Crashworthiness Assessment of Square and Circular Crash Boxes with Single and Dual Screw-Groove Triggers under Axial Impact

Teddy Samuel R
Hindustan Institute of Technology and Science, Chennai, Tamil Nadu, India

Jaikumar Mayakrishnan
Hindustan Institute of Technology and Science, Chennai, Tamil Nadu, India

Abstract

This study investigates the design and development of square and circular crash box models with enhanced crashworthiness through the investigation of screw-groove combinations. Two designs were investigated: one with a single screw positioned in two grooves, and the other with two screws positioned in four grooves. Crash boxes made out of aluminum alloy 5052 were manufactured and strengthened using thick mild steel sleeves. These were tested numerically, LS-DYNA, and experimentally, by impact test at 4.2 m/s with a 700 kg mass. The most valuable parameters that were examined were energy absorption (EA), specific energy absorption (SEA), peak force, mean crushing force and crush force efficiency (CFE). Experimental results showed that transitioning from two to four grooves increased EA by 3–5× and improved CFE from ~54% to ~70%, indicating more stable progressive crushing. Square crash boxes consistently outperformed circular ones w.r.t. EA (up to 24% higher for the four groove design), while circular designs exhibited better load uniformity. Simulations captured overall deformation modes but underestimated peak forces and CFE compared to experiments, primarily due to idealized material modeling and boundary conditions. The results verify that geometry and screw-groove placement play a critical role toward control of crash energies with a four-groove square crash box having the best energetic crash-handling capacity in high-impact zones. The numerical experimental method employed in this study can serve as a springboard for optimizing - crash box design to further enhance the safety of a vehicle occupant.

Keywords

Crashworthiness, Screw-Groove Design, LS Dyna Simulation, Axial Impact Testing, Energy Absorption.