**Noise Management & Its Control**
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**Lecture – 60**
**Acoustic Enclosures – Example Problems**

Hello, welcome to Noise Control and its Management. Today is the last day of this week and what we plan to do today is, continue our discussion on small acoustical enclosures, and actually develop relations which will help us compute the sound power level, sound pressure level at a point faraway from, sound source which is enclosed in such an enclosure.

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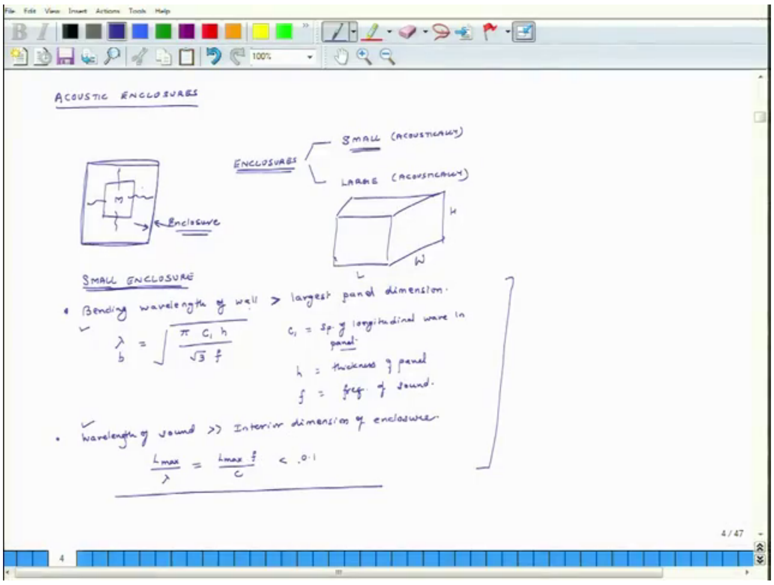


So, we had said that an acoustical enclosure is a small, if it meets two conditions. The first condition is that, the bending wavelength of the wall of the enclosure should be large than, it should be more than the largest panel dimension, and if we wanted to compute the bending wavelength of the wall, especially if it has uniform thickness and if it is made of homogenous material, then that is lambda b, and that equals square root of Pi times c 1 h divided by root 3 times frequency. And the second condition was that the wavelength of the sound should be very large, compare to interior of the dimension, or mathematically we can say that L max, which is the largest interior dimension of the enclosure times frequency divided by speed of sound in air is less than 0.1.

So, if that is the condition, then we would like to know how much of a sound can such small acoustical enclosures stop.

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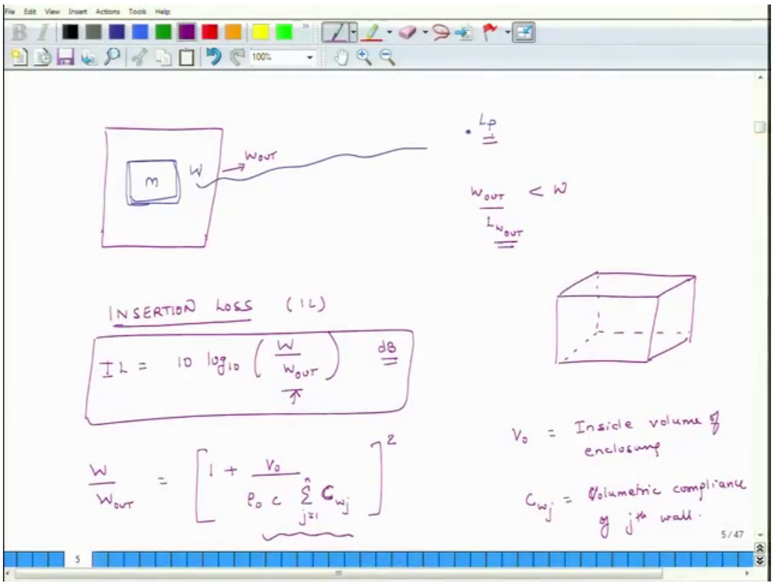


So, you have a sound source, let us say this machine is there, which is producing sound, and if I do not have an acoustical enclosure, then it will produce w watts of energy, sound energy, and that all, that sound energy will go, and at a point faraway using the relations which we have explained earlier, we can compute L P. Now if I put an acoustical enclosure around it, small acoustical enclosure, then all of this energy or all of this power will not go out, only part of w will go out. So, the machine still continue to emit w watts of acoustical power, but the amount of power emitted, it will be w out, and this w out will be less than w, because of the presence of enclosure.

