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# Experimental investigation of metal foam for controlling centrifugal fan noise

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ABSTRACT

This paper presents an experimental investigation on the metal foam for controlling a centrifugal fan noise. Nine samples of metal foam with different types of cells, i.e., open, semi-open and close, are employed to compare their effects on the aerodynamic performance and noise level of the centrifugal fan. Experimental data confirms that the open cell metal foam is the most effective to control the fan noise because it not only significantly suppresses the tonal noise but also attenuates the broadband noise. Moreover, the geometrical parameters of the open cell metal foam, i.e., pores per inch and porosity, are studied to investigate their effects on the aerodynamic performance and noise level of the centrifugal fan.


## 1. Introduction

Controlling noise level of centrifugal fans is highly demanded in many engineering applications. Previous studies have indicated that the tonal noise generated from the periodic flow interaction between the impeller and the volute tongue is usually predominant [1–6]. Additionally, the noise level of the broadband component is lower than that of the tonal component, but its contribution to the overall noise level is also non-negligible and its generation mechanism is more complicated.

Many passive noise control methods have been developed to control the centrifugal fan noise. All the passive methods can be categorized into two aspects: suppression of the noise source strength and absorption of the acoustic energy. Usually, the first control method is suitable for controlling the tonal noise by suppressing the surface pressure fluctuation of the volute tongue. Some methods, such as increasing the impeller-tongue clearance and inclining the volute tongue [7–9], have been reported to successfully reduce the tonal noise level. The second control method is to absorb the broadband noise components, where the porous materials, e.g. micro-perforated panel and fiberglass, are commonly employed owing to its good acoustic absorption performance in wide frequency range. Gu et al. [10] has developed a structure combined with the micro-perforated panel, fiberglass and air cavity to control the broadband noise of a centrifugal fan.

A new type of multifunctional porous material, i.e. metal foam [11–14], has been developed since the 90s of the last century. Because of its excellent fire-, moisture- and corrosion-proof advantages over the conventional porous material, metal foam has extensive application fields [15,16]. Based on the previous studies, the porous material with the pore size about sub-millimeter has a good acoustic absorption performance mainly through the mechanism of the viscous and thermal dissipation [11,14]. Sutliff et al. has showed that metal foam with the pore size about 0.3 mm can achieve up to 4–5 dB of broadband attenuation for the turbofan noise [17,18]. Another function of the metal foam is to control flow, such as postponing the flow separation from the buff body [19,20], suppressing the wall pressure fluctuation (i.e. dipole source strength) [21,22]. Sueki has reported the application of the metal foam to control the noise of the cylinder and high-speed train [23].

The volute tongue is the primary noise source region of centrifugal fans owing to the strong and periodic impingent of the wake flow out from the blades. In the present paper, the volute tongue made by the metal foam is employed to reduce the noise radiated from a centrifugal fan. Various samples of metal foam with different structural parameters are investigated experimentally. The aims of the present research are to validate the application of the metal foam for controlling the centrifugal fan noise and to study the effect of the structural parameters of the metal foam on the noise reduction of the centrifugal fan.

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**Nomenclature**

| | |
|---|---|
| $d_p$ | pore size, mm |
| $m$ | mass of the metal foam, kg |
| $V_p$ | pore volume of the metal foam, m$^3$ |
| $V_t$ | total volume of the metal foam, m$^3$ |
| $\varepsilon$ | porosity |
| $\rho_s$ | density of skeletal material, kg m$^{-3}$ |

*Abbreviations*

| | |
|---|---|
| BEP | best efficiency point |
| CCMF | close cell metal foam |
| OASPL | overall A-weighted sound pressure level |
| OCMF | open cell metal foam |
| PPI | pores per inch |
| SCMF | semi-open cell metal foam |
| SPL | sound pressure level |
| TPR | total pressure rise |
| VFR | volume flow rate |

## 2. Experimental setup and method

### 2.1. Centrifugal fan

As shown in Fig. 1, a forward-curved centrifugal fan is employed in the present study owing to its relative high speed at the impeller outlet. The periodic impingement of the flow from the impeller outlet on the volute tongue easily causes the serious tonal noise associated with the broadband component [3,10]. Since the number of the impeller blades is 12 and the nominal rotating speed of the impeller is 2900 r/min, the corresponding blade passing frequency (BPF) is 580 Hz. This centrifugal fan has been used in the previous studies, and the detailed structural parameters can be found in Refs. [10,24].

