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Effect of Rockwool Fibers on the Mechanical Properties and Average Time of Burning of Low Density Polyethylene

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Abstract

The mechanical properties and average time of burning of composite were made from low density polyethylene with different wt% of Rockwool fibers (1, 2.5, 5, 7.5, 10)% w/w and found that the best ration of composites 7.5%. The elastic deformation properties of samples were evaluated by Loaded-elongation measurement. The stress - strain results found that the elastic properties decrease with increasing of Rockwool fibers, while 10% is the best ratio that achieved best average time of Burning (ATB).

Keywords: Mechanical Properties, average time of burning, low density polyethylene, Rockwool fibers, fillers, Stress-strain curve

1. Introduction

Low density Polyethylene (LDPE) is an one famous commercial polymers used as industrial applications. Electrically, it's used on of insulating materials. It was good insulation and excellent mechanical properties (high tensile strength); that candidate their utilizing in different applications as active material replacing other materials [1].The wide range temperature between its glass transition and melting point (-80,120^{o}C) displayed efficient characteristics to utilize the polymer as

properties such as rigidity, thermal softening, and melting behavior, the ultimate mechanical properties are

insulating cover for cables and wires[2].

Mechanical properties of polymeric materials are important industrial applications, technology, and the household. Particularly, stiffness, strength, and toughness are important properties in many uses. Mechanical properties depend strongly on chemical as well as on super molecular structure of the polymeric material. While the chemical, molecular structure defines some basic properties such as rigidity, thermal softening, and melting behavior, the ultimate mechanical fixed by the super molecular structures or morphology. The same molecular structure can yield to many varied morphologies dependent on some factors such as orientation due to fabrication, different cooling rates, changes in thermal history, and secondary crystallization [3].

Fillers are solid organic or inorganic materials added to the polymers for improving of their properties; lower cost and have the opposite effect of plasticizers as decrease the softer polymer, which reduces the cost or may improve some mechanical properties [4,5]. The effect of fillers in the polymer matrix almost exclusively, e.g. to improve mechanical, thermal, electrical properties and dimensional-stability. LDPE composites are used in various applications as decks and docks, packaging film, pipes, tubes, window frames or, in the last years, also as materials in the automobile industry [6-11].

The additive affected on mechanical properties parameters of polymers such as tensile strength and rigidity modulus.

In the present paper; the mechanical properties of (low density polyethylene: Rockwool fibers composites) have been investigated for different Rockwool fibers weight percentage (1%-10%). Tensile strength (σ_M), tensile strain (ε_M) , tensile strees at break(σ_B) , tensile strain at break (ε_B), tensile strain at yield(ε_y) and Young's modulus(Y) have been measured at room temperature(25^{o}C). The results were analyzed based on (stress - strain) relationship and microscopic analysis used to interpret the physical behavior.

2. Experimental

2.1 Materials

1. Low density polyethylene (SCILEN 22004) grade supplies from the state company for the Petrochemical Industry (SCPI) in Basra/Iraq has melt index =0. 39 gm/10min., density = 0.922 gm/cm^3.

2. Rockwool, as a filler which supplied by that-alsawwary company in Baghdad/Iraq. The average Rockwool fibers particle size used in this work is (<212)µm. The chemical composition Rockwool is shown in table(1).[12,13]

Table 1: The chemical composition of Rockwool

Chemical composition	SiO_2	Al_2O_3	Fe_2O_3	CaO	MgO	Na_2O	K_2O
wt.%	43.54%	15.01%	10.82%	11.82%	4.51%	0.14%	14.16

