula there are other formulas.

So, I will just write one more and then the final one, so this one as I mentioned explicitly uses, damping damping, motion motion and this is damping is a term that actually contains the information of the wave that the body creates (Refer Slide Time: 21:35).

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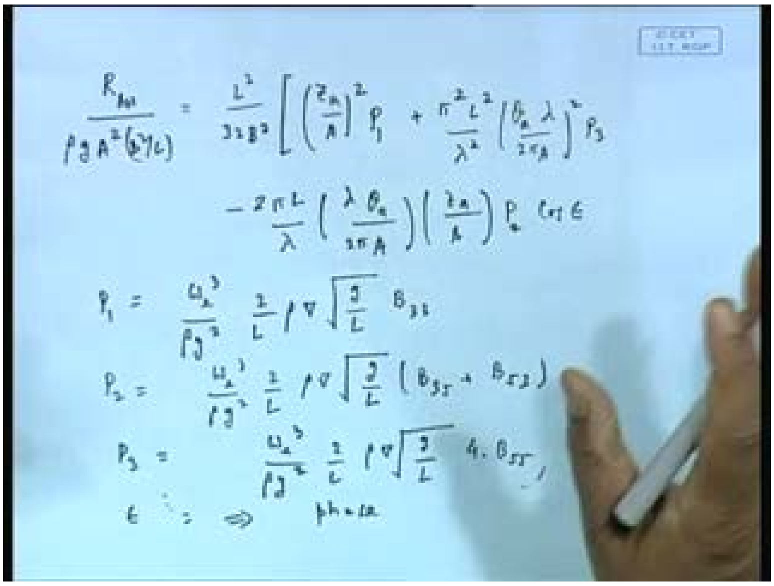

Then, we have another formula, may be I will just write this one very quickly non dimensional form this is given rho g A square B square by L is given something like L square, this is only to give you some idea regarding in terms of R A o here (No audio from 22:16 to 23:21). Let me just write it down then I will explain to you the physics behind it little bit, and let me just write up to this much then (No audio from 23:38 to 23:51) and other terms are there you know like some phase angle, again you will see.

See, what you will see here you know this is again a combine heave and pitch motion, z A by A is nothing but, heave R A o so, it is heave R A o square exactly same as what we have got z A square, if you look at the form what I am trying to say look at the form, look at this comparison z A square is amplitude of heave square which is nothing but, embedded here, p 1 is a term which is a function of B 3 3 that is heave damping which is exactly here b z. Now, theta A lambda by A, actually theta A by A is nothing but, pitch R A o it is nothing the reason why it is written theta A lambda by 2 pi A is basically to make it non dimensional, that is all.

Essentially you are dividing the slope by k A rather than actually theta by k A, you can see this theta A by 2 pi by lambda A where k is suppose to be this you know wave number, now so this is same as this term p 3 is nothing but, the term equal to B 5 5 exactly same as b theta. The only thing that modification that has happened here is that, it has taken a combined you know like action theta heave and pitch something like heave plus x pitch square, which is why there is a term that comes out like you know, when you do a plus b square additional term curve heave pitch, one can call this a heave pitch coupled term.

So, the form of the equation look somewhat similar and however, I tell you the most common and the most used form that today is used is none of this, it is it is this one the one that I am going to write now but, that is slightly more difficult to compute.

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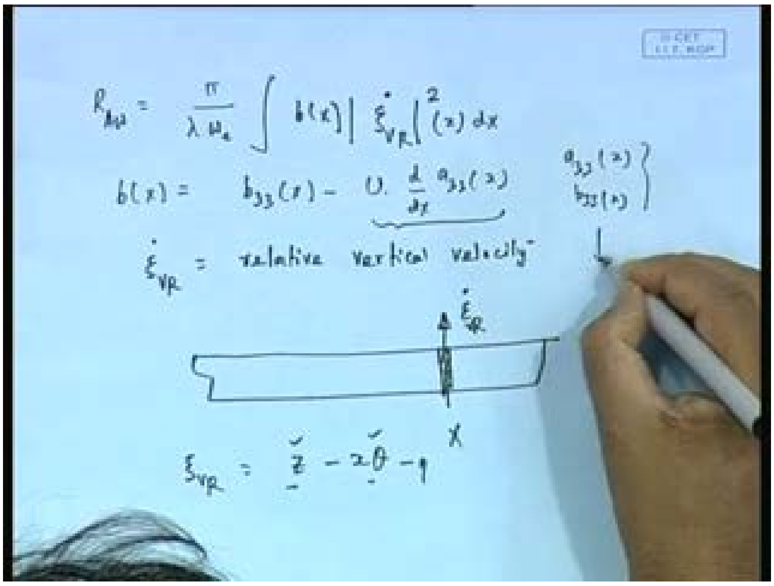

