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Simulation of Dispersal of Fuel Particles with STAR-CCM+

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Introduction

- Recently, an operational cycle of a power plant has been increasing, and accordingly, burnups of fuel rods have been also increasing.
- The increase in a burnup has effects on fuel fragmentation, relocation, and dispersal (FFRD).
- Relocation and dispersal of fragmented fuel pellets inside a cladding and out of a cladding affect the limit on peak cladding temperature (PCT), shapes of coolant flow in a reactor core, and long-term cooling after LOCA.
- Because of these effects, the need to revise current acceptance criteria of emergency core cooling systems (ECCS) has been raised, and it is very significant to develop a model that can handle FFRD
- Dispersal of fragmented fuel pellets was analyzed in use of the information in Studsvik 192 and 198 tests with STAR-CCM+ code.

Geometry

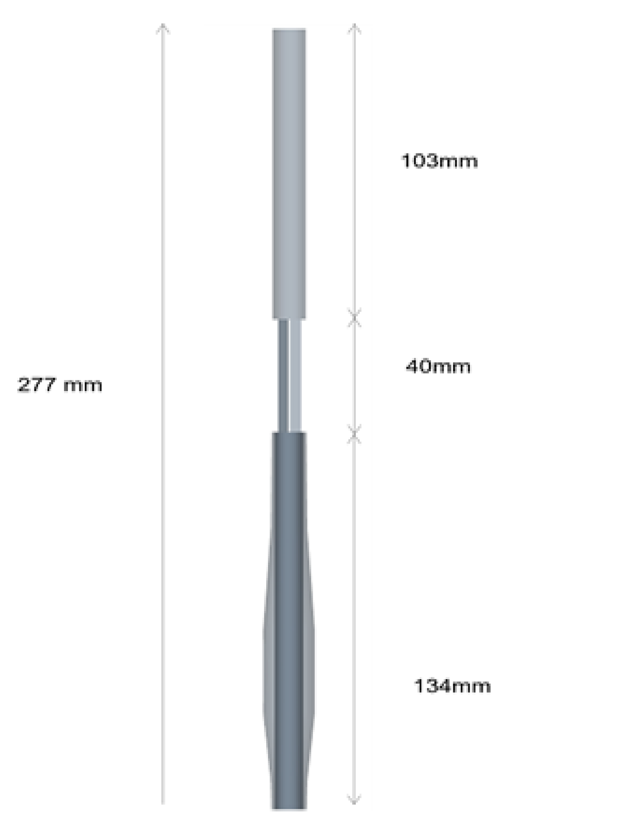

Fig. 1 The geometry of 192 model

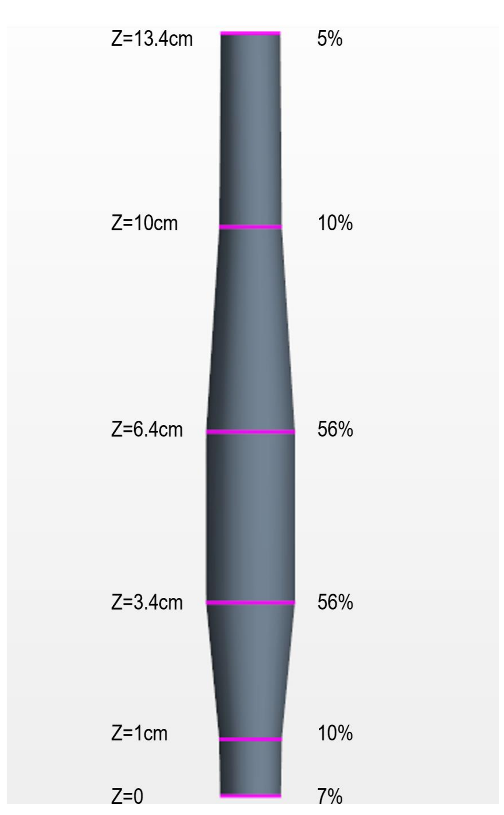

Fig. 2 The strained cladding in 192 model

Fig. 3 The burst shape in 192 model

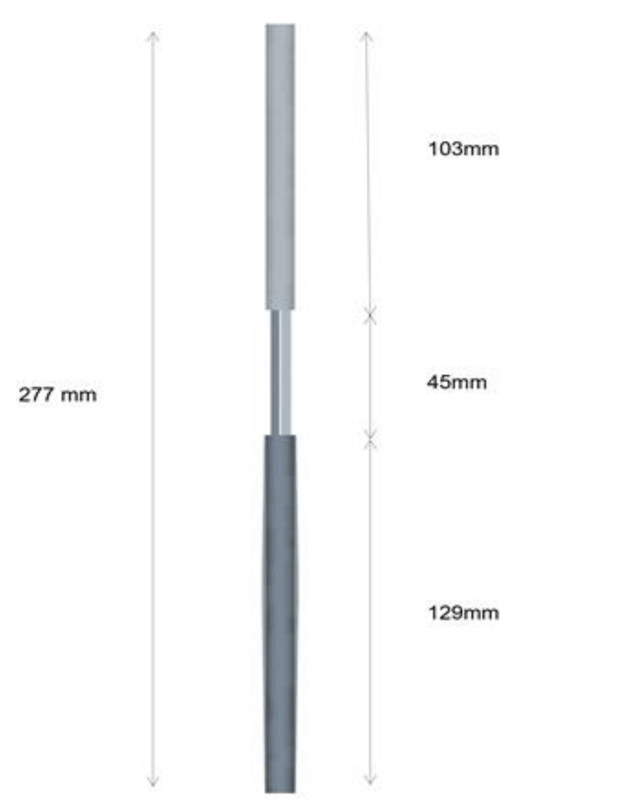

Fig. 4 The geometry of 198 model

