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Pump Cavitation Noise Estimation from Acceleration Signals

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1. Introduction

One of the main causes that lead to the degradation of pump performance is the cavitation erosion damage on an impeller. In order to predict the cavitation erosion damage, the cavitation noise created by bubble collapse should be measured or estimated. The cavitation noise can be measured directly by using pressure sensing devices. However, penetration of pipes or pump casings is inevitable to install the devices. This increases the risk of leaks. In an effort to reduce that risk, a cavitation noise estimation model based on vibration signals has been proposed [1]. In the present study, the applicability of cavitation noise estimation methods including the previously proposed model is investigated.

2. Experimental Methods

2.1Experimental Facility

A closed-loop type flow facility for cavitation experiment was constructed as shown in Fig. 1. Pump flow rates are controlled by a control valve installed downstream of the pump. Cavitation conditions are created by adjusting upstream tank pressure. The pump used for present experiments is a centrifugal radial type.

Fig. 1. Flow loop for cavitation experiment

2.2 Estimation of Cavitation Noise

In order to measure signals necessary for assessing the cavitation noise, one dynamic pressure sensor and five accelerometers were installed as shown in Fig. 2. The effective measurement range of the pressure sensor is 500psi. On the other hand, the effective frequency range of accelerometers is 1 Hz to 20 KHz.

The pressure and acceleration signals are sampled at the same sampling rate and filtered with the same cut-off frequency. Each filtered signal is averaged for 10 seconds to calculate an RMS value for each NPSH (Net Positive Suction Head). The RMS values calculated from acceleration signals are converted to the cavitation noise by the formula derived from the statistical energy analysis theory [2].

It is known that the cavitation noise generated from collapsing of small bubbles occupies the high frequency region over 1kHz of the sound spectrum. To capture only the cavitation noise, high pass filtering is generally applied. However, flow or mechanical noises cannot be fully removed even though high pass filtering is applied. For this reason, the background noise left in the high pass filtered signal is removed again by using a quadratic relationship.

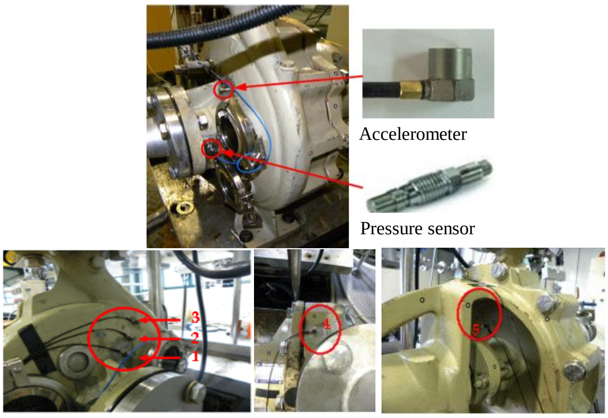

Fig. 2. Installation locations of sensors

3. Experimental Results

Figure 3 shows the relation between NPSH and two measurement variables, the cavitation noise and dynamic head. At a high NPSH condition, no evidence of cavitation is found in the figure. As NPSH gradually decreases, the acoustic cavitation inception is observed at around NPSH=35m. At this point, the difference between the cavitation noise and the background noise starts to increase due to the occurrence and collapse of cavitation bubbles. As NPSH is lowered more, the cavitation noise goes up to the peak point rapidly and afterward drops sharply. The rapid drop of the cavitation noise from the peak is attributed to the increase of cavitation bubbles and air dissociated from the water. The cavitation noise is partly absorbed in the two phase fluid.

The cavitation noise estimates from the five accelerometers are compared with the cavitation noise signals measured by the pressure sensor in Figs. 4 and 5. Figure 4 shows the cavitation noise signals in which the cut-off frequency for the high pass filtering is set to 1 kHz. A good agreement is found between the cavitation noise estimates from accelerometers and the pressure sensor signal from the NPSH=35m to 15m. However, the cavitation noise estimates from accelerometers are less than the cavitation noise from a pressure sensor in the region between NPSH=15m and 7m. This fact can be explained by the theory of the statistical energy analysis. As cavitation becomes stronger, the two phase fluid covers more and more the inside of the pump. In accordance with increasing the void fraction, the density and the sound speed of the fluid change. Since the effect of the sound speed change is more dominant, the cavitation noise from the acceleration signals is under-predicted. When NPSH is less than 7m, the cavitation noise obtained from the pressure sensor is smaller than the estimates from the accelerometers. In this region, cavitation bubbles are merged and the irregular motion of the bubble lumps results in the increase of the pump casing vibration. Therefore, the cavitation noise from the acceleration signals is overestimated.

