PREPARING OF COMPOSITE POLYMER REINFORCED WITH GLASS FIBER FOR WEAR APPLICATION

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Abstract:

In the present study, polymer composite reinforced with different ratios of glass fiber were prepared to improve mechanical and thermal characteristics for wear applications. Five samples with percentages (5%, 10%, 15%, 20%, 25%) of glass fiber of choppes range from (0.1 – 5 mm) length used as additives to a matrix of unsaturated polyester were tested. Mechanical tests include: wear, impact, tensile and hardness, while thermal tests include: thermal conductivity. The results show that the sample with 25% glass fiber indicates high wear resistance and hardness, while 10% is the higher impact resistance and 5% is the higher tensile strength. Also thermal conductivity decreases with increasing glass fiber percentage .To obtain optimum polymer properties, suitable balance between mechanical and thermal properties must be performed by controlling on additives ratios and shape which mentioned above, Therefore 15% percentage glass fiber is indicate good agreement with purpose of this work.

Key words: Composite polymers, Polyester, Glass fiber, Mechanical and thermal properties and wear application

في هذه الدراسة , تم تحضير مواد مركبة بوليميرية مقواة بنسب مختلفة من الياف الزجاج لتحسين المواصفات الميكانيكية والحرارية لتطبيقات البلى حيث اختبرت خمس عينات بنسب تتراوح بين (٥%,١٠%,١٥%,٢٠%,٢٥%) من الياف الزجاج مقطعة باطوال مختلفة تتراوح بين (٠,١-٥ ملم) استخدمت كأضافات للمادة الاساس (البولي استر الغير مشبع).الاختبارات الميكانيكية تشمل (البلى والصدمة والشد والصلادة),بينما الاختبارات الحرارية تتضمن (الموصلية الحرارية)واثبتت النتائج بأن النسبة ٢٥% تعطي اعلى مقاومة بلى وصلادة بينما النسبة ١٠% تظهر اعلى مقاومة صدمة واخيرا النسبة ٥% بينت اعلى مقاومة شد.اما الموصلية الحرارية فتقل بزيادة نسبة الاضافة من الياف الزجاج لغرض الحصول على افضل مواصفات للبوليمر يجب عمل موازنة مناسبة بين المواصفات الحرارية والميكانيكية عن طريق التحكم بنسب الاضافات المذكورة اعلاه, لذلك ١٥% من الياف الزجاج تظهر مطابقة جيدة مع هدف هذه الدراسة.

Introduction

Unsaturated polyester resins (UPRs) are one of the most widely used thermosets. UPRs find use in industrial applications because of their good mechanical properties especially when reinforced with fibres or fillers.Glass-fiber reinforced polyester composite materials are used instead of metallic materials because of their low density,high strength, and high rigidity. Because of such properties,GFRP materials are preferably used in automotive and aerospace industries such as bushes, seals,gears, cams and shaft, etc. Mechanical properties of fibre-reinforced composites are depending on the properties of the constituent materials (type, quantity, fibre distribution and orientation and void content)[El-Tayeb,2005,Edwards,1998].

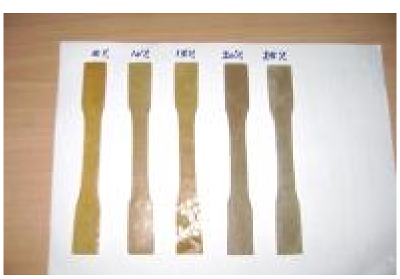
1. Experimental work:-

1.1. Materials :-

Unsaturated polyester supplied by (SIR) Saudi Company had been used as matrix material for reinforced composites in our experimental work. The polyester resin had the density of 1.2 g/cm^3 at 25 °C and styrene content of 30%. For reinforcing the polyester matrix, chopped glass-fiber materials was used. Type of glass fiber was E-type. There composition is of low basicity contains high proportion of silica(SiO_2) and other oxide in a varying proportions of(K_2O , Na_2O, B_2O_3 , CaO , MgO , Al_2O_3).There are other materials found in trace amount as impurities for example (TiO_2 , Fe_2O_3, F)[Martin,1983].

