Strength and Vibration of Marine Structures
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Lecture - 35
Calculation of Natural Frequency of Hull Girder

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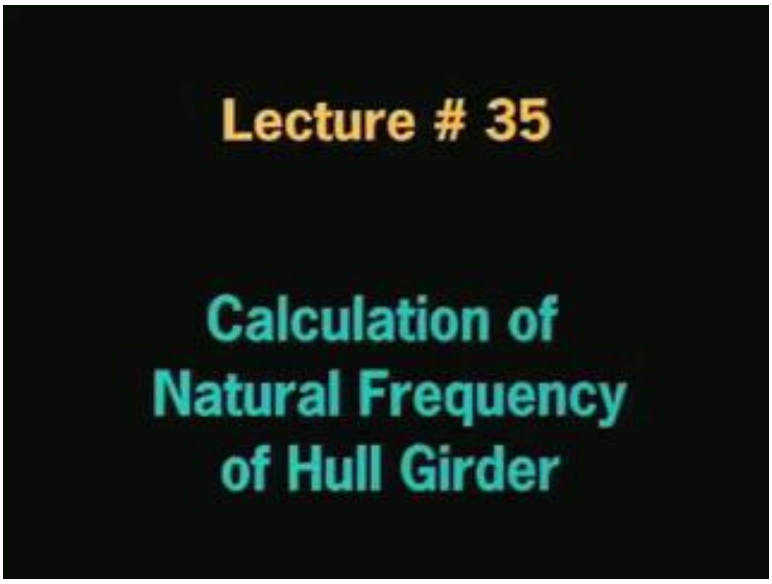

Yes, now it is ready.

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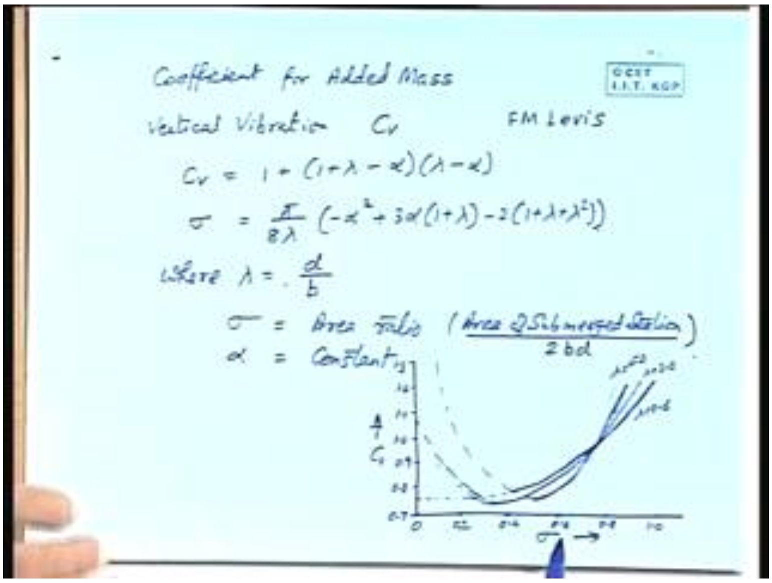

So, let us start this Coefficient for added mass vertical vibration Cv. So, this is the coefficient and Levis has given this expression Cv is equal to 1 plus 1 plus lambda minus alpha into lambda minus alpha. I do not know how he got all these expressions. Then he says in which sigma is some another coefficient involved 8 lambda minus alpha square plus 3 alpha 1 plus lambda where lambda is equal to d by b sigma is the area ratio and alpha is constant as defined here. Now, this area ratio is area of submerged section divided by 2 bd. This was given by FM Levis or Levis, as people call.

Student: Sir, d and b are small d and small b

Say b is here it is defined; b is the half breadth and d is the

Student: Half breadth and water plane and half breadth of

D is the depth of submerged portion. Now, actually you see, the whole thing is looking very complex here. What is to be done is sigma is to be found out and this lambda can be obtained by seeing the section. So, if you go back to this particular expression, you will find that sigma is known, lambda is known; so lambdas are known here. So, what is unknown is alpha and this alpha can be calculated from this expression is around about 9. Then this lambda is known and alpha is obtained from here. These two when you put it back, then you will get the CV.

So, what normally happens, that the engineers always want something readymade and who is going to do all this calculations? So, this has been given in terms of a diagram available for engineers, which has a representative. I will just plot it here. This is 0 1 2 3 4 5 6 7 8 9 I think I can write it here; 0.2, 0.4, and 6, 1.0 and CV is plotted on this side to this.

Student: CV started with 0.7 Sir.

