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Acoustic absorption behaviour of an open-celled aluminium foam

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Abstract
Metal foams, especially close-celled foams, are generally regarded as poor sound absorbers. This paper studies the sound absorption behaviour of the open-celled Al foams manufactured by the infiltration process, and the mechanisms involved. The foams show a significant improvement in sound absorption compared with close-celled Al foams, because of their high flow resistance. The absorption performance can be further enhanced, especially at low frequencies, if the foam panel is backed by an appropriate air gap. Increasing the air-gap depth usually increases both the height and the width of the absorption peak and shifts the peak towards lower frequencies. The foam samples with the smallest pore size exhibit the best absorption capacities when there is no air gap, whereas those with medium pore sizes have the best overall performance when there is an air gap. The typical maximum absorption coefficient, noise reduction coefficient and half-width of the absorption peak are 0.96–0.99, 0.44–0.62 and 1500–3500 Hz, respectively. The sound dissipation mechanisms in the open-celled foams are principally viscous and thermal losses when there is no air-gap backing and predominantly Helmholtz resonant absorption when there is an air-gap backing.

1. Introduction

Acoustic absorption is one of the most important functional properties of metal foams [1]. Many authors have proposed that metal foams can be prospective candidates for noise control, particularly in hostile surroundings [2–7]. However, the majority of the studies to date have concentrated on the mechanical properties instead of the functionality, including sound absorption behaviour. The few studies conducted so far have resulted in a rather limited database for the corresponding applications.

Itoh *et al* [2] conducted a study on the sound absorption of a close-celled Al foam. Wang *et al* [3] analysed the sound absorption of Al alloy foams and honeycombs using the point-matching method. They concluded that the optimal pore size for best sound absorption is of the order of ∼0.1 mm. However, structural parameters, like sample thickness and open porosity corresponding to this pore size were not considered. More recently, Lu *et al* [4, 5] conducted experimental work on the sound absorption of close-celled and semi-open-celled Al foams. For semi-open-celled foams, the sound absorption increased with decreasing open pore size, and a peak absorption coefficient of 0.8 was obtained in the frequency range 800–2000 Hz. For a close-celled foam with a pore size of 2–4 mm, they suggested that the initial relative density has a decisive influence on the absorption performance. Han *et al* [6, 8] investigated the acoustic absorption behaviour of a close-celled Al foam with pore size and porosity ranges of 0.5–5.0 mm and 66–86%, respectively. They proposed that the airflow resistance could be used as a criterion for evaluating the absorption performance in the context of the energy dissipation mechanisms in rigid-framed porous materials. The best absorption performance takes place at a medium airflow resistance, roughly 0.04–0.045 rayls m^{-1}, no matter how the pore size or the porosity varies. In addition,

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for close-celled Al foams, their absorption can be effectively enhanced by a compressive deformation operation combined with an appropriate air gap.

A few conclusions can be drawn on the main acoustic features of porous metals from earlier studies. First, close-celled metallic foams have relatively low sound absorption capacity compared with the currently prevalent acoustic materials such as polymer foams and glass wool, mainly because of the low intrinsic damping of the rigid cell walls [9] and the limited open porosity. These metal foams have a low noise reduction coefficient (NRC) in most conditions [11]. Second, although in some situations an absorption coefficient peak of ~0.9 can be attained, the peak is rather narrow, with the half-power band width less than 100 Hz. In contrast, polymer foams and glass wool materials give a wide-band absorption. Finally, in order to improve the absorption performance, such operations as compressive deformation or hole-drilling are needed to increase the open porosity. It has been suggested that, for sound absorption, it could be more advantageous to use open-celled porous metals rather than close-celled ones. However, very little information on the sound absorption characteristics of open-celled metallic foams and their relationship with material structure and acoustic environment has been documented.

For most rigid-frame porous materials, the acoustic absorption properties generally depend on three factors: airflow resistance, porosity and pore morphology [11]. These three factors, however, are interlinked. For instance, a low porosity and complex pore morphology are correlated to higher airflow resistance and vice versa. The structural morphology of the Al foam used in this study is very different from that of conventional non-metallic porous materials as well as that of close-celled porous metals. Its acoustic behaviour therefore is expected to be different. A complete understanding of this difference is undoubtedly crucial for future applications of the foams as sound absorbers. This study aims to characterize the sound absorption behaviour of the open-celled Al foam, explore its dependence on the pore structure and discuss the associated mechanisms.

2. Experimental

2.1. Samples

The open-celled Al foam specimens were fabricated by a high-pressure infiltration process. This process consists of three stages. First, a porous compact made of NaCl powder is prepared by a die-press under an appropriate pressure. Second, the compact is infiltrated with a commercially pure Al melt under pressure, yielding an ingot composed of NaCl and Al. The ingot is then machined to the required sample geometry. Finally, the NaCl particles in the finished sample are removed by leaching in hot water. The pores of the final Al foam are virtually replicas of the individual particles of the NaCl powder used. The particle sizes of each of the NaCl powders used in this study fell within a narrow range, normally within ±10% of the nominal particle size. The average diameter of the NaCl particles was, therefore, used to denote the pore size of the foam. The porosity of the foam, P, was determined by

$$P = \left(1 - \frac{\rho_0}{\rho_s}\right) \times 100\% \quad (1)$$

Table 1. Characteristics of Al foams investigated.