1.2.Preparation of samples:-

Samples were prepared for composite materials composed of unsaturated polyester reinforced glass fiber at different percentages (5%, 10%, 15%, 20%, 25%).They have been casted in a mould made of wood for all the tests mentioned in this study according to ASTM. After casting the samples were placed in the oven at 100°C for two hours for the purpose of curing.
The figures below show the samples used in this study for all tests:-


a: tensile sample


b: impact sample


c: wear sample

d:hardness and thermal samples

2. mechanical tests:-

2.1 Tensile strength :-

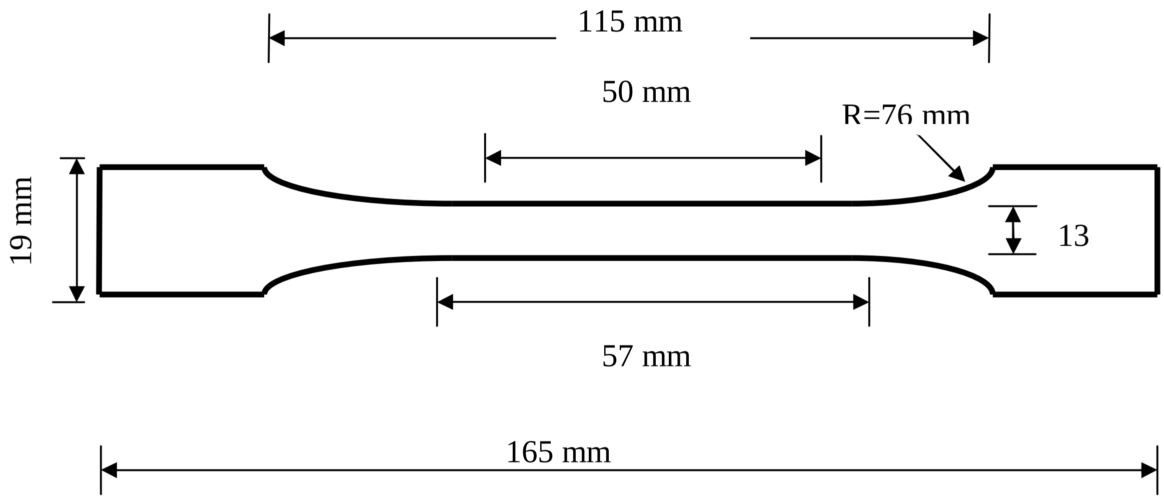
The Instron1195 machine is used to perform tensile tests. The Instron 1195 (illustrated in Figure (1-1) has the following specifications:

- ■ Load Cells: 0.5 - 5 KN.
- ■ Crosshead Speed Range: 0.5 - 500 mm/min.
- ■ Return Speed: 500 mm/min.
- ■ Crosshead Speed Accuracy: 0.1% of Set Speed.
- ■ Testing Type: Tension and Bending.

The speed (5 mm/min) and load (5KN) were used in this test.

Samples used in this test were prepared according to ASTM (D 638) as shown in the figure (1-1) below.

a



b

Fig. (1-1):a:tensile test machine b: dimensions of the tensile specimen.

2.2 Impact:-

Charpy impact test consists of standard test piece that will be broken with one blow of a swinging hammer. The test piece is supported at both its ends in a way that the hammer strikes it at the middle. The testing method of this instrument includes lifting of the pendulum to its maximum height and fixing it firmly as shown in Figure (1-2). The specimen was prepared according to ASTM (D4812) is fixed in its pertaining place, and then the energy gauge is initialized (on zero position) after that, the pendulum is freed where its potential energy would be changed to kinetic energy. Some of this kinetic energy is utilized to fracture the specimen, while the energy gauge reads the value of fracture energy (UC) for the sample under test. Impact strength (I.S.) is calculated by applying the relationship:

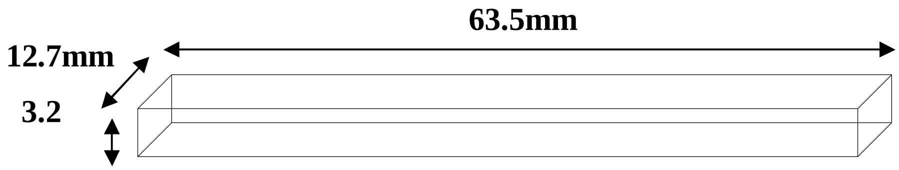
I.S. =US/A …………. (3-1)

Where:

US: is the fracture energy (Joule) which is determined from Charpy impact test instrument.

