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Influence of paint coatings on the sound absorption coefficient

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ABSTRACT

Paint coatings are commonly used to protect industrial components, but their influence on acoustic behaviour is still not fully understood. The aim of this study was to quantify how the type of paint and the number of coating layers affect the sound absorption of metal, expanded polystyrene (EPS), and extruded polystyrene (XPS) samples. Normal-incidence sound absorption coefficients were measured in an impedance tube over the 100–5700 Hz frequency range for uncoated samples and for the samples coated with ceramic paint and water-based acrylic lacquer in one- and two-layer configurations. For metal substrates, applying two layers of ceramic paint resulted in the main resonance being observed to move from about 3.8 kHz to around 3.0 kHz and reduced the peak absorption coefficient from ~0.87 to ~0.60, indicating a clear mass-induced tuning of the resonance frequency. In the XPS and EPS samples, coatings generally broadened and flattened the absorption curves, while slightly reducing the maximum absorption. For XPS, results were averaged over 17 samples to reduce the effect of material heterogeneity, and measurement uncertainty was evaluated according to ISO 10534-2. Microscopic observations confirmed that the coatings smooth the surface and partially close open pores; combined with the increased surface mass, this modifies the resonance behaviour of the samples. The results demonstrate that paint coatings can influence the resonance frequency and bandwidth of sound absorption in lightweight structures, which may be exploited in future studies on the passive acoustic tuning of materials. The work was limited to normal-incidence tube measurements and did not include direct thickness measurements or detailed resonance modelling, which will be addressed in further research.

INTRODUCTION

Paint coatings constitute an essential component of numerous industrial and engineering applications, providing protection against corrosion, UV radiation, mechanical wear and other environmental factors [2–5], including lightweight components of pneumatic rehabilitation devices and training systems designed for long-term human stays in space [6–9]. In modern surface engineering, proper preparation of the surface layer of construction materials is extremely important [10]. Among the many surface preparation methods, environmentally friendly techniques can be used, such as ozonation [11], which do not adversely affect the natural environment and provide effective cleaning of the surface. Their mechanical, chemical and microstructural properties, such as adhesion, flexibility, resistance to micro-cracking and stability under environmental exposure, have been extensively documented [3–4,12].

Several studies have also highlighted the influence of mechanical vibrations on the degradation or functional performance of coatings, as well as the potential of certain coating layers to modify the vibration responses of structural components [13–15]. Furthermore, the global stiffness of composite structures can be controlled using shape memory alloys (SMA), which, in addition to paint coatings, provide another means of tailoring the vibration characteristics of lightweight components [16].

In contrast, significantly less attention has been devoted to understanding how thin paint coatings affect the acoustic behaviour of structural materials, particularly lightweight, porous or thin-walled elements. Such effects are particularly relevant in architectural and building acoustics, where even moderate changes in surface absorption can influence reverberation time and acoustic comfort in enclosed spaces [17]. Classical acoustic theory indicates that thin layers, typically below a millimetre, cannot substantially improve airborne sound insulation of massive partitions due to the mass law [18–19]. However, even thin coatings can modify surface mass, local stiffness or surface impedance, which are key parameters governing resonance-based sound absorption in lightweight systems [20–21]. Similar relationships are observed in structural joints, where small geometric modifications lead to noticeable changes in stiffness and stress distribution, as demonstrated, among others, in the studies on riveted joints [22–26]. Modern studies on resonant absorbers and micro-engineered acoustic surfaces show that small variations in surface mass or stiffness may shift resonance frequencies and influence absorption spectra [21,27]. The effect of surface treatments has also been investigated in porous materials, where sound absorption strongly depends on open porosity and airflow resistivity. Thin surface films may partially close pores, reduce effective porosity and consequently decrease sound absorption [28–29]. This effect is particularly relevant for the materials with small or closed pores, such as extruded or expanded polystyrene, where even minimal surface sealing alters acoustic impedance [27,30]. Similar sensitivity of resonance behaviour to microstructural variations has also been reported in foamed polymer panels, where both modelling and experiments show that surface modifications can significantly affect the absorption spectrum [31]. Although early work by Chrissler (NBS, 1940) [28] reported that painting can change the sound absorption of porous materials, modern coating systems, such as ceramic paints or acrylic lacquers, have not been systematically examined, especially across different classes of substrates (rigid, porous-closed, and lightweight plates). Despite increasing interest in surface-dependent acoustic phenomena, a clear research gap remains regarding the systematic evaluation of how thin paint coatings alter the normal-incidence sound absorption in materials with different microstructures. Little is known about the quantitative effect of coating type or number of layers on resonance frequency shifts or on the shape of absorption curves. Furthermore, the interaction between microstructural surface modifications and resonance-driven absorption has not been fully characterised. The present study bridged this gap by analysing how ceramic and acrylic coatings, applied in one- and two-layer configurations, modify the acoustic response of metal, EPS and XPS samples. The study combined impedance-tube measurements with microscopic surface characterisation to examine the relationship between coating-induced surface changes and the resulting sound absorption behaviour. The findings contribute to the broader understanding of how thin coatings influence the acoustic properties of lightweight and porous construction materials and may support future developments in passive acoustic tuning.

