Simulations for Evaluating RCP Characteristics at 50 Hz Condition

Sang Seob Lee [a*], Yung Kwon Jin [a], Gyu Cheon Lee[a]
[a] *KEPCO-E&C, 1045 Daedeok-daero, Yuseong-gu, Daejeon, 305-353*
[*] *Corresponding author: sslee1@kepco-enc.com*

1. Introduction

The characteristics of 50 Hz RCP are evaluated for the thermal margin during RCP Coastdown. To have a better knowledge of the RCP characteristics, a sensitivity study for parameters such as the homologous curve, RCP speed, RCP head and RCP inertia has been performed using a computer code, COAST. The effect of each parameter is described herein, and the simulation results are shown to evaluate RCP parameters.

2. Methods and Results

The sensitivity study includes the responses of the core flow to the change of the homologous curve, head, speed, and kinetic energy. In this section the sensitivity study results are given.

2.1 Response to RCP Homologous Curve Change

Homologous curve is used to obtain head and torque vs. flow over the test range. To obtain head and torque vs. rated flow, HAN and BAN are used. To obtain head and torque vs. beyond rated flow, HVN and BVN are used.

Higher BAN value has more adverse effect on RCP coastdown, e.g., core flow (fraction) is in inverse proportion to BAN, and Fig. 1 shows RCP coastdown characteristics for various homologous curve parameters.

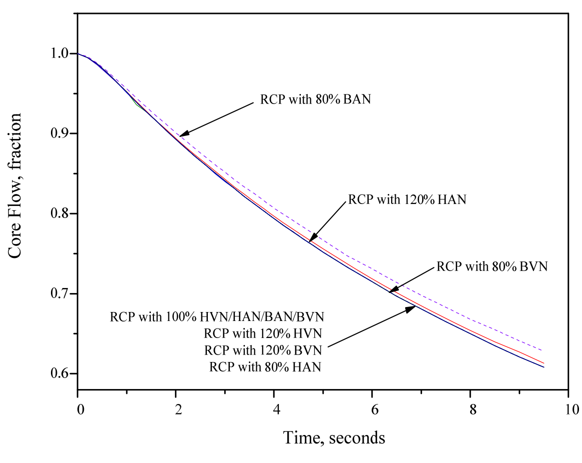

Fig. 1. RCP coastdown characteristics for homologous curve parameters

2.2 Response to RCP Head Change

For reactor coolant pump flow that falls within the range of the tested pump flow data, the pump head and efficiency are simply obtained from the data, and the pump torque is calculated using the following equation;

$$T = 5250 * \frac{Q * H * sg}{3960 * \eta * N} \quad ft - lbf$$

where, Q is flow (gpm)
H is head (ft)
sg is specific gravity
η is pump efficiency
N is pump speed (rpm)

Higher RCP head has more adverse effect on RCP coastdown, e.g., core flow (fraction) is in inverse proportion to RCP head, and Fig. 2 shows RCP coastdown characteristics for various RCP heads.

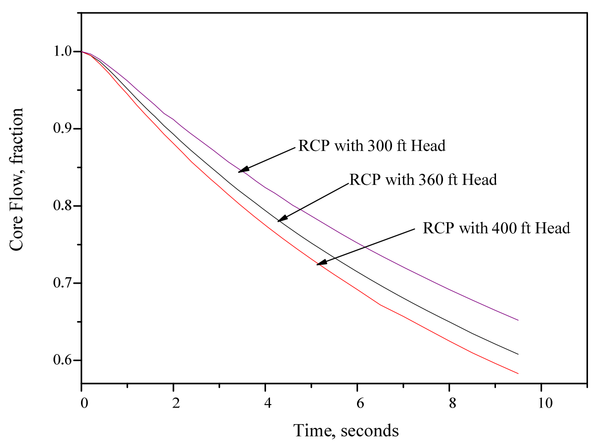

Fig. 2. RCP coastdown characteristics for RCP heads

2.3 Response to RCP Speed Change

RCP speed may be increased to provide the required kinetic energy for 50 Hz. Hydraulic torque is decreased with RCP speed increased, and it affects RCP coastdown analysis results.

Lower RCP speed has more adverse effect on RCP coastdown, e.g., core flow (fraction) is in proportion to RCP speed, and Fig. 3 shows RCP coastdown characteristics for various RCP speeds.

