MEASUREMENT OF ACOUSTIC DISSIPATION IN POROUS MEDIUM WITH WET WALL

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A porous medium made with ceramics is set inside a resonator and the acoustic dissipation occurring in it is measured. Two conditions are tested. One is that the wall of the porous medium is wet by water, and the other is that it is dry. Measured results show that water does not affect dissipation caused by velocity oscillation; however, it affects the dissipation caused by pressure oscillation. Furthermore, it is found that the effect of water increases with the temperature of the working gas.

Keywords: acoustic propagation, wet wall

1. Introduction

It has been known that the condensation and evaporation of a working fluid affects acoustic propagation. For example, Pandit and King experimentally demonstrated that the sound speed in sandstone is decreased by 20%-30% when the relative humidity is increased to 0.98. These effects are not taken into account in conventional theories describing acoustic propagation equations. Hence, researchers have addressed the effect of evaporation and condensation. In the theories, the uniform-cross-section channel, along which an acoustic wave propagates, is assumed. However, in the experiments, complex flow channels, such as sandstone, are used. This means that there is very few or no experimental results that can be qualitatively compared with the theoretical results.

In this study, we constructed an experimental setup shown in Fig. 1 and measured acoustic dissipation in the porous medium; The porous medium is made with ceramics and has uniform-square-cross-sectional channels. Two conditions are tested. One is that the wall of the porous medium is wet and the other is that the wall of the porous medium is dry. The experimental results demonstrate that the acoustical dissipation due to velocity oscillation under the wet condition is comparable to that under the dry condition. On the other hand, the acoustical dissipation due to pressure oscillation under the wet condition is found to become larger than that under the dry condition. Note that this paper is based on the results shown in

2. Experimental setup and procedure

As shown in Fig. 1, the experimental setup is composed of an acoustic driver (speaker), resonator, and the porous medium. The resonator is made with stainless steel and its diameter is 40 mm. The porous
medium is made with ceramic and have many square channels. Half the length of one side of the square cross section is 0.47 mm. There are two unique points. One is that the resonator is covered by a (hot) water bath. This allows us to control the temperature of the gas, $T_{\text{gas}}$ inside the resonator. The other is that the membrane is set at the vicinity of the center of the resonator. The humidity of Section 2 (see Fig. 1) may increase but that of Section 1 does not increase because of the membrane. This allows us to use a conventional acoustic theory, which can be used to describe acoustic propagation in dry air, in section 1.

![Schematic illustration of the constructed experimental setup.](image)

Figure 1: Schematic illustration of the constructed experimental setup.

On the tube wall, pressure sensors are mounted to measure pressure amplitude and phase. By using the transfer matrix and the obtained data[7], pressure $P_1$ and cross-sectional mean acoustic velocity $U_1$ at the membrane are calculated, where the subscript 1 means the value at the membrane. Note that $P$ and $U$ are complex values. Acoustic intensity $I$ can be expressed as

$$I = \frac{\omega}{2\pi} \int \text{Re}[P] \text{Re}[U] dt = \frac{1}{2} \text{Re} [P\bar{U}].$$  (1)

Because the power flowing into Section 2 is all dissipated in Section 2, the dissipated power in Section 2 can be written as

$$W_1 = AI_1,$$  (2)

where $A$ is the cross-sectional area of the tube composing Section 1. We measure $W_{\text{mem}}$ by changing $T_{\text{gas}}$ under the following four conditions. (a) The porous medium is dry and is located at the pressure antinode, (b) it is wet and is located at the pressure antinode, (c) it is dry and is located at the velocity antinode, and (d) it is wet and is located at the velocity antinode. The wet condition is realized as follows: the porous medium is dipped into water to wet the surface of its wall and then is inserted in Section 2. The measured power $W_1$ under the above (a), (b), (c), and (d) conditions are denoted as $W_{1a}$, $W_{1b}$, $W_{1c}$, and $W_{1d}$, respectively.

3. Experimental results

The ratios $W_{1b}/W_{1a}$ and $W_{1d}/W_{1c}$ are shown in Fig. 2 as a function of $T_{\text{gas}}$. As can be seen from this figure, $W_{1b}/W_{1a}$ is above unity. This indicates that the dissipation due to pressure oscillation is increased by the presence of water on the wall of porous media, because the pressure amplitude and velocity amplitude are maximum and minimum at pressure antinode, respectively. Furthermore, $W_{1b}/W_{1a}$ was
found to increase with $T_{gas}$. Based on this result, we consider that the evaporation and condensation are important to increase the dissipation due to pressure amplitude because the upper limit mass amount of evaporation and condensation increases with $T_{gas}$. On the contrary, $W_{1d}/W_{1c}$ is independent of $T_{gas}$ and takes a value near unity. This indicates that the dissipation due to velocity oscillation is not affected by the presence of water.

![Graph showing the ratio of power to $T_{gas}$](image)

**Figure 2:** The experimental results.

### 4. Summary

The acoustic dissipation in the resonator that contains a wet-wall porous medium was measured. The experimental results indicated that the dissipation caused by acoustic velocity oscillation was not affected by the water. On the contrary, the dissipation caused by acoustic pressure oscillation was affected by water.

### REFERENCES


