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Short Paper

Characteristic Flow Phenomena on a Tee-Branch Pipe

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1. Introduction

This study focuses on flow phenomena in a tee-branch pipe. Although these kinds of flows exist in many fields such as piping systems in engineering plants, and blood vessel systems or their models in living bodies (ex. Osao et al., 2008), nature of the flows has not been fully reported. In this research the elemental nature of them has been investigated by experimental visualization. Consequently the following phenomena were found: 1) two cylinder-type cores are generated near the outside of the jet flow from the inlet pipe to induce pseudo-Karman vortices; 2) a pair of longitudinally spiral vortices is generated in each outlet pipe; and 3) interaction between the pseudo-Karman vortices and the paired longitudinal vortices causes wavering flows. The purpose of this paper is to show visualization of the characteristic phenomena on tee-branch pipe flows and discuss on their mechanism.

2. Experimental Method

The experimental model for a tee-branch pipe is structurally simple. As shown in Fig. 1, two acrylic pipes with the same bore (D = 14 mm) are joined at an angle of 90° to make an inlet pipe (Li = 700 mm in length) and two outlet pipes (Lo = 500 mm in length for each side). The schematics for the experimental setup are shown in Fig. 2. The working fluid is the water, and the head tank is overflowed to keep the water level constant and make steady inlet flows. The volume rate of the inlet flow is controlled by a valve. The inlet flow is set as the Hagen-Poiseulle flow, and at the two ends of the outlet pipes, the volume rates are same. The bore of pipes is taken as the representative length, and the temperature is maintained at 16 °C to keep the physical quantities constant: viscosity 1.110 × 10^{-3} Pa·s and density 998.9 kg/m^3. The Reynolds number (Re) for the inlet flow is taken as a comparative parameter. The PIV method is applied for visualization. The Rhodamine aqueous solution is adopted as a fluorescent tracer. Each section of side view, bottom view, and quasi-front view shown in Fig. 3 is irradiated with laser sheets, and taken by a CCD video camera with the resolution of 720 × 480 pixel (about 65 dpi) and the frame rate of 30 fps. The ranges of measurement are limited to the colored regions shown in Fig. 3.

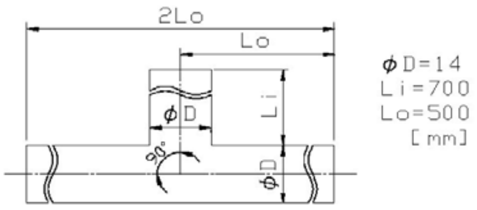

Fig. 1. Tee-branch pipe model.

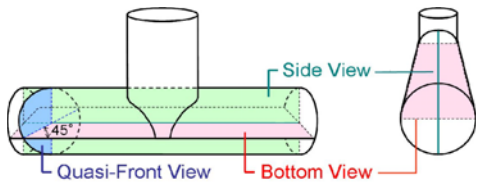

Fig. 3. Visualized sections.

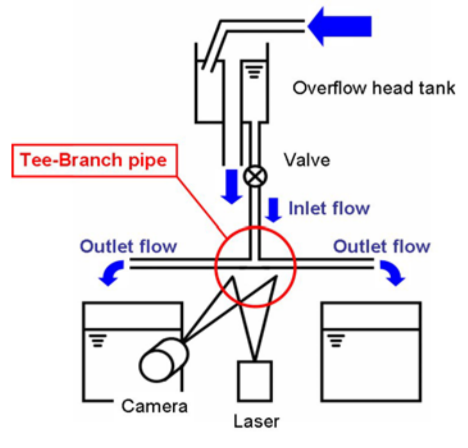

Fig. 2. Schematics for experimental setup.