This one says R A w is equal to pi by this part of course, we do not worry but, it is integration of b x into I will write in this form (No audio from 26:06 to 26:46), now what see this this form is basically derived based on energy balance that is the energy of the waves, that has been created by heave and pitch motion; and relating that with wave resistance. See here, what the terms are is like that if I take a ship here take any section at x, this part is going to be my vertical velocity of the section B 3 3 x is the sectional damping coefficient, two dimensional sectional damping coefficient (Refer Slide Time: 27:12).

A 3 3 x is sectional added mass coefficient, what you find out is that I require to have therefore, if I want to calculate use this formula, I actually have to have for each section added masses along the section known, damping should be known and I need to find out the slope of the added mass curve. So, therefore, applying this is slightly more complex, the reason why I am saying that, if you look at this previous formula all I needed was added damping, there is no added mass actually damping, but for the full hull whether you call this or whether you call this (Refer Slide Time: 28:08).

Of course, if you call the first one you need exciting force, as I said exciting force can also be connected to added mass and damping, they are can be related but, never mind let us say; but, in this form which is actually more you know people think this has a better fit, and this is what is recommended today for using is little more complicated to use. Why because, you need to find out sectional added masses first, and then you have to find out this sectional added mass you know like, you have to also find out the relative velocity remember, that this velocity here this contains both heave and pitch.

So, my heave is there pitch is there in fact, I also have eta because, is the relative velocity with respect to water surface, so I have heave here pitch here just like those things we I had (Refer Slide Time: 29:09). So, this one what we find out is that, all the formulas involve necessarily heave motion, pitch motion and the phase between them remember, if I want to do this, I also need the phase between the two what we have mentioned yesterday.

So, I need heave motion, I need pitch motion, I need heave damping, I need pitch damping, I need well in this case why it is actually no pitch damping, because in sectional case we have discuss earlier, that sectional vertical damping into x square gives you pitch damping, know A 5 5 is nothing but, x square A 3 3 integrated. So, essentially when we when I do sectional damping I have only sectional damping in vertical that is a

3 3 and b 3 3, small a 3 3 and b 3 3 which basically a 3 3 and b 3 3 x this gives rise to me B 3 3 as well as B 5 5.

What I am trying to say is that therefore, the information content is all same, but how do you make a formula is different and that depends on different physical approximation that is used. So, you you therefore, will wonder which is correct, why there is so many formulas, the reason is very simple, this is second order part, you cannot calculate, you just cannot calculate. In fact, if you look at R A o also you will make various kind of approximation, but these are the kind of formulas for added mass.

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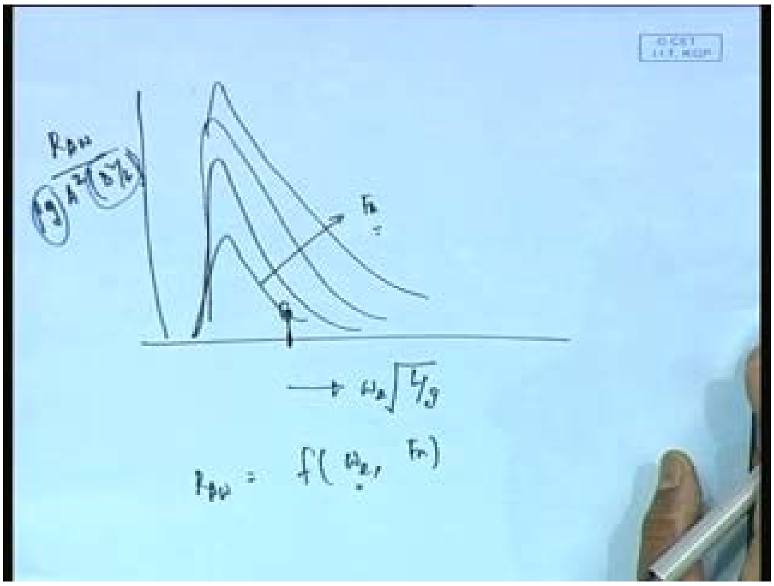

