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Analyses of the Collapse Behavior of a Spacer Grid

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1. Introduction

Multi-layered spacer grids (Fig. 1) are generally used for a nuclear fuel cell assembly to protect the fuel rods from external loads. In order to protect the fuel rods from external loads such as collision and vibration, the spacer grid consists of strong grid and soft spring. The deformation characteristics of the spacer grid for impact load are investigated in this study. In order to investigate the protection capability of a spacer grid assembly for impact load, a hammer impact test [1] has been carried out. The crush strength is measured in the hammer impact test. Song et al. [1] carried out the experiment and finite element analysis for the hammer impact test for various weld line depth. Park et al. [2] designed the spacer grid shape to get required crush strength via finite element analysis. Song et al. [3, 4] also optimized the spacer grid shape to maximize the crush strength [3], and carried out the finite element analysis for the hammer impact test considering the weld properties [4]. Kim et al. [5] carried out finite element analysis for various guide tube hole shape and compared the crush shape and crush strength.

In this study, the effect of shape defect on the crush behavior in the hammer impact test is investigated. The spacer grid cannot be exactly the square. Therefore a lateral displacement (imperfection) is imposed to square spacer grid and then hammer impact is carried out. The effect of the lateral imperfection on the crush strength is investigated.

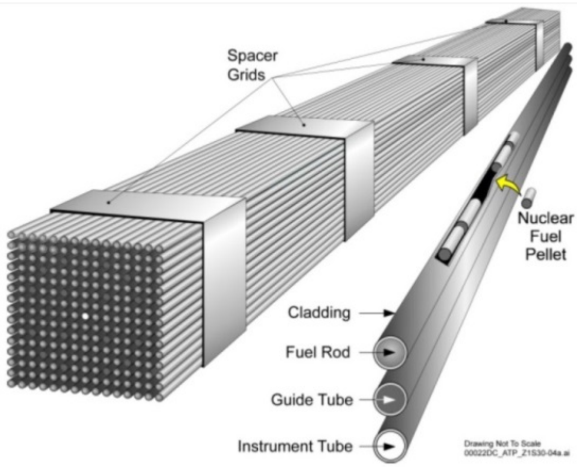

Fig. 1. An example of multi-layered spacer grid [6].

2. Finite Element Analysis and Results

2.1 Analysis model

Fig. 2 shows the analysis model and boundary conditions. Two side plates and the left surface of the spacer grid are fixed in all directions. No boundary conditions are imposed for the impact hammer and impact plate. Initial velocity in z-direction is imposed for the impact hammer.

Zircaloy-4 and general steel are used for the spacer grid and impact plate, respectively. The mechanical properties for the materials are shown in Table I. Only elastic properties are assigned for the impact plate. The stress-strain curve for Zircaloy-4 is obtained from the paper of Song el al. [4] and fitted for the equation shown in Table I. The mass of the impact hammer is 80 kg.

Analysis is carried out using ABAQUS/Explicit [7]. General contact scheme is used for the contact treatment and frictionless condition is used.

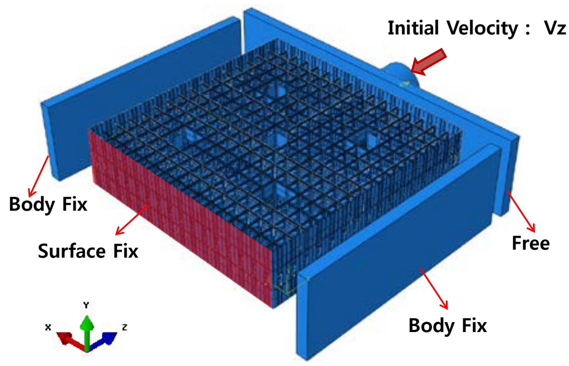

Fig. 2. Analysis model and boundary conditions.

Table I: Mechanical properties of Zircaloy-4 and steel

	Zircaloy-4	Steel
Young's modulus	113.7 GPa	200 GPa
Poisson's ratio	0.29	0.3
Stress-strain relation	$\sigma = 157+543\varepsilon^{0.163}$	–

To impose the lateral imperfection, analysis is carried out in two steps. In the first step, lateral inclination is imposed as shown in Fig. 3. Then the hammer impact test is carried out in the second step.