A: is the cross-sectional area of the specimen.

a



b

Fig.(1-2):a: Charpy impact testing machine b: dimensions of the impact specimen .

2.3 Wear:-

The test apparatus design (pin on disc) was made in the present study as shown in figure (1-3). The disc was connected through an interchangeable flange rotation rate to a shaft which was connected by two pulleys to the motor. The disc rotation rate was fixed at 500 rpm to conform that test .the movement in the wear device has been carried by two stages:

At the first stage the movement was carried by the pulley which was fixed on the motor. There was a carrier belt for movement kind (v-belt) to the shaft on which the two pulleys were fixed. One of them receives the movement and the other to carry it. In the second stage the movement was carried from the middle shaft to the shaft on which the disc was fixed.

The load on the pin is (2 kg) which was adopted from the literature study for the gear box and recovery tests. The high load led to break the samples in the form of brittle fracture.

The pin diameter is 10 mm and 20 mm height according to ASTM G99. Three mechanical specimens for each sample where molded in the laboratory and compared with the commercial specimens of heavy vehicles. It must be mentioned that the wear test device are designed and

manufactured totally in the present work. The wear test device was designed to undertake the heavy loads by using motor power of 30 minutes. The wear device also contains a rectangular section arm. At the end of arm there was a holder to fix the sample.

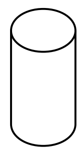
The following law shows how to calculate wear rate.

$$wr = \frac{\Delta w}{SD}$$

$$SD = 2\pi r' nt$$

Wr: wear rate.
Δw : sample weight difference before and after test.
SD: slipping distance.
t : time in minute.
n: cycle number.
r´: slipping distance.

a



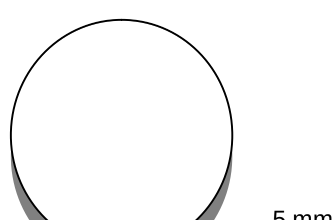
b

Fig(1-3):a: wear test machine b:wear sample.

2.4 micro hardness:-

This test used to estimate hardness (Rockwell and Vickers) for samples as shown in figure (1-4). And the load used (9.8N).

a



b

Fig(1-4): a: micro hardness test machine b: dimension of hardness specimen.

3. Thermal tests:-

3.1 thermal conductivity:-

Thermal conduction net work that is connected to electrical oven was used. The net work consists of two copper plates and inside it a copper heater. The sample is placed above the heater and all of plates, sample and heater are placed inside the oven. As shown in figure (1-5). Then the temperatures at which thermal conduction coefficient calculation is required are determined (60,50 °C). After that reading of upper and lower plates voltage and heater voltage are taken and recorded. By substituting these reading values in the following law, the temperature. then temperature change can be obtained.

$$T_H = 173.1125426 \{ -1.746417087 + (11.30634112 + V_H)^{1/2} \}$$
$$T_U = 173.1125426 \{ -1.746417087 + (11.30634112 + V_U)^{1/2} \}$$
$$T_L = 173.1125426 \{ -1.746417087 + (11.30634112 + V_L)^{1/2} \}$$
$$T_{U,L} = (T_u + T_L) / 2$$
$$\Delta T = T_{U,L} - T_H$$
$$Q = I * V$$
$$K = Q L / A \Delta T$$