Wherever you can start; you can start here; there is no hard and fast rule. So, something like this. I am putting lambda is equal to 0.6, 3, 5; the curve goes like this. So, from this curve, if you have the lambda, you have sigma. You can take the sigma while you go to that particular lambda and then straight away you can come to the CV value.

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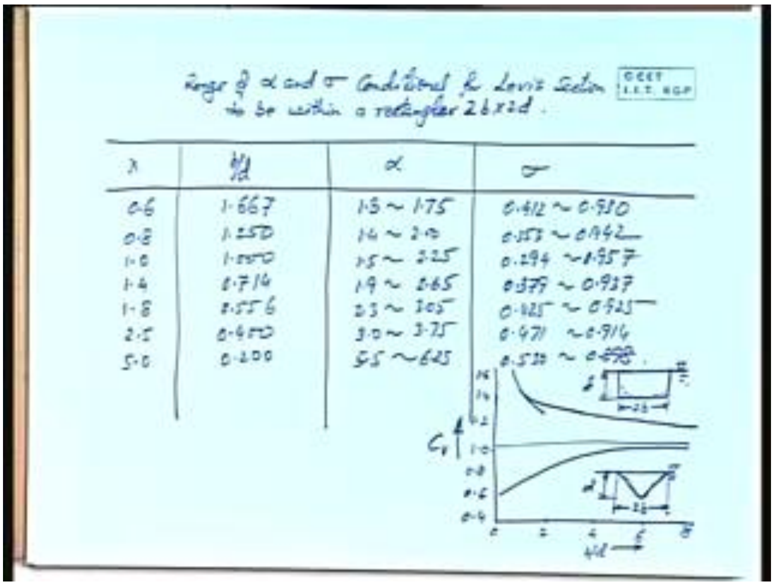

But many a times engineers prefer that let us have the digital values. So, range of alpha and sigma, this is also given here. Sigma conditional for Levis section to be within a rectangular 2b by 2d; is it visible on that screen?

These are the ranges given; alpha and sigma.

Student: Sir, b by ds are after lambda were here b by d but lambda itself is b by d

Lambda is the area ratio

Student: B by d

Where lambda and d by b.

Student: Sir it is 1 by lambda

1 by lambda; 1 by 0.25; let me check. 1 by lambda, lambda is d by b basically. Either you have the b by d ratio or the lambda given to you and the range of alpha and sigma will be within this. You know what happens if too many instructions are given or information are given; then also confusion comes.

Now, just as an example, if this is 1, 0, 2, 4, 6, 8, this is our b by d ratio. I have 1 here 0.8, 0.6, 0.4. This becomes a CV curve for a triangular section like this and if you take the 1.2, 1.4, 1.6 here, then (( )) 1.4 a rectangular section like this. So, this is what is 2b; this is d here.

This is just a representation that if you are going to have a rectangular section, then this is how the CV curve will go like and for a triangular section the CV curve is something like this.

Now, if you take the ship shape, I will just try to something here that your ship shape may be something like this here and it may be something like this. So, it is between these two extreme cases. You can say the one extreme will be the triangle and another extreme will be the rectangle. So, our CV will fluctuate for any b by d ratio between these two curves; it will be somewhere here. So, if it becomes rectangle, then it should attain a value of 1. This is also becoming asymptotic here and this is also becoming asymptotic here. So, that what basically is depicted here. Now, then comes the JV coefficient.

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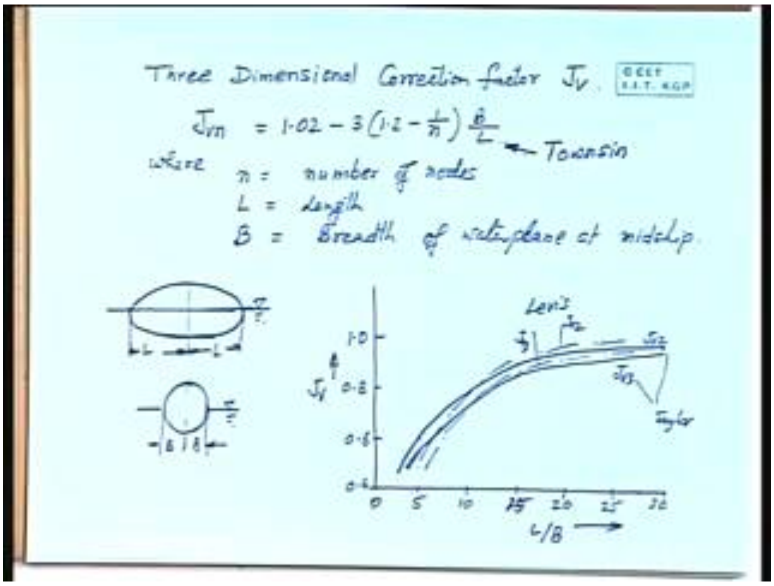