2.2Sample preparation

In this study, five weight percents of Rockwool fibers (1, 2.5, 5,7.5and 10) % were used to prepare the polymeric composites. Rockwool powder is mixed with LDPE using Rheomix mixer 600 instruments attached to the Haake Rehochard meter (United States of America)with the following conditions; mixing time 15 min; mixing temperature 160^{0}C ; mixing velocity 32 RPM. After that the final mold product is introduced in a laboratory compress (Iraq/Basra) under 5 tons at 175^{0}C for 3 minutes in a square frame where the pressure rises gradually up to 15 tons for (6) minutes and after this period the sample sheet is cooled up to reach room temperature . This sheet of final product is used to prepare dumbbell Samples for measuring of the mechanical properties by using Instron instrument Zwick/Roel (Germany) type [BT1-FR2.5 TN.D14]Picture(1)with the following conditions; chart speed (10) mm/min., crosshead speed 50 mm/min. The test specimen is positioned vertically in the grips of device then the grips are tightened evenly and firmly to prevent any slippage. The relationship between elongation and load is obtained directly from the instrument. [14-16]

2.3Tensile Properties

The tensile properties were tested according to the ASTM Standard D-638: Standard Test Method for Tensile Properties of Plastics (2008) [17]. The dimensions of the dumbbell-shaped specimens are shown in Picture (2).The amount of strength (σ),tensile strength and *Young's modulus* were calculated by the following equation [18,19]:

$\sigma = F / A$ **…..(1)**

Where F = force (N) , and A =sample section area (mm^2).

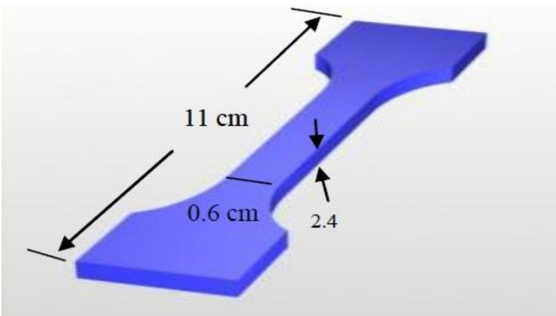
$$Tensile \quad strain\% = \frac{L - Lo}{Lo} \times 100$$

…..(2)

Where:

L: final length of sample, L_0: original length of sample.

(Young's modulus) Y = stress/strain **……(3)**



Picture2:The tensile dumbbell shape specimen coupon dimensions centimeters.

2.4Average Time of Burning ATB

In this research the average time of Burning (ATB)was measured according to the standard method ASTM D635 (1981)[20].Calculating the time required for combustion model to a distance of 75 mm from sample, also re-measurement three times for each sample was extracted average values. By equation (4) in Figure (3)

$$ATB = \frac{\Sigma\,(t - 30\,s)}{number\ of\ specimens} \quad \textbf{…….(4)}$$

Where:
ATB: average time of burning, t : time, s: second.

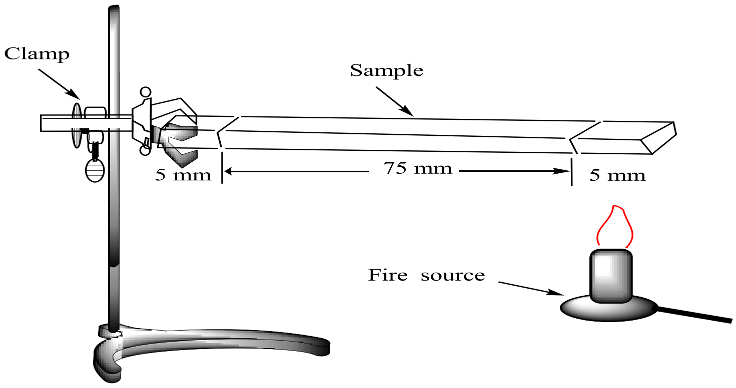


Figure 3: Test apparatus of Average Time of Burning (ATB)

