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ScienceDirect

Procedia Engineering 173 (2017) 175 – 181

Procedia Engineering

www.elsevier.com/locate/procedia

11th International Symposium on Plasticity and Impact Mechanics, Implast 2016

Energy absorption characteristics of Carbon /Epoxy nano filler dispersed composites subjected to localized impact loading.

Pushparaja M[a], Balaganesan G.[a]*, Velmurugan R.[a], Gupta N. K.[b]

[a]II T Madras, 600036, Chennai, India

[b]IIT Delhi, 110016, New Delhi, India

Corresponding author: *gbganesh@iitm.ac.in

Abstract

Energy absorbing capacity of carbon/epoxy nanocomposite laminates subjected to impact loading is studied in this paper. Nano fillers of 1% to 5% are dispersed in the epoxy matrix. The laminates with and without nano filler are prepared by hand lay-up and compression moulding process. Nanocomposite laminates and carbon/epoxy laminates are subjected to impact testing by using a gas gun with spherical nose cylindrical projectile. The velocity of impact is above the ballistic limit of the laminates. Energy absorbed by the laminates is calculated from initial and residual velocity of the projectile. The energy absorbed by the laminates in various failure modes and influence of nano filler dispersion are analyzed. It is observed that dispersion of nano filler in the matrix enhances the energy absorbing capacity of carbon/epoxy laminates during impact loading.

Peer-review under responsibility of the organizing committee of Implast 2016

Keywords: Nanocomposites; Carbon/Epoxy; Impact loading; Energy absorption

1. Introduction

For the past few decades, extensive studies were carried out for synthesizing new variety of materials and improving the mechanical properties to replace traditional metals in many applications such as aerospace, military, container and high pressure applications. In that connection, composite materials and nanocomposites are finding attractive solution due to their superior mechanical properties and light weight. [1]. Moreover, unlike other polymer

* Corresponding author. *Email address:* gbganesh@iitm.ac.in

Peer-review under responsibility of the organizing committee of Implast 2016

doi:10.1016/j.proeng.2016.12.055

composites, carbon fiber reinforced composites exhibit excellent damping properties, enhanced electrical, high resistance, thermal conductivity, rigidity and lower density and also uses of CFRP(Carbon Fiber Reinforced Plastics) are inexorable in protective structures and high pressure applications. However, these phenomena aren't sufficient enough to conclude the promising design criteria for material to replace the traditional materials, since polymer composites are brittle in nature. Also, on account of poor performance in dynamic loading conditions and absorb mechanical energy through only elastic behavior [2], investigating impact resistance and ability of absorbing energy would be one of the important manifestations to achieve the desire improvements [3].

Impact damages are vulnerable threats to polymer composites material's structural integrity that even causes invisible interlaminar damages to visible penetration of the targets, depending on target speed and type [4]. Unlike, low speed impact events, as reported in [5], in the ballistic impact events, contact time between target and structure is comparatively very less and induces localized damage in the laminate. At the impact of velocity below the ballistic limit, vibration of target laminate absorbs more energy than the failure of laminate in delamination and matrix crack [6]. The energy absorbed by the laminates above the ballistic velocity is due to failure of fibers, deformation of secondary fibers, delamination and matrix crack in delaminated area [7].

The mechanical properties of CFRP can be enriched by hybridization of active matrix system with micro or nano fillers reinforcements such as nano clay, Al2O3, CNT and etc., [8]. Addition of nano fillers in composite materials increases interlaminar strength with lower percentage of filler dispersion in the matrix [9]. On other hand, increasing these phenomena serves in increasing mechanical properties as well as impact resistance and energy absorption capacity. Very first study on nano fillers reinforced composites materials performed by Toyota Central Research Laboratories and proved that intercalating polymer into silica layers provided strong interface between organic and inorganic phases that leads to considerable improvements on mechanical properties [10]. Yuvan et al. studied nano fillers dispersed CFRP and reported that montmorillonite nano clay modified TGDDM epoxy system increase the interlaminar fracture toughness by 85 % when 4% nano clay dispersed in matrix. Also small amount of nano clay presence increase the flexural strength by 38% [11]. Velmurugan et al., demonstrated a comparison study between modified and unmodified nano Garamite as filler elements in epoxy that revealed homogenously dispersed orgono clay and unmodified clay improved hardness, mechanical properties, thermal properties and stiffness. Moreover, Considerable improved properties are estimated in modified orgonoclay dispersed epoxy system compares with unmodified clay. They also reported that treated montmorillonite dispersed epoxy resin system and composites possess superior tensile strength over unmodified clay dispersed epoxy resin system [12]. Balaganesan et al. investigated energy absorbing mechanism of nanoclay loaded glass fiber reinforced composites (GFRP) elaborately and they confirmed that addition of nanoclay act as a secondary fibers and improves energy absorption capacity and ballistic limits in dynamic loading [13] and also optimum loading of 5% nano clay in GFRP is absorbed more energy and deformation of laminates absorb 70% of projectile energy irrespective of projectile velocity and nano clay loading [14]. Kosar Iqbal at al. verified the influence of nano fillers in CFRP under low speed impact events and they reported that nano clay presence brought significant improvement in damage tolerance and impact resistance [15]. There are limited studies on ballistic impact of carbon fiber reinforced nano composites.

The purpose of this article is to investigating the influence of nano particles in ballistic performance and energy absorption behavior of carbon fiber reinforced composite materials. Nano fillers of 1% to 5% are dispersed in the epoxy matrix. The laminates with and without nano filler are prepared by hand lay-up and compression moulding process. Nanocomposite laminates and carbon/epoxy laminates are subjected to impact testing by using a gas gun with spherical nose cylindrical projectile. The velocity of impact is above the ballistic limit of the laminates. Energy absorbed by the laminates is calculated from initial and residual velocity of the projectile. The energy absorbed by the laminates in various failure modes and influence of nano filler dispersion are analyzed.

Nomenclature

E_{frac} Energy absorbed by tensile failure
E_{defv} Energy absorbed due to deformation