Strength and Vibration of Marine Structures

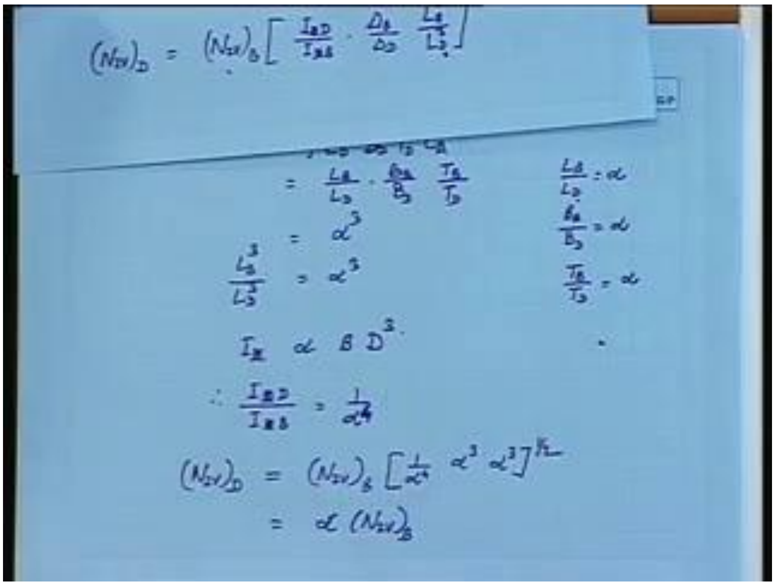
Prof. A. H. Sheikh and Prof. S. K. Satsongi
Department of Ocean Engineering and Naval Architecture
Indian Institute of Technology, Kharagpur

Lecture - 29
Hull Frequency Estimation from Basic Ship (Continued)

(Refer Slide Time: 00:40)

After we get this for an identical type of shape, not the dimension, then plugging these values into this expression here. I will just write here for your convenience.

(Refer Slide Time: 01:15)



So, n to v for the design vessel can be written in terms of the frequency of the basic ship. Now, I by, this works out to be 1 by alpha to the power 4. This works out to be alpha cube, this works out to be alpha cube and then half power. So, 6 by 4 alpha 6 by alpha 4 gives you alpha square and taking a square root of them, you will get alpha into. So, if the entire features are identical, then it is very simple to estimate the frequency of the design vessel on the basis of the basic ship frequency, and the design stage when nothing is available to you except few mean dimensions and for the ship which has already performed built and served, you have all the detailed calculations.

So, this for the basic ship is a detailed calculation frequency. So, I am trying to estimate the frequency of the proposed vessel on the basis of the detailed calculation of this, but I am trying to use this type formula because this also gives me an approximate this thing. I am using this frequency for the basic ship which has been exact along and calculation, but I am trying to use the main particular, so that this phi can be calculated, but I am trying not to calculate the phi. I am simply eliminating it and then ultimately I try to estimate. So, this should give me a good estimation.

You can ask me few questions here that I have not taken the added weight into consideration. Now, instead of added weight, if you take the added weight formula may be the result here delta by delta may also workout to be same. Now, if you try to take that was proposed by Todd’s, so if you try to use the Todd’s formula, you will find that added weight will be coming into picture, and if you want to, you can modify the equation little bit there, but I part there, it is simply saying that BD cube. We have also taken the same thing proportional to BD cube.

So, even if you want to use what is the Todd’s type of formula, you can check it from that and try to get it. So, this gives a very good estimation. If you are having the long hand calculated values here, then from basic ship method, you can get a very good estimation provided the features are identical. Now, questions come that I say that I am taking a vessel which has already performed well and to check the performance, at least 3 to 5 years, you will give for the ship to operate. So, that will come to know about its behavior properly and if the vessel has served for 3 to 5 years when was it delivered and when it was constructed, and when the design was conceived if everything is taken in an accelerated manner like any foreign ship here.

