

Experimental Study on Flow Rate Measurement Downstream of an Elbow Pipe using the Clamp-on ultrasonic Flowmeter

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Abstract

This paper presents experimental measurements using the clamp-on ultrasonic flowmeter. To obtain an uncertainty of flow rate measurement using the clamp-on ultrasonic flowmeter, experiments are carried out at the national standard calibration facility of water flow rate in Japan (the National Institute of Advanced Industrial Science and Technology, National Metrology Institute of Japan). Flow rate given by the clamp-on ultrasonic flowmeter is compared with the static gravimetric method using a tank system weighing 50 t. The uncertainty of the reference flow rate given by the 50 t weighing tank system is 0.060% ($k = 2$). The transducers of clamp-on ultrasonic flowmeter are mounted downstream of an elbow pipe. The length from the elbow to the transducers is five times of the pipe diameter and ten times of the pipe diameter, respectively. The curvature radius of the elbow is equal to the pipe diameter. Flow rate measurement is based on a time of flight of pulsed ultrasound. The multi-pass mode of the clamp-on ultrasonic flowmeter is used to measure the disturbed flow condition, and the number of ultrasound pass is up to four. The pipe is made of stainless steel with the outer diameter of 216.3 mm and the thickness is 6.5mm. The flow rate condition is from 100 m³/h to 700 m³/h. The results show that the clamp-on ultrasonic flowmeter using the multi-pass mode can measure the flow rate accurately, even if the velocity profiles are disturbed by the upstream elbow pipe.

1. Introduction

It is well known that the measured flow rate given by flowmeters, such as ultrasonic, electromagnetic, and turbine flowmeters, generally depends on the velocity profile in a pipe. This dependence demonstrates that the measurement accuracy of these flowmeters is influenced by the upstream pipe configuration and flow rate conditions, even if the flowmeters are calibrated by a calibration facility. In calibration facilities, the construction of a complete equivalent pipe layout in an actual field is often difficult. In consideration of the application of these flowmeters to actual flow fields, such as industrial facilities and power plants, the issue of disturbed velocity profile influenced by the upstream pipe condition is important.

This paper presents the experimental results of flow rate measurement using the clamp-on ultrasonic flowmeter. Two upstream pipe conditions, a long straight pipe and an elbow pipe, are applied. The influence of the number of

ultrasound path on the uncertainty of flow rate measurement is evaluated.

2. Experimental facility and conditions

2.1 Experimental facility

The experiments were performed at the water flow rate calibration facility of the National Institute of Advanced Industrial Science and Technology, National Metrology Institute of Japan (AIST, NMIJ). This facility is the national standard calibration facility of water flow in Japan. The flow rate given by the clamp-on ultrasonic flowmeter was evaluated with respect to the static gravimetric method using a tank system weighing 50 t. The uncertainty of the reference flow rate given by the 50 t weighing tank system is 0.060% (the coverage factor $k = 2$). For the details of the system, see reference [1].

2.2 Experimental conditions

Figure 1 shows the schematic of the test facility and the test section. The transducers of clamp-on

ultrasonic flowmeter are mounted downstream of a straight pipe and an elbow pipe. The length of the straight pipe is $65D_1$. Where, D_1 is the pipe diameter of the test section. The pipe is made of stainless steel with the outer diameter of 216.3 mm and the thickness is 6.5 mm. In the case of downstream of an elbow, the length from the elbow outlet to the transducers is $5D_1$ or $10D_1$. The curvature radius of the elbow is equal to the pipe diameter. The flow rate condition is from $100 \text{ m}^3/\text{h}$ to $700 \text{ m}^3/\text{h}$.

Flow rate measurement is based on a time of flight of pulsed ultrasound. Figure 2 shows the layout of transducers. The multi-pass mode of the clamp-on ultrasonic flowmeter is used to measure the disturbed flow condition, and the number of ultrasound path is up to four. In four paths mode, the ultrasound paths are bisected at right angles as shown in the figure. To measure along the other circumferential path, transducers are mounted with an interval of 30° .

