Available online www.jsaer.com

Journal of Scientific and Engineering Research, 2017, 4(8):151-158

Review Article

ISSN: 2394-2630
CODEN(USA): JSERBR

Study the effect of the adding the Copper powder on the Mechanical properties for unsaturated polyester

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Abstract The Study of the Effect of Copper powder on the Mechanical properties of unsaturated polyester which is manufactured in the Turkey, as function of the percentages of Copper powder (0.5%, 0.8%, 1%, 1.5%, 2%, 2.5%), at particular size (150 µm), were investigated through several variables, such as, Young's modules, strength, elongation and the flame resistance. The obtained results have appeared that the added Copper powder to reduce the spaces between the polymer chains, which reflects the high ability of the polymer against the applied stress, and this increase will give further property that increases the hardness of the prepared specimens, the results lead to that the strength at both breaks will be affected little till the percentage (0.8%), and lowered after that with increasing the percentage also indicate a lowered in young's modules at the percentage (0.8%). The proportional limit was (1046 N) for (1%).

Keywords Polymer composites; unsaturated polyester; Copper powder

1. Introduction

Polyesters are one of the most versatile synthetic copolymers, and the polyesters are produced in high volume that exceeds 30 billion pounds a year worldwide [1-3]. They are widely used commercially as fibers, plastics, composites and for coatings applications too [4-5]. They are hetero chain macromolecules that possess carboxyl ate ester groups as an integral component of their polymer backbones. Polyesters have received a great deal of attention since the early work of Carothers, who initiated study on many step-growth polymerizations [6]. Mechanical properties of polymeric materials are important for nearly all applications in industry, technology, and the household. Particularly, stiffness, strength, and toughness are decisive properties in many uses [7]. Mechanical properties depend strongly on chemical as well as on the super molecular structure of the polymeric material, from the mechanical properties is stress-strain curve to the polymeric material [8]. Polymer composite is a combination of a polymer matrix and a strong reinforcing phase, or filler. Polymer composites provide desirable properties unavailable in matrix or filler materials alone [9]. The addition of fillers to polymers is a fast and cheap method to modify the properties of the base materials. For this reason, particulate filled polymers have been, and are, a subject of increasing interest in both industry and research. In this way, strength, stiffness, electrical and thermal conductivity, hardness and dimensional stability, among other properties, can be tailored to the required values [10]. Fillers find application in the polymer industry almost exclusively to improve mechanical, thermal, electrical properties and dimensional-stability [11]. Fillers are solids added to polymers to improve their properties and decrease the cost and have the opposite effect of plasticisers as decrease the softer polymer, or known as organic or inorganic added to the polymer either for the purpose of increasing the volume of material plastic, which reduces the cost or may improve some mechanical properties [12-14]. Studied Ali Hussein and et al, Mechanical properties for a Polymer material reinforcement with Chip or Powder Copper such as flexural strength and impact test of polymer reinforcement copper (powder and chip) were done. The obtained results showed that the maximum flexural strength for the polymer reinforcement with copper (powder and chip) are (85.13 Mpa) and (50.08 Mpa) respectively was obtained, while the maximum observation energy of the impact test for the polymer reinforcement with copper (powder and chip) are (0.85 J) and (0.4 J) respectively [15]. Watan I. W. [16], Studied mechanical &thermal properties of polyester reinforced with ceramic particles Mechanical properties for a Polymer material reinforcement with ceramic Alumina such as thermal conductivity and flexural strength and impact test of polymer reinforcement were done. The obtained results of impact and hardness showed an increase with the increase of weight fraction as non-linear relationships whereas the thermal conductivity increased with the Increment of weight fraction for ceramic particles which has reached the maximum Value of (0.319 w/m. ^{o}C) for the composite material reinforced with alumina Particles at weight fraction of (20%) which has been at the maximum value. The aim of this study is to find out the effect of adding Copper powder to the mechanical properties of the unsaturated polyester and flame resistance.

