© June 2022 | IJIRT | Volume 9 Issue 1 | ISSN: 2349-6002

Design and Analysis of Hybrid Laminated Composites

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***Abstract*— This paper focuses on the study of the hybrid laminated composite made from Kevlar and Dyneema fabric. The aim is to achieve a flexible and protective shield. Ballistic impact tests have been done on the both the Dyneema and Kevlar fabrics and we can absorb that the Kevlar fabric can absorb more energy than the Dyneema fabric where the areal density plays the important role. When the areal density of the Kevlar fabric panel reached approximately 1.42 kg/m2, we can see they began to outperform the Dyneema equivalent in terms of the energy absorption. As a result, hybrid panels combining the two types of fabric were created, and these panels were found to have a higher specific energy absorption than single phase panels. In comparison to panels manufactured un reverse order, positioning of the Kevlar fabric layer close to the impact face and the Dyneema fabric layer towards the back face resulted in a ballistic performance gain of roughly 16% percentage.**

***Index Terms:* Hybrid Laminated Composite, Ultra-High Molecular Weight Polyethylene, Ballistic impact, Dyneema, Kevlar.**

INTRODUCTION

High strength, high modulus, and low-density fibers are preferred materials for ballistic protection. However, the choice of fibers for flexible bullet proof vest is restricted. In parallel with ongoing attempts to develop lighter and stronger fibers, Aramid, and ultra-high molecular weight polyethylene (UHMWPE) fibers are the most often used materials for ballistic protection. The latter has a greater specific strength than the former. UHMWPE fibers are most often used as laminated angle-plied fiber nets such as unidirectional (UD) textiles, where some flexibility in the laminates may be kept because of the lower resin content. Because of its low yarn–yarn and fiber–fiber friction, UHMWPE woven fabric could not successfully contact with a projectile during a ballistic event. Materials facing the impact have the tendency to illustrate shear failure mode, whereas those towards the rear face are stretched and shattered. In this regard, mixing different materials in the proper order would maximize the utilization of their unique capabilities, enabling the ballistic panel being more energy absorbent [1]. When a composite panel is damaged, the bullet usually causes through-thickness structural failure in the impact layers, resulting in a plug, but the fiber state of deterioration in the back layers resembles tensile failure [9]. Non-penetration ballistic tests revealed that single-phased woven panels had a deeper back face signature than hybrid panels. Researchers investigated the impact behavior of plain-woven and uni-directional(UD) fabrics in a hybrid panel and concluded that fabric is having shear-cut resistant and so more suitable for use on front layers. This research focuses on the ballistic performance and panel flexibility of hybrid panels made from Kevlar and Dyneema fabrics [1].

Methodology

Ballistic Panel Specification

Ballistic panels were devised and evaluated using various mixes of Kevlar and Dyneema woven materials. In this study, both single layer fabric and hybrid fabric has to be created for examination. In addition, hybrid panels with varying component ratios and sequences were created. The letters K for Kevlar and D for Dyneema are used to identify the panels. '1K1D', for example, refers to a hybrid panel made up of one layer of Kevlar woven fabric and one layer of Dyneema woven fabric, with Kevlar on the side of impacting and Dyneema on rear face. The shape of the fabric is trimmed into the required size of 23*23cm squares, then kept through a ballistic penetration test with the four corners clamped [1].

Ballistic Impact Test

Ballistic panels were devised and evaluated using various mixes of Kevlar and Dyneema woven materials. In this study, both single layer fabric and hybrid fabric has to be created for examination. In addition, hybrid panels with varying component ratios and sequences were created. The letters K for Kevlar and D for Dyneema are used to identify the panels. '1K1D', for example, refers to a hybrid panel made up of one layer of Kevlar woven fabric and one layer of Dyneema woven fabric, with Kevlar on the side of impacting and Dyneema on rear face. The shape of the fabric is trimmed into the required size of 23*23cm squares, then kept through a ballistic penetration test with the four corners clamped [1].

Hybrid Laminated Composite

Kevlar and Dyneema were used to create the hybrid fabric panels. Based on the findings of the ballistic testing on the hybrid panels, regression curves for energy absorption and impact velocity were produced. For comparison, the energy absorption was measured at an impact velocity of 500 m/s. The energy absorptions were then normalized by the panel areal densities. It can be shown that in all circumstances, the opposite procedure offers better outcomes than positioning the Kevlar fabric near the impacting fabric. This is thought to be due to Kevlar having a greater inter-yarn friction coefficient than Dyneema [1].

Ballistic Impact on Hybrid Laminated Composite

Laminated composites should be able to withstand high- and low-velocity impacts in general. The resistance to high velocity impact should be prioritized for high performance laminated hybrid composite structural applications [2]. Laminated hybrid composites are prone to impact reactivity given their high specified strength and stiffness. The analysis of the ballistic effects implies and the source of damage for laminated composites is complicated, and the amount of complexity grows with impact velocity due to some parameters such as fiber friction, volume and composition of the fiber and matrix, geometry, and layup technique.