So, now we can compute L w out and using this L w out you can compute L p. So, the aim is that how do we compute w out. The smaller this value of w out is, the better is this enclosure; that is what we want. So, these enclosures are quantified by a mathematical number. It is called insertion loss, and what is this insertion loss. So, in short they are known as I L, I L is equal to 10 log 10 of w, w divided by w out. So, if there is no enclosure then w will be equal to w out, and the insertion loss will be 0 decibels, and the movement you insert an enclosure in the system, the value of w out will be less. So, this term will be more than 1. And as you, this entire thing in the parenthesis keeps on increasing, the insertion loss becomes more and more. So, the efficiency of an acoustical enclosure can be quantified by this parameter known as insertion loss. So, if you know the insertion loss of an enclosure, then you can very easily compute L w out from L w out, you can calculate L L P.

So, now what we will do is? We will also discuss how to find out this ratio w divided by w out. So, w divided by w out is equal to 1 plus v naught divided by rho naught c square. Excuse me this is small c and this is C. So, this is the relation and I will not prove this relation, but it is important to understand what it means. So, v naught is the inside volume of enclosure and C w j is the volumetric compliance of jth wall. What does this mean? So, suppose you have an enclosure, the first thing you have to identify is, how many different walls the enclosure has. It can be 1 cylindrical wall or it can be 6 separate walls like this, it depends on the shape of the enclosure.

So, in this, it is a box which. So, it has 6 walls. So, here I will add in this case 1 to n, where n is the number of wall. So, in this case n will be 6. Now what this equation tells us is, that if I increase the compliance, if I increase the compliance what will happen. This ratio, it will go down as we as this compliance c increase, this ratio will go down. If c is infinite what will happen. The value of w will be same as w naught w out right. So, physically what does compliance mean? Compliance means that if you have an object and you put some force on it, how easily does it compress, or how easily does it expand, how easily does it compress or how easily does it expand.

Now, if there is a system, if there is a box which has very high compliance, then it will very easily expand or very easily compress. Now if you have an enclosure which is extremely complaint, which means it is very easy to expand or compress what will happen when the sound waves will come and hit. The enclosure will expand very easily, and when there will be compression in the enclosure, because sound wave is all positive and negative you know. So, it will easily increase in size or easily reduce in size, and because of that the enclosure will expand and contract by very large amplitudes. And when it expands and contracts what will happen. Sound will get generated outside and that sound will spread.

So, if the compliance and this is volumetric compliance. If the compliance is very large or infinite, then it is as good as having no enclosure. On the river side, if compliance is 0, which means when pressure hits the inside walls of the enclosure, the system does not expand or contract at all right. What does that mean? The walls of the enclosure will not vibrate at all, and there will be no sound, which will get transmitted outside mathematically, what does that mean. When C w j or C w is 0, then the denominator is 0, this thing becomes infinite, then the ratio of w over w out is infinite which means no sound is getting outside.

So, what it means is that, if we have to have an enclosure, which is very effective. We have to make sure that each wall is as less complaint as possible; that is what it means each wall as less complaint as possible, it should be as rigid as possible, and as less compliant as possible. So, this is the general relation for all small acoustical enclosures, and for these enclosures we can easily calculate the internal volume v naught. We know the what is the density of air inside the cylinder or inside the enclosure. We can we also know the speed of sound inside the enclosure, and if we can somehow calculate C w j, where j is the C w j is the compliance of the jth wall, and we add them up, then we can calculate w by w naught. Once we know w by w naught we can calculate insertion loss, and once we know insertion loss, we can know L w out, and once we know L w out we can calculate L P.

