Mechanical Properties of High Density Polyethylene and Linear Low Density Polyethylene Blend

NWAPA, C. [1], OKUNWAYE, O. J. [2], OKONKWO, C. L. [3] & CHIMEZIE, O. W. [4]

[1, 2, 3 & 4] *Department of Polymer and Textile Engineering, Federal University of Technology, Owerri, Imo State, Nigeria*

Abstract

This work investigated the mechanical properties of high density polyethylene (HDPE) and linear low density polyethylene (LLDPE) blend at various ratios (95 % HDPE & 5 % LLDPE, 85 % HDPE & 15 % LLDPE, 75 % HDPE & 25 % LLDPE, 65 % HDPE & 35 % LLDPE and 55 % HDPE & 45 % LLDPE). Specimen 1 (100% HDPE) was used as the control. This blend would be used in the production of plastic buckets (twenty and four litres) for packaging of chemicals and paints. It was found that specimen 4 (75 % HDPE & 25 % LLDPE) had 6.72 % rise in modulus of elasticity, 31.50 % rise in elongation at break and 7.59 % rise in impact resistance. While specimen 5 (65 % HDPE & 35 % LLDPE) had 17.52 % rise in abrasion resistance, 12.58 % rise in hardness and 10.87 % rise in flexural strength.

Keywords — *Blending of HDPE & LLDPE, Mechanical properties of HDPE & LLDPE .*

I. INTRODUCTION

Blending can minimize the price of the polymer. Blending a substantial amount of inexpensive polymer B into polymer A may reduce the polymer cost without substantially reducing its overall performance. On rare but economically important occasions, blending polymer A and B can result in a synergistic effect. That is the property of the blend can be substantially better than that of either of the two polymers alone [15].

With respect to the usual structure of the ethylene units themselves and the poor extent of branching, high density polyethylene (HDPE) chains pack more closely leading to material with better crystallinity (generally up to 90 %), higher density (0.96), with improved chemical resistance, hardness, stiffness, barrier properties, melting point (about 130 ^{0}C), and tensile strength. Low molecular weight (chain lengths in the hundreds) HDPE is a “wax” while “regular” HDPE is a tough plastic. Linear low density polyethylene (LLDPE) possess density between 0.915 and 0.925 g/ml. It is really a copolymer of ethylene with say 8 % - 10 % of an alpha-olefin such as 1-butene, 1-pentene, 1-hexene, or 1-octene, through control of the nature and amount of alpha-olefin. LLDPE does not possess the long branches seen in low density polyethylene (LDPE). It is tough, transparent and flexible [3].

Theoretically, HDPE does not have branches (however, a few may be present due to oligomers formed by the catalyst and then copolymerised with the ethylene). Copolymerising alpha-olefins with ethylene, particularly from C1 to C8 in length results in a whole new family of polyethylenes commonly referred to as LLPDE. Never-the-less, LLDPE is basically much tougher than HDPE and LDPE [1]. Often it can be more cost effective to tailor the properties of a material through the blending of existing materials [6].

II. MATERIAL AND METHODS

Materials

High density polyethylene

The high density polyethylene is a product of Indorama group, a subsidiary of Eleme petrochemical company Ltd, Nigeria. The High density Polyethylene is of injection grade. It has melt flow index of 20.0 g/10 min. and solid density of 0.958 g/cm^3 according to their technical data sheet.

Linear low density polyethylene

Again the linear low density polyethylene is a product of Indorama group, a subsidiary of Eleme petrochemical company Ltd, Nigeria. The linear low density Polyethylene is of roto grade. The melt flow index is 4.2 g/10 min. and solid density is 0.932 g/cm^3 according to their technical data sheet.

Equipment used

- Electronic weighing balance
- Plastic containers with labels for measurement and proper identification
- Injection molding machine

Testing machines

- Asker shore D (Durometer hardness D type)
- Universal Tensile Testing machine (UTM)
- RESIL Impact for impact test and
- Wallace test abrader.

Methods

Processing conditions

The processing conditions for the various samples were the same. These conditions include the processing temperature, pressure and line speeds.

Machine name – Injection moulding machinery, Jinn Shin machinery works co., ltd, Taiwan

Machine tonnage – 100 tonnes

Machine pressure – 50kg/cm^2 – 55kg/cm^2

Barrel temperature – 200 to 240 °C

Cycle time – 40 seconds

Table 1. Formulation

	HDPE (g)	LLDPE (g)
Sample 1	200	0
Sample 2	190	10
Sample 3	170	30
Sample 4	150	50
Sample 5	130	70
Sample 6	110	90

Table 1 shows the formulation: sample 1 is 100 % HDPE, sample 2 is 95 % HDPE and 5 % LLDPE, sample 3 is 85 % HDPE and 15 % LLDPE, sample 4 is 75 % HDPE and 25 % LLDPE, sample 5 is 65 % HDPE and 35 % LLDPE while sample 6 is 55 % HDPE and 45 % LLDPE.