So, having said that typically what I will now, I am going to tell is that now, see you calculate that for different whichever formula against omega e now, normally what would happen you will have some non dimensional form, so you might make it L by g. And here, I have got R A w, but R A w is proportional to A square, so you put A square but, you know this is not non dimensional, so normally you non dimensionalize for example, it might be rho g A square into B square by L, I mean this this extra part is just use for non dimensionalization, that is this part.

See this, and this you are using for non dimensionlizing and typically you will be calculating that using any of the formula, and they will look something like this you know etcetera, that depends on various you know like Froude numbers as you go to speed, higher the speed, higher the resistance etcetera, you end up getting this (Refer

Slide Time: 31:19). So, this this tells me therefore, average added resistance in a single wave or you can say R A o for that, having said that our next job is that how do I find out mean added resistance in an irregular wave right.

See, these are regular wave which means, if I have this wave length this, then I know what is for this particular speed, what is my after all added resistance is a function of omega e, you can also say speed, actually you can say omega is speed but, we normally do it separately, because same one can occur for different combination (Refer Slide Time: 32:09). So, essentially, so right so this like an R A o, but the question is that now next is that now next is that how do I construct or how do I determine added resistance in irregular waves, so for that we do that.

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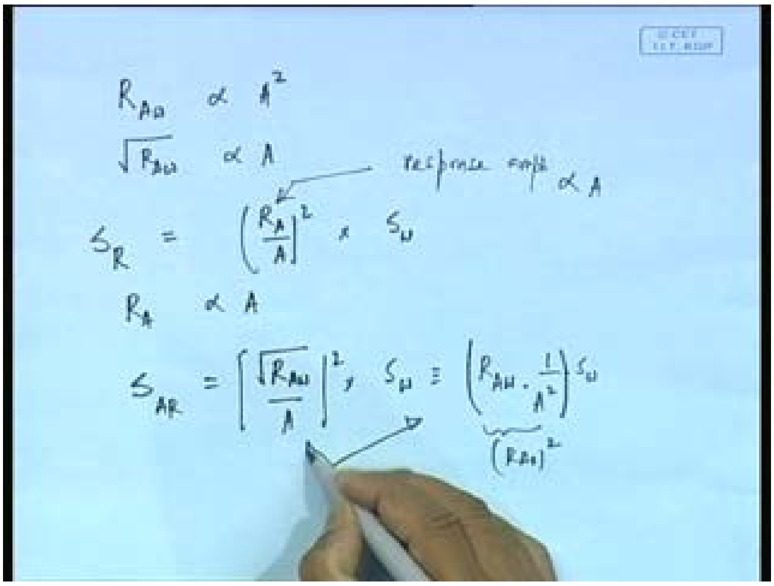

Remember, I need to have a spectrum, so I will just try to tell you this that see, added resistance is proportional to A square, so therefore, root over R A w to A. Now, remember that when I it is spectrum of any response, what was it, it was the response amplitude by A square into wave that is what we did, why because response R A here was proportional to A, remember what is R A, R A was response amplitude.

See, when we did all these things so far, all the quantities like basic motions, accelerations, and relative motions, whatever that this parts this response, we said it is proportional to A means it is linear function of A; that is why I could do that. But, here problem is that this is not a linear function, this is the function of A square, so what we have to do therefore, is that is very simple though S added resistance added resistance becomes simply you can say, see it has be proportional to A square of the quantity.