So, that is how the process is going to work around for rectangular walls for instance in this case. This is a rectangular wall right. This enclosure has 6 rectangular walls, there are closed form formulas to compute their compliance. So, I am going to give you the relationship for compliance for rectangular walls

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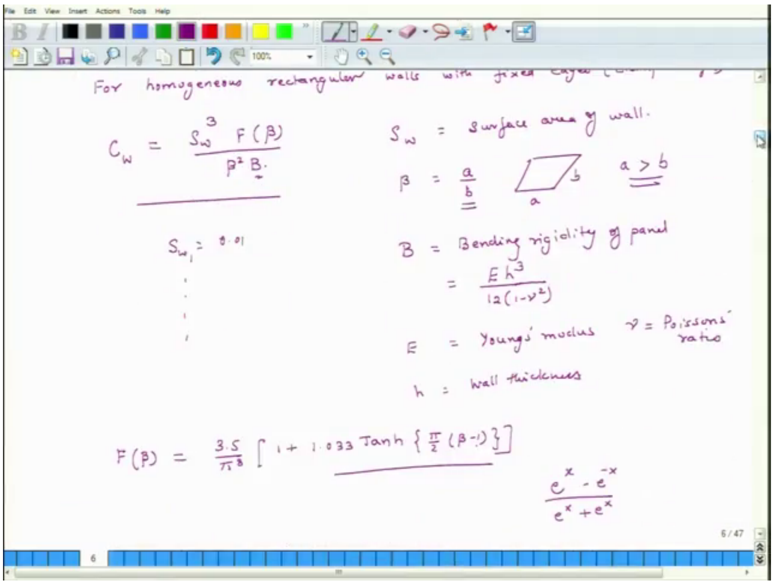

So, for homogenous rectangular walls with fixed edges, once again it is fixed here, each edges fixed, its not. There is nothing there, everything is, all the edges are fixed and actually more mathematically correct thing is clamped edges. The compliance of such walls is given by this.

So, what does all this mean? S w is the surface area of wall, beta is the ratio a by b. So, you have a wall, let us say this is a and b, then beta is the ratio of a by b, where a is larger than b, where you have to decide whether you put larger number on the top or bottom or in the or in the bottom. So, a whichever number is larger you put up, you make that a and the other number is b. This B relates to the rigidity of the bending rigidity of panel or wall, and this can be calculated as E h cube divided by 12 into 1 minus mu square, where E is what; Young's modulus. This is Poisson's ratio, and h is wall thickness, and the last thing is what, and this is a function of beta. So, what is this function

And this is the complicated function, but now we have calculators and computers. So, it is not a problem to compute all these things. So, this is equal to 3.5 divided by pi to the power 8 1 plus 0. Oh excuse me 1.0 3 3 tan hyperbolic pi by 3 times beta minus 1 ok.

So, what do you do, this with this you have to calculate w by w out to calculate that you have to find the compliance of each wall. If there are right for each wall you have to find out the compliance, and then you have to add up all those compliances multiply by rho naught C, and then divide v naught by this entire thing, and then you will get w by w naught and to find the compliance of each wall. If the each wall is rectangular like this and with fixed ends, this is the relation for compliance of each wall, this is the relation for compliance of each all. So, you have to be patient and for. So, especially for rectangular boxes, you can compute the compliance of each wall using this for all the 6 walls and do the math.

So, we will do very quickly an example.

