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Investigation of Passenger Car Impact Absorbers Applying Energy Absorping Concept

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ABSTRACT

Energy dissipation during an impact to avoid loss of life and damage in an accident is a must. Energy absorbers are used to dissipate collision energy upon plastic deformation to prevent critical parts damaging of the vehicle structure. In this paper, simple cell thin-walled tubes made from aluminum foil with triangular, square and hexagonal sections were subjected to quasi-static axial loading to simulate the dynamic impact. The results showed that the energy absorption capacity of simple hexagonal sections is greater than for that of other simple sections. Also, epoxy connected specimens absorbs more energy than plastic tape connected specimens. As well as, hexagonal sections absorbed the greatest amounts of energy per unit of mass. The influence of various configurations of the patterns on the deformation and energy absorption of the tubes is also discussed.

Keywords: Axial Crushing, Aluminum tubes, Crash worthiness, Energy Absorption, Quasi-static loading, Thin-walled tubes, and Hybrid energy absorbers.

1. INTRODUCTION

Nowadays, most of road vehicles have energy absorption device between the bumper and the chassis specifically designed to absorb part of the energy produced in a frontal impact. Usually, these devices consist of a hollow steel beam which collapses in axial crushing when a frontal collision occurs, dissipating part of its energy through plastic deformation. With increasing advances in technology, the need for creative initiatives to increase safety levels, particularly for transportation systems are essential. To avoid loss of life and damage in an accident, the need for components that can absorb collision energy and prevent injury and damage to critical parts is essential. Energy absorbing devices dissipate the kinetic energy of impact via plastic deformation of the absorption element. The energy absorption element is usually made of thin walled structures. The benefit of thin-walled structures stems varies from their low weight, low cost and ease of production. These structures can employ circular, square, triangular, polygonal, and conical sections. They can be used individually or in combination with polymeric and metallic foam.

In this paper, energy absorbers in the form of thin-walled tubes with simple triangular, square, and hexagonal sections are experimentally studied. The specimens are made from thin aluminum sheets (foil). The sheet edges are connected using either epoxy or plastic tape during the fabrication process. Testing is done under quasi-static axial loading using a WDW-10 Computer Control Electromechanical Universal Testing Machine. The paper consists of a literature survey of previous work in the field of energy absorption testing and simulation, then a brief description of the samples is introduced in section 3. The testing procedure is introduced in section 4.

2. LITERATURE REVIEW

For the first time, Alexander [1] analyzed the axial loading of cylinders and introduced these structures as energy absorbers. Subsequently, the folding of the thin-walled tubes was introduced as a mechanism for absorbing energy. Abramowicsz and Wierzbicki [2, 3], Abramowicz and Jones [4, 5], and Andrewsetal [6] carried out experimental and theoretical studies evaluating square and circular tubes under dynamic and quasi-static loading. Abramowicz and Jones [4, 5] tested square tubes made of mild steel and showed that both symmetric and asymmetric folding occurred during testing. Langseth and Hopperstad [7] conducted static and dynamic load tests on square-sectioned specimens made of aluminum and showed that the mean crushing force in static mode is greater than in dynamic mode. The folds for circular and square cross- sections were similar; the load–displacement curve for folding of these tubes under axial compressive loading started with a peak and then showed oscillations. Alavi Nia and Hamedani [8] compared the behavior of circular, square, triangular and tapered sections by using numerical simulation and experimental tests. They used argon welding of aluminum sheets to fabricate specimens. In their simulations, the effect of the weld line on the results was ignored. Mamalis et al. [9] studied the behavior of octagonal sections both theoretically and experimentally. Zhang and Zhang [10] investigated steel polygons with rhomboid, square, and octagonal sections both experimentally and using numerical simulations. Test specimens were welded at the middle of the opposite sides symmetrically to mitigate the effects of the weld. Because of the slight effect of the weld line on the results, they also ignored these effects in simulations. In this work experimental approach is used to determine the energy absorption of the different shapes under quasi-static testing showing the effect of shape and adhesive material used to connect each sample.