Fig. 4 shows the deformed shape and maximum lateral displacement for various lateral imperfections when the impact velocity is 0.2 m/s. As expected, the collapse displacement increases as the lateral imperfection increases. When the imperfection displacement is lower than or equal to 0.4 mm, no collapse behavior is shown. When the imperfection displacement is greater than or equal to 1.0 mm, collapse behavior is clearly shown. Fig. 5 shows the reaction force-time curve. As the imperfection displacement increase, the maximum reaction force decreases and the time of the maximum force is fast.

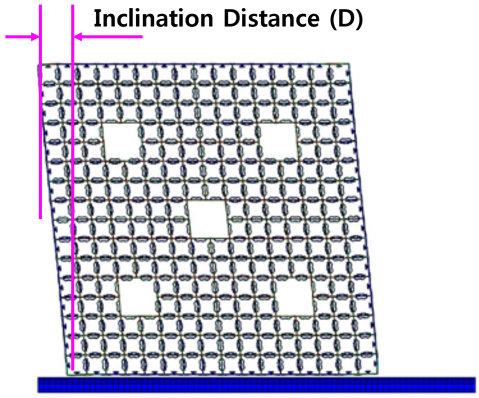

Fig. 3. Imposition of lateral imperfection.

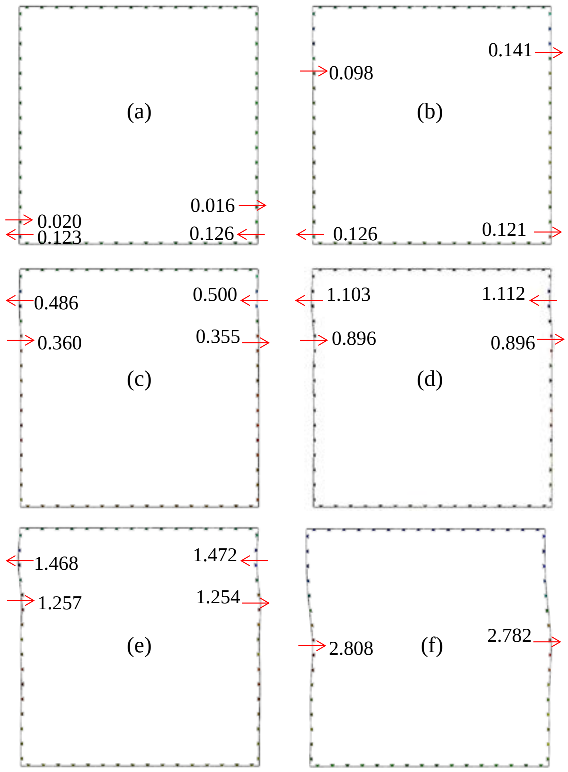

Fig. 4. Deformed shape and maximum lateral displacement for various lateral imperfections of (a) 0.0, (b) 0.1, (c) 0.4, (d) 0.7, (e) 1.0, and (f) 3.0 mm. (Unit : mm)

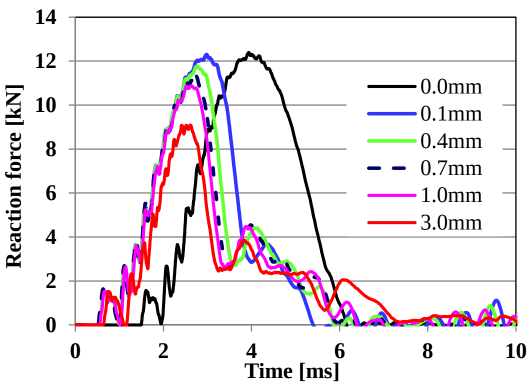

Fig. 5. Reaction force at the fixed surface for various lateral imperfections.

3. Conclusions

The effect of the shape defect on the crushing behavior in the hammer impact test is investigated by finite element analysis. It is shown that the collapse become severe as the lateral imperfection displacement increases, especially when the imperfection is greater than or equal to 0.7 mm.

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