So, this becomes simply R A w root over by A square of that into S w which gives you nothing but, which which makes it simply R A w into 1 by A square into S w in other words, this becomes my function R A w by A square, I will just I will come that; that means, this is my equivalent of R A o square, square not R A o (Refer Slide Time: 34:13).

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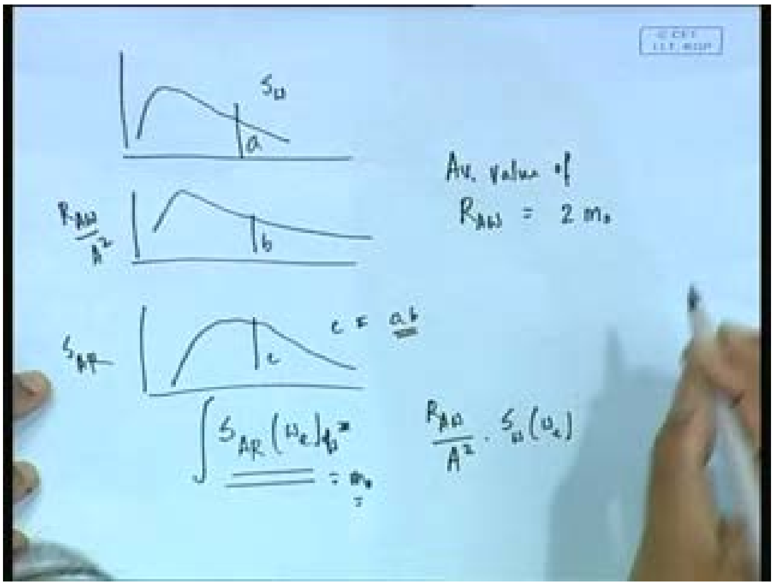

See remember, once again if you look at that this part, what is this, this is nothing but, this root over R A root over of added resistance by A square root over of that, which means now coming to this if I have spectrum formula, I have here S omega, then here I have to have say remember here, R A w by A square this is what I have plotted remember, this is what I have plotted here, that is what I have done in a non dimensional form, if you just take that.

See I have plotted here what did I plot I always plot R A w by A square, because R A w is proportional to A square. So, I in other cases what would have plotted resistance amplitude, not resistance response amplitude by A, but here I am plotting this by A square remember, this is the most significant difference that one have to remember (Refer Slide Time: 35:30). So, I am doing that, now I get this spectrum here, that is S added resistance added resistance this thing, but here remember in this diagram

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a b c yeah, c equal to a into b compare to a b square this is very important for us to realize, that means S added resistance at omega e let me put it omega e only is becomes essentially R A w by A square into A wave omega e, this is very important to understand. Now, there is one more point to that I find out this, but you see here we are not interested in this spectrum to find out what is my 1 3 rd significant value, what is my 1 10 th significant value etcetera, all that we want to know is mean value of added resistance or average value of added resistance (Refer Slide Time: 36:43).

So, what is that average value the average value of added resistance or maybe we can do it here itself. If I integrate this d omega then I call it m 0, then average value this is my formula 2 m 0, remember not 2 square root of m 0, but 2 m 0 I will write it down properly (Refer Slide Time: 37:05).

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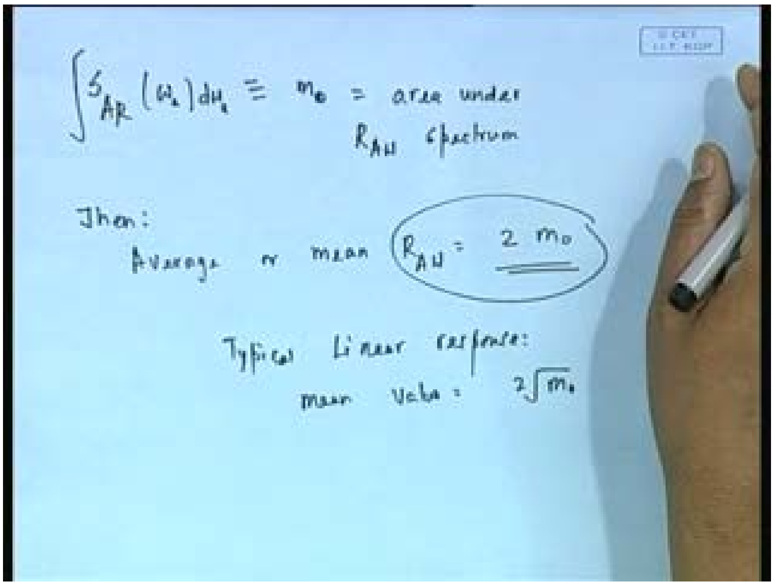

