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A Comparative Study on Acoustic Parameters of Porous Absorber of polyamide, polyester and polyurethane

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ABSTRACT

The analysis and simulation of porous absorbers using COMSOL Multiphysics software is a powerful tool for predicting the acoustic performance of these materials. Porous absorbers are widely used in various industries, including automotive, aerospace, and architectural acoustics. The study aims to provide a better understanding of the acoustic properties of porous absorbers, and the simulation results could be used for optimizing the design of porous absorbers for specific applications. The main objective of this research is to investigate the effect of various parameters on the acoustic performance of porous absorbers, Sound pressure level, scattered acoustic pressure, Incident acoustic pressure, Point pressure, Normal Impedance, Absorption Coefficient. The absorber made from polyamide, Polyester and polyurethane are selected for the studies. The better absorbing results are obtained from the absorber made from polyurethane. The COMSOL software is used to simulate the acoustic behavior of porous absorbers, and the results are compared with experimental measurements to validate the accuracy of the simulation.

Keywords: porous absorber, analysis and simulation, acoustic properties, comsol software.

INTRODUCTION

An absorber is a device or material that absorbs or attenuates a specific type of energy or radiation, such as sound, light, or electromagnetic waves. In the field of acoustics, an absorber is a material that is designed to reduce the reflection of sound waves and to absorb sound energy [1]. Absorbers are widely used in various industries, including automotive, aerospace, architectural acoustics, and industrial noise control.

COMSOL Multiphysics is a software tool that enables engineers and scientists to simulate and analyze physical systems in a multiphysics environment. The software provides a comprehensive platform for modeling and simulating physical phenomena involving multiple physical processes such as structural mechanics, electromagnetic, fluid dynamics, and chemical reaction [2]. The COMSOL software uses finite element analysis (FEA) to solve complex multiphysics problems. It allows users to create and solve numerical models that simulate physical systems using various physics-based modules. COMSOL also provides a graphical user interface that enables users to build models quickly and efficiently without needing to write code [2].

METHODS AND MATERIALS

A Porous Absorber is a type of acoustic absorber that is designed to reduce sound reflections and echoes in a room or enclosed space. It is made up of a porous material that is able to absorb sound waves by converting them into heat energy through frictional losses [1]. Porous absorbers are typically made up of a material with a high porosity, such as fiberglass or mineral wool, which is encased in a perforated or open-faced panel. The sound waves enter the panel through the perforations or openings and then are absorbed by the porous material [3]. In this analysis, we have to use different types of foam materials like Polyester, Polyurethane, polyamide used as an absorbent and air used as an absorbate. Here is a 2D model of the porous absorber used here.

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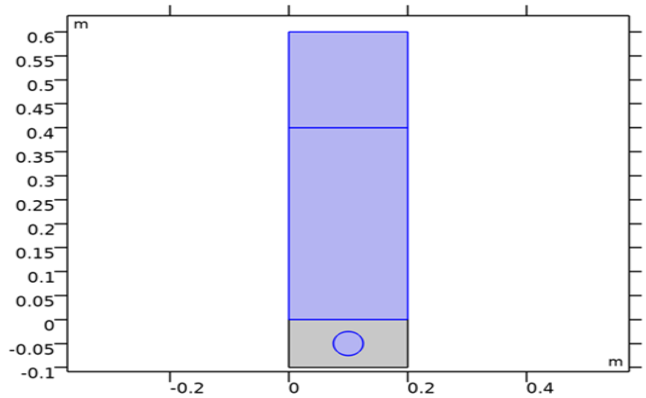

Fig. 1 Air and foam domain

From the Fig.1 bottom rectangle box is where the foam domain above its air domain is located.

It's important to note that the specific benefits of foam in porous absorbers may vary depending on the type of foam used, its density, thickness, and the intended application [3]. In this study the following acoustic parameters total acoustic pressure, sound pressure level, scattered acoustic pressure, incident acoustic pressure, point pressure, normal impedance, and absorption coefficient were analyzed using COMSOL software

RESULTS

Case Study 1: Polyamide

In this case study air is a constant material which is passed through the absorber, polyamide used as a foam material. Polyamide has a moderate level of moisture absorption. It can absorb and release moisture from the surrounding environment, leading to dimensional changes.

Input Parameters:

Name	Expression	Value	Description
f_max	10[kHz]	10000 Hz	Maximal frequency in the model
lambda_min	343[m/s]/f_max	0.0343 m	Minimal wavelength
theta0	0[deg]	0 rad	Incident wave angle
W	20[cm]	0.2 m	Domain width
H	40[cm]	0.4 m	Air domain height
Hp	10[cm]	0.1 m	Porous layer height
A	2.5[cm]	0.025 m	Inclusion radius
Hpml	20[cm]	0.2 m	PML Domain Height
mu0	1.8e-5[Pa*s]	1.8E−5 Pa·s	Dynamic viscosity of air
epsilonP0	0.995	0.995	Melamine foam porosity
Rf0	10.5e3[Pa*s/m^2]	10500 $Pa·s/m^2$	Flow resistivity

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tau0	1.0059	1.0059	Tortuosity
Lv0	240[um]	2.4E−4 m	Viscous characteristic length
Lth0	470[um]	4.7E−4 m	Thermal characteristic length

Table 1 input parameters Polyamide

Analysis of acoustic parameters

1a. Total Acoustic Pressure:

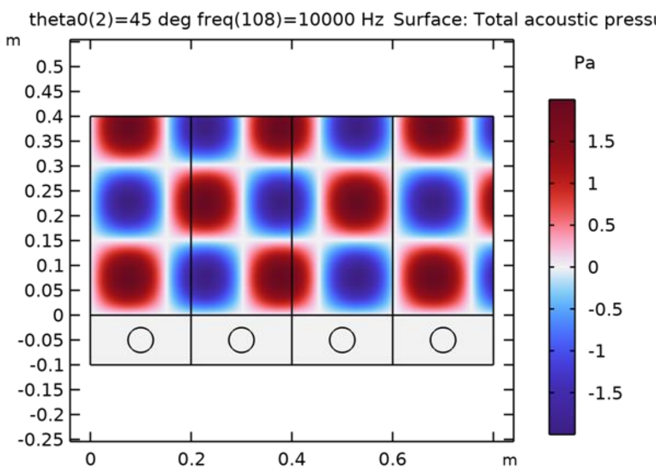

Fig. 2 Total Acoustic Pressure

Here the minimum pressure is -1.5 and the maximum pressure is 1.5. If the total acoustic pressure increases, then the amplitude will increase. And if the total acoustic pressure decreases, then the amplitude will decrease. If the amplitude decreases, then the reflection of the sound wave also decreases. In the above figure, the blue color denotes the minimum pressure and there is a minimum in amplitude so the reflection of a sound wave is also minimum. The dark red color denotes the maximum pressure and there is a maximum in amplitude so the reflection of a sound wave is also maximum. The distance from the source of the sound can also affect the total acoustic pressure. As the sound wave travels further away from the source, its amplitude decreases, resulting in a lower total acoustic pressure. Conversely, if the sound source is closer, the sound wave will have a higher amplitude and a higher total acoustic pressure.