Now, the formula for 3 dimensional correction factor; n is the number of nodes; L is length, I will simply stop there as length, and breadth of water plane at midship. Now, cleverly I am avoiding the terminologies. This is the correction factor for a 3 dimensional cross flow and this is the expression given for an ellipsoid of revolution. So that means, you take an ellipse; the cross section is something like this. So, this is flexing like this. Now you have say one focal length here; another focal length of the ellipse here; this is the mid way which is I say midship. So, here is length of this ellipsoid; half length here and half length here; this is these are L here. Similarly, the cross section, if you take it will be a cylinder floating like this. This also I will consider to be floating here. So, this is B; this is B; this is L; this is L. I use this definition here because this formula is based on the same. So, this length is the length of the ellipsoid. And breadth, now, when I am considering the ellipsoid to be a ship, then this is the midship and this is the cross section of the midship because it is circle.

Student: Is it represented in the form a circle?

What?

Student: The cross section

Cross section is all circle here because you take an ellipse and then rotate it. So, it becomes an ellipsoid of revolution. So, any section you take is a circle and this hydrodynamic coefficient we assume is valid for the ship shape. So, that is the assumption and this is mathematically derived and this can be given for that.

See, two researchers are there. One has predicted this JV coefficient against this L by B ratio for this ellipsoid of revolution. Taylor gives this curve and Levis gives this curve. Once again for three nodded Taylor gives this curve and Levis gives this curve. And this formula is given by Townsin. I do not know if someone of you have met Townsin or not. He was a senior lecturer in university of Newcastle, Atlanta. I do not know whether he is still serving or not; he is still alive. So, he is the man who was done a lot of work and this formula is given by him. He must have taken account into this and accordingly he has given the thing.

Now, what can be seen here that JV 3 and JV 2 there is a difference. It is definitely dependent on L by B ratio; that is number one. As L by B ratio increases, you will find that the JV coefficient is trying to approach unity; that means, it is becoming that not any form, rather infinitely long vessel. So, that means, going towards the 2D case; not the 3D, but the 2 D case. If this is 1, now usually there is no reduction. So, as you go on increasing the length, it is approaching the value of JV is 1. So, as the L by B ratio is less and less, this becomes more pronounced.

Now, normally, our sea going ships are in this region; 10 to 13 or something of that sort. And therefore, for all the vibration, we will find that there will be a reduction in this added mass coefficient because there will be definitely some cross flow taking place across the row towards the end of the ship.

When the ship is fluctuating or vibrating like this, obviously, due to the bow shape and the turn shape, water will try to cross flow. Instead of getting displaced up and down because of the to and fro motion in the vertical direction, this will also try to flow towards the front or towards the out.

Student: If it implies, then there will be more vibration and from then the

No we are not talking about that. We are talking about the added mass coefficient. Now, what is happening basically is that when vibration takes place, we have already recognized that some sort of an energy input is there to create that vibration. Now, once that energy is dissipated, then only it will come down. Now, how that energy will be dissipated? Energy is going to the surrounding medium by virtue of to make its path. It will have to fight against the resistance; neutralize against the water resistant; that is number 1. Number 2 - it is imparting energy to the water particles which in turn will try to have motion. So, these are the two ways by which energy will be dissipated basically; sound etcetera will come later on.

So, when you are imparting the energy, the water is supposed to go like this, but it also goes like that. So, it is imparting in a faster way. So, once it is faster, then the energy content is less and then you get the frequency less there. So, this is how some sort of a physical interpretation can be given, but what this gentleman had try to show that it is definitely dependent on the number of nodes in which the ship will be vibrating. And this is an attempt to give the value of this coefficient based on the number of nodes. Of course, main dimension is also there, but number of node is also there.

So far, there was no such attempt made by anybody that what is going to be the added mass coefficient for more than 3 nodded vertical vibration and the JV coefficient for more than 3 years, given a plot for 5, 6 also 4, 5, 6. 1, 2, 2, 3, 4, 5, 6 are also given here.

Any questions here? So, this will take care of what is your added mass.

Now, for horizontal and other this thing, I am not going to take it up. What I will do I will give it to you and you can xerox it and keep it for your reference and this original you return to me. Now, So far any problem you are having? This I have taken from one of the manuals recently.

