Fundamentals of Acoustics
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Lecture – 43
Noise Reduction by Mass Attenuation

Hello. Welcome to Fundamentals of Acoustics. Today is the eighth week of this 12 week course. And what we will do today and also in our subsequent weeks is a series of applications, or we will try to, that is why what we will do is we will try to solve problems which have practical application in mind. And the intention here is that whatever you learnt from this course you should be able to apply feedback or some real situation in types of situations.

So, last week we had developed an expression for impedance and we have also explained how using a course tube you can measure the impedance of a material. So, that is one example of real problem. So, if you have a particular type of material whose sound absorption properties are to be known then you can use acoustic and the method described in the last week to determine those properties of the material.

This week we will focus on two important applications; the first application is that how do you induce a sound suppose there is a lot of sound in one particular area, and you want to make sure that adjacent to that area not a lot of sound is heard. So, how do you reduce if a sound coming from a noisy area to area where we want a little being less noise? So, that is done probably we will try to address. And the way we will try to addresses by using a special method known as mass attenuation. So, that is one problem we will try to address.

The other problem is that if you have source which is emitting sound for instance an engine or a (Refer Time: 02:19) and it has a particular frequency which is dominant in nature, then how do you reduce this kind of a sound where one particular frequency it is dominant. And this week what we will do is we will develop the ground work for developing a muffler or a silencer for this kind of an application. And the next week especially in the first half of the next week we will actually explain how you can design a muffler to meet your application needs.

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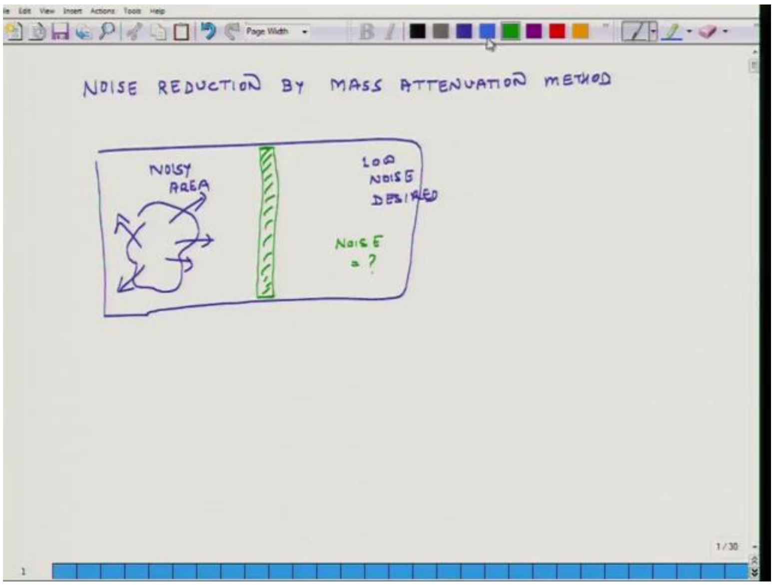

So, in the first problem we will try to solve sound reduction or probably instead of sound may be that a noise will be more appropriate; noise reduction by mass attenuation method. So, let us explain the problem. Suppose you have a one big room and there is some machinery here which is emitting a lot of noise, then what you want is that so this is a noisy area and you want that here there should be no noise. So, we desire the area should have less amount of noise. Then what do we do. So, a lot of times what people do is, people will put some partitions.

So, we will put then construct a wall or put a partition if there is a board or something and then what you want to understand is that what will be the noise transported in this area. So, that is what the aim is. This is the problem we will try to address in the first part of this week, and when we do that; let us first set up the problem.