Mechanical and vibroacoustic properties of coatings

Paint coatings are primarily used to protect substrates against corrosion, moisture, UV radiation and mechanical wear [2-5]. Their performance is governed by mechanical properties, such as adhesion, hardness, flexibility and resistance to micro-cracking, which determine the long-term stability of the coating when exposed to environmental or vibrational loading [3–4,12,14–15]. Vibrations can degrade coatings over time, while coatings themselves may slightly modify the dynamic response of thin structural elements by adding surface mass or changing local stiffness [13–14] and similar sensitivity to cyclic loading has been reported for polyurethane sealing elements in pneumatic actuators [32]. From an acoustics perspective, thin paint layers do not significantly improve the airborne sound insulation of massive partitions due to the mass law [18–19]. However, for lightweight plates and porous materials, even small changes in surface mass or surface morphology can influence the resonance-based sound absorption mechanisms [20–21,27]. In thin plates, an additional surface layer alters the effective mass–spring behaviour and may shift the resonance frequency. In porous materials, coatings may partially seal surface pores, reduce effective porosity and modify the surface impedance, which affects the shape of the absorption spectrum [29–30].

The acoustic influence of coatings is therefore not related to bulk insulation, but to local modifications of mass distribution, stiffness and pore accessibility. Modern studies show that ceramic, polymer or composite coatings can slightly tune the acoustic response of lightweight materials by altering surface mass and microstructural boundary conditions [27,30]. These mechanisms provide the physical motivation for examining how different coatings and application thicknesses affect the sound absorption of metal, EPS and XPS materials.

Acoustic effects of thin paint coatings

Although paint coatings are primarily designed to protect substrates and improve their durability, the addition of a thin surface layer may influence the acoustic behaviour of lightweight plates and porous materials. Unlike massive building partitions, where thin coatings do not produce any meaningful increase in airborne sound insulation due to the mass law [18-19], lightweight structures are more sensitive to small changes in surface mass, stiffness and surface impedance. For thin plates, a coating increases the effective surface mass and may modify local stiffness. These changes alter the mass–spring behaviour of the plate and can lead to measurable shifts in the resonance frequency, typically toward lower frequencies when additional mass is introduced [20–21]. Such resonance shifts may affect both the peak value and the effective bandwidth of sound absorption, depending on the coating mass and its distribution. In porous materials, such as EPS or XPS, the mechanism is different. Paint coatings may partially seal surface pores, reduce effective porosity and modify airflow resistivity, thereby altering acoustic impedance at the surface boundary [27,29–30]. Even small degrees of pore closure can influence the absorption curve, particularly at mid and high frequencies where surface effects are dominant. Early work by Chrissler [28] demonstrated that paint coatings can modify the acoustic behaviour of porous absorbers, while more recent studies report frequency shifts or reduced absorption when surface films limit pore accessibility or alter the microstructure of the boundary layer [29–30]. Despite these observations, the available research remains limited, and systematic comparisons between different coating types and application thicknesses are scarce. In particular, little is known about the vibroacoustic influence of modern ceramic paints or water-based acrylic coatings applied to the materials with markedly different microstructures, such as metals, expanded polystyrene and extruded polystyrene. The present study bridged this gap by examining how thin paint coatings modify the normal-incidence sound absorption coefficient of selected construction materials. The analysis focused on resonance shifts in metal plates and on porosity-related effects in EPS and XPS samples.

CHARACTERISATION OF MEASUREMENT COATINGS

Samples of three types of materials were prepared for the study: a steel plate, extruded polystyrene (XPS), and expanded polystyrene (EPS). From each material, specimens with a diameter of 34.25 mm (Figure 1) were cut to match the inner diameter of the impedance tube measurement chamber (Figure 2). The surfaces of the samples were coated with two types of paint coatings: a stain-resistant ceramic interior paint and a water-based acrylic lacquer. For the steel plates, additional industrial coatings were also applied, including a synthetic rubber protective coating, a primer-enamel for metal, and an automotive metallic lacquer. Each coating was applied in one or two layers using a flat brush, with care taken to achieve a repeatable film thickness. Due to the lack of sufficiently precise non-destructive methods for directly measuring the coating thickness, the added mass – determined as the difference between the mass of the uncoated sample and the mass after applying one or two layers – was used as the characteristic parameter describing the coating layer. In the case of the XPS material, considerable variability was observed between individual samples due to the heterogeneous microstructure of the material. To obtain representative values, a total of 17 XPS samples were prepared (8 coated with ceramic paint and 9 coated with acrylic lacquer), and the values presented correspond to their arithmetic means. A summary of the prepared samples, including their mass before and after coating application, is presented in Table 1. The mass of each sample was determined using a calibrated GH-300 analytical balance (A&D Company, Japan) with a readability of 0.1 mg (0.0001 g).

