Strength and Vibration of Marine Structures

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Lecture - 14
Longitudinal Bending of Hull Grider – II

Now coming to the buoyancy distribution, now ship is designed usually for a life period of 20 years; I think that is an accepted norm allover without saying unless, otherwise, stated one takes it for granted that launcher ship is designed launched and put it in service will last for 20 years. It will try to earn revenue for the organization for the shipping company for 20 years without failing. Now during these 20 years of expected life, it will undergo different types of loading conditions which are market driven, seasonal and so on, so forth

So, one particular loading condition we do not know, what is that loading condition, but we know one thing that the total weight component which we have talked about the two of the weight component that is the hull and the machinery and semiconcentrated items; that is light ship of the vessel, it can never come down below that. So, that is one which is constant throughout the life. Cargo, yes, it will keep on changing; depending on the availability of cargo, the type of cargo, the type of pattern of business and so on, so forth. So, that part will keep on changing. Depending on that the buoyancy distribution will also change, because weight has to balance by the buoyancy, and therefore, the buoyancy will be changing. Now how the buoyancy distribution will change?

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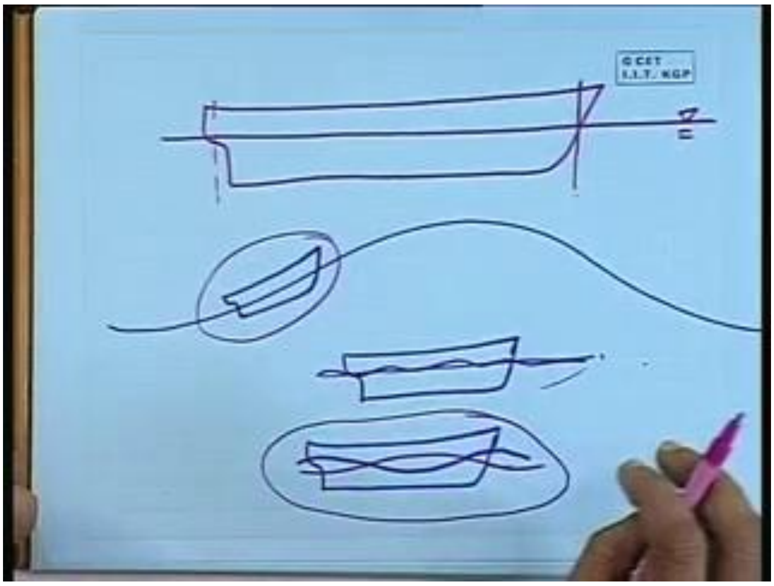

Now the ship can be considered to be floating in calm water; when do we see the calm water? In actual operation you people will know better than me that there is no situation when you can consider a ship to be sailing in calm water, very rarely; even I would not say that is a calm water condition. And moreover when the ship is sailing, the surface is never calm because the ship generates its own wave pattern, okay. So, it is never a calm water condition. So, what is the wave condition we should consider in which the ship is floating?

Now the sailors have designated right from calm condition buffet number 0 to 11 or 10 whatever it is to cyclone or hurricane, okay. And according to the definition different wave patterns can be seen in these conditions and we have also studied, and we say that the ship should be in position to even sail during the hurricane condition. It may be tuff for the sailor; it will be tuff for manning the vessel, but still you should not try to disturb the route and follow the predetermined route to go to a destination even under adverse condition; ship should be still in the safe floating condition.

Keeping that in our mind what type of forces will be generated? Now I can consider this particular ship to be floating; I will just try to draw few diagrams here. One is that it is a very big wave is there with wave height, and the ship is floating something like this. This is one condition; it is moving in a big wave. There can be a condition when the ship is something like this and the waves are like this. There can be a condition when the ship is something like this, and this may be a wave pattern, or this may be a wave pattern.

You see the second diagram which I have shown, the ship is floating in waves which are very small wave lengths having very small wave lengths. Let the picture down below is a ship more or less floating in a wave, the wavelength of which is more or less equal to the length of the ship. And the top one is a ship which is floating in a wave, the wavelength of which is much larger than the length of the vessel. Out of these three conditions, which condition is going to give me the worst possible buoyancy distribution?

This condition if you just try to enlarge this, it looks like the top figure. This if you enlarge it looks like this only, and if try to draw a mean line here, then this also gets reduced to this itself. So, it is this condition which will try to give you the worst possible loading condition, because the loading is weight minus the buoyancy per unit length. And here we see the visible difference in the buoyancy distribution, okay. Now under this condition, sorry, here again we have depicted two wave patterns. In one case we are saying that there are the crests are at the perpendiculars and the other one we say that crest is at the mid ship. So, anyone of them can be one of the worst conditions.

