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Tip-Over Analysis of Freestanding SF Storage Cask

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Abstracts

The objective of this study is to develop a technical assessment methodology on tip-over due to the earthquake which is expected to be major issues during the evaluation of storage cask integrity. This study has derived the equations of motion for evaluating the tip-over of the storage cask, and an in-house program was developed. The tip-over and rocking motion of the freestanding dry storage cask was evaluated by the real earthquake time history. Then various variables and influences affecting the tip-over of the SF storage cask were analyzed.

1. Introduction

Recently, regarding the safety evaluation of SF storage cask, it is becoming an important issue to determine whether or not the storage cask is turned over due to external factors such as earthquakes and the recovery of canister after an accident. In order to solve this problem, it is necessary to develop a technique for evaluating the possibility of the tipping-over of the storage cask in the dry storage system and the possibility of the collision between the neighboring storage casks due to slippage.

Numerous studies have been conducted on the behavior of a single rigid structure under dynamic loading. The mathematical solution of the rigid body behavior is verified through experiments. In the test, various uncertainties including the friction coefficient with the bottom surface due to the surface roughness of the structure, the shape of the rigid structure. Therefore, there has always been an error between evaluation and test results. In order to evaluate more precise behaviors, studies have been carried out to accurately calculate the behavior characteristics using a nonlinear governing equation or a broader approach such as case studies on various conditions, but the prediction of the correct behavior had been known as a very difficult task.

On the other hand, in order to evaluate the tip-over of the spent fuel storage cask for seismic load from the regulatory viewpoint, a simplified evaluation method that can accurately evaluate the tip-over only from a conservative point of view is required rather than a complicated governance equation or a finite element method. JAERI has conducted studies on the analytical method for drop and tip-over conditions, which are the main accident conditions of spent fuel storage facilities [1].

In this study, the equation of motion for the rocking motion of the dry storage cask was derived, and the tip-over and the locking motion of the SF storage cask were evaluated by in-house evaluation code.

2. Methods and Results

2.1 Governing Equations

To derive the governing equations, we use the coordinate system in Figure 1 and assume that the storage cask has two translational coordinates(x and y) and one rotational coordinate(Θ). The governing equations and the load are expressed as follows[2].

$$m\ddot{x} = -m\ddot{x}_b + F_F \quad (1)$$

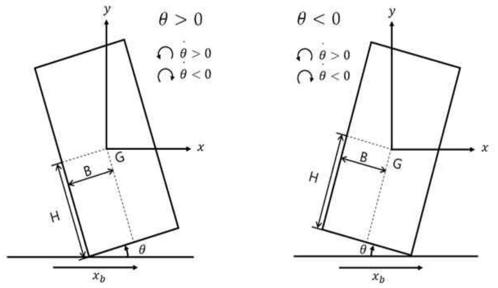
$$m\ddot{y} = -m(\ddot{y}_b + g) + F_C \quad (2)$$

$$I\,\ddot{\theta} = M_{F_F} + M_{F_C} \quad (3)$$

In order to solve the governing equations (1), the friction force between the cask and the floor pad and the associated moments, the vertical impact contact loads and their associated moments should be derived mathematically and substituted into the governing equations.

2.2 Code Development

Figure 2 shows the SF storage cask rocking motion and tip-over evaluation program GUI developed by applying the equations of motion, each load and moment described in Section 2.1. The GUI has a UI for setting input file name, directory and output file name. And the result GUI is composed of an UI for confirming



(a) Counter-clock wise (b) Clock wise

Fig. 1 A cask in rocking motion and sign of rocking angle

animation file, input seismic waves, and rocking motions.

2.3 Code Verification

The seismic waves for the tip-over evaluation is an artificial seismic waves corresponding to the design response spectrum of Regulatory Guide 1.60[3]. The analysis model is based on the assumption that the storage cask is installed in a free standing state on the concrete pads.

The tip-over evaluation program developed in this study should verify the accuracy and reliability before use. For this purpose, the seismic test results performed by KAERI in 2016 were used[3].,

Figure 3 shows the results of the seismic test and the analysis results, and confirms that the angle of rotation and the vertical displacement of the bottom surface are quite consistent. From this, we confirmed the accuracy and reliability of the tip-over evaluation code.

3. Conclusions

In this study, the equation of motion for the rocking motion and tip-over of the SF storage cask against the earthquake load was derived, and its evaluation code was developed using Matlab program. In order to show the reliability of the developed program, we newly obtained various experimental parameters using the seismic test results of the SF storage cask performed by KAERI. The accuracy of the tip-over evaluation code was verified through the comparison with the real test

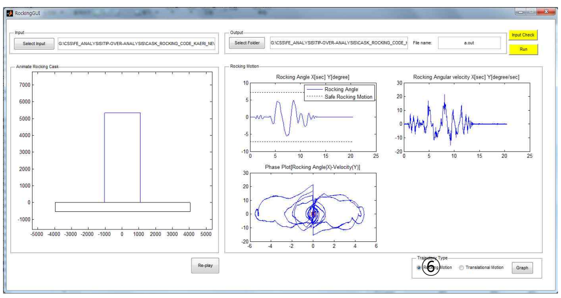
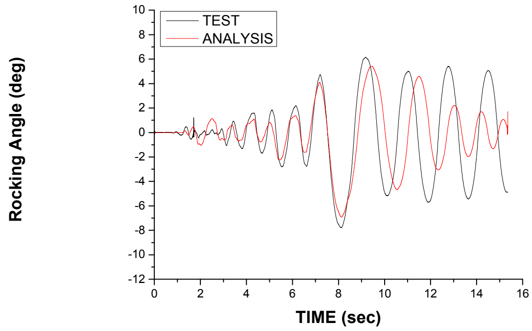
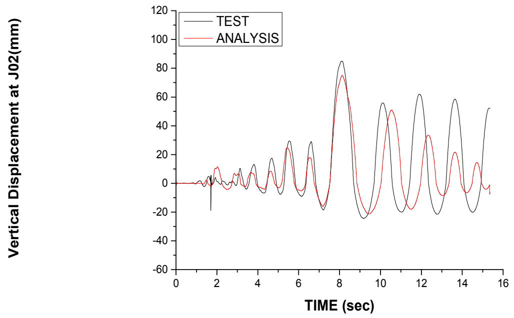


Fig. 2 GUI for evaluating tip-over and rocking motion of SF cask



(a) Rocking angle



(b) Vertical Displacement at Bottom

Fig. 3 Comparison results of seismic analysis and test in case of PGA=0.6G

results.

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