Table 1. Description of measurement samples

Sample ID	Substrate material (n – number of specimens)	Paints	Weight before applying the paint [g]	Weight one layer of paint [g]	Weight two layer of paint [g]
1	Metal plate (n=1)	Synthetic rubber protective coating (red)	3.7793	0.0351	0.0669
2	Metal plate (n=1)	Primer-enamel for metal surfaces (white)	3.8026	0.1955	0.4679
3	Metal plate (n=1)	Metallic car paint (gold)	3.7794	0.1246	0.2192
4	Extruded polystyrene (XPS) (n=8)	Stain-resistant ceramic paint for interiors (white)	0.4105 (average)	0.1687 (average)	0.2457 (average)
5	Extruded polystyrene (XPS) (n=9)	Water-based acrylic lacquer (clear)	0.4108 (average)	0.0859 (average)	0.1361 (average)
6	Polystyrene (n=1)	Stain-resistant ceramic paint for interiors (white)	0.5151	0.417	0.6064
7	Polystyrene (n=1)	Water-based acrylic lacquer (clear)	0.4655	0.1458	0.233

The samples are shown in Figure 1. After preparation, they were placed in the measurement chamber of the impedance tube and subjected to a series of measurements in accordance with the ISO 10534-2 [1] procedure.

During mounting, care was taken to ensure that the samples were in direct contact with the tube termination, without leaving any air gap, as such a gap could create a cavity resonance and distort the measurement results.

DESCRIPTION OF THE MEASUREMENT SETUP

The research device used for sound absorption analysis consisted of an impedance tube and the necessary set of tools required to perform the measurements. This set included structural elements, electronic devices, and a measurement apparatus with a PC. The following equipment is necessary for sound absorption testing:

a) impedance tube (Figure 2), featuring sections with an internal diameter of 34.86 mm, comprising: the main tube from Mecanum Inc., serial number 2444-408, equipped with a sound source (speaker) and microphone holders as shown in Figure 2 and labelled with symbol (1), a rigid tube for placing samples for measurement (3), an anechoic tube for phase calibration of the measurements (2).
b) quarter-inch microphones, model PCB 378A14 from Mecanum Tube (4),
c) amplifier (5),
d) SCADAS data acquisition system (6),
e) PC with Simcenter Testlab software.

Additionally, various cables are required, such as:

a) ethernet cable for connecting SCADAS to the data acquisition computer,
b) cables connecting the amplifier to SCADAS and the amplifier to the main tube,
c) cables connecting the microphones to SCADAS [33].

Figure 1. Images of samples after applying the paint coating

The system conducts measurements in accordance with specified standards, including PN-EN ISO 10534-2:2003 [1], ASTM E1050 [34], ASTM E-2611 (TL) [35], which regulate the measurement procedures.

Before starting the measurements, the device was assembled and configured, and the microphones were set up accordingly. The preparation process included phase calibration. Two microphone positions were used to determine the complex acoustic transfer function between the measurement points, which is required for calculating the normal-incidence sound absorption coefficient according to ISO 10534-2 [1]. This arrangement of microphones allows for the measurement of a frequency range from 100 Hz to 5700 Hz. This arrangement of microphones allows for the measurement of a frequency range from 100 Hz to 5700 Hz. In this setup, the distance between the microphones is 29 mm.

Both microphones were connected to two channels of the Simcenter SCADAS system. The SCADAS DAC output is equipped with a BNC adapter, which is converted to RCA to serve as a connection to the amplifier. The output of the amplifier is directed to the speaker input.

The test samples had a diameter of 34.25 mm. Measurements were carried out in a rigid pipe chamber. The choice of a rigid pipe ensures that the acoustic conditions allow sound to be either absorbed or reflected by the tested samples. A key advantage of the rigid pipe is the piston mechanism, which moves a small disc inside the pipe, allowing samples of varying lengths to fit the pipe dimensions, ensuring rigid boundary conditions.

The sample was placed inside the rigid pipe chamber, ensuring that its surface was flush with the connection between the rigid pipe and the main pipe. A wide-band acoustic wave was emitted through the loudspeaker mounted in the main pipe, directed toward the sample. When a sound wave strikes the surface of the sample perpendicularly, part of the wave is absorbed or reflected by the sample, while the remainder passes through the successive layers of material and escapes. During the measurement, the microphones recorded changes in acoustic pressure inside the pipe. On the basis of the collected data, the sound absorption coefficient of the sample was determined [33].

TESTING THE SOUND ABSORPTION COEFFICIENT OF COATING LAYERS

The sound absorption coefficient was measured at the test setup using an impedance tube. A comprehensive summary of all test results was compiled in the form of graphs and comparisons. The tests were carried out on the prepared measurement samples, which were described in the previous chapter. The first series of measurements concerned the test samples with a backing layer consisting of metal discs. Several measurement series were conducted for each sample, with a complete description and interpretation of the results presented below, applicable to all graphs. For each configuration (uncoated, one layer, two layers), at least three repeated measurements were performed, and the obtained spectra were averaged to reduce random measurement uncertainty.

