Performance of Marine Vehicles at Sea

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Lecture No. # 26

Ship Motion in Regular Waves - II

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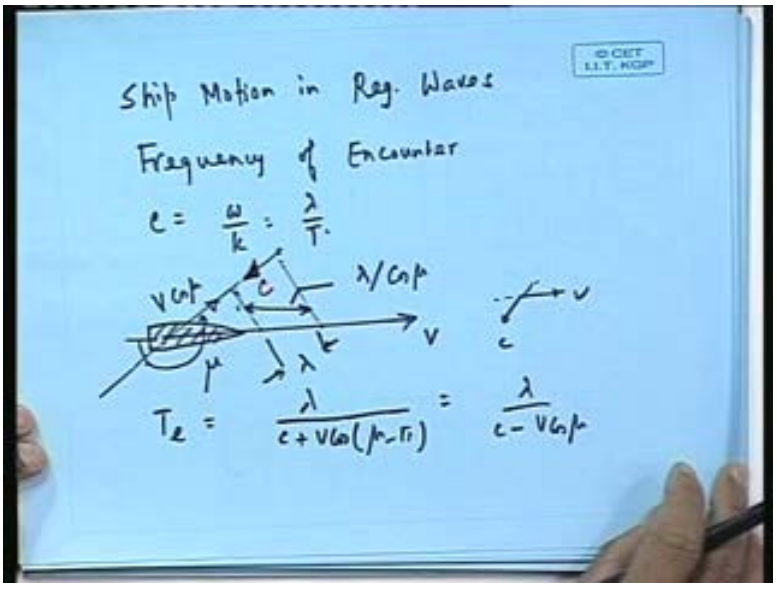

Now we will talk about, see, we will continue our discussion on ship motion in regular wave. We will come that little later, first let us now, let us now derive, try to derive a formula for frequency of encounter. See we know from regular wave, c was given by omega by K, given by lambda by T. Now let us take a case - ship is moving like this and the waves are moving in this direction. See this is my V; let us say this is my wave speed; I think I should have taken another colour.

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See this, I do not know whether this diagram might have become little small. Let me, let me try to explain. There is a ship here. What happened is that, this ship is moving in this direction, speed V; waves are coming in this direction with angle c.

And we are going to call, actually the, the you know, vectorally K, vectorially the angle between this V vector and this vector to be equal to mu - the heading angle actually, you see. So, this is my one vector one; see this is my V vector and this is my c vector. So, V to c we are going to call, that is you know, from this other axis to be mu angle.

Now, what is happening is that, the wavelengths of the ships are this. See this is a crest line; this is a crest line; this is a crest line. So, the ship is, the waves are moving along this direction with c and this distance is a distance of crest line. And the period that the wave takes to move from here to here is c. Now what is happening is that as the ship moves here, see it meets a crest here, and meets the next crest here, and this distance is lambda by cos mu.

Now, T e, what we call encounter period, is going to be lambda. Actually, you can say other way round, that encounter period is - how the ship is encountering the two crest travelling as two direction; now what is happening here? Now, if you sit on the ship, ship here, the relative speed of the wave is going to be c minus V cos mu, see c minus V cos mu in this direction. So, the encounter period is obviously the length lambda divided by c minus V, c minus V, not cos mu; mu is actually written here in this way. So, it is going to be here c plus, I just write the way it is written here, mu minus pi, because the way here that they have defined the mu here, it becomes, this minus this V cos mu.

Basically, you can, you can work it out. mu is actually written as this angle here. So, naturally mu minus pi becomes this angle; this is the, this is, this becomes the mu minus pi angle, and so, the relative speed, obviously sitting from one to other is c minus minus V cos mu. So, it is c plus V cos mu mu minus pi etcetera.

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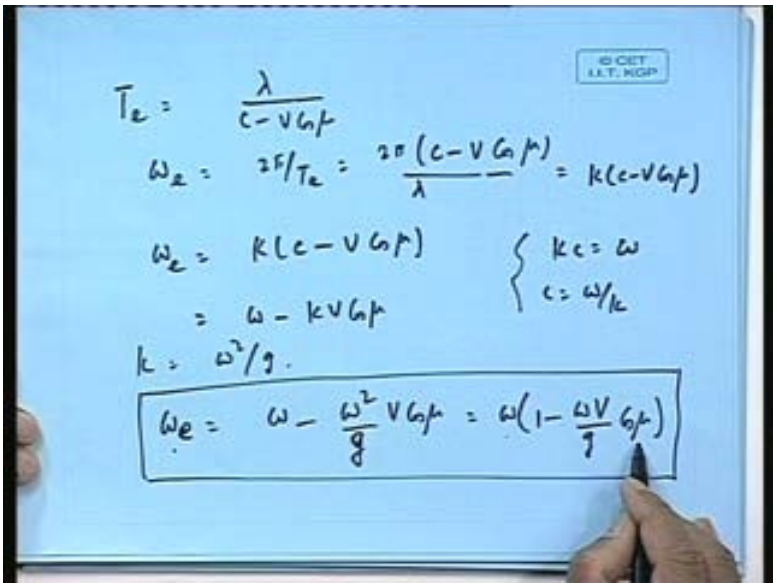

Now, this is my T e. So, therefore, now again if I write T e becomes lambda by c minus V cos mu. This is a very elementary one; so, I do not want to go too much on that. So, omega e is becomes 2 pi by T e. This will become, if you work it out, it is 2 pi c minus V cos mu by lambda. This will become equal to K, 2 pi by lambda is K here. So, c minus V cos mu. Now, so, omega e becomes here K into c minus V cos mu, but K c equal to omega, because you see by definition c equal to omega by K. If you use that relation, if you use this relation, it turns out to be equal to omega minus K V cos mu.

In fact, now if K equal to omega square by G, if you use this formula, because K is omega square, this is a famous relation that comes, omega into minus omega square by V sorry not V G V cos mu or you can write is omega 1 minus omega V by G cos mu. This is the classical relation that tells us between the, you know this thing, between the, relation between encounter frequency and wave frequency. If wave frequency is omega, you see this is the ((external)) relation, I will discuss little, little lenght.

