

## Flexural Strength of Composite Materials Reinforced by Kevlar Fiber and Aluminum Oxide Nano-Particles

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**Abstract:** In this study, the theoretical method of measuring the bending strength of the composite material consisting of epoxy and phenol formaldehyde resins with aluminum oxide nano-particles was used with different weight ratios (10, 30, 50%) of woven Kevlar fiber (0-90°). To study the effect of different reinforcement under load variation on the flexural force of composite materials. Standard ASTM D790 was used to manufacture test samples in ANSYS (13). The theoretical results show that the high flexural strength of epoxy resin with phenol formaldehyde after reinforcement with kevlar fibers due to high elasticity coefficient of this fiber will increase with increased fiber ratio.

**Key words:** Flexural strength, aluminum oxide nano-particles, Kevlar Fiber, ANSYS program, composite material, formaldehyde

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### INTRODUCTION

The use of composite materials in the civil and military industry and the idea of strengthening particles or fibers are not new. Over the centuries, natural fibers such as grass or lint have been used to improve durability in mud houses and to reduce weight and reduce the use of fire for pottery. This idea was exploited with the development of glass, carbon and aramid with fiber (Rajab *et al.*, 2017a, b, 2018a, b). After the Second World War, polyester fiberglass was used for domes, airframe designs and some equipment. Composite materials supported by fiber glass were used in the late 1950's to produce and manufacture submarine shell casings. Research efforts in the market focused on aluminum and titanium. Boron fiber was the first result of this effort (1963) followed by carbon, beryllium oxide and graphite especially in the field of automotive applications (Rajab *et al.*, 2018a, b; Zheng, 2008). The main advantages of composite materials are low density, high bearing strength, hardness, good abrasion resistance and improved curing properties. As a result of these properties, traditional metals have been replaced with composite materials successfully (Rajab *et al.*, 2017a, b, 2017a, b). Polymer composite materials Some of the problems associated with conventional steel and other

polymeric materials can be solved in aircraft structures, cars, ships, pipelines, storage tanks, etc. which are made up of a mixture of two or more substances, each of which has physical properties or a substantially different chemical than it used to manufacture new material properties that differ from the properties of each of the original materials and a coherent structure resulting from the homogeneity of two different substances in terms of composition. Normal compounds differ in terms of type and order of supported particles (regular or random), fiber type (Mallick, 2007; Allah *et al.*, 2009). Composite materials are manufactured to improve the mechanical properties of resistance, hardness, durability and high temperature resistance. On the basis of this, composite materials reinforced with particles or fibers are classified (Rajab *et al.*, 2017a, b) Fig. 1.

Crticles can significantly improve mechanical properties, especially, when used to support composite materials without loss of thermal or mechanical properties (Mallick, 2007; Allah *et al.*, 2009). The three-point bending test shown in Fig. 2 shows that a rectangular sample is drawn from its ends and is centrally loaded (De Garmo *et al.*, 2008). Polymer nano-particles are a two-phase reaction, a polymer matrix and a solid phase in the nanometer scale. Polymer nano-particles are characterized by small particle sizes

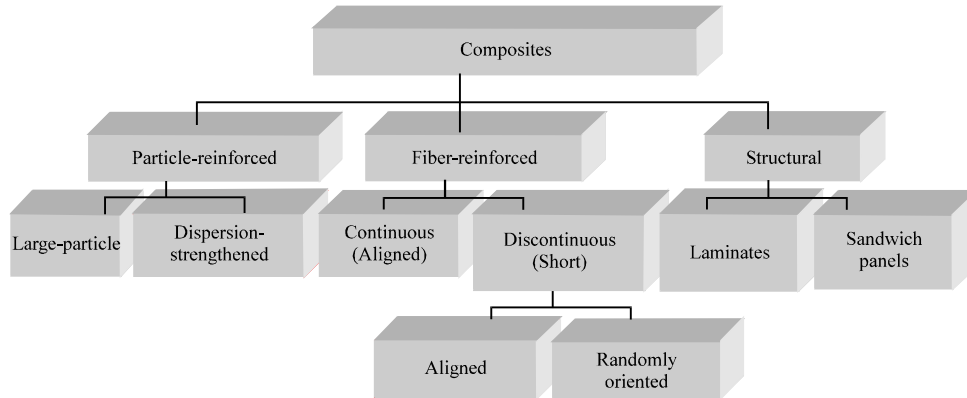


Fig. 1: A classification scheme for the various composite types (Rajab *et al.*, 2017ab)

