The Performance test of Mechanical Sodium Pump with Water Environment

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1. Introduction

As a part of a development project of Prototype Generation IV Sodium-cooled Fast Reactor (PGSFR), SFR NSSS System Design Division of Korea Atomic Energy Research Institute (KAERI) is performing a large-scale separated effect test for demonstrating the thermal-hydraulic performances of major components such as a Sodium-to-Sodium heat exchanger (DHX), Sodium-to-Air heat exchanger (AHX) of the decay heat removal system, and mechanical sodium pump of the primary heat transport system (PHTS) using the STELLA-1 (***S***odium in***T***egral ***E***ffect test ***L***oop for safety simu***L***ation and ***A***ssessment)[1].

As contrasted with PWR(Pressurized light Water Reactor) using water as a coolant, sodium is used as a coolant in SFR because of its low melting temperature, high thermal conductivity, the high boiling temperature allowing the reactors to operate at ambient pressure, and low neutron absorption cross section which is required to achieve a high neutron flux. But, sodium is violently reactive with water or oxygen like the other alkali metal. So Very strict requirements are demanded to design and fabricate of sodium experimental facilities. Furthermore, performance testing in high temperature sodium environments is more expensive and time consuming and need an extra precautions because operating and maintaining of sodium experimental facilities are very difficult.

Water is therefore often selected as a surrogate test fluid because it is not only cheap, easily available and easy to handle but also its important hydraulic properties (density and kinematic viscosity) are very similar to that of the sodium.

Normal practice to thoroughly test a design or component before applied or installed in reactor is important to ensure the safety and operability in the sodium-cooled fast reactor (SFR).

So, in order to estimate the hydraulic behavior of the PHTS pump of DSFR (600 MWe Demonstraion SFR), the performance tests of the model pump such as performance test, four quadrant pump characteristic curve test, cavitation test, coast-down flow test, pressure pulsation test, flow resistance test, and etc. were already carried out using a model pump in the water environment by pump vender's experimental facility in 2011[2].

In 2015, to compare the hydraulic characteristic of model pump with water and sodium, the performance test of model pump were performed using vender's experimental facility and STELLA-1.

The present paper describes performance test results of mechanical sodium pump with water which has been performed with some design changes using water test facility in SAM JIN Industrial Co..

2. The Performance Tests of the Mechanical sodium Pump with Water Environment

An original model pump was scaled down to preserve the major hydraulic phenomena according to the related similarity criteria using the corresponding prototype pump of the 600 MWe Demonstration SFR (DSFR).

The vertical submersible prototype pump had a rated flow rate of 17,415 m^3/h, a rated pressure head of 62.9 m, and a rated rotational speed of 433 rpm.

The impeller of model pump was scaled down a factor of 5.5 of the impeller of prototype pump while keeping the same specific speed. The model pump had a rated flow rate of 510 m^3/h, a rated pressure head of 50.3 m, and a rated rotational speed of 2,140 rpm [3].

The major specifications of the prototype and the original model pumps are follows.

Table 1 The major specifications of mechanical pumps

	Prototype	Original model
Specific speed	330.3 $rpm \cdot m^3/min \cdot m$	330.3 $rpm \cdot m^3/min \cdot m$
Rated flow rate	17,415.1 m^3/h	510.3 m^3/h
Rated head	62.833 m	50.31 m
Efficiency	80 %	71.8 %
Impeller Out Dia.	1,768 mm	320 mm
Rated Rotation speed	433 RPM	2,140 RPM
Rated power of Motor	3,700 kW	110 kW

The pump is a high speed rotary machine that converts absorbed power from the motor to the fluid pressure or head. So, the gap size between the parts of pump is very small. Pump operated in water at room temperature don't need consideration of the thermal expansion of the parts, but pump operated in sodium at high temperature need to consider the thermal expansion of the parts because of thermal deformation caused by non-uniform thermal expansion.

To accommodate non-uniform thermal expansion and to secure the operability and the safety, the gap size between suction cover of pump and impeller, and impeller and diffuser are increased from 0.5 mm to 5 mm and from 1 mm to 6 mm, respectively.

Fig. 1. Mechanical sodium pump

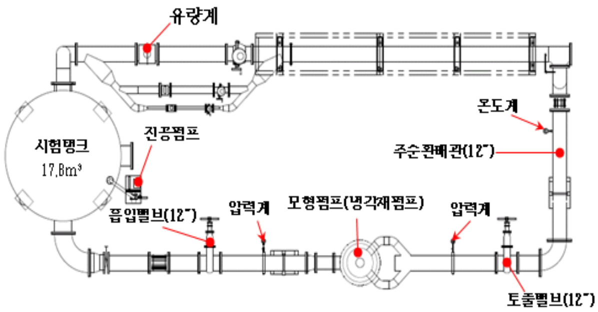

Fig. 2. Diagram of pump performance test facility with water environment

Fig. 3. Photograph of pump performance test facility with water environment

Also, the journal bearing material was changed from SiC to STS316 because thermal expansion ratio of SiC was different from that of the other parts of pump.

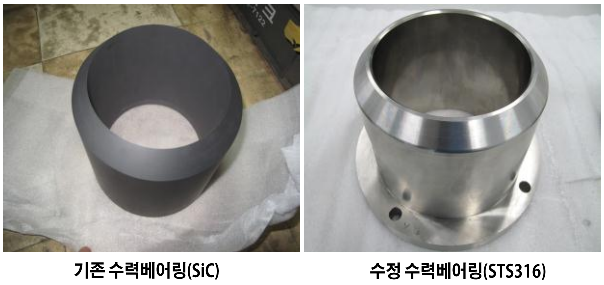

Fig. 4. Material changes of Journal bearing

An annular inlet nozzle of prototype pump was modified to adapt closed-loop type experimental facilities. Fig. 1, Fig. 2, and Fig. 3 show the mechanical sodium pump and diagram of pump performance test facility with water environment, and photograph of pump performance test facility with water environment, respectively.