See omega is the encounter frequency; omega e is an… omega is equal to wave frequency. So, you will now… cos mu equal to the heading angle, that is the vector angle between the two.

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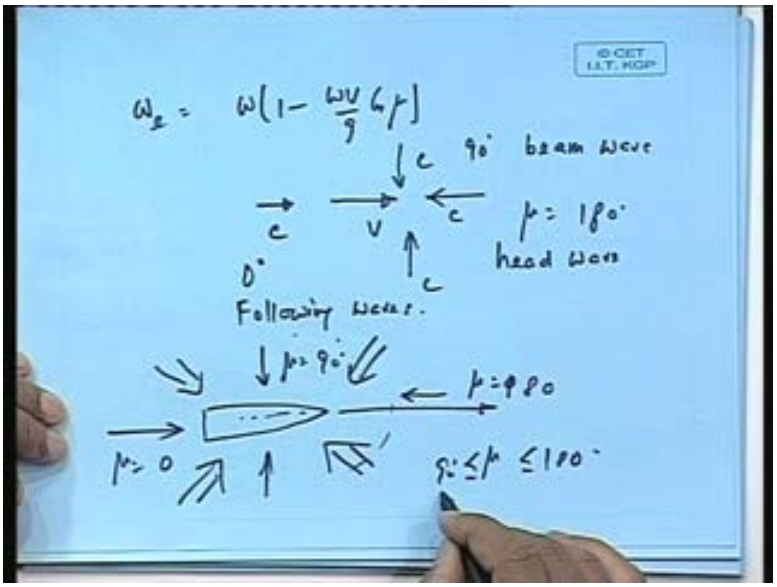

Now, what happened here? Let us go back to this relation here. Now mu, if this is the V and this is c, then mu equal to 180 degree. We call it head waves, when it is coming exactly like that, you see. When supposing, now here, now I will just talk about this wave condition little bit here; that is very important. If ship speed is here, and the waves are coming exactly opposite, then the angle between the two vectors is 180 degree, that is called head waves; if it came this way, that is c, then this is 90 degree, called beam waves, this or this wave; and if it came this side, c then we call 0 degree following wave.

Or more, more people will do it like this. The ship is moving this side. If the waves are coming this way, then mu equal to 0 sorry 180; if waves are coming this side, mu equal to 90; waves are coming this side, mu equal to 0. Waves can come from this side or this side or this side or this side. Normally what happens, if the waves are coming within this angle, within this part, between mu is 90 to 180 or 270; you know, actually, one sector is good enough, you do not go to, because of symmetry, you do not go; if it is within this; this means the minus 90, you know, you can have the other side, we do not go for that.

If it comes from this side, we call this to be head wave condition, because waves are actually coming in a direction. If you take any component, which is actually the ship is heading into the waves, may be less, but it is heading. This is actually exactly head wave condition. You can call this to be… people, they use various terms - bow quartering sea. This is beam waves. This entire thing can be called head wave condition. Exactly

opposite is this thing. Why I am saying that is because, in this angle, the cos mu will become, see what is cos hundred 180? Minus 1. So, cos mu here becomes a negative quantity. So, in the following, in the head wave condition, cos mu is negative quantity. So that omega e becomes omega e into 1 plus omega V by G into something. So, that omega e has become more than omega; this is what I want to tell here.

On the other hand, if it is following wave condition cos mu is a plus quantity, and you can see from here, that this becomes a negative quantity, less. In fact, if I do a graph between omega e and omega it looks something like this.

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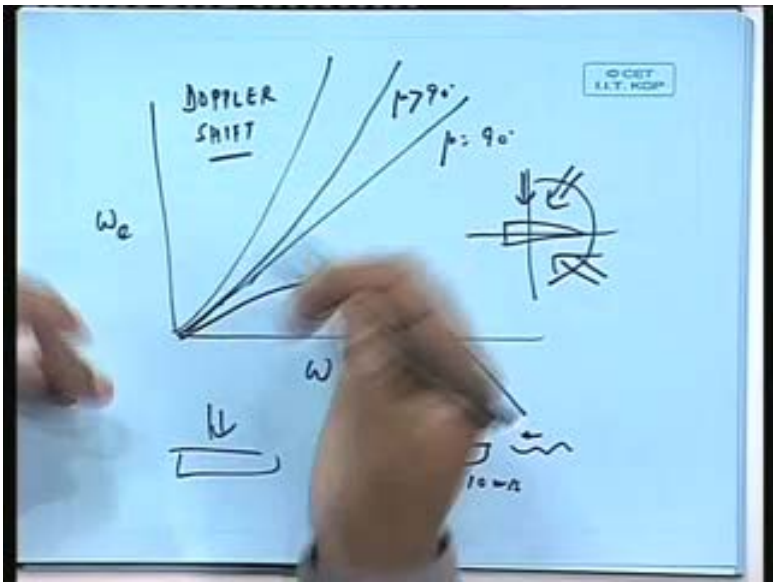

See, if I say here, omega and omega e, in head wave condition, it goes like that. In beam beam wave, this is actually mu equal to 90 degree. This is mu, this side is mu more than 90 degree; it becomes something like that, you know like, for any omega there is a more… this is for 45 degree line. So, you get my point? In 90 degree, there is a one-to one-correspondence.

So, if there is a encounter frequency is, you know, omega, I mean absolute frequency omega, encounter is omega, same; that is because, ship is going this side, and waves are coming this side, so you know it is same, since relatively you are just going across the crest, but if you go actually into the wave, then you, you end up getting higher and higher frequency. That makes sense; higher frequency means lower period; that makes

sense. See, if you are heading into that, what was 10 second wave, will appear as 8 seconds, 7 seconds, 6 seconds; depends on the speed; the faster you go, smaller the period is, but the interesting part comes on the following wave where the graph becomes something like that which is very interesting. You will find this formula that, in fact, it can even become negative sometime, which we are not going to discuss.

