Investigation on Nodalization for Analysis of SFR Channel Blockage Accidents

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1. Introduction

The present paper demonstrates nodalization analysis results obtained in application of the MATRA-LMR/FB [1] to channel blockage accidents for a SFR (**S**odium cooled **F**ast **R**eactor), KALIMER-150 [2]. In the earlier study [1], a uniform node size over the total sub-channel length in a subassembly was used. The study was carried out not only for the radially different positions, i.e. central, medium between the center and the duct wall, and edge sub-channels in the assembly, but also for larger blockage sizes larger than 6 sub-channels, the blockage size of which was classified into a DBE(Design Basis Event) in the KALIMER-150 design. The present investigation focuses mainly on the identification of conservatism as well as consistency in the analyses of the maximum coolant temperature for the 6 sub-channels blockage accidents.

2. Analysis

2.1 Uniform nodalization scheme

The total length of a sub-channel in the sub-assembly was segmented with a few uniform node sizes to investigate the node size effect in the MATRA-LMR/FB calculation. A uniform nodalization scheme, a total of 117 nodes with a size of 3.02 *cm* a node, was used in the previous analyses. In the present analyses, the node numbers were increased to 140 and 170 nodes for the same geometry. Each node size was reduced to be 2.52 *cm* and 2.08 *cm*, respectively. Figures 1~2 depict the axial temperature and flow profiles for the central 6 sub-channels blockage with 140 and 170 nodes, respectively.

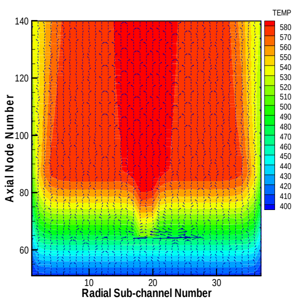

Fig. 1 Flow and temp. profiles for 140 nodes

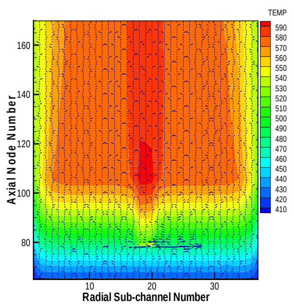

Fig. 2 Flow and temp. profiles for 170 nodes

The blockage clearly affected the downstream in a short distance above it. It was also evident that the coolant in the downstream far behind the blockage was mixed with the coolant outside the blockage shadow. These results exhibit a similar trend as that for 117 nodes without a significant difference. Table 1 presents the maximum temperatures for two nodalizations with different radial positions including those for the basic case. The basic nodalization with the 117 nodes usually led to a higher maximum temperature.

Table 1 Analysis results using the uniform node size for the central 6 blockage

Position	**Center**		**Middle**		**Edge**	
Nodes	140	170	140	170	140	170
Size(*cm*)	2.52	2.08	2.52	2.08	2.52	2.08
Radial Position	18 (18)	19 (18)	26 (26)	28 (26)	34 (34)	34 (34)
Axial Height (*cm*)	219.6 (217.5)	218.3 (217.5)	219.6 (217.5)	218.3 (217.5)	217.1 (217.5)	218.3 (217.5)
Max. Temp (^{o}C)	598.3 (600.8)	593.8 (600.8)	597.6 (591.3)	593.6 (591.3)	585.2 (595.2)	582.9 (595.2)

** ( ) for nodalization with 117 nodes*

2.2 Non-uniform nodalization

The effect with a different local node size was analyzed. The sub-channel length was divided into 3 regions for the non-uniform nodalization. An axially interesting region along the sub-channels was represented with a detailed node size (1/3 of the basic node size; 1.01 *cm*), while rest regions were modeled with the basic node size.

2.2.1 Detailed nodalization in the vicinity of the blockage

Since most of changes were expected to occur in the vicinity of the blockage, the central region was modeled with the detailed node size. In this analysis, total 181 non-uniform nodes were applied. The bottom region retained the 52 basic size nodes, and the central region was nodalized with the 96 detailed nodes (1.01 *cm* node size), and the 33 basic nodes were again applied to the top region.

