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STUDY OF THE MECHANICAL PROPERTIES OF HIGH DENSITY POLYETHYLENE (HDPE) COMPOSITES WITH ALUM POWDER.

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ABSTRACT

The mechanical properties of (HDPE - Alum powder) composites were studied. The range of added powder of Alum has the values (0%, 2.5%, 5%, 10%, 15%, 20%,25% and 30%) of polyethylene weight and, the best ratios were 10 % and 15 %. The obvious improvement in the mechanical parameters was recorded when adding Alum powder with 10% weight ratio. The properties of (HDPE / Alum powder) composites were analyzed as a function of the added powder amount. All prepared composites showed improved powder dispersion in the high density polyethylene matrix. All composites displayed lower elongation of break compared to pure HDPE. The highest value of the proportional limit was when the proportion of the added polymer (5%) is (367.5 N) as it will be at this homogeneity rate strong between powder Alum with chains of polymer while the less proportion limit of which (234 N) at the percentage is (25%).

Keywords: Polymer composites; high density polyethylene; Flam resistance Alum powder, mechanical properties; proportional limit.

1. INTRODUCTION

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. 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, this curve consists of three main regions ; first is the linear region, a 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 of the inter atomic bonds between the polymer atoms. Also, there is no permanent displacement of molecules relative to others. 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 . While the chemical, molecular structure defines some basic properties such as rigidity, thermal softening, and melting behavior, the ultimate mechanical properties are fixed by the super molecular structures or morphology. The same molecular structure can yield to many varied morphologies dependent on factors such as orientation due to fabrication, different cooling rates, changes in thermal history, and secondary crystallization [1]. performance of filled polymers is generally determined on the basis of the interface attraction of filler and polymers. Incorporating inorganic mineral fillers [2]. Fillers are solids added to polymers to improve their properties and decrease the cost and have the opposite effect of plasticisers as decreasing 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 [3-5].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 [6-7]. Studied Nadhim A. Abdullah et al. the Mechanical Properties of High Density Polyethylene (HDPE) Modified with Local Cheap Fillers. The obtained results showed that the adding of sawdust as a filler to HDPE decreasing the elongation by 80% relative to its original value were this decrease was rapid in filler range (5%-25%) and explained in the term of decreasing the polymeric chains distance [8]. HDPE 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 [9-13]. The aim of this study is to find out the effect of adding Alum powder to the mechanical properties of polyethylene.

2. EXPERIMENTAL

2.1 Material basis

High Density Polyethylene (HDPE) used in this work, as the basis of material, HDPE product by the General Company for Petrochemical Industries (Basra-Iraq) in the form of powder. Table (1) shows some of the properties of high density polyethylene (HDPE).

Table (1) properties of High density polyethylene[8]

Property	HDPE
Trade Name	Scpilex (M624)
Density (g/cm^3)	0.961
Melt Index (g/10 min)	5-7

2.2 Fillers

This research used the Alum powder fillers with polymer as natural organic filler [14]. The cubes of Alum were cut into small pieces and then grind to small parts by a grinding machine electric (French made) to the powder, and then treated the Alum 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).Figure (1) shows a photograph Alum powder.

Figure (1): Photograph of the Alum powder.

2.3 The Preparation of Composites.

Alum Powder is mixed with HDPE using mixer 600 instrument attached to Haake Rehochard meter under following conditions; mixing time 15 minutes, mixing temperature 160 °C and mixing velocity 50 RPM., by using the cross section (mixer 400) with description 16 R.P.M, 60 °C for 10 minutes. The final mold product is introduced in a laboratory compress under 5 tons at 175 °C for 3 minutes in a square frame. The pressure then rises gradually up to 15 tons for 10 minutes and after this period, the sample is cooled up to reach room temperature. Samples, dumbbell in shape, are prepared for measuring the mechanical properties by using Zwick Rell instrument. Table (2) shows the weight ratio of the Alum powder %. and the weight ratio of the HDPE %.

weight ratio of the Alum powder %	0	2.5	5	10	15	20	30
The weight ratio of the HDPE %	100	97.5	95	90	85	80	70

Table (2) shows the weight ratio of the Alum powder and HDPE %.

