



Effect of Graphene Oxide Nanoparticles on the Mechanical Performance of Kevlar/Epoxy Composites After Thermal Exposure

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Abstract

This study examines the influence of graphene oxide (GO) nanoparticles on the mechanical properties of Kevlar/epoxy composites after thermal treatment at 150°C for 10 minutes. Specimens were prepared with four different GO concentrations: 0%, 0.5%, 1%, and 1.5% by weight. Tensile testing was conducted according to ASTM D3039, and key parameters such as ultimate tensile strength, fracture strain, and absorbed strain energy density were extracted. Results show that the addition of 1% GO led to the highest improvement (approximately 16% increase in strength), while 1.5% caused a slight reduction due to nanoparticle agglomeration and stress concentration.

Keywords: Graphene, nano, mechanical, composite, thermal

1. Introduction

Kevlar/epoxy composites are well-known for their favorable strength-to-weight ratio and reliable performance under moderate temperatures. They are widely used in safety applications, including firefighting gear such as helmets and gloves. Graphene and its derivatives—such as graphene oxide (GO)—exhibit exceptional mechanical stiffness, thermal conductivity, and surface activity, making them valuable nano-fillers in polymer matrices. This study aims to evaluate the extent to which GO improves the mechanical performance of Kevlar/epoxy composites after exposure to elevated temperatures.[1-19]

2. Materials and Methods

2.1 Materials

- Bidirectional Kevlar fabric (0.5 mm thickness, 450 g/m² density)
- Thermoset epoxy resin with hardener (weight ratio 80:20)
- Graphene oxide nanoparticles (GO), particle size approx. 5–10 nm

2.2 Preparation Process

1. Cutting five layers of Kevlar fabric (16×25 cm), each weighing approximately 80 g
2. Measuring 64 g of epoxy and 16 g of hardener per batch
3. Accurately weighing GO for each batch: 0%, 0.5%, 1%, and 1.5% by resin weight
4. Dispersing GO using ultrasonic mixing.

2.3 Composite Fabrication (Hand Lay-up)

- Laying fabric sheets onto a flat mold
- Applying mixed resin with a brush and compressing with a roller
- Stacking five layers to reach a final thickness ≈ 2.5 mm
- Initial curing in oven: 2 hours at 80°C.

2.4 Sample Cutting and Heat Treatment

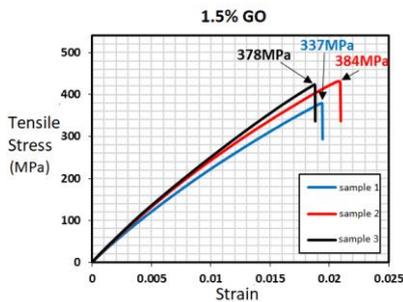
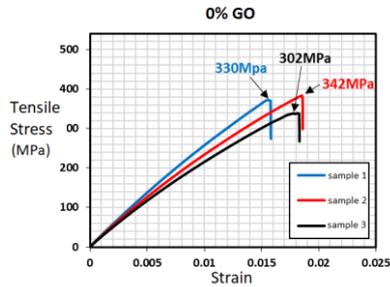
- Tensile specimens: 250 mm total length, 25 mm width, 150 mm gauge length (ASTM D3039)
- Cutting samples using a precision blade
- Thermal exposure: 10 minutes at 150°C simulating firefighter conditions

2.5 Tensile Testing

- Machine: Gotech tensile tester with screw-driven grips
- Displacement rate: 2 mm/min

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- Recording force–displacement curves and converting to stress–strain
- Each group: 4 samples tested; one sample discarded due to cutting damage
- Tensile testing was conducted in accordance with ASTM D3039 standard for polymer matrix composites.



3. Results and Analysis

3.1 Tensile Strength and Fracture Strain

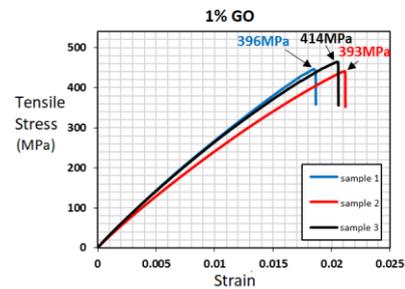
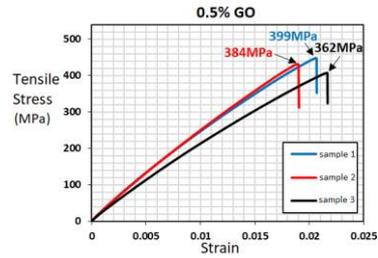


Table 1 summarizes the average tensile strength (σ_u) and fracture strain (ϵ^f) across different GO concentrations:

GO (%)	Avg. σ_u (MPa)	$\Delta \sigma_u$ vs. Control	Avg. ϵ^f (%)
0	325	—	1.80
0.5	382	+17.5%	2.09
1.0	401	+23.4%	2.08
1.5	366	+12.6%	1.90

- 1% GO yielded the highest increase in strength (≈ 401 MPa)
- 1.5% GO showed a slight decline due to agglomeration
- Fracture strain showed minor improvement but remained $< 3\%$

3.2 Force–Displacement and Stress–Strain Behavior

- All graphs showed linear elastic behavior with brittle failure
- 1% GO group had the steepest slope, indicating higher stiffness:

3.3 Strain Energy Density

Energy absorbed per unit volume (w) was calculated from the area under the stress–strain curve:

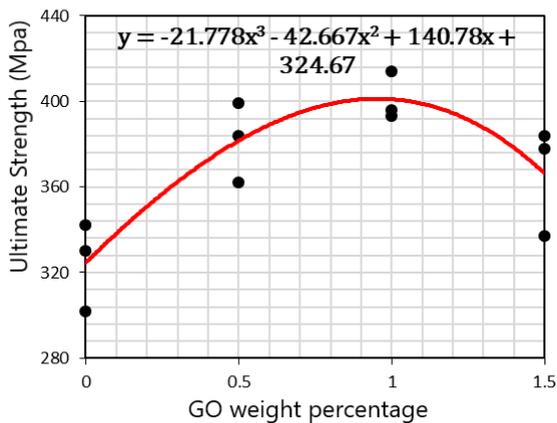
GO (%)	Avg. w (MJ/m ³)
0	3.56
0.5	4.78
1.0	5.02
1.5	4.48

- 1% GO recorded maximum energy absorption
- Increasing beyond 1% reduced energy due to particle clustering

3.4 Empirical Modeling

A third-order polynomial regression was developed to model σ_u versus GO concentration (r): $\sigma_u(r) = -21.78 \cdot r^3 - 42.67 \cdot r^2 + 140.78 \cdot r + 324.67$.

Ultimate tensile strength as a function of GO weight percentage



4. Conclusion

Adding 1% GO to Kevlar/epoxy composites results in a significant boost to mechanical performance post-heating, with a 23% increase in tensile strength and 41% increase in absorbed strain energy. Beyond this concentration, nanoparticle agglomeration reduces effectiveness. Fracture mode was brittle across all groups, and stress-strain graphs were consistent with similar studies.

5. Recommendations

1. Use surface-modified GO (e.g., silanized or polymer-functionalized) for improved dispersion
 2. Compare GO with alternative nanofillers such as CNTs, nanoclay, or metal oxides
 3. Evaluate fatigue, impact, and creep performance under varied temperatures
 4. Investigate behavior under extended thermal cycles (up to 300°C)
 5. Apply numerical simulations to study heat-induced damage and mechanical failure
- Kirsch and Stechkina presented the fan model in 1975, which can be used in both continuous and discontinuous flow regimes:

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