

## The Effect Of Blending Of Linear Low –Density Polyethylene On Mechanical Properties Of High Density – Polyethylene

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### Abstract

High – density polyethylene is an important commercial polymer and it is widely used for different engineering applications. In the present work, polymer blends were fabricated by mixing two types of polyethylene, high – density polyethylene was mixed with different weight percent of linear – low – density polyethylene using two – roll mill, the mixing machine was operated at a temperature of 135°C.

A series of standard tests (destructive), tensile, impact, hardness, and compression were carried out on the prepared samples it was found that the addition of linear – low – density polyethylene to the high – density polyethylene leads to decrease in the modulus of elasticity, tensile strength, tensile strength at break and increase in the % elongation at break.

For the impact test it was found that the addition of linear – low – density polyethylene caused an increase in the impact strength of the material, the polymer blend with 45 % wt of linear – low – density polyethylene gave the highest value of impact strength.

On the other hand the hardness test was carried out and it was found that the addition of linear – low – density polyethylene leads to decrease the hardness of the polymer blends. Therefore, the neat high – density polyethylene gave the highest hardness value.

**Keywords:** HDPE/LLDPE blend mechanical properties

### تأثير مزج البولي اثيلين الخطي على الخواص الميكانيكية للبولي اثيلين عالي الكثافة

#### الخلاصة

البولي اثيلين عالي الكثافة من البوليمرات المهمة تجارياً والذي له استخدامات واسعة في مختلف مجالات التطبيقات الهندسية. في البحث الحالي تم تصنيع مخاليط بوليمرية بواسطة مزج نوعين من انواع البولي اثيلين, تم مزج البولي اثيلين عالي الكثافة مع نسب وزنية مختلفة من البولي اثيلين واطى الكثافة الخطي وذلك باستخدام الاسطوانات المدفنة حيث تم تشغيلها عند درجة حرارية مقدارها (135 °م).

تم اجراء العديد من الفحوصات (الاتلافية) حيث تم اجراء فحص الشد, الصدم, الصلادة, والانضغاطية على النماذج المحضرة , ووجد ان اضافة البولي اثيلين واطى الكثافة الخطي الى البولي اثيلين عالي الكثافة قد ادى الى تقليل كل من معامل المرونة, اجهاد الشد, اجهاد الشد عند الكسر وزيادة النسبة المئوية للاستطالة عند الكسر. اما بالنسبة الى فحص الصدم فقد وجد ان اضافة البولي اثيلين واطى الكثافة الخطي قد ادى الى زيادة مقاومة المواد للصدم حيث ان المخاليط البوليمرية الحاوية على 45 % من البولي اثيلين واطى الكثافة الخطي اعطى اعلى مقاومة للصدم.

من ناحية اخرى تم اجراء فحص الصلادة ووجد بأن اضافة البولي اثيلين واطى الكثافة الخطي ادى الى تقليل صلادة المخاليط البوليمرية. لذلك فإن البولي اثيلين عالي الكثافة وبدون اي اضافة قد اعطى اعلى قيمة للصلادة.

## 1. Introduction

High density polyethylene (HDPE) is the highest-volume polymer in the world [1]. HDPE resins have linear molecular chains with comparatively few side chain branches, the chains are packed more closely together. The results are crystallinity up to 95 percent and densities ranging from 0.94 to 0.96 g/cm<sup>3</sup> [2]. This is a new type of polyethylene which was introduced by Union Carbide in 1977 [3], LLDPE is actually a copolymer of ethylene and 5-12 % by weight of an  $\alpha$ -olefin such as 1 – butene, 1 – hexene or 1 – octene [4] As the name implies, it is along linear chain without long side chains or branches. The presence of short chains which disrupts the polymer chain uniformity enough to prevent crystalline formation and hence prevents the polymer from achieving high densities [5]. LLDPE resins have crystallinity from 60 percent to 85 percent and densities range from 0.915 to 0.94 g/cm<sup>3</sup> [2]. Most of the differences in properties between branched and linear polyethylenes can be attributed to the higher crystallinity of the latter polymers. Linear polyethylenes are decidedly stiffer than the branched material and have higher crystalline melting point and greater tensile strength and hardness [1].