1b. Sound Pressure Level:

Here, the minimum sound pressure level is -20, the mid sound pressure level is 30 and the maximum sound pressure level is 80. The minimum level is denoted by the color blue, the medium level is denoted by the color green, and the maximum level is denoted by the color red. At the initial stage, it is at the minimum level then it gradually increases to the maximum level. If the sound pressure level increases, then the effectiveness of the absorber will increase. So more energy can be absorbed. If the sound pressure level decreases, then the effectiveness of the absorber will decrease. So more energy cannot be absorbed. Higher sound pressure can be obtained by lower frequency level. Sound pressure level can be minimized in porous polyamide absorbers due to their ability to absorb sound waves through a process called sound attenuation. Porous polyamide absorbers are designed to have a large surface area and a high porosity, which allows them to effectively dissipate sound energy by converting it into heat. The mid-sound pressure level is attained in some areas. The sound pressure increases due to the energy transfer of the sound wave from the sound source to the surrounding medium, and it

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is affected by the intensity of the sound, the distance from the sound source, and the properties of the medium. As the SPL of a sound increases, it can have different effects on the human body.

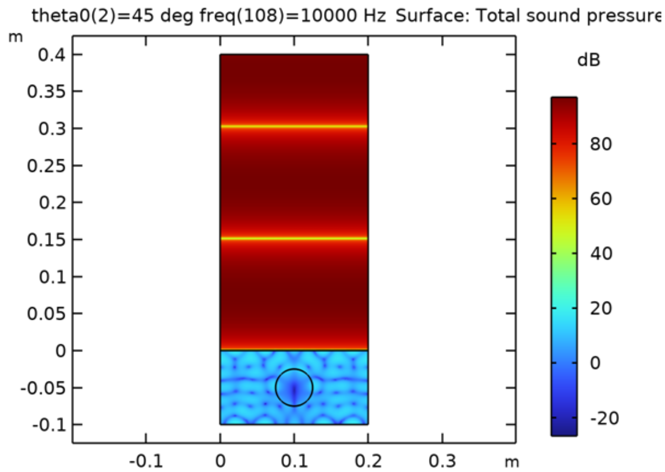

Fig. 3 Sound Pressure Level (dB)

1c. Scattered Acoustic Pressure:

Here, the minimum scattered acoustic pressure level is -0.8, the middle scattered acoustic pressure level is 0 and the maximum scattered acoustic pressure level is 0.8. The minimum level is denoted by the color blue, the medium level is denoted by the color white, and the maximum level is denoted by the color red. In the above figure, it is obvious that it is gradually increasing from the minimum value to the maximum value. When sound waves come into contact with a polyamide porous absorber, some of the sound energy is absorbed by the material, while some of the energy is scattered or reflected back into the surrounding environment. The scattered acoustic pressure in a polyamide porous absorber can be affected by several factors, including the porosity, thickness, and density of the material, as well as the frequency of the sound waves. At low frequencies, the polyamide porous absorber will behave like a barrier, reflecting or scattering a significant portion of the sound waves. However, as the frequency of the sound waves increases, the absorber's porous structure begins to resonate, causing the absorber to become more efficient in attenuating sound waves. In general, polyamide porous absorbers are designed to minimize scattered acoustic pressure and maximize sound absorption.

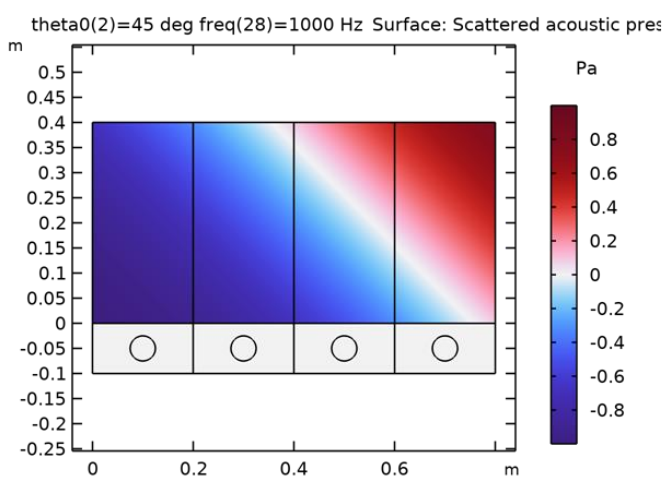

Fig. 4 Scattered Acoustic Pressure

1d. Incident Acoustic Pressure:

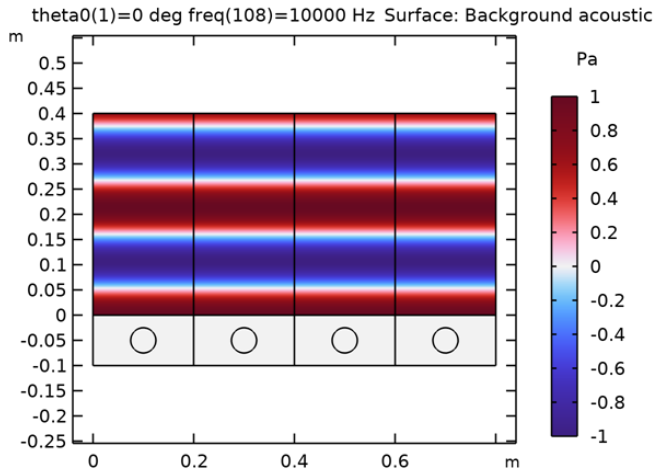

Fig. 5 Incident Acoustic Pressure (Pa)

Here, the minimum scattered acoustic pressure level is -1, the middle scattered acoustic pressure level is 0 and the maximum scattered acoustic pressure level is 1. The minimum level is denoted by the color blue, the medium level is denoted by the color white, and the maximum level is denoted by the color red. It is used to find the sound absorption performance of the material. Higher levels of acoustic pressure can lead to a greater level of sound absorption. Incident acoustic pressure also affects the impedance of the porous absorber. At the initial and final stages, maximum incident acoustic pressure occurs. In Between the initial and final stages minimum and mid-level incident acoustic pressure occurs. If the incident pressure is too high, the porous absorber may reach its nonlinear acoustic range, where the absorption coefficient decreases with increasing pressure. In this case, the increased pressure causes the pores of the absorber to close up, reducing the amount of airflow and limiting the viscous and thermal losses within the absorber material. As a result, the absorption coefficient decreases, and the porous absorber becomes less effective at attenuating sound waves at higher pressures.