Foam	Nominal pore size (mm)	Porosity (%)	Pore type
A	0.5	57	Open
B	1.5	60	Open
C	2.5	59	Open
D	3.5	61	Open
E	3.0	88	Close

where ρ_0 is the apparent density of the foam, which was determined by measuring its dimensions and weight, and ρ_s is the density of the Al matrix.

Table 1 lists the nominal pore size and porosity of the Al foams investigated. A close-celled Al foam was also examined for comparison. The typical pore morphologies of the open-celled and close-celled foams are shown in figure 1.

2.2. Acoustic measurements

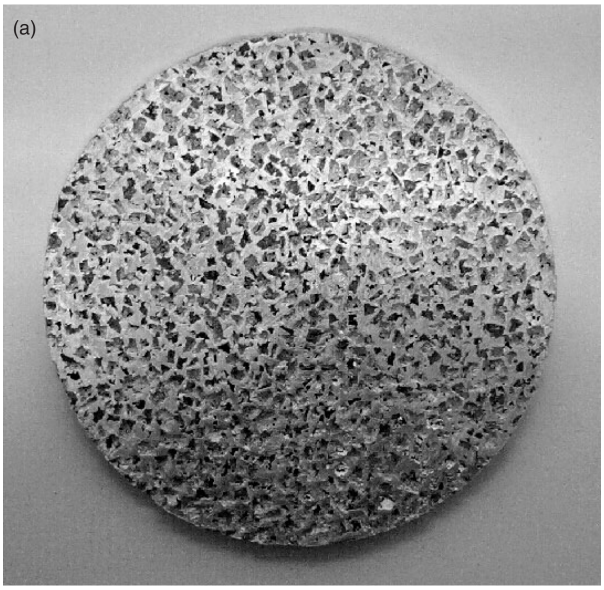
There are mainly two types of methods for the determination of the absorption coefficient of acoustic materials: the reverberation time method and the standing wave tube method. In this investigation, the latter was used since it is faster and generally reproducible and, in particular, requires relatively small circular samples, either 100 or 30 mm in diameter. There are two standing wave tube methods available. The one-third-octave frequencies method is based on the standing wave ratio principle and uses an audio frequency spectrometer to measure the absorption coefficients at various centre frequencies of the one-third-octave bands. The transfer function method is a relatively recent development [7, 12]. In this method, a broadband random signal is used as a sound source. The normal incidence absorption coefficients and the impedance ratios of the test materials can be measured much faster and easier compared with the first method. Figure 2 compares the sound absorption coefficients of an Al foam sample measured by the two methods. The results obtained by the two methods were found to be consistent across the frequency range of interest. Therefore, the transfer function technique was adopted in this study.

2.3. Theoretical background

A detailed description of the transfer function method is given in the British Standard BS EN ISO 10534-2:2001 [12]. The transfer function technique is based on the fact that the sound reflection factor at normal incidence, r, can be determined from the measured transfer function, H_{12}, between two microphone positions in front of the material being tested. The complex acoustic transfer function, H_{12}, is normally defined as

$$H_{12} = \frac{p_2}{p_1} = \frac{e^{jk_0x_2} + re^{-jk_0x_2}}{e^{jk_0x_1} + re^{-jk_0x_1}} \quad (2)$$

where p_1 and p_2 are the complex sound pressures at the two microphone positions, x_1 and x_2 are the distances of the two microphone positions from the reference plane ($x = 0$), and k_0 is the wave number defined by $k_0 = 2\pi f/c_0$, where f is the frequency and c_0 the speed of sound.



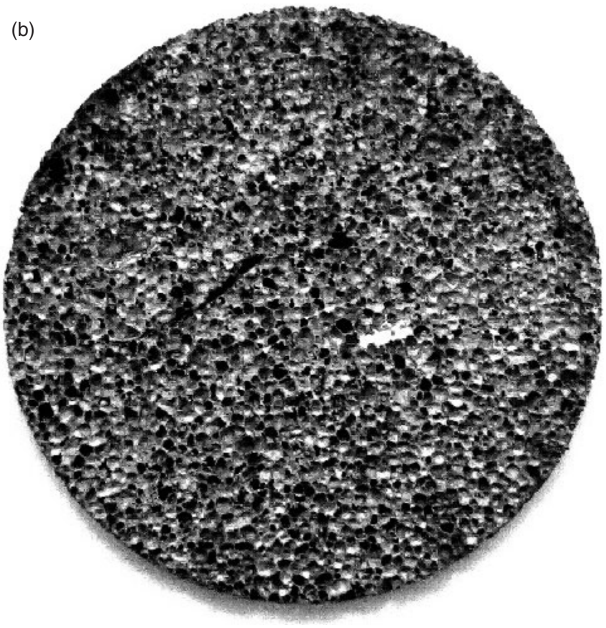


Figure 1. Typical structure of (*a*) open-celled and (*b*) close-celled Al foam samples (100 mm in diameter).

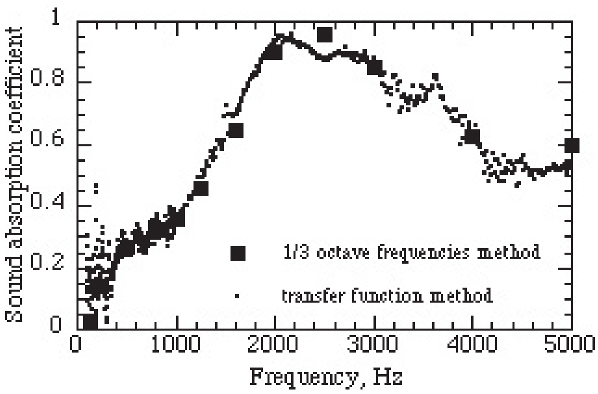


Figure 2. Comparison of the one-third-octave frequencies and the transfer function methods (foam A with a sample thickness of 20 mm).

