Preliminary Approach of Impact Simulation for the Simplified Unit Grid

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1. Introduction

As the amount of Spent Nuclear Fuel (SNF) in domestic spent fuel pool substantially increases, the storage capability for the SNFs will be expected to be saturated in 2020 [1]. The SNFs in the pool have to transfer to a designated wet or dry spent fuel storage facility. Among the issues of the SNF treatment, the handling and transportation of the SNF have been considered as key factors. Experimental evaluation about the soundness of the mechanical behavior during the SNF management requires a lot of time and effort. The computational methodology like FE simulation is usually employed as a technical solution instead of experiment. Lee et al. [2] conducted the drop impact simulation using dynamic properties. The study was conservative approach by applying the simplified properties.

In this study, we investigate the effect of strain rate on the impact simulation through experiment and simulation of the simplified unit grid in order to verify the dynamic analysis of the SNF.

2. Simulation of the drop impact test

2.1 Drop impact modeling

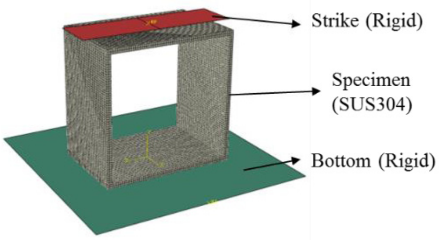


Fig. 1. Finite element model for drop impact simulation.

Fig. 1 shows the finite element model of the strike and specimen for drop test. The specimen was modeled using ABAQUS/explicit 6.14.5, C3D8R (8-node linear brick reduced integration element) was used for the specimen, and analytic rigid elements were used for the strike and bottom. Total number of elements and nodes are 722,459 and 831,875 respectively. The material of the specimen is stainless steel (SUS304).

2.2 FE analysis considering the strain rate

Metal can behave very differently at the higher strain rates like drop tests and impacts. SUS304 is highly strain-rate dependent [3]. Stain-rate sensitivity can be included in a number of different explicit dynamics material models. For metals, Cowper-Symonds and Jonson-Cook models are often used. These models, and others like them, are readily available in commercial FE analysis software codes like LS-Dyna, ANSYS and ABAQUS. The flow stress of Jonson-Cook model, which includes strain hardening, stain rate, and temperature effect, was used as constitutive equation in this model.

$$\begin{aligned}\sigma\left(\varepsilon_p,\dot{\varepsilon},T\right) &= f_1\left(\varepsilon_p\right)\cdot f_2\left(\dot{\varepsilon}\right)\cdot f_3\left(T\right)\\ &= \left(A+B\varepsilon_p^n\right)\left(1+C\ln\dot{\varepsilon}^*\right)\left(1-\left(T^*\right)^m\right)\\ \text{where}\quad \dot{\varepsilon}^* &= \frac{\dot{\varepsilon}}{\dot{\varepsilon}_0},\ T^*=\frac{T-T_r}{T_m-T_r}\end{aligned} \quad (1)$$

The used Jonson-Cook parameters of SUS304 are presented in table 1 [4].

Table 1. SUS304 properties

A [MPa]	B [MPa]	n	C
310	1,000	0.65	0.07
$\dot{\varepsilon}_0$ [/s]	M	T_r [K]	T_m [K]
1	1.0	293	1,673

These properties were applied to a 2 mm thick rectangle box impacted by a 22.9 kg rigid block travelling at 2.09 m/s. The total impact energy is 50 J.

3. Result & discussion

3.1 Result of drop impact test

The drop impact test for rectangle box was carried out in order to evaluate the simulation result. Fig. 2

shows the experimental apparatus and the deformed specimen for drop impact test.

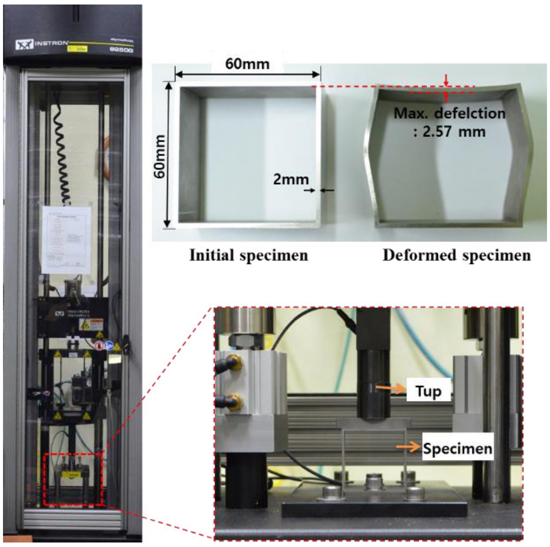
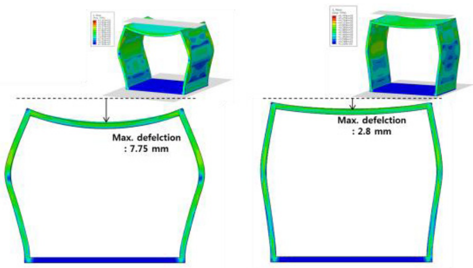


Fig. 2. Experimental apparatus and tested specimen.

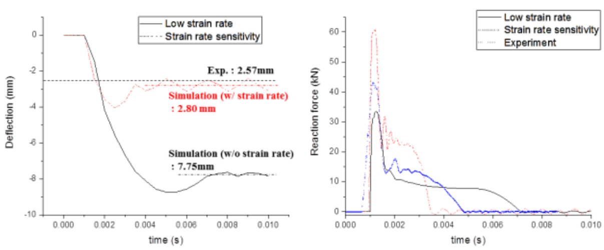
3.2 Results of the finite element analysis



(a) (b)

Fig. 3. Deformed shapes for drop impact simulation (50 J) (a) Low strain rate and (b) Stain-rate sensitivity model.

Fig. 3 shows the deformed shapes of the specimen for 50 J drop impact test. In comparison with the cross-section of the experimental results shown in Fig. 2, the extent of deformation with FEM is higher than that of the test. The reason could be thought as that in the FE analysis the model was considered ideally.



(a) (b)

Fig. 4. Comparison between experiment and simulation (a) Max. deflection and (b) Reaction force.

Fig. 4 shows the resulting maximum deflection and reaction force versus time for the strain-rate sensitivity Jonson-Cook plastic model, for the same plasticity model but without the strain-rate sensitivity, and for experiment. It's obvious that the deformation and reaction force are significant influenced by the strain-rate. Also, a check of maximum deflection for the model with the strain-rate sensitivity shows that the value is close to the experimental result.

4. Conclusion

Drop impact test for the simplified unit grid was performed to evaluate the dynamic model of SNF. The finite element analyses considering strain rate and not considering that were carried out. By comparing the two results with or without strain rate, the material input data at the simulation should contain the rate-dependent effect to simulate the impact behavior of the grid made with a property which is very sensitive to the strain rate.

ACKNOWLEDGMENTS

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