



Numerical and Experimental Study Of Energy Absorption of Multi-Layer Aluminum-Composite Conical Frustum Structures under Axial Loading

A. Tafazoli¹, M. Asgari^{1*}, A. Ghaznavi²

¹ Department of Mechanical Engineering, K. N. Toosi University of Technology, Tehran, Iran

² Department of Renewable Energy Research, Niroo Research Institute, Tehran, Iran

ABSTRACT: Passive safety is the most important part of protecting the lives of occupants in accidents and collisions when it comes to vehicle safety. The crash box is one of the most basic passive safety components in the vehicle and is expected to be able to absorb kinetic energy in longitudinal crashes in order to minimize occupant injury in safe areas. Despite the use of a variety of geometric shapes and materials in the construction of crash boxes, conical structures and aluminum have attracted much attention. In this study, aluminum and aluminum-composite conical structures were investigated. Under quasi-static loading, experimental experiments and numerical simulations showed that the addition of composite to aluminum structures could triple the specific energy absorption of the structure on average. And the use of 0 and 90 directions of glass-epoxy fibers advances the process of structural destruction step by step and cross-sectional. The result is that the folds are regular and close together, which has positive effects on specific energy absorption, mean force, and stroke efficiency of the structure.

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1- Introduction

Car safety is one of the most important pillars of the automotive industry. The crash box, as one of the passive safety items, must be able to absorb kinetic energy in longitudinal crashes and minimize damage to occupants in safe areas [1]. Factors affecting the behavior of the crash box are divided into three groups: geometric characteristics, structure material, and loading conditions of the structure. In the field of geometric characteristics, various types of thin-walled structures such as cylindrical, quadrilateral, polygonal, and conical cross-sections have been studied and compared to understand their plastic deformation behavior [2, 3]. Also, various design modes such as fillers [4], and composite and multicellular structures are other issues that have been raised in research [3, 5]. To improve the design and performance of crash boxes, many researchers have investigated the effect of crash box components and their essential role in enhancing the energy absorption performance of energy absorbers [6]. On the topic of crash box material, we can mention three groups of metal alloys, composites, and metal alloys-composites structures. Aluminum has recently attracted much attention in research due to its low weight and good impact resistance [7]. Despite extensive research on the efficiency of composite materials in crash boxes and the effects of the number of layers, fiber angle, and fiber length on energy

absorption [8, 9], the problem of composite fragility has led to the use of composite-metal materials in the application of crash boxes [7]. Combining metal alloys with composites has had better results than using each of them alone [7].

2- Methodology

The aluminum structure was made by the spinning method and mechanical properties of aluminum were obtained based on tensile test and standard pattern ASTM E8/E8M. Also, in order to manufacture the aluminum-composite structure with three layers of twill woven fibers weighing 165g/m² and epoxy resin EPL1012 as [0/90]₃ on the aluminum structure, the hand lay-up process was utilized. To create a good adhesion between aluminum and composite, a chromate-free primer was used as a substrate. Experimental tests on constructed samples and numerical analysis on corresponding simulated models provided energy absorption characteristics. Fig. 1 shows the structure. The geometric characteristics of the structures are given in Table 1.

3- Results and Discussion

The results of experimental and numerical studies showed the improvement of energy absorption results by using composite. So that the aluminum structure could achieve a maximum force of 4.05 kN, an average force of 2.14 kN,

*Corresponding author's email: asgari@kntu.ac.ir



Table 1. Geometric characteristics of the structures

Name	Height (mm)	Thickness (mm)	Bottom Diameter (mm)	α_1 (degree)
AL-118-135	135	0.87	118.4	8.51
ALGF-120-135	135	1.87	120.4	8.51

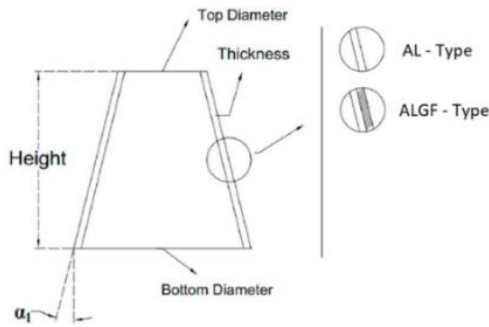


Fig. 1. Specifications of the tested structure and introduction of how the composite is placed on aluminum

