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Study of the Mechanical properties of Low density polyethylene composites with Cannabis (Hemp fibers)

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Abstract

The mechanical properties of hemp fibers (cellulosic fibers) composites were studied. The range of added Hemp fibers has the values (0%, 3%, 5%, 7%, 10%, 15%, and 20%) of polyethylene weight and, the best fibers ratio was 5%.

The properties (LDPE / Cannabis) composites were analyzed as a function of the fibers amount. All prepared composites showed improved fibers dispersion in the low density polyethylene matrix. All composites displayed lower elongation of break compared to pure LDPE.

Keywords: Polymer composites; low density polyethylene; Hemp.

1. Introduction

Low density Polyethylene (LDPE) is a famous commercial polymers used in a many industrial applications. Electrically, it's known as insulating material. It's compatible properties, such as, good insulation together with its excellent mechanical properties (high tensile strength) make it as a candidate their utilizing in different applications as an active material replacing other materials [1]. Different parameters, concerning this response, have been measured and investigate, such as, young's modulus, elongation, tensile strength stress at a yield and break. The polymer characteristics can be controlled and altered by adding different additives such as antioxidants, antiblocking agent, slip agent, antistatic agents, stabilizers, color compounds and fillers [1, 2].

Fiber reinforced polymer matrix composites (PMCs) have been widely used in various applications, i.e., aerospace, defense, automotives, marine and sporting goods due to their high specific stiffness and strength. These materials provide high

durability, design flexibility and lightweight which makes them attractive materials in these applications [3-5]. The properties of composites are significantly related to the properties of composite constituents, i.e., fiber, matrix and the interphase between them [6].

A wide attention is currently being dedicated to the exploitation of natural fibers mainly lignocellulosics as reinforcement for plastics in place of glass and other synthetic materials, mostly in non-structural applications. So far, a certain number of automotive components, appliances and packaging products are now being manufactured using thermoplastic and thermoset natural fiber composites [7]. The fundamental advantage of employing natural fibers is that these are biodegradable and renewable, and exhibit low cost, low density, high toughness and good thermal resistance. Moreover polymer materials reinforced with natural fibers (jute, Hemp, flax, sisal, wood-fiber, etc.) can combine satisfactory mechanical properties with a low specific mass. So far studies on the properties of natural fibers based composites have been the subject of a large number of papers and reviews [8, 9].

However, some drawbacks such as the incompatibility with the polymer matrices, the tendency to form aggregates during processing and poor resistance to moisture, greatly reduce the use of natural fibers as reinforcement in polymers. Incompatibility of components is responsible for a poor interfacial fiber/matrix adhesion and low dispersion of the fibers, which cause a decrease of the mechanical properties of these materials. In fact, fiber - fiber interactions as well as fiber-matrix interactions play a fundamental role in transferring the stress from the matrix to the fiber, enhanced interfacial adhesion for composites containing natural fibers can be achieved either by fiber and matrix modification with chemical/physical treatments or by use of interfacial additives [9,10].

Traditional chemical treatments of the fibers include extraction with alcohol, benzene or NaOH (delignification, bleaching, etc.). More recently, effective methods of chemical modification of fibers have been developed by means of reaction with various monomers such as acetic anhydride, stearic acid [11], maleic anhydride [12], glycidyl methacrylate [13], silane and isocyanate [14]. Zhou et al. reported that grafting of methyl methacrylate (MMA) onto Sisal fibres improved the surface adhesion and dispersion of the fibers in composites with PP matrix, giving rise to enhanced thermal stability and mechanical properties [15]. Similar findings were reported for PVC based composites reinforced with MMA grafted henequen cellulose fibers [16].

Polymer modification with polar molecules (such as maleic anhydride, itaconic anhydride, bismaleimide, etc.) is the other explored way to enhance interfacial adhesion, especially for polyolefin based composites [8]. Polymer modification appears as a quick, effective method to provide good interfacial adhesion, in contrast to fiber modification, which mostly involves solvent based processes. Another important opportunity is that the modification of the fiber surface with a multifunctional monomer can be exploited in secondary reactions (i.e., radical grafting) with the polymer matrix, providing a stable network of bonding between the fibers and the matrix.

The aim of this study is to find out the effect of adding hemp fibers on mechanical properties of polyethylene.