See (No audio from 37:26 to 38:14) remember not 2 square root of m 0, see in a in any other responses it was (()) what is happen in in compare to the other, if it was another another response, typical response (No audio from 38:27 to 38:40) it was 2 square root of m 0 square root because, it was proportional to A, this is proportional to A square that is why 2 y m 0; so this is what you need this is what you need. See, then what happens is that you will calculate for various sea state, this added resistance said and they will try to you know like average value.

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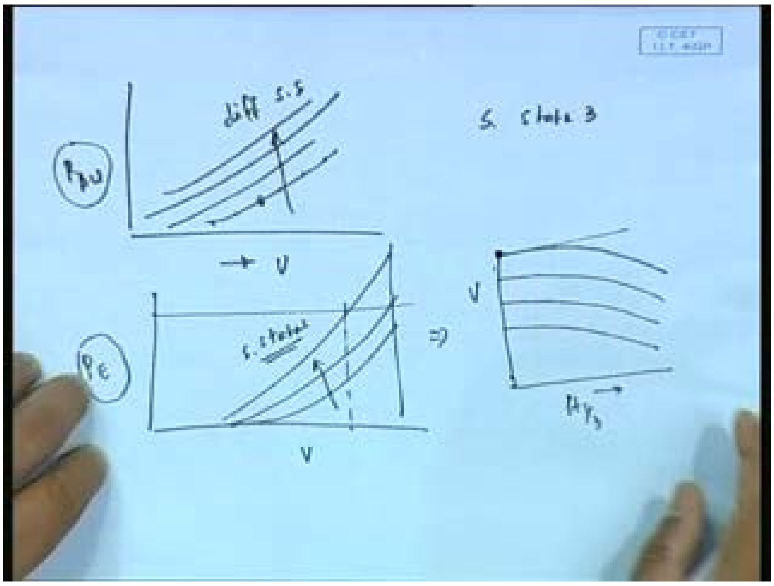

So, what I mean ultimately what you can you will do is that say here a sea state, state 3 speed, mean value of R A w it will of course, look like something like that, then of course, this is may be some sea state, so it may look different sea states, understand what see what what we have done therefore, is that see in actual calculation you will do the reverse way, you would be determining. Therefore, the added resistances you will consider different speed, say let say you take 10 knot, 12 knot say let say you take 10 knots.

So, for 10 knots I will find out added resistance or rather other way round, I will take a particular sea state, say sea state 3 then I will find out what is my mean R A w at 10 knot, 12 knot, 14 knot, 16 knot I plot them then I repeat that, so I will end up getting this that means, you are getting all the points from the spectrum again. So, you see this calculations are done like that you end up getting therefore, speed versus R A w etcetera, but mostly people though they do not use that way what they will try to find out is other way round right, instead of R A w you will try to find out v versus effective power, which will of course, become similarly.

The effective power that you need go like that for different H 1 3 rd this will be of course, different sea state what what I am trying to say is you see, that this you can translate to a speed loss sometime. That means, you will say here, H 1 3 rd significant wave height, here v and depending on the thing the speed loss, this will may be at particular angle you know like, I will explain the meaning of this, see the if the question of how do we use these diagrams form the actual practical point.

Once again what would happen is that we are finding out average added resistance in a given sea state from the R A o of the added resistance that means, first of all I calculate the you can you can say R A o or you can say regular you know regular sea added resistances. So, I calculate this points this this points this of course, is a function of ship speed, this is also function of heading let us say we take head sea mostly, so for a head sea for different speed I have done this (Refer Slide Time: 41:37).