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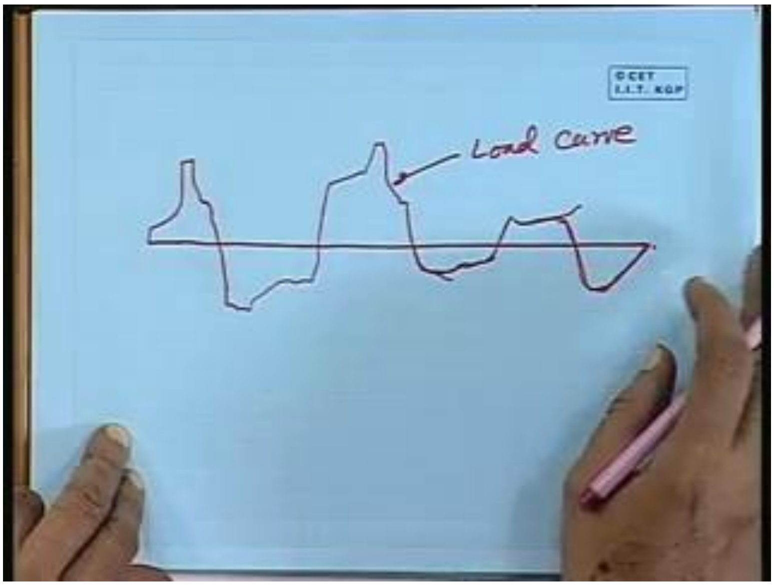

Let us assume that worst condition and take the loading and I draw the load curve like this, okay. Now how many such condition should I consider? Because I said that the life of the vessel is 20 years. Let me assume that every two weeks one sailing is there up or down. Now two sailings means in a month you are going to have, say, around 20 voyages, and in 20 years you are going to have say 400 voyages. So, before the ship finishes its life theoretically, it will sail 400 times; 400 times what loading pattern it will have? I do not know and what will be the sea condition when it is floating? That also I do not know.

But I have to ensure that for these 400 voyages, this vessel is still same, and therefore, the usual proposition will be considered the worst loading condition. Now worst loading condition can be an extreme worst for which I am not going to design the vessel. So, I may go for a statistically worst loading condition; these days the statistics is coming into picture, okay. So, now what are the loading conditions I should consider? Now depending on the cargo pattern, these days we are having product anchors; we are having one-way traffic in a vessel you go taking the cargo and come back with empty holes.

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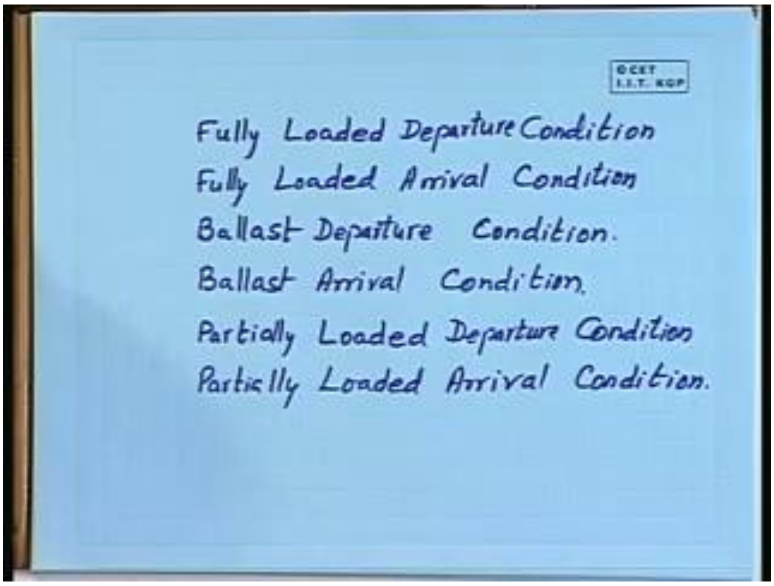

So, I do not have to tell you that because you know all the terms, and therefore, we have a fully loaded condition. I have ballast condition, and I have partially loaded condition. Under each condition you have a departure condition and you have an arrival condition. When you depart from a port you are having all the consumables intact; when you reach the destinations your consumables are consumed. Fuel oil is consumed, lubricating oil is consumed, fresh water is consumed, and all provisions are consumed.

So, it is a fully loaded departure condition. Then we say fully loaded arrival condition, ballast departure condition, ballast arrival condition, partially loaded departure condition, partially loaded; there has to be another one here, arrival condition. What do we mean by this partially loaded condition? There are two things we have already talked about that the ship has to be economic; it must maximize the profit and so on, so forth. We talk about the profit and then when all the expenditures are met, then only additional revenue will go towards the profit. And therefore, there must be something as a breakeven loading condition which will give you the profit.

