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Response of E-glass/epoxy and Dyneema® composite laminates subjected to low and high velocity impact

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Abstract

Energy absorption of two different types of composite laminates i.e. glass composite (E-glass/epoxy) and ultra high molecular weight polyethylene (UHMWPE) (Dyneema®) laminates were studied under low and high velocity impact. Instrumented drop weight impact tester was used for low velocities and sub machine carbine (SMC) gun was used for high velocity impact. Failure behaviour of both E-glass/epoxy and dyneema laminates during impact was studied and results of the energy absorption of the tested composite laminates have been presented. Dyneema laminates showed 2 times higher energy absorption than E-glass/epoxy laminate under high velocity impact. However, both the laminates have showed higher energy absorption at high velocity impact as compared to low velocity impact. Failure analysis on impacted laminates reveals that the E-glass/epoxy laminate undergoes elastic deformation, delamination and brittle failure of fibres, whereas dyneema laminates undergo plastic deformation and associated tensile stretching of fibres. The results obtained from this study bear significance in the development of light weight add-on and structural composite armours for the real time applications.

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

1. Introduction

Improving the combat survivability of armour personnel carrier (APC) vehicles and personnel protection is the important aspect of military technology. Hence it is essential to develop light weight composite armour systems. For the past two decades, glass fibre reinforced composites and ultra high molecular weight polyethylene (UHMWPE) fibre reinforced composites have gained considerable importance for structural and add-on armour applications due to their high specific strength and high energy absorption under dynamic loads[1,2].

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During service, armoured systems experience different low and high velocity impact loads due to tool drop, flying debris, bullets etc. Low velocity impact causes internal damage like debonding, matrix cracking etc. which cannot be seen by naked eye under normal conditions. However, it reduces the load bearing capacity of the composites and can lead to catastrophic effect on actual performance [3, 4].

Various researchers have studied the low velocity impact behaviour of glass composite laminates [5, 6]. Belingardi et al. carried out low velocity impact studies on unidirectional and woven glass/epoxy composite laminates in the velocity range of 0.7 to 2.42 m/s and determined the saturation impact energy as well as degree of damage. They observed that mechanical characteristics of glass/epoxy laminates were not sensitive to strain rate in the considered range of impact speed [7]. Kersys et al. investigated the influence of impact energy and force on energy absorption of carbon/epoxy and E-glass/epoxy composites and concluded that elastic deformation for E-glass/epoxy was 1.5 times higher than that of carbon/epoxy in the impact energy range of 2-28J [8]. Yang and Cantwell conducted a series of low velocity impact experiments on glass/epoxy composites to realize the effect of various parameters like target dimensions, impactor geometry and testing temperature on damage initiation threshold [9]. They observed that impact force required to initiate damage varied linearly with $t^{3/2}$, where t is the specimen thickness. Amaro et al. studied the influence of mulitiple impacts on glass/epoxy composite laminates and reported that sole impact energy was more detrimental relative to the cumulative damage from multi impact events [10]. Zang et al. carried out comparative study on low velocity impact of UHMWPE based laminates having different fibre architectures and showed that composites of single-ply 3D orthogonal woven fabric exhibited better energy absorption capacity and impact damage resistance as compared to unidirectional and 2D plain-woven fabrics [11].

High velocity impact studies were also carried out on few thermoset (carbon/epoxy, aramid/epoxy, etc.,) and thermoplastic laminates (aramid/polypropylene, etc.,) against armour picercing (AP) and mild steel projectiles. It was found that thermoplastic laminates experienced higher energy absorption than the thermoset laminates [12-16]. Reddy et al. studied the effect of projectile velocity and target thickness on the energy absorption of glass/phenolic composite laminates subjected to 7.62 mm mild steel projectile and observed a non linear behaviour in energy absorption with an increase in thickness [17]. Attwood et al. demonstrated that, the out of plane compressive response of Dyneema composite resulted in the generation of an indirect tensile stress within the fibres of the composite. Such a compressive stress state in general, is expected to get generated immediately under a projectile during the ballistic impact of a dyneema composite [18].

Though impact performance studies on E-glass/epoxy composites were extensively carried out by various researchers, there is a scanty information available on comparative performance of E-glass/epoxy (thermoset) and dyneema (thermoplastic) composites under low and high velocity impact. The reason for selecting these two materials is that, they are considered to be the best choice materials for making structural and add-on composite armour systems. Hence the objective of this study is to compare the energy absorption efficiency of E-glass/epoxy and dyneema composite laminates under low velocity impact using 16mm diameter steel impactor and high velocity impact using 9mm full metal jacket (FMJ) led projectile. Another objective is to study the failure behaviour of the laminates through visual observations and high speed video camera and to propose how failure mechanisms change for E-glass/epoxy and dyneema laminates at low and high velocity impacts.

2. Experiments

2.1. Materials& Methods

Epoxy resin and hardener (LY556, HY5200) from M/s.Huntsman chemicals was used. Commercially available E-glass woven roving was used as reinforcement. Dyneema® HB50 prepreg fabric was procured from M/s DSM, The Netherlands. E-glass/epoxy laminate was prepared by hand layup technique followed by hydraulic hot pressing. Dyneema laminate was made by laying up the as received prepregs followed by hot pressing. Cure conditions for the fabrication of the above laminates were followed as per supplier's recommendations. Epoxy resin was cured at 120 °C and 160 °C under 40 bar pressure. Dyneema laminate was cured at 125 °C under 170 bar pressure. Thickness of fabricated composite laminates was controlled at 5±0.2mm. Specimens were cut in to the dimensions of 150 x100 mm for low and high velocity impact tests.