Study the Adhesion Force of Tubular Shaped Fiber Reinforced Composites

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Abstract

In the present work tubular –shaped fiber reinforced composites were manufactured by using two types of resin epoxy (EP) and unsaturated polyester (UP),each was separately reinforced with glass, carbon and kevlar-49 fibers (filament and woven roving), hybrid reinforcement composites of these fibers were also prepared. The adhesion force test of the prepared specimens was carried out. These adhesion forces exhibited a peak value at a percent of hardener/resin (H/R)= 3% for UP matrix with all type of fiber arrangements while 30% was obtained for EP matrix .Such behavior was declined with increase in temperatures. Glass transition temperatures were determined from these measurements, and found to be 90°C for EP–glass and 83 °C for UP –glass composites.

Keywords: Adhesion force, tubular shaped, composites

الخلاصة

في البحث الحالي تم تصنيع مواد متراكبة أنبوبيه باستخدام نوعين من الراتنجات وهي الايبوكسي و البولي استر غير المشبع وتم تسليح هذه الراتنجات بالألياف بصوره منفردة حيث استخدمت ألياف الزجاج, الكار بون و الكفلر-49 (بشكل خيوط أو حصيره محاكه) للتقويه كما تم استعمال هجين من هذه الألياف لاجل تسليح الراتنجات أيضا. تشمل عمليه تصنيع المتراكبات الانبوبيه بطريقه اللف الخيطي, تصميم و تصنيع قالب معدني للحصول على هذه الاشكال و بعدها تتم عمليه ترطيب الالياف اولا بأمرارها خلال محلول الراتنج ثم لفها على قالب التشكيل باستخدام مخرطه حورت لهذا الغرض للحصول على الاشكال الانبوبيه المطلوبه و بزاويه لف 55^0 للالياف .

أظهرت قوى الالتصاق لنماذج من المتراكبات أعلى قيمة لها عند نسبة مصلب / راتنج (H/R) مساوية ل (30%) تقريبا بالنسبة لمتراكبات الايبوكسي. أما بالنسبة لمتراكبات البولي استر غير المشبع وجدت أعلى قوة لصق عند نسبة مصلب /راتنج (H/R) مساوية 3%.وقد وجد ان زياده درجة الحرارة يودي الى انخفاض قوة الالتصاق. كذلك وجد ان درجة الانتقال الزجاجي تقارب 90 درجه سيليزيه لمتراكب الايبوكسي المسلح بألياف الزجاج و83 درجه سيليزيه لمتراكب البولي استر المسلح بألياف الزجاج .

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1. Introduction

Composites are combination of two or more materials present as separate phases and combined to form desired structures, so as to take advantage of certain desirable properties of each component. The constituents can be in the form of particles, rods, fibers, plates, foams, etc.

A high performance composite can produced by using a filament winding technique, in which continuous resin impregnated roving or twos are wound over a rotating male mandrel.
Thus overall objective in this preparation of the sample is to produce an adhesive bond between matrix and fiber and latter adhesive network during curing.

The two most important types of bonding action can be classified as mechanical and chemical interaction. The first is important when one of the substances is porous and other can penetrate the pores and solidify[1], while the second is obtained when chemical bonding is developed by wetting the solid interface with a fluid; the two phases can interact through intermolecular forces. Chemical bonding can be classified into primary and secondary bonding. [2]

Several theories were proposed of adhesion [(4-6)] and the effect of interface has been studied by several workers.

Shih and Ebert [7] studied interface effects on the fatigue performance and other mechanical properties of unidirectional E-fiber glass/epoxy composites subjected to flexural loading, they found that the coated glass has a superior fatigue performance to the composite with uncoated fibers.

Harris [8], Dikson et al., [9] all stated that improved interfacial adhesion would result in an improved fatigue performance, in addition to the beneficial effects of using high strain fibers and matrices.

Pukanzky [10] studied the influence of interface interaction on the ultimate tensile properties of polymer composites and concluded that one advantage of composite materials for the designer is that the properties of a composite can be controlled to a considerable extent by the choice of fiber and matrix and by adjusting the nature of the fiber – matrix interface.

In the present work a tubular polymeric composite were developed by filament winding technique, the adhesion between matrix and reinforced phase had been investigated.