1e. Point Pressure

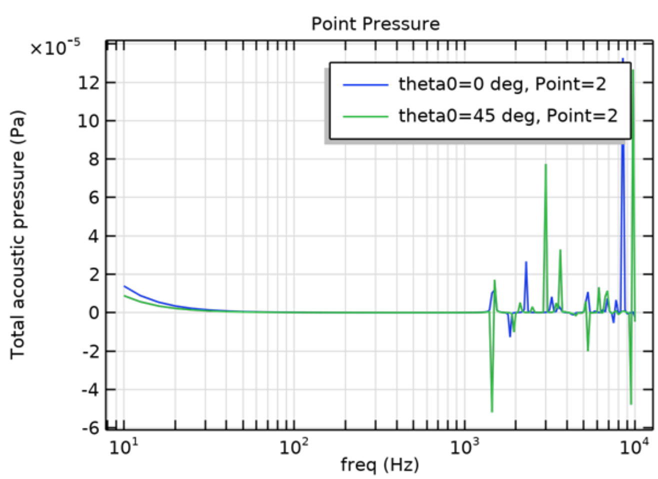

Fig. 6 Point Pressure

Fig. 6 shows the relationship between the total acoustic pressure and the frequency. The x-axis denotes the frequency in hertz and the y-axis denotes the total acoustic pressure in pascal. The scale of the above figure is, the x-axis 1 cm is equal to 10 to the power of 1 unit and the y-axis 1 cm is equal to 2 units. The blue line represents the theta 0=0 deg in point 2 and the green line represents the theta 0=45 deg in point 2. At theta 0 deg the maximum frequency is at 9 and at theta 45 deg the maximum frequency is at 12. If the point pressure increases, then the sound wave is not being sufficiently used, which is why most of the sound waves are reflected in the environment? So, the point pressure should be at the minimum value so that the sound waves are absorbed in a high manner. Point pressure refers to the force applied at a specific point on the surface of the absorber. In the context of polyamide porous absorbers, the point pressure can affect the absorption properties of the material. When a point pressure is applied to the surface of a polyamide porous absorber, it can cause the pores to collapse or compress, which can reduce the material's ability to absorb sound or vibration. Additionally, the point pressure can cause deformation or damage to the material, which can also affect its absorption properties. To optimize the performance of polyamide porous absorbers, it's important to consider the distribution of pressure across the surface of the material. Uniform pressure distribution can help ensure that the pores remain open and uncompressed, maximizing the material's absorption capabilities.

1f. Normal Impedance:

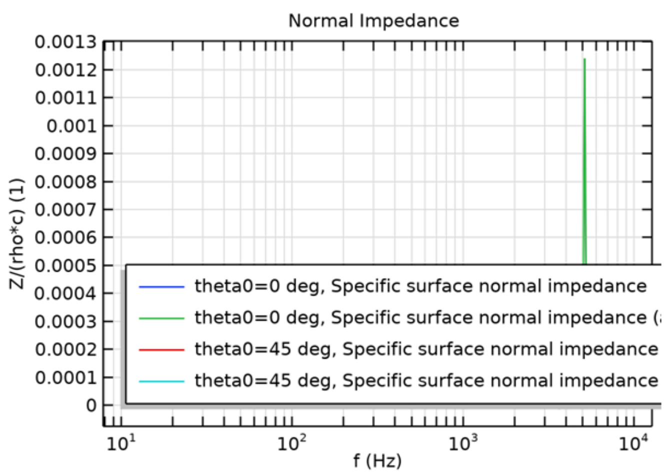

Fig. 7 Normal Impedance

Here, the graph shows the relationship between the acoustic pressure and the frequency. The x-axis represents the acoustic pressure and the y-axis represents the frequency in hertz. The scale of the x-axis is 0.0001 units and the y-axis is 10 to the power of 1. In the above figure, the theta 0 deg the frequency is maximum at 0.00125. The normal impedance depends on the property of the material and the frequency sound wave. The frequency is classified into two types, they are low frequency and high frequency. At lower frequencies, the normal impedance of a porous absorber can be determined by its flow resistivity and it is very easy to determine. At higher frequencies, the normal impedance of a porous absorber can not be determined because it is affected by the porosity. So the lower frequency is very helpful to determine. In the above figure, the green line is increased at a certain point.

1g. Absorption Coefficient:

Here, the graph shows the relationship between the absorption coefficient and the frequency. The x-axis represents the absorption coefficient and the y-axis represents the frequency in hertz. The scale of the x-axis is 0.05 units and the y-axis is 10 to the power of 1. In the above figure, the theta 0 deg (green line) the frequency is maximum at 0.00459. If the absorption coefficient increases, then there is a better sound absorption

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performance. And if the absorption coefficient decreases, then there will be the least sound absorption performance. Polyamide porous absorbers typically have a high absorption coefficient, especially at higher frequencies. The absorption coefficient can vary widely depending on the specific material and frequency range of interest.

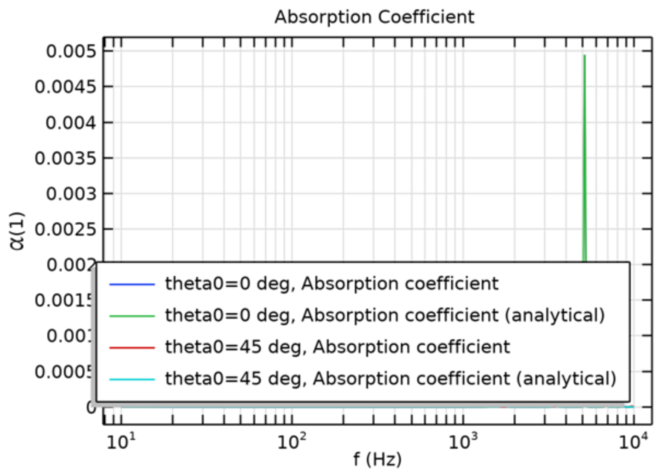

Fig. 8 Absorption Coefficient

Case Study 2: Polyester

In this case study air is a constant material which is passed through the absorber, polyester used as a foam material. Polyester can be used in the construction of acoustic panels, baffles, and other sound-absorbing materials. Its structure and arrangement help trap and dissipate sound energy, reducing echo, reverberation, and overall noise levels in a given space. Polyester acoustic panels are commonly used in environments where sound control is important, such as recording studios, theaters, and office spaces.

