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Flow measurement on Oscillating pipe flow near the Entry using UVP method

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1. Introduction

Purely oscillating flow is the most simple unsteady flow, and it is the basic flow of blood flow in the arteries, oil pressure engineering and reciprocating compressor. So many researchers investigated this problem theoretically and experimentally.

Hino et al.[1] investigated the critical Reynolds number of laminar to turbulence in oscillating pipe flow, and they pointed out that there are 4 types of the flow. Merkri & Thoman[2] determined the similar result in the resonance tube. The investigations of the entrance region in unsteady flow has recieved some attention. Avula[3, 4] investigated the entrance region in flow started from rest. About the entrance region in the oscillating pipe flow, theoretical work was performed by Atabek et al.[5] and experimentally by Gerrard & Hughes[6]. They showed that laminar flow in front of an oscillating piston is fully developed at a distance $L = 0.3\delta R_\delta$, where R_δ is Reynolds number defined by Stokes layer thickness δ as a characteristic length.

In the present experiment, the velocity profiles in the entrance region of the oscillating pipe flow was investigated by the mean of ultrasonic velocity profile method (UVP)[7], and compared the measured data with Gerrard & Huge's results.

2. Experiment

Fig. 1 shows the schematic diagram of the experimental apparatus of an oscillating pipe flow. Test fluids are the solutions of glycerol, whose concentrations are 18vol% and 68vol%. The present work is performed in circular tube made of plexiglass having inner diameter 46mm, outer diameter 48mm and length 3000mm. The fluid motion is induced by an oscillating piston at the one end of the pipe. The oscillating piston is driven by a crank–gear system connected to a constant–speed electric motor. In the present experiment, oscillatory frequency is changeable. The frequency of the electrical motor is measured by the rotational meter. The motion of the oscillation piston is measured with the laser rangefinder. The pipe is connected to a water tank at the other end to reduce disturbance of water head. The pipe is placed inside a rectangular tank filled with water.

The water is used to reduce the reflection of the ultrasonic beam from the pipe wall and as a acoustic coupler between pipe and transducer, and its temperature is controlled to keep the temperature of the test fluid. The test fluid is set to be at a constant temperature of 25°C.

The velocity profile is measured by a UVP monitor model X-3 PS (Met-Flow SA). We measured the two kinds of velocity profiles, which are the axial velocity components to radial position and the axial relative velocity along the center axis of the pipe. In the measurement of the axial velocity to radial position, the transducer is positioned along the axis at various positions, and fixed onto the pipe with an angle of 15° between the transducer axis and the vertical line to the pipe axis. In the axial relative velocity measurement, the transducer is setted on the oscillating piston and moved with the oscillating piston. As the reflectors of ultrasonic, MB-100 made of plymetacril with the 68vol% glycerol solution and SB-100 made of polysthylene with the 18vol% glycerol solution are mixed. The averaged diameter of MB-100 is 100μm and SB-100 is 80μm respectively.

3. Result

Fig. 3 shows the developed velocity profiles to the non-dimensional position r/R, where r is the distance from the center axis and R the radius of the test pipe. The axis of the ordinate is the non-dimensional velocity by the averaged velocity amplitude U_0.

Fig. 4(a)~(c) shows the developing process of velocity with respect to the normalized distance x/D, where x is the distance from the piston at the upper dead point ($\varphi = \pi$) and D the diameter of the pipe. It seems that the velocity developed in the region farther than $x/D = 5$. However, the difference of velocity profiles in the relatively large distance ($x/D > 5$) is not clear from the figure. Hence Fourier analysis of the time dependent velocity on the center line of the pipe was attempted, and the results are plotted the component of the oscillation frequency of the piston and its harmonic (2nd and 3rd) components with respect to x/D in Fig. 4(e)~(f). It can be seen from the figure that the velocity in the region $x/D > 10$ is developed.