We should not consider the vessel to apply below that breakeven point; otherwise, the company is definitely going to sink. So, that is one partially loaded condition we can define which will give you a breakeven condition. Another one, how do we consider that breakeven loading condition because it is again a function of the freight rate, and freight rate can change from season to season. In this 20 years even year to year basis, the freight rate may change taking into account the inflation, whatever is the competition, and if in a particular season you do not have much cargo, then you will try to reduce the freight rate to get more cargo to operate it in a viable condition.

So, it is a very difficult proposition that how do you define what is this partially loaded condition. We said that 400 voyages you can make now which of these 400, what is the loading condition? We do not know. In absences of all these we say that if you do not have any such figure, we say that 60 percent partially loaded condition. Whatever is the vessel designed for, you take 60 percent of that as the load, and the last two conditions you fill up with that. So, one is a fully loaded condition; another is a fully empty condition, and third one is partly loaded condition. So, we consider these six conditions as the conditions which may induce the worst possible loading to the vessel during its entire life.

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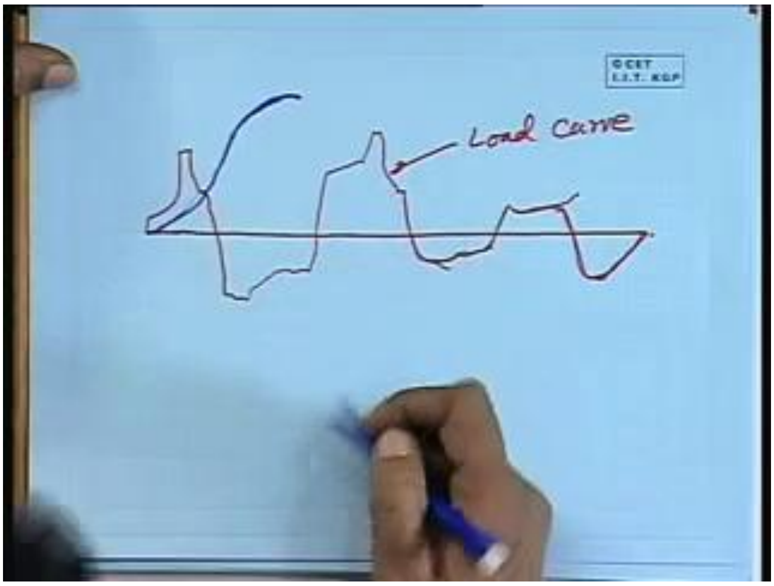

So, under this condition we take one of them, and we say that this is the load curve. Now we go back to our basics and we will say that if you integrate this load along the length, then we get what is known as the shear force curve. So, if you try to integrate it, how it will go is something like this; it will keep on increasing. Then there is a point of inflection will come; it will come out like that, and then the rate of increase will decrease, no sorry. I have drawn a wrong curve, please eliminate this.

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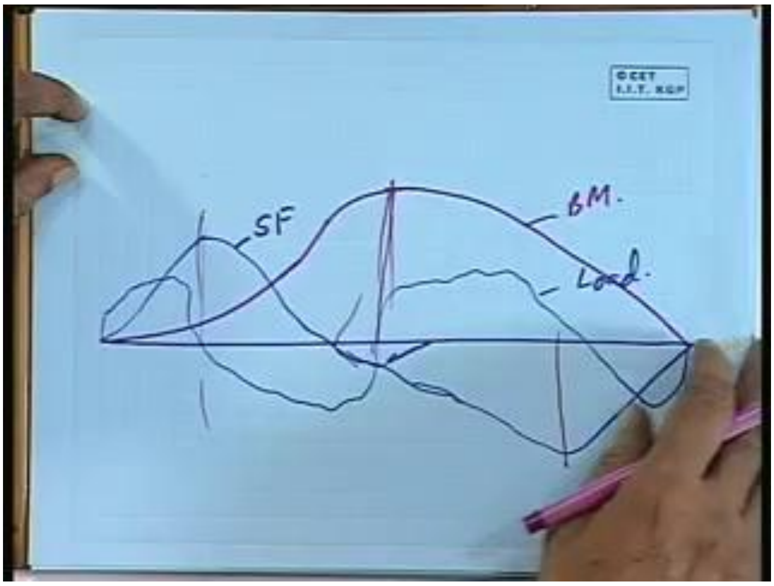

Okay, let me try to do from here. It will keep on increasing till this point here, okay, and then it will start decreasing and somewhere here may be that it will come down, okay. Then this will be some perturbation here, then it will reduce; reduce means it will increase on the other side, increase, increase on this side. I think it has to increase like this only. Anyway let me try to draw it a standard curve. So, this is what is the shear force curve, this is what is the load curve I say. And then when you try to integrate the load curve, it will keep on increasing till it comes to this point here, and then it will start decreasing, and it will become 0 somewhere here. So, this becomes a bending moment curve, okay.

