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INFLUENCE OF ADDING DIFFERENT PARTICLES FILLERS ON ELECTRICAL CONDUCTIVITY AND MECHANICAL PROPERTIES OF HIGH DENSITY POLYETHYLENE (HDPE) MATRIX COMPOSITES

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ABSTRACT:

Mechanical and electrical conductivity properties of high density polyethylene (HDPE) with three different parctical fillers [aluminum oxide (Al2O3), met coke ash (MCA), Nano fibrillated composite (NFC)] composites were evaluated with relation to the influence of the reinforcement materials content. The reinforcement (10% wt.) in the matrix. Forming the sample groups P1, P2, P3, P4, P5, and P6. After processing, the composites were evaluated by Shore D hardness, electrical conductivity, and charpy impact. Clear effect in the mechanical and electrical conductivity test factors was recorded depending on the particles reinforcement type and its percentage added to the Polymer. No experimental difficulties were demonstrated in any composite, and these difficulties are attributed to the phase separation that makes area possible to treat in it was found that an extruder of normal. Results showed that the best improvement in hardness occurs at (80% HDPE+10 % Al2O3, 10% met coke ash). The highest conductivity occurs also at (80% HDPE+10 % Al2O3, 10% met coke ash). The highest impact test occurs at (100% HDPE); this means that the reinforcement did not improve the impact properties.

KEYWORDS: *High density polyethylene, Fillers, Shore hardness, Electrical conductivity, Impact test.*

1. INTRODUCTION

High-density polyethylene (HDPE) is one of the most widely applied semi crystalline material for packaging application, because it is resistant to environmental stress cracking, chemical attack and mechanical impact and provides good process ability [1]. High density polyethylene (HDPE) used in the pipe systems because add of high strength to density, resistance to corrosion, very low thermal and electrical conductivity, and has a low cost. When designing an HDPE pipe, it is depends on the premise that the pipe wills distortion and lead to stress relief. HDPE is used instead of other materials in the manufacture of pipelines for transporting oil and water derivatives because of its favorable properties, such as, construction and maintenance costs, weight is light, installation is easy, very good resistance for erosion and chemical [2]. HDPE composites became an important category of materials With the increasing advancement of technology, it is increasingly used instead of metals in a wide range in the industry as in, oil derivatives tanks, some ship parts, water pipes, pump vanes, pipeline carrying sand slurry, and rotary aircraft blades, because their high strength to Wight, Stiffness relative to weight, High malleability in forming, the cost is suitable, erosion and corrosion resistance, in addition to other properties [3]. With increasing demand for high technology apace such as aircraft structure, jet engines, space shuttles and field of atomic energy. The need for lightweight materials with high strength and stiffness has led to the development of (MCA) based composites [4], the composite concept allows us to produce stiffer, stronger and tough materials with improved elevated temperature capability. A composite materials is a substance consisting of two or more components that are combined at a microscopic level and are insoluble in each other.One constituent is called the filler phase and other one called the matrix. In polymer composites, the binder (matrix-HDPE) phase consisting mostly of the polymer remains the primary phase, which is more flexible phase and it bears the filler that is the considered secondary phase. The mechanical properties of the filler higher than the mechanical properties of the matrix therefor, the addition filler to the maximize the mechanical properties of the composite [5]. The HDPE application has been limited due to its low thermal and mechanical properties. To improve these properties the