The transfer functions for the incident wave, H_I, and for the reflected wave, H_R, can be calculated by

$$H_I = e^{-jk_0(x_1-x_2)} \qquad H_R = e^{jk_0(x_1-x_2)} \tag{3}$$

Combining equations (2) and (3), the normal incidence reflection factor, r, can be calculated using

$$r = \frac{H_{12} - H_I}{H_R - H_{12}} e^{2jk_0 x_1} \tag{4}$$

The sound absorption coefficient, α, can then be determined in terms of r by

$$\alpha = 1 - |r|^2 = 1 - r_r^2 - r_i^2 \tag{5}$$

where r_r and r_i are the real and imaginary components of r, respectively.

2.4. Measurement procedure

In this study a one-microphone technique was used in order to eliminate phase mismatch between microphones. The measurement system was composed of an impedance tube, a signal generator, a loudspeaker, a portable dual-channel fast Fourier transform (FFT) analyser, a power amplifier and a precision sound level meter. A series of preliminary tests were performed to minimize the errors and to identify the best values for several basic parameters, one of which, the number of power spectrum average, was fixed at 128. The sound absorption coefficient of the back plate of the impedance tube was also measured and found to be around 0.02 on average and lower than 0.1 at all frequencies. Its effect on the measurements was therefore negligible.

The upper working frequency of an impedance tube is determined by its inner diameter [12]. The acoustic measurements for the frequency ranges below and above 1000 Hz were carried out separately in 100 and 30 mm diameter impedance tubes, respectively, in order to improve the measurement accuracy and to avoid the occurrence of non-plane wave mode propagation. Accordingly, the Al foam samples were machined to a diameter of either 100 or 30 mm and a thickness of 5, 10 or 20 mm. In each measurement, the foam sample was placed either directly against the back plate or with an air gap of 30 or 60 mm to the back plate in the impedance tube. The interstices around the sample edges were sealed with Vaseline to secure a complete incidence surface. A random signal with a flat spectral density within the frequency range of interest was supplied to the loudspeaker. The transfer function, H_{12}, was determined by measuring successively the sound pressures at two microphone locations by the signal processing system. Given the constant value of separation between the two microphone locations, $x_1 - x_2$, and the transfer function, H_{12}, the complex normal incidence reflection factor, r, was obtained by equation (4) and then the sound absorption coefficient, α, was obtained by equation (5).

3. Results

3.1. Characteristics of sound absorption behaviour

Figures 3–5 show the sound absorption coefficients as a function of frequency for the open-celled Al foam samples