So, once you have this type of a curve, then we see that bending moment will be maximum somewhere here where the shear force is 0 here; sorry, shear force is 0 somewhere here. So, somewhere around in the mid ship region it will be maximum; shear force will be maximum somewhere here, and another value will be somewhere here.

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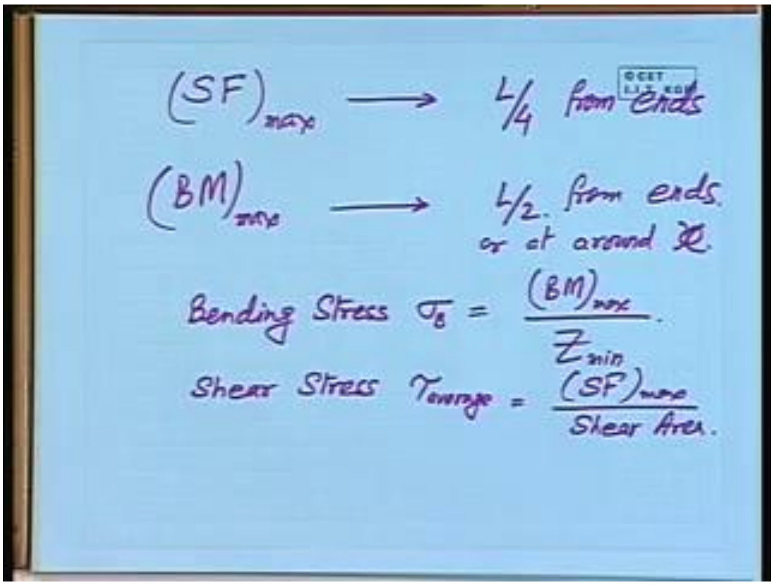

So, what we can say is that shear force maximum value is somewhere at around L by 4 from ends. BM will be maximum somewhere near L by 2 from ends or at around mid ship is the same thing L by 2 from ends or at around mid ship, but we are not interested in the shear force value or the bending moment value. What we are interested in the stress which the material can withstand.. So, we try to find out what is the bending stress? Bending stress this notation is sigma B which is equal to BM max by the section modulus of this section.

Now the section modulus is Z, and Z should have the minimum value there. We will come to this later on once again, because when we take the mid ship section, we will find that Z minimum will have two meanings here. One for the deck and one for the key, and regarding the shear force, we have to find out what is the shear stress. And we get shear stress tau which is basically average shear area. We do not get tau max A; we get the shear stress average, okay.

Now this what we would like to find out? And this we should calculate for those six loading conditions or those six defined conditions at least, and whatever is the absolute maximum stress for the shear and for the bending that we will say that this is what we expect is going to be the maximum during the 20 years life or the expected life of the vessel. And that stress value we will check against the permissible limit of the material. Usually these days you will find that for normal mild steel, the bending stress or the normal stress value is specified as 135 Newton's per millimeter square.

So, if the bending stress works out to be less than equal to 135 Newton's per millimeter square, then we are satisfied. And the corresponding shear stress maximum value may work out to about 105 Newton's per millimeter square. That is the maximum not the average, okay. So, this is what we would like to see whether we are going to get this much or not. Now we talked about the buoyancy distribution, we talked about the wave length; we have not talked about the wave profile. Wave profile will define what is the wavelength and what is the wave height.

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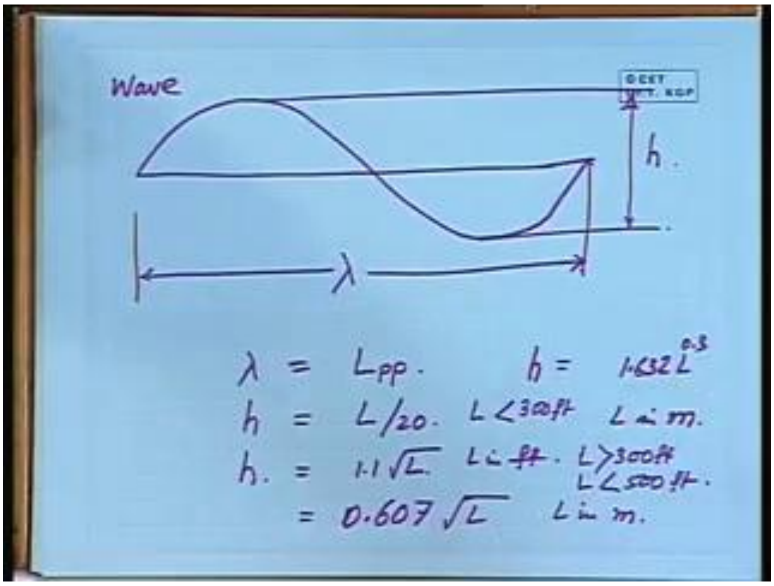

So, if we talk about the wave pattern, you take a wavelength. This is known as lambda wavelength, and this is the wave height. We talked about lambda that it should be somewhere near the length of the vessel, why near? We will say that for our calculation purposes we will take lambda is equal to length between perpendiculars. What is this height? So, we say that lambda is equal to LPP, and how much is height? Height has also to be defined.