2. Experimental

2.1. Material basis

In this study, polyester is used as a base material a of Turkish origin and supplied by company (Henkel A.S Turkish), a polymer that is used in various industries and is as viscous liquid the Brown color is thick with a strong and distinctive odor. Its density is about 1.5 g / cm^3. It has a viscosity of 1000 (p) at 25 °C. The solid state is transformed after the addition of the crucifixion, which is also a transparent viscous liquid (ketone ethyl peroxide) and added percentage 2% and supplied by the same company.

2.2. Fillers

This research used the Copper powder fillers with polymer as natural metal filler [17]. Copper is a chemical element with symbol (Cu) and atomic number (29). It is a soft, malleable, and ductility metal with very high thermal and electrical conductivity. A freshly exposed surface of pure copper has a reddish-orange color. Copper is used as a conductor of heat and electricity, as a building material, and as a constituent of various metal alloys, such as sterling silver used in jewelry. The Copper grind to small parts by a grinding machine electric (French made) to the powder, and then treated the Copper powder by use the Sieve Analyzer of the type (Allen-Bradley Sonic Sifter Model L3P) and provided by the company (ATM corp. American) equal to or less than (250 μm). Table (1) shows some of the properties of Copper powder. Figure (1) shows a photograph Copper powder.

Figure 1: A photograph of Copper powder

Table 1: Properties of the Copper powder [18-19].

Name of material	Density g/cm^3	Atomic number	Phase	Melting point °C	Boiling point °C	Heat of fusion kJ/mol	Molar heat capacity J/(mol·K)
Copper (CU)	8.96	29	Solid	1084.62	2562	13.26	24.440

2.3. Shape (template) used in the search

The Shape (template) has been manufactured from transparent glass with a thickness (4 mm), and the sides are moving and attached to the base by silicon rubber that is easy to move. These aspects are variable depending on the size of the sample to be manufactured. The Shape(mold) used is rectangular and the dimensions are (length 11 cm, width 1.5 cm, height 4 mm).

2.4. The Preparation of models

In this research a Hand-lay-out is used in the Preparation of models (polymer with fillings), where we start the blending process. As function of the percentages of Copper powder (0.5%, 0.8%, 1%, 1.5%, 2%, 2.5%), The base material is mixed with the crucifixion at room temperature, Mix the mixture continuously and slowly and continue mixing for (5-8) minutes until the mixture homogenizes well, then flow the liquid mixture in the shape(template) of a stream from one side of the mold so that it flows continuously and regularly to the other side of the template and then put the shape(template) on a manual mechanical vibrator, then start with the process of shaking the shape for a period of (1-2) minutes to remove of the air molecules. Figure (2) shows a photograph of the sample of the polyester added the Copper powder.

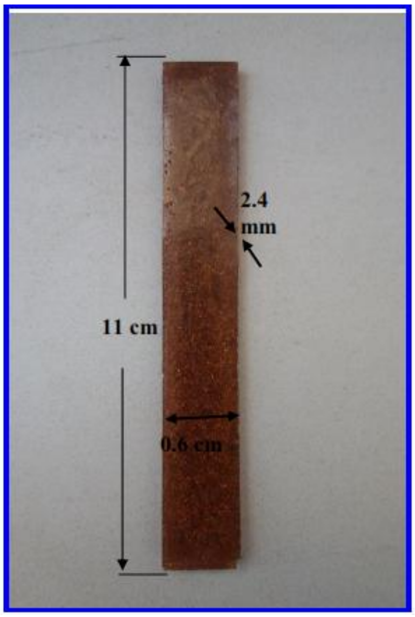

Figure 2: Photograph of the tensile specimen coupon dimensions centimeters.

2.5. Mechanical testing

A universal testing machine Zwick Rell (2.5 KN) was used. The tensile modulus was calculated as the ratio of stress to elastic strain in tension for both pure and modified polyethylene.

The tensile properties were tested according to the ASTM Standard D-638: Standard Test Method for Tensile Properties of Plastics [20]. A photograph showing a mechanical measuring device (Tensile) shown in Figure (3), the study sample thickness in this research is (2.4 mm) and the weight ratios of each the samples. The tensile strength Q was calculated by the following equation [21]:

$Q = F / A \quad (N/mm^2)$ ....(1)

Where:

F = force (N) .

