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Evaluation of the DNBR-POL algorithm in SMART Core Monitoring System

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1. Introduction

SMART COre Monitoring System (SCOMS) consists of several modules for monitoring core, calculates the Limiting Conditions for Operation (LCO) with measurable process variables, and provides effective margin information to the operator. In order to calculate the operating margin, we have to know about Power Operating Limit (POL) which is defined as a distance between the present local power at a present operating condition and the limiting power that occurred at limit DNBR. The POL requires the iteration until present local power reach limit power.

The POL consists of LPD-POL and DNBR-POL. LPD-POL is calculated using the 3-dimensional peaking factor and azimuthal tilt value. But, this study is verified through the value of DNBR-POL.

In this study, the DNBR-POL of the SCOMS compares with the FAST algorithms. It is checked to the results of converged MDNBR and converged maximum quality through the severe cases.

2. Methods and Results

2.1 POL algorithm

DNBR-POL of SCOMS is calculated by a function of reactor coolant flow, core power distribution, core inlet temperature, and primary system pressure [1]. Using the channel model, the minimum DNBR (MDNBR) and maximum quality of the core are calculated and compared with the limiting values. The DNBR-POL is determined by repeatedly increasing the core power until the MDNBR or maximum quality reaches the limiting conditions.

FAST code [2, 3, 4], a fast DNBR calculation code for SMART, is used as a reference code to be compared. In this code, 4 channel core lumping model to evaluate the minimum DNBR is used. The core model and DNBR calculation algorithm of FAST code is exactly implemented in the POL module in SCOMS to preserve thermal margin which is evaluated by thermal margin design.

2.2 Results

The verification condition are shown in Table I, where Axial Offset (AO) used typical chopped cosine shape and saddle type shape in Fig. 1. The verification condition are selected under bounding region the LCO.

Table I. The conditions of each case

Case No.	AO	Temp.	Pressure	Mass flux	Heat flux
1	1	295.52	15	1784	406.36
2		297.5	14.3	1695	418.55
3		293.5	15.4	2052	406.36
4		297.5	15	1695	418.55
5		297.5	15	2052	418.55
6	2	295.52	15	1784	406.36
7		297.5	14.3	1695	418.55
8		293.5	15.4	2052	406.36
9		297.5	15	1695	418.55
10		297.5	15	2052	418.55

Note) Unit of temperature, pressure, mass flux, and heat flux is respectively ºC, MPa, kg/m2-sec, and kW/m2-sec.

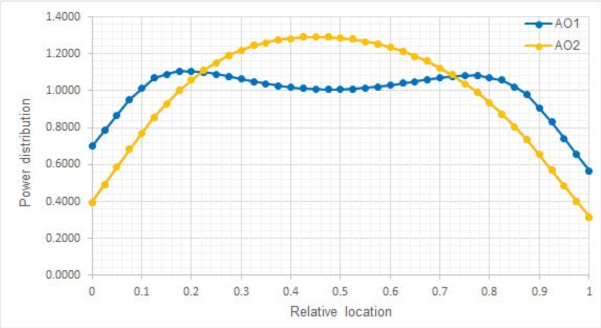

Fig. 1. Axial power distribution used in POL algorithm test

Initial MDNBR and maximum quality are compared to verify the consistency of SCOMS DNBR module and FAST code. As shown in Table II and III, the initial MDNBR and maximum quality are approximately 5.344 and -0.085 in case of 1. These values are shown as the exactly same value in all cases in the FAST and SCOMS code because the calculation algorithm of DNBR in SCOMS is based on the FAST algorithm.

Power iteration to evaluate POL value which specified thermal margin in operating condition is required. Table IV shows that POL value evaluated by FAST and SCOMS are slightly different because of difference of iteration algorithm. The SCOMS consists of an algorithm that uses the current POL value to calculate the DNBR and quality values in the next stage.

The maximum differences of POL, MDNBR, and quality in SCOMS codes compared with FAST are approximately 1.32%, 0.27%, and 34.29% in case 8, respectively.

Table II. The result of each condition (AO is '1')

	CODE	Initial value		POL	POL converged condition		
		DNBR	Quality		Iteration	DNBR	Quality
1	FAST	5.344	-0.085	2.2009	5	1.501	0.186
	SCOMS	5.344	-0.085	2.2010	5	1.505	0.185
2	FAST	4.801	-0.028	2.0483	5	1.500	0.219
	SCOMS	4.801	-0.028	2.0527	5	1.499	0.218
3	FAST	6.101	-0.148	2.4406	5	1.501	0.145
	SCOMS	6.101	-0.148	2.4531	6	1.500	0.147
4	FAST	4.830	-0.051	2.0467	5	1.500	0.201
	SCOMS	4.830	-0.051	2.0471	5	1.500	0.202
5	FAST	5.631	-0.096	2.3006	5	1.501	0.166
	SCOMS	5.631	-0.096	2.3007	5	1.505	0.165

Note) DNBR and Quality are the MDNBR and maximum quality.

