Four-Quadrant Characteristics of the Primary Cooling Pump in a Research Reactor

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1. Introduction

An open-pool type research reactor is widely designed in consideration of the reactor operability and accessibility. A reactor structure assembly is generally placed at the pool bottom as shown in Fig. 1. Primary cooling system circulates the coolant from the reactor core to the heat exchanger in order to remove the heat generated from the reactor core continuously. Two primary cooling pumps are assumed to be operating when the reactor is in the normal operation. In the previous research, a centrifugal pump with a non-dimensional specific speed of 0.59 [-] and specific diameter of 4.94 [-] was designed as the primary cooling pump.

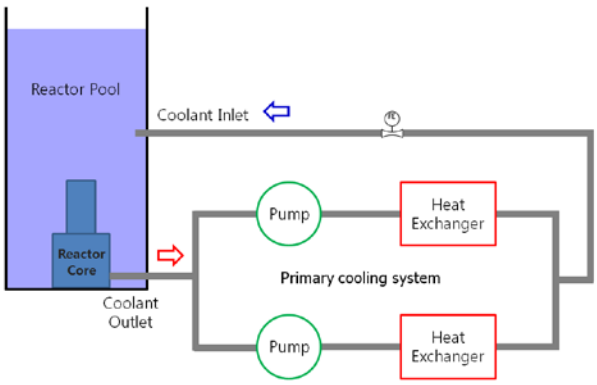


Fig. 1. Schematic diagram of an open-pool type research reactor and a flow path of a coolant

Four-quadrant characteristics of a pump show the hydraulic performance of possible operating cases. (Sometimes, called four-quadrant curves or complete characteristics) Four-quadrant characteristics consist of the normalized head, flow rate, torque, and rotating speed for all four quadrants. Homologous curves are produced from four-quadrant characteristics by using characteristic parameters and the pump similarity law. They are used for the safety analysis to simulate the pump status.

2. Test

The head and torque of a pump are measured with changing the flow rate and rotating speed. The test map for single phase four-quadrant characteristics is shown in Fig. 2.

- 1st Quadrant
  Positive flow rate and positive rotating speed
- 2nd Quadrant
  Negative flow rate and positive rotating speed
- 3rd Quadrant
  Negative flow rate and negative rotating speed
- 4th Quadrant
  Positive flow rate and negative rotating speed

Instruments shall provide the acceptable accuracy in consideration of the test range.

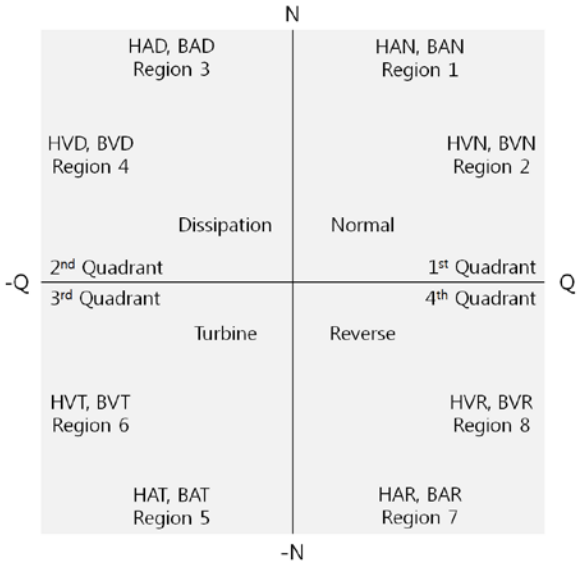


Fig. 2. Test range for four-quadrant characteristics

3. Homologous Curves

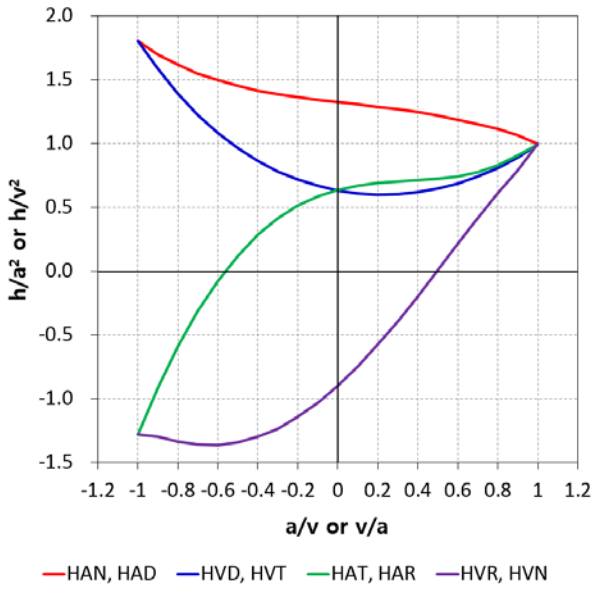
Homologous curves are generated from normalized values as follows:

$$v = \frac{Q}{Q_R} \tag{1}$$

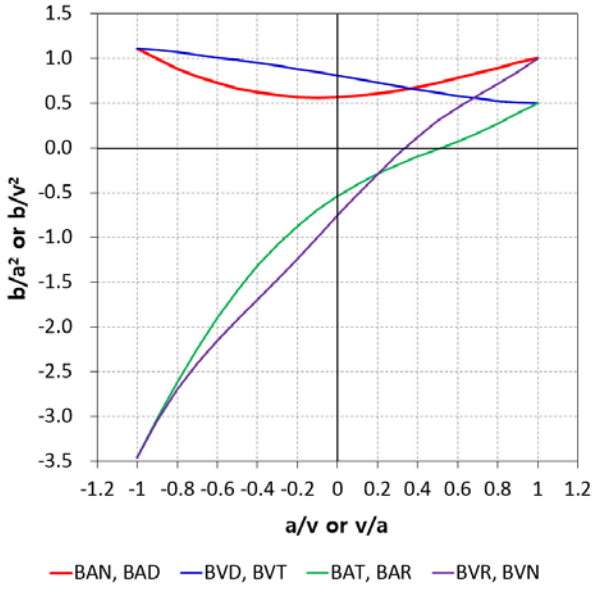
$$a = \frac{N}{N_R} \tag{2}$$

$$h = \frac{H}{H_R} \tag{3}$$

$$b = \frac{T}{T_R} \quad (4)$$



(b) Homologous head curves



(b) Homologous torque curves

Fig. 3. Homologous curves of the primary cooling pump

Homologous head and torque curves for a pump described previously are shown in Fig. 3. These curves are used for the input data of the safety analysis.

4. Conclusions

Homologous curves cover all hydraulic performance characteristics of a pump. These data are used for the safety analysis to simulate the abnormal operation related to the hydraulic performance of the pump. Homologous curves were obtained from the test results of four-quadrant characteristics for the primary cooling pump with a non-dimensional specific speed of 0.59 [-] and specific diameter of 4.94 [-].

ACKNOWLEDGEMENT

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Nomenclature

d_s	Specific diameter, $D\cdot(g\cdot H_R)^{0.25}/Q_R^{0.5}$, [-]
g	Acceleration of gravity, 9.81[m/s^2]
n_s	Specific speed, $\omega\cdot Q_R^{0.5}/(g\cdot H_R)^{0.75}$, [-]
D	Diameter of the impeller outlet, [m]
H	Head, [m]
N	Shaft rotating speed, [rpm]
Q	Flow rate, [m^3/s]
T	Torque, [N]
ω	Shaft rotating speed, [rad/s]

Subscription

R	Rated value of a pump