Numerical Simulation of the Flow in an Axial Water-Jet Pump using Scale-Resolving Method

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ABSTRACT

In high-speed vessels, water-jet propulsion systems are mostly used as they can deliver a higher efficiency at high velocities compared to conventional propellers and their designs provide options for better maneuverability of the vessel. A typical water-jet system consists of an intake channel, a pump, and a nozzle. The water flow is ingested into the intake channel and it passes through the pump where its total head increases. The flow then enters the nozzle and is discharged into ambient flow behind the vessel. Although the performance of the water-jet system depends on the flow in all three components, the flow in the water-jet pump plays a major role in the overall performance of the system and has been a subject of both numerical and experimental studies due to its complexity.

A set of experimental studies has been devoted to investigate the flow in water-jet pumps. These studies have mainly focused on the flow in the tip leakage region, i.e. a region between the impeller blade tip and the shroud casing. As an example, Wu et al. [2011] studied the flow structures and turbulence in the tip leakage region using Stereo Particle Image Velocimetry measurements and provide a detailed analysis on the formation of the Tip Leakage Vortex (TLV). However, there are only a limited number of papers where numerical simulation has been used to study the flow field inside water-jet pumps. Zhang et al. [2015] numerically studied the effect of flow rate on the flow field in tip leakage region using Reynolds−averaged Navier−Stokes (RANS) approach. Their results showed that changes in the flow rate leads to the variation of blade loading and a pressure difference between the pressure side and suction side at the tip which in turn result in changes in the starting point and the trajectory of TLV. Both numerical and experimental studies show that the flow inside the water jet pumps, especially inside the tip gap, is highly unsteady and anisotropic and is controlled by several interacting shear layers. Capturing this unsteadiness and the dynamics of these shear layers requires a scale-resolving approach, such as hybrid RANS/LES (HRLES).

In this paper, numerical simulations of the axial water-jet pump, AxWJ-2 [Michael et al., 2008], using a scale-resolving approach are presented. The simulations are performed on three different mesh resolutions and the predicted performance is compared with the experimental data available in Tan et al. [2015]. Then, the flow field in the gap region and the dynamics of the tip leakage vortex captured by the simulations are compared with the experimental data.

References

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