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Original Article

Development of a Probabilistic Safety Assessment Framework for an Interim Dry Storage Facility Subjected to an Aircraft Crash Using Best-Estimate Structural Analysis

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ABSTRACT

Using a probabilistic safety assessment, a risk evaluation framework for an aircraft crash into an interim spent fuel storage facility is presented. Damage evaluation of a detailed generic cask model in a simplified building structure under an aircraft impact is discussed through a numerical structural analysis and an analytical fragility assessment. Sequences of the impact scenario are shown in a developed event tree, with uncertainties considered in the impact analysis and failure probabilities calculated. To evaluate the influence of parameters relevant to design safety, risks are estimated for three specification levels of cask and storage facility structures. The proposed assessment procedure includes the determination of the loading parameters, reference impact scenario, structural response analyses of facility walls, cask containment, and fuel assemblies, and a radiological consequence analysis with dose–risk estimation. The risk results for the proposed scenario in this study are expected to be small relative to those of design basis accidents for best-estimated conservative values. The importance of this framework is seen in its flexibility to evaluate the capability of the facility to withstand an aircraft impact and in its ability to anticipate potential realistic risks; the framework also provides insight into epistemic uncertainty in the available data and into the sensitivity of the design parameters for future research.

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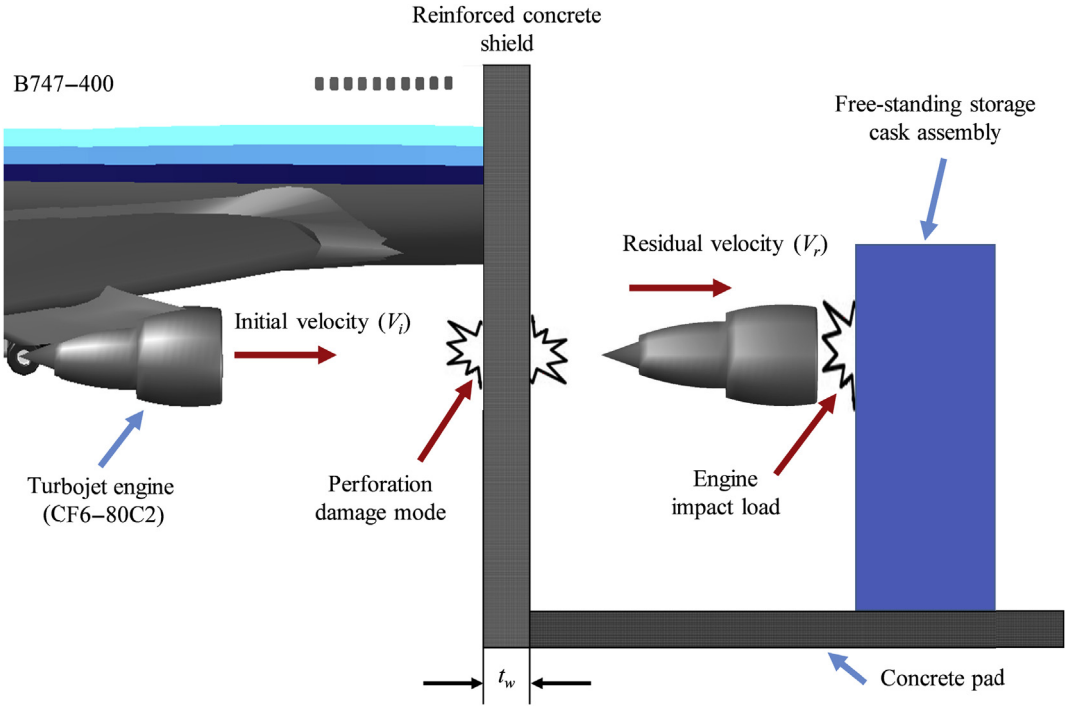
1. Introduction

An intentional aircraft impact (AI) into hazardous facilities became a prominent issue after September 11, 2001. The questions then arose as to what extent an interim storage facility (ISF) can adequately protect against a large commercial AI and what momentous consequences an AI may pose to society and the environment. To answer these questions, possible damage scenarios with various AI loading conditions should be investigated to estimate the potential risks. Several safety assessment studies have considered various mechanical and thermal loadings that represent severe impact conditions in the frame of a probabilistic safety assessment with conservative assumptions, or just to evaluate the structural integrity of a cask assembly based on a deterministic approach [1–10]. However, no risk assessment with a scenario of a realistic aircraft crash into an ISF has yet been completed. Development of a comprehensive and systematic framework that comprises several elements of risk evaluation would make it possible to determine the feasibility of using such a framework to predict the expected hazard posed to the public, in addition to enhancing the reliability of facility/cask designs under possible severe impact loadings from aircraft crash. Further, this approach will enable the development of a so-called risk-informed regulatory framework, which is more reasonable than conventional approaches that rely more on conservatism. Thus, under the frame of a probabilistic approach, this study attempts to integrate more elements into the development of a realistic aircraft crash scenario, including possible damage consequences and associated release of fission products to the environment.

The current study covers only the first assessment stage of the accident scenario, which is a direct mechanical impact from an intended AI. The second assessment stage in follow-up research will examine associated radiological releases from subsequent fire and multicask collisions that will supplement the radiological consequences of the first stage. The current analysis is divided into four major parts:



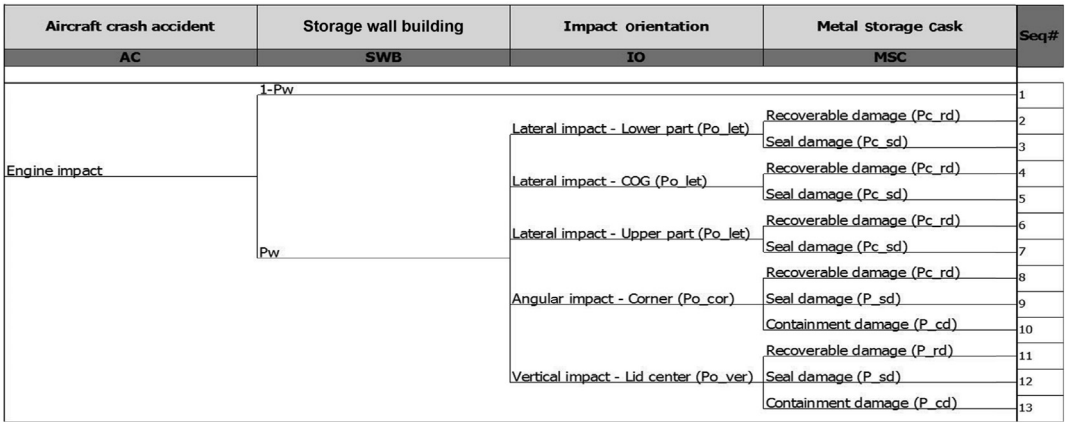


Fig. 1 – Illustration of impact scenario with aircraft crash event tree model.