3. Results and Discussions

Visualization of flows in the outlet pipes is shown in Fig. 4 on the conditions of Re = 450 and 630. We notice that in the former case the flow is almost steady, while in the latter case the flow is wavering. On the side views, for both the Reynolds number conditions, the inlet flow from the center of the inlet pipe strikes the wall inside the outlet pipes, with a stagnation point generated. The inlet flow along the near wall of the inlet pipe separates at the corners of the tee-branch pipe, and reattaches to the wall near the corners, and two corner vortices are formed at symmetric locations on the center line of the inlet pipe. On the quasi-front views, a pair of longitudinally spiral vortices is observed. In the case of Re = 450, each vortex in the pair keeps almost same size in the outlet pipes, while in the case of Re = 630 a pair of imbalanced vortices, i.e., slightly larger vortex and smaller one, appears and each vortex alternates between larger and smaller sizes. On the bottom views two "cores" are observed at the symmetric positions on the center line of the inlet pipe; in the case of Re = 630 phenomena similar to the Karman vortices (ex. Imai, 1973) are observed about the "core", while in the case of Re = 450 fluid streams almost straightly in the downstream of the "core". In order to seek how the cores are generated, the flow is visualized on bottom view sections a, b, and c specified in Fig. 5 in the case of Re = 630. In each section two cores are observed near the outside of the circle in red broken lines representing for the inner wall of the inlet pipe, and they are removed downstream from the circle as the section is taken below. Since these positions correspond to those of the vortices at the tee-branch corner indicated in the side views in Fig. 4, it is considered that the tee-branch corner vortex acts as a cylinder to form the core. Each core is formed by a pair of smaller vortices. We remark that with the Reynolds number raised to Re = 840 the symmetric cores still exist and the flow becomes much more unsteady and complicated. From these results, it is inferred that interference of the pseudo-Karman vortices and the pair of longitudinal vortices causes the alternation of the imbalanced longitudinal vortices in the higher Reynolds number condition (Fig. 6).

In summary, when the jet flow from the inlet pipe takes place in the tee-branch pipe, 1) the vortex ring by the jet remains just as the vortices at the two corners of the pipe, which act as "cylinders", and pseudo-Karman vortices are induced in some Re condition, 2) a pair of longitudinally spiral vortices is generated in each outlet pipe, and 3) interaction of the pseudo-Karman vortices with the paired longitudinal vortices causes the wavering of the imbalanced longitudinal vortices.

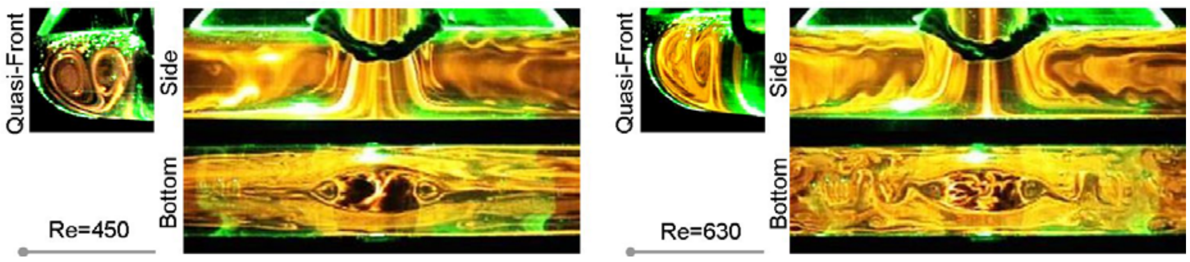

Fig. 4. Visualization of Tee-branch flows.

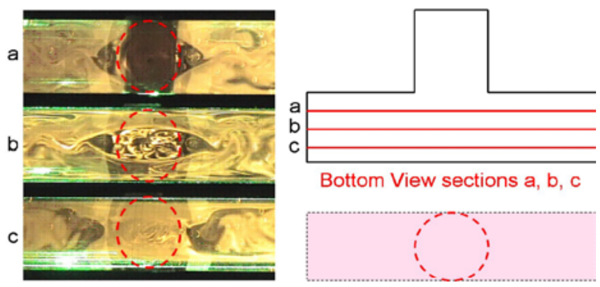

Fig. 5. Bottom views in case of Re = 630.

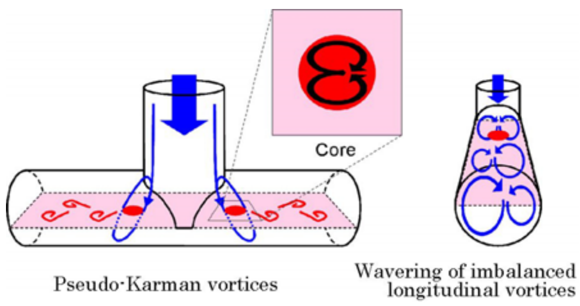

Fig. 6. Diagram for flow patterns in case of Re = 630.

References

Osao, A. et al., Advanced Materials Research, 33-37 (2008), 1037-1042.
Imai, I., Fluid Dynamics, 1 (1973), 193-197, Syokabo.