Experimental and numerical investigation of quasi-static bending crashworthiness of double hat-section Al-CFRP beam used in the automotive structure

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Introduction

The design of the composite ply-angle is one of the most important characteristics examined in hybrid composite/metal structures [1]. have illustrated the significant influence of composite play-angles on energy absorption and failure mechanisms in hybrid structures. Other influential factors encompass the number of composite layers, mass considerations, and the application of reinforced length of composite on the metal surface. Therefore, the objective of this research paper is to experimentally and numerically investigate the quasi-static crashworthiness behavior of adhesively-bonded double hat-section CFRP/aluminum hybrid beams under transverse loading, which has not been previously addressed in existing studies

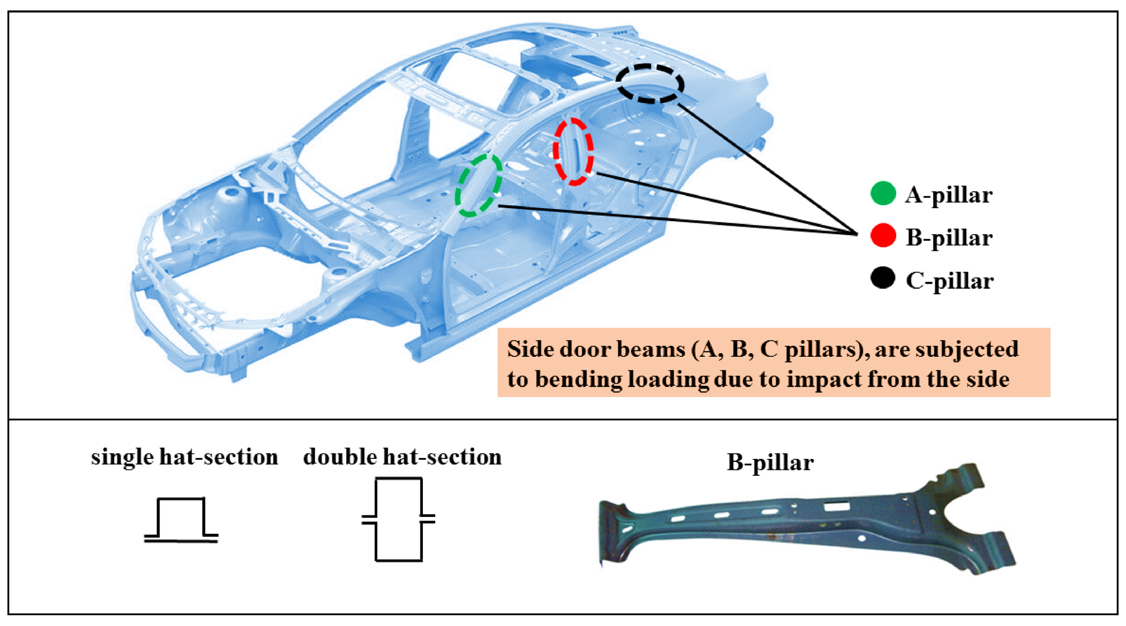


Figure 1: The schematic view of automotive side door beams

Experimental Methodology

In the stage of the specimen fabrication, the interior and outer surfaces of the aluminum beams were sanded for a few minutes with 150-grit sandpaper to ensure optimal bonding. After sanding, the aluminum beams were treated with acetone for approximately 10 minutes to eliminate the grease that remained. Then, the prepared CFRP sample and the aluminum beams were closed using special holding fixtures to maintain the pressure level during the adhesive's one-week curing process at room temperature. The bonding procedures for the sample components are depicted in Figure 2 depicts the obtained dimensions of the specimens, including an upper hat-shaped beam, CFRP parts, a lower hat-shaped beam, and the requisite test measurements.

