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Reactor Coolant Pump (RCP) Performance Test with Installation of Flow Straightner

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1. Introduction

Reactor Coolant Pump (RCP) of the APR1400 (Advanced Power Reactor 1400 MWe) is required to carry out various kinds of performance tests under the real operation condition, in prior to be installed at a nuclear power plant. Therefore, for the development and commercialization of the APR1400 RCP, KAERI (Korea Atomic Energy Research Institute) has constructed a test facility for validating the performance of the pump and the operating reliability.[1] Among the test matrix for the facility, a hydraulic performance test is most important with respect to the validation of the H-Q (Pump head – Flow rate) curve of the pump. In this study, to minimize the measurement uncertainty and decrease the flow disturbance during the test, a flow straightner was designed and installed in the main pipe of the facility. The test result was compared and discussed to evaluate effect of the flow straightner.

2. Design of Test Facility

2.1 RCP Test Facility

RCPTF (RCP Test Facility) 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. Figure 1 shows the RCP test loop constructed in RCPTF. The desired pump flow rate is obtained by simultaneously regulating two (26-inch diameter) butterfly valves and two (16-inch diameter) globe valves installed in the branch line of the main test loop.[2] 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.

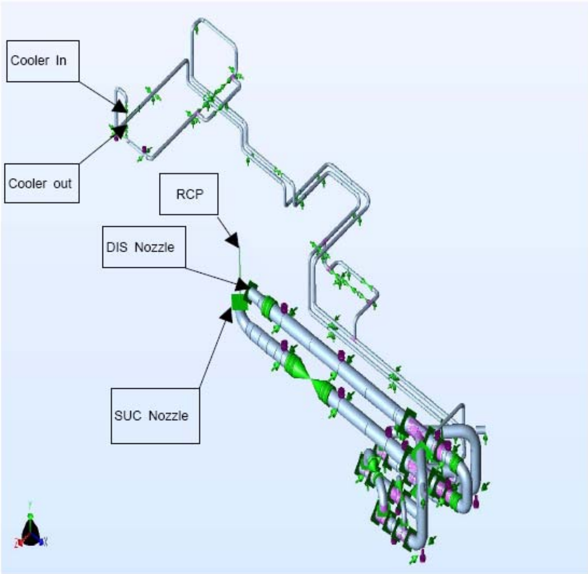

Fig. 1. Main pipes of the RCPTF

2.2 Design of Flow Straightner

As shown in Fig. 1, flow in the RCPTF loop consists of the flow through a restriction orifice in a main loop and the flow through two branch pipes. At the Y-Branch of the lower part, the flow from two branches and the main loop is gathered. It makes a disturbance in the flow field and the disturbed flow can affect accuracy of the flow rate measurement when the flow entered a ventrui flowmeter.

To reduce the flow disturbance in the loop and enhance the accuracy of the flow measurement, a flow straightner has been designed and installed at the position between the Y-Branch and the venture flowmeter as shown in Fig. 2.[3]

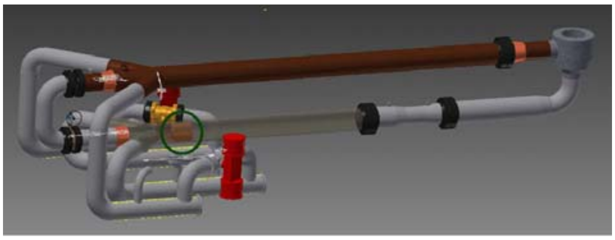

Fig. 2 Installation of the flow straightner

In order to make a uniform profile of the flow at the downstream of the Y-Branch, the flow straightner is designed as shown in Fig. 3. It is composed of three bended plates which divides the flow area into six equal regions, so that the disturbance of the flow field can be mitigated by friction on the plate surface.

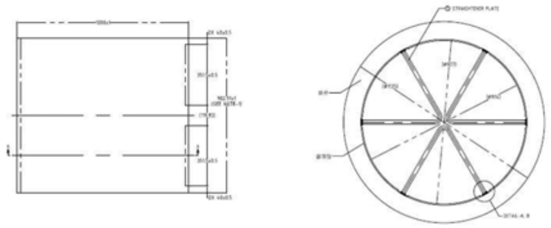

Fig. 3 Design of flow straightner

3. RCP Performance Test Result

Hydraulic performance test of the RCP was conducted for the entire operating flow range from 90% of rated flow to the runout flow, where the pump performance curve will intersect the lowest system resistance curve. The test is performed at a hot condition (Pressure: 14.8 MPa, Temperature: 290.6 °C). Major measurement parameters include the RCP performance data such as the flow rate, the pump head, the brake horse power, and the pump efficiency. Also, the vibration level and pressure pulsation are measured. H-Q (Pump head – flow rate) curve, motor power, and pressure pulsation are compared to evaluate the effect of the flow straightner as follows.