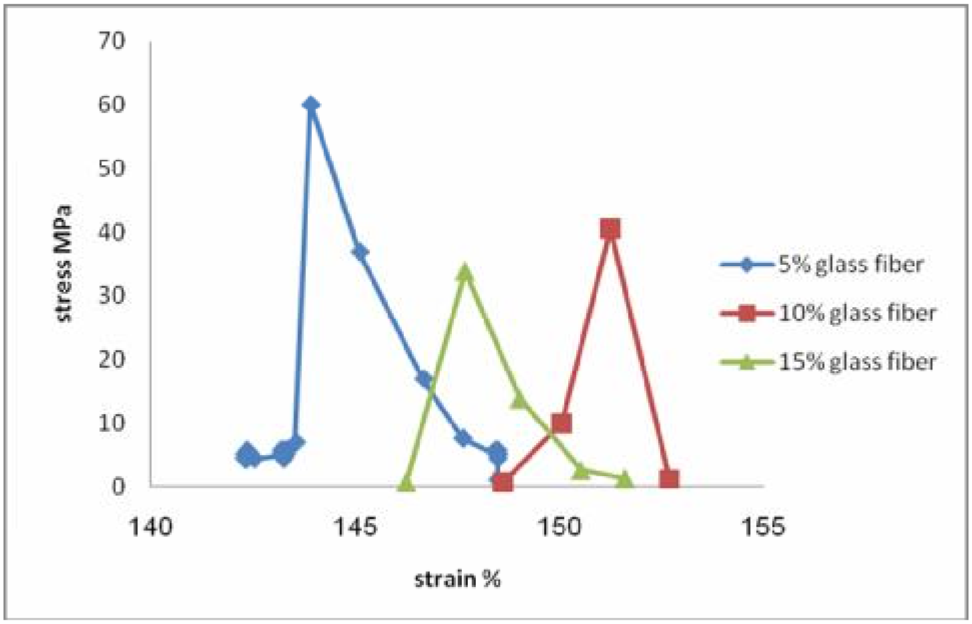
K: thermal conductivity coefficient.
T_H: temperature of heater.
T_U: temperature of upper plate.
T_L: temperature of lower plate.
ΔT: difference in temperature.
I: Alternate current .
V: voltage.
Q: flowing heat amount through the sample.
L: sample thickness.

Fig(1-5):thermal conductivity test machine.

