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# A Method for Improving SNR in Vortex Flowmeter using Piezoelectric Ceramics

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The great leader Comrade Kim Il Sung said:

"One of the most important tasks facing the engineering industry at present is to make a decisive improvement to the quality of what it produces."

The vortex flowmeter using piezoelectric ceramics as sensor is affected by various noises such as vibration noise of tube, environment noise and so on [1－3].

We improved the accuracy of flow measuring by enhancing noise cancelling characteristic of vortex flowmeter when vibrational acceleration of tube is greater than 1.5g with pump and fluid current and environmental noise level greater than 90dB.

The following section of this paper is preceded by brief theoretical consideration of vortex flow rate sensor. Experimental results of vortex flowmeter using this sensor are also shown.

## 1. Theoretical Background

When the piezoelectric vortex flow rate sensor is set in the tube through which liquid flows, vortex signal generated at the back of triangular vortex generator is affected by noise of angular direction.

In order to detect the vortex signal from noisy signal, the piezoelectric ceramics with their electrodes split into two parts and polarized opposite each other is established in the sensor. Then noises from fluid flows, vibration of tube and environment are compensated due to their opposite polarities and vortex signals are doubled due to their same polarity.

In practice, however, it is hard to split the electrode exactly and set the sensor in the same direction of fluid flow in Fig.1. Because of that, two ceramics are fixed suitably on the top of vortex generator to cancel these noises.

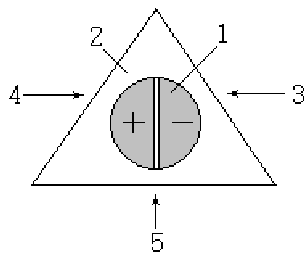


Fig. 1. Establishment of piezoelectric ceramics
1－Ceramics, 2－Vortex flow generator, 3, 4－Vortex force, 5－Flow direction of fluid

In this case electric charges of two electrodes are

$$q_1 = S_1(\omega)\sin\omega t + N_1(\omega)\sin\omega t, \tag{1}$$

$$q_2 = S_2(\omega)\sin\omega t + N_2(\omega)\sin\omega t, \tag{2}$$

where $q_1$, $q_2$ are electric charges of two electrodes, $S_1$, $S_2$ are vortex signals, $N_1$, $N_2$ are noises and $\omega$ is angular frequency.

Simple algebraic operation results in the following.

$$q_1 - \lambda q_2 = S_1(\omega)\sin\omega t - \lambda S_2(\omega)\sin\omega t + N_1(\omega)\sin\omega t - \lambda N_2(\omega)\sin\omega t \tag{3}$$

$$q_1 - \lambda q_2 = S_1(\omega)\left[1 - \lambda\frac{S_2(\omega)}{S_1(\omega)}\right]\sin\omega t + N_1(\omega)\left[1 - \lambda\frac{N_2(\omega)}{N_1(\omega)}\right]\sin\omega t \tag{4}$$

Choosing the $\lambda$ such that $1 - \lambda\dfrac{N_2(\omega)}{N_1(\omega)} = 0$, it follows

$$q_1 - \lambda q_2 = [S_1(\omega) - \lambda S_2(\omega)]\sin\omega t \tag{5}$$

From Eq. 5, $\lambda$ with $N_1 = \lambda N_2$ lead us to the possibility to cancel the noise and improve SNR.

## 2. Experimental Result

Experiment of flow measuring and noise cancellation proceeded in 160mm-diameter circulating water tube of geothermic equipment.

Pumps to provide the geothermic equipment with the circulating water are settled in the range of 10 meters from the equipment in parallel, so that the circulating water tube vibrates strongly due to the influence of pumps.

Vibration acceleration sensor B&K81636 and instrument amplifier B&K2636 are used to measure the vibration of the tube.

Fig. 2 shows the distribution of vibration noise when tube is vibrating.

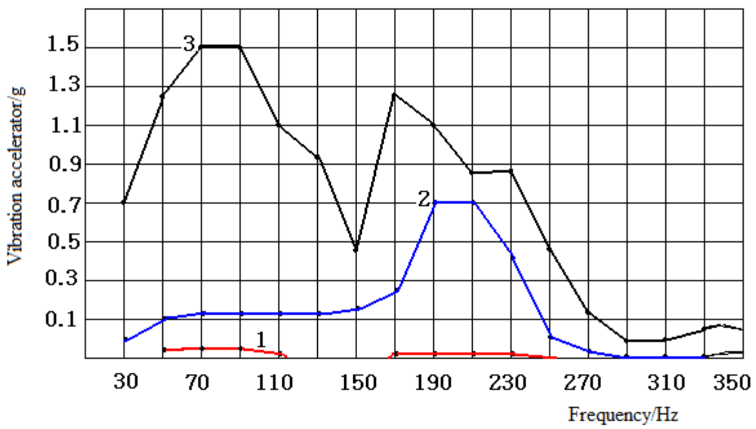


Fig. 2. Distribution of vibration noise

1—Pump at rest, 2—An acting pump, 3—Tow acting pump

As shown in Fig. 2, when two pumps acting, vibration of tube has its peak at frequency of 40～100Hz which coincides with vortex signal. In addition, 8 pumps linked in parallel to the tube of circulating water and 6 pieces of geothermic equipment cause environmental sound noise with its level greater than 90dB and frequency higher than 1kHz. So without cancelling of such noises, measuring accuracy is surely affected or even measuring itself may be impossible.

Experimental schematic is shown in Fig. 3

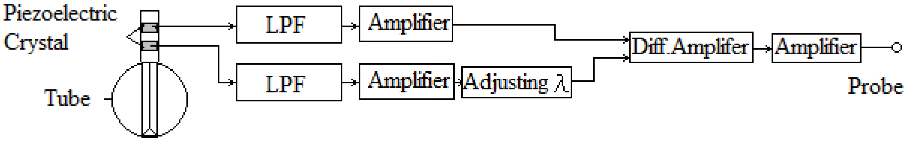


Fig. 3 Experimental schematic

Two piezoelectric ceramics are fixed on the triangular-prism-shaped vortex generator with its gap of 8mm determined by FEM simulation.

Flow sensor is fixed as shown in Fig.1 to cancel the inherent noise of sensor. In addition, adjusting the $\lambda$ in the range of 0.6~1.3 and differential amplification are used to cancel the noise from the direction of vortex force and the noise due to imperfect fixing of sensor.

Sound noise is canceled by low pass filter with cut-off frequency of 80Hz.

In the experiment the flow speed of water in the tube is changed from 1m/s to 2.7m/s. The experiment shows that the levels of noises due to vibration of tube and environment are lower than 0.3V and vortex signal is greater than 4.5V, so that they are clearly distinguished. Resulting SNR is about 23dB and it leads us to exact measurement.

## Conclusion

In this paper, we come to a conclusion that the vortex flow sensor with two opposite polarized piezoelectric ceramics fixed suitably and adjusting the coefficient $\lambda$ makes it possible to improve SNR up to 90dB and accuracy of flow rate measuring under adverse condition of tube vibration acceleration greater than 1.5g and noise level higher than 90dB.

## References

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