Now, what it implies here that we have a set of empirical formula or so called empirical relationships ready to use based on what Schlick has proposed or Todd has proposed to estimate the natural frequency of hull girders vibration in 2 nodded vertical mode. And when we say estimate, we would like to have a realistic estimate and they found that over the years that the surrounding medium does affect it and that is how Todd tried to rectify Schlick's formula, and many of the researchers tried to put their input and tried to fine tune that expression. And this is the latest one as per as SR 94 which compiles all the researchers into a nutshell and trying to tell you that there is the most efficient set of formulae which can be used for the estimation of various hull vibration frequencies namely 2 nodded vertical, 2 nodded horizontal, and 1 nodded torsional vibration.

What are we going to do with all this? Now, as a ship builder, a person has got one role as a ship operator the person has got slightly different role and as a ship designer the person has got a role which is same as the ship builder or designer, whatever you call it. Now, ship designer will design only when the ship is to be built, but many a times what happens that, the consultant, the ship designer, the ship builder may be one and the same person.

A shipping company would like to acquire a particular ship. Now, he may have knowledge of the types of ships, but he definitely has the knowledge of shipping, about the technical specifications of a ship; he may not be fully geared to have the knowledge, and therefore, he appoints a consultant to advice him; therefore, for this type of a business, what type of a ship is required.

So, they draw a specification which is a very broad specification which meets a shipping requirement or his business requirement. And then the ship, then his consultant, through the sorry then he through the consultant floats an enquiry for the design and bid whatever you call it, and whoever tries to give him the best package, that design he will accept.

Obviously, there is a time frame and as far as the bidder is concerned, he is going to give all these things with the hope that he is going to get the offer to design that ship. Majority of them are not going to get it; one of them will be selected. So, the one who gets selected will be paid. Others will have to spend from their pocket. And obviously, for doing all these calculation, they cannot afford to spend a lot of time energy and money, and therefore, there has to be some sort of a readymade formula sort of a thing which will give the estimation to a certain level of accuracy. Once it is within that accuracy acceptable to an engineer, and after the bid is finalized and if he gets the order, then he will do a detailed analysis and try to fine tune the all thing; that is the basic thing.

So, when it uses this particular calculation, then what he does with this? Basically this is required to select the machinery so that after knowing a particular hull frequency, he selects the machinery in such a fashion that tries to avoid any sort of resonance during the operational condition. Now, the machinery has to be compatible with your power output and the propeller; that is the basic mode of machinery we have. So, when we talk about the main machinery, then comes the main engine and the corresponding propeller, whether directly driven or through a gear box. So, this propulsion plant is to be selected. There are certain things which can be changed at the time of final design, but certain things which has to be selected right in the beginning and once you selected the fixed cost pricing system, you have to specify what you are going to give; some main machinery is one of them.

You have to say that I am going to put this engine or you may give an alternate that either this engine or this make or this brand or whatever it is, but once you specify, you have to stick to it and the pricing will be according to what the engine builder is giving you. Today you design something and tomorrow you say, no, I do not want to give you this engine; I will try to put some other engine. Now, that some other engine may be that some other bidder would have proposed and you have rejected his quote, and therefore, it is not acceptable to the ship owner. So, at this stage, when you try to fix the engine, that part is sealed and therefore, there is no modification in the engine specification; the pricing remains; the specification of the engine remains.

Now, when we say that the engine specification remains, that means, we are talking about the horsepower of the engine and the corresponding RPM horsepower will be taken up in resistance part, but RPM part is important as far as the excitation is concerned. So, once we are giving that specification, we are limiting or we are restricting ourselves to use of that particular RPM, and therefore, we have to be very careful and find out that which RPM is acceptable to us and that is why these formula come very handy to estimate the frequency level, and find out which RPM is acceptable to that particular design ship.

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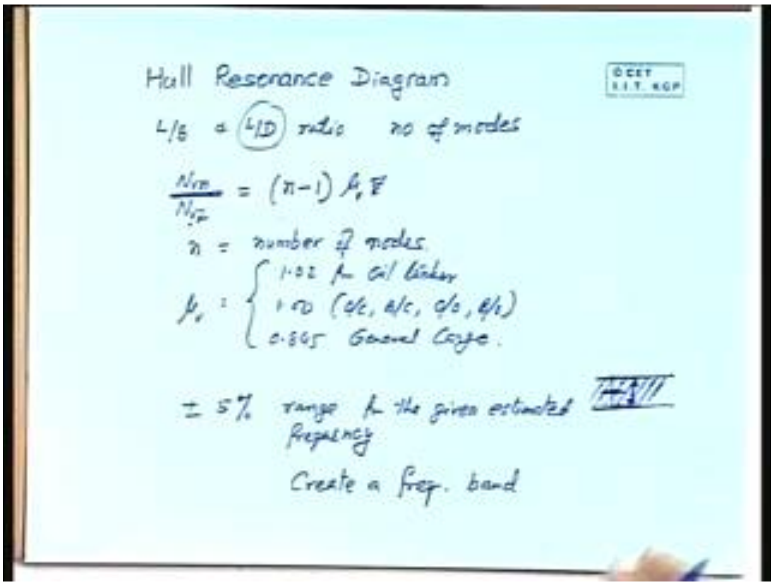

