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Investigation of Cavitation in a Centrifugal Pump Using Synchronized Pump Head Measurements, Vibration Measurements and High-Speed Image Recording

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Abstract : It is a challenge to directly monitor cavitation in a pump application during operation because of a lack of visual access to validate the presence of cavitation and its form of appearance. In this work, experimental investigations are carried out in an inline single-stage centrifugal pump with optical access. Hence, it gives the opportunity to enhance the value of CFD tools and standard cavitation measurements. Experiments are conducted using two impellers running in the same volute at 3000 rpm and the same flow rate. One of the impellers used is optimized for lower $NPSH_3$% by its blade design, whereas the other one is manufactured using a standard casting method. The cavitation is detected by pump performance measurements, vibration measurements and high-speed image recordings. The head drop and the pump casing vibration caused by cavitation are correlated with the visual appearance of the cavitation. The vibration data is recorded in an axial direction of the impeller using accelerometers recording at a sample rate of 131 kHz. The vibration frequency domain data (up to 20 kHz) and the time domain data are analyzed as well as the root mean square values. The high-speed recordings, focusing on the impeller suction side, are taken at 10,240 fps to provide insight into the flow patterns and the cavitation behavior in the rotating impeller. The videos are synchronized with the vibration time signals by a trigger signal. A clear correlation between cloud collapses and abrupt peaks in the vibration signal can be observed. The vibration peaks clearly indicate cavitation, especially at higher NPSHA values where the hydraulic performance is not affected. It is also observed that below a certain NPSHA value, the cavitation started in the inlet bend of the pump. Above this value, cavitation occurs exclusively on the impeller blades. The impeller optimized for $NPSH_3$% does show a lower $NPSH_3$% than the standard impeller, but the head drop starts at a higher NPSHA value and is more gradual. Instabilities in the head drop curve of the optimized impeller were observed in addition to a higher vibration level. Furthermore, the cavitation clouds on the suction side appear more unsteady when using the optimized impeller. The shape and location of the cavitation are compared to 3D fluid flow simulations. The simulation results are in good agreement with the experimental investigations. In conclusion, these investigations attempt to give a more holistic view on the appearance of cavitation by comparing the head drop, vibration spectral data, vibration time signals, image recordings and simulation results. Data indicates that a criterion for cavitation detection could be derived from the vibration time-domain measurements, which requires further investigation. Usually, spectral data is used to analyze cavitation, but these investigations indicate that the time domain could be more appropriate for some applications.

Keywords : cavitation, centrifugal pump, head drop, high-speed image recordings, pump vibration
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