Particle-based simulation on heat transfer behavior between molten pool and duct wall in EAGLE ID1 and ID2 in-pile tests

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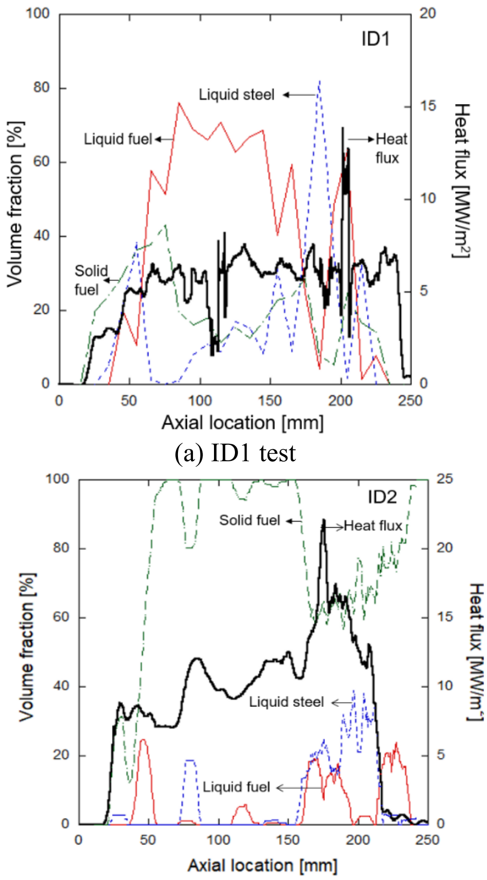
The EAGLE ID1 and ID2 in-pile tests suggest that the inner duct wall failure could be initiated by high heat flux from molten pool in FAIDUS. In this study, the ID1 and ID2 tests, which were performed under different power conditions, were simulated numerically using the finite volume particle (FVP) method to study the thermal-hydraulic mechanisms underlying the heat transfer process.

Keywords: Sodium-cooled fast reactor, Core disruptive accidents, Particle-based simulation, Molten pool heat transfer

1. Introduction The EAGLE ID1 and ID2 were in-pile tests of EAGLE project aiming to demonstrate that the fuel in the molten pool could be discharged through an inner duct structure in FAIDUS during a core disruptive accident in a sodium-cooled fast reactor[1]. Although the ID1 and ID2 tests were conducted under different power conditions, both of the two experimental results suggested that the early duct wall failure was initiated by high heat flux from the molten pool[2]. In this study, using an enhanced FVP method[3], 2D numerical simulations of the ID1 and ID2 tests were performed to investigate mechanism of the large thermal load imposed on the duct wall.

2. Test and simulation conditions In the ID1 and ID2 tests, a 75-pin fuel assembly surrounding an inner duct was melted by nuclear energy. The nuclear power history inserted into the fuel in the two tests showed a similar curve in shape, but in ID2, the power rose and stabilized at a smaller magnitude during the course of the molten pool formation. Caused by this power condition, in ID2 test, it was at 2 s after the heat transfer initiation when the inner duct wall failure occurred, while in ID1 it was 0.72 s. In the present study, the particle-based simulations were performed to investigate the effect of the difference in power conditions between ID1 and ID2 tests on molten pool-to-duct wall heat transfer.



(a) ID1 test

(b) ID2 test

Fig. 1 Axial distribution of materials and heat flux when duct wall failure occurred in ID1 and ID2.

3. Results and discussion In the present simulations, the duration from heat transfer initiation to duct wall failure was 0.65 s and 1.99 s, respectively, for ID1 and ID2 tests, which agreed well with experimental results. Figure 1 shows the axial distribution of pool materials and heat flux at duct wall failure occurrence. It can be seen that under lower nuclear power supply, in the ID2 simulation, more solid fuel remained in the pool when duct wall failure was initiated. Nevertheless, the common mechanism, that the duct wall failure was mainly caused by liquid fuel and enhanced by liquid steel, can be deduced from the comparison of ID1 and ID2 simulations.

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