Input Parameters:

Name	Expression	Value	Description
f_max	10[kHz]	10000 Hz	Maximal frequency in the model
lambda_min	343[m/s]/f_max	0.0343 m	Minimal wavelength
theta0	0[deg]	0 rad	Incident wave angle
W	20[cm]	0.2 m	Domain width
H	40[cm]	0.4 m	Air domain height
Hp	10[cm]	0.1 m	Porous layer height
A	2.5[cm]	0.025 m	Inclusion radius
Hpml	20[cm]	0.2 m	PML Domain Height
mu0	1.8e-5[Pa*s]	1.8E−5 Pa·s	Dynamic viscosity of air
epsilonP0	0.995	0.986	Porosity of polyester
Rf0	10.5e3[Pa*s/m^2]	10500 Pa·s/m²	Flow resistivity

tau0	1.0059	1.0059	Tortuosity
Lv0	240[um]	2.4E−4 m	Viscous characteristic length
Lth0	470[um]	4.7E−4 m	Thermal characteristic length

Table 2 input parameter of polyester

Analysis of acoustic parameters

2a. Total Acoustic Pressure:

From Fig. 9 minimum pressures is -2 and the maximum pressure is 2. If the total acoustic pressure increases, then the amplitude will increase. And if the total acoustic pressure decreases, then the amplitude will decrease. If the amplitude decreases, then the reflection of the sound wave also decreases. In the above figure, the blue color denotes the minimum pressure and there is a minimum in amplitude so the reflection of a sound wave is also minimum. The dark red color denotes the maximum pressure and there is a maximum in amplitude so the reflection of a sound wave is also maximum. The total acoustic pressure at a given point is the sum of the pressures created by all the sound waves arriving at that point from different directions. This means that if multiple sound sources are present, their individual pressure waves will combine to produce a complex pattern of pressure variations that can result in increases or decreases in the total acoustic pressure at different points in space.

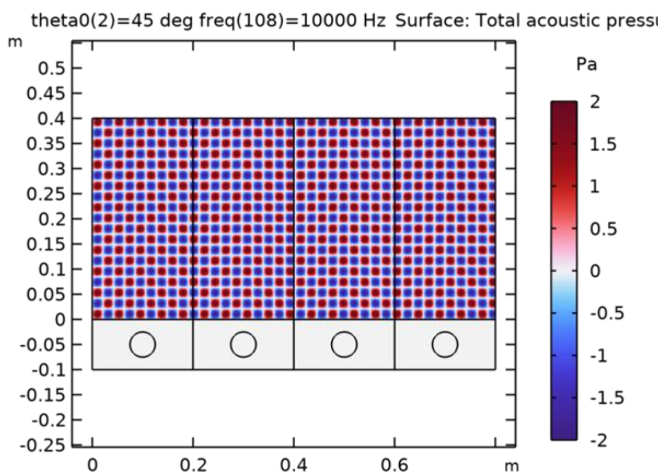

Fig. 9 Total Acoustic Pressure (Pa)

2b. Sound Pressure Level:

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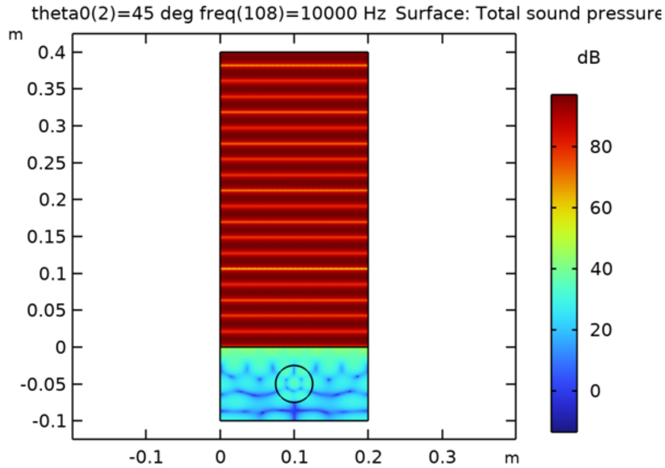

Fig. 10 Sound Pressure Level (dB)

From Fig. 10 minimum sound pressure level is 0, the mid sound pressure level is 40 and the maximum sound pressure level is 80. The minimum level is denoted by the color blue, the medium level is denoted by the color green, and the maximum level is denoted by the color red. The minimum sound pressure level occurs at the initial point, the middle level occurs at the 0th of y axis then the maximum level of sound pressure level occurs up to the 0.4th of the y-axis. If the sound pressure level increases, then the effectiveness of the absorber will increase. So more energy can be absorbed. If the sound pressure level decreases, then the effectiveness of the absorber will decrease. So more energy cannot be absorbed. When sound waves come into contact with a porous material, such as a polyester absorber, the sound waves will penetrate into the material and cause vibration of the fibers or particles that make up the material. This vibration converts the sound energy into heat energy, which effectively reduces the sound pressure level. If the absorber is not thick enough or the space between the absorber and the reflective surface behind it is too small, sound waves can reflect off the reflective surface and be redirected back into the room, leading to an increase in sound pressure level. However, this is not a characteristic of the porous polyester absorber itself, but rather a result of incorrect design or installation.

2c. Scattered Acoustic Pressure:

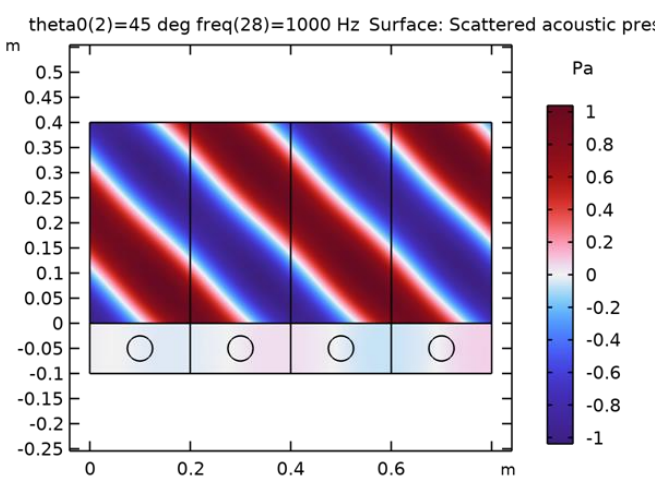

Fig. 11 Scattered Acoustic Pressure (Pa)

From Fig. 11 minimum sound pressure level is -20, the mid sound pressure level is 30 and the maximum sound pressure level is 80. The minimum level is denoted by the color blue, the medium level is denoted by the color green, and the maximum level is denoted by the color red. If the scattered acoustic pressure increases, then the amount of sound energy reflected back into the environment decreases which means it absorbs a high amount of energy when scattered acoustic pressure increases. So that the acoustic pressure improves. In the above figure, some areas are at the minimum level and some are at the maximum level of scattered acoustic pressure. When sound waves come into contact with a polyester porous absorber, some of the sound energy is absorbed by the material, while some of the energy is scattered or reflected back into the surrounding environment. Polyester porous absorbers are designed to minimize scattered acoustic pressure and maximize sound absorption. This is achieved by optimizing the material's porosity, thickness, and density to provide the most effective sound attenuation across a wide range of frequencies.

