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A study for a practical use of thermoacoustic silencer -Influence on silencing effect by multistage stack method-

熱音響サイレンサーの実用化へ向けた研究 -多段スタック方式が消音効果へ与える影響-

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1. Introduction

When the sound wave propagate in the narrow tube, the fluid particle receives the influence of the thermal conduction and viscosity from the tube wall. These influence on thermal conduction and viscosity are greatly different according to the temperature difference formed on the tube wall. Under the condition of that the sound wave incident from high temperature side, the sound wave is attenuated. The silence system using this phenomena is called thermoacoustic silencer[1-2]. To realize thermoacoustic phenomana, thermoacoustic silencer is consisted of stack with many nallow channels less than 1 mm. Temperature difference is maintained by two heat exchangers set up at both ends of the stack. By practical use of this silencer cause as automobile muffer, it is thought that silence system have simplified structure and lightweight is realized.

Authors have succeeded in the improvement of silencing effect by introducting the multistage stack method. However, it is expected multistage installation of stacks cause change of sound field in an acoustic tube. The change of sound field in thermoacoustic phenomena impact for energy conversion between heat energy and sound energy[2]. In this report, the utility of the multistage stack method is considered by measuring silencing effect with mulistage installation of stacks.

2. Theory

2.1 Energy conversion efficiency and Sound field

In energy conversion efficiency of thermoacoustic phenomena, two impotant parameters exist. One is nondimensional parameter $\omega\tau$ that shows thermal conduction in the stack[2-3].

$$\omega\tau = 2\pi \cdot \frac{\tau}{T} \qquad (1)$$

From equation 1, $\omega\tau$ represent the ratio between cycle period:T and thermal relaxation time:τ. $\omega\tau$ is decided by frequency of sound wave, channl radious of the stack, and temperature of stack wall. Another parameter is phase difference:ϕ between sound pressure and particle velocity[3]. Phase difference shows relationship between displacement of partcle fluid and heat absorption and heat release according to pressure fluctuation. Therefore, when thermal relaxtion time is decided, phase difference of sound field dominate the energy conversion efficiency.

3. Experiments

Figure 1 shows an experimental setup. An 8-m-long stainless tube with 42 mm inner diameter is used. An electrodynamic full-range speaker is connected at one end of the tube. A stack is placed in the tube 1 m and 1.5 m distant from the speaker. The stainless-steel lamination meshes is used as a stack. The stack length is 10 mm, mesh number of the stack is #10(channel radius:1.06 mm), #40(channel radius:0.23 mm), and #60(channel radius:0.15 mm). At the speaker-side of the stack, an electric heater is placed as heat exchanger of high temperature; the room temperature heat exchanger at the counter-speaker-end of the stack is maintained using circulating water.

A single sine-wave is transmitted from the speaker; the sound pressure after passing through the stack is measured using a probe microphone (4182; B&K) set 2.0 m distant from the speaker. The temperature difference created in the stack is set to 0 K, 200 K, or 400 K by varying the heat energy supplied to the heater. The sound pressure after passing through the stack without a temperature difference is defined as the reference sound pressure. The change of sound pressure change of the sound pressure after passing through the stack with a temperature difference of 200 and 400 K is calculated based on the reference sound pressure amplitude. The frequencies of the sound transmitted from the speaker are 50-1000 Hz.

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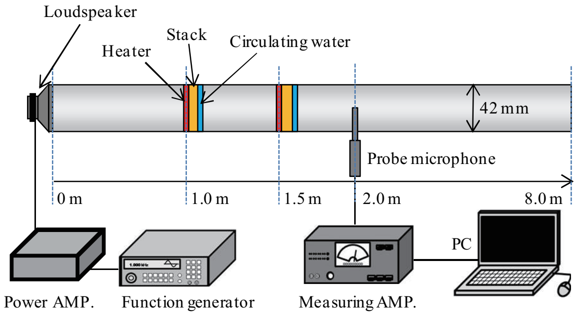

Fig. 1 Experimental setup.