We can say that if I am taking a basic ship, today the initial design must have started a decade ago. So, at that time the designers must be having some idea about the design and in last one decade, things have changed towards the advancement and when I am trying to design a ship today, I would like to incorporate all the new features in my new design. Therefore, if I have to incorporate the new features in the new design, why should I say that everything is same here? I will only say that the features are similar and not identical. In that case, I will try to leave it at this stage itself. I take this as the correct value and whatever these values you are getting for the proposed vessel; compare to the basic ship you take. It may not work out to be alpha cube if I define l by l is equal to alpha, then this is alpha cube, but this may not work out to be alpha cube because b by b ratio will be slightly different. It will not be same as l by l ratio t by t ratio will also be different from the basic and the design ship.

Therefore, whatever value you assume, you try to incorporate that and of course, here we can still take this relationship, but you convert this to B by BD cube part and then take the B by B ratio and D by D ratios whole cube. So, doing that we still do not lose the generality and we will try to get as accurate as possible at the first estimate here. This is what I just wanted to emphasize and once this frequency is calculated on this basis, then the hull resonance diagram which we try to make will be more realistic than using blindly the values of this phi here given in a table which is much more updated, but one thing is still a very big question mark that how do you select the basic ship.

So, you have to select the basic ship on the basis that it needs your requirement of the firm proposed design. If suppose what was the design requirement at that time and what are the design requirements today. If the requirements are identical or very close to each other, I think you have chosen a good basic ship and the difference between the sizes should not be much higher. You cannot have a ship and a model sort of a thing. You take the two ships can be sister ships having similar features, similar requirement, different size. They may not be identical, looking identical. Features may not be there, but similar features should be there. That is how we will try to. So, if the basic ship is chosen properly, then rest of the things will follow it in a very neat manner.

Any questions here? So, should we go further for a little bit more?

Now, one thing by now we should realize that vibration is a quality of an elastic body which is present in all elastic structures. So, whatever best you try, you cannot eliminate vibration from a structure, and we do not want to eliminate also because it has got the positive aspect also which we would like the structure to retain it. So, if you eliminate everything, then life will become hell, but only thing that the bad aspects of vibration of which one is scared can always be reduced.

How do we try to reduce it? What are the bad aspects? The bad aspect is the resonance, vibration and structure which lead to stress and ultimate failure of the structure and that can be met by two ways which we discussed earlier also. One is by changing the design of the structure, and the other one by choosing the brought out items in such a fashion that it do not try to, do not lead to the resonant vibration and many items it is not possible to do that or do this. If suppose your design is already completed, the ship is built and after that you are trying to put the things and you find that it is going to a give some sort of an excitation which is undesirable, then we will like to see that how it can be reduced, the effect can be reduced.

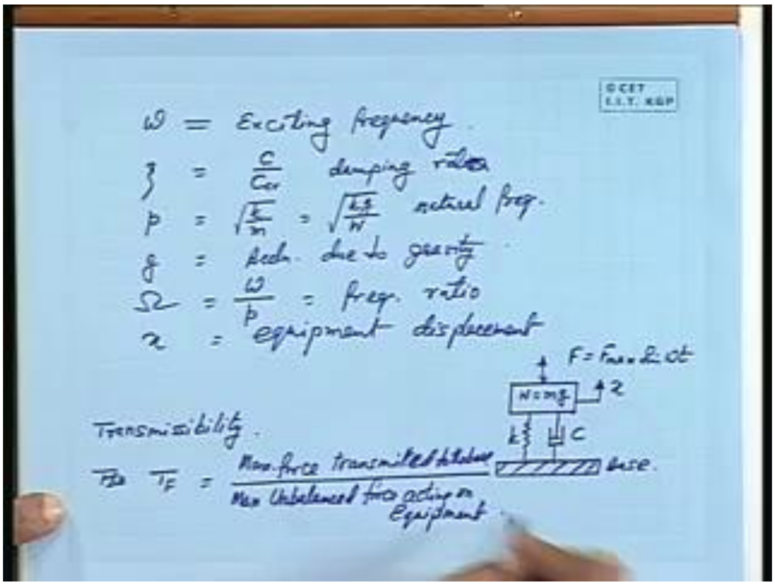
So, the thing is that temporary arrangement or I would not say temporary arrangement, a shortcut method by extra reinforcing structure or redistributing the mass in that particular place, and thereby you try to change the frequency of the structure. That is one way if it can be done. I think nothing better than that is possible. Other thing is that whenever we try to put machinery, we try to secure it to the structure because ship is also subjected to all sorts of motions and we do not want that it should be loose and start moving from here to there. So, we would like to secure it and for that securing, we always have some sort of seats or seating arrangements for the machinery or equipment on to the structure.