2. Experimental

2.1. Materials and procedures.

Hemp fibers are used as a reinforcement to enhance the mechanical properties of low density polyethylene. Table (1) shows the chemical composition of hemp fiber. Before use those fibers, they were washed with water in order to remove any dust and

ash. The hemp fibers were cut into microfibers of the range 212-75 micron in length, and then sterilized in boiling distilled water at 100 °C for 1 h. After that the fibers were rinsed in tap water and dried in an oven at 70 °C for 12 hrs [17].

Figure (1) shows the shape of the used hemp fibers. Five concentrations of hemp fibers 3, 5, 7, 15 and 20 wt % are used in the LDPE compounds.

Table (1)The chemical composition of hemp fibers [18, 19].

Chemical composition	Cellulose	Pectin	Hemicelluloses	Lignin	Waxes and oils
wt.%	70.2-76.12	0.9-1.55	12.28-22.4	3.7-5.7	0.8-1.59

Figure (1) hemp fibers in micrometer measurements.

Low Density polyethylene was supplied (Scpilex 463, Melt Index 0.3 g/10 min and density 0.922 g/cm^3) by the State Company for Petrochemical Industries (Basra / Iraq).

2.1.1. Preparation of composites.

Hemp fibers as a micrometer fibers are mixed with LDPE 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.

2.2. Instruments.

2.2.1. Mechanical testing.

A universal testing machine Zwick Rell 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]. The dimensions of the dumbbell-shaped specimens are shown in Figure (2).

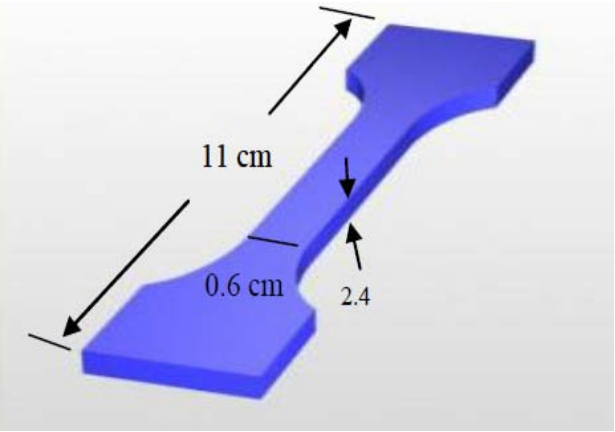

Figure (2) tensile specimen coupon dimensions centimeters.

3. Results and discussion

The mechanical properties of low density polyethylene are shown in Figure (3), where the stress - strain curves of polymer composite that reinforced with different ratios of hemp fiber. The fibers length range was (75 - 212) microns. The stress - strain curve of pure LDPE have the shape of ordinary one. The proportional limit was 143 N but this value reduced to 105 N when we add the hemp by 3% of polyethylene weight. The values were increased to 115 N, 127 N and 130 N with increasing the added filler ratio to 7%, 10% and 15% respectively .A noticeable saturation value has been obtained at 130 N with increasing concentration of the filler to reach 20% of polyethylene weight.

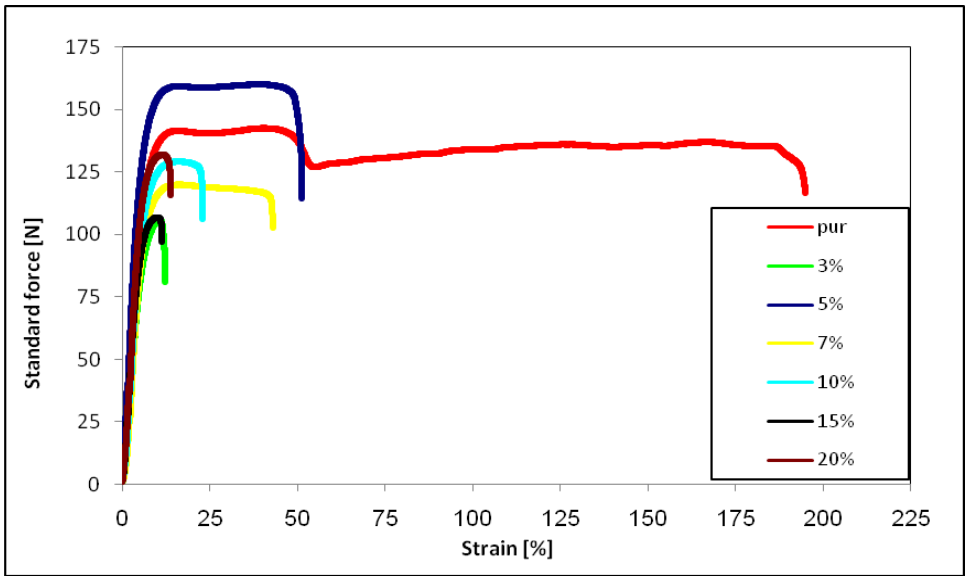

Figure (3) The stress - strain curves and cannabis fiber-LDPE composites.