A =sample section area (mm^2).

(Young's modulus) Y = stress/strain ....(2)

Figure 3: a photograph showing a mechanical measuring device (Tensile)

3. Results and discussion

The (stress-strain) curve shows in figure (4), Polyester with Copper powder percentage measured at a constant rate loading at room temperature. Stress- strain curve has been dependent in the description instead of the load-elongation curve because it describes the material characteristics and is less dependent on the arbitrary choice of specimen profile. In the first region, (linear region), where the deformation was not very large, Hook's Low is obeyed which characterized the instantaneous and recoverable deformation associated with the bending and stretching of the interatomic bonds between the polymer atoms. Also, there is no permanent displacement of molecules relative to others. The Linear region can reflect the elastic limit region of the polymer, in which the uniform extension ensues due to stress increased with a constant rate. The proportional limit was (1140 N) when the percentage of (0%) but this value reduced to (512 N) when we add the Copper powder by (2%) of polyester weight.

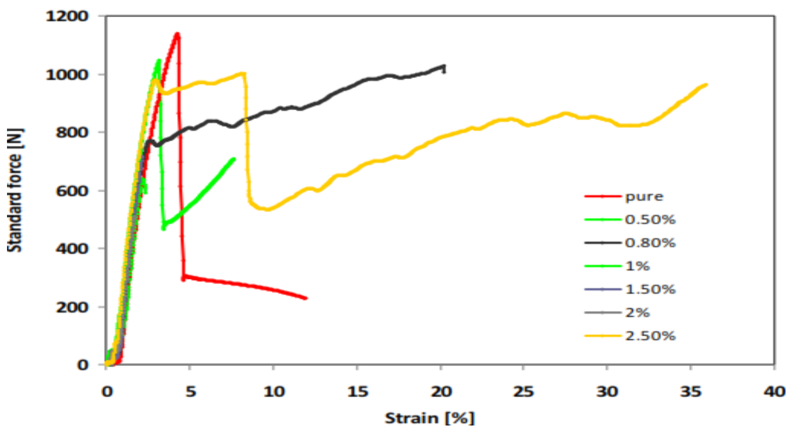

Figure 4: The stress - strain curves and Copper powder-Polyester

The relation between the Stress at yield and Stress at Break with percentages added to the polymer shows in figures(7,8), shown in Figure (7). The behavior of stress at break (Breaking strength is the stress coordinate on the stress-strain curve at the point of rupture), begins the low effect when the percentage of (0.5%) of the additive, and then to increase it to (20.4 Mpa) when the percentage is (0.8%) for tensile strength at break and (15.6 Mpa) with Stress at yield, and we note that Stress at yield (yield strength is the stress at which a material begins to distort plastically. Prior to the yield point the material will distort elastically and will return to its original shape when the applied stress is removed), and Stress at Break decreases when you increase the percentage of adding the powder of Copper when the percentage is (2%) and the behavior of tensile strength at yield increases when the percentage is (2.5%).This shows that the Copper powder works to improve the hardness property at a percentage when the polymer hardness extends at this rate of the effect of the distribution of homogeneous material nature solid.

