# Effects of Inlet Flow Mal-Distribution on the Thermal Margin Model of SMART-PPE

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## 1. Introduction

This paper has been prepared to study the effects of the inlet flow mal-distribution on the DNBR (Departure from Nucleate Boiling Ratio) by using MATRA-S code [1]. MATRA-S is a subchannel code which has been developed for the SMART (System-integrated Modular Advanced ReacTor) core thermal hydraulic design and analysis. In addition, MATRA-S is used for developing SMART during the PPE (Pre-Project Engineering).

The fuel integrity of SMART-PPE core is assured when the SAFDL (Specified Acceptable Fuel Design Limits) are not exceeded during any condition of normal operation and AOO (Anticipated Operational Occurrences). This is evaluated from the flow and temperature fields in the core that are predicted by the subchannel analysis code MATRA-S.

For the design of a reactor, a lot of subchannel analyses should be conducted and it is a practical approach to develop a simple, fast, accurate, and conservative analysis model that can represent the thermal hydraulic behavior of the SMART-PPE core. The thermal margin model [2] for SMART-PPE core consists of 38 lumped channels including 19 lumped channels within the HFA (Hottest Fuel Assembly) for the 1/8 symmetry of SMART-PPE core. The fuel assembly radial power distribution, pin power profile, and operating conditions were conservatively used for the thermal margin model.

In this paper, four different cases have been analyzed in order to investigate the integrity of the thermal margin analysis model of SMART-PPE against the various possible inlet flow mal-distribution and to investigate its impact on the MDNBR (Minimum DNBR).

## 2. Evaluations and Results

Four different cases of inlet flow distributions were postulated to investigate the effects of inlet flow mal-distribution on MDNBR of the thermal margin analysis model as follow:

(1) Inlet flow of the HFA varies 95~100% of the core average**,**
(2) Inlet flow of the HFA is fixed but the remaining FAs randomly vary for 1,000 cases**,**
(3) Core flow reduced from the nominal value**,** and
(4) Flow mal-distribution induced by a flow blockage within the HFA.

### *2.1. Case 1 - Inlet flow reduction of the HFA*

In this case, the mass flux of the HFA has been reduced from 100% to 95%. The mass flux of the remaining fuel assemblies has been adjusted to make the core average mass flux as 1.0. The axial offset (A.O.) of the axial power shape used are -0.35 and 0.0 which is the 1.55 chopped cosine shape.

Figure 1 shows that the effect of different inlet mass flux fraction of the HFA and its effect on the MDNBR. The difference in the relative MDNBR with changing the inlet mass flux fraction of the HFA for axial power shape of A.O.=-0.35 and the cosine are 1.64% and 0.35%, respectively.

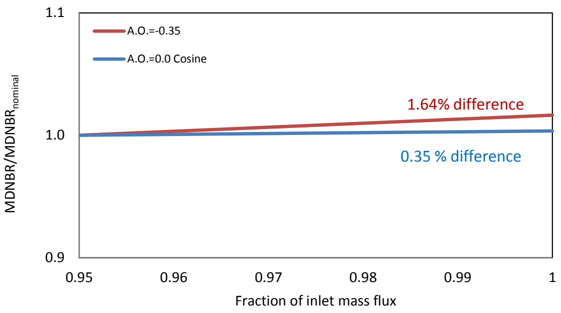

Figure 1: Hottest FA Inlet Mass Flux vs. MDNBR variation

### *2.2. Case 2 – Inlet flow distribution of the remaining FAs other than HFA*

In this case, the effect of inlet flow distributions on MDNBR are evaluated when the inlet flow of the HFA is fixed as 0.95 and the inlet flow of the other assemblies randomly vary between 0.9 and 1.1. A total of 1,000 random cases for the inlet flow distribution were generated for this calculation. Figure 2 shows that the results of the 1,000 cases for an axial shape of A.O.=-0.35 and 1.55 chopped cosine, respectively. The deviation of relative MDNBR for both axial power shapes is very small.

