Study the Electrical Insulation of Polymeric Composite

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Abstract

Electrical insulators in this research were made from reinforced epoxy with three kinds of fiberglass (wool, low surface density and high surface density). Samples made manually, resistivity, insulation voltage, tensile strength and bending test were done. The results showed that the highest tensile strength for reinforced epoxy with low surface density fiberglass was (195 N/mm^2), while highest bending stress was for reinforced epoxy with high surface density fiberglass (84 N/mm^2). Mechanical properties test was done for samples to ensure that they can be used as replacement of ceramic insulators (porcelain) which is used as insulators in transformer, cabins manufacturing and as electrical wiring's load which transmitter for electrical current. Reinforced epoxy with wool fiberglass has highest resistivity ($28.4*10^{+1}\Omega$ cm) and increasing in insulation voltage for reinforced epoxy with high surface density fiberglass (30 kv).

Keywords**:** electrical insulation, polymeric composite, fiberglass, mechanical test, electrical test.

Introduction

Generally materials are divided in to conductors, semi conductors and insulators. When atoms combine to form substance, the outermost shells, subshells and orbital's merge providing a high number of available energy levels. When large numbers of atoms closed to each other, these available energy levels formed a continuous band [1]; therefore, it is the width of those bands that determines the movement of those electrons when exposed to an electrical field, thus the outer electrons are said to be free and ready to move in an electrical field. Band overlap will not occur in all substances, in some substances a substantial gap remains between the highest band and containing electrons (it called valance band) and the next band which is empty (called conduction band)[2].As a result valance electrons are bound to their constituent atoms and cannot become mobile within the substance without a significant amount of imported energy. These substances are electrical insulators. Composite materials results two or more substances are combined (physically) to create a new material with properties are superior in specific applications [4], these composite are classified to: metallic, ceramic and polymeric [3]. Polymers are good insulators, brittle and fractural materials and classified according to their properties to 1. Thermoplastic polymer (polypropylene, poly ethylene). 2. Elastomers. 3. Thermoset polymers (epoxy resins, phenol phormaldehyde resin) this type is used as electrical and thermal insulators; therefore, reinforcing them with fiberglass change their mechanical properties. Epoxy resin has high compressive load and low tensile strength while fiberglass has high tensile strength and low compressive strength so by combining resin with fiberglass ,this process gives strong material resistant to compressive load and tensile strength.

Experimental Method

1- Epoxy type (Dur cupan Araldite c12 (M) resin.
2- Three types of fiberglass; Wool fiberglass, Low density fiberglass, High density fiberglass, Supplied from local market.

Epoxy type (Dur cupan Araldite C12 (M) resin) was used with its hardness where reinforcing with three kind of fiberglass (wool, low density 225 g/m^3 and high density 450 g/m^3) Tools used to prepare sample are :- sheet of glass (30×30 cm) which was used as mold for preparing Epoxy composite sheets, -the glass sheets where coating by paraffin to prevent the adhesion of samples, -rotary brush for distributing Epoxy on the fiberglass,.

Hydraulic press with mold (20×20 cm) and 5 ton compress. Samples were made manually, wool fiberglass were cut and used for preparing the first sample weight for determination resin's and mixed with Epoxy resin and hardener. Wool fiberglass ratio was 2:1 at room temperature then placed in mold and compressed with 5 ton and left for whole day then removed from the mold and prepare for test. While the second and third samples were prepared by cutting fiberglass layers with (20×20 cm) and weighted, for determination resin's weight glass sheet waxed and 4 fiberglass layers and between each layer amount of Epoxy resin (2:1) put to ensure resin's distribution equally and air bubbles were removed by passing rotary brush on them and glass sheet were put with compress and left for all a day for drying and then cutting these fiberglass layers for tests.

