Validation of the POSCA Code Using the OGL-1 Experiment

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1. Introduction

Accurate prediction of the fission product plateout and circulating coolant activities is important in the design of a high temperature gas-cooled reactor (HTGR). The results of the calculations can be used for the design of the purification system, the shielding of the components, and the maintenance and repair [1]. They can also be used for the safety analysis. For example, the plateout and circulating activities are contributed to early source terms under loss of coolant accident scenarios [2]. Therefore, the development of a new computer code named POSCA (Plate-Out Surface and Circulating Activities) [3-4] has been in progress at the Korea Atomic Energy Research Institute (KAERI) to predict fission product plateout and circulating coolant activities under normal operating conditions of a HTGR. In the past, the verification study of the POSCA code using analytic benchmark examples was done [3-4].

This paper describes a validation work of POSCA using the Oarai Gas Loop No. 1 (OGL-1) experiment which was carried out in an in-pile helium loop installed in the Japanese Materials Testing Reactor (JMTR).

2. OGL-1 Experiment

Japan Atomic Energy Agency (JAEA) performed the OGL-1 experiment to obtain the fission product plateout data. The experimental data was used to validate the PLAIN code [5] which was developed by JAEA to design a HTGR. Fig. 1 shows a schematic drawing of the experimental loop of OGL-1.

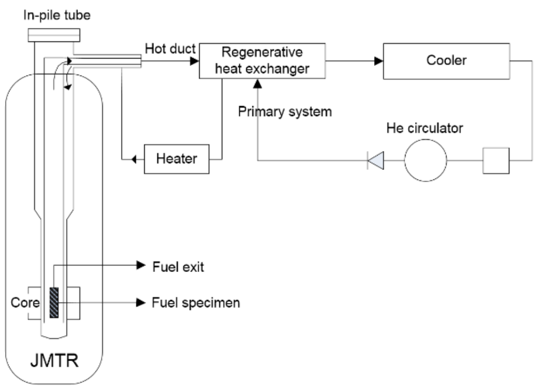

Fig. 1. Schematic flow diagram of OGL-1 experiment.

The plateout distributions were measured from the outside of the primary pipes after every operational cycle using a Ge-detector. The range of helium temperatures was from 1000 °C at the fuel exit to room temperature. The helium flow was fully turbulent. The operating conditions, the measured temperature profiles, and the measured plateout concentration distributions are available in the IAEA report [6]. The geometry of the OGL-1 facility is shown in Table I. As a structure material of the primary loop, Hastelloy-X was used in high temperature regions (from the in-pile tube to the first heat exchanger) whereas stainless steel was used in lower temperature regions.

Table I: Geometry of OGL-1 facility [6]

Location	Length (m)	Hydraulic diameter (m)	Flow area (m2)	Material
In-pile tube	6.50	0.08	5.027E-3	Hastelloy-X
Duct	6.85	0.059	2.734E-3	Hastelloy-X
Duct	18.25	0.0446	1.562E-3	Hastelloy-X
HX1	7.52	0.0119	1.112E-3	Hastelloy-X
Duct	4.55	0.0527	2.181E-3	SUS
HX2	6.87	0.0127	1.267E-3	SUS
Duct	11.53	0.0527	2.181E-3	SUS
Cooler	12.21	0.0214	3.597E-3	SUS

Two operational cycles (i.e., 69th and 73th cycles) were selected in this work. The major operating conditions of 69th and 73th cycles are provided in Table II. The measured wall temperatures are plotted in Fig. 2.

Table II: Major conditions of OGL-1 experiment [6]

	69th cycle	73th cycle
Helium pressure	3 MPa	3 MPa
Mass flow (g/s)	58.5	63.9
Operating time (hr)	472	484

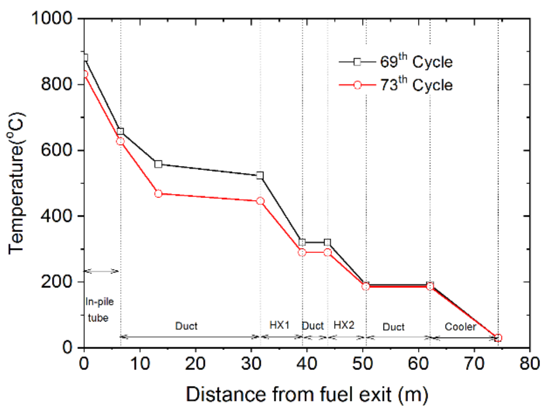

Fig. 2. Measured temperature distributions in OGL-1.

