Investigation on the transient characteristics of the pump system using MOC-CFD coupled method

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Long Abstract

Introduction

The security and stability of the pump system have received extensive attention in hydraulic engineering, especially in nuclear system. Transient operations, such as the rapid closure of a valve, a sudden switch over and start procedure of pumps and pump failure will cause sudden flow variation in the pipe system. This phenomenon, known as water hammer, will cause transient effects on the pump. So it is essential to study the transient characteristics of pump during the hydraulic transition process.

Up to now, one dimensional MOC (Method of Characteristic) and three dimensional CFD (Computational Fluid Dynamics) analyses have been two relatively independent ''modeling cultures''. MOC is commonly used in solving the hydraulic transients in pipe and giving important information at system levels[1][2]. CFD is increasingly being used to capture complex local 3D features inside the fluid machinery[3]. During the traditional analysis, when analyzing transient characteristics of the system, the pump is often described by a simple one-dimensional(1D) model, and when analyzing transient characteristics of the pump, a three-dimensional(3D) independent analysis is done for the pump without considering the outer pipe system. Therefore, it is difficult to get the pump transient characteristics in the transient events and the pump transient effects on system characteristic. That is to say, it failed to fully consider the interaction of pump and system. However, the two simulations methods are to be seen as complementary. Thus, a multi-scale modeling approach, namely MOC-CFD, can be proposed by combining both models together to utilize the strengths of both approaches.

1. Methods

The dynamic interaction between pump and system are closely related with the safety and the operating stability of the whole system[4]. In this paper, the MOC-CFD coupled method was proposed and developed to study the interaction.

The basic idea of the MOC-CFD coupling is to divide one complex computational domain into two parts according to the flow patterns. The CFD code is used to model the regions where 3D effects are important, while the MOC code is mainly used to model all those regions where the flow is expected to remain largely 1D. And the boundary conditions (flow rate and pressure) at the interface are transferred back and forth between the two code systems.As for the pumping system, the coupled model is shown in Figure 1.

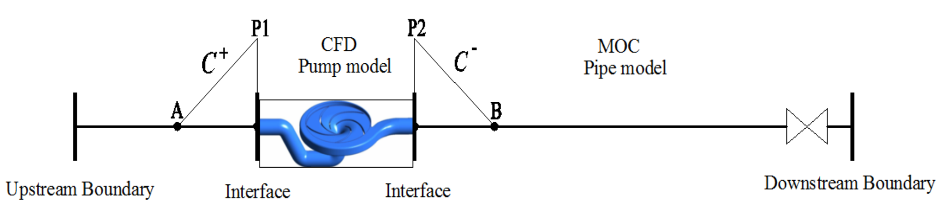

Figure 1. The schematic diagram of a coupled model

The coupled method can save computing resources and time when simulating the whole system with a single CFD model and avoid imposing approximated boundary conditions to the separate analysis of individual components, and avoids using inaccurate model when analyzing the whole system with MOC calculation, which cannot also provide detailed flow information.

In this paper, a typical pump-pipeline-valve system was designed and built, and the valve is rapidly closed and opened to achieve a rapid change in operating conditions. To highlight the influence of fluid acceleration when a water hammer occurs, the dynamic behavior obtained through MOC-CFD cosimulation was comparatively analysed with the corresponding results using the pure MOC. The research contents and conclusions have a guiding significance for the transient analysis of complex pumping system, and provide references for the analysis on the transient characteristics of the nuclear system.

References

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