

# Charpy Impact Response of Glass Fiber Reinforced Composite with Nano Graphene Enhanced Epoxy

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## Article Info

### Article history:

Received May 30<sup>th</sup>, 2017

Revised Aug 20<sup>th</sup>, 2017

Accepted Oct 18<sup>th</sup>, 2017

### Keyword:

Graphene nano platelets, epoxy, glass, composite, low velocity impact

## ABSTRACT

Fiber reinforced polymer composite materials show several superior properties over conventional engineering materials; on the other hand, most of composite materials also have some drawbacks such as brittle behavior of matrix. This study is aimed to improve the impact response of composite material by adding nano particle into epoxy matrix. For this purpose; an experimental study was conducted to investigate the effect of graphene nano particles inclusion in epoxy resin with glass fiber reinforced composite plate on the Charpy impact response. Glass fiber reinforced (GFR) epoxy composite plates were produced with various graphene nano platelets content such 0, 0.1, 0.25 and 0.5 wt%. Low velocity impact response was investigated by using Charpy impact test method. Impact energy and impact damage results presented in detail.

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## 1. Introduction

In the past few decades, composite materials have been focused more by the engineering and research world due to their superior performance to weight ratio compared to conventional engineering materials. With these superior performance characteristics, fiber reinforced polymer (FRP) composites have seized the supremacy of usage in marine, aerospace, automobile, and construction industries. In fiber reinforced polymer composites, as the name suggests, fibers are used as a reinforcement materials into resins. Glass fibers are widely used reinforcement type due to their low cost (compared to Kevlar, carbon) and good mechanical properties. And, resin material can be polymer, ceramic or metal based. Epoxy is one of the most used polymer type as resin material. The brittle and poor impact resistance nature of resin has led the researchers to improve these properties of resin with adding micro and nano-sized particles to resin material. Riley et al [1, 2] found that the inclusion of large particle in matrix adversely affects the impact properties of material, since

they can act like a crack initiation site. Also, they stated that the presence of nanosized fillers can affect the morphology of polymers and improve the toughness of materials in consequence of crack deviating processes.

Carbon nano materials have attracted a huge attention because of their remarkable mechanic, thermal and electrical properties since their discovery [3]. Graphene nano platelets (GnPs) which has been recently developed single layered carbon nano material is a useful polymer reinforcement material which has a large surface area led to increase the stress transfer between polymer and nano material [4, 5, 6, 7]. Graphene has a 2-D nanostructure and leads an enhancement in toughness of fibers [8, 9]. Several researchers reported that the graphene nano material addition in the fiber reinforced composites significantly affects the mechanical [10, 11], dynamic [12], thermal [13] and electrical [14] properties materials. Madhukar et al. [15] stated that GnPs inclusion in unidirectional composites significantly increased the interfacial adhesion and interlaminar shear strength as well as the flexural and tensile properties. Rafiee [16] concluded that the 0.125 wt% GnPs incorporation in graphene/epoxy nanocomposite the fracture energy was increased about 115%. Bulut [17] studied the effect of GnPs on the tensile, flexural and impact properties of Basalt fiber reinforced epoxy composite and stated that the addition of 0.1 wt% GnPs resulted the increase in impact strength of composite material.

In this study, the influence of graphene nano platelets on the low velocity impact behavior of glass fiber reinforced polymer composites will be investigated experimentally by conducting Charpy impact test. The change in energy absorption property and impact strength will be characterized at different weight ratios of nano material.