A polymer blend is defined as a combination of two or more polymers. They may be prepared in a number of ways some of them industrial method while others are useful for small scale laboratory work [6, 7]

Clearly, the plastics industry is moving toward more complex systems. The future will bring a further increase of complexity in the form of multicomponent / multifunctional blends [6]. In (1982), A. Gupta, and V. Gupta studied the effect of addition of HDPE on the crystallization and mechanical properties of polypropylene and glass – fiber – reinforced polypropylene (PP) [8]. Karbasheski and Kale (1993)

studied the effect of additions of high density polyethylene on the processability of the linear low density polyethylene [9]. Rana (1996) studied the effect of co-crystallization on kinetic parameters of high – density polyethylene / linear – low – density polyethylene blend [10]. Bischel, VanLandingham and Schultz (1998) studied blends of LLDPE and HDPE using the atomic force microscope [11]. In (1998) Rana found that the high density polyethylene (HDPE) and linear low density polyethylene (LLDPE) formed strong co-crystalline mass when they were melted and blended in a single screw extruder [12]. Lee and Denn (1998) studied the thermal properties of binary and ternary blends of high – density (HDPE), low – density (LDPE) and Linear low – density (LLDPE) polyethylene in the melt and solid state [13]. In this work, the mechanical properties of HDPE/LLDPE blends has been investigated. The amount of LLDPE used was changed from 0 wt% to 45wt%. The effect of change the percentage of LLDPE on mechanical properties was quantitatively analyzed.

## 2. Experimental

### 2.1 Materials

In this work two types of commercial polyethylene were used, one was the high-density polyethylene (EHM 6003) of a density equal to 0.963 g/cm<sup>3</sup> that was used as a matrix and the other was linear-low-density polyethylene of density equal to 0.94 g/cm<sup>3</sup>. Thermoplastic resins used in present work were locally manufactured in Petrochemical Complex (Basrah-Iraq).

### 2.2 Methods

This process involves mixing of high-density polyethylene with different weight percent (0, 15, 30, 45) % of linear-low-density polyethylene using the two roll mills. The mixing machine is operated at a temperature of 135 °C and at speed approximately 10 mm/min. The

compounding time involved ranged between (2-5 min). Compression moulding technique was performed to obtain testing samples, after compounding process was completed, the material was pressed in the hydraulic press by applying temperature and pressure at the same time, the temperature applied to the upper and lower sides of mold and the sample was still at the applied pressure (10 Mpa) and a temperature (135°C) for a (5 min). The mixing machine and the hydraulic press used for this purpose available in the National Company for Chemical and Plastic Industries in Baghdad.

The prime consideration in determining the general utility of a polymer is its mechanical behavior ,tensile properties ,impact resistance and hardness tests were carried out for examining the mechanical properties of the samples ,the tensile test is the most widely – used test for evaluating the strength of plastics. Plastics parts must be designed to accommodate stress considerably below that of the yield point. Tensile strength was measured by using Instron testing machine .Data on toughness are usually supplied from Izod or charpy impact test, in this work the impact resistance was determined using Charpy impact test instrument, samples were notched ( 1 mm depth ) by using Ceast notch instrument. Brinell method was used to determine the hardness of the polymer materials, A rigid steel ball was used in Brinell test with (5 mm) diameter, and (700N) load was applied at the sample for (15 sec) . The mechanical tests instruments used for this purpose available in the university of technology laboratories .