Result and Discussion

1- Tensile Test :-

Mechanical properties of composite's effect by several factor such us type of binder type of fibers and there orientation. Epoxy resin is type of polymer which has high brittle where broken readily in high stress and in temperature between (80 -180) °C it will be elastic, high strength for Epoxy resin is about 60 Mpa. In this research Epoxy reinforced with three kind of fiberglass (wool, low surface density (450 gm/m^2) and high surface density (225 gm/m^2) random orientation). Tensile and bending for samples tested by (universal material tester testometric) as shown in figures (1, 2, 3, 4, 5, 6) and high tensile and bending shown in Table (1). It has been observed that high tensile was for reinforced epoxy composite with low surface density fiberglass is (195 N/mm^2), while tensile for fiberglass with density (450 gm/m^2) was dropped to (100 N/m^2) because of fibers distribution in high density samples will lead to difficulty permeation of binder between layers and then Epoxy will be aggregate in spots these rich by binder. These spots being between composite layers will lead to easy track for cracks which will be created when stress loaded and then broken (because of high brittle for binder) [5]. While in low surface density fiberglass the permeation of binder between fibers layers will be easier ,the fibers distributed on certain area and form gaps, these gaps allow to permeate binder to another layers and lead to full cohesion between composite's parts. While in samples made from wool fiberglass tensile strength was dropped because of this fiberglass is irregular which is like rock wool in manufacturing. When fibers with regular dimensions (length and diameter) found that will lead to distribution stresses when they loaded to the sample and that leaded to increase fracture resistance.

2. Bending Test :-

Tests result shown in Table (1) the reinforced samples with random fibers expressed high bending resistance, while its value decreased to the lowest grade with reinforced by wool fiberglass and that's because of in testing sample affected in two stresses the top surface of sample load by compress while bottom surface exposed by strain stress.

The presence of random fibers and interfere with each other with epoxy being will be lead to increase bonding strength between layers and that effect on stress value. The reinforced samples with high surface fiberglass expressed bending resistance greater than the other because of increasing fiber distribution for unit area that lead to increase stress distribution and then effect on increasing bending resistance. While in wool fiberglass because of irregular in fiber and orientation also will lead to expansion cracks when any stress load on the sample. Ceramic materials tested by bending test the results in previous researches shown ceramic had high resistance [6], high brittle and cracking fast, but the materials in this research have a resistance which is wanted to make these electrical insulators because these materials resist impacts and difficulty cracking. max. flecture stress founded from (3):- $S=3PL/bd^2$.

Table (1)
Tensile and bending test results.

SAMPLE	*MAX. STRESS (N/mm^2)*	*MAX. STRAIN (%)*	*MAX. FLECTURE STRESS (N/mm^2)*	*MAX DEFLECTION (mm)*
Epoxy+wool fiberglass	4.2	1.2	27.5	12.8
Epoxy+low surface density fiberglass	195	4.8	75	13
Epoxy+ high surface density fiberglass	100	5	84.4	14.1

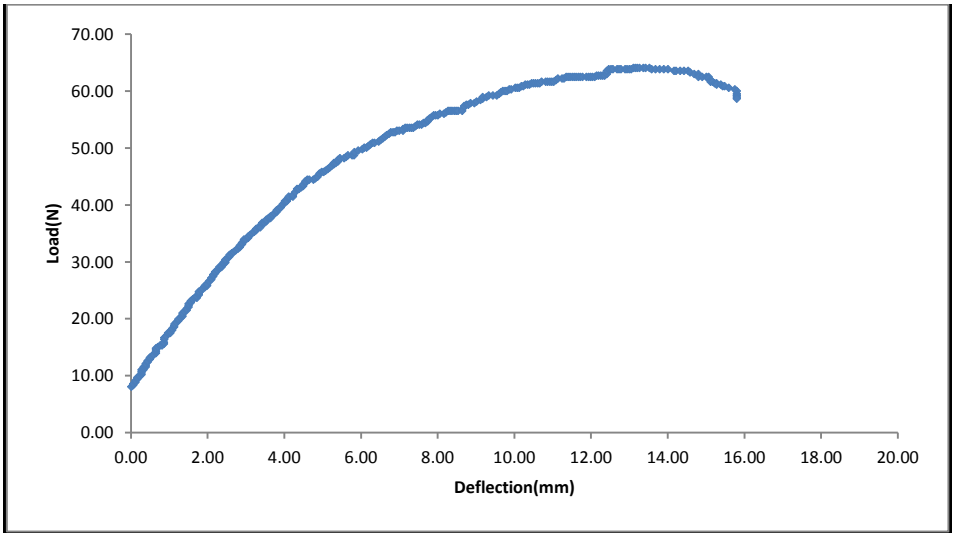

Fig. (1) Bending test for reinforced epoxy with wool fiberglass.