4. Results and Discussion

Figure 2-4 show results of a experiment. In therse figure, "#10-#40" indicates that the first stage of stack is #10 and the second stage is #40. Figure 2 is comparison between sigle stack(#40) method and double stack(#40-#40) method. It is understood that silencing effect is high though the input energy is low with double stack method. This results denote silencing effiency is improved by multistage stack method.

Figure 3 represents difference in silencing effect of #40 and #60. When the stack is set up by one stage, silencing effects are of both stacks was almost corresponding. On the other hand, when the multistage method is applied, silencing effects are not corresponding. It is thought that change of sound field by multistage method is a factor of causing change of silencing effect. However, because $\omega\tau$ is difference in #40 and #60, it is difficult to compare.

Whereat, the condition of multistage is set up the stack of #10 and #60 is compared by Figure 4. When $\omega\tau$ is constant, the parameter that dominante the energy conversion efficiency in the stack is phase difference ϕ between sound pressure and particle velocity. Therefore, it is thought that sound field(phase difference) is changed because $\omega\tau$ is the same between #10-#60 and #60-#10.

From these results, it is thought that there is a necessity for examining the influence on silencing effect by measuring the sound field forward of the stack in detail.

5. Conclusion

In this study, the effectivity of multistage stack method is considered by measuring silencing effect of each mesh numbers. As a result, both of results increase and decrease of silencing efficiency is observed. This results indicated potentials to improve the efficiency by investigating the factor in increacement and decreasement

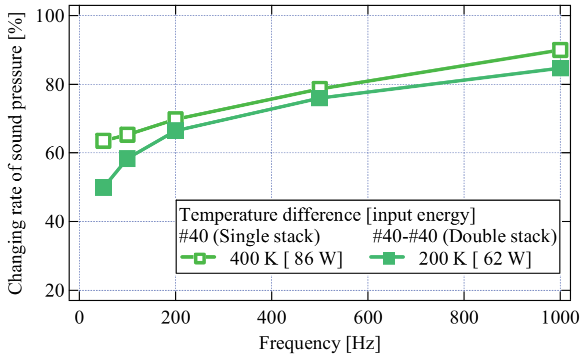

Fig. 2 Conparison between sigle stack and double stack method (#40).

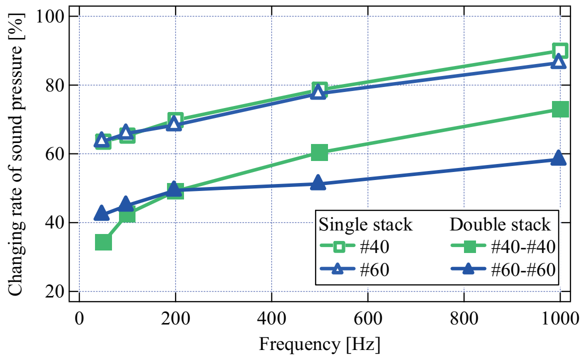

Fig. 3 Difference in silencing effect between #40 and #60.

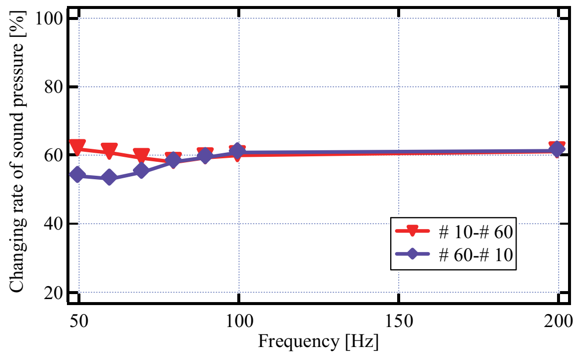

Fig. 4 Difference in silencing effect of installation order of stacks.

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