3. Validation Results and Discussions

Fig. 3 shows the POSCA model to simulate the OGL-1 experiment. The number in bracket represents the number of computational cells. The same numbers were used to validate the GAMMA-FP code in the reference [7].

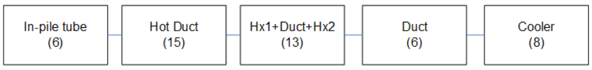

Fig. 3. POSCA model to simulate the OGL-1 experiment.

The fission product concentration at the fuel specimen outlet was applied to the inlet boundary. The returning loop after the cooler was neglected because it was assumed that the fission products are completely removed by the purification filter. The same boundary condition and assumption were used to validate the PLAIN and GAMMA-FP codes.

The sorption model developed by the General Atomics (GA) [6] was applied. For example, the vapor pressure (Pa) of iodine at the boundary layer is expressed as follows:

$$p_B = \frac{S}{a_l \cdot (K - S)} \qquad (1)$$

where S is the surface concentration and K is the empirical constant, and

$$a_l = a\exp(-Q/RT) \qquad (2)$$

where a and Q are the empirical constants. The empirical constants for iodine are provided in Table III.

Table III: Empirical constants of the GA sorption model for iodine [6]

Constants	Hastelloy-X	SS-304	Hastelloy-X	SS-304
	Unoxidized surface		Oxidized surface	
K(μg/cm^2)	0.4	0.4	3.0	1.5
a (Pa^{-1})	5.11E-6	5.11E-6	3.49E-5	3.49E-5
Q (J/mol)	-1.11E5	-1.11E5	-1.11E5	-1.11E5

Figs. 3 and 4 show the validation results of the POSCA calculations for I-131 at 69th and 73th cycles, respectively. Initially clean wall surface was assumed for I-131 in the POSCA calculations since the contamination from the previous cycle was negligibly small. The shutdown interval between the cycles was sufficiently long for the decay of I-131. The overall differences between the predicted and measured values are less than a few orders of magnitude. The reported results by the PLAIN calculations are added as a comparison. The GAMMA-FP calculations were updated in this work. The figures show that POSCA and GAMMA-FP produces the similar results. For the comparison between the results of POSCA and PLAIN, it can be seen that the deviations between the measured and calculated data are comparable. The deviation is smaller than the impact of surface oxidation. It was also found that POSCA is more than 2000 times faster than GAMMA-FP to produce the results shown in Figs. 3-4.

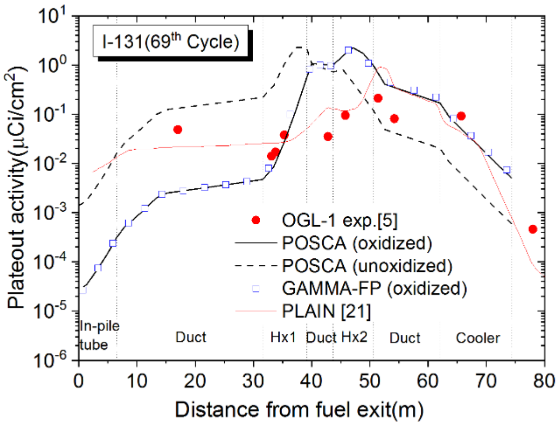

Fig. 3. Validation of POSCA using I-131 measurement at cycle 69.

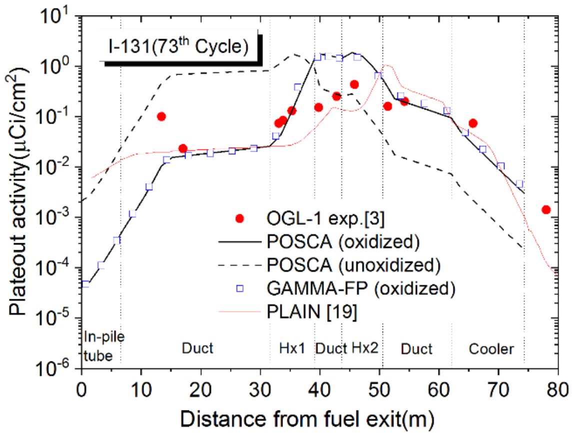

Fig. 4. Validation of POSCA using I-131 measurement at cycle 73.

4. Conclusions

In this paper, the validation of POSCA using the OGL-1 experiment was summarized. The results of the validation show that the numerical model of POSCA is reliable and its accuracy is comparable to the existing codes. Significant improvement was achieved in the computing time compared to GAMMA-FP. Further validation studies to enhance the reliability of POSCA are on-going toward practical applications to HTGR designs.

Acknowledgements

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