2. Experimental Work

2.1 Matrix

The materials used in this work as a matrix were: 1) Epoxy resin type (Cy- 223), with a density of (1.3-1.4) g/cm^3 and Mwt = 380 g/gmole. Hardener used was HY 956 (Diethylene tri amine) with a density ranging (1.15-1.25) gm/cm3, this hardener was added to the resin, 2) Unsaturated polyester used in present work POLYCOL03-003C with density of (1.19- 1.5) gm/Cm^3, the initiator used for crosslinking is MEKP (methyl ethyl ketone peroxide), cobalt Octoate 6% was used as accelerator. They were used

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in the following weigh percentages; MEKP 1.5-3% cobalt Octoate 0.2-0.5%.

2.2 Reinforcement Materials

Fiber glass (type E), Kevlar-49 fiber, and carbon fiber (HS) were used as reinforcement materials

2.2.1 Fiber Glass

Fiber glass type "E" was used. Its chemical composition is shown in the following table (1)

Table (1) Chemical composition of glass fiber

SiO_2	Al_2O_3	CaO	MgO	Na_2O K_2O	Ba_2O_2
52.4	14.4	17.2	4.6	0.8	10.6

2.2.2 Kevlar fibers

Woven roving Kevlar- 49 (0°-45°) was used and its surface density was (340g/m^2).

2.2.3 Carbon Fiber

HST carbon fiber was used as woven roving (0°-90°), and its surface density was 225g/m^2).

2.3 Experimental Apparatus

Experimental apparatus consists of the followings:

2.3.1 Resin Bath

It is a tank equipped with thermostat electrical heater; it was used for the preparation of the resin. A mixer of helical ribbon type with 1500 rpm was used for a continuous mixing of the viscous liquid, the specifications of this mixer were: RPM is 1500 (750 rpm used), type is helical ribbon. Resin bath and mixer are shown in Fig (1)

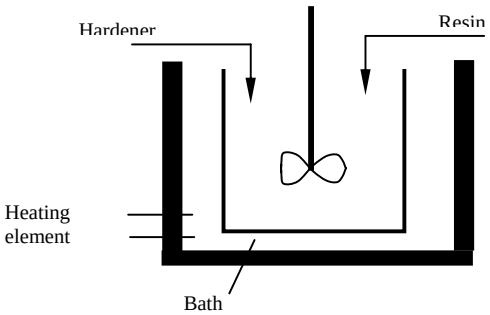

Fig (1) Resin Bath

2.3.2 Mandrel

There are several factors affecting the selection of mandrel materials. These factors include the number and size of the moldings to be produced, the type and finishing requirements of the products as well as the molding process itself.

The mandrel used during the course of this work was fabricated from low carbon steel coated with a thin layer of nickel chrome to give the required impact resistance, strength, smooth and shiny surface.

The dimensions of mandrel was L= 160 Cm and D_o = 16 Cm.

2.4 Winding Machine

Filament winding was used to fabricate the structural cylindrical samples, based on polymer matrix-fibrous composite; these samples were fabricated using a modified winding machine shown in fig (2). The fabrication steps were as follows:

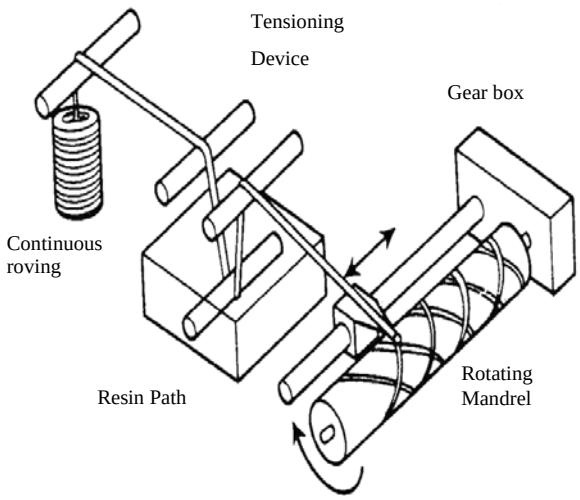

Fig 2 Schematic of Modified Winding Machine

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2.4.1 Preparation of Mandrel

The mandrel was coated with a thin homogenous layer of honey wax for 15 minutes, then it was polished with a dry piece of cloth, after that the mandrel was sprayed with poly vinyl alcohol solution three times at interval of 15 minutes.