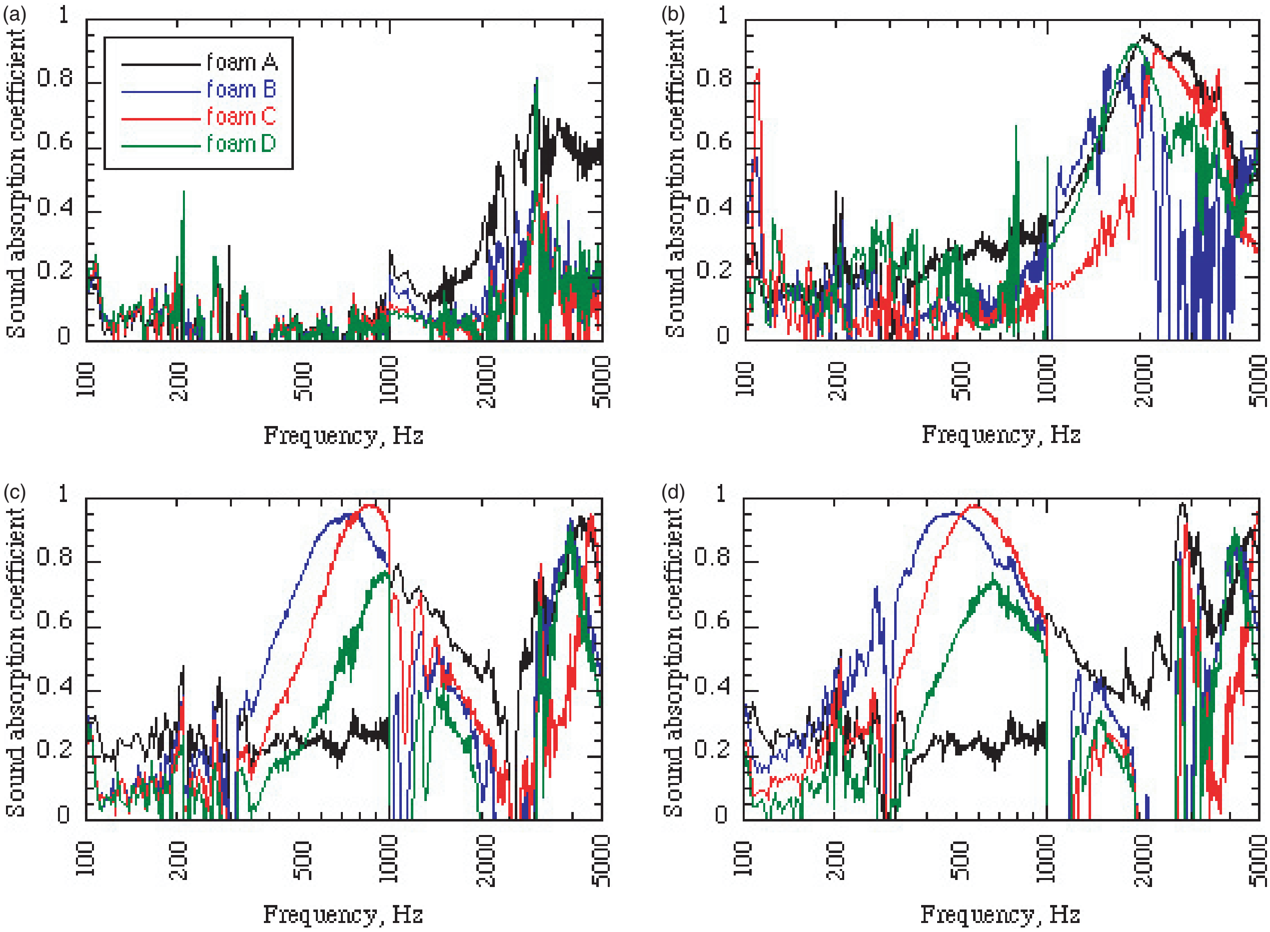


Figure 3. Effect of pore size on sound absorption of open-celled Al foams with different sample thickness and air-gap depths of (*a*) 5 and 0 mm, (*b*) 20 and 0 mm, (*c*) 20 and 30 mm, and (*d*) 20 and 60 mm, respectively.

with different pore sizes, open-celled samples with different air-gap depths and close-celled samples, respectively. In order to make a quantitative and easy comparison among the samples, the characteristic parameters of the sound absorption curves, including peak absorption coefficient, half-width of the resonant peak and NRC are summarized in table 2 and shown graphically in figure 6. The peak half-width is defined as the width of the frequency band of the sound absorption peak at an absorption coefficient of 0.5. NRC is the mean or arithmetic average of the absorption coefficients at the frequencies of 250, 500, 1000 and 2000 Hz [10]. These parameters serve as a convenient set of values for the assessment of the acoustic performance of the materials.

The close-celled Al foam (sample E) has a porosity of 88%, which is much higher than that of the open-celled foams (57–61%). However, the samples of the close-celled foam have low sound absorption coefficients as shown in figure 5. The sound absorption coefficient is well below 0.5 in all cases except for a few sharp resonant peaks. None of the sound absorption curves of these samples exhibits strong and broad absorption peaks. The effects of sample thickness and air-gap depth are not significant. In contrast, the open-celled foams have much better sound absorption properties with the existence of one or two broad resonant absorption peaks on nearly all the curves shown in figures 3 and 4. The maximum absorption coefficient can exceed 0.98 at certain frequencies. The greatest peak half-width is greater than 1500 Hz, with sample A showing an effective range of over 3000 Hz. Compared with the close-celled foam samples, the open-celled foam samples also show a wider resonant peak at a lower frequency.

3.2. Effect of pore size

The open-celled foams A, B, C and D have a similar porosity within a small range of 57–61% but different pore sizes of 0.5 mm, 1.5 mm, 2.5 mm and 3.5 mm, respectively, as shown in table 1. The differences among the foams in sound absorption behaviour can therefore be attributed to the effect of pore size. Figure 3(*a*) shows that when there is no air gap behind the relatively thin samples, sample A, which has the smallest pore size of 0.5 mm, has the highest and broadest peak in the sound absorption curves, while the other samples, with the pore size ranging from 1.5 to 3.5 mm, exhibit very similar absorption behaviour. For thicker samples, the differences become small, although sample A still has a slightly broader and stronger absorption peak than the other samples, as shown in figure 3(*b*). Figure 6(*a*) also shows that the NRC decreases with increasing pore size when no air gap is present.

When the samples are backed by an air gap, however, samples B and C, with medium pore sizes of 1.5 and 2.5 mm, show higher and broader peaks on the sound absorption curves