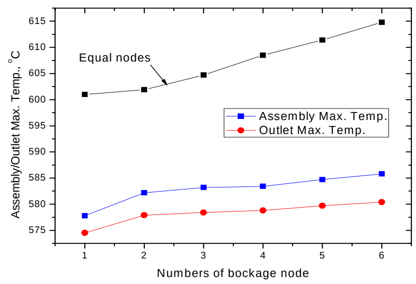

Fig. 3 Comparison of max. temp. with the blockage node numbers for the case that the reduced node size was applied to the central region

The result using the uniform basic node size always showed the highest maximum temperature regardless of numbers of blockage nodes, as illustrated in Fig. 3.

2.2.2 Detailed nodalization in the region below the blockage

Table 2 presents the results when the reduced node size was applied to the region below the blockage. The highest maximum temperature was predicted for the 153 nodes case. The maximum temperature occurred in the node right above the blockage node for the 153 nodes case, while it was always predicted near the end of the fuel slug for the other cases including multiple nodes blockage cases. Figure 4~5 represent the flow and temperature distribution for several interesting nodes. The node numbers of 89, 91, and 92 are the node right below the blockage, right above the blockage, and the next node (166.1 *cm*), respectively. The height of nodes numbers of 100, 109, and 153 are located at 190.3 *cm*, 217.5 *cm*, and the top (350.4 *cm*) from the sub-channel bottom, respectively, while the blockage is located at 160.1 *cm* (node# 90) from the bottom.

Downward flow was predicted in the node right above the blockage. The coolant above the blockage was nearly stagnant or recirculated locally around the blockage from Fig. 4, and thus it was likely to cause the highest temperature. For the other cases, however, either forward flow or slight recirculation of a single sub-channel was predicted. A question remains why the 153 nodes exhibited the recirculation in all 6 blockage sub-channels, compared with the 125 and 157 nodes cases where the maximum temperature occurred near the end of the fuel slug.

Table 3 Analysis results for the detailed nodalization below the blockage

Total node numbers	125	153	157
Blocked node #	62	90	96
Node distributions	49-12-64	35-54-64	35-60-64
Radial Position	20	19	20
Axial node # (*Height, cm*)	81 (217.5)	91 (163.1)	114 (220.5)
Max. Temp. (^oC)	595.1	609.9	579.6

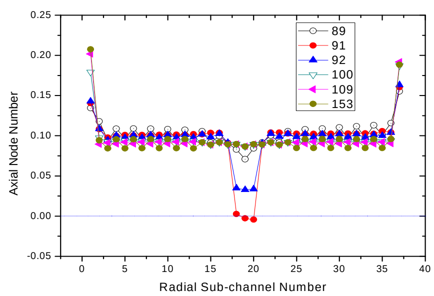

Fig. 4 Radial flow distributions for several nodes

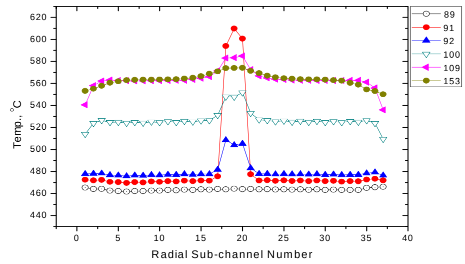

Fig. 4 Radial temperature distributions for several nodes

2.2.3 Detailed nodalization in the region above the blockage

Table 3 is the results for the case that the detailed nodalization was applied to the region above the blockage. No significant dependence on node distributions was found.

Table 3 Analysis results for the detailed nodalization above the blockage

Total node numbers	149	177
Blocked node #	54	54
Node distributions	54-48-47	54-90-33
Radial Position	18	20
Axial node # (*Height, cm*)	106 (217.5)	111 (219.5)
Max. Temp. (^oC)	582.0	581.6

3. Conclusion

The effect of the nodalization scheme for the MATRA-LMR/FB application was investigated. As a result, the analysis using the basic node size usually produced a higher maximum temperature except one case with the node numbers of 153 in the lower region of the blockage. The explanation of it is not available at this time. The other cases, however, were consistent with the trend of the case with the basic node size not only in the maximum temperature but also in the occurrence position. Therefore, the basic node size could be said to be quite reasonable for the MATRA-LMR/FB analysis.

REFERENCES

[1] W.P. Chang et al., "A Comparative Study of the Code Calculations for Local Flow Blockages in the KALIMER-150 Core," KAERI/TR-3860/2009 (2009).

[2] D. Hahn et al., "KALIMER Preliminary Conceptual Design Report," KAERI/TR-1636/2000, Korea Atomic Energy Research and Institute (2000).