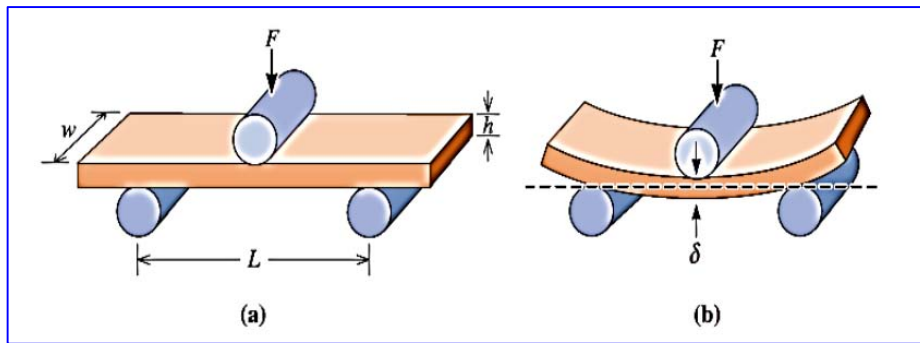


Fig. 2: a) The three-point bend test and b) The deflection  $d$  obtained by bending (De Garmo *et al.*, 2008)

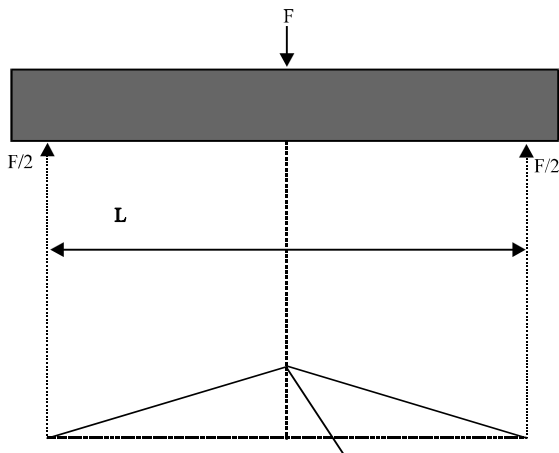


Fig. 3: Three-point bending test setup and force distribution (Allah *et al.*, 2009)

that greatly increase the interstitial area, leading to polymer interaction with nanoparticles. Incropera and De Witt (2000) Reinforcing the structure of polymer

nanoparticles plays an important role in improving properties through particle interaction which results in enhanced and greatly improved mechanical, thermal, electrical and optical properties without increasing in density (Incropera and De Witt, 2000; Al-Mosawi, 2009) (Fig. 3).

## MATERIALS AND METHODS

**Experimental procedure:** In this study ANSYS (13) was used to calculate the bending force value of epoxy resin and phenol formaldehyde (Rizole) before and after it was reinforced with different weight ratios of woven Kevlar fiber (10, 30, 50%). The fibers were reinforced using aluminum oxide nanoparticles. A theoretical and experimental match for the test after which the data obtained after the loads are applied. The properties of theoretical and experimental materials are supposed to be convergent. There should be homogeneity in the distribution of fibers and particles during the process of epoxy resin and

phenol formaldehyde reinforcement (Allah *et al.*, 2009).  
Where:

$$M = \frac{FL}{4} \quad (1)$$

$$M_m = \frac{hw^2}{6} \quad (2)$$

For rectangular beam the flexural strength ( $\sigma_f$ ) or modulus of rupture, describes the materials strength (Allah *et al.*, 2009):

$$\sigma_f = \frac{M}{M_m} \quad (3)$$

$$\sigma_f = \frac{3FL}{2h_w^2} \quad (4)$$

The modulus of elasticity in bending. The Young modulus in bending or the flexural modulus calculated in the elastic region of Fig. 5:

$$E_f = \frac{L^3S}{4hw^3} \quad (5)$$

where, S is the slope of the straight part of the force deflection curve (Allah *et al.*, 2009), stress and emotion are proportional to each other through the relationship of drawing test samples used including:

