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Investigation of Axial Blockage Position Effect in the SFR Flow Blockage Analysis

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1. Introduction

The sub-channels inside a fuel subassembly in SFRs(**S**odium cooled **F**ast **R**eactors) may partially be blocked by an ingression of damaged fuel debris or foreign obstacles into the subassembly, due to the geometrically compact design of the core fuel pin arrangement. When the partial blockage occurs, sodium coolant flow would be disturbed in the vicinity of the blockage, and the affected flow could lead to a high local coolant temperature, and subsequently the degradation of the fuel pin should be concerned. Therefore, a partial flow blockage accident must be a safety concern in the SFR design.

Analyses were performed for the flow blockage accident postulated in a conceptual design of a 600 MWe demonstration SFR with a TRU** core, using the MATRA-LMR-FB code. In the previous analysis [1,2], the blockage was assumed to take place near the axial position with the highest heat flux. The assumption was based on the background that the coolant heat-up would be large at that position, because flow would slow down or may be temporarily stagnant in the vicinity of the blockage.

In this regard, the present analysis addresses the effect of the axial blockage position on coolant, cladding, and fuel centerline temperatures for blockage sizes larger than 6 sub-channels. The interest are how much the axial blockage position would be sensitive for the larger blockage cases, i.e. 24 and 54 sub-channel blockage, where a flow recirculation dominantly affects the results

** Mixture of TRUs(TRans Uraniums) extracted from both LWR fuel and self-recycled SFR fuel

2. Analysis

2.1 Inputs for the analysis

A similar input to that used in [1,2] was also applied to the present analysis. The blockage sizes of 24 and 54 sub-channels were analyzed, including a case of 6 sub-channel blockage for comparison. The three radial positions and the same radial and axial heat flux distribution were applied as assumed in the previous analysis.

A node size was aimed at a length of 1/6 wire-wrap pitch to keep a periodic wire-wrap degree along the axial direction. It corresponded to 3.44 cm/node. This size, however, caused a numerical problem, and so the sub-channel was axially divided into 117 nodes (3.14 cm/node) in the MATRA-LMR-FB input. The form loss coefficient and the flow area were reasonably adjusted to estimate the reduced flow rate arising from the blockage effect.

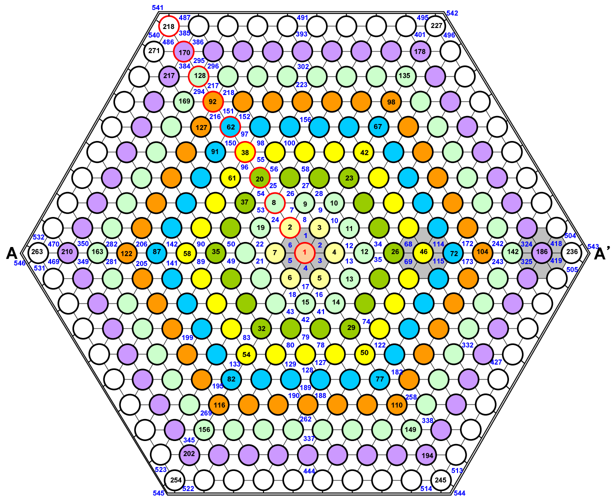

Figure 1. Numbering of the sub-channels and fuel rods, and blockage positions for the analysis

2.2 Analysis results

Figure 2, 3, and 4 represent the results of the key maximum temperatures depending on axial blockage positions.

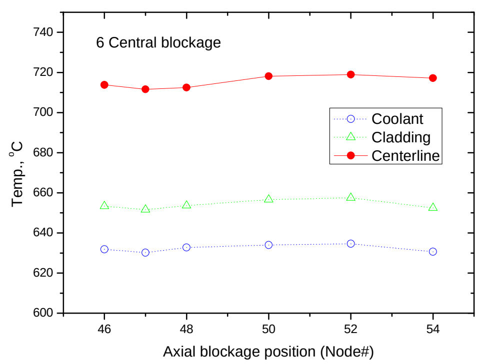

Fig. 2 Maximum temperatures on axial blockage position for the central 6 sub-channel blockage case

The temperatures were not sensitive to the blockage position near the highest heat flux region for the 6 sub-channel blockage, while the discrepancy on the blockage position are found for the 24 and 54 blockage cases. The difference seems to be yielded from the flow behavior in the blockage downstream. Since the maximum coolant temperature was predicted near the end of the fuel slug for the 6 sub-channel blockage case, the flow distribution in the nodes above the blockage might less affect the coolant temperature. For the cases of the larger blockages, however, recirculation was formed in the blockage downstream, and so part of heated coolant above the recirculation region moved downward. A larger blockage size as well as the wire-wrap wounding direction was such that the recirculating coolant had a less chance to be mixed with the coolant outside the blockage wake, the temperature of which was relatively lower. The occurrence position, however,

