Study the improvement of thermo - mechanical properties for polyester adhesive by using different fibers (glass, kevelar, and carbon).

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Abstract

The mechanical properties of fiber-reinforced-polymer (FRP) composites are dependent on the type, amount, and orientation of fiber that is selected for a particular service. There are many commercially available reinforcement forms to meet the design requirements of the user. The ability of failure in the fiber architecture allows for optimized performance of a product that saves both weight and cost (12).

A modern technology is adopted to produce fibers (glass, kevelar, and carbon) reinforced composite by using unsaturated polyester, where different volume fraction of these fibers are used (0, 0.2, 0.4, 0.6, 0.8, 1) reinforcement to unsaturated polyester and the samples are cured at 25C° for 24hrs.The results of thermo-mechanical properties indicates that:-

All the mechanical properties are improved for composite samples with preference for kevelar fiber, and good thermal properties are appeared with preference for carbon fiber. All these results are explained on the surface of research.

Introduction

Natural and synthetic fiber can substituted glass, Kevlar and carbon fiber in polymer composite. Their potential for use in molded articles doesn't need high strength for acceptable performance in equipment housing, roofing, for low cast housing and in large diameter piping(1-5).

As in synthetic fiber composites, the mechanical properties of the final product depend on the individual properties of the matrix, fiber, and the nature of the interface between them. Typically glass fiber is treated with a silane coupling agent to improve the properties at the interface within the resin. The agricultural fiber, opportunities exist to tailor the end properties of the composite by selection of fibers with a given chemical or morphological composition (16-8). Another familiar term that is used is fiber reinforced plastics. In addition, other acronyms were developed over the years and its usage depends on the geographical location or market use. For example, fiber reinforced composites (FRC), glass reinforced plastics (GRP), and polymer matrix composites (PMC) can be found in many references although each of the above mentioned terms means the same thing; (FRP) composites (9-11).

Each of these constituent materials or ingredients plays an important role in the processing and final performance of the end product. The resin polymer (glue) holds the composite together and influences the physical properties of the end product.The reinforcement provides a mechanical strength; while fillers and additives are used as process or performance aids to impart special properties to the end product. The mechanical properties and composition of FRP composites can be tailored for their intended use. The type and quantity of selected materials in addition to the manufacturing process will affect the mechanical properties and performance such as "type of fiber volume fraction, orientation of fiber (0°,90°,45°), type of resin, cost of product, volume of production, manufacturing process, and service conditions" (12-14).

The primary functions of the resin are to transfer stress between the reinforcing fibers, act as a glue to hold the fiber together, and protect the fibers from mechanical and environment damage. The most common thermosetting resins used in the composites industry are unsaturated polyester, epoxies, vinyl esters and phenolic, due to specific application (15-17).

Unsaturated polyester resins (UPR) are the workhorse of the composites industry and represent approximately (75%) of the total resin that is used. To avoid any confusion in terms, readers should be aware that there is a family of thermoplastic polyester which is best known for its use as a fiber for textiles and clothing (15-17).

Several studies of fiber composition and morphology found that cellulose content and microfibril angle tend to control the mechanical properties of cellulosic fiber (15-17).

Other authors have studied the mechanical properties of fiber /polyester composites with well defined fiber orientation (unidirectional or bidirectional) (18-20).

Others studied the application of different fibers (glass, Kevlar, and carbon) in the design structure of composite polyester resin .which was developed to give a high strength / modulus, also best chemical and wear resistance data to aramids fiber (Kevlar) (21).

Also Gilbert R.D have studied the high temperature performance for composite structures of carbon fiber (22).

Woven composite reinforcement generally falls into the category of cloth or woven roving. Particular weave patterns include plain weave, which is the most highly interlaced; basket weave, which has warp and fill yarns that paired up; and satin weaves, which exhibit a minimum of interlacing. The directional strength characteristics are possible with a material that is still fairly drapable (23).

Aim of the Work

The present work aims to improve the characteristic properties of unsaturated polyester by the use of different types of fibers (glass, kevelar, and carbon). Also obtimizing which types of fibers has excellent thermo – mechanical properties and the volume fraction that gives these results

Experimental:-

Materials:

1- Different types of fibers (glass, kevelar, and carbon) commercially available.

2- Unsaturated polyester Tuf cote NT GIC No.68.

3- Hardener for polyester Tuf cote NT GIC No.68.

Methods

The composite systems are prepared by two steps:

Firstly the polyester resin system is prepared at the weight design ratio of mixing 100:2 (R/H) with a continuous mixing velocity 500 cycle per/min for 5min to give a homogeneous base resin system.

