Speculation on the Boundary Conditions of Spent Fuel Evaluation During Transportation

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1. Introduction

Integrity of spent fuel (SF) shall be assessed conservatively with general applicability. Characteristics of SF and boundary conditions such as cask properties etc. are necessary to evaluate the integrity of SF. Especially, SF transportation cask shall be designed to meet the regulatory drop accident impact onto unyielding surface. In order to satisfy the requirements, detachable impact limiters which can absorb the kinetic energy are used, but each design is unique and characterized by vendor-proprietary [1]. Using the results of the EPRI [2], impact limiters are replaced by concrete pad with target hardness model. In this paper, we analyzed the target hardness model and the scheme of SF integrity evaluation is to suggest.

2. Methodology of SF Cask Drop

2.1 Target Hardness Model

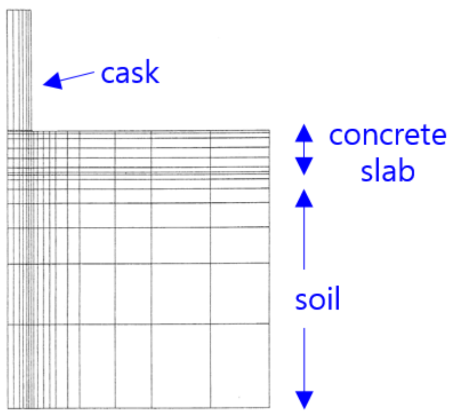

Fig. 1. Finite element model of the cask and the target.

Impact limiter reduces the impact loads on the cask and internal SF. Because of vendor-proprietary, EPRI developed target hardness model. In the model, crushing and cracking of the concrete and deformation of the soil present dissipation of impact energy instead of impact limiter. Target means concrete pad with reinforcements and soil layer. A finite element model of the cask and the target is shown in Fig. 1. Using this model, responses of the target considering complex concrete properties are obtained. In simulation of falling cask onto impact target, coupling between cask and target is complex. To simplify the analysis, assumption that the cask is infinitely rigid is used. Characteristics of target is described by single non-dimensional variable, target hardness number S. S is given below.

$$S = 2rAkM_u\sigma_u/(W^3(1-e^{-\beta r}cos\beta r)) \qquad (1)$$

Parameters are given by:

r: radius of the cask

A: cask footprint area

k: foundation modulus

M_u: ultimate moment capacity of the concrete

σ_u: ultimate strength of the concrete

W: weight of the cask

$\beta = (E_s/4D_c)^{1/4}$

$D_c = E_ch^3/(12(1-\nu_c^2))$

E_s: Elastic modulus of soil

E_c: Elastic modulus of concrete

h: height of concrete

ν_c: Poisson's ration of concrete

Target hardness number is dependent on properties of concrete and soil

2.2 Full-Scale Drop Tests

In order to verify the target hardness model, NRC contracted British Nuclear Fuels Limited (BNFL) to conduct full-scale drop tests. In tests, a 64.5-metric-ton cask was dropped onto a 3-foot reinforced concrete slab at 18-inch, 40-inch, and 60-inch drop heights.

3. Results and Discussion

Table 1. Summary of calculated decelerations with data

Drop Height	Data	Analysis
18 in	48 g	50 g
40 in	56 g	64 g
60 in	73 g	73 g

The experimental steady deceleration was achieved by integrating the first pulse of the acceleration data divided by the time duration of the pulse. Table 1 shows the summary of decelerations. The model has been validated by experimental data [3]. As can be seen from the Table 1, analysis and tests results are in good agreement.

4. Conclusion

Integrity evaluation of SF is essential for transportation and dry storage of SF. To evaluate the integrity of SF, global analysis of cask-SF is required, as shown in Fig. 2. KNF developed indigenous integrity evaluation model for dry storage and transportation. Target hardness model is to be used in integrity evaluation of SF before the design of specific cask and impact limiter is decided.

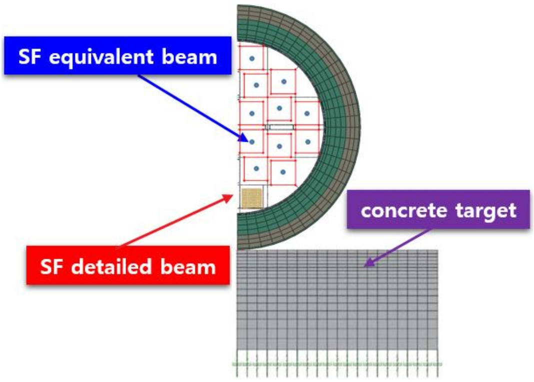

Fig. 2. KNF integrity evaluation model of SF.

ACKNOWLEDGEMENT

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