Component Model for Reactor Coolant Pumps in SPACE code

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1. Introduction

The SPACE code is a system code for predicting the thermal-hydraulic behaviors of PWR nuclear power plants. A RCP(Reactor Coolant Pump), which is a type of centrifugal pump, is used to circulate the primary reactor coolant in nuclear power plants. This paper presents the design, model, and the test results of the pump component embedded in SPACE code.

2. Pump model

2.1 Head and Torque

The momentum developed by the pump head is added to the momentum equations. The temperature increase appears as a dissipation term in the energy equations. The head and torque are obtained by dimensionless homologous data in which the head and torque are expressed with the pump velocity and the volume flow rate. In SPACE code, the homologous data set of 1-1/2 loop MOD1 Semiscale pump is included, but users can enter the pump data. The head and torque for two-phase flow are calculated from the heads and torques of single-phase flow and fully-degraded two-phase flow as follows,

$$H_{hy} = H_1 - M_H \times (H_1 - H_2),$$

$$T_{hy} = T_1 - M_T \times (T_1 - T_2),$$

where H and T represent head and torque, respectively. The subscript 1 and 2 stand for single-phase flow and two-phase flow, M_H and H_T the multipliers, and *hy* hydraulic property, respectively.

2.2 Angular Velocity

There are two ways to calculate the pump angular velocity. One is to set the pump velocity as a function of time. Unless the time table for the pump velocity is entered, the pump velocity is calculated by the inertia-velocity relation equation.

$$T_{net} = Id\omega / dt$$

where I is the momentum of inertia of the pump rotor. The net torque T_{net} is computed as follows,

$$T_{net} = T_m - (T_{hy} + T_{fric}),$$

where T_m and T_{fric} are the motor torque and the frictional torque, respectively. The motor torque can be entered as a function of pump velocity. Unless entered, it is assumed to be equal to the sum of the hydraulic and frictional torques, which results in constant velocity. If the pump is tripped, that is, the electricity is disconnected, the motor torque is set to zero. The frictional torque increases with the pump velocity. If the pump rotor is locked, the pump stop at once unconditionally.

3. Test

Figure 1 show a nodding diagram for test. Since a pump is a cell-oriented component, cell properties must be entered. The pump is connected to two identical pipes. At the connection faces, the form loss factors are set to 2.0. At the initial state, the pump and pipes are filled with sub-cooled water of 15.5MPa and 560K with zero water velocity. A pressure boundary condition is imposed on both TFBCs. The rated values are set to be ω_R=124.6rad/s, Q_R=7.67m^3/s, H_R=109.7m, T_R=$T_{motor,R}$= 59432N·m, and I=6211kg·m^2, respectively. Semiscale homologous data is used to calculate the single-phase head and torque.

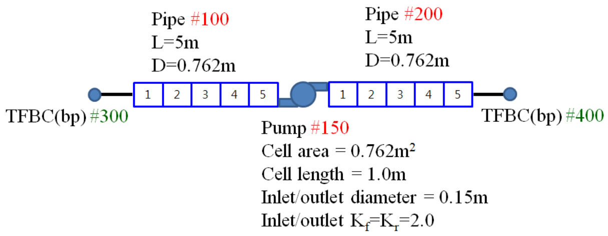

Fig. 1. Nodding diagram for pump tests.

3.1 Pump startup and trip test

The electricity is not supplied to the pump until 20s. The pump starts to work from 20s, and a trip signal occurs at 80s. The results are shown through Figs. 2 ~ 4.

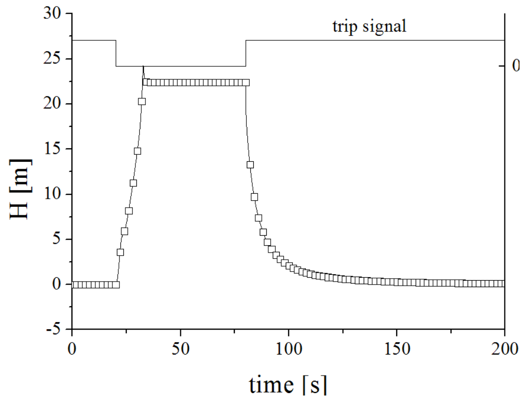

Fig. 2. Hydraulc head developed by the pump.

