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Development of Nuclear Spent Fuel Onsite Transportation Scenario

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1. Introduction

Within 10 to 15 years, spent fuel onsite storage will be full. Kori site has 81% of spent fuel comparing to its capacity, Hanbit has 67%, Hanwool has 62%, Wolseong has 76% respectively [1]. We need to transport them to the interim storage, reprocess facility or disposal area. Also there are unbalance of storage capacity and stock between sites, so inter-site transportation might be necessary. All four nuclear power plant sites (Kori, Hanbit, Hanwool, Wolseong) are located near coast. Maritime transportation is more applicable than overland transportation for plants location and it transports larger amount of spent fuel at a time than overland transportation. And Korea is one of the densest population country (3rd among countries with population above 10 million), thus the overland transportation is more risky. We expect that the spent fuels will be transported to the interim storage or reprocess/disposal facility and they are assumed to be near one of power plant sites.

Eventually, spent fuel transportation in Korea will be divided by two parts, the one is overland transportation and the other one is maritime transportation. This study deals with part of whole transportation, that is, overland transportation. The overland transportation is none other than onsite (from plant to wharf) transportation. To assess its safety, we use Probabilistic Safety Assessment (PSA) method. It calculates risk of the transportation that is a product of accident probability and consequence and analyze them probabilistically. Total risk is sum of the products along accident sequences. Accident sequences are found only if the scenario is developed.

USNRC has been assessed overland spent fuel transportation and the latest research is NUREG 2125 [2]. They used PSA method to calculate overland transportation risk. It is well organized and detailed, however, it concentrates on plant-storage transportation not on onsite transportation and uses American domestic statistical data. Mills et al. conducted event tree analysis for highway truck accident [3], Volpe conducted event tree analysis for rail accident and loss of lead shielding with fire accident [4].

2. Onsite Transportation Scenario

Onsite transportation of the spent fuel is assumed to be a transportation of the spent fuel from the power plant to wharf for shipping.

Transportation of the spent of light water reactor in the plant is divided broadly by 6 parts [5]. They are taking over, preliminary fuel loading, fuel loading, transportation preparation, cask loading and cask transportation. Transportation of the spent fuel of heavy water reactor in the plant is divided broadly by 8 parts. They are taking over, preliminary fuel loading, basket fuel loading, basket salvage and dry, cask fuel loading, transportation preparation, cask loading and cask transportation. It takes about 10 days in Kori, non-accidental exposure need to be calculated.

Cask transportation is a transportation of the cask from the plant to the wharf. The accident sequence is assumed to follow the sequence as Mills et al. described. It is shown in Fig.1.

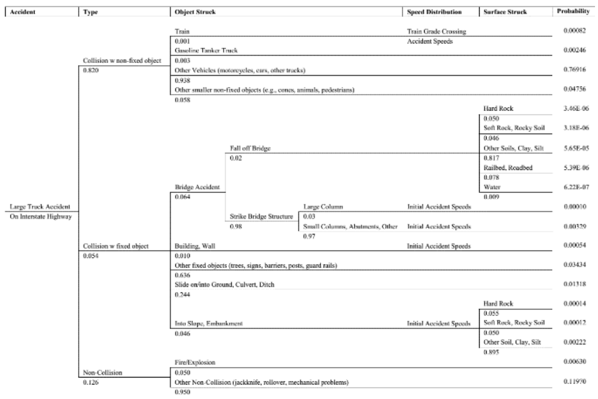

Fig. 1. Truck accident event tree (accident scenarios that might lead to cask failure)

However, the event tree is for highway truck transportation. We have concern only for the onsite transportation, branch probabilities need to be modified. For example, bridge accident branch should be removed because ther are no bridge in the plant site.

To calculate the cask failure probability by the impact, we use stress-strength interference method. When accident during the overland transportation happens, impact velocity, impact angle will follow probabilistic distribution. From those variables, stress (energy or acceleration of the impact) can be calculated and it also follows probabilistic distribution. This is called stress. Strength is ability of a system to endure stress, not to be failed. In this case, the strength is a strength of the cask to the impact energy or acceleration. The strength also follows probabilistic distribution in real world. It is shown in Fig.2, for example.

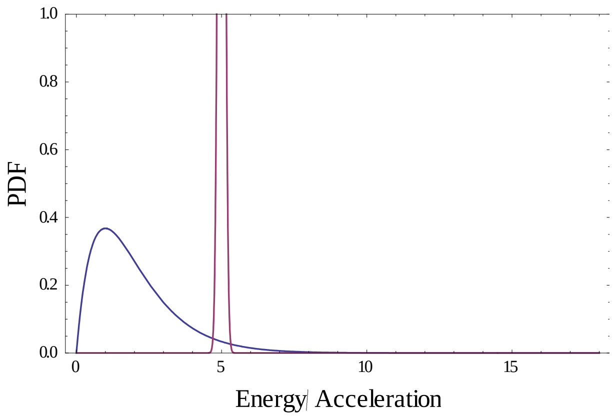

Fig. 2. Stress-strength interference method

Blue line is stress and red line is strength distribution. It is assumed that stress has gamma distribution (2, 1) and the strength has normal distribution (5, 0.1).

$$\int_0^\infty (Stress \times Strength)dx \qquad (1)$$

Equation (1) is a failure probability of the cask when stress comes. “Stress” and “Strength” is their probability density function. In this case, the failure probability of assumed branch accident is 3.34%. On the other hand, strength distribution might not be found. However we can also calculate failure probability of the cask in deterministic way. Let us assume that cask will be failed some criterion z. Than the failure probability of the cask to the same strength with previous example is

$$\int_z^\infty (Stress\ density\ function)dx \qquad (2)$$

It can be shown also in Fig. 3.

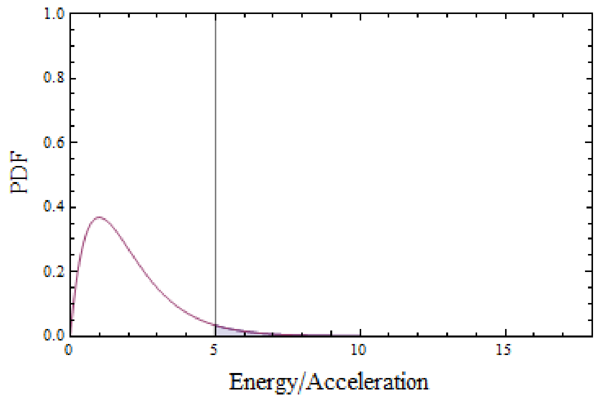

Fig. 2. Failure probability calculation with deterministic criterion

The criterion is assumed to be unit-less number 5. Failure probability is 1.49%, that means deterministic calculation underestimate the accident probability and thus the risk.

3. Conclusion

Spent fuel of the power plant need to be transported in near future. The overland transportation of the spent fuel expected to be onsite transportation. To regulate the transportation and minimize its risk, it is necessary to be assessed. Initial step of the risk assessment, we develop the scenario and suggest accident probability calculation method in probabilistic way.

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