

RESEARCH TITLE

EFFECT OF DEGRADATION AND LINEAR LOW DENSITY POLYETHYLENE CONTENT ON THE MECHANICAL PROPERTIES OF POLYETHYLENE BLENDS

Abduelimged B. E. Abduallah¹, Abubaker A. Alshuiref², Salem M Alburki², Mahmoud M Bin Mahmoud² and Ahmed A Maraie²

¹Chemical Engineering Department, Faculty of Engineering, Sabrata University, Sabrata, Libya

²Chemical Engineering Department, Faculty of Engineering, El-Mergib University, Al-Khums, Libya
abd_mbrk@yahoo.com¹, a.alshuiref@gmail.com², smalburki@elmergib.edu.ly²

Corresponding author. E-mail: abd_mbrk@yahoo.com

HNSJ, 2022, 3(4); <https://doi.org/10.53796/hnsj3417>

Published at 01/04/2022

Accepted at 12/03/2022

Abstract

In the present work study on preparation of series of polyethylene blends to improve some of the mechanical properties of high density polyethylene is achieved. The work consists of three main sections. Firstly, blends of high density polyethylene/linear low density polyethylene were prepared at different percentage (0, 17, 33, 50) wt. % relative to the linear low density polyethylene. The blends were exposed in artificial weathering test at different exposure times in the second part of this work, and then quantifying the change in mechanical behavior of polymer, standard mechanical testing was carried out in the third stage of the work, namely tensile test.

Key Words: Polyethylene, Blend, Weathering and Tensile Test.

INTRODUCTION

A polymer blend is a combination of two or more polymers. There is no doubt that the main reason for blending, compounding and reinforcing is economy. Over the last two decades the interest in polymer blend systems as a way to meet new market applications with minimum development cost has rapidly increased and a number of researches on PE blends have been published [1-7]. Schellenberg (1997) studied the high density (HDPE) and homogeneous branched polyethylene blends with low and high comonomer content in the homogeneous branched polyethylene over, the total range of composition of the blend components. The properties of blends of HDPE and long chain branched HBPE were compared with HDPE blends of polyethylenes without long – chain branching but similar molecular parameters in relation to the HBPE [1]. Bischel, Van Landingham and Schultz (1998) studied blends of LLDPE and HDPE using the atomic force microscope. From the results, the relative modulus of crystalline regions is observed to increase with increasing HDPE content [2]. 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 and found that HDPE / LLDPE blends are homogeneous in the melt and in both crystalline and amorphous regions in the solid state, and exhibit a single melting peak [3]. In (2002) Colin Li Pi Shan found alternative method to control the molecular weight and short chain branching distribution of polyethylene. Resins with controlled microstructures were produced and blends of high molecular weight and low molecular weight were also produced. The physical properties of these resins were tested for dynamic mechanical (tensile) and rheological properties [4]. In (2003) Shishan, and Jun , studied the structure properties of high density polyethylene functionalized by ultraviolet irradiation at different light intensities in air [5] and further in 2018 the influence of LDPE content on the mechanical properties of HDPE/LDPE blends has also been investigated by Shebani and his coworkers at Polymer Research Center, Libya [7], Although most high density polyethylene materials are subjected to weathering in many of their applications, which causes loss of properties due to photo – oxidation attack or degradation. Such important study is extremely limited in literature for polyethylene blends. The main components of the

weather which causes degradation are sunlight, temperature, moisture, wind, dust and pollutants. Moisture and humidity can have secondary effects in weathering, the primary process occurring is photo – oxidation or perhaps more accurately photo initiated oxidation, the effect of light is primarily on the generation of free radicals [7]. The main purposes of the present work is to modify the properties of high density polyethylene by blending with different percentages of linear low density polyethylene and to find the change in mechanical properties namely tensile properties before and after exposure to outdoor environment.

2. EXPERIMENTAL WORK

2.1. Materials

In this work two types of commercial polyethylene were used, one was the high density polyethylene of a density equal to 0.962gm/cm^3 and melting flow index of 0.034gm/min , that was used as a matrix, and the other was linear low density polyethylene of density equal to 0.94 gm/cm^3 and melting flow index of 0.020 gm/min . Pellets form of two to three millimeter (2-3 mm) polymer was used.

2.2. Preparation of HDPE / LLDPE Blends

This process involves mixing of HDPE with different weight percent (0, 17, 33, 50) % of LLDPE using twin screw extruder (Brabender Plastic Corder) with (L/D ratio 48), with screw speed of (30 r.p.m.). The host HDPE was fed into the twin screw extruder at the feed zone and the LLDPE were introduced subsequently at the melting zone. The barrel, die temperatures and screw speed were monitored and controlled at 140°C . After compounding process was completed, the blend 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 (140°C) for a (3 min) to obtain sample sheet with dimensions of (250 x 200 x 4) mm, the test specimens for mechanical measurements were cut from this sheet.