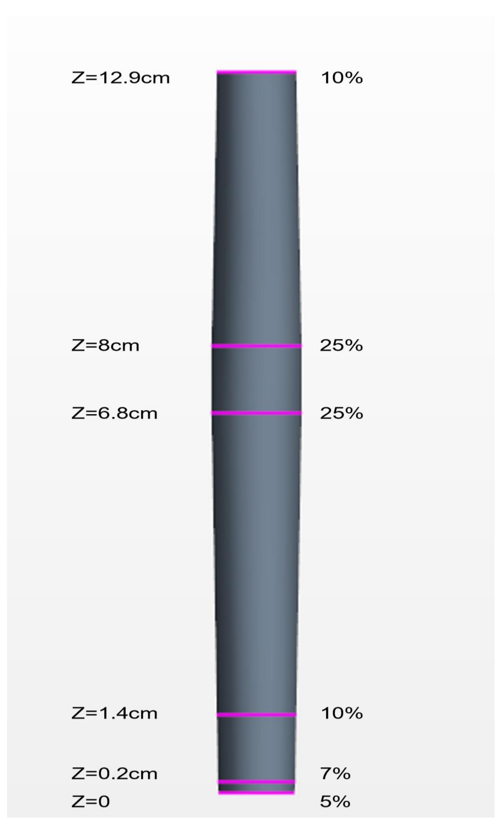

Fig. 5 The strained cladding in 198 model

Fig. 6 The burst shape in 198 model

Simulation Methodology

- DEM Model for simulating actual behavior of fragmented fuel
  - In both models, DEM particles are all spherical
  - The diameter of the particles in 192 model : 1mm,
    in 198 model : 1.95 and 0.5mm
- Schiller-Naumann Model for simulating drag force between fission gas being expelled from a burst opening and fragmented fuel
- Two-Way Coupling for calculating momentum exchange between continuous phase and DEM particles
- Pressure loss coefficient (K=300) at the rupture opening
- Table. 1 The initial conditions in 192 and 198 model

	192 model	198 model
Inner Pressure [MPa]	**8**	
Outer Pressure [MPa]	**0.1**	
Density of particles [g/cm^3]	**10.44**	
Total mass of DEM particles [g]	**94.49**	**78.76**
Total number of DEM particles [#]	**172850**	**2316**

Result

- In 192 model, the amount of the dispersed DEM particles from the cladding (“Mass_out”) was 60g, and the one of the rest of the DEM particles in the cladding (“Mass_in”) was 35g.
- In 198 model, no DEM particles were dispersed outside due to the particles size 1.95mm bigger than the burst width 1.6mm

