A Study on Cavitation Detection of Centrifugal Pumps

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1. Introduction

Research for on-line diagnosis technical development to monitor performance deterioration of centrifugal pump which was installed at nuclear power plant is performing at KEPRI. As a part of research, we are investigating the pump performance deterioration caused by cavitation. It is well known that cavitation decreased the pump performance due to the hindrance of impeller passage and damaged both impeller and casing wall [1]. And also some of researchers reported that pump failures were mainly caused by acoustic emission (AE) generated by bubble collapse and high amplitude pressure pulse [2]. Accordingly, a series of tests have been carried out on a 11kW single stage centrifugal pump, acquiring various signals. We examined feature of AE RMS signal by cavitation. And we also confirmed the detection feasibility of pump performance variation from the signals measured by various sensors.

2. Methods and Results

2.1 Equipment Set-up

A series of tests were carried out on a single stage volute centrifugal pump and detailed specifications were following;

Table I: Pump Specification

Total head	45 m
Motor speed	1760 rpm
Motor power	11 kW
Impeller type	Radial Closed

Figure 1. shows the experimental apparatus for pump performance test. Vacuum pump was connected with the top of water tank in order to take place the cavitation in pump by adjusting the pump suction pressure (2.5 ~ -0.1kgf/cm^2). And control valve was installed at common pipe of pump discharge downstream to adjust fluid flow.

Pressure transmitters with uncertainty ±0.2% F.S. were placed on the suction and discharge pipe. Electronic flow meter with uncertainty ±0.5% Reading was connected with the pipeline near the water tank. Encoder and torque sensor were placed on the motor. Pressure and flow rate were converted into digital signal by the NI-6233 Card and then sampling frequency was set 10Hz.

For AE detection of high frequency level occurred by cavitation within the impeller, commercial PZT acoustic emission sensors (PAC D9241A) were placed on the pump casing and inlet pipe at about 0.15m from the pump. Sensor operating range is 20~180kHz and resonant frequency is 30kHz. Each sensor was linked via a pre-amplifier, which was set at an amplification of 40dB, to a signal conditioning units. Acoustic emission signal was converted into digital signal by the PXI-4496 Card (24bit) which maximum sampling frequency per channel is 204kHz and then sampling frequency was set 180kHz.

Fig. 1 Experimental Setup for Pump Performance Test

2.2 Test Results

For two fixed flow rate conditions (0.4, 0.5 m^3/min), tests were performed by varying pump suction pressure. For AE RMS value, raw signal acquired from AE sensor was filtered to 30kHz by using the digital high pass filter and then RMS value was calculated with the time-averaged method with interval 0.1sec. From suction and discharge pressure signal, we confirmed that pump suction pressure was normally controlled by vacuum pump.

Figure 2. shows that RMS value on the pump casing at each of flow rate as NPSH is reduced. At around 10~12m, some features are verified that RMS value is significantly increased as the inception is reached [2].

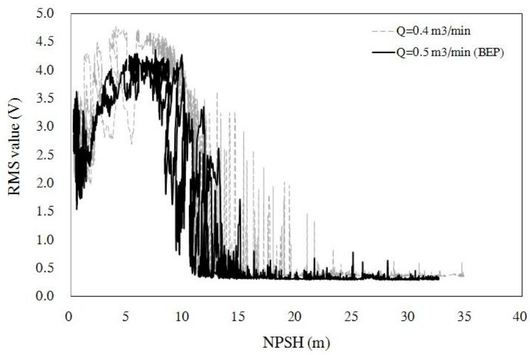

Fig. 2 Variation of RMS value with NPSH on the pump casing at flow rate of 0.4, 0.5 m^3/min

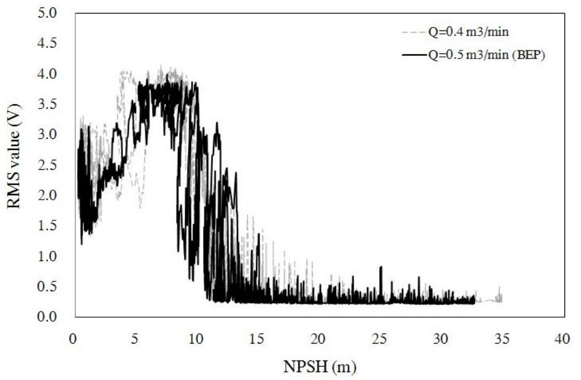

Fig. 3 Variation of RMS value with NPSH on the suction pipe at flow rate of 0.4, 0.5 m^3/min

