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Dissertation Outline

"Study on the Influence of the Inlet Swirling Flow in a Double and Triple Elbow Using Phased Array UVP"

San Shwin

This thesis presents a study on swirling flow structure and velocity fluctuation analysis in a compact pipe layout flow. Ultrasonic Velocity Profiler (UVP) and Phased Array UVP systems were applied to measure one dimensional velocity profile and two-dimensional velocity fields. The primary objective of this study is to investigate swirling flow structure and to analyze velocity fluctuation downstream of a double and triple elbow. The measurement data were imposed as the inlet boundary condition of Computational Fluid Dynamics (CFD) simulation. From the simulation results, the fully structure of fluid flow were visualized by two-dimensional velocity fields and velocity contours for the axial plane and cross-sectional plane. There are two main aspects of investigation taken into consideration, such as:

1. The characteristic of swirling flow structure in the secondary flow region
2. Velocity distribution and fluctuation of axial, radial and tangential velocities

This thesis is arranged into six chapters based on order of the working process, with the descriptions as follows:

Chapter 1 Introduction – The introduction part introduces the research background and the turbulent swirling flow structure in the bend pipe or the elbow are discussed from the viewpoint of the previous studies and the history of pipe break accident in the piping system of the power plant. The primary objectives of this dissertation and the outline of each chapter are written in the introduction part. The developing process of ultrasound technique is describe to provide the information of the measurement system.

Chapter 2 Numerical Investigation of Turbulent Flow in a Single Elbow Using Inlet Velocity Profile – This chapter presents the fluid velocity measurements in a circular straight pipe using UVP system. The fully develop region can be observed for the turbulent flow at several Reynolds number. The velocity profiles from the measurement results are imposed as the inlet boundary condition for a single elbow simulation using CFD Fluent 16.2. The basic flow theory of turbulent flow in a single elbow pipe is mentioned in this chapter. The fluid flow structure and turbulent kinetic are analyzed base on the different Reynolds number downstream of a single elbow. From this investigation, the appropriate Reynolds number is choice to use in the next chapter of the turbulent flow measurement and inlet swirling flow measurement.

Chapter 3 Turbulent Flow Measurement Downstream of Double Elbow Using Phase Array UVP and PIV - The investigation of two-dimensional velocity fields was presented in the condition of turbulent flow downstream of double bend pipe , which made by 90º double elbow. Particle Image Velocimetry and Phased Array UVP systems are applied to compare the measurement results. The flow distortion and recirculating flow occur in the measurement region downstream of the double elbow. The reverse secondary flow region and the reattachment point is clearly observed from both measurement results. In the velocity fluctuation analysis, the axial velocity fluctuation apparently occurs at the boundary of the main flow and the recirculating flow. The radial velocity fluctuation occurs at the center of the pipe.

Chapter 4 Influence of Inlet Swirling Flow on Flow Structure and Velocity Fluctuation – This chapter observes influence of inlet swirling flow on the flow structure and velocity fluctuation downstream of double bend pipe layout, which made by 90º double elbow with inlet swirling flow and without inlet swirling flow condition. Phased Array UVP measurement done in the case of with and without inlet swirling flow condition. The inlet swirling flow is confirmed by measuring the cross-section plane 7D downstream of the swirling generator in the condition of swirl intensity S = 1. The swirling generator generates the homogeneous swirling flow. The experiment results of one-dimensional normalized axial and tangential velocity with their standard deviations in four positions downstream of the double bend pipe with and without inlet swirling flow. According to one-dimensional velocity profiles, the velocity magnitude of inlet swirling flow is much stronger than without inlet swirling flow in the secondary flow region. These differences are due to the influence of the inlet swirling flow. In two-dimensional velocity of without inlet swirling flow, the flow separation occurs around $x/D = 0.1$, and the reattachment point is located at $x/D = 1.5$. In case of inlet swirling flow, the flow separation phenomenon is same as the condition of without inlet swirling flow, but the reattachment point is located at *x/D* =1. Therefore, the reverse flow region is narrow. At *x/D* = 1.5, the fluid becomes the accelerated swirling flow. In the condition of without inlet swirling flow, the axial velocity fluctuation is higher than with inlet swirling flow, but tangential velocity fluctuation is lower than inlet swirling flow.

Chapter 5 Experimental and Numerical Investigation of Swirling flow Downstream of Triple Elbow – This chapter presents the experimental investigation and numerical simulation to observe the flow structure and velocity distribution at the inlet swirling flow condition. The axial, radial and tangential velocities of the swirling flow were measured at 7D downstream of the swirling generator by using a phased array sensor. The sensor position was turned into the axial and cross-sectional planes to get the axial, radial and tangential velocities. The velocities were utilized for the boundary inlet conditions of the numerical simulation. The inlet swirling flow velocities from the experimental results were utilized to compare with experimental result and validate CFD numerical simulation. We used the axial, radial and tangential velocity profiles of swirling flow as the inlet boundary conditions and the geometry of the pipe layout was same as the experimental setup. In addition, Phased Array UVP system is applied to measure two-dimensional velocity field downstream of the triple elbow and can confirm the flow separation and reattachment point. The numerical simulation result show that the swirling flow structure is quite similar with the experimental result. Therefore, the validation of the CFD simulation is acceptable. In case of cross-sectional plane visualization, two counter rotation vortex cells were observed at *x/D* = 0.2 and *x/D* = 0.6 positions. When the high velocity axial flow reached the outside wall, this flow was changed from outside to lateral side of pipe wall in clockwise and counterclockwise directions. In addition, the axial velocity distribution is too different between the intrados and extrados of pipe.

Chapter 6 Conclusions – This chapter summarizes the conclusions obtained from this study.