Now, for that, we go for what is known as hull resonance diagram. Now, what is there in hull resonance diagram? We have seen that JV is dependent on L by B and JV is responsible for the added mass, and therefore, the mass which we are taking into account for the frequency calculation.

So, the actual frequency of the ship vibration is directly connected to L by B ratio. And we have seen 2 nodded, 3 nodded, 4 nodded, and we can with our practical this thing also we can see that if you have a particular length of beam and you put it in free free condition, then you can excite in which other modes. If it is becoming a longer thing, it may vibrate in a number of modes and being a continuous thing, all the modes are available. And what we have to see is that which are the predominant modes and what are the corresponding frequency that what we will be interested in; so first of all, based on L by B and L by D ratio.

It is basically L by D which will dictate the number of modes; you decide the number of modes. So, how many modes will be available? One more thing I will require from there and just give me in a (( )) just a minute.

Now, we have got the 2 nodded mode either in vertical or in horizontal by one of these expressions and we have to estimate the higher mode frequencies which will be given by this here. This is for 2 nodded, this is for the vertical mode, sorry this is mu v; mu v is a coefficient which is 1.024 oil tanker; one for oil carrier, bulk carrier, oil and ore carrier, bulk and oil carrier, and 0.845 for general cargo. So, the higher nodes divided by the 2 node vertical vibration is given by this expression where n is the number of nodes in a particular mode and mu v is a coefficient which will vary from this.

What practically one can say is that even if you take n is equal to 2, n is equal to 3, for 3 nodded vertical vibration, 3 minus 1 is equal to 2 and corresponding mu v is equal to 1. So, that means, N 3 v is 2 times the N 2 v, Nv 2, double the frequency, and that way you know 3 times the frequency for the next higher node, 4 times the frequency of the fundamental frequency for next higher nodes, and so on and so forth.

Now, we are estimating a particular level of frequency. We are not calculating the exact value. Now, this Nv n which we are calculating will have some error; either we are over estimating or we are under estimating; we are estimating. So, whenever you say estimation, it is never an exact value. Now, what is the level of error there available? We do not know because we are trying to design a particular ship and all the design parameters are not available. And therefore, we do not know exactly and at this stage we do not have the information; we are still trying to estimate.

So, however we going to go about it, obviously, we have to depend on whatever this researchers have given us, and then on that calculation you would like to add some sort of a confidence level by trying to estimate some sort of an error which you as a designer, with your own experience, will say that if I take this much of error estimate, I will be well within the value.

So, if suppose this is the value we are looking for or this is the exact value of the structure's frequency and this is the higher level and this is the lower level, if suppose we do not know what is this, we have a higher level and a lower level, we know that somewhere in this space the actual value will lie. So, we try to estimate what is the range. So, how do you get that range? In this also, again, so this range is based on what is this value. So, what we do, we take a plus minus 5 percent range for the given frequency, given estimated frequency let me say.

We estimate the frequency from here and the fundamental frequency from one of those. You see we are using 2 twice; rather some sort of approximation. Once when we are estimating the fundamental frequency and then when we are trying to get the higher frequency from this fundamental frequency using this particular relationship, and therefore, we do not know whether the error is additive or going to cancel each other. So, we do not know and therefore, we do not know whether we are actually reaching here or the actual value is here; we are estimating some value here.

Therefore, we take plus 5 percent; we also take minus 5 percent and we get this range of frequency and we create a frequency band. This is a band. When you are giving a lower limit and an upper limit, obviously, you are giving, you are creating a band. Now, the other thing is that a particular frequency will create resonance in the structure when the structural natural frequency is very close to the resonant frequency. It has got its own damping and therefore, it is not the exact frequency. We have seen in the last class, that what is the frequency ratio, which will amplify your response. So, that ratio we are looking for. Now, that ratio is not omega is equal to 1.

