Comparison of sound absorbing performances of copper foam and iron foam with the same parameters

X C Yang, X M Shen¹, P J Xu, X N Zhang, P F Bai, K Peng, Q Yin and D Wang

College of Field Engineering, PLA University of Science and Technology, No. 1 Haifu Street, Nanjing, Jiangsu 210007, P. R. China

¹ E-mail: shenxmjfjlgdx2014@163.com

Abstract. Sound absorbing performances of the copper foam and the iron foam with the same parameters were investigated by the AWA6128A detector according to standing wave method. Two modes were investigated, which included the pure metal foam mode and the combination mode with the settled thickness of metal foam. In order to legibly compare the sound absorbing coefficients of the two metal foams, the detected sound frequency points were divided into the low frequency range (100 Hz ~ 1000 Hz), the middle frequency range (1000 Hz ~ 3200 Hz), and the high frequency range (3500 Hz ~ 6000 Hz). Sound absorbing performances of the two metal foams in the two modes were discussed within the three frequency ranges in detail. It would be calculated that the average sound absorbing coefficients of copper foam in the pure metal foam mode were 12.6%, 22.7%, 34.6%, 43.6%, 51.1%, and 56.2% when the thickness was 5 mm, 10 mm, 15 mm, 20 mm, 25 mm, and 30 mm. meanwhile, in the combination mode, the average sound absorbing coefficients of copper foam with the thickness of 10 mm were 30.6%, 34.8%, 36.3%, and 35.8% when the cavity was 5 mm, 10 mm, 15 mm, and 20 mm. In addition, those of iron foam in the pure metal foam mode were 13.4%, 20.1%, 34.4%, 43.1%, 49.6%, and 56.1%, and in the combination mode were 25.6%, 30.5%, 34.3%, and 33.4%.

1. Introduction
Metal foam has been gradually introduced in the noise reduction of large-scale mechanical equipment, because it has the advantages of high sound absorbing coefficients, high strength, easy processability, fine associativity, outstanding permeability, excellent fire resistance, and a long service life [1-3]. Among these known metal foams, copper foam and iron foam are two promising materials for the sound absorption [4, 5]. In different ranges of sound frequency, the sound absorbing performances are different [6, 7]. Therefore, in order to establish the optimal option for sound absorption with different ranges of sound frequency, comparison of sound absorbing coefficients of copper foam and iron foam with same parameters were conducted in this study.

The investigated sound frequency could be divided into three ranges, which included the 100 Hz ~ 1000 Hz, 1000 Hz ~ 3200 Hz, and 3500 Hz ~ 6000 Hz. For different ranges of the sound frequency, the sound absorbing coefficients of copper foam and that of iron foam with the same parameters were detected. Meanwhile, for the purpose of thoroughly comparing the sound absorbing performances of copper foam and iron foam, metal foams with different thickness were investigated. In addition, it had been reported that the sound absorbing performances of metal foam would be obviously improved by combining with cavity [8-10]. Therefore, sound absorbing coefficients of metal foam with different cavity were also studied. Finally, the synthetical sound absorbing performances of copper foam and that of iron foam with same parameters were primarily given. Research on the comparison of sound
absorbing performances of the copper foam and the iron foam with same parameters would promote application of the metal foam and ameliorate the noise reduction method.

2. Experimental setup and parameters
Detection of the sound absorbing coefficients of metal foam was obtained by the AWA6128A detector, as shown in the figure 1, which was realized according to the standing wave method [11, 12]. The detected metal foam was fixed in the standing wave tube, and the back cavity could be adjusted by the adjustment. The input audio power signal was generated by the computer, and the received sound signal was obtained by the pickup with acoustic probe. The detection process was tracked by the computer and displayed on the monitor.

![Figure 1](image)

Figure 1. Schematic diagram of the experimental system for detection of sound absorbing coefficients.

Parameters of the copper foam and those of the iron foam were summarized in table 1. It could be found that the porosity, pore-per-inch (PPI), bulk density, open-cell rate, and aperture of the two metal foams were same, which indicated that the comparisons of sound absorbing performances of the two metal foams were conducted with the same parameters.

| Material     | Porosity | Pore-per-inch (PPI) | Bulk density | Open-cell rate | Aperture |
|--------------|----------|---------------------|--------------|----------------|----------|
| Copper foam  | 75%      | 90                  | 0.3 g/cm³    | 98%            | 0.2 mm   |
| Iron foam    | 75%      | 90                  | 0.3 g/cm³    | 98%            | 0.2 mm   |

Two series of experiments were conducted by experimental system shown in figure 1 to compare sound absorbing performances of the two metal foams, as shown in table 2. On the basement of these experiments, the sound absorbing performances of copper foam and that of the iron foam with the same parameters were compared respectively. In the pure metal foam mode, the investigated thickness of the metal foam was 5 mm, 10 mm, 15 mm, 20 mm, 25 mm, and 30 mm, respectively. Meanwhile, in the combination mode, thickness of the metal foam was settled as 10 mm, and dimension of the cavity was set as 5 mm, 10 mm, 15 mm, and 20 mm, respectively.