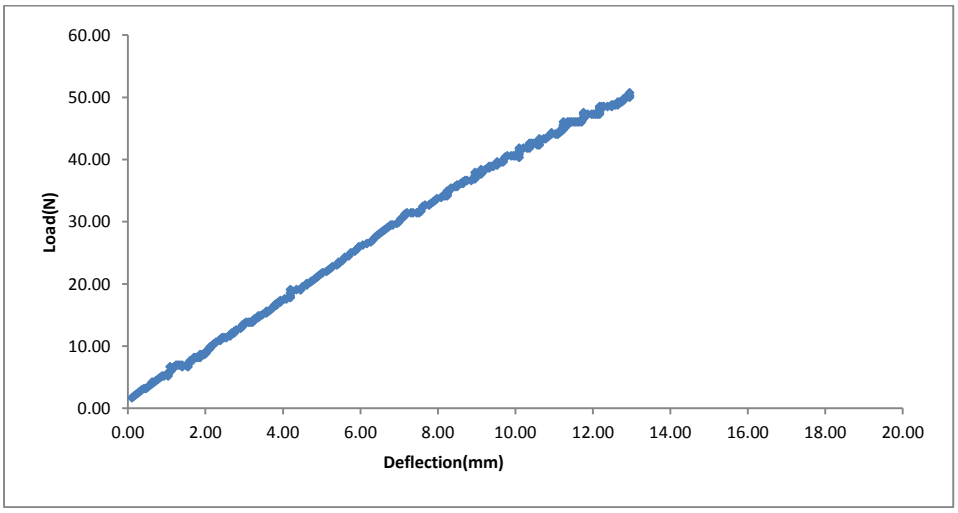

Fig. (2) Bending test for reinforced epoxy with low surface density fiberglass.

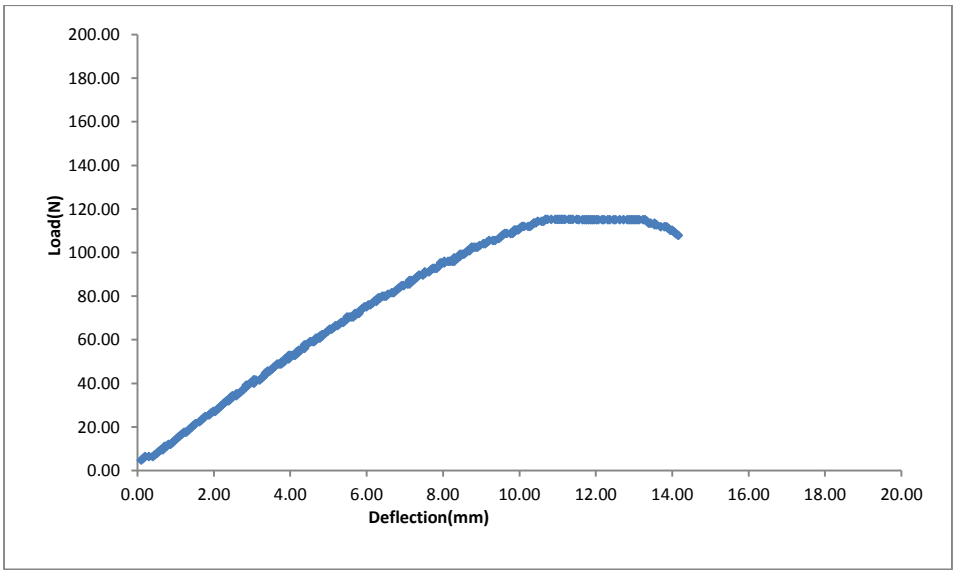

Fig. (3) Bending test for reinforced epoxy with high surface density fiberglass.

