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Ultrasound open channel flow-speed measurement based on the lateral directional echo observations

横方向エコー観測に基づいた超音波開水路流速計測

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1. Introduction

In recent years, along with the growing interest in environmental issues, the demand for monitoring the flow in the drain pipe and the flume has increased[1]. Much of the conventional ultrasonic flowmeters are for the filled flows such as in the closed pipe. There are few methods applicable for the unfilled fluid flows in the pipe or small open channel flume. To resolve above problems, a technique[2-4] was presented based on the lateral observation of the pulse echo signals, assuming the existence of random particles in the drainage water. Flow speed of the fluid was estimated from the variation of the correlation amplitude between the repetitively excited pulse echo signals. Since the method uses the correlation amplitude variation, not the correlation peak time shift as usual, it may be applied for the fluctuating ill-conditioned flows. However, it has not been fully demonstrated, as yet. It was partly due to the failure of the collection of the data from the non-turbulent stable particles.

In this paper, to resolve the problem, an aspirator was installed to reinforce the bubbles as random particles in the flow. Procedure is used to extract the signals reflected from the stabilized particles. By incorporating the strategy, experiments are conducted to demonstrate the capability of the method using the unfilled open channel fluid flow experimental set-up.

2. Experiment method

2.1 Open channel fluid flow set-up

An open channel pipe was prepared with length L=2.0 m and diameter D_p=150 mm, photographic view is as shown in Fig.1. Flour powder mixed water with density 0.125% was prepared as a drainage mimicking water. For the generation of random particles, bubbles were injected in advance and reinforced by the aspirator in operation. The fluid solution was circulated into the pipe through the inflow and the outflow pumps and valves as shown in Fig.2. Rotating vane piping

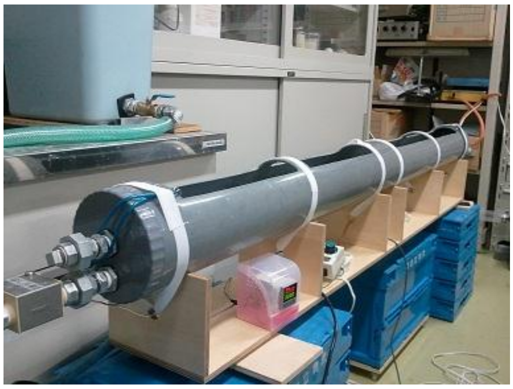

Fig.1 Photographic view of the open channel fluid flow experimental set-up.

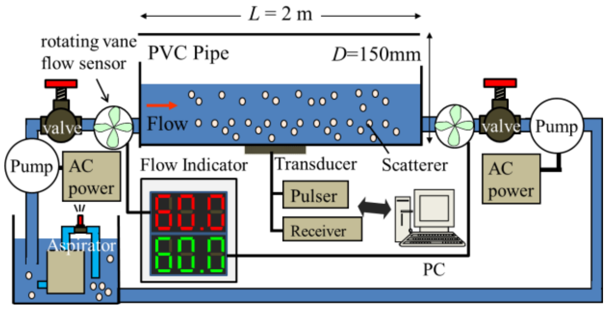

Fig.2 Schematic of the ultrasound flow speed measurement system.

flow sensors were attached to monitor the flows. In and out of the flows are controlled to balance by monitoring the piping flow sensor. The exciting voltage of the pumps and the closing of the valves were adjusted to make the constant flows in the pipe at the desired flow speed keeping constant water level at 90mm.

2.2 Ultrasonic flowmeter system

A piezoelectric circular transducer with center frequency f_c=5MHz and diameter D_x=25.4 mm (Panametrics:V307) was attached at the center bottom of the pipe. Pulser/receiver (Panametrics: 5058PR) was used for the excitation and amplification of the ultrasonic waves. Other experimental conditions are listed in Table 1.

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Method and principle of the flow speed measurement was reported in the previous paper.[3,4] Detailed explanations are omitted here.

3. Results and discussion

3.1 Selection of the echo signals

Under the experimental conditions described above, pulsed waves were repetitively excited at time instant $\tau = nT_{prt}$ (n=0,1,2...) for every time interval T_{prt}. Echo signals $e(t;\tau)$ scattered from the particles in the flow medium were observed, where t is the elapsing time starting from each excitation τ. Example of the measured consecutive signals are as shown in Fig.3, where (a) is the case for the low correlativity signal, on the other hand, (b) is high correlativity. In this study, low correlativity signals as in (a) was removed from the estimation calculation of flow speed, to select the echo signals reflected from the stable scattering particles in the non-turbulent flow.

3.2 Estimation of the flow rate from the slope of the correlation coefficient

After the calculation of the correlation coefficients $R(\tau)$ between the consecutive signals $e(t;\tau)$, their decline slopes with respect to τ were obtained. Measured results are shown in Fig.4 with circles as a function of preset flow volume rate V [ml/s]. Where, average values are connected with a solid line, regression line is fitted to the measured vaules with a dashed one (regression coefficient was estimated as r^2=0.87). The results demonstrate that they have good proportionality with the preset flow volume rate in the fluid. Some large deviations of the data may due to the generation of the turbulent flows in the pipe and caused the inaccuracy of the preset flow rate. The authors are proceeding with much elaborations on these points.

Table.1. Experimental conditions.

Transducer	
Type	Circular non-focused
Diameter D_x	ϕ 25.4 mm
Freq. f_c	5MHz
Data collection	
Excitation interval T_{rep}	0.01, 0.001 s
Num. excitation	250
Pipe	
Length L_p	2000 mm
Diameter D_p	ϕ 150 mm
Fluid	
Material (turbid water)	flour powder mixed water
Density of powder	0.125%
Flow volume rate	0 – 100 ml/s
Water level h	90 mm

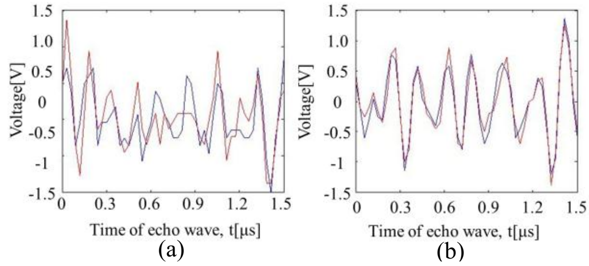

Fig.3 Example of two consecutive echo waves samples, (a)low correlativity signal, (b)high correlativity.

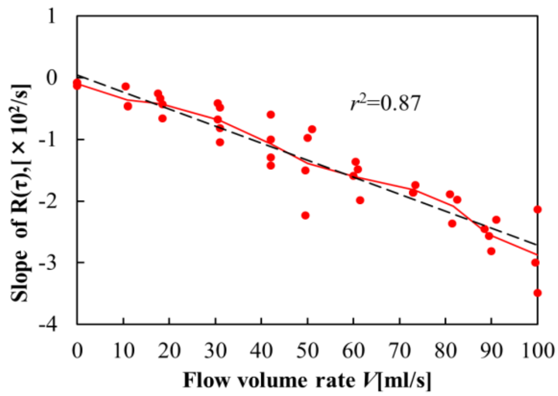

Fig.4 Experiment result of slope of $R(\tau)$ as a function of the preset flow volume rate.

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