## 2. Materials and specimen preparation

### 2.1 Materials

Glass plain fabric having areal weight of 202 g/m<sup>2</sup> and thickness of 0.15 (±5%) mm produced by Hexcel Corporation, Italy was used as reinforcement phase. Chemical products of epoxy (MOMENTIVE-MGS L285) and hardener (MOMENTIVE –MGS H285) were supplied from DOST Chemical Industrial Raw Materials Industry in Turkey. Graphene nano Glass plain fabric having areal weight of 202 g/m<sup>2</sup> and thickness of 0.15 (±5%) mm produced by Hexcel Corporation, Italy was used as reinforcement phase. Chemical products of epoxy (MOMENTIVE-MGS L285) and hardener (MOMENTIVE –MGS H285) were supplied from DOST Chemical Industrial Raw Materials Industry in Turkey. Graphene nano platelets were supplied from GrafNano Technological Materials Industry & Trade Ltd. Co., Turkey. Nanomaterial has purity of 99.5%, bulk density of ~ 0.05 g/cm<sup>3</sup>, 5 µm diameter of graphene, thickness of 5–8 nm, and specific surface area of 150 m<sup>2</sup>/g, as well as Raman spectra ID/IG Ratio of 0.08 and XRD 2-theta of 26° peak.

Table 1. Material properties

Material	Density	Thickness
Glass Fabric	202 g/m <sup>2</sup>	0.15 mm
Graphene Nano Platelets	50 kg/m <sup>3</sup>	5-8 nm
Epoxy Resin	1.18 g/m <sup>3</sup>	-

### 2.2 Sample Preparation

The composite material preparation was carried out by vacuum infusion method in Fig.1. Twelve plies of glass fabric were cut into a certain size and laid by [0/90] lay-up sequence. Matrix phase was prepared by mixing the epoxy with hardener in the 100:40 weight ratio as well as different amounts of GnPs (0.1, 0.25 and 0.5 wt%). After epoxy was mixed with GnPs filler, the mixture was stirred for 20 min to reach a good dispersity. Following this step, the mixture was stirred with hardener for 10 min. During composite production, first, all twelve plies were laid on to a thin release agent on production desk, then peel ply and resin infusion mesh were laid on the fabrics. And finally, vacuum bag was sealed onto mesh. After these steps, resin mixture was transferred with the help of vacuumed bag. When the resin mixture impregnated, the

composite material subjected vacuum 10 h curing time and under temperature of 45 °C for 5 h. Nominal thickness of samples was measured as  $2.1 \pm 0.1$  mm.

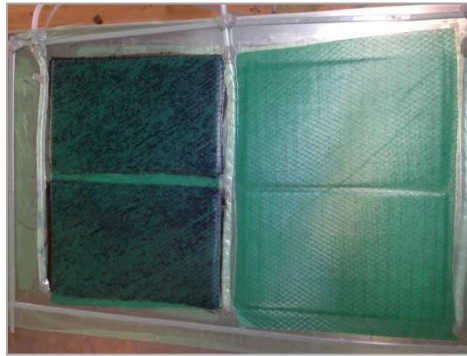


Figure 1. Composite plate production

### 2.3 Charpy Impact Test

In this test, Charpy tests were performed following ISO 179/92 standard [18] with Köger 3/70 Charpy impact test device shown in Fig.2. Both notched and unnotched test specimens with dimensions of 55 x 10 mm as seen in Fig. 2(b) were subjected to impact loads flatwise and edgewise respectively. In Charpy impact test device, a pendulum with a defined mass attached to a rotating arm connected to device body. Pendulum falls from a certain height and hits the test specimen and specimen absorbs part of pendulum's kinetic energy. The absorbed impact energy and impact strength of material were calculated as follows:

$$E = E_1 - E_2 \quad (1)$$

$$U = E/(bh) \quad (2)$$

where  $E$  is the absorbed energy after impact,  $U$  is the impact strength,  $E_1$  and  $E_2$  are initial and final potential energies,  $b$  and  $h$  are width and thickness of the specimen respectively.