2d. Incident Acoustic Pressure:

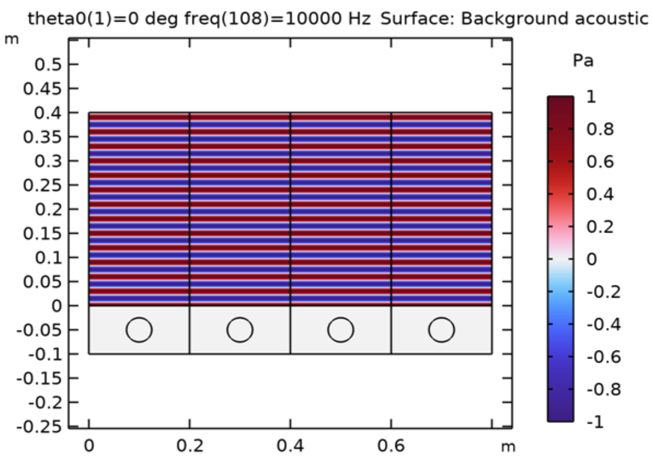

Fig. 12 Incident Acoustic Pressure

Here, the minimum scattered acoustic pressure level is -1, the middle scattered acoustic pressure level is 0 and the maximum scattered acoustic pressure level is 1. The minimum level is denoted by the color blue, the medium level is denoted by the color white, and the maximum level is denoted by the color red. It is used to find the sound absorption performance of the material. Higher levels of acoustic pressure can lead to a greater level of sound absorption. Incident acoustic pressure also affects the impedance of the porous absorber. In the above figure, only the maximum and minimum values occur. It is in the form of maximum and minimum as one by one. The incident acoustic pressure of a polyester porous absorber is the amount of sound energy that comes into contact with the absorber and is not reflected or transmitted back into the environment. It depends on several factors, including the design and properties of the absorber, the intensity and frequency of the incident sound waves, and the acoustic environment in which the absorber is located. The incident acoustic pressure of a polyester porous absorber will depend on its specific design and the characteristics of the sound waves it is exposed to. Generally, the incident acoustic pressure of a polyester porous absorber will be lower than that of a non-porous reflective surface, as the material is designed to dissipate sound energy rather than reflect it. However, the efficiency of the polyester porous absorber in reducing incident acoustic pressure will depend on its porosity, thickness, density, and other design factors.

2e. Point Pressure:

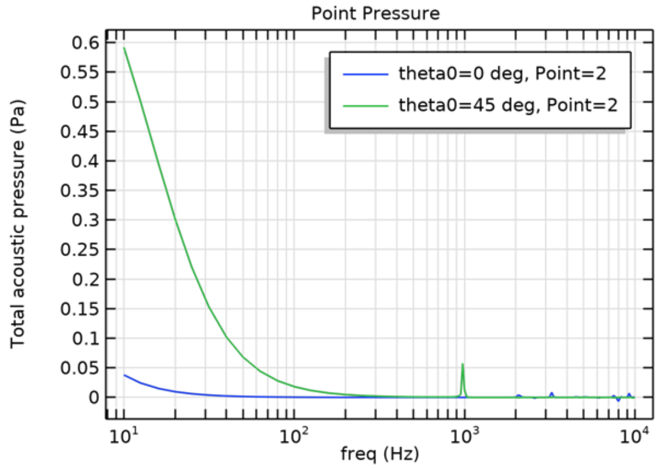

Fig.13 Point Pressure (Pa)

Fig. 13 shows the relationship between the total acoustic pressure and the frequency. The x-axis denotes the frequency in hertz and the y-axis denotes the total acoustic pressure in pascal. The scale of the above figure is, the x-axis 1 cm is equal to 10 to the power of 1 unit and the y-axis 1 cm is equal to 0.5 units

2f. Normal Impedance:

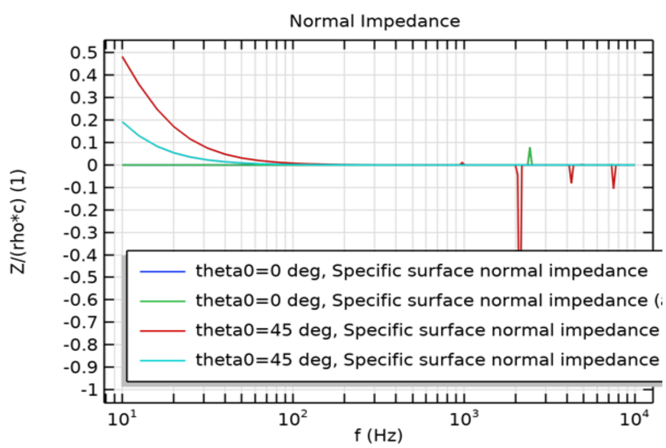

Fig. 14 Normal Impedance

Here, the graph shows the relationship between the acoustic pressure and the frequency. The x-axis represents the acoustic pressure and the y-axis represents the frequency in hertz. The scale of the x-axis is 0.1 units and the y-axis is 10 to the power of 1 unit. The frequency of theta 45 deg is maximum at 0.48 of acoustic pressure. The normal impedance depends on the property of the material and the frequency sound wave. The frequency is classified into two types; they are low frequency and high frequency. At lower frequency, the normal impedance of a porous absorber can be determined by its flow resistivity and it is very easy to determine. At higher frequency, the normal impedance of a porous absorber cannot be determined because it is affected by the porosity. So the lower frequency is very helpful to determine. Polyester porous absorbers typically have relatively low normal impedance, typically ranging from around 0.1 to 0.5 acoustic ohms. However, this value can vary depending on the thickness, density, and porosity of the material. The normal impedance of a porous absorber is also influenced by the frequency of the sound wave. At low frequencies, the normal impedance tends to be closer to zero, while at higher frequencies, it increases towards the characteristic impedance of air.

