Unsteady Behavior of Radial Fan under Pulsating Flow Field

Saki Shiratori, Department of Applied Mechanics, Graduate School of WASEDA University, Tokyo, Japan
Yohei Nakamura, Department of Applied Mechanics, Graduate School of WASEDA University, Tokyo, Japan
Kensuke Yasui, Department of Applied Mechanics and Aerospace Engineering, WASEDA University, Tokyo, Japan
Sho Yamada, Department of Applied Mechanics and Aerospace Engineering, WASEDA University, Tokyo, Japan
Kazuyoshi Miyagawa, Department of Applied Mechanics and Aerospace Engineering, WASEDA University, Tokyo, Japan

Long Abstract

Introduction

To prevent global warming and conserve natural resources, it is important to improve automobile engine efficiency. For this purpose, downsizing of an engine with turbocharging is considered an effective way. In general, turbocharger is designed based on steady flow performance, while actual exhaust and intake gas of an engine has unsteady flow due to rapid opening and closing of engine valves. Under this pulsating flow, compressor and turbine operating point don't match their performance curve under steady flow, but make a hysteresis curve. Not only turbocharger but also any other turbo machineries may occur same phenomenon under pulsating condition. Nevertheless, only a few attempts have so far been made at this phenomenon. Therefore a detailed mechanism of the hysteresis curve has been not clarified yet. The purpose of this paper is to clarify the mechanism of the hysteresis curve. To accomplish this purpose, an experimental investigation of a radial fan was performed under pulsating flow. Although a turbocharger attached to an automobile engine is operated in compressible fluid, flow in the radial fan can be treated as incompressible fluid. For simplicity, a mechanism of the hysteresis curve in incompressible fluid was investigated at first. In this experiment, the radial fan operating point and pulsating flow properties, i.e., a frequency and a waveform of the pulsating flow, were changed to investigate the influence of them on the issajous figure.

1. Test Facility and Method

The experimental investigation was performed at the radial fan test facility. The test facility is described in Figure 1. The number of impeller is 11 and diffuser is 9. The impeller is 0.15 meter in diameter. In this experiment, measurements of pressure and velocity were performed at inlet and outlet of the fan. For measurement, pressure transducers and hot wires were set at inlet and outlet of the fan. To obtain performance curve, discharge coefficient and pressure coefficient were calculated. Here, discharge is calculated by using velocity at inlet of the fan. In order to investigate influence of operating point on the hysteresis curve, rotational speed and discharge at outlet of the fan were changed. As pulsation generating device, rotational and stationary disks with holes was used in downstream of the fan. Figure 2 shows this pulsation generating device. A pulsating frequency could be changed freely by changing rotational speed of the rotational disk. In this experiment, it was changed from 5Hz to 100Hz to investigate the influence of frequency. A wave form could be changed by changing shape of holes on the disks. Moreover, CFD analysis of the radial fan with Unsteady RANS code in pulsating flow was performed to compare the result of experiment. Flow field of the fan is computed for the boundary condition of pressure in pulsation flow measured in experiment.

