Transactions of the Korean Nuclear Society Spring Meeting
Jeju, Korea, May 10-11, 2007

Simulation of the Pebble Bed Micro Model Benchmark Problem using MARS-GCR

Dong-Un Seo[a], Sung-Won Bae[b], Won-Jae Lee[c]
a Seoul National University, San56-1, Sillim-Dong, Kwanak-Gu, Seoul, 151-742, Korea
b Korea Atomic Energy Research Institute, Dukjin-Dong 150, Yuseong-gu, Daejeon, 305-353, Korea
c Korea Atomic Energy Research Institute, Dukjin-Dong 150, Yuseong-gu, Daejeon, 305-353, Korea
[a] mingui77@snu.ac.kr, [b] bswon@kaeri.re.kr, [c] wjlee@kaeri.re.kr

1. Introduction

The Pebble Bed Micro Model (PBMM) is a benchmark model of the Power Conversion Unit (PCU) to demonstrate the dynamic behavior of a three shafts power conversion system with nitrogen as a working fluid. This closed recuperative Brayton power conversion cycle is one of the viable options for the power conversion unit (PCU) of the very high temperature gas cooled reactor (VHTR). [1]

It is important for the safety analysis code to be able to accurately predict the behavior of the PCU. In order to obtain data for a validation of the safety analysis code, the MARS-GCR code [2], is applied to the steady state and mass injection test runs of the PBMM benchmark problem.

2. Methods and Results

The PBMM is a model of PCU for the demonstration of behavior with three shafts system using nitrogen as a working fluid. The schematic diagram of the MARS-GCR nodalization for PBMM is shown in Fig.1. The LPT and HPT provide the work to drive the compressors. The ELC is assumed as a generator. Three heat exchangers and one recuperator are used. The nitrogen heater consists of three longitudinal heater cassettes and total heat generation is 420 kW.

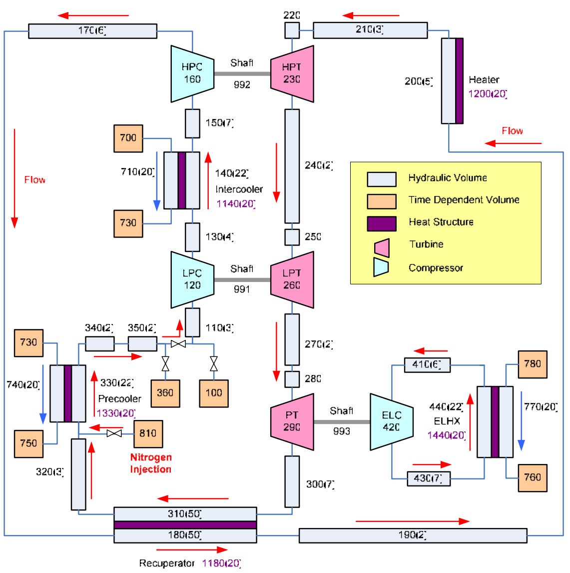

Fig. 1 Schematic Diagram of MARS-GCR code

MARS-GCR code for application to the GCR was improved to model the coolant properties of nitrogen (N_2) as well as helium (He) and carbon dioxide (CO_2) as the working fluid. The gas property routines of the MARS-GCR code was verified and validated with various problems by using NIST database. [3] The compressor model for PBMM was improved by extending the existing "PUMP" model. The performance of the compressor model was evaluated by computing the pressure ratio between inlet and outlet pressure and the efficiency given in a function of circulator rotational speed and mass flow rates. [4]

The compressor head (*Δh*) is obtained by the pressure ratio (*PR*), which is interpolated from the experimental data. [5] The head can be expressed as

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

$$PR = \frac{P_2}{P_1} \quad (2)$$

$$\tau = \frac{\dot{m}P_1(PR-1)}{\omega\eta\rho_m} \quad (3)$$

P1 and P2 is inlet and outlet pressure, respectively. τ is a compressor torque, $\dot{m}$ is mass flow rate, ω is compressor rotational velocity, η is efficiency and ρ_m is mean density of compressor working fluid.

The steady state and mass injection transient runs for PBMM benchmark problems were carried out by using the MARS-GCR.

The results of the steady state run using MARS-GCR show a good agreement with experimental results as shown in Fig. 2 and 3. The average percent difference of the temperature and the pressure are 2.52 % and 2.59 %, respectively.

