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Short Paper

Occurrence of Asymmetric Flow Pattern behind a Double Orifice in a Square Pipe

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1. Introduction

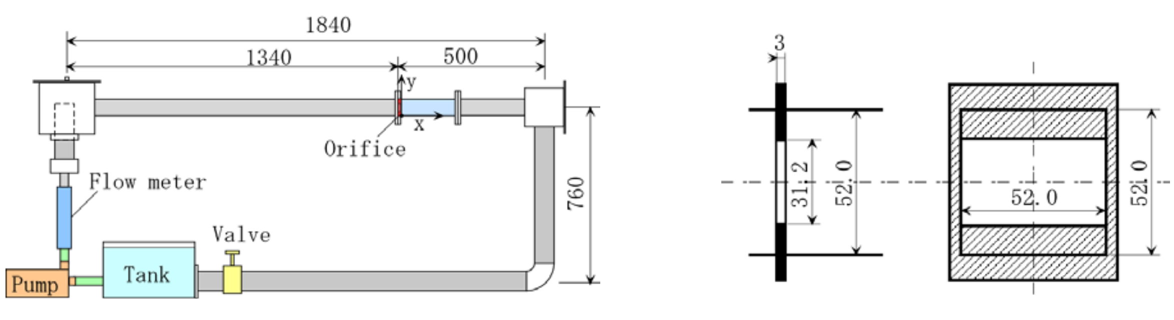
The flow through an orifice has been an important subject in measuring the flow rate through a pipe in engineering. Recently, this subject received considerable attention in the pipe thinning problem of nuclear power plant associated with the flow accelerated erosion (FAC), which is highly promoted by the turbulence behind the orifice. Therefore, the fluid dynamic research has been started by Tohoku cluster to clarify the mechanism of FAC and to predict the pipe thinning phenomena in power plants under operation.

The purpose of this short paper is to report an experimental finding on the occurrence of asymmetric flow pattern behind a double orifice with and without height bias in a square duct.

2. Experimental Apparatus and Procedure

The measurement of the flow behind a double orifice was carried out using an experimental apparatus as shown in Fig.1(a). The working fluid of water is powered by a pump and flows through a settling chamber and a straight square pipe. The flow is fully developed before entering into the test section. It consists of a double orifice followed by a square pipe of transparent material for flow visualization purpose. The side length of the square pipe is d=52.0mm. Details of the structure of double orifice is described in Fig.1(b). The double orifice is made of a structure having a clearance of 31.2mm in the middle. The thickness of the plate is 3mm having square edges. It can be moved slightly in vertical direction, so that the height bias effect of the orifice can be studied. The experiments are conducted at Reynolds number Re(=Ud/ν)=5,000 (U: bulk velocity, ν : viscosity of fluid), which corresponds to a turbulent state.

The flow measurement in the test section behind the double orifice is carried out using a standard PIV system, which consists of a double pulse Nd:Yag laser (50mJ/pulse), a CCD camera with frame straddling function (1018x1008 pixels with 8 bits) and a pulse controller. The flow field was visualized by nylon sphere particles of 40 μm in diameter. The vertical cross-section of the flow field was visualized at the center of the double orifice using the laser sheet illumination of 1mm thickness. The PIV analysis was carried out using a direct cross-correlation algorithm with sub-pixel analysis, where the interrogation window size was set to 31x31 pixels (Kiuchi et al. 2005; Fujisawa et al., 2008). Measurements are carried out for 1,000 instantaneous velocity fields taken at every 1 sec. to obtain statistical flow properties.



(a) Water tunnel (b) Double orifice model

Fig.1 Experimental apparatus and double orifice model (unit in mm)

3. Results and Discussion

An example of instantaneous velocity field behind the double orifice is shown in Fig.2. It shows that the flow through the double orifice is highly accelerated in the core region near the center, while it is decelerated downstream due to the presence of unsteady reattachment of the flow near the pipe walls.

