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# EVALUATION OF A BI-DIRECTIONAL ALUMINUM HONEYCOMB IMPACT LIMITER DESIGN

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## 1. INTRODUCTION

A 120 Ton shipping cask is being developed for the on-site shipment of dry spent fuel at the Idaho National Engineering Laboratory. Impact limiters were incorporated in the cask design to limit the inertial load of the package and its contents during the hypothetical 9-meter (30-foot) drop accident required by 10CFR71. The design process included: 1) a series of static and dynamic tests to determine the crush characteristics of the bi-directional aluminum honeycomb impact limiter material, 2) the development of an analytical model to predict the cask deceleration force as a function of impact limiter crush, and 3) a series of quarter scale model drop tests to qualify the analytical model. The scale model testing, performed at Sandia National Laboratory in Albuquerque, New Mexico, revealed several design aspects which should be considered in developing bi-directional aluminum honeycomb impact limiters and several other design aspects which should be considered for impact limiter designs in general.

## 2. WORK DESCRIPTION

Unlike standard uni-directional honeycomb, bi-directional honeycomb has strength in two directions which can be oriented towards the sides and ends of the cask. With this configuration, the honeycomb impact limiter material is expected to exhibit essentially the same crush strength in all cask drop orientations (end, side, and corner impacts). Testing on two and four-inch thick samples of material was performed to evaluate the static and dynamic crush characteristics of the bi-directional honeycomb material.

The results from the material characterization testing were used to predict the cask deceleration force produced by the impact limiter during a hypothetical drop accident. The initial model calculated the cask deceleration force by multiplying the material crush strength by the crush area (footprint) of the impact limiter. However, after completing several quarter scale model drop tests, the analytical model was revised to consider the relative geometries of the cask and impact limiter and the effective backed area provided by the cask.

## 3. RESULTS

Material Characterization

Testing was performed on nominal 24.1 MPa (3,500 psi) Cross-Core bi-directional aluminum honeycomb (ALC 1/8 5052 .0059 40.0) manufactured by the Hexcel Corporation. Based on the test results, factors were determined for the various conditions shown in Table 1 which can be applied to the nominal material strength to approximate the crush characteristics of the Hexcel material.

Table 1

| Characteristic | Factor |
|---|---|
| Variation in Crush Strength | 0.90 / 1.10 |
| Temperature Effect | Essentially linear from 1.10 at -28.9°C (-20°F) to 0.85 at 121.1°C (250°F) |
| Dynamic Effect | 1.25 |
| Lock-up (% of original thickness) | 55% |

Side Drop

The 121.1 °C (250 °F) side drop test of the design shown in Figure 1 revealed that internal crushing of the honeycomb occurred once the external impact limiter crush area exceeded the effective backed area of the cask. This resulted in the cask moving relative to the impact limiter with the cask actually driving into the impact limiter and acting as a wedge to split the impact limiter. Also, the impact limiter to cask attachments were excessively loaded due to the relative motion between the cask and impact limiter.

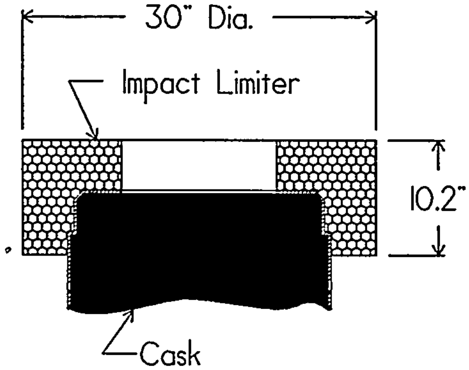


Figure 1: Side View Cross-section of Cask and Impact Limiter Design #1

A second design, shown in Figure 2, included a backing plate, backing ring, and twelve gussets to provide additional support in side and corner impacts. A 121.1 °C (250 °F) side drop test of the gusset design shown in Figure 2 resulted in only external crush of the impact limiter with a maximum deceleration force of 64 g's compared to 60 g's as predicted by the analytical model. With this design, the backed area of the cask is controlled by the projection of the gussets. Without the gussets, the effective backed area of the cask appears to be bounded by an approximate 70° included central angle of the cask diameter (see Figure 3).

