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Short Paper

Visualization of Noise Sources and Surface Flows over a Rotating Fan Blade

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1. Introduction

The detection of noise sources over a rotating blade has been a topic of interest for many years in order to design a low noise fan for industrial application. Therefore, measuring the velocity of an unsteady flow field around a fan blade has been carried out by LDV (Cai et al., 2002) and PIV (Nashimoto et al., 2004) to understand the flow mechanism leading to noise generation. However, the acoustic approach for detecting the noise source is very limited in this research area (Yamada et al., 2003). This is partly due to the difficulty in detecting the moving sound sources over a complex geometry and partly due to the interaction between the emitted sound and the blade surface in acoustic measurement of sound sources.

The purpose of this study is to propose an experimental technique to detect the noise sources over a fan blade by measuring the phase-averaged sound pressure levels at various spatial locations. The result is then compared with the surface flow visualization by oil-film method to understand the mechanism of noise generation.

2. Experimental Technique

Figure 1 shows an experimental arrangement for detecting the noise sources over a fan blade. The detecting device consists of eight microphones of 1/2 inch diameter, which is placed in line at intervals of 20 mm. After amplifying each microphone signal by DC amplifier, the signal is transmitted to the data recorder having a frequency response up to 10 kHz. Then, the signal is transmitted to a computer for calculating the mean sound pressure level. The noise source position was obtained by evaluating the highest peak from the phase-averaged distribution of sound pressure levels at the various positions of the microphones in x-y plane. Note that the test fan consists of 4 blades with D = 280 mm in diameter, which is rotating at 2000 rpm. The experiment is carried out in an anechoic room having a background sound pressure level less than 24 dB. The acoustic measurement was conducted by traversing the microphone array in x and y direction at intervals of 10 mm, so that the total number of measurement points is 31(x) × 19(y) in the present measurement. The data sampling was carried out for a period of 0.625 ms at each point, which corresponds to the blade movement of 10 mm and the averaging procedure is conducted over 200 times to obtain the phase-averaged sound pressure levels. The sampling of noise signals from each microphone is started by a photo-sensor signal.

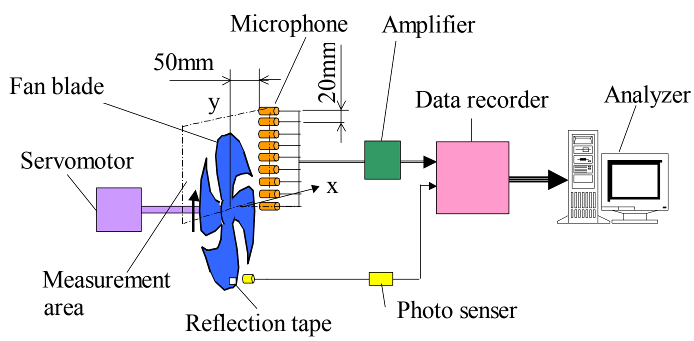

Fig. 1. Experimental setup.

To determine the maximum sound pressures, the time delay of the sound transmitting from the target position on the blade surface to the microphone and the delay in measuring system is taken into account in the analysis. It was estimated as 0.35 ms, when the microphone array is placed 50 mm away from the fan blade.

In order to confirm the validity of the present detection method of sound sources, the preliminary experiment is carried out using a rotating circular disk of 240 mm in diameter rotating at 2000 rpm, where a buzzer at 3.6 kHz frequency is attached flat to the surface not to disturb the flow over the disk. The detection of the sound source position was conducted by the present method and the result agreed with that obtained from the photo-sensor measurement within an accuracy of 3 mm.

3. Results and Discussion

Figure 2 shows a contour plot of the phase-averaged sound pressure level (1600 to 9600 Hz) over a suction surface of a fan rotating at 2000 rpm, which corresponds to the Reynolds number Re (= DU/ν) = 5.3×10^5. Note that the intersection of the grid lines shows the position of the microphone in the measurement. The result indicates that the noise sources are distributed near the leading edge and trailing edge of the blade and the highest sound pressure level is found along the leading edge on the tip side of the blade.

In order to understand the mechanism of noise generation, the surface flow visualization on the suction side was carried out in water by oil-film method at the same Reynolds number (Nashimoto et al., 2000). Figure 3 shows the illustration of the surface flow pattern obtained from the visualization. The flow separates near the leading edge of the blade and reattaches in a short distance downstream, which forms a reattachment line along the leading edge of the blade. It is interesting that the position of the highest noise matches the flow separation region downstream of the leading edge and the reattachment line. The smaller peak on the rear side of the blade is expected to be due to the vortex shedding noise from the trailing edge of the blade. This is because the surface-flow velocity on the hub side of the blade is low and the flow on the tip side shows a secondary flow pattern to be due to the roll-up motion of the flow from the pressure surface to the suction surface (Nashimoto et al., 2004).

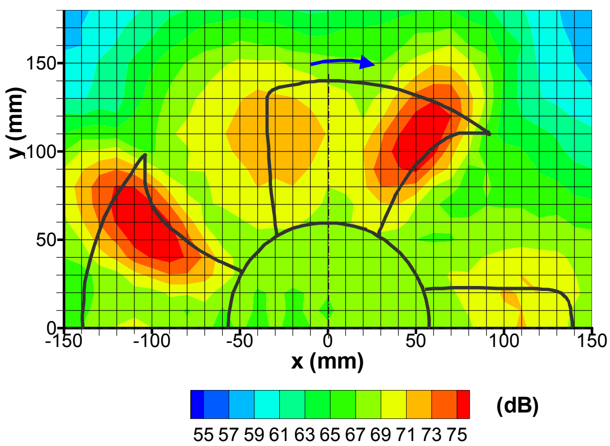

Fig. 2. Contour map of sound pressure levels.

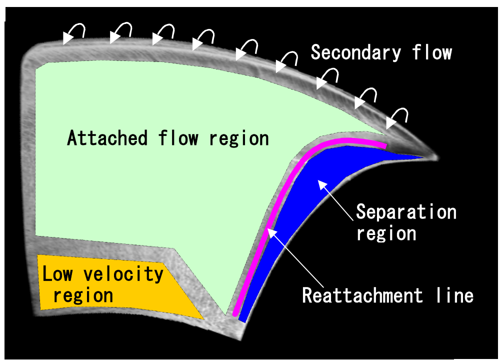

Fig. 3. Surface flow visualization by oil-film method.

References

Cai, W. X., Shiomi, N., Sasaki, K., Kaneko, K. and Setoguchi, T., Visualization of Tip Vortex Flow in an Open Axial Fan by EFD, Journal of Visualization, 5-3 (2002), 293-300.

Nashimoto, A., Fujisawa, N., Akuto, T. and Nagase, Y., Measurement of Aerodynamic Noise and Wake Flow Field in a Cooling Fan with Winglets, Journal of Visualization, 7-1(2004), 85-92.

Nashimoto, A., Fujisawa, N., Kimura, E. and Akuto, T., Visualization of Surface Flow over a Blade of Rotating Machinery by Oil-Film Technique and Measurement of Shear Stress Distribution by Image Analysis, Journal of the Visualization Society of Japan, 20-79 (2000), 56-61 (in Japanese).

Yamada, S., Nakasima, S. and Ootsuta, K., Inquiry into Discrete Frequency Noise Source of Cross Flow Fan (Reconstruction of Discrete Frequency Noise Propagation), Transactions of the Japan Society of Mechanical Engineers -B, 69-682 (2003), 113-120 (in Japanese).