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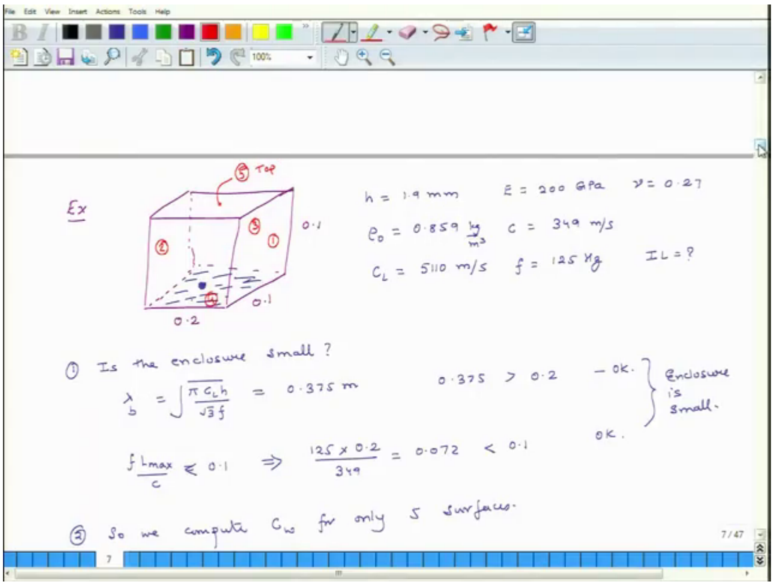

So, you have a machine which is inside a small acoustical enclosure. We do not know whether it is small or not, but it is inside an enclosure, and the dimensions of the enclosures are 0.1 is the height 0.1 0.2 and the machine is inside it. So, I will put the machine somewhere here. The thickness of each wall is 1.9 millimeters. The material of all the walls is steel, and the Young's modulus of a steel is 200 GPA Giga Pascal Poisson's ratio is 0.27 rho naught is 0.859. So, it is not at atmospheric pressure there is a little bit of vacuum in it, because the density is less, the speed of sound is still 349. So, this is kg per cubic meters. The value of C L speed of sound and steel longitudinal speed of sound and steel is 5110 meters per second. This machine is running at a certain RPM, and its producing a constant frequency sound, and the frequency is 125 hertz and so the question is, what is the insertion loss for this enclosure.

So, the first thing we check is the enclosure what small, is the enclosure small. So, the first condition is, that bending wavelength should be more than the largest dimension of the enclosure. So, bending wavelength is Pi C L H divided by root 3 f, and we have all the 7 values here. So, this comes to be 0.375 meters, and the largest size of the dimension, largest dimension of the enclosure is 0.2. So, 0.375 is more than 0.2. So, first condition is for small enclosures.

The second condition is f L max divided by C should be less than 0.1. So, let us compute that 125 times L max 0.2 divided by c 349. So, that comes out to be 0.072, and this is less than 0.1. So, this is also which means our enclosure is small. So, if the enclosure is small, then we can compute its insertion loss. And to compute the insertion loss, we will use this relation, and to compute this relation we have compute w by w naught w out, and to compute w by w out, we have to compute all these v naught rho naught c C w j all that stuff, good stuff.

So, the most complicated is finding out compliances, everything else is given directly. The other thing is that this enclosure is sitting on a floor in such a way that this surface of the bottom surface of the enclosure is bounded very nicely to the ground. It is very tightly held to the ground, if it is very tightly held to the ground what does that mean that this bottom surface of the enclosure will not vibrate, it will not vibrate. So, which means its compliance is, what infinity the bottom surface compliance is infinity. It will not vibrate at all. I am sorry, it is 0, it is compliance is 0. So, we have to calculate only the compliance of 5 surfaces. The sixth surface compliance is 0. So, we do not have to worry about it. So, we compute c w for only 5 surfaces, only 5 surfaces. So, let us number these surfaces, let us say this is surface 1, this is surface 2, this is surface 3, and this is surface 4. So, 3 is, actually 3 is this back surface, and the top surface is 5, everyone understood.

So, the back surface and the front surface are 3 and 4, and the top and the bottom are 5 and 6, but sixth we are not concerned about. So, this is our convention. So, beta 1 is 100 divided by 100 or 0.1 divided by 0.1. See what is betas, beta is the aspect ratio of each surface a by b, and a is the larger dimension b is the smaller dimension.

