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Clamp-on ultrasonic steam flowmeter using transducer with supercritical angle and damping material with high temperature endurance

超臨界角トランスデューサと耐熱ダンピング材を使ったクランプオン超音波蒸気流量計

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1. Introduction

Steam is used in many factories and office buildings as heat source and hot water supply. For energy management purposes, it is important to manage and control steam consumption. In order to manage steam consumption, it is necessary to monitor the amount of steam produced and the actual amount of steam consumed. Both in factories and buildings, steam is usually supplied from a boiler to the specific locations where it is required using piping. Therefore, a flowmeter is required to monitor the actual steam consumption at the usage locations, whereas the steam production is monitored from the boiler setting. It is ideal to monitor the actual steam consumption using permanent flowmeters at all specific locations where steam is used. However, it can become expensive as the number of those locations is often high. For this reason, it is desirable to monitor actual steam consumption with a removable clamp-on type ultrasonic flowmeter.

We aim at producing an ultrasonic clamp-on steam flowmeter that can be used with small diameter and high temperature steam piping.

2. Measurement System and Device

2. 1 Clamp-on ultrasonic flowmeter

A clamp-on ultrasonic flowmeter measures fluid flow rate using two ultrasonic transducers located upstream and downstream of each other on the outside surface of piping.

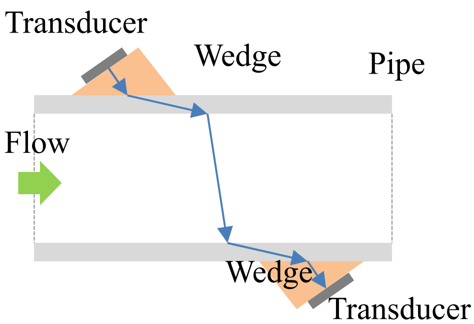


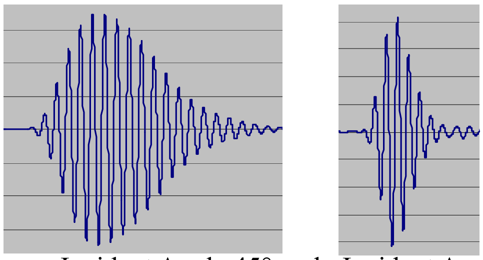
Fig.1 Clamp-on Ultrasonic Flowmeter

The ultrasonic transducer is mounted at a specific angle using a plastic wedge so that the beam of ultrasonic waves enters the pipe at an incident angle. (Fig.1)

Both transducers are used for emitting and receiving in such as a way that upstream and downstream transit times can be measured. Flow velocity and flow rate can be calculated from the sums and differences between upstream and downstream transit times. This is called the transit time method.

2. 2 Transducer with supercritical angle

A challenge with ultrasonic flow measurement is to sharpen the measuring signal waveform with respect to time. The expanded signal waveform is caused by the transducer which acts as a resonator and brings multiple reflections in the pipe wall. Because of those multiple reflections, ultrasonic waves are continuously supplied to the fluid from the pipe wall. When using cross-correlation to find the difference in transit time, the expanded signal waveform with respect to time involves peaks of the same height signal. This can result in incorrect calculation of the transit time. For these reasons, it is desirable to improve the signal. (Fig.2a) We developed a new transducer which uses the supercritical angle to remove unnecessary ultrasonic wave in the pipe. Using this new transducer, we were able to measure a sharper signal with respect to time. (Fig.2b)



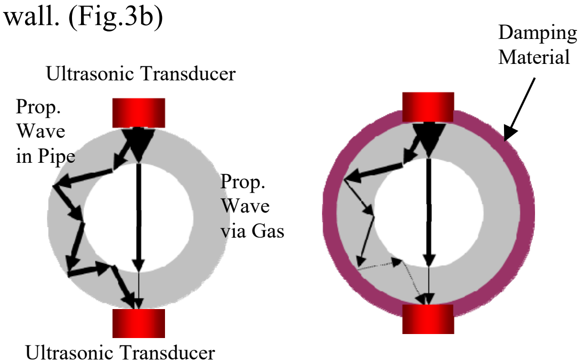
a. Incident Angle 45°　b. Incident Angle 57°

Fig.2 Comparison of Ultrasonic Signal at Different Incident Angles

It was experimentally found that the signal has a satisfactory intensity and form when an incident angle of 57 degrees is used [1].