2g. Absorption Coefficient:

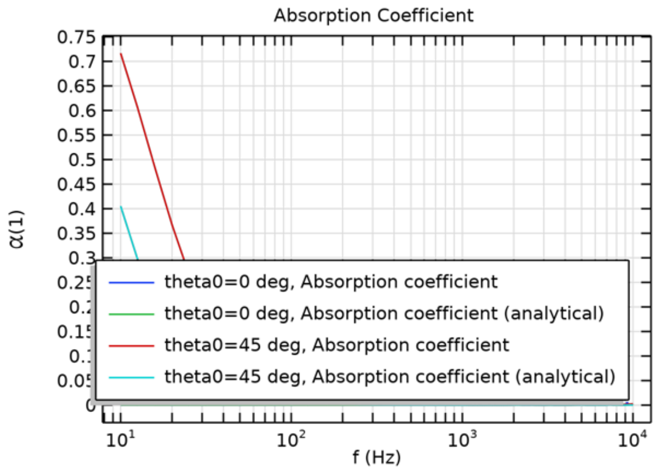

Fig. 15 Absorption Coefficients

Here, the graph shows the relationship between the absorption coefficient and the frequency. The x-axis represents the absorption coefficient and the y-axis represents the frequency in hertz. The scale of the x-axis is 0.05 units and the y-axis is 10 to the power of 1. In the above figure, the theta 45 deg (skyblue line) the frequency is maximum at 0.4 of absorption coefficient and theta 45 deg (red line) the frequency is maximum at 0.725 of absorption coefficient. If the absorption coefficient increases, then there is a better sound absorption performance. And if the absorption coefficient decreases, then there will be at least sound absorption performance. The absorption coefficient of a polyester porous absorber can depend on various factors, such as the thickness, density, and porosity of the material, as well as the frequency range of interest. It is important to carefully consider these factors when selecting a porous absorber material for a specific acoustic application.

Case Study 3: Polyurethane:

In this case study air is a constant material which is passed through the absorber, polyurethane used as a foam material. Polyurethane foam is widely used as a sound-absorbing material due to its open-cell structure. When sound waves pass through the foam, they get trapped and converted into heat energy through friction and air resistance. Polyurethane foam effectively absorbs and reduces sound reflections, reverberation, and overall noise levels in a given space. It finds applications in soundproofing studios, auditoriums, offices, and automotive interiors.

Input Parameters

Name	Expression	Value	Description
f_max	10[kHz]	10000 Hz	Maximal frequency in the model
lambda_min	343[m/s]/f_max	0.0343 m	Minimal wavelength
theta0	0[deg]	0 rad	Incident wave angle
W	20[cm]	0.2 m	Domain width
H	40[cm]	0.4 m	Air domain height

Hp	10[cm]	0.1 m	Porous layer height
A	2.5[cm]	0.025 m	Inclusion radius
Hpml	20[cm]	0.2 m	PML Domain Height
mu0	1.8e-5[Pa*s]	1.8E−5 Pa·s	Dynamic viscosity of air
epsilonP0	0.995	0.989	Porosity of Polyurethane
Rf0	10.5e3[Pa*s/m^2]	10500 Pa·s/m²	Flow resistivity
tau0	1.0059	1.0059	Tortuosity
Lv0	240[um]	2.4E−4 m	Viscous characteristic length
Lth0	470[um]	4.7E−4 m	Thermal characteristic length

Table 3 Input parameters of polyurethane

Analysis of acoustic parameters
3a.Total Acoustic Pressure:

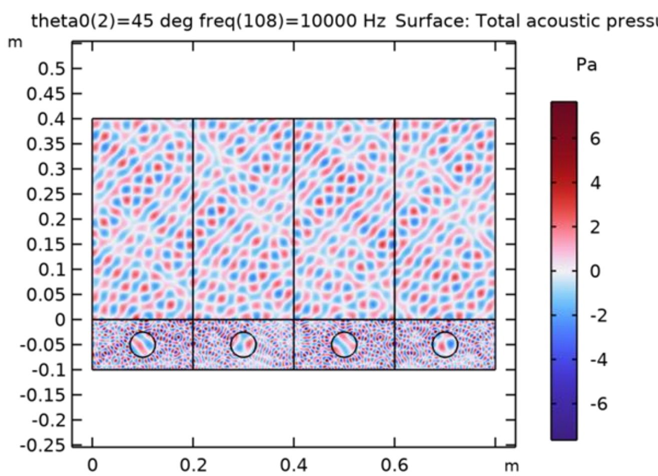

Fig. 16 Total Acoustic Pressures (Pa)

From Fig. 16 minimum pressure is -6 and the maximum pressure is 6 and the mid-value of the pressure is 0. From the above figure, we can see that it is a combination of all the minimum, mid and maximum values. The minimum value is represented in the color of blue, the mid value is represented in white and the maximum value is represented in red. The total acoustic pressure decreases in a porous absorber using polyurethane due to the dissipation of sound energy as heat as the sound waves interact with the porous structure of the foam. When the wavelength of the sound wave matches the size of the pores in the foam, the sound wave can effectively penetrate the material and interact with a larger surface area, leading to increased absorption and a maximum in the total acoustic pressure. The total acoustic pressure in a porous polyurethane absorber is not necessarily "average" but can vary depending on several factors, including the characteristics of the porous material and the incident sound wave. It's important to note that the maximum total acoustic pressure in a porous polyurethane absorber is dependent on several factors such as the porosity and thickness of the material, the incident sound frequency and angle, and the specific geometry of the pores and fibers in the material. Therefore, careful design and optimization of the porous material are necessary to achieve maximum absorption performance.

3b. Sound Pressure Level:

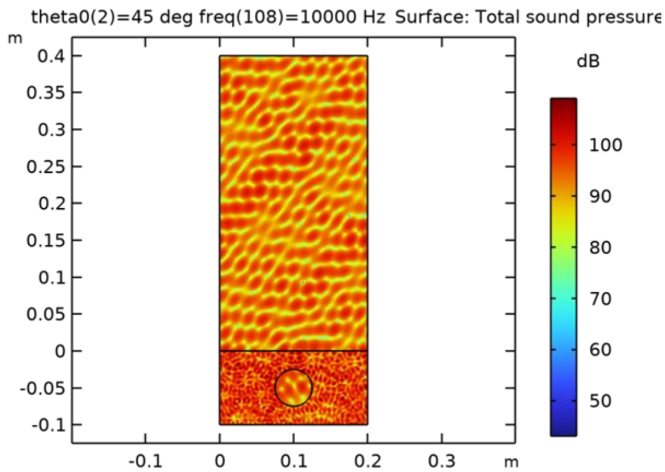

Fig. 17 Sound Pressure Level (dB)

From Fig. 17 minimum sound pressure level is 50, the mid sound pressure level is 75 and the maximum sound pressure level is 100. The minimum level is denoted by the color blue, the medium level is denoted by the color green, and the maximum level is denoted by the color red. At the initial stage, it is at the minimum level then it gradually increases to the maximum level. If the sound pressure level increases, then the effectiveness of the absorber will increase. So more energy can be absorbed. If the sound pressure level decreases, then the effectiveness of the absorber will decrease. So more energy cannot be absorbed. Higher sound pressure can be obtained by lower frequency level. In the above figure, there is no minimum sound pressure level. Mid-level and maximum levels have occurred in this material. Most mid-level is obtained by this material. Polyurethane porous absorbers can help to reduce sound pressure level through sound exhaustion. Polyurethane absorbers are designed to have a large surface area and a high porosity, which allows them to effectively dissipate sound energy by converting it into heat. The efficiency of the polyurethane porous absorber in reducing sound pressure level depends on the material's porosity, thickness, and density. The higher the porosity and thickness of the absorber, the more effective it will be in attenuating sound waves.

