INTERNATIONAL JOURNAL OF REFRIGERATION 36 (2013) 1098–1108

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Prediction and measurement of axial flow fan aerodynamic and aeroacoustic performance in a split-type air-conditioner outdoor unit

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ARTICLE INFO

Article history:
Received 11 August 2012
Received in revised form
15 October 2012
Accepted 20 November 2012
Available online 24 November 2012

Keywords:
Air conditioner
Outdoor unit
Axial flow fan
Computational fluid dynamics
Computational aerodynamic acoustics
Noise reduction

ABSTRACT

The study has focused on outdoor unit noise reduction by fan geometry modification with the refined numerical and experimental approaches. The outlet louver, electric motor and its support are included to refine the flow and acoustic model and a hybrid method incorporating CFD and CAA is used to predict the noise behavior. The fan performance curve is well-predicted; the moderate acoustic power is obtained on the outlet louver, motor support and motor exhibiting a significant contribution to overall noise behavior. The aeroacoustic test is conducted in an anechoic chamber and the obtained results are compared with the semi-anechoic chamber ones, and the unremarkable differences are produced, which indicate the ground floor being of some influence. Both modified fan geometries are effective to reduce the noise but the flanging outer-edge blade is more effective. The noise directivities of three geometry fans are investigated both numerically and experimentally and the produced asymmetric characteristics are analyzed.

Prévisions et mesures de la performance aérodynamique et aéroacoustique du ventilateur axial d'un système extérieur de conditionnement d'air de type split

Mots clés : conditionneur d'air ; système extérieur ; ventilateur axial ; mécanique des fluides numérique ; acoustique aérodynamique numérique ; diminution du bruit

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http://dx.doi.org/10.1016/j.ijrefrig.2012.11.024

Nomenclature

A	A-weighted level
BPF	Blade Passage Frequency, Hz
c	sound speed, m s^{-1}
f	frequency, Hz
n	rotating speed, rpm
p_j	instantaneous sound pressure, Pa
p_{mean}	mean sound pressure, Pa
p_{ref}	standard reference pressure, Pa
SPL	Sound Pressure Level, dB
SPL_A	A-weighted Sound Pressure Level, dBA
$OASPL_A$	A-weighted Overall Sound Pressure Level, dBA
t	time, s
Z	number of blades

1. Introduction

The split-type air conditioners are widely used on a daily basis in residential and commercial applications, and the high-level aerodynamic performance and low-level aero-acoustic noise are always expected for the fans. The overall noise of the air conditioners comes mainly from the refrigeration compressor and axial flow fan. The latter is used to enhance the airflow and cool the heat exchanger (condenser) of the air conditioner outdoor unit. The noise of the fan in the outdoor unit is resulted mainly from the strong interactions between the rotating fan blade and stationary casing. In recent years, much work has been conducted on the air-conditioner noise behavior with both numerical and experimental approaches and the advances have been achieved in various aspects, such as noise prediction and attenuation. Based on the work of Jiang et al. (2006, 2007), the flow field and noise of axial flow fan in the air conditioner outdoor unit was investigated and it was demonstrated that the fan blade tip vortex dominates in the fan flow. Zhu and Tian (Zhu et al., 2008; Tian et al., 2009) focused on the aerodynamic and aeroacoustic performance of outdoor unit fan with two different type grilles, and it was found that the vortex shedding from the impeller and grille trailing edge contributed dominantly to the overall broadband noise level. Tian et al. (2010) reported their experimental and numerical work on the noise generation mechanism in the collateral axial flow fan system of an air-conditioner outdoor unit. Quite recently, Lee et al. (2010) have reported some work on the centrifugal fan noise prediction and attenuation in a household refrigerator, and the Low-noise centrifugal fans are developed by modifying the linear trailing edge of the fan blades into the inclined S-shaped lines (Heo et al., 2011).

The effect of the fan geometry modifications on noise attenuation has been demonstrated by previous work of other investigators. In recent years, we have also worked on the fan noise attenuation by modifying the fan geometry through both experimental and numerical approaches. The effect of fan geometry variation on noise attenuation was justified as reported in previous study (Zhao et al., 2011). The objective of present study is to further confirm the benefits in noise reduction brought by the fan geometry tuning with the refined numerical models and experimental approaches. In the numerical simulation, the outlet louver, electric motor support, and electric motor on the flow are included in the present model, with which the flow simulation accuracy has been enhanced. In the aeroacoustic measurement, the tests are conducted respectively in the semi-anechoic chamber and the anechoic chamber, and the obtained results of two test cases are compared. To study the aeroacoustic directivity of the fan, the measuring points are arranged in a half planar circumference ahead of the fan and the results of the fan are presented and analyzed.

2. Experimental test

Aerodynamic and aeroacoustic experimental tests were conducted respectively for the outdoor unit of a house-hold split-type air conditioner. As shown in Fig. 1(a), the outdoor unit has an overall dimension of 700 × 240 × 530 mm and consists of an axial flow fan, refrigeration compressor, heat exchanger, motor, motor support, partition board, shroud and air outlet louver, where the red closed line outlines the outdoor unit air duct system for the present consideration and the blue arrows denotes the air flow directions. Fig. 1(b) is the zoomed-in view of the axial flow fan. The fan uses 3 forward-swept blades, and its diameter and axial dimension is 401 mm and 119 mm respectively. The fan blade hub to tip ratio is 0.26, and it is

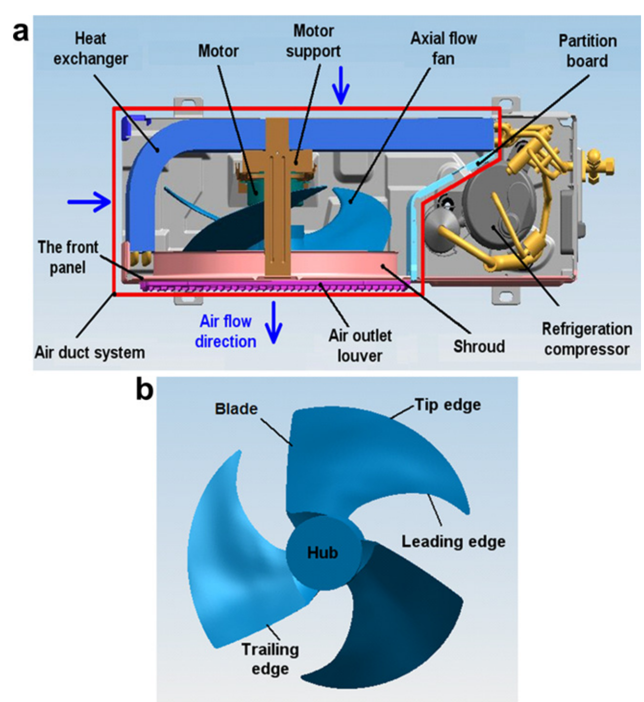

Fig. 1 – Layout of test rig and fan. (a) Outdoor unit of air conditioner (b) axial flow fan.