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AXIAL CRUSHING ANALYSIS OF CIRCULAR TUBES WITH DIFFERENT MATERIALS USING FINITE ELEMENT METHOD

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Abstract - On roads throughout the world, there have been major accidents. The car structures collided as a result of the accident, seriously injuring people. A vehicle bumper design with greatest absorption energy is necessary to prevent the issue. Galvanized iron and stainless steel materials are utilized to develop and fabricate circular tubes in this work, which uses a variety of materials and manufacturing techniques to meet specified design specifications. The tubes had a variety of cross sections, including conical and circular taper. These materials are tested using electronic universal testing equipment under continual axial loading. The use of FEA software and explicit dynamics to provide the necessary results under dynamic loading conditions led to the introduction of a finite element model for experimental analysis of test results. Ultimately, the test results and FEA results were compared for the optimal crashworthiness values.
***Keywords* – Crashworthiness, Galvanized iron, Stainless steel, FEA software, Dynamic loading**

I. Introduction

The rapid advancement of automotive, railway, transportation, and aerospace engineering has led to an increasing significance being placed on the energy absorption capacity of vehicles and structures in terms of occupant safety and systems protection. In the last few decades, a great deal of research has been focused on enhancing the safety and crashworthiness of transportation vehicles. Since metallic thin-walled constructions are inexpensive, strong, and capable of supporting large loads, they are frequently used as energy-absorbing components [1]. The minimal amount of force applied to the occupants and the progressive deformation at collision disperse the kinetic energy in thin-walled parts. Alexander pioneered the axial loading analysis of thin-walled circular cylinders in 1960 [2].

He presented a great theoretical model to determine the average crushing force for an axisymmetric fold pattern based on experimental research Wierzbicki et al [3]. Abramowicz, Jones, and colleagues examined mild steel square tubes and assessed the average crushing load [4]. Under quasi-static pressure, Abramowicz and Wierzbicki compared the experimental findings with mean crushing force predictions made theoretically for square and circular tubes [5].

Mamalis et al.'s study [6] used both theoretical and experimental methods to examine the energy absorption capacity of bi-material circular cylinders under axial loading. Through quasi-static and

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dynamic compression tests, K. Vinayagar et al. [7] demonstrated the notable variations in energy absorption between stainless steel, mild steel, and aluminum alloy tubes. Two circular tubes, one rigid and the other deformable were studied for their expansion as impact energy absorbers by Shakeri et al. [8], who also determined the crashworthiness design parameters.

The energy absorption characteristics of double cell tubular sections were also studied by Yuen et al. [9]. Quasistatic compression tests were performed on specimens with different cross-sectional geometries by Velmurugan and Muralikannan et al. [10], Alavi Nia and Hamedani [11], who demonstrated that the geometry of the tubes was also crucial in energy absorption. Researchers have employed foam or honeycomb as filler materials to enhance the crashworthiness of thin-walled structures. These materials have the ability to absorb energy through deformations.

Under quasi-static axial load, Haghi Kashani et al. [12] carried out experimental and finite element analysis on square sectional bi-tubes with two distinct arrangements, including Parallel and Diamond arrangements. According to reports by Sharifi et al. [13] and Haghi Kashani et al. [12], bitubal structures' ability to absorb energy is impacted by length dissimilarity.

In their study, Vinayagar and Senthilkumar [14], [15] examined the crushing behavior of bi-tubes with various geometric sections and combinations. Their findings demonstrated that bi-tubes outperformed simple tubes in terms of energy absorption and that geometry is a common parameter to increase the capacity for energy absorption in thin-walled structures. Numerous academics improved the thin-walled tubes' crashworthiness parameters.

G. Venkatesh et al. carried out the experimental study on aluminium sheet with various bitubulur sections under quasistatic load [16]. G Nagaraj et al [17] uses ANSYS to numerically study the structural performance of a structure with thin-walled twisted box sections. The results are verified by comparing them with experimental data.

