Numerical Prediction of Unsteady Turbulent Flow and Pressure Fluctuation in an Axial-flow Pump by LES

Guohui Cong*, Fujun Wang and Ling Zhang

College of Water Conservancy & Civil Engineering
China Agriculture University, Beijing, 100083 China
E-mail: andycong@126.com

Key Words: axial-flow pump; Large Eddy Simulation; CFD

ABSTRACT

Axial-flow pump has high flow rate, low pressure head, and simple structure, so it is widely used in various fields to pump large volumes of water against low pressure head, such as irrigation, city water supply and drainage, water transfer project and so on. In China, the construction of South-to-North Water Transfer Project, which is the biggest water supply project through the whole country, needs a number of axial-flow pumps for water transfer. Hydraulic pressure fluctuation is one of the hot problems in axial-flow pump research, and it has been the main objective of many previous investigations. [1]

In this study, three dimensional Large Eddy Simulation (LES) is implemented to predict the unsteady turbulent flow and pressure fluctuation in an axial-flow pump. The governing equations employed for LES are obtained by filtering the time-dependent Navier-Stokes equations in either Fourier (wave-number) space or configuration (physical) space. The filtering process effectively filters out of eddies whose scales are smaller than the filter width or grid spacing used in the computations. Smagorisky-Lilly Subgrid-Scale (SGS) model[2] is taken as the turbulent eddy model for LES. The near wall treatment is assumed that the centroid of the wall-adjacent cell falls within the logarithmic region of the boundary layer. And the calculation is carried out with FLUENT 6.2, which is a commercial CFD code.

The rotor of the axial-flow pump is equipped with 6 blades, and the guide vane consists of 11 blades. The diameter of impeller is 300 mm, the diameter of hub is 75 mm, and the diameter of pump outlet is 350 mm. The rotor has a rotational speed of 1450 rpm. The specific speed of the axial-flow pump is 518.

An unstructured grid model is employed for the numerical simulation, and the sliding mesh methodology is applied at the interface of the rotating domain and the stationary domain.

A velocity-inlet condition is set as the boundary condition on pump inlet, a out-flow condition

is used to set the boundary condition at pump outlet, and all the physical surfaces of the pump are set as wall boundary conditions. A finite volume method which is applied on an unstructured mesh is used for discretization of the governing equations. The collocated arrangement is utilized for all primitive variables. The bounded central differencing scheme is used for the convective terms while the Euler implicit scheme is used for time advancement. The coupling between the velocities and the pressure is dealt with the PISO algorithm. The time step size is 0.0001s and each revolution of the impeller takes 413 time steps.

In this research, different calculated flow rates which are Q/Q_d = 0.7, 0.8, 0.9, 1.0 and 1.1 are simulated, where Q_d is the design point. The predicted total head and pump efficiency are compared with the experimental data, and the pressure fluctuation prediction is also carried out.

The results show that the heads created by the pump are well predicted and result in a close agreement with experimental data. At most calculation points, pump head is slightly over predicted. The predicted efficiency is also close to the experimental results at low flow rate, but a little lower in the high flow rate. The monitor points for pressure fluctuation prediction are between the rotator and guide vane. When at the optimum flow rate, the pressure fluctuation has good periodicity in nature. When at the 70% of optimum flow rate, pressure fluctuation has a reasonable change compared with the status at optimum flow rate.

REFERENCES

[1] Wang Fujun. CFD Analysis Of Axial-flow Pump Using Multiple Rotating Frames. 8TH Asian International Fluid Machinery Conference, 2005, 566~573.

[2] J. Smagorinsky. General Circulation Experiments with the Primitive Equations. I. The Basic Experiment. Month. Wea. Rev., 91:99-164, 1963.