The mean velocity field behind the double orifice without height bias is shown in Fig.3. Each figure shows the mean velocity field attached on upper wall (Fig.3(a)) and that on the lower wall (Fig.3(b)). These results show the presence of two flow patterns in the flow behind a double orifice in a square pipe, which is in contrast to the observation of singularity in the sudden expansion in a rectangular pipe (Aloui and Souhar, 2000; Zilwa et al., 2000). Although these two flow patterns are found to be repeatable, the selection mechanism is not clear in the present state. Once the flow selects one of the patterns, it will be kept for a while during the experiment.

Figure 4 shows the flow patterns behind the double orifice with height bias. When the positive height bias (0.4mm) of upper short plate and lower tall plate is given to the orifice, the flow attaches on the upper wall (Fig.4(a)). This is vice versa for the negative height bias (-0.4mm) (Fig.4(b)). In these experiments, the singularity of flow pattern was not observed. Thus, such flow patterns are reproducible. It is considered that the strength of the flow attachment due to height bias of the orifice is stronger than that due to the flow singularity. It should be mentioned that the asymmetry of the flow pattern behind the orifice is strengthened in the biased case in comparison with that without bias. These results indicate that the small height bias of the orifice is highly influential on the asymmetry of the flow pattern behind the orifice in square pipe.

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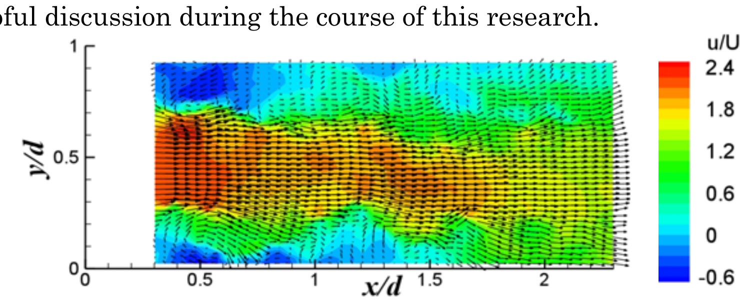

Fig. 2 Instantaneous velocity field behind a double orifice without height bias

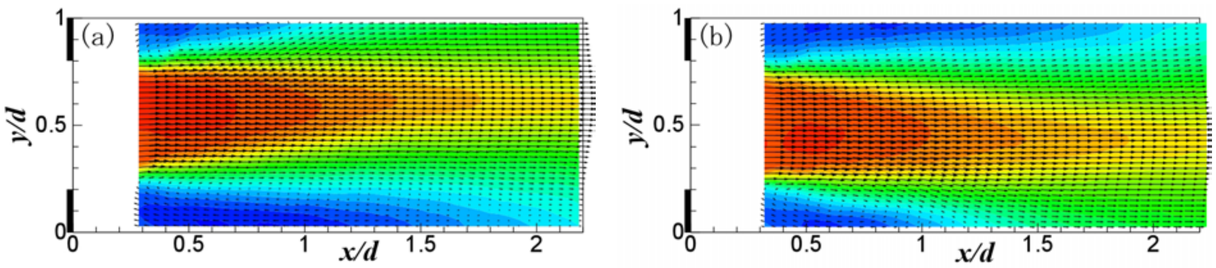

Fig.3 Mean velocity field behind a double orifice without height bias

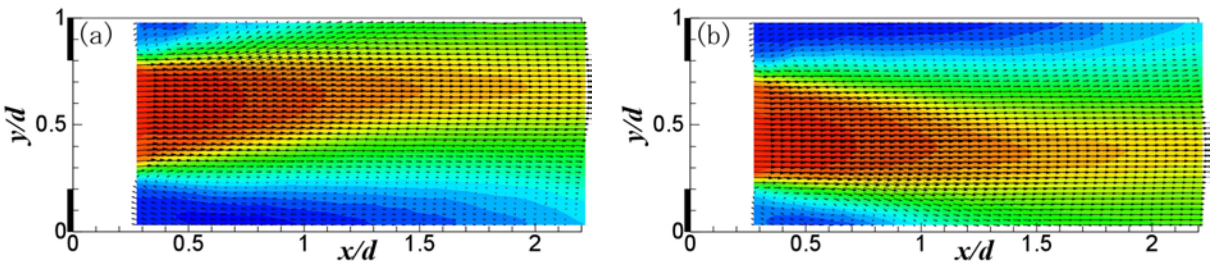

Fig.4 Mean velocity field behind a double orifice with height bias

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