3. SAMPLE SPECIFICATIONS

A. GEOMETRY AND MATERIAL OF SPECIMENS:

The height and thickness of the samples were 70 mm and 0.1 mm, respectively. Section geometry and dimensions of specimens are shown in Fig.1. For simplicity and cost-effectiveness, the samples were made from 0.1 mm thick aluminum sheets. The specimens are simple sections triangular, square and hexagonal sections. The aluminum sheet is cut to the desired dimensions and epoxy (liquid adhesive), and plastic tape is used to connect the edges. The adhesive strength is adequate and the specimens are ready for testing 10 hours after application. Binding is assumed to be symmetric, to reduce the effect of the adhesive. The mechanical properties of the samples are determined according to ASTME8M standards. The stress–strain curve of the material is shown in Fig.2 and the mechanical properties are presented in Table1.

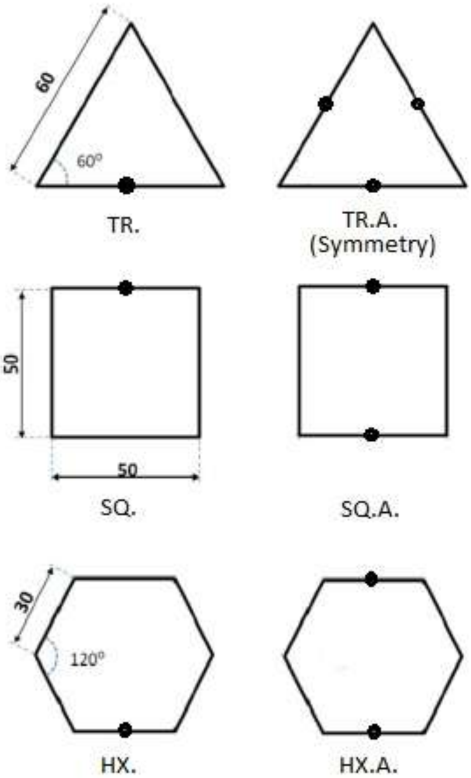

Fig.1. Sections geometry and dimensions of specimens (all dimensions in millimeter)
Note: the black spots represent the connected edges

Table1. Mechanical Properties of samples material

Young's Modulus	66 GPa
Yield Stress	24 MPa
Elongation at break	8%
Ultimate Stress	58 MPa

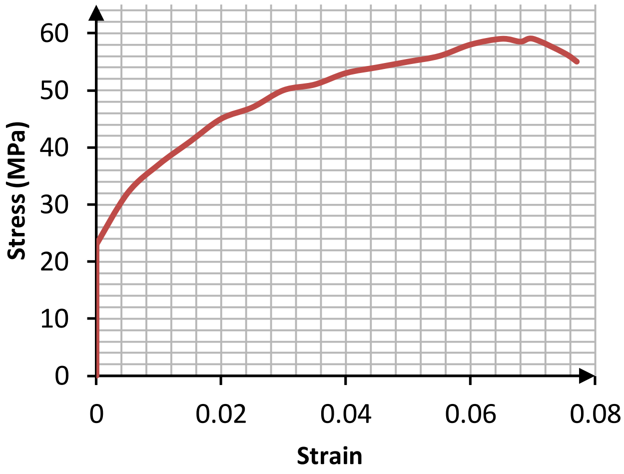

Fig.2. Stress–strain curve of specimens.

B. QUANTITIES AND CODING:

For each triangular, square or hexagonal section, two types of samples are built. The first is simple (no blade); the second is also simple with symmetrical contact edges (type A).
Codes for the specimens are as follows:

Triangular (Tr), square (Sq) and hexagonal (Hx). For type A sections are denoted by mc.A, after the codes for the simple sections. Six samples of each type are built and designated as (1-2-3-4-5-6) after the type code to denote the samples, respectively. The codes of all samples are listed in Table2.

