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The Performance Estimation of PHTS Pump of DSFR

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1. Introduction

Sodium is used as coolant in SFR (Sodium-cooled Fast Reactor). Very strict requirements are demanded to design and fabricate of sodium components because various components in the sodium environment need to be efficient, highly reliable, and long lived. So, it is normal practice to thoroughly test a design or component before it is installed in reactor. However, performance testing in sodium environments is more expensive and time consuming and need an extra precautions because operating and maintaining of sodium experimental facility is very difficult. Therefore, water is 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.

In order to estimate the hydraulic behavior of the PHTS pump in sodium environment, model tests were conducted in water experimental facility by SAMJIN Industrial Co. before model tests using the STELLA-1 with sodium environment in 2015.

STELLA-1 (***S***odium in***T***egral ***E***ffect test ***L***oop for safety simu***L***ation and ***A***ssessment) is a large-scale separate effect test facility 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), which are important to ensure the safety of the sodium-cooled fast reactor (SFR).

Fig. 1 STELLA-1

The specifications of STELLA-1 are as follows [2].

- Working fluid: Sodium
- Max. power: 2.5MW
- Storage of sodium: 18 tons
- Max. operating temperature: 600 ℃
- Heat exchanging rate: 1.0MWth

A 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 model pump was scaled down 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 [1].

The major specifications of the mechanical pumps are follows.

Table 1 The major specifications of mechanical pumps

	Prototype	Model
Specific speed	330.3 rpm·m	330.3 rpm·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 present paper describes the hydraulic behavior of the PHTS Pump of DSFR which is estimated from the results of the performance test for the model pump in water environment.

2. The Performance tests of the Model Pump

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 carried out using a factor of 5.5 model of prototype in the water environment by pump vender's experimental facility.[1]

An annuls inlet nozzle in prototype pump was modified for the installation to closed-loop type STELLA-1. Fig. 2 and Fig. 3 show the process diagram of pump performance test facility with water and major part of the model pump of DSFR, respectively.

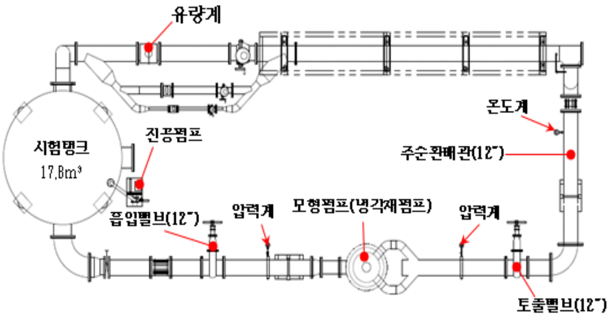

Fig. 2 Process diagram of pump performance test facility with water

Fig. 3 Model pump of DSFR

Fig. 4 Pump performance test facility with water

Fig.4 shows a scene of the four quadrant pump characteristic curve test using the pump manufacture.

Fig. 5 shows the performance test result of model pump with rated RPM and rated flow rate. A rated total head of model pump is good agreed with the design value.

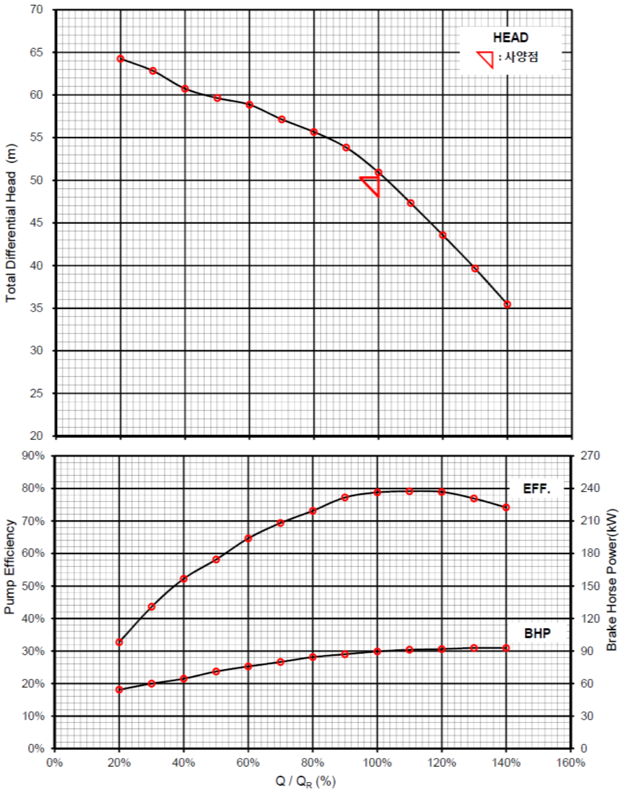

Fig. 5 Performance test result of model pump with rated RPM and rated flow rate

3. Estimation of Prototype pump performance

When the model and the prototype have the same the flow coefficient, to maintaining the dynamic similarity both model and prototype the non-dimensional coefficients to be simulated are head coefficient and power coefficient. It is so called "scaling relationship" or "Fan law" [2].

Flow coefficient;

$$\frac{Q_M}{\omega_M D_M^3} = \frac{Q_p}{\omega_p D_p^3}$$

Head coefficient;

$$\frac{h_M}{\omega_M^2 D_M^2} = \frac{h_p}{\omega_p^2 D_p^2}$$

Power coefficient;

$$\frac{P_M}{\rho_M \omega_M^3 D_M^5} = \frac{P_p}{\rho_P \omega_p^3 D_p^5}$$

Where, subscripts 'M' and 'P' denote model and Prototype, respectively. Q is a volumetric flow rate (m^3/h). ω is a impeller rotation speed (rpm). D is a impeller diameter (m), h is a total differential head of pump (m). P is BHP (Brake Horsepower) of pump. ρ is a density of test fluid (kg/m^3).

Fig. 6 shows the pump performance curve of the PHTS pump of DSFR estimated by scaling relationship. A rated total head of prototype pump is also good agreed with the design value.

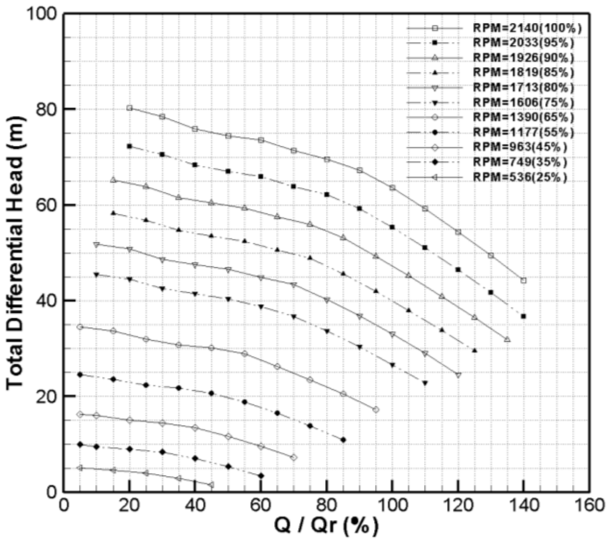

Fig. 6 Performance curve of PHTS pump of DSFR

4. Acknowledgement

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[2] Robert W. Fox, et. al., Introduction to Fluid Mechanics 7th ed., John Wiley & Sons Inc., 2010.