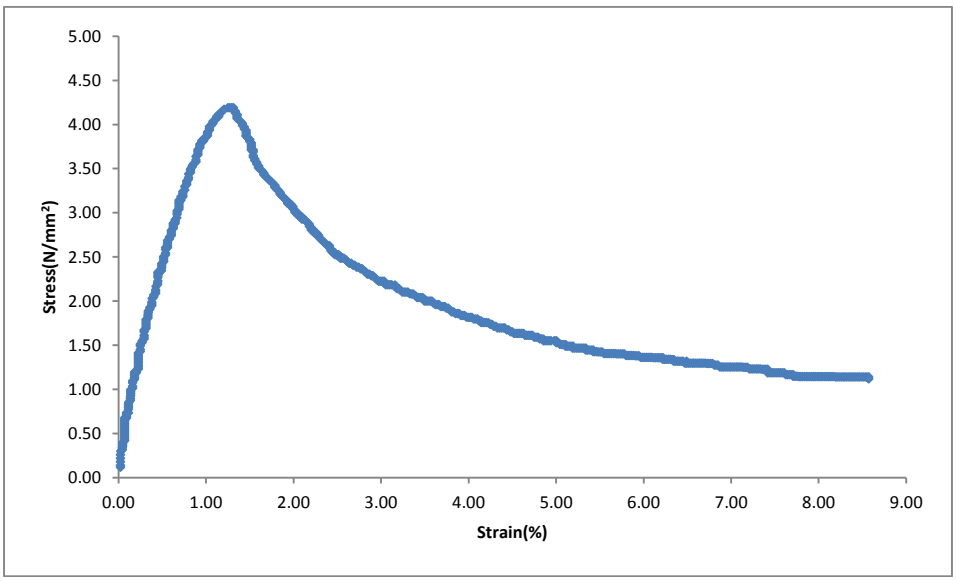

Fig. (4) Stress test for reinforced epoxy with wool fiberglass.

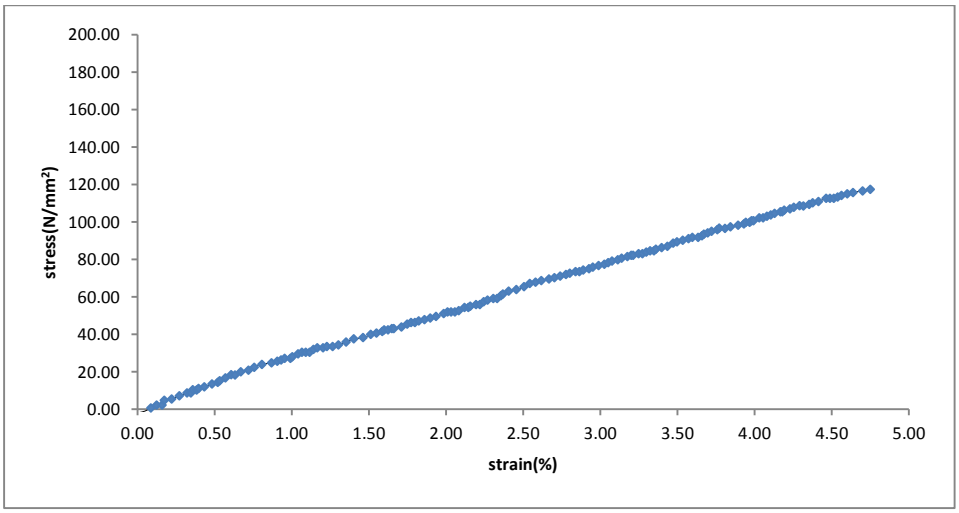

Fig. (5) Tensile test for reinforced epoxy with low surface density fiberglass.