- Epoxy resin and phenol formaldehyde
- Homogeneous woven Kevlar fibers (0-90°) with aluminum oxide nanoparticle particles

Table 1 : Specifications used to draw test specimens

Model	Type of element	No. of element	No. of nodes
Linear	Solid 212 geometry, 8 nods, 3-D modeling	6235	12378

- Test samples used according to ASTM D790 standards which are manufactured by measuring rectangle (150×10×10 mm) (Table 1)

## RESULTS AND DISCUSSION

Figure 4 represents the flexural force of epoxy resin and phenol formaldehyde prior to reinforcement. Note that the bending strength of this resin is low when overloaded because resin is generally considered a fragile material which is accepted by experimental results. Figure 5 shows the flexural strength of epoxy resin and phenol formaldehyde, reinforced by 10% Kevlar fibers and Aluminum oxide nanoparticle particles where resin resistance increases due to fiber presence. And will be more increased as a result of the reinforcement of the resin by the aluminum oxide particles and thus, the high mechanical properties of the composite material. The flexural strength will increase with the added fiber ratio as shown in Fig. 6 and 7 which represents the flexural strength of epoxy and phenol formaldehyde resins after reinforcement using 30% aluminum oxide nanoparticles and 50% Kevlar fibers. These fibers will be distributed over a large area of resin which will greatly improve the flexural force.