2.4.2 Winding Process

After the preparation of the resin with the specification mentioned in section (2.1), by using the resin bath, the winding process was carried out using the winding machine as follows:

The fiber is usually wetted before winding and laid down under tension, then impregnation or soaking of the filaments, woven fabrics (tapes) was carried out by passing them through the resin bath at low speed (20 rpm) and at constant rate to ensure sufficient saturation of fibrous with the resin. After leaving the resin bath the reinforced fiber were passed over tensioning devices; to keep the required tension; after which the fibers were wound onto the mandrel a part- layer after layer with preset tension. The mandrel can make one or two rotational movements and with a thread guide, an inverted translational or rotational movement, this permits to control the reinforcement laying scheme both within one and the same layer and through the thickness of article, by varying the angle of filament or tape placement.

The winding angle (55°± 2°) was determined by the relative speeds of the lateral movement of the traverse and rotation of the mandrel and the diameter of the mandrel.

The samples were kept in the mandrel for 48 hrs before they were drawn from the mandrel.

The winding process is shown schematically in Fig (2)

2.5 Preparation of Samples

The following samples were prepared:

2.5.1 Resin with One Type of Fiber

Samples with single fiber were used with volume fractions of 50% as follows:

Epoxy
UP
+ glass fiber (four layer)

Epoxy
UP
+ Kevlar fiber -49 (four layer)

2.5.2 Hybrid Samples

Samples with more than one fiber were used with volume fractions of 50% as follows:

Epoxy
UP
+ Kevlar-49 (two layer) + Carbon (two layer)

Epoxy
UP
+ glass fiber (two layer) + Kevlar -49 (two layer)

Epoxy
UP
+ Fiber glass (two layer) + Kevlar (One layer) + Carbon (One layer)

The following diagram illustrates the possibilities of having more than one hybrid compound

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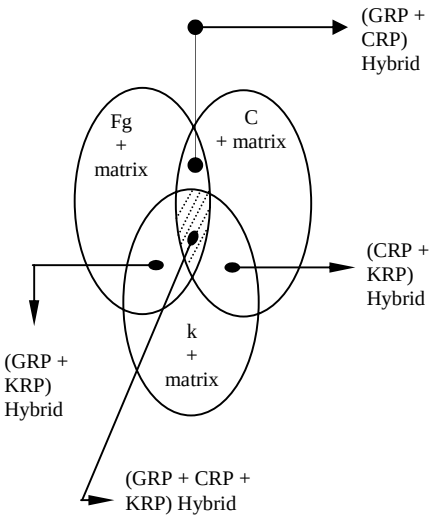

Fig. (3) Schematic shown the possibility of making hybrid composites

Where:
GRP: Glass reinforced plastic
CRP: Carbon reinforced plastic
KRP: Kevlar reinforced plastic
C: Carbon fiber
K: Kevlar fiber
Eg: "E" Glass fiber

2.6 Adhesion Force Test

This test was carried out according to ASTM (1002). The adhesion test involves stripping or tearing way of a flexible member of an assembly that has been bonded to the outer member (which may be flexible). The sample is usually loaded to 80%. The test is shown in fig. (4). the dimension of samples was: Length: 10.5cm, width 2.54cm

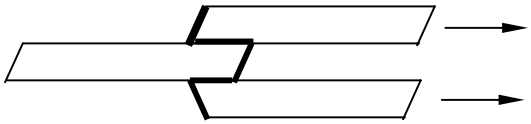

Fig (4) Adhesion force test

3. Result and discussion

In a simple system bonding at an interface is due to adhesion between fiber and matrix; the fibers are often coated with a layer of material which forms a bond between the fiber and matrix.

3.1 Epoxy composite samples:

In order to convert the resins into cross linked structures; which leads to the formation of a tightly bond three dimensional net-work of polymer chains, it is necessary to add curing agent or the hardener. The hardener used in present work for epoxy was tertiary amines which are commonly referred to as catalytic curing agent.