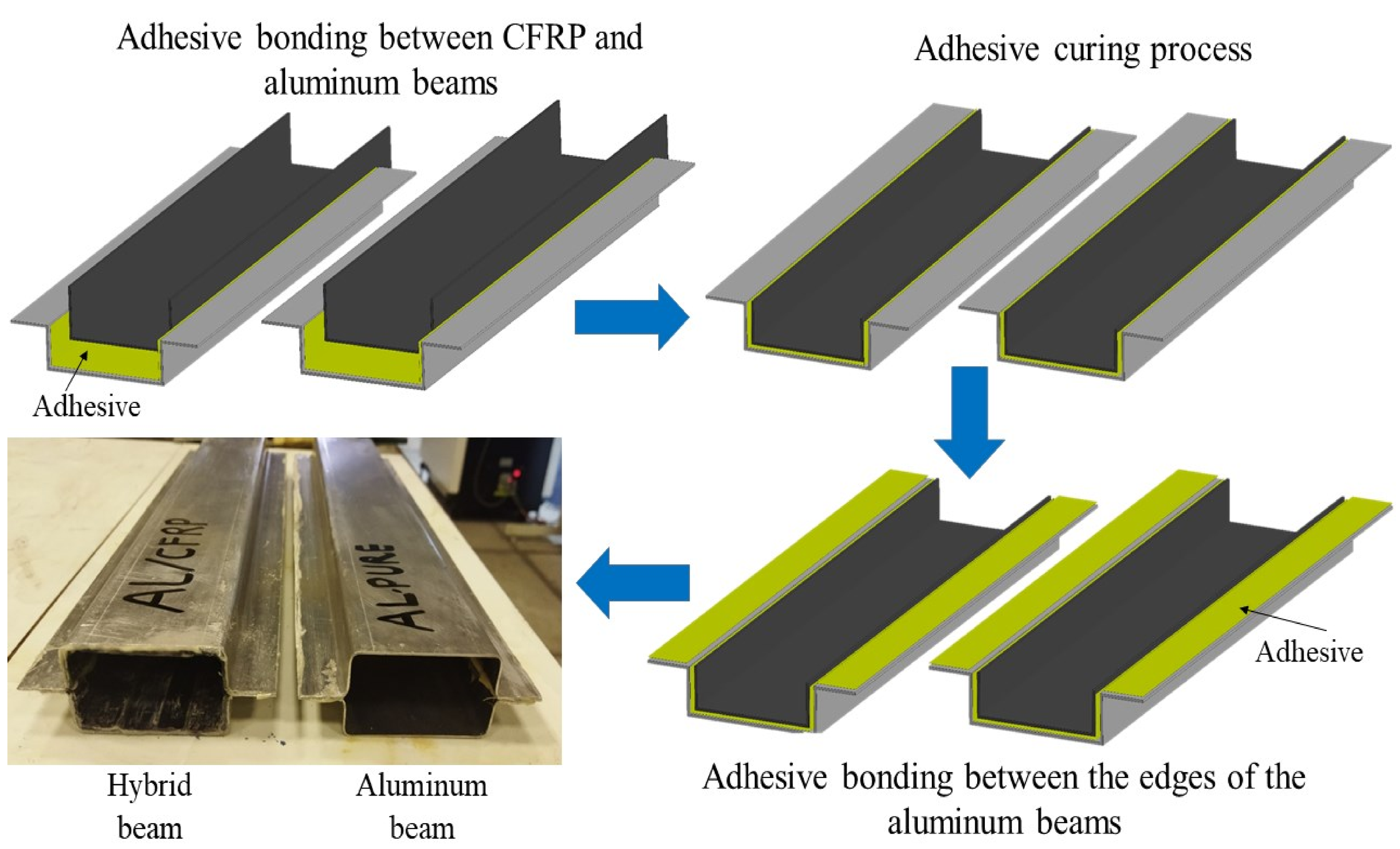


Figure 2: Schematic of adhesive bonding process of hybrid Al/CFRP double hat-section beam.

Results and Discussion

The aluminum beam's load-displacement characteristics can be divided into four distinct regions. Linear elastic behavior was observed in region I immediately after loading started. The load displacement characteristics of the hybrid beam can also be divided into four separate regions. In general, delamination, cracks in the matrix, and adhesive failure between aluminum and CFRP in the metal-plastic hinge region were the failure mechanisms in this specimen.

