Analysis of Loss of Flow for an Assembly of LMR using MATRA-LMR-FB

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1. Introduction

Sodium is usually used as the primary coolant in the liquid metal fast breeder reactor (LMFBR). In normal operation the sodium is well below its boiling point. However, Boiling could occur in hypothetical accident situations, and so the loss of flow (LOF) accident is needed to be considered to evaluate the safety of LMFBR.

The numerical simulation using the MATRA-LMR-FB code was performed for 37-rod LMFBR fuel subassembly undergoing a loss of flow transient.

The MATRA-LMR-FB code has been developed to analyze the accident of flow blockage in an assembly of liquid metal reactor. The major feature of the code is distributed resistance model which specifically account for the presence of the wire-wrap spacer. Additionally, time step restriction has been intensified to improve numerical stability and the friction factor of Blasius equation in the turbulent region has been modified as Cheng and Todreas model to consider the sub-channel type.

2. Methods and Results

In 1967 an international forum known as the Liquid Metal Boiling Working Group was formed to provide a focus for the experimental and theoretical studies of sodium boiling phenomena. The test of 37FC34/5-2/ which was conducted at the O-arai Engineering Center, PNC, was presented through the forum [2, 3]. The test was selected for the simulation of LOF.

The test section geometry and calculation parameters are presented in Table 1. The 36 rods are electrically heated and remaining one is unheated due to malfunction identified as shown in Fig. 1. Input model has the sub-channels of 78 and the axial meshes of 26 with the mesh length of 25 mm. The heated zone is the axial mesh number of 5 to 22. The steady-state conditions are flow velocity of 5.24 m/s, heat flux of 888 kW/m^2, inlet temperature of 530 ^{o}C, and the pressure at the end of heated region of 1.7 x 10^5 Pa. The axial heat flux distribution is trapezoidal and maximum heat flux to average heat flux ratio is 1.08. The inlet velocity decreases to approximately 10 % of its steady state value in about 10 seconds.

Table 1. geometry and calculation parameters

Parameter	Value	Parameter	Value
Number of pins	37	Diameter of spacer wire (mm)	1.3
Diameter of pins (mm)	6.5	Flow area (mm^2)	924
Pin pitch (mm)	7.9	Equivalent hydraulic diameter (mm)	3.43
Total length of pins (mm)	1515	Inner flat-to-flat distance (mm)	50
Length of unheated entrance (mm)	100	Length of unheated downstream (mm)	715
Heated length (mm)	450	Wire-wrap pitch (mm)	265

The distributions for the temperature and velocity according to the transverse and axial directions prior to the boiling initiation are presented because the MATRA-LMR-FB code calculates the single phase transient thermal-hydraulic field of the coolant. The calculation was continued to the boiling inception. The saturated temperature of the test condition is set 944 ^{o}C at which boiling is assumed to occur. Fig. 2 shows the transient behavior of temperatures of the representative central and edge sub-channels at the axial locations of 438.7 mm and 306.2 mm downstream from the lower edge of the heated zone. The MATRA-LMR-FB predicted the boiling inception at the 13.1 seconds whereas 13.9 seconds in the experiment. Fig. 3 shows the calculated transverse temperature distributions at the 438.7 mm downstream from the lower edge of the heated zone at the steady state and boiling inception. It is notable that there is tendency that the calculated transverse profile does not vary significantly from its steady state profile. The sub-channels 11 and 14 are predicted to undergo boiling inception, whereas experimental results identify the location of the boiling inception as the sub-channel 3. These discrepancies, however, are slight since the predicted temperature differences between sub-channels 11, 14 and 3 are less than 0.3 ^{o}C and the calculated sodium temperature transient of the sub-channel 3 fairly good agreement with the experiment.

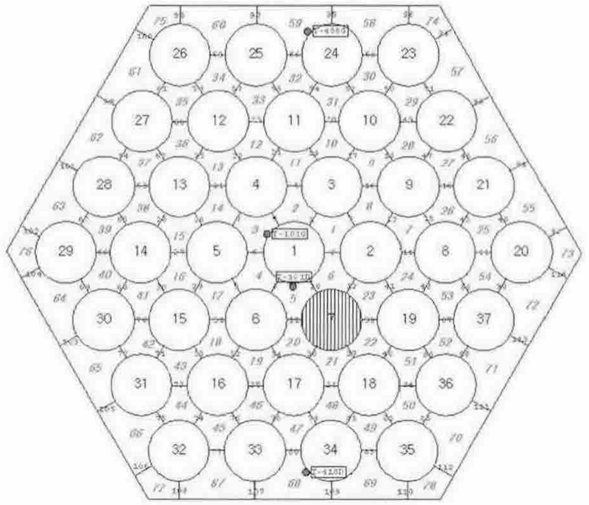

Fig. 1. MATRA-LMR-FB input nodalization for the simulation of 37-pin Loss of Flow Test

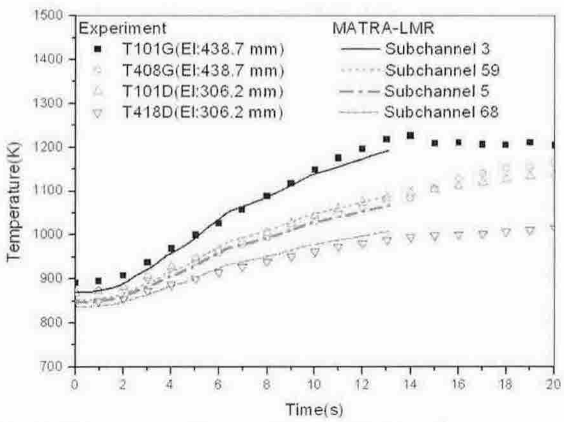

Fig. 2. The comparisons of the behavior of coolant temperatures

3. Conclusion

It is concluded that the MATRA-LMR-FB code prediction of the non-uniform temperature field through the transient is accurate enough to estimate the complicated radial profile of boiling progression after triggering of boiling.

REFERENCES

[1] Stewart, C. W., et al., 1977, *COBRA-IV: The model and the method*, BNWL-2214.

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[3] PNC,1981, PNC N941 81-74, pp. 5-31 ~ 5-41.