Secondly the preparation of the composite system by using different types and volume fraction of fibers (glass, kevelar, and carbon), and (0, 0.2, 0.4, 0.6, 0.8, 1) where an oily Vaseline is used to oil the surface of mold. Then we put half the amount of resin in the base of mold and speared the weight fibers on this resin.Later we and transfer the remain amount of resin on the surface of fibers and smoothen the surface of the mold by brushing and leave it to stable at 25C° for 24hrs, Finally all the characteristic properties of both thermal and mechanical properties (thermal conductivity, hardness, bending, and impact) resistance are achieved for all samples.

Metholedazation

-Thermal properties:-

The thermal conductivity of prepared samples is achieved by the use of Lee disk tester in a polymer lab / Material Engineering Department. The prepared sample is placed between two disk of copper, then rising the temperature until we reach the stability then we record the increase of reading temperature (T1, T2, T3), The equation below is used to calculate the thermal conductivity coefficient (e) and (K).

1- $K [T_2 - T_1 / ds] = e [T_1 + 2 / r (d_1 + 1 / 2ds) T_1 + 1 / r\, ds\, T_2] \longrightarrow$ [1]

2- $I V = \pi r^2 e (T_1 + T_3) + 2 \pi r e [d_1 T_1 + 1 / 2ds (T_1 + T_2) + d_2 T_2 + d_3 T_3] \longrightarrow$ [2]

Mechanical properties:-

1- Bending test:-

The bending resistance is achieved by the use of three point bending tester from the center of a specified dimension specimen from its center until the distortion occurred with recording the change in height (mm) by increasing and decreasing the load.

2- Impact test:-

The impact resistance force is achieved by the use of pendulum impact tester (XJU – 22) found in the polymer – lab of Material Engineering Department which has a specimen dimensions (1 x 1 x 5)cm. by recording the force that cracks the specimen (J / Cm^2).

3- Hardness test:-

This test is achieved by the use of hardness tester of (shore – D) found in the polymer –lab of Material Engineering Department on the specimen of specified dimensions (1 x 1 x 5)cm which was exposed to creep force in order to record the force that distorted the prepared specimen (J / Cm^2).

Results and Discussion

Thermal properties:-

Figure (1) shows the effect of set volume fraction (0, 0.2, 0.4, 0.6, 0.8, 1.0) and different types of fibers (glass ,Kevlar, carbon) on the stability (thermal stability) of final composite specimen where, a decreasing in thermal conductivity follows the increasing of fibers volume fraction with respect to carbon reinforcement specimen of lower thermal conductivity and higher thermal stability , due to the high thermal energy of (C-C) bond ($0.2 W/m.\dot{C}$) (17 , 23) .

In comparison to other types of fibers, we found that glass has glass ($0.3 W/m.\dot{C}$) of (Si – O) bond Kevlar has ($0.25 W/m\dot{C}$) of and low thermal (C – N) bonds of less energy force craking (21, 23).

Mechanical properties:-

1- Bending load resistance:-

Figure (2) shows the effect of set volume fractions and types of fibers on the distortion properties of prepared composite specimen.

The increase in volume fraction of Kevlar and glass fiber causes a decrease in distortion resistance at (6 mm) , while the distortion value for the carbon type is (10mm) at the same conditions (25C˚ , 1). that could be due to the ceramic nature of both glass and Kevlar fiber and the toughness and brittleness nature of carbon fiber (1, 6).

2- Impact resistance (J / Cm^2):-

Figure (3) shows the effect of set volume fractions (0 – 1) and types of fibers (glass, Kevlar , and carbon) on the impact resistance of the final prepared composite specimen at the same operation conditions.

The results indicated that composite samples gave high impact resistance at high values of volume fractions with preference for both (carbon and Kevlar fiber) at (1.5 J / Cm^2), and lower resistance (1 J / Cm^2) for glass, and that could be due to the higher breaking energy of both (C – C) and (C – N) bond than that for (Si – O) bond (17 , 21 , 23).

3-Hardness resistance (J /Cm^2):-

Figure (4) shows the effect of set volume fractions (0-1) and types of fibers (glass, Kevlar, and carbon) on the hardness resistance of the final prepared composite specimen at the same operation conditions.

Results showed that all composite samples would give high hardness resistance to the creeping load with preference to (glass and carbon fibers) at (41 J/Cm^2), than those of Kevlar at (31 J/Cm^2) due to the high adhesion resistance between (C – C) and (Si – Si) than (C – N) bonds of Kevlar) 17, 21, 23).