R. Sridhar et al [18] The use case of a quasi statically deformed crash box made of steel DP600 for the optimization target "energy absorption" illustrates a novel method. Purwo Kadarno et al [19] This study used Ansys LS Dyna to investigate the crashworthiness of a crash box structure made of carbon fiber reinforced plastic (CFRP) under quasi-static axial loading. Auwalu I. Mohammed et al [20] and [21] the main objective of this study is to perform axial compression and quasi-static tests at crosshead speeds of 500 mm/min and 2.5 mm/min, respectively, using universal testing machines.

Chassis Crash Test In Automobile:

Ansys Mechanical analysis of a chassis enables testing of several configurations to optimise chassis stiffness while reducing manufacturing costs. A chassis (frame) is subjected to FEA analysis that takes into account a variety of loads, including torsional, twisting, aerodynamic, and front impact. Any car's foundation structure, commonly referred to as its "Frame," supports it from underneath and is called the "Chassis." This method allows for the improvement of the vehicle's safety features, as shown in Fig. 1. The car with the lowest safety factor is then sent back for quality inspection.

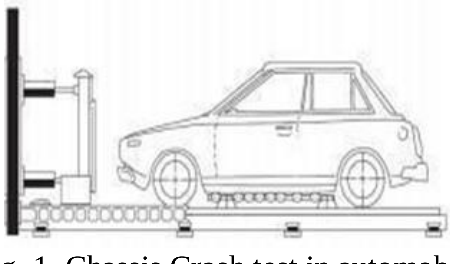

Fig. 1. Chassis Crash test in automobile

II. Problem Description

Since the body of an automobile is a solid structure, impact energy is transferred from the outside to the interior in the event of an accident. Structures are bent by this energy, and people are hurt. Thin walled structures are used to prevent the aforementioned issues and will lessen the deformation of the structure.

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The objectives are: (i) To fabricate thin walled tubes with required thickness (ii) To conduct compression test in electronic UTM machine (iii) To evaluate the results using FEA software.

III. Methodology

The process flow chart is shown in Fig. 2. The process starts with crashworthiness parameters and end with optimal design solution. The material selection was done and the test results were carried out on UTM machine and then the simulation results was carried out in FEA software.

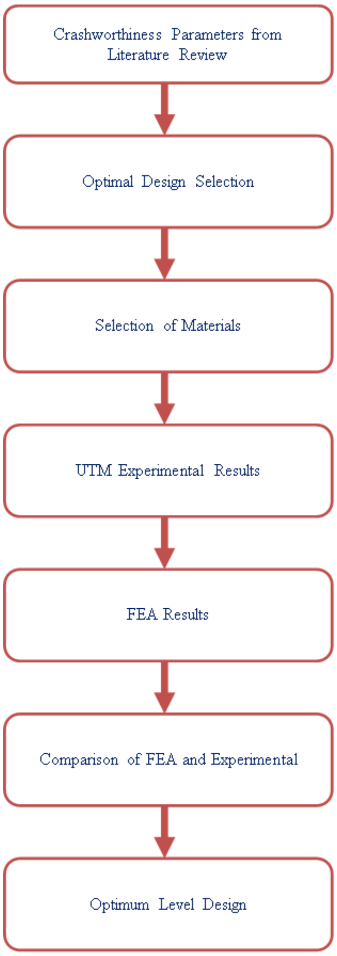

Fig. 2. Process Flow chart

IV. Specimen Modeling And Geometry

Stainless steel and Galvanized iron circular and taper shapes were modelled using Creo software, as illustrated in Fig. 3,4,5. Table I displays the specimen geometry for each material and Table II displays the specimen mass calculation.

