Evaluation of RCP Model for TASS/SMR-S Code

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1. Introduction

RCP model is a component model of TASS/SMR-S code that is describing hydraulic effects of RCP. So the RCP model should be capable of analysis for forced circulation of coolant and pump coast down.

Totally 10 cases of test for pump coast-down, 3 cases among them have been analyzed with TASS/SMR-S code. With the computational analysis, RCP model of the code will be verified.

2. RCP Model

2.1. General Description

The RCP model is consists of rotational momentum equation of equivalent axis of rotation, mainly. The pump speed is calculated from axis inertia and torques, and pump head is deduced from pump speed and flow conditions. For an adequate calculation, rated pump speed, rated torque and homologous curves are should be offered to the code through code input.

2.2. General Equation

General equation of the model starts from a simple assumption that pumps of reactor systems are powered by electricity. So, the equation contains electric torque term caused by electric power. And the electric torque could not be transferred to coolant with 100% efficiency. Thus the equation contains friction loss term, surely. And there is hydraulic torque that works on coolant, too. So, the rest portion of electrical torque rotates the axis. With these considerations, the general equation used for RCP model is formulated as below[1].

$$J\frac{d\omega}{dt} = \tau_e - \tau_h - \tau_f \qquad (1)$$

J : *Rotational Inertia*
ω : *Rotational Speed*
τ_e : *Electrical Torque*
τ_h : *Hydraulic Torque*
τ_f : *Friction Torque*

2.3. Coast-down

Every pump has its inertia, it doesn't stop instantly right after power attenuation. The phenomenon is called as coast down, and it is a very important issue for reactor safety.

In the code, power attenuation was assumed as an instant cut-off. So, electrical torque was changed to 0 instantly right after power drop.

3. Coast-down Test

10 cases of coast-down test were performed to verify the pump coast-down characteristics. The tests had been performed with various conditions, especially for RPM, flow rate and moment of inertia [2].

3.1. Test Loop

Test loop was consisted of pump, valves and coolant tank. The pump specifications are summarized as below.

- *Rated Flow Rate* : *539.4 m^3/hr*
- *Rated Head* : *22.4 m*
- *Rated Pump Speed* : *3476 rpm*
- *Rated Torque* : *206.04 N-m*

And the homologous curve is drawn as Fig. 1.

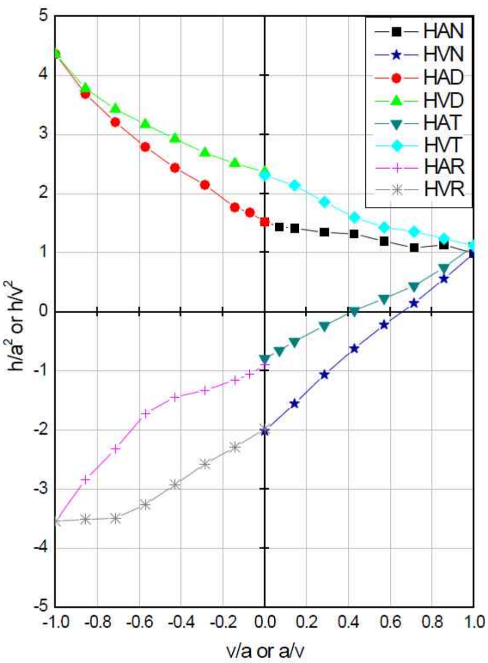

Fig. 1 homologous curve of Test Pump.

3.2. Test Matrix

Coast-down tests are performed with various pump speed, flow rated and moment of inertia. With these variables, 10 test cases are made up. The test matrix is tabulated as Table. 1.

Among the matrix, case 9 was chose for rated pump condition. And Case 2 and 9 was picked for sensitivity analysis for the flow rate and moment of inertia.

