Unsteady Flow and Pressure Pulse Characteristics Analysis of Rotating Stall in Centrifugal Pumps under Off Design Conditions

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Long Abstract

Introduction

Pump, an important machinery in industrial production, is widely used in many kinds of fields. Unsteady flow phenomena like rotating stall can occur in centrifugal pumps under off design conditions. Rotating stall can lead to flow instabilities and unsteady pressure pulsation, which affect normal operation of pumps.

Rotating stall flow structure in pumps needs to be completely researched by both numerical and experimental methods. Sinha [1] described rotating stall occurred at the exit part of a centrifugal pump with vanned diffusers, which is detected by PIV measurements. Yuan [2] investigated broadband noise caused by rotating stall in a centrifugal pump under the low flow rate condition though frequency analysis. Lucius [3] argued rotating stall can excite structural vibrations in pumps by numerical simulations. Despite those studies, the mechanics of rotating stall has not been sufficiently understood in previous researches. This paper simulates flow characteristics in a centrifugal pump by CFD technology, analyzes pressure pulsation caused by rotating stall and explores origin and propagation mechanism of rotating stall.

1. Methods

Large eddy simulation (LES) is rapidly developed for the past few years. LES is able to accurately describe the feature of asymmetric flow in contrast to traditional RANS method. Byskov [4] used LES method to calculate a shrouded six-bladed centrifugal pump and demonstrated that velocities predicted by LES matched perfectly to the experiment data. Tokyay [5] validated a developed LES model can capture details of unsteady flow structure. In the current study, LES calculations are performed to model the unsteady flow within the entire flow passage of a centrifugal pump with clearance under $0.2Q_{BEP}$ - $0.6Q_{BEP}$ working conditions.

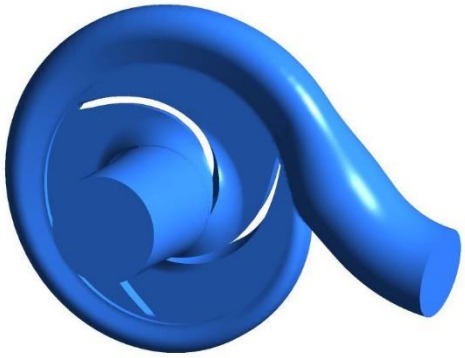

Figure 1. Computational domains

This paper simulates a centrifugal pump at rotational speed of 1450 rpm, nominal flow rate of 200 m^3/h and designed head of 32 m. The gap between blades and front and back cover boards is considered. Computational domains are showed in figure 1, including volute, impeller and pump inlet. Structure mesh cells generated by ANSYS ICEM are utilized in this pump model. Cells near the solid wall are densities to capture the flow structure precisely. Monitoring points are set in every channels in the rotating impeller and volute to record signals of pressure pulsation. Simulations are done with the ANSYS FLUENT 15.

This study analyzes flow characteristics, especially the clearance flow behavior, at the stage in which stall occurs in detail, investigates pressure pulsation in the flow passage, and summarizes propagation rules of low-frequency pressure pulsation through the whole flow passage. Flow characteristics research finds the operation condition when rotating stall occurs and the location and propagation of stall cells, explores how relative position between blades and volute tongue affects the discrepancy on rotating stall locations in each blade channel. In pressure pulsation analysis, rotating stall frequencies and amplitudes are presented in pressure spectrum to investigate mechanism of fluctuating pressure propagation along the whole flow passage.

References

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