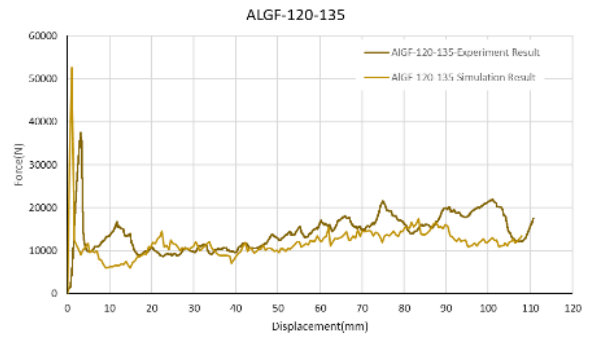


Fig. 4. Force-displacement diagram of ALGF-120-135 in experimental and simulation study

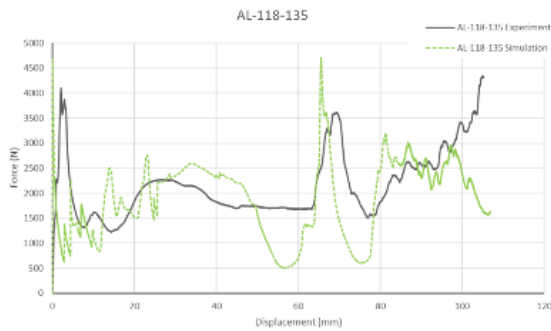


Fig. 2. Force-displacement diagram of AL-118-135 in experimental and simulation study

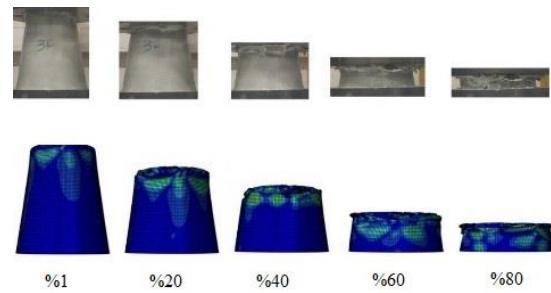


Fig. 5. Structural demolition process of AL-120-135 in experimental and simulation study

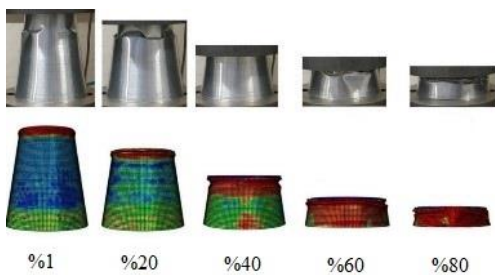


Fig. 3. Structural demolition process of AL-118-135 in experimental and simulation study

and specific energy absorption of 3.5 J/g. As shown in Figs. 2 and 3, in the experimental study the structure experiences degradation, which causes the average force to decrease. It is also worth noticing that due to neglecting construction related imperfections in the simulation process, simulated models are able to shrink more than 0.8 of their initial length, which explains the non-uptrend of its chart at this length.

Experimental and numerical studies of aluminum-composite structures show that the application of composites, not only regulates the demolition process but also is able to cover construction related problems. Figs. 4 and 5 depict good agreement between simulation and experimental procedure. The aluminum-composite structure was able to achieve a maximum force of 37.4 kN, an average force of 11.8 kN, and specific energy absorption of 13.88 J/g.

4- Conclusion

In this study, the energy absorption of conical frustum structures in aluminum and aluminum composite was investigated experimentally and numerically. The results showed that the use of composite could increase the specific energy absorption of the structure compared to the aluminum structure by up to 3 times, which can be attributed to the angles of the fibers and the improvement of the degradation process. A significant increase in maximum force and average force, as important parameters in energy absorption, is obvious, as well.

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