The 5th IAHR Asian Working Group Symposium on Hydraulic Machinery and Systems (IAHR-Asia 2025), 4-7 August 2025, Jeju, Korea

IAHR-Asia 2025-***

Numerical Investigation of Sediment Erosion in Hydraulic Machinery

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1. Introduction

Sediment erosion in components in flow paths is one of the significant issues to enhance the reliability and to reduce maintenance cost of hydraulic machineries such as pumps and hydraulic turbines. To consider the mechanisms and methods to suppress the sediment erosion, numerical simulations are useful. However, there are two kinds of challenges to predict the erosion using numerical simulation: one is to solve the liquid-solid two-phase flows in the hydraulic machinery and the other is to predict the erosion due to impingement of the sediment particles on solid walls. The erosion in the seal between a Francis turbine runner and casing is examined. As a flow solver, ANSYS CFX was adopted, which equipped functions to solve the liquid-solid two-phase flow and to predict the erosion of the solid walls. Authors had considered the influences of empirical parameters on prediction of the motions of particles in the previous study [1]. In the present study, the methodology to predict the erosion of the solid walls quantitatively by considering the difference of properties of metal used for the solid walls. The erosion model proposed by Grant and Tabakoff [2] was adopted, and the empirical parameters of the model were identified by referring to the accelerated erosion tests. The numerical result was validated by comparing the experiment using a small-scale model of a hydraulic turbine runner seal. From the viewpoint of the practical use, however, it is also important to reduce the computational cost. A 1-D numerical model to predict the erosion of the runner seal in hydraulic turbine based on the model in IEC-62364 guideline [3].

2. Numerical Methods and Results

Firstly, the quantitative accuracy is improved for the erosion prediction by means of 3-D simulation based on computational fluid dynamics (CFD). ANSYS-CFX was used in the study. The erosion model proposed by Grant and Tabakoff was adopted. The empirical parameters in the Grant-Tabakoff model should be identified considering difference in properties of materials to improve the quantitative accuracy. Accelerated erosion tests were carried out by using a facility shown in Figure 1. The flow impinging angle was varied between 30-70 degrees. The empirical parameters in the erosion model were identified by conducting 3-D simulation using similar geometry to the test condition. The values of the empirical parameter set in the erosion model was evaluated by fitting the relationship between the impinging angle and maximum value of the

erosion rate on the test piece. The evaluated the empirical parameter set was validated by comparing experiments using small scale model of the hydraulic turbine runner seal.
Using the improved erosion model, 3-D numerical simulations were carried out for evaluating erosion in the runner seals in various hydraulic turbine condition. The results were summarized as the maximum values of erosion rate as functions of specific speed of the hydraulic turbine. In the guideline, IEC-62364, there is a prediction model of erosion in various components in hydraulic turbines as well as the seal. In the present study, 1-D flow model was adopted to predict the characteristic velocity considering geometries in the seal gap[4], and several modifications were implemented in IEC-62364 model. Comparison between the 3-D and 1-D predictions of erosion in the runner seal were shown in Figure 2. The prediction by using the modified IEC62364 model is almost equivalent to 3-D CFD results.

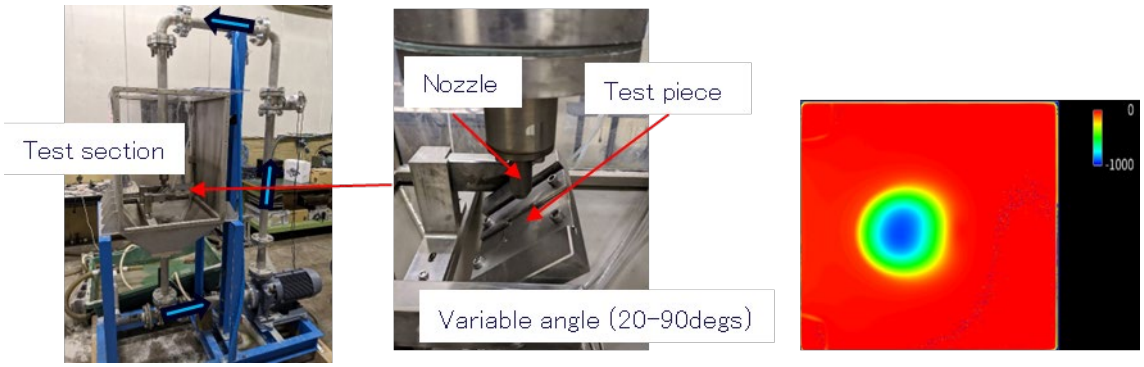
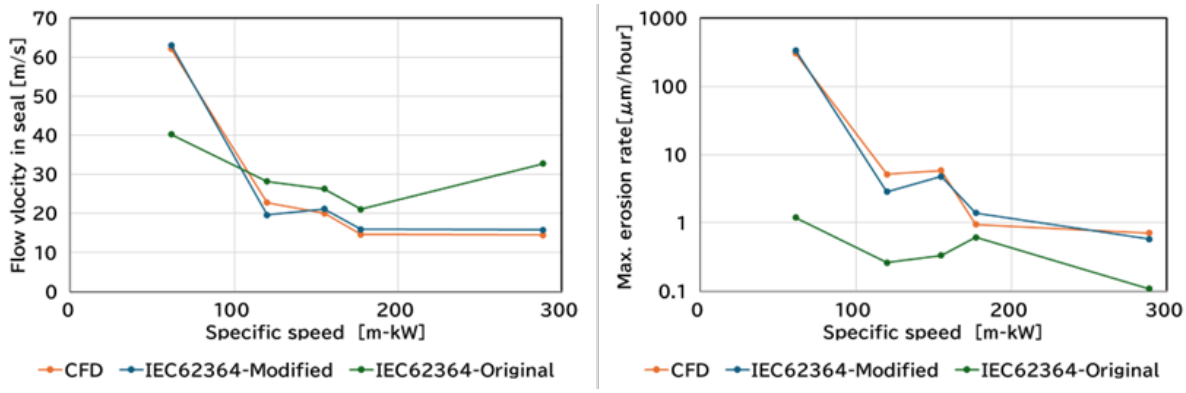


Figure 1. Accelerated erosion test facility (Left and center) and typical distribution of eroded depth on test piece (right).



References

[1] K. Yonezawa and T. Watamura, A study of sediment erosion of runner seal of a Francis turbine, J. Phys.: Conf. Ser. 2217 012059, 2022.

[2] G. Grant and W. Tabakoff, Erosion Prediction in Turbomachinery Resulting from Environmental Particles, J Aircraft 12 471-478, 1975.

[3] IEC 62364:2019 Hydraulic machines - Guidelines for dealing with hydro-abrasive erosion in Kaplan, Francis and Pelton turbines, International Electrotechnical Commission.

[4] J. F. Gülich, Centrifugal Pumps, Springer Nature, 2014.