addition of Aluminum Oxide (Al2O3) [6]. The properties of the polymer composite based on the many facters of reinforcement and binding material such as the ductility or hardness of reinforcement. If the shape of the spherical fillings is irregular, the strength of composite may decrease in the absence of binding due to inability of the reinforcement to retain local stress from the matrix [7]. In general, electrical conductivity, move of electrons between the atoms. In metallic semiconductors and conductors, electrons act as charge carriers, whereas in ionic compounds such as sodium chloride, Ions play a conducting role. Depends the electronic transport on parameters such as strength, lattice imperfections, and atomic bond, whereas ion transport is governed by the diffusion rates of ions [8]. Impact test is a widely applied standard method for evaluating the rapture toughness of plastics, such as, Transport pipes and tanks. It is considered one of the economic materials in addition to the high quality and compounds [9]. The purpose of this search is to realization the influence of (NFC), (Al2O3), (MCA)]. (NFC) which is new type of reinforcement on mechanical properties specification of polymer composite. In this search we studied, mechanical characteristics of (HDPE with NFC, Al2O3 and MCA) for filler weight percentage (10%). Parameters such as measured densities shore hardness, electrical conductivity of the composites, and impact test, the results of charpy impact test analysis showed the energy that specimen absorbed during impact test is strongly dependent of the relative notch [10].

2. EXPERIMENTAL WORK:

2.1. Materials:

The materials which used for experimental tests was (HDPE-SABIC-FJ00952) matrix polymer .The melt flow of (HDPE) polymer was 9.0 g/10 minute at (190°C and 21.6 kg) in accordance with ASTM D1238 and the density was 952 kg/m^3 at 123°C in accordance to ASTM 1505, Melting point/range (120°-140°), and reinforced with fillers [Aluminum Oxide Al2O3: Molecular Weight =101.96 g/mol, density=3.95 g/cm^3,melting point=2072 C$^\circ$), met coke ash (MCA), Nano fibrillated composite (NFC)]. The shapes and technical composition of the base material and reinforcing materials are as shown in Figure. 1 and tables (1, 2, 3), respectively.

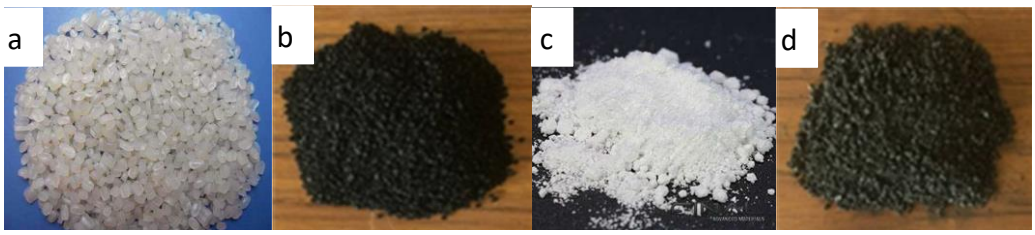

Fig.(1):- (a) HDPE, (b) NFC, (c) Al2O3 and (d) MCA.

Table (1):-Chemical composition of (NFC) [11].

Elements	SiO_2	Cr_2O_3
Percentage (%)	70	30

SiO_2: silicon dioxide; Cr_2O_3: chromium (III) oxide.

Table (2):-Max limits of impurities of (Al2O3=101.96).

Elements	Loss on ignition	Water-soluble matter	Sulphate (SO4)
Percentage (%)	1	0.5 Max	0.05 Max

Table(3):- Chemical composition of (MCA) [11].

Elements	Fixed Carbon	Ash	Volatile Matter	Moisture	Sulfur
Percentage (%)	72 Min	24 Max	4 Max	2 Max	0.70 Max

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2.2 Preparation of composite:

Weighed quantity of fillers (NFC, Al2O3, MCA) and matrix HDPE with the constant rate of (10%) for each fillers and the rest is a matrix, as recorded in table 4, then filler are added to matrix taken in the bowl and stirred by hand. The stirring operation by hand and time were performed about 10 minutes to help improve the distribution of the fillers particles in the matrix. After blended polymers with the fillers, composite was supplied by the factory Deltas for plastics/Erbil by Injection machine molding model (FT280-2012-Chain) as in Figure.2.

Type machine used is the most widely used molding process for thermoplastics. Thermoplastics rely on their ability to soften with heat and harden on cooling. The process mainly consists of softening the plastics materials in a heated cylinder and injected under appropriate pressure into the required mould, by cooling the material hardens. Performed each step in a separate area of the same machine in the cyclic process. Type machine used nozzle inside the barrel, through a maintained at a specified barrel temperature were set at 200°C, mean residence time was (2 minute), mold pressure is (30 bars) and injection (10g/min.) and screw speed of (70 rpm) the hot extruded part was molded into a shaped die (30cm length, 20cm width and 0.6 cm thickness die gap). The details of the composites and codes are reported in table 4.