| The designed experiments | Thickness of the metal foam | Dimension of the cavity |
|--------------------------|-----------------------------|-------------------------|
| Pure metal foam mode     | 5 mm, 10 mm, 15 mm, 20 mm, 25 mm, 30 mm. | 0 mm                    |
| Combination mode with the settled thickness of metal foam | 10 mm | 5 mm, 10 mm, 15 mm, 20 mm. |
3. Results and discussions
According to the characteristics of the experimental system, the detected sound frequency in the range of 100 Hz ~ 1000 Hz was 100 Hz, 200 Hz, 300 Hz, 400 Hz, 500 Hz, 600 Hz, 700 Hz, 800 Hz, and 950 Hz. Similarly, the detected sound frequency in the range of 1000 Hz ~ 3200 Hz was 1000 Hz, 1100 Hz, 1200 Hz, 1300 Hz, 1400 Hz, 1500 Hz, 1600 Hz, 1700 Hz, 1800 Hz, 1900 Hz, 2000 Hz, 2100 Hz, 2200 Hz, 2300 Hz, 2400 Hz, 2500 Hz, 2600 Hz, 2700 Hz, 2800 Hz, 2900 Hz, 3000 Hz, 3100 Hz, 3200 Hz, and that in the range of 3500 Hz ~ 6000 Hz was 3500 Hz, 3600 Hz, 3700 Hz, 3800 Hz, 3900 Hz, 4000 Hz, 4100 Hz, 4200 Hz, 4300 Hz, 4400 Hz, 4500 Hz, 4600 Hz, 4700 Hz, 4800 Hz, 4900 Hz, 5000 Hz, 5100 Hz, 5200 Hz, 5300 Hz, 5400 Hz, 5500 Hz, 5600 Hz, and 5700 Hz. In each frequency range, the detected sound frequency point was 9.

3.1. Pure metal foam mode
In the pure metal foam mode, the investigated thickness of the metal foam was 5 mm, 10 mm, 15 mm, 20 mm, 25 mm, and 30 mm, respectively. The obtained sound absorbing coefficients of the two metal foams in the frequency range of 100 Hz ~ 1000 Hz were shown in figure 2. It could be found that for the same material of metal foam, no matter copper foam or iron foam, the sound absorbing coefficients increased along with the increase of thickness from 5 mm to 30 mm in most detected frequency points, which was coincident with the results reported in the research of sound absorbing performances of the porous materials [13-15]. Meanwhile, it could be observed that the sound absorbing coefficients of the two metal foams in the low frequency range were low, and the maximum was no more than 40%. The major reason was supposed that wavelength of the sound signal was long in the low frequency range, so the sound wave diffracted the metal foam and the sound energy could not be absorbed. In addition, the experimental results indicated that the sound absorbing coefficients of copper foam were lower than that of the iron foam with the same parameters in most detected frequency points when the thickness was 5 mm, 10 mm, and 30 mm. When the thickness was 15 mm, 20 mm, and 25 mm, the synthetical sound absorbing performances of the two metal foams were almost same. Thus, it could be concluded that in the low frequency range, the sound absorbing performances of copper foam was worse than that of the iron foam with the same parameters.

Figure 2. The obtained sound absorbing coefficients of the two metal foams in the frequency range of 100 Hz ~ 1000 Hz in the pure metal foam mode.

The obtained sound absorbing coefficients of the two metal foams in the frequency range of 1000 Hz ~ 3200 Hz were shown in figure 3. It could be observed that the sound absorbing coefficients were almost linear with the sound frequency for the metal foam with a certain thickness. Meanwhile, sound absorbing coefficients were also near linear with thickness of the metal foam for a certain frequency point. It was interesting to notice that the two lines had intersection. For example, when the thickness was 30 mm, sound absorbing coefficients of the copper foam were worse than that of the iron foam in the frequency range of 1000 Hz ~ 2000 Hz, and be better than that of the iron foam in the frequency range of 2000 Hz ~ 3200 Hz. There also existed an intersection frequency 2000 Hz when the thickness was 15 mm. It could be found that except the thickness of 20 mm, sound absorbing performances of
the copper foam was better than that of the iron foam along with the increase of sound frequency. Thus, sound absorbing performances of the copper foam was better than that of the iron foam with the same parameters in the middle frequency range, especially when the sound frequency was increased.

Figure 3. The obtained sound absorbing coefficients of the two metal foams in the frequency range of 1000 Hz ~ 3200 Hz in the pure metal foam mode.

The obtained sound absorbing coefficients of the two metal foams in the frequency range of 3500 Hz ~ 6000 Hz were shown in figure 4. It would be observed that sound absorbing coefficients of the two metal foams increased along with the increase of thickness. When the thickness increased from 5 mm to 20 mm, improvement of the sound absorbing performances of the two metal foams was obvious, and the further increase of thickness had no obvious improvement to the sound absorption. It could be found that except when the thickness was 5 mm, sound absorbing coefficients of the copper foam were better than those of the iron foam with the same parameters in the high frequency range. Judging from evolutions of the two metal foams it could be primarily concluded that sound absorbing performances of copper foam was worse than that of the iron foam with same parameters in the low frequency range, and it was changing better along with the increase of sound frequency.

