Electrical Behavior of Hybrid Blend Reinforced by Fibers with Different Mixing Ratios

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Abstract. That technological development depends on progress in materials, so one has to realize that the best design for vehicles or aircraft is for materials to be able to carry the loads and conditions of the service, whatever the field, the final restriction on progress depends on materials. Composite material is composed by combining two or more substances that often have very different properties. The two materials work together to give unique composite properties. Properties are not only used for their mechanical properties, but also for electrical, thermal and environmental applications. Typically, modern composites are improved to achieve a certain balance of properties for a particular set of applications and a wide range of uses for which complex materials may be designed. Composite materials have a continuous matrix component that is linked together and provides a form of a combination of stronger reinforcement components. The resulting composite materials have a balance in the structural properties that exceed any of the constituent materials alone.

Keywords: Hybrid Blend, Mechanical Behavior, Fibers, Electrical Behavior, Mixing Ratio

1. Introduction

Electric charges do not flow through the material when an insulating material is placed in a constant electric field (E), but a slight shift (the creation of dipoles) from the average polarization (P) production positions and redistribution of the charge to a material affected by an external electric field can be considered [1]. The electrical moment obtained by an atom or molecule under the influence of an electric field is proportional to the imposed field, and the relationship between polarization and the electric field is given by [2, 3]:

1) \( P = \chi(\epsilon) \epsilon_0 E \)
2) \( \chi(\epsilon) = \epsilon - 1 \)

Where \( \chi \) is the electrical susceptibility of material,
\( \epsilon \) is the permittivity of the material
\( \epsilon_0 \) is the permittivity of vacuum.
There are four basic types of electro depolarization: electronic polarization, ionic or atomic polarization, bipolar polarization, space charge polarization, and interface polarization. The total polarization of the insulating material contributes to all types of polarization. As shown in Figure 1 [4, 5].

Figure 1: Classification of electro depolarization as follows: (a) electron polarization, (b) atomic or ionic polarization, (c) bipolar polarization, (d) interface or space charge polarization [5].

The polymer matrix composites classified as insulators. The electrical response for polymer matrix nanocomposites refers to their conductivity and dielectric performance. Since the primary electrical character of polymers is insulating, polymer composites seem to be dielectrics, (which can be polarized under the effect of an external electric field). Considering the character of the employed nano filler or nano inclusions, polymer nanocomposites categorizes in two major classified: first the insulating matrix-dielectric reinforcing phase and second the insulating matrix-conductive reinforcing phase. The nature of the nano filler will defers in kinds, shape, and properties where it could be organic, inorganic, conductive, insulation, spherical, non-spherical [9]. The introduction of nanoparticles into an insulator is influenced by two key factors to consider. First, nanoparticles affect the physical and chemical composition of matter. Second, the effect of nanoparticles on the electrical properties of the surrounding material. This leads to increased electrical conductivity depending on size. This reaction zone may overlap, resulting in leak-related effects through the reaction zone as shown in Figure 2 [10].

Figure (2): Illustration of interaction zones for (a) a microparticles and (b) an assembly of nanoparticles [10].

The electric field leads to a distortion of the symmetrical distribution of electrons, atoms or molecules, and this is essentially the displacement of external electrons related to atomic nuclei [10]. This effect is shared in all materials, and the polarization effect is small, despite the huge number of atoms inside the material, because the dipole arm is too short, which may contain only a small part of the angstrom [11]. The electric field causes the displacement of ions, atoms, or a polyatomic molecule relative to each other, which is essentially a normal capillary vibration, which is sometimes referred to as vibration polarization, or ionic displacement that is common in ceramic materials [12]. This polarization occurs only in materials consisting of bipolar molecules or molecules, causing the electric field to redirect bi-directional poles towards the direction of the field [13]. An interpolarization or space charge is produced by separating positive and negative movable molecules within the imposed field,
and thus a negative space charge is formed in the bulk of the material, which in turn modifies the field distribution, mainly in crystalline or amorphous solids. [14].

2. The Aim of the Research

The research aims to use epoxy mixture with formaldehyde resins in different mixing ratios, for the purpose of knowing, analyzing and comparing the physical and mechanical properties of the previous results, to determine the suitability of these materials in the workplace.

3. Experimental Procedure

Materials: epoxy resin and resins phenolic formaldehyde resins. The samples were prepared by mixing epoxy resins and phenol formaldehyde at different weight ratios.