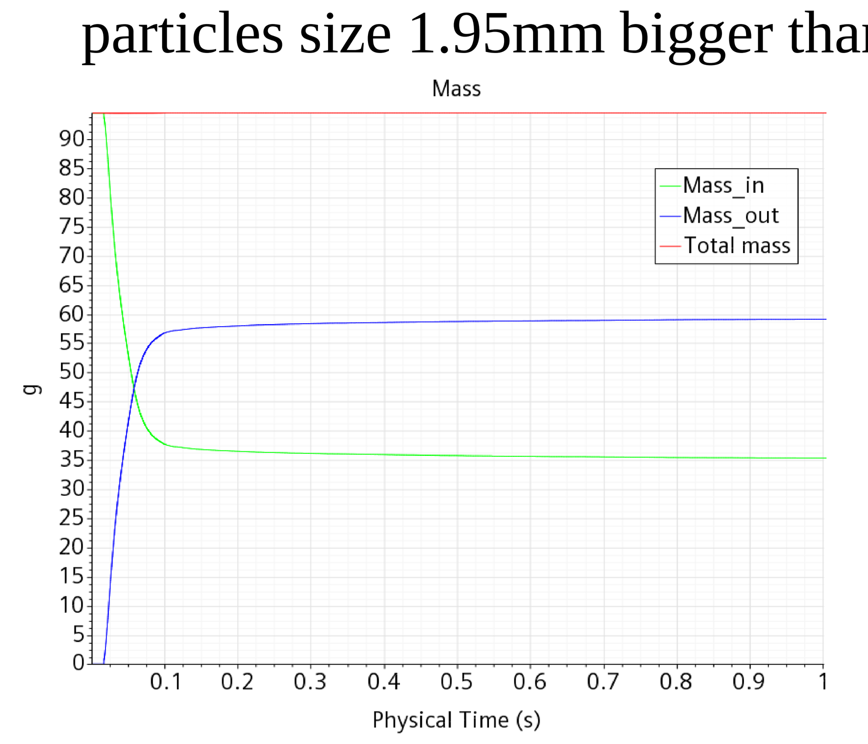

Fig. 7 Dispersed fuel calculation in 192 model

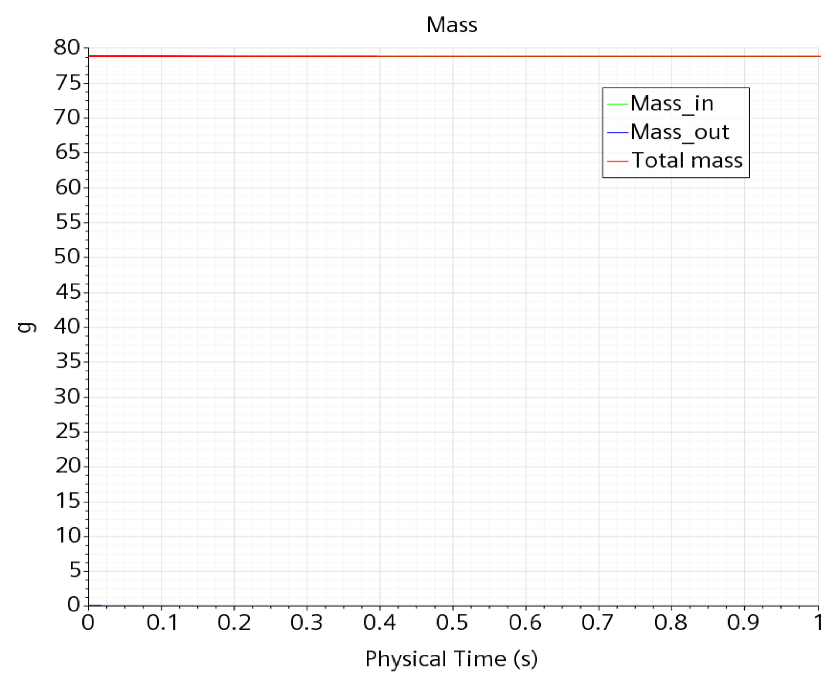

Fig. 8 Dispersed fuel calculation in 198 model

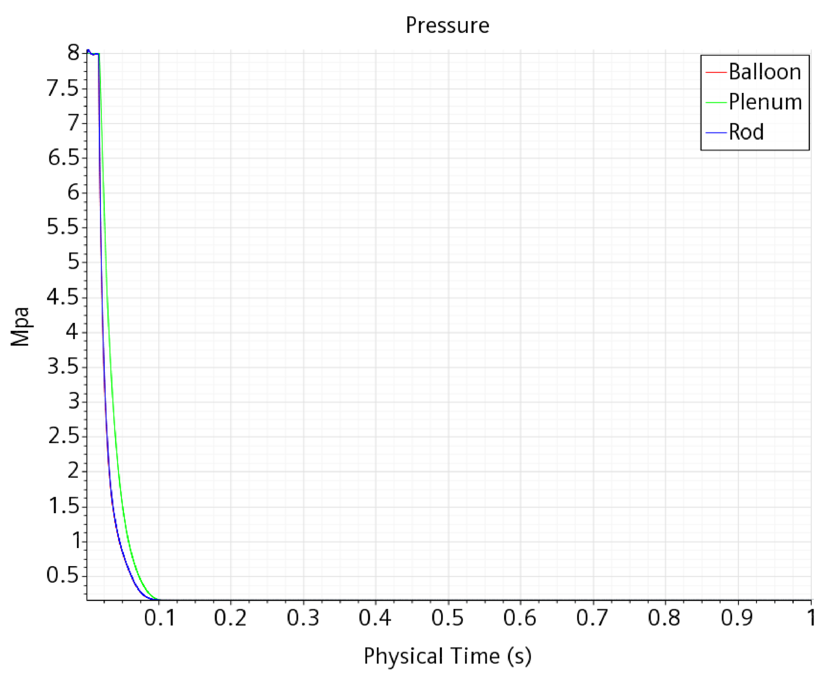

Fig. 9 Pressure calculation in 192 model

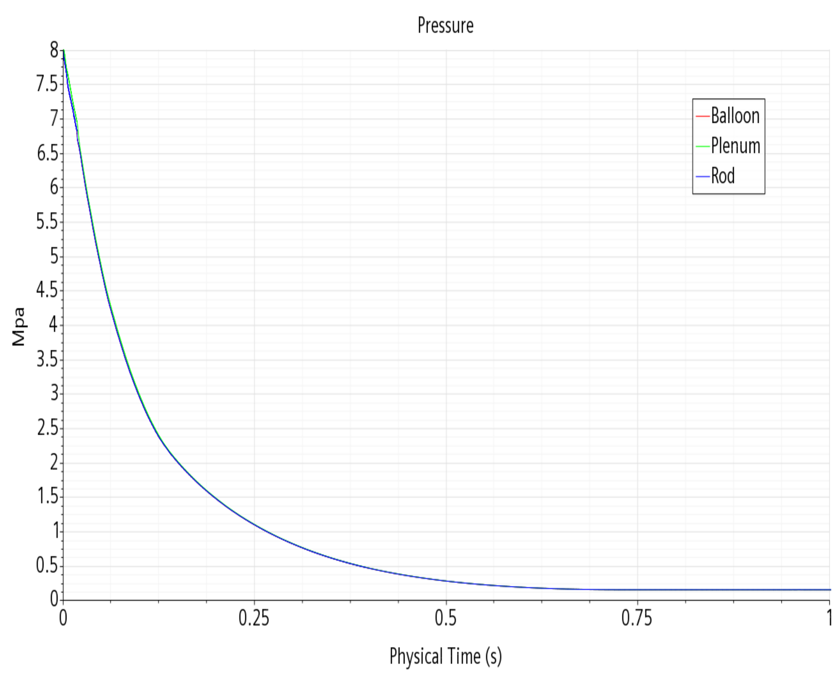