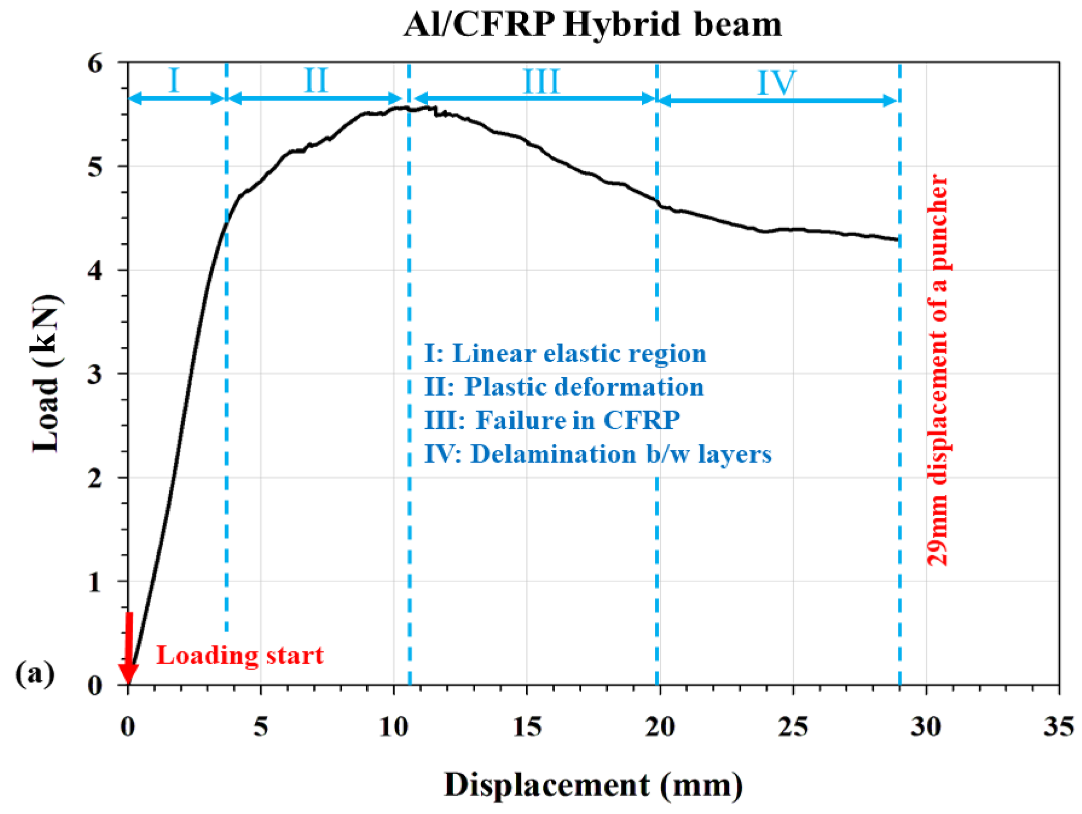
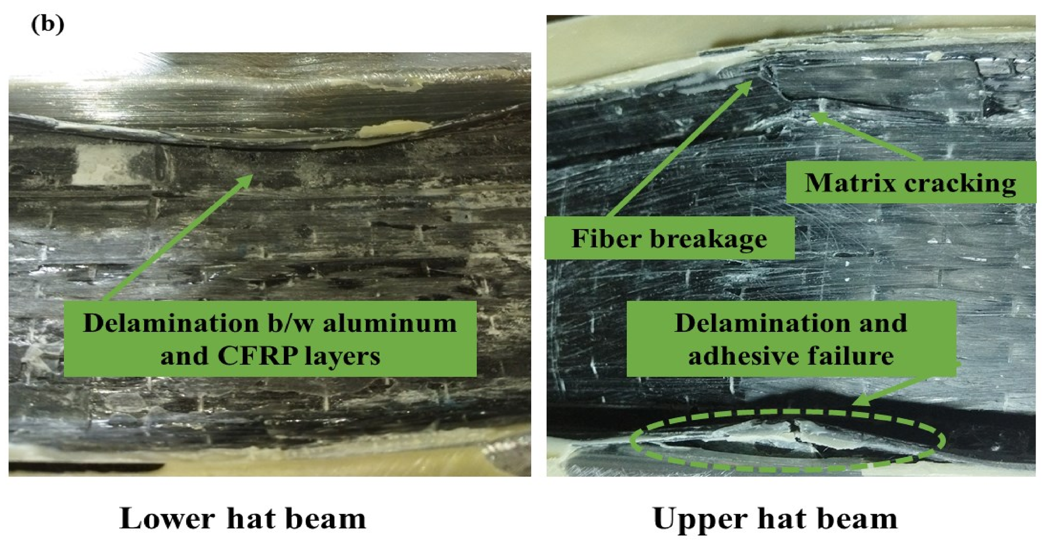