### 3 Results and Discussion

#### 3.1 Tensile Test

The modulus of elasticity is determined by taking the slope of straight line of stress – strain curve using tensile test, Figure (1) shows the modulus of elasticity of the materials as a function of % LLDPE content. From this

figure, showing that the increasing % LLDPE content causes a decrease in modulus of elasticity and from this curve also it is clear that the modulus of elasticity for the neat polymer is distinctly different from that of the blends. This may be attributed to the fact that the presence of linear – low – density polyethylene makes the blend material more elastic, also the decrease of modulus of elasticity (E) is due to the decrease of binder force between the molecules of the matrix [14]. The tensile strength values were determined, Tensile strength may be defined as the maximum tensile stress sustained by the material being tested to its breaking point.

$$\text{Stress} = F / A \dots (1)$$

Where: F=Force applied in KN

A = original area (mm<sup>2</sup>)

Figure(2) shows the tensile strength as a function of % LLDPE content. From this figure it is clear that there is a pronounced effect of addition of LLDPE at different weight percents ranging between (15-45) wt. % on the tensile strength of the material, increasing % LLDPE content leads to decrease in the tensile strength, this may be due to fact that the mechanical properties such as tensile strength are dominated by the strength of the chemicals bond between atoms [15].

The values of tensile strength at break ( $\sigma_B$ ) were determined; Fig. 3 shows the tensile strength at break ( $\sigma_B$ ) as a function of % LLDPE content. From this figure it is clear that the increasing of % LLDPE content leads to a decrease in the fracture stress because the addition of LLDPE causes an increase in the elasticity which leads to reduce the strength of the material.

The elongation at break is the extent of elongation at the point where the sample ruptures. It is expressed in terms of the percentage of the original length.

$$\text{Elongation}(\%) = \frac{L - L_0}{L_0} \times 100 \dots (2)$$

Where: L = extensional at breaking point.

$L_0$  = original length

In the present work the values of % elongation at break ( $\zeta_B$ ) were determined, Fig.4 shows the ( $\zeta_B$ ) as a function of % LLDPE content. From this figure it is clearly seen that the increasing of % LLDPE content leads to increase the % elongation at break. This may be attributed to the fact that the LLDPE acts as a solid plasticizer, therefore the addition of LLDPE to polymer matrix usually would increase the elastic movement of polymeric chains; however the most important observation is that all the blends have strongly improved the elongation compared with pure HDPE and without use compatibilisers.

### 3.2 Impact Test

The notched Charpy impact tests were chosen to characterize toughness of the blends. The material such as polymer, which has a high toughness, has high fracture energy and it is calculated by using this equation:

$$\text{impact strength} = \frac{\text{fracture energy required}}{\text{area of the sample}} \dots (3)$$

The unit of the impact strength is Joule / m<sup>2</sup>.

A tough polymer is one which needs high energy to break in an impact test, Fig. 5 shows the impact strength as a function of % LLDPE content, the results show that increasing % LLDPE content leads to increase the impact strength, this is due to the fact that when LLDPE is added to HDPE it acts like a solid "Plasticizer", therefore the flexibility of the polymer increase and its ability to absorb and dissipate energy increases, so the polymer needs high impact energy to

fracture. From the result it can be concluded that HDPE / LLDPE blends exhibit synergistic improvement in impact strength, the synergy might be explained by the fine dispersion of the second component (LLDPE) achieved due to a good viscosity match with HDPE.

### 3.3 Hardness Test

Hardness is commonly defined as the resistance of a material to static penetration by a harder material; also it can define as a resistance of material to local deformation [15]. In the present work Brinell hardness test was used to measure the hardness, Fig.6 shows the hardness as a function of % LLDPE content and at different exposure times. From this figure it is clear that there is a pronounced effect of the addition of LLDPE at different weight percents on the hardness of the material. Increase in % LLDPE content leads to a decrease in the hardness, this may be due to the fact that the hardness is generally considered to be a property of the surface therefore this behaviour of hardness is expected. The addition of the LLDPE leads to an increase in the elasticity and a decrease in the matrix surface resistance to the indentation.

