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Ultrasound open channel flow velocity profile measurement based on the lateral directional ultrasound echo observations

横方向超音波エコー観測に基づいた開水路流速分布測定

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1. Introduction

There are few methods for flow volume monitoring in small open channel flume or unfilled drain pipe[1]. To encounter the problem, a technique[2-4] is investigated based on the lateral observation of the pulse echo signals assuming the existence of scattering particles in the drainage water. Particularly, ultrasound waves are emitted from the bottom of the pipe from the lateral observation direction (which is normal to the fluid flow direction). Flow velocity profile in water depth direction is then measured from the correlation between the repetitively excited pulse echo signals. As yet, feasibility and advantage of the method over the conventional Doppler method is not fully demonstrated. In this paper, we will show the validity of the vertical flow velocity profile measurement and its applicability to the flow volume estimation, especially as compared to the Doppler method.

2. Strategy of the study for open channel flow volume measurement

We consider a open channel fluid flow measurement such as in the flume or the unfilled drain pipe. The arrangement of the conventional Doppler measurement based on the oblique directional observation with view angle θ is as shown in Fig.1(a), on the other hand, the present method based on the lateral directional observation in Fig.1(b). The reflection type single transducer is attached either over the water surface or at the bottom. Principle of the present method was reported in the previous paper.[3,4] Hence, detailed explanations are omitted here.

We note here that, different from the conventional filled water flow, simple laminar flow cannot be assumed since the generation of the turbulent or convection flow is unavoidable in the open channel flow environment. That is to say, flow rate profile does not obey the simple theoretical formula. For this reason, to obtain the flow volume, which is the purpose of the open channel flow measurement, vertical flow velocity profile must be measured. Doppler method has a disadvantage due to the existence of the dead area near the water surface or bottom of channel. Therefore, it is not appropriate for flow volume measurement. On the contrary, the present method makes it possible to measure the profile over the entire vertical interval without dead zone. Normal slice section of the flow velocity profile can be directly measured. By accumulating the horizontal cross sectional flow rate area, flow volume can be finally obtained.

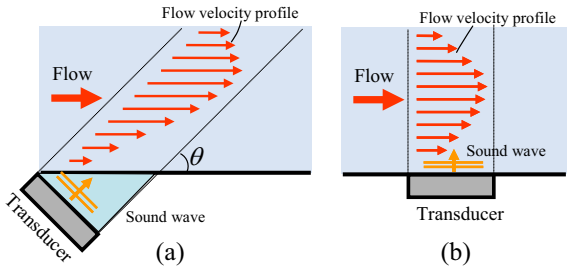

Fig.1 Arrangement of the transducer for the flow velocity profile measurement using (a) Doppler method, (b) present method.

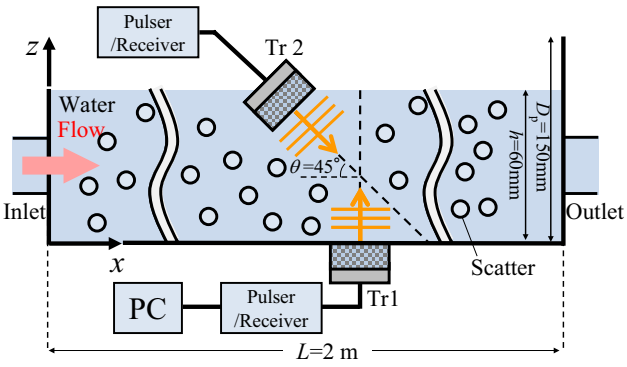

Fig.2 Experimental apparatus.

3. Test experiment

3.1 Experimental set-up

An open channel pipe was prepared with

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length L=2 m and diameter D_p=150 mm as shown in Fig.2. 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. Rotating vane piping flow sensors were attached, in and out of the flows are controlled by monitoring the sensors. The exciting voltage of the pumps and the closing of the valves were adjusted to maintain the flows in the pipe at the desired flow velocity and constant water level at h=60 mm.

A piezoelectric circular transducers with center frequency f_c=5 MHz and diameter D_x=25.4 mm (Panametrics:V307) were prepared. For the measurement using the proposed method, it was attached at the center bottom of the pipe with Tr1 in Fig.1. On the other hand, for the Doppler measurement, it was attached over the water surface with Tr2 in Fig.1. Pulser/receiver (Panametrics: 5058PR) was used for the excitation and amplification of the ultrasonic waves.

3.2 Flow velocity profile measurement

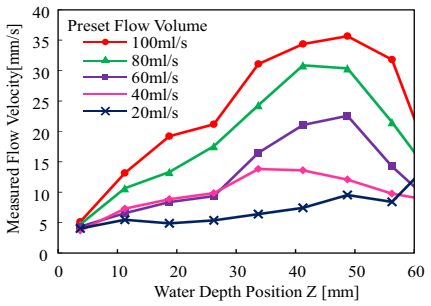
The measured flow velocities as a function of the water depth are shown in Fig.3 where (a) shows the results using present method, (b)shows the Doppler method. Preset flow speed was changed at five different values as a parameter. Flow velocity by the present method was calibrated from the results of the Doppler measurement, since the present method cannot provide the absolute flow velocity value. It is noted that flow velocity profiles agreed well with the simulations, which was conducted in separate investigation. We can say that reasonably good results are obtained by the present method. On the other hand, results by the Doppler method were limited due to the presence of the dead zone (indicated as the dark colored region). As a results, measurable range was too small to obtain the entire depth region.

3.3 Flow volume measurement

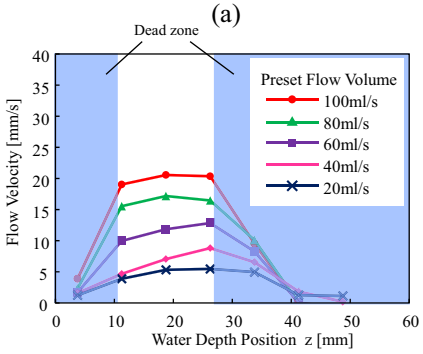
Figure.4 shows the measured results of the flow volume as a function of the inlet and outlet preset flow rates. Flow volume was calculated from the multiplication of the flow velocity at specified depth and the corresponding area of the circular cross-section in the pipe. The values were accumulated in depth direction. To correct the horizontal variation of the flow velocity in the cross section of the pipe, correction factor (=0.625) was multiplied. Agreement between the measured results and the true values (straight line) is relatively good.

4. Conclusion

It was demonstrated that the present method, in place of the conventional Doppler method, provides the useful means to measure the open channel flow velocity profile and volume flow.



(a)



(b)

Fig.3 Measured results of the flow velocity profile using (a)Present method and (b)Doppler method.

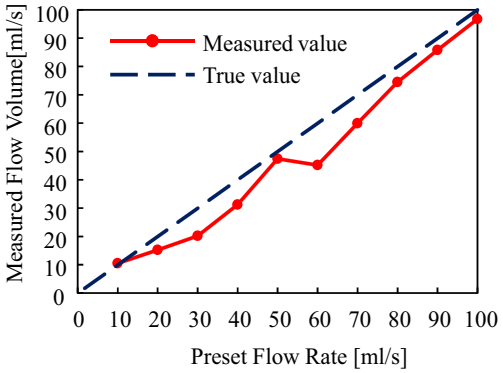


Fig.4 Measured results of the flow volume.

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