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A STUDY ON RESONATOR TYPE MUFFLER

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1. INTRODUCTION

The resonator muffler is an application of the Helmholtz resonator. It features a large noise reduction effect near the resonant frequency, being effective in the low-frequency region as well and a small pressure loss. Therefore, it is effective for muffling the discrete component noise, e.g. the rotating noise of the blower, etc. Designing a muffler has problems due to there being many experimental factors, however. During our test, therefore, the effects on noise reduction and noise reduction characteristics were examined by varying the hole diameter d, the number of holes n, the length of the neck part t, etc. while maintaining the resonant frequency and the transmission loss (TL) constant respectively at 80 [Hz] and 20 [dB].

2. THEORY

The Helmholtz resonator composes an equivalent resonant system of the air in its neck part being considered to be a mass and that in its cavity being considered to be a spring. At the incidence of a sound wave of a frequency close to the resonant frequency, the air particles in the neck part vibrate violently to lose energy by viscous drag. Therefore, sound absorption apparently occurs. The resonator muffler comprises a resonator having been formed by holes opened through the duct surface and the back space using that principle. The noise reduction characteristics have a large effect on reducing the noise of a specific frequency. The theoretical value of the resonant frequency if there are n holes is:

$$f_r = \frac{C}{2\pi}\sqrt{\frac{nG}{V}}$$

Also, the theoretical formula of noise reduction is:

$$TL = 10\log_{10}\left[1 + \left(\frac{\sqrt{nGV}/2S}{f/f_r - f_r/f}\right)^2\right]$$

where: n = number of holes; V = volume of back space; G = conductivity per hole [r/(t+1.6r)]; t = length of neck (sheet thickness); S = cross-sectional area of inner tube; f = frequency; d = 2r = hole diameter

3. TEST APPARATUS AND METHOD

Figure 1 shows the test apparatus used.

Assume the sound pressure measuring point before passing the muffler to be the input side and the measuring point after passing to be the outlet side. Sound the sine/noise generator's sine wave and white noise through the speaker and control the sound wave so that the sound pressure becomes constant at the measuring point on the input side. Fig 2 shows that measure the sound pressure level at each measuring point using the sound source at one end and the reflection-free termination at the other end and the test apparatus attached with the muffler between them and assuming them to be the measuring points on the input and outlet sides and record it on the FFT and the X-Y recorder. And obtain the noise reduction by subtracting the measured value of output from that of input. Call such a value the transmission loss (TL).

The sound sources used in the test were pure tone of frequencies having been automatically swept in a range of 30 ~ 200 [Hz] and white noise at 20 [Hz] - 2 k[Hz]. Similar measurement was conducted on each of them. The measured values obtained from the pure tone were to be studied for the noise reduction spectrum while those obtained from the white noise were to be put through 1/3-octave band analysis and the values thus obtained were to be studied as the band's noise reduction level. Regarding fluctuations in the resonant frequency, the noise reduction at the theoretical resonant frequency of 80 Hz was measured.

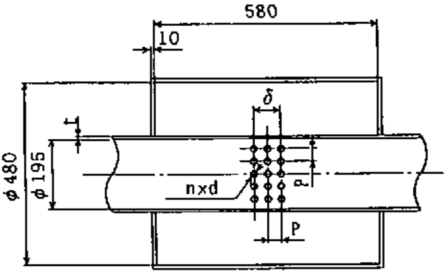

Fig.1 Schematic view of resonator maffler

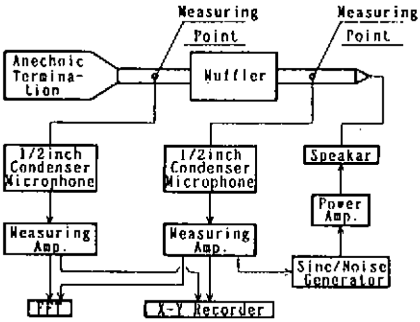

Fig.2 Schematic view of pure tone and white noise

4. TEST RESULTS AND CONSIDERATION

4.1 Effect of Hole Diameter d on Noise Reduction Characteristics

Figures 3 and 4 show the 1/3-octave band analysis and spectrum analysis characteristics by white noise. Now, the muffler's noise reduction effect when the hole diameter was varied while maintaining the sheet thickness constant at 1.6 [mm] was studied. As known from Figure 3, the larger the hole diam. ter, the larger the noise reduction and the curve is sharp near the theoretical resonant frequency of 80 [Hz]. The same tendency is shown in Figure 5 too. Consequently, it came to be known that larger noise reduction is obtainable from a muffler with a comparatively large hole diameter.

