ABSTRACT

Thin-walled tubular structures have been emerged as efficient impact energy absorbing members to mitigate the adverse effects of impact forces and protect occupants from injury during collision events. From the existing literature, it is evident that, among the other geometry configuration, cylindrical tubes have attracted the attention of researchers in the recent decades due to their light weight, high energy absorption capacity and ease of fabrication. Despite the cylindrical tubes have higher energy absorption capacity, high initial peak force is a major shortcoming when they are subjected to axial impact. According to the injury criteria (e.g. HIC), excessively high initial peak force is undesirable because it will lead to a large deceleration with much enhanced probability of damage and human fatality.

Though various triggering methods (holes, grooves, dents, patterns etc.) have been proposed in the previous literature with the aim of reducing the initial peak forces, these kinds of geometrical discontinuities will change or decrease the stiffness of the structure under impact loading conditions. It also has a drawback of reduced energy absorption capacity. Therefore, a configuration, which does not affect the performance of the structure in normal use, whilst it could be improving its energy absorption characteristics and the level of deceleration pulse with delayed transfer of impact crush force is highly desired. Harnessing end-cap (plain, shallow spherical, and hemi spherical cap) over the simple cylindrical tubes is one of the suitable alternatives which has the potential for enhanced performance with reduced high initial peak force.
The primary objective of this present investigation is to study the axial crushing characteristics of aluminium and composite wrapped aluminium combined geometry tubes when subjected to static and impact loading conditions. The combined geometry tubes consist of cylindrical portion harnessed with plain end-cap, shallow spherical end-cap, and hemispherical end-cap. Quasi-static compression and dynamic impact tests were conducted experimentally. The entire crushing process, including the initial stage of crushing, its localization, and the subsequent progressive folding has been carefully investigated by experiments. The axial crash performance of the various proposed end-capped tubes was also compared with non-capped cylindrical tubes and it was found that the initial peak force of the end-capped tubes is significantly reduced by 15–30% than the non-capped cylindrical tube without compromising the energy absorption capacity.

For a good energy absorber, specific energy absorption (SEA) is also an influencing parameter to be considered and it should be high for better crashworthiness. Hybridization is one of the techniques to improve the SEA and hence hybrid composite wrapped aluminium tubes were also fabricated and tested. Further, the performance of the hybrid composite wrapped aluminium tubes were compared with bare aluminium combined geometry tubes and it was found that the specific energy absorption capacity of the hybrid tubes is 10-20% higher than the aluminium bare tubes. It is evident that both the aluminium and composite wrapped aluminium combined geometry tubes significantly reduce the initial peak force and stabilize the crushing response without compromising the energy absorption capacity for both static and impact loading conditions. The significant outcomes of this study highlighted the advantages of using combined geometry cylindrical tubes in the automotive industry to design a convenient passive crash protection system for absorbing energy during car crash events.