See, if you solve this problem with this is a quadratic equation, because it is bringing back that again, omega minus omega square by G V cos mu; this is a so-called quadratic equation. We need not go through this mathematics, but it turns out that in the following wave compression, there can be an omega, which can be even negative. Negative omega means, very interesting, because what happens? You are going in a ship here, waves are following, but wave speed is smaller than you. So, if you stand here, to you it will appear as a wave is actually going on the other direction. See, you are going at say 10 meter per second, this is going as 8 meter per second; so, if you stand here, you will think as if the wave is going away from you, on the other side, at 2 meter per second. This is what is meant by negative frequency, you know, at the physical concept of negative frequency.

What happens is something like this. Suppose waves are coming this side, so obviously, you are heading into it. So, you are meeting the crest much faster and faster. As the waves comes this side, you meet the crest at the same time; as in this side, you meet crest lesser and lesser; as it is exactly same time, as it is exactly, you know where omega 0 you meet, you know, like the T becomes 0, you do not meet the wave, because you are, you are going along with the crest, and if you are going faster, you actually have an hypothetical situation, because crest will appear to be moving away from it.

Normally, what happens? This is just to tell you general part; normally what happens? We are not concerned much about in sea keeping, about the wave coming from following; we are mostly bothered about the head wave condition, mostly; because it is the head wave condition that gives large motions. Beam wave would give you large roll motion, as you expect; head waves will give you large heave and pitch motion, and as far as (( )) go, largest bending moment etcetera, would occur more in head waves. And you know another thing, we will see, that as you are meeting the crest faster and faster, see instead of 10 second, you meet at every 6 seconds, your oscillation period is faster. So, you are actually having higher acceleration. It is more uncomfortable in many ways. So, we will talk about that more.

So, this is the, this is versus encounter frequency. This encounter frequency is absolutely same as what is known as Doppler shift. In school physics, we are learnt that when a train comes to a station, you hear that the whistle sound pitch goes up, because the frequency goes up; as it goes away, it goes down.

In fact, this is very, so common, that you have even the theory called the Red Shift of Stars, you know, like the spectrum that we have, electromagnetic wave, we have got violet to red, various frequency; red is having a low frequency. Now, if the stars are moving away from you, away, then the light that comes would be shifting towards low frequency, by this theory, and it will be the spectrum, the light will look more reddish. This is the fact that the lights come from the star looks reddish has been used to tell that the universe is receding or say expanding. It has same Doppler shift idea.

I am (( )) of telling relation with, you know, same thing with other areas, but same thing is the same encounter frequency idea, which tells us why - one of the theory - why universe is expanding. Red shift of stars - light that comes from that looks more red; that means, that star and earth distance is increasing; therefore, it must be expanding. So, this is very common thing.

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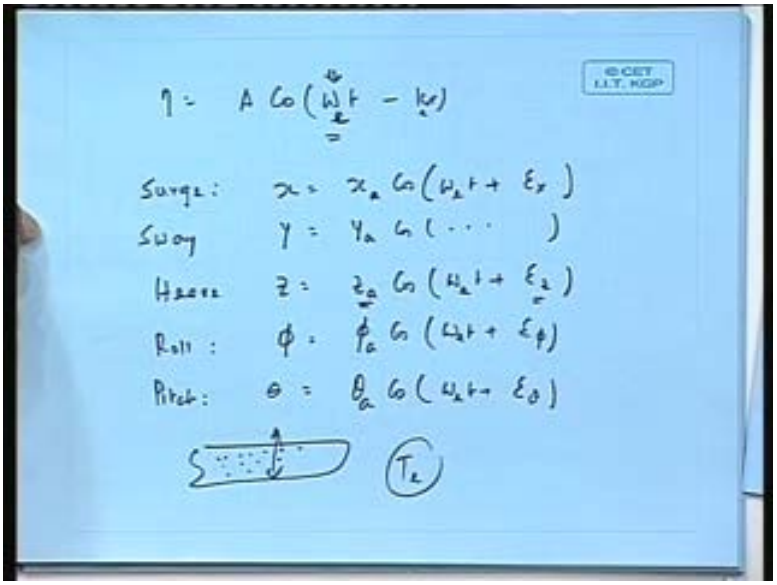

Let us now look at, to look into, now we know; what we know? Now if there is a wave here, see I am calling eta as a cos omega T minus say K x or whatever; this omega T is

the absolute wave, but if you sit on the ship it will appear as omega T minus may be K e x. So, therefore, the excitation that will be obtained by the ship is going to be of this frequency - omega e frequency. So, I can now write all the motion, say surge and all that, sway, etcetera, I will just write one of them, as if it will become n amplitude into plus a phase angle. See I will explain that you. Say y is may be sway; can be written as y amplitude cos like that. I will just write some, some of them more. Then roll; roll may be I can call phi equal to phi a.

See, now, these all equation you find all are actually same equation. What we are saying here is like this, now I want to find out if there is a wave here, how much the ship has a surge and sway and roll and heave and pitch on here? That is my aim of finding out ship motion in regular wave. Now, I know, that because my wave is the one that is giving my pressure; the pressure is all now being given at the frequency omega e. Therefore, my response also, when you when you add up everything changing at, you know, every omega e times or T e T e times, then the response and everything else also will have same kind of period.

You see, you think of this. I have a ship here; every point I have got a pressure coming; these pressures are changing, repeating exactly at T e period; means encounter period, Suppose 8 seconds is my encounter period; then every 8 seconds, there was a pressure repetitions. So, that naturally my next, the force also will repeat at every 8 seconds. Therefore, the amount that is moves up and down also will repeat that every 8 seconds. Therefore, I can write the heave motion as if it is having amplitude Z a and a cos function with period omega, I mean frequency omega e T.

Of course, I do not know how much it is the phase. I have to add always the phase, because when you add them all up, you do not know the phase where it is. I will talk about the phase in a minute. What is the meaning of the phase - that I will talk about in a minute. But this is the general form that I can write in a regular wave. When I have a sin wave, which is regular, I must have all the motions which are also regular, so I know that with time, they will every 10 seconds or 8 seconds, they will change; they will go like a 10 second. What I do not know is what the amplitude is and what I do not know is what the phase is. I will tell you what is phase in the next diagram, that is when it is occurring with respect to wave. See, so this is a general form; that means, I can represent actually every, see when the waves are sinusoidal, everything else, everything of a ship response

becomes also sinusoidal, because the simple fact, you break it down, every, the all the fluid in the smallest particle, they are giving velocity pressure; everything repeating at 10 seconds, that period. So, naturally the result will also repeat at 10 seconds, you know.