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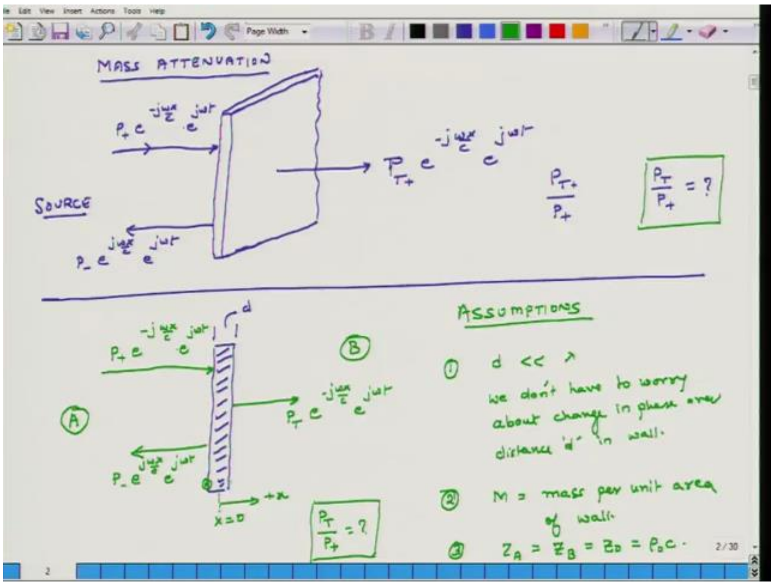

So, we will discuss the method of mass attenuation. So, the term attenuation means reduction, so mass attenuation. So, the intent is that we by using mass we want to reduce the spread of noise from a noisy area to area where we want less noise. So, what do we do? So let say this is a partition and this partition is infinitely long. So, it is a very wide partition and so there is some source and the source is emitting a noise and such that there is an incident wave which goes and hits this wall. So, the incident noise is P plus e minus j omega x over c times e j omega t. And when it hits this wall some of the noise gets reflected. So, I will say like that the complex pressure due to reflected sound if e minus j where e P minus to the power P minus times e to the power of j omega x over c e j omega t. And then there is some noise which gets transmitted through the wall and level of that noise is here P T and its moving in the positive direction, and that noise is complex pressure is P T plus to the power of e minus j omega x over c times e j omega t.

So, what is that that we are interested in? We want to figure out how effective this wall is in terms of producing the noise which is getting transmitted. So, essentially what I am doing it trying to figure out is that what is the ratio of P T to P plus; P T and I am going to make a graph this to the plus time for P T because there is no reflected sound here, so I will just say P T over P plus. So, the assumption is that once the noise is transmitted it is getting transmitted in to an open field there is no reflecting wall. So, on the transmitted side there are no reflections had been.

So, we want to find this ratio P T over P plus; if P T over P plus is less than the wall is doing which is of very well, if P T over P plus is high and the maximum it can be is 1. So, if it is 1 then all the sound which the wall is receiving its transmitting (Refer Time: 08:26) so that kind of a wall is not a good noise reducer. So, that is our problem statement. So, our goal is to find out this ratio P T over P plus. So, we will now simplify this picture and if I look at this picture from the end and this is how it looks like.

So, this represents the wall and this wall is infinitely long and infinitely deep, but its thickness is maintained. So, its thickness is d and there is a sound source which is generating noise and because of that noise there is an incident pressure field which is and the complex magnitude or complex incident pressure field is yield P plus times exponent minus j omega x over c times e j omega t there is a reflected thing P minus exponent j omega x over c e j omega t and then you have a transmitted sound pressure. So, it is P T e minus j omega x over c e j omega t.

And let say that x is equal to 0 at the wall and this is the direction of positive x. So, I will define coordinate system, and then we make some assumptions. So, what are the assumptions? The first assumption is; that d this is the thickness of the wall is very small compare to lambda. So, if I am striking this wall with the particular frequency the thickness of the wall is extremely small compare to the wavelength of the wall. Or what does that mean? That when a sound travels through the wall it will take some time for sound to travel from one side to the other side, and as it travels with a that moment of time the change in phase in the transmitted wave will be extremely small.

