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# DNBR Evaluation in SMART Core Monitoring System with Non-uniform Axial Spacing

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## 1. Introduction

SMART Core Monitoring System (SCOMS) consists of processor and algorithms performed by the Information Processing System (IPS), calculates the Limiting Conditions for Operation (LCO) with measurable process variables, and provides related information to the operator [1]. In Power Operating Limit (POL) module of SCOMS, NBR-POL is calculated based on DNBR and quality at the node of the minimum DNBR (MDNBR).

In this study, DNBR is evaluated when the non-uniform axial spacing is applied to SCOMS under LCO conditions and representative axial power shape. Moreover, the DNBR difference between using uniform and non-uniform axial spacing is presented in the view of conservatism.

## 2. Methods and Results

### *2.1 Determination of axial node*

The DNBR-POL algorithm of SCOMS is originated from FAST-S code [2]. The FAST-S code is a fast DNBR calculation code for SMART application and 4 channel core lumping model is implemented. In the previous study [3], it has seen that DNBR algorithm of FAST-S was properly implemented to SCOMS.

CHF correlation of SCOMS, which are identical with FAST-S code, is a function as following Eq. (1). When the CHF is calculated at location near below the spacer grid, the value of CHF may be dominantly affected by a parameter of DG. Moreover, this correlation has characteristics that DNBR decreases as DG increases. This means that DNBR will be more conservative as increasing DG at near an identical spacer grid. Thus, it is expected that DNBR near below the spacer grid will be minimized when the CHF location to be calculated is identical with the space grid. Besides, it is difficult to match two locations if the uniform axial spacing is applied to SCOMS because the distance between each spacer grid is not uniform in case of SMART core. Therefore, the non-uniform axial spacing is considered in order to match two locations.

$$CHF = func(DG, GSP, G, X, etc) \tag{1}$$

where, GSP means grid spacing at CHF location to be calculated and DG means the distance from CHF location to upstream last grid.

Fig. 1 shows the rough description about uniform and non-uniform axial spacing in SCOMS. Uniform axial spacing was divided into the same size for the entire length, non-uniform axial spacing was divided equally between each grid likewise the same number of node is used in non-uniform axial spacing.

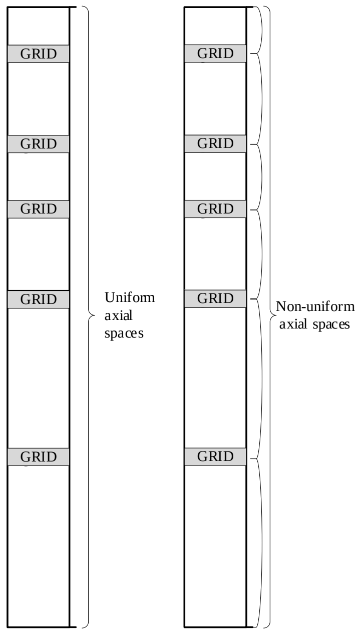


Fig. 1. Schematic of uniform and non-uniform axial spacing

### *2.2 Results*

DNBR and quality with non-uniform axial spacing are evaluated with given conditions. The verification condition are selected under bounding region of the LCO. The verification condition are shown in Table 1, where typical chopped cosine and saddle type shape are used as shown in Fig. 2.

Table 1. Test Conditions

| No. | Temperature (°C) | Pressure (MPa) | Mass Flux (kg/m$^2$-sec) | Heat Flux (kW/m$^2$-sec) | Axial Shape |
|---|---|---|---|---|---|
| 1 | 295.52 | 15 | 1784 | 406.36 | 1 |
| 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 | 295.52 | 15 | 1784 | 406.36 | 2 |
| 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 | |

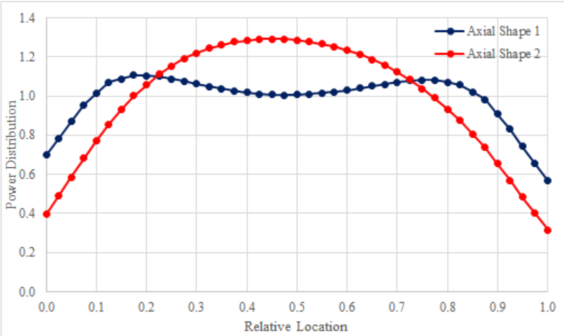

Fig. 2. Axial power distribution used in POL algorithm test

Calculation results are summarized in Table 2. MDNBRs were evaluated as 5.3436 and 5.3249 when uniform and non-uniform axial spacing were used in Case 1, respectively. It is shown that MDNBR when the non-uniform axial spacing is applied to SCOMS is lower than when the uniform axial spacing is considered in Case 1. In Cases 2 and 4, MDNBR increased when non-uniform axial spacing is used. This is caused by another factors, such as local mass flux, local thermodynamic quality, and grid spacing, etc. MDNBRs of remaining cases are evaluated as a decrease.