Table (1) shows the properties of the composite materials

| Properties                  | Epoxy                  | Phenol formaldehyde |
|-----------------------------|------------------------|---------------------|
| Appearance                  | Comp. A: yellowish     | Pale brown liquid   |
|                             | Comp. B: brownish      |                     |
| Solid content               | 50% - 52%              |                     |
| Gelatin at (130 °C)         | 10 – 15 min            |                     |
| Specific gravity            | 1.11 - 1.18 gm/c.c     | 1.15 – 1.20 gm/c.c  |
| PH                          | 8.0 – 8.5              |                     |
| Water tolerance             | Infinite               |                     |
| Free phenol content         | 1.0 – 1.5 %            |                     |
| Free formaldehyde content   | 6 – 7 %                |                     |
| Viscosity at (25°C)         | 250 (MPa.s)            | 150 – 350 (MPa.s)   |
| Density (20°C)              | Comp.A+B: 1.1 Kg/l (mixed) | 1.21 Kg/l          |
| Shelf-life at (25°C)        | 12 month               | 45 days from the manufacture |
| Pot life (2kg) at (20°C)    | 60 min                 |                     |
| Mechanical strength at (20°C, 10 days) | Compressive = 53 N/mm² | Flexural = 50 N/mm² |
|                             |                        | Tensile = 25 N/mm²  |
| Coefficient of thermal expansion | 89 x 16 - 6 per (-20 to 60) °C |                     |

Table (1): Resin materials and some of their properties

The fibers reinforcement materials are:

1. Glass fibers (E-glass fiber, glass fiber Biaxial Fabric 0/90), the basis of textile-grade glass fibers is silica, (SiO₂).

2. Carbon fibers are very fine fibers and are mostly composed of carbon atoms, so that carbon atoms are bound together in microscopic crystals parallel to the fiber axis, and this parallelism or direction makes the fibers extremely strong compared to their size.

When spinning Kevlar fibers produce fibers with high tensile strength (3000 MPa), with relative density (1.44), and when used as woven material, it is suitable for docking ropes, and other applications under water. Kevlar fibers consist of long molecular chains. The strength of Kevlar fibers lies in the
multiple chemical bonds between molecular chains. Part of the high strength Kevlar fiber comes from the hydrogen bonds of the polymer chains. The fiber materials used in this work are shown in figure (3) and table (2).

![Figure (3): (a) kevlar-49 fibers, (b) carbon fibers and (c) E-glass fibers.](image)

| Property       | Tensile Strength (MPa) | Compressive Strength (MPa) | Elastic Modulus (GPa) | Density (g/cm³) |
|----------------|------------------------|-----------------------------|-----------------------|-----------------|
| E-glass        | 3445                   | 1080                        | 73                    | 2.58            |
| Carbon fiber   | (3–7 GPa)              | (1–3 GPa)                   | (200–935 GPa)         | 1.75–2.20       |
| Kevlar fiber   | 2757.9                 | 517.1                       | 151.7                 | 1467 (kg/m³)    |

4. Composites Preparation:
Hand lay-up technique was used to prepare sheets of epoxy composites pure or reinforced with many types of fibers mat and with nanoparticles with filler. The casting mold consists of glass plates with dimensions (200 x 200 x 4 mm) and under the casting mold putted nylon sheets to prevent adhesion of the composite material as figure (4). All test samples are finished by scraping the edges.

![Figure (4): The casting mold consists of glass plates with dimensions (200 x 200 x 4 mm).](image)

The epoxy resin and the hardener were determined for the appropriate mixing ratio. It was manually mixed and then the epoxy resin and the hardener were mixed by magnetic stirring at (800 rpm) for (15 minutes) to obtain a good homogeneity between the epoxy resin and the hardener. Finally add the hardener with an appropriate mixing ratio to be well homogeneous of the hybrid resin as Table (3).
Table (3): Hybrid blend mixing ratio of epoxy risen and resol resin.

| No. | Mixing Ratio of Epoxy Risen | Mixing Ratio of Resole Resin |
|-----|----------------------------|-----------------------------|
| 1   | 100%                       | 0%                          |
| 2   | 95%                        | 5%                          |
| 3   | 90%                        | 10%                         |
| 4   | 85%                        | 15%                         |
| 5   | 80%                        | 20%                         |
| 6   | 70%                        | 30%                         |
| 7   | 60%                        | 40%                         |
| 8   | 50%                        | 50%                         |