3.1 H-Q Curve

Figure 4 shows the H-Q curve and RCP efficiency from the RCP performance test without the flow straightner, while Figure 5 shows the test result with installation of the flow straightner. Both of the results were compared to the model test data. As compared in two figures, the H-Q curve with the flow straightner revealed more similar result to the model test data in a region of a high flow rate. However, as the flow rate is higher, the H-Q curve from the performance test result shows a larger gap when compared to the model test curve. It means that the flow straightner could not fully resolve the problem of the H-Q curve in the RCP performance test. This problem can be resolved by a variable restriction orifice in the further study.[4]

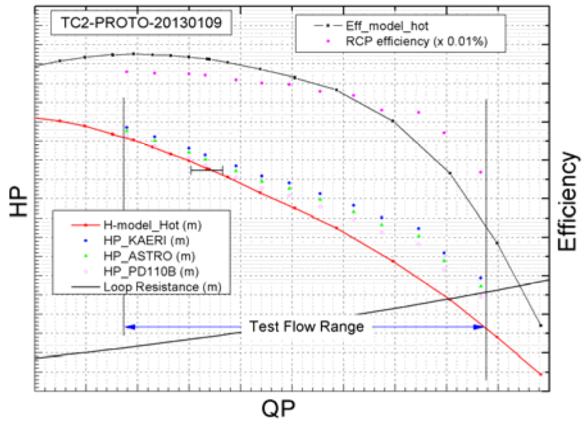

Fig. 4 H-Q curve without flow straightner

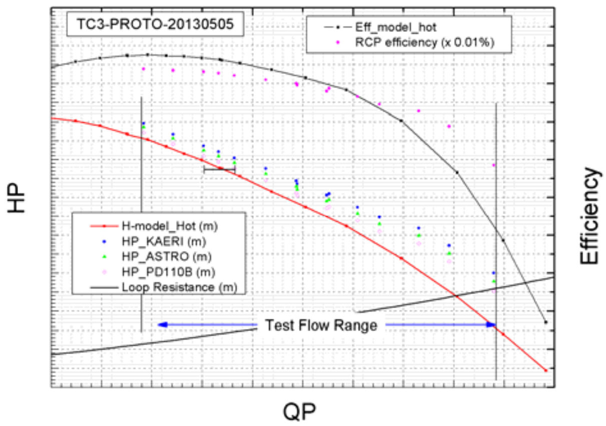

Fig. 5 H-Q curve with flow straightner

3.2 RCP Motor Power

RCP motor power is dependent on the friction of the fluid and the shaft of the RCP impeller. Also, it is affected by the fluid temperature and the flow disturbance. Figures 6 and 7 compare the test result of the RCP motor power measured during the performance test without and with the flow straightner, respectively. From the result, it was found that the flow straightner significantly contributed to decrease oscillation of the motor power, where the oscillation amplitude with the flow straightner was reduced to 1/6 of the test data without the flow straightner. It means that the disturbance in the flow field was mitigated by the flow straightner and instability of the motor power measurement was reduced.

