

Quantifying Cavitation

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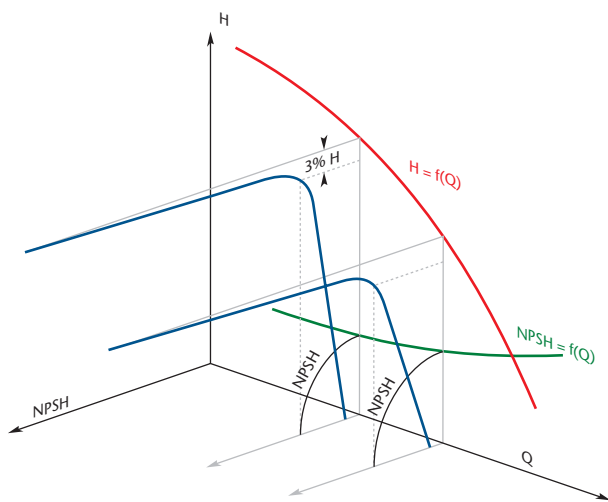
CAVITATION IS ONE OF THE MOST IMPORTANT CHALLENGES for pump manufacturers and end users, because it causes both erosion and vibration. It occurs when the local pressure drops below the vapor pressure of the liquid, causing boiling to occur. Depending on the local conditions, the vapor bubbles can block the flow and collapse, sending shock waves through the liquid and causing damage to the surrounding components in a relatively short time.

One parameter that is used to quantify the cavitation characteristic of a pump is the net positive suction head, or NPSH. This quantity is the difference between the total absolute pressure of the liquid and the vapor pressure of the liquid. It is typically expressed in units of head (meters or feet, for example). There are two variants. When the total absolute pressure is measured at the pump inlet, the quantity is called the net positive suction head available, or NPSHA. When it corresponds to the minimum NPSH the pump can withstand without cavitating, the quantity is called the net positive suction head required, or NPSHR.

If NPSHA is lower than NPSHR, then cavitation occurs. Different types of cavitation characteristics exist depending on the bubble length, noise, material loss or the drop of the pump head.

NPSH specifications are often used to determine the depth of the sump in multi-stage vertical turbine pumps and the installation depth of geothermal pumps. Multi-stage pumps such as these are used for irrigation and industrial applications as well. By increasing the number of stages, the pump head can be increased. Cavitation causing a 3% drop in pump head (called NPSH3) is commonly used for vertical turbine pump installations.

In a recent study, a vertical turbine pump having 95 l/s capacity and 13.5 mwc (meters water column) head at 1450 rpm was simulated using FLUENT to determine a value for the NPSHR. A mesh of



Schematic view showing how the NPSHR curve is built from the standard H vs. Q curve using data obtained from experiments. At a given inlet flowrate (Q), the head rise (H) will be constant provided the inlet pressure (NPSH) is sufficiently high. As NPSH drops, cavitation begins and the head rise eventually goes down

approximately 1.85 million cells was generated using GAMBIT. The cavitation model was used with water as the primary phase and water vapor as the secondary phase. The k-ε model was used for turbulence and the multiple reference frames (MRF) model was used to account for the motion of the rotor in the presence of the stationary stator and housing.

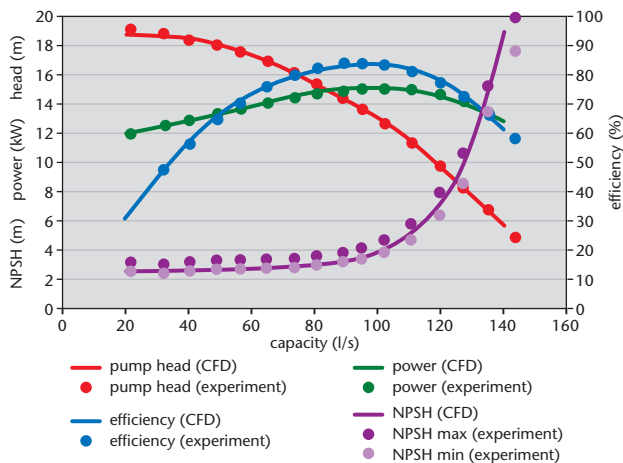
Several simulations were performed using mass flow inlet and pressure outlet boundary conditions to generate the pump characteristic curves. This choice of inlet condition fixes the flowrate, allowing the inlet pressure (and head rise across the stage) to be predicted as a result of the analysis. The predicted pressures were then compared with the stage head near cavitation at the same flow rate.

A series of simulations was performed to determine NPSHR – the required pressure above which non-cavitating operation will occur. To do so, the NPSHR was initialized as the inlet pressure that corresponds to the pump operating at a head that is 3% below the non-cavitating head. At this point, some cavitation is probably occurring, but not enough to negatively impact the pump operation. The first simulation was performed at the maximum inlet pressure (high NPSH) and the pumping capacity (flow rate, Q) was recorded. For the same capacity, the inlet pressure (NPSH value) was then decreased until the stage pressure difference dropped 3% below the stage head, H. The inlet friction losses and the vapor pressure at the duty temperature were added to the inlet pressure and the NPSHR value was calculated.

As the inlet pressure was decreased further, a cavitation region developed and sudden drops in the efficiency and power curves were recorded. The NPSHR characteristic curve for a 3% head drop was obtained by repeating the same method for various mass flow rates. Power, head, and efficiency NPSHR curves were obtained in this manner and were compared with the test results. The characteristic curves were found to be in good agreement, especially near the best efficiency point. The results suggest that the NPSHR curve can be determined using CFD rather than the traditional experimental method. ■

Suggested Reading

- 1 Europump, 1999: NPSH for Rotodynamic Pumps: A Reference Guide.
- 2 Deger, T.: The investigation of the effects of pump inlet conditions to cavitation by experiments and using the finite volume method. Ege University, Master Thesis (Supervisor: Assoc Prof. Dr. Aydogan Ozdamar), Izmir, 2005.



Comparison of the experimental pump test curves with the CFD results



Iso-surfaces of water vapor for a pump operating with developing cavitation