2.4. 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 [15]. The dimensions of the dumbbell-shaped specimens are shown in Figure (2), 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 [16]:

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

Where:
F = force (N) .
A =sample section area (mm^2).
(Young's modulus) Y = stress/strain (2)

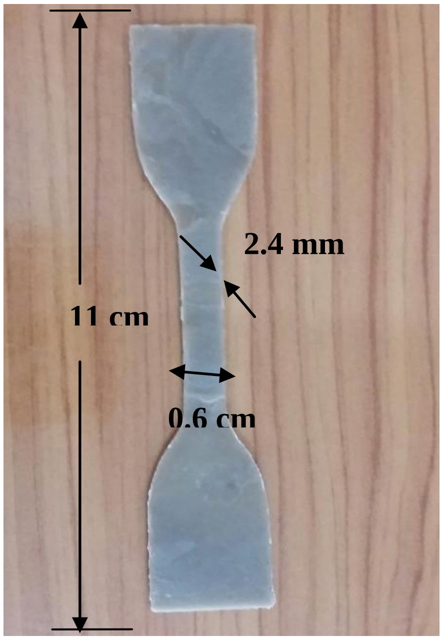

Figure (2) Photograph of the tensile specimen coupon dimensions centimeters.

2.5 Average Time of Burning ATB.

Average Time of Burning (ATB) and Average Extent of Burning (AEB) for each sample measured in this work by a device measuring the Burning Rate, 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. Figure (3) shows a diagram of a device measured average time of burning (ATB), and the average time of Burning (ATB) and average extent of burning (AEB) using the following equation [17].

$$\text{ATB}=\frac{\Sigma\,(t-30\ s)}{number\ of\ specimens} \qquad (3)$$

where: t : time(s), s: second.

$$\text{AEB}=\frac{\Sigma\,(100\ mm-unburned\ lenght)}{number\ of\ specimens} \qquad (4)$$

The Rate of Burning (RB) using the following relation:

$$\text{RB}=\frac{(AEB)\ \ cm}{(ATB)\ \min.} \qquad (5)$$

2.6. ASTM: D-635.

The measurement of a rate of burning(R.B), an average extent of burning(A.E.B), the average time of burning(A.T.B) [18].

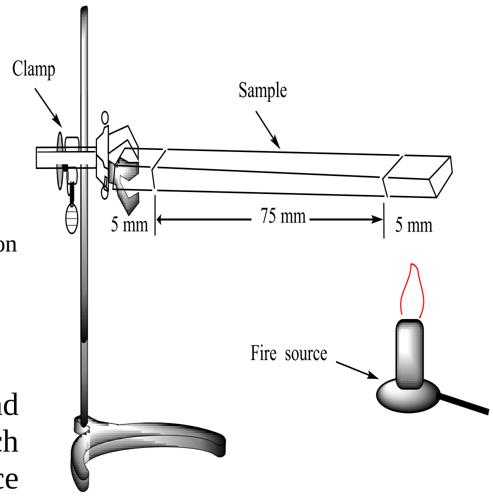

Figure (3) diagram of device measured average time of burning.

3. RESULTS AND DISCUSSION

Figure(4) shows the (stress-strain) curve of HDPE loaded with Alum powder percentage measured at a constant rate loading at room temperature. Stress- strain curve has been dependent in 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 been 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. 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 of the inter atomic bonds between the polymer atoms. Also there is no permane displacement of molecules relative others. Linear region can reflect the elast limit region of the polymer, in which tl uniform extension ensues due to stre increased with a constant rate. Tl proportional limit was (351 N) when tl percentage of (0%) but this value reduc to (234 N) when we add the Alum powd by (25%) of polyethylene weight.