Now, having done that for a typical for all those speeds, I will also come back to this and I will find out R A w average in that particular sea state, this is my sea sea state, this is my added resistance and regular waves, combine that I get this, from there I get this (Refer Slide Time: 42:15), so I have got this as a function of sea state speed. Now, I can plot then against speed versus sea whichever way I want whether, I have I can do sea state versus this for different speeds or other way round normally this is more beneficial.

But, instead of R A w you can also relate that to effective power, similar kind of graph you will get then, converse I can find the speed loss because what would happen, if my ship power is this much I will know that I will make this speed. See, suppose I am going at 20 knots and now my effective power is so and so, and my engine is giving, so much power, so I can conversely find out available power is, so and so. Therefore, what speed I will make, in a sea state this also can be plotted in this way that means, sea state versus initial speed with that how much speed reduction comes out, that reduction of speed you can also plot it that (Refer Slide Time: 43:09).

In fact, this is what is ultimately used more, because you would like to know not how much resistance increase or power increase, but for the given power what speed loss you have got because, the reason is very simple I cannot increase my power I am actually running at the whole power, so therefore, I want to know how much. So, this is what is called speed reduction again this is the function of course, see here I plotted this but, you can plot this (Refer Slide Time: 43:41).

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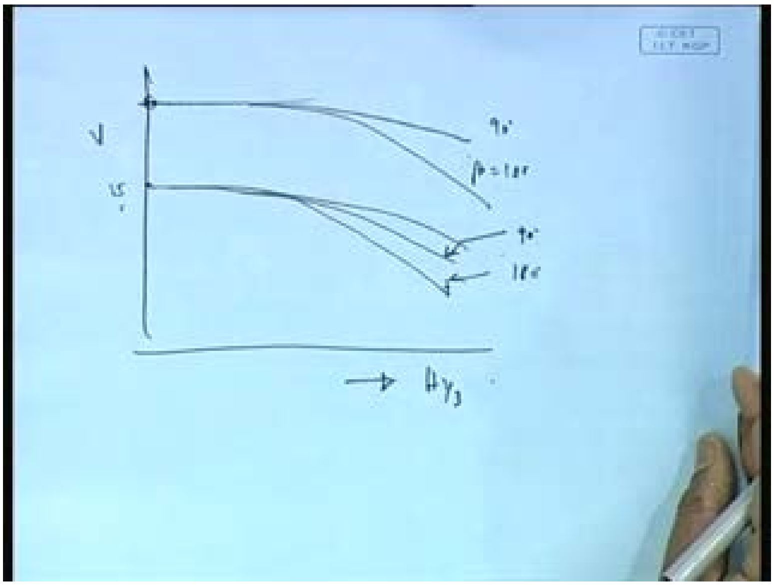

If you want to do the more calculation, you can calculate this speed loss as here, you know this is as say H 1 3 rd there is this is actually a sea state, this is a initial speed v and this may be at head sea, this may be at 90 degree etcetera, you can also do that for different heading angle although this is most important, but you can also do that for. So, when you start at 20 knots, so when I started 10 knots again I will have graph like that, so I can have this graph see, what it means is that this would be supposing I start from say 15 knot.

Then this is my as the sea state goes up my speed reduction comes to this this corresponding to 180 degree heading that is one head sea, this would the the speed loss in 90 degree etcetera. You may say converse speed the in the opposite side will be pushed up, but normally that is not taken it is only the head condition that we take, so this is how we can calculate this added resistance you know, this is a kind of part of added resistance.

So, to summarize added resistance therefore, the only difference that it has got with other responses it is a term proportional to A square not a therefore, my R A o calculation is not same it is not spectrum, it is not R A o square into this here I will take simply different wave.

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Second thing is that in here I do not have much of statistical property of importance, I only want to know the mean value or average value, so this average you know remember even single wave, what added resistance is in average value, because it in average mean value and this is kind of average of averages. So, there lot of averaging there and you end up getting this, so this is what about and regarding the calculation of added resistance therefore, well there are number methods nobody knows which is very good as I said the last one, suppose to be more widely used today in practice, in in industry.