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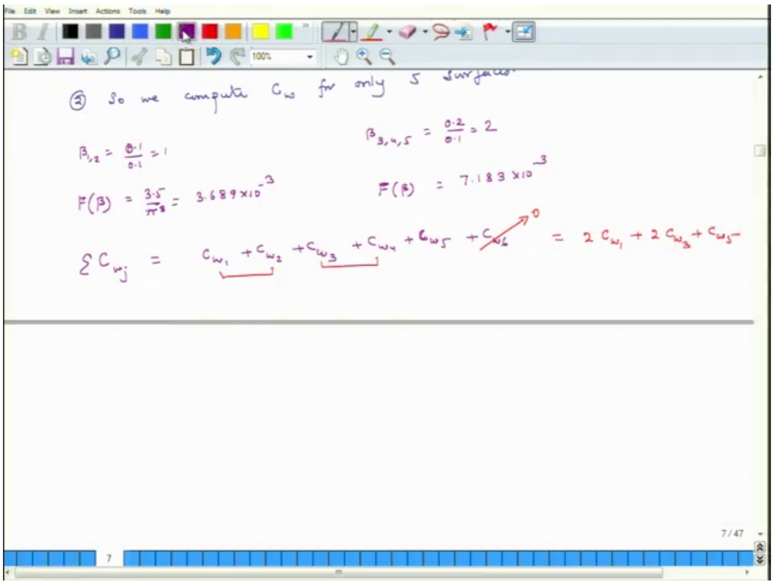


So, beta 1 and 2, beta 1 and beta 2 is 1 right. Similarly beta 2, no beta 3 4 and 5, they are same dimensions, same aspect ratio. Next we compute this term, when beta is 1, then this thing in the brackets become 0. So, 0 times Pi by 2 is 0 tan hyperbolic of 0 is 0, what is tan hyperbolic E to the power of.

Student: Minus x plus e or x.

This is the right.

Student: Yes.

Yeah. So, if this entire x is 0, the numerator is 0. So, this entire term goes to 0. So, we are left with just 3.5 divided by pi to the power of 8. So, tan beta is what 3.5 divided by pi to the power of 8, and that comes out to be 3.689 into 10 to the power minus 3.

Student: (Refer Time: 24:44).

Student: F of beta.

Oh I am sorry, this is F of beta. Yes you are right, not tan of beta F of beta. Similarly in this case for all these third fourth and fifth surfaces, the value of beta is same 2. So, F of beta will be same, and if you do the math you will use this relation, and here beta is 2. So, this become 1 pi by 2. So, you instead of x you should replace it by pi by 2 and you can do all the calculation, and you come up with 7.183 into 10 to the power of minus 3.

So, what is this j? So, this is equal to c w 1 plus c w 2 plus c w 3 plus c w 4 plus c w 5 and c w 6 is 0 right, c w 6 is 0. So, we are not going to worry about it. So, this is equal to 2 c w 1 plus 3 c w 3, why, because these two guys are having the same value, and these three guys are having the same value. Why will they have the same value? Well beta 3 4 5 as same, and you look at c w beta is same s w for each panel is same, the only thing which is different in. So, you can compute it right. No actually I am not correct c w 1 and c w 2 is going to be the same, same area, same beta, everything same, same thing with 3 and 4 c w 3 and c w 4 will be same, but c w 5 will be different ok.

So, this is not correct. So, it is equal to 2 c w 1 plus 3 and 4 are area same. So, you do all the calculations which I am not going to reproduce, but I think now we understand how to calculate it, because we have computed beta F, F beta for everyone. We have also computed b for beta for everyone. We also know the surface area, what is s w 1 surface area of the first surface. So, that is what 0.1 times 0.1. So, it is 0.01, and like this we can go and on computing surface area of each of the surface ok.

So, we know how to compute all these parameters same thing about b, b is e times h cube h is 0.019, 0.0019 1.9 millimeter is the thickness of the plate divided by 12 into 1 minus mu square mu is 0.27. So, we can compute everything. So, if I do all this the overall some of compliance is comes out to be 94.79 into 10 to the power of minus 12 cubic meters per Pascal. Remember this is volumetric compliance. What does this mean, that if I apply a pressure of 1 Pascal the volume is going to increase by so much amount. So, many cubic meters, if I apply a pressure of 1 Pascal the volume of the system is going to increase by 94.79 times 10 to the power of minus 12 Pascals, this is what it means. So, now, that I have computed C w j w by w out equals 1 plus, what is our relation.