Fig. 10 Pressure calculation in 198 model

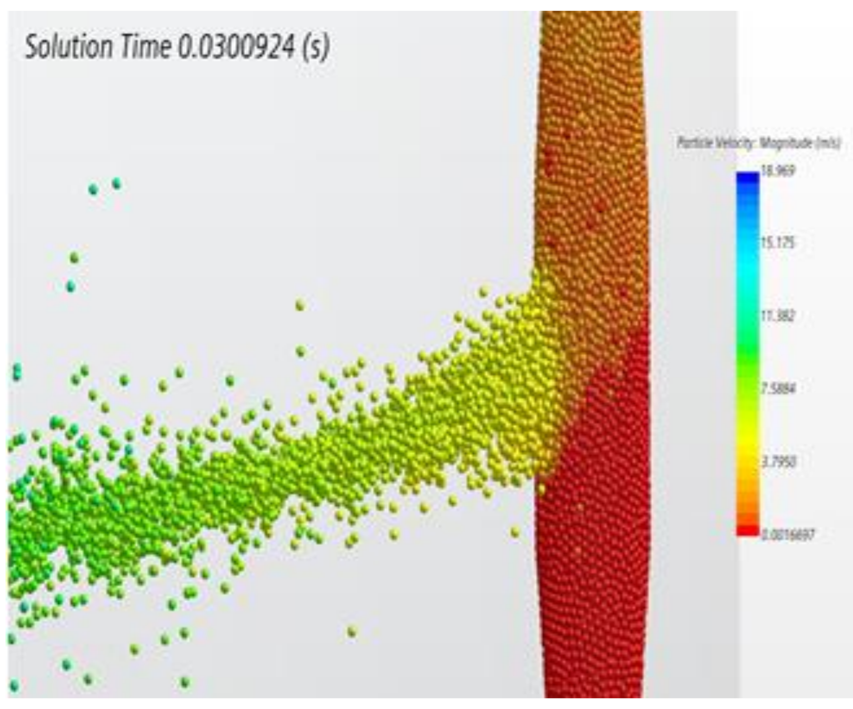

Fig. 11 A snapshot in 192 model

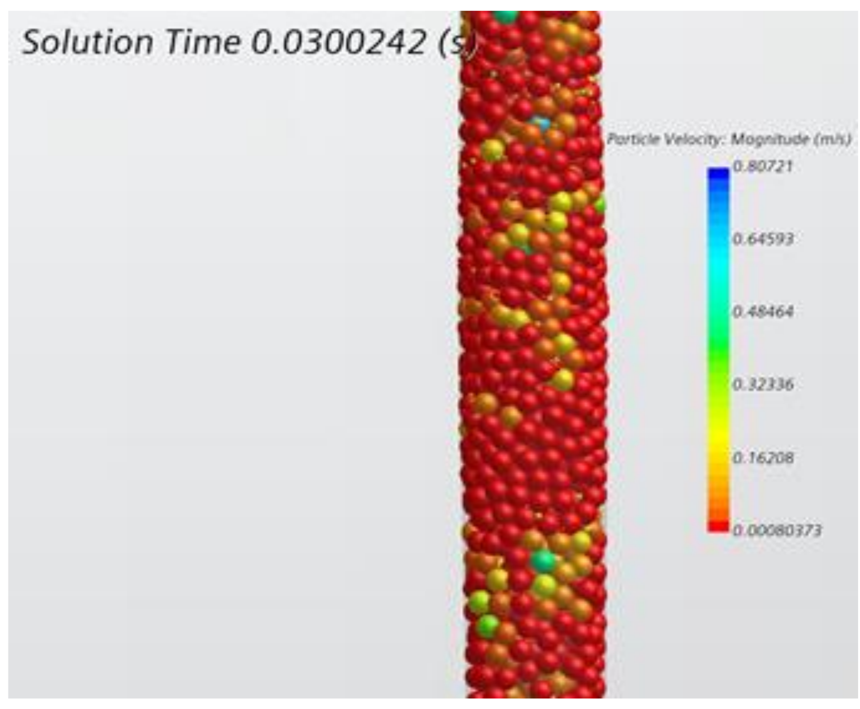

Fig. 12 A snapshot in 198 model

Conclusion

- It was found that the sum of the dispersed particles in 192 model was 60g, and the one in 198 model was 0, which is nearly consistent with the test results.
- The pressure drops over time were not reasonably simulated mainly due to the limitation of DEM model.
- To obtain an enhanced result about fuel dispersal, it is necessary to apply a drag model and a mesh control method overcoming the limitation of DEM model.