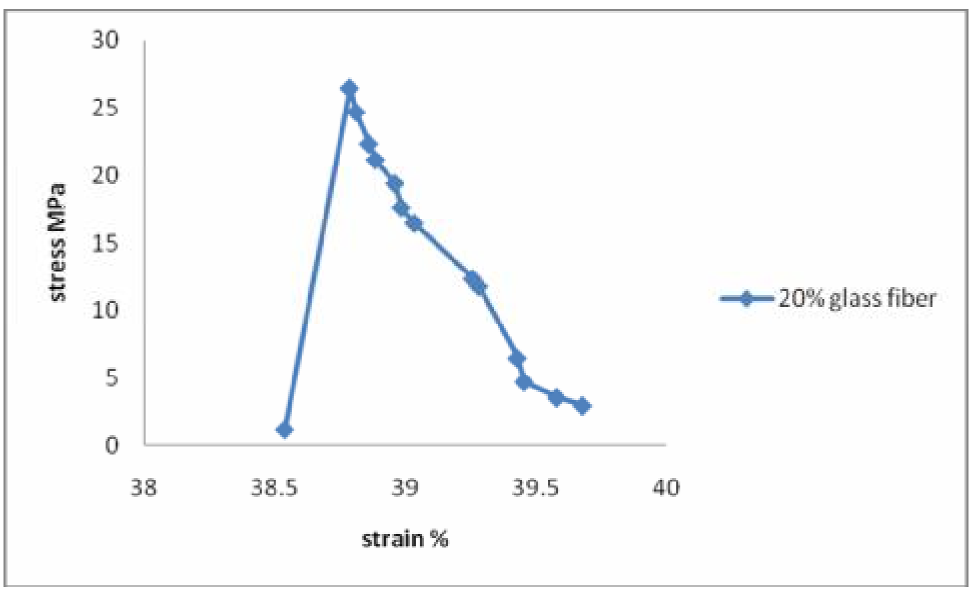
4. Results and discussions :-

4.1 tensile test:-

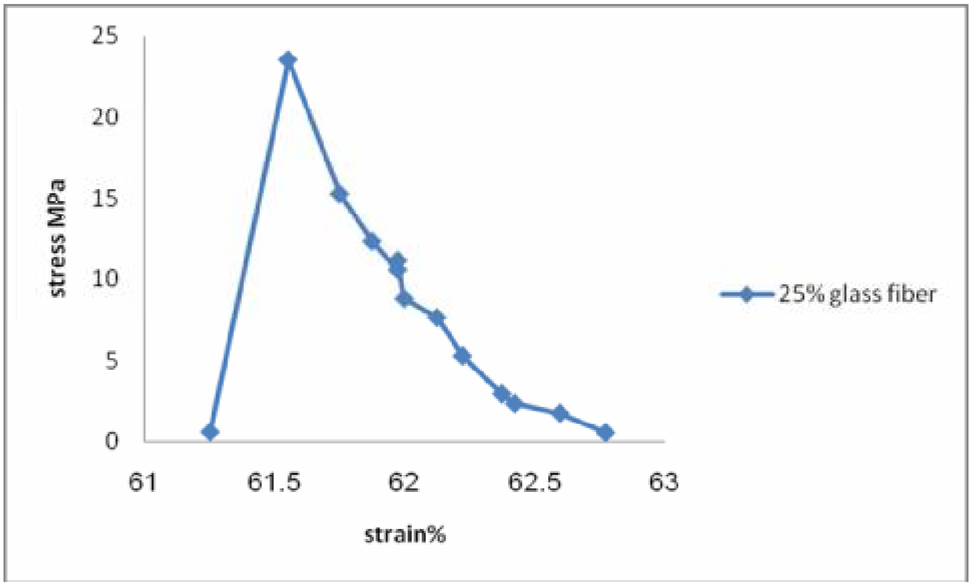
Figure (1-6) illustrate the behavior of stress- strain diagram at different percentage of glass fiber (5%,10%,15%,20%,25%) to predict the tensile strength in these percentages .The results show that the tensile strength are (60,40,33 MPa),which correspond to strain percentage (144%,151.2%,147.7%) respectively at glass fiber percentage (5%,10%,15%) respectively as shown in figure (1-6: a) ,whereas at (20%,25%) the tensile strength (26,23 MPa) respectively as shown in figures (1-6: b) and (1-6: c). Thus the tensile strength decreases with the increasing of glass fiber ratio, which is produced from the debonding depending on interfacial bond strength and this may lead to a break in the composite[Suresh,2006].As we observe the curves, the following can be noticed at 10% glass fiber the tensile strength were reduced by one-third the original tensile strength(60MPa).While at 15% glass fiber, the tensile strength were decreased by approximately one-fifth the original tensile strength(40MPa).Whereas at 20% and 25% glass fiber, the tensile strength were lowered by lesser ratio. Therefore the higher and desirable tensile strength obtained at 5% and 10% glass fiber.


stress MPa
strain %
70
60
50
40
30
20
10
0
140
145
150
155
5% glass fiber
10% glass fiber
15% glass fiber

a


stress MPa
strain %
30
25
20
15
10
5
0
38
38.5
39
39.5
40
20% glass fiber

b



c

Fig(1-6) : a, b and c stress-strain diagram for unsaturated polyester with (5%,10%,15%,20%,25%) of glass fiber at load 5KN.

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4.2 impact test :-

Figure (1-7) shows impact resistance at different ratio of glass fiber (5%,10%,15%,20%,25%).The impact resistance was increased by one-half the original value (0.42) at glass fiber 10% . At glass fiber 15% the impact resistance was enhanced by one-tenth the original value (0.66).While at 20% and 25% glass fiber, the impact resistance remained constant and is not affected by any further increase in the glass fiber ratio. Thus the impact resistance increasing with increasing glass fiber ratio until 15% of glass fiber and this may be because That fibers work to bear the bulk of the applied effort impact on the composite material .Thus the fibers are working on the distribution of stress on the larger area and reduce the probability of stress concentration on a specific area[Manas, 2006 , لميس, ٢٠٠٦].