For the mass injection transient, the experimental condition was run from the steady state end states that 95 kPa suction pressure of low pressure compressor (LPC) and 650 °C outlet temperature of heater. Nitrogen was injected at 0.0227 kg/s for 63 seconds at the LPC inlet. The mass injection point is located in the node number 810, the upstream of the precooler (PC).

The results of mass injection are shown in Fig. 4. Due to the neglect of the heat leak of the components, the transient calculation results show some discrepancies from the experiment.

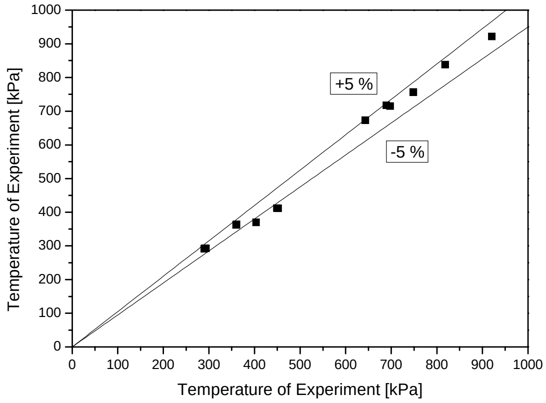

Fig. 2 The temperature of the MARS-GCR and the Experimental Results

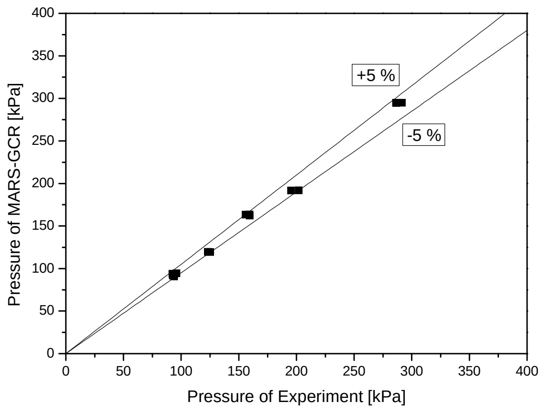

Fig. 3 The Pressure of the MARS-GCR and the Experimental Results

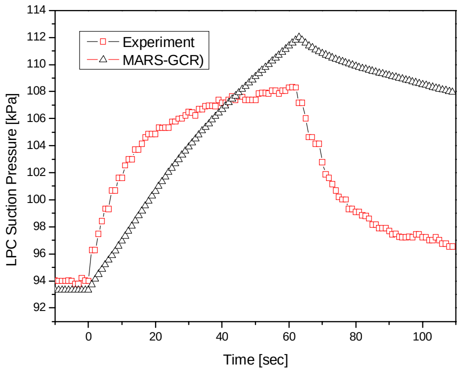

Fig. 4 Suction Pressure during the Injection Transient

3. Conclusion

The MARS-GCR code is applied to simulate the steady state and mass injection transient of the three shafts power conversion system, PBMM. From the steady state run, the capabilities of the MARS-GCR code for simulating the PBMM were demonstrated. The MARS-GCR code shows a good accuracy in predicting the temperature and the pressure distributions with an average error of about 3 % at the end of steady state calculation.

From the mass injection transient, however, after stopping the mass injection of nitrogen, the LPC pressure of MARS-GCR had not recovered to experiment speed.

Further improvements and assessments are required for the reliable prediction of turbo-machinery performance of the MARS-GCR.

In future, various transient events using the MARS-GCR for PBMM will be performed.

REFERENCES

[1] IAEA, Evaluation of High Temperature Gas Cooled Reactor Performance, IAEA-TECDOC-TBD, 2004.

[2] W.J. Lee et al., Development of MARS-GCR/V1 and its Application to Thermo-Fluid Safety Analysis of Gas-Cooled Reactors, ICAPP'05 Paper 5231, Seoul, Korea, 2005.

[3] NIST Standard Reference Database 12, NIST Thermodynamics and Transport Properties of Pure Fluids – NIST Pure Fluids, Version 5.0, 2000.

[4] MARS Code Manual Volume I: Code Structure, System Models, and Solution Methods, KAERI/TR-2812/2004, Korea Atomic Energy Research Institute, 2004.

[5] S.W. Bae et al., Development of Circulator Component in MARS-GCR for Gas Cooled Reactor System, Proc. KNS Autumn meeting, 2005.