Homologous Curve Generation for SMR Reactor Coolant Pump using CFD

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1. Introduction

A nuclear reactor predicts safety by assuming various situations, and the flow rate of the primary coolant is one of the important factors determining the safety. In a nuclear reactor, the reactor coolant pump (RCP) circulates the primary coolant and transfers the heat generated from the core to the steam generator, so the flow rate of the primary coolant is determined according to the operating conditions of the RCP. Therefore, performance data according to the various operation conditions of RCP are required for the safety prediction of nuclear reactors.

The RCP uses the homologous curve as a method to represent all performance according to various operating conditions [1-3]. This curve is used as data for reactor safety analysis. Since nuclear power plant uses developed RCP, safety analysis can be performed using verified homologous curves from the reactor design stage. However, small modular reactor (SMR) does not have a verified homologous curve because there is no developed RCP for SMR. Therefore, in this study, the CFD analysis method is proposed as a method to generate the homologous curve.

2. Pump geometry

The hydraulic part of the RCP applied an axial flow type as shown in Fig. 1. The impeller has 5 blades in the shape of a double circular arc, and the diffuser has 9 blades. A guide vane is installed at the inlet of the impeller.

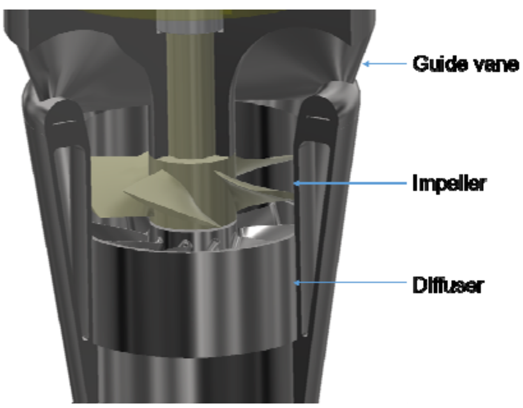


Fig. 1. The geometry of the hydraulic part of RCP.

3. Numerical model

CFD is used for generation of the RCP homologous curve, and SC/tetra, a general-purpose CFD solver, is used for analysis. About 21 million meshes are used for the analysis, and five prism layers are applied as shown in Fig. 2. The boundary conditions are specified in Fig. 2. The flow rate that is required for the homologous curve condition is given as a volume flow inlet, and the outlet is set as a pressure outlet. The conditions for the CFD analysis are shown in Table I.

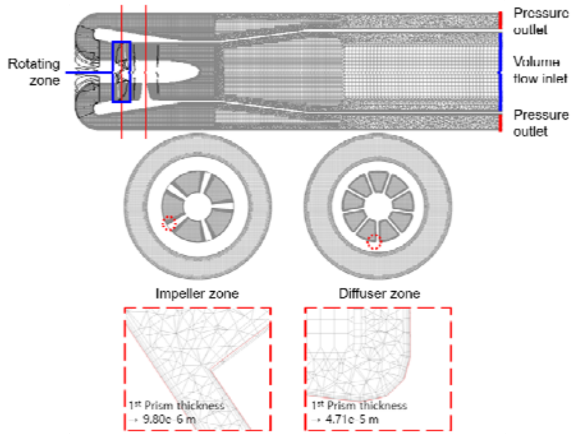


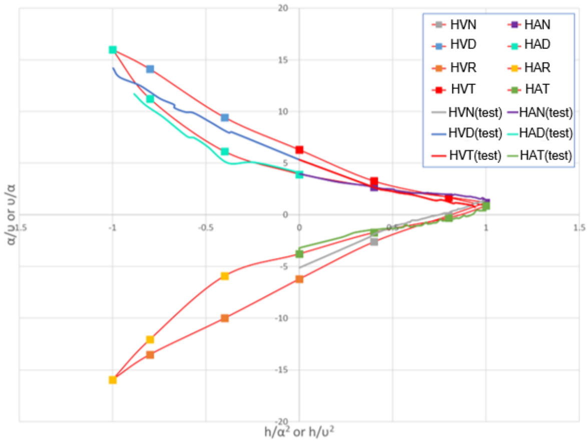
Fig. 2. CFD mesh and boundary condition for the RCP homologous curve generation.

Table I: CFD analysis settings

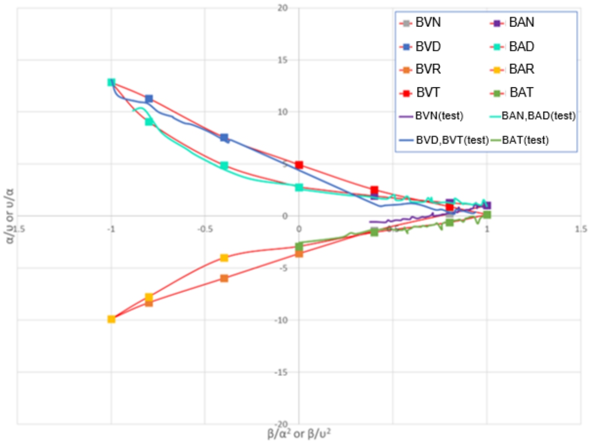
Turbulence Model	k-w SST
Analysis cycle	6000
Pressure correction method	SIMPLEC
Convective term	2nd order MUSCL
Fluid density (kg/m^3)	998.2
Fluid viscosity (kg/m·s)	1.003×10^{-3}

4. Results

In this section, the test results and analysis results of the RCP homologous curve are compared. The test was performed except for HVR, HAR, BVR, BAR part of the homologous curves. As a result of comparison, it is confirmed that the analysis result and the test result are similar except for the area where there was no test result.



(a)



(b)

Fig. 3. Comparisons of generated homologous curves with test results: (a) Head, (b) Torque.

5. Conclusion

The test result of the homologous curve of the RCP and the CFD results are similar. It is expected that it will be possible to use the analysis results by this method as the initial value of the RCP homologous curve in the future.

REFERENCES

[1] K. Choi, Y. Kim, S. Yi, and W. Baek, Development of a pump performance model for an integral effect test facility, Nuclear engineering and design, Vol. 238, No. 10, pp. 2614-2623, 2008.

[2] B. Huang, M. Zhang, K. Pu, P. Wu, and D. Wu, Study on the four-quadrant homologous characteristic and two-phase flow head degradation of a reactor coolant pump, Journal of pressure vessel technology, Vol.143, 041404, 2021.

[3] J. Park, J. Kim, and J. Lee, Complete and homologous pump characteristics for a reactor coolant pump, Nuclear engineering and design, Vol. 357, 110425, 2020.