Evaluation of FCI with the pre-flooded cavity through simple models

KHNP CRI[a], Samsung Electronics[b], KAERI[c], KAIST[d]
Seung Hyun Yoon[a]*, Jegon Kim[b], Moon Won Song[c], Hee Cheon NO[d]

Introduction

Fuel-Coolant Interaction (FCI)

- Corium-water interaction in a pre-flooded cavity
  - ✓ This research does not consider the steam explosion
- Intermediate stage during a ex-vessel severe accident progression
  - ✓ Corium release (Vessel breach) -> FCI -> MCCI
- Large heat transfer and pressure-buildup during this phenomenon
  - ✓ Approximately 40~50% of the initial corium energy releases to the surroundings in a few seconds
  - ✓ Main heat transfer mechanism : film boiling with corium particles

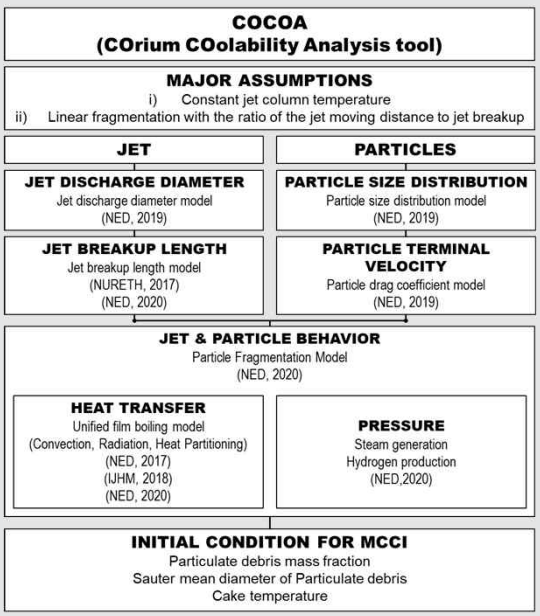
Objectives

- Evaluation of the coolability and the pressure behavior during FCI
- Calculation for initial conditions for MCCI

Method

Tool with lumped and Lagrangian systems

- Corium : Lagrangian approach, Water and Cavity : Lumped approach
- Explicit time discretization, no momentum conservation equation



Models

- Jet breakup length : modified Epstein correlation (corium data-based)

$$E_0 = \frac{1}{13.88 + 22.66 \exp\left(\frac{-D_j \times 10^3}{18.86}\right)}$$

- Jet fragmentation : linear fragmentation
- Heat transfer : film boiling for the corium jet and particles
- Pressure : Van der Waals with steam and hydrogen production

$$\left(P^{n+1} + \frac{a\left(n^{n+1}\right)^2}{V^2}\right)\left(V - bn^{n+1}\right) = n^{n+1} R T_{gas}^{n}$$

- Average corium temperature at bottom :

$$T_{corium} = f\left(\frac{E_{total}}{m_{corium}}\right)$$

Results

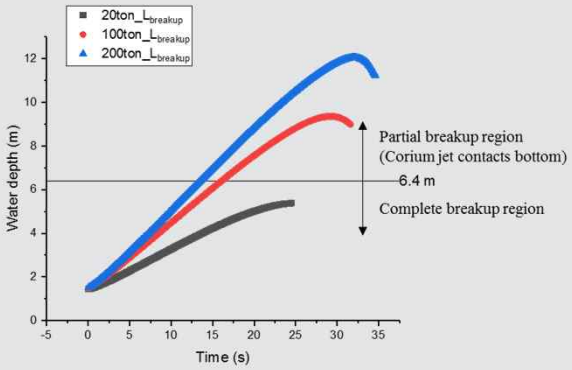
Input parameters

Parameters	20ton_sat	20ton_sub	100ton_sat	100ton_sub	200ton_sat	200ton_sub
Corium mass (ton)	20	20	100	100	200	200
Corium temperature (K)	3000					
Initial Pressure (MPa)	0.1					
Water depth (m)	6.4					
Initial ΔT_{sub} (K)	0	50	0	50	0	50
Initial $D_{release}$ (m)	0.0762					
Mean $D_{particle}$ (mm)	3.7*					
C_{H2} (1e-3)	2.5**	0.6***	2.5**	0.6***	2.5**	0.6***

* We applied the average value of 6 available data from FARO tests, same as L-27 in Table 3-1.
** Average value of the FARO results with the initially saturated water.
*** Value of the FARO test with the initially subcooled water.

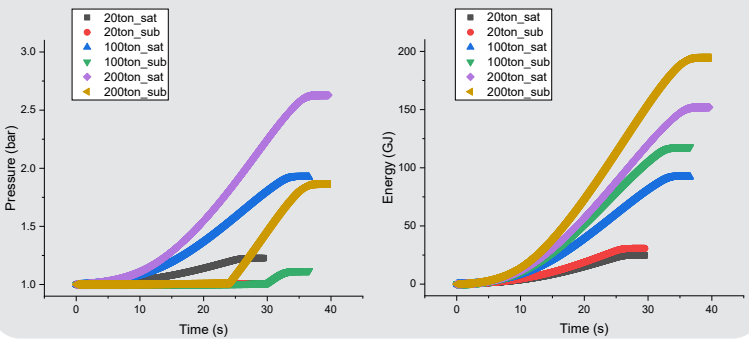
Corium release

- Jet breakup length increases as jet discharge diameter increases
  - ✓ Jet discharge diameter increases as the high temperature corium interacts with the vessel hole (initially 0.076 m, ICI nozzle)



Pressure and energy

- Final pressure is 2.6 bar for 200 tons of corium with the saturated water condition, when all corium is at bottom
- Also, release energy is 152 GJ and the average corium temperature is 2126 K



Conclusions & Acknowledgement

- With 200 tons of corium release for the water level of 6.4 m and the saturated water, the containment keeps its integrity
- The average corium temperatures show lower values than 2126 K, when all the corium settle down to the bottom
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Contact : shyoon20@khnp.co.kr