Different percentages of hardener were used, Fig(5) shows the variation of adhesion forces with (% H/R) with different fiber used to reinforce the resin, it is clearly seen that the adhesion forces increase with the increase of the percentage of H/R and this is because of the curing agents effects which might enhance a direct linkage of epoxy groups to one another and the increase continued until the percentage of H/R reached 30% is achieved after which the adhesion forces decreases and this may be attributed to the chain termination which frequently occurs.[11]

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Also it is clear from Fig (5) that optimum adhesion forces was obtained when hybrid of fiber was used (G + K+C) which indicates that the use of hybrid tend to reduce the shrinkage and increase a compressive modulus and the compressive yield strength a stiffening effect. [12]

Kevlar fibers surface shows a higher affinity for epoxy resin thus it gives a higher adhesion force than glass fiber due to very smooth surface of the latter (glass) make the direct mechanical adhesion with epoxy resin quite small. [13]

3.2 Unsaturated polyester composite samples:-

Fig (6) shows the variation of adhesion forces with Hardener/Resin percentage for different type fibers. It is quite clear that the adhesion forces increase with the increase of percentage of hardener to resin ratio and this is due to presence of styrene monomer which act as a cross linking agent and forms bridges between the unsaturated bonds of polyester chains [11]. Also it is clear from Fig (6) that a maximum adhesion force was achieved at 3%.

3.3 Effect of temperature on Adhesion Force:-

Fig (7, 8) shows the variation of adhesion force with temperature for epoxy and unsaturated polyester reinforced with glass fiber, it is clear that the adhesion force of both reinforced resins decrease with the increase in temperature.

Also Fig (9) shows a comparison of the variation of adhesion force for both resins reinforced with temperature.

The decrease in adhesion force with temperature could be attributed to the viscoelastic behavior of both resins and fibers with temperature. As it is well known that the variation of viscoelastic system with temperature involves several stages, for a composite with polymer matrix, at all temperature the configurations of the molecules are not stationary, but execute a kind of Brownian motion. Below a certain temperature this motion is relatively weak and is incapable of overcoming the inter- molecular hindrances caused by the presence of neighboring molecules. At these temperatures (room temperature) the materials is relatively hard and unyielding, and it is said to be in the glass like state. Beyond the glass-transition temperature the motion energy becomes sufficient enough, consequently softening of the material occurs. At temperature above the glass transition region chain rotation and uncoiling can take place with relatively little viscous effect, so that rubber like behavior is observed. [12]

From Fig (7, 8) the samples exhibit viscoelastic behavior, at room temperature (25°C) samples are in the glassy state. By heating beyond the glass transition temperature, samples brought into rubbery state. The glass transition temperature obtained from Fig. (7, 8) was (83°C) for UP reinforced with glass fiber and (90°C) for Epoxy reinforced with fiber glass. These temperatures agree well with the values reported in literatures [14].

Conclusions

The objective of this work was to develop some fiber reinforced polymer tubular composites; adhesion property had been investigated.

it is clearly seen that the adhesion forces increase with the

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increase of the percentage of hardener and this is because of the curing agents induced the direct linkage of epoxy groups to one another and the increase continued until the percentage of H/R reached 30% is achieved after which the adhesion forces decreases and this may be attributed to the chain termination which frequently occurs, for unsaturated polyester also the adhesion forces increase with the increase of percentage of hardener to resin ratio and this is because the presence of styrene which forms bridges between the polymer chains and cross-linking is achieved.

It is clear seen that optimum adhesion forces was obtained when hybrid of fiber was used (G + K+C).

The adhesion force of both reinforced resins epoxy and unsaturated polyester epoxy and unsaturated polyester reinforced epoxy and unsaturated polyester reinforced decrease with the increase in temperature.

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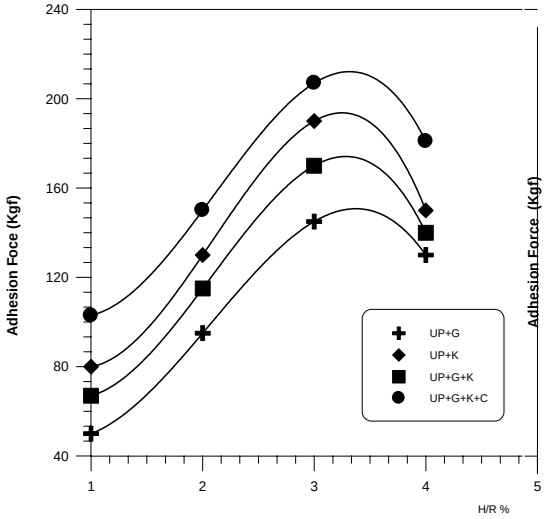