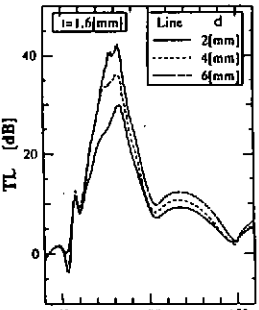

Fig.3 Frequency characteristics of TL

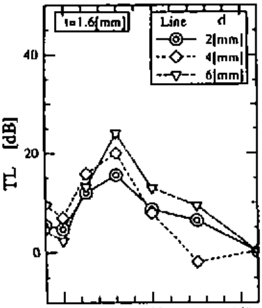

Fig.4 Frequency characteristics of TL

4.2 Sharpness Index Qs

Letting fu and fe [Hz] equal the frequencies to take the values of the amplitude M = Mmax - 10 [dB] respectively on both sides of the resonant frequency fr [Hz] and Δf equal the band width, the sharpness index Qs was defined as expressed below.

$$Q_s = \frac{f_r}{\Delta f} = \frac{f_r}{f_u - f_e}$$

Incidentally, the formula above implies that the greater the Qs, the sharper the noise reduction curve.

Figure 5, the horizontal and vertical axes of which represent d/t and Qs/t respectively, shows their relationship. The parameter is the hole diameter d. It is known from the figure that the greater the d/t, the greater the Qs/t on the average, i.e. the sharper the noise reduction characteristics. There is a relationship that the pressure loss Δp of a fluid passing through a pipe is proportional to the length of the pipe and is inversely proportional to the diameter of the pipe. According to that hydrodynamic anthology, the ratio d/t between the length of the neck part t (the length of the pipe) and the hole diameter d (the diameter of the pipe) being great means Δp being small, i.e. the resistance in the neck part being small and the noise reduction being large. It is safe to say, therefore, that d/t has a strong correlation to the sharpness index.

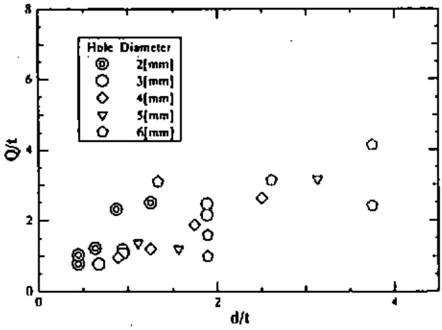

Fig.5 Relationship between Q s and TL

4.3 Effect of P/d on Theoretical Noise Reduction

Figure 6, the horizontal and vertical axes of which represent P/d and the white noise reduction TL respectively, shows their relationship. The sheet thickness t is used as the parameter. In our test, where the theoretical noise reduction is assumed to be 20 [dB], the hole diameters 2 [mm] and 3 [mm] fail to satisfy that condition. Now, paying attention to the hole diameter 2 [mm], it exceeds the theoretical noise reduction of 20 [dB] near where P/d is 4 or greater. As mentioned in the preceding section, it is considered that, as long as P/d is 4 or greater, the theoretical noise reduction is satisfied even if the hole diameter may not be large.

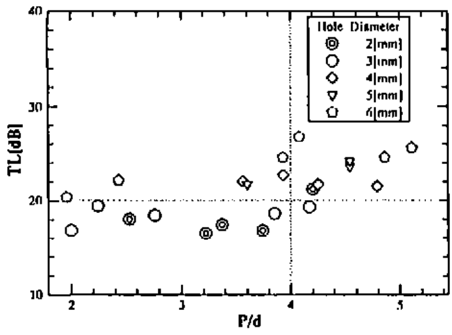

Fig.6 Relationship between P/d and TL

4.4 Relationship between Noise Reduction TL and nv/V (Volumetric Ratio)

Figures 7, the horizontal axes of which represent the ratio between the volume of the muffler and the total volume of the holes respectively and the vertical axes of which represent the white noise reduction TL, show their relationships. The parameter here is the sheet thickness t. Looking at Figure 7, it is known that the noise reduction increases as the value of nv/V increases. It came to be known that, therefore, there is a tendency of noise reduction to be larger as the total area of the holes is larger. Regarding the theoretical noise reduction, 20 [dB] is satisfied if nv/V is a minimum of 0.0001. Consequently, it is considered that the correlation to the noise reduction TL is strong. Regarding the sheet thickness t only, being the parameter, it is considered that the effect on noise reduction is small.

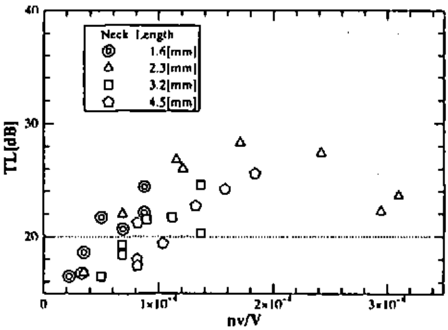

Fig.7 Relationship between nv/V and TL

5. CONCLUSION

(1) The larger the muffler's hole diameter, the larger the noise reduction.
(2) d/t has a strong correlation to Qs/t.
(3) The theoretical noise reduction of 20 [dB] is satisfied if P/d is a minimum of 4.
(4) The theoretical noise reduction of 20 [dB] is satisfied if nv/V is a minimum of 0.0001.