But, for that you need to have a good program to determine sectional added mass and damping along the length. If we not we can use some other ones, but there is always a debate over how close they are etcetera, because computationally determining a quantity that is second order is always more difficult, I am going to now just change to another topic slightly, just in the next 5, 10 minutes time very quickly, before we talk something else tomorrow.

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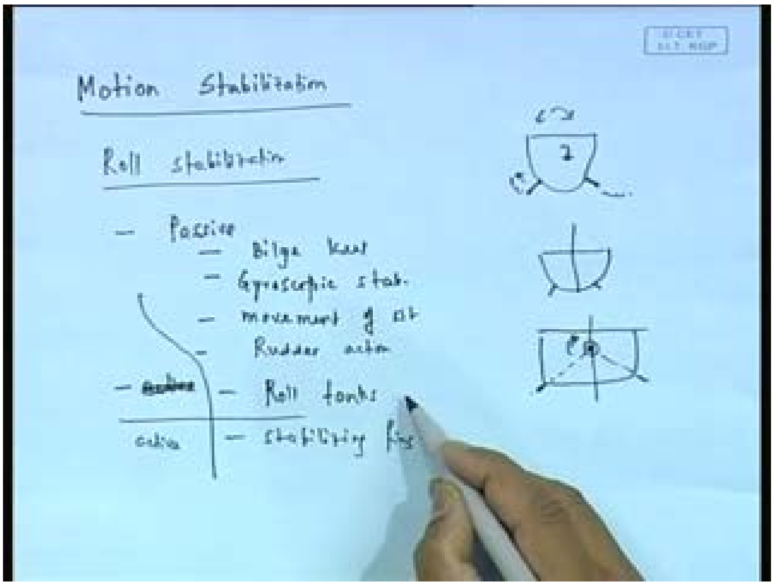

So, I am going to shift in to this something call motion stabilization just basic ideas, because in short time we have some 20, 22 hours for sea keeping, there are too many things to just mention. Now, a days it is becoming more important you see, everybody wants a comfortable ship, everybody wants to reduce motion, so there are number of stabilization ideas that are coming, but I will not be able to talk about that, I will simply talk of roll stabilization first just little bit.

Now, you know the ship is rolling badly, as you know that roll only larger you do not expect pitch to go more than 5 degree or 2 degree, now if it is wave length 5 degree the bow would have come up, but it is roll which can go 10 degree, 15 degree, and 20 degree etcetera. So, that is why people want to always reduce roll motion, so they have been much more talk on roll motion from beginning. Now, roll stabilization can be passive type and active type, what is mean by passive means you just make an instrument and do not do anything you just leave it.

Now, the biggest example of that is of course, is basically bilge keel the most common example is bilge keel, all what you are in bilge keel simply put a keel (()) here, what does it do?

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It essentially produces damping why because, as it try to rotate you see try to rotate it will kind of act as a damper in equation of motion b goes up, discos phenomena because, the damping occurs because, flow gets separated. Now, roll actually otherwise is low damping because, as you know if I took a circle, and if I just oscillated that it will keep on going for a long time, even if I put a bilge keel it actually goes on a long time and as a result what is happening my resonance period depth, your roll is very high you want to reduce it.

So, this is the most simple common type that is used and it has been found out the most effective one is to put of course, you know at this bilge location more or less along this line because, if it is c g here is rotate about that making a line like that gives a largest kind of a effect (Refer Slide Time: 49:10). Then of course, there have been many other ideas for example, there have been ideas of gyroscope, I will just mention some of them then there is idea of movement of waves, weight sorry, then there are rudder action people also me time use rudder, rudder also act as a stabilizer because, rudder is a plate.

But, let me go back to this side, then here we have got passive and active roll tanks actually you can say this is passive, so let me call it roll tanks I will mention this roll tanks and then of course, here stabilize actually roll tanks and among the active we have got stabilizing fins and there can be other ideas also (Refer Slide Time: 49:47).