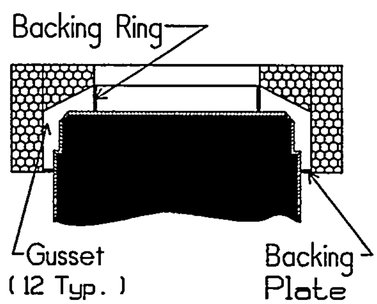


Figure 2: Side View Cross-section of Cask and Impact Limiter Design #2

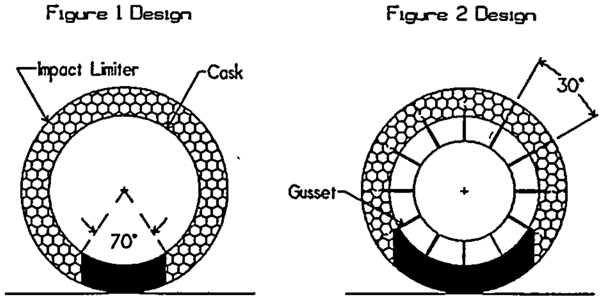


Figure 3: Effective Backed Areas for Side Drop Orientation

Corner Drop

The 121.1 °C (250 °F) stable corner drop using the Figure 1 design revealed that the impact limiter material will shear in both the radial and axial directions at locations which are not fully backed by the geometry of the cask. Shearing of the material reduces the effective crush area of the impact limiter to an area which is bounded by the projection of these shear locations. The smaller backed area resulted in internal rather than external crush with relative movement between the cask and impact limiter.

As shown in Figure 4, the backing ring and plate of the Figure 2 design increases and provides control of the backed area in the radial and axial directions for corner drop orientations. Two stable corner drop tests with the Figure 2 gusset and backing ring design resulted in only external crush of the impact limiter with the full scale maximum deceleration force of 52 g's at -28.9 °C (-20 °F) and 45 g's at 121.1 °C (250 °F) as respectively compared to 54 g's and 47 g's as predicted by the analytical model.

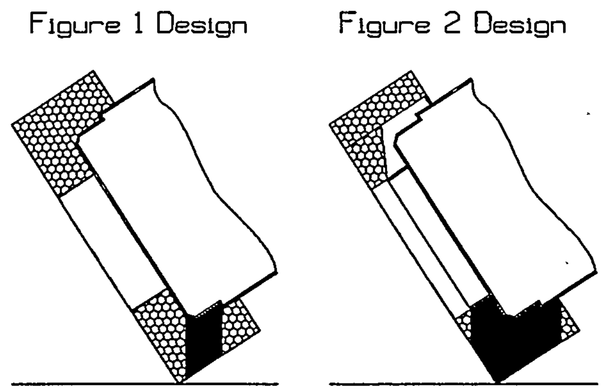


Figure 4: Effective Backed Areas for Corner Drop Orientation

End Drop

An end drop test with the Figure 2 design revealed that the backed area was controlled by the backing plate and that the maximum full scale deceleration force was 115 g's at -28.9 °C (-20 °F) as compared to 110 g's as predicted by the analytical model.

## 4. CONCLUSIONS AND DISCUSSION

Impact limiter materials should be characterized by static and dynamic testing. In developing an impact limiter design, shear of the impact limiter material should be controlled in both the axial and radial directions to ensure the impact limiter material will react as expected during the drop accident. An impact limiter will exhibit external crush until the impact limiter crush area exceeds the effective backed area of the cask. Once the crush area exceeds the backed area, internal crush will occur resulting in less than expected deceleration forces, greater than expected crush damage, and relative movement between the cask and impact limiter at the impact limiter attachment location. Relative movement between the cask and impact limiter could produce strains in the impact limiter attachments and result in separation of the impact limiter from the cask during the hypothetical drop accident.