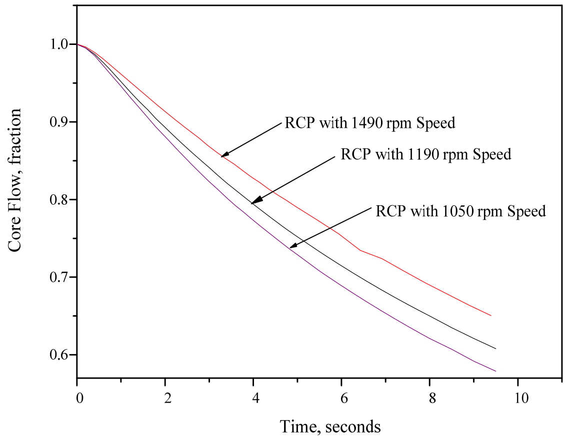

Fig. 3. RCP coastdown characteristics for RCP speeds

2.4 Response to RCP Inertia Change

The relationship between RCP inertia (I) and kinetic energy (KE) is as follows [1];

$$KE = \frac{1}{2} I \omega^2$$

where, w is angular velocity

At the same operating flow, a faster pump coastdown will reduce the operating power limit, a slower pump coastdown will improve the operating power limit.

Lower RCP inertia has more adverse effect on RCP coastdown, e.g., core flow (fraction) is in proportion to RCP inertia, and Fig. 4 shows RCP coastdown characteristics for various RCP inertias.

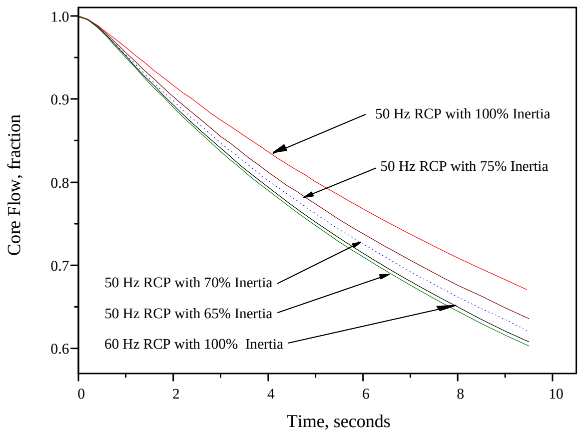

Fig. 4. RCP coastdown characteristics for RCP inertias

2.5 Preliminary RCP Coastdown Analysis

For the preliminary analysis of 4 pumps coastdown, typical 50 Hz RCP data are assumed as follows;

- Head : 113.4 m (372 ft)
- Flow rate : 7.672 m^3/s (121,600 gpm)
- Rated shaft speed : 1490 rpm
- KE : 37.5 X 10^6 ft-lb or 41.25 X 10^6 ft-lb

The sensitivity study for RCP inertia change shows that the smaller pump inertia produces faster reduction rates in core flow.

Since, at the same operating flow, a faster pump coastdown will reduce the operating power limit, the pump KE must be great enough to provide an adequate flow and guarantee minimum DNBR during a four pump coastdown.

In addition to that, if a proposed RCP is a first-of-a-kind (FOAK) type, the manufacturing uncertainties shall be considered. Therefore, a 10% increased KE considering the integrated design uncertainties is desirable for 50 Hz RCP. Four pump coastdown analysis results with two KEs are shown in Fig. 5.

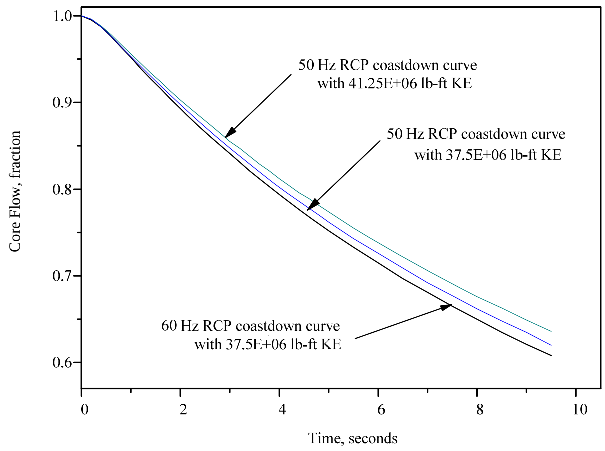

Fig. 5. Preliminary RCP coastdown analysis

3. Conclusions

RCP KE is a critical parameter for RCP coastdown analysis, and also it can be adjusted to obtain additional thermal margin. Therefore, simulation for various conditions can be an effective way for determining a FOAK type RCP KE.

With 50 Hz conditions, RCP KE shall be determined to guarantee the thermal margin considering all uncertainties. To guarantee the thermal margin, a 10% increased RCP KE is recommended.

REFERENCES

[1] Hyosung EBARA Co., LTD., HEC Pump Hand Book