So, the seating arrangement which we try to make, we can have a resilient mounting. We choose a material which can absorb some sort of a shock. So, the mount design becomes important and we can take advantage of this by selecting a proper material, the force which is being generated by the structure, by the equipment. The same force is not directly transmitted to the structure. Only a percentage of that is allowed to be transmitted. Remaining is absorbed by the mounts there, and if we can do that, then quite a lot of problem is solved.

The latest example I was telling you that you are now using. So, many PC's, on vessel, for controls, for maneuvering, for this, for that and I do not know for whole even for calculations, and everywhere you cannot say that a pc has to be designed according to the ship personal requirement. Nobody is going to design it. If somebody is ready to design it, then he is going to charge you much more than what is the market value of that particular piece of item. So, we have to go to the market, select a thing, bring it and then try to put it, right. We have not asked the chairs to be designed to suit this building. Whatever was available and we think that it is this suitable for our use, we have purchased it and used it and we have to adjust. So, bought out items are purchased and then we try to adjust it.

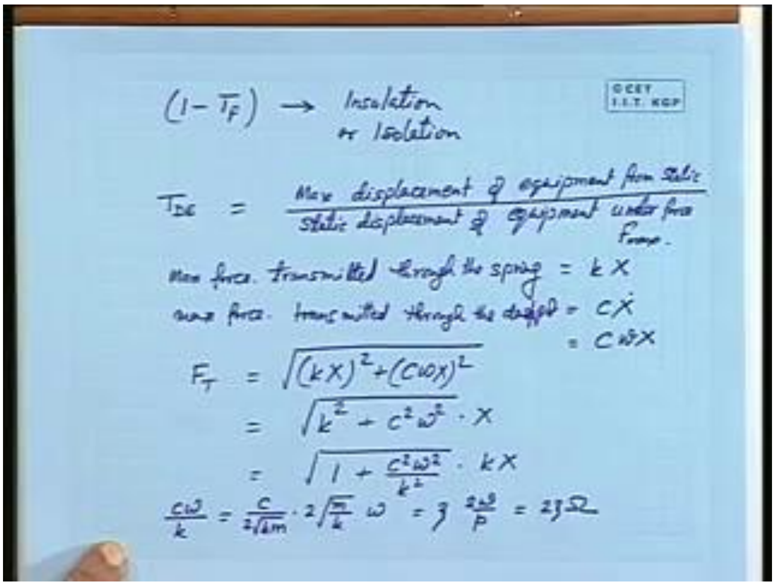
Now, the way we are trying to adjust is we are saying that how to design the mount, so that it meets our requirement. So, let us see that what is there in the mount. Now, the design of vibration mount or a shock mount involves the calculation of forces or motion transmission from equipment to foundation or vice versa. Say there is some force being generated from the external environment which comes in case of the PC. The forces are being generated in the structure and getting transmitted through the structure to the equipment, and in the process that particular equipment may not function properly. Therefore, we would like that from the structure to the equipment, the force, the entire force is not transmitted.On the other hand, when the motor is working, the pump is working, and the engine is working, we do not want the entire force, the excitation force. We transmit to the structure. So, now what is done here? So, there are six quantities which work into play.

(Refer Slide Time: 15:29)



One is the exciting frequency, another is the damping ratio, third is the natural frequency which is given by this four quantity, this acceleration due to gravity. Then, we talk about the frequency ratio and all inter connected there, but still this one is the equipment displacement. Now, in such a case, we try to model the equipment with a single degree freedom system mounted on a spring and dashpot, and this is the base we consider. This is sinusoidal force. So, these two together at the property of the mount and the performance of vibration mount can be measured by a factor known as transmissibility. TF here is defined as maximum force transmitted to the base divided by maximum unbalanced force acting on equipment, and this is being a ratio.

