Acoustic Materials and Metamaterials

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Lecture – 22
Microperforated Panel Absorber - 2

Welcome to lecture 2 on the series of Acoustic Materials and Metamaterials. So, in this lecture we will continue a discussion on Microperforated Panels.

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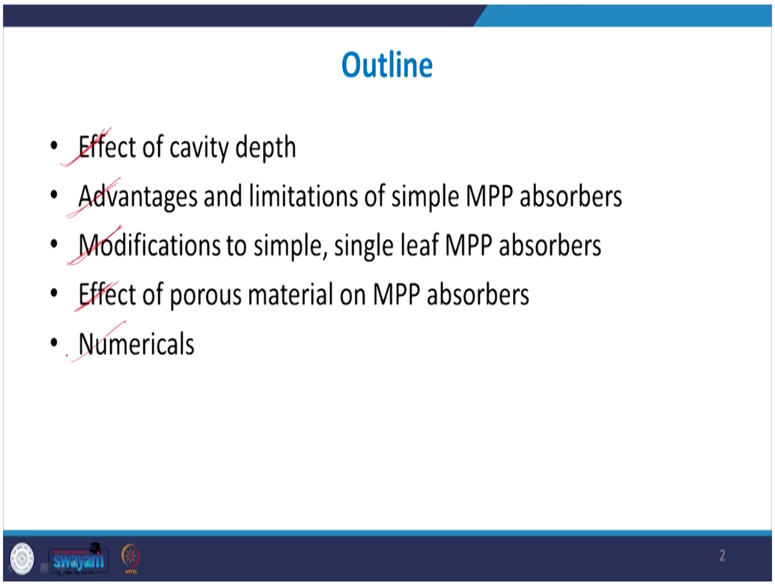

So, let us begin this lecture. So, what we will see in this lecture is we will see what is the effect of cavity depth and then what are the advantages and limitations of MPP absorbers and what modifications have now been done to this single leaf MPP absorbers to remove this limitations.

And then we will study about the effect of porous material on MPP absorbers and we will then solve on numerical based on that.

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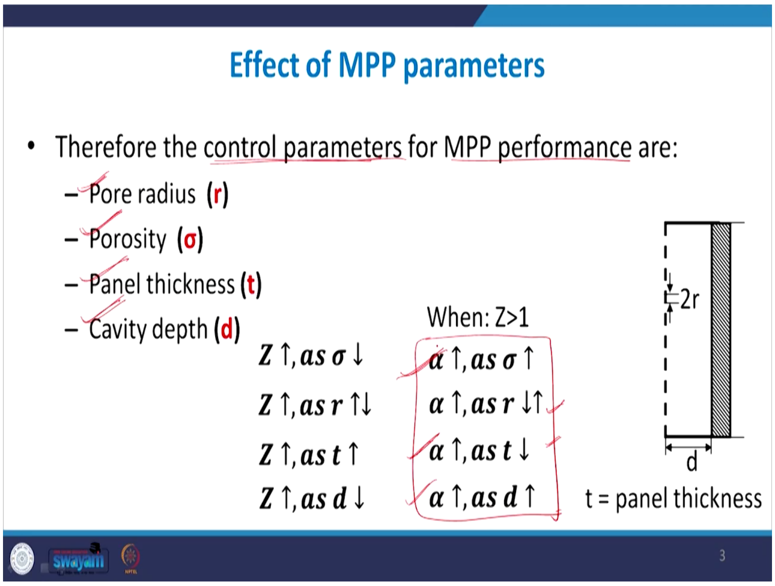

So, in the last class we already saw and we derived how the various design parameters of an MPP the effect the overall acoustic impedance which inturn then effects the absorption coefficient of the MPP; so, this is what we have found. So, if you have a look here then the various design parameters which control the absorption of an MPP or which control the performance of an MPP they are; the radius of the pores of the radius of perforations, the porosity of the MPP, the panel thickness and the cavity depth and we have already defined what is porosity in our lecture on perforated panel.

So, these are the four parameters and absorption increases as you increase the porosity; absorption increases as you decrease the, an absorption follows a the different kind of a relationship with r. So, it initially decreases with absorption increases as r is decreased, but after certain value r has to be increased for increase in absorption. And then absorption also increases with decrease in the thickness of the panel and it increases with the decrease with the increase in the cavity depth.