The percentage of saturation of additives is depending on its nature, size, quantity, and the interaction between the additive and polymer.

It is worth to mention that the highest percentage of hemp fibers is 20%, where this result can be explained in term of the homogenization process between the polymer and the additive becomes very difficult due to the difficult gliding polymeric chains with particles of filler. The best added ratio was 5% of LDPE weight which gave Proportional limits 158 N. This result shows that the modified LDPE is better than pure one, as illustrated in Figure (3).

Other important results that both of the amount of toughness which is represented by the area under the line curve and the proportional limit and elongation are height at 5% of added hemp fiber. The last results can be explained in term of the highest homogeneity in three processes: the first is the homogeneity between polymers chains, the second the homogeneity between hemp fibers, and the third is the high interaction between fillers and polymers chain .The three mentioned reason gives the best three dimensional matrix of modified polyethylene. The homogenization process between the polymer and the additive in 3% give brittle polymer without any plasticity due to absence of slide ability of the polymeric chains .The increasing the percentage of filler to 7% also a slight sliding effect between polymer and filler is appear where we have some plasticity. The figures (4), (5) and (6) are showing the force at max and cannabis fiber-LDPE composites, Elongation at break and cannabis fiber-LDPE composites and Young modulus and cannabis fiber-LDPE composites respectively.

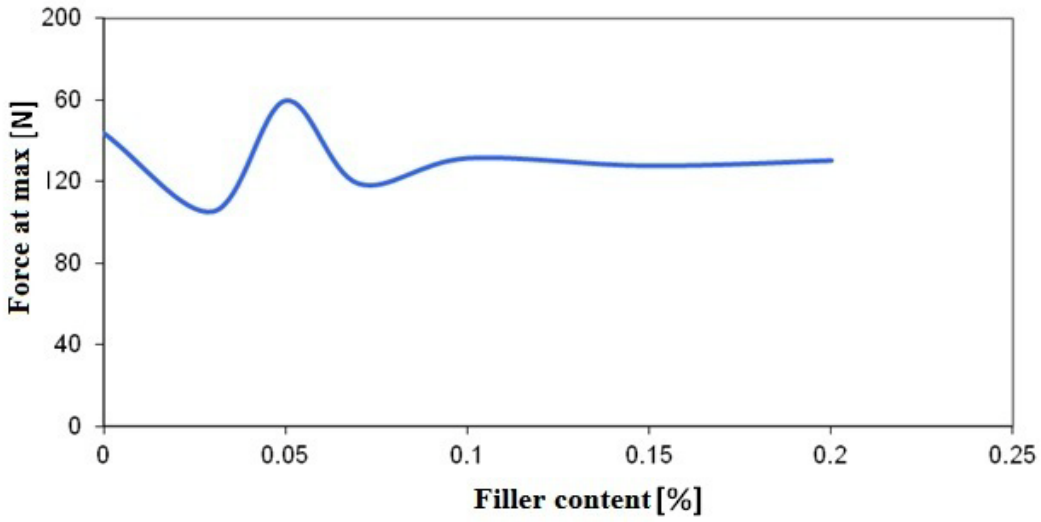

Figure (4) Force at max and cannabis fiber-LDPE composites.