Table 2. Samples coding

Specimen Shape	Simple			
	Epoxy	Tape	Epoxy	Tape
Triangular	TR. 1,2,3	TR. 4,5,6	TR.A. 1,2,3	TR.A. 4,5,6
Square	SQ. 1,2,3	SQ. 4,5,6	SQ.A. 1,2,3	SQ.A. 4,5,6
Hexagonal	HX. 1,2,3	HX. 4,5,6	HX.A. 1,2,3	HX.A. 4,5,6

Fig.3. WDW-10 Computer Control Electromechanical Universal Testing Machine.

4. TESTING PROCEDURE

Quasi-static axial crushing test of specimens is done using a WDW-10 Computer Control Electromechanical Universal Testing Machine as shown in Fig.3. This machine has two jaws; the lower is fixed and upper is movable. The compressive axial loading speed was set to 5 mm/min. Because of samples minimal thickness, small force is required to compress them. This machine uses a 1kN load-cell to increase measurement accuracy. Also to minimize slippage and eccentricity of the samples, the samples are fixed to squares of pads. Fig.4 shows a square sample before loading. Fabricated samples are shown in Fig.5 and the sample during the test is shown in Fig.6; deformation of samples after loading is shown in Fig.7.Comparison between experimental values of absorbed energy of specimens is shown in Fig.8. Comparison between experimental values of maximum crushing load of specimens is shown in Fig.9.Percentages of increase in absorbed energy of sections in comparison with the taped triangular is shown in Fig.10.Comparison between experimental values of Mean specific absorbed energy (SAE) of specimens is shown in Fig.11.Percentages of increase in mean value SAE of sections in comparison with the taped square is shown in Fig.12.