If you see correctly for a resonant frequency in the damp frequency case that omega will be slightly below. And therefore, even if we try to say that omega is equal to p and we knowing fully that the structure has got its own damping part, and therefore, omega will be less than p, but for all practical purposes we will say that omega is equal to p will be the resonance frequency. So, if we have a range of frequency, omega exiting frequency is some omega and we have estimated the natural frequency as p plus minus 5 percent. So, the excitation frequency will be within this range only; am I right?

So, if you are giving a range, then the excitation frequency we do not know. So, we start with the band and we say that somewhere here, even if we say omega is equal to p is coming here, but it is lower than that, will be the resonance case. It should lie within the band. So, that is why this band is important.

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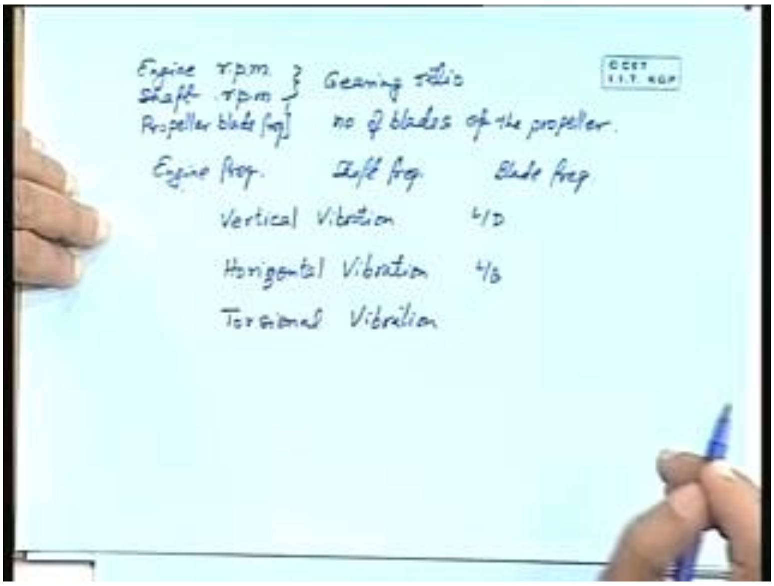

Now, what are the forcing functions? One is the engine RPM, I am talking in terms of engineering terms; RPM - this may be one of the exciting frequencies; one may be the shaft RPM. I am purposely writing shaft RPM because if the engine RPM and the shaft RPM, if it is not a direct drive and we have a gear box in between, then the shafting ratio or the gearing ratio will come in to picture, and engine RPM and shaft RPM will be 2 different frequencies. The relationship between these 2 RPM is your gearing ratio. Then we have the propeller blade frequency.

Now, on this shaft, you have the propeller blade, propeller, and the propeller has got number of blades depending on the design; whether it is 3 bladed, 4 bladed, or 5 bladed, we do not know. So, for every RPM of the shaft, this propeller blade frequency will be n times. n times means the number of blade times the shaft RPM. So, here, number of blades of the propeller is the controlling factor. So, accordingly, we say engine frequency, this is one of the exciting frequency; shaft frequency, this is the second excitation, and third is the blade frequency. So, when we select a particular propelling system, we must be careful about these 3 frequencies and all these 3 frequencies, we will check up in the hull resonance diagram.

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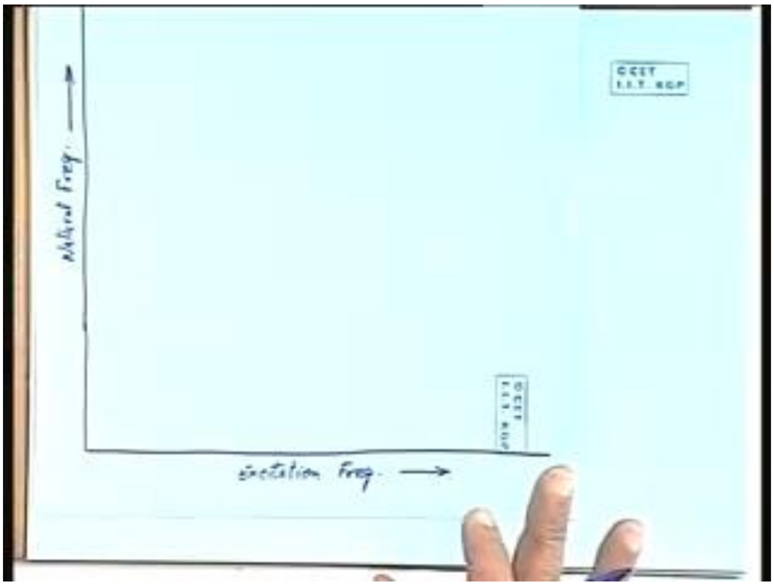

For the resonance diagram I will take a different sheet and try to draw here. One more thing I will write to add here. We have, in the normal course, you have the vertical vibration, we also have the horizontal vibration, and we have the torsional vibration, and then the combination of all these may also be present there. Usually what happens that horizontal and torsional always comes in combination, but for certain type of vessels, the vertical and torsional will also be combined.