(Refer Slide Time: 19:29)

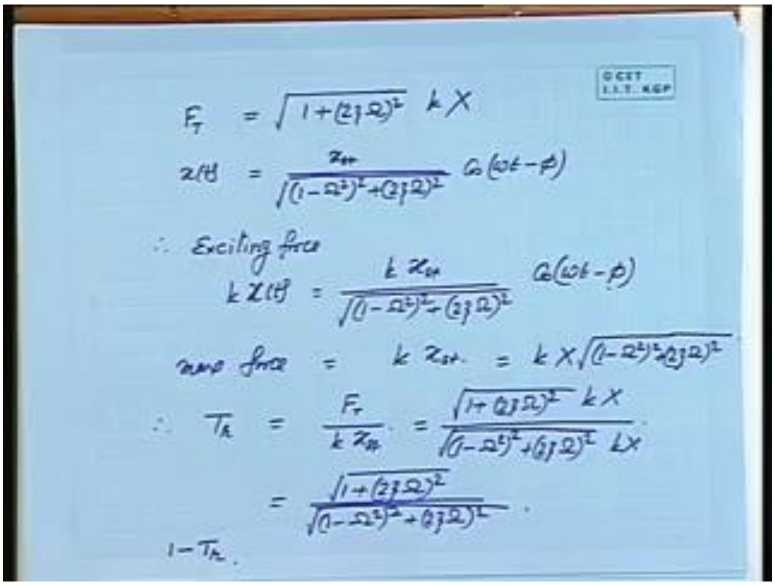


The quantity 1 minus TF is normally used, and this term is known as insulation. There is another term also for isolation. So, we do not say that 20 percent of the force to be transmitted to the base rather will say that it should have an isolation of 50 percent. The same time, the motion amplification of the equipment can be measured by comparing the maximum equipment displacement to the static displacement under unbalanced static force. This leads to displacement transmissibility of the equipment, and we define displacement transmissibility of equipment TDE as maximum displacement of equipment from static condition, so it is the ratio of static displacement of equipment under force F max. See we have taken F max sin omega t. So, under force F max.

Now, maximum force transmitted through the spring say the maximum force transmitted will be the force transmitted is k into x, and under this you will find that sin omega t minus something will come. So, k xt is the force. So, the maximum will be the maximum value of xt. So, I will write it as capital X here and maximum force transmitted through the dashpot is the CX dot, but what is X dot in terms of X. So, we can write this as modulus we are taking sin. So, plus sin will be there.

Now, when you are taking the differentiation of this, sin will give me a cos term here. So, they are at a phase of 90 degree. One maximum is now the other maximum is after pi by 2. So, if they are acting like that, then what is the force which is being transmitted because the two forces are at a phase of 90 degree. So, the actual force which is transmitted is this square plus this square under root, right. So, now we can say that this is k square c square omega square and x square x square. Common I take out, then this can be further simplified and we can write for c omega by k as it is.

(Refer Slide Time: 25:40)

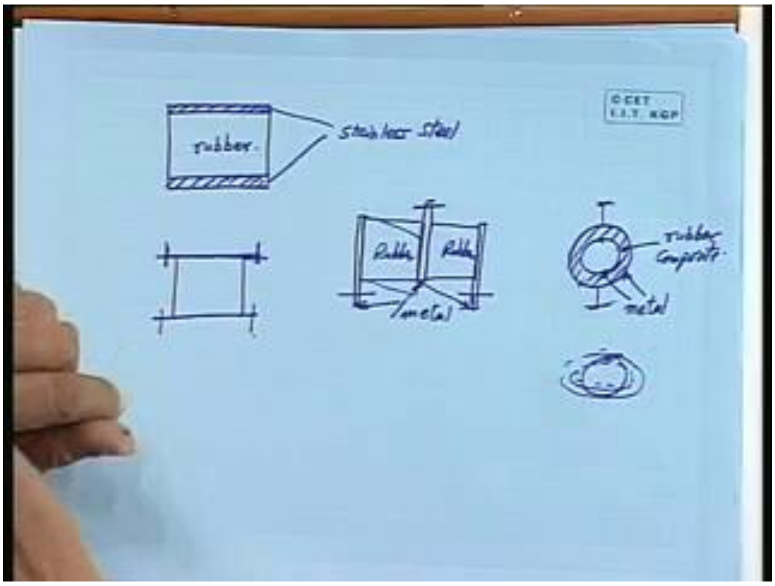


So, substituting this in the expression for FT, we get FT is equal to 1 plus 2 zeta omega whole square into kX. Now, the displacement except t, we have done earlier is given by this expression under this condition. Therefore, we can write the exciting force which will be given by k into x, x of t k times the displacement is the force. So, we are writing it. So, what is the maximum force? Maximum force is here. So, transmission ratio Tr is given as F of T divided by kxst. So, F of T is this. So, this is the final expression for Tr and we normally say the insulation. So, 1 minus Tr.