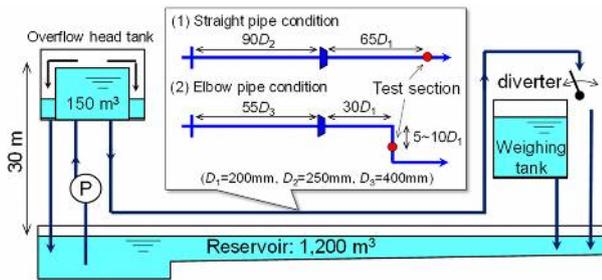


Figure 1: Experimental facility and test section.

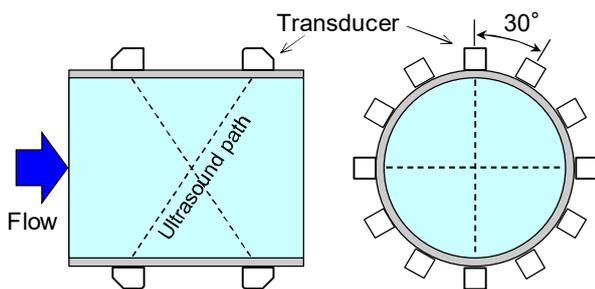


Figure 2: Setting of Transducers.

3. Results

Figure 3 and Figure 4 show the errors and standard deviations of flow rate measurement using the 1 path and 4 paths mode downstream of the long straight pipe. The error is obtained as following equation.

$$E = \frac{Q_u}{Q_w} - 1 \quad (1)$$

Where, Q_u and Q_w are the flow rate measured by the ultrasonic flowmeter and the weighing tank system, respectively. E_{arg} is the average value of all measured E . These results indicate clearly that 4 paths can measure the flow rate accurately compared with 1 path.

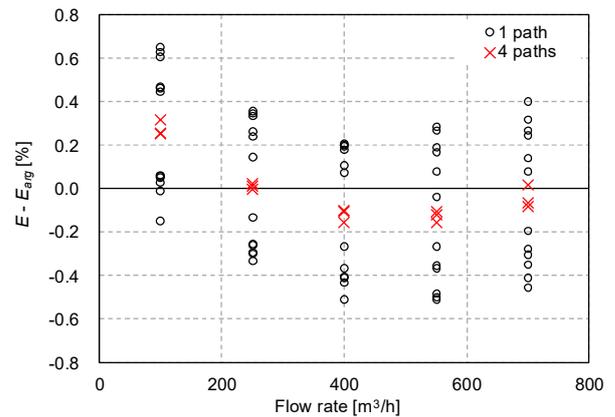


Figure 3: Errors of flow rate measurement using 1 path and 4 paths downstream of the long straight pipe.

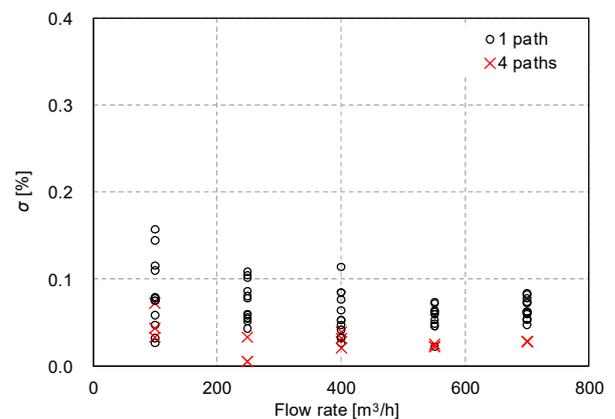


Figure 4: Standard deviations of flow rate measurement using 1 path and 4 paths downstream of the long straight pipe.

Figure 5 and Figure 6 are the errors and standard deviations of flow rate measurement using 1 path mode downstream of the elbow pipe. Both errors measured at $5D_1$ and $10D_1$ are plotted in these figures. These results indicate that the accuracy of flow rate measurement depends on the circumferential position of transducer because of the strongly disturbed flow by the elbow.

On the other hand, Figure 7 and Figure 8 show the results using 4 paths mode downstream of the elbow pipe. The errors and standard deviations of

flow rate measurement are almost equivalent to the errors downstream of the long straight pipe condition.