From Fig. 4, two facts can be observed. The values of cavitation noise estimation from accelerometers significantly vary with accelerometer positions. The cavitation inception points predicted by acceleration signals almost coincide with that measured by pressure signal. This suggests that the acoustic cavitation inception point can be detected by acceleration signals with high accuracy.

Figure 5 depicts the case where the cut-off frequency is 10 kHz. Compared with Figs. 4 and 5, it is found that the influence of the cut-off frequency for the high pass filtering is noticeable for the cavitation noise obtained from the pressure sensor. In the case of the 10 kHz cut-off frequency, the cavitation noise estimates from acceleration signals are not reduced as much as the cavtation noise obtained from the pressure signal. This is presumed that the significant amount of high frequency vibration contents attributable to cavitation exist even after the high pass filtering. From the observations of Figs. 4 and 5, it should be mentioned that an appropriate cut-off frequency of high pass filtering is important for acceleration signals to estimate the cavitation noise accurately.

4. Conclusions

In order to assess the severity of cavitation, the cavitation noise estimation is necessary. In the present study, the cavitation noise is estimated by using acceleration signals measured outside of pumps and the theory of the statistical energy analysis. The applicability and limit of the cavitation noise estimation from the acceleration signals are examined by comparing the cavitation noise obtained from the pressure signal. The results suggest that the acoustic cavitation inception can be detected by the cavitation noise estimation from acceleration signals. The accuracy of the cavitation noise estimates is highly dependent on the locations of the pump casing that accelerometers attached on and the cut-off frequency of high pass filtering.

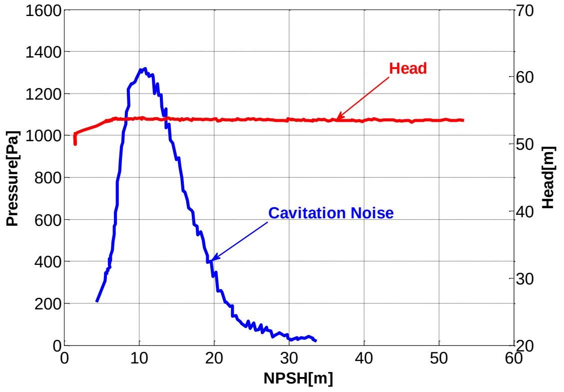

Fig. 3. Cavitation noise and dynamic head

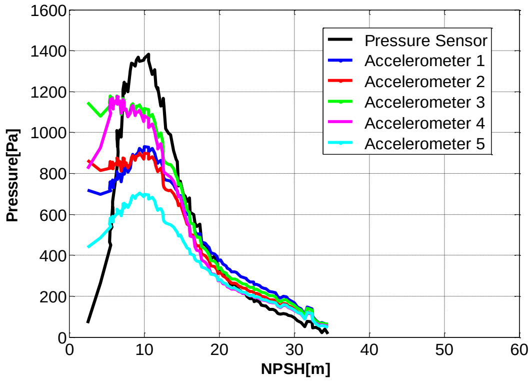

Fig. 4. Cavitation noise estimates at 1 kHz high pass filtering

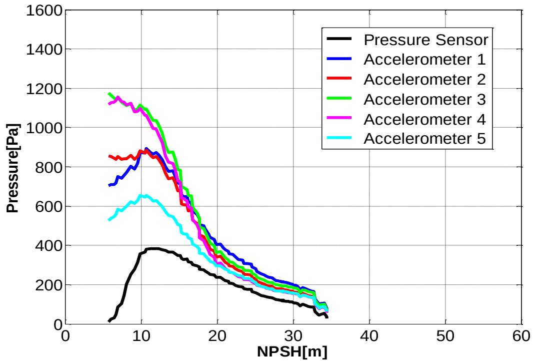

Fig. 5. Cavitation noise estimates at 10 kHz high pass filtering

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