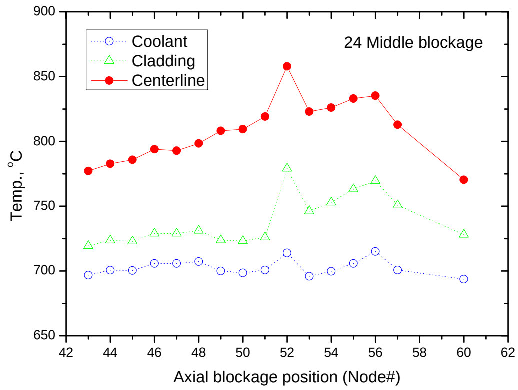

Fig. 3 Maximum temperatures on axial blockage position for the middle 24 sub-channel blockage case

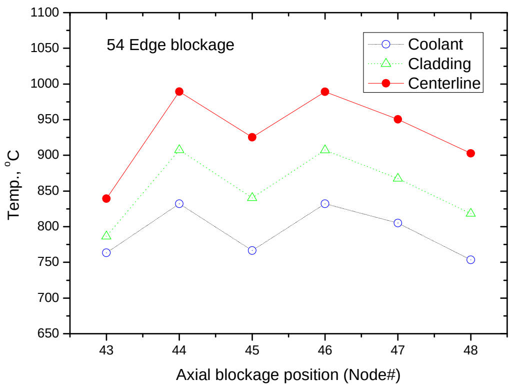

Fig. 4 Maximum temperatures on axial blockage position for the edge 54 sub-channel blockage case

was still located not far from the maximum heat flux region even for larger blockage cases, but the cladding temperature difference arising from the blockage position gave more than ~30 ^{o}C which could be critical for some cases. The maximum temperature occurred in a node where those factors like the temperature of the recirculating coolant, the heat flux, and the distribution of the wire-wrap wounding direction, were favorably combined.

Figure 5 and 6 illustrate the effect of a total number of axial nodes. A node size was a sensitive parameter for a certain case, i.e. 54 edge sub-channel blockage, for instance. It could be explained similarly based on the favorable combination of such aforementioned factors.

3. Conclusion

The effects of the blockage axial position and a total number of axial nodes on predicting the maximum temperatures in the blockage analysis, mostly seems to be based on a favorable combination of such factors as recirculating coolant temperature, heat flux, coolant mixing associated with the wire-wrap direction in a node. Therefore, the present result suggest that sensitivity studies for the axial blockage position as well as total axial node numbers must be followed before leading to a conclusion.

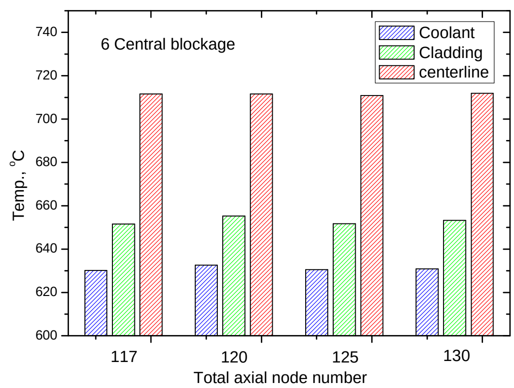

Fig. 5 Maximum temperatures on total axial nodes for the central 6 sub-channel blockage case

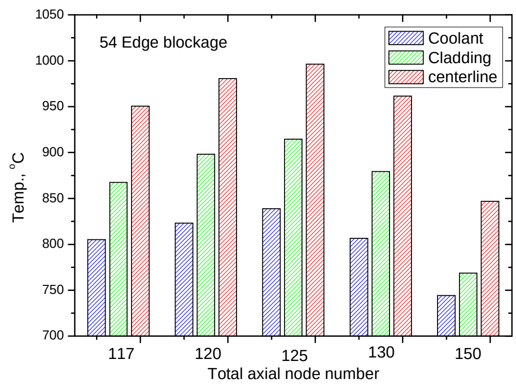

Fig. 6 Maximum temperatures on total axial nodes for the edge 54 sub-channel blockage case

REFERENCES

[1] W.P. Chang et al., "The Analysis of Flow Blockage Accidents in an Assembly for the Demonstration Sodium Cooled Fast Reactor," KAERI/TR-4492/2011 (2011).

[2] W.P. Chang et al., "The Analysis of Partial Flow Blockage Accidents for a Sodium Cooled Fast Reactor," Proceedings of ICONE20, July 30-August 3, 2012, Anaheim, California, USA (2012).