3. Results and Discussion:

Tensile test is widely used for measuring stiffness, strength and ductility of the polymer. Stress-strain relationship in polymers is considered as complex dependencies, and is not linear in nature. Figure (1) and table (2) showed that the (stress - strain) curve of LDPE loaded with different percentages of Rockwool fibers were measured at a constant of loading rate at room temperature. Stress- strain curve has been dependent on the description instead of load-elongation curve because it describes the material characteristics and is less dependent on the arbitrary choice of specimen profile. It's well known that polyethylene belongs to where this behavior has characterized with low modulus and low yield stress. According to the break down classification, the stress-strain curve is exemplifying the second behavior of the fracture nominally cold drawing [21]. In this type three regions can be distinguished; first is the linear region, second is the yield region, third is the elongation region up to the break. 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 the inter atomic bonds between the polymer atoms. [22]

One of the most important engineering parameters which reflects the material resistance against deformation, and should be measured before designing polymer is Young's modulus. Young's modulus can be estimated from the slope of the portion of the first region, which is found a higher for a sample with a higher extension rate. The variation of Young's modulus against Rockwool fibers filler is shown in Figure (2) Young's modulus varied between 105.61MPa to135.64MPa for Rockwool fibers ratio between 1-10% respectively. Young's modulus can refer to increase the resistance of material to deformation. The volume of the specimen remains constant during elastic deformation, so as the gauge length elongates, its cross-sectional area is progressively reduced. Mechanical properties essentially depend upon the molecular behavior, include chemical composition and physical structure. The nonlinearity in the stress-strain curve neither caused by increasing free volume or filler contents nor to be connected to the viscous flow. It can be related to the shear component of the applied stress. In the region confined between the proportionality limit and the yield point the deformation in this region is not stantanuosely recoverable, but it's ultimately and can be characterized like straightening out of a coil portion of the molecular chains [23]. The uncoiling mechanism is known as a relatively slow mechanism.

The result of the tensile strain at break of composites shown in Figure (3). The tensile strain at break (ε_B) decreases gradually, it appears as a shoulder. Maximum tensile may be explained due to the perfect homogeneity of filler distribution in the polymer matrix. studied the mechanical properties of low density polyethylene, tensile strain (ε_B) show the relation between the percentage of elongation with the concentration of additive, the elongation of the polymer begins at the percentage (0%) of the polymer pure it (256.2%) then decreases with the increasing of filler ratio; at the percentage (1%) a (25.5%) which the a polymer has few flexibility and high a hardness high thereby acting Rockwool fibers to fill the spaces between the chains main polymer limited movement of the chains and thus less elongation and then increases until it reaches the maximum value when the ratio (7.5%) a (48.5%), and the polymer when this ratio high flexibility and low hardness, decreased with the increasing of filler ratio; at the percentage (10%) a (38.5%).Polymeric chains that are not constrained by any free movement as a result of lack of homogeneity of the mixture, including the nature of the Rockwool fibers characterized by rigidity, which in turn increase the stiffness of the polymer and reduce elongation increased concentration of additive and worked to increase the density of the polymer.

It is clear from Figure (3) and table (2) that the maximum tensile strength(σ_M) at 7.5% is 13.7MPa so that amount of load tensile strength(σ_M) reversible when decreasing the concentration of additive which works Rockwool fibers to reach 10.7 MPa at 2.5% the hardness increases when the polymer and thus the polymeric chains is constrained to decrease its flexibility.

Table 2. Some Parameters from stress-strain curve of LDPE with different percentages of Rockwool fibers

Filler content (wt.%)	σ_M (MPa)	ε_M%	σ_B (MPa)	ε_B%	Y(MPa)
0	14.4	11.6	5.97	256.2	124.13
1	11.3	10.7	6.65	25.5	105.61
2.5	10.7	10.7	2.84	36.2	100
5	12.7	11.0	9.56	42.6	115.45

7.5	**13.7**	**10.1**	**8.96**	**48.5**	**135.64**
10	**12.0**	**9.8**	**6.94**	**38.5**	**122.45**

Definition of **Parameters** *Used in This Study*

σ_M=tensile strength in MPa, ε_M=tensile strain , σ_B=tensile strees at breakin MPa , ε_B=tensile strain at break , Y =Young's modulus in MPa.