So, if you increase the cavity depth in the porosity its absorption that is increasing with r and t; the relationships are bit more complicated. So, these are the various control parameters.

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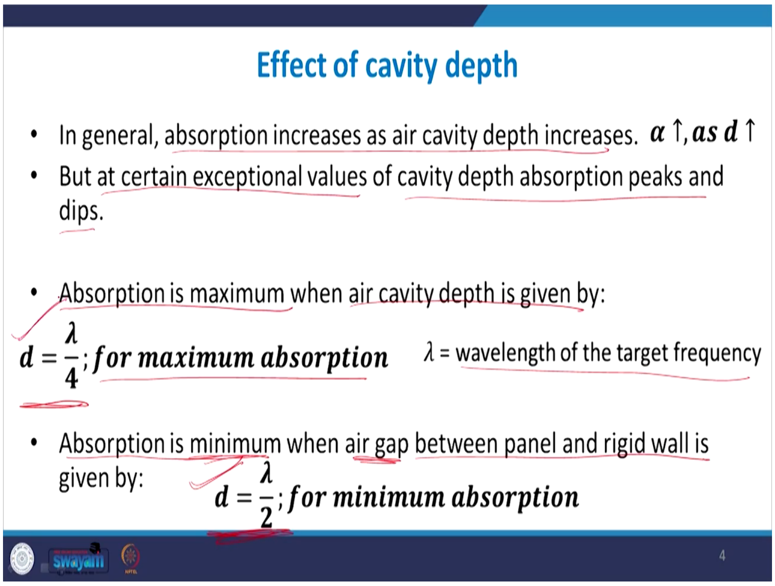

So, what is the effect of cavity depth? As you already saw, as you increase the cavity depth; absorption is going to increase, but absorption will increase with increase in cavity depth. But at some certain exceptional values; the cavity depth absorption will peak and dip. So, although in general for most all the remaining values as d increases, alpha will increase, but at certain typical values there will be a sudden jump in the absorption and then there will be a sudden dip in the absorption.

So, what are those values? The absorption will peak when the air cavity depth is given by lambda by 4, where lambda is the wavelength of the target frequency. The absorption will dip or it will reach us certain minimum when this air gap between the panel and the rigid wall becomes d is equal to lambda by 2. So, we have already seen what is this effect; why d equals to lambda by 4 we get maximum absorption and d equals to lambda by 2 minimum absorption. We saw it in the case of panel absorbers and also in the case of perforated panel absorbers.

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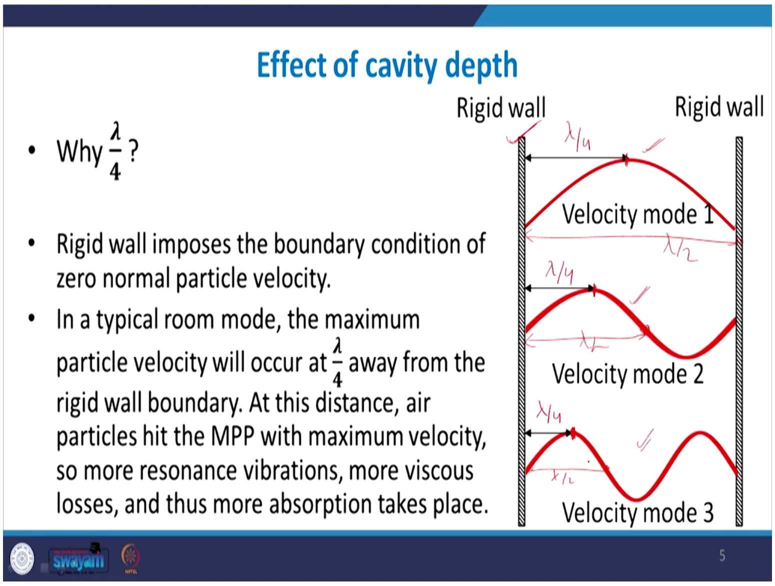

So, this is the explanation here. So, when the perforated panel is used indoors in a closed room, so there is going to be a boundary between the rigid walls. So, whenever the; so this shows us the various velocity modes that are set up with this rigid wall boundary.

