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# INVESTIGATION ON STATIC AND DYNAMIC BEHAVIOUR OF 3D WOVEN HYBRID CARBON ARAMID EPOXY COMPOSITE LAMINATE


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## INTRODUCTION

A composite is a material made from two or more different materials that, when combined, are stronger than those individual materials by themselves. If we classify composites in terms of dimension then there are 2D and 3D composites. According to research, in 3D weaving, weft, warp and binder fibres meet, along and through the fabrics within the X, Y and Z directions, respectively. The present research is aimed at investigating the effect on mechanical characterisation of hybrid Kevlar and carbon 3k tow fibre with different combination of weft warp and binder with respect to 3D woven composites. This paper “3D Woven Composites: From Weaving to Manufacturing” by Hassan M. El-Dessouky and Mohamed N. Saleh - discusses the weaving of 3D fabrics, manufacturing of 3D composites, and the physical characterization and mechanical testing of infused composite samples, the conversion of fabric into preforms involves slow manual processes, which need to be eliminated for an integrated manufacturing approach. The objective of the paper “Recent advancements in mechanical characterization of 3D woven composites” by Mohamed Nasr Saleh and Constantinos Soutis is to review the available research on the mechanical characterization of 3D woven composites and highlight the lack of utilization of damage testing methods, while 3D weaving enhances mechanical properties, the study did not considerdifferent binding angles. The primary objective of this research is to fabricate four combinations of 3D woven composite fabrics from Carbon and Kevlar fibre using hand weaving and vacuum bagging method, keeping the weaving of the binder at 45 degrees with respect to weft and warp. The experiments performed are Tensile test with ASTM standard D3039, Flexural test with ASTM standard D4255-A, Fracture toughness with ASTM standard D5528 and impact test with ASTM standard D7137M-12. The main objective of this researchis to create a lighter 3D woven fabric with higher inter laminar strength and to determine the superior combination based on established performance metrics that can have useful application in the aerospace industry.

## OBJECTIVES

To fabricate a 3D woven hybrid curved composite panel by using the following combination of carbon/Kevlar and Epoxy.

• Combinations: (X, Y, Z) - (C, C, C); (C, C, K); (K, K, K); (K, K, C) (Where C is Carbon and K is Kevlar)

• To test the mechanical characteristics of these combinations by performing the Tensile test, Impact test, Toughness test, and Flexural test.

• No one has yet attempted to bind the 3D woven composite at an angle. Even though the Trellis frame test attempts to find the strength of the composite by applying force in all the directions equally, the composite itself isn't binded at an angle. We aim to bind the layers of weft and warp at an angle of 45 degrees to find out the change in its mechanical characterization. We will be using fully carbon and kevlar as our tows. We will make four types of 3d woven composites and they are:

• (X,Y,Z): (Carbon, Carbon, Carbon) : Carbon will be used as weft, warp and binder.

• (X,Y,Z): (Carbon, Carbon, kevlar) : Carbon will be used as weft, warp and kevlar will be used for binder.

• (X,Y,Z): (kevlar, kevlar, kevlar) : kevlar will be used as weft, warp and binder.

• (X,Y,Z): (kevlar, kevlar, Carbon) : kevlar will be used as weft and warp and carbon will be used as binder.

## METHEDOLOGY

The fabric weaving process involved the following steps:

Initially, five layers of 2D fabric were placed on the knitting frame as the base. Carbon and Aramid yarn was introduced in the Z direction, serving as a binder for creating a 3D fabric. The carbon yarn was positioned at a 45-degree angle. To prevent the fibers from being pulled during the weaving process, masking tape was applied along the borders of the fabric layers. Once the weaving was complete, the masking tape was carefully removed from the frame ensuring the integrity of the woven fabric.

(a) (b)

(c) (d)

Figure 1 (a) - KKK, (b) - KKC, (c) - CCC, (d) - CCK

Figure 2 - Hand Lay Up Process.