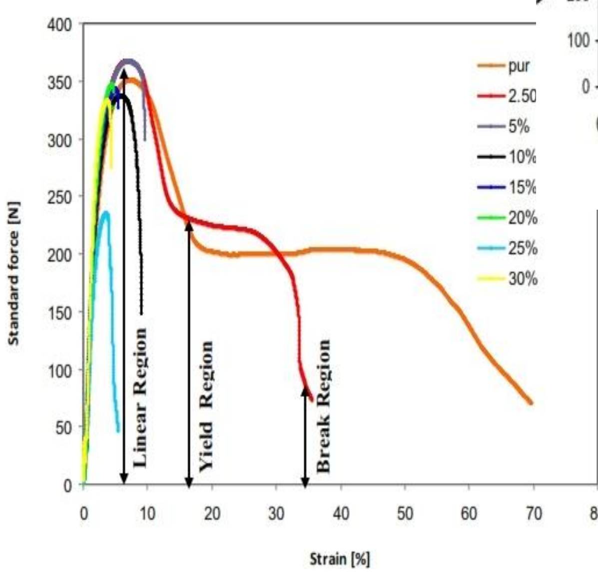

Figure (4) stress - strain curves and Alum powder -HDPE

Figure (5) shows the effect of the Alum powder on modulus of elasticity (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 (751 Mpa) when the percentage of (20%), and then decreases when the percentage (25%) is (570 Mpa), the probably explains the decline in the Alum powder when the percentage of (25%) 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.

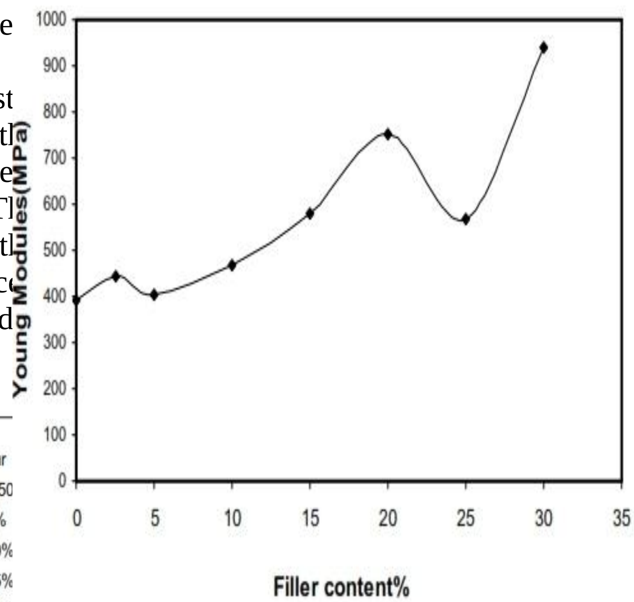

Figure (5) Young modulus and Alum powder - HDPE composites.

Figure (6) shows the relation between the percentage of elongation at break with the concentration of additive, the elongation of the polymer begins at the percentage of (0%) of the pure polymer (62.8%) and then decreases when the percentage (2.5%) is (24.7%), which is a few flexibility polymer and has a hardness high thereby acting Alum powder 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 to them when the ratio (10 %) is (9.2%), and the polymer when this ratio high flexibility and low hardness, and then decrease when the percentage is (30%) is (3.2%)

polymeric chains that are not constrained by any movement as a result of lack of homogeneity of the mixture, including the nature of the Alum powder characterized by rigidity, which in turn increases the stiffness of the polymer and reduces elongation which increased the concentration of additive and worked to increase the density of the polymer.

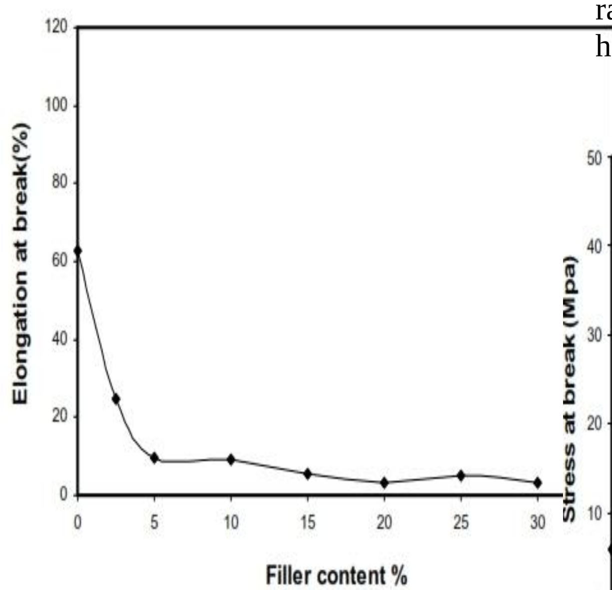

Figure (6) Elongation at break and powder of Alum - HDPE composites.