### 2.2. Metal foam

The installation position of the metal foam is shown in Fig. 1 to substitute the conventional volute tongue made by the non-porous material. Various samples of the metal foam employed in the present study are displayed in Fig. 2. According to the different kinds of connectivity among porous cells, metal foams can be classified into the following three types: close cell metal foam (CCMF), semi-open cell metal foam (SCMF) and open cell metal foam (OCMF).

The sample C1 is a CCMF. Since the pores of the CCMF mostly do not connect with each other and the ambient gas, the previous study has shown that the CCMF has a good acoustic insulation performance but is not an effective acoustic absorber [11]. In the present study, one sample is still employed to investigate its effect on the aerodynamic performance and noise of the centrifugal fan.

Samples O1–O6 are OCMFs with different porosities and pore sizes. Opposite to the CCMF, each pore of the OCMF connects with the adjacent pores and the ambient gas. The porosity $\varepsilon$ and pore size $d_p$ are two important geometrical parameters to characterize the OCMF. The porosity $\varepsilon$ of the metal foam is defined by

$$\varepsilon = \frac{V_p}{V_t} \tag{1}$$

where $V_p$ and $V_t$ are the pore volume and total volume of the metal foam, respectively. Since the pore volume is not easily directly measured, the porosity $\varepsilon$ is actually calculated as

$$\varepsilon = 1 - \frac{m}{\rho_s V_t} \tag{2}$$

where $m$ is the mass of the porous material sample, $\rho_s$ is the density of skeletal material. Moreover, pores per inch (PPI) is usually employed to characterize the pore size of the foam metal which is defined by

$$\mathrm{PPI} = \frac{25.4}{d_p} \tag{3}$$

Another commonly used parameter is the flow resistivity, which usually has an important effect on both the flow loss and the acoustic absorption performance. Based on the Ergun's equation [25], the flow resistance is related to not only the geometrical parameters of the OCMF, i.e., porosity $\varepsilon$, pore size $d_p$, but also the viscosity and flow velocity. In the present study, we do not

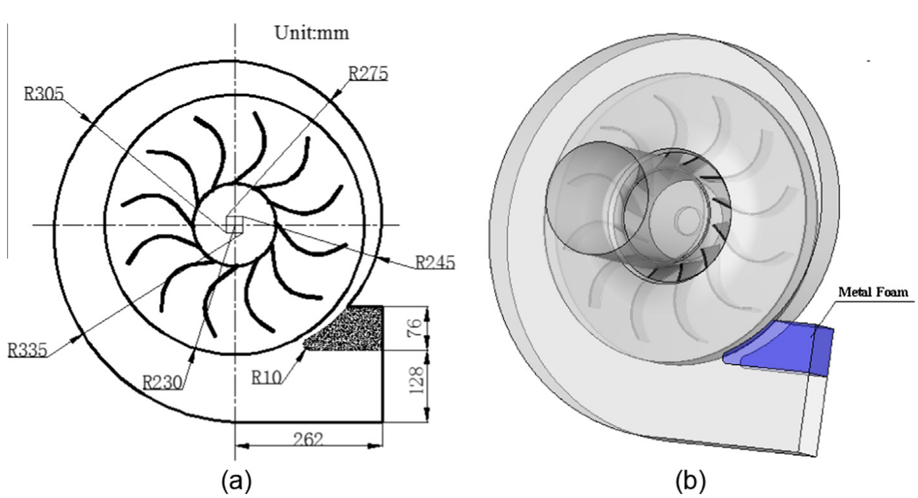


**Fig. 1.** CAD drawings of centrifugal fan: (a) two-dimensional side view; (b) three-dimensional view.