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Safety Analysis for Sub-channel Blockage of the Assembly in the PGSFR

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1. Introduction

A sub-channel blockage may be occurred by an ingression of damaged fuel debris or foreign obstacles into a core fuel subassembly for a Sodium cooled Fast Reactor(SFR) due to its geometrical compactness of the core design. The flow perturbation caused by the blockage could raise the local coolant temperature in the incident and it might eventually lead to the degradation of the fuel rods. Therefore, a partial flow blockage accident must be a safety concern in the SFR design.

In this regard, analyses were performed for the flow blockage accident postulated in a conceptual design of a 150MWe Proto-type SFR using the MATRA-LMR/FB and analysis result was compared to the safety acceptance criterion shown in Table 1 developed by KAERI [1].

2. Methods and Results

2.1 Inputs for the analysis

An assembly of the 150MWe Proto-type SFR has 217 fuel rod shown in Fig. 1 contrary to previous a 600MWe Demonstration SFR [2,3,4] which has 271 fuel rods. The MATRA-LMR/FB code was used for the analysis and an input was made as for the new design. The hot assembly which represents the lowest flow among the core assemblies with the maximum power was chosen. The blockage sizes were represented with 6, 24, and 54 sub-channel blockages, and the radial positions were located in the center, middle between the center and duct wall, and the edge of the subassembly. The blockage position was assumed near the axial position with the highest heat flux due to the background that the coolant temperature would be large at that position

A node size was roughly divided into a length (3.1 cm) of 1/6 wire-wrap pitch to keep a periodic wire-wrap degree along the axial direction. The form loss coefficient and the flow area were reasonably adjusted to estimate the reduced flow rate arising from the blockage effect.

2.2 6 channel blockage analysis

Fig. 2 represents the axial distribution of coolant, cladding, fuel temperature and flow for the normal operation as well as 6 channel blockages in the hottest sub-channel. The highest coolant temperature appears near the fuel slug end position in case that the blockage position was located in the middle of the subassembly. The maximum cladding temperature was less than 600 ℃ and it satisfied the safety limits. Coolant temperature was heated up right above the blockage due to the flow reduction but it was stabilized by the coolant mixing. And no recirculation occurred at the blockage downstream.

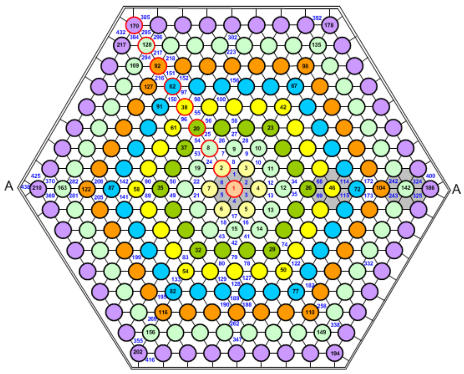

Figure 1. Numbering of the sub-channels and fuel rods, and blockage positions for the analysis

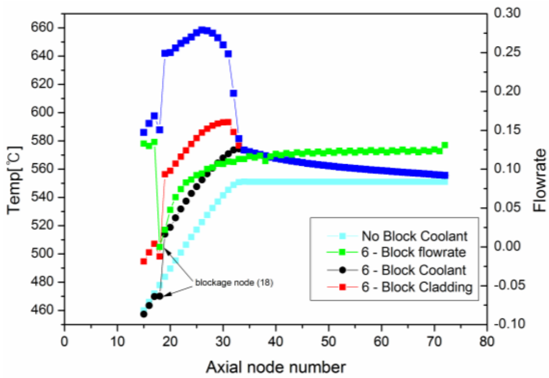

Figure 2. Axial temperature distribution for the 6-middle blockage

2.3 24 and 54 sub-channel blockage analysis

Figure 3 represents the axial distribution of coolant, cladding, fuel temperature and flow for 24 channel blockage in the hottest sub-channel. The maximum coolant temperature occurred at the end of the fuel slug for 24 channel blockage in case that the blockage was located in the middle of the subassembly. The peak coolant temperature was found in the downstream of the blockage. Meanwhile, Fig 4 shows the flow distribution calculated in radial direction of A-A cross section shown in Fig. 1. The recirculation was predicted around a range of the blockage downstream. Therefore, it means that the heated coolant caused by the recirculation was mixed with the coolant in the downstream of the blockage. For the 24 channel blockage, the maximum cladding temperature was less than 650 ℃ and it satisfied the safety limits.