Conclusion

From the above study it concluded that:

1- The optimum mixing ratio of volume fraction that gave characteristic thermo-mechanical properties for all types of fiber (glass, Kevlar and carbon fiber) is 0.2 .

2- The Kevlar fiber gave the best mechanical properties between two fibers for (impact, bending and hardness), at the same operating conditions.

3- The carbon fiber gave the best thermal properties (insulating, and stability) than others types of (glass and kevelar).

4- The optimum operating properties that gave good results are (500 rpm), (25C˚), (24hrs), for all properties and good stability to test.

5- Kevelar fiber have characteristic properties between carbon and glass fibers due to the atomic structure of nitrogen atom that have per electrons.

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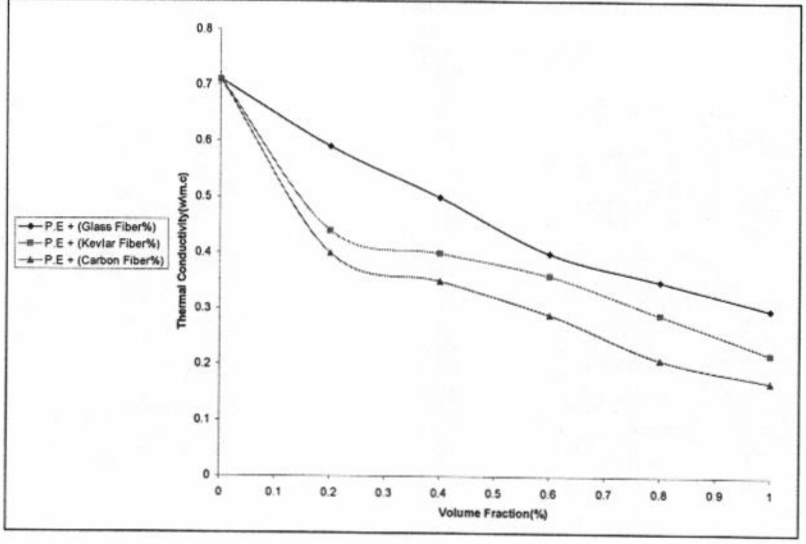

Fig. (1): The relationship between thermal conductivity and volume fraction of fibers (glass, kevelar and carbon)

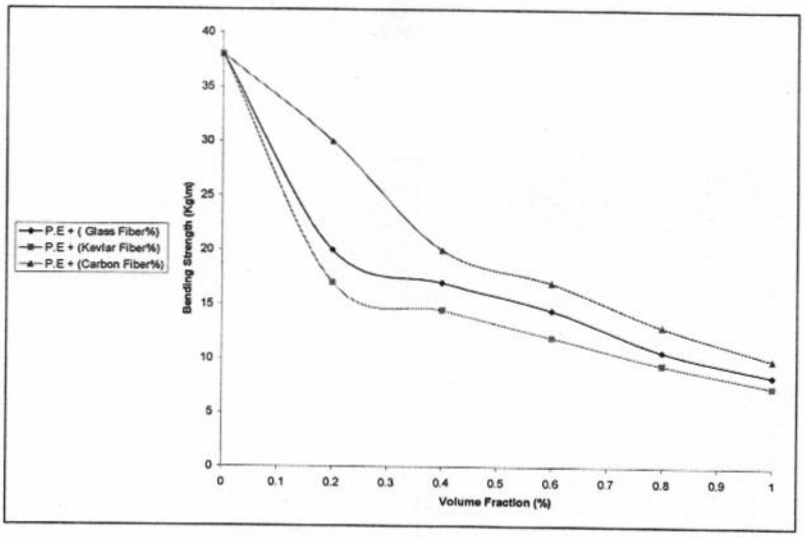

Fig. (2): The relationship between bending resistance and volume fraction of fibers (glass, kevelar and carbon)