Table 2 The test matrix of the performance test

N/N_R Q/Q_R	25%	35%	45%	55%	65%	75%	80%	85%	90%	95%	100%
5%	◎	◎	◎	◎	◎						
10%		◎	◎			◎	◎				
15%	◎			◎	◎			◎	◎		
20%		◎	◎			◎	◎			◎	◎
25%	◎			◎	◎			◎	◎		
30%		◎	◎			◎	◎			◎	◎
35%	◎			◎	◎			◎	◎		
40%		◎	◎			◎	◎			◎	◎
45%	◎			◎	◎			◎	◎		
50%		◎	◎			◎	◎			◎	◎
55%				◎	◎			◎	◎		
60%		◎	◎			◎	◎			◎	◎
65%				◎	◎			◎	◎		
70%			◎			◎	◎			◎	◎
75%				◎	◎			◎	◎		
80%						◎	◎			◎	◎
85%				◎	◎			◎	◎		
90%						◎	◎			◎	◎
95%					◎			◎	◎		
100%						◎	◎			◎	◎
105%								◎	◎		
110%						◎	◎			◎	◎
115%								◎	◎		
120%							◎			◎	◎
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130%										◎	◎
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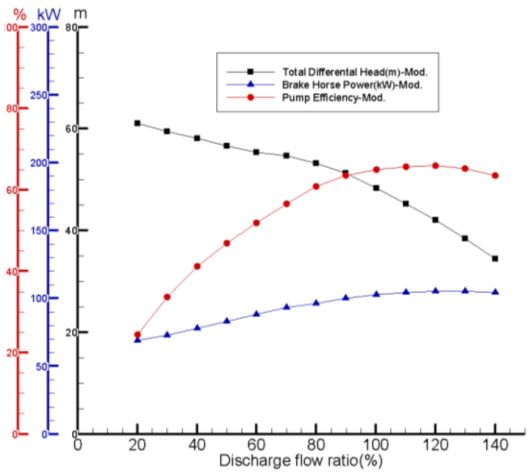

Fig. 5. The rated performance curve of mechanical sodium pump with water environment

Table 2 shows the test matrix of the performance test of mechanical sodium pump with water environment.

Fig. 5 shows the performance test result of model pump with water environment for rated RPM and rated flow rate. A rated total head of model pump was measured about 4.8% lower than the design value.

Fig. 6 shows the pump performance curve with RPM variation.

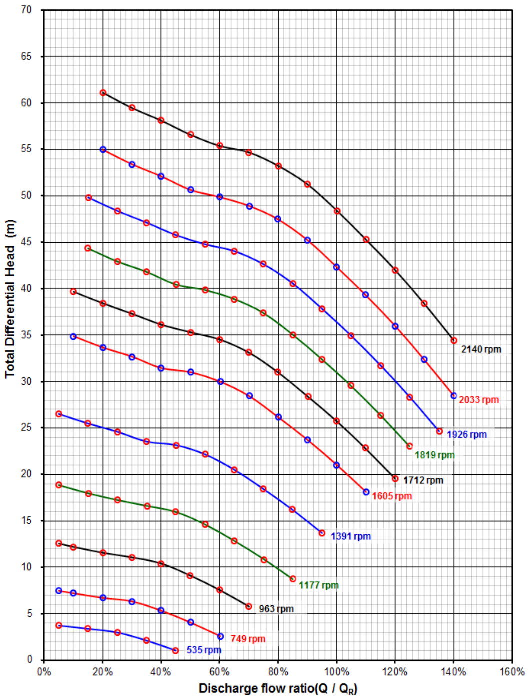

Fig. 6. Performance curve with RPM variation

Fig. 7 shows the comparison between original and modified pump performance curve at rated RPM. The modified pump's total head and pump efficiency at the rated operation point were measured about 6.3% and 17.4% lower than that of original pump, respectively.

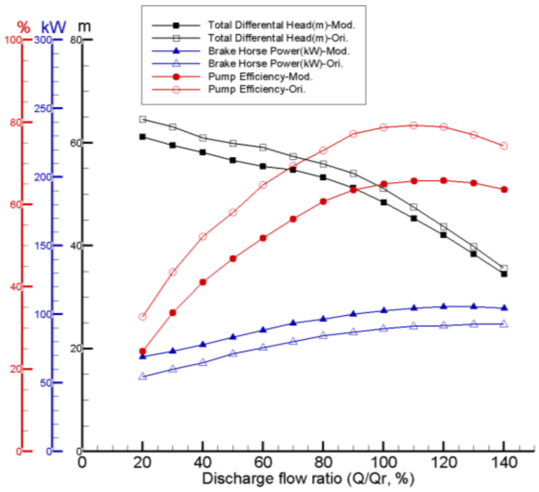

Fig. 7. The comparison between original and modified pump performance curve at rated RPM

3. Conclusion

To compare the hydraulic characteristic of model pump with water and sodium, the performance test of model pump were performed using vender's experimental facility for mechanical sodium pump.

To accommodate non-uniform thermal expansion and to secure the operability and the safety, the gap size of some parts of original model pump was modified.

Performance tests of modified mechanical sodium pump with water were successfully performed.

The modified pump's total head and pump efficiency at the rated operation point tend to lower than that of original pump because of the pressure leak according to gap size increasing and an increase of friction drag according to changing journal bearing material.

4. Acknowledgement

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