Experimental Study on Relative Flow Regime and Broadband Noise of a Propeller Fan

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Long Abstract

Introduction

Propeller fans are widely used in heat exhaust fans, ventilation fans, engine cooling fans, and so on. Therefore, it is important to not only increase the aerodynamic performance but also decrease the fan noise. T. Fukano and C.-M. Jang studied that the noise due to tip clearance flow in axial flow fans operating at the design and off-design conditions is analyzed by an experimental measurement [1]. According to the results, the fan noise increase due to tip clearance flow at low flow rate condition is analyzed with relation to the distribution of velocity fluctuation due to the interference between the tip leakage vortex and the adjacent pressure surface of the blade. From their contributions, in the off-design condition, the model of the broadband noise due to the blade tip vortex was established as adjacent blade interference. On the other, because the axial flow fan in the design condition, such as the maximum efficiency point, flows to the axial direction, the flow becomes hard to interference to the adjoined blade. In this case, the broadband noise becomes the most important factor in the aerodynamic noise except for the discrete frequency noise in the blade passing frequency. For the broadband noise, M. Roger and S. Moreau [2] has been suggested the analytical model using Amiet's model [3]. However, the analytical model is for the broadband noise in the high frequency domain, that is, this analytical model is distinguished the broadband noise in the transition frequency domain around the 1000 Hz. Therefore, the present research is an experimentally consideration towards establishment for the analytical model of the broadband noise of a propeller fan within the transition frequency domain in the vicinity of the design condition.

Experimental Setup

Figure 1 is the schematic view of the test bench for the estimation of the fan performance. The diameter of the impeller is 613 mm, the hub tip ratio is 0.424 and the number of blades is 14. A 1/2-inch microphone is set at a distance of 1.0 m from the impeller inlet on the rotational axis of the impeller. The normalized characteristics of the fan are summarized as follows.

$$\phi = \frac{4\,Q}{\pi\,(1-\nu^2)\,D^2\,U}\,,\psi_s = \frac{2P_s}{\rho\,U^2}\,,\lambda = \frac{8\,L}{\rho\,\pi\,(1-\nu^2)\,D^2\,U^3}\,,\eta = \frac{\varphi\,\psi_t}{\lambda} \tag{1}$$

where, the φ is the flow coefficient, ψ_s is the static pressure coefficient, λ is the power coefficient, and η is the efficiency. In Fig. 2, the thin wall cylindrical blade cascades model of the propeller fan is shown. The solver of the CFD is SCRYU/Tetra V12 of Cradle Co., Ltd. In order to suppress the calculation load, we made the two dimensional rotation blade cascade model with the thickness of 4 mm. The minimum grid space is set as $y^+ < 10$. The available frequency range is less than 2000 Hz in this condition.

