proceedings

Abstract

Develop a Smart Material Based on Carbon-Aramid Hybrid Composite for Health Monitoring Structure †

Khalid Alblalaihid, Saad Aldoihi *, Abdulaziz Alharbi, Meshal Abuobaid, Sabri Alkhaibari, Khalid Khormi, Sami Alsaleh, Khaled S. Almutairi and Majid A. Albahkali

Institute of Earth and Space Science, King Abdulaziz City for Science and Technology (KACST), Riyadh 11442, Saudi Arabia; alblehed@kacst.edu.sa (K.A.); abharbi@kacst.gov.sa (A.A.); mabuobaid@kacst.edu.sa (M.A.); salkhaibari@kacst.gov.sa (S.A.); kkhormi@kacst.edu.sa (K.K.); salsaleh@kacst.gov.sa (S.A.); kmutiri@kacst.edu.sa (K.S.A.); mbahkali@kacst.edu.sa (M.A.A.)

* Correspondence: saldoihi@kacst.edu.sa; Tel.: +966-533331798

† Presented at the XXXV EUROSENSORS Conference, Lecce, Italy, 10–13 September 2023.

Abstract: This paper discusses the use of Kevlar-carbon hybrid composites in the aerospace industry for structural and non-structural components. By combining the high tensile strength and impact resistance of Kevlar fibers with the high stiffness and dimensional stability of carbon fibers, a material with enhanced mechanical properties can be achieved. However, the combination of two materials with different properties can cause delamination between layers, making real-time monitoring of structural integrity important. This study investigates the feasibility of embedding sensors into Kevlar-carbon hybrid composites and presents the basic characterization using a mechanical tensile test. It been shown the embedded sensor has a linear response toward the axial stress and the damage can be detected at the turning point where the capacitance begins to decrease.

Keywords: sensing; matrix cracking; intra-ply hybrid composites; Kevlar fibers; carbon fibers; SHM

Citation: Alblalaihid, K.; Aldoihi, S.; Alharbi, A.; Abuobaid, M.; Alkhaibari, S.; Khormi, K.; Alsaleh, S.; Almutairi, K.S.; Albahkali, M.A. Develop a Smart Material Based on Carbon-Aramid Hybrid Composite for Health Monitoring Structure. *Proceedings* **2024**, *97*, 28. https://doi.org/10.3390/proceedings2024097028

Academic Editors: Pietro Siciliano and Luca Francioso

Published: 15 March 2024

1. Introduction

In the aerospace industry, Kevlar-carbon fiber hybrid composites have been used widely for both structural and non-structural components like fairings, fillets, wingtips, and braking systems where weight saving and impact resistance are priorities [1]. Aramid (Kevlar) and carbon fibers are two of the most commonly used high-performance fibers for reinforcing polymer matrix composites. Kevlar fibers have high tensile strength and impact resistance, while carbon fibers have high stiffness and dimensional stability. By combining these two fibers into a hybrid composite, it is possible to achieve a material with enhanced mechanical properties. However, a combination of two materials with different mechanical properties can cause different types of failure such as delamination between layers. Therefore, implementing real-time monitoring for the structural integrity of hybrid composite is important for mitigating this problem. An early study was conducted on developing smart materials for carbon-glass hybrid composites, whereas the novelty of this work is to investigate the feasibility of embedding sensors into Kevlar-carbon hybrid composites. This paper presents the basic characterization of smart Kevlar-carbon hybrid composites using a mechanical tensile test.

2. Materials and Methods

The 3k filaments of carbon fiber (Torayca® T300, 3k, Toray Composite Materials Tacoma, WA, USA) was woven into the Kevlar fiber (Kevlar (Plain, hp-textiles, P170A, HP-Textiles GmbH, Schapen, Germany)) to produce intra-ply hybrid woven fabric as illustrated in Figure 1a. This carbon fiber was also used as an electrode to form a capacitive sensor, whereas the Kevlar fabric was used as the dielectric material. To manufacture a sample of Kevlar-carbon hybrid composites which consisted of seven layers as shown in

Figure 1b, the hand layup process was used. More detail of the process of integrating and manufacturing the smart material can be found in [2]. To characterize the smart material, a tensile test was conducted as shown in Figure 1c.