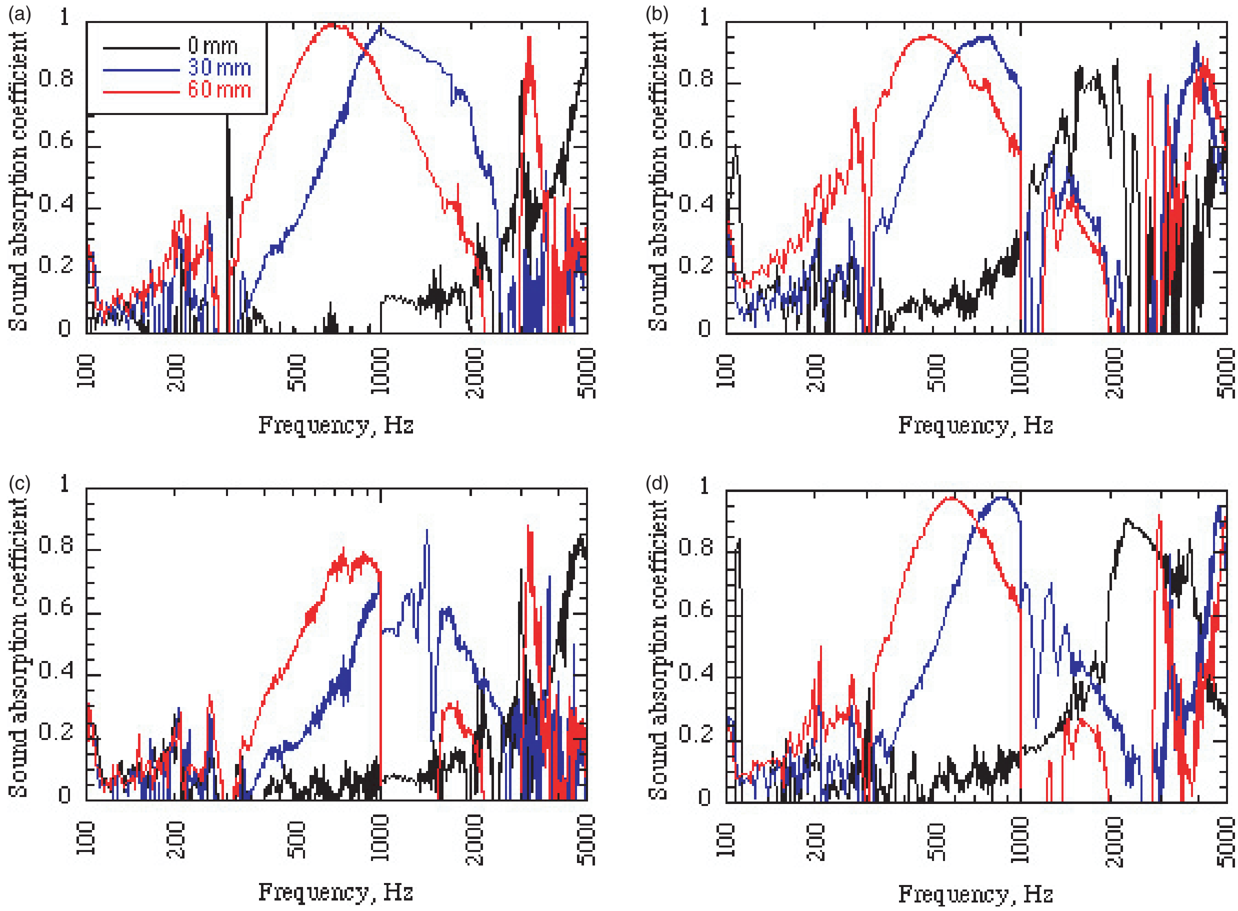


Figure 4. Effect of air-gap depth on sound absorption of open-celled Al foams (*a*) B, (*b*) B, (*c*) C and (*d*) C, with a sample thickness of (*a*) 10 mm, (*b*) 20 mm, (*c*) 10 mm and (*d*) 20 mm, respectively.

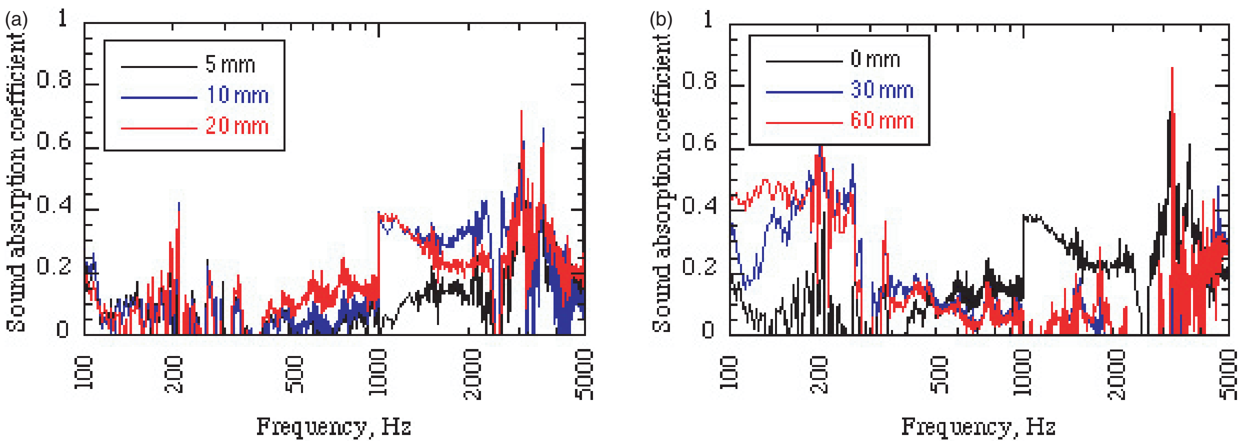


Figure 5. Sound absorption curves of a close-celled foam showing the effects of (*a*) sample thickness, with no air gap, and (*b*) air-gap depth, with a constant sample thickness of 20 mm.

than samples A and D, as shown in figures 3(*c*) and (*d*). This trend is also demonstrated by the changes in the NRC, with sample B having the highest values, as shown in figures 6(*b*) and (*c*).

