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# Mechanical Properties of Alumina Nano-Particles and Glass Fiber, Kevlar Fiber Reinforced Composites

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**Abstract:** In this study, the study of mechanical properties of Kevlar/glass fiber hybrid composite laminate with nanoparticles. Composite laminates were fabricated using vacuum bagging process with a phenol-formaldehyde, epoxy matrix reinforced with twill Kevlar weaved fiber and plain glass was woven fiber. Four different types of composite laminates different (polymer composite and nanoparticles ($AL_2O_3$)), polymer composite and glass fiber, polymer composite and glass fiber and Kevlar ) were manufactured. The effect of Kevlar/glass fiber content on the mechanical properties (hardness, tensile and impact ). Results indicated that hybridization of Kevlar fiber to glass fiber improved the hardness values, impact energy absorbed with a slight reduction of tensile strength of fibers that were spun with Kevlar fibers and of composite laminates.

**Key words:** Kevlar fiber, glass fiber, polymer composite, hybrid composites, phenol-formaldehyde, fiber

## INTRODUCTION

Several studies have been conducted to improve the mechanical properties of reinforced fiber compounds due to the increasing demand for these materials in the sectors of machinery, marine, aviation, military machinery, petroleum and sports equipment (Mohanty and Srivastava, 2012). Most studies have focused on promoting single natural or synthetic fibers such as carbon fibers, fiberglass, Kevlar fibers, Kenav, jute, hemp, abaca, sisal and many others for polymer matrix this is due to good mechanical properties, good corrosion resistance and design flexibility compared to metals (Shaari *et al*., 2014). The use of vehicles has increased widely due to the development of new fibers such as carbon, glass, Kevlar and new composite systems with ceramic and metal matrices. The wide use of epoxy as matrix materials to manufacture of glass fiber composites because improving mechanical properties and good chemical resistance and their ability to distort the influence of forces (Kaybal and Ahmet, 2016). Another polymeric substance mixed with epoxy is phenol formaldehyde resin, one of the polymers made up of two basic materials.

Formaldehyde and phenol. Phenol is a colorless, odorless solid compound used in the manufacture of plastic materials including drinking water cans, clothing manufacturing and multiple medical. Recently, epoxy has been reinforced with nanoparticles to improve the mechanical properties of compounds such as nano $Fe_2O_3$/propane/epoxy, nano $SiO_2$/epoxy (Bakar *et al*., 2014) net/epoxy (Kaybal and Ahmet, 2016) and nano-clay/epoxy, the optimal utilization of nanomaterials to improve the performance of mechanical properties is generally determined by the degree of dispersion, impregnation with matrix and interstitial adhesion (Khoee and Hassani, 2010).

The advantage of nano-scaling compared to micro-fillers is the large surface area which can serves as a stress management interface and improves hardness and abrasion resistance (Chandramohan and Bharanichandra, 2013). Studies published, so far have focused on improving the mechanical properties of polymer compounds, especially, improving the process of vehicle synthesis, using nanoparticles prepared. Improvements of property and performance that can be achieved by strengthening nanoparticles are beneficial for aluminum compounds or epoxy glass fibers used in high performance applications. Throughout the decades, the concentration of research was for improving the mechanical properties of polymers by fusing filaments and fillers research studies refreshing the condition of craft of polymer-based composites for auxiliary applications (Jin *et al*., 2010; Liu *et al*., 2017). A few examinations on mechanical portrayal of polymer framework and their composites strengthened with strands and fillers have been completed (Johnsen *et al*., 2007).

In this study, two synthetic fibers are glass fiber and Kevlar fiber have been hybridized as a reinforced material. They fibers reinforced with nanoparticles ($AL_2O_3$) and their effect on mechanical properties (hardness, tensile strength and impact strength) used in marine applications, sports equipment and military equipment.

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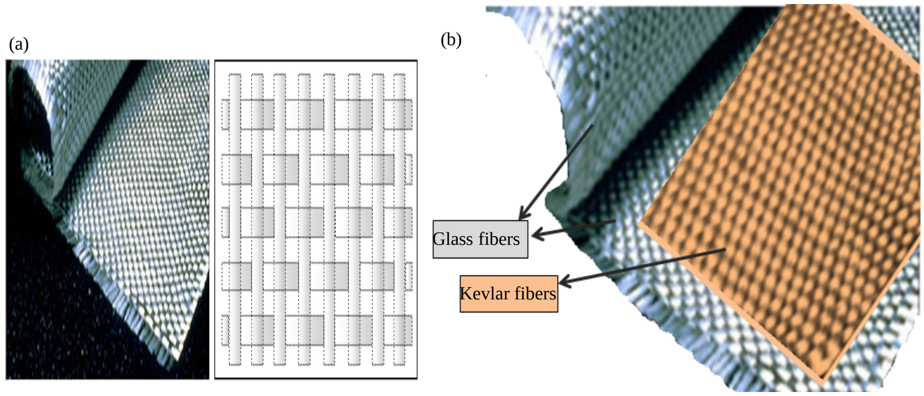