Fig.(2):- Injection molding machine (FT280-2012 Chain).

Table (4):- Percentage weight proportion of the samples**.**

SPECIMENS	HDPE %	NFC %	Al2O3 %	MCA %
P1	100	0	0	0
P2	90	10	0	0
P3	90	0	10	0
P4	90	0	0	10
P5	80	10	10	0
P6	80	0	10	10

2.3 Samples preparation:

Three specimens were produced for each group, for the average calculation of results. The samples (HDPE) matrix and resulting dry mixture (HDPE composite) was then transferred into the work shop to machining by milling machine in order to prepare the specimens for tests according to standard dimension. Samples were prepared for the shore hardness testers was according to ASTM-D2240-15 standard using type D [12], and it was dimensionless (25mm length, 25mm width and 4 mm thickness) as shown in figure (3) .The electrical conductivity of sample materials was determined according to ASTM-B-193-95 [13], and samples was dimensionless (80mm length, 10mm width and 4 mm thickness) as shown in figure (4). For charpy impact tests prepared specimens by milling and V-notch by device (JJANM-Series) was according to standard dimension (ISO-179-1eA: 1996) (8.0 ± 0.2 mm length, 10mm width, 4 mm thickness, with 2mm depth (V), and the radius of the notch tip was rN = (0.25 ± 0.05) mm as shown in figures 5. [14]. Finally, transferred into the Grinder / Polisher machine for each sample was grinded with (220 to 600)

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grit emery paper before conducting any test to obtain an accurate and smooth surface of the specimen for the purpose of examination in the private laboratory.

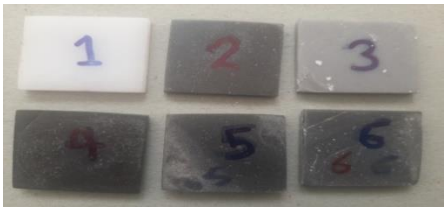

Fig.(3):- Picture of shore hardness samples.

Fig.(4):- Picture of electrical conductivity sample (P1).

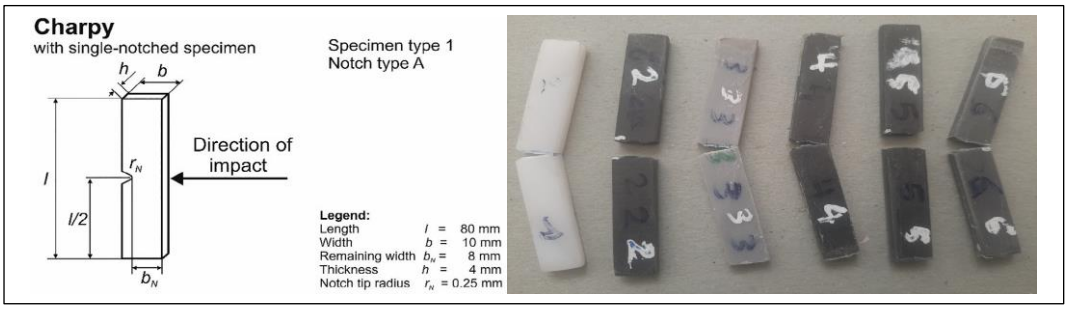

Fig.(5):- Scheme of a notched specimen and picture of failed impact samples.

2.4 Characterization.

2.4.1 Hardness Test

The **Shore D** Hardness Scale measures the hardness of hard plastics, semi-rigid rubbers and hard plastics. A 'Shore Hardness' gauge (similar to a round tire pressure gauge) has a needle on a spring protruding from one end. The needle is placed on the plastic and pressed. Once press the gauge firmly against the material and the needle has penetrated as far as you can, the gauge needle will indicate the corresponding hardness gauge.