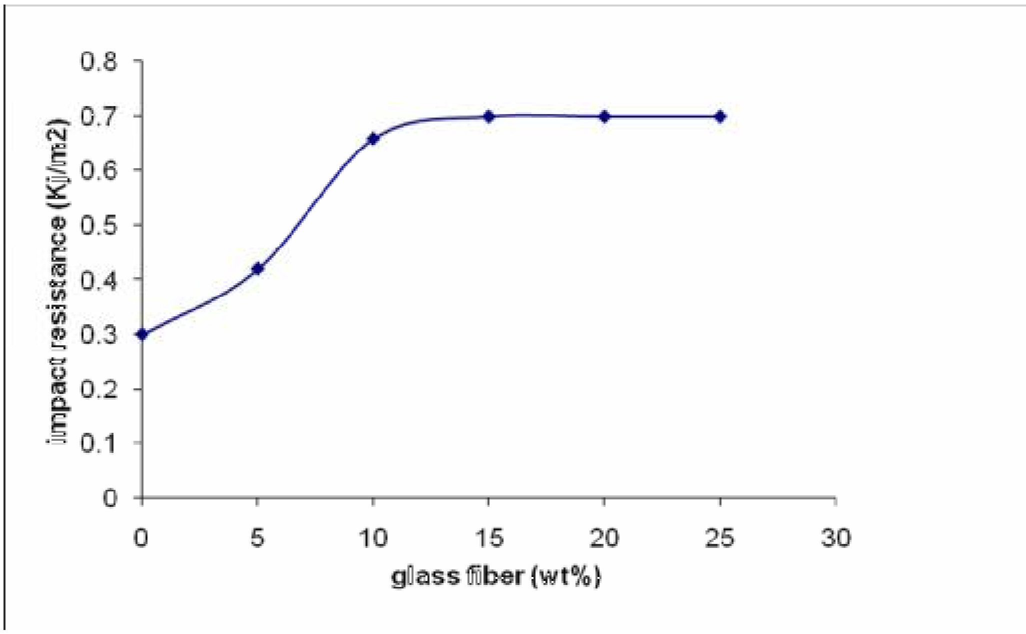

Fig (1-7): impact resistance for unsaturated polyester with (5%,10%,15%,20%,25%) of glass fiber.

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4.3 wear test:-

Figure (1-8) indicate the wear resistance at different ratio of glass fiber in certain time (30 min) and load (2Kg). The results show the wear rate decreases with increasing glass fiber ratio and the minimum wear rate is (64) in 25% of glass fiber i.e. the wear rate is decreased by one-seventh the wear rate at 5% glass fiber and the wear rate at 10%,15%,20% glass fiber is decreased by very small amount. This corresponding with the results of researcher A.Mimaroglu[Mimaroglu,2007].

