The Study on Primary Heat Transport and ECC System Behavior in Large LOCA for CANDU NPP

Kim Yun Ho, Park Dong Hwan and Choi Hoon
KEPRI
kyunho@kepri.re.kr

1. Introduction

Emergency Core Cooling System (ECCS) is critical for the cooling of heated fuel arising from the power pulse and channel flow stagnation in Large LOCA. In general, void generated from the loss of coolant in Primary Heat Transport (PHT) system induces power increase within the initial 5 seconds after the break of PHT system due to the positive void reactivity. The amount of increased heat in the fuel is strongly dependent on the channel flow condition as well as the power pulse. Here the behavior of PHT system and ECC system in Large LOCA is analyzed.

2. Analysis Methods

Large LOCA analysis needs to consider feedback between physics and thermal-hydraulics. The break in large LOCA induces void from rapidly discharged coolant and the void make core power increase via the positive void reactivity. The amount of void may be different in different position of channels according to the elevation and flow condition. For the more detailed calculation of power pulse and channel flow, 380 fuel channels are modeled into separate 28 channel groups. The feedback between power and thermal hydraulic condition such as coolant density, coolant pressure is modelled separately in 28 different channel groups. Physics calculation is performed with WIMS based RFSP and thermal-hydraulics is performed with CATHENA. Coupling calculation between RFSP and CATHENA is performed with perl script.

2.1. Power pulse

It is known that the void from large LOCA induces power excursion due to the positive void reactivity in CANDU NPP. Fuel cross section table is generated considering wide range of void amount. RFSP model based on WIMS is made and for the transient calculation CERBERUS model is used for coupling calculation with CATHENA.

2.2 Thermal hydraulic Steady State

CATHENA steady state is made as shown in Table 1. The break size for each break positions are chosen such that sheath temperature is known to be most limiting. The break sizes for RIH, ROH and PS are 40%, 100% and 90% respectively.

Table 1 Steady state value at 103%

Parameters		Value
Outlet head pressure (MPa(a))	ROH 1	10.0
	ROH 3	10.0
	ROH 5	10.0
	ROH 7	10.0
Inlet head pressure (MPa(a))	RIH 2	11.2
	RIH 4	11.2
	RIH 6	11.2
	RIH 8	11.2
S/G drum pressure (MPa(a))		4.7
Inlet coolant temperature (℃)		267
Outlet coolant temperature (℃)		310
Core flow per pass (kg/s)		2,037
Pressurizer level (m)		12.54

2.2. Thermal Hydraulic Behavior

2.2.1 Flow stagnation

For fuel channels in which the normal flow is toward the break location, the occurrence of a break would act to increase the flow. In contrast the flow in the downstream channels in the broken loop would be reduced as the flow is pulled back towards the break. For certain break sizes, periods of low flows through the downstream channel could result. During this period of low flow, fuel temperature can rise. The flow behavior in RIH break is shown in Figure 2. For RIH 40% break case, the channel flow becomes near to zero around from 5 second to 12 second after break. This low flow condition is called as stagnated flow. This stagnated flow along with power pulse induces much higher fuel sheath temperature than other break sizes as shown in Figure 3.

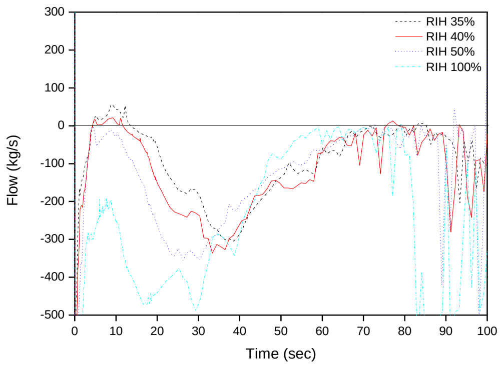

Figure 1 Channel flow for RIH break LOCA

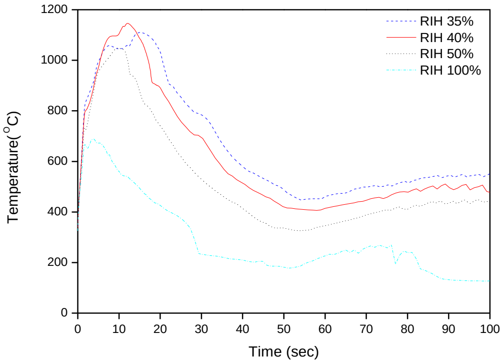

Figure 2 Fuel sheath temperature for RIH break LOCA

2.2.2 ECC injection

The ECC injection is very important for fuel cooling. General ECC injection flow is shown as shown in Figure 3. The injection is different on the location of channel. The channels on the boundary core such as W10 have flow restricting orifice. So the ECC injection in boundary channel is slower than the core center channel as shown in the Figure 4 and Figure 5. The figures show the integrated void in the downstream pass for different channel groups from RIH 40% break circuit calculation. Channel void disappears much earlier (120 sec) in the core center channel than channel located in the outer region of the core(220 sec). ECC is injected into the channels which have more heated fuel located in core center region easily than outer region channel

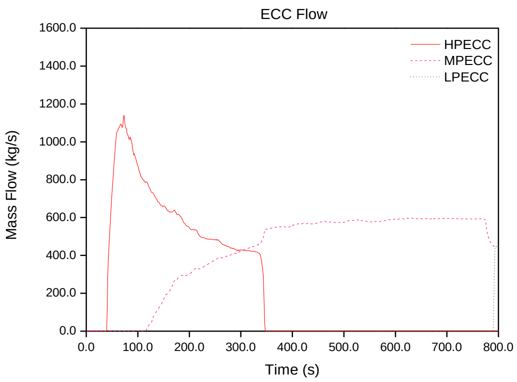

Figure 3 ECC flow for 40% RIH LOCA

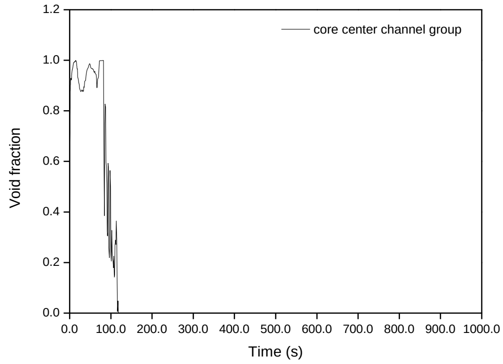

Figure 4 Integrated channel void in core center channel

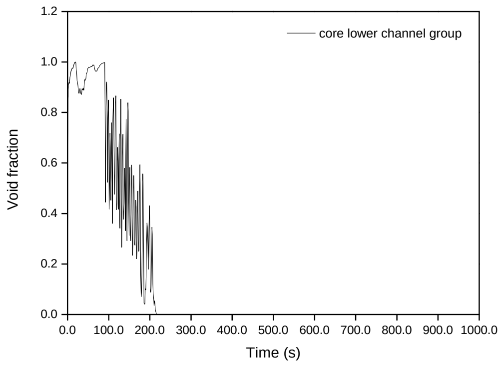

Figure 5 Integrated channel void in core lower channel

Figure 6 Fuel sheath temperature behavior

3. Results

The channel coolant behavior and ECC behavior for large LOCA is examined. Power pulse and flow stagnation is important for fuel heatup. For RIH break LOCA, 40% break is the most limiting case due to the combined effect of power pulse and flow stagnation. For long-term cooling of fuel ECC injection is critical for fuel cooling. The channels located outside of core are shown to be more slowly injected than the channels located center region of the core.

REFERENCES

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