2.3 Weathering Test

A cylindrical geometric array of fluorescent tube lamps are used to simulate solar ultra violet radiation, such lamps were used as the artificial weathering effect. The lamps

that used are ERICHSEN with intensity of 20W/m^2 and weave length of 305 nm). The fluorescent tubes are arranged in the center of the test chamber and emit radiation similar to that of natural sunlight. The tests were done on 36 samples of the HDPE / LLDPE blends with different weight percents (0, 17, 33, 50) % LLDPE by exposing three of each different weight percents of LLDPE samples for various time 3, 6, and 10 days. The treatment is achieved in 60 % relative humidity and temperature of 30°C . The tests were carried out according to the test specification of ASTM (D 4329 – 84) [8].

2.4. Tensile strength

The tensile test is the most widely used test for evaluating the strength of plastics. The tensile strength of the blends observed in this study was tested on an Instron tensile strength tester, (Model 4444), with a constant rate of extension. This machine can be used to investigate different mechanical properties, such as tensile, tearing, flex, compression, and shear properties, with a load cell that can be adjusted according to the strength of the sample to improve accuracy. In this study the steady strain rate mode was used. The sample was mounted in the pneumatic jaws and the program allowed running until the sample broke. For data recording the Instron software of Series IX Automated Materials Testing was used.

The tensile properties that can be recorded include: displacement at maximum load (load at break), load, stress, strain, maximum percent strain (displacement at break), the modulus and a load/elongation curve or a stress/strain curve. The parameters of interest in this study were the Elongation and Modulus of elasticity.

Elongation was measured by measuring the extension of the sample at breaking point, while Modulus of elasticity was determined by extending the initial linear portion of the load – extension curve and dividing the difference in stress corresponding to any segment of section on this straight line by the corresponding difference in straining [9]. The presented results in the following section are average of three tensile tests.

3. RESULTS AND DISCUSSION

3.1 Modulus of Elasticity

The modulus measures the resistance of a polymer to elastic deformation. 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 polyethylene blend as a function of % LLDPE content using different exposure times, from three days to ten days. From this figure, the first curve represents an exposed sample 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 blends more elastic, also the decrease of modulus of elasticity is due to the decrease of binder force between the molecules of the matrix [10]. As a support for the present results, Bischel and Van Landingham (1998), found the modulus of elasticity of HDPE/LLDPE blends decrease with increasing LLDPE content [2].

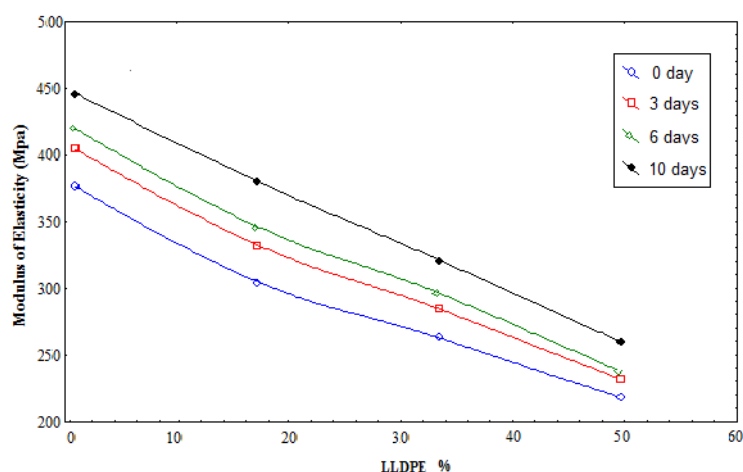


Figure (1): Modulus of elasticity as a function of LLDPE content (wt %) at different exposure times.

From this figure it is also clearly seen, that the increasing of the exposure time from three days to thirty days causes an increase in the modulus of elasticity, this may be due to the fact that increasing the exposing time causes an increase in the chain scission and cross linking due to degradation occurring because of UV – light that will lead to increase in the crystallinity degree and density as the exposure time increases as shown by Hoekstra, Breen and Audouin [11].

3.2 Tensile Strength

The tensile strength values (the stress at maximum load) were determined by using tensile test. Figure (2) shows the tensile strength as a function of % LLDPE content and at different exposure times. From this figure it is clear that there is a pronounced effect of addition of LLDPE at different weight percent ranging between (0-50) 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 chemical bond between atoms [12].