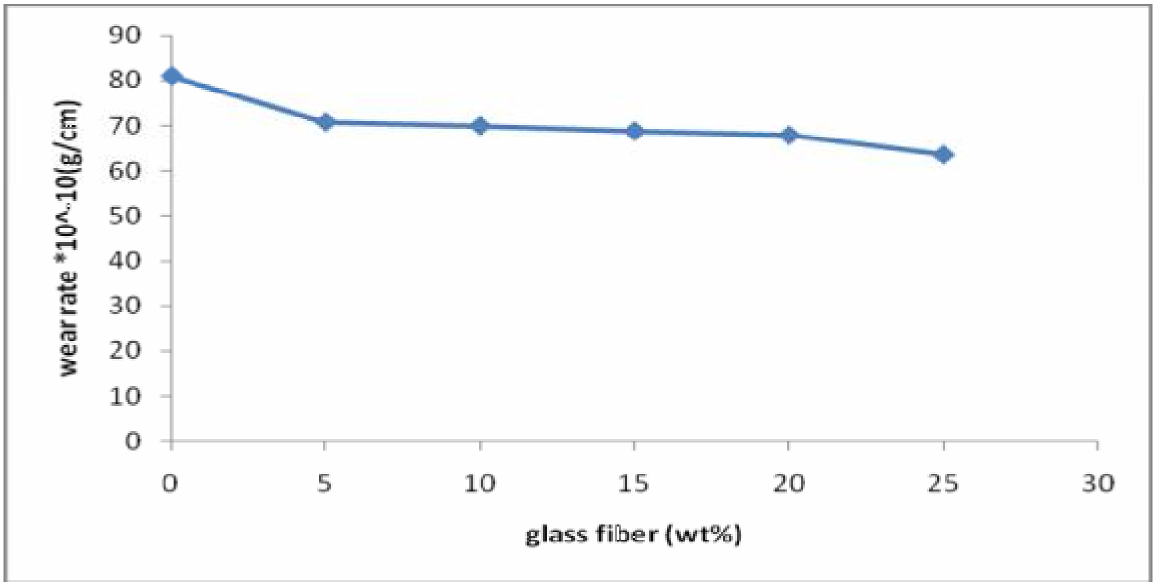

Fig (1-8) wear rate for unsaturated polyester with (5%,10%,15%,20%,25%) of glass fiber at load(2Kg),time(30min) and speed(500 rpm/min) .

4.4 micro hardness test:-

Figure (1-9) illustrate the behavior of micro hardness at different ratios of glass fiber and in this curve we can observe the maximum Rockwell hardness is(60) at 25% glass fiber and the minimum Rockwell hardness is(40) at 5% glass fiber .Thus at 25% glass fiber the Rockwell hardness was increased by one-third the original value at glass fiber 5% . the Rockwell hardness increases with increasing glass fiber ratio because the fiber carry the bulk of the applied stresses on the samples[أمل, ١٩٩٦].

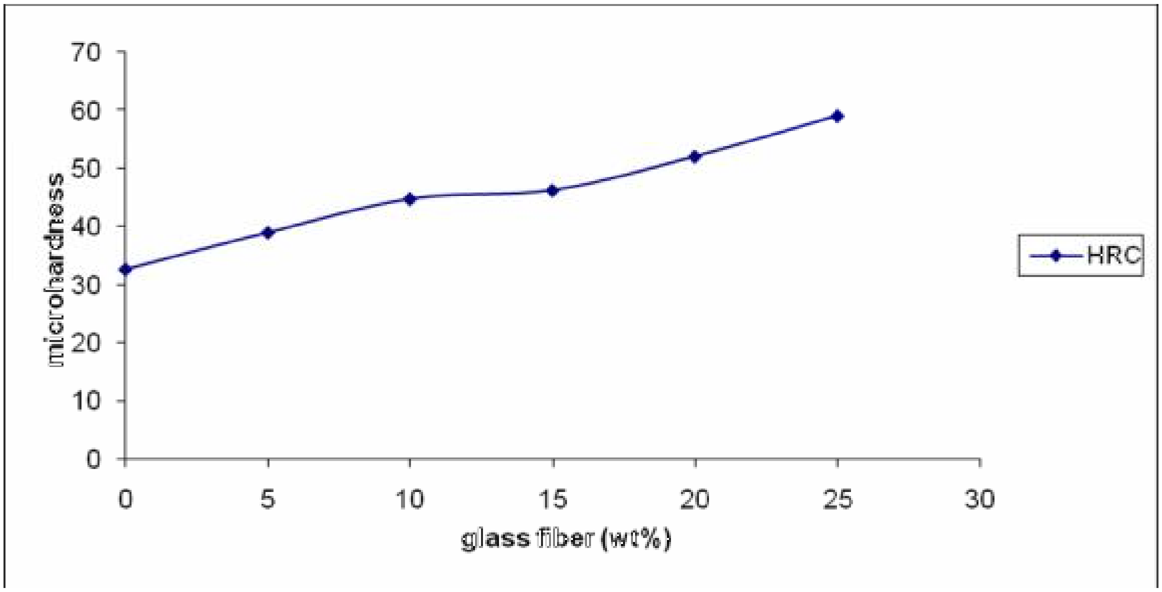

Fig (1-9) : micro hardness for unsaturated polyester with (5%,10%,15%,20%,25%) of glass fiber at 9.8N.

