Decision of design requirements and scales for mechanical sodium pump in STELLA-1

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1. Introduction

In the process of sodium-cooled fast reactor design, it is very important to verifying thermo-hydraulic performance of each component in the sodium environment. In Korea Atomic Energy Research Institute(KAERI) STELLA(Sodium Integral Effect Test Loop for Safety Simulation and Assessment) project is under process under a Mid- and Long-term Nuclear R&D Program. The STELLA project is composed of two stage. In the 1st stage the performance for heat exchangers such as DHX(Decay heat exchanger) and AHX(Air heat exchanger) and for PHTS(Primary heat transport system) mechanical-typed pump will be evaluated. The detailed design of each component is based on that of a 600MWe demonstration reactor.

In this study the design features of mechanical sodium pump is described and the scaling parameter is examined. Since the full-scale components could not be installed in STELLA-1[1], the model pump is designed based on the scaling law.

2. Design features of PHTS pump

The PHTS pump, which provides a driving force to coolant, is one of the most important components in SFR. The PHTS pump for SFR could be categorized into two by the methods of supplying the driving force. One is Electromagnetic pump and the other is mechanical pump. Since liquid sodium is conductive electromagnetic pump as well as a mechanical pump can be adopted for PHTS pump in SFR system.

The advantages and disadvantages of mechanical pumps over electromagnetic pumps[2] are shown in Table. 1 and PHTS circuit configuration and type of installed pump in various SFRs are compared in Table. 2.

Table. 1 Comparison of mechanical pump to electromagnetic pump

Advantages	Disadvantages
-Matured technology -High efficiency (70-85%) -Large capacity	-Moving parts (bearing, seal for rotating shaft) -Expected to be more prone to cavitation -Existence of Na/Cover gas interface

Table. 2 PHTS circuit configuration and pump type in various SFRs

Reactor	PHTS	Mechanical/ Electromagnetic	Capacity (kg/s)
BR-10 (Russia)	Loop	E	24
Joyo (Japan)	Loop	M	380
PFBR (India)	Pool	M	3540
CRBRP (USA)	Loop	M	1747
S-Phenix2 (France)	Pool	M	4925

As shown in Table 2 most of SFRs adopts the mechanical pumps as a primary system regardless of PHTS configuration and its capacity.

The experienced problems from the operation of mechanical pumps in SFRs[2] are listed as follows:

- Erosion of the impeller due to cavitations
- Bearing housing deformation due to thermal shock
- Rotation problem due to sodium condensation between shaft and thermal shields
- Shaft deformation due to a non-uniform circumferential temperature distribution
- Gap reduction in the sodium bearing due to thermal shock

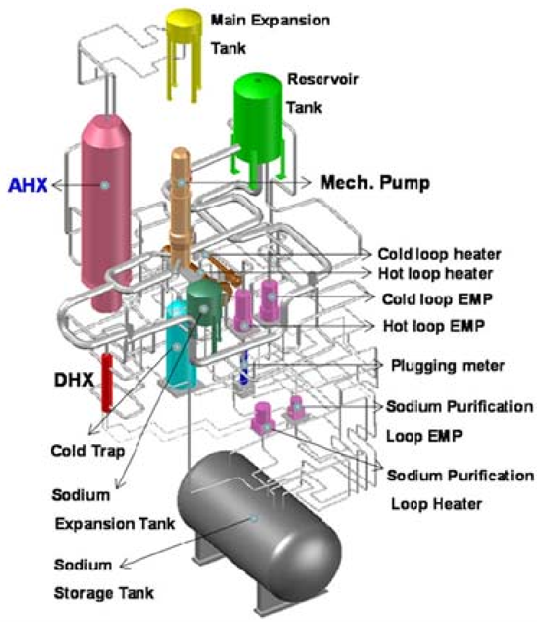

Fig. 1 General arrangement of the sodium test loop, STELLA-1

3. Design Requirements of Model Pump

The reference reactor of STELLA-1 is a 600MWe pool type demonstration reactor. STELLA-1, however, is designed as a loop type as shown in Figure 1. Therefore some design modification is inevitable between submersible prototype pump and loop type model pump, such as outer case, inlet pipe and etc. The design temperature of model pump is 500°C and the design pressure is 1MPa. The internal structure should be designed to help sodium drain easy.

4. Scaling of the PHTS pump

The hydraulic characteristic of prototype pump is as follows:

- Capacity[kg/s] : 4183
- Head[m] : 63
- Pump speed[rpm]: 433
- Operating temperature[°C] : 365

In order to predict the hydraulic behavior correctly the model pump is scaled down based on a few dimensionless parameters. Based on the procedure proposed by Buckingham[3], three independent dimensionless parameters such as specific speed(Ns), specific capacity(Qs), and specific head(Hs) can be expressed as follows;

- Specific speed

$$N_s = \frac{NQ^{1/2}}{H^{3/4}}$$

- Specific capacity

$$Q_s = \frac{Q}{Nd^3}$$

- Specific head

$$H_s = \frac{gH}{N^2d^2}$$

Where N, Q, H, d are the rotational speed, the capacity, the pump head and the impeller diameter, respectively. The subscript s indicates a specific quantity. For the flow to be dynamically similar the three parameters remain constant. The ratio of the dimensionless parameters of prototype and model can be defined as follows:

-Specific speed ratio

$$N_{sR} = \frac{N_{s,m}}{N_{s,p}} = \frac{N_R Q_R^{1/2}}{H_R^{3/4}}$$

-Specific capacity ratio

$$Q_{sR} = \frac{Q_{s,m}}{Q_{s,p}} = \frac{Q_R}{N_R d_R^3}$$

-Specific head ratio

$$H_{sR} = \frac{H_{s,m}}{H_{s,p}} = \frac{H_R}{N_R^2 d_R^2}$$

Where the subscripts m and p indicate a model and prototype, respectively. During scaling process the following rules also should be kept to guarantee the same hydraulic behavior.

- Specific speed ratio should be the same.
- Impeller outer diameter of model pump(d_m) should be larger than 12 inch
- Specific head ratio should be 80% at least.

The final design parameter is determined by following the prescribed rules and the dependencies of dimensionless scaling parameters on impeller diameter ratios are shown in Figure 2.

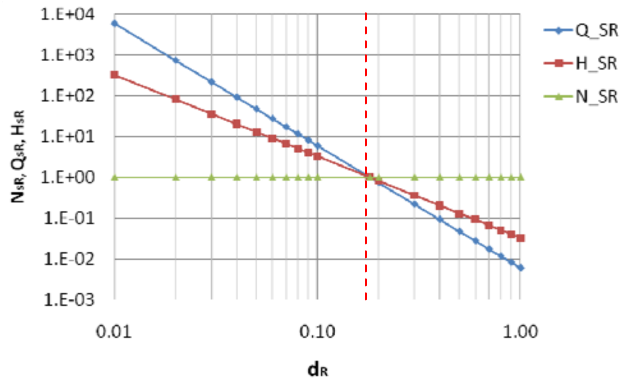

Fig. 2 Variation of dimensionless scaling parameters

5. Conclusion

In this study design features of mechanical sodium pump is described. The advantage and expected problem is listed and design requirement for model pump is described. Based on the scaling laws hydraulic design parameter of PHTS model pump is determined for STELLA-1.

REFERENCES

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