Fig.4. Square sample before loading

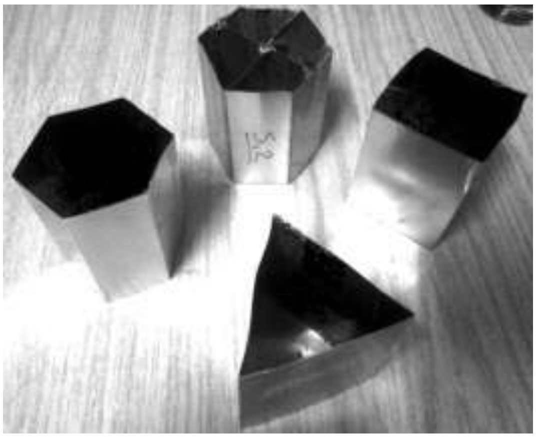

Fig.5. Fabricated samples before loading

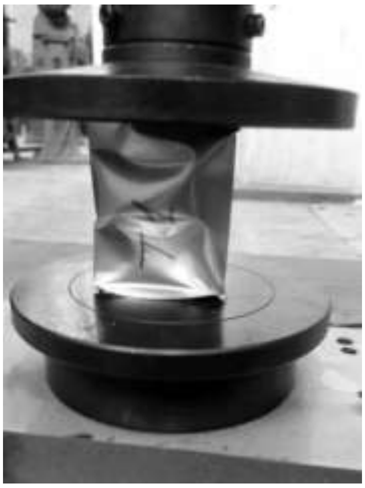

Fig.6. Sample during test

Fig.7. Deformed samples after test

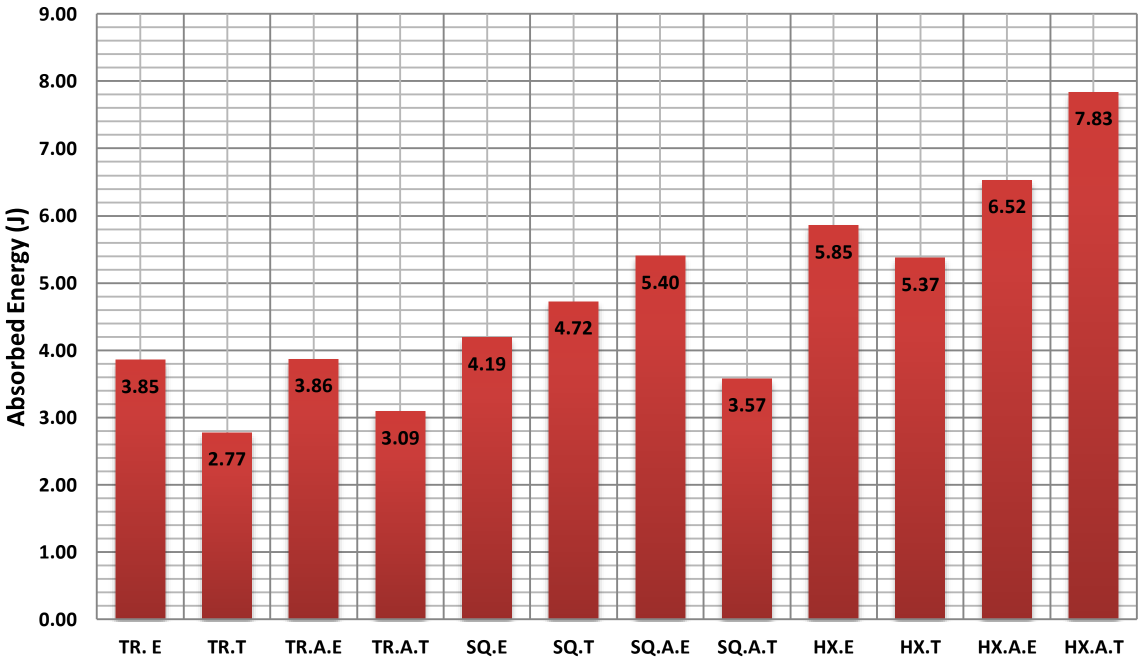

Fig.8. Comparison between experimental values of absorbed energy of specimens