Now height is taken as L by 20 for ships less than 300 feet in length. It is taken as 1.1 root L for ship more than 300 feet in length, and then it is also taken as a different formula. This is L in feet; let me write L in feet which is equal. Here it is dimensionless, and here it is if we want to convert it, then 0.607 root L L in meter, okay. Another one formula given is 1.632 L to the power 0.3 where L in meter. This is applicable for L less than 300 feet. This is L greater than 300 feet but less than 500 feet, and this one is applicable for length beyond that length of the vessel.

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L (m)	L/20	$0.607\sqrt{L}$	$1.632\,L^{0.3}$
60	3.00	4.71	5.57
90	4.50	5.76	6.29
120	6.00	6.66	6.86
150	7.50	7.44	7.33
180	9.00	8.15	7.75
210	10.50	8.80	8.12
240	12.00	9.41	8.45
270	13.50	9.98	8.75
300	15.00	10.52	9.03

Now a little calculated values I will give here. If you take L in meters, how it gives you the figure; if I write on this, is it visible?

Student: Yes sir.

1.632 L to the power 0.3. So, let me complete this table here. I should have brought a Xerox copy of this to put it on but anyway 60, 90, 5.76, 6.29. Then, say, I have 120, 6.66, 150, 7.50; of course, one can calculate also. Now this gives you this table with the help of various formulae. If you see the formula, they are all empirical in nature. One says L by 20, somehow the height of the wave is coming out to be in meter; the next one is a factor multiplied by root L, okay .So, this is not a dimensionally correct.

So, one has to say it is totally empirical, and third one is L 2 to the power 0.3. So, that is also empirical, but one thing can be seen here that L by 2 gives you less value of the wave height up to a ship length of, say, 120 or 130 meter. This was invoked during the till you can say 1970 to 78 when the ship sizes were of that size. And then after the closure of the Suez Canal when the ship size suddenly became larger, then this became useless. And they have to go for this 1.1 root L or equivalent in metric is 0.607, and you can see that around 120 to 130 meters, all of them will give the similar wave height.

But if the ship's length is more than 130 or 140, usually after that period the ships length was about 180 to 190 meters or 200 meters you can say 180 to 200. Then one need not consider 9 or 10 meters height of wave rather 8.155 or eight 8.5 meter wave height is more than sufficient. And even some ships were built like logarithmic curve, etcetera of a very ULCC, VLCC much larger length. What is the point considering 15 meter wave height for that type of a ship? So, obviously, this formula holds good then.

Now this comes from the shear experience I suppose, and from the statistic that over the past record one can find out that what type of wave is occurring on the sea most of the time. What is the probability of a particular vessel encountering a wave of its own length? That is another figure, and then if it is encountering the wave of this sorted length, then what is the height of that? Now some oceanographic data is available not complete but yes, something is available for certain seas, and for those seas one can analyze the data and find out and categorize it.

We already take in our consideration that the worst condition; we have already assumed that the ship is poised in a wave of its own wave length. So, that itself is a gross assumption I should say, and what is the possibility that ship is always going to encounter that type of a wave length? It may not; it can encounter a wave length which is larger than this whose effect is less, in fact, always smaller than that.

So, the effect is you should not stretch the extreme conditions always. So, some sort of flexibility is to be brought in some way or the other, but even then we are quite conservative; we still want to consider the worst condition, worst condition, worst condition. If you consider always the worst condition, then maybe that your ship is going to become so uneconomical that you can never run it. And therefore, somewhere or the other one has to make some sort of a realistic assumption; I should say realistic assumption, and this helps in finding out what should be the wave height.

So, if the vessel is, say, up to this, yes, wave height should be taken as L by 20, no doubt about it, but beyond that unnecessarily why should you try to strain your calculation or strain your vessel when it is not going to be strained to that much, okay. Next comes what should be the shape? What I have drawn here is basically a sine curve or cosine curve. Now those seafarers who have sailed for years together, they have seen the sea waves; they report that it is not a sine wave, there is no wave near a sine wave. Now what is it that?