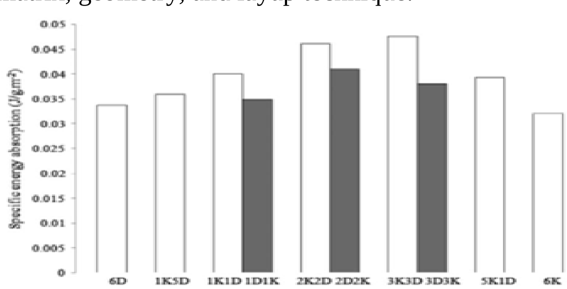

Fig Energy absorption for different panels

Figure 1 also analyses the specific energy absorption of hybrid panels with different component ratios (energy absorption normalized by areal density) [5]. The combinations of 50% Kevlar and 50% Dyneema fabrics had the maximum specific energy absorption, whereas the single-phase Kevlar fabric panel has the lowest performance of all the panels studied. Furthermore, panels containing Kevlar fabric at the impact face absorb more energy than the reversed sequence (3K3D over 3D3K) [3].

It is also important to note that increasing the number of fabric layers in hybrid panels increases ballistic performance, especially in panels containing Kevlar fabrics at the impacting face. Tables 1 and 2 illustrate the values of yarn mechanical characteristics for Dyneema and Kevlar yarns, respectively.

E_{11}	E_{22}	E_{33}	G_{12}	G_{13}	G_{23}	V_{12}	V_{13}	V_{23}
130	1.21	1.21	3.28	3.28	0.504	0.2	0.2	0.2

Table 1: Material Parameters for Dyneema

E_{11}	E_{22}	E_{33}	G_{12}	G_{13}	G_{23}	V_{12}	V_{13}	V_{23}
78	1.21	1.21	3.28	3.28	0.504	0.2	0.2	0.2

Table 2: Material Parameters for Kevlar

A double-layer setup was used to investigate the impact of stacking sequence. Figure 2 presents the temporal history of energy absorption for four panels, namely 1D1K, 1K1D, 2K, and 2D [6]. Although the fracture times initially looked to be identical, the gap widens after 4 µs. The 1K1D panel exhibits the more amount of energy absorption (5.2 J) among the four double-layer panels, according to FE findings [4]. Combining with the reversed sequence yields poor results, whereas single-phase systems yield average results.

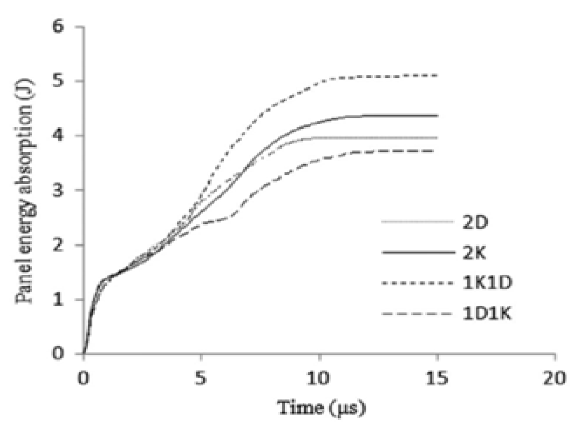

Fig 2 : Energy absorption vs Time

The transverse inclination of contour plots of a ballistic event of panel 1K1D with one main yarn for each layer was explored at four crucial time points [7].

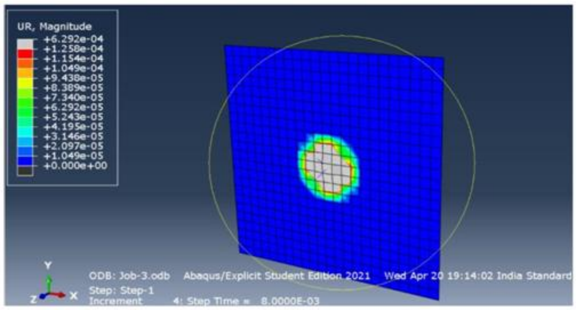

Fig 3 Impact of the projectile on Hybrid Laminated Composite

From the above we can be able to see the impact of the projectile in terms of the magnitude. And the projectile with speed of 510m/s and here the kinetic energy is observed by the fibers[8].

CONCLUSION

Panels were created using Dyneema and Kevlar fabric materials for flexibility and ballistic impact performance. At low panel areal densities, it was discovered that single-phase Dyneema panels absorb more amount of energy than Kevlar panels. When the number of fabric layers was increased, the Dyneema panels absorbed less energy than the Kevlar panels.

The ballistic results for hybrid panels made up of the two kinds of textiles revealed that placing the Kevlar fabric just on impact face is preferred due to increased energy absorption.

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