Table 1. Acceptance Safety criterion

Event Category	Frequency	Core Outlet Average Temperature, °C		Peak Clad Temperature, °C	
		Temp., °C	Allowance Time (hours)	Temp., °C	Allowance Time (hours)
AOO	$F \geq 10^{-1}$	560	≤40,000	< 650	≤52,000
	$10^{-1} > F \geq 10^{-2}$	560 - 600	≤1,000	650 - 670	≤ 240
DBA Class Ⅰ	$10^{-2} > F \geq 10^{-4}$	600 - 650	≤30	< 700	≤ 0
DBA Class Ⅱ	$10^{-4} > F \geq 10^{-7}$	650 - 700 700 - 760	≤ 5 ≤ 1		
BDBA	$F < 10^{-7}$				

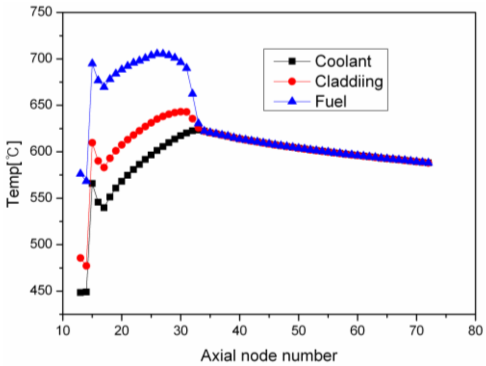

Figure 3. Axial temperature distribution for the 24-middle blockage

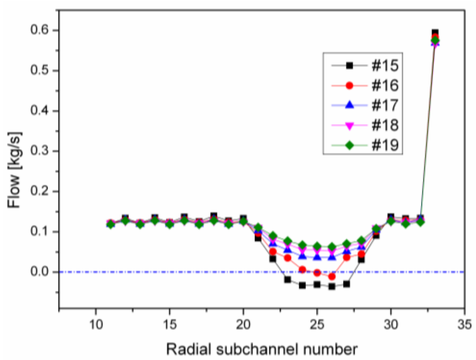

Figure 4. Axial flow distribution for the 24-middle blockage

The coolant, cladding, fuel temperature distributions for the middle 54 channel blockage shown in Fig. 5 exhibits a different behavior compare to the 6, 24 channel blockages. The peak cladding temperature was found in the downstream of the blockage such as for 24 channel blockage, but this temperature was calculated as the maximum coolant temperature which was about 710 ℃. It could not meet the safety limits. And, the recirculation occupied a larger region than that for 24 channel blockage shown in Fig 6.

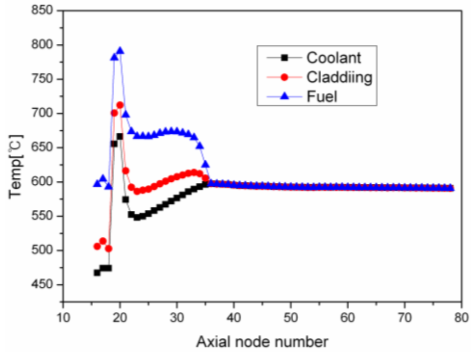

Figure 3. Axial temperature distribution for the 54-middle blockage

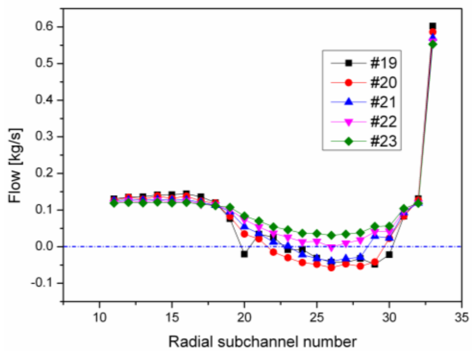

Figure 5. Axial flow distribution for the 54-middle blockage

3. Conclusions

The maximum coolant temperatures for 6, 24 channels blockage occurred at the end of the fuel slug and both of them satisfied the safety limits. However, for the 54 channels blockage, the maximum coolant temperature was found in the downstream of the blockage and it could not meet the safety limits. It was caused by the recirculation region in the downstream of the blockage. In conclusion, satisfactory margins were obtained for 6, 24 channel blockage cases.

REFERENCES

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