So, the velocity modes they will have always these kind of shapes and so on 1, 2, 3 or 4. So, every time at a distance of lambda by 4; so this distance is lambda by 4, this is lambda by 4 and this is lambda by 4. So, every time at a distance of lambda by 4 just ahead of the rigid wall, you will have a velocity you will have a velocity and the modé or velocity will be maximum.

So, the acoustic particle velocity will reach a maximum at a distance of lambda by 4. So, whenever an MPP is placed at a distance of lambda by 4 ahead of a rigid wall. So, in that case the mode that is being setup; so what will happen is that in that case is that the particle velocity it will, the particle velocity will be maximum. So, the incident sound wave will hit with the maximum particle velocity into the panel and as we know as that; as the velocity there the acoustic particle velocity increases, the viscous loss will also increase.

So, the higher the velocity with which the air molecules they are entering the holes the higher will be the viscous losses between the surface of the boundary and the air molecules.

And in the same way the higher the velocity with which they are heating; the higher or more vibrations will take place, the higher will be the magnitude of the resonance and therefore, more losses will take place. And similarly at every lambda by 2; if you see this is lambda by 2, this is lambda by 2; so at every reputation of lambda by 2; what you get for is that you get v equals to 0. So, the acoustic velocity is the minimum or a 0 at the distance of lambda by 2 from the rigid wall or the rigid backing.

So, in that case because the velocities almost 0; so resonance the oscillations in that case; the resonance does not take place and this also know viscous losses the. So, the higher the velocity with which these; these particles they hit the surface of the MPP, the more will be the losses and that is why at lambda by 4; we have maximum absorption and lambda by 2 we have minimum absorption and for the remaining values this is the relationship.

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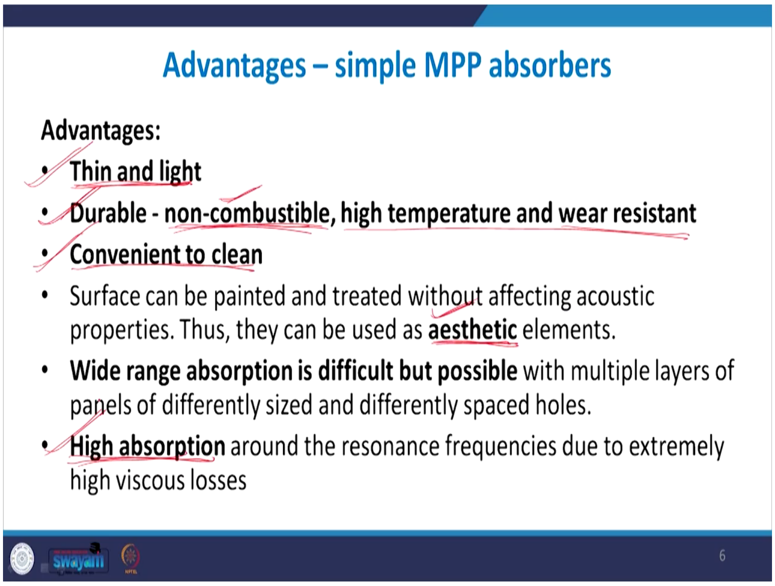

So, what is some of the advantages and limitations of some; some simple MPP absorbers? So, the advantages are pretty clear; so they do not; they are not made up of porous material or fibrous medium, so they are not clean, unclean. They do not need to be maintain time in again to see that all the fibers are properly located, they are not falling apart etcetera. So, they do not contaminate the machine re component or wherever they are used; so they are; obviously, convenient to clean.

Then also because it is made up of a very thin material; so very thin any hard thin panel can be used as a micro perforated panel and you do not even need a rigid backing all the time. If you just install this panels some distance away like lambda by 4 distance away from the wall, this wall with the panel together will make a total MPP absorber.

So, in that case they are very thin and light solutions to sound absorption. Then they are; obviously, durable because it is not like the porous medium; they are also non combustible. So, what happens with porous medium is then when we are using porous and fibrous mediums; they have the tendency to catch fire; they are made a flammable materials, they can catch fire easily.

But here we have a metal or a thin sheet of hard material which can be non combustible and it can be more resistant to high temperature and can be more wear resistant as well. So, it is more durable overall and then if you paint or make some finishing some decorative finishing on you paint the surface of the material or make it more decorative and then you punch holes; then you get a more aesthetic look to the MPP. So, they can also be used for as aesthetic elements.

