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Ballistic impact studies on carbon and E-glass fibre based hybrid composite laminates

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Abstract

The present study is aimed at developing Carbon and E- glass based hybrid composite lamiantes for armour applications in order to get advantages of both the types of fibers. Three hybrid composite laminates based on carbon and E-glass in the weight ratio of 75:25, 50:50 and 25:75 with epoxy resin matrix were fabricated. For comparison purpose all carbon (C 100) and all E-glass (E 100) composites were also fabricated. High velocity impact tests were performed on laminates keeping carbon as strike face against 7.62 mm mild steel projectile. Present study revealed that the composite laminates comprising carbon and E-glass in the ratio of 50:50 (CE 50-50) has shown maximum performance in terms of energy absorption. It showed 17 % & 30% higher energy absorption than C 100 and E 100 composites respectively. Damage areas at front and rear sides as well as damage volume are determined and found that its increase with increase in thickness.

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Keywords: Hybrid composite laminate, ballistic impact, energy absorption, damage volume, carbon, E-glass.

1. Introduction

Ever increasing penetration capabilities of ammunition and demands from the users for increased mobility of fighting vehicles has put great impetus on composite armour fraternity to look for various options to design a lighter armour having better energy absorbing ability. Failure of armour involves a complex combination of failure modes like localized penetration, compressive, flexural, shear , etc. The prominence of thick laminate failures also

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varies along the thickness. One single reinforcement may not be able to show best possible performance against all these failure modes. One possible method to achieve better performance is by the use of hybrid composites, that are made up of two or more different fibres or resins using same matrix or vice versa. Combining two or more fibres in the composite laminate will provide performance improvement by the use of the merits of individual fibres. The synergy effect thus resulted due to different fibres is called 'hybrid effect'. The 'positive hybrid effect' is to obtain a composite property whose value is higher than the value obtained from the individual reinforcement [1]. Characterization of impact properties of these composites is very important to realise the intended applications. A great deal of work on low and high velocity impact studies of various hybrid composites is published in the literature. For example Naik et. al [2,3] carried out low velocity as well as ballistic impact experiments on Carbon and E-glass with epoxy matrix hybrid composites. They observed that the presence of carbon fabric layers on top and bottom of the hybrid composite shows improvement in energy absorption, decrease in displacement and increase in compressive strength after impact (CAI) for low velocity impact tests. Similarly for ballistic impact also the combination of E-glass and carbon improves ballistic limit velocity of hybrid composites. It was confirmed by V. S. Galvez et. al through simulation studies [4]. Zhang et. al studied the effect of stacking sequence on mechanical properties of carbon/E-glass based hybrid composites and concluded that the studied stacking sequence did not show any noticeable influence on tensile properties but affected significantly on flexural and compressive properties [5]. Effect of temperature and impactor geometry on performance of carbon, glass based hybrid composites under low velocity impact tests has been studied [6,7]. Munoz et al studied ballistic performance of 3D woven hybrid composites using glass/carbon/PE fibers with epoxy matrix. It was reported that 3D laminates are good energy absorbers for low velocity impact whereas for ballistic impact 2D hybrid laminates have shown better energy absorption [8]. Bouwmeester et al reported use of dyneema fibers in combination with carbon for making intralaminar hybrids for the improved impact and decreased aerial weight of the composite [9]. Aswani et al have carried out numerical simulations on hybrid composites based on kevlar, carbon and glass fibers and reported that stacking sequence of hybridized layers shows significant effect on ballistic performance [10].

All these studies were highlighted on use of hybrid composites and their sequence for better energy absorption under high velocity impact. However, there are no studies reported on optimization of hybrid composite configuration interms of volume fraction of different fibers. Our earlier studies have shown that the performance of composites varies significantly with its thickness of composites and velocity of impactor. Hence, it is important to study the behaviour of the hybrid composites as a function of thickness which is not reported in the literature. In addition to this most the reported studies were conducted on thin laminates i.e. 3-5 mm thickness which is very low thickness for the ballistic impact. Hence it will be a value addition to carry out a study on optimization of the hybrid laminates and their ballistic performance as a function of thickness.

2. Experiments

2.1. Materials& Methods

Epoxy resin (LY556) and Diamine hardener (HY1972) supplied by M/s. Huntsman Chemicals were used as a matrix in the present study. Commercially available E-glass fiber woven roving having 0.22mm thickness with 360 GSM was used as one of the reinforcements. Carbon fibre woven roving having thickness of 0.3mm with the same GSM was used as another reinforcement for the fabrication of hybrid composite laminates. Laminates were made through hand layup technique followed by hot pressing at 80 ºC under 40 bar pressure for 180 min. Three varieties of hybrid composite laminates were prepared by varying the weight ratio of Carbon: Glass fibers in the ratio of 75:25, 50:50 and 25:75. Composites with carbon fibre alone i.e carbon/epoxy (C 100) and glass fiber alone i.e. E-glass/epoxy (E 100) were also prepared for comparison purpose. Hereafter these composites shall be referred to C 100, CE 75-25 (Carbon:75% and E-glass:25%), CE 50-50, CE 25-75 and E 100 throughout this manuscript. Thickness of the laminates is 20mm. To study the effect of thickness, the laminates were prepared in four different thicknesses viz. 5, 10, 15 and 20mm, with the optimized configuration based on the initial results. Ballistic impact tests were carried out using 7.62 x 39 mm mild steel core service ammunition. The projectile was fired from AK-47 rifle at a distance of 10 m from target at normal impact angle. Details of the experimental setup and determination of