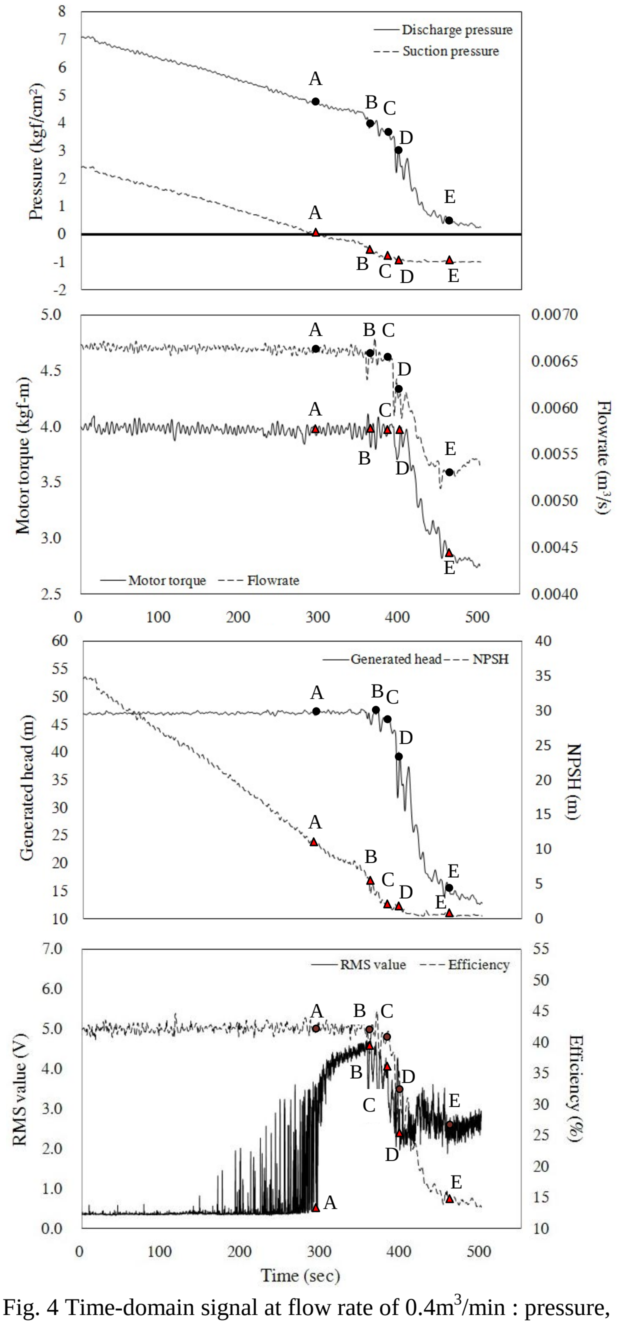

Fig. 4 Time-domain signal at flow rate of $0.4m^3$/min : pressure, motor torque, flow rate, head, NPSH, RMS value, efficiency

And also further reduction in the NPSH (under about 5m) shows a decrease in the amplitude of RMS value. It has already been indicated by many researchers that bubble cloud within the impeller attenuated the AE signal prior to reaching the sensor on the wall casing [2]. This variation also appeared similarly at sensor placed on the suction pipe (Fig.3.) but maximum amplitude of RMS at casing wall is higher than at suction pipe. This means that cavitation severity using RMS increase at pump casing was detected stronger than at suction pipe.

Figure 4. show the time-domain signals for detection of pump performance variation as suction pressure is reduced. As "A" is a point that cavitation inception occurs, signals of motor torque and flow rate except AE RMS are constantly maintained. "B" is a point called "$NPSH_0$" that head drop in pump begins. As "C" is a point that pump efficiency reduction begins, motor torque and flow rate also are decreased. As suction pressure is much lowered (Point C-D-E), pump efficiency is suddenly decreased. It is thought to be attributed to the reduction of pump suction capability due to the increase of micro bubble clouds within the flow area of impeller. From these features of signals, we confirmed that variation of pump efficiency can be monitored from the signals (flow rate, pressure) associated with flow characteristics including motor torque [3].

3. Conclusions

The experimental work reported in this paper was oriented towards the identification of both feature of RMS signal variation using the AE sensor and detection feasibility of pump performance variation using the various sensors under the cavitation condition. The main findings are as follows.

1. RMS value calculated from raw signal measured by AE sensor is useful tool to detect the degree of cavitation severity.
2. Results show that sensitivity of cavitation detection depends on the positioning of AE sensor.
3. Signals of flow rate and motor torque can be used to monitor the pump efficiency variation.

REFERENCES

[1] L. Alfayez, D. Mba, G. Dysonl, The application of Acoustic Emission for detecting incipient cavitation and the best efficiency point of a 60kW centrifugal pump; case study, NDT & E international, Vol. 38. p. 344, 2005.
[2] G. D Neill, R. L. Reuben, P. M. Sanford, E. R. Brown, J. A. Steel, Detection of Incipient Cavitation in Pumps Using Acoustic Emission, IMechE, Vol. 211 Part E. p267-277, 1997
[3] S. Al-Sulti, B. Samanta, K.R. Al-Balushi, M. Al-Zedjali, S. A. Al-Araimi, R. A. Siddiqi, Comparison of Signal Processing Techniques for Detecting Pump Cavitation Inception, Proceedings of the 18th International Congress and Exhibition on Condition Monitoring and Diagnostic Engineering Management, p. 183-194, 2005