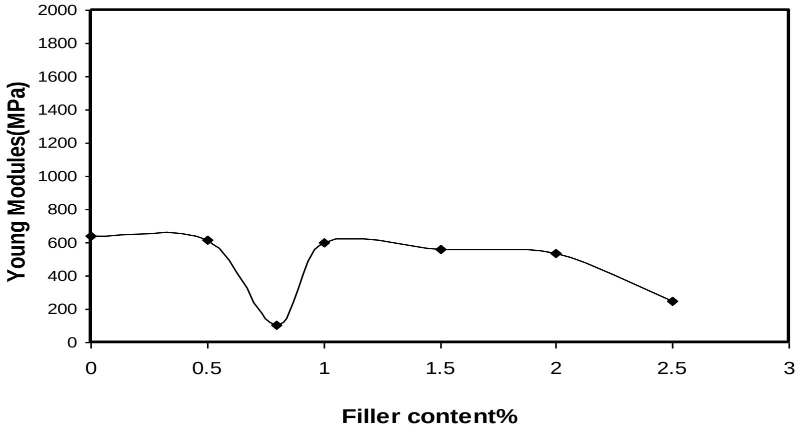

Figure 5: Young modulus and Copper powder -Polyester composites

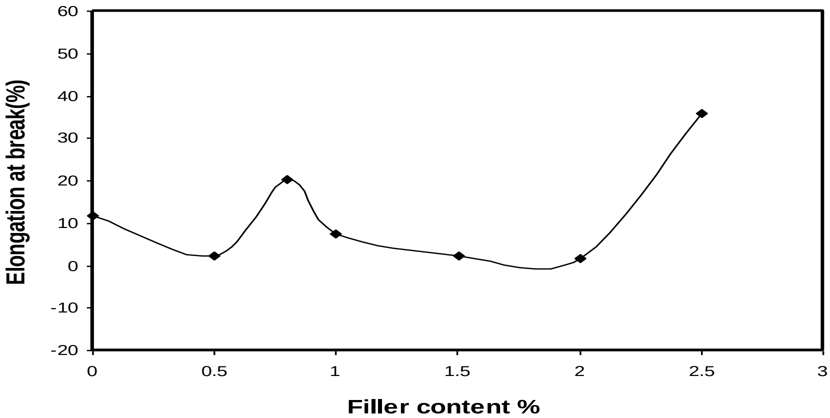

Figure 6: Elongation at break and powder of Copper -Polyester composites

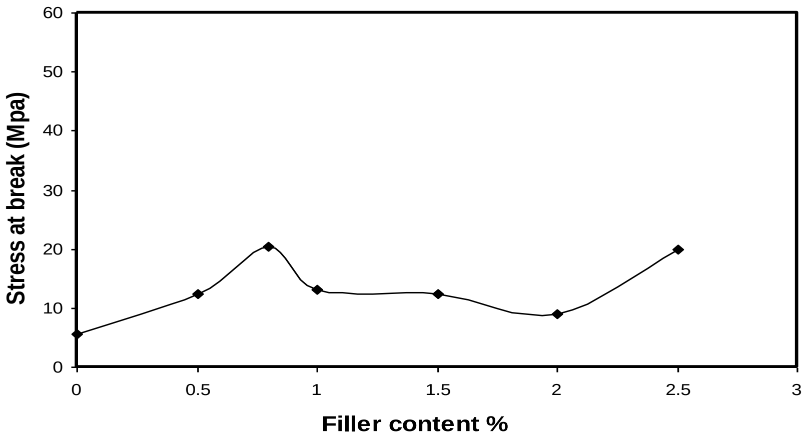

Figure 7: Stress at Break and Copper powder -Polyester composites

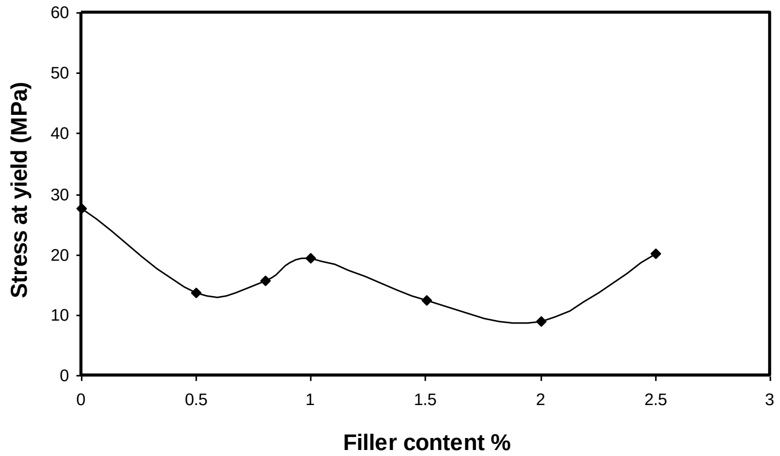

Figure 8: Stress at Yield and powder of Copper powder -Polyester composites

The relation between the percentage of elongation at break with of the percentages of Copper powder shows in figure (6) , the elongation of the polymer begins at the percentage of (0%) of the pure polymer (11.9%) and then decreases when the percentage (0.5%) is (2.4%), which is a few flexibility polymer and has a hardness high thereby acting Copper powder to fill the spaces between the chains main polymer limited movement of the chains and thus less elongation and then decrease until it reaches the maximum value to them when the ratio (2%) is (1.7%), and the polymer when this ratio high flexibility and low hardness, and then increases when the percentage is (2.5%) is (35.9%) polymeric chains that are not constrained by any movement as a result of lack of homogeneity of the mixture, including the nature of the powder of Copper characterized by hardness.

Figure (10) represents the proportional limit (A yield strength or yield point of a material is defined in engineering and materials science as the stress at which a material begins to distort plastically. Prior to the yield point the material will deform elastically and will return to its original shape when the applied stress is removed) with the percentage added Copper powder to the polymer, the highest value was when the proportion of the added polymer (0.8%) is (1028 N) as it will be at this homogeneity rate strong between powder of Copper with chains of polymer while the less proportion limit of which (512 N) at the percentage is (2%), and probably explains the increase in the Copper powder when the percentage is (2.5%) is (1000.3 N), of the additive to the heterogeneity of the model although the mixing models have been in the same circumstances.