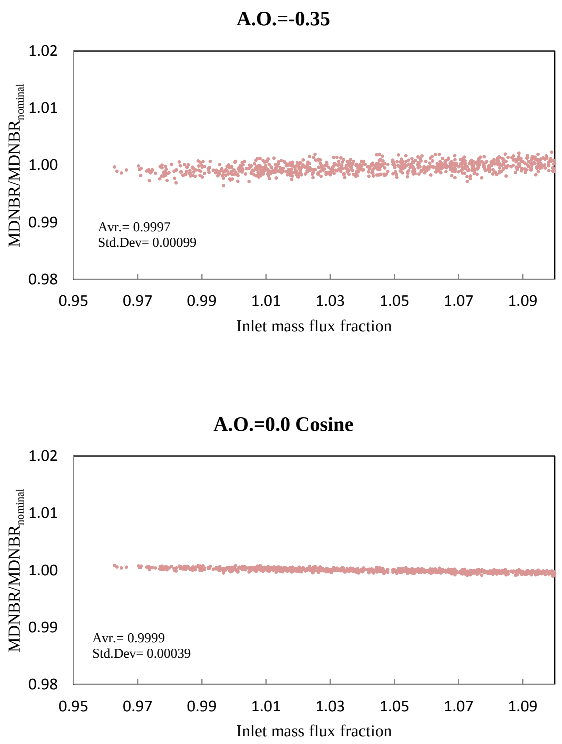

Figure 2: Random inlet flow distributions vs. MDNBR variation

### *2.3. Case 3 – Core inlet flow reduction*

In this case, the core inlet flow is reduced to see when the relative MDNBR reaches the relative design limit DNBR of SMART-PPE. While the inlet flow is continuously decreased**,** the inlet flow fraction of the HFA fixed as 95% and flow rate of the remaining fuel assemblies are normalized so as to make the core average as1.0.

The results are shown in Figure 3. The red dash line represents the relative design limit DNBR. Figure 3 shows the relative MDNBR decreases as the inlet flow decreases. It is observed that the relative MDNBR reaches the relative design limit DNBR when the core inlet flow ratio reduced to 32.37% and 33.92% for the axial power shape of A.O.=-0.35 and cosine shape, respectively. This shows that SMART-PPE has enough MDNBR margin until the core inlet flow is reduced to 34% from the nominal value.

### *2.4. Method 4 – Flow blockage in HFA*

In this case, the effect of flow mal-distribution induced by a flow blockage within the HFA was investigated. This case is similar to the first case. However, the following conditions were changed:
Each of the flow areas in the first, second, third, fourth, and fifth grid of the HFA were blocked by 62%.

Figure 4 shows that the location of the grid and the relative channel flow area blockage ratio.