### Vacuum Bagging

The vacuum bagging process was employed to convert the prepared fabric into a laminate, chosen for its cost efficiency. The steps involved were as follows:

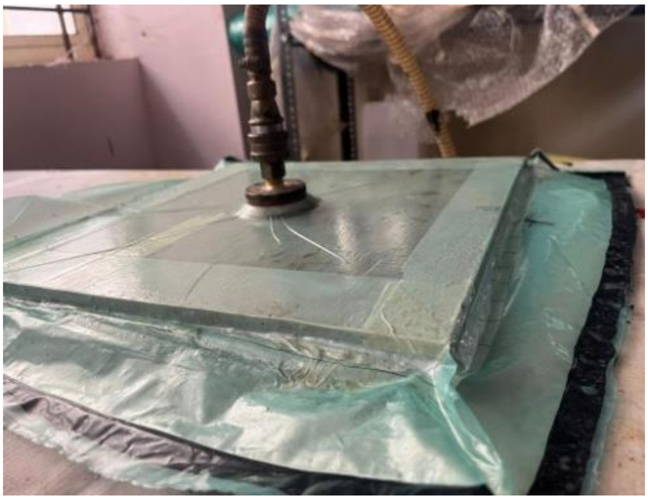

Figure 3 - Vaccum Bagging

The mold was covered with a Mylar sheet and release wax was applied. Peel ply and the 3D woven fabric were stacked on the Mylar sheet. The mixture of resin and hardener (in a 10:1 ratio) was poured and spread evenly on the fabric. Peel ply and breather fabric were stacked on top of the wetted fabric. A vacuum bag film of appropriate size was cut and sealed with tape, with a one-way valve attached. The mold was placed on the vacuum bag film and sealed. A pipe was connected to the vacuum pump. A vacuum pressure of 25 in Hg was maintained. The vacuum pump was turned on and left for 6 hours, then disconnected and left for 48hours.

## TESTING

### Tensile test

The goal is to determine the tensile strength. The dimensions of the test specimen are 250 mm (length) x 25mm (width) x 3mm(thickness).

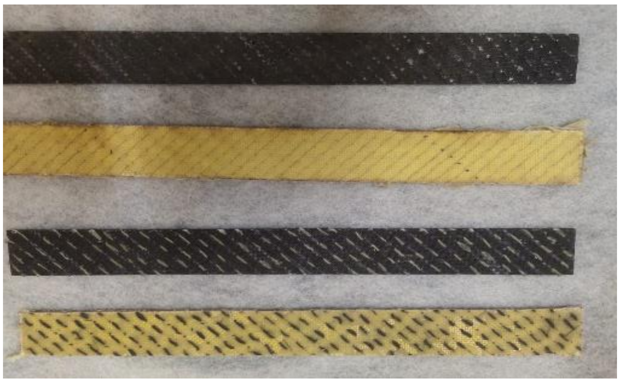

Figure 4 Tensile Test Specimens


Figure 5 UTM used for tensile test

**Flexural test**

It tests the ability of reinforced beam to withstand failure in bending. The dimensions of the test specimen are 150 mm (length) x 25mm (width) x 3mm(thickness). Fracture toughness test.

Figure 6 - Flexural Test Specimens

**Fracture toughness test**

It is a mechanical test performed to evaluate the resistance of a material to crack propagation it provides crucial information about the material's ability to resist the growth of pre-existing cracks. The test specimen with dimensions of 150mm (length) x 25mm (width) x 3.08mm (thickness). Pre crack a 0=40mm.

**Impact test**

It performed on the sampled material to measure the amount of absorbed energy during fracture. The dimensions of the test specimen are 150 mm (length) x 100mm (width) x 4.5mm(thickness)