So, now if you are asked to design a particular mount, normally what people say you know that you design a mount which will isolate say 80 percent, and it will have an isolation of 80 percent. That means, 1 minus Tr is equal to 0.8 and Tr is equal to 0.2. So, this factor should be equal to 0.2. Now, the natural frequency of the structure is known to you, the exciting frequency is known to you. So, the capital omega is known to you here, and this Tr is known to you. So, what is to be obtained is this zeta value here. Now, getting this zeta from this term is quite a tedious thing. So, basically what have been done is that in the hand books, you will find that mount deflection. Mount deflection is plotted in terms of frequency ratio, and then for a particular frequency ratio for a particular isolation, what should be the mount deflection.

So, once that is known, then you chose a mount based on the equipment weight. That is what the number is, what the material is and how it will be behaving. So, once you know that, then you can say that you are in a position to design the mount. Now, there are certain ships of the mounts, which are being used these days. Mostly one goes for a rubber based mount, but sometimes you will find the oil environment. Rubber deteriorates very fast because the oil contains sulphur as a purity and sulphur heats away the rubber, but still some sort of a hydrocarbon based material is used in combination with many other things.

(Refer Slide Time: 32:11)



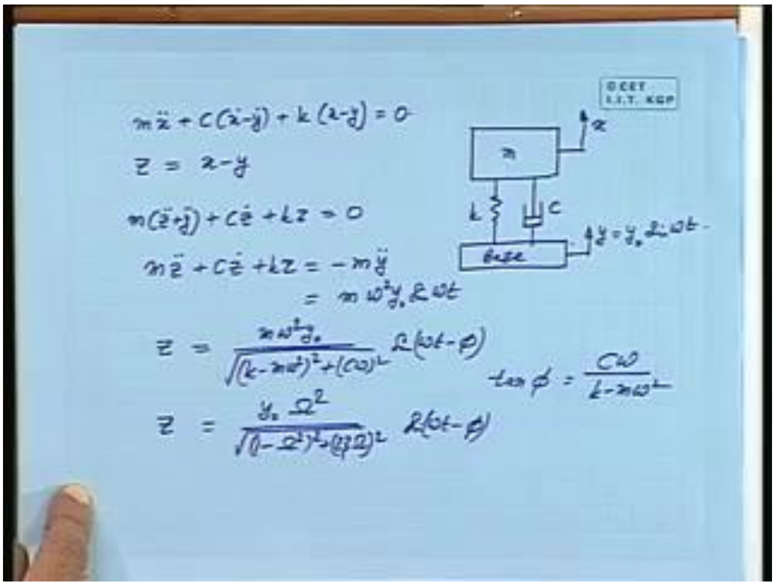
In olden days, cast iron was used as engine chalks for the alignment, and these days they are trying like one has got a mount which is stainless steel plate here, and then you have the rubber here and then again stainless steel. So, these two are stainless steel and this is rubber. Now, this type of a mount you can bolt it or you can have some other arrangement in like this that you are taking a cross-section, you bolt this part to the equipment and this part to the foundation.

Now, there is another one in which you are taking advantage of shear stress. So, what is done here is that these are all metal here. This is rubber. You try to connect this to the foundation, connect this to the equipment and when this will be in shear connection, this will go up and down and the thing vibrates or this will go up and down. So, this will take a shape like this which is under shear. This is a compression mode, this is shear mode. Then, there is another design which is used like this. You have a metal ring and you have another metal ring, and in between you fill it up with some sort of a composite material rubber based. This is some sort of a rubber based, rubber composite. This is metal. Now, you can connect this to the foundation, you can connect this to the equipment here.