If d is extremely small compare to lambda. If d was equal to lambda then the phase difference would be 2 pi radius. If d was lambda over 2 then phase difference would be pi radius. If d was lambda over 4 then it would be pi over 2, but if it is extremely small then the transmitted waves phase will be more or less same at x is equal to 0 relative to the incident wave phase. So, what that means is when as we are going the mathematics we do not have to account for the phase difference which is introduced due to the thickness of the wall. So, if these very small compare to lambda then we do not have to worry about change in phase over distance d in wall.

Second, if we assume is that M is equal to mass per unit area of wall, so as per unit area. In the third thing we assume is, so let us call this side A and on the transmitted side because and it will B. So, Z on side A is equal to Z on side B is equal to Z naught. So, Z A and Z B are characteristic impedance. So, media on side A is same as media on side B which means characteristically impedance on side A side B is same as Z naught and that is air so it was equal to rho naught C. Then rho naught and C naught are corresponding to density and see the sound in air at HTP conditions.

So, with these assumptions what we are interested in finding is this ratio P T over P plus, so this is what we are interested in finding. So what do we do? How do we start solving this problem? So, the first thing is that we look at side A and look at side B and we develop the transmission line equations for both side A and side B.

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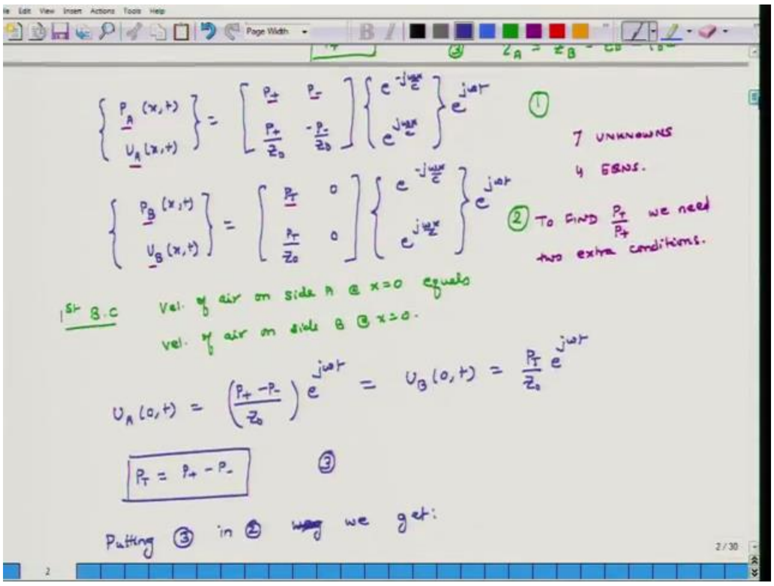

So for side A; P and I will call it P A x t and velocity on side A is U A. So, this is complex pressure on side A and side B, this is equal to P plus P minus P plus over Z naught minus P minus over Z naught e minus j omega x over c e j omega x over c e j omega t. Similarly, for transmitted side P B is same as; so P B x t and U B. So, B corresponds to the transmitted side the other side of the wall that is equal to, from the transmitted side what is the incident wave P T and what is reflecting wave is none. So, its amplitude is 0; complex amplitude, so 0 P T over Z naught 0 e minus j omega x over c e j omega x over c e j omega t.

So, let us you get these equations. So, the first set of equations is for side A, the second set of equations is for the transmitted side. These are total of 4 equations. And the number of unknowns in these equations is, so you will have (Refer Time: 15:54) of course P A, we do not know U A, we do not know P plus, we do not know P minus; then we do not know P B, we do not know U B, we do not know P T. So, total of 7 unknowns and equations is 4 equations.