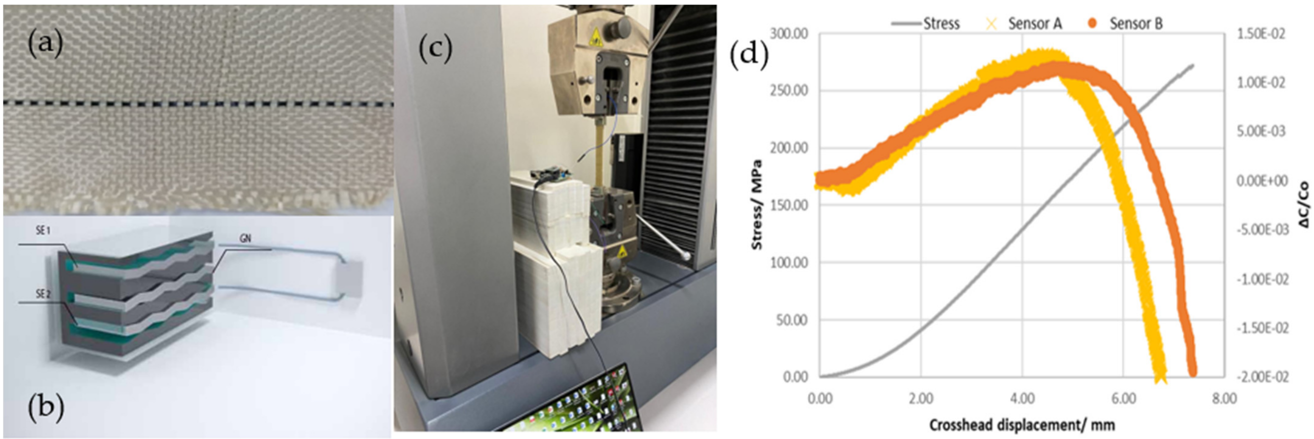

Figure 1. (**a**) Image of weaved carbon fiber into aramid (Kevlar) woven fabrics; (**b**) schematic diagram of inserting two capacitive sensors (sensors A and B) into a carbon-aramid hybrid composite; (**c**) experimental setup for characterization of the smart material; (**d**) graph showing the sensor response and the axial stress versus the crosshead displacement of the tensile test.

3. Discussion

To obtain the relative change in two capacitance sensors (sensors A and B) against the crosshead displacement and axial stress, the sample was pulled up to the breaking point which was around 270 MPa, using the tensile test machine as shown in Figure 1d. It is clear that the sensor response against the axial stress started to increase up to the turning point. The onset of deterioration or failure occurred at the turning point where the capacitive value began to decrease. It has been shown that the embedded sensor into the Kevlar-carbon composite had a linear response over a broad range of axial stress (up to 170 MPa) compared to it embedded into a glass-carbon hybrid composite which is up to 100 MPa [3]. The observed improvement may be attributed to a significant difference of the Young's modulus between glass and carbon fibers which was minimized by hybridization of Kevlar fibers with carbon fibers, in turn leading to delaying the onset of failure at the turning point. This indicates a high capability of the new developed technique to monitor structures integrity in real time for Kevlar-carbon hybrid composites.

Author Contributions: Conceptualization, K.A. and S.A. (Saad Aldoihi); methodology, S.A. (Saad Aldoihi), S.A. (Sami Alsaleh), and A.A.; software, K.S.A.; validation, K.K., K.A. and S.A. (Saad Aldoihi); formal analysis, M.A., K.A. and S.A. (Saad Aldoihi); investigation, K.A.; resources, S.A. (Sabri Alkhaibari), K.S.A., and M.A.A.; data curation, K.A. and S.A. (Saad Aldoihi); writing—original draft preparation, K.A. and S.A. (Saad Aldoihi).; writing—review and editing, K.A. and S.A. (Saad Aldoihi); visualization, K.A.; supervision, K.A. and S.A. (Saad Aldoihi); project administration, S.A. (Saad Aldoihi) and K.A. All authors have read and agreed to the published version of the manuscript.

Funding: This research received no external funding.

Institutional Review Board Statement: Not applicable.

Informed Consent Statement: Not applicable.

Data Availability Statement: Data are available in this manuscript.

Acknowledgments: The authors would like to thank King Abdulaziz City for Science and Technology (Riyadh, Saudi Arabia) for all support during this research project.

Conflicts of Interest: The authors declare no conflicts of interest.

References

1. Clyne, T.W.; Hull, D. *An Introduction to Composite Materials*; Cambridge University Press: Cambridge, UK, 2019.
2. Alblalaihid, K.; Alghamdi, S.A.; Alburayt, A.; Almutairi, S.H.; Alwahid, A.; Abuobaid, M.; Alkhibari, S.; Almutairi, K.S.; Alarifi, I.M. Interlayer Defect Detection in Intra-Ply Hybrid Composite Material (GF/CF) Using a Capacitance-Based Sensor. *Sensors* **2022**, *22*, 2966. [CrossRef]
3. Alblalaihid, K.; Alghamdi, S.A.; Alburayt, A.; Alwahid, A.; Abuobaid, M.; Alshaikh, A.; Alkhibari, S.; Alarifi, I.M. Self-Sensing Hybrid Fibre-Reinforced Polymer for Structural Health Monitoring (SHM). *Key Eng. Mater.* **2022**, *922*, 87–93. [CrossRef]