Figures(7,8) show the relation between the 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 (Breaking strength is the stress coordinate on the stress-strain curve at the point of rupture) with a percentage added to the polymer, shown in Figure (6). The behavior of stress at break begins the low effect when the percentage of (2.5%) of the additive, and then to increase it to (26.2 MPa) when the percentage is (15%) for tensile strength at break and (28.9 MPa) with Stress at yield, and we note that Stress at yield and Stress at Break decreases when you increase the percentage of adding the powder Alum when the percentage is (25%) and the behavior of tensile strength at yield increases when the percentage is (30%).This shows that the Alum powder works to improve the hardness property at percentage of (15%), when the polymer hardness extends at this rate of the effect of distribution of homogeneous material nature solid.

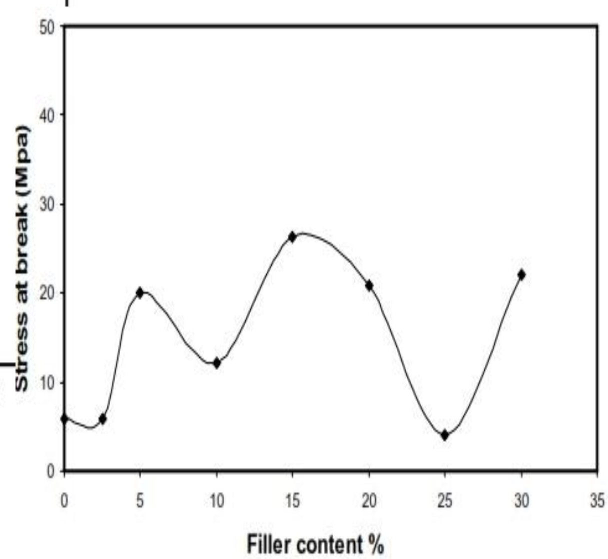

Figure (7) Stress at Break and Alum powder - HDPE composites.

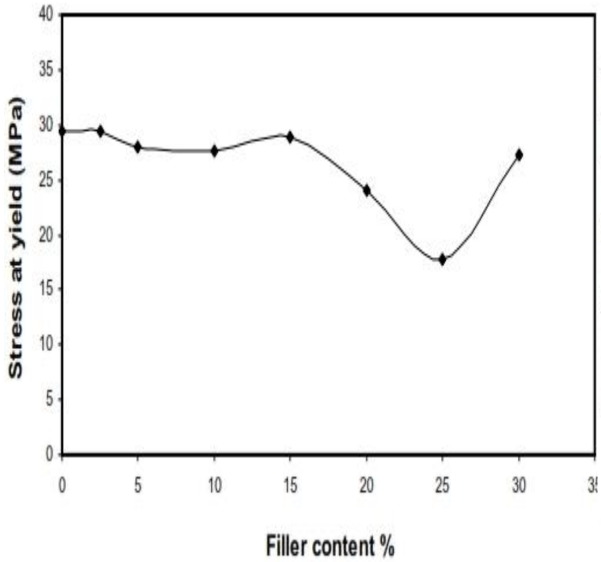

Figure (8) Stress at Yield and powder of Alum - HDPE composites.

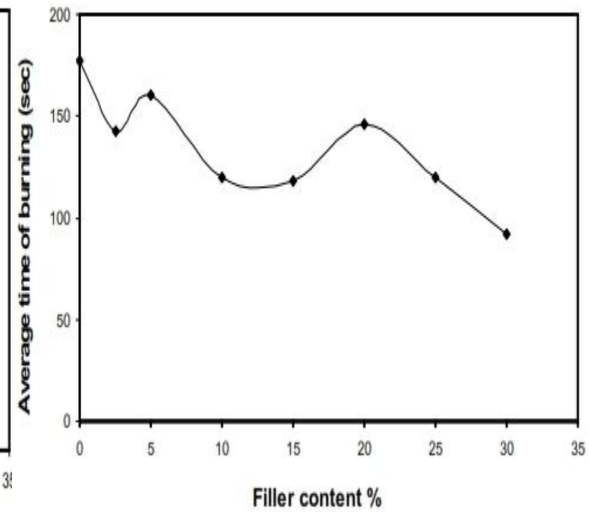

Figure (9) relation between the ATB and Alum powder-HDPE composites.