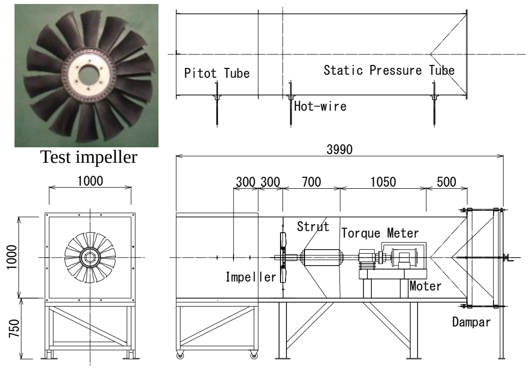

Fig. 1 Experimental apparatus of the propeller fan

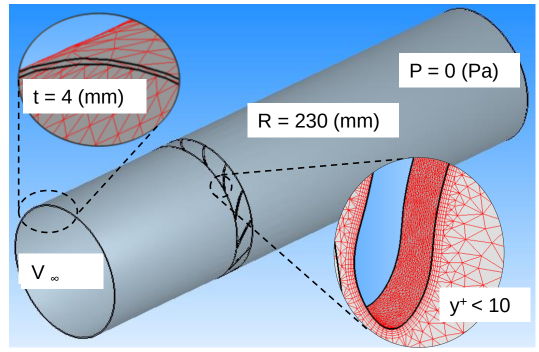

Fig. 2 Thin wall blade cascade model

Results

On comparison of the measured fan noise spectra in the different operation condition within the transition frequency domain from 500 Hz to 2000 Hz, the broadband noise becomes the dominant factor except for the discrete frequency noise synchronized with the blade passing frequency (Fig. 3). The pressure fluctuation of CFD indicates that the pressure fluctuation at the leading edge and the trailing edge becomes strong (Fig. 4).The pressure fluctuation on the pressure surface side is larger than that of the suction surface side in the transition frequency domain (Fig. 5). A pair of vortices is formed in the relative flow regime in the blade passage in the vicinity of a certain span location (Fig. 6).

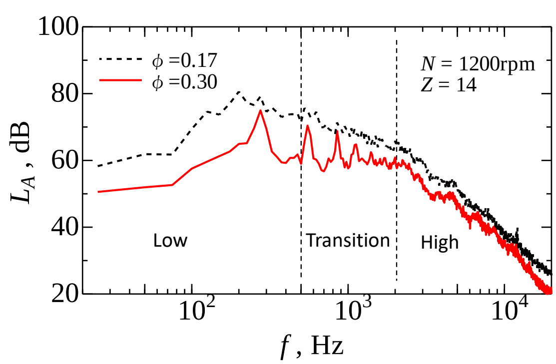

Fig.3 Noise spectra of the propeller fan (EFD)

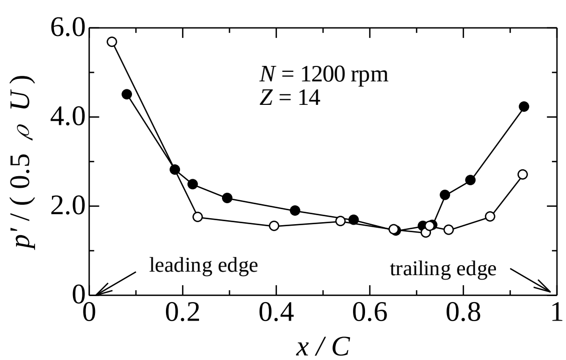

Fig.4 Pressure fluctuation on the blade (CFD)

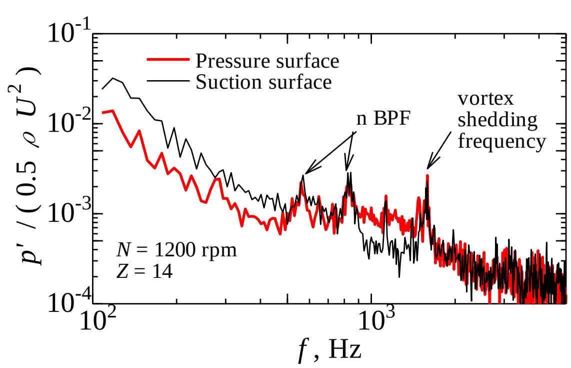

Fig.5 Spectra of the pressure fluctuation (CFD)

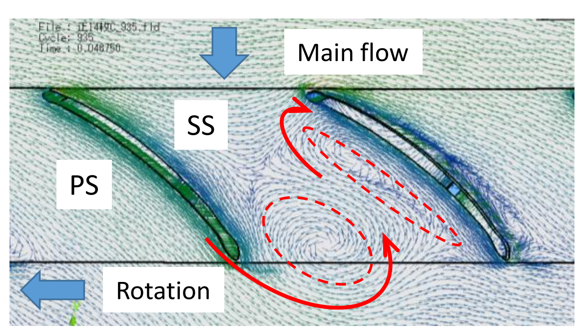

Fig. 6 Relative flow regime in blade passage (CFD)

In the full-length paper, we will discuss the generation mechanism on the aerodynamic noise in the transition frequency domain based on the measured relative flow regime in the blade tip in the experiment, and the relative flow regime in the blade passage in CFD.

References

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[3] R.K. Amiet, Noise due to turbulent flow past a trailing edge, *Journal of Sound and Vibration,* 47 (3), pp. 387–393, 1976.