Figure 3: Load displacement behavior of the hybrid beam.

Figure 4: (a) Description of bending collapse of hybrid beam in load-displacement behavior (b) The failure mechanism of hybrid beam specimens.



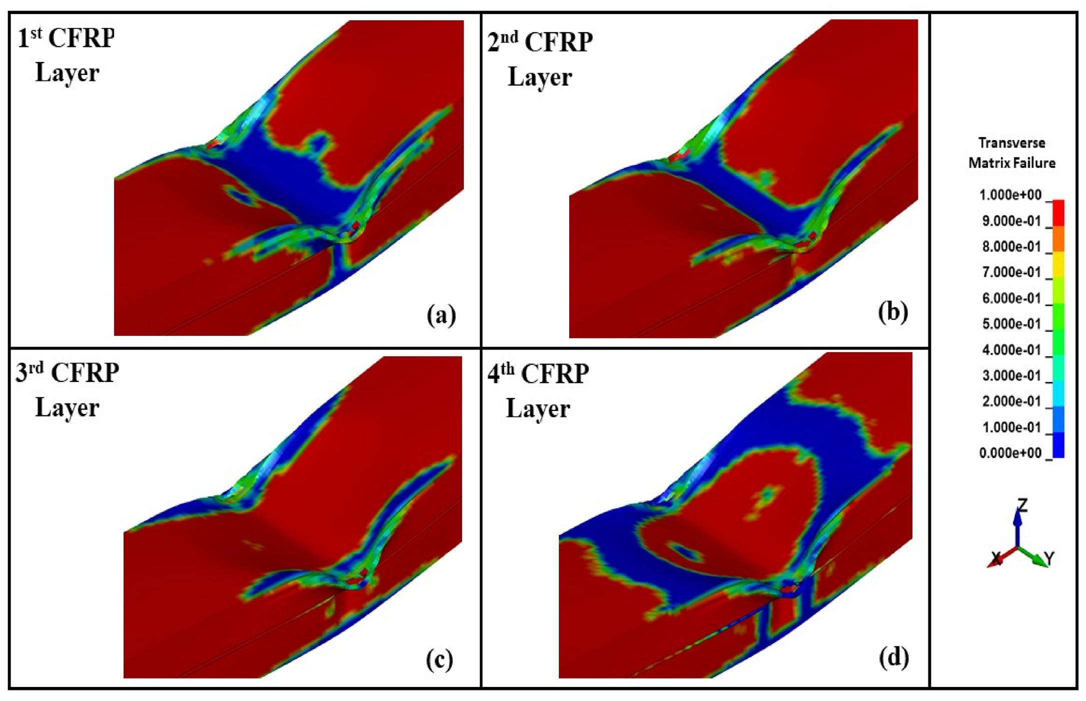


Figure 5: Matrix damage and interface damage in the beam.

Critical damages are indicated in blue color, whereas red areas are healthy and undamaged. In the right figure, red color denotes places with various damage statuses stated in the FEM, such as critical damage and others, while blue color denotes areas that are healthy and undamaged.

