The Performance Test for Reactor Coolant Pump (RCP) adopting Variable Restriction Orifice Type Control Valve

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1. Introduction

RCP test facility (RCPTF) is constructed for performing the type test of the APR1400 RCP adopted in the SHN 1&2. RCPTF is constructed to perform the test of the hydraulic performance characteristics over the flow range of the test loop and that of the mechanical characteristics relating to bearing and seal performance, stop/start cycles and coast down time. The design values of the RCPTF are 17.2 MPa, 343 ºC, 11.7 m^3/s, and 13 MW in the maximum pressure, temperature, flow rate, and electrical power, respectively. In the RCPTF, various types of tests can be performed including a hydraulic performance test to acquire a H-Q curve as well seal transient tests, thrust bearing transient test, cost down test, NPSHR verification test, and so on [1].

After a commissioning startup test was successfully perfomed [2], mechanical structures are improved including a flow stabilizer and variable restriction orifice. Two- branch pipe (Y-branch) was installed to regulate the flow rate in the range of performance tests. In the main pipe, a flow restrictor (RO: Restriction Orifice) for limiting the maximum flow rate was installed. In the branch pipe line, a globe valve and a butterfly valves for regulating the flow rate was located on the each branch line. When the pressure loss of the valve side is smaller than that of the RO side, the flow rate of valve side was increasing and the flow disturbance was occurred in the lower pipe line. Due to flow disturbnace, it is to cause an error when measuring RCP head and flow measurement of the venturi flow meter installed in the lower main pipe line, and thus leading to a decrease in measurement accuracy as a result. To increase the efficiency of the flow control availability of the test facility, the variable restriction orifice (VRO) type flow control valve was designed and manufactured.

2. RCP Test Facility

Figure 1 shows the RCP test loop constructed in RCPTF. The desired pump flow rate is obtained by simultaneously regulating variable restriction orifice type valve installed in main pipe line and two (26-inch diameter) butterfly valves and two (16-inch diameter) globe valves installed in the branch line of the main test loop. The desired test loop pressure and temperature is controlled by two (1-inch diameter, globe) pressure control valves in letdown lines and two (10-inch diameter, globe) temperature control valves in main loop cooling lines, respectively. A heat exchanger with 20MW heat capacity was installed to remove the heat from the RCP through main loop of the RCPTF. An additional heat exchanger is also installed to extract the heat in the component cooling water for the seal injection, air cooler in a motor, and so on. The diameter of the main pipe is 0.914 m corresponding to the cold leg of APR1400. The pipe of 0.762 m diameter is used where the venturi flow meter and the RCP were connected.

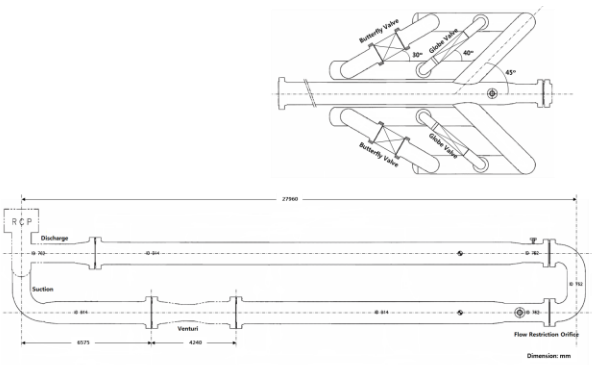

Fig. 1. RCP main test loop

Main measurement parameters are the main flow rate, pump head, system pressure, temperature, motor power, and shaft speed. For the endurance test, the pressure pulsation, frame vibration, and shaft vibration are also measured. The pressure and differential pressure transmitter is used to measure a flow rate, static pressure, differential pressure, total head, and differential head. A 36-inch venturimeter is used to measure the flow rate of RCP. The differential pressure transmitters measure the differential pressure produced by the venturi as a function of flow rate. The resistance temperature detectors measure the fluid temperature. The pressure transmitters also measure the fluid pressure of the upstream/downstream of the venturi. The temperatures and pressures of the fluid are used to determine the fluid density. The differential pressure used in the calculation for the total head is measured with differential pressure transmitters.

