Experimental Studies on Turbulence Kinetic Energy in Confined Vortex Flows

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Turbulence kinetic energies in confined vortex flows have been studied. The studies were based on the experiments performed in a vortex chamber. In the experiments, a Laser Doppler Anemometry (LDA) was used to perform flow measurements inside the vortex chamber, which provided the data for the kinetic energy analysis. The studies concentrated on the influences of the contraction ratio and the inlet air flow rate on the kinetic energy, and analyzed the characteristics of the kinetic energy in the confined vortex flows, including the distributions of the tangential component, radial component and total turbulence kinetic energy. In the paper, both the experimental techniques and the experimental results were presented. Based on a similarity analysis and the experimental data, an empirical scaling formula was proposed so that the tangential component of the turbulence kinetic energy was dependent only on the parameter of the contraction ratio.

Keywords: turbulence, kinetic energy, vortex flow, laser Doppler anemometry.

Introduction

Kinetic energy is one of the important aspects in the flow studies. Many researchers have investigated the behaviors of the kinetic energies in different flows. Stieglmeier et al.[1] carried on an experimental investigation on the kinetic energy of the flow through axisymmetric expansions. Liou et al.[2] obtained the value of the kinetic energy in periodic fully developed main and secondary flows in a channel with rib-disturbed walls by using Laser Doppler Velocimetry. The inter phase transfer of kinetic energy due to the viscous drag force was measured experimentally in a turbulent shear layer by Kiger and Lasheras[3]. A multiposition hot-wire technique was used for the study of swirling flows in vortex chambers by Fitouri et al[4].

The kinetic energy is defined as the half of the square of the velocity. If velocity, either mean or fluctuating, is obtained, the kinetic energy of the mean motion or the fluctuating motion can be obtained by calculation. The differential equations in the general form to represent the kinetic energy by velocity components are listed in many books[5]. Solving these differential equations, however, requires many assumptions and experimental data. In this work, kinetic energies in confined vortex flows are studied experimentally through velocity measurements in a vortex chamber. Air vortex flow is generated by the vortex chamber. A Laser Doppler Anemometry (LDA) is used for the velocity measurements. The study concentrates on the turbulence kinetic energy and is mainly based on the measurement of instantaneous fluctuating velocities. As the flow behavior in the tangential direction has significant meaning in the vortex flows, more effort has been made to investigate the tangential component of the turbulence kinetic energy. The results of the tangential as well as the radial component of the turbulence kinetic energy are presented and discussed in the following sections. The total turbulence kinetic energy is obtained based on the combination of the contributions from each component.

Experiments

The experimental system used for this study consists of two major parts: air vortex preparation and flow measurement as shown in Fig.1. Compressed air is conducted from the resource to the inlets of the vortex generator. A control valve is installed on the air supply line to control the desired flow rate. A rotameter is used to measure and display the flow rate.
When the air passes through the vortex generator, a vortex flow is formed inside the vortex chamber. When the flow particles move through the measurement point of the LDA, light signals are generated and converted to electric signals. A computer system processes the signal to provide the results.

Vortex Chamber and Vortex Generator

The vortex chamber has a cylindrical shape with constant circular cross-section area as shown in Fig. 2. It is made of plexiglas so that the laser beams can pass through its wall and the flow inside the vortex chamber can be visualized. On the top of the vortex chamber, an exit plate with a central circular opening is mounted. The geometrical parameters of the vortex chamber as well as the exit plate can be changed easily by replacing different components. The vortex chamber used for this study has a diameter of 140 mm (5.5 in.) and a length of 432 mm (17 in.). The diameter of the exit opening varies from 35 to 140 mm (1.375 to 5.5 in.).