Test carried out on sample

a) Hardness test

The sample hardness tests were done using Asker shore D (Durometer hardness D type) in accordance with ASTM D 2240. The tests were carried out at temperature of (23 ± 2) °C and relative humidity of (50 ± 5) % for 15 seconds. Five replicates were tested from each sample and the average values recorded. The samples were placed on a hard horizontal surface while the durometer was held in a vertical position with the point indentor at least 12 mm from the edge of the sample, the presser foot was applied to the sample as quickly as possible, keeping the foot parallel to the sample. Sufficient pressure was applied to obtain firm contact between presser foot and the sample. The hardness value was read from a display device within the first second of the test. Hardness was determined at different positions in the sample at least 6 mm apart and the average values were recorded.

b) Flexural strength

Universal Tensile testing machine (WL 2100) was used and the test was conducted according to ASTM D 790M at strain rate of 5 mm/min. The maximum breaking load was obtained and used to calculate the modulus of rupture (MOR). The flexural moduli were determined from the initial slope of the stress-strain curves. Load cell capacity and support span were 200 N and 25 mm respectively. The tests were carried out at a temperature of (23 ± 2) °C and related humidity of (50 ± 5) %. Five replicates were tested from each sample and the average values determined. The samples used were 40 x 10 x 30 mm.

Flexural strength = $3P^L / 2bd^2$

Where P = load

L = span

b = breadth (width) of the sample

d = depth (thickness) of the sample.

c) Tensile Strength

The tensile strength of the samples were determined by cutting them with a dumb bell cutter into dumb bell shapes according to ASTM D 638M. Then samples were placed in the grips of an instron testing machine taking care to align the long axis of the sample. The grips were tightened evenly and firmly to prevent slippage of the sample during the test. The speed of the test was set at 50 mm/min. and the machine was started and the tensile strength values were read.

d) Elongation at break

The universal tensile testing machine was also used here and the elongation at break (E_b) is obtained as shown below

$E_b = (L_f – L_o) / L_o$

Where L_f = final distance between marks at the grips (mm)

L_o = original distance between marks at the grips.

e) Modulus of Elasticity

This test was done with the instron testing machine. The modulus of elasticity (Young's modulus) was determined from the slope of the linear portion of the load.

f) Impact resistance

The impact resistance test was conducted using a RESIL impactor based on ASTM D 256. The hammer with potential energy of 150 joules was used to impact the samples and the absorbed energy was recorded. The sample is 10 mm x 10 mm x 5 mm notched at the middle to the depth of 3 mm to create an area of stress concentration for initiating fracture. Each of the sample is fixed on a charpy impact testing machine to receive a blow from the fast moving hammer released from a fixed height of the machine. The reading of the dial gauge on the machine showed the impact energy absorbed by the respective samples. The test was repeated four times and the average reading recorded.

g) Abrasion resistance test

The Wallace test abrader was used to conduct the abrasion resistance using ASTM G 65. The samples were cut and placed over a rotating drum of about 150 mm diameter that moves a lateral distance of about 42 mm. The drum would rotate at 40 rev/min thereby achieving abrasion at 0.32 m/s. An abrasive material of 60 abrasiveness value was placed on the sample and a constant pressure of 10 N was applied. The test was started and it ran automatically. Each sample had to be weighed before and after the test to an accuracy of 1 mg. This test was repeated four times and the difference in the weights of the tested samples were recorded and abrasion resistance generated.

Results

Discussion

Table 2 is the mechanical test results carried out on the samples. Sample 4 has the best impact resistance of 3.40 j/m while sample 1 has the least of 3.16 j/m. The best tensile strength was shown to be sample 1 which is 16.08 MPa while sample 5 had the least of 12.16 MPa. Sample 1 showed the least flexural strength of 42.14 Mpa, but sample 5 had 46.72 MPa which is the best. Besides, sample 4 have the best elongation at break of 16.78 % while sample 1 had the least at 12.76 %. Also sample 4 had the best modulus of elasticity of 87.72 N/m^2 while sample 1 had 82.20 N/m^2. Moreover, sample 5 had hardness of 39.01 Shore D which was the best while sample 1 had 34.65 Shore D being the least. Finally, sample 5 had the best abrasion resistance of 46.16 Mpa while sample 1 had 39.28 Mpa as the least.