If you have say 10 people are giving or push and every 10 seconds you give a push, he gives a push every 10 seconds. You sum them up, the net force is also every 10 seconds. This is what I want to tell; this is a very important physical concept that you must have in mind, that, that necessarily the response or force or pressure must be at the period of encounter at which the ship is meeting the waves, it is repeating.

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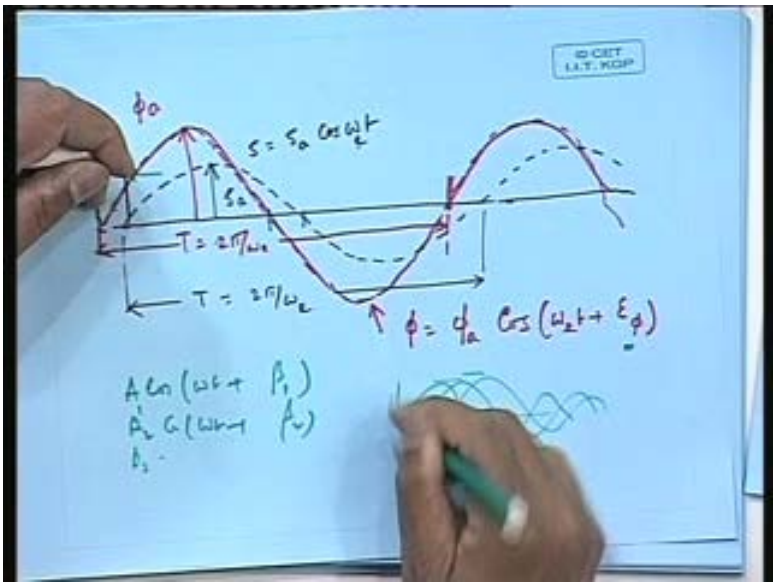

So, you see, the phase, now this I need to draw slowly, may be two graph. So, I have got let us say here – wave. This, is let us say xi equal to, I will writing now xi a. This is the wave xi a equal to xi cos omega T plus K x; let us say x equal to 0; some point I am taking, so it is like this.

Now, roll signal; let me take another colour. Roll signal. Roll signal is going to be, now here, you see this diagram; this is my amplitude; see this, remember, this is my xi a and this period, see here, if you take the time here to here, this is my period; this is my T actually equal to 2 pi by omega; actually we should strictly use omega e T e; let me say it is… I mean I am using this, this way, whatever the period is.

Now, the roll signal may look something like that, or rather let me make it dark only. Now this is Roll signal phi equal to phi a cos omega T e plus e phi. I am writing it this way. Now, what is e phi? That is what we want to find out. First of all, we understand that here, this amplitude is phi a; here also sinusoidal function. And if you see the period, now, this to this, same thing as T, but what is happening is that, now if you look carefully, this distance, now this I will write with respect to another colour.

So, it becomes the same.

Yeah.

But…

No no no.

But in that shift ok.

No no see what is happening there is a shift there. See first of all, there is an amplitude different. So, when this wave is at its crest, the roll was not at this crest, the crest of the roll, the highest roll was occurring at some other time. Therefore, the question is the phase is very important to understand; it is a time gap between the response and the signal; the input and the output.

See this is a wave, now at this, let me say that when the wave was at height 0, at some time you know at, this is my T axis, at this time my wave height is this, but at that time my roll was so much. On the other hand, my roll become maximum at this time when wave height is so much, but when the wave height was maximum, then roll starts to drop down. So that there is a gap between response and your input and the output; wave and the roll; and this gap is given by this distance. How much is this distance? See this distance; this distance; that is when it is 0, when it is 0 or any other equivalent point, you can take these two the same thing, because it is repeating.

What is the difference or by what this signal is in this case leading or lagging the other signal? You know that in this case it is leading, because it is occurring before, and then this, and this the distance is exactly what this distance is going to be, what is we are calling this phase angle e phi. This is the measure of e phi; this part. So, what is, if you, if

you actually find out from here, you will find out that, that this the way the graph is that, this cos curve and sin curve exactly it will match this; see one curve is just cos omega e, one is cos omega e T plus e phi, because it is plus e phi, it is occurring like this. So, this tells me the phase gap between the two.

Now it is very, I do not know how to explain, but in the video, but see, if you take a see-saw, you know, if you, what you call, that is this children's game where you do like that in a…. You know, you take a spring on a ball, you do like that, ball wave also oscillate. You observe your hand and the ball motion, when you are sometime tired, the ball is not exactly down, there will be a phase gap; you do, eventually you will see that sometime the ball is coming down and other time it is going to go up. So, the ball will fall; it will go something like that; that is a something like that; not exactly same; this is the phase gap; when you are pushing down, little later it starts getting pushed down. Then when you are start pulling up, it is still going down, and then, little later it goes up. So, that is what is called phase gap, you see.

That the, you know, anything, you go like that with a bag, go like that, you will see that the response and your hand movement, there is a difference. This is a most interesting way of looking at the phase gap. You have to understand that, because phase has a (( )) of a lot to do with respect to ship motions ultimately; cause if, you know, there was a same phase you are having much difficulty.

This is a very interesting example, that you should realize, when you do that, any movement, you will see there is a… in a video, it is difficult to demonstrate this thing but, because phase is a very, very important concept. You must understand that you always write, in this case, of course, what I have done is that, I have written it to be 0 wave and this is to be… I can write say number of signal. I can write it a signal a cos omega T plus beta 1; another one as a 2 as cos omega T plus beta 2; another one, etcetera. All that we have will be that, one is happening here, another is happening here, another is happening here; that is beta 1, beta 2, etcetera, will actually tell us the difference between the happening of the between signals. When this is maximum, the other one becomes maximum so much time later or earlier, whatever. So, that is the most important part to realize as far as this phase is concerned.

Now we will find out an interesting part - phase between velocity, acceleration and displacement. You see because what happen, because it is all time dependent.