3.3. Effect of sample thickness

The open-celled foam samples with a thickness of 5 mm exhibit very low sound absorption capacities as shown in figure 3(*a*). When the thickness is increased to 20 mm, however, their sound absorption performance over the whole frequency range is much improved, as shown in figure 3(*b*). Figures 6(*a*)–(*c*) also show that for most samples the greater the thickness the higher the NRC values. Nevertheless, comparing figures 4(*a*) with (*b*) and (*c*) with (*d*) shows that there is no significant difference in sound absorption between the samples with a thickness of 10 mm and those of 20 mm, independent of whether there is an air gap or not.

Table 2. Characteristic parameters of sound absorption curves.

Foam	Sample thickness (mm)	Peak absorption coefficient Air-gap depth (mm) 0	30	60	Half-width of resonant peak (Hz) Air-gap depth (mm) 0	30	60	NRC Air-gap depth (mm) 0	30	60
A	5	0.80	0.60	0.88	—	—	—	0.13	0.24	0.13
	10	0.64	0.75	0.58	900	1662.5	—	0.23	0.33	0.29
	20	0.95	0.94	0.98	3450	>2237.5	>2450	0.44	0.39	0.36
B	5	0.44	0.81	0.86	—	—	—	0.11	0.32	0.39
	10	0.87	0.98	0.99	>1062.5	1737.5	1455	0.12	0.53	0.51
	20	0.86	0.96	0.96	1387.5	1105	1174	0.28	0.47	0.62
C	5	0.40	0.54	0.52	—	—	—	0.10	0.20	0.28
	10	0.85	0.70	0.79	1575	1120	1007.5	0.12	0.36	0.38
	20	0.91	0.98	0.98	2200	952.5	935	0.24	0.45	0.48
D	5	0.34	0.48	0.48	—	—	—	0.06	0.33	0.20
	10	0.99	0.97	0.97	2775	885	1078	0.16	0.42	0.46
	20	0.92	0.76	0.73	2625	572.5	535	0.38	0.31	0.32
E	5	0.30	0.43	0.24	—	—	—	0.10	0.20	0.12
	10	0.47	0.31	0.29	—	—	—	0.18	0.07	0.1
	20	0.48	0.29	0.29	—	—	—	0.16	0.1	0.2

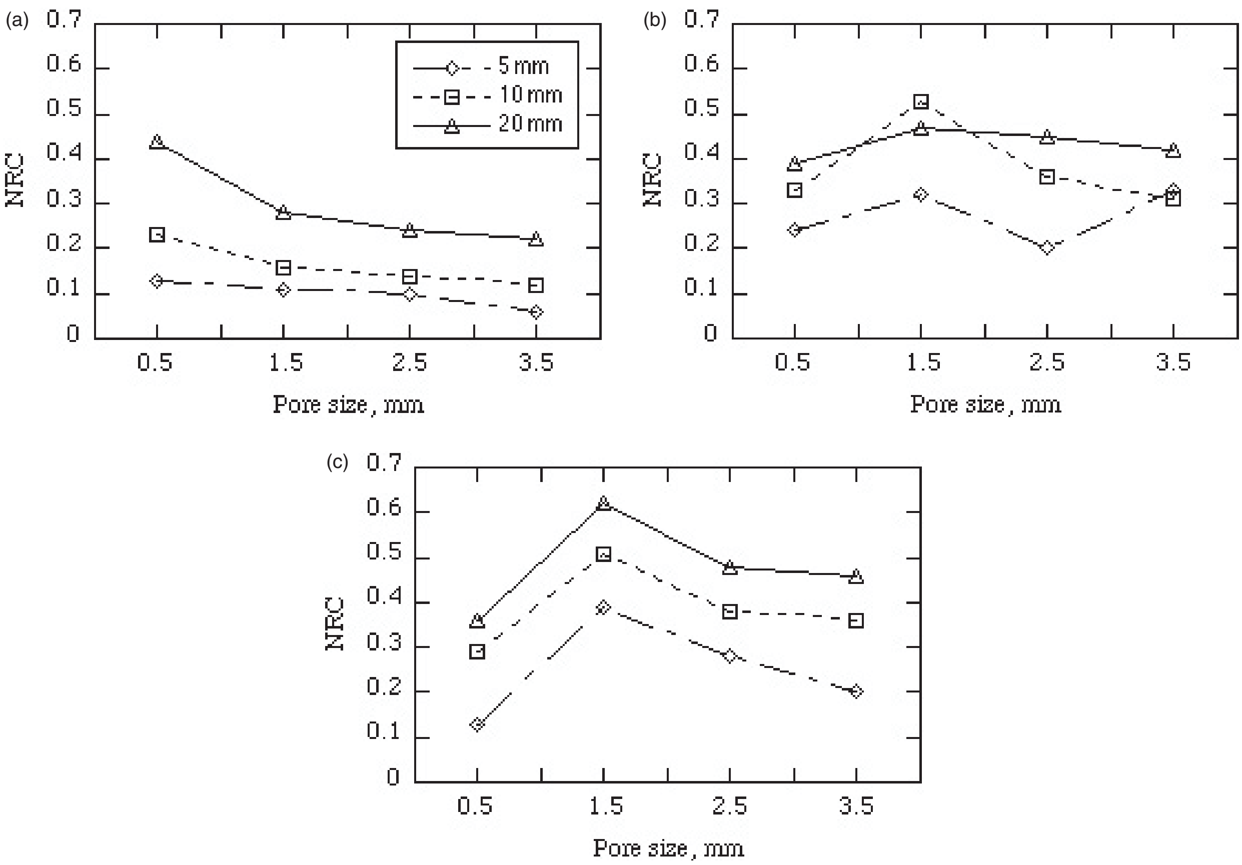


Figure 6. Variations of NRC with foam pore size at different air-gap depths of (*a*) 0 mm, (*b*) 30 mm and (*c*) 60 mm.