So, in this case what happens that the whole thing when the displacement takes place, the circle will get deformed to a sort of an ellipse and the rubber inside will be there and another ellipse. So, this is basically coming in the bending mode, and there are many such designs which are being used now. So, depending on the force and depending on the space available, one is going for all these combinations and trying to take the (( )). Now, what is being done here is basically that if you are taking ring, ring also gives you is like leaves spring in the vehicle, where trying to give you the springing action. So, basically what is required is the springing action.

So, this is how things move a lot of work is going on this because literature is not available on the mount design. They are of defense use much and therefore, whatever research work is going on is with the research people, and they do not want to publish them. It is only for internal use and every country is doing some research and keeping it to his, and not letting others to know about it. Any questions here? So, this is what we have seen that from the equipment, the force is going to the foundation. A similar calculation I have here for which if the foundation is moving, then how the forces will be transmitted. Just opposite calculation and one can calculate what the exciting force is etcetera. So, if you are interested, I will give this. If not forget it, we will still have some 20 minutes time . So, what do you say? We will do it. So, I am just going the other way round and it is the same thing.

(Refer Slide Time: 37:53)

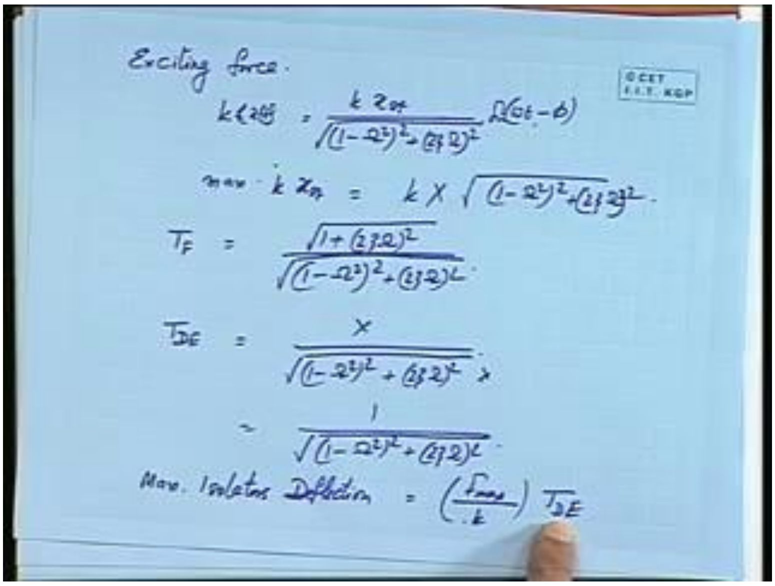


This is your mass here, this is the moment. I take this is the spring, this is the dashboard and this is the base. So, equipment displacement is given by x foundation is by y which is given by some y 0 sin omega t. So, now if you draw the free body diagram of this, what happens is the initial force. Mx double dot what is the force coming here x dot is this velocity and y dot is this velocity. So, it is the algebraic sum of two. That means, the x dot minus y dot. Similarly, the force here for the stiffeners is k x minus y. It should be equal to 0.

So, let us say that I take a coordinate z which represents x minus y. So, z dot is equal to x dot minus y dot and if I put x dot, x dot will become z dot plus y. Double dot. So, substituting this here, right. Now, I write mz double dot plus cz dot plus kz is equal to minus of and this is nothing, but m omega square y 0. You put y double dot from this expression here. So, that will give you minus omega square y 0 sin omega t. So, minus minus plus. This is equal to this.

Now, this part we have already solved earlier. So, I simply take the solution and write the solution with this. Only thing that this is not there. Put in the same format with tan phi or if you want to put it in the similar format, z is equal to y 0 omega square 1 minus omega square. So, the maximum displacement and all those we are trying to find out. So, let us write down from here.