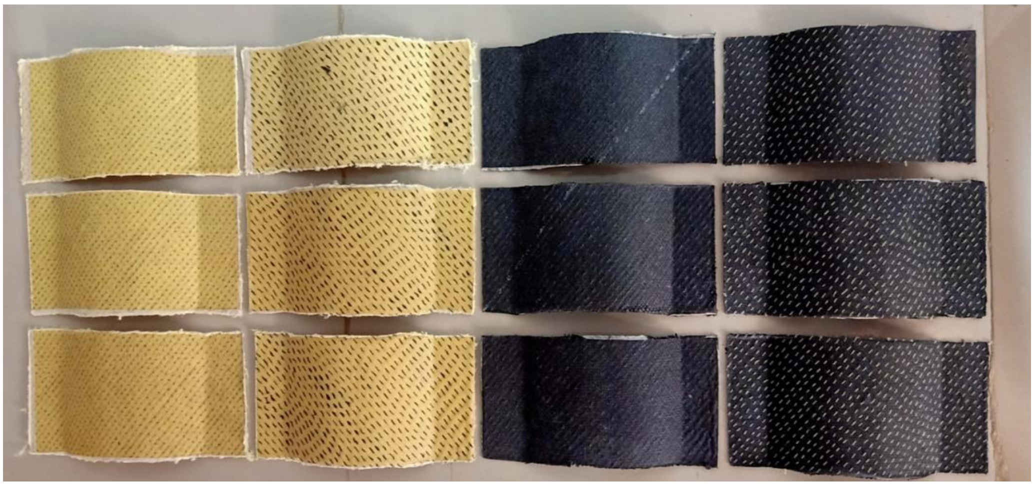

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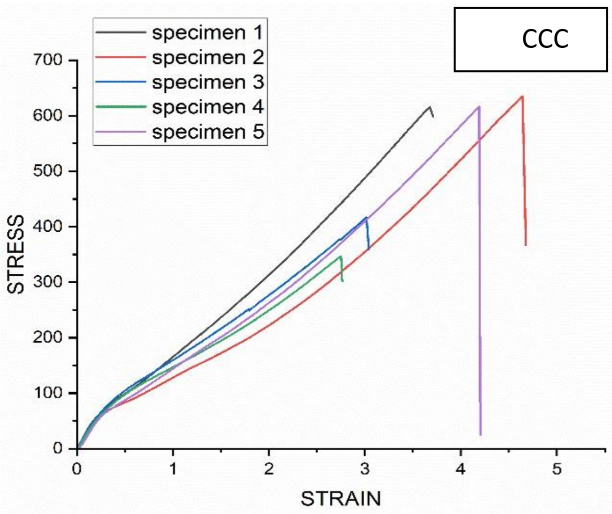
Figure 7 - Impact Test Specimens

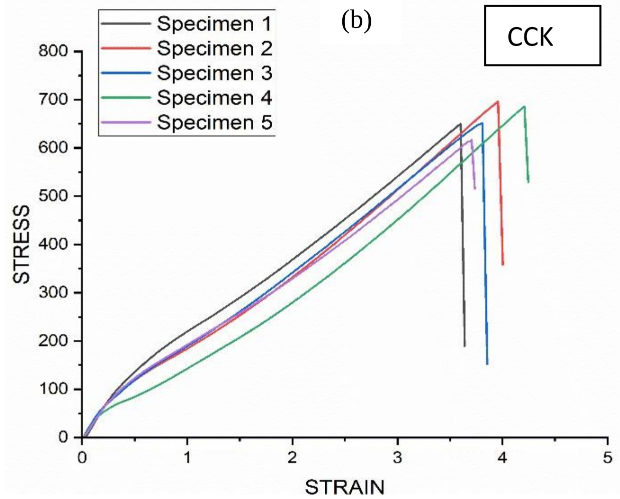
## RESULTS AND CONCLUSIONS

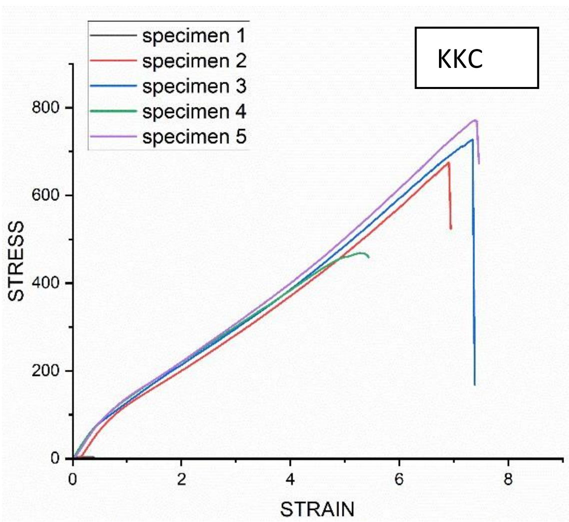
### TENSILE TEST



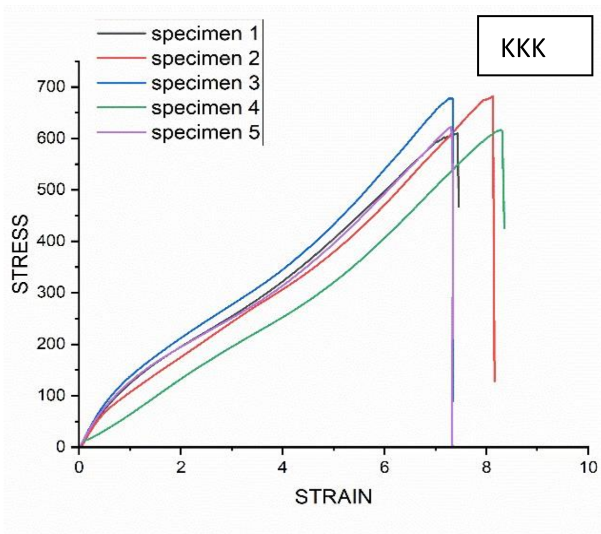

(a)

(b)




(c)




(d)

Figure 8 - (a) - CCC graph, (b) - CCK graph, (c) - KKC graph, (d) - KKK graph

The provided graphs illustrate the stress-strain curves for four distinct combinations of 3D woven carbon and Kevlar materials. Each combination underwent a series of five tensile tests, and the resulting data points were averaged to derive representative values for all four combinations. Subsequently, a separate graph was generated, displaying the average values of these combinations. The purpose of this graph is to facilitate a comparative analysis of the combinations and identify which among them exhibits the highest tensile strength.