The result of impact resistance shown by sample 4 and 5 is an indication that both samples would absorb more shock that may be encountered when used as chemical and paint buckets. Moreover, sample 4 and 5 elongate 24 % and 23 % respectively more than the control sample. Also sample 4 and 5 have 7 % and 11 % respectively more hardness than the control sample. This implies that buckets produced from samples 4 and 5 would not break in a brittle manner due to their reasonable elongation at break, also the improved hardness quality is an indication that of better stacking strength needed during stacking paints buckets in stores.

[19] in their research reported that the impact resistance of HDPE blended with LLDPE increased with increase in LLDPE. The results were indicative of the network consisting of crystals joined together by the tie molecules, which contain the short chain branches from the LLDPE. The strength rises when the network rises. The result of our research showed a similar behaviour however the rise in impact resistance reduced slightly after 75 % HDPE and 25 % LLDPE.

Elongation at break had the highest value of 16.78 % at 75 % HDPE and 25 % LLDPE from Table 2 and from Figure 4, this is comparable to the work of Rana, (2002) which had it peak at 65 % HDPE and 35 % LLDPE. Generally there was increase in the elongation at break as the percentage of LLDPE was increased. Hence the inclusion of LLDPE increased the elongation at break.

[18] reported that blends with higher LDPE content have poor tensile strength. This is in agreement with findings of our research.

From Figure 1, sample 5 had the best abrasion resistance of 46.16 MPa while sample 1 had the least of 39.28 MPa. In Figure 2, sample 5 had the best hardness of 39.01 Shore D while the value for sample 1 was 34.63 Shore D. However, for Figure 3, sample 4 had 87.72 N/m^2 as it modulus of elasticity while sample 1 had 82.20 N/m^2. Also in sample 4, the values of elongation at break are 16.78 % and 12.76 % for samples 4 and sample 1 respectively. The flexural strength values shown in Figure 5 had the best as 46.72 Mpa for sample 5 and the least at 42.14 Mpa for sample 1. Furthermore, in Figure 6 the highest tensile strength is sample 1, 16.08 Mpa while sample 5 had the lowest of 12.16 Mpa. Finally, the best impact resistance was shown by sample 4 to be 3.40 j/m while sample 1 had the least of 3.16 j/m.

Conclusion

From this study, it was noticed that sample 4 had the best impact resistance, elongation at break and modulus of elasticity. Therefore, the best blend is sample 4, 75 % HDPE/25 % LLDPE as it showed the best property from the analysis carried out. This sample would be able to resist sudden blow hence customers and dealers of these paint and chemical bucket would not loose their products due to the inability of the inability of the buckets to expand and bear load on top of one another. The improvement in impact strength and elongation at break was largely due to the high toughness and flexibility of LLDPE

where it acted as a reinforcing additive. However, the high modulus of elasticity was contributed due to the hardness and stiffness of HDPE. More research is needed in this area and it should focus on blends within 80 % HDPE/20 % LLDPE to 70 % HDPE/30 % LLDPE.

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Correspondence

Nwapa, Chinedu
Department of Polymer and Textile Engineering,
School of Engineering and Engineering Technology
Federal University of Technology, Owerri, Imo State
Email: edunwapa@yahoo.com

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Table 2: Mechanical test results

Sample	Wt %	Impact Resistance (j/m)	Tensile Strength (Mpa)	Flexural Strength (Mpa)	Elongation at break (%)	Modulus of Elasticity (N/m^2)	Hardness (Shore D)	Abrasion Resistance (MPa)
1	100% HDPE	3.16	16.08	42.14	12.76	82.20	34.65	39.28
2	95% HDPE – 5% LLDPE	3.25	14.16	43.09	14.16	84.10	36.08	42.38
3	85% HDPE – 15% LLDPE	3.29	14.07	44.06	15.72	86.01	36.76	42.44
4	75% HDPE – 25% LLDPE	3.40	13.09	46.16	16.78	87.72	37.16	42.02
5	65% HDPE – 355% LLDPE	3.38	12.16	46.72	16.58	87.01	39.01	46.16
6	55% HDPE – 45% LLDPE	3.33	12.72	46.66	15.62	86.56	38.62	46.09