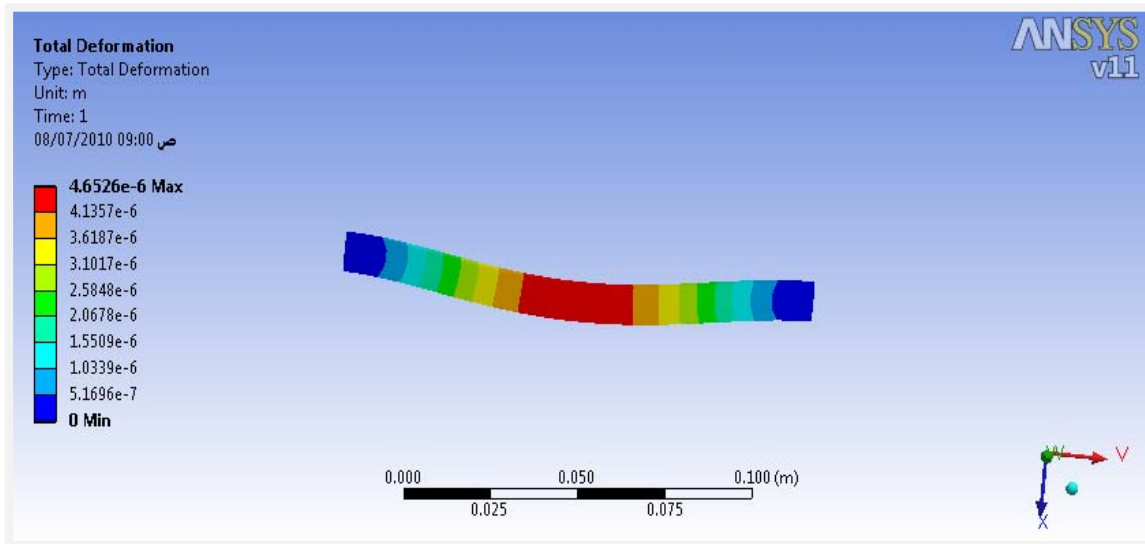


Fig. 4: Flexural strength to araldite resin before reinforcement

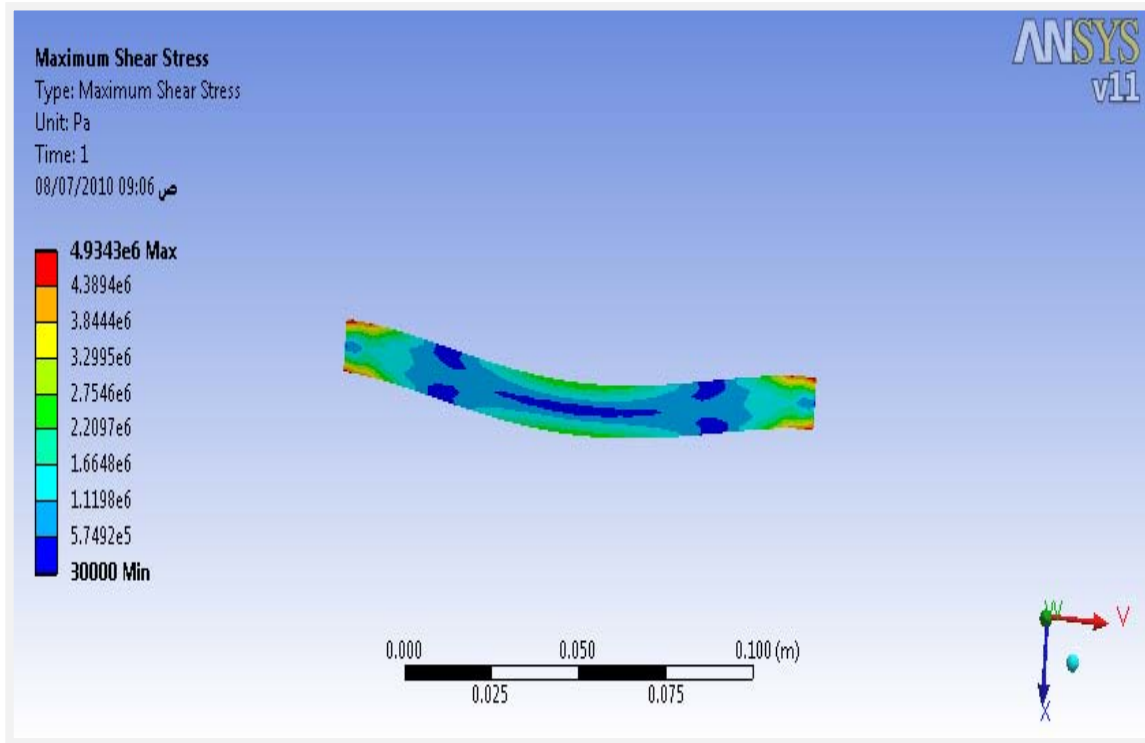


Fig. 5: The bending strength of epoxy resin and phenol formaldehyde after reinforcement with aluminum oxide nanoparticles and kefler fibers (10%)