Here in this case of MPP; just like in the case of perforated panel; a wide range absorption could be possible, but it is difficult to achieve. For wide range of absorptions here we might need more than one panels 2 to 4 panels with different sized holes and porosity. Because the absorption the for the fundamental frequency and the absorption magnitude all of them they depend on the various parameters like the porosity, the hole radius and the rigid backing depth or the air cavity depth.

So, as you increase this parameters; then you can have absorption at different different peaks and at different different frequencies. So, you would need a large series or numerous such MPP absorbers to obtain a wide range absorption. So, unlike Helmholtz resonator it is possible, but again it requires; even in Helmholtz resonator it is possible, but it requires and number of such elements of different sizes.

The main advantage with respect to the other absorbers except for the porous fibrous medium all the other resonating absorbers like the panel resonators, the Helmholtz resonators and the perforated panels; the MPP offers the highest absorption. So, it has a very high absorption because now here we have resonance as burn mode of reducing the incidence sound energy and then we have a heavy viscous loss as well.

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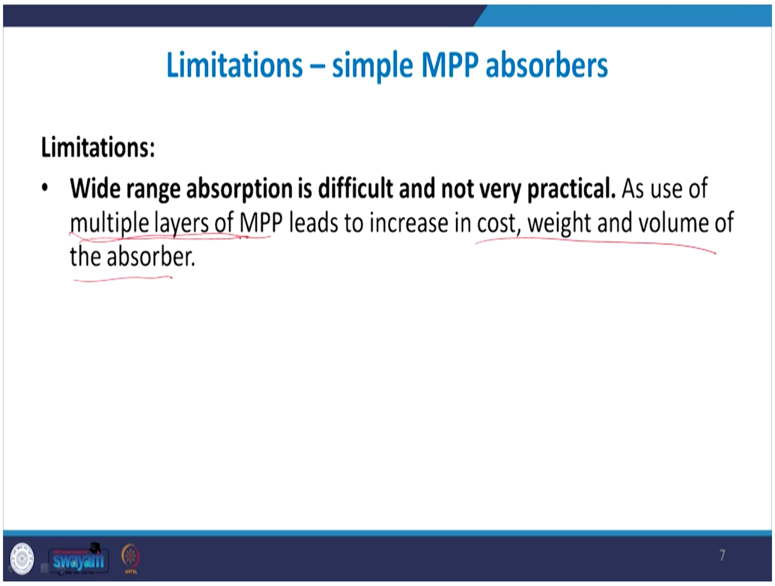

So, high absorption is possible because of this two mechanism and then limitation as I said the; the advantage is actually a limitation here that to get a broad band absorption. So, that porous materials can be easily use to get a broad band absorption; the only, but the limitation with them is that first of all they are not very durable and then they do not they have a poor performance at low frequencies; they give a broad band absorption only at high frequencies.

In case of MPP, they one MPP that is design will only be able to give have one absorption peak, but if you have a series of such MPPs together with different layers. So, if you use multiple layers of MPP; then maybe we can get a wider absorption, but using such large systems will again increase the cost, the weight and the volume of the absorber. So, wide range absorption is always difficult which these simple MPPs.

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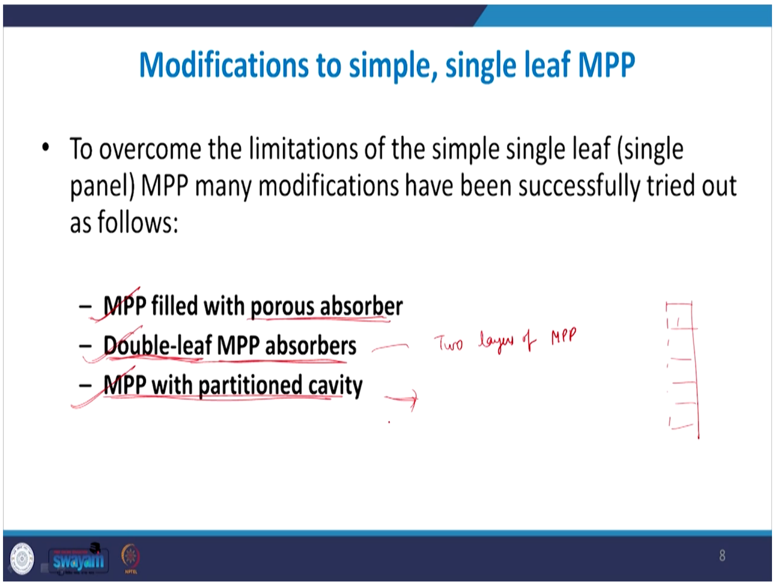