(Refer Slide Time: 42:16)

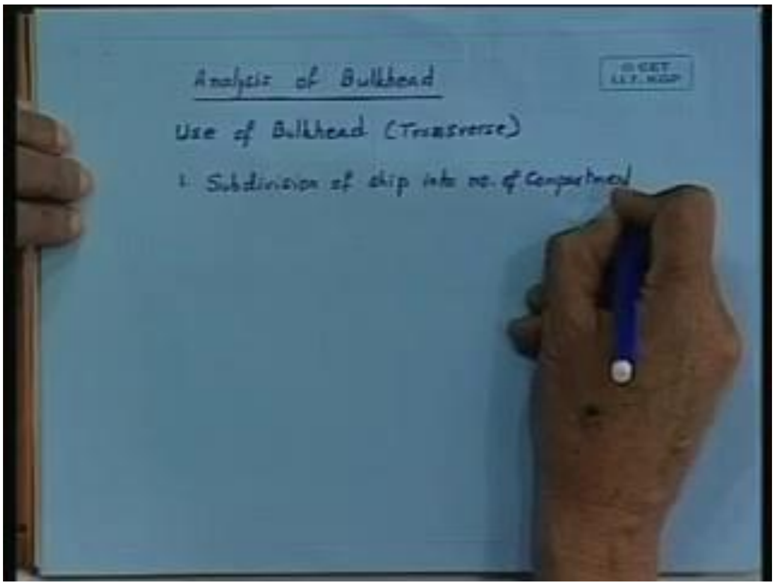


Exciting force with the same thing. We have to work out to be same. You are getting here maximum force once again from same maximum will be xt kX into same. So, transmissibility ratio will be same, and TDE displacement X by maximum isolated deflection will work out to be force by stiffness multiplied by, I will let you further displacement ratio. You wanted some problems, I have got the problems here on vibration, single degree, freedom system. Let me see mostly it is taken from book you know. There are 20 problems here. If you want to, you can Xerox and give back this to me, and we have from the books, only text books.

It is no hurry. You can take your own time. If you want to give me today, you can give me today. If you want to give me tomorrow, day after tomorrow, next working day, it is I think I will stop now. So, they will keep on expanding like that. In our case, it is not like that. If it is beams, beam bending, that is all two words will cover everything. It may be simple beam, it can be redundant beam, it will be having this type of beam or that type of beam. So, then what happens is the teacher and the student, they will try to see, judge each other. If the teacher sees that the students can grasp it, they have the capacity to grasp at a faster rate. He will go in an accelerate manner, and he will try to deliver as much as possible. The limit is whatever you can grasp if we find that students are not in a position to grasp, then they will say it is let me go slow, and again the examination the same way.

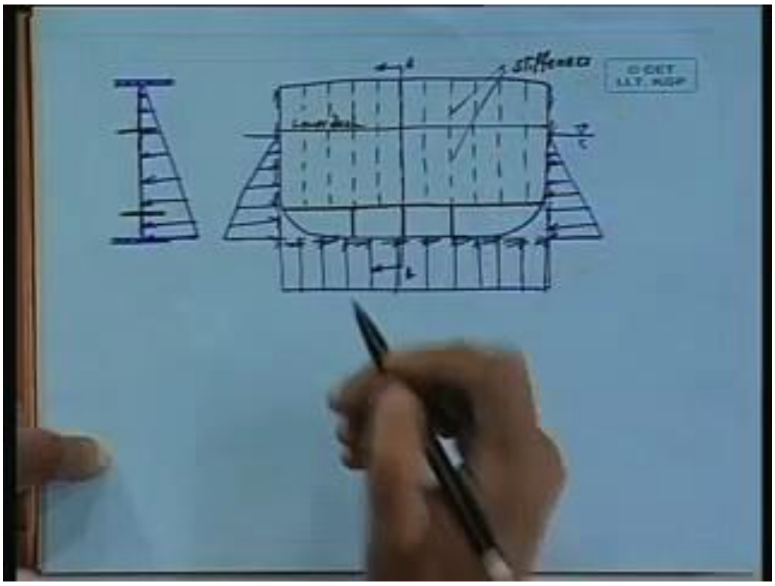
So, no set pattern. In fact, over the years, now a pattern is become set, but there is not suppose to be set pattern, not suppose to be distribution known distribution something of that like ours. So, that is what happens actually. Anyway we start with the analysis of bulkhead.

(Refer Slide Time: 49:14)



Now, before we go to the topic of bulkhead or the analysis, we should try to understand that why bulkheads are required and once we know why bulkheads are required, then only will try to gauge what type of analysis we require. So, let us say use of bulkhead, this can be listed like this. Number one is that when we say bulkhead, it can be transverse bulkhead or it can be longitudinal bulkhead. So, we try to differentiate between the two and we say that transverse bulkhead.