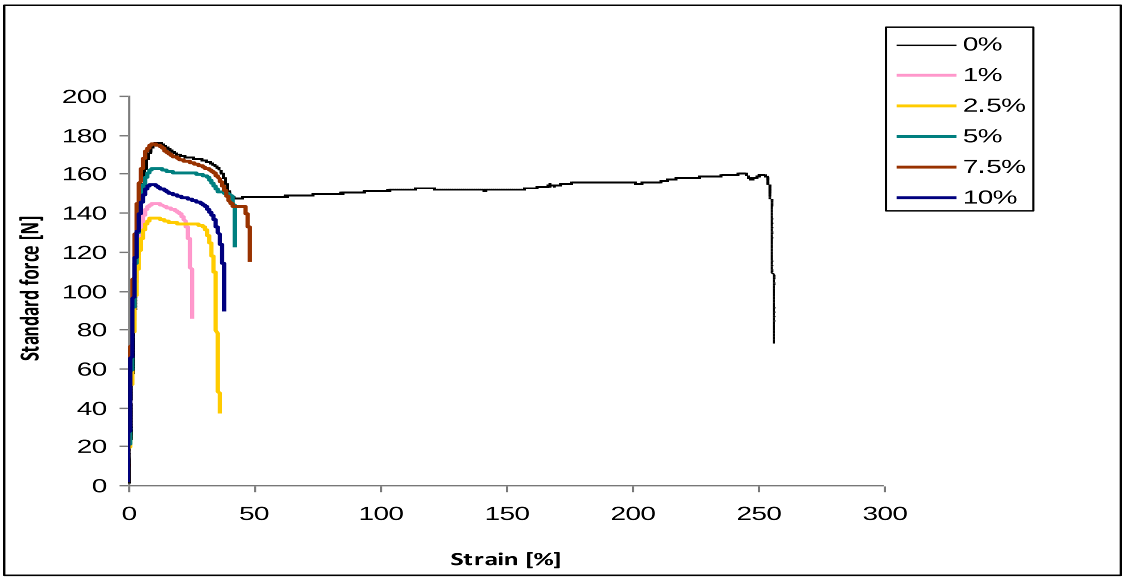


Figure. 1: The stress - strain curves of polymer composite with Rockwool fibers

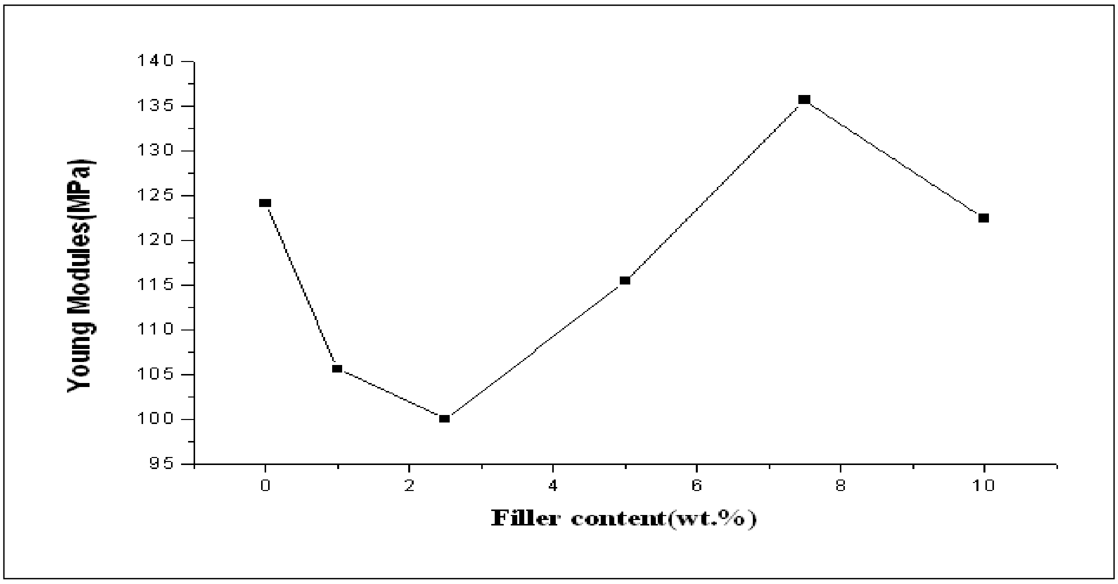


Figure.2: Variation between Young Modules and Filler content (wt.%).

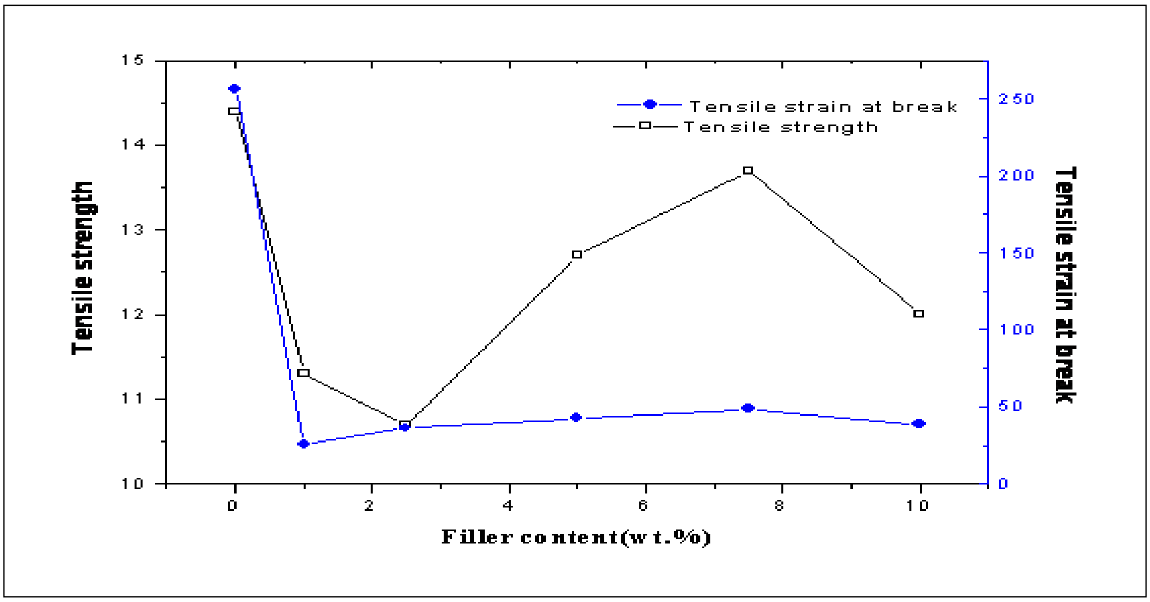


Figure.3: Tensile strain at break and tensile strength with Filler content (wt.%).

Figure (4) shows the relation between average time of burning with the percentages added of Rockwool fibers, and it is clear the behavior begin low effect when the percentage (1 %) is (144Sec), while shows the increasing Rockwool fibers start to increase gradually, where we get high value when the percentage is (196Sec). The proportions of the Rockwool fibers have a positive effect on the flame resistance and heat spread through the matrix polymer. This is due to the homogeneity between the additives and polymer.