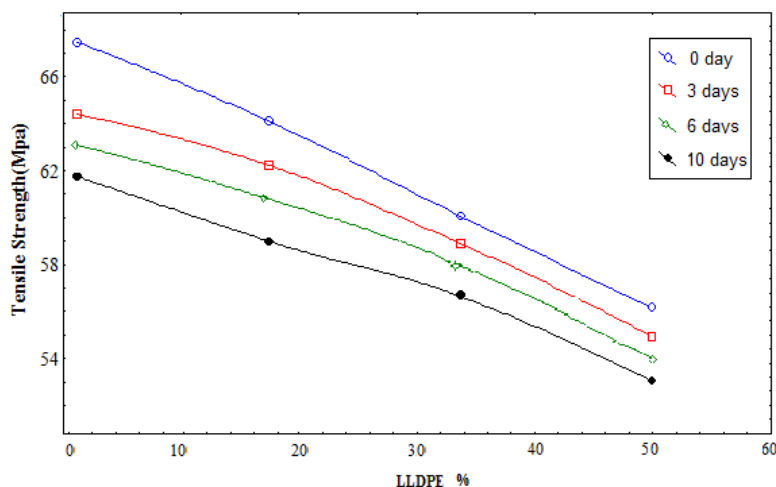


Figure (2): Tensile strength as a function of LLDPE content (wt %) at different exposure times.

Figure (2) also shows that increasing the exposure time from leads to decrease the tensile strength. This results agrees well with Hoekstra (1997) who found the polymer shows a decline in mechanical properties when it is exposed to UV – light. Due to chemical reactions, initiated by a U–V quantum and in the presence of oxygen, the long polymer chains can break. If many chains are broken, the polymer is unable to transfer a load effectively and as a result the polymer becomes brittle [13].

3.3 Tensile Strength at Break

The values of tensile strength at break were determined by using tensile test. Figure (3) shows the tensile strength at break as a function of % LLDPE content and at different exposure times.

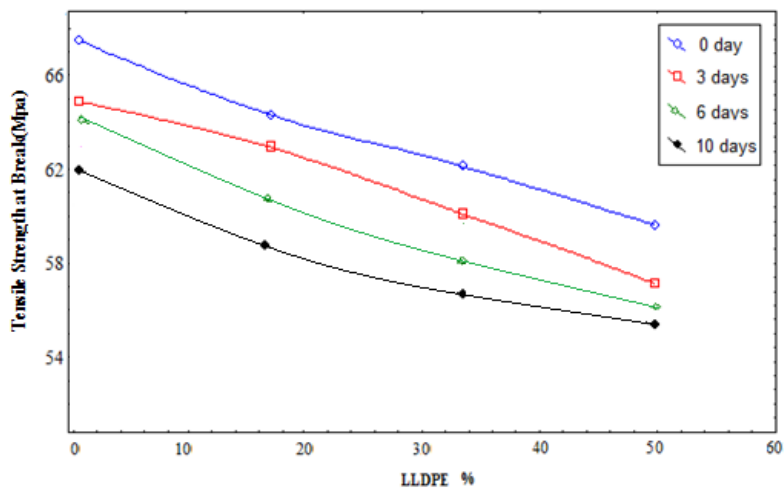


Figure (3): Tensile strength at break as a function of LLDPE content (wt %) at different exposure times.

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 polymer. The Figure also shows that the tensile strength at break for all polymer blends decreases with increasing exposure time, this is due to the brittle behavior of the polymer that it is unable to transfer load effectively and as a result its fails. The samples failed as a brittle material at a stress which was equal to the values of tensile strength, and gradually decreased with increasing the exposure time, this is due to the photo – oxidation degradation which causes a breakdown of the bonds in the polymer chain and cross linking and leads to decrease the molecular weight and increase the crystallinity, this is the direct cause of mechanical failure.

3.4 Elongation at Break

The elongation at break is the extent of elongation at the point where the sample ruptures. In the present work the values of % elongation at break were determined by using tensile test. Figure (4) shows the elongation as a function of % LLDPE content and at different exposure times.

