844. A quantitative study of the blade passing frequency noise of a centrifugal fan

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(Received 8 Jun 2012; accepted 4 September 2012)

Abstract. Tonal noise constitutes the major part of the overall fan noise, particularly the blade passing frequency (BPF) noise, which is generally the most annoying component. This paper quantitatively studies the BPF tonal noise of a centrifugal fan, including casing aerodynamic noise, blade aerodynamic noise and casing structural noise. Firstly, fan noise generation and propagation is discussed and the measured spectra of fan noise and casing vibration are presented. Secondly, a fully 3-D transient simulation of the internal flow field of the fan is performed. Flow interactions between the impeller and the volute casing result in the periodic pressure fluctuations on solid walls of the impeller and casing. This pressure fluctuation, in the aeroacoustic study, is modeled as aeroacoustic dipole source according to the Lighthill's acoustic analogy theory. With the inhomogeneous wave equations solved by the boundary element method, the BPF casing and blade aerodynamic noise radiation is obtained. Finally, in the casing structural noise study, the casing structural vibration under the excitation of BPF pressure fluctuation is calculated by the finite element method and sound radiation is solved by the boundary element method subsequently. Results demonstrate that the casing aerodynamic noise is the main contribution to the centrifugal fan noise with the sound power level of 103 dB followed by the blade noise (91 dB), and the casing structural noise is 79 dB.

Keywords: centrifugal fan, unsteady flow field, blade passing frequency, aerodynamic noise, structural noise.

Introduction

As a type of turbomachinery, centrifugal fans are widely employed for industrial and civilian use because they achieve high pressure ratios in a short axial distance compared to axial fans. However, the noise generated by centrifugal fans can become a serious problem. According to the spectrum characteristics of fan noise, it can be divided into discrete tonal noise, induced by the periodic interactions between the rotating impeller and the volute casing especially the volute tongue, and a broadband noise, mainly due to the turbulent flow fluctuations in the inlet stream, in boundary layer, and wake behind the blade. The blade passing frequency noise is in general the most notable and annoying component [1-3]. According to the noise generation mechanism, fan noise can be classified into aerodynamic noise generated by turbulent flow fields directly and vibroacoustic noise caused by structural vibration. Jeon [4] points out that in the case of large-sized fan, the levels of the vibration-induced noise and the flow-induced noise are comparable, but in the case of small and the middle-sized fans, the flow-induced noise is dominant.

The internal turbulent flow is the root cause of fan noise: on the one hand, it generates aerodynamic noise as the aeroacoustic source; on the other hand, it induces structural vibration and generates vibration-induced noise. Mechanical excitations such as unbalanced rotors, vibration of motors, defected bearings can cause fan structural vibration as well. In this study, the flow-induced vibration is considered. Therefore, for a reliable prediction of fan noise, precise analysis of flow field is essential. The capability of the existing computers allow the numerical simulation of complex flow features that commonly take place in centrifugal fans: unsteady turbulent flow, important 3-D effects and complex configurations. Nowadays, some commercial CFD packages, showing their validity and reliability for the description and prediction of the

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