



RESEARCH ARTICLE

NUMERICAL STUDIES ON LASER WELDED TOP-HAT COLUMN UNDER AXIAL COLLISION BASED ON THE CONCEPT OF SUPER-FOLDING ELEMENT

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ABSTRACT

Extruded longitudinal double-skinned aluminium body plates with integrated stiffeners are recently used for manufacturing in automobile industry like front rails and railway carriages. These extrusions provide light and heavy rigid structures. However, since it is not feasible to produce large parts by extrusion, these plates need to be connected, mostly by welding techniques. The crashworthiness performance of laser welded columns is evaluated using finite element (FE) analysis. This is very important in automobiles, since more attention is being paid to crashworthiness of the structures in recent years. The analysis method is based on the Super folding Element (SE) concept, which originates from experimentally observed folding patterns of crushed shell elements. The FE model is used to predict accurately the progressive axial collapse of the laser welded columns and impact strength is greatly improved by laser welding technique.

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INTRODUCTION

One of the major challenges of the automotive industry is to reduce the structure weight, leading to a decrease of the CO₂ emission. During recent years, the car body assembly techniques were dominated by laser welding. When using Aluminium in the body structure of a vehicle, weight savings of as much as 25 % may be possible compared with conventional steel structures, which will reduce fuel consumption (Langseth and Hopperstad, 1996). What's more, aluminium alloy has good corrosion resistance and high capability of energy absorbing. Crashworthiness of aluminium extrusions is affected by material microstructure, loading speed, and geometrical dimensions (Fyllingen *et al.* 2009). A motivation of this work arises from the various types of hat cross-section column members are extensively used in vehicle applications and play an important role in absorbing kinetic energy during a collision. In general, the car front rails are made from single-hat elements. Therefore, it is necessary to understand their axial crushing behavior for the structural design of a vehicle and ultimately to reduce the likelihood of passenger serious injury in an accident. Laser beam welding (LBW) will be a vital joining technique for thin steel sheets with their increasing applications in aerospace, aircraft,

automotive, electronics and other industries. LBW is a modern welding process used to join multiple pieces of similar and dissimilar metal through the use of a laser beam. The first step in laser welding is laser absorption. The absorbed energy is transferred into bulk material by conduction. The laser energy absorbed by the material starts to heat and melts the material (Dhaval Soni *et al.*, 2013). The body-over frame structure of a passenger car or a sport utility vehicle consists of a vehicle body, frame, and front sheet metal. A light duty truck consists of a frame, cab, and box. The vehicle body provides most of the vehicle rigidity in bending and in torsion. In addition, it provides a specifically designed occupant cell to minimize injury in the event of crash (Vehicle Crashworthiness and Occupant Protection, 2004). In order to assess the crashworthiness of vehicles, all major passenger car makers today employ numerical simulations as a support in the design process.

LBW on crashworthiness

Fusion welding process in which coalescence is achieved by energy of a highly concentrated, coherent light beam focused on joint. LBW normally performed with shielding gases to prevent oxidation. In this welding process filler metal not usually used. In spite of the tremendous progress achieved in crashworthiness simulations of vehicle structures from components to full-scale vehicles, using the latest techniques in computational mechanics and super computers, final crashworthiness assessment still relies on laboratory tests

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MATERIALS

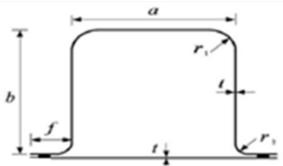
Aluminium 5052 alloy is selected for modeling of top hat section and base stiffener plate. 5052 is an aluminium alloy, primarily alloyed with magnesium and chromium. Weight saving and impact safety requirements are calling for the application and structures with high specific energy absorption to vehicle and this obtained of aluminium 5052 alloy.