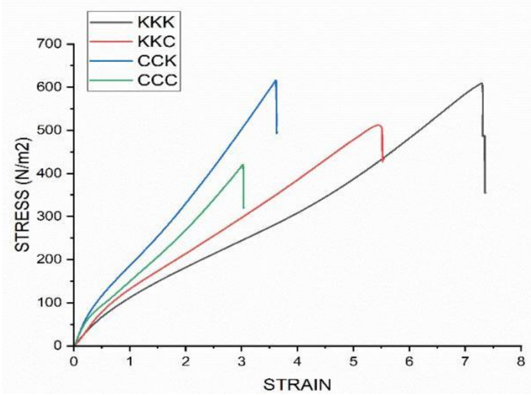



Figure 9 - Averaged graph of all four combinations

Based on the analysis of the provided graph and data, it can be concluded that the CCK combination demonstrates superior performance in terms of strain reduction while experiencing higher stress compared to the other combinations. This finding indicates that the CCK combination exhibits the least amount of strain but higher stress levels in comparison to the alternative combinations. The conclusion is derived from a comprehensive examination of the stress-strain curves and the associated Young's modulus data for each combination. The observed lower strain values in the CCK combination suggest its ability to withstand deformation or elongation to a lesser extent, while the higher stress values indicate its capacity to handle greater applied forces.