3c. Scattered Acoustic Pressure:

Here, the minimum sound pressure level is -3, the mid sound pressure level is 0 and the maximum sound pressure level is 3. The minimum level is denoted by the color blue, the medium level is denoted by the color green, and the maximum level is denoted by the color red. If the scattered acoustic pressure increases, then the amount of sound energy reflected back into the environment decreases which means it absorbs a high amount of energy when scattered acoustic pressure increases. So that the acoustic pressure improves.

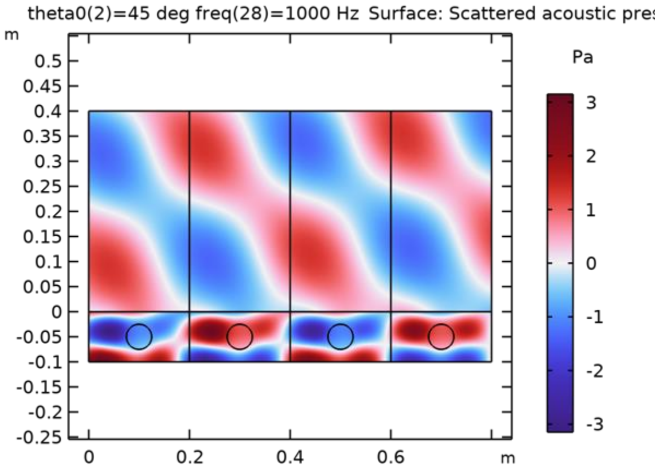

Fig. 18 Scattered Acoustic Pressure (Pa)

Polyurethane porous absorbers are designed to minimize scattered pressure levels and maximize sound absorption. This is achieved by optimizing the material's porosity, thickness, and density to provide the most effective sound attenuation across a wide range of frequencies. The scattered pressure level in a polyurethane porous absorber will be lower than that of a non-porous reflective surface, as the material is designed to dissipate sound energy rather than reflect it. However, the efficiency of the polyurethane porous absorber in reducing scattered pressure level will depend on the specific design and application of the absorber, as well as the acoustic environment in which it is installed.

3d. Incident Acoustic Pressure:

From fig minimum scattered acoustic pressure level is -1, the middle scattered acoustic pressure level is 0 and the maximum scattered acoustic pressure level is 1. The minimum level is denoted by the color blue, the medium level is denoted by the color white, and the maximum level is denoted by the color red. It is used to find the sound absorption performance of the material. Higher levels of acoustic pressure can lead to a greater level of sound absorption. Incident acoustic pressure also affects the impedance of the porous absorber. In the above figure, only the maximum and minimum values occur. It is in the form of maximum and minimum as one by one. When sound waves come into contact with a polyurethane porous absorber, some of the sound energy is absorbed by the material, while some of the energy is transmitted through the material and into the surrounding environment. The incident acoustic pressure of a polyurethane porous absorber will depend on its specific design and the characteristics of the sound waves it is exposed to. Generally, the incident acoustic pressure of a polyurethane porous absorber will be lower than that of a non-porous reflective surface, as the material is designed to dissipate sound energy rather than reflect it.

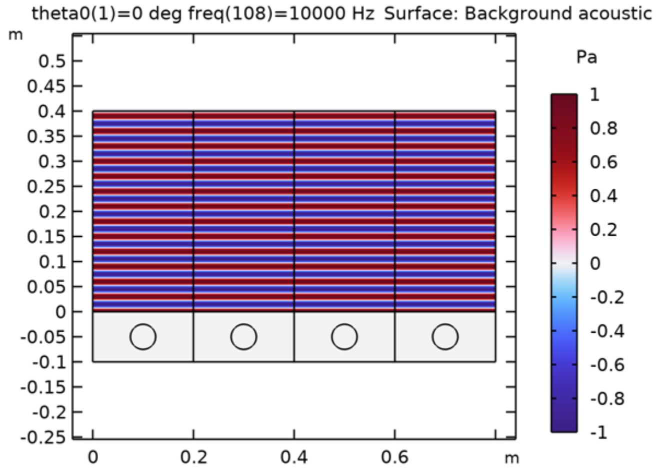

Fig. 19 Incident Acoustic Pressure (Pa)

3e. Point Pressure:

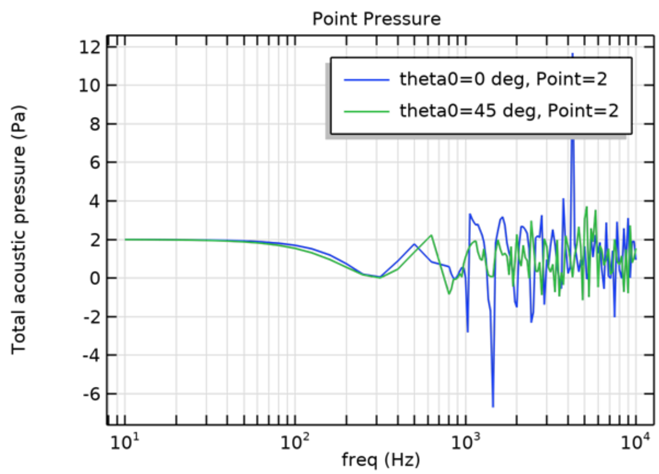

Fig. 20 Point Pressure (Pa)

Fig. 20 shows the relationship between the total acoustic pressure and the frequency. The x-axis denotes the frequency in hertz and the y-axis denotes the total acoustic pressure in pascal. The scale of the above figure is, the x-axis 1 cm is equal to 10 to the power of 1 unit and the y-axis 1 cm is equal to 2 units. If the point pressure increases, then the sound wave is not being sufficiently used, which is why most of the sound waves are reflected to the environment? So, the point pressure should be at the minimum value so that the sound waves are absorbed in a high manner. To optimize the performance of polyurethane porous absorbers, it's important to consider the distribution of pressure across the surface of the material. Uniform pressure distribution can help ensure that the pores remain open and uncompressed, maximizing the material's absorption capabilities. Additionally, the thickness and density of the material can also play a role in determining the optimal point pressure for maximum absorption performance.

