Transactions of the Korean Nuclear Society Spring Meeting
Jeju, Korea, May 7-8, 2015

Reflood Phenomena in a 5x5 Ballooned Rod Bundle

Byoung Jae Kim [a*], Jong Rok Kim [a], Kihwan Kim [a], S. K. Moon [a]
[a] *Thermal-Hydraulic Safety Research Division, Korea Atomic Energy Research Institute, Daejeon*
[*] *Corresponding author: byoungjae@kaeri.re.kr*

1. Introduction

In the 1980s, various experimental programs were carried out for the coolability of an assembly containing a partial blockage in a group of ballooned fuel rods under LOCA conditions. A review on these experimental programs is well documented in [1].

Recently, an experimental program was started in KAERI to study the coolability of the partial blockage and to develop two-phase flow models such as heat transfer and liquid droplet breakup by the blockage [2-4]. One key distinguished feature of KAERI research activities is the consideration of local power increase owing to fuel relocation, whereas the past experimental program did not consider the effect of fuel relocation.

The purpose of this study is to investigate the reflood phenomena in the partial blocked 5x5 rod bundle. A series of the forced reflood tests were performed with/without consideration of local power increase by fuel relocation. The experimental data were evaluated with numerical predictions using MARS code.

2. Partial Blocked 5x5 Rod Bundle

2.1 Partial Blocked 5x5 Rod bundle

Figure 1 shows the partial blocked 5x5 bundle. The total heated length is 3.81 mm. Sixteen type-A heater rods are not deformed, but nine type-B heater rods are postulated to be deformed in the region of $x = 1.704$~2.054 m from the bottom of the heated part.

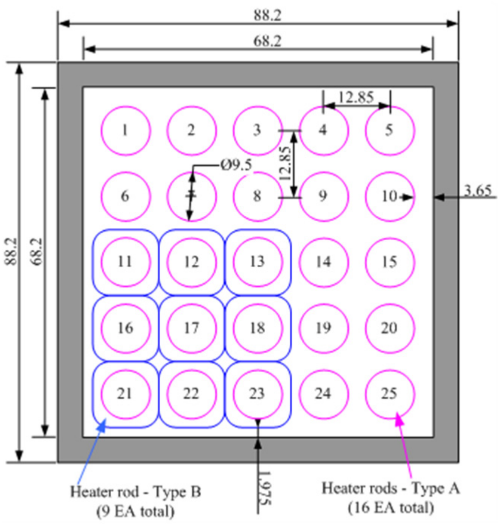

Fig. 1 Schematic of a partial blocked rod bundle

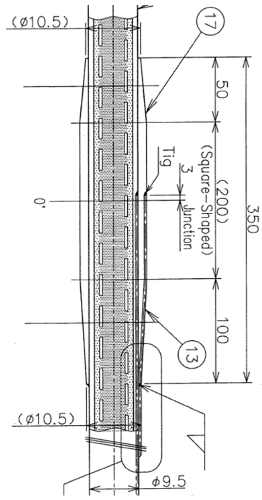

Fig. 2. Geometry of the ballooned rod (Type-B)

Figure 2 shows the detailed geometry of a deformed heater rod which is realized by inserting the rod into a sleeve. The diameter increases up to 10.5 mm, yielding a maximum blockage of 90%. The sheath of the rods is made of Inconel 600.

Figure 3 delineates the normalized axial power profiles along the elevation from the bottom of the heated part. One profile is for the typical power shape (blue). The other is for the modified shape considering the effect of fuel relocation (red). The power is intentionally increased in the region where the fuel fragments slumping from the upper region are accumulated. At the same time, the local power is intentionally decreased to zero in the upper region, in order to preserve the total power.

