One Dimensional Analysis Method for Cavitation Instabilities of a Rotating Machinery

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Long Abstract

Introduction

Rotating cavitation is one of the important problems to design the reliable rotating machine. Theoretical and numerical analyses (2-D, 3-D) of rotating cavitation have been performed to explain the instability mechanism [1][2]. On the other hand, the analysis method of pump dynamic characteristics by cavitation compliance, mass-flow gain factor and dynamic gain has been used to evaluate the 1-D phenomena such as cavitation surge. For example, POGO oscillation caused by an interaction between the structural and the propulsion system has been analyzed by this method [3].

In the present study, simple analysis method was tried to evaluate the cavitation instabilities of a rotating machinery by using the 1-D system analysis software. Cavitation compliance and mass-flow gain factor are divided and distributed in each flow path of the inducer. The variation of leakage flow rate through the tip clearances of each inducer blade is simulated by the motion of variable flow area orifice.

Analysis results show that there exist cavitation instabilities including rotating phenomena. With this analysis model, effects of various parameters on the eigenvalues of the system were investigated.

1. Methods

1-D system analysis software, AMESim is used. In this software, function submodels of fluid systems and signal systems are connected with pipes and wires to model actual systems. Figure 1 shows schematic diagram of the system analysis model. Three-bladed inducer for a rocket hydrogen turbopump installed in a testing feed line system. It is supposed that rotating cavitation is caused by the characteristics of fluid motion among the flow paths divided by the inducer blades. This model seems as if three pumps are installed in parallel.

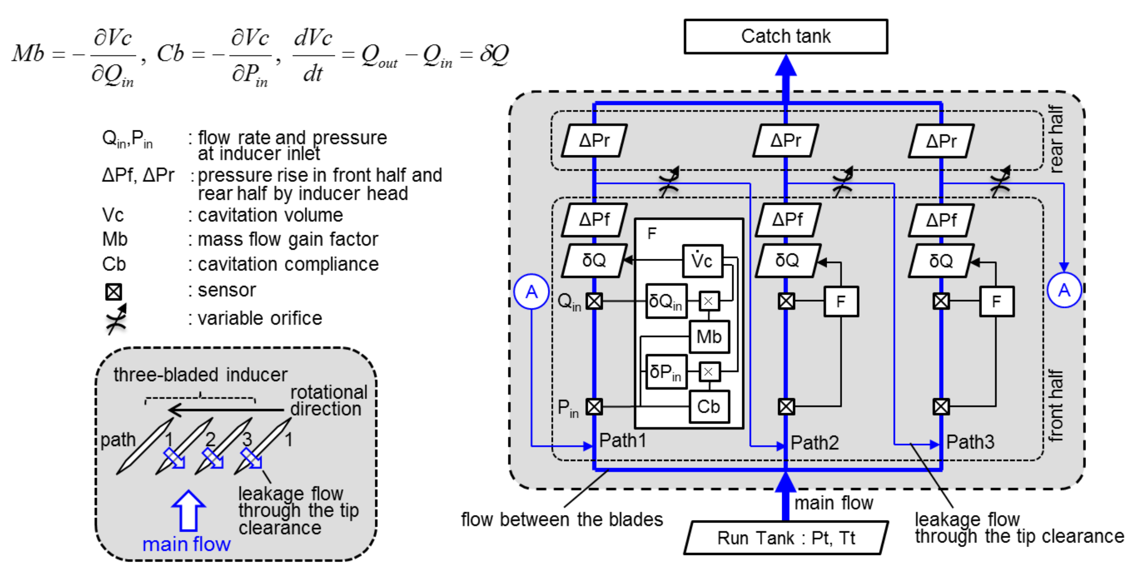

Figure 1. Analysis model

Each flow path is divided into front and rear half. Cavitation compliance and mass flow gain factor are divided by the number of inducer blades and distributed equally in the front half of the three paths. Cavitation compliance and mass flow gain factor are given by the results obtained in the past experiments.

Leakage flow through tip clearance of inducer is described by variable flow area orifice connecting the middle of each path and the inlet of the next path. Figure 2 shows tip clearance variation caused by whirl motion of inducer. In this analysis model, the flow area of variable orifice in each path varies in sequence corresponding to the whirl motion.

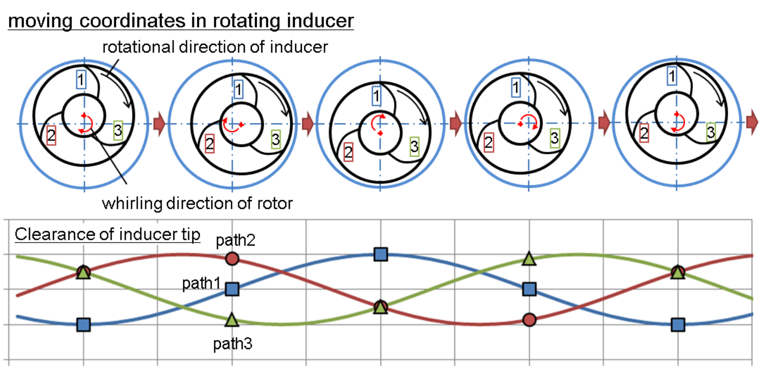

Figure 2. Whirl motion of inducer

2. Results

Figure 3 shows calculated eigenvalues of the system shown in Fig. 1 on the complex plane. Oval shape lines show iso-frequency lines and radial lines show iso-damping ratio lines. Tank pressure was varied from 0.60 MPa to 0.25 MPa parametrically. The eigenvalues designated by symbol A, B and C were determined to be super-synchronous rotating cavitation, sub-synchronous rotating cavitation and cavitation surge respectively. These types of cavitation instabilities were determined by modal analysis of the pressure at each flow path inlet.

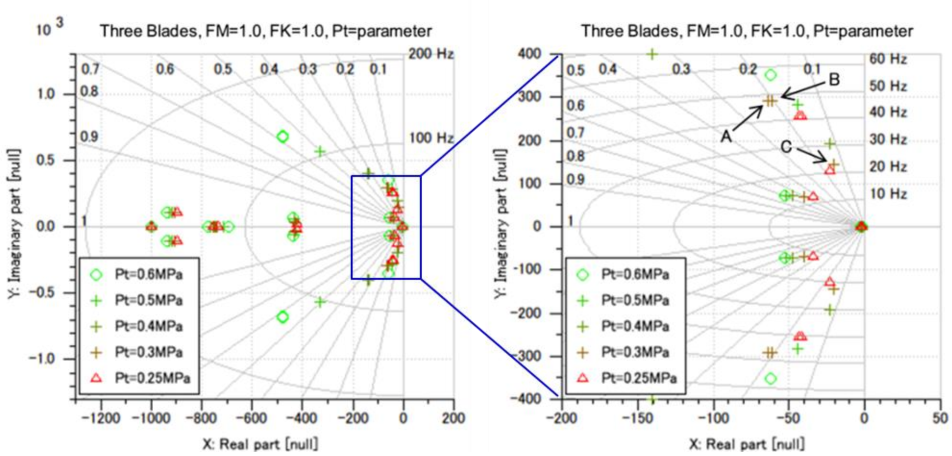

Figure 3. Eigenvalues of the system

References

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