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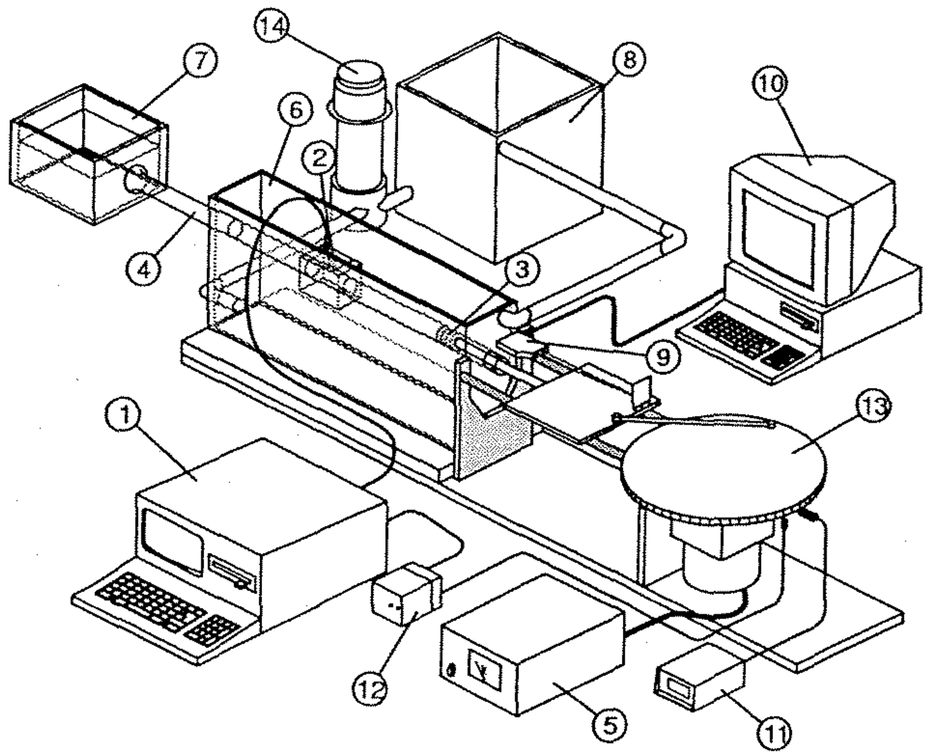

1.	UVP monitor	8.	Tank
2.	U.S. transducer	9.	Laser rangefinder
3.	Piston	10.	Parsonal computer
4.	Test pipe	11.	Rotational counter
5.	D.C. supply	12.	Relay circuit
6.	Tank	13.	Rotating disk
7.	Reserver Tank	14.	Pump