Table 2. The result of each condition

| No. | Axial Power Shape | Type | Initial value | | MDNBR location |
|---|---|---|---|---|---|
| | | | DNBR | Quality | |
| 1 | 1 | Uniform | 5.3436 | -0.0854 | 0.9000 |
| | | Non-Uniform | 5.3249 | -0.1055 | 0.7960 |
| 2 | | Uniform | 4.8010 | -0.0280 | 0.9000 |
| | | Non-Uniform | 4.8143 | -0.0257 | 0.8893 |
| 3 | | Uniform | 6.1010 | -0.1480 | 0.8750 |
| | | Non-Uniform | 6.0366 | -0.1609 | 0.7960 |
| 4 | | Uniform | 4.8300 | -0.0510 | 0.9250 |
| | | Non-Uniform | 4.8362 | -0.0543 | 0.8893 |
| 5 | | Uniform | 5.6310 | -0.0960 | 0.9000 |
| | | Non-Uniform | 5.6067 | -0.1139 | 0.7960 |
| 6 | 2 | Uniform | 4.3890 | -0.1660 | 0.5500 |
| | | Non-Uniform | 4.3656 | -0.1634 | 0.5350 |
| 7 | | Uniform | 3.9610 | -0.1120 | 0.5500 |
| | | Non-Uniform | 3.9363 | -0.1091 | 0.5350 |
| 8 | | Uniform | 5.0510 | -0.2150 | 0.5500 |
| | | Non-Uniform | 5.0383 | -0.2127 | 0.5350 |
| 9 | | Uniform | 4.0210 | -0.1440 | 0.5500 |
| | | Non-Uniform | 3.9969 | -0.1418 | 0.5350 |
| 10 | | Uniform | 4.6420 | -0.1680 | 0.5500 |
| | | Non-Uniform | 4.6190 | -0.1658 | 0.5350 |

**Note)** - DNBR and Quality are the MDNBR and quality at the node of MDNBR
- Case 1 to 5 used axial shape 1 and case 6 to 10 used axial shape 2.

Figs. 3 and 4 show the trend of DNBR and quality between uniform and non-uniform axial spacing in Case 1. It can be seen in Fig.3, the trend of DNBR is changing at the position of the grid. An increase of DNBR is induced by the increased mixing due to the spacer grid.

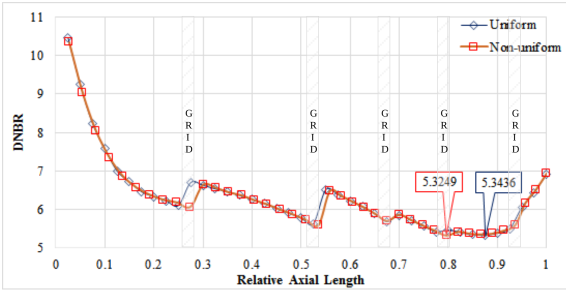

Fig. 3. Calculated DNBR of SCOMS along the axial location (Case 1)

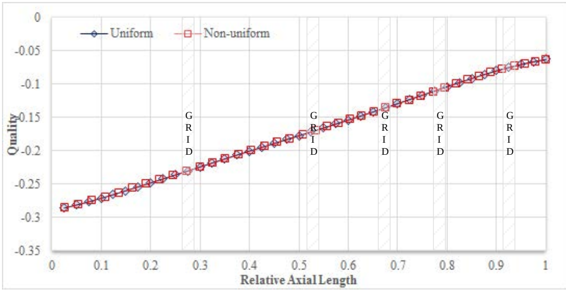

Fig. 4. Calculated quality of SCOMS along the axial location (Case 1)

## 3. Conclusion

In this paper, an effect of the uniformity of axial spacing in SCOMS on MDNBR was evaluated. Considering characteristics of CHF correlation implemented in SCOMS, non-uniform axial spacing was proposed and compared with results using the uniform axial spacing. From the results, it is concluded that usage of non-uniform axial spacing improves conservatism of MDNBR in SCOMS.

## 4. Acknowledgements

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