Improved mechanical properties and flame retardant of low density polyethylene (LDPE) with adding different percentages of powder carboxymethyl-cellulose (CMC)

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تحسين الخواص الميكانيكية ومقاومة اللهوبية لبوليمر الاثيلين واطئ الكثافة بإضافة نسب مختلفة من مسحوق كاربوكسي مثيل سليلوز

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المستخلص

تم في هذا البحث تحسين الخواص الميكانيكية للخليط البوليمري (بوليمر الاثيلين واطى الكثافة 463 /مسحوق كاربوكسي مثيل سليلوز) كدالة الى نسبة المضاف ألوزنية 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 المستحصلة ان مسحوق كاربوكسي مثيل سليلوز 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 والحشوات المضافة وان نسبة الاستطالة في هذا البوليمر تتناقص بصورة تدريجية مع زيادة النسبة المئوية للمالئات وتشهد الاستطالة نقصانا كبيرا في القيم عند النسب العالية من المضاف وأشارت النتائج أيضا على ان قوة الشد عند القطع وقوة الشد عند الوهن تنخفض مع زيادة نسبة المضاف مما يعكس الانخفاض في مرونة البوليمر المطعم بمسحوق كاربوكسي مثيل سليلوز حيث يتضح من النتائج إن افضل نسبة هي 2.5% . كما دلت نتائج مقاومة اللهوبية انه بزيادة نسبة المضاف يقل معدل زمن الاحتراق حيث لوحظ ان النسبة 1% هي افضل نسبة مقارنة ببقية النسب.

Abstract

The mechanical properties of (LDPE-463): powder carboxymethyl-cellulose composite was assessed with respect to the effect of filler content carboxymethyl-cellulose varying from 1% to 10% by weight in the composite. Obvious improvement in the mechanical parameters was recorded best ratio 2.5% weight. The mechanical properties of loaded film have been evaluated through several parameters concerning the elastic deformation based on measuring the load – elongation characteristics. The behavior of the stress - strain curve was analyzed in terms of the cold drawing model. Experimental difficulties appeared above 3.5% mixing ratio, and these difficulties were due to the separation in phase which makes the sample processing so difficult. The elastic behavior increased with increasing carboxymethyl-cellulose filler up to 2.5 %. While 1% is the best ratio that achieved best flame retardant.

Keywords: Improving, Mechanical Properties, flame retardant, LDPE, CMC

Introduction

Low density polyethylene represents the majority of thermoplastics currently used as food packaging materials. Since the production and consumption of these polymers is incessantly increasing, the environmental impacts have become an important problem for considering the biopolymers(1).Polymer composites with special mechanical properties are widely used in various applications such as electrostatic discharge protection, electromagnetic shielding and field grading (2). 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 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 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 (3).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 (4,5,6). Fillers find application in the polymer industry almost exclusively, e.g. to improve mechanical , thermal, electrical properties and percentage (1%-10%). 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 (7,8). In the present investigation, mechanical properties of (LDPE: powder carboxymethyl-cellulose) have been investigated for different powder carboxymethyl-cellulose weight

Table (1): Some of the properties of Low Density Polyethylene (9)

Property	LDPE
Trade Name	Scpilex (463)
Density (g/cm^3)	0.921-0.924
Melt Index (g/10 min)	0.28-0.38

Parameters such as maximum tensile strength (σ_M), tensile strain at break (ε_B) and Young's modulus(Y) have been measured at room temperature. The results were analyzed based on (stress - strain) relationship and microscopic analysis is used to interpret the physical behavior.

Experimental Procedure

This research used Low Density Polyethylene as the basis of material and product by the General Company for Petrochemical Industries (Basra-Iraq) in the form of powder and Table (1) shows some of the characteristics of this pure polymer used in this research.

In this research we used powder carboxymethyl-cellulose, which supplied by Fluka. The average powder carboxymethyl-cellulose particle size used in this work is (<212) μm. The structure powder carboxymethyl-cellulose is shown in Figure (1). Five concentrations of powder carboxymethyl-cellulose particles (1, 2.5, 3.5, 5 and 10 weight %) are used in the LDPE compounds.

Carboxymethyl-cellulose as a fine powder is mixed with LDPE using Rheomix mixer 600 instruments attached to the Haake Rehochard meter with the following conditions; mixing time 15 min; mixing temperature 160^0C ; mixing velocity 32 RPM. After that the final mold product is introduced in a laboratory compress under 5 tons at 175^0C for 3 minutes in a square frame where the pressure rises gradually up to 15 tons for a (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 Samples dumbbell for measuring the mechanical properties by using Instron instrument Zwick/Roel type [BT1-FR2.5 TN.D14] with the following conditions; chart speed (10) mm/min., crosshead spee50 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 (10, 11). All measurements are made according to [ASTM D638 2008] (12).