3f. Normal Impedance:

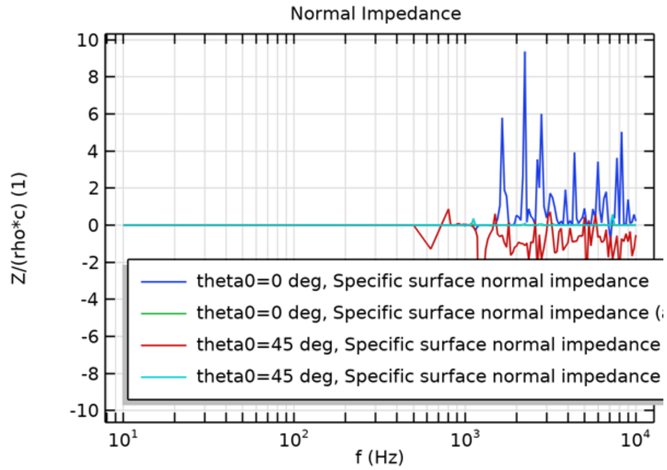

Fig. 21 Normal Impedance

Here, the graph shows the relationship between the acoustic pressure and the frequency. The x-axis represents the acoustic pressure and the y-axis represents the frequency in hertz. The scale of the x-axis is 2 units and the y-axis is 10 to the power of 1. In the above figure, the theta 0 deg the frequency is maximum at 9.5. The normal impedance depends on the property of the material and the frequency sound wave. The frequency is classified into two types; they are low frequency and high frequency. At lower frequency, the normal impedance of a porous absorber can be determined by its flow resistivity and it is very easy to determine. At higher frequency, the normal impedance of a porous absorber cannot be determined because it is affected by the porosity. So the lower frequency is very helpful to determine. Polyurethane porous absorbers tend to have relatively low normal impedance, typically ranging from around 1 to 9.5 acoustic ohms. However, this value can vary depending on the specific formulation and manufacturing process used to produce the material. Similar to other porous absorbers, the normal impedance of polyurethane porous absorbers can also vary with frequency. At lower frequencies, the normal impedance tends to be closer to zero, while at higher frequencies, it increases towards the characteristic impedance of air.

3g. Absorption Coefficient:

From Fig. 22 the graph shows the relationship between the absorption coefficient and the frequency. The x-axis represents the absorption coefficient and the y-axis represents the frequency in hertz. The scale of the x-axis is 0.1 units and the y-axis is 10 to the power of 1. In the above figure, the theta 0 deg (blue line) the frequency is maximum at 0.9 of absorption coefficient and theta 45 deg (red line) the frequency is maximum at 0.98 of absorption coefficient. If the absorption coefficient increases, then there is a better sound absorption performance. And if the absorption coefficient decreases, then there will be at least sound absorption performance.

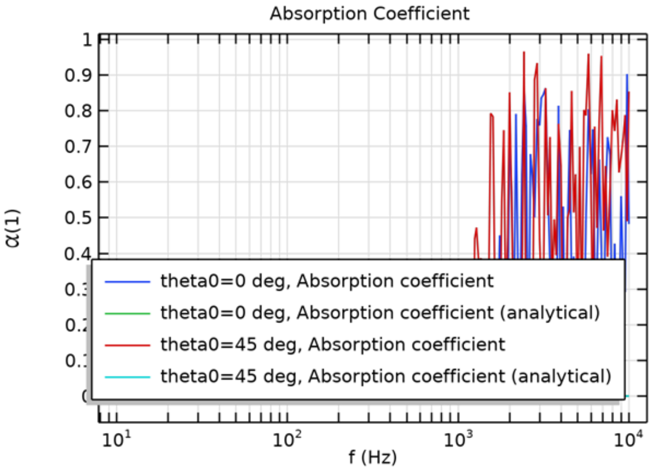

Fig. 22 Absorption Coefficient

Polyurethane porous absorbers typically have a moderate to high absorption coefficient, depending on the specific formulation and manufacturing process used to produce the material. The absorption coefficient of polyurethane porous absorbers can range from around 0.2 to 0.9 across a broad frequency range.

Comparison of Porous Absorbers:

S.No	Elements	Total Acoustic pressure (Pa)	Sound level Pressure (dB)
1.	Polyamide	Min : -1.5 Max : 1.5	Min : -20 Max : 80
2.	Polyester	Min : -2 Max : 2	Min : 0 Max : 80
3.	Polyurethane	Min : -6 Max : 6	Min :50 Max : 100

Table 4 Comparisons of porous absorber

From table 4 the acoustic pressure is a measure of the amplitude of the sound wave, which is the amount of pressure variation from the ambient pressure level. When a sound wave passes through a porous absorber, some of its energy is absorbed by the material and converted into heat, resulting in a reduction in the amplitude or magnitude of the wave. This reduction in amplitude corresponds to a decrease in the acoustic pressure of the sound wave. Depending upon the acoustic pressure Polyurethane provides a high acoustic pressure which results in an increase in amplitude and decrease in reflection of sound waves. At higher SPLs, the porous absorber will be more effective at attenuating the sound wave due to the greater amount of energy being absorbed by the material. This is because the sound wave has a greater acoustic pressure, and therefore, more energy that can be absorbed by the porous material. Depending upon the sound level pressure Polyurethane has a high sound level pressure which results in a high absorber effectiveness, and more energy can be absorbed. Considering all the properties Polyurethane is the best foam which is used in the porous absorber.

CONCLUSION

In conclusion, the analysis and simulation of porous absorbers using COMSOL Multiphysics software is an effective tool for predicting and optimizing the acoustic performance of these materials. By simulating the acoustic behavior of porous absorbers, engineers and scientists can gain a better understanding of how these materials work and optimize their design for specific applications. The results obtained from the simulation can be used to identify the effect of various parameters on the acoustic performance of porous absorbers, such as porosity, flow resistivity, thickness, and material properties. These results can be validated by comparing them with experimental measurements, making it possible to ensure the accuracy of the simulation. The use of COMSOL software has several advantages, including the ability to simulate multiphysics phenomena, create accurate numerical models, and provide a user-friendly graphical interface. This makes it a powerful tool for optimizing the design of porous absorbers in various industries, such as automotive, aerospace, and architectural acoustics.

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