Physical tests samples: Hand-held technique is used to make reinforced epoxy board with fiber matting types: Kevlar fibers, carbon fibers and glass fibers. First: the mold made of glass panels with dimensions of (20 x 15 cm) thickness of (4 mm) and repaired by Glue Gun, a mold that was placed on the sheets of nylon to prevent the adhesion of the sample. Second: epoxy resin + phenol formaldehyde resins. Mix (95%) of the epoxy resins with (5%) resole resins manually and then mix with the stirrer by magnetic stirrer at (800 rpm) for (15 min) to obtain a good homogeneity between hybrid and crucified resin and remove the trapped air bubbles in the sample. The weighted part of the materials used was obtained by weighing the kevlar fibers, carbon fibers and glass fibers into the mixed resin mixture. The mold was uniformly spread by hybrid resin, and the first layer of mats was placed above it and was published by hybrid resin. After the second layer, a serrated steel cylinder was used to roll the cloth before placing a hybrid resin. The casting was done at room temperature for (24 hours). They have finally been removed from the mold to get a fantastic vehicle plate.

5. Dialectical Tests Samples

The final samples shape prepared for dialectical test identical to the specification of ASTM (D 150) the diameter was (2.1 cm) as in illustration in figure (5).
6. Results and Discussions

6.1. Dielectric constant

Frequency dependence:

Figure 7, shows that the dielectric constant of epoxy and phenol formaldehyde decreases with increasing frequency, and the dielectric constant is the frequency reliability of polymer systems in epoxy resin treated. In the present study, orthogonal molecular groups in the longitudinal polymer chain have contributed to the mechanism of electrical insulation, especially at low frequencies, and all groups in the epoxy chain can direct themselves leading to a higher static electrical insulation value at these frequencies [6]. As the electric field increases, larger bipolar groups find it difficult to reduce the dielectric constant resulting in a continuous decrease in the insulation of the epoxy system at higher frequencies. In contrast, the dielectric constant decreases with increasing frequencies in the applied field. This decreasing and static insulation effect of both epoxy and fillers leads to a decrease in the insulation constant of the composite materials of epoxy and phenol formaldehyde.

6.2. Weight fraction dependence

Figure 6 also shows that the increase in electrical insulation is constant due to increased filler volume in composite materials and the system becomes more homogeneous than pure epoxy with the addition of more fillers, and the increase in the electrical insulation constant with increased filler is due to the formation of groups [7]. The group can be considered an area in the polymer matrix where the particles are in contact or very close to each other, so the average polarization associated with the mass is larger than the individual particles due to the increased dimensions, and this leads to a larger interfacial space.

6.3. Electrical conductivity

Frequency dependence

Figure 8 shows the variation in electrical conductivity as a function of frequency, where electrical conductivity increases slowly with increasing frequency in the range (100 Hz - 400 kHz), possibly because composite materials increase the displacement density [4]. Electrical conductivity, in turn, depends on the number of charge carriers in the material, the relaxation time of the charge carriers, as well as the frequency of the applied electric field.

6.4. Weight fraction

The conduction mechanism of fiber-reinforced polymer compounds is essentially the conductive path theory, which indicates the presence of conductive paths (fibers with particles) that lead to conduction with increased filler content, due to increased pathways between the supported materials, and the average distance between the fillers becomes smaller. Consequently, the resistance of composite materials decreases and electrical conductivity increases [5].
7. Conclusions

1. The electrical insulation constant for epoxy and rheumatoid non-fibers compounds decreases with increasing frequency.
2. All free bipolar functional groups in the epoxy chain are routed the same, leading to high value of the static insulation at low voltage frequencies applied.
3. Increasing the frequency leads to a decrease in the electrical insulation constant of the fiberglass, and this decreasing effect with the insulation constant of both epoxy and reinforced materials leads to a decrease in the insulation constant of the composite material when the frequency increases.
4. The dielectric constant increases with the increase of the volumetric fraction of the padding because the system becomes more homogenous, and the increase in the dielectric constant leads to the formation of groups, which are in close contact with each other.
5. The presence of conductive paths (reinforcement with fibers and particles) increases the conductivity of composite materials, where the average distance between the fillings becomes smaller and therefore the resistance of the composite material decreases and the electrical conductivity increases.

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