# Design of a GFRP crash energy absorber: cross section and stacking sequence optimization

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## Abstract

Over the last two decades, the capability of composite materials to absorb energy was investigated in several studied such as [1]. In the automotive industry, the safety performance of cars is mainly ensured by bumpers and car crash absorbers, which are made of aluminum or steel. In view of weight reductions, traditional metals properties are compared to those of composite materials, usually characterized by higher energy absorption-to-weight ratios. Mamalis *et al.* [2] dealt with shape optimization of fiberglass composite crash absorbers for automotive applications. Failure and collapse modes, and the effect of strain rate were taken into consideration in the absorption mechanism. Recently, in [3] the energy absorption capability of carbon-epoxy and glass-epoxy composite structures was compared by numerical simulations and experiments. In the present work, a methodology for fiberglass crash absorbers design is discussed. Optimization techniques, FE simulations and experimental tests are performed on glass-epoxy specimens in order to characterize their dynamic behavior. The predictive capability of the numerical models was validated against the experimental results. At first, static tests were made to evaluate the tensile, compressive, and shear properties of the fiberglass composite materials. The dynamic properties are also investigated by drop testing according to ASTM D7136 standard. At a later stage, drop-tests are performed on cylindrical specimens in order to simulate the crash absorbers dynamic behavior. Finally, in the light of the previous dynamic results, the stacking sequence of the composite crash absorbers is numerically optimized by means of design of experiments and optimization techniques for different regular cross-section shapes, such as circular, hexagonal, and octagonal. An experimental-numerical correlation was developed and applied for setting the material properties in the numerical model. Finally, the optimum lay-up for a four-ply fiberglass composite automotive crash absorber was found by means of an optimization process.

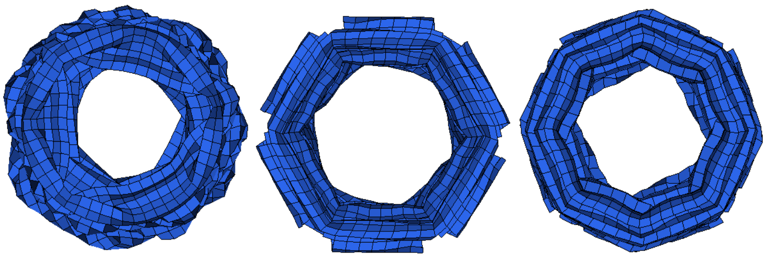

Fig. 1: Deformed shapes after crash for the fiberglass composite crash energy absorbers: circular cross-section (left), hexagonal cross-section (centre), and octagonal cross-section (right).

| **Cross- Section** | **Impact Speed** | **Optimum Stacking Sequence** | **Absorbed Energy after 10 ms** | **Specific Energy** | **Energy Ratio Absorbed per Ply** | | | |
|---|---|---|---|---|---|---|---|---|
| | | | | | ***1st*** | ***2nd*** | ***3rd*** | ***4th*** |
| Circular | 40 m/s | [45°,20°,5°,15°] | 6321 J | 20.55 J/g | 13.6 % | 23.7 % | 38.6 % | 24.0 % |
| Hexagonal | 40 m/s | [40°,25°,40°,35°] | 7687 J | 24.97 J/g | 24.3 % | 7.6 % | 22.6 % | 45.5 % |
| Octagonal | 40 m/s | [5°,5°,0°,15°] | 8244 J | 26.78 J/g | 10.9 % | 27.5 % | 11.8 % | 49.8 % |

Tab. 1: Optimum Crash Absorbers: Lay-Up and Energy Ratio Absorbed per Ply

It was found that the optimum octagonal crash absorber allows specific energy absorption similar to that of an equivalent aluminum crash absorber. The main results are summarized in Fig. 1 and Tab. 1. Guidelines for further optimization could involve different shapes, cross-section sizes, different ply numbers, and different and more performing reinforcement types, such as carbon fiber.

[1] C. Bisagni, G. di Pietro, L. Fraschini, and D. Terletti, Progressive crushing *of fiber-reinforced composite structural components of a formula one racing car*, Composite Structures, vol. 68, pp. 491–503, 2005

[2] A. G. Mamalis, D. E. Manolakos, M. B. Ioannidis, and D. P. Papapostolou, *Crashworthy characteristics of axially statically compressed thin-walled square CFRP composite tubes: experimenta*l, Composite Structures, vol. 63, pp. 347–360, 2004.

[3] S. Ochelski, and P. Gotowicki, *Experimental assessment of energy absorption capability of carbon-epoxy and glass-epoxy composite*, Composite Structures, vol. 87, pp. 215–224, 2009.