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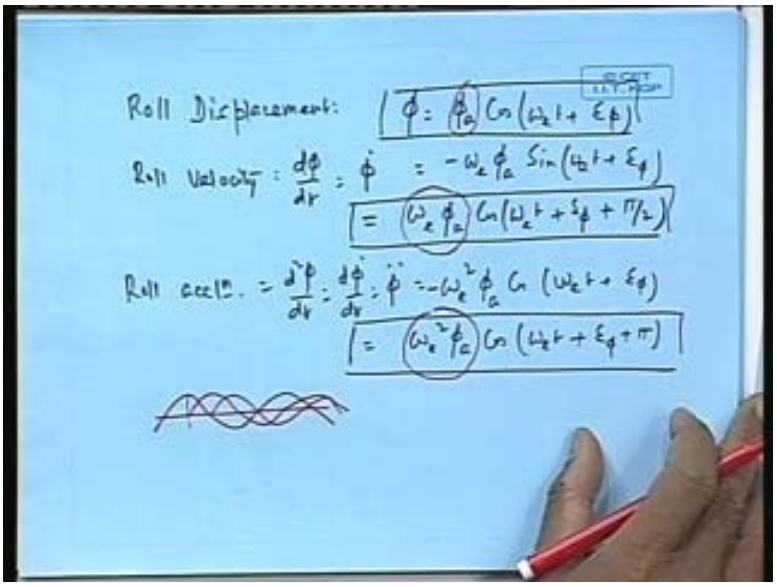

Now, I have got roll. Now what I said is roll? When I said roll, I made actually roll displacement, remember. That was written as phi equal to phi a cos omega e T plus e phi. Now, what is roll velocity? It is going to be phi dot, if you know, that is d phi by d T. If you do that, what you get? You get here minus omega e phi a into sin e phi and this can be written as, actually the here there with omega e phi a into cos omega e T plus e phi plus pi by 2. Roll, acceleration.

You know, like second differentiation of displacement or first differentiation of velocity phi dot dot equal to here omega e square phi a cos becomes sin now; no this will become sorry, this is how we are doing here; sorry sorry. So, sin becomes, this becomes cos. So, it is minus omega e minus omega e square phi a cos omega e T plus e phi; this can be in order to make it…

So, you have got this as displacement; this as velocity; this as acceleration. What you see? Important points: number one - is amplitudes, you see that this displacement of amplitude of an phi a. What is the amplitude of velocity? It is omega e phi a; amplitude with the maximum that can occur. What is your amplitude acceleration? It is omega square phi a. Now you see what happens? That is one thing you can find out, that as you

go down, go up rather, displacement to velocity to acceleration, the amplitude gets multiplied by frequency – number one.

What about phase? The phase between displacement and this thing is 90 degree; though it is at least 90 degree leading. And then, this to this is another 90 degree or this to this and this is 90, another 90, 180 degree. So, you see when the roll at its highest plus, then acceleration is highest minus, and things like that. When your this is maximum, this is 0, these two are 0, because when this is maximum, this will occur actually when this, you know, the way it is this will be 0.

In other words, one will go like that, another will go may be like that, another will go like that, and the amplitudes are all multiplied by omega square. Why I say that this is important? In fact, this graph I can…

Before that, I will show you perhaps this graph is here.

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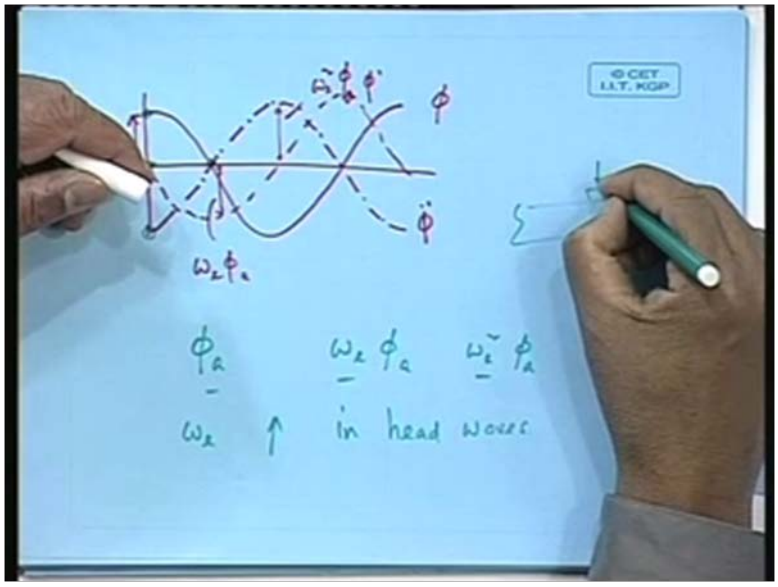

So, I have got here phi going, this is phi. Then I will have here phi dot, and then, I will have here… this is, this is what will happen. And amplitude, this will be equal to say phi a; this is going to be omega e phi a; and this is going to be omega e square phi a. I mean, I do not worry about the writing if you cannot see it, but the point is to tell you that there is a relative phase gap. See here you can see, when I have got my maximum roll

displacement, I have got a 0 roll velocity and I have got maximum negative acceleration. Similarly, when I have got maximum acceleration, I have got 0 velocity, like this.

Second thing is that omega e square. See I have got omega phi a, omega e phi a, omega e square phi a; this is very important. When you are heading into waves, omega e is going up, in head you are increasing frequency. So, the acceleration frequency goes up even further at a higher rate, you see, acceleration, because omega e square term comes in.

They should square times…

Yes.

So, what happen is that, also if you see, that means, that if supposing, this is also make sense. Something is going like this, it has some velocity; same thing it went much slowly, it will have much lower velocity. You see, if a signal is repeating every 10 seconds, you have some velocity. If it is a same signal, same 10 degree was repeating every 5 seconds, it will have higher velocity, because it is going and coming back and forth in 5 seconds time. So, that is acceleration going to be even higher. So, this is why your acceleration and velocity goes up in head waves very much.