FLEXURAL TEST

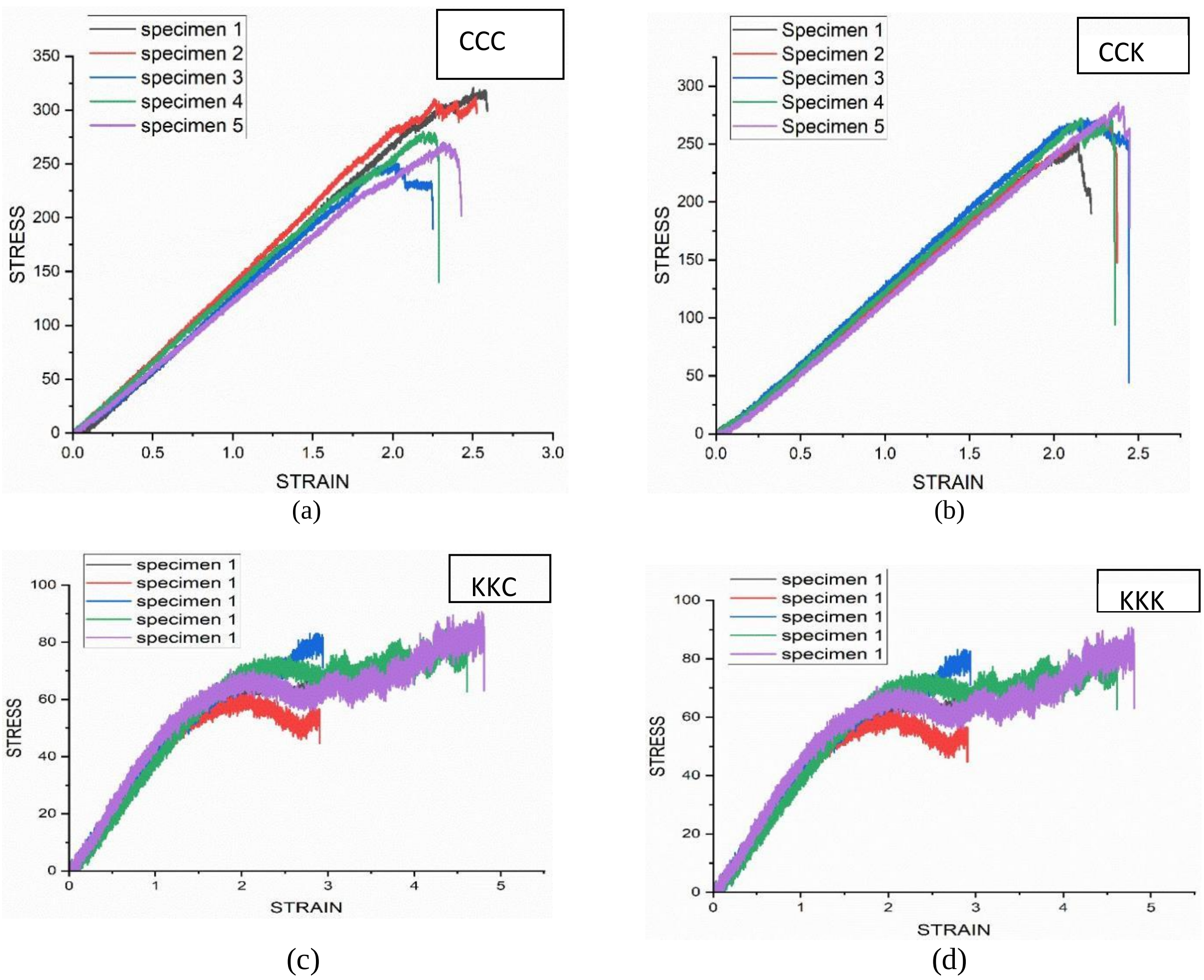



Figure 10 - (a) - CCC graph, (b) - CCK graph, (c) - KKC graph, (d) - KKK graph

Based on the provided information, the depicted graphs illustrate stress-strain curves for four distinct combinations of 3D woven carbon and Kevlar materials. Each combination underwent five separate flexural tests, and the resulting data from these tests were averaged for each combination. Subsequently, a separate graph was generated, presenting the average values of the four combinations. The objective of this graph is to facilitate a comparative analysis of the combinations and determine which among them exhibits the best flexural strength.

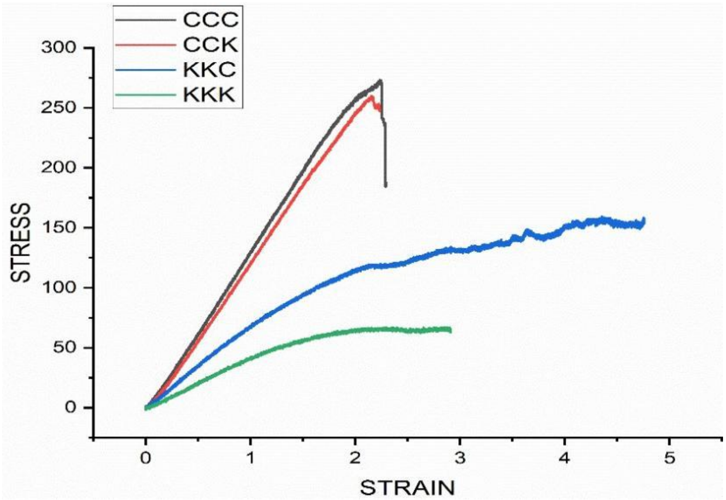



Figure 11 - Averaged graph of all four combinations

From the analysis of the provided graph and data concerning Young's modulus, it can be concluded that the CCC combination exhibits the most favorable characteristics among the tested combinations in terms of strain reduction and stress levels. Specifically, the CCC combination experiences the least amount of strain while demonstrating higher stress levels compared to the other combinations. This conclusion is drawn by examining the stress-strain curves and considering the Young's modulus values associated with each combination. The observed lower strain values in the CCC combination suggest its ability to withstand deformation or elongation to a lesser extent, while the higher stress values indicate its capacity to handle greater applied forces.

## SCOPE FOR FUTURE WORK

The scope for future work of this project is broad and offers numerous opportunities for research, development, and application in the aeronautical industry. Researchers can continue to explore ways to optimize the properties of 3D woven carbon Kevlar composites to meet specific requirements of different aircraft components. This includes improving strength, stiffness, impact resistance, and thermal properties. Research efforts can focus on designing and validating composite structures that offer increased strength, durability, and weight reduction while ensuring compliance with safety regulations.

Integrating additional functionalities like incorporating sensors for structural health monitoring or embedding electrical conductivity for lightning strike protection. Research can explore the development of composite materials that offer multiple functionalities, reducing the need for additional components and improving overall system efficiency.

Further advancements in manufacturing techniques specific to 3D woven carbon Kevlar composites can significantly impact their adoption, which includes refining automated manufacturing processes, developing cost-effective fabrication methods, and scaling up production capabilities to meet the demands. Continued research can focus on streamlining production, reducing waste, and improving process efficiency.

Research can focus on developing more sustainable manufacturing processes, recycling methods, and end-of-life solutions for composite materials. While the cost of 3D woven carbon Kevlar composites has been a barrier to widespread adoption, future work can target cost reduction strategies.

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