3.4. Effect of air-gap depth

Figures 3 and 4 show that the Al foams have poor sound absorption capacities at low frequencies if they are secured directly to a rigid backing. Introducing an air gap between the foam and the back plate shifts the sound absorption peak towards a lower frequency. The greater the air-gap depth, the lower the peak frequency. As a consequence, the absorption performance is considerably enhanced [2–8]. However, the effect of air-gap depth on the maximum sound absorption coefficient and the effective frequency band width of the absorption peak is not significant.

4. Discussion

Sound propagation and attenuation in rigid-framed porous media have been subjected to extensive studies for several decades and the theories developed for the explanation of sound dissipation and for the prediction of acoustic behaviour are well documented [13–20]. The matrices in rigid-framed porous materials such as Al are of low intrinsic damping compared with fibrous polymeric materials. The acoustic loss factor due to the structural damping contribution from the rigid matrix is of the order of 10^{-3}. Therefore, the absorption coefficient of a rigid-framed porous material depends mainly on the pore structure, including porosity and the size, shape and connectivity of the pores.

The acoustic behaviour of the open-celled Al foams is significantly different from that of the dominantly close-celled [2–7] and semi-open-celled Al foams [4] as well as the porous ceramics [14]. The open-celled Al foams investigated in this study exhibit much improved sound absorptive performance over a wider frequency range, especially when they are backed by an air cavity. This favourable absorptive behaviour can be attributed to the unique pore morphology in this kind of Al foams as shown in figure 7. The melt infiltration process used for manufacturing the foams dictates that all the pores are virtually interconnected. Large pores are connected by irregularly shaped and sized holes on the pore walls, forming a complex network of interlinking air channels. The diameters of the small holes are of the order of tens of microns, roughly two orders of magnitude smaller than the diameters of the pores. Another distinct feature of the foams is the rough internal surfaces in the pores.

Sound absorption in metal foams secured directly to a rigid backing arises principally from two mechanisms: viscous losses due to flow resistance and thermal losses due to heat transfer to the matrix. Zwikker and Kosten [13] analysed the separate contributions of these two mechanisms through the introduction of the frequency-dependent dynamic density and dynamic bulk modulus of air. Lu *et al* [5] adopted the same approach and calculated the sound absorption coefficients of a model porous metal consisting of an array of uniform pores of selected pore sizes from 0.5 to 5 mm. The calculations

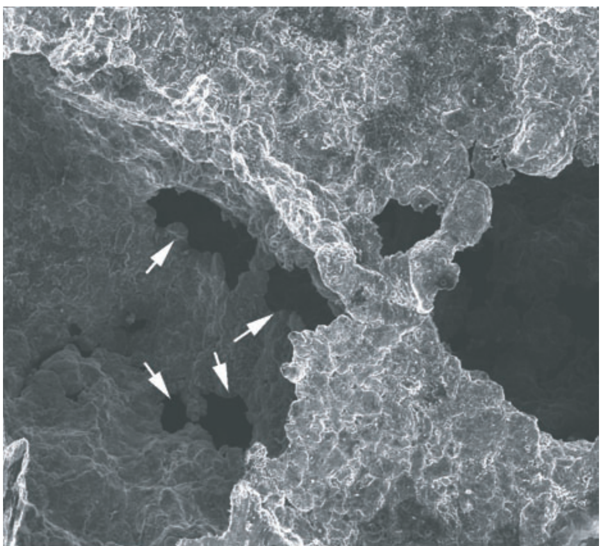


Figure 7. Pore morphology with interconnecting channels indicated by arrows.

showed that the contribution of the viscous effect increases with increasing frequency and decreasing pore size. Although the viscous effect is found to be comparable to the thermal effect for relatively thin foams (∼1 cm), it becomes dominant at frequencies >1000 Hz for relatively thick foams (∼10 cm). It seems that the overall sound absorption coefficient is largely dependent upon the contribution of the viscous effect. The viscous losses in turn are determined by the flow resistance of the foam, which is often governed by the conditions in the narrowest parts of the pore channels [17, 20].

The present open-celled Al foams have a high flow resistance because of the complex channel structure combined with rough internal pore surfaces. The small holes connecting the large pores allow considerable sound wave dissipation via friction because of the significant increase in air velocity when the air travels from the large pores into these much smaller holes. The contribution of the small holes to the sound dissipation is much more significant than that produced by viscous and thermal losses in the large pores [5]. The existence of a number of smaller holes as the connective channels of large pores may be the main reason for the much enhanced absorption capacity compared with the other porous metal structures of similar porosity and pore size.

For foams with similar porosity, pore shapes and tortuosity, the flow resistance is determined by pore size and sample thickness. Foam A has the smallest pore size and therefore the highest flow resistance. It therefore has the highest sound absorption capacity as shown in figure 3(*a*). Increasing the sample thickness also increases the flow resistance and therefore increases the absorption capacity, as confirmed by comparing figures 3(*a*) and (*b*). It should, however, be pointed out that excessively large flow resistance, as in the case of the close-celled foams, is unfavourable for sound absorption because of the low transmission and high reflection rates of the incident sound wave.