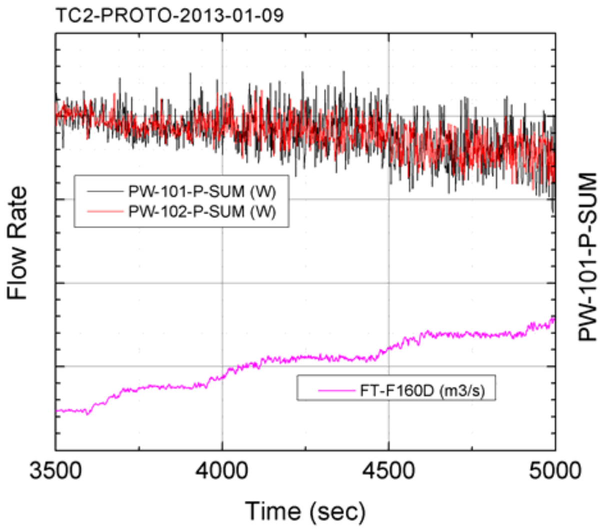

Fig. 6 RCP motor power without flow straightner

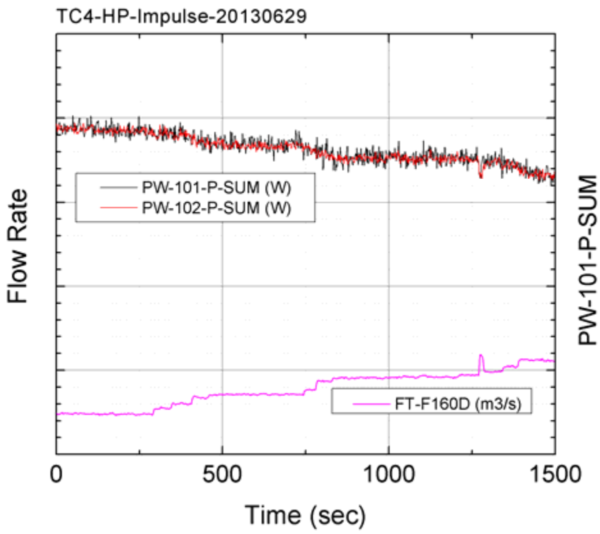

Fig. 7 RCP motor power with flow straightner

3.3 Pressure Pulsation

In the RCPTF, measurement of pressure pulsation at the suction and discharge nozzles of the RCP was conducted with piezo-type pressure transmitters. Figures 8 and 9 represent the pressure pulsation measurement without and with the flow straightner, respectively. In the figures, PP-140 means the measurement at the suction nozzle and PP-150 and PP-160 are measured at the discharge nozzle.[5] As found in the result, it is evident that the installation of the flow straightner contributed to decrease the pressure pulsation level at the suction nozzle due to the reduced disturbance in the flow field.

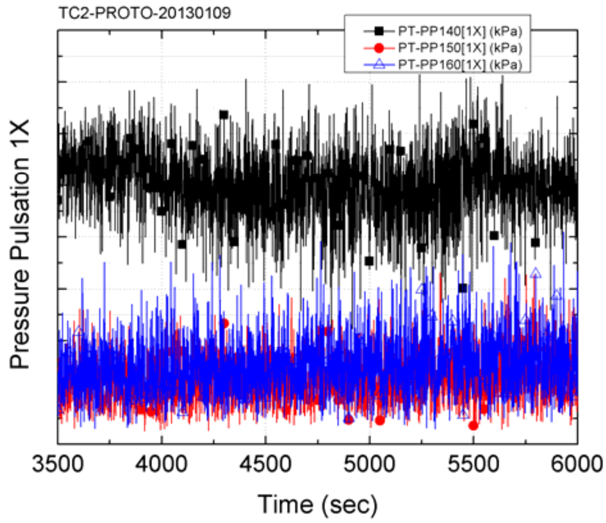

Fig. 8 Pressure pulsation without flow straightner

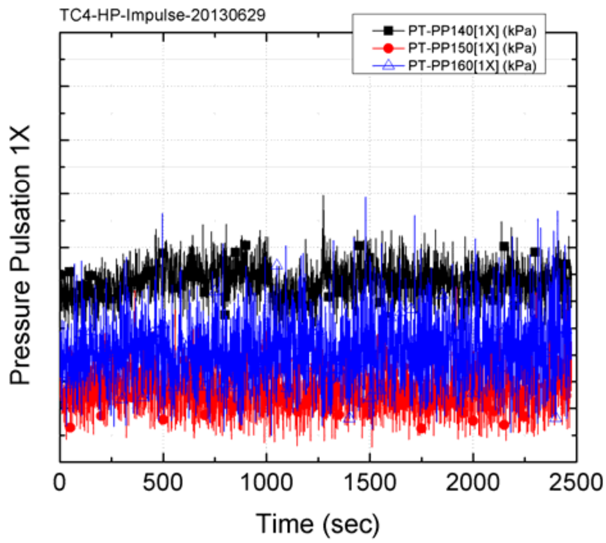

Fig. 9 Pressure pulsation with flow straightner

4. Conclusions

The flow straightner was designed and installed in the RCPTF, to reduce the flow disturbance and enhance the accuracy of the flow measurement. From the hydraulic performance test of the RCP, it is proved that the flow straightner contributed to decrease the oscillation of the motor power and the pressure pulsation at the RCP suction nozzle. It also affected to produce more appropriate H-Q curve from the performance test result. In the further study, the variation restriction orifice in the loop is expected to resolve the problem in the H-Q curve within a high flow rate region.

ACKNOWLEDGMENTS

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REFERENCES

[1] Korea Atomic Energy Research Institute, Conceptual design report of RCP test facility, KAERI/TR-3715, 2009.
[2] S. Kim, et al., Type Test Report for APR1400 Reactor Coolant Pump, RCPTF-TR-13-01, 2013.
[3] S. Cho et al., Installation and Performance Verification Test of Flow Straightener, KAERI/TR-5483/2014, 2014.
[4] B. U. Bae et al., Installation and Performance Verification Test of Flow Straightener, KAERI/TR-5483/2014, 2014.
[5] B. U. Bae et al., RCPTF Signal Processing Map, RCPTF-OT-12-05, 2012.