The materials resist to the indentor called hardness. So durometer type D indentor was used as shown in Figure (6). The display shall indicate from (0-100) with no less than 100 equal divisions throughout the range at a rate of one hardness point for each 0.025 mm (0.001 in.) of indentor movement. The test frame should be placed in a stable smooth work stage, and then adjuste wishbone height. Durometer hardness test is used to measure the relative hardness of materials.

2.4.2. Electrical Conductivity

The device MIT1020/2 used for measure electrical conductivity of samples shown in figures (7), offers measurement equipment. This instrument scales test voltage range from 50V to 10kV, in increments of 10 volts to 1 kV and in increments of 25 volts above. The instrument is supplied with two sets of test leads, one with large insulated clips and the other with medium insulated clips.

2.4.3. Impact Test

In impact test, the apparatus used is a pendulum Impact Tester model (XJJD-50) series shown in figure (8). This has a pendulum with a known length and mass torque of the hammer 8.03878 N.m. Has impact energy range (7.5, 15, 25, and 50) J, accuracy of energy is 0.001-J, pendulum angle 150°. Values for the best used dielectrics in the upper range in capital letters tend to be 35 TΩ to provide.

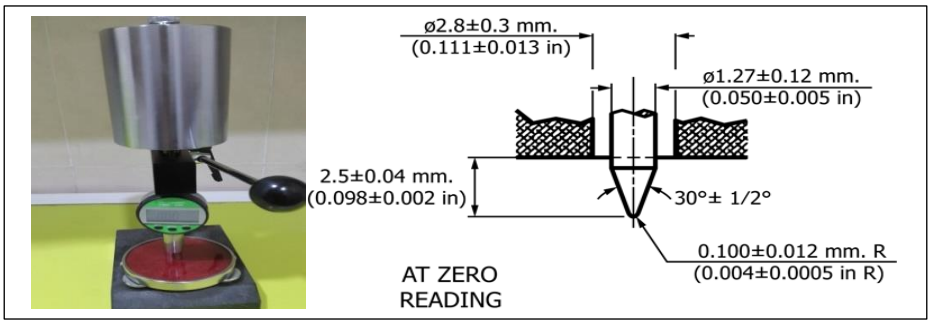

Fig.(6):- Durometer scales (type-D-Indentor).

Fig.(7):- Megger MIT.

Fig.(8):- Impact tester (XJJD-50) series.

2.5. Calculation procedure:

2.5.1 Electrical Conductivity:

Resistivity is electrical resistance of a body of that material of the unit area of cross-sectional and unit length. Volume Resistivity As measured in ohms (Ω) for a theoretical conductor of unit length and cross-sectional area; $\Omega.mm^2/m$ in units of metric. By the following equation it can be calculated:

$\rho_v = (A/L)\, R$

Where:

ρ_v = volume resistivity in (Ω.mm),
A= cross sectional area (mm^2).
L= gage length in (mm)
R = resistance in (Ω) ohms.

Conductivity and Resistivity the one inverses the other. The reciprocal of resistivity is conductivity [12]:

$$\gamma = 1/\rho_v \qquad (1)$$

γ=Electrical conductive. In $((\Omega.mm)^{-1}$.

2.5.2 Charpy impact:

Impact energy is the energy required to rupture a standard test sample under the influence of severe loading. The Charpy impact test is the most common measurement of impact energy [15]. The energy absorbed by the sample during its fracture is an energy dissipated for the pendulum. The hammer is lifted to a (h_o) height and then allowed to fall. As the pendulum swings, it impacts and fracture the sample,

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Hammer initiation angle before impact (α = 150°) and hammer torque (8.03878 Nm), initially lifted to a height (h_o), and then released. Clearly the difference between the two heights it is directly proportional to the amount of energy that is absorbed because of rupturing the specimen. Total energy of rupture is determined by the following eqution: [13]:

$$T_{total} = mg\,(h_o - h_f) \qquad (2)$$

Where:

(T) is the total energy in (J), (m) is the pendulum mass in (g) is acceleration due to gravity, (ho) is the original height in (mm), and (h_f) is the final height in (mm).