So, now that we know the limitation of the MPP that is again this also does not; although it increases the absorption magnitude, but it does not offer a wide range absorption easily. So, to overcome this limitation many such variations and modifications have been done time and again and three successful modifications that I will discuss are; if an MPP is filled with porous absorber. The second one is that if still now we had only one layer of per microperforated panel; what if we have two layers back to back. So, that is called as a double leaf MPP absorber which has two layers of. So, this has two layers of MPP or microperforated panel.

And then we can; the third modification that is successfully tried is MPP with partitioned air cavity. So, where we have the MPP and the air cavity it is sectioned or partitioned into different segments with different properties. So, many other modifications are being tried because MPP is; obviously, a very very MPP is a very you can say a hot topic in the case of acoustic materials and it is being use to widely and much research is being developed in the is being done in the recent years, but these are some of the three successful modifications that we will study one by one.

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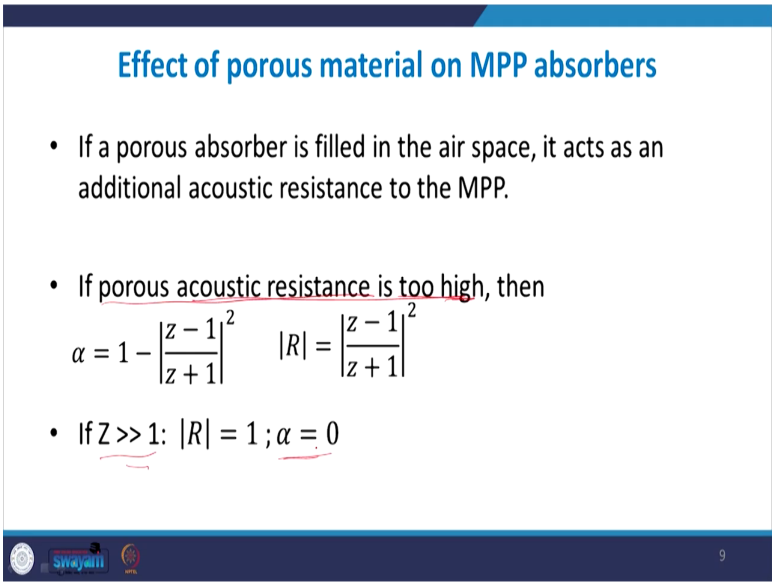

So, let us study the first one which is the effect of porous material on MPP absorbers. So, if you add a porous material which means that you had an impedance due to MPP. Now, with the porous material you are actually adding one additional resistance. So, porous materials some additional acoustic resistance is being added and provided that this resistance is not too high because your resistance becomes too high then all of the; then alpha becomes 0 none of the sound will be able to enter in no dissipation will take place.

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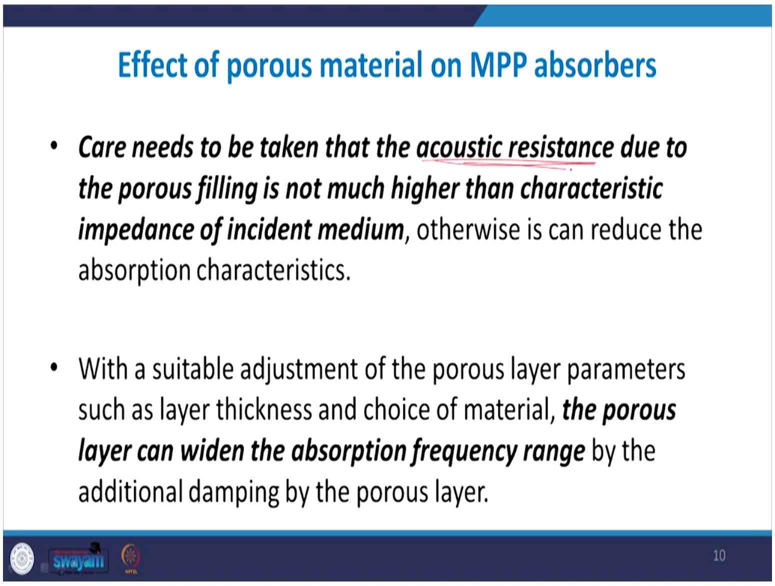