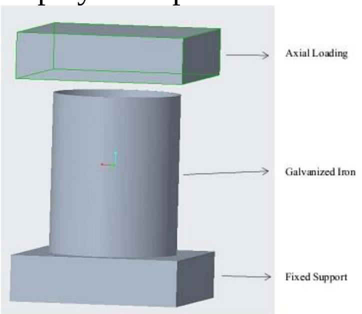

Fig. 3. Design of GI circular shape specimen

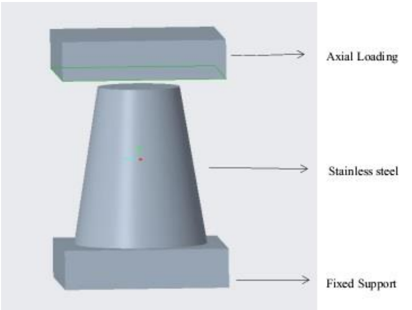

Fig. 4. Design of SS taper circular shape specimen

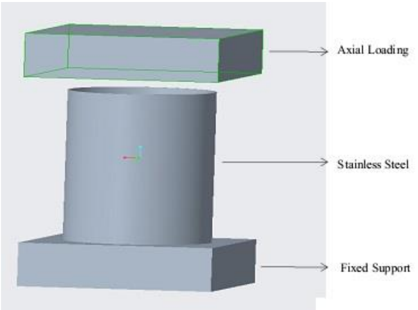

Fig. 5. Design of Stainless Steel circular shape specimen

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TABLE I. SPECIMEN GEOMETRY

Parameters	**GI**	**SS**	**SS Taper**
Outer Diameter (mm)	75	75	81
Inner Diameter (mm)	74.8	73	79
Height (mm)	103	103	120
Shape	Circle	Circle	Circle

TABLE II. SPECIMEN GEOMETRY

Material	**Shape**	**Diameter (mm)**	**Mass (gram)**
GI	Circle	75	65
SS	Circle	75	113
SS Taper	Circle	81	120

V. EXPERIMENTAL TESTING

The experimental tests were conducted at Electronic Universal Testing machine having capacity of 40 tons. The Quasi-static loading is applied for the specimens with a speed of 10mm/min. The test results were shown in the following figures 6,7,8 & 9.

Fig. 6. GI Circular specimen before crushing

Fig. 7. SS Circular specimen before crushing

Fig. 8. SS Taper specimen before crushing

Fig. 9. Specimens crushed UTM

The main focus is to find out the best structure of maximum energy absorption in thin-walled tubes. So, the results of the energy absorptions are studied and recorded as follows.

