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Easy setup clamp-on ultrasonic flowmeter
簡易取り付けクランプオン超音波流量計

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1. Introduction

Recentry, in the field of measurement of liquid flowrate in industrial plants, ultrasonic flowmeter has rapidly enhanced awareness to it and increased its market share. Particularly, it gains market share in the field of water, oil and gas, chemical. Reason for this is its improved accuracy, reliability, and being recognized its advantage that measurement on any type fluid is possible without pressure loss.

There are two kinds of industrial ultrasonic flowmeter [1]. One is in-line type of which transducers are embedded in piping wall and wetted to fluid. Advantage of in-line type is high accuracy owing to free layout of ultrasonic paths [2]. The other is clamp-on type of which transducers are located on outside of pipe and non-wetted. Advantage of clamp-on type is that it can be installed on existing pipeline without draining pipeline and plumbing.

Clamp-on type ultrasonic flowmeter has two types of problem. One is its low accuracy compared to in-line type because its transducers are non-wetted to measurement fluid. The other is setup of transducers which takes many man-hours since transducer's relative position is dependent on pipe diameter, pipe wall thickness, and pipe material [3].

In this paper, we propose the clamp-on ultrasonic flowmeter with opposed transducers configuration to reduce man-hours of setup and show measurement results.

2. Principle

There are two kinds of principle to measure flowrate by ultrasonic. One is Doppler method. It is applicable to fluid containing micro air bubbles or particles [4]. The other is transit-time method. It is applicable to clean fluid. We have developed the clamp-on ultrasonic flowmeter to target clean fluid. Thus, we decided to adopt transit-time method.

Ultrasonic velocity which propagates through fluid is influenced by the fluid velocity. Transit-time method utilizes difference of transit time from transmitter to downstream receiver and to upstream receiver to obtain flowrate. Equation relating fluid velocity to difference of transit time ΔT is Eq(1).

$$V = \frac{C^2}{2d_x}\Delta T, \quad \Delta T = T_d - T_u \tag{1}$$

V is fluid velocity, C is ultrasonic velocity, d_x is distance between transmitter and receiver, T_d is transit time from transmitter to downstream receiver and T_u is transit time from transmitter to upstream receiver.

3. Experimental setup

Fig. 1 shows schematic view of experimental equipment. Transducers are composite type PZT (Japan Probe). These diameters are 8 mm and center frequency is 1 MHz. Pulse generator is JPR-10CN (Japan Probe). Received signals are passed through low noise pre-amplifier 9913 (nf) and are measured by data logger DL850 (Yokogawa). Reference flowrate is obtained from electromagnetic flowmeter AXF (Yokogawa). Measurement fluid is water. Measurement pipes are 50A vinyl chloride whose wall thickness is 1.8mm, 100A stainless steel (SUS) whose wall thickness is 5.7mm, 150A SUS whose wall thickness is 3.4mm.

In general, in order to tilt incident ultrasonic to axis of pipe, transducers' surfaces are attached at an angle with axis of pipe. This setup demands location alignment of transducers. By contrast, at our developed flowmeter, transducers' surfaces are attached parallel to axis of pipe to avoid location alignment of transducers. In this setup, ultrasonic is vertical to flow velocity. However, ultrasonic spreads to propagate through fluid, thus contains flow direction component. By utilizing flow direction component, flowrate can be measured.

Distance between upstream receiver and downstream receiver is preliminarily fixed at 30 mm. This unit of receivers is attached to pipe with fixture tool suited to pipe diameter.

4. Results

Fig. 2 shows typical received signal at 100A SUS pipe. Ultrasonic, which propagates along pipe wall, is received first and another ultrasonic which propagates through water, overlaps it. This overlap is remained at different diameters of pipe because ratio of propagation distance along pipe wall to propagation distance through fluid is constant.

Difference of transit time is obtained by cross-correlation method between signal of downstream receiver and signal of upstream

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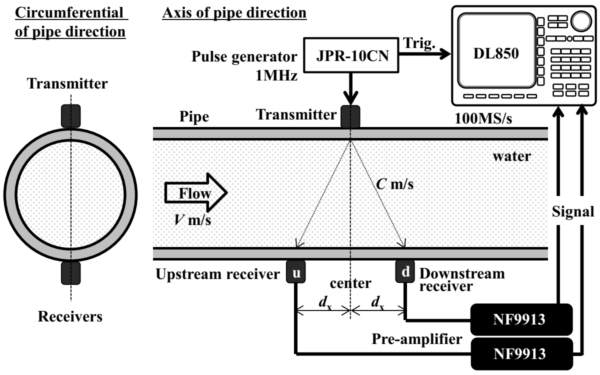

Fig. 1 Schematic view of experimental equipment.