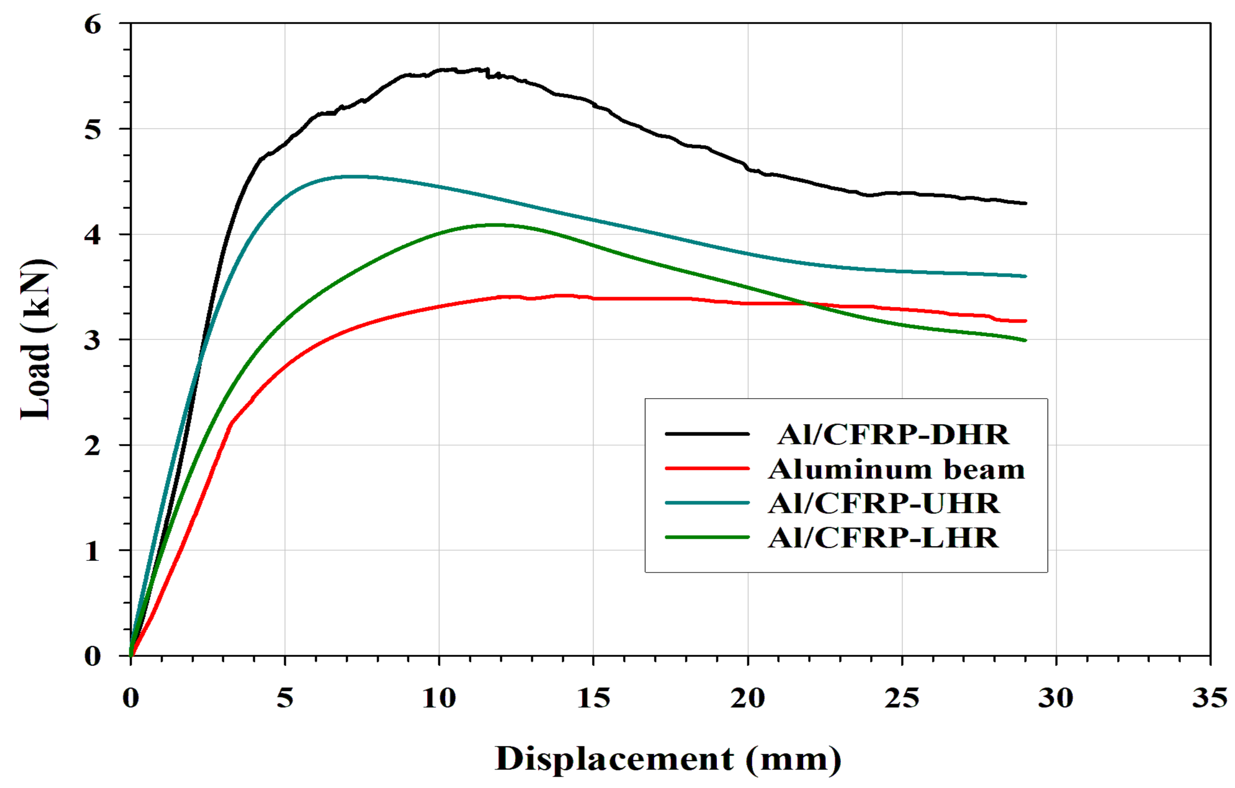


Figure 6: load-displacement curves depending of different values of CFRP coverage.

Conclusions

The experimental findings revealed that aluminum and hybrid specimens exhibited different bending collapse behaviors. Consequently, the utilization of CFRP reinforcement resulted in an increased peak force and greater energy absorption of the hybrid specimen. However, in contrast, the increase in load stability subsequent to the peak load drop could be attributed to the occurrence of failure in the CFRP.

Reference

[1] J. Y. Zhang, B. Lu, D. Zheng, and Z. Li, "Experimental and numerical study on energy absorption performance of CFRP/aluminum hybrid square tubes under axial loading," Thin-Walled Struct