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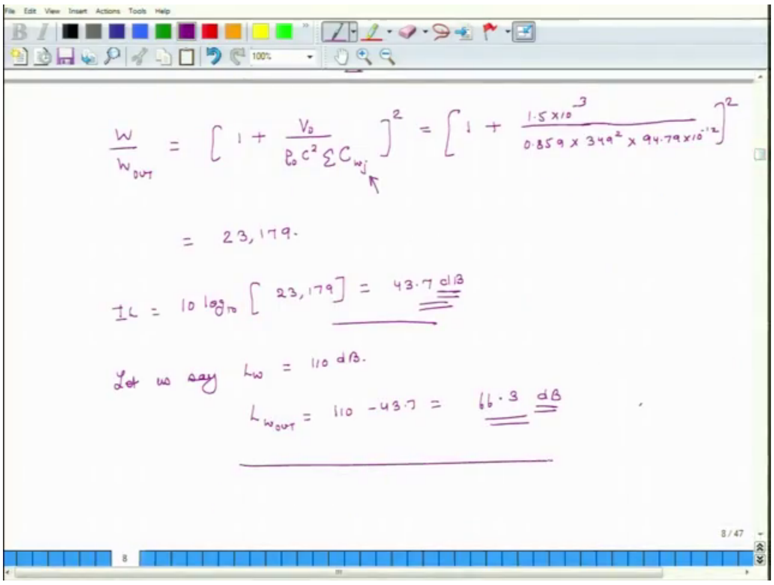


Student: 1 plus V 0 divided by P.

The relation is V naught divided by rho naught c square summation of all the compliances. So, and the whole thing is squared. So, this is equal to 1 plus V naught. What is the volume of the thing? So, this is something I forget to mention. So, the volume may not be same as the multiple of 0.1 times 0.1 times 0.2, why would that be the case, because some volume will also be occupied by the.

Student: Machine.

Machine. This is a small enclosure., we from a small amount of volume, if you take out the machine volume, it may become even smaller. So, it is the volume if you don't, if the machine is there, whatever is the volume left; that is the volume we have to worry about. So, that volume I am giving you, it is 1.5 into 10 to the power of minus 3 cubic meters, this is being given. So, with that understanding I write 1.5 into 10 to the power of minus 3 divided by rho naught. Rho naught is how much? 0.859 times speed of sound square times 94.79 into 10 to the power of minus 12 square, and if you do all the math correctly you will get 23179, which means that the small acoustical enclosure is letting out only 1 over 23000 times of the internal power. So, if inside you are producing 23179 watts of power, the amount of watts which are getting out of the enclosure is how much 1.

So, insertion loss is 10 log 10 23179 and that is 43.7 decibels 43.7 decibels. Let us say L w was 110 decibels. Suppose, let us say that machine was having a sound power level of 110 decibels, then L w out would be 1 110 minus 43.7 is equal to 56.53 decibels. So, this is L w out, and if you have to compute L P at a distance far away, you will use this L w out to compute L P, this is 66 3.

Student: Yeah.

So, this is what, suppose you were not happy with this insertion loss, and you wanted to increase it further, what would you do. You would like to reduce the compliance further or make the thing system stiffer, and you can reduce the compliance. So, how would thus compliance get changed? In our case compliance can be reduced either by reducing the surface area of each plate or by increasing F beta or by reducing beta or by reducing or by increasing b. So, if you and the most effective way in this case, to reduce compliance is by playing with b, because material you are already using steel. What else material will you use. So, but if you increase the value of h; suppose you are using right now 1.9 millimeters thick of steel, if you make it 3.8, just double the thickness of the steel plate what will happen to b.

Student: (Refer Time: 34:01).

B will go up by a factor of 8. So, compliance will reduce by a factor of, this is the most important parameter in this case, the thickness of the plate. If you make it even slightly thicker, you will have significant benefit in terms of this thing. So, this is something important to understand, and I think that concludes our discussion for today. We will meet once again next week, and we will continue our discussion on different noise, control and mitigation strategies, and with that I hope you have a wonderful weekend and I look forward to seeing you next week.

Thank you, bye.