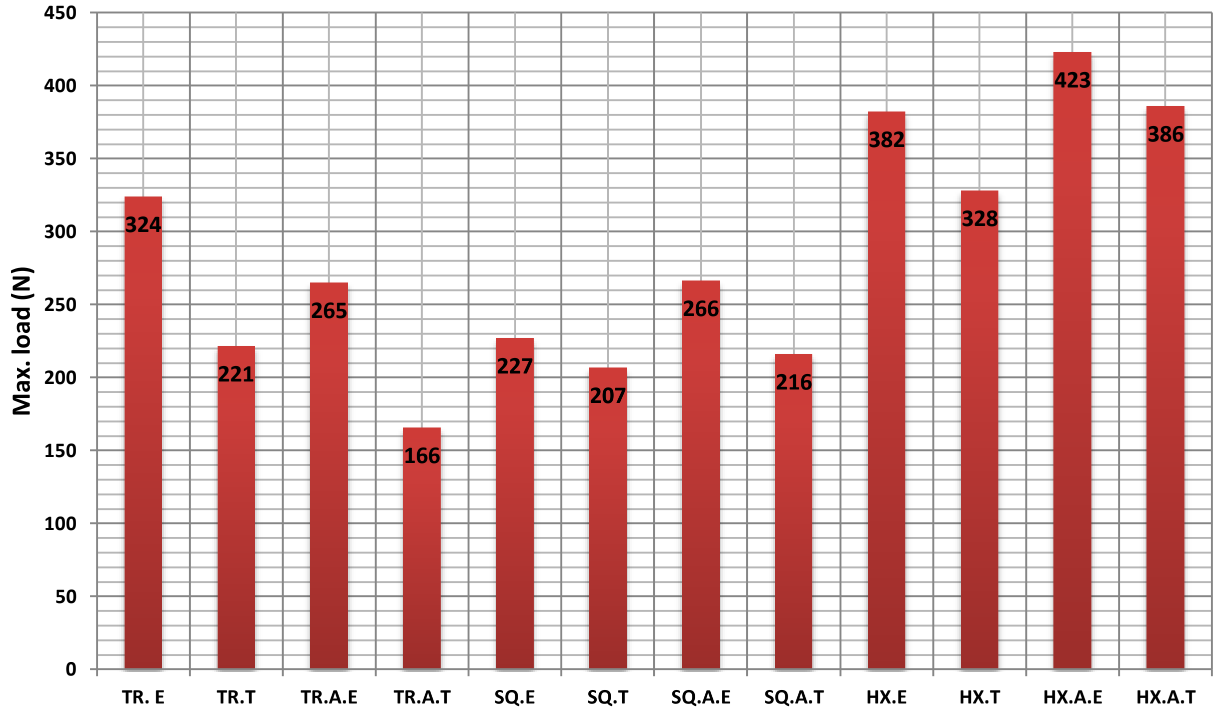

Fig.9. Comparison between experimental values of maximum crushing load of specimens

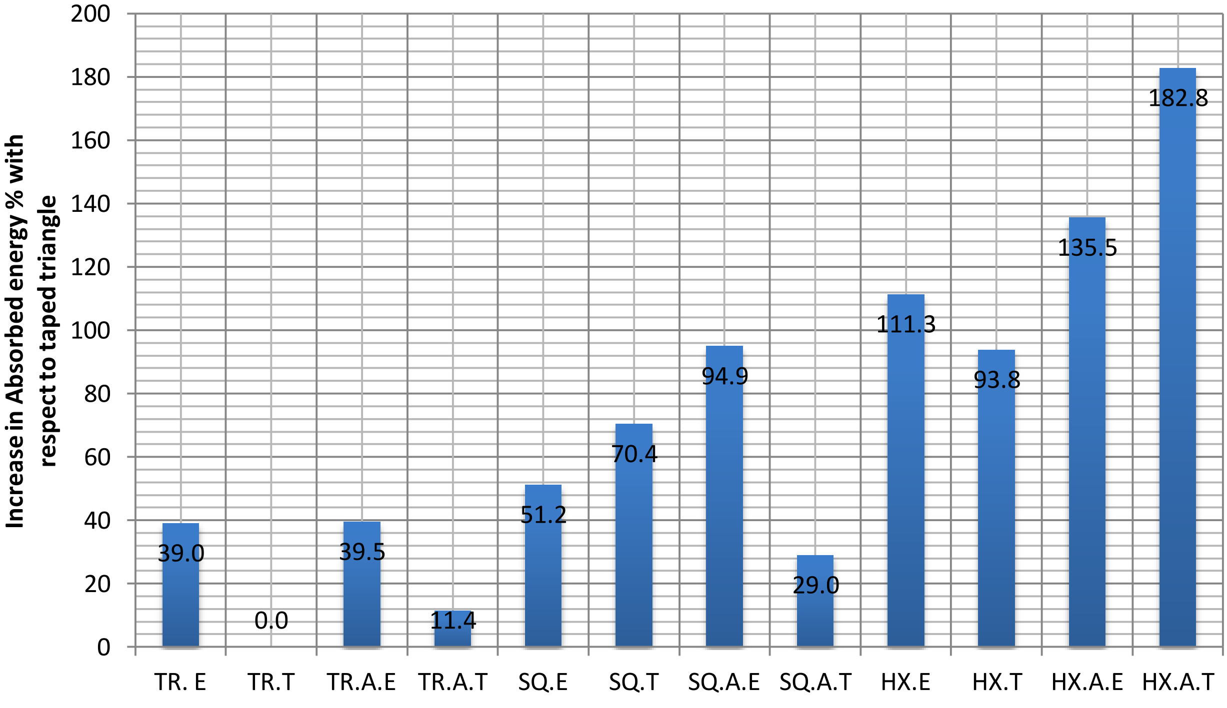

Fig.10. Percentages of increase in absorbed energy of sections in comparison with the taped triangular

