Wake and Potential Interferance of Contra-Rotating Small-Sized Axial Fan at Design Flow Rate

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Long Abstract

Introduction

Small-sized axial fans are used as air coolers for electric equipment i.e. laptop, desk top computers and servers. There is a strong demand for high performance of fans according to the increase of energy consumption from electric devices. Then, the adoption of the contra-rotating rotors for the small-sized axial fans is proposed for the improvement of the performance. In the case of contra-rotating rotors, it is necessary to design the rear rotor considering the unsteady circumferential velocity distributions at the outlet of the front rotor [1]. Further, it is important to clarify the influence of the wake from the front rotor to the rear rotor on the performance and the potential interaction between the front and rear rotors [2]. Therefore, there is the strong demand to establish the design method for small-sized axial fans. In the case of contra-rotating rotors, the internal flow and potential interference between the front and rear rotors influence on the performance and the noise. From the performance, noise and stable operation point of view, it is necessary to clarify the internal flow and potential interference between the front and rear rotors.

In the present paper, the performance curves of the contra-rotating small-sized axial fan with 100mm diameter are compared with the unsteady numerical analysis results to verify the validity of the unsteady numerical analysis results. After that, pressure fluctuations around the rotor phase locked each front and rear rotor's rotation are shown and the influences of the wake and potential interference at the design flow rate are discussed by the unsteady numerical analysis results.

1. Experimental Procedure and Numerical Analysis Conditions

The geometry of the rotor for the contra-rotating small-sized axial fan (RRtype) are shown in Fig.1. The hub tip ratio was D_h/D_t=45[mm]/98[mm], tip clearance was c=1[mm] and the design flow rate was Q_d=0.016[m^3/s]. Fan static pressure at the design point was ΔP_{dRR}=14.7[Pa] for RRtype with the same fan static pressure of each front and rear rotor. The rotational speed of front and rear rotors of RRtype was N_f=N_r=1780[min^{-1}]. The experimental apparatus was designed based on the Japanese Industrial Standard and the air blown in the test section passed the rotor, chamber, measurement duct and booster fan and blew out in the ambient atmosphere.

The commercial software ANSYS-CFX 14.5 was used to investigate the flow condition and potential interference between the front and rear rotors of contra-rotating small-sized axial fan which couldn't be measured by the experiment. In the numerical analysis, the numerical model which was almost the same with the experimental apparatus was used and three dimensional unsteady numerical analysis was conducted. At the inlet boundary, the uniform velocity was given and the constant pressure was given at the outlet boundary condition.

2. Performanc and Internal Flow

Fan static pressure curves of each blade row distance (L=10, 30, 100[mm]) of RRtype, obtained by the experiment are shown in Fig.2. In Fig.2, the fan static pressure obtained by the numerical analysis is also shown to compare with the experimental results. The numerical analysis results could predict the experimental results accurately and capture the tendency of the performance curves of the experimental results. The fan static pressure kept almost constant by the blade row distance between the front and rear rotors was *L*=30[mm]. The difference of the fan static pressure between *L*=10[mm] and *L*=30[mm] were ΔP_s=0.02(Exp.), 0.4(Cal)[Pa] at the design flow rate Q_d=0.016[m^3/s] and ΔP_s=-0.6(Exp.), -0.02(Cal)[Pa] at the low flow rate *Q*=0.0016[m^3/s]. In the experimental and numerical analysis results, the fan static pressure of *L*=30[mm] was almost the same with that of *L*=10[mm] at the design flow rate Q_d=0.016[m^3/s].

The pressure fluctuations with the rear rotor rotation at the trailing edge of the front rotor from the numerical analysis results are shown in Fig.3. The flow rate was the design flow rate *Q*=0.016[m^3/s]. It could be found in Fig.3 that the pressure fluctuations associated with the pressure distribution around the rear rotor were generated and 5 peaks of the pressure fluctuation, which corresponded to the blade number of the rear rotor, were observed in Fig.3. The potential interference from the rear rotor became small in the case of *L*=30mm as the increase of the blade row distance from *L*=10mm. The potential and wake interference were discussed based on the flow condition around each rotor in this paper.

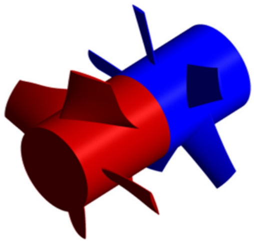


Figure 1. Geometry of Rotor

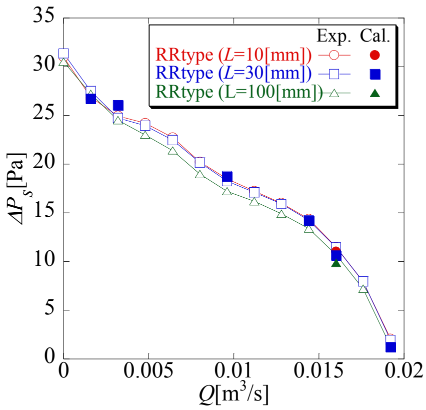
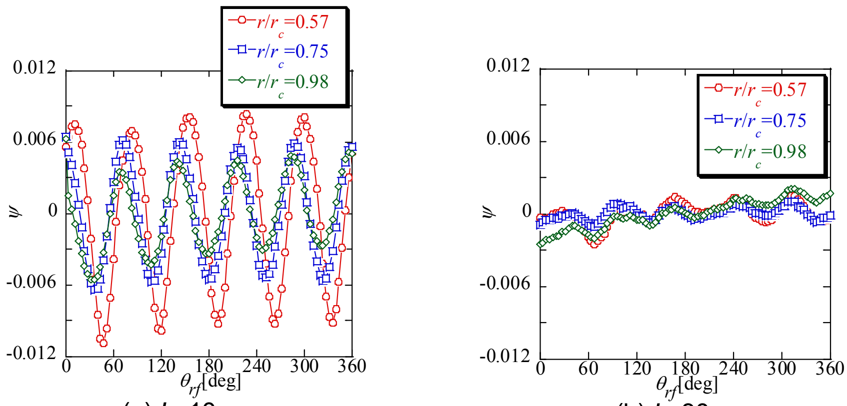


Figure 2. Performance curves



(a) *L*=10mm (b) *L*=30mm

Figure 3. Pressure fluctuation at TE of front rotor

References

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[2] Sanders, A, J., Papalia, J and Fleeter, S., (2002), "Mul-ti-Blade Row Interactions in a Transonic Axial Com-pressor: Part I - Stator Particle Image Velocimetry (PIV) Investigation," ASME Journal of Turbomachinery, Vol. 124, pp. 10 - 18.