2.3 Damping material with high temperature endurance

Another challenge is caused by the unnecessary ultrasonic signal transmitted through the pipe and received by the transducers. It is difficult to distinguish the ultrasonic signal transmitted through the steam from the signal through the pipe wall. (Fig.3a) A solution is to use a damping material surrounding the outside of the pipe to absorb ultrasonic signal through the pipe wall. (Fig.3b)

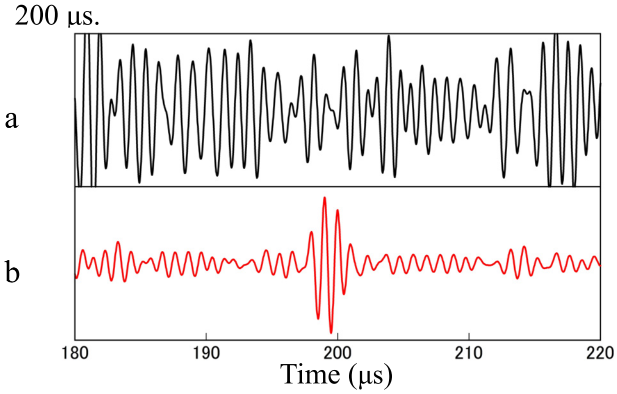


a. Without Damping Material b. With Damping Material

Fig.3 Setup with Damping Material

The most commonly used damping material is rubber. However, rubber cannot be used at temperatures higher than 150°C. One proposed solution is to use heat resistant materials such as silicone. This new damping material was evaluated for its damping effect with steam and with a 25A pipe size (SGP)
(Pressure of 0.8 MPaG, Flow Rate at 0 m/s).

A sharper signal was measured using silicone as heat resistant material as shown in Fig.4 around 200 μs.



a. Without Damping Material b. With Damping Material

Fig.4 Effect of Damping Material

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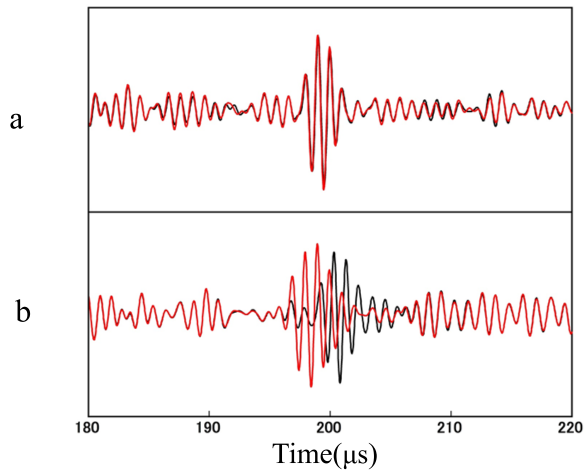
Fig.4 shows the measuring signal waveform. The horizontal axis shows the time from applying the drive signal and the vertical axis shows the intensity.

3. Experiments and Results

The conditions used for the experiment are presented in Table 1. Fig.5 shows the measuring signal waveforms.

Table 1 Measurement Conditions

Item	**Value**
Pipe	25A SGP (OD 34, t3.2, Carbon Steel)
Steam	0.8 MPaG
Flow Rate	0,12 m/s
Straight Length	Upstream: 20D Downstream: 20D
Boiler	1.2MPaG, water tube



a. 0 m/s b. 12m/s

Fig.5 Ultrasonic Signal with Steam Flow

The red plot shows the signal of the upstream direction, and the black plot shows the downstream direction signal. A difference can be observed around 200 μs. This difference in propagation time is used to calculate the velocity of the steam.

4. Conclusion

In conclusion, we were able to measure steam flow rate at a pressure of 0.8 MPaG using the flowmeter described here. However, the intensity of the signal through lower pressure steam is expected to be somewhat low to accurately measure flow rate at such pressure.

Further work is required to understand the damping effect of the heat-resistant material in order to use the flowmeter with lower pressure steam flow

References

1. H.Sasaki et al. : azbil Technical Review, 2015-4 (2015), 63