Fig.1 Experimental apparatus

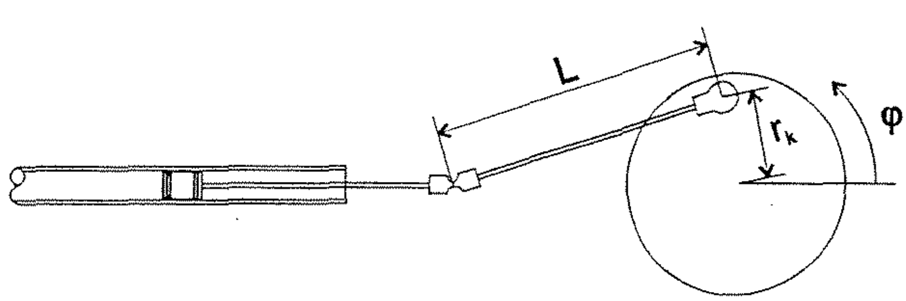

Fig.2 Schematic survey of the oscillating system

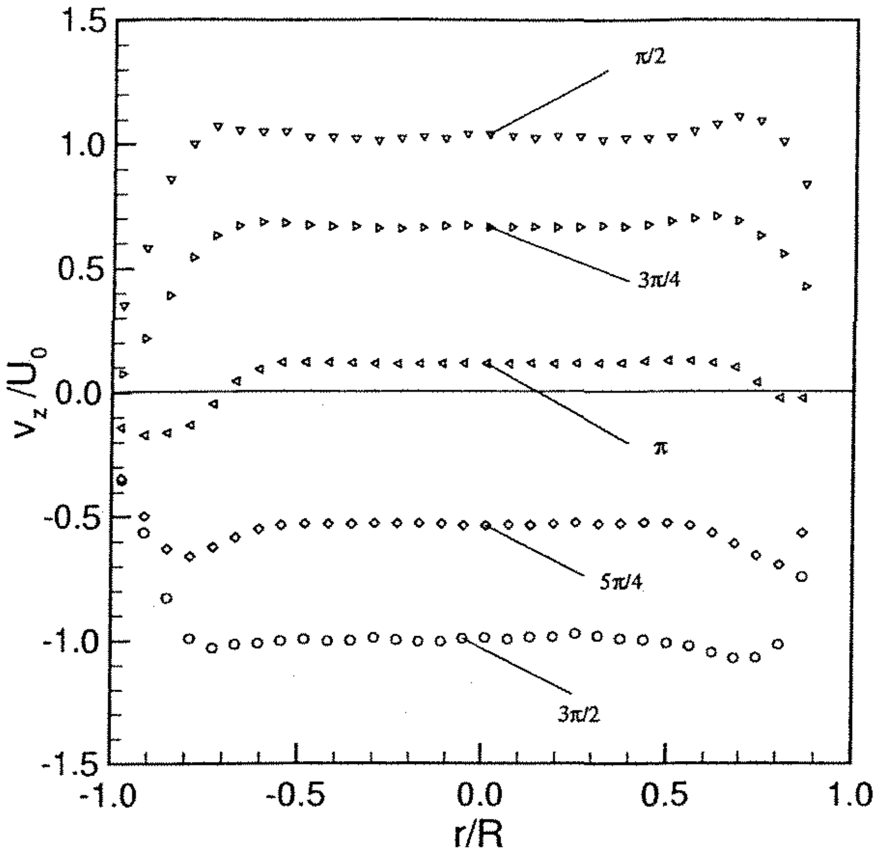

Fig.3 Time dependent velocity profiles in the developed region

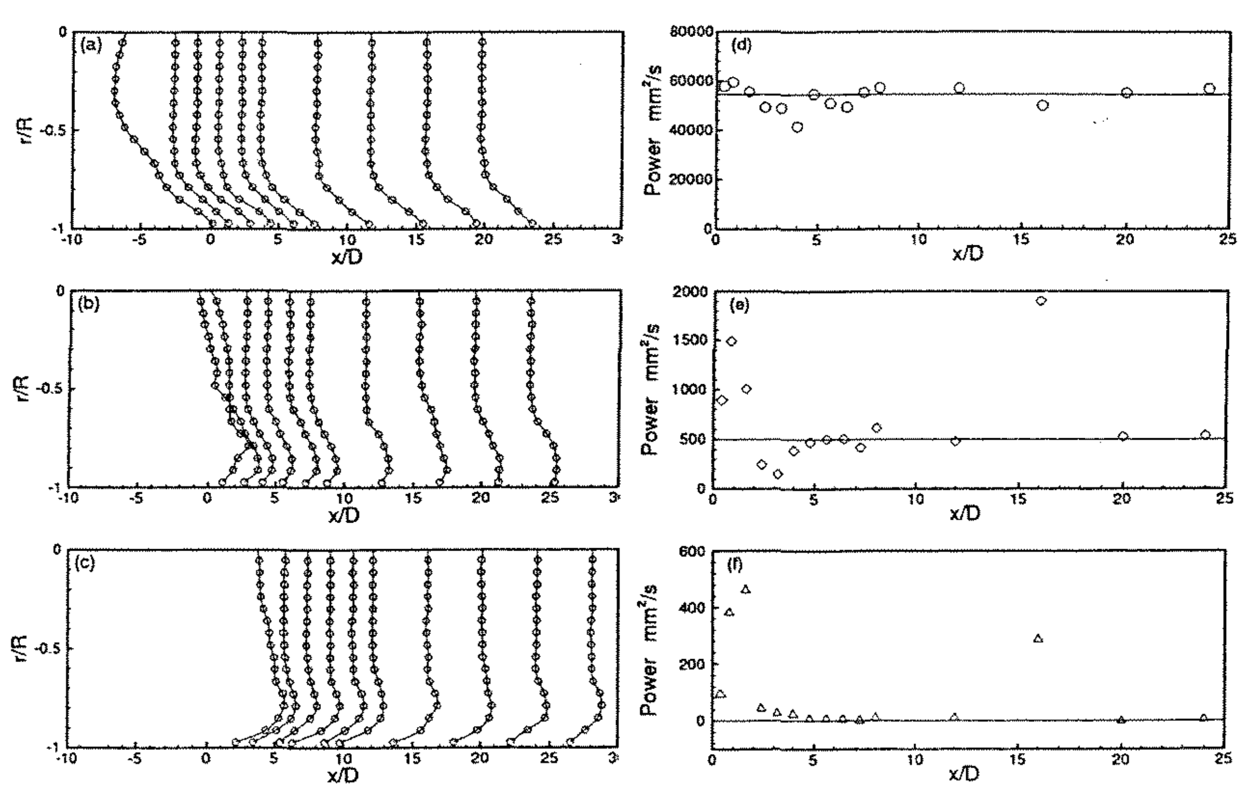

Fig.4 Velocity profiles in the entrance region at (a) $\varphi = -\pi/4$, (b) $\varphi = 0$, (c) $\varphi = \pi/4$, and the change of the spectram components of (d) 1st peak, (e) 2nd peak, (f) 3rd peak