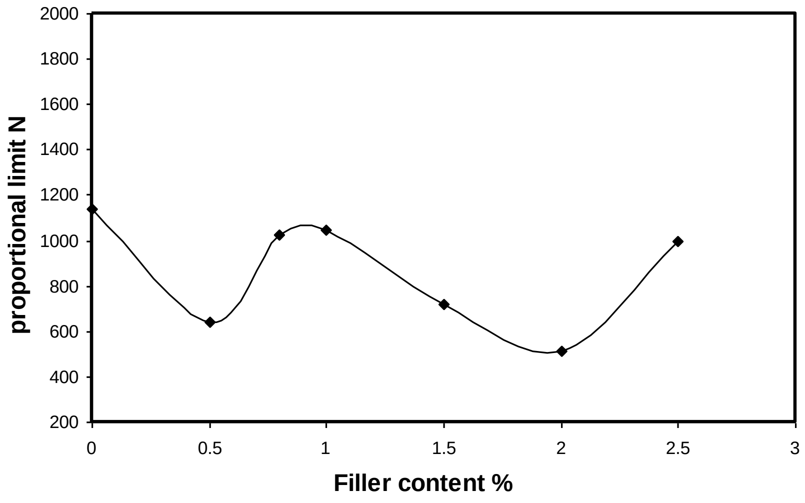

Figure 10: Relation between the proportional limit and powder of Copper -Polyester composites

Figure (5) shows the effect of the Copper powder on Young modulus, which is known as a proportion of stress to elongation for solids only shown in figure increasing Young modulus progressively with the increasing concentration of additive. The Young modulus was (618 Mpa) when the percentage of (0.5%), and then decreases when the percentage (0.8%) is (103 Mpa), the probably explains the decline in the Copper powder when the percentage of (0.8%) of the additive to the heterogeneity of the model although the mixing models have been in the same circumstances, and this indicates that the polymer has the high elasticity (large elongation) and decreases in hardness at this percentage.

Conclusion

The Metal filler like Copper powder can be added in form of filler where their effect on mechanical properties depends on the concentration. This effect on the mechanical properties is due to the functional groups and the ability of Copper powder that improves the mechanical properties and increases the strength by increasing the binding between the functional filler groups and the polymer. The Copper powder used as filler in this study improves the mechanical properties (stress - strain) and the best results with (0.8%) and (2.5%) content, the changing of added Copper powder ratio certainly made big changes to those mechanical properties like stress-strain, toughness, and elongation due to the type of interaction between the polymers chains. Polyester with (0.8%) Copper powder is recommended for industrial applications.

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