Especially with torsionally weak structure, for example, container ships. These days, open hatch container ships, they are torsionally weak structures, and therefore, horizontal torsional and vertical torsional will be there. So, we would like to, instead of going into those details, we say that vertical horizontal and torsional vibrations are the vibrations which has to be taken into account.

Here, the leading ratio is L by D ratio. Here, it will be L by B which will be read and here it is the polar moment of inertia of the open section; j of the section; this j is not to be mislet with the correction factor or the 3 dimensional flow factor; it is the polar moment of inertia of a cross section. So, these will tell us that how many of which frequencies are required. So, usually, you will find that L by B having a smaller value than L by D; L by D will be of the range of 10 to 13; L by B will be something between 6 to 8. And therefore, less number of frequencies are required here and more frequencies are required here.

In fact, the classification society guide lines will guide you that how many vertical frequencies and how many horizontal frequencies, and how many torsional frequencies, if any, are required to be considered. So, now we try to draw this diagram and in this diagram, I am trying to plot it like this. We say the excitation frequency here and we put the natural frequency here. So, the natural frequency is the structural property and the excitation frequency is the machinery property or whatever it is you can say. We will have a stop here and then we will start it.

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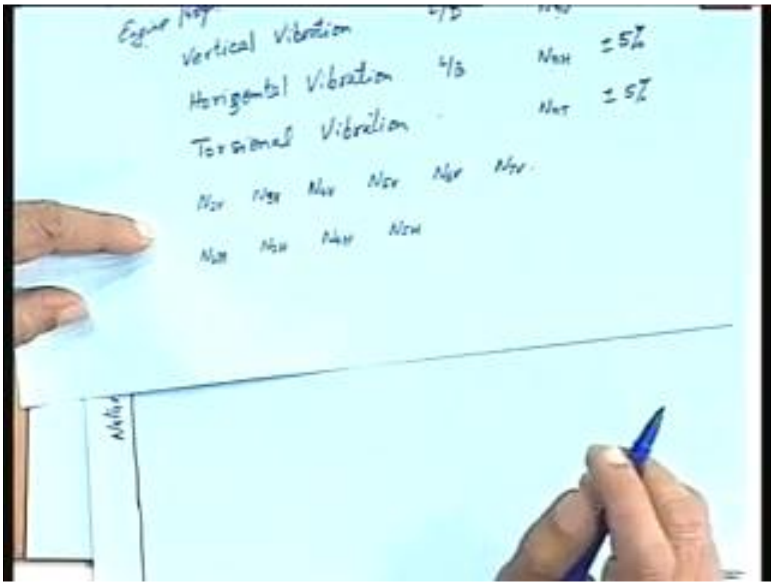

So, now these frequencies can be calculated. We say that that is N nv know; then accordingly we say N nH and N nT, vertical horizontal torsion and number of this thing. So, for a particular frequency, we are taking the margin as plus minus 5 percent and we will keep it all through.

Now, this is no hard and fast rule that you should keep plus minus 5 percent. If your experience says something else, you can choose accordingly. So, now, let me simply accept that for the vertical node I am taking 2v is the fundamental; 2v sorry 3v. What was the notation used earlier? vN or v Nv anyway does not make much difference.

Student: 2 v sir.

2v, 3v, 4v, 5v, multiple of each frequency, 6v, now whatever is given by that say 7v and you have N 2H, N 3H, N 4H say N 5H. For the time being, I am not taking the torsional frequency. In this particular case assuming that this is not a container ship because lot many will only complicate the thing.