So, in that case; so in that case the acoustic material it acts has many the porous material will give a more resistance. So, overall the effect will be that add the resonance, the MPP will have large loss due to absorption, but if you add the porous material; then it will offer some resistance to air flow. So, it will offer some resistance to the resonance oscillations.

And therefore, at the resonance frequencies; the absorption magnitude will drop a little because of this porous filling. But porous materials there operative throughout all the frequencies; therefore, even at other frequencies where the resonance effect does not take place even then some energy loss will be there as the particles the air particles they pass through the MPP. So, the overall effect will be something like this. So, if you go here into this graph here.

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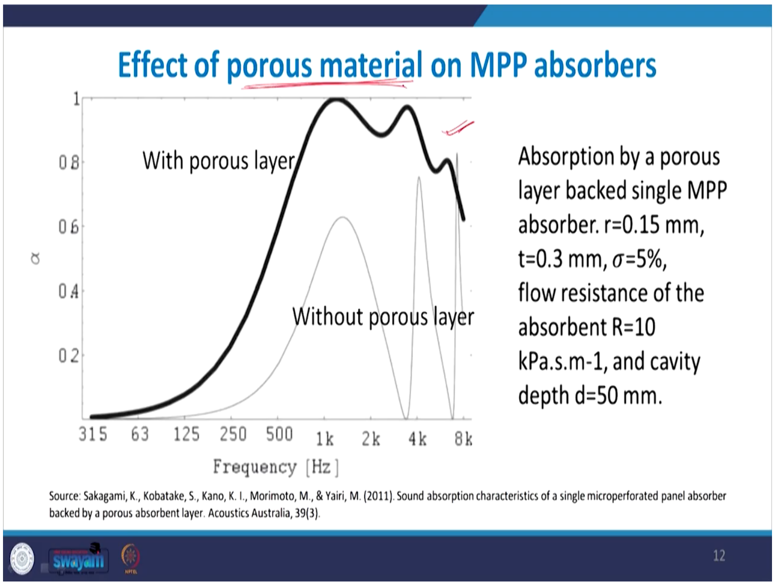

So, if you carefully choose it. So, you can get a more broad band type of absorption with a porous material on the MPP, but always you have to take care that; you have to take care of what is the total resistance what is a total Z value after the addition of MPP; the total Z value should not be too high so that no particles enter at all. So, a very carefully chosen value has to be taken.

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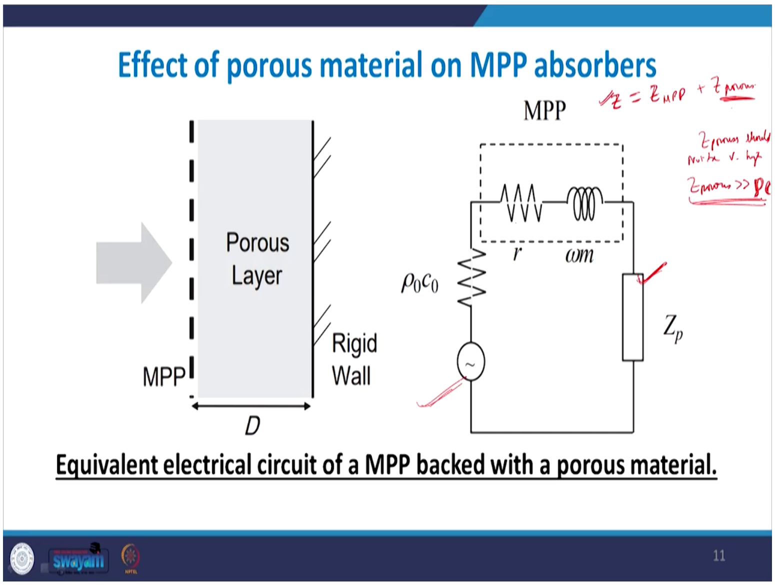

Equivalent electrical circuit of a MPP backed with a porous material.