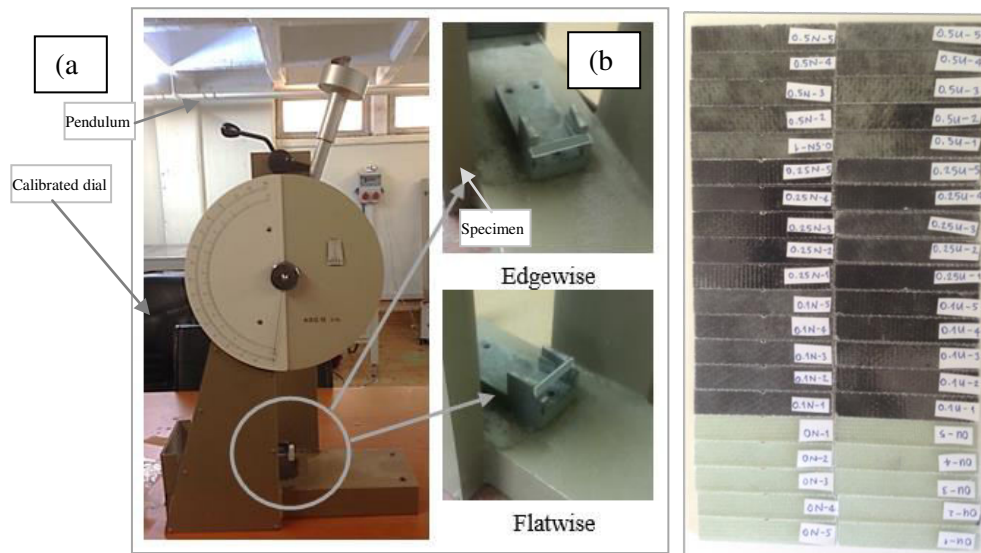


Figure 2. (a) Charpy impact test device and specimen positions, (b) Test specimens

### 3. Results and Discussions

Impact resistance of glass reinforced composite samples was investigated by using Charpy impact test. In experiments notched and unnotched specimens were subjected to impact energy of 15 J at room temperature. Fig. 3 presents the absorbed energy values of specimens with respect to GnPs contents. It can be seen that subsequent the inclusion of nano particle to matrix, absorbed impact energy values increases drastically. Maximum absorbed energy was reached with the 0.5 wt% GnPs inclusion. It was 123% greater for notched

and 41% greater for unnotched specimens than the neat epoxy/glass specimens. In case of impact strength, the variation had the same increasing profile with the absorbed energy variation with respect to GnPs contents. Increase in impact strength can be interpreted as enhancement in bonding between fiber-matrix and nanoparticle. This enhancement also leads to the increase in energy absorption capacity.

The fractured notched and unnotched test specimens after impact load can be seen in Fig. 5. And, it can be observed from figures, delamination failure first decreased 0.25 wt% GnPs content, until 0.5 wt%. Also, multiple fiber breakage failure decreased with the GnPs inclusion.

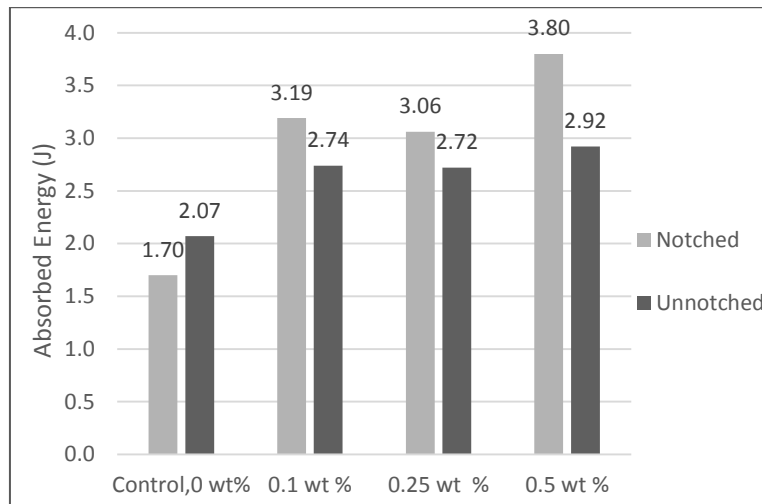


Figure 3. Absorbed energy of notched/unnotched impacted glass fiber reinforced epoxy composites with respect to GnPs content