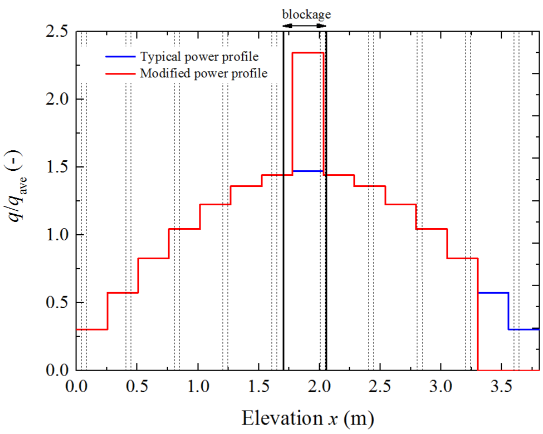

Fig. 3. Axial power profiles

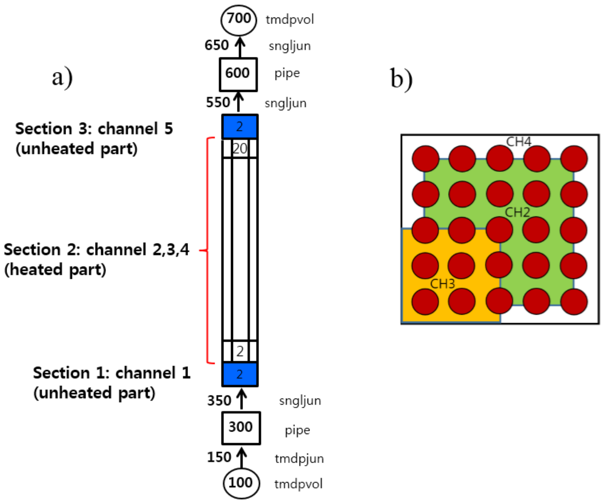

Fig. 4.MARS code modelling for the test section

2.2 Modeling of the MARS Code

Figure 3a shows a nodding diagram for MARS code. Simulations were performed with the aid of COBRA-TF capability consolidated into MARS. The rod bundle is divided into three sections. Section 2 corresponds to the heating region. Figure 3b shows three flow channels in the heating region, which are connected to each other, allowing cross flows. The deformed heater rods are placed in channel 3. The heater rods in section 2 are heated according to the power profiles shown in Fig. 3. Tables I and II list evaluation conditions, where ΔT_{sub}, V_f, P, and $T_{w,\max}$ are the coolant subcooling, reflood velocity, total heating power, and initial maximum wall temperature, respectively. The system pressure is 2 bar for all cases.

3. Results & Discussion

A total of six cases were simulated. Figure 5 shows the results of case 1. The peak temperature of ballooned rods (Type-B) is similar to that of the intact rods (Type-A). However, the temperatures of deformed rods are slightly increased. In addition, the time period during which the wall temperatures are high is somewhat elongated. The peak wall temperature and final quenching time are well predicted by MARS.

Figure 6 shows the results of case 5 in which the effect of fuel relocation is considered at $x = 2$ m. One can see clearly that the temperature trends observed in Fig. 5 become more obvious. The peak temperature of the deformed rods (Type-B) is considerably increased. In addition, the time period during which the wall temperature is high is remarkably elongated. However, these trends are not well predicted by MARS. This is attributed to two-phase flow models embedded in COBRA-TF, which were developed without consideration of local power increase by fuel relocation.

Table I: Simulation conditions with the typical power profile

Case	ΔT_{sub} (°C)	V_f (cm/s)	P (kW)	$T_{w,\max}$ (°C)
1	90	2	47	600
2	50	2	47	600
3	90	4	47	600
4	50	4	47	600

Table II: Simulation conditions with the modified power profile

Case	ΔT_{sub} (°C)	V_f (cm/s)	P (kW)	$T_{w,\max}$ (°C)
5	90	4	47	600
6	90	6	47	600

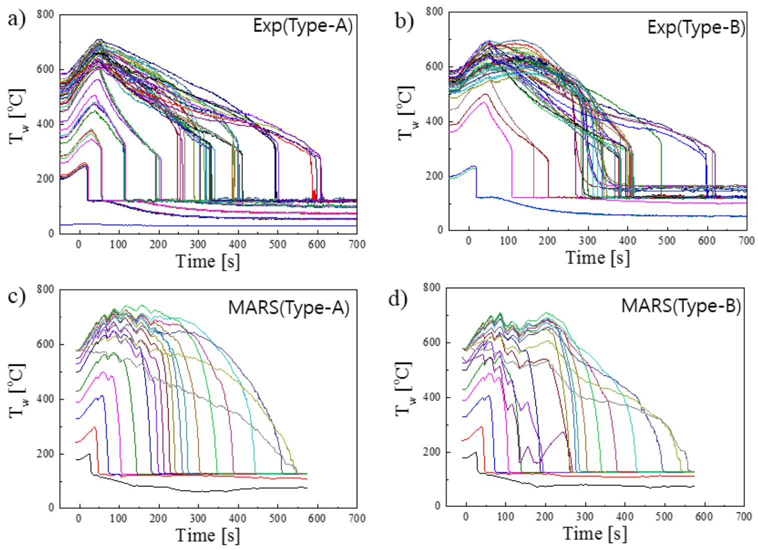

Fig. 5. Result of Case 1

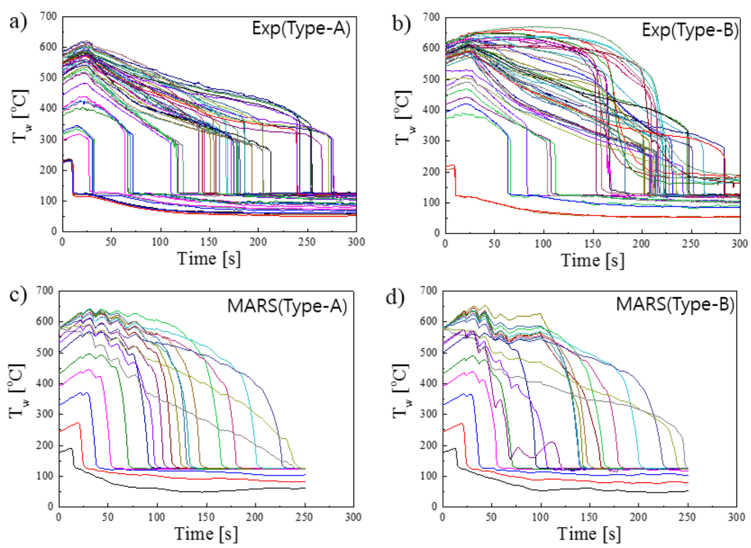

Fig. 6. Result of Case 5

4. Conclusions

The flow blockage alone has little effect on the peak wall temperature. However, the local power increase by fuel relocation affects considerably the peak wall temperature and the time period during which high wall temperatures continue.

Acknowledgements

This work was supported by the National Research Foundation of Korea (NRF) Grant funded by the Korean Government (MSIP)
(no. 2012M2A8A4026028).

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