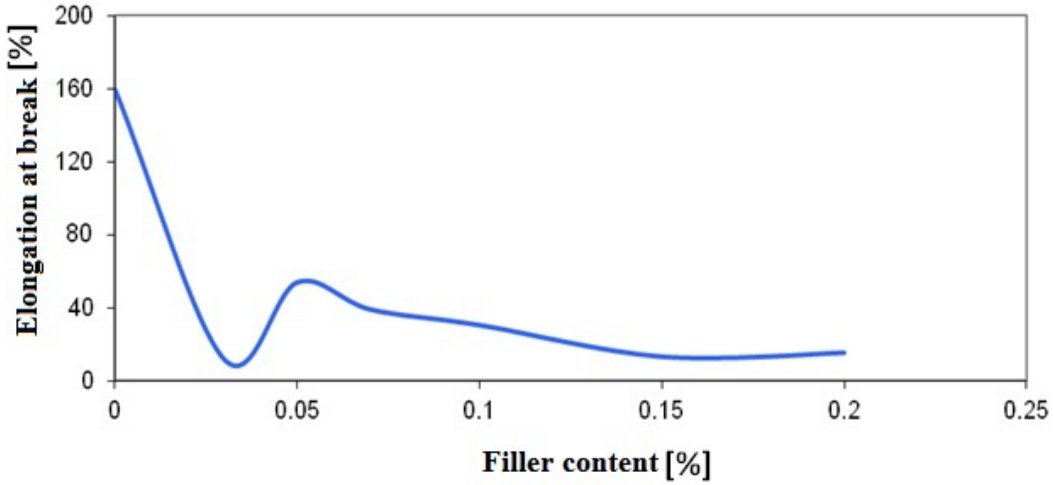

Figure (5) Elongation at break and cannabis fiber-LDPE composites.

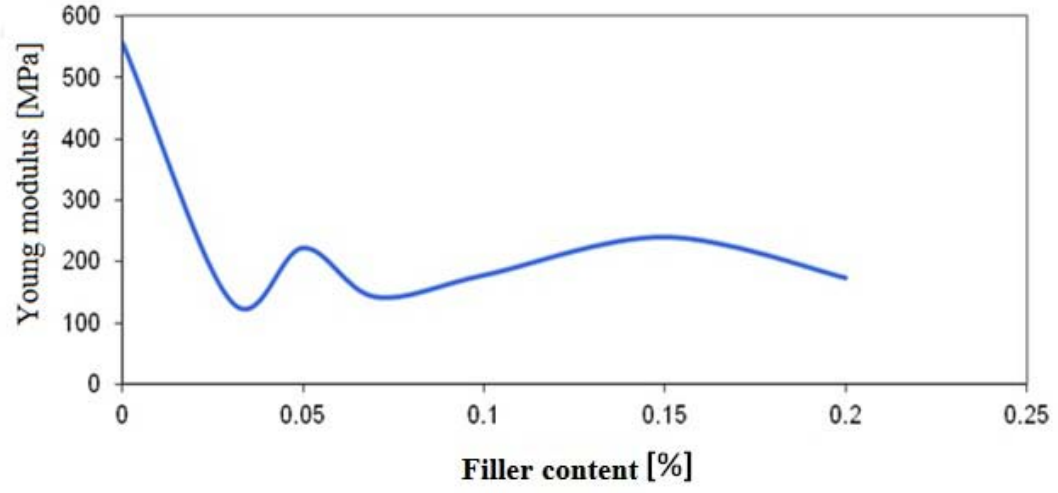

Figure (6) Young modulus and cannabis fiber-LDPE composites.

4. Conclusion

The natural filler like hemp can be added in form of fibers where their effect on mechanical properties depends on their lengths and the concentration. This effect on the mechanical properties due to the functional groups and the ability of hemp fibers improve the mechanical properties and increase the strength by increase the binding between the filler functional groups and the polymer. The hemp fibers used as filler in this study improves the mechanical properties (stress - strain) and the best results with 5% content, the changing of added hemp ratio certainly made a big changes to those mechanical properties like stress- strain, toughness and elongation due to the type of interaction between the polymers chains, fillers fibers and the filler polymer interaction.

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دراسة الخصائص الميكانيكية للبولي ايثيلين واطئ الكثافة المدعم بالياف القنب كمالئات بوليمرية

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المستخلص

تمت دراسة الخواص الميكانيكية للألياف القنب (ألياف السليولوز) كمواد مالئة للبوليمر. وقد تم تحضير نماذج بنسب وزنية (0٪، 3٪، 5٪، 7٪، 10٪، 15٪، و 20٪) من وزن البولي اثيلين و، كانت أفضل نسبة الألياف 5٪، وقد تم تحليل الحشوات كدالة لكمية من كمية الألياف. وأظهرت جميع النماذج المحضرة تحسن في انتشار الالياف بشكل متجانس في البولي ايثيلين واطئ الكثافة ،ومن الملاحظ ان جميع النسب المضافة للبوليمر عملت على تقليل نسبة الاستطالة مقارنة مع البوليمر النقي.