Mini Review

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A review of cavitation effects on vibration in centrifugal pump

Abstract

When pumps are operating at flow rates considerably lower or higher than normal, intensity of cavitation is likely to be greater than that at the best efficiency point. In particular for high specific speed pumps such as mixed flow and axial flow pumps, various kind of cavitation has been seen and similar cases was reported for low specific speed pump. Cavitation is a local vaporization of liquid induced by a hydrodynamic pressure reduction; it usually disturbs the normal flow field in pumps with various effects. This article will glimpse about the effects of cavitation in centrifugal pump with the help of vibration monitoring system and the technique is suggested to predict the onset of cavitation by means of average magnitude in frequency band, predominant frequencies, and repeatable frequencies.

Keywords: cavitation, vibrations, net positive suction head, centrifugal pump

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Introduction

The cavitation process consists of discrete events: the formation, development and collapses of cavitation bubbles. It must be avoided, or at least brought under control. The accompanying phenomena of cavitation, such as head and flow drops, damage to solid boundary surfaces, noise generation over a wide frequency spectrum, pressure pulsation, and vibration. In high energy process pumps, the forces generated by cavitation as well the internal recirculation can reduce the lives of bearings to few working days or hours. In recent days, the tendency to increase the rotational speeds of new pumps is desired to obtain required head and flow rate. Vibration analysis is used to determine the operating and mechanical condition of equipment. A major advantage is that vibration analysis can identify the problem before they become too serious and cause unscheduled downtime. This can be achieved by conducting regular monitoring of machine vibrations either on continuous basis or at scheduled intervals. Vibration analysis is used primarily on rotating equipment such as steam and gas turbines, pumps, motors, compressors, paper machines, rolling mills, machine tools, and gearboxes. In water pumps, the cavitation would have limited the impeller life due to cavitation erosion to a few hundred hours.

The dynamic pressures will lead to mechanical vibrations and alternating stresses in various pump components, which is called as flow-induced vibration.[1] The basic vibration generating mechanisms for both structure-borne vibration and airborne noise are the same for a sealed pump system.[2–4] The vibration spectra show practically no synchronous vibrations, quite small (<0.1 in/s) vibrations at the blade passing frequency,[5] but considerable variation in broad band frequency ranges between 1000 and 2000 Hz for double suction crude oil pump. Tan et al.,[6] predicted that the high frequency random vibration was shown to be a good indicator for flow induced vibrations and cavitation detection. Experiments have shown that the characteristic discrete frequency tone, which is in close correlation with the cavitation process,[7] is a result of structural vibrations (modes) or resonances caused by implosion of bubbles and bombardment of the inner surfaces of the pump.[8] The trend of using variable speed drives in the pumping stations increases the necessity of applying predictive maintenance and periodic inspection as vibration level increases with increasing speed as well with increasing excitation forces. Nasiri et al.,[9] established the method of neural network system for vibration analysis to detect cavitation in centrifugal pump and found to be more useful. Condition monitoring of a mono block centrifugal is carried out using vibration signals and the statistical features are extracted,[10] which helps in reducing the maintenance overheads. With the expansion in internet based technologies,[11] the procedure for condition monitoring were made simple for remote locations and were continuously recorded and observed for any abnormalities in machines. Similar to advancement in condition monitoring systems,[12] computation fluid dynamics (CFD) helps to predict the onset of cavitation in marine propeller in simpler way than the experimental methods.[13] The maximum fluctuation can be found at the blade trailing edge near the blade pressure side for every flow channel under the part load condition, which results in vibration.[14] At high flow rates the structure vibration of cavitation phenomena in the centrifugal pump are different from those at low flow rates.

The vibration frequency in each monitoring point occurred mainly in the shaft, multiple shaft and the dominant frequencies.[15] The frequency spectra of vibration signals of cavitation are used to analyse cavitation phenomenon and to obtain a critical NPSH (Net Positive Suction Head) using the average magnitude in frequency band, predominant frequencies, and repeatable frequencies. Noise and vibration signals were better parameters to sense the occurrence of cavitation than the 3% head drop based on NPSH value obtained irrespective of all flow rates, speeds and the choice of leading edges.[16] It is seen from this study that cavitation occurs long before the performance characteristics is affected (i.e. much before 3% head drop) and likely to have peak of the cavitation vibration curve, and thus to the point where cavitation erosion is most likely.[17] Figure 1 shows the cavitation characteristics of centrifugal pump (low metric specific speed pump of 23) at 1500 rpm for three flow rates (80%, 100%, and 120%) along with the vibration curve for 992 Hz frequency (repeated frequency) with reference to NPSH (in X-axis). NPSH is defined as the difference between energy at the suction side of pump and the vapour energy corresponding to the temperature of water. It is inferred that the trend of vibration changes for reduction in NPSH (Net Positive Suction Head) with respect nominal flow rate. The head drop for 3% is drawn in the cavitation curve to get the idea of cavitation effects with reference to vibration signal.

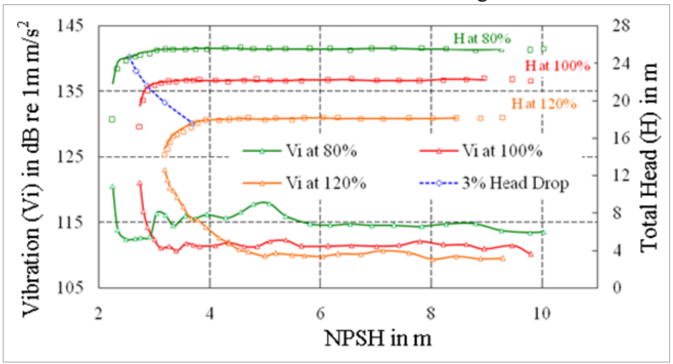

Figure 1 Cavitation characteristics of centrifugal pump at 1500 rpm for three flow rates.

Conclusion

In this work, vibration is used as a monitoring device for detection of abnormalities in pump. Vibration predicts better than the performance drop such as 0.5%, 3% and so on. Analysis of vibration during cavitation test will be performed through the entire frequency band and it is suggested that, out of different vibration frequencies, repeatable frequency is far better than the predominant frequencies and the average magnitude between the frequency bands. This enables the pump user to use as a monitoring device to find out the abnormalities in pump during running condition. So, it is necessary to identify the repeatable frequency for any test rig of pump after commissioning of set into normal operation.

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Conflict of interest

Author declares there is no conflict of interest in publishing the article.

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