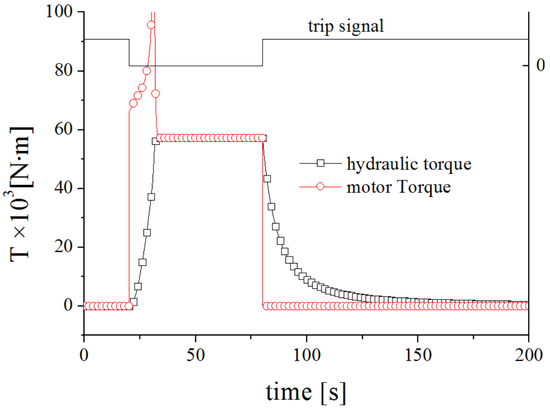

Fig. 3. Hydraulic torque and motor torque.

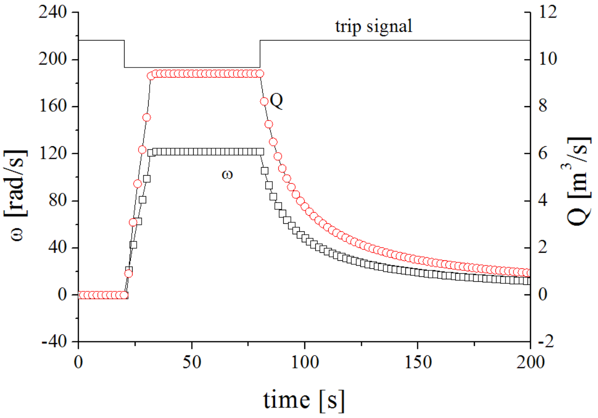

Fig. 4. Volume flow rate and pump angular velocity

The head, torque, volume flow rate, and pump velocity behave as designed. After onset of trip, the motor torque is zero, as a result, the pump speed decreases.

3.2 Locked pump test

The pump must stop unconditionally when a locked signal is on. Tests were made using the same model in the previous section, except that a locked signal was activated at 50s or 100s. It can be found from Figs. 5 and 6 that the pump stops in response to the locked signal, regardless of the trip signal.

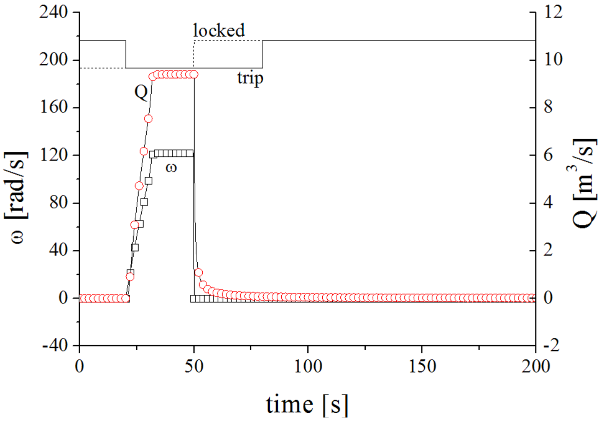

Fig. 5. Result when the locked signal occurs at 50s.

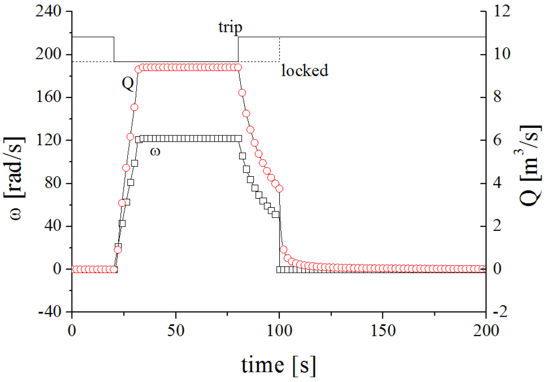

Fig. 5. Result when the locked signal occurs at 100s.

4. Conclusion

A component model for reactor coolant pumps has been developed. This paper demonstrated qualitatively that the pump work as designed. Additional tests are scheduled to be made for comparison with experimental data.

Acknowledgments

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REFERENCES

[1] S. B. Park, Report of design and implementation for pump model in SPACE code, S06NX08-F-1-TR-20 Rev.1, Korea Nuclear Fuel, 2009.