### 4. Conclusions

Results obtained in this work shows that , pure HDPE gives higher values of tensile strength than HDPE/LLDPE blends, and the same conclusion is reached for modulus of elasticity . The elongation is enhanced upon blending HDPE with LLDPE and the higher LLDPE content exhibits a higher elongation. Addition of LLDPE to HDPE matrix reduces the tensile strength at break, but the addition of LLDPE was found to improve the impact strength of the polymeric matrix. Hardness values were observed to be the highest in pure HDPE, and these values decrease with increasing LLDPE wt% blend.

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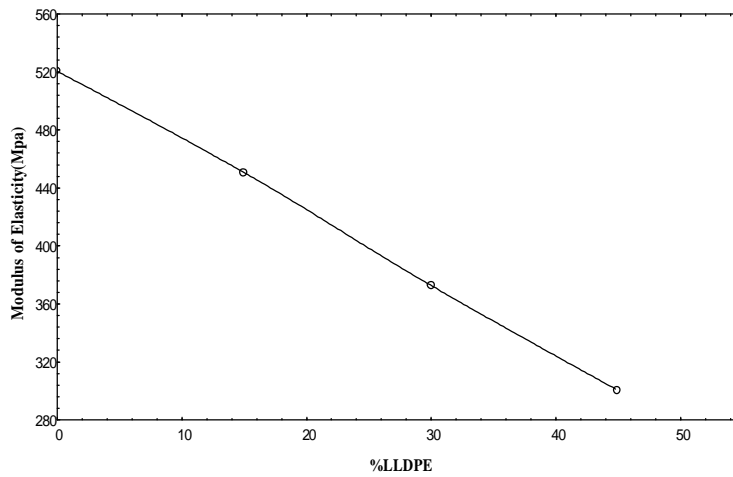


Figure (1) Modulus of elasticity as a function of LLDPE content (wt %).

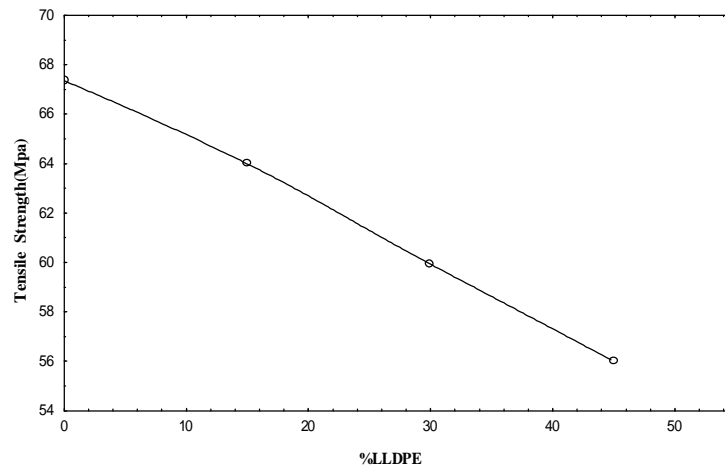


Figure (2) Tensile strength as a function of LLDPE content (wt %).

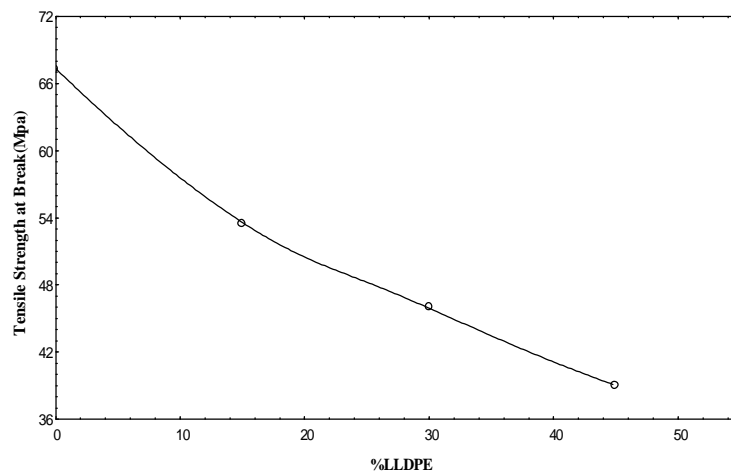


Figure (3) Tensile strength at break as a function of LLDPE content (wt %).