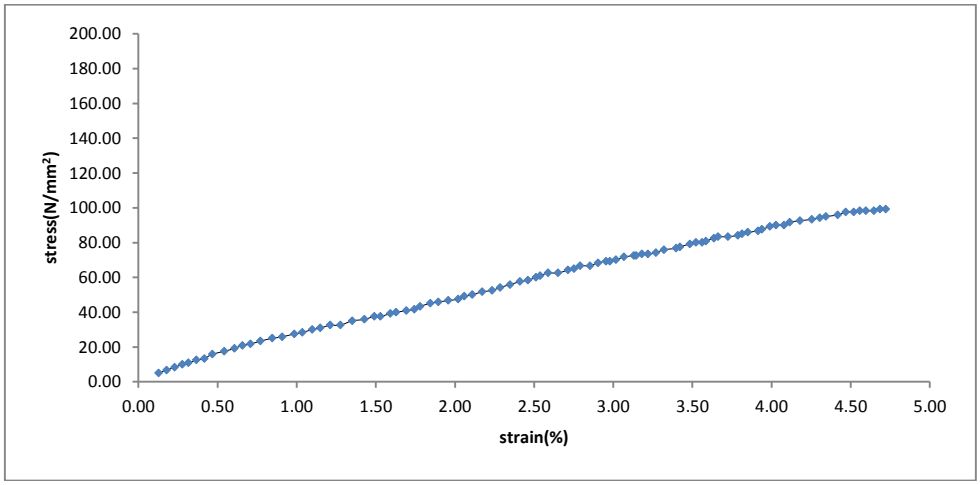

Fig. (6) Tensile test for reinforced epoxy with high surface density fiberglass.

3. Electrical Resistivity Test :-

The samples tested by (Hall Effect Measurement system HMS-300) and the results shown in Table (2). The test shown the composite had high resistivity compared with the conductors material. The test shown the samples reinforced wool fiberglass had high resistivity breaking down voltage (insulator electrical) was less than the other samples, on the contrary in samples reinforced by high surface density fiberglass the tests shown the breaking down voltage increased to (30 Kv) that is because of high surface density fiberglass being these lead to polarimetric when exposed to an electrical field and that effect on current result's from polarimetric [7].

Table (2)
Resistivity and insulation voltage results.

SAMPLE	*Resistivity (Ωcm)*	*Insulation voltage (KV)*
Epoxy+ wool fiberglass	$28.4*10^{+9}$	21
Epoxy+ low surface density fiberglass	$1.614*10^{+9}$	25
Epoxy+ high surface density fiberglass	$3.653*10^{+9}$	30

Conclusion

1- Wool fiberglass has high resistivity comparing with the other samples.
2- High surface density fiberglass has breaking down voltage about 30 Kv .
3- Low surface density fiberglass has high strength.
4- This preparation composite can be use as replacement of ceramic insulators in transformer and also can use as cabins to keep electric generators form nature factor such us water and rain
5- Composite material has higher tensile resistance comparing to porcelain because its brittle and does not bare stress.

Composite has high bending resistance because increasing fiber distribution in surface area will increase the distribution of stresses and this will increase bending resistance.

Acknowledgements

The authors acknowledge the Chemical & petrochemical research Centre, Corporation, of Research and Industrial Development, Ministry of Industry and Minerals for technical and financial support.

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الخلاصة

يتضمن البحث تصنيع عوازل كهربائية من مادة الايبوكسي المدعم بالالياف الزجاجية (الصوف الزجاجي، الياف ذات كثافة سطحية واطئة و الياف ذات كثافة سطحية عالية). تم تصنيع عينات من المواد المتراكبة بتقنية التشكيل اليدوي و اجريت عليها فحص المقاومة الكهربائية، جهد الانهيار، مقاومة الشد و فحص الانثناء و بينت النتائج ان اعلى متانة شد كانت (١٩٥ نت\ملم^{٢}) لمتراكب الأيبوكسي المدعم بالالياف الزجاجية ذات الكثافة السطحية الواطئة وفي فحص الانثناء ابدت العينات المدعمة بالالياف الزجاجية ذات الكثافة السطحية العالية مقاومة عالية للانثناء (٨٤ نت\ملم^{٢}) واظهر فحص المقاومة الكهربائية للعينات المدعمة بالصوف الزجاجي مقاومة عالية ($٢٨,٤*١٠^{+٩}\Omega cm$) اما في فحص جهد الانهيار لوحظ زيادة الجهد الى (٣٠ كيلوفولت) للعينات المدعمة بالالياف ذات الكثافة العالية.