Aeroacoustic analysis of the tonal noise of a large-scale radial blower.

Aurélien Marsan, Dr., Department of Mechanical Engineering, University of Sherbrooke, Québec, Canada.

Stéphane Moreau, Pr., Department of Mechanical Engineering, University of Sherbrooke, Québec, Canada.

Long Abstract

Introduction

Industrial plants are an important source of noise pollution for the neighbouring inhabitants, and acoustics studies have to be conducted in order to improve the noise of these facilities.

Large-scale radial blowers are in particular widely used in steel factories and are one of the main source of noise disturbances. The present study aims at identifying the noise generation mechanisms in such a radial blower in order to suggest simple modifications that could be made in order to reduce the noise radiated by blowers.

Test case

The test case is a 2 meter diameter radial blower composed of an entry block, a radial wheel whith 8 vanes, and a volute. Its rotational speed is 1000 rpm. A sketch is shown in figure 1. Figure 2 shows a view of the rotor. For mechanical reason, the rotor vanes are tied together by flat plates, see figure 2. This radial blowers is mounted in a metallurgical plant as part of a coal drying system.

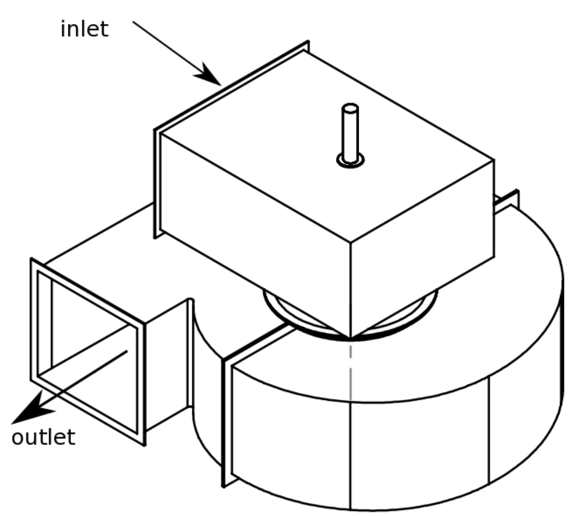


Figure 1. Sketch of the test case.

Figure 3 shows the sound pressure level (SPL) measured at the outlet of the exit chimney. A peak emerges at the blade passing frequency 15 dB higher than the broadband noise. The objective of the present study is to determine the source of that tonal noise.

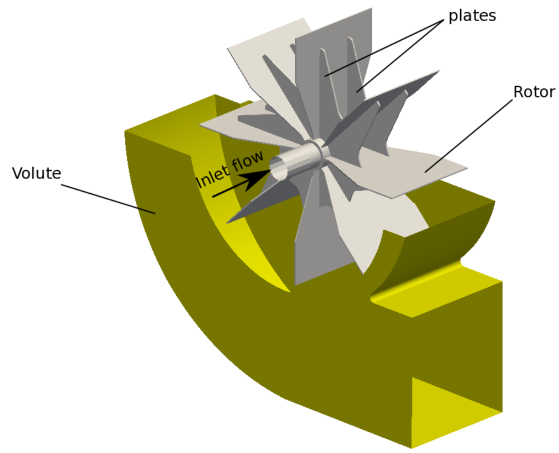


Figure 2. View of the radial rotor.

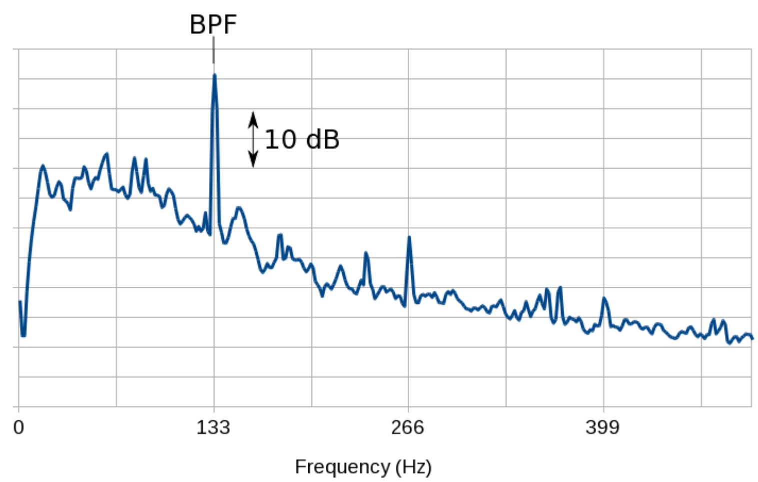


Figure 3. SPL at the exit of the chimney.

Numerical investigation

RANS numerical simulations of the flow in the blower have been performed, using the ANSYS CFX software. This code solves the three-dimenionnal Navier-Stokes equations, using an implicit element-based finite-volume formulation, and a pressure-based coupled algorithm solver. Flow is modeled as a fully turbulent ideal gas using the shear-stress transport (SST) k-ω turbulence model [1].

