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Development of Partial Blockage Detection Logic Based on Temperature Fluctuation in the Upper Plenum in KALIMER

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1. Introduction

A local cooling deficiency inside the pin bundle of a liquid metal reactor's fuel assembly caused by a partial blockage is considered as one of the possible initiating events of a whole core accident. In a cooling deficiency zone, the coolant temperature is increased by a reduction of the local mass flow. The resulting temperature perturbation is convected by the flow towards the bundle outlet of an assembly. So, the temperature fluctuations in the upper plenum could provide important information about a local blockage of an assembly in liquid metal reactors. [Kim, 2004]

For developing the flow blockage detection logic, we analyzed the temperature fluctuations in the upper plenum in KALIMER (Korea Advanced Liquid Metal Reactor) and evaluated the characteristics of the fluctuation.

We found that skewness of temperature fluctuation was a good alternative for detection the partial blockage in an assembly through evaluating the statistical characteristics of numerical analysis results. We, therefore, developed the detection logics for partial blockage by comparing the ratio of changed skewness according to the block size.

2. Fluctuation Analysis

LES (Large Eddy Simulation) turbulence model among various turbulence models has a good capability for analyzing the time dependent temperature fluctuation. [Jung, 2004] So, we used the LES model in the CFX-5.7 code for analyzing the temperature fluctuations in the upper plenum due to a partial flow blockage in an assembly.

When analyzing the temperature fluctuation in the upper plenum, the profiles of the exit temperature and the exit velocity at the outlet of the assemblies in a core are required for the initial and boundary conditions. They can be obtained from the thermal hydraulic analysis of the core and the sub-channel analysis of a partially blocked assembly in the core. [Ha, 2003] Then, we analyzed the temperature fluctuation in the breakeven 1/6 upper plenum and 1/6 core to save on computation efforts because the core had a symmetric breakeven structure in an angular direction of 60˚ degree. [Han 2002] Also, we analyzed the temperature fluctuation in the upper plenum in case that the hottest assembly (target assembly) was partially blocked with cases of reduced flow and not reduced flow conditions that were assumed by blockage characteristics such as shape and location and so on. [Ha 2003] Fig. 1 shows the analysis results at two monitor points in the upper plenum.

4. Evaluation of Statistical Characteristics

For clearly representing the characteristics of the temperature fluctuation of each case, we introduced some statistical analysis such as the mean, the standard deviation, the skewness and the kurtosis of the temperature fluctuation data. Fig. 2 shows the statistical analysis results of the temperature fluctuations data during 2 sec along the axial direction at the center of the target assembly.

In previous studies, the skewness was known to be one of the important factors to determine the flow blockage for a partially blocked condition. [Kim, 2004; Huges, 1985; Biserna 1977; Haga, 1981] Through evaluating the results of analyses, we found that the changes of the skewness were relatively larger than those of the other statistical parameters (mean, standard deviation and kurtosis). We assumed that the temperature fluctuation in the upper plenum was measured by a thermocouple located at height 5cm from the exit of each assembly, respectively. At this position, the ratios of relatively changed values of characteristics are shown in Table 1. Each ratio was the percentage ratio of statistical characteristics between blocked condition and non-blocked condition.

4. Results and Conclusions

Through analysis and evaluation of the characteristics of temperature fluctuation in the upper plenum, we developed the detection logics for partial blockage in an assembly. We have chosen the skewness of the fluctuation as the input for the logic. As shown in Table 1, the value of the skewness changed from -0.72 to -1.04 when the assembly was partially 5% blocked. So, we found that if the skewness of temperature fluctuation in the upper plenum changed at ratio of more than 40%, then the assembly was partially 5%. If the assembly was, also, partially 10% blocked, the ratio of skewness was changed to more than 60%. In addition, we found that the exit velocity of an assembly was changed, the skewness was dramatically changed. At this case, the partial blockage could be easily detected.

Afterward, we will analyze more fluctuation data according the various block conditions such as location, size and flow condition in a partially blocked assembly. Then, we will develop general detection logics for partial blockage and validate the usefulness in a real liquid metal reactor.

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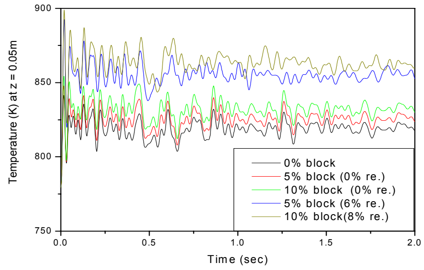
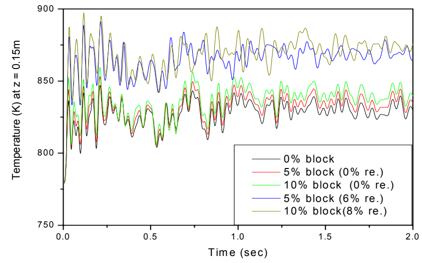
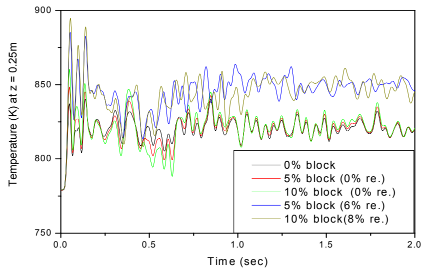


(a) Z=0.05m



(b) Z=0.15m

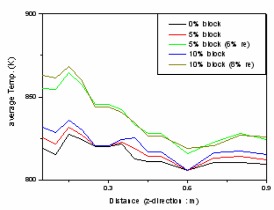


(c) Z=0.25m

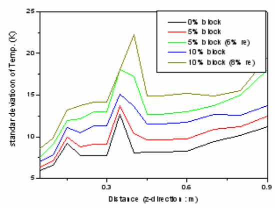
Fig. 1 Analysis Results

Table 1 Ratios of Some characteristics (%)

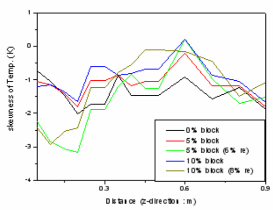
block condition	mean	S.D	Skew ness	kurtosis
0%	0.0	0.0	0.0	0.0
5%	1.3	6.7	44.0	28.0
10%	2.6	17.5	68.0	48.0
5%(flow)	6.8	27.8	214.0	236.0
10%(flow)	8.3	44.4	236.0	260.0



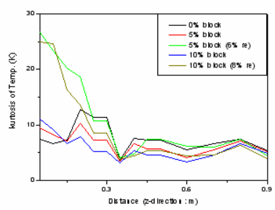
(a) mean



(b) standard deviation



(c) skewness



(d) kurtosis

Fig. 2 Statistical Characteristics