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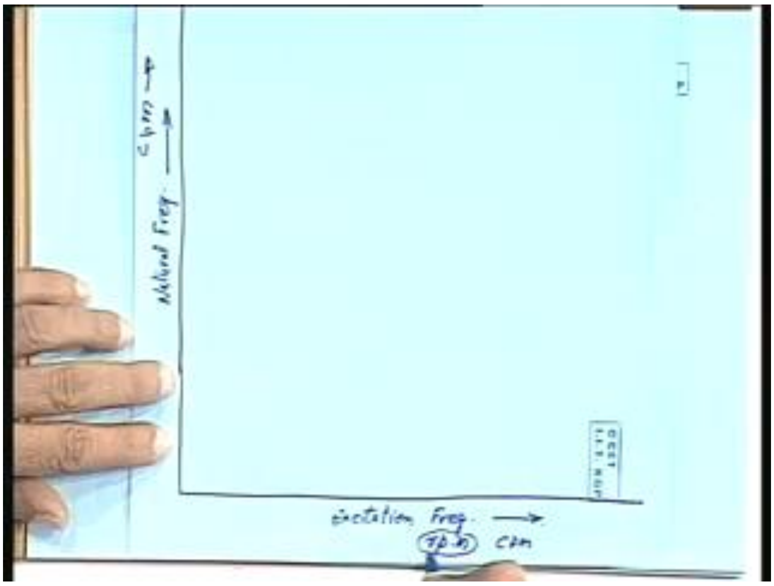

So, I find that the fundamental frequency N 2v is coming somewhere here. Now, this we will take in cycles per minute here because all these formula directly give me a cycles per minute and the exiting frequencies also I take it in RPM. RPM is revolution per minute. So, that is also basically cycles per minute. This is the trend, but this is also cycles per minute. When we say frequency, cycles per minute it imply.

Student: Shaft RPM external.

No. Exciting frequencies, Exciting; it can be anything; it can be shaft; it can with whatever log book will give you.

Student: ((Refer Time: 56:28))

No, No. It is all depending on the thing you know because it is when you are going say full ahead.

Student: May be this and which we are talking about these are the is MCRs.

No. I am not taking about MCR. I am saying that the operational RPM.

Student: Operational rpm.

You may even operate the vessel at 80 percent of MCR, 85 percent of MCR. You see it is all your policies. Suddenly, when there was a fuel crisis, one of the shipping companies, I do not know whether it is a sea or something, they decided that let them operate all the ships at 85 percent of MCR. By doing so may be that you will save some 30 percent of fuel cost. 85 percent MCR may reduce your speed by say 10 percent, but you may save 30 percent of the fuel cost because that goes up like that. If you see the performance curve of an engine, you will find that there is an optimum speed, and after that it goes in a parabolic fashion or exponential fashion; whatever it is, it is not linear.

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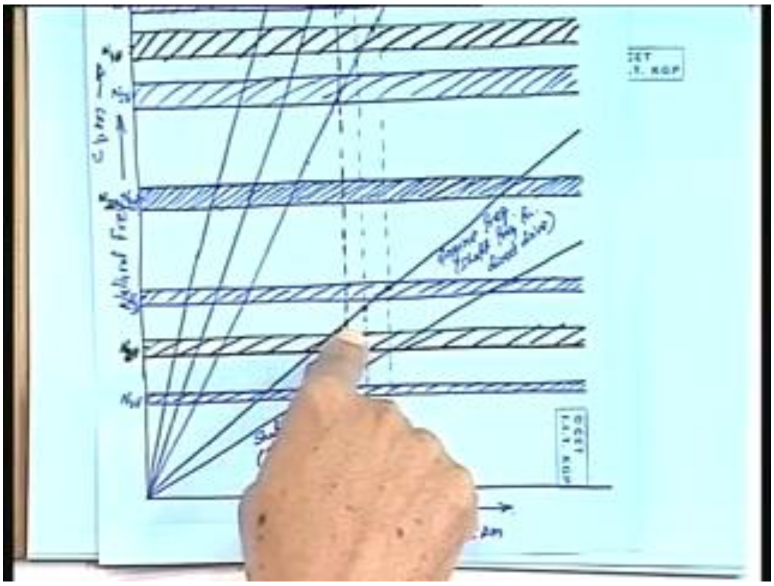

So, if you try to cut down the MCR, so what I am trying to say that all these RPM and the engine RPM what we are talking about is, whatever is the operating RPM. If you are designing a vessel to operate at 85 MCR or 85 percent MCR, then we have to select 85 percent. Then this is 85 percent MCR. RPM if you say it is 100 percent, MCR it is 100 percent.

And if you suppose decide to operate a ship at 100 percent MCR, and you are also ready as a company, that in case if the fuel prices go up, you will reduce it; now our fuel prices are fluctuating. So, if suppose it increases, and you say that if it increases beyond this particular level, then we will restrict our consumption to so many this thing so that our fuel bill does not increase. So, that, what is that percentage of the mcr will be known to you. And in case of emergency, if you have to overload your engine, say 100 and 10 percent of MCR or whatever it is, overload condition, I think overloaded condition is for 4 hours or something; is it not?

Student: 10 percent.

10 percent for a continuous operation of how many hours? 4 hours, 24hours.