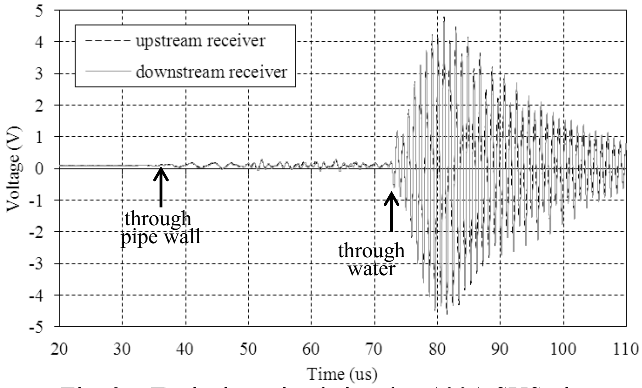

Fig. 2 Typical received signal at 100A SUS pipe.

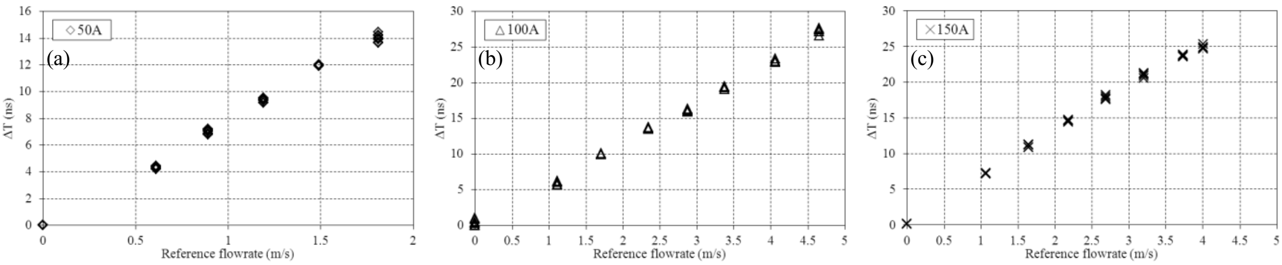

Fig. 3 Difference of transit time ΔT versus reference flowrate. (a)50A vinyl chloride, (b)100A SUS, (c) 150A SUS

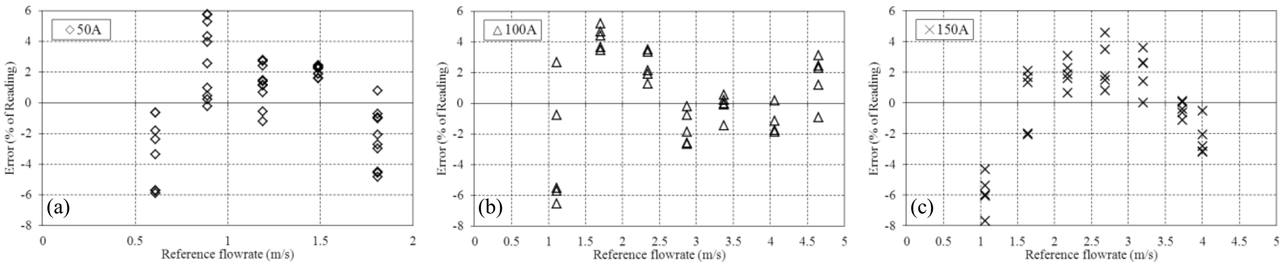

Fig. 4 Error (% of Reading) versus reference flowrate. (a)50A vinyl chloride, (b)100A SUS, (c) 150A SUS

receiver. 1024 points (corresponding to time window of 10.24 μs) from onset of received signal for ultrasonic propagating through water are processed. Position, at which correlation coefficient is maximum, is used as difference of transit time.

Fig. 3 shows calculated difference of transit time ΔT versus reference flowrate in case of 50A vinyl chloride, 100A SUS, and 150A SUS.

Error (% of Reading) versus reference flowrate is shown in **Fig. 4**. Calibration formula is linear expression. Accuracy is almost ±6 %.

5. Conclusion

The developed clamp-on ultrasonic flowmeter adopted the structure, in which transducers' surfaces are parallel to axis of pipe to avoid location alignment of transducers which is one of the problems with clamp-on ultrasonic flowmeter. In the result, the developed flowmeter is able to measure flow velocity with fixed pipe axis distance of transducers at different pipe diameter and material. Thus, we demonstrated that flowrate can be measured by clamp-on ultrasonic flowmeter without location alignment of transducers.

Accuracy of the developed flowmeter is ±6 %, which is three times as large as general clamp-on ultrasonic flowmeter. We are going to improve the accuracy to overcome general clamp-on ultrasonic flowmeter accuracy. For this purpose, signal-noise ratio, signal processing, multipath to decrease dependence on asymmetric flow distribution, temperature correction, and so on need to be considered.

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