Numerical Analysis of Suppression Effect of Random Slit on Rotating Cavitation and Cavitation Surge in Cascade

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Long Abstract

1. Introduction

Unsteady cavitation sometimes brings undesirable oscillation for turbomachineries, which is called cavitation instabilities. The cavitation instabilities are generally classified into two types: one is cavitation surge and the other is rotating cavitation. Cavitation surge is a system and one dimensional instability, which cases pulsation in flow rate and pressure. Rotating cavitation is a local and two dimensional instability which causes asynchronous axial vibration in turbomachinery. The cavitation instabilities sometimes take place in development of liquid propellant rocket turbopump. Although there is a well-known suppression technique for the rocket turbopump, the process to confirm the suppression requires many cost and time. Therefore, it is effective to find the reliable new suppression technique of the cavitation instabilities.

In the present study, suppression effect on cavitation instabilities by using random slit on blade is examined numerically in cascade flow. Occurrence region of cavitation instabilities are compared between cascades with and without random slit on the blades. The most effective arrangement of the random slit is investigated for the suppression effect with avoiding a decline of the head performance.

2. Numerical Method

In the present study, locally homogeneous compressible gas-liquid two-phase medium model [1] is used for numerical simulation of cavitation. In the locally homogeneous model, gas liquid two-phase field is assumed as a pseudo-single phase medium. The speed of sound in the homogeneous medium is found to be in good agreement with experimental data for variation of void fraction [1]. Thus, the present numerical method is able to reproduce pressure wave propagation in a gas-liquid flow field. That is important for stable simulation of compressible strong unsteady flowfield such as cavitation surge.

The present numerical method has been applied to the analysis of the wide range of cavitation conditions except for cavitation inception. For example, two kinds of mechanism of break-off of sheet cavity were reproduced numerically: one is re-entrant jet and the other is pressure wave propagation inside the cavity [2]. Time averaged pressure distribution on hydrofoil and frequency of sheet cavity break-off are validated with experimental data and availability of single phase RANS turbulence model is examined in the time averaged and unsteady characteristics of cavitation [1]. Additionally, three kinds of cavitation instabilities caused by different mechanisms was reproduced in cascade without adding any additional models or boundary conditions [3]. For rotating cavitation, the propagation mechanism was proposed [1]; the mechanism can explain why the order of occurrence of rotating cavitations is always from super-synchronous to synchronous to sub-synchronous with decreasing of pressure. For the cavitation surge, occurrence mechanism of pulsation in cascade was proposed [4]. Also for cavitation surge, influence of inlet pipe length on the frequency was reproduced numerically and compared with theoretical frequency by estimating cavitation compliance [5]. In above previous research, the predictions of the occurrence condition and unsteady characteristics of cavitation instabilities in cascade agreed with experimental data of inducer and the theoretical predictions. Therefore, it can be said that our numerical method provides reasonable numerical predictions of cavitation instabilities and numerical examination of suppression of cavitation instabilities is possible.

3. Results and Discussion

The flow field simulated in the present study is unsteady cavitating flow arising in a flat-plate three-blade cyclic cascade with and without random slit. The solidity, stagger angle, chord length, and blade thickness are 2.0, 75°, 0.1 m, and 0, respectably. In the present study, few arrangement of the random slit is examined numerically.

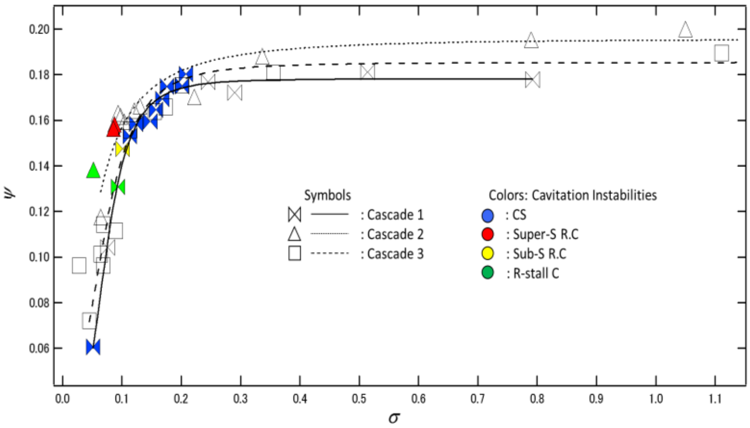

Figure 1. The head performance and occurrence region of cavitation instabilities of the present cascades with and without random slit

Figure 1 shows head performance and occurrence of cavitation instabilities in two types random slit cascades (Cascade 2 and 3) and single-stage cascade (Cascade 1). The head performance of the cascade is almost same or slightly improved by arranging the random slit in each blade. Also, the many case of the cavitation instabilities are suppressed by the random slit, especially in certain arrangement (Cascade 3), the all cavitation instabilities are completely suppressed. In cascade with random slit, the cavity volume and the slit jet fluctuates non-periodically in each cycle in each blade. It is because that pressure gradient at the slit is different in each cycle in each blade because of the relative situation between pressure side and suction side at the slit is different in each cycle in the random slit cascade.

In the present study, numerical simulation of additional arrangement and the slit width are performed and the most effective one will be investigated in the view point of the suppression effect with avoiding a decline of the head performance.

Reference

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