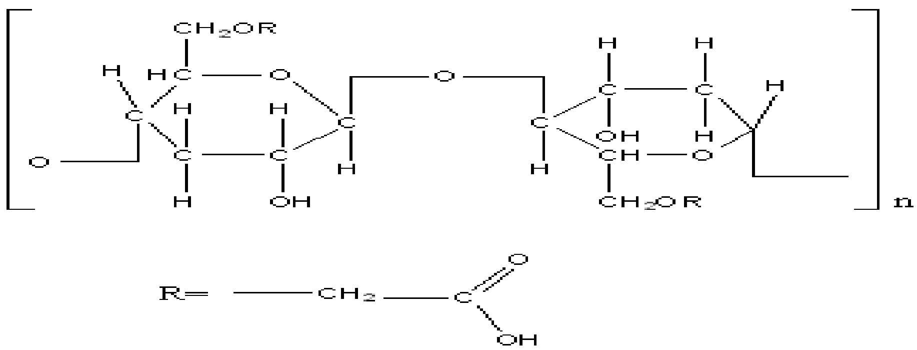

Figure (1): Chemical structure of CMC

To measure the tensile strength of a polymer sample, we usually stretch it using an Instron machine. This machine simply clamps each end of the sample and stretches the sample. It measures the amount of strength (σ) of force (F) it is exerting. When we know the force being exerted on the sample, we then divide that number by the cross-sectional area (A) of our sample. The answer is the stress that our sample is experiencing by increasing the amount of force, and stress naturally, on the sample until it breaks. The stress needed to break the sample is the tensile strength of the material. Tensile strain is a type of deformation where the sample deforms by stretching, and becomes longer, we call this tensile strain. Usually we talk about percent tensile strain, which is just the length the polymer sample is after it is stretched (L), divided by the original length of the sample (L_0), and then multiplied by 100 (13, 14).

$\sigma = F / A$ **……….. (1)**

Where:

σ **:** tensile strength, F**:** force**,** A**:**area

$$Tensile\ strain\ \% = \frac{L - Lo}{Lo} \times 100$$ **….. (2)**

Where:

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

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

To measure tensile modulus, we do the same thing as we did to measure strength and ultimate elongation. This time we measure the stress we're exerting on the material, just like we did when we measured tensile strength. We slowly increase the amount of stress, and then we measure the elongation the sample undergoes at each stress level. We keep doing this until the sample breaks. Then we make a plot of stress versus elongation. This plot is called a stress-strain curve. (Strain is any kind of deformation, including elongation. Elongation is the word we use if we're talking specifically about tensile strain.) The height of the curve when the sample breaks

Burning (ATB) according to the standard method 81 - ASTM D635 (15). By equation (4)

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

Where:
ATB: average time of Burning, t: time,
s: second

are the tensile strength, of course and the tensile modulus is the slope of this plot. That plot of stress versus strain can give us another very valuable piece of information. Measured the average time of

Results and discussion

Figure (2) and table 2 show the (stress - strain) curve of LDPE loaded with powder carboxymethyl-cellulose 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 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 theinter atomic bonds between the polymer atoms (16, 17, 18).

The result of the tensile strain at break of carboxymethyl-cellulose particle: low density polyethylene composite is

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.Study the mechanical properties of low density polyethylene, tensile strain at break (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%) and then decreases when the percentage (1%) a (171.7%) which is a polymer few flexibility and has a hardness high thereby acting powder carboxymethyl-cellulose 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 (2.5%) a (386.8%), and the polymer when this ratio high flexibility and low hardness, and then decrease when increasing the percentages up to 2.5%. Polymeric chains that are not constrained by any be free movement as a result of lack of homogeneity of the mixture, including the nature of the carboxymethyl-cellulose powder 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 the Figure (3) that maximum tensile strength (σ_M) at 2.5% is 17.5 MPa so that amount of load tensile strength (σ_M) reversible when increasing the concentration of additive which works powder carboxymethyl-cellulose to reach 15.7MPa at 10% the hardness decreases when the polymer and thus the polymeric chains is constrained to increase its flexibility.

On the other hand of the most important engineering parameter 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 powder carboxymethyl-cellulose filler is shown in Figure (4) Young's modulus varied between 5.33 to 42.64 for powder carboxymethyl-cellulose ratio between 1 - 10% respectively. This increment in Young's modulus can referred 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 are essentially depend upon the molecular behavior, includes chemical composition and physical structure. The nonlinearity in the stress-strain curve neither be 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 (19).