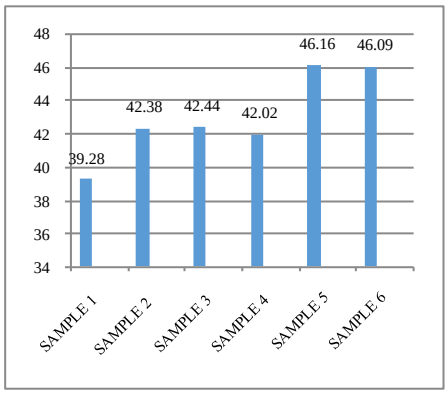

Figure 1. Abrasion resistance

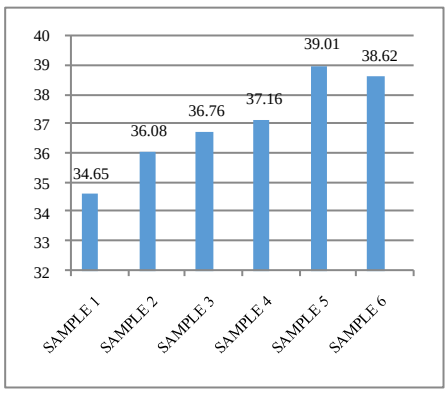

Figure 2. Hardness shore D

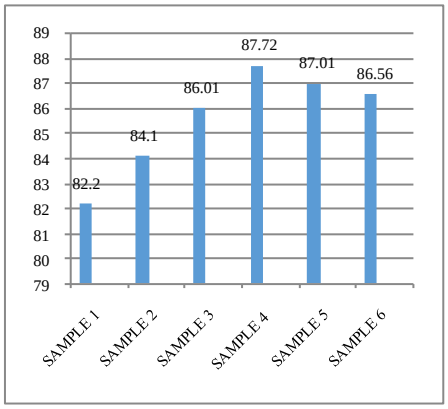

Figure 3. Modulus of elasticity

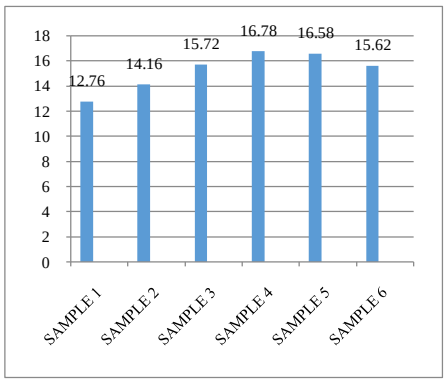

Figure 4. Elongation at break

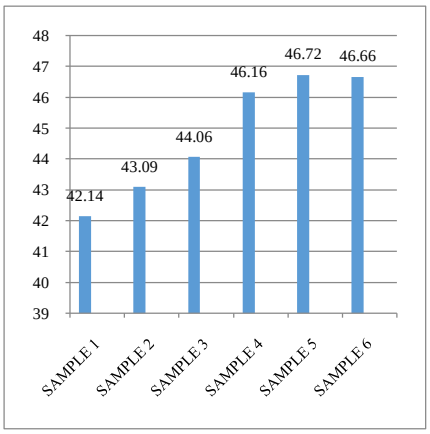

Figure 5. Flexural strength (MPA)

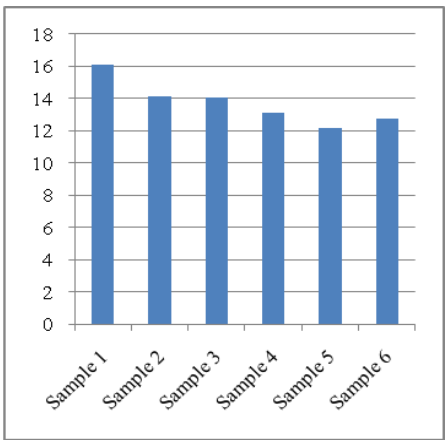

Figure 6. Tensile strength (MPA)

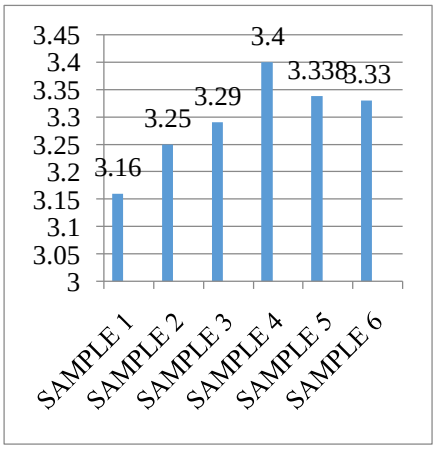

Figure 7. Impact resistance (J/M)