Table(3) shows values of the average time of burning(ATB), average extent of burning(AEB) and rate burning (RB) as at action added Alum powder.

Additives% Test	Non	2.5	5	10	15	20
AEB (cm)	10	9.5	9.2	8.9	8.6	8.2
ATB(min.)	2.95	2.38	2.66	2	1.96	2.43
RB (cm / min.)	3.38	3.99	3.45	4.45	4.38	3.37

Figure (9) shows the average time of burning with the added percentages of Alum powder, the behavior starts strong when the percentage is (5 %) to (160 Sec) and then begin a decrease behavior when increasing percentages, which demonstrates that increasing the proportion of the Alum powder has a negative effect on the flame resistance and heat spread through the matrix polymer where we get low when the percentage is (30%) which is (92 Sec). Table (3) shows the values of the average time of burning (ATB), the average extent of burning (AEB) and rate burning (RB) as the percentages of added to the Alum powder.

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 Alum powder to the polymer, the highest value was when the proportion of the added polymer (5%) is (367.5 N) as it will be at this homogeneity rate strong between powder of Alum with chains of polymer while the less proportion limit of which 234 N at the percentage is (25%), and probably explains the decline in the Alum powder when the percentage is (25%) of the additive to the heterogeneity of the model although the mixing models have been in the same circumstances.

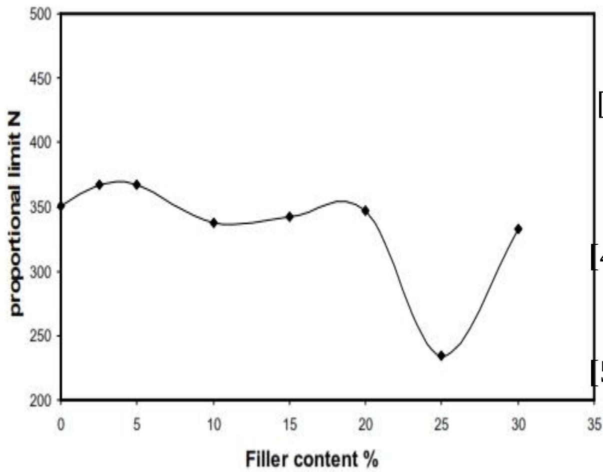

Figure (10) relation between the proportional limit and powder of Alum -HDPE composites.

CONCLUSION:

The natural filler like Alum 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 Alum powder that improve the mechanical properties and increase the strength by increasing the binding between the functional filler groups and the polymer. The Alum powder used as filler in this study improves the mechanical properties (stress - strain) and the best results with 10-15% content, the changing of added Alum 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. HDPE with 10% Alum powder is recommended for industrial applications.

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دراسة الخواص الميكانيكية للبولي ايثيلين عالي الكثافة المضاف إليه مسحوق الشب كمالئات بوليمرية.

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الملخص

تم في هذا البحث دراسة تأثير إضافة مسحوق الشب على الخواص الميكانيكية للبولي اثيلين عالي الكثافة وللنسب الوزنية (0%،2.5%،5%،10%،15%،20%25%،30%) وكانت أفضل نسبة للبولي اثيلين مع مسحوق الشب عند النسب 10% و 15%، وقد أظهرت النتائج بان إضافة مسحوق الشب يعمل على تحسين الخواص الميكانيكية للبوليمر من ناحية الصلادة والاستطالة ومعامل يونك ،وقد تم الحصول على اعلى قيمة لحد التناسب عند النسبة الوزنية 5% وهي 367.5 نيوتن اي يكون البوليمر عند هذه النسبة الوزنية ذو صفة تجانس عالية مع مسحوق الشب، واوطأ قيمة كانت عند النسبة الوزنية 25% وهي 234 نيوتن.