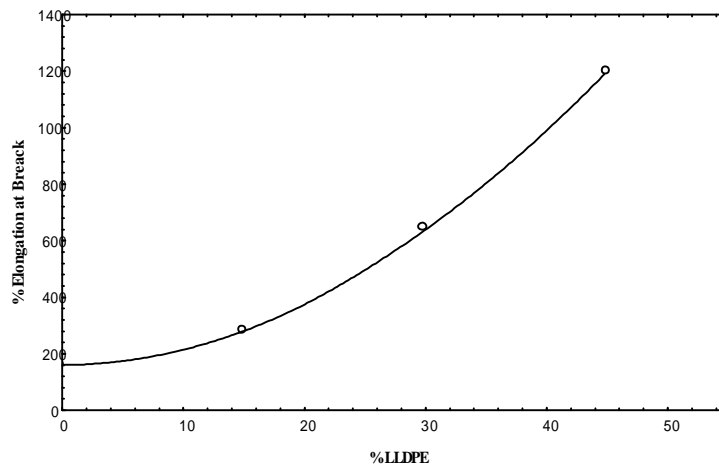


Figure (4) % Elongation as a function of LLDPE contents (wt%).

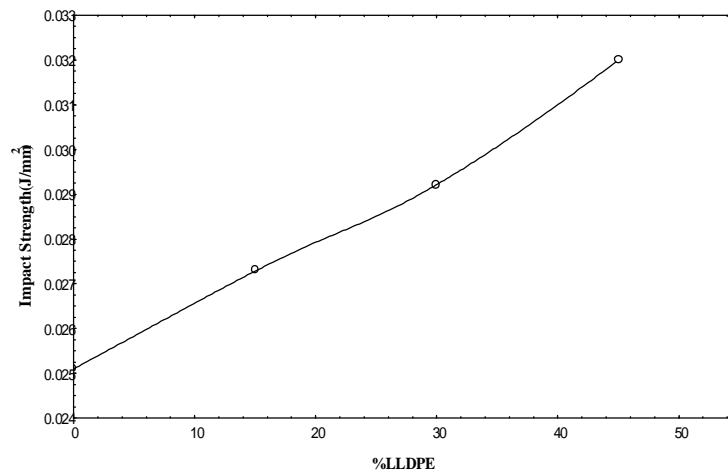


Figure (5) Impact strength as a function of LLDPE content (wt %).

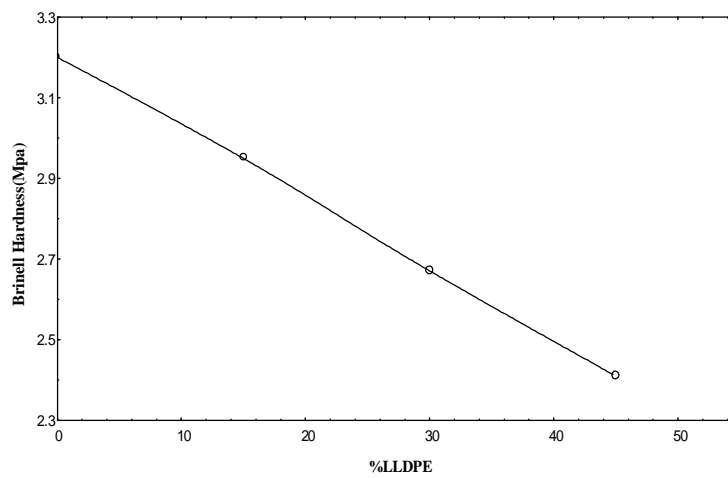


Figure (6) Brinell hardness as a function of LLDPE content (wt %).