# Development of RCP Characteristic Models for the ATLAS Facility

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## 1. Introduction

Korea Atomic Energy Research Institute (KAERI) has been operating a thermal-hydraulic integral effect test loop, ATLAS since its construction in 2005 [1, 2]. Non-seal canned motor type pumps were installed at the ATLAS facility to simulate the reactor coolant pumps of the APR1400 plants. A characteristic test program is necessary to identify the characteristics of the ATLAS reactor coolant pumps and to verify a similarity between the reactor coolant pumps of the ATLAS facility and the APR1400. Non-dimensionalized homologous curves for the head and torque of the pumps were obtained from separate tests. The friction loss coefficients for the sheared shaft and the locked rotor conditions were also obtained. The obtained pump characteristics data will be used for preparing the input deck for the safety analysis system code MARS.

## 2. Scaling of the RCPs

The ATLAS facility is designed according to the three-step scaling method suggested by Ishii and Kataoka [3]. It was designed to have a reduced primary coolant flow rate to maintain the same temperature difference across the core due to its 8% power limitation. Considering an operation and maintenance convenience, the flow capacity $Q$ and the head $H$ of the pumps was determined to be 25% and 50% of the scaled values, respectively. A summary of the scaling parameters of the model pump is shown in Table 1.

Table I: A summary of the geometric diameters of the primary piping

| Primary piping | APR1400 | ATLAS | |
|---|---|---|---|
| | | diameter | Ratio |
| Hot leg | 1066.8mm | 128.8mm | 1/8.3 |
| Cold leg | 762mm | 87.3mm | 1/8.7 |
| Interm. leg (Vertical) | 762mm | 66.9mm | 1/11.4 |
| Interm. leg (Horizontal) | 762mm | 87.3mm | 1/8.7 |

## 3. Test Results

### *3.1 Description of the test loop*

A test loop for the RCP of the ATLAS facility was constructed by the manufacturing company of the ATLAS reactor coolant pumps. The test loop consists of a storage tank, a booster pump, a test pump, and several instruments. Operating conditions of the centrifugal pumps can be divided into four quadrant regions by the flow capacity and speed coordinates [4]. The pump characteristics in the 1st ($Q>0, N>0$) and 4th ($Q>0, N<0$) quadrants was obtained from the test loop configuration shown in Figure 1. The characteristics in the 2nd ($Q<0, N>0$) and 3rd ($Q<0, N<0$) quadrants was obtained by swapping the nozzle locations of the test pump to test a reverse flow condition.

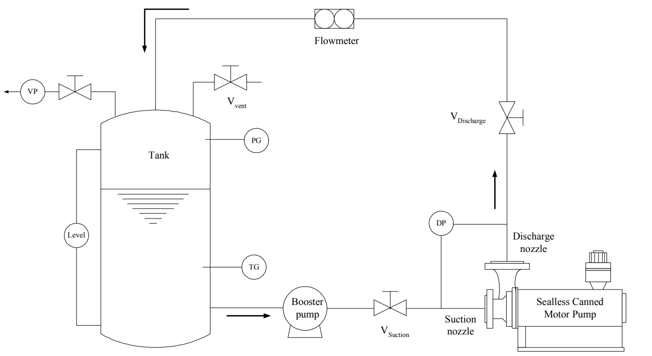


Fig. 1. A loop configuration for the homologous tests and the k-factor in the first and fourth quadrants of the pumps

### *3.2 Homologous curve tests*

Homologous, normalized pump parameters are usually defined in four quadrant regions and are commonly used for a pump performance representation in transient analyses. The following set of homologous parameters used in the present work:

| | |
|---|---|
| $h/a^2$ and $h/v^2$ | : head parameters |
| $b/a^2$ and $b/v^2$ | : torque parameters |
| v/a and a/v | : flow parameters |

where v, a, h, b is defined as $Q/Q_R$, $N/N_R$, $H/H_R$, $T/T_R$, respectively.

