Assessing Wood Composition Influence on Impact limiters in Dry Storage Containers

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1. Introduction

As wet storage facilities for Spent Nuclear Fuel (SNF) near saturation, multi-purpose dry storage containers (DSCs) have emerged as a critical solution for long-term interim storage and transportation. However, DSCs are vulnerable to damage from accidental drops or earthquakes. This study evaluates optimal wood compositions (redwood and balsa) in impact limiters to protect DSC integrity. Drop-impact analyses from vertical, oblique, and horizontal drops (9 m height) were conducted, comparing various wood proportions to a conventional reference model.

2. Finite element model

In this study, a finite element model of a DSC was developed, as depicted in Fig. 1, to analyze the effect of wood composition in impact limiters on structural response during accident scenarios. The model simulated a 9 meter vertical, horizontal, oblique drop, comparing various proportions of redwood and balsa wood within the impact limiters to evaluate their effectiveness in minimizing damage to the containers

2.1 DSCs Model

DSCs include internal components such as nuclear fuel, a canister, a cask, and impact limiters. Each component was modeled precisely, emphasizing structures that critically affect the container's dynamic behavior and impact response.

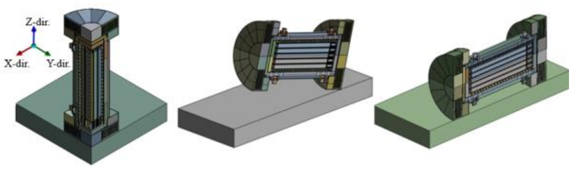

Fig. 1. FE models for vertical, oblique, horizontal drop

2.2 Wood composition

Effectively utilizing the structural strength of redwood and the high shock-absorbing capability of balsa wood, the reference model for the impact limiter comprises balsa wood at the center protected by outer redwood. Two such impact limiters are mounted on the top and bottom of the DSC. Due to stiffness considerations, reversing wood positions was not considered. To identify the optimal composition for shock absorption, four configurations were evaluated by varying the proportions of redwood and balsa within the fixed volume of the impact limiters, as shown in Fig. 2.

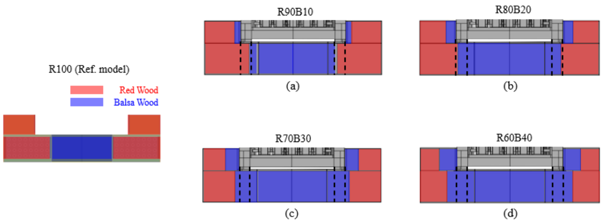

Fig. 2. Impact limiter configurations: (a) Ref. (R100), (b) R90B10, (c) R80B20, (d) R70B30, (e) R60B40

2.3 High balsa content and trunnion-ground collision

When the proportion of balsa wood in the impact limiter reached 40% for the oblique drop or between 30-40% for the horizontal drop, the trunnion directly collided with the ground, penetrating the impact limiter. Under these conditions, the impact limiter's energy absorption performance significantly decreased, and most stress and plastic deformation occurred within the trunnion itself rather than in the cask body. Consequently, while the impact limiter absorbed less energy, critical internal structures experienced reduced damage as the trunnion took on a larger portion of the impact load.

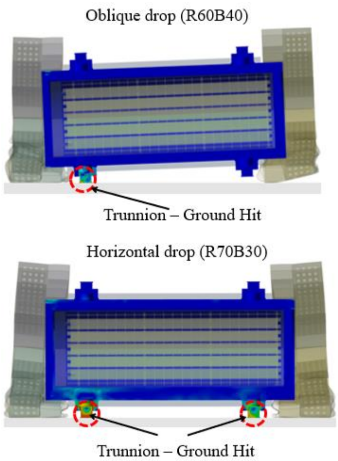

Fig. 3. Trunnion-ground collision: (a) oblique drop, (b) horizontal drop (R60B40).

3. Conclusions

This study analyzed the impact-absorption performance of DSC impact limiters by optimizing redwood and balsa wood proportions. Due to balsa wood's excellent shock-absorption capability, increasing its proportion generally improved impact limiter performance by reducing energy transmitted to the cask. However, beyond a certain optimal ratio, further increases in balsa content diminished performance improvements, as excessive balsa wood allowed direct collisions between the trunnion and the ground during oblique (≥30%) and horizontal (≥40%) drops. Therefore, optimal wood compositions were identified that consistently minimize transmitted impact energy, enhancing DSC safety while satisfying structural integrity under vertical, oblique, and horizontal drop scenarios.

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