Fig (5) Adhesion force variation with H/R% for different type of fibres (EP composites)

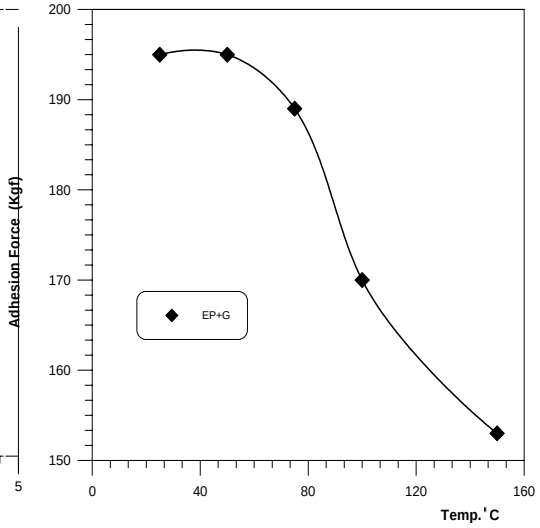

Fig (7) The effect of temperature on adhesion force for glass reinforced EP.

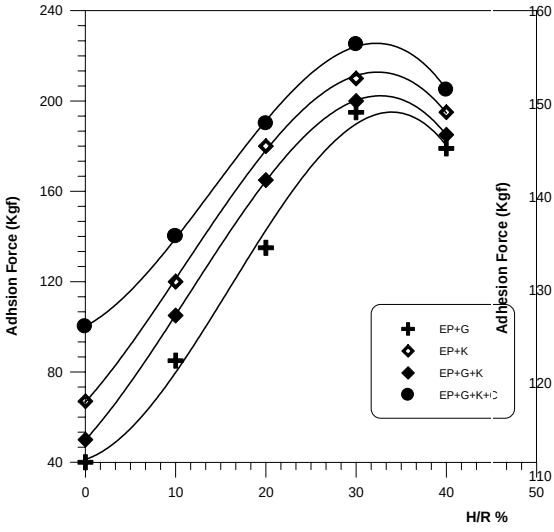

Fig (6) Adhesion force variation with H/R% for different type of fibres (UP composites)

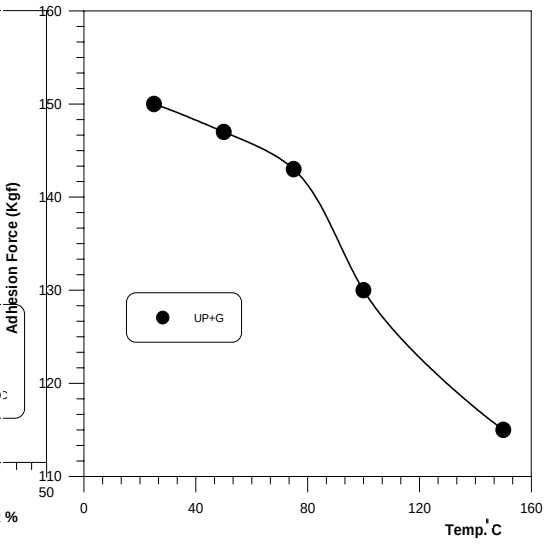

Fig (8) The effect of temperature on adhesion force for glass reinforced UP.

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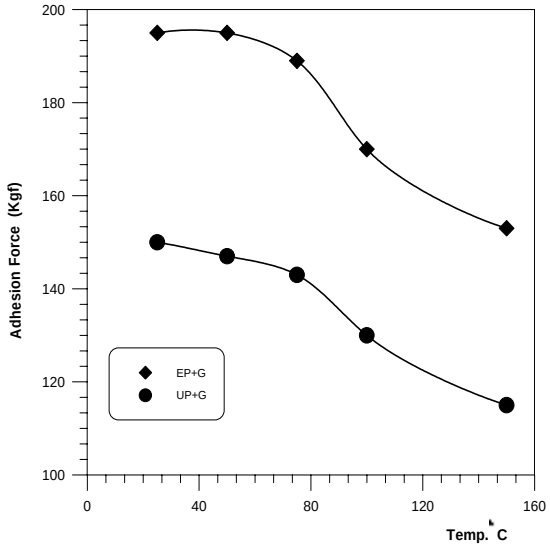

Fig (9) The effect of temperature on adhesion force for glass reinforced (EP , UP)

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