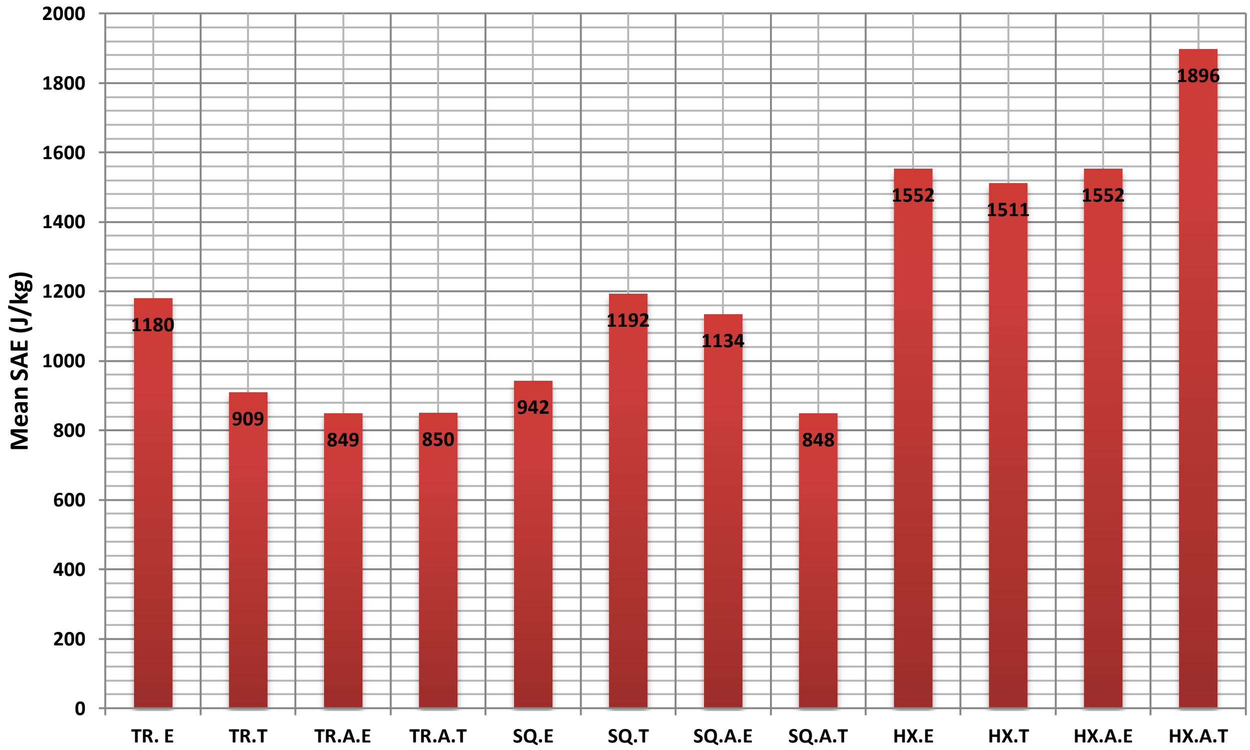

Fig.11. Comparison between experimental values of Mean SAE of specimens

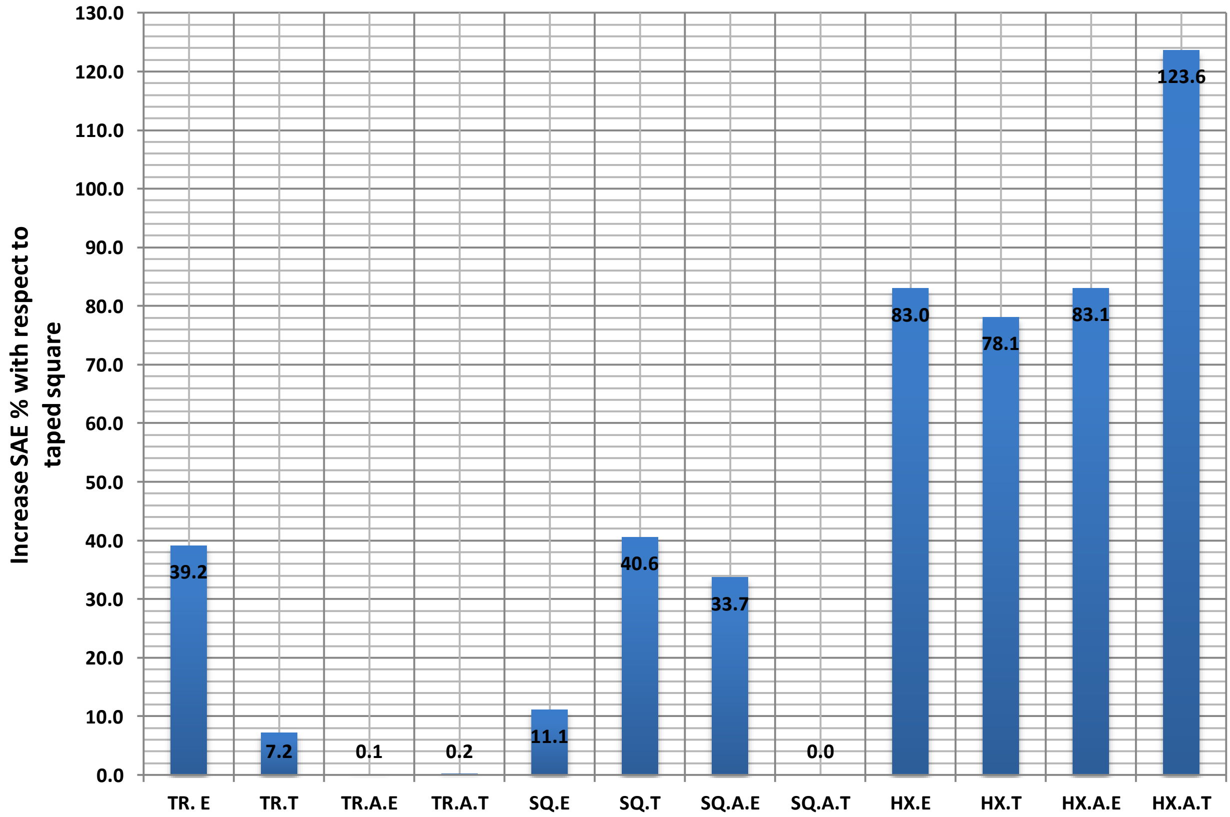

Fig.12. Percentages of increase in mean value SAE of sections in comparison with the taped square

5. CONCLUSION

In this paper, the mechanical behavior of thin-walled aluminum structures with triangular, square, and hexagonal sections in simple forms was studied under quasi- static compression. Samples were loaded using a WDW-10 Computer Control Electromechanical Universal Testing Machine. There was good consistency between the test data. A comparison of the results showed that square and hexagonal sections had greater absorbed energy in comparison with triangular geometry. Hexagonal geometry had the greatest maximum load capacity then triangle and square samples due to adhesive status and corners failure in square samples. Absorbed energy for HX.A.T, HX.A.E geometries was about 183% and 136% greater, respectively, than for the one-sided taped triangular geometry. The mean SAE values for hexagonal samples were greater than triangles and squares. Taking into the consideration epoxy or tape samples, we can conclude that epoxy samples had the max load carrying capacity due to hardness, but taped samples absorbed more energy due to flexibility.

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