

## ABSTRACT

In the present study, similar thickness laser welded blanks (LWBs) and dissimilar thickness laser welded tailored blanks (LWTBs) of extra deep drawing (EDD) steels were fabricated using a 2 kW fiber laser system. The forming performance of these blanks was evaluated in terms of limiting dome height and forming limit diagram, and it was found that the presence of weld zone (WZ) and increase in thickness difference led to the reduction in formability. On the basis of these insights, laboratory scale combined geometry domes and shells of LWBs and LWTBs were fabricated using stretch forming and deep drawing processes, respectively. These domes and shells were subsequently crushed quasi-statically between two flat platens to get insight into the effect of WZ, thickness ratio, deformation speed, forming histories and material anisotropy on the crushing performance. It was observed that the modes of collapse were predominantly affected by the presence of thickness ratio, whereas the load-displacement response and energy absorption of the domes and shells were enhanced because of the presence of WZ and thickness difference in LWTBs. Also, finite element (FE) model of combined forming and crushing process was developed to assess the prediction capabilities of three different anisotropic material models viz. Hill48, YLD89, and Stoughton non-associated flow rule (S-NAFR) based model. All these material models were successfully calibrated to predict the collapse modes, but the S-NAFR model was found to closely predict the load-displacement curves, energy absorption and mean crushing load. It was further suggested through FE modeling that the incorporation of strain rate, material anisotropy and forming histories such as non-uniform thickness and strain distributions along with WZ properties improved the prediction of collapse modes, load-displacement response and mean crushing load. It was observed that the non-uniform thickness distribution across the WZ induced irregular folding and non-uniformity in load-displacement response during crushing of drawn shells. In order to promote progressive folding, the effect of circular holes as discontinuities was investigated, and it was found that 8 mm holes encouraged the uniformity in load-displacement response by suppressing the influence of non-uniform thickness distribution. On the basis of above overall findings, a bumper beam prototype was fabricated in the present work by deforming LWTB of EDD steels of thicknesses 1.6 mm and 1 mm through single point incremental forming process. Subsequently, the crushing performance of LWTB prototype was evaluated using a hemispherical indenter and the results were compared with that of the prototype of monolithic EDD 1.6 mm materials (BM). Results showed that the presence of thinner sections in the LWTB prototype altered the deformation mode, and the load was distributed more uniformly compared to the BM prototype during crushing. Approximately 9.33% and 11.28% increase in the crushing force efficiency and specific energy absorption was achieved in the LWTB prototype compared to the BM prototype.

*Keywords:* Laser welded tailored blanks, Stretch forming, Deep drawing, Combined geometry shells, Crushing, FE modeling, Forming histories, Non-associated flow rule, Prototype, Single point incremental forming.