The first stage of the measurements consisted in determining the mass of the substrate materials, including three metal discs, two made of XPS, and two made of polystyrene. Subsequently, the sound absorption coefficient as a function of frequency was determined from the measured acoustic transfer functions in an impedance tube, in accordance with ISO 10534-2 [1]. The following measurements were conducted in a similar manner. However, in the second step, the first coat of paint was applied to the sample substrate,

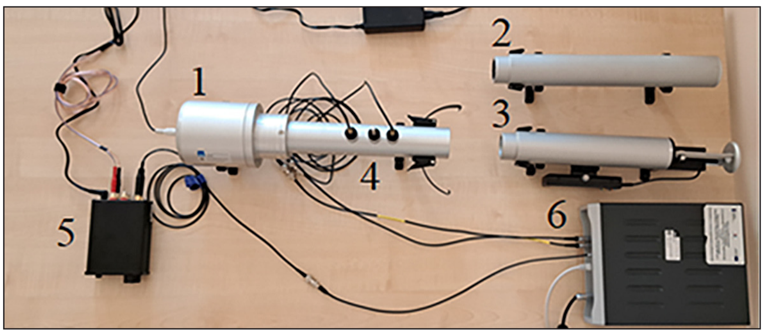

Figure 2. Research setup for measuring sound absorption [33]

followed by subsequent coats of paint in subsequent steps. The mass of the samples was measured after each paint application to monitor the changes related to the coating process.

ANALYSIS AND COMPARISON OF RESULTS

Sound absorption coefficient tests were conducted for the samples (Table 1). The results are presented in the form of graphs and comparisons.

Substrate material – metal plate

The following graphs (Figure 3) present the sound absorption characteristics as a function of frequency for samples 1–3 (Table 1) without paint, with the first layer of paint, and with the second layer of paint.

When analysing the graph (Figure 3), it can be seen that the substrate material in each case has very similar sound absorption characteristics. For a resonance frequency of approximately 3800 Hz, the absorption coefficient reaches a value close to 0.87. This unusually high peak value is associated with a pronounced panel-type resonance of the thin steel disc backed by a rigid termination, which temporarily increases the effective energy dissipation at this frequency.

In the case of a metal plate covered with a synthetic rubber protective coating (Figure 3a), the main resonance peak was observed close to 3000 Hz. After applying the protective coating, the absorption characteristic was maintained or slightly decreased, while the main resonance peak was observed at lower frequencies.

The graph (Figure 3b) illustrates the sound absorption coefficient as a function of frequency for a metal disc coated with primer-enamel for metal surfaces (white). The sound absorption curve shows characteristic resonances at higher frequencies, typical of uncoated metal surfaces. After applying the first layer of primer-enamel, the main resonance peak was observed close to 2300 Hz, with a slight decrease in the maximum absorption coefficient to 0.8. After applying the second layer, the main resonance peak occurred at approximately 2000 Hz.

The enamel primer layer covered minimal surface defects and created a smooth surface for sound wave reflection, owing to which the absorption coefficient decreased to 0.6.

For the metal disc uncovered with metallic car paint (Figure 3c), the addition of paint layers resulted in the main resonance peak being observed around 2300 Hz, similarly to the first primer-enamel layer. Similarly to the metal plate with a synthetic rubber protective coating, the absorption characteristic decreased slightly to a value of 0.82, while the main resonance shifted towards lower frequencies.

Substrate material – extruded polystyrene

The initial tests of samples with an extruded polystyrene (XPS) substrate revealed significant discrepancies in the measured values of the sound absorption coefficient. These inconsistencies were attributed to the highly heterogeneous internal structure of the material, which considerably affected the acoustic characteristics of individual samples. In response to this observation, an extended series of tests was conducted, involving 17 XPS samples coated with two types of paint: water-based acrylic lacquer and stain-resistant ceramic paint for interiors. Due to the considerable variability in the individual results, average sound absorption coefficients were calculated for each group of samples. Figure 4 presents the

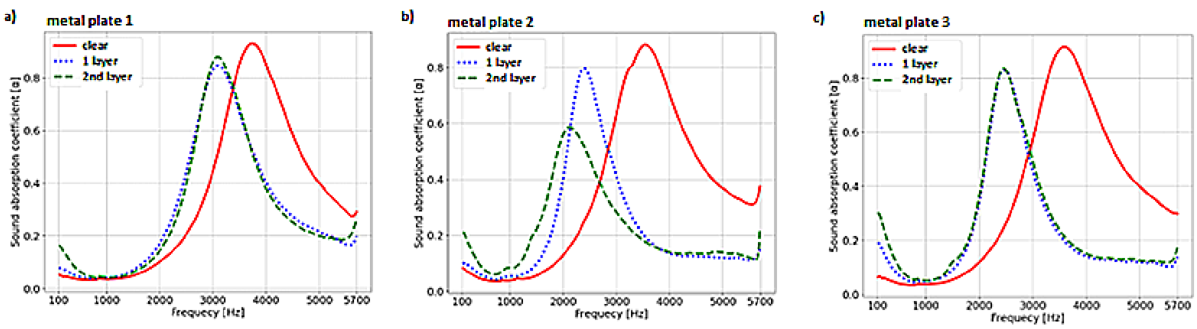

Figure 3. Sound absorption coefficient for: (a) metal plate with synthetic rubber protective coating, (b) metal plate with primer-enamel for metal surfaces, (c) metal plate with metallic car paint

