Development of Reactor Coolant Pump for APR1400

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1. Introduction

Doosan Heavy Industries & Construction(hereafter DOOSAN) has completed the development of APR1400 Reactor Coolant Pump(hereafter RCP) which circulates reactor coolant in the Reactor Coolant System with cooperation of ANDRITZ. The development was focused on the performance requirements for APR1400 and to achieve the goals of the safety, reliability and adaptability for APR1400 system design. In addition, APR1400 RCP design was customized considering convenience of installation, operation and maintainability. This paper describes the details of the development process, improved design feature and type test results.

2. Development Process

Development process includes hydraulic design, model pump test, basic design, detail design, fabrication and 500 hr type test.

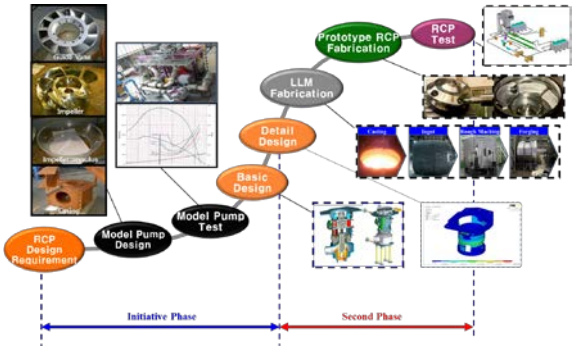

Fig. 1 RCP development process

2.1 RCP Hydraulic design and model pump testing

To satisfy the hydraulic requirements, the development commenced with hydraulic design by numerical 3D simulations (CFD) of the impeller, diffuser and casing. Constraint on the number of impeller blades(6) and diffuser blades(11) were also considered to have same blade passing frequency(120Hz).

Based on CFD hydraulic design, the model pump were designed and manufactured with scale-down factor(1:2.4) for the hydraulic parts(Impeller, Diffusor and Casing).

Table. 1 RCP Hydraulic requirements

Parameters	Design Value
Rated Head (m)	114.3
Rated Flow (m^3/sec)	7.672
Rated Pump Speed (rpm)	1190
Suction Pressure (kg/cm^2)	156.07
Pump Inlet Temperature (℃)	290.6
Negative Slop (m/(m^3/sec))	18
Reduced Operating Head (m)	102.1
No. of Blades (Impeller/diffuser)	6 / 11

Model pump test were performed to predict and verify the hydraulic performance of full scale RCP and to get the characteristic data. Especially, four-quadrant characteristic data is significantly important for system safety analysis. Four-quadrant performance data was successfully made under the various condition which entails both forward and reverse flow and rotating direction. Through several times of the fine tuning of hydraulic geometry and model testing, the hydraulic design were finalized.

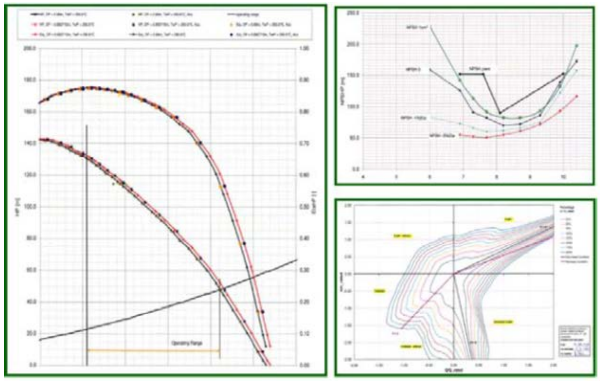

Fig. 2 Model pump characteristic graph

2.2 RCP Basic and Detail Design

Based on the accurate 3D measurement on model pump hydraulic parts, the dimensions of down-scale pump were translated into the dimensions of full-scale pump. From those scale-up dimension, dimension of hydraulic parts were defined, and then RCP layout drawing was designed.

RCP assembly consists of 1,336 kinds of item and about 7,000 parts. Pressure boundary part is to maintain high temperature and high pressure, rotating part to transfer power from RCP Motor to impeller, seal assembly part to seal reactor coolant in pump, auxiliary part to supply lubricant oil and cooling water, and stationary part to support other parts.

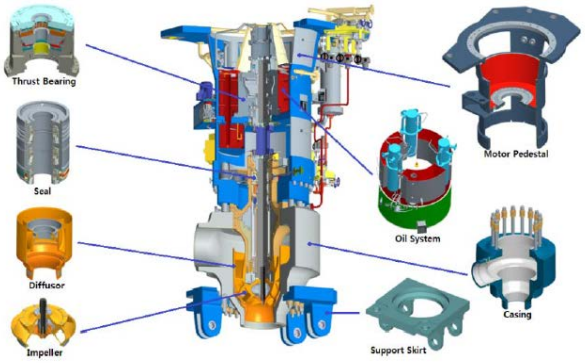

Fig. 3 APR1400 RCP layout

The size of parts was determined based on sizing calculation. And each part and sub-assembly were evaluated by stress analysis under the plant transient condition.