Fig. 1: The shape of the glass and Kevlar fibers

## MATERIALS AND METHODS

**Experimental:** In our study, commercially available $Al_2O_3$ (80 nm), particles are used to modify the polymer composite matrix (epoxy 80% and phenol formaldehyde 30%) as shown in Table 1. Nano fillers of $Al_2O_3$ were purchased from Hefei EV Nano Technology. Glass and Kevlar fiber used in the form of a woven mat, the epoxy which is used Sikadur-52 base as the (mixing ratio A:B = 2:1 parts by weight and by volume) the form of transparent viscous liquid at room temperature, the phenol formaldehyde used in the manufacture of plastic materials.

**Mixing process:** The phenol formaldehyde resin (20%) was mixed with epoxy resin with the ratio 20:80% as a matrix and the reinforcing material was three types as shown in Table 1.

Adding the nanoparticles $Al_2O_3$ of the ratio (2%) into the mixture and stirring it for a period of 30 min to obtain homogeneity (Kaybal and Ahmet, 2016). The rise in the temperature of the blend will result as an indication to the beginning of the association process (Khoee and Hassani, 2010). It is very important that the blend must have a decent consistency to protect the particles from precipitation which may bring the heterogeneity of the mixture that leads to the agglomeration after hardening. was manufactured using manual plucking method. The hybrid samples were arranged according to the following stacking sequence: the Kevlar fibers inside while the glass fibers were outside as shown in Fig. 1. So, emptying the blend into the mold as shown in Fig. 2 . Demonstrates of the mold shape at that point putting the glass fiber tangle into the form and proceeding of blend pouring until the point that it covers the whole tangle pressing the mixture with an appropriate load. To complete the way toward solidifying, all samples were prepared at room temperature and leaving the samples in the mold for a time 24 h at room temperature as shown in Fig. 2. The samples were then dried in a 65°C drying furnace for 4 h (Bakar *et al*., 2014).

Fig. 2: The shape of the prepared moulid

Table 1: Designation and composition of composites

| | Reinforcement (%) | | |
|---|---|---|---|
| Sample No. | Glass fibers (CF) (%) | Kevlar fibers Kf (%) | Nano $AL_2O_3$(A)(%) |
| ER3 (80% epoxy +20% phenol formaldehyde) | - | - | 2 |
| ER3+GF+Kf+$Al_2O_3$ | 20 | 10 | 2 |
| ER3+GF+Kf+$Al_2O_3$ | 30 | - | 2 |

Specimens of required dimensions for mechanical characterization are cut by laser machines, hardness of the composite polymer mixture was tested as per ASTM D2240 type (hardness shore D). The hardness value is shown on the display as appeared in Fig. 3.

The sample tensile tests were performed according to ASTM D638-Type 1 using the universal testing machine (Lloyds, capacity 1-50 kN testing speed was set at 5 mm/min and carried out at room temperature as shown in Fig. 4 and specimen dimensions are (115×25×3.5) mm,

Fig. 3: Shore D test

Fig. 4: Tensile test machine

Fig. 5: Impact test machine

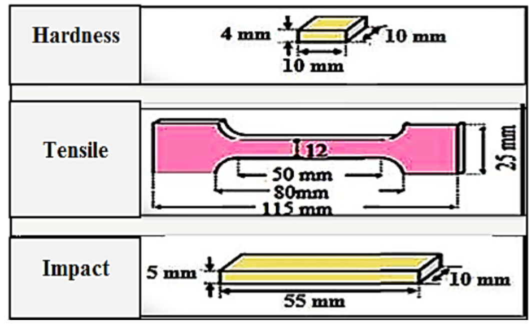


Fig. 6: Test samples of hardness, tensile and impact

charpy impact strength was performed according to ASTM-E23 as shown in Fig. 5, standard suitable to sample impact is Notch depth is (0.5 mm) and notch base radius is (0.25) mm, dimensions sample was (55×10×3.3) mm as shown in Fig. 6.

## RESULTS AND DISCUSSION

**Hardness (shore D):** It is clear that there is a pronounced effect of the addition 2% nanoparticle to the increases hardness values. Adding the nanoparticles will raise the hardness of the material due to increases in material resistance against the plastic deformation, since, the use of particles as a filler improves the hardness of the product, especially when using very small size particles (nanoparticles) because during the manufacturing process, the small particles are easy to penetrate into the base material and into the thousands of interfaces and interstices formed during the preparation process. Which in turn increases the area of contact between the components of the prepared material and thus, increases the coherent between them and in an integrated manner which gives more positive values when examining the hardness (Baker *et al*., 2010).