And when you choose a carefully chosen value then the electrical circuit for this value becomes; let us see we have a source here and this is the resistance and the reactants of the MPP. So, porous material add the; add just filled up the porous material just behind the MPP sort of adds like another series impedance that is being added to this system.

So, now instead of total Z; so previously it was the total Z was Z of MPP plus Z of cavity; now it becomes now the total impedance becomes Z due to the MPP. So, if you see here Z due to MPP plus Z due to the porous material. So, the only care has to be taken Z this Z porous should not be very high very high Z due to porous material should not be much greater than rho c. So, that because if Z is too high then the overall material will now become so resistant to air flow that none no none of the; the air will not even pass through it and deflections will take place; so that condition has to be avoided.

So, once you have a carefully chosen value; then you get a white scale absorption. So, the absorption overall increases a lot and becomes more broad band. So, the peaks; so originally we had sharp peaks, but now we have more broader peaks. So, this way this is one such example of a adding a porous layer.

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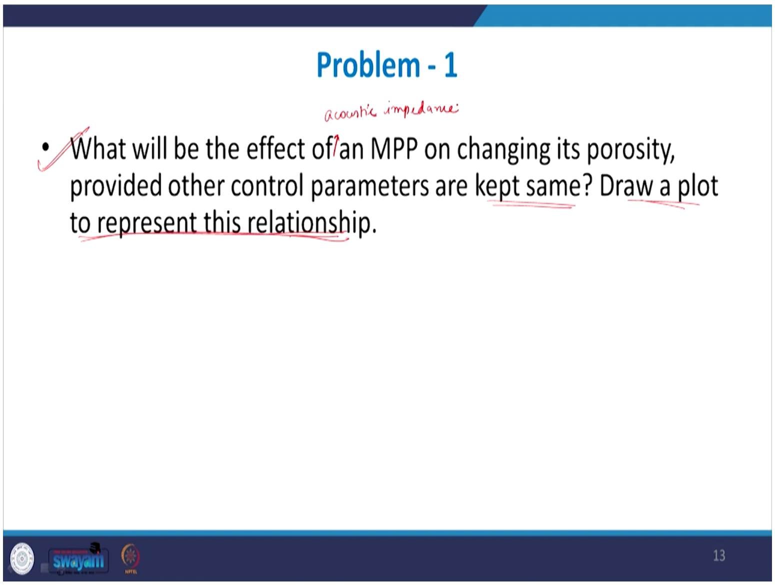

So, let us solve one problem related to whatever we have study till now. So, the problem here is that what will be the effect of an MPP on changing its porosity provided that the control parameters are kept the same, draw a plot to represent this relationship.

So, here just one a modification here; what will be the effect of the acoustic impendence of an MPP because it is just showing you what is the effect. So, let us say we are trying to find out what is the effect of the acoustic impendence of an MPP when its porosity is changed and draw a plot that can represent this relationship. So, let us solve this particular problem here.

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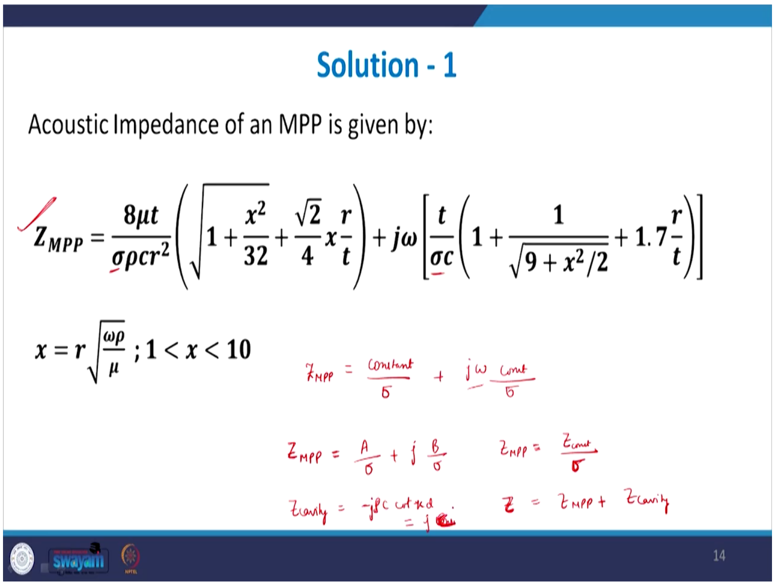