So, when you are going in head waves, you have got a very high acceleration. Why it is important? Supposing I have a equipment on a ship some point here and equipment here. Now, this is the acceleration on that comes as a load - mass into acceleration - on the say gun mount, for example. There is a gun there; there is a gun mount. So, naturally, if it is accelerating very much higher, then you have to account for that. So, it is not only displacement, it is not only the fact that it rolls 10 degree, but this 10 degree occurs how fast, you know, you know, becomes a issue. We will see later on, that it is a velocity and acceleration that causes it to vomit - the sea sickness; there is a certain combination in which you tend to through up.

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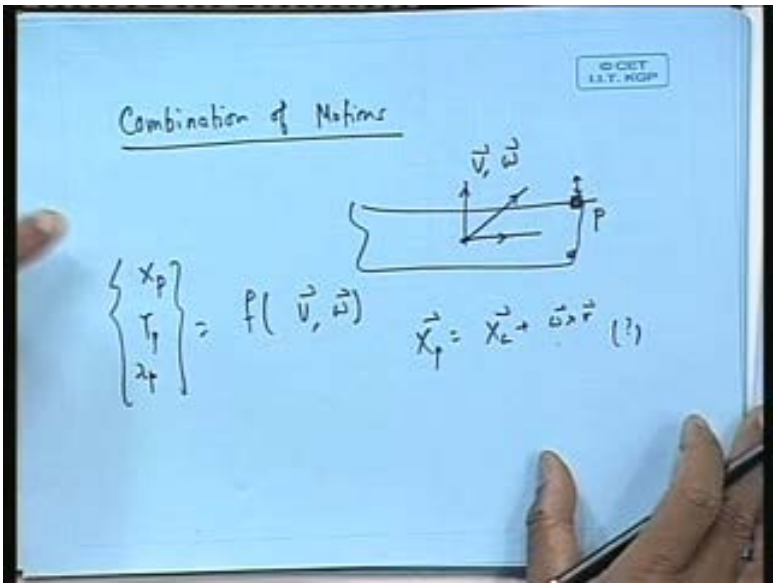

Now, we will talk about, we have to discuss this more little bit. Now, you see, in very generic term I will try to say about combination of motion. Now, if you see a ship here, now, it is this point, axis, that I have found the motion, velocities, etcetera.

So, I have got here, you can say velocity vector and a rotation vector. Now, if I want, for example, to find out this point or this point, how much it is accelerating, at any point p on the hull, you can find out the displacement c at x p or y p or z p, as a function of V and omega. There is a relation actually, you can you can find out at the x p probably equal to x into G plus some omega cross, some formula is there, omega cross r or something like that, I do not recall. This may not be may not be question.

But what I want to say here is that, that is not important. That you can find out now, if you knew the six motions - primary motions - you can combine them to find out motions at any other point. Example here - suppose you take this point here p, now this we will work out; this is most important point about vertical direct heave and pitch combination. We will try to work it out this one. So the combined, you take a point here, some point here.

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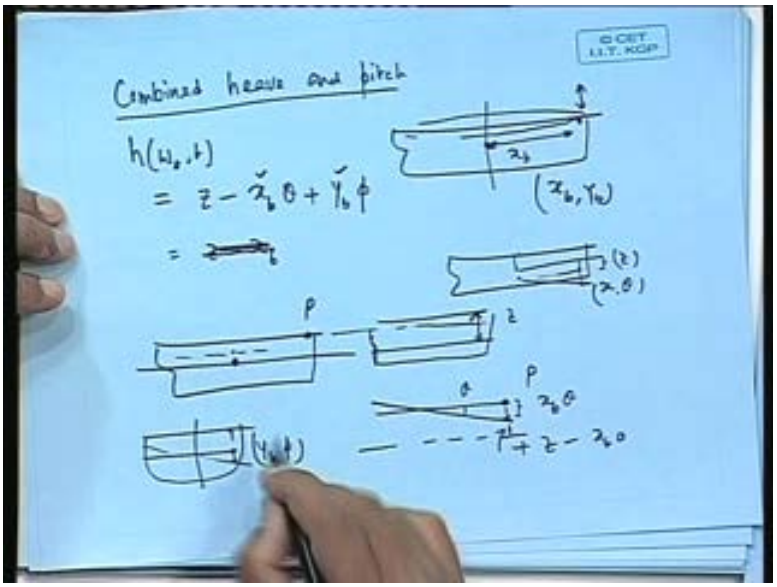

Now, your this, this height that will goes h omega e T; this is going to be equal to Z minus x b theta plus y b phi. Actually we can call it, we can call it a. Now, we can, we can write it like that. See, supposing I take a point here which is located x b y b. Suppose I take a point here, somewhere, which is located x b y b. What happens is that the vertical height, how much it moves, will depend on how much this full body moves Z plus how much it is pitched, because supposing this is x b, then if it has pitched by angle theta, then it will actually have Z value of x b into theta. So, there is an contribution comes out.

Similarly, if it is rolls, because if it is on the centre line, it will have y b into phi. What I mean is that it, you, you can find out that, this actually this can be example given more. See, if supposing, the ship has come down, this point will come down by an amount. So, this will come down by an amount. And it has pitched further, then it will come down a further amount. So, you will have here is that and here is what you call x into theta. You see, if you carefully see, essentially the displacement of any point becomes sum of combination of the heave, roll, pitch, and all things.

So, here if I am looking at how much it is a point located at x b and y b will heave, if the ship gives by an amount Z, pitches by an amount theta, closed by an amount phi; it will become Z minus x b theta plus y b phi. Do you

Sir, angle of moment will be there and heave will also be there.

Yes, now. So, so here actually this picture let me, let me show this picture in a in a break form. Now this is my ship. So, it has first just heaved. So, it has heaved means it later on heave means gone up here. So, it, let us say, it has heaved here. So, the ship has gone up by this much. So this point has now gone up; earlier it was here; so, it has gone up by an amount Z. See, supposing the ship was here, and the point was here, this is my point p. So, this point, now the ship is gone up by amount Z; therefore, this p point has gone up by an amount z.

Point one - now on that, now this p point is… now I will just draw this line p point; this is now, the my p point is here; this is my axis; this p point has gone up by Z. Now this p point is going to have a pitch. Now pitch positive is pitch down. So, it has got pitch up theta degree. So, it now, it has pitched by theta degree. So, now, it has come down by an amount of x b into theta. So, now, this height has become plus Z minus x b theta. So, this is become, my, this distance is plus Z minus x b theta.