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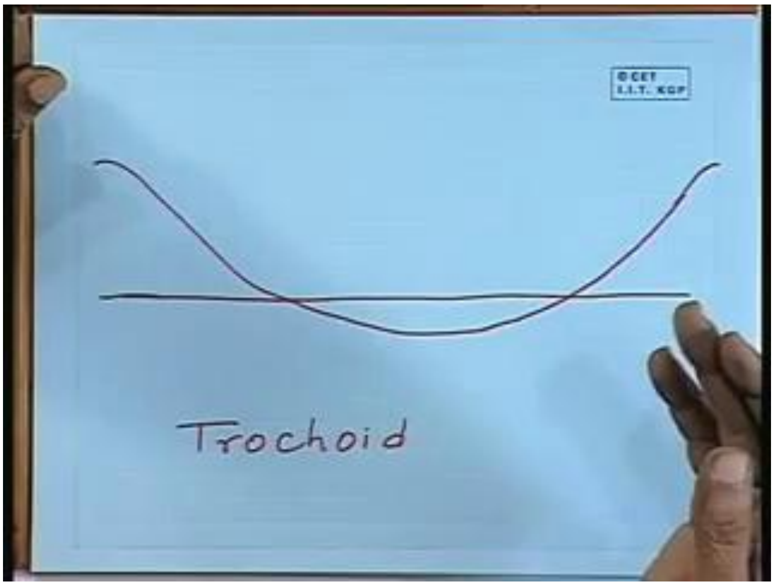

So, what one can see is you have a sharper crest and a flatter trough; this is what people have observed. It is not a symmetrical one with the same type of trough and the same type of crest. And what the analyst would like to do? We are not sailing; we are trying to do something calculation in a piece of paper, and when we try to do the calculation on a piece of paper, we make use of simple arithmetic and mathematics; that is what engineers normally try to do. You should be in a position to do the calculation in a simplified manner and try to get a reasonably correct result; that is what is the aim of these calculations.

We are making so many assumptions; we can make many more assumptions, but what the results which are supposed to be the output of our calculations should be near about what actually you see. It may not be 100 percent correct, but it should not be, say, more than a particular error limit; it should not be out more than a particular prescribed error limit. If I say that the weight of a vessel is, say, 40,000 tons, I should do all the calculations. I do not get a value of 20,000 tons, but it should be say 39800 and odd tons or 40750 tons or something very close to that, which we say it is within plus minus, say, 3 percent of the result or 3 percent of error or 2 percent error or 1 percent error or whatever it is, because that error margin I have prescribed or pre prescribed the whole thing.

So, the actual wave profile may be that we are not in a position to mathematically define like when we say sine curve or a cosine curve, it is a mathematical curve, but the seafarers who have observed the waves on the sea surface, they say that they do not resemble like a sine curve; what do they resemble? They say that it has got a sharper crest and a flatter trough; that is the nature of the curve which you meet in a sea surface. Now the mathematicians will try to tell you that where do you get this type of a curve which mathematical.

So, it is a trochoid and we say it is a trochoidal wave. What is a trochoid? Trochoid is basically you take a circle, and on the circle you take one of the radius, draw a radius, on that you fix up a point which is half the wave height and rotate this along a flat surface. So, in one round you will get the trace of that particular point which will give you one particular wave length. It will start from this position, and it will go back to that position. So, the periphery of this particular circle is equal to the length or the wave length; should I draw it on the same thing or?

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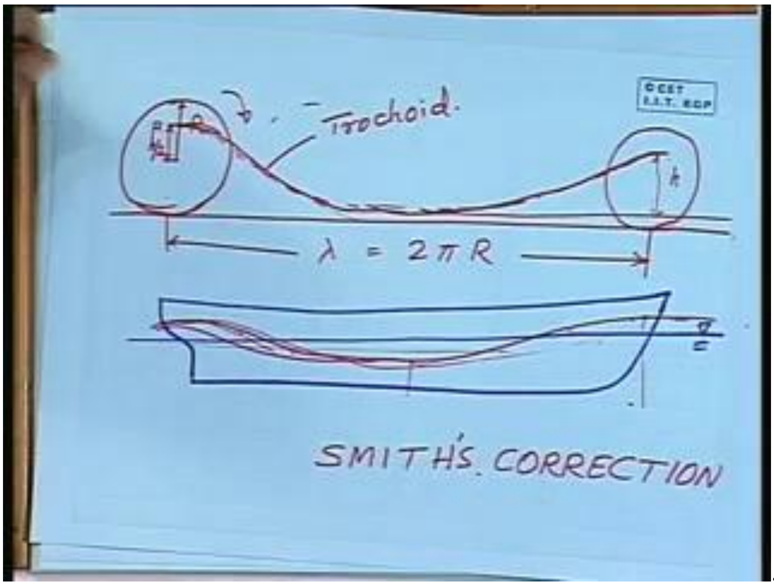

You are taking a circle of radius R. This is the surface where you are trying to roll it, and on this R you take a point P somewhere here, and this height is h by 2. So, when you rotate it here, this will come to this position, and this P point will again come back to this, but in the process this P will travel like this. It has to travel somewhere here; it cannot go beyond this know, so somewhere here. So, this will be the trace, and this becomes your h, and this length here is lambda which is equal to 2 pi R, and this curve is a trochoid.