#### *3.2.1 Head parameter test results*

For the head parameters, an independent parameter is either v/a or a/v and the dependent parameter is $h/a^2$. The parameter v/a or a/v can be either positive or negative depending on the signs of v and a. The independent variable is varied from zero to 1.0 with a step of 0.1 Tests were carried out at four different speeds, i.e., 500, 1500, 2500, 3600rpm. The data obtained at four different pump speeds is collapsed to a curve, when they are reduced to homologous parameters. The eight homologous curves are plotted in Figure 2. In the region where the test cannot be conducted due to a limitation of the maximum flow rate of the booster pump, the curve was extrapolated to complete the homologous curve. During this extrapolation process, the k-factor test results in the case of the locked rotor which will be described in the next section were also incorporated.

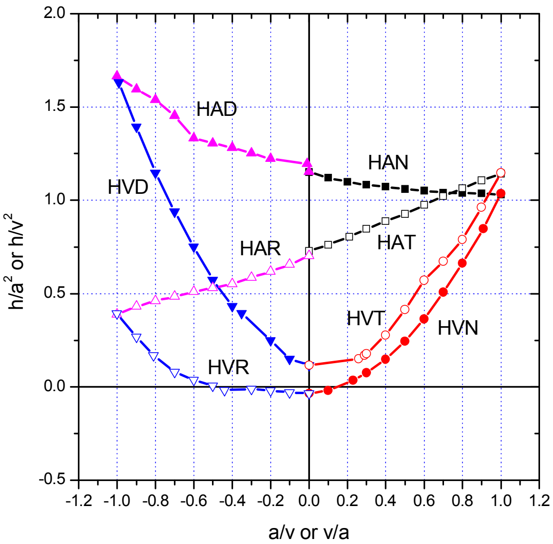


Figure 2. Measured homologous head curves of the RCPs

*3.2.2 Torque parameter test results*

The shaft torque was obtained by measuring the electric power supplied to the pump and by considering the mechanical efficiency of the pump induction motor. The calculated shaft torque was used to generate the homologous torque curves of the ATLAS pump. Reduced homologous torque curves are shown in Figure 3.

*3.3 The k-factor tests*

Experimental tests were carried out to obtain the k-factor of the RCPs for two cases: a sheared shaft and a locked rotor. The sheared shaft test is the case where the rotational rotor of the pump is assumed to be broken mechanically. Then, the impeller of the pump is allowed to run freely. On the other hand, the locked rotor test is the case where the rotational rotor is locked. In this case, the impeller becomes stuck and is not allowed to run. The flow direction can also be either forward or revere direction depending on the conditions. The k-factors obtained from the tests of the four different cases are summarized in Table 2.

Table 2. A Summary of the measured k-factors

| case | Flow Direction | |
|---|---|---|
| | Forward | Reverse |
| Sheared Shaft (Free Run) | 2.0 | 32.0 |
| Locked Rotor | 6.4 | 22.4 |

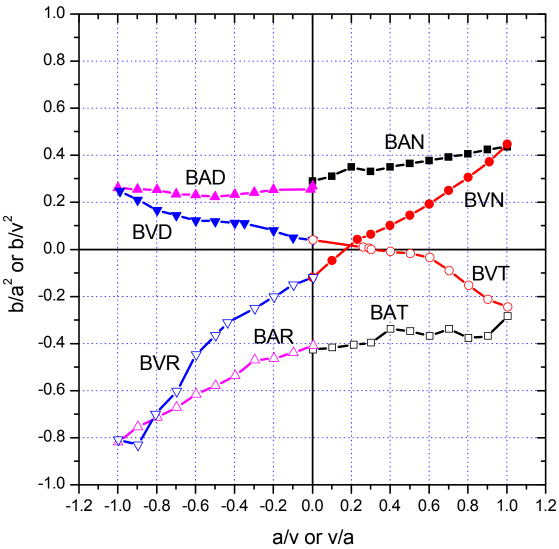


Figure 3. Measured homologous torque curves of the RCPs

### 4. Conclusions

Pump characteristic tests have been carried out for the RCPS installed at the ATLAS facility and non-dimensional pump homologous data has been obtained from four quadrant operation regions. Two kinds of data were obtained: 1) homologous data 2) k-factor data. The obtained k-factors were used to extend the homologous curves to the limiting cases of the sheared shaft and locked rotor cases at forward or reverse conditions.

The homologous data of the RCPs will be used as fundamental information in order to understand the transient behaviors of the RCPS during postulated target scenarios of the ATLAS facility. Furthermore, the present homologous pump data is essential for the thermal hydraulic system code such as the MARS code to predict the transient system behavior properly.

### REFERENCES

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