So, if we have to find all these unknowns then I have to know 3 extra conditions. If I have to just find the ratio of P T and P plus then I have to know 2 extra conditions. So, to find P T over P plus we need two extra conditions. So, see 4 equations and 2 extra conditions will do those have sufficient information to find the ratio of P T and P plus. So, that is what we planned to do. So, what are those extra conditions? So, the first extra condition is; that at x is equal to 0, so let us look at this point at x is equal to 0 the air on the wall, the pressure on the wall; excuse me whatever is the velocity of this wall will be same as the velocity of air on the right side and it will be same as the velocity of air at the left of the wall. And, it is not 0 because the wall is splitting move, because it is split to move.

So, when I put a partition between two rooms, if some pressure is may applied on the thing unless the wall is rigid, but if wall is spilt to move then it can move back and forth, even though that distance displacement and velocity will be small, but it is free to move. So, whatever is the value of velocity on left side of the wall is same as velocity on the right side of the wall. So, that is our first boundary condition.

So, first boundary condition is velocity of air on side A at x is equal to 0 equals velocity of air on side B at x is equal to 0; this is the first boundary condition. So, what we are doing in this case if this is equation A. So, I do not want to use A and B again to create a confusion. So, let say this is equation 1 this is equation 2. I can calculate the expression for velocity from 1 and 2 and at x is equal to 0 these two numbers are same, so I can equate them. So, that is what we will do.

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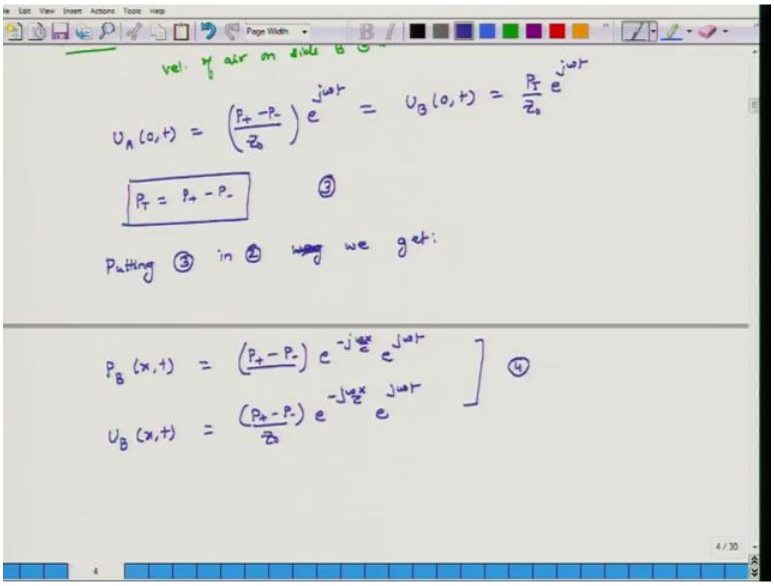

So, U A and 0 t is equal to P plus by Z naught and if I put x is equal to 0 in exponential terms e j omega x and e minus j omega x everything will be 1. So, what I will get is P plus minus P minus divided by Z naught e j omega t and that equals velocity on side B at x is equal to 0, this is equal to P T over Z naught e j omega t. So, this is complex velocity. Velocity is same then complex velocity has to be same. So, from this what I get is that P T equals P plus minus P minus. So, this is one relation I get, this very important relation. So, this is equation 3. So, putting 3 in 2 we get; what do we get? We get P B x t equals P plus minus P minus e minus j omega x over c e j omega t. And U B is equal to P plus minus P minus divided by Z naught e minus j omega x over c e j omega t. So, this is a fourth set of equations.

So, at this stage; so what we have done till so far is we have developed our equations for complex pressure and complex velocity, and to those we have applied the first condition at the boundary that velocity on right side is same as velocity on left side equated these two and in that way I could a develop a relation between P T P plus and P minus, and you have using that I have modified or reframed the expression for pressure and velocity on side B.

So, with that we close our discussion for today. And what we will do tomorrow is continue this discussion, and apply the other condition, one more condition and then use that extra condition to solve for the ratio P T and divided by P plus. So, that it is all for today, and we will meet once again tomorrow.

Thank you.