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Development of a Real-time Core Thermal-hydraulics Model for SMART Simulator

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1. Introduction

A multi-purpose best-estimate simulator for SMART is being developed for utilizing in design improvement, operator training, and evaluation of the impact of passive safety system to the performance of SMART. MATRA-SSIM(MATRA SMART SIMulator) code is a part of simulator engine software which has a function of calculating core thermal hydraulic fields during the simulated transients as well as provide TH parameters to the neutron kinetics code for reactivity feedback calculations. The SMART simulator has a requirement of a real time simulation capability. Moreover, each code loaded in SMART simulator has to preserve the robustness of simulation. Therefore, it is necessary to develop an appropriate subchannel model to satisfy the requirement of the real time simulation and have the robustness, simultaneously. In this paper, 58-channel model is developed and proposed as the subchannel model to satisfy these requirements for MATRA-SSIM code of the SMART simulator.

2. 58-Subchannel Model

In this section 58-subchannel model of MATRA-SSIM code is proposed and described. The proposed 58-subchannel model is validated by simulating the core transient situation.

2.1 Development of 58-Subchannel model

Basically, 57-subchannel satisfied the requirement of the real time simulation when the transient time interval is above 0.05 sec(this value can be dependent on specification of the calculating machine). In the 57-subchannel model, 1 FA(fuel assembly) of the SMART core consists of one subchannel. The detail description of the 57-subchannel model and validation for real time simulation [1] are not included in this paper.

Besides, the MATRA-SSIM code might be failed in the simulation under very low mass flux condition. In that case, the failure of the MATRA-SSIM code can effect on other simulator code directly or indirectly. It means that the robustness of the SMART simulator is broken. A single channel switching method was proposed to prevent the failure of the MATRA-SSIM code under very low mass flux condition. The single channel switching is the method to change calculation model from multi-channel subchannel to single channel under unsuitable conditions to be calculated by subchannel analysis code. The detail description of single switching method is not included, too.

The single channel switching method can improve the robustness of the MATRA-SSIM code. However, two inputs, 57-subchannel and single channel input, are needed to embody the single channel switching method in the SMART simulator. An extra weight and complexity might be added to the simulator by using two independent inputs. Therefore, the 58-subchannel model is proposed to solve these problems.

The concept of the 58-subchannel model is a superposition both 57-subchannel and single channel model. Both the 57-subchannel and single channel information are simultaneously included in a single input. The first subchannel of the 58-subchannel model becomes the single channel and others (subchannel number 2 ~ 58) become 57-subchannel. Moreover, the first subchannel is isolated with others, which means that adjacent subchannels with the first do not exist. In the 58-subchannel model, a relationship between the first subchannel and others is followings:

$$AC(1) = \sum_{I=2}^{58} AC(I)$$

$$PW(1) = \sum_{I=2}^{58} PW(I)$$

$$PH(1) = \sum_{I=2}^{58} PH(I)$$

where, AC, PW, and PH mean the flow area, wetted perimeter, and heated perimeter of subchannel, respectively. The number in a parenthesis means the subchannel number.

2.2 Validation of 58-Subchannel model

The validation of the 58-subchannel model was executed by simulating REA(Rod Ejection Accident). At this time, the power transient of REA is depicted as shown in Fig. 1. The used test matrix to validate the 58-subchannel model is summarized at Table 1. As shown in Table 1, four values were compared. The bundle averaged value of an established 57-subchannel model and 58-subchannel model, and the value of the first subchannel in the 58-subchannel model were compared with the reference value resulted from single channel calculation. The compared variables related to fluid are, pressure drop, density, enthalpy, quality, mass flux, coolant temperature and so on. In view of the fuel rod, heat flux and heat transfer coefficient at the fuel rod surface, rod surface temperature and rod center temperature are compared. In this paper, the only profile of these variables and trend respect to time are shown in Fig. 2 and 3 when the simulation time is 1.0 sec. As shown in Figs., all values of fluid and fuel rod property correspond. This means that the 58-subchannel model simultaneously have all of two calculation results, 57-subchannel and single channel result, even if the calculation is executed at one time.

