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Original Article

Safety Assessment of a Metal Cask under Aircraft Engine Crash

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ABSTRACT

The structural integrity of a dual-purpose metal cask currently under development by the Korea Radioactive Waste Agency (KORAD) was evaluated, through numerical simulations and a model test, under high-speed missile impact reflecting targeted aircraft crash conditions. The impact conditions were carefully chosen through a survey on accident cases and recommendations from literature. In the impact scenario, a missile flying horizontally hits the top side of the cask, which is freestanding on a concrete pad, with a velocity of 150 m/s. A simplified missile simulating a commercial aircraft engine was designed from an impact load–time function available in literature. In the analyses, the dynamic behavior of the metal cask and the integrity of the containment boundary were assessed. The simulation results were compared with the test results for a 1:3 scale model. Although the dynamic behavior of the cask in the model test did not match exactly with the prediction from the numerical simulation, other structural responses, such as the acceleration and strain history during the impact, showed very good agreement. Moreover, the containment function of the cask survived the missile impact as expected from the numerical simulation. Thus, the procedure and methodology adopted in the structural numerical analyses were successfully validated.

1. Introduction

Safety assessment against an aircraft crash has been an important issue in the design of facilities with hazardous materials such as nuclear power plants [1,2]. For accidental aircraft crashes, the probability of a crash is calculated, and its consequences are selectively evaluated for those facilities with significant crash probabilities. Facilities sited far enough from the airport and airplane routes have been exempted from the requirements for a detailed assessment of the consequences of an aircraft crash. Since the 9/11 terrorist attacks, the issue of aircraft crash into safety-important facilities,

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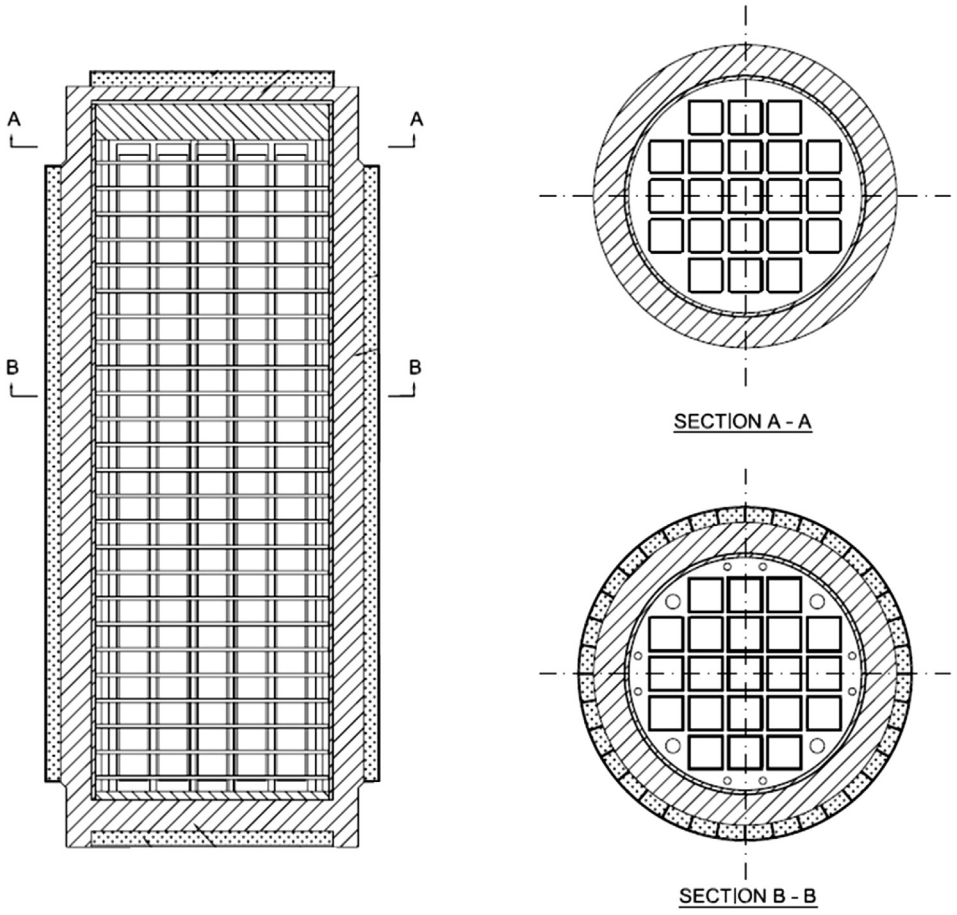

Fig. 1 – Concept drawing of a dual-purpose metal cask without impact limiters.

especially a crash of a large commercial aircraft, has become ubiquitous. In many aspects, the conditions for a targeted aircraft crash are different from those for accidental crashes and tend to be more severe. Recently, the United States Nuclear Regulatory Commission (NRC) revised regulation 10 CFR 50.150 [3,4] to include the requirements for a safety assessment against a targeted aircraft crash for the licensing of newly introduced nuclear power plants. In addition to nuclear power plants, many countries have performed safety assessments of spent nuclear fuel (SNF) storage facilities against targeted aircraft crashes using numerical simulations and tests. The Electric Power Research Institute (EPRI) analyzed the effect of targeted aircraft crashes into nuclear power plant containment buildings, SNF storage pools, dry storage facilities, and SNF transportation casks [5]. Thomauske [6] presented the analyses results of the mechanical and thermal impacts caused by a targeted aircraft crash on SNF interim storage buildings and storage casks inside the buildings. Stepan et al [7] analyzed the consequences of a large commercial aircraft crash into an interim storage building. They built a computer model of the impacting aircraft to consider various angles and locations of impact. Shirai et al [8] performed numerical analyses and tests considering an aircraft engine crash into a metal cask with an impact velocity of 60 m/s. They developed an evaluation model for the integrity of the bolted closure of the metal cask and validated the model under high-speed impact conditions.

In Korea, the safety assessment of nuclear power plants against aircraft crashes has been performed using numerical simulations, but very few studies have been conducted to evaluate the safety of SNF storage systems or facilities. In addition, efforts to verify the simulation results for aircraft crashes using tests have yet to be reported. In this research, the safety assessment of a dual-purpose metal cask (DPMC) under development by the Korea Radioactive Waste Agency (KORAD) was performed using numerical simulations and model tests. A scenario of a targeted aircraft crash was established from a literature survey, and the impact conditions were derived from the scenario. The verification of the methodology used in the numerical simulation was performed through a comparison of the test and simulation results. However, it should be noted that the results of the assessment in this study are not conclusive as the cask is still under development and the design is subject to change. Moreover, the impact conditions considered in this research do not reflect the standpoint of Korean competent authorities on the issue of targeted aircraft crashes.