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4.5 thermal test:-

Figure (1-10) show the thermal conductivity at different ratio of glass fiber and the results indicate the thermal conductivity decreases with increasing glass fiber ratio .This can be explained by The presence of glass fibers, which is characterized by poor thermal conductivity heat[A.M.Collieu, 1973].

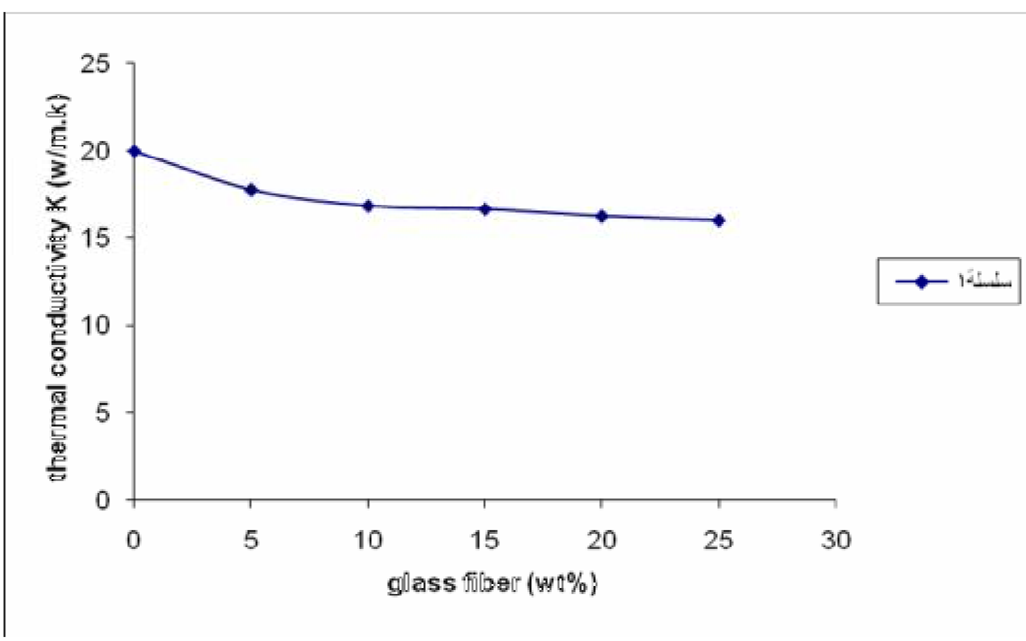

Fig (1-10) :thermal conductivity for unsaturated polyester with (5%,10%,15%,20%,25%) of glass fiber at 60°C.

Conclusion:

In this research, it has been concluded that with increasing glass fiber ratio, tensile strength is decreased, wear resistance is decreased, Rockwell hardness is increased, thermal conductivity is decreased. While impact resistance is increased with increasing glass fiber ratio until 15%.

References:-

El-Tayeb NSM, Yousif BF, 2005'' **Wear and friction behavior of CGRP composite subjected to dry sliding''**, In: Proceedings of WTC2005 world tribology congress.

Edwards KL, 1998" **An overview of the technology of fiber-reinforced plastics for design purposes''**. Mater Des;19(1-2):1–10.

Suresh. A.and Harsha, A. P., 2006, "**Study of erosion efficiency of polymers and polymer composites,**" Polymer testing, **25** (2), pp. 188-196.

A.Mimaroglu**,** 2007**" Friction and wear performance of pure and glass fiber reinforced polyether-imide on polymer and steel counterface materials",**J. Wear 262-1407-1413.

A.M.Collieu and D.J. Powney **,**1973 **" The mechanical and thermal properties ",** Butter and

Tanner , London**.**

Manas Chanda, salil K. Roy,2006 '' **Plastics Technology Handbook** '' Taylor and Francis Group

.

Martin. Grayson, 1983**"Encyclopedia of Composite Materials & Components"**, John wile &Sons.

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