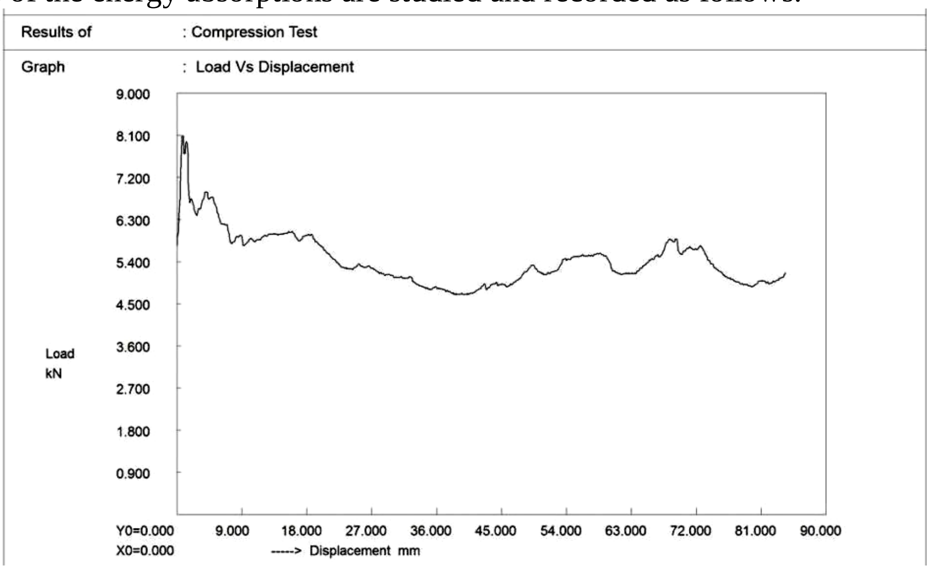

Fig. 10. Load vs Displacement Diagram for GI Circular specimen

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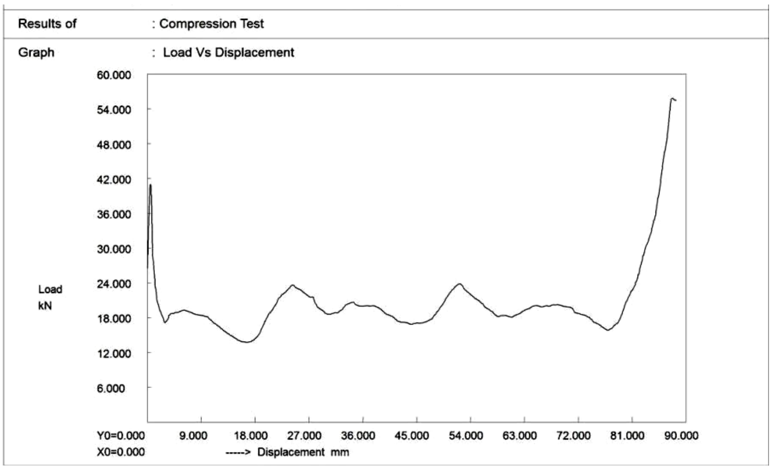

Fig. 11. Load vs Displacement Diagram for SS Circular specimen

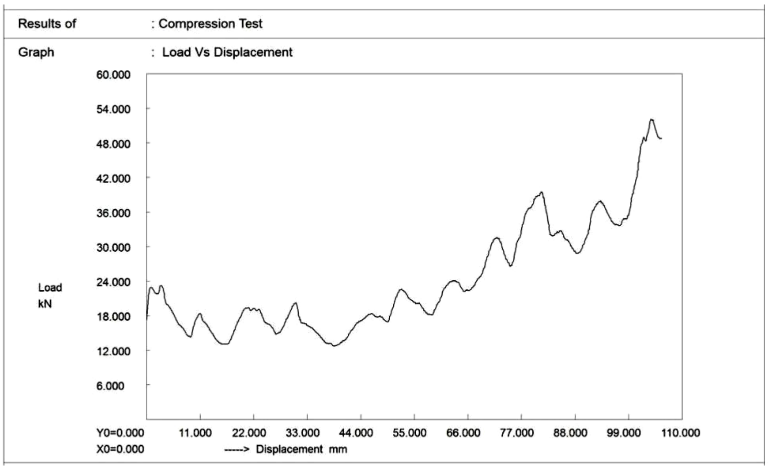

Fig. 12. Load vs Displacement Diagram for SS Taper specimen

From this testing the taper cross sections are much more efficient compared to both GI and SS circular cross sections. Hence the energy absorption is much higher in the tapered sections. The results were compared with FEA software for better enhancement.

VI. FEA Results

The dynamic analysis of the above specimens was done by Ansys work bench dynamic mode. The specimens were modeled in Creo software and then imported into Ansys work bench for simulations. The results of Ansys software are shown in below. Compared to the 3 specimens the tapered sections were absorbed more energy compared to the other specimens.