3. Design of Variable Restriction Orifice

To acquire H-Q curves of a RCP, the flow rate should be controlled by regulating flow control valve. In this study, the RCPTF uses a Variable Restriction Orifice (VRO) whose flow area can be controlled by moving the two orifice plates parallelly installed. The need of the flow control valves and bypass lines were eliminated by using the VRO so that the flow disturbance was minimized. The design of the VRO utilized the data for the flow area and the minimum flow rate during the test with RO-1 and RO-2. The minimum and maximum flow rates were considered to conservatively determine the flow area of the VRO with a sufficient margin. The design condition is 17.0 MPa and 343 ºC, and the valve position can be controlled by an operator. The VRO is installed at the U-bend pipe in the main loop. Figure 2 shows a schematic of the VRO. The VRO consists of two orifice plates with multi-holes that have almost same configurations. The motor electrically powered is installed at the top side of the VRO to move one orifice plate so that the flow area can be changed.

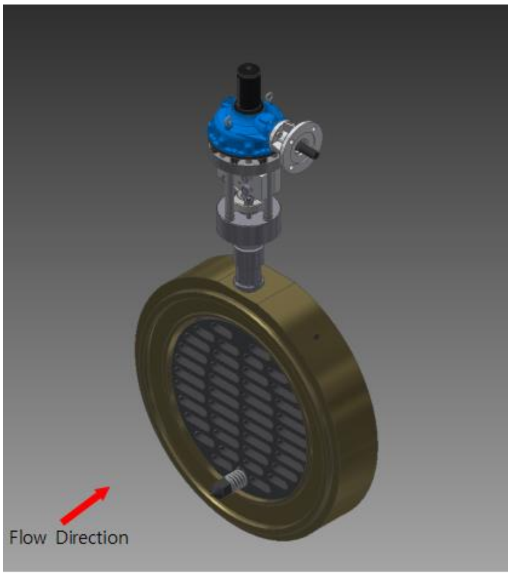

Fig. 2. Schematic of VRO

By using the VRO, it is possible to minimize the vortices and turbulent effect that can occur at the junction after the Y-branch because the butterfly valves and globe valves in the Y-branch can be excluded during the operation. This means that the use of VRO may improve the accuracy of measurement of main flow rate, pressure pulsation, frame vibration, and shaft vibration. The current VRO can vary main flow rate from 6.5 m^3/s to 9.8 m^3/s when the APR1400 RCP is used. The operating range by using the VRO can broaden after the design optimization.

4. Evaluation of Performance Test

Cold and hot performance tests were conducted using the VRO in the RCPTF. Test condition of the cold performance test is 93.3 ºC and 14.8 MPa, and that of the hot performance test is 290.6 ºC and 14.8 MPa. From the test result, H-Q curve of the pump using the VRO revealed a similar trend to the result from two ROs as shown in figure 3 and figure 4.

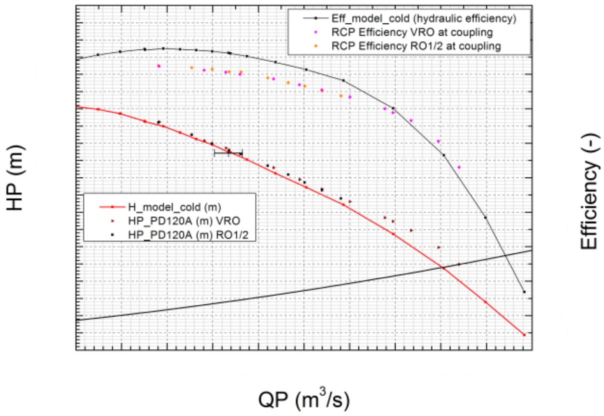

Fig. 3. H-Q curve of cold hydraulic performance test

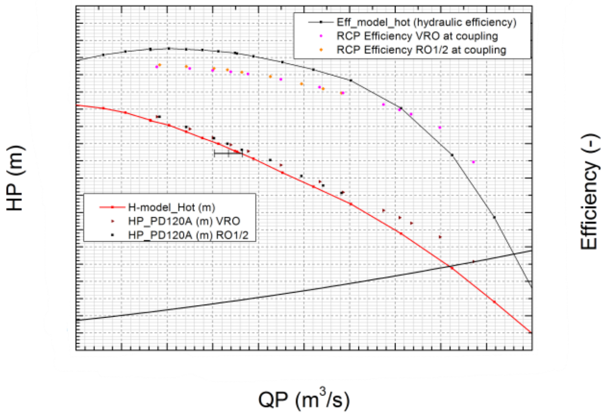

Fig. 4. H-Q curve of hot hydraulic performance test

5. Conclusions

In the RCPTF in KAERI, the performance tests and various kinds of transient tests of the RCP were successfully performed. In this study, H-Q curve of the pump using the VRO revealed a similar trend to the result from two ROs. The VRO was confirmed to effectively cover the full test range of the flow rate.

ACKNOWLEDGMENTS

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