So, now we are in a position to define a curve which we can consider as the wave profile and are mathematically acceptable to us, okay. So, now once we have this trochoid, then we consider the ship to be poised on a trochoidal wave and then try to find out that what is the buoyancy and what are the draft position it is going to attain to give you that buoyancy which is required to balance the weight of the vessel. This is what we try to do, any questions here?

Student: This point when you try to roll, what is next?

This point when you try to roll it next position this will be that thing you know; it is rotating without any slip edge. So, this will rotate in this direction.

Student: Locus?

Locus of this point P basically. Basically there is a point P whose locus is in this curve here or what we will say the trace of this, okay. So, this is how we try to find out. Now once we have got this, then what is to be done basically? How do we find out the buoyancy contribution under that particular loading condition? Now that calculation I will try to show it here itself. This part of the calculation is little tricky, and see for the loaded condition, let us assume that the vessel is supposed to float in this particular even a flat water line. It may have some trim; draft forward I have taken slightly more than the draft aft, okay.

Let us be try to be a little realistic that the vessel is moving with say heads down forward perpendicular or the forward draft is slightly more than the after draft in this particular drawing. How do you try to find out this buoyancy distribution? Now when I have calculated my weight and the CG; that tells me that where is the longitudinal center of gravity. Now the longitudinal center of buoyancy must pass through the same vertical. If it does not pass through the same vertical; that means the weight is acting like this; the buoyancy is acting somewhere else.

The difference between the two positions will try to give you the moment which will try to trim it, and moment we change the trim by 1 millimeter or 1 centimeter or 1 inch whatever is the unit which one uses that is plotted in the hydrostatics. So, when we have the weight total weight of the vessel that is the displacement, corresponding to that this displacement we can find out what is the even keel draft. Corresponding to the even keel draft we can find out what is the moment to change to in where the LCB location or what is the tons per inch of emulsion or TP 1 centimeter, how which is this? These quantities are known to me from the hydrostatic for the given bit. Accordingly, I can do the trimming calculation, find out of draft aft, find out the draft forward but for a flat water surface.

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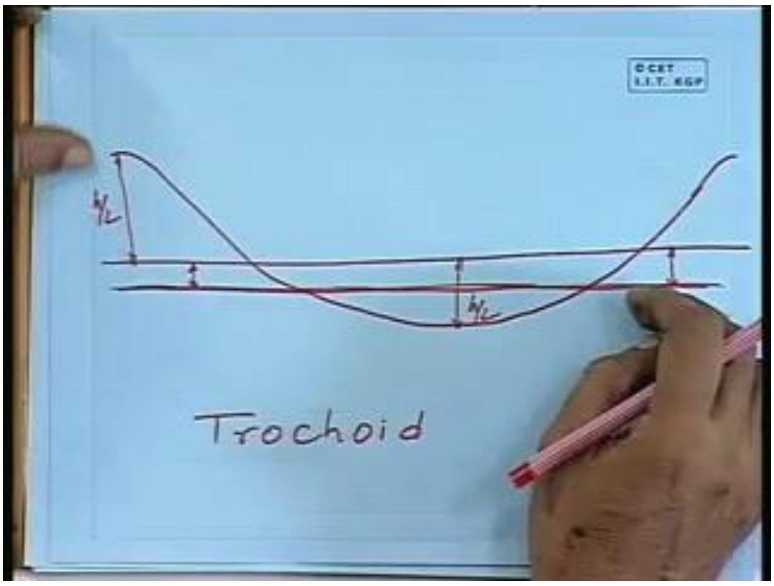

Now for this particular case, we have to consider that a line which is passing through the centroid of this curve; it is a mean line for this particular curve which normally is below the half depth curve if you call this to be, say, h by 2. This is h by 2, then this line is slightly below that; I will give you figure in the next class how much it is; actually, it can be calculated. So, what we can do because this line is passing through the centroid of this curve; that means area above the curve when we are considering only this part; that means this area is equal to this; this area plus this area is equal to this area.

So, this line we can look it. We draw this on a tracing sheet, coincide this line with this here as a first approximation, and my wave profile will be something like this here, sorry. This is the first approximation and then through the buoyancy which is drawn at each section, I can take of the area corresponding to this water line or the water height.

Integrating it towards the length or that multiplied by the density and unit length gives me the buoyancy contribution per unit length or the buoyancy distribution which I have drawn here, okay.