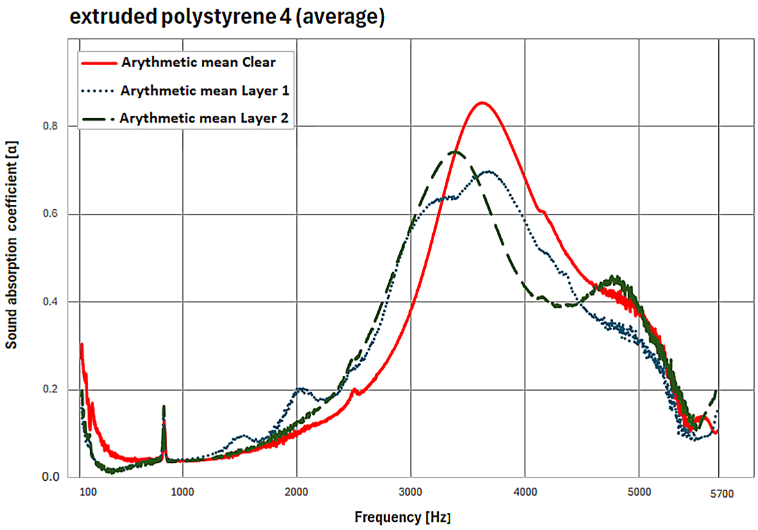

Figure 4. Average sound absorption coefficient for the XPS samples coated with stain-resistant ceramic paint: uncoated substrate, one paint layer, and two paint layers. Values are averaged over 8 samples (n = 8) for each configuration

averaged sound absorption characteristics for the samples coated with stain-resistant ceramic paint: uncoated XPS, XPS with one paint layer, and XPS with two layers.

The absorption curve for the uncoated XPS sample shows one resonance frequency around 3700 Hz, for which the absorption coefficient reached a value of 0.85. The use of one or two layers of ceramic paint results in a reduction of the damping properties in the main frequency range. Pronounced differences between the samples were observed in the 1500–3400 Hz range, where the absorption coefficient was higher compared to the primary sample. The local increase in the coefficient results from the main resonance peak observed at lower frequencies. The absorption curve becomes broader and flatter with respect to the original sample, which in many applications may be more desirable than a narrow resonance peak. Therefore, the influence of the ceramic coating on the sound absorption properties in a narrow frequency range can be projected. Similarly, Figure 5 shows the results for the samples coated with water-based acrylic lacquer.

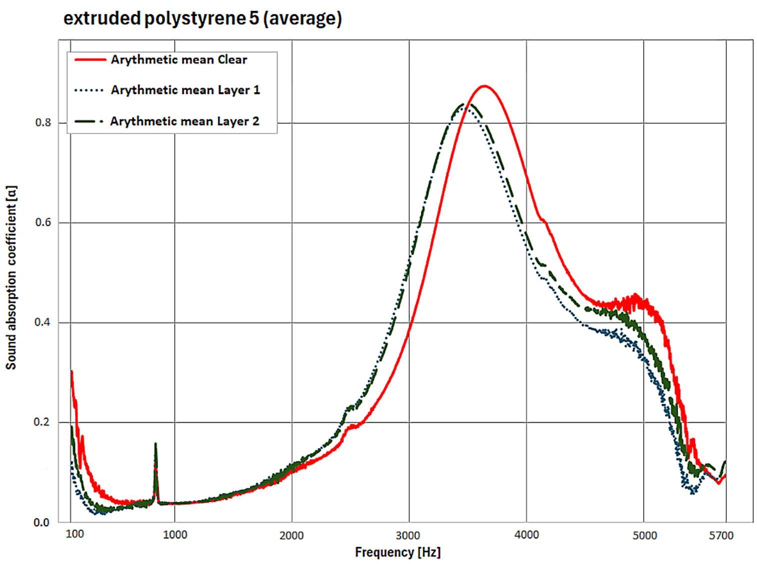

Figure 5. Average sound absorption coefficient for the extruded polystyrene (XPS) samples coated with water-based acrylic lacquer: uncoated substrate, one paint layer, and two paint layers. Values are averaged over 9 samples (n = 9) for each configuration

Figure 5 presents a comparison of averaged sound absorption characteristics for extruded polystyrene (XPS) samples in three configurations: uncoated, coated with one layer of water-based acrylic lacquer and coated with two layers of the same paint. For the uncoated sample, the absorption curve has a main resonance at 3700 Hz at which the absorption coefficient has a value of 0.88. Both one and two layers of acrylic varnish result in the main resonance peak occurring at lower frequencies. The sound absorption characteristics after applying the first and second coat of varnish retain their values, with a loss of approximately 0.05. The difference between the two coatings is minimal, indicating that both provide comparable attenuation over the entire frequency range.

Substrate material – polystyrene

Figure 6 shows the sound absorption characteristics as a function of frequency for samples 6 and 7 (Table 1), where the substrate is made of expanded polystyrene (EPS). Similarly, the tests were conducted for the bare substrate, followed by the substrate with the first and second paint layers.

From Figure 6 it can be seen that the substrate material in the two cases has very similar sound absorption properties. For the first resonance frequency around 2200 Hz the absorption coefficient reaches a value close to 0.3. The next frequency occurs at 5000 Hz and has a value close to 0.85.