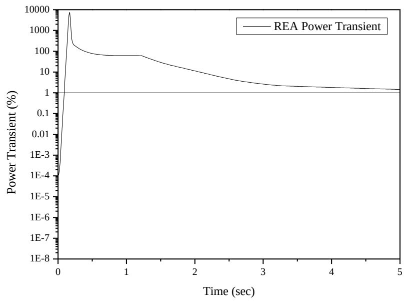

Fig. 1. REA power transient

Table I: Validation Description

Subchannel Model	Value
Single Channel Model	Reference
57-Subchannel	Bundle average
58-Subchannel	Bundle average
58-Subchannel	Subchannel #1

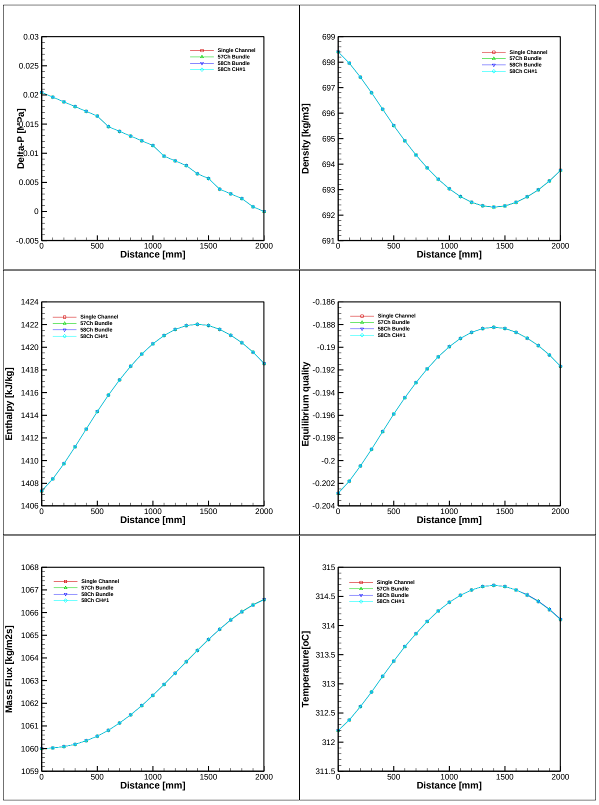

Fig. 2. Fluid properties (REA 1.0 sec)

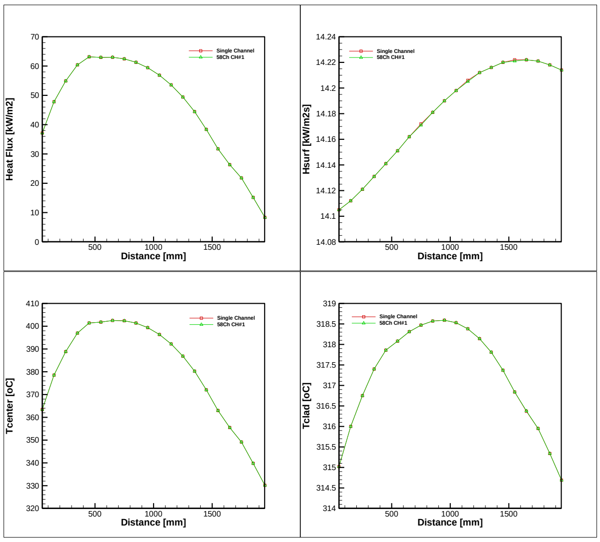

Fig. 3. Fuel rod properties (REA 1.0 sec)

3. Conclusions

The 58-subchannel model for the SMART simulator is proposed and validated. It is shown that the 58-subchannel model can produce multi-channel and single channel result, simultaneously, without an extra input or modification of source code. The 58-subchannel model will be used to a real-time core thermal-hydraulics model for the SMART simulator whose robustness is improved with a capability of single channel switching option.

REFERENCES

[1] S.J. Kim at al., Development and Assessment of Core T/H Code's Real Time Model for SMART Simulator, KAERI/TR-4904/2013, KAERI, 2013.

ACKNOWLEGEMENTS

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