Now, let us just talk these two things quickly and then we will this in these two. Basically, all these, what they do even weight and all see the idea is like that, which is same as this tank also. You have this particular I mean just look at this little but, of this thing. You put a tank here water tank, water is here what it does I mean just the physics of it know there are lot of other maths; as it rolls see water also rolls but but there is a phase gap means as it is going to this side, water is still trying to go on that side.

So, that acts as a damping what is happening the forcing function? If the motion is like that my water motion is delayed action. This is exactly what it does this is the delay action, that is what is trying to act as a retardation, there is a phase gap between the motion, when it has gone to the maximum angle and trying to come back water is still going on this side. So, that will always try as a damper, this is the same idea for all this principle of gyroscopic movement of wave etcetera (Refer Slide Time: 51:30).

That means you have an pendulum type of thing and make a phase gap between the displacement and the weight shift, and the weight is trying to hold you back. You know that because weight is following you which is like when you I kind of fond of telling it is like when you try to go in a mass somewhere group you want to go out at at sometime you will see that, there is always slowing down process because the whole group last slow you down, as they group when you go.

See, there is kind of a effectively like a slowing down process, because you have been retarded pull back by somebody else. So, same ideas are here but, the why passive, because you do nothing you just make a design it takes care of its own thing; like for example, this one all that you have to do there are lot of calculations is that, you have to tune properly. So, may be that the water level etcetera has to be adjusted depending on the kind of loading condition yeah.

So, this is one, now just the final thing is active stabilizer this is now becoming very important what they do, you have here fins not throughout in the particular hull may be there is a fin here coming out and there is a fin here coming out these fins this is of course, active stabilization.

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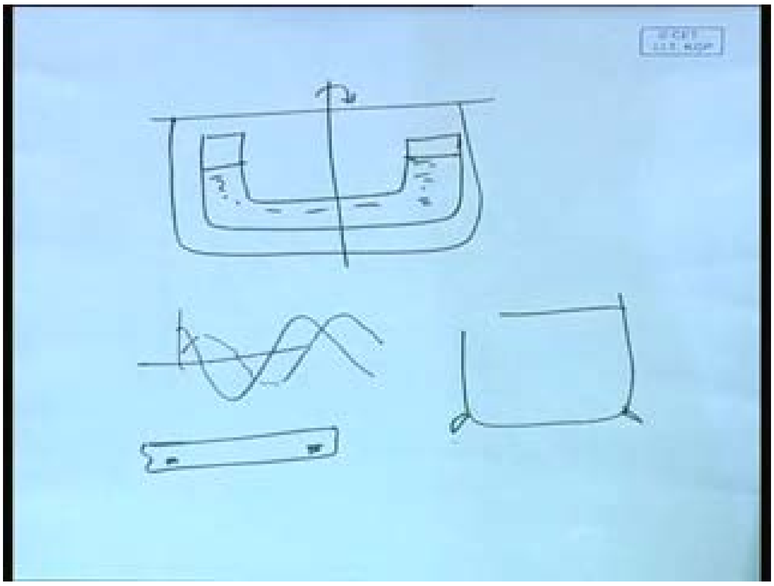

Here depending on the response, how the roll you have to control you have to have a complete controller, this angles you have to keep changing like, it is like a how should I say it is a it is A arrow section normally. So, it is like the arrow are there, so you basically ship is going as it rolls you change these angles effectively by a controller to minimize the roll motion.

And this of course, is used for pitch also for heave also. Now a days it is apparently very common to use, so active stabilizer of course, the entire part cannot be there only a small part, a small fin with a rod connected and there is a mechanism that will control that. That means, there is a feedback you measure the roll motion, depending on the roll motion you change this angle that will give a counter affect that will reduce the roll.

So, these are kind of and this is not awe can only mention this briefly here, because there the subject of that control is a different subject altogether, active control; you have to have knowledge of control theory but, these are the things that are being used. So, today we are closing it here, the last lecture for seakeeping part of the course will be tomorrow, where we will talk about design the seakeeping in design; how do you consider seakeeping design should you consider etcetera etcetera, thank you.