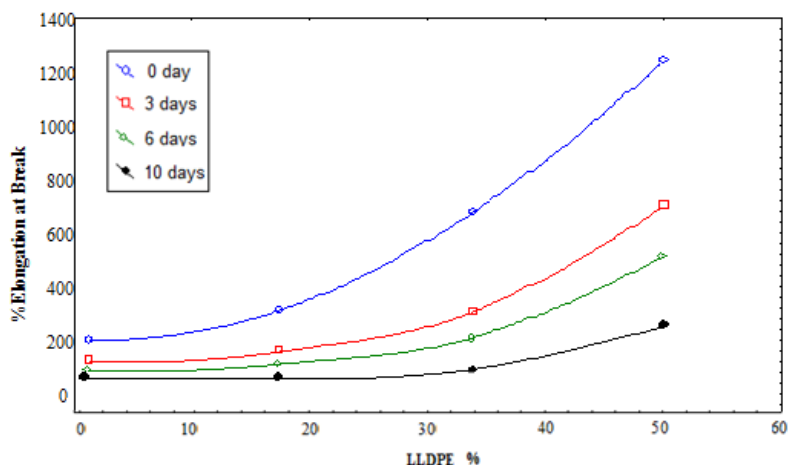


Figure (4): Elongation as a function of LLDPE contents (wt%) at different exposure times.

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 [14], 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. These results agree well with Colin Li Pi Shan's (2002) who reported elongation, can be a measure of the material's ability to deform and dissipate energy and that the sample with highest co-monomer content, would exhibit the highest elongation at break. A sample with low crystallinity possesses a large fraction of amorphous polymer. It is the slippage and disentanglement of amorphous polymer that allow it to deform. So with decreasing crystallinity a higher % elongation was observed [4]. Figure (4) also shows that increasing the exposure time leads to decrease the elongation at break which is attributed to the fact that the polymers show a decline in mechanical properties when they are exposed to UV – light, the crystallinity increases and the material loses its elasticity.

4. CONCLUSIONS

From the results obtained in this work, the following conclusions can be drawn:-

- 1- Pure HDPE gives higher values of tensile strength than HDPE/LLDPE blends, and the same conclusion is reached for modulus of elasticity .
- 2- Higher exposure times yield higher modulus of elasticity.

3- Increasing exposure times decreases tensile strength.

4-The elongation is enhanced upon blending HDPE with LLDPE and the higher LLDPE content exhibits a higher elongation, while increased the exposure times was found to decrease the elongation of the polymeric matrix.

5-Addition of LLDPE to HDPE matrix reduces the tensile strength at break and the higher exposure times the reductions are less pronounced and it seems to be less for a given blend.

REFERENCES

- [1]. Sehellenberg, J., *Advances in Polymer Technology*, 16, 135 – 145, 1997.
- [2]. Bischel, M.S., Van Landinham, M.R., Eduljee, R.F., Gillespie, J.W., and Schultz, J.M., *On The Use of Nanoscale Indentation with the AFM in the Identification of Phases in blends of HDPE and LLDPE*, University of Delaware, 1998.
- [3]. Lee, H.S., Deen, M.M., *The Society of Rheology*, University of California at Berkeley, 1998.
- [4]. Colin Li Pi Shan, *Approaches to Tailoring the Structure and Properties of Polyethylene*, Ph.D. thesis, University of Waterloo, Canada, 2002.
- [5]. Shishan, W.U., and Jun Z., *Polym. International*, 52, 350 – 355, 2003.
- [6]. Anour Shebani, Abdalah Klash, Rabea Elhabishi, Shalh Abdsalam, Hassan Elbreki and Wael Elhrari, *The Influence of LDPE Content on the Mechanical Properties of HDPE/ LDPE Blends*. *Res Dev Material Sci.* 7(5), 1-7, 2018.
- [7]. Davis, A., Sims, D., *Weathering of Polymers*, Applied Science Publishers, New York, 1983.
- [8]. *Annual book of ASTM*, Vol. 08.03 Plastic, Am. Soc. Test. Mat., Philadelphia, 1988
- [9]. *Annual book of ASTM*, Section 8, Vol. 08.01 Plastic, Am. Soc. Test. Mat., Philadelphia, 1989.
- [10]. Crum, N.G.Mc, Buckleg, C.P., and Bucknall, C.B., *Principle of Polymer Engineering*, John Wiley and Sons, 2nd ed., New York, 1997.
- [11]. Hoekstra, H.D., Breen, J., and Audouin, *UV – exposure on Stabilized and non – stabilized HDPE Foils*, 251 – 262, 1995.
- [12]. Dorsherman, David Brandon, *Mechanical Properties of hard materials and their relation to microstructure*, *Advanced engineering material*, Vol. 1, 1999.
- [13]. Hoekstra, H.D., *The Mechanical Behavior of UV – degrade HDPE : Consequences for Designers*, Thesis, Delft University Press, Delf, The Netherlands, 1997.
- [14]. Natalia, K., and Georg, S., *The effect of blending on the viscosity reduction of recycled milk bottle grade HDPE*, Monash University, Australia, 2000.