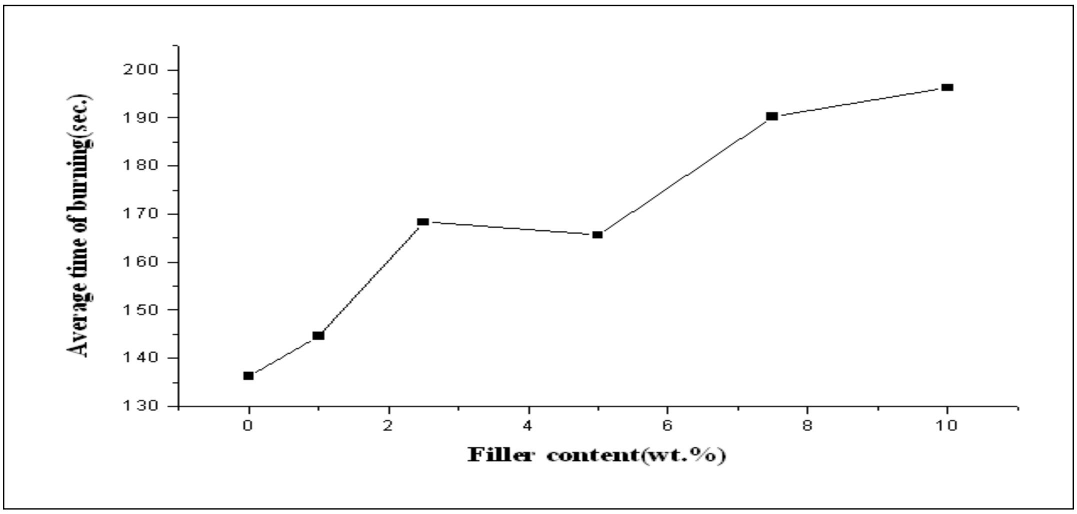


Figure.4:The average time of burning at LDPE/ filler composites

Conclusion

Mechanical properties of low density polyethylene were changed by adding (Rockwool fibers) with different weight percentage. Polymer phase was decreased by stiffer material (Rockwool fibers). This interprets the weekend observed in mechanical properties less than 5% percentage. Accordingly, LDPE with 7.5% Rockwool powder is recommended for industrial applications and the best average time of Burning at 10%.

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دراسة تأثير ألياف الصوف الصخري على الخصائص الميكانيكية ومعدل زمن الاحتراق للبولي اثيلين واطئ الكثافة

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المستخلص

تناول البحث تقييم الخواص الميكانيكه للخليط البوليمري (بوليمر الاثيلين واطى الكثافه463 /الياف الصوف الصخري) كداله الى نسبه المضاف ألوزنيه والتي تمتد ما بين (1 % إلى10 %) وعند حجم دقيقة مساوي او اقل من (212>) مايكرومتر حيث تمت الدراسة من خلال عدة متغيرات بالاعتماد على منحني الإجهاد – المطاوعة وبينت النتائج المستحصله ان مسحوق الصوف الصخري المضاف يعمل على تباعد السلاسل البوليمرية مما يعكس إمكانية البوليمر الضعيفة بتحمل الإجهاد المسلط عليه وان منحني (الإجهاد–المطاوعة) من النوع السحب البارد للحالة النقية وان درجة التجانس عالية بين كل من البوليمر المضيف والمالئ المضاف وان نسبة الاستطالة في هذا البوليمر تتناقص بصورة تدريجية مع زيادة النسبة المئوية للمالئات وتشهد الاستطالة نقصانا كبيرا في القيم عند النسب العالية من المالئ المضاف وأشارت النتائج أيضا على ان قوة الشد عند القطع وقوة الشد عند الوهن تنخفض مع زيادة نسبة المالئ مما يعكس الانخفاض في مرونة البوليمر المطعم بمسحوق الصوف الصخري حيث يتضح من النتائج إن افضل نسبة هي 7.5%. كما دلت نتائج الاحتراقية انه بزيادة نسبة المضاف يزداد معدل زمن الاحتراق حيث وجدت ان النسبة 10% هي افضل نسبة مقارنة ببقية النسب.