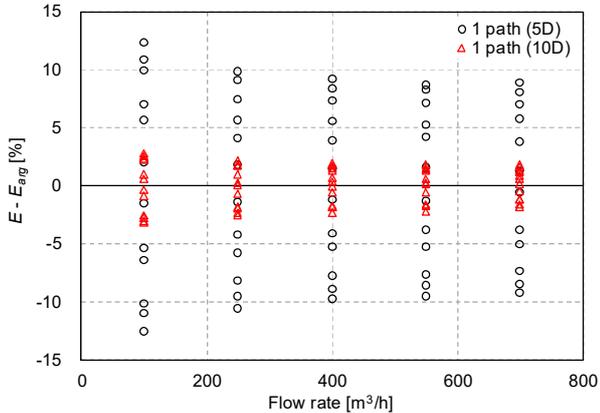


Figure 5: Errors of flow rate measurement using 1 path downstream of the elbow pipe.

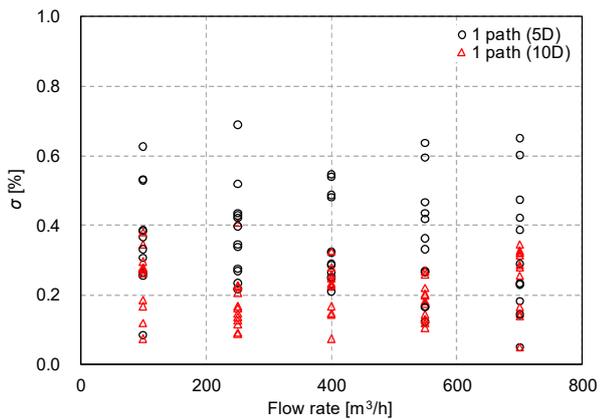


Figure 6: Standard deviations of flow rate measurement using 1 path downstream of the elbow pipe.

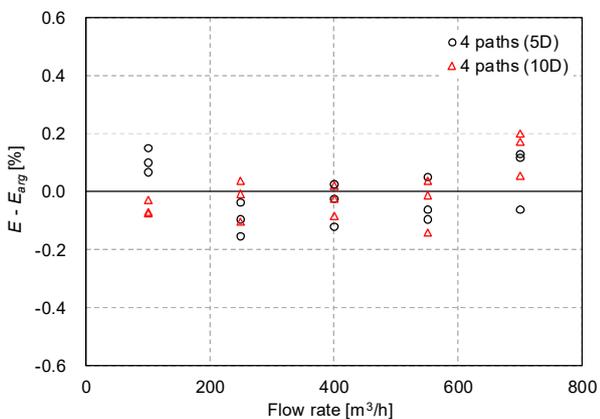


Figure 7: Errors of flow rate measurement using 4 paths downstream of the elbow pipe.

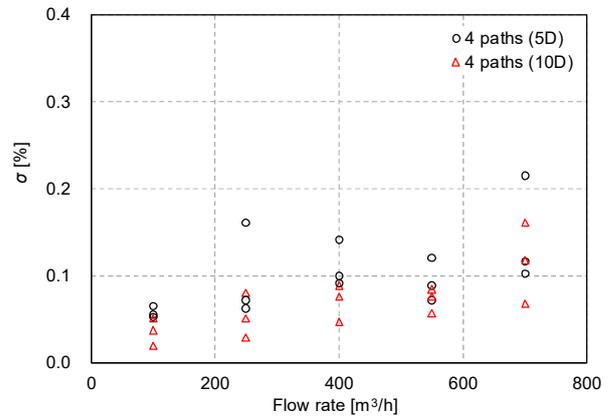


Figure 8: Standard deviations of flow rate measurement using 4 paths downstream of the elbow pipe.

4. Conclusion

The clamp-on ultrasonic flowmeter using 4 paths can measure the flow rate accurately compared with 1 path downstream of the long straight pipe. Additionally, the errors and standard deviations measured downstream of the elbow pipe using 4 paths are equivalent to the case of the long straight pipe, even if the velocity profiles are disturbed strongly by the upstream elbow pipe.

References

- [1] Furuichi N, Terao Y and Takamoto M: Calibration facilities for water flowrate in NMIJ, *Proceedings of 7th International Symposium on Fluid Flow Measurement*, Anchorage, USA, August (2009), pp.12–14.