In the case of a polystyrene plate covered with ceramic paint (white) (Figure 6a), the main resonance peak was observed around 3700 Hz. After applying another layer, the resonance peak occurred at approximately 3100 Hz. The stain-resistant ceramic paint for interiors (white) reduces the maximum sound absorption coefficient and moves the peak towards lower frequencies.

This effect is more pronounced when two layers of paint are applied, indicating greater mechanical damping and a change in the resonance of the material. The graphs clearly show that the "clean" sample, without any paint coating, demonstrates the best absorptive properties, achieving the highest attenuation coefficient.

In the case of the polystyrene plate covered with acrylic varnish (Figure 6b), the main resonance peak was observed around 4500 Hz. The next layer of paint maintains this tendency, with the main resonance peak occurring at approximately 4200 Hz.

The sound absorption coefficient is lower for two layers of paint compared to one layer, suggesting that multiple layers of paint are less effective at higher frequencies.

MICROSCOPIC EXAMINATION OF THE FRONTAL SURFACE

The frontal surface examination was examined using a HAWK DUO workshop microscope. The measurement accuracy of the Hawk Duo optical measuring microscope used in the study is specified by the manufacturer as 2 µm + 4.5 µm per 1000 mm (X-Y) at 100× magnification, with Z-axis accuracy up to 10 µm. The tests were carried out on the prepared measurement samples, which were described in the previous chapter. The first part of the measurements involved examining different types of substrates and their frontal surfaces. In the next part, the first layer of paint was applied to the sample substrate

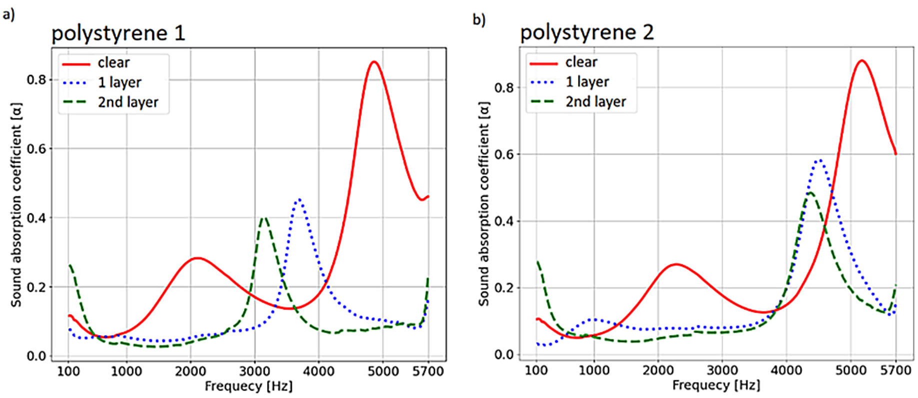

Figure 6. Sound absorption coefficient for: a) the polystyrene sample coated with stain-resistant ceramic paint for interiors (white), b) the polystyrene sample coated with water-based acrylic lacquer

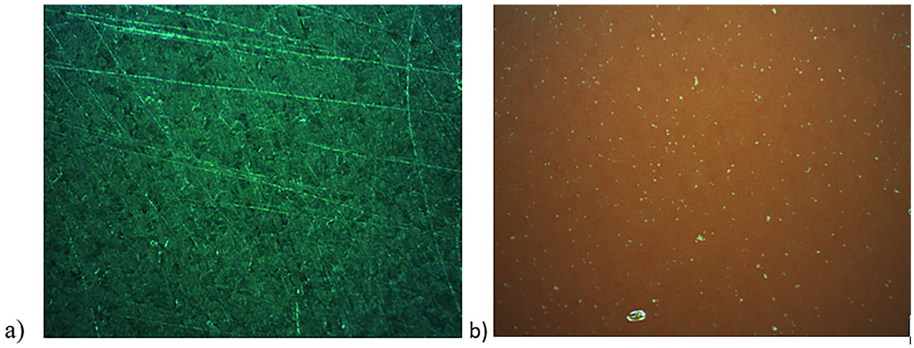

Figure 7. Frontal surface (a) sheet metal sample without paint coating, (b) sheet metal sample covered with synthetic rubber protective coating

and the changes occurring on the surface of the acoustic wave incidence were observed. Figure 7 shows the frontal surface of the steel sheet sample in two conditions: without a paint coating and with a synthetic rubber protective coating. On the basis of the microscopic observations conducted for the tested metal samples covered with synthetic rubber protective coating paint, clear differences in surface structure were found depending on the application of the paint coating. Uncoated samples showed significant roughness and irregularity of the surface topography, which indicates the presence of micropores and cavities. On the other hand, the samples covered with paint were characterised by a more uniform and smooth surface, which suggests that the paint layer effectively fills microscopic irregularities. The observed morphological changes have significant acoustic consequences. The smoother surface created by the paint coating may increase the reflectivity of the sample at certain frequencies, which is consistent with the observed reduction in sound absorption in the impedance tube measurements. The results indicate that the paint coating not only affects the aesthetics and protection of the material, but also significantly modifies its acoustic properties. After the analysis of the samples coated with the synthetic rubber protective layer, a second type of protective coating was evaluated, namely the primer-enamel for metal surfaces, shown in Figure 8.