Table 1. Mechanical Properties of 5052 Aluminium Alloy

S.No.	Properties	Units
1	Density	2.78 g/cc
2	Ultimate Tensile Strength	186 Mpa
3	Yield Strength	78.5 Mpa
4	Hardness	47 HB
5	Poission's ratio	0.33

Geometry Dimension

Top hat section and stiffener base plates are modeled using Abaqus

Dimensions	Geometry
Wall thickness(t)= 2 mm	
Width(a)= 50 mm	
Width(b)= 50 mm	
Height(h)=200 mm	
Flange(f)=15 mm	
Inner radius(r ₁)=6 mm	
Outer radius(r ₂)=4 mm	

Numerical analysis using the FEM

The numerical simulations were carried out using the finite element software Abaqus/Explicit. For applying boundary conditions on the edges of the laser-welded columns, two rigid plates were used that were attached to the ends of the columns. All degrees of freedom in the lower plate and all degrees of freedom in the upper plate, except in the direction of longitudinal axis, were constrained. The crushing is done with the help of a mass of 100 Kg moving with a velocity of 50 m/s applying a pressure of 10 KN to the top hat section. The static and dynamic coefficients of frictions are 0.1 in the contacts. The characteristic size of mesh is 5 in the analysis for all places in the model. The deformation, lobe formation, energy absorption is depends on properties of material, weld strength, pressure and velocity applied. Numerical result shows that the lobes are formed at the upper part of the top hat section.

Calculation of energy absorption parameters:

Specific energy absorption(SEA)

SEA is one of the important performance indicators in energy absorption devices, particularly when considering weight reduction. It is a ratio between absorbed energy and the mass of the specimen.

$$SEA = \text{Absorbed Energy} / \text{Mass} = 1335.398 / 260 = 5.14 \text{ J/g}$$

Mean crushing load: It is the mean of the values of the applied force, which fluctuates along the test. It can be

obtained as the ratio between energy absorbed and total displacement of the crushing length.

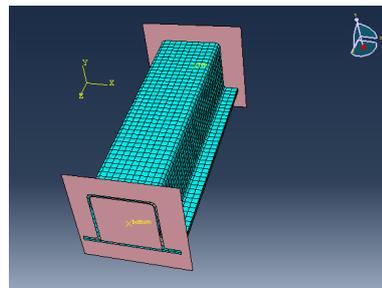
$$\text{Mean crushing load} = \text{Absorbed Energy} / \text{crushing length} = 1335.398 / 66 = 20.23 \text{ kN}$$

Load Ratio(LR)

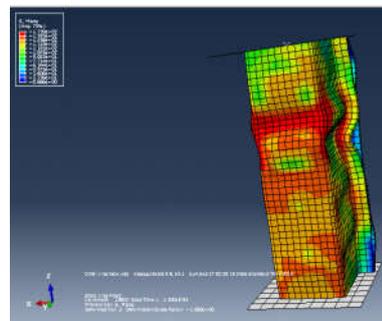
It is the ratio between initial peak load and mean load.

$$LR = \text{Initial peak load} / \text{Mean load} = 64 / 20.23 = 3.164$$

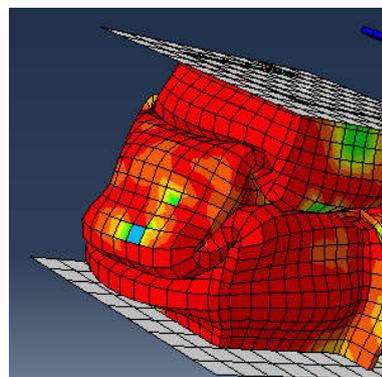
FE Analysis in Abaqus



(a) FE Mesh Model



(b) Crushing at 10 mm displacement



(c) Crushing at 66 mm displacement

Fig. 1. FE Model and Result

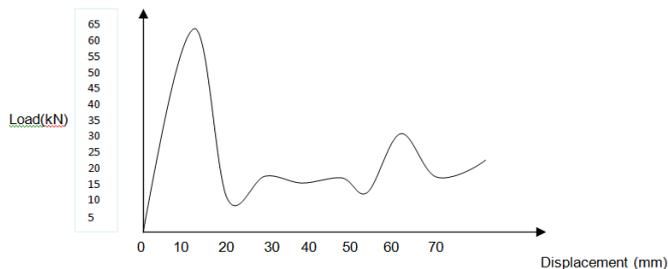


Fig. 2. Load–crush displacement responses

Conclusion

In today's quest for continued improvement in automotive safety, various restraint systems have been developed to provide occupant protection in a wide variety of crash environments under different directions and conditions. The primary discussions on the vehicle/occupant response in frontal impact analysis only, even though side crash events are lightly touched upon. Axial crushing behavior of hat-type Laser-welded columns has been studied numerically. The robust numerical model can be effectively used to predict the crashworthiness efficiency of hat-type column specimens prior to conducting the actual axial crush test. Aluminium 5052 alloy, which are considered effective in improving crash safety and reducing the weight of automobiles

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