Figure 4. The obtained sound absorbing coefficients of the two metal foams in the frequency range of 3500 Hz ~ 6000 Hz in the pure metal foam mode.

3.2. Combination mode with the settled thickness of metal foam
The achieved sound absorbing coefficients of the two metal foams in the frequency range of 100 Hz ~ 1000 Hz were shown in figure 5. It could be found that when dimension of the cavity was low, sound
absorbing coefficients of the copper foam and those of the iron foam were almost same. When the cavity increased to 15 mm and 20 mm, it could be observed that sound absorbing coefficients of the copper foam were better than those of the iron foam with the same parameters. Relative to the sound absorbing performances of the pure metal foam with thickness of 10 mm in figure 2, introduction of cavity would be propitious to improve sound absorbing performances of the metal foam, although the improvement was no remarkable in the low frequency range.

**Figure 5.** The achieved sound absorbing coefficients of the two metal foams in the frequency range of 100 Hz ~ 1000 Hz in the combination mode with the settled thickness of metal foam.

The achieved sound absorbing coefficients of the two metal foams in the middle frequency range were shown in figure 6. It would be observed that sound absorbing coefficients of the copper foam were obviously better than those of the iron foam with same cavity. Meanwhile, relative to sound absorbing performances of the pure metal foam in figure 3, it could be found that the improvements of the sound absorbing coefficients were remarkable by the introduction of cavity, and the improvement level of the copper foam was larger than that of the iron foam.

**Figure 6.** The achieved sound absorbing coefficients of the two metal foams in the frequency range of 1000 Hz ~ 3200 Hz in the combination mode with the settled thickness of metal foam.

The achieved sound absorbing coefficients of the two metal foams in the middle frequency range were shown in figure 7. Firstly, it could be found that introduction of the cavity would be obvious to improve the sound absorbing coefficients of the metal foam. In figure 4, the average sound absorbing coefficients of the metal foam with the thickness of 10 mm were 35%. Through introducing the cavity, sound absorbing coefficients were 1.5 times even when the cavity was only 5 mm. Secondly, it could
be observed that evolvement of the sound absorbing coefficients along with increase of the cavity were disordered for the two metal foams [16-18], which was quite different from that in the pure metal foam mode, and also be different from that in low or middle frequency range in the combination mode. It was supposed that the major reason was that there existed sound absorption by the sympathetic vibration in the cavity, and the efficient of the sympathetic vibration was not in the positive correlation with dimension of the cavity. Thirdly, sound absorbing performances of the copper foam was always better than that of the iron foam when dimension of the cavity was 5 mm. When the cavity was 10 mm, 15 mm, and 20 mm, there existed intersectional frequency points for the two metal foams, and the corresponding point was near 5600 Hz, 4700 Hz, and 4100 Hz, respectively. Before the intersectional frequency points, sound absorbing performances of the copper foam was better than that of the iron foam. Meanwhile, after the intersectional frequency points, sound absorbing performances of the copper foam was worse than that of the iron foam. Thus, in the high frequency range, sound absorbing performances of the two metal foams with the same cavity were almost equivalent.

![Figure 7](image-url)

**Figure 7.** The achieved sound absorbing coefficients of the two metal foams in the frequency range of 3500 Hz ~ 6000 Hz in the combination mode with the settled thickness of metal foam.

It would be calculated that the average sound absorbing coefficients of copper foam in the pure metal foam mode were 12.6%, 22.7%, 34.6%, 43.6%, 51.1%, and 56.2% when the thickness was 5 mm, 10 mm, 15 mm, 20 mm, 25 mm, and 30 mm. meanwhile, in the combination mode, the average sound absorbing coefficients of copper foam with the thickness of 10 mm were 30.6%, 34.8%, 36.3%, and 35.8% when the cavity was 5 mm, 10 mm, 15 mm, and 20 mm. In addition, those of iron foam in the pure metal foam mode were 13.4%, 20.1%, 34.4%, 43.1%, 49.6%, and 56.1%, and in the combination mode were 25.6%, 30.5%, 34.3%, and 33.4%.

4. **Conclusions**

Comparison of sound absorbing performances of the copper foam and iron foam with same parameters were conducted in this study. The pure metal foam mode and the combination mode with the settled thickness of metal foam were investigated. The investigated frequency was ranged into three parts. The experimental result indicated that sound absorbing coefficients of the metal foam had relationship with the sound frequency and the metal parameters, which meant that the optimal option for the best sound absorbing performances should be determined by the concrete conditions.

**Acknowledgments**

This work was supported by a grant from National Natural Science Foundation of China (Grant No. 51505498), a grant from Natural Science Foundation of Jiangsu Province (Grant No. BK20150714), and a grant from National Key Research & Development Program (Grant No. 2016YFC0802903).
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