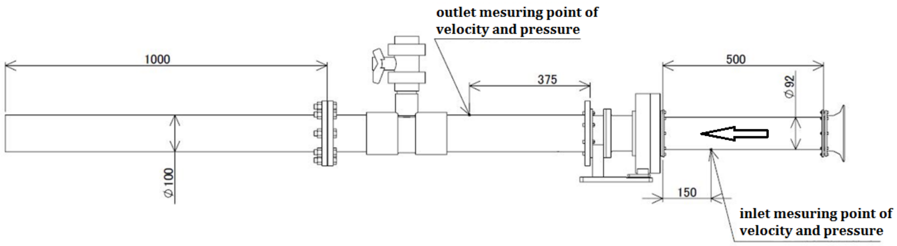


Fig.1 Radial fan test facility

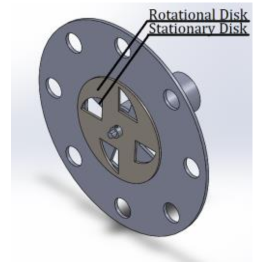
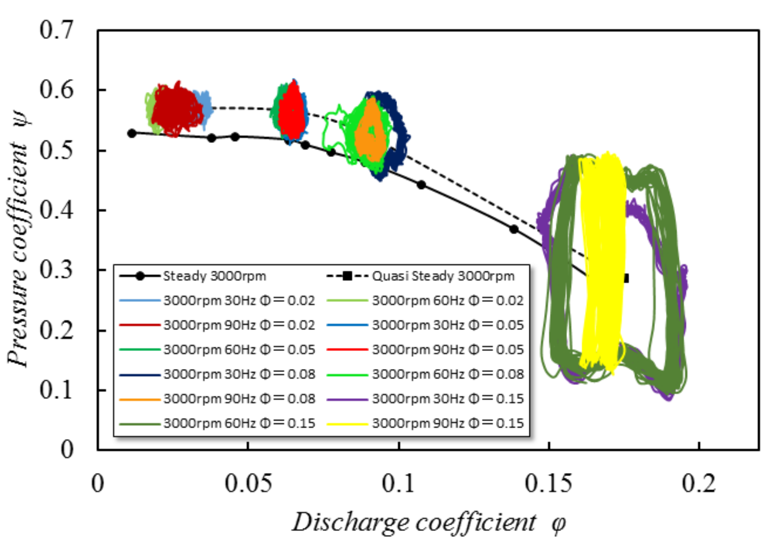


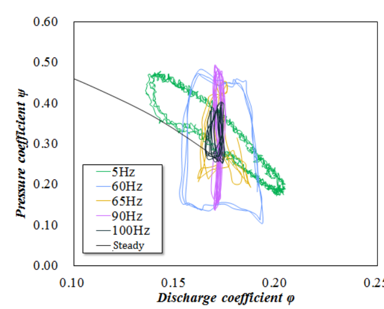
Fig. 2 Pulsation generating device

2. Result and Discussion

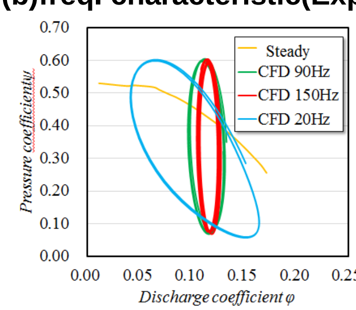
The results of the experiment are summarized in Figure 3(a). It was confirmed that the operating point of the radial fan in pulsating flow wasn't on the steady performance curve but made the hysteresis curve. Figure 3(b) shows the frequency characteristic of the results. The hysteresis curve of the operation was closer to the steady performance curve in low frequency of the pulsating flow. However, in case of the high frequency of the pulsating flow, there are large difference between the performance curve in the pulsating flow and the steady flow. The frequency response of discharge and pressure indicates that the gain of discharge was worse than that of pressure. These results lead to the conclusion that the gain characteristic influenced on the hysteresis curve. As the results of CFD, occurrence of the hysteresis curve was confirmed and it agrees well experiment result in Figure 3(c). Moreover, the distribution of secondary flow vectors and the high total pressure loss area were calculated by using results of CFD to investigate detailed internal flow and influence of it on the hysteresis curve.



(a)Results of Experiment



(b)freq. characteristic(Exp.)



(c)freq. characteristic(CFD)

Fig. 3 performance curve under unsteady flow

Reference

[1]S Mareli, "M Capobianco, Experimental investigation under unsteady flow conditions on turbocharger compressors for automotive gasoline engines", 2012.
[2]D. Palfreyman, R. F. Martimes-Botas, "The Pulsating Flow Field in a Mixed Flow Tubocharger Turbine: An Experimental and Computational Study", ASME, 2015.
[3]N. C. Baines, "Turbocharger turbine pulse flow performance and modelling", 2010.