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Development of Circulator Component in MARS-GCR for Gas Cooled Reactor System

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1. Introduction

A gas cooled reactor, which operates in high temperature over 900 °C is considered as a meaningful heat source to produce the hydrogen. Currently, world-wide efforts to use the gas cooled reactor with helium as working fluid are ignited and some countries already equipped and use the gas cooled reactor for research or commercial electricity[1,2,3]. KAERI also launched a gas cooled reactor research program in 2004[4]. The project set the goal to construct a gas cooled reactor in 2019 and to prove the hydrogen production with the aid of high temperature gas cooled reactor.

In that project, MARS-GCR has been adapted as a safety research code. MARS-GCR has been modified to have a modeling capability for both of PBMR(Pebble Bed Modular Reactor) or PMR(Prismatic Modular Reactor) type reactor core, whose shape is abnormal compared to pressurized water reactor.

The turbo machinery, like turbine and circulators, requires additional considerations come from the compressibility of gas.

2. Circulators in GCR

The primary system of gas cooled reactor consists of reactor core, heat exchangers to secondary loop, and circulator. Turbine can be added, too. Among these, the circulator provides the driving force of gas and gives pressure jumps. Similar to pumps, it requires external motor torque and power to run. During an accident, the coast down and trip behaviors of circulator decides the propagation scenarios.

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In general, the commercial circulator performance information consists of pressure ratio of outlet to inlet ports and efficiency as shown in **Figure 1**. These two information are tabulated with the circulator rotational speed and mass flow rates.

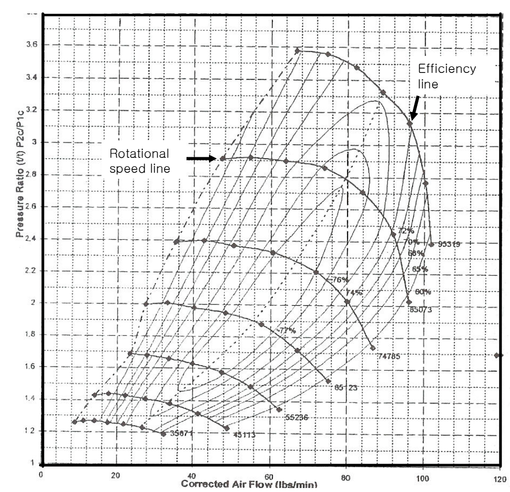

Figure 1. Typical circulator performance information: pressure ratio and efficiency

3. implementation of the Circulator Model in MARS-GCR

The encoding work is focused to the double interpolation of the pressure ratio between inlet to outlet port and the efficiency with the given circulator rotational speed and the mass flow rate. First, the recognition routine for component identified by ‘circltr’ has implemented in MARS. After the recognition, the structure of component input is designed to get the tabulated pressure ratio data and efficiency data.

The initial operation conditions like, rated circulator velocity, mass flow rate, and torque, etc. are accepted. Based on these initial operation conditions, the states of outlet port of circulator are calculated.

The pressure head jump is calculated by using pressure ratio (*PR*), which comes from the interpolation of tabulated data. The equation (1) is used to obtain the head jump (Δh). The circulator torque τ is calculated by equation (2) using the interpolated efficiency value, η.

$$\Delta h = \frac{P_1(PR-1)}{\rho_m g} \quad (1)$$

$$\tau = \frac{\dot{m}P_1(PR-1)}{\omega\eta\rho_m} \quad (2)$$

$$PR = P_2 / P_1 \quad (3)$$

where, P_1 is the inlet port pressure, P_2 is the outlet port pressure, ω is the circulator rotational velocity, $\dot{m}$ is mass flow rate, and ρ_m is the mean density of inlet and outlet port of circulator.

4. Verification

For the verification of circulator, simple one and two circulator loops have been conceptually designated. As shown in **Figure 2**, the verification loop is closed by time dependent volumes at both ends with pressure of 6.0 bars and 380 K temperature of helium. Note that the friction coefficients and lengths of single volume 006 and 007 are postulated to $1.0\text{x}10^{-3}$ and 100.0 m for the stability of outlet port of circulator. Other important description data for both circulators are as follows; rated velocity is 9223.6 rad/s, rated flow is 10.0 kg/s, rated head is $3.0\text{x}10^{5}$ Pa, and rated torque is 20173 N.m.

With these initial circulator description and operation conditions, the steady states of both loops are obtained with MARS-GCR.

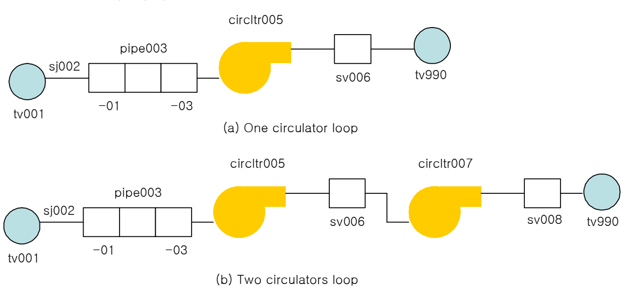

Figure 2. Schematics of circulator verification loops

Table 1. Comparison of circulator steady operation

Loop	MARS-GCR		Hand-calculation	
	Head jump (bar)	Mass flow rate (kg/s)	Head jump (bar)	Mass flow rate (kg/s)
1 circltr	1.1525	0.707	1.1524	0.706
2 circltr	1.146 1.258	0.642	1.145 1.257	0.641

The coast down behavior after trip of circulator component is accomplished. For the one circulator loop in **Figure 2**, the circulator trip is initiated after 5.0 seconds. During the next 5.0 seconds, the circulator rotational velocity is controlled to decrease from 9223.6 to 0.0 rad/s. **Figure 3** shows that pressure of outlet port and helium flow rates. The results show that the trip operation acts well in circulator component.

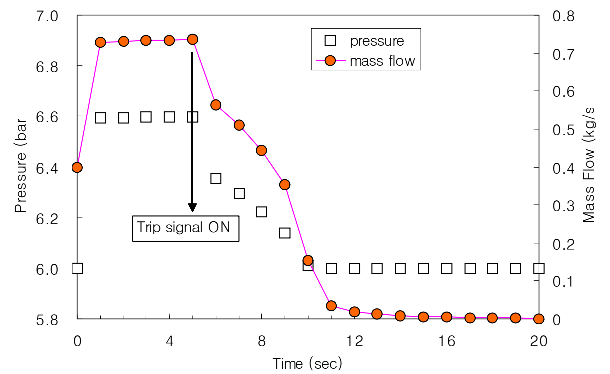

Figure 3. Coast down behavior of circulator after trip

5. Conclusions

In MARS-GCR, a new component 'circltr' has been implemented to simulate the circulator, which is the turbo machinery component with small pressure head jumps for gas phase fluid. Simple conceptual closed loop problems were designated and verified. In addition, the coast down behavior of a closed loop was also demonstrated. In conclusion, it was confirmed that the 'circltr' component can simulate the dynamic behavior of a circulator reasonably well.

Acknowledgement

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