Figure 8 shows that the surface of the uncoated sample shows clear scratches and directional abrasions, which are most likely the result of mechanical processing. The surface structure is clearly rougher and more irregular, with visible depressions and micropores. This topography favors the absorption of sound waves, because the surface irregularities allow for the dispersion and attenuation of acoustic energy. The observations were reflected in the results presented in the previous chapter.

In Figure 8, the microscopic image of the primer-enamel for metal surfaces paint shows a homogeneous surface with small and evenly distributed surface defects. There are no obvious scratches or porosities that would indicate a rough structure. The observed surface is relatively smooth and devoid of deep faults or scratches. This means that the paint coating has effectively filled the micro unevenness of the substrate,

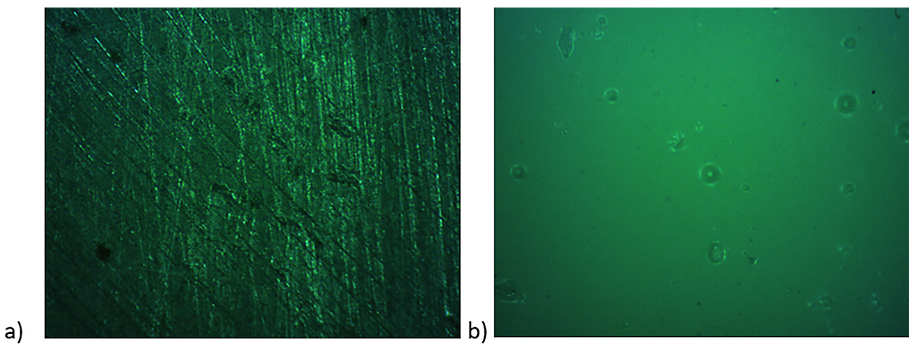

Figure 8. Frontal surface (a) sheet metal sample without paint coating, (b) sheet metal sample covered with primer-enamel for metal surfaces

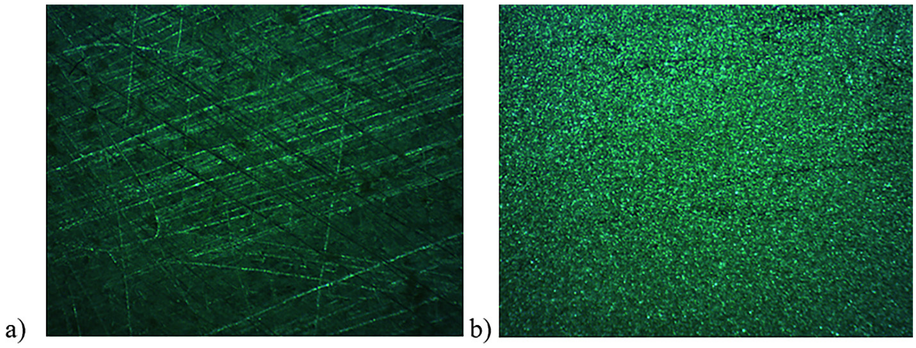

Figure 9. Frontal surface (a) sheet metal sample without metallic car paint, (b) sheet metal sample covered with metallic car paint

creating a continuous and closed protective layer. Next, a third type of protective coating was evaluated, namely metallic car paint. Figure 9 shows microscopic images of the frontal surface of the steel sheet sample without this coating and with the metallic paint applied.

Microscopic observations presented in Figures 7, 8 and 9 confirm significant differences in surface morphology depending on the type of paint coating applied. The surface of the sample coated with metallic car paint (Figure 9b) shows high homogeneity and a uniform structural distribution, with no visible scratches or deeper damage. Such a structure suggests effective filling of micro-gaps and irregularities by the paint layer, which results in smoothing the surface. In turn, the sample without the paint coating (Figure 9a) is characterised by the presence of numerous, deep scratches and a clearly marked directional texture, typical for surfaces subjected to mechanical processing. Such irregularities favor the dispersion of sound waves and increase the absorption of acoustic energy. Thus, the obtained images are consistent with the measured decrease in sound absorption and suggest that the coating may reduce the ability of the rough surface to dissipate acoustic energy. For comparison, the surfaces of the XPS samples coated with a water-based acrylic lacquer and a stain-resistant ceramic interior paint, as well as an uncoated sample, were also analysed; their microscopic images are shown in Figure 10. The microscopic images presented in Figure 10 illustrate the changes in the surface structure of XPS depending on the applied paint coating. Figures 10a and 10b show the samples covered with paint, with Figure 10a showing numerous irregular light reflections suggesting the presence of a rough structure under a thin layer of paint. In Figure 10b, on the other hand, the surface is much smoother and more uniform, which may indicate a more complete coverage of the material by the paint in this version of the sample. For comparison, Figure 10c shows the uncoated surface, which is characterised by distinct graininess and irregularity, characteristic of the porous structure of XPS. The use of a paint coating therefore results in a reduction of the visible porosity of the material and partial or complete smoothing of its surface, which may reduce the ability of the base material to absorb sound. To assess the influence of paint coatings on the surface of expanded