Table III. The result of each condition (AO is '2')

	CODE	Initial value		POL	POL converged condition		
		DNBR	Quality		Iteration	DNBR	Quality
6	FAST	4.389	-0.166	2.2222	5	1.501	0.202
	SCOMS	4.389	-0.166	2.2222	7	1.505	0.203
7	FAST	3.961	-0.112	2.0536	5	1.502	0.231
	SCOMS	3.961	-0.112	2.0552	6	1.499	0.231
8	FAST	5.051	-0.215	2.4838	5	1.501	0.165
	SCOMS	5.05	-0.215	2.5167	5	1.505	0.108
9	FAST	4.021	-0.144	2.0615	5	1.499	0.216
	SCOMS	4.021	-0.144	2.0603	6	1.500	0.217
10	FAST	4.642	-0.168	2.3291	5	1.502	0.182
	SCOMS	4.642	-0.168	2.3386	6	1.505	0.183

Table IV. Differences of each case (raw)

Case No.	POL Error* (%)	DNBR Error (%)	Quality Error (%)
1	0.0	-0.29	0.12
2	-0.21	0.10	0.16
3	-0.51	0.02	-1.50
4	0.0	0.04	-0.45
5	0.0	-0.27	0.16
6	0.0	-0.26	-0.44
7	-0.18	0.19	-0.10
8	**-1.32**	**-0.27**	**34.29**
9	0.06	-0.05	-0.23
10	-0.41	-0.16	-0.87

* Error(%) = (FAST value - SCOMS value)/FAST value × 100

These differences between FAST and SCOMS are compared when using with the same condition, the results of comparison using the value of core average heat flux are shown in Table V. The value of POL is using the finally converged MDNBR in FAST code and the initial MDNBR in SCOMS. Fig. 2 and 3 show values of the DNBR and quality about case of 8. Two codes have similar trend as shown in Fig. 2 and 3.

Table V. Differences of each case (heat flux corrected)

Case No.	Heat flux (MBtu/hr-ft^2)	DNBR Error (%)	Quality Error (%)
1	0.28348	-0.06	0.08
2	0.27181	-0.29	0.47
3	0.31435	-0.09	0.16
4	0.27160	0.19	-0.39
5	0.30529	-0.08	0.12
6	0.28622	0.28	-0.41
7	0.27251	-0.04	0.07
8	**0.31991**	**0.02**	**-0.05**
9	0.27356	0.24	-0.34
10	0.30907	-0.08	0.12

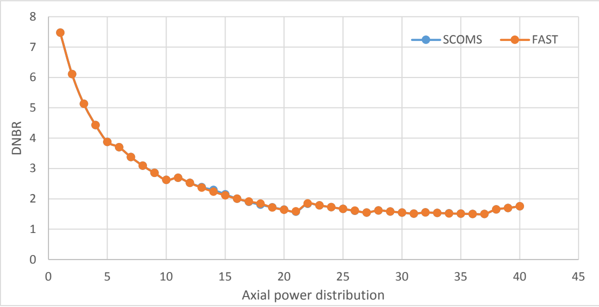

Fig. 2. Difference DNBR of case 8

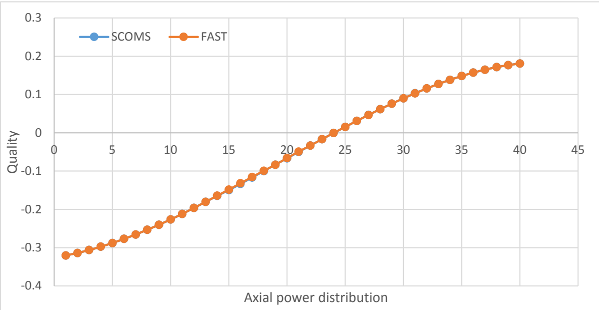

Fig. 3. Difference Quality of case 8

3. Conclusion

Initial DNBR and quality was firstly compared to verify the DNBR calculation algorithm. These comparison showed the good agreements with FAST code within 0.5 %.
In sequential verification of SCOMS, power margin through POL iteration was compared to that of FAST code. Difference of power value in POL iteration results in the significant difference in quality in case of 8. Further study to resolve the issue is required on the POL iteration.

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