All rigid-framed porous materials, however, have low absorption at low frequencies if they are backed directly by a rigid surface. In order to enhance the sound absorption in the low frequency range, an air gap between the face of the material and the rigid backing surface behind it is necessary. With an air gap behind the sound absorbing material, the cavity resonator, or Helmholtz resonator, mechanism becomes effective and, in many cases, predominant. A Helmholtz resonator is composed of a cavity with a small neck and has a definite absorption peak at the resonant frequency of the mass of the enclosed air in the resonator. The resonant frequency, f_r, can be calculated by [15]

$$f_r = \frac{c}{2\pi}\sqrt{\frac{A}{LV}} \tag{6}$$

where c is the velocity of sound, A the cross-sectional area of the neck, L the neck length plus $0.8\sqrt{A}$ and V the volume of the cavity.

In the present open-celled Al foams, the combination of each pore channel with the backing air gap can be regarded as a Helmholtz resonator, with the channel as the neck and the air gap as the cavity. As an illustrative example, consider a system consisting of foam B with a thickness of 20 mm and a diameter of 100 mm and an air gap behind it with a depth of 30 mm. Assuming that the neck of one resonator is a straight tube across the foam thickness with an internal diameter of

2.5 mm, the dimensional parameters of this resonator are: $A = 4.9 \times 10^{-6}\,m^2$, $L \approx 0.02\,m$ and $V = 2.36 \times 10^{-4}\,m^3$. Substituting these values into equation (6) gives a first-order estimation of the resonant frequency in the region of 50 Hz. Because of the existence of numerous air channels in the foam, with different lengths and cross-sectional areas, the whole system is composed of a large number of such resonators. Although the resonant peak occurs at a selective low-frequency and over a narrow frequency band for each resonator, the whole system can accomplish the attenuation of a wide range of frequencies with each tuned to a different frequency within the range.

Figures 3 and 4 show that the maximum sound absorption coefficients appear at high frequencies of above 2000 Hz for the open-celled foams without an air gap but move towards frequencies as low as 400 Hz if the foams are backed by an air gap. For any foam, the frequency corresponding to the maximum sound absorption coefficient decreases with increasing air-gap depth. For example, the frequencies at maximum absorption coefficients for the 20 mm thick samples of foam B without air gap, with 30 and 60 mm deep gaps are approximately 2000 Hz, 990 Hz and 690 Hz, respectively. The absorptive peaks are also extended to broader frequency ranges by introducing an air gap, due to the large number of different-dimensioned Helmholtz resonators. The air-gap backed foams still exhibit significant sound absorption capacities at lower frequencies than these characteristic values. The results are consistent with the above analysis.

Figures 3 and 4 also show that the foam samples, if backed with an air gap, with medium pore sizes perform better than that with the smallest pore size. This can be understood by examining the sound absorption mechanisms. As has been mentioned above, the sound dissipation in these conditions is principally attributed to the Helmholtz resonator effects whilst viscous and thermal losses become insignificant, particularly in the low frequency regime. This effectiveness of the Helmholtz resonators is also dependent upon the flow resistance in the pore channels. If the pore size is too small, the flow resistance of the pore channels may be too high for the sound waves to propagate through the long, narrow channels and set the air in the air gap in motion. As a consequence, the resonant absorption is not effective. Comparing the curves of foam A in figures 3(*b*)–(*d*), for example, little change occurs in absorption coefficient, regardless of whether there is an air gap or not. This means that the Helmholtz resonator effect is not significant in this case. With increasing pore size, all the foam samples display the resonant absorption phenomenon but only the samples with medium pore sizes, i.e. from foams B and C, perform better. The sound absorption behaviour of foams with an air gap is apparently different from the circumstances without an air gap. One implication is that for fine-pored Al foams to be used in low-frequency sound absorption applications a thin, rather than thick, sheet combined with an air gap behind it may have the best performance because of the functioning of the Helmholtz resonators.

It should be pointed out that the small holes combined with large pores in the open-celled Al foams can also be considered as Helmholtz resonators, with the small holes as necks and the large pores as cavities. However, because of the small volumes of the pores the resonant frequencies of these Helmholtz resonators are likely to exceed 20 kHz, just like in the case of the compressed Alporas foams [5]. The Helmholtz resonator mechanism is therefore not significant for foams without an air backing in the practically important frequency range of 20–4000 Hz.

5. Conclusion

The sound absorption behaviour of the open-celled Al foams manufactured by the infiltration process has been studied. The foams have much improved sound absorption capacities at frequencies higher than 1000 Hz compared with the commercial metal foams currently available, because of their high flow resistance resulting from the complex channel structure combined with rough internal pore surfaces. Relatively small pores and great foam thickness are beneficial to sound absorption when the foams are secured directly to a rigid backing. The sound absorption performance of the foams can be significantly enhanced, particularly at low frequencies, by introducing an air gap behind the foam. With an air gap, the foam samples with medium pore sizes exhibit the best absorption capacities. The half-width and maximum value of the peak in the absorption-coefficient-versus-frequency curves can be as high as 3500 Hz and 0.99, respectively. The location of the peak shifts towards lower frequencies with increasing air-gap depth. The sound dissipation mechanisms in the open-celled foams are principally viscous and thermal losses when there is no air-gap backing, and predominantly Helmholtz resonant absorption when there is an air-gap backing. The present Al foam can be a competitive candidate for noise control applications.

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