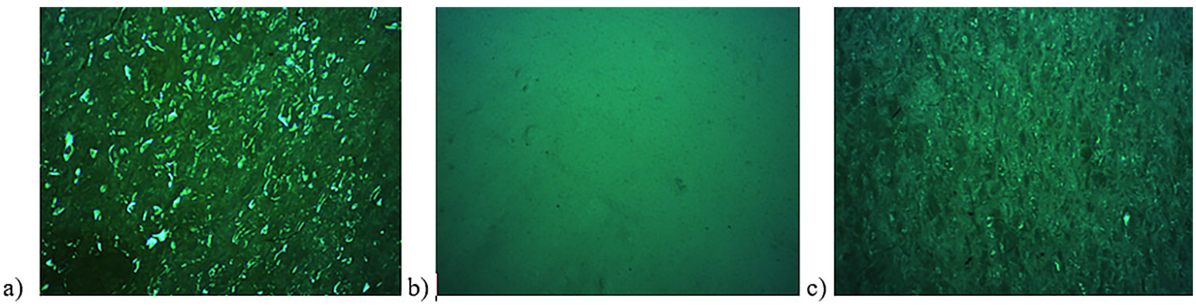

Figure 10. Frontal surface (a) XPS covered with water-based acrylic lacquer, (b) XPS covered with stain-resistant ceramic paint for interiors, (c) picture of XPS without cover

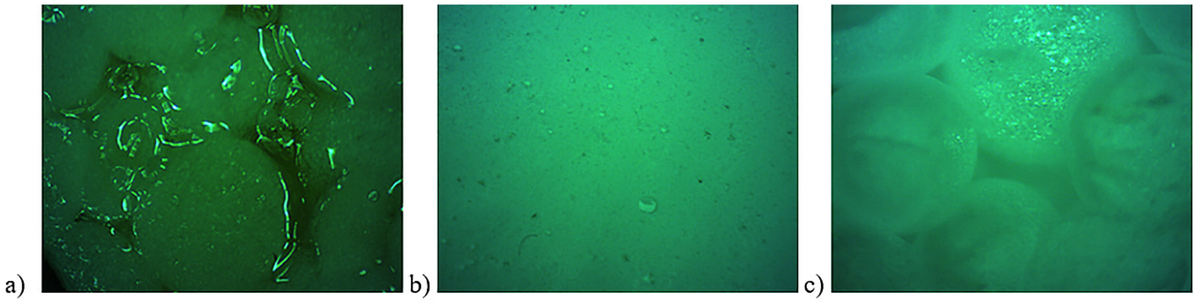

Figure 11. Frontal surface (a) polystyrene covered with water-based acrylic lacquer, (b) polystyrene covered with stain-resistant ceramic paint for interiors, (c) polystyrene without paint coating

polystyrene (EPS), an additional series of samples was analysed, and their microscopic images are presented in Figure 11. On the basis of the microscopic analysis presented, differences in the surface structure of the polystyrene covered with a layer of varnish can be seen. In Figure 11a, the surface of the polystyrene appears to be more irregular and rough – there are visible thickenings and unevenness resulting from the application of the varnish. In contrast, Figure 11b shows a smoother and more uniform surface, which suggests a more even coating of varnish or greater penetration of the smoothing agent. The smoother the surface, the lower the sound absorption coefficient, because sound waves tend to reflect off smooth surfaces. In turn, the roughness visible in Figure 11c promotes the dispersion and absorption of acoustic waves, which makes such a material more effective in sound dampening.

CONCLUSIONS

In this study, the influence of paint coatings on the sound absorption properties of selected construction materials was experimentally evaluated using the normal-incidence impedance tube method in the 100–5700 Hz frequency range. The results demonstrate that thin coatings can modify the acoustic response of both metallic and polymeric substrates by altering their resonance behaviour and changing the effective magnitude as well as bandwidth of sound absorption. The extent of these changes depends on both the coating type and the substrate material. For metal discs, the applied coatings reduced the peak absorption coefficient and resulted in the main resonance peak occurring at lower frequencies. The results suggest that, within a limited range, the resonance characteristics of such lightweight structures may be adjusted by selecting an appropriate coating type and thickness.

Among the tested coatings, the samples with ceramic paint exhibited a more pronounced change in the frequency position of the main absorption peak compared with those coated with acrylic varnish. For polymeric materials (XPS and EPS), the uncoated samples exhibited low absorption efficiency, particularly at lower frequencies. The application of coatings resulted in a shift of the main resonance towards mid-frequency ranges, together with a flattening of the absorption curve at higher frequencies. In the case of XPS, acrylic varnish maintained the absorption level while shifting the resonance, whereas ceramic paint introduced a more noticeable modification of the absorption spectrum. These effects are consistent with the added surface mass and the partial closure of surface pores observed in the microscopy images. Overall, the findings indicate that paint coatings can influence the acoustic properties of lightweight materials by shifting their resonance frequencies and slightly modifying the effective bandwidth of sound absorption. Although the effect is limited and strongly dependent on the substrate as well as coating characteristics, the results show that thin surface layers may act as passive elements affecting the acoustic behaviour of materials in the applications where lightweight structures are used, such as construction, transportation, or machine component design.

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