3. RESULTS AND DISCUSSION

3.1. Shore hardness:

Five indentations were performed in different regions of the each sample for the same face because the two faces are similar, for the average calculation of hardness. The test was performed at room temperature. The sequence of values of the resistance to elastic deformation on the surface of the composites from minimum to maximum is as follows (P1, P4, P2, P3, P5, and P6) shown in Figure 9 and Table 4, hardness of composites increased with filler (Al2O3+MCA) From the data it was evident that the P6 has the higher than the other fillers. This means the best improvement in hardness occurs at (80% HDPE+10 % Al2O3, 10% MCA), Because the density of the composite increased with increasing fillers concentration, also its hard components, it helps resist indentation.

3.2. Electrical Conductivity:

One of the basic properties of a material that distinguishes it as a metal is its ability to conduct electricity and heat. A majority of the elements are classified as metals. [12], the values of the results of Electrical Conductivity of the samples from minimum to maximum are as follows (P4, P3, P2, P1, P5, and P6) shown in Figure 10. From results composite P6 (80% HDPE+10%Al2O3+10% MCA) composite gave the highest electrical conductivity, because with adding fillers decrease resistance of sample material, this means that the reinforcement did improve the electrical conductivity properties.

3.3. Impact test:

For Charpy impact tests, three specimens notch were produced for each group; for the average calculation of impact energy, the variations of impact strength of composite polymer are presented in figure (11). Charpy test method works by placing a notched sample (with the notch facing away from the point of contact) in a machine with a pendulum of a weight is known specimen and composite materials results. The results showed that the Charpy impact energy of the sample was decreased from 1.014 J to 0.146 J. The highest impact test occurs at (P1) (100% HDPE) was 1.014 J; It can be deduced from the results that the impact strength decreases with adding in the fillers content, because with adding fillers becomes more brittle, Hence, the reinforcement did not improve the impact properties.