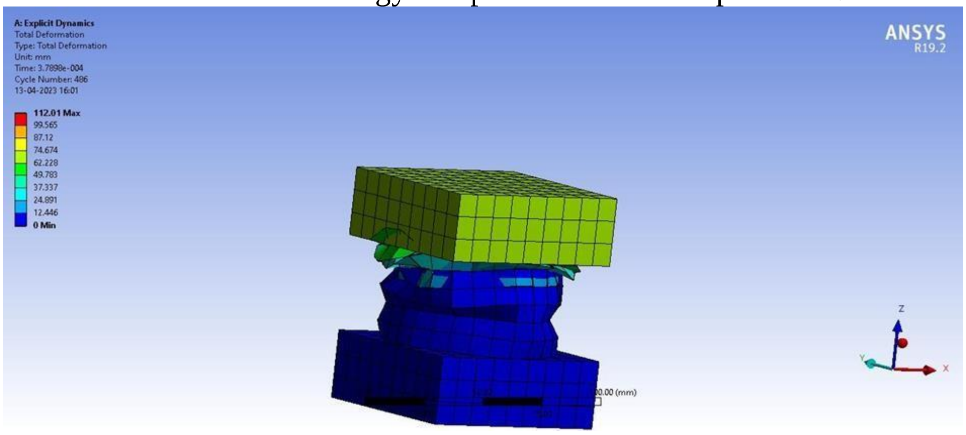

Fig. 13. GI Specimen Total Deformation

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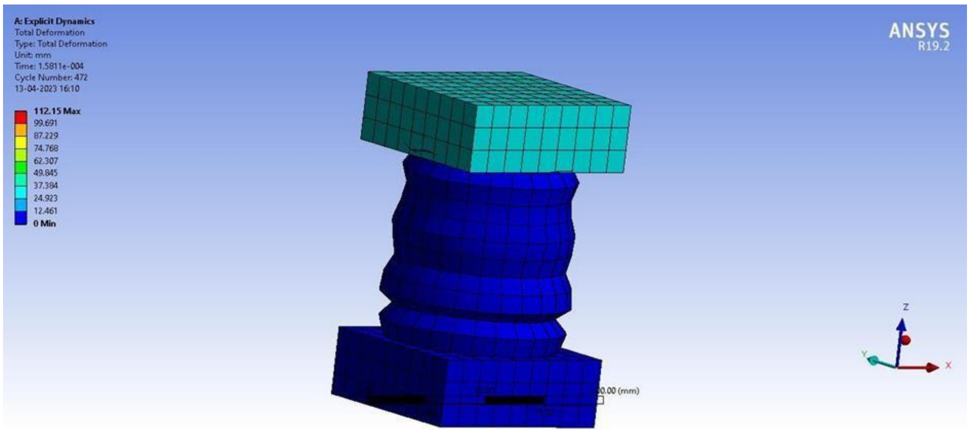

Fig. 14. SS Circular Specimen Total Deformation

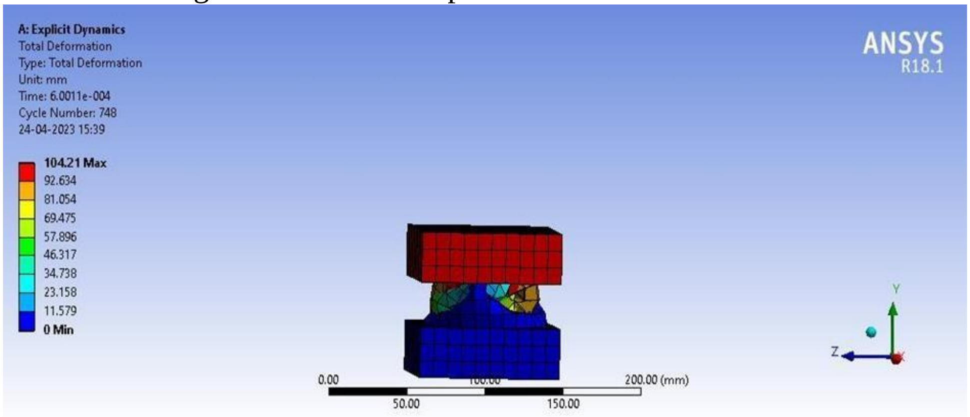

Fig. 15. SS Taper Specimen Total Deformation

VII. Conclusion

The crashworthiness criteria for the vehicle's structure were examined in this study. FEA software was used for the finite element modeling, whereas the electronic universal testing equipment was used to acquire the experimental data. The primary goal is to increase the energy absorption of thin-walled structures. In order to examine the design parameters of stainless steel and galvanized iron material was analyzed. The test results from universal testing machine and findings from Ansys software were suggested that the taper section was absorbed energy more compared to the other sections. Stress vs strain and force vs displacement graphs are used to compare and interpret the findings. According to the findings, the materials made of tapered stainless steel absorbed the more energy.

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