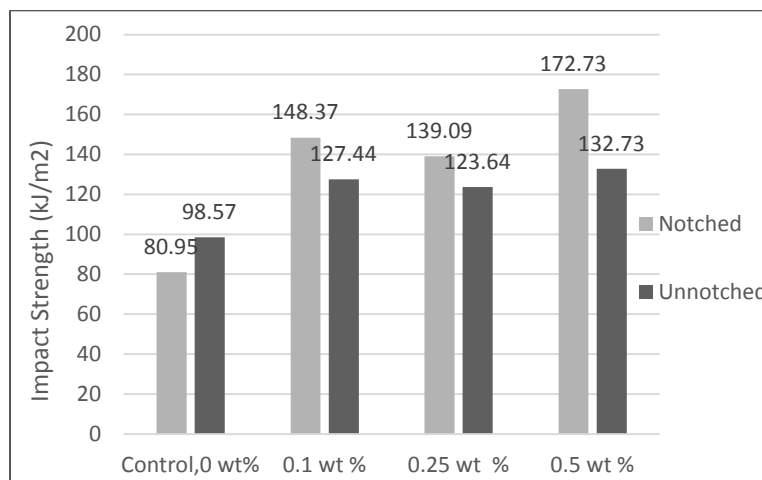


Figure 4. Impact strength of notched/unnotched impacted glass fiber reinforced epoxy composites with respect to GnPs content

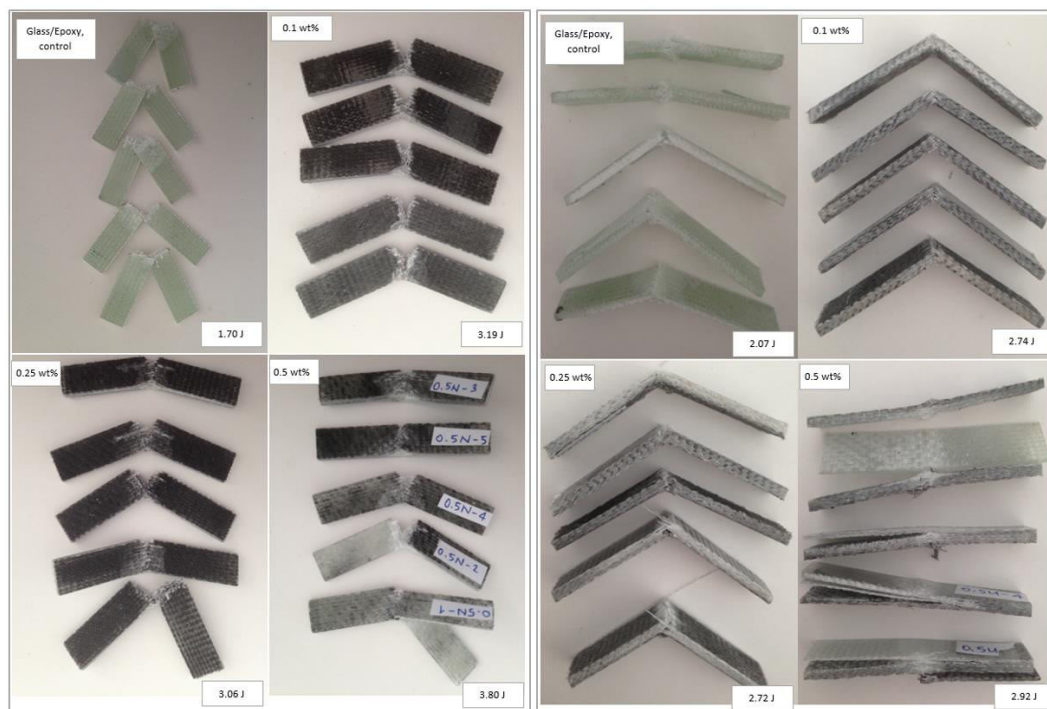


Figure 5. Fractured notched and unnotched specimens

#### 4. Conclusions

During experimental study, the Charpy impact properties of glass fiber reinforced (GFR) composite under graphene nano platelets inclusion were studied using notched and unnotched specimens. It can be concluded as the GnPs inclusion in GFR composite improves the impact strength of the material as well as the energy absorption capacities. For notched specimens, this improvement was 123% and 41% for unnotched specimens in terms of absorbed energy by 0.5 wt% GnPs content. However, presence of delamination failure increased with this content, and it can be interpreted because of nano materials' nature, the agglomeration in particles takes place with the higher content of nano materials.

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