Now, if you see this point to be actually on the roll side; actually here the ship has rolled further. So, as I rolled, this point would have come down by this much distance, which will be y b into phi. So, if you add them all up, this points total vertical displacement, the total vertical displacement is going to be the rigid body displacement, because of the ship hull, that is the ships heave plus depending on this location and the pitch of the ship. So, the pitch of the ship would make it to go up little more or down, and roll of the ship also is going to make it go up or down. So, therefore, you can, if I knew this Z, and theta, and phi, for any point I can combine them to find out what is my desired displacement.

See there is a crane point here. You want to find out how much this crane point will go up? So obviously, it will go up. First of all, if the ship has heave 2 meters, it will go up 2 meters, but it has also pitched, because of pitching it has gone up by some other angle, also rolled by some other. So, you can add them up, you get the total; that is the point I am making here. So it can be linearly combined to find out these motions, very simply.

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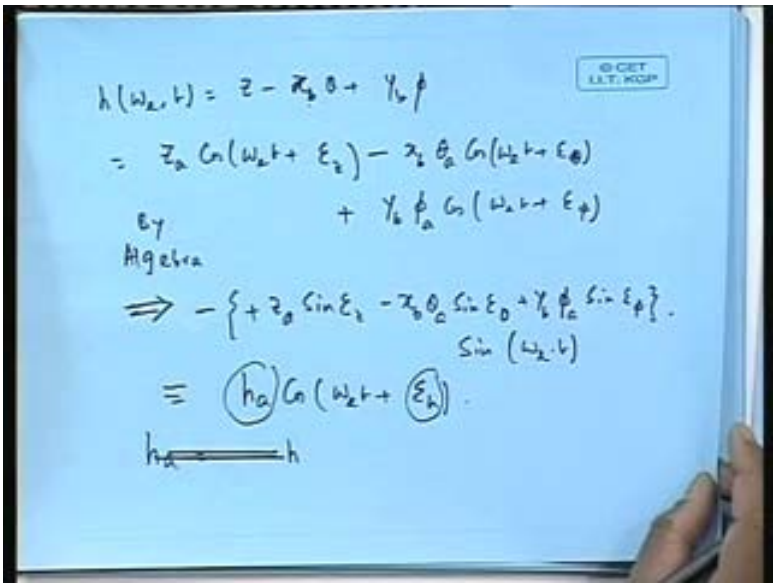

Now, why I say that, because you see this interesting part is that if you linearly combine here. So, we start with this. Here again, Z minus x b theta plus y b phi. Now, I am writing all these in combined form. See Z was my, Z a into cos omega a T plus eta Z; this was my Z, minus x b was x b, theta was theta a into cos omega e T plus epsilon theta, and y was plus y b into phi a into cos of y a T plus e phi. If you do this algebraic manipulation, without this, this thing by algebraic, I just write here by algebra, you can, this will turn out to be equal to minus of plus Z a sin of e Z minus x b theta a of sin of e theta plus y b into phi a into sin of e phi into sin omega T.

See what happened is that you can write… this we do algebraic manipulation add them all up, you know, in a cos cos a plus cos b as cos a cos b etcetera etcetera, it will turn out to be an expression of something into sin omega e T, which you can write as equal to, as if, h a into cos omega e T plus e h. See you can express this, this full thing again as a sinusoidal function. My point of saying all these is that, these when you combine them, this is a sin curve; this is a sin curve; this is a sin curve. You add them all up. What you get this, this expression will also be a sin curve with an amplitude and with an phase angle; this becomes equivalent to that; you can actually work out how much is h a, actually. It will be, it will turn out that h a will here become h, you know, one can find out this various ways.

This ultimate value be at a particular instant.

That is no no no no see let me.

What is this changing?

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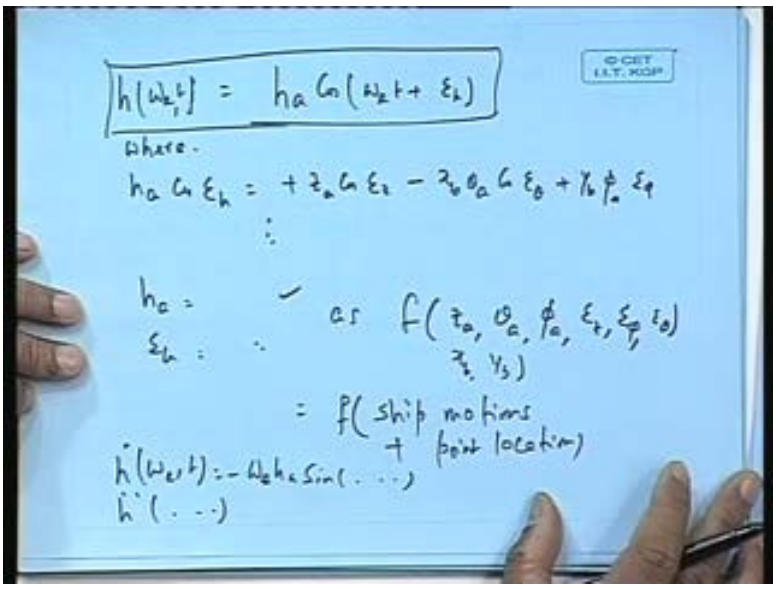

Let me just complete that; here then again I will write…. Now, therefore, what we get h omega e t.

Sir here h will denoting number.

Vertical (( )). It has become h a into cos omega e T plus e h, where h a cos e h is equal to plus Z a cos e Z minus x b theta a cos e theta plus phi b phi a a phi etcetera etcetera. And h a becomes, you know… you can find this h a and e alpha expressions as function of…. I… let me write Z a theta a phi a e Z e phi e theta. Basically what happened, you will get an algebraic expression, never mind they are tedious algebra all right, but you get an algebraic expression, which will tell me that this can be expressed as this form.

Now, you are asking this question - whether it is instant time? No, this is actually height at any time omega e and any time T. So you see, the point has a vertical displacement; obviously, that is changing with time; any time it has value; that will obvious can be expressed as something into cos omega T plus e alpha, which means that can also be expressed as if it has an amplitude and a phase angle. This is not, this h a is not changing with time; obviously, h is having a time function, because h is a function of T.