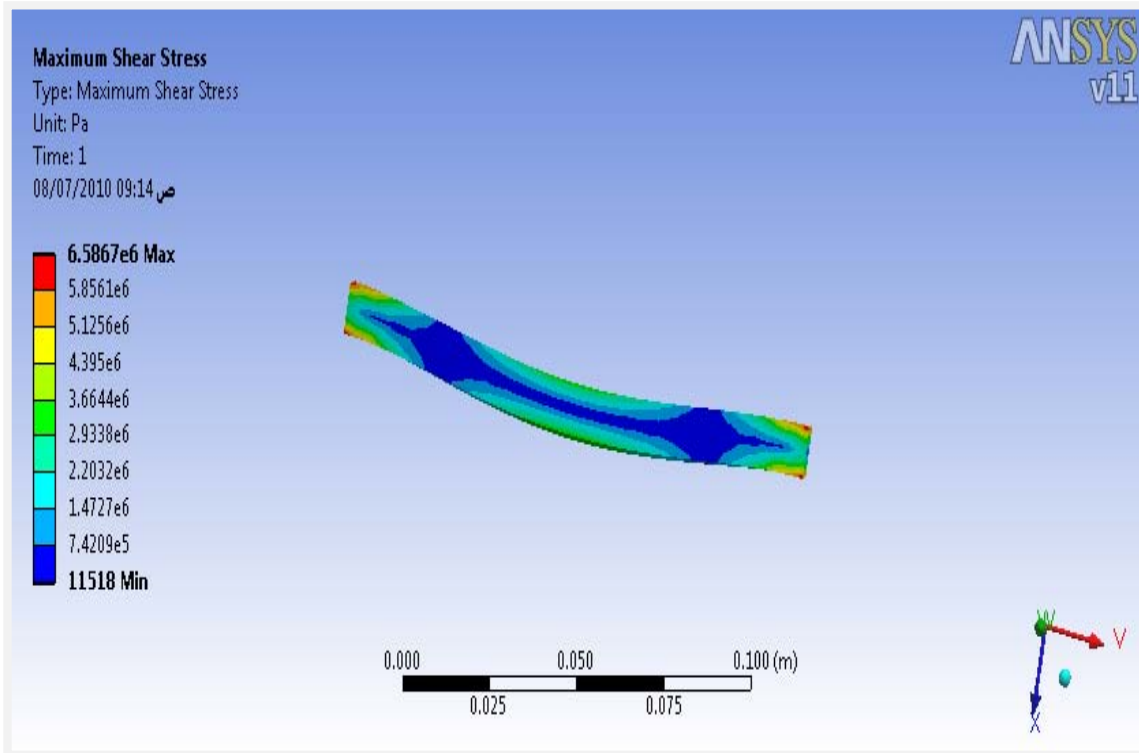


Fig. 6: Flexural epoxy resin and phenol formaldehyde after reinforcement with aluminum oxide nanoparticles with 30% kefler fibers

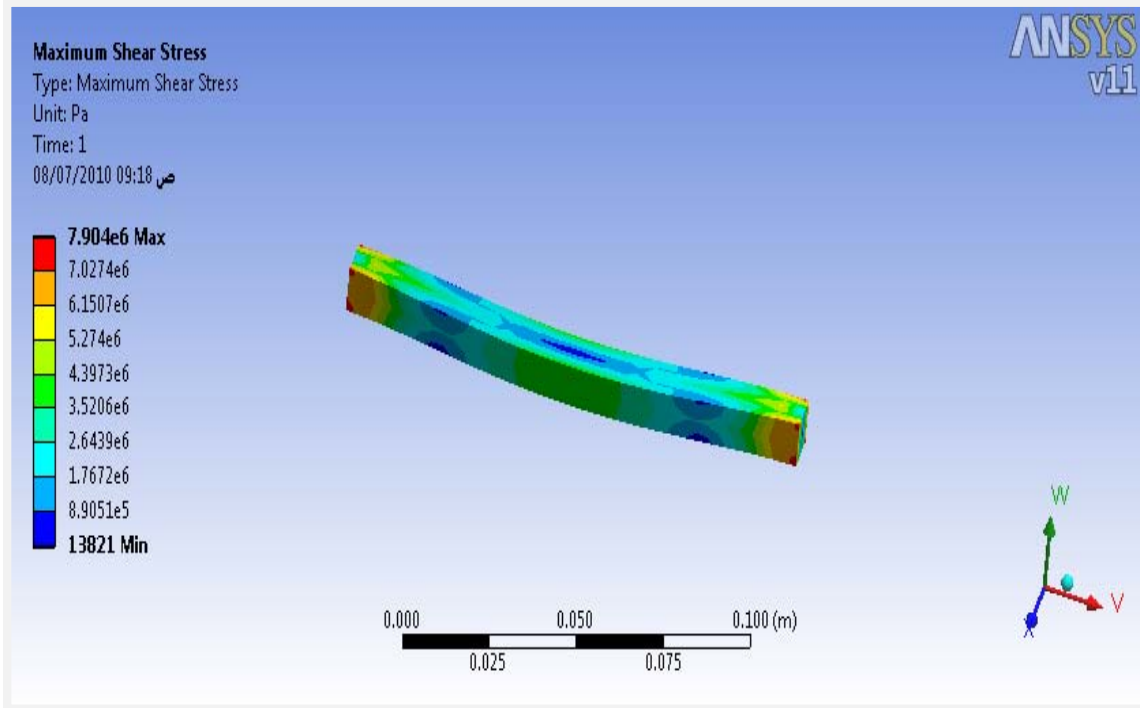


Fig. 7: Flexural epoxy resin and phenol formaldehyde after reinforcement with aluminum oxide nanoparticles with 50% Kevlar Fiber

### CONCLUSION

- Low strength emotion for epoxy resin and phenol formaldehyde
- Improving the mechanical properties after reinforcement with aluminum oxide nanoparticles and Kevlar fibers

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