Result show that the hardness of epoxy and phenol formaldehyde with glass fiber is (68 shore D) compared to the hybridizing Kevlar fiber and glass fiber of maximum value (77) with the nanoparticles (2% $AL_2O_3$) because of the distribution of load on the fiber which reduces the penetration rate of the composite surface and increases the hardness values as shown in Fig. 7.

**Tensile strength:** Resins are fragile materials with resistance to tensile strength is very low equal to (90 MPa). Tensile strength is increased when the resin is reinforced by nanoparticles ($AL_2O_3$) to (200 Mpa). This is what we see in Fig. 8 when adding nanoparticles to polymer, since, the nanoparticles act as impediments to the movement of interferences within the base material

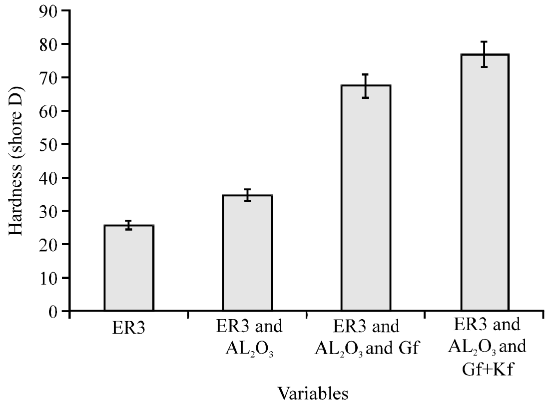


Fig. 7: The influence of hardness

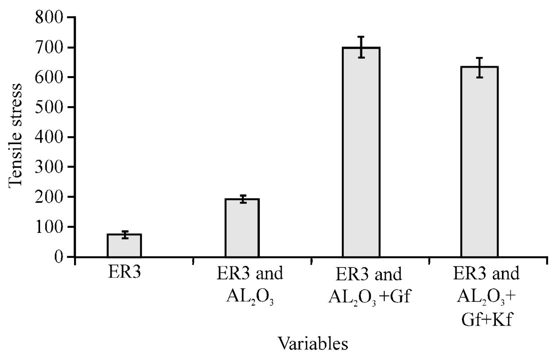


Fig. 8: The Influence of tensile strength

which reduces the possibility of plastic deformation and the density of the resin impact on the mechanical properties as the greater density of polymer increases the hardness, hardness and material abuse to increase the crystal property. The fibers are reinforced with fiber reinforced glass fiber gives a stronger matting strength to (680 MPa) while the fibers of hybridized fiberglass with Kevlar fiber gives tensile strength (630 MPa) because the use of fiber leads to the prevention of cracks and a deeper increase in the material where the fibers act as breakers, thus, reducing the possibility of plastic deformation resistance to submission (Fig. 9).

**Impact resistance:** Impact resistance of resin is generally low because of its fragility. The failure occurs in the non-corroded resin material undergone the impact test results in the breakdown of the bonds or forces in the polymer by the growth of the initial cracks caused by the impact stress. These cracks grow and multiply significantly and rapidly toward the interstitial interfaces between the polymer chains because the forces between these chains are vander waal forces that require little energy to overcome them.

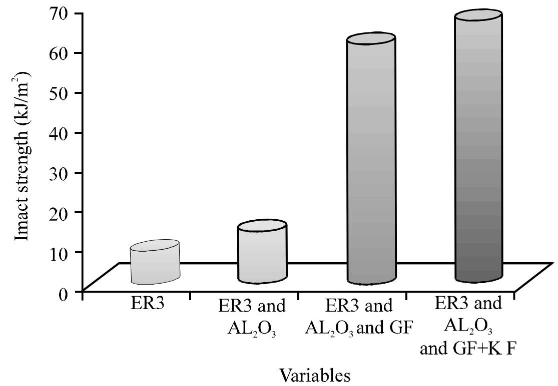


Fig. 9: The influence of impact energy

These cracks extending vertically in direction of the polymer chain destroy these chains during the distribution process to overcome those forces responsible for associating the covalent units with the covalent bonds. When the polymer material is reinforced with glass fibers, hybridized Kevlar fiber increase the energy needed for breaking polymer to (63 kJ/m$^2$) because the fibers bear the bulk of the energy as well as movement of units and relaxant ties between them, leading to the increases of the forces of interdependence between the molecular chains basis for the substance in which a great strain occurs, leading to improved impact strength lead to increase the impact resistance, since, the overlapping material passes through two stages before the failure. The first breaking the material and the second is the failure accrued in fibers undergone from rupture or dissociation of the base materials in which the energy spent for breakage is large (Liu *et al*., 2017).

## CONCLUSION

The mechanical properties of epoxy-phenolic formaldehyde resins are enhanced after addition of nanoparticles ($AL_2O_3$).

By the addition of nanoparticles $AL_2O_3$ as fillers increases the mechanical properties such as hardness, impact strength and tensile strength.

Hybridizing Kevlar fiber to glass fiber enhanced the hardness values and impact strength values.

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