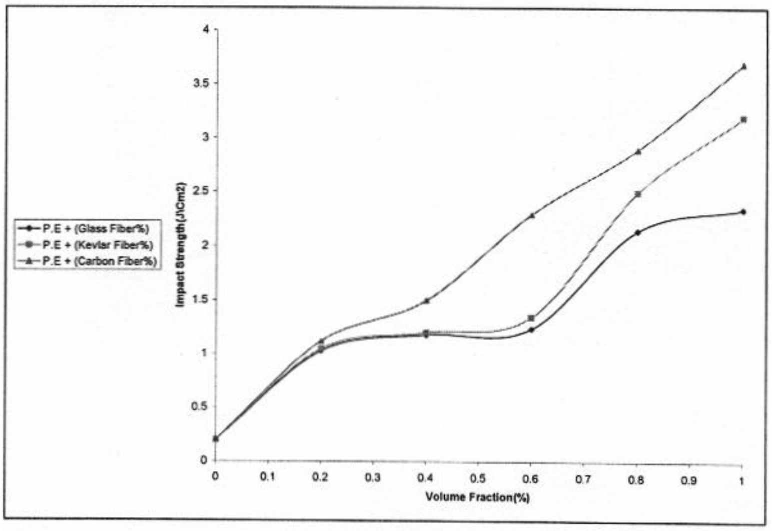

Fig. (3) The relationship between impact strength and volume fraction of fibers (glass, kevelar and carbon)

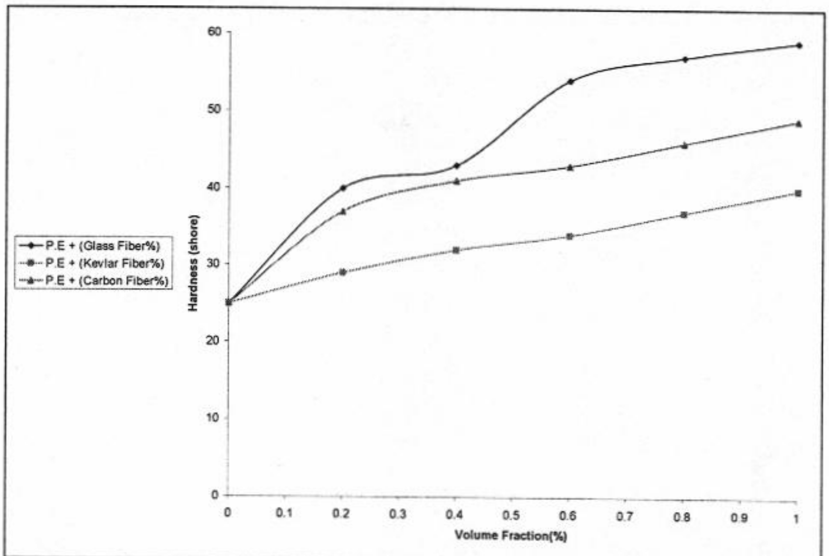

Fig. (4) The relationship shore hardness and volume fraction of fibers (glass, kevelar and carbon)

دراسة امكانية تحسين الخصائص الثرمو-ميكانيكية للواصق البولي استر بأستخدام الياف صناعية مختلفة (زجاج ، كفلر ، كاربون).

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الخلاصة

ان الخصائص الميكانيكية للبوليمرات المدعمة بالألياف والمتراكبة تعتمد بالدرجة الاساس على نوع ، كمية ، وترتيب تلك الالياف التي أختيرت فضلا" عن التطبيق النهائي المؤمل انجازه لتصنيع هكذا مواصفات من المواد المتراكبة.

وهنالك العديد من اشكال التدعيم المتوافرة تجارياً التي تلبي كل المتطلبات التصميمية والتطبيقية للمتراكبات البوليمرية بحيث تكون لها المقدرة على اعطاء الأداء المثالي لتلك المتراكبات فضلا" تقليل اوزانها وكلف تصنيعها وتطبيقها وهذا ما يميز هذه الصناعة من غيرها من الصناعات.

لذلك فقد اتبعت تقنية جديدة في العمل الحالي لتلبي تلك المتطلبات وهي اعتماد انواع مختلفة من الالياف (زجاج ، كفلر ، كاربون)، وعند نسب حجمية مختلفة (0,0.2,0.4,0.6,0.8.1) % نسبة حجمية في تصنيع وتدعيم لواصق من البولي استر وعند ظروف خلط قياسية (25C̊) مدة (24hrs) لغرض الانضاج للعينات ثم دراسة بعض الخصائص الثرمو-ميكانيكية لهذه المتراكبات وقد اظهرت النتائج التطبيقية مايأتي :-

جميع الخصائص الميكانيكية (مقاومة الانحناء ، مقاومة الصدمة ، الصلادة) للمتراكبات تم تحسينها ولاسيماً للمتراكبات المدعمة بألياف الكفلر مقارنةً بالنوعين الاخرين الزجاج والكاربون، وكذلك تحسن كبير وملحوظ للخصائص الحرارية (التوصيلية الحرارية)، التي قد اظهرتها المتراكبات المدعمة بألياف الكاربون مقارنةً