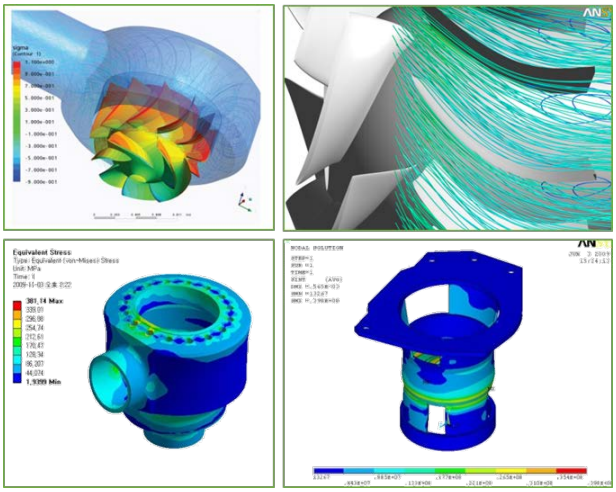

Fig. 4 APR1400 RCP detail part analysis

RCP analytical model was based on finite element analysis with detail shape. This solid model was not only extracted to mass and stiffness of each part, but also confirmed to contact stiffness at assembly. The detailed analyses were performed based on two restrictions; preloading condition and welded condition.

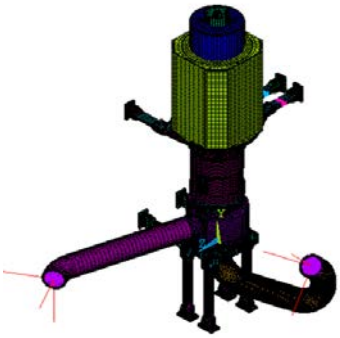

Fig. 5 APR1400 RCP analytical model

3. Improved Design Features

APR1400 RCP applied the improved design features for not only manufacturing aspect such as integrated forged material, but operability aspect such as integrated oil system which allows no oil leakage.

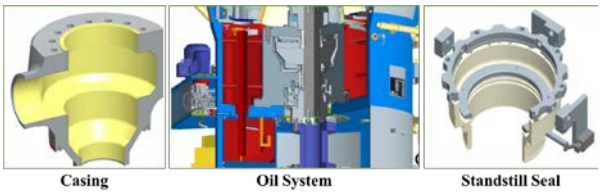

Fig. 6 APR1400 RCP improved design feature

During the operation and maintenance assessment phase, 45 improvement requests were issued by NPP operators and maintenance staffs. The mechanical seal withdrawal design, thrust bearing maintenance design without motor removal, and other distinguished specialized design features were applied to APR1400 RCP through the numerous researches.

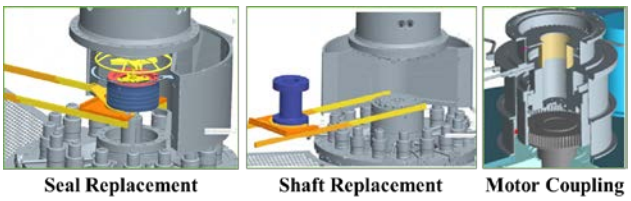

Fig. 7 APR1400 RCP improved maintenance

4. RCP 500 Hr Type Test

After completion of prototype RCP manufacturing, RCP was installed at Full flow test facility established by KAERI for 500 hour type testing. The 500 Hr Type tests to verify the performance, integrity and endurance of prototype RCP require more than 10 test items. To verify the performance, cold and hot hydraulic performance test and NPSH verification test were performed. And 30 start-stop test, runout flow test and

continuous operation test were conducted to demonstrate operability and endurance of RCP. In addition, the several seal and bearing transient tests were performed under the abnormal condition such as loss of seal injection water and/or component cooling water and SBO condition. Through those transient tests, the integrity of seal assembly and bearing assembly were demonstrated.

During more than 700 hours test, all of the required type tests were successfully completed. Test results fulfilled the hydraulic requirements without trimming impeller. And RCP performance data during test satisfied with acceptance criteria, such as vibration, temperature, seal leakage.

5. Conclusions

Based on development of core technology of RCP, DOOSAN supplies the localized and improved APR1400 RCP to Shin-Hanul 1 & 2 Project. This would be good experience that the RCP core technology can break foreign monopoly in supplying the domestic nuclear industry. Also, there expect APR1400 RCP can be sustainable revenue models in nuclear industry. Moreover, development of RCP will be a catalyst to enhance design capacity for equipment and system of nuclear power plant as well as evaluation and verification skills of Korean nuclear industry.

REFERENCES

[1] APR1400 Reactor Coolant Pump Design, Fabrication, Application and Core Technology Development by Ministry of Knowledge Economy.