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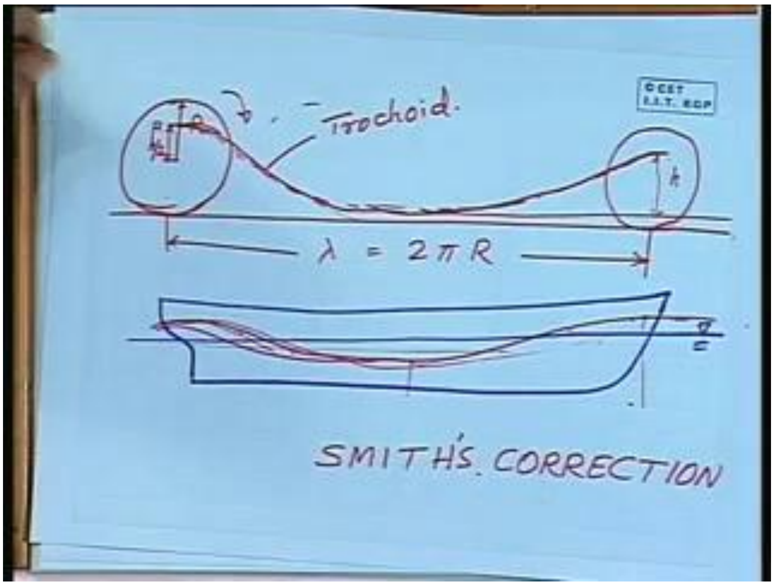

So, based on this water line which I consider that on this, the vessel is getting poised, and the buoyancy is equated with the weight of the vessel. This is the first approximation; obviously, there will be some difference, because the volume here is more, the volume here is less, and therefore, when you consider this way, it may not match. So, maybe one or two trials of calculation will actually fix me up to this position here; that itself is a detailed calculation how to consider it, but once that is done this ordinates of the areas submerged under this particular water height gives me this buoyancy distribution.

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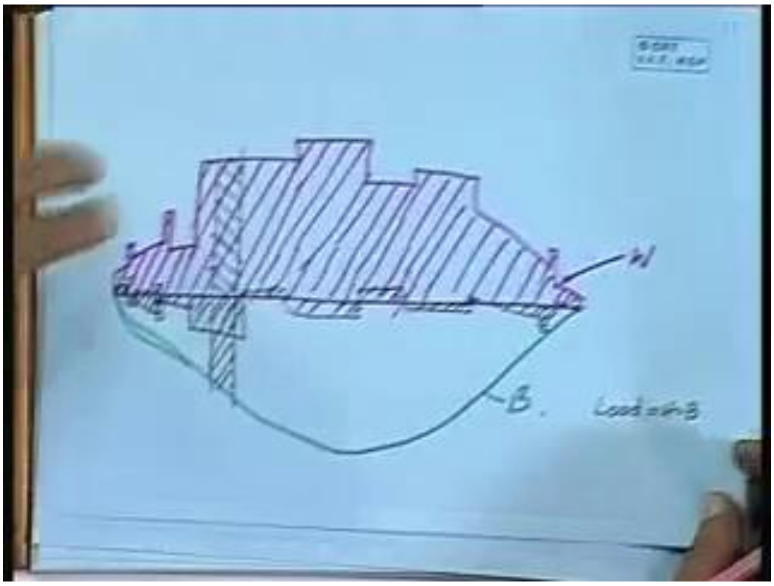

But the hydrostatics or the hydrodynamics will tell you something else. It says that if I consider this as the water depth, it is not that true, because when the waves are being generated, the water particles are under motion, and they go under some sort of a circular motion there. And because of that, the pressure here under this head will be slightly less than what exactly the static height will give you, and considering that trough, the pressure height will be slightly more. This was first brought out by Mister Smith, and he proposed a sort of a correction which is named after him, Smith's correction.

If we apply Smith's correction to this curve, then under the static condition we get the buoyancy distribution, but that correction is so negligible or so small in amount that we more or less ignore it from our calculation and observe it under the engineering accuracy or inaccuracy, whatever you call it. We try to ignore; though, Mister Smith has proved that it is not correct, and he has given the method of making some corrections to the buoyancy distribution, but still because the correction is considered to be tedious by the practicing engineer, they do not want to correct it and consider it to be removed from here.

So, we normally do not consider the Smith's correction. The whole process is basically a dynamic condition, but we do not consider it to be dynamic. Dynamic in the sense that water particles are under movement, then only the waves are been generated. Waves are there in the sea, and the ship is poised, ship is moving etcetera, etcetera, but we take a still photograph under this condition and try to analyze it as a static condition, okay. We have also made neglected the motions which are being generated over the six axes, and the force is generated by that.

Of course in the final calculation for the stress or the parts which are vulnerable to these accelerations; say, for example, the extreme forward and the extreme aft, the pitching motion will definitely have a long effect, and we cannot ignore it and we consider those. And of course, the rules are also taken into account, and that is why in the fore body and the after body, the rules tells you that how the forces are to be taken. So, this much I wanted to cover today; I do not know if you have any questions, we can discuss over that.