Table (2): Parameters of mechanical properties

Filler content (wt.%)	σ_M (MPa)	ε_B%	Young modulus (Y) (MPa)
0	14.4	256.2	7.38
1	13.8	171.7	9.84
2.5	17.5	386.8	5.33
3.5	15.8	78.2	36.32
5	13.5	67.1	30.91
10	15.7	43.9	42.64

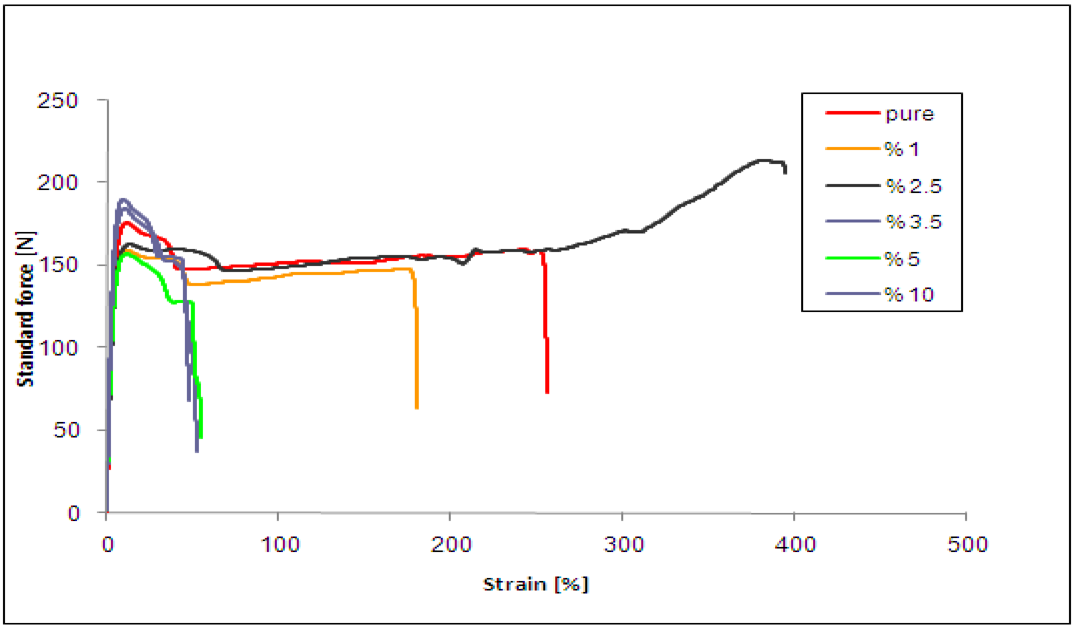

Figure (2): The stress - strain curves of polymer composite with powder carboxymethyl-cellulose

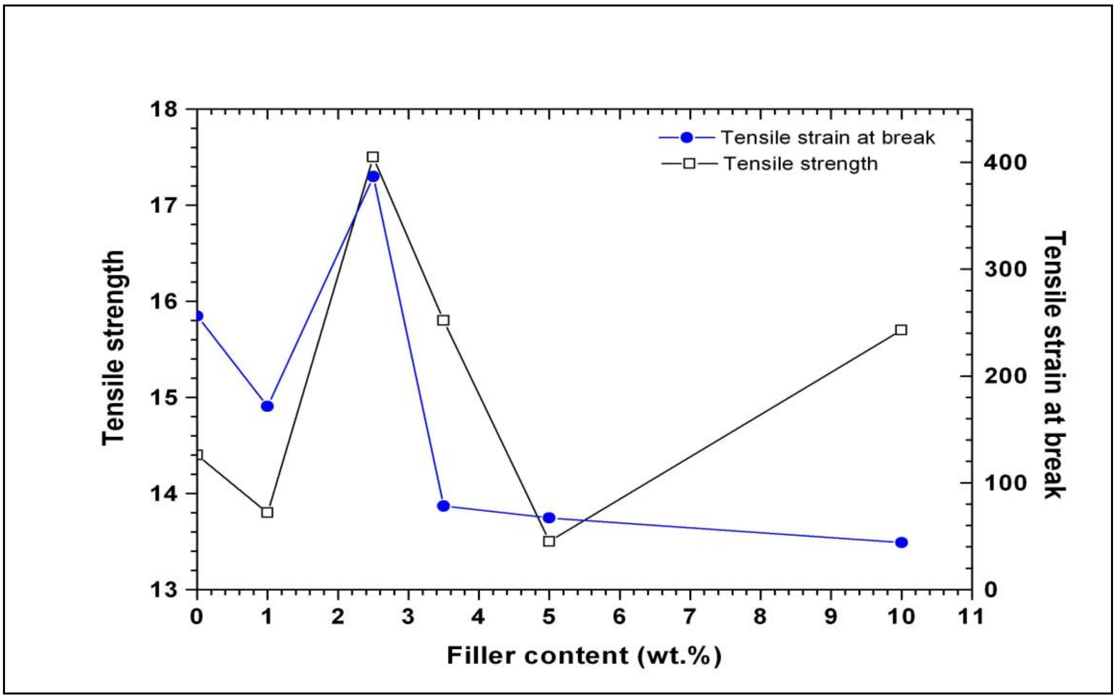

Figure (3): Variation between Tensile strain at break and tensile strength with Filler content (wt.%).