An unstructured mesh composed of tetrahedra in the volume and prisms layers at the vicinity of the walls has been generated thanks to the Centaur software. It is composed of 840 000 cells in the entry block, 1.7 million cells per rotor blade, and 7 million cells in the volute. The cell width at wall is 1 millimeter, and the dimensionless wall distance y^+ is below 8 on all walls, except at the volute tongue where it reaches its maximum $y^+ \approx 16$.

First, the performance curve of the blower has been computed thanks to steady-state numerical simulations. The interfaces between the inlet block and the rotor and between the rotor and the volute have been modeled thanks to the mixing-plane approach. The resulting curve is shown in figure 5, which plots the inlet-outlet pressure difference against the inlet standard volume mass flow rate. A change of slope is visible, which suggests a change of working condition. According to maintenance measurements, the operating point of the blower during the exploitation is between $47000 m^3/h$ and

$56000m^3/h$, which corresponds to the left side of the performance curve.

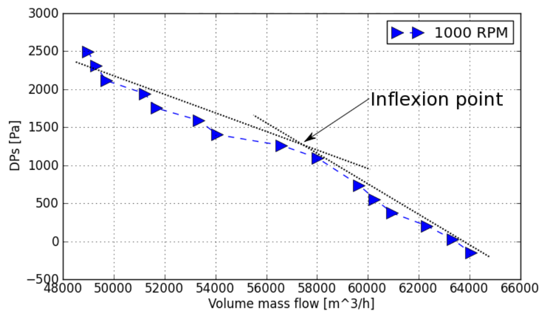
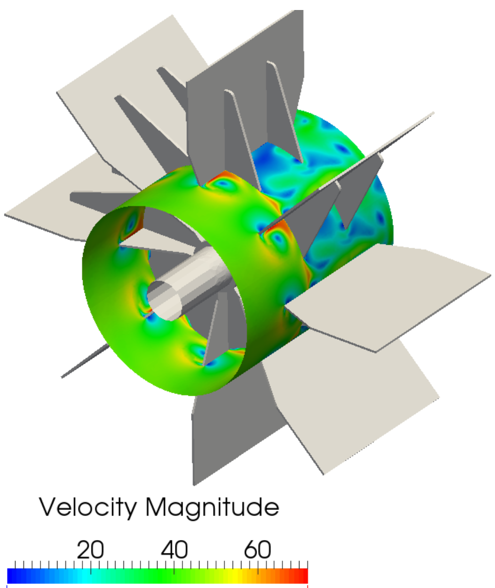


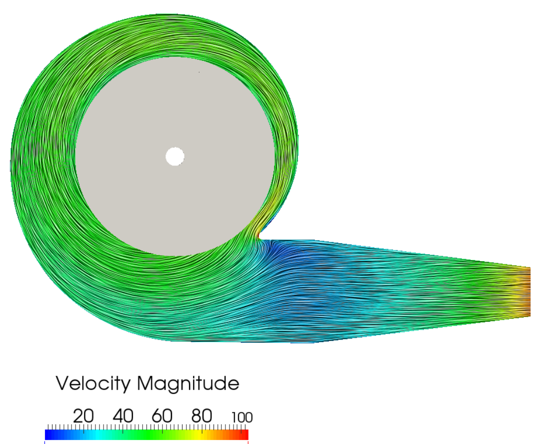
Figure 4. Performance curve of the blower – steady-state RANS simulations.

In order to study the acoustics of the blower, unsteady RANS simulation have also been performed with Ansys CFX. The mass flow rate has been chosen equal to $52000m^3/h$. The result highlights three main mechanisms that could contribute to the BPF tonal noise :

1. the substantial inlet distorsion of the flow due to the geometry of the inlet block ;
2. the pulsating flow within the cavities formed by the flat plates that tie the rotor vanes together, see figure 5a ;
3. the interaction between the vanes tip and the tongue of the volute, which is amplified due to the mismatch of the volute at this operating point, see figure 5b.



(a) Plane at constant radius in the rotor



(b) Middle plane of the Volute. Streamlines of absolute velocity, colored by velocity magnitude

Figure 5. Velocity magnitude in the blower [m/s]

The relative importance of each mechanism will be quantified thanks to the Ffowcs Williams and Hawkings' (FWH) analogy, and results will be compared to those given by an analytical model [2].

References

[1] F. R. Menter. Two-equation eddy-viscosity turbulence models for engineering applications. *AIAA Journal*, 32(8), 1994.

[2] Sturm M., Sanjose M., Moreau S., and T. Carolus. Application of an analytical noise models using numerical and experimental fan data. In *11th European Turbomachinery Conference, March 23-27*, Madrid, Spain., 2015.