So, here you know that the acoustic impendence of an MPP is given by this formula; it is a complicated one ok. So, this entire expression is given to you and the porosity is this and this is the porosity; all the remaining expressions they are independent of porosity. So, overall the Z of MPP can be written as some constant by porosity plus j o omega; some constant by porosity. If you take this constant, this also has a constant; then what we can write is a Z of MPP becomes some constant A by the porosity plus some constant plus j times some constant B by porosity.

So, Z of MPP is going to be some Z value; some Z constant by porosity. So, universally proportion to porosity and the Z of cavity was given by minus rho c cot k d; so minus j times of this right. So, the total Z then becomes Z of MPP plus Z of cavity.

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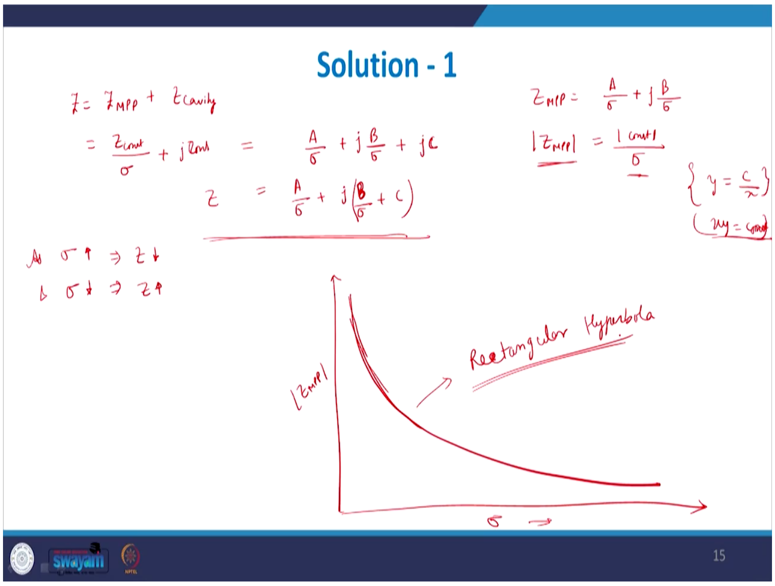

So, we go to the next slide here; so this is what we have found. So, this becomes some consume Z constant by the porosity plus again some Z constant or let us say j constant or if you represented in terms of constant; it is A by sigma plus j times of B by sigma and Z cavity here was given by this which was some j times some constant; let us say some constant C.

So, all of these constants are independent of porosity. So, plus again some j times of C. So, these are the constants and the only varying factor here is this sigma in the first two; in these first two equations. So, what we get is; so the relationship is very clear; as Z increases, as porosity increases, as porosity is increased; this implies Z will decrease and as porosity is decreased, Z will be increasing and this is the sort of relationship we have found.

Now, let us see if you were to plot only the Z of MPP with respect to porosity. So, Z of MPP was given as A by sigma plus j by B of sigma. So, mode of this Z MPP will be some constant mode. So, it will be some constant divided by sigma; so it will be an inverse relationship. So, it is going to be; so this if you plot this with respect to this, what we get is ok. So, Z this with respect to sigma; so it is an inverse relationship. So, this is this is of the same form is y is equal to some constant times of x or x y is equal to some constant.

So, you know that this particular equation represents rectangular hyperbola x y is equal to constant is some rectangular hyperbola and the relationship will be and the graph is something like this. So, this is the kind of graph that we will get which belongs to a rectangular hyperbola. So, this will be the relationship between the two.

And anyway; so this; so to in today's class, we discussed about this numericals as well as what is the effect of introducing a porous material inside an MPP. So, as you saw that it increase the overall absorption magnitude and it broaden the peaks; so that was the effect. In our next class, we will study about the other two modifications that is what is the effect of adding multiple layers of perforated panel or partitioning the cavity. So, see you for the next lecture.

Thank you.