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Analysis of the Coastdown Speed for a Canned Motor Pump

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1. Introduction

A canned motor pump as a reactor coolant pump (RCP) for an integral reactor has a short coastdown time because it has small polar moment of inertia. Generally, commertial RCPs have a high-inertia rotor that provide rotating inertia to increase the pump's coastdown time following a pump trip and loss of electric power. Continued coastdown flow of the reactor coolant pump is important in ensuring that the fuel's DNBR limit will not be violated in the event of a partial or complete loss of the forced reactor coolant flow analyzed in the SAR.

There is no ready made tool to predict the coastdown characteristics of the canned motor pump. We tried to find a method that can predict a canned motor pump coastdown and confirm that the momentum conservation method describes coastdown speed well.

2. Analysis Methods

2.1 Momentum Conservation Method

We use momentum conservation theory to analyze the coastdown speed of a canned motor pump in a test loop. Two momentum equations, fluid momentum equation and angular momentum equation, are used to predict the coastdown speed of the canned motor pump. The pump homologous data of the canned motor pump should be given to solve two momentum equations simultaneously. [1, 2]

$$\sum_{loop} \frac{L}{A}\frac{dQ}{dt} = g(H_{pump} - H_{friction})$$

$$I\frac{d\omega}{dt} = -T_{hydraulic} - T_{friction}$$

2.2 Energy Balance Method

The time derivative of the total kinetic energy is equal to the power losses in a closed flow system during a coastdown event. The kinetic energy of the fluid and rotating parts must be summed for the total kinetic energy [3]. We used this method as a secondary tool to compare the results obtained by momentum equations.

$$\frac{dE_t}{dt} + L_f + L_{hy} + L_m = 0$$

$$\frac{dE_t}{dt} = \rho \sum \frac{L}{A} Q \frac{dQ}{dt} + I\omega \frac{d\omega}{dt}$$

$$E_t = E_f + E_r$$

$$E_f = \frac{1}{2}\rho(\sum_{loop}\frac{L}{A})Q^2$$

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

$$L_f = \gamma Q h = \gamma Q_0 h_0 (\frac{Q}{Q_0})^3 = P_0(\frac{Q}{Q_0})^3$$

$$L_{hy} = \frac{P_0}{\eta_{hy}}(1-\eta_{hy})(\frac{Q}{Q_0})^3$$

$$L_m = T_m\omega = \alpha\omega^2 = \frac{P_0}{\eta_{hy}\eta_m}(1-\eta_{hy}\eta_m)(\frac{\omega}{\omega_0})^2$$

3. Test Loop

A test loop was constructed to verify the canned motor pump characteristics such as flow rate versus head curves, four quadrant curves, coastdown curves, etc.. The test loop shown in Fig. 1 consists of simple pipes, valves, instruments and a canned motor pump. The operating conditions of the test loop are high pressure and hot temperature. The areas of the pipes along the complete loop are different each other so the values of length over area at specific region must be recorded for coastdown analysis.

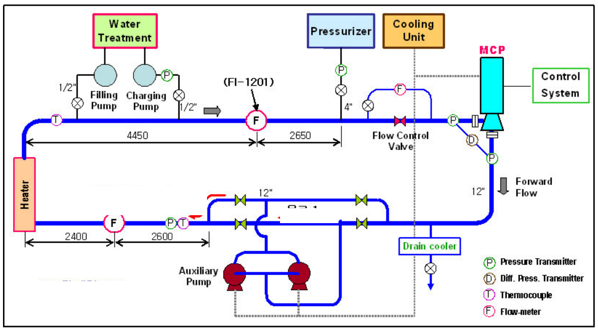

Fig. 1. Test loop for canned motor pump performance test

4. Analysis and Test Results

Fig. 2 shows the coastdown predictions by the momentum equations and the energy balance method with the variations of the rotor inertia. Two predictions are almost the same values. Fig. 3 shows the coastdown speed obtained from the test and momentum equations at the initial pump rotational speed, 3600 rpm. Fig. 4

shows the coastdown speed at the initial pump rotational speed, 1800 rpm.

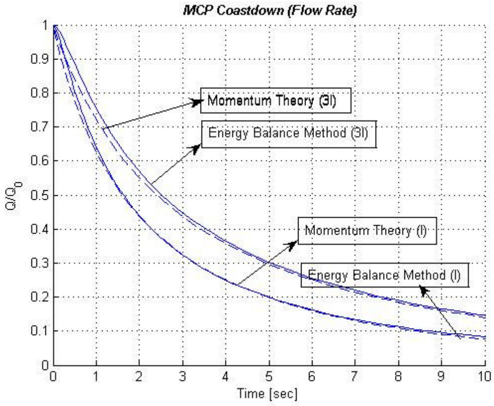

Fig. 2. Coastdown prediction by momentum equations and energy balance method

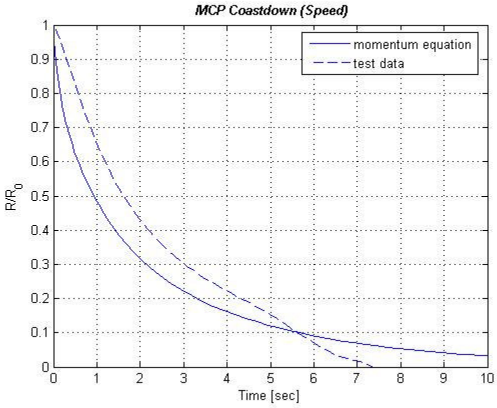

Fig. 3. Coastdown speed obtained from momentum equations and test at 3600 rpm

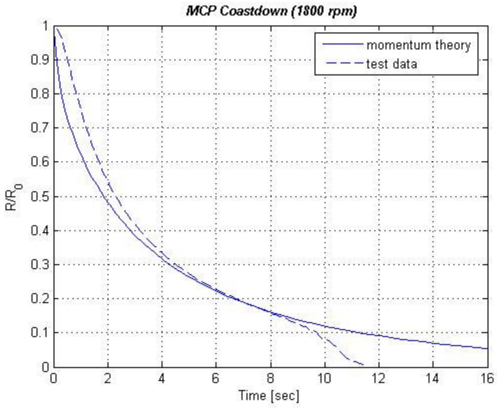

Fig. 4. Coastdown speed obtained from momentum equations and test at 1800 rpm

5. Conclusions and Remarks

We predicted the coastdown speed of a canned motor pump by momentum equations with pump homologous data. The maximum difference between the analytical predictions and test results is about 30% of the speed at a specific time during a pump coastdown but the decreasing speed tendency of the analytical results is very similar to that of test results.

The time delay of the speed sensor of the canned motor pump was not considered so the deviations of the two results may be reduced if the time delay is taken into account. Further studies are needed to explain the reason of a rapid change of the coastdown slope in the test results at the slow speed of the pump.

Acknowledgment

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Nomenclatures

A	Pipe area
E_t	Total kinetic energy
E_f	Kinetic energy of fluid
E_r	Kinetic energy of rotor
h	Pump head
h_0	Initial pump head
H_{pump}	Pump head during a coastdown event
$H_{friction}$	Friction head along the loop
I	Polar moment of inertia
L	Pipe length
L_f	Friction power losses
L_{hy}	Power losses of impeller
L_m	Power losses due to mechanical friction
P_0	Initial hydraulic power
Q	Volumetric flow rate
Q_0	Initial volumetric flow rate
t	Time
T_f	Friction torque on a shaft
$T_{hydraulic}$	Hydraulic shaft torque
η_{hy}	Impeller efficiency
η_m	Mechanical efficiency
ω	Angular speed
ω_0	Initial angular speed

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