Analysis of performance variation with cavitation test for a mixed-flow pump

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Abstract. Cavitation phenomenon affects the reduction in performance of the pump, as it exerts significant damage to the impeller of the pump. The user should avoid driving this phenomenon and the criterion is set as NPSHa. Along with the cavitation phenomenon, noise and vibration can occur, which can predict cavitation. This study analyzed the characteristics of vibration emitted when cavitation occurred using the accelerometers.

1. Introduction

Cavitation phenomenon in pumps appears where the pressure at a point is lower than the saturated vapour pressure, resulting in forming a void. These bubbles collapse with increasing pressure and result in generating the shock waves. The shock waves cause damage to the impeller and also adversely affect the performance of the pump.

Net positive indented suction head (NPSH) is a standard for which pump can operate safely without cavitation. Usually required NPSH (NPSHr) is determined when the head of pump has dropped by 3% at a constant rotational speed and flow rate. To avoid cavitation phenomenon, available NPSH (NPSHa) should be over 30% of NPSHr.

Observing noise and vibration is also other method to measure cavitation. Jan et al. [1] tested the suction performance at different flow rate and measured the cavitation noise in centrifugal pumps. In this paper, the mixed-flow pump was tested to check suction performance, and vibrations were monitored by a three-axis accelerometer during the suction testing.

2. Experiment

Pump experimental facility consists of closed-loop arrangement which satisfies ISO 5198 standard. Absolute static pressures at the inlet were measured upstream at a point which is two times the diameter of inlet flange. Inlet pressures were regulated by vacuum pump and compressor that was connected with tank. Flow rates were measured by magnetic flowmeter with an accuracy of ±0.2%. While keeping the flow rate constant, inlet pressure was reduced gradually using vacuum pump and differential pressure between the inlet and the outlet was measured to calculate head of water.

The three-axis accelerometer was mounted on casing of bearing to observe vibration characteristic of the pump. The accelerometer should be located on solid body for good accuracy, usually on the bearing in the case of pump. Sampling rate of the accelerometer was 1,280 samples/sec and frequency range was 0 Hz to 500 Hz. For real-time FFT acquisition and vibration analysis, IOtech DSA 650u was
used. Because rotating speed was low, it is better to express the vibration as the velocity integrated with the acceleration. Figure 1 shows the schematic view of the test facility and figure 2 shows a location of accelerometer sensor.

![Figure 1. Schematic view of the test facility](image1)

**Figure 1.** Schematic view of the test facility

![Figure 2. Mixed-flow pump and accelerometer location](image2)

**Figure 2.** Mixed-flow pump and accelerometer location

3. Test target pump
The test target pump is one of the series pump being developed [2]. We have considered about hydraulic efficiency and suction performance and this test pump was developed for suction performance. Table 1 shows that specifications of the test pump.

| Item                  | Unit     | Value |
|-----------------------|----------|-------|
| Specific speed (Ns)   | rpm, m³/min, m | 1000  |
| Flow rate             | m³/min   | 8     |
| Total head            | m        | 12.9  |
| Rotating speed        | rpm      | 2400  |

Table 1. Specifications of test target pump

4. Results
Figure 3 shows the distribution of vibrations about three-axis and total head drop at design flow rate. This vibration magnitude was calculated by summing up all velocity of frequency range per each axis. Among the three-axis, the largest vibration magnitude was in the vertical direction component and the least was axial direction component. For relative comparison of vibration magnitude, the calculated value was normalized by each direction component. While the inlet pressure decreased, the vibration
magnitude of each axis kept increasing gradually until 3% head drop and rapidly decreased after 3% head drop. This phenomenon is known as the rise of cavitation bubble and during pressure drop in pump inlet, part of the noise is absorbed into the two-phase fluid [3].

**Figure 3.** Distribution of total head drop and vibrations at design flow rate
Figure 4. Frequency spectrum of three-axis direction at design flow rate

In frequency spectrum, 1x (1 order, 1st harmonic frequency of rotating speed, 40Hz) showed most prominent value. But each component indicated different trend (figure 4). We can see that the vibration magnitude of 5.82x was increasing with decreasing NPSH in the axial frequency spectrum. And the horizontal direction has not indicated that big vibration magnitude after 2x. In case of vertical direction, there were lots of vibration after 5x. The frequency spectrum result of each axis was not in common, but when vibration velocity of each direction was compared with NPSH at 5.82x, we can express like figure 5. Before cavitation region, vibrations of three-axis direction were rarely seen. As the inlet pressure dropped, the total head of water decreased, and the magnitude of vibration increased sharply.
Figure 5. Variation of vibration velocity according to NPSH at 5.82x

5. Conclusion
The vibrations were measured using three-axis accelerometer with NPSH test. At the design flow rate, the total vibration magnitude of each axis direction was increased smoothly and decreased after starting the head of water drop, but the vibration of each axis has different trend in the frequency spectrum. In case of the 5.82x in the spectrum, especially the variation of axial vibration was obviously appeared. These vibrations could be defined to occur by cavitation. Thus it can be possible to predict cavitation by analyzing occurred phenomenon in particular spectrum.

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