Why we say that? The reason we are trying to say is that, if you combine motions, which are sinusoidal, it turns out that motion at any other point also is a sinusoidal, and the amplitude of that motion at any point and the phase can be simply by written in terms of the amplitude of those, the location of the point, of course, the location of the point will come here x b y b.

So, it becomes function of, I can write, of ship motion plus point location; if you know the point location, if you know the ship motion parameter - that is heave roll, pitch, the primary motion - you can combine them, and motion at any point becomes nothing but some kind of combination of those; that is all, but it is also a sin function; the most important point is to say it is also a sinusoidal function. So, you see, now if this is sinusoidal function, you can now find out h dot omega, this is also sin function, because it becomes nothing but omega e into h a minus into sin etcetera and h dot dot also become a sin function.

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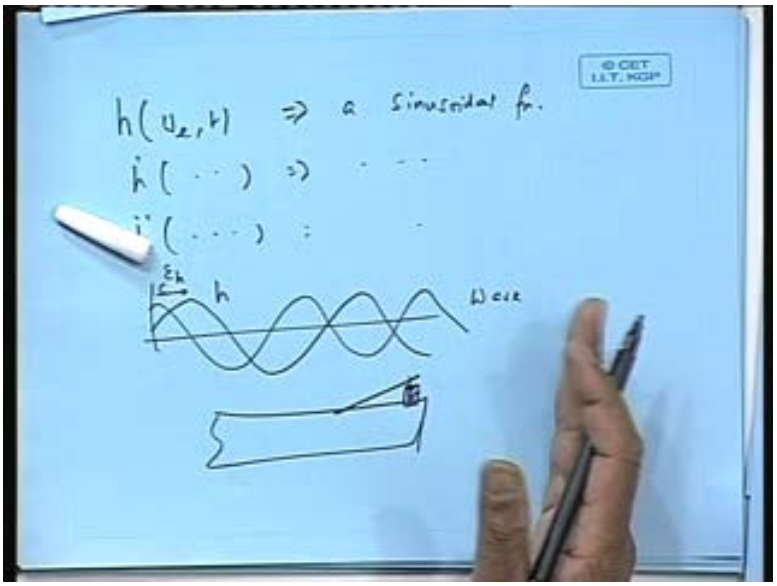

So, I will just sum it up. See, basically, what I am trying to say is that h becomes h omega also becomes a sinusoidal function and so is h omega dot dot. So, if you plot now, you will find that supposing I start with h, this may be my wave and it will, if you work it out, it may be the this this might be my h h. So, what I am trying to say and obviously, then this will become my so-called e h. See it is… the interesting point of this is that to

get motions at any other point or anything that you want, everything is dependent only on those first six motions.

If I figured out by heave, roll, pitch… surge, sway, heave, roll, pitch, yaw then anything else that I want to know, any (( )) thing else or anything, in any point anywhere or whatever, it will turn out that they are all expressible in terms of those basic parameters, and they are also a sinusoidal function, and any sin function the unknown thing is only two: one is the amplitude; one is phase.

So, therefore, suppose I want to find out for a ship, let me give an example, I want to find out, you want to know what is my acceleration. There is a deck crane here; you want to know what my acceleration of this point is. If I want to know that point acceleration, I actually know it is sinusoidal function, I will know everything, every time, every instant what is the value of that acceleration, provided I knew surge, sway, roll - I mean those six motions - and the location of the point. Of course, the location is a geometric parameter; so, I would know.

Why we say that is, because it turns out that ship motion, therefore is primarily dependent on those six primary motions. So, our biggest challenge would be to find out those motions. Once you find it out those motions, the complication is maximum to find out those motions. So, I just write the summary.

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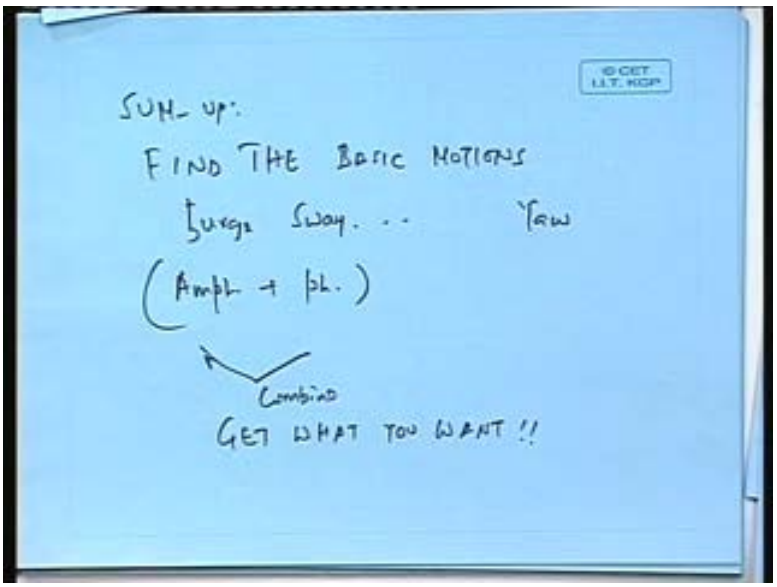

Find, that is you know, surge, etcetera, yaw. What you find? Find amplitude plus phase. So, if you can find this, you can combine these to all together, get what you want. I will write that. You see…

I think by phase to mean the wave angle.

No, not wave angles; the difference between the… when it is occurring, when it is occurring with respect to the wave.

Back the lag of wave.

When, let me say when it is occurring with respect to the wave. If you know that, the rest part is pure simple algebra. So, what, while stop here because, I want to now; obviously, knowing that we have to figure out how we can find the basic motions; that is the most biggest challenge, which we do not see.

As a practitioner, you know, most practitioners will be bothered about this, because what you want is what is ultimately you are interested, but to get from here to there is actually algebra, simple algebra. To get to this point is the most difficult point, you know, but here to here is absolutely simple algebra; it is just question of two more pages of just doing… it is like if you have add 10 tables in a figure, it is just tedious, but nothing brainy.