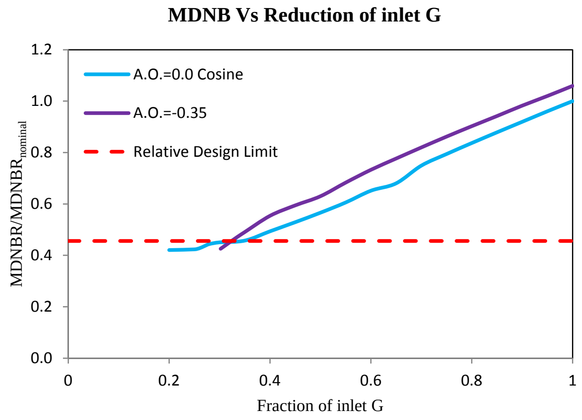

Figure 3: Inlet flow reduction vs. MDNBR variation

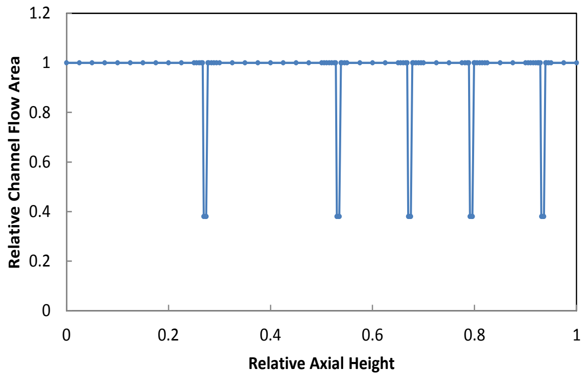

Figure 4: Possible Blockage Locations and Channel Flow Area

Tables 1 and 2 list the change of MDNBR from the nominal value. The column header is the flow rate of the HFA, the row header is the flow blockage location, and the cell values are deviated from the nominal MDNBR. The maximum change in MDNBR for the axial power shape of A.O.=-0.35 is 0.8531 and it occurred in the first grid when the inlet flow was reduced by 5%. While in case of the cosine axial power shape, the maximum change in MDNBR is 0.8472 and it occurred in the second grid when the inlet flow was reduced by 5%. The relative design limit DNBR is 0.45. From these results, it is found that there is enough MDNBR margin although a flow channel is blocked in the HFA.

Table 1: Flow blockage vs. MDNBR variation (A.O.=-0.35)

| A.O.=-0.35 | | | | | | |
|---|---|---|---|---|---|---|
| Case | 95% | 96% | 97% | 98% | 99% | 100% |
| Normal | 0.9887 | 0.9915 | 0.9943 | 0.9943 | 0.9971 | 1.0000 |
| Grid$^{1st}$ | 0.8531 | 0.8552 | 0.8572 | 0.8593 | 0.8614 | 0.8635 |
| Grid$^{2nd}$ | 0.9619 | 0.9627 | 0.9635 | 0.9644 | 0.9652 | 0.9660 |
| Grid$^{3rd}$ | 0.9886 | 0.9915 | 0.9943 | 0.9943 | 0.9971 | 1.0000 |
| Grid$^{4th}$ | 0.9886 | 0.9915 | 0.9943 | 0.9943 | 0.9971 | 1.0000 |
| Grid$^{5th}$ | 0.9887 | 0.9915 | 0.9943 | 0.9943 | 0.9971 | 1.0000 |

Table 2: Flow blockage vs. MDNBR variation (A.O.=0.0 cosine)

| A.O.=0.0 Cosine | | | | | | |
|---|---|---|---|---|---|---|
| Case | 95% | 96% | 97% | 98% | 99% | 100% |
| Normal | 0.9981 | 0.9985 | 0.9989 | 0.9992 | 0.9996 | 1.0000 |
| Grid$^{1st}$ | 1.0512 | 1.0522 | 1.0532 | 1.0541 | 1.0535 | 1.0545 |
| Grid$^{2nd}$ | 0.8472 | 0.8474 | 0.8476 | 0.8478 | 0.8480 | 0.8482 |
| Grid$^{3rd}$ | 0.9614 | 0.9618 | 0.9622 | 0.9626 | 0.9630 | 0.9635 |
| Grid$^{4th}$ | 0.9979 | 0.9983 | 0.9987 | 0.9990 | 0.9994 | 0.9998 |
| Grid$^{5th}$ | 0.9980 | 0.9984 | 0.9988 | 0.9992 | 0.9996 | 1.0000 |

## 3. Conclusion

We evaluated the effects of the flow mal-distribution on the MDNBR of the thermal margin model of SMART-PPE core using MATRA-S for this evaluation. Four different cases of flow mal-distribution were postulated and their effects on the MDNBR of the thermal margin model were investigated. From the results of the four cases, it is found that;

(1) The inlet flow mal-distribution has a small effect on MDNBR of the thermal margin analysis model for SMART-PPE,
(2) SMART-PPE has enough MDNBR margin so as to reach the limit DNBR when the core inlet flow is reduced to 34% for the nominal condition, and
(3) Although a flow blockage in the HFA decreases the MDNBR, but there is still enough margin.

## ACKNOWLEDGMENT

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[2] S. J. Kim et al., “An Evaluation of Thermal Margin Analysis Model for SMART,” Trans. of the Korea Nuclear Society Autumn Meeting, Gyeongju, Korea, Oct. 26-27, 2017.