Table 1. Test Matrix

Case	*Pump Speed* [rpm]	*Flow Rate* [kg/sec]	*Inertia* [kg-m^2]
1	*2617*	*150.48*	*0.190*
2	*3476*	*149.09*	*0.190*
3	*2617*	*150.76*	*0.215*
4	*3476*	*148.26*	*0.215*
5	*2879*	*165.47*	*0.729*
6	*2617*	*150.76*	*0.729*
7	*1309*	*75.24*	*0.729*
8	*2824*	*165.20*	*0.729*
9	*3476*	*149.09*	*0.729*
10	*1738*	*75.52*	*0.729*

4. Computational Analysis

4.1. Nodalization

For analysis, the test loop should be nodalized with the TASS/SMR-S code proper form. So, the pipes were divided in several nodes and coolant tank was described in a node. Also pump was described with code input, according to input requirements for pump model. Nodalization is shown as Fig. 2.

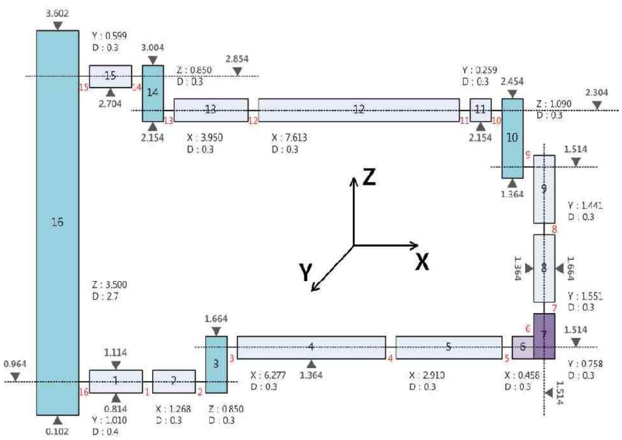

Fig. 2 Nodalization of Test Loop.

4.2. Calculation Results

3 cases were analyzed with TASS/SMR-S code. And calculation results are represented as below. Fig. 3 and 4 represents RPM behavior and Flow Rate Behavior of Test Cases. Before the transient, 100 sec null transient analyses have been performed.

As results, little difference of RPM between calculation and experiment are observed at Case 2 after 105 sec. But TASS/SMR-S code predicts the RPM behavior well, generally.

And there are differences between calculations and experiments. But the calculated flow rates were attenuated more rapidly than experimental results. Also flow rates were calculated less than experiments. With these results, the conservativeness of TASS/SMR-S code could be verified.

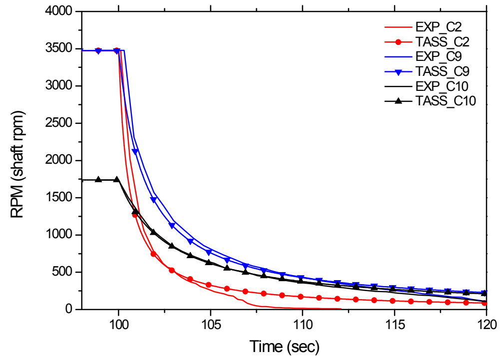

Fig. 3 RPM behavior of Test Cases.

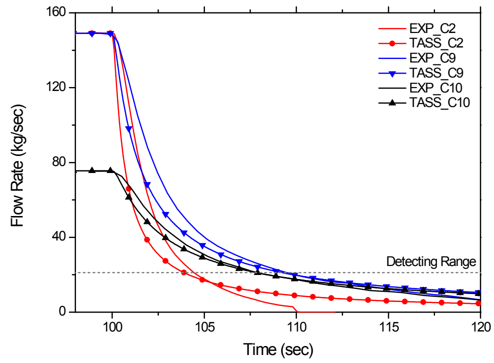

Fig. 4 Flow Rate behavior of Test Cases.

5. Conclusion

In this study, RPM model of TASS/SMR-S code were verified. 10 cases of coast-down test are performed and 3 cases of test were analyzed. To confirm initial states, null transient calculation performed for each case, and then transients started.

As results, TASS/SMR-S code predicts the RPM behavior well, generally and code predicts the flow rate conservatively.

But there were over-calculations of flow rate in the latter phase of coast-down. It is considered an imperfection of RCP model that is caused by internal friction loss of RCP. It could be resolved by general equation modification.

REFERENCES

[1] Hyeong Rae Kim, “Research Report for RCP Model Development : 917-TH492-002”, KAERI, 2009.

[2] Soon Kuk Kwon, “3rd coast-down report for SMART scale-down RCP(rev 01) : 180-TC458-010”, KAERI, 2011.