(Refer Slide Time: 51:06)

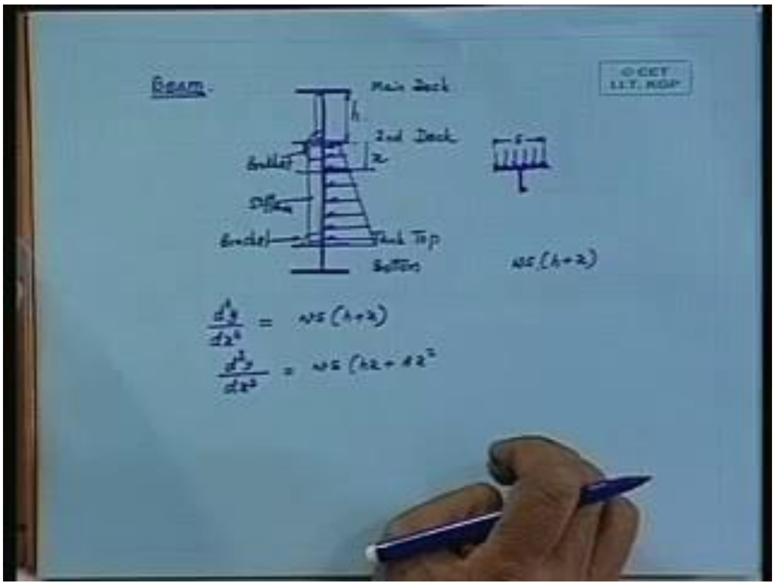


The first and the foremost is that these transverse bulkheads are required to subdivide the ship into number of compartments. So, subdivision into number of compartments, right. Then, let us take a section somewhere here, draw the plate. This is the bulkhead plating and then the hydrostatic loading in flooding condition will go right up to the top. When we say flooding condition, then we are saying that it is still floating, but wherever is there whether it is up to the deck or up to the some predefined line or whatever it is, so this is loaded like this, right.

Now, this is the load which we have seen, but if you see the construction, then usually what we will find that somewhere here you will have a double bottom here. Usual construction technique within the double bottom, you will have certain girders here, and the bulkhead. This is the inner bottom, may be that you can have some sort of a intermediate deck. We can say some lower deck and then there are stiffeners provided to this plate here and I am simply drawing with the dotted lines at some constant intervals. So, this stiffness I can draw it here. We are considering the flooded condition of the bulkhead and then the stress generated due to the transverse load is much larger than whatever is imposed due to the in planed stresses.

So, if we try to isolate in plane with the out of plane, we find that it will be better to just make an analysis on the basis of out of plane method. And then we can also super impose the stresses calculated on the basis of in planed forces, but yes, when we try to do a detailed analysis, at that time attempt is made to take all the forces simultaneously to get the true nature of the stresses in that particular structural element, right.

(Refer Slide Time: 55:08)



Now, here one primary member is between the second deck and the tank top because the span is more and the load is of this nature. So, we set up, we are considering as a beam. So, from here I set up some coordinate system and I say that my x is measured this way to some level here, all right. Now, if you take a cross-section here for this particular strip, you will find that this is the plate width to which some stiffener is attached usually a bulk plate and at this level a constant pressure is acting here which is of this intensity. I have just taken a cross-section here and drawn here, right.

Now, this spacing as we have seen is s and if we say that the water density here or whatever you call it per unit area, then the pressure which is acting here or the loading on to this being the intensity is w into s, and the pressure is basically the distance between from here to here. This is your rho. Rho is embedded here. Mass per unit volume into acceleration due to gravity is this. So, actually what we are trying to do here is this is the pressure. Pressure multiplied by rho and acceleration due to gravity is giving me the intensity of force at this, and this is the strip on which that intensity is acting. So, basically multiplying by that frame spacing gives me the intensity of loading at that particular position of the bulkhead plate and stiffener combination.

So, now for this bending analysis, I can say the basic equation which in two-dimensional d 4 y by dx 4 is written as ws h plus x. That means, the fourth derivative of the displacement with respect to the linear coordinate gives you the intensity of load and from here, this first integration will give you Ax square.