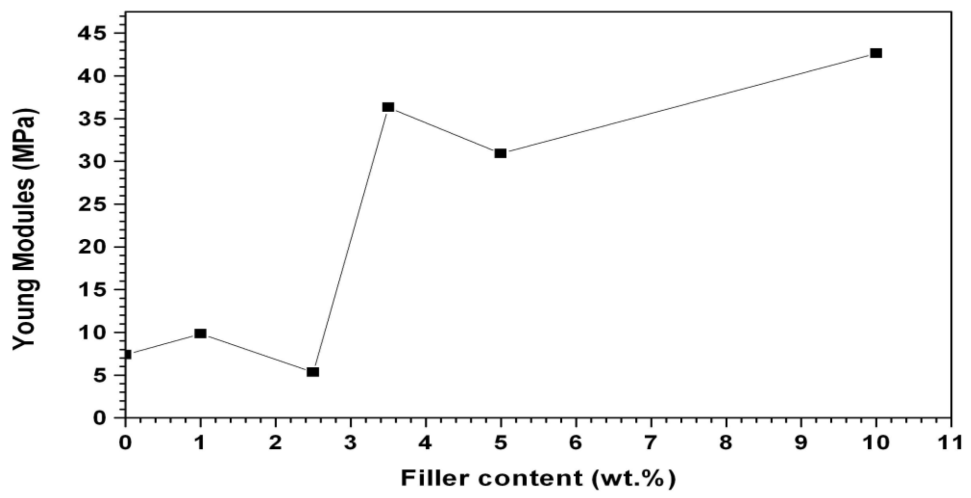

Figure (4): Variation between Young Modules and Filler content (wt.%)

Figure (5) shows the average time of burning with the percentages added of powder carboxymethyl-cellulose, to note that the behavior starts strong impact when the percentage (1 %) to (153 Sec) and then begin decreased behavior when increasing percentages (2.5 %) to (146 Sec), which demonstrates that increasing the proportion of the powder carboxymethyl-cellulose have a negative effect on the flame resistance and heat spread through the matrix polymer.

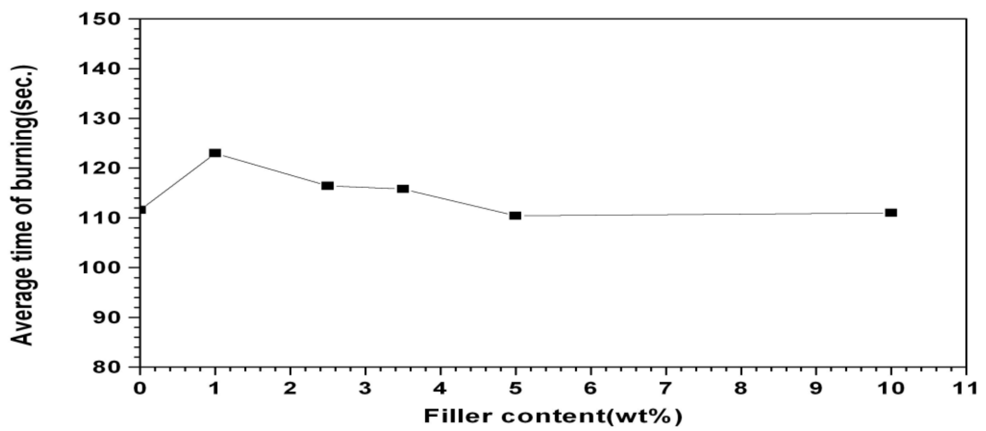

Figure (5): Relation between the average time of burning and powder CMC - LDPE composites

Conclusion

Mechanical properties of high density polyethylene were changed by adding (powder carboxymethyl-cellulose) with different weight percentage. Polymer phase was diluted by stiffer material (powder carboxymethyl-cellulose. This interprets the weekend observed in mechanical properties above 5% percentage. Accordingly, LDPE with 2.5% powder carboxymethyl-cellulose is recommended for industrial applications and the best flame retardant at 1%.

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