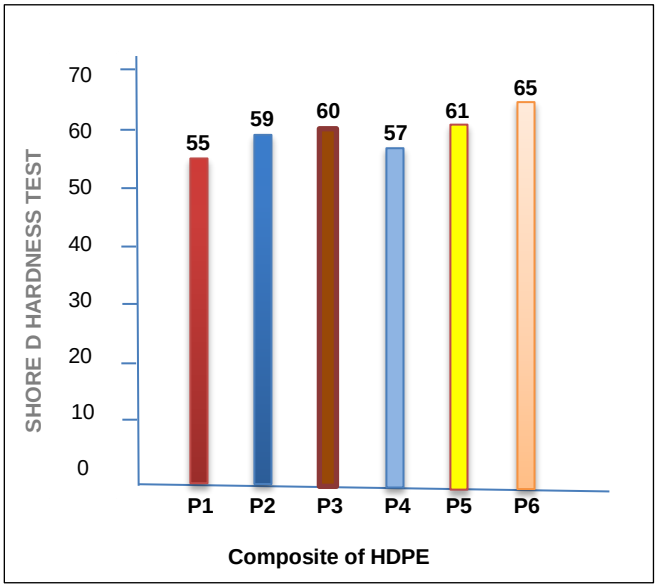

Fig.(9):- Shore D hardness

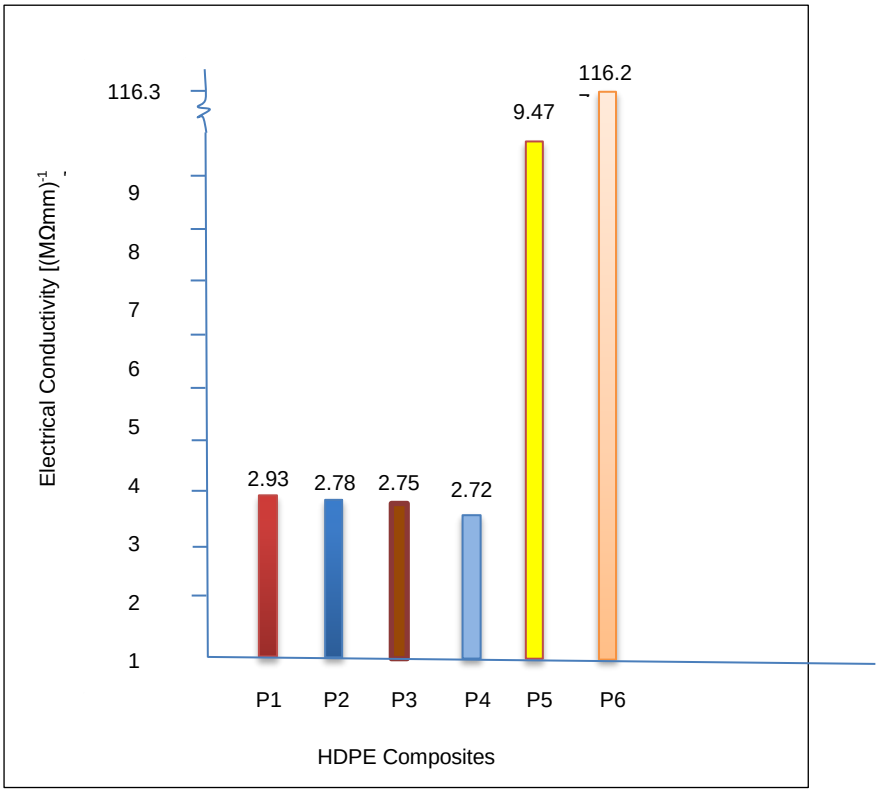

Fig.(10):- Electrical resistivity at voltage of 5 kV after 30 sec, T=16 c°.

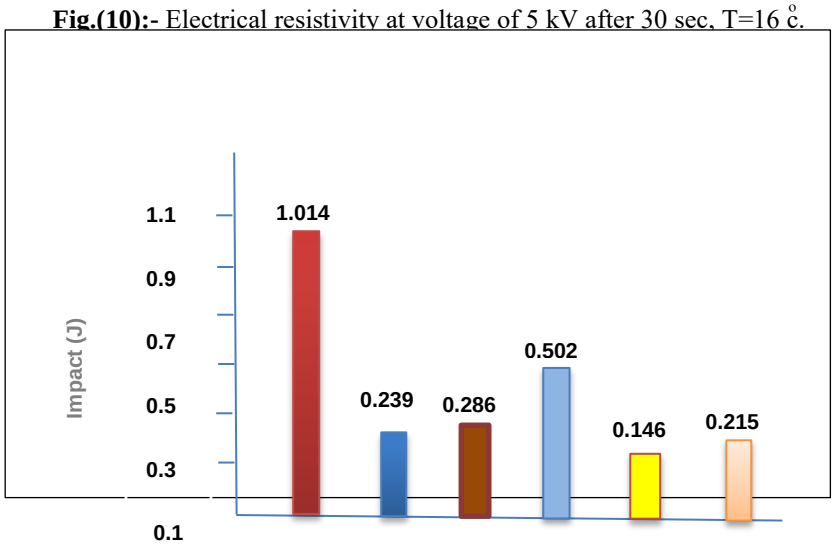

Fig.(11):- Impact test of HDPE composite.

4. CONCLUSIONS

After conducting the experimental work and discussing the results of test materials particle fillers to matrix.

1- The best improvement in hardness occurs at (80% HDPE+10 % Al2O3, 10% met coke ash).

2- The highest electrical conductivity occurs at (80% HDPE+10 % Al2O3, 10% MCA).

3- Addition of particles Al2O3 and MCA to HDPE at percentage of addition (10 wt. %) would lead to good properties of electrical conductivity and shore D hardness.

4- Highest impact test occurs at (100% HDPE); impact tests showed a significant decrease in composite hardness due to additions of [aluminum oxide (Al2O3), met coke ash (MCA), Nano fibrillated composite (NFC)], this means that the reinforcement did not improve the impact properties.

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