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# Water Absorption and Mechanical Properties of High – Density Polyethylene / Ferric Chloride Composite

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**Abstract***: Water absorption and mechanical properties of the composite material based on high-density polyethylene resin were investigated. High-density polyethylene resin was reinforced with (5, 10, 15, 20 and 25% by weight) ferric chloride. The parameters such as tensile strength, tensile modulus, hardness and impact test were carried out on the prepared samples. It was found that the addition ferric chloride to the polymer leads to increase the tensile strength, modulus of elasticity, hardness and impact strength. The water absorption of the composite behaviors as a function of days was also studied. The result shows that it increases with increasing exposure time for the same filler content, while the absorbed asmount of water increases by increasing the wt% of ferric chloride constant exposure time.*

**Keywords:** *HDPE, Ferric chloride, Water absorption, Mechanical properties.*

## 1. Introduction

Modern structure composites, mostly referred to as ‘advanced composite’ are a blend of two or more components; one is made from stiff, long fibers, and others, a binder or ‘matrix’, which holds the fibers in place. The matrix material can be polymeric, metallic or ceramic.[1] When the fiber and the matrix are combined to form a composite, they retain their individual identities and a structure influences the final composite properties. The result of composite is usually composed of layers of the fibers and matrix stacked in order to achieve the desired properties in one or more directions.[2,3]

Information on the usage of ferric chloride in reinforcing polymers is limited in the literature. Subita et al. investigated graphite fiber reinforced epoxy composite and found that the mechanical properties increase with increasing filler content.[4] In addition, ceramic fiber reinforced polyethylene was studied by Abdul Razaq[5]; this study concentrated on the effect of fiber contents. It was found the maximum mechanical properties in 60% fiber contents. Al – Mosawi, tested Kevlar fibers with varying fiber contents.[6] The analysis of tensile, flexural, and impact properties of these composites revealed that the composite with high strength could be successfully developed using Kevlar as the reinforcing agent.

The objective of this work is to study the mechanical properties and water absorption of ferric chloride filler reinforced high-density polyethylene.

## 2. Experimental

### 2.1. Materials

a) Matrix Material: High–density polyethylene (HDPE–M624) obtained from the state company of Petrochemical, Basra, Iraq was used as the polymer matrix.
b) Reinforcing Material: Ferric chloride (FeCl3) powder with a particle size (□ 100 µm) was obtained from a sigma Aldrich.

### 2.2. Preparation of Composites

Five concentrations of ($FeCl_3$) were used (5, 10, 15, 20 and 25) wt. % as a fine powder mixed with HDPE by using mixer 600 instruments attached to Haake Rohochard meter under the following conditions, mixing time (15 min), mixing temperature (175 □C) and mixing velocity (32 rpm). The final mold of the sample was introduced in a laboratory by compressing under (5 tons at 175 □C for

15 min) in a square frame. The pressure then rises gradually up to (15 tons) for (5 min), after this period the sample was cooled up to reach room temperature.

### 2.3. Test Specimens Preparation

Three types of specimens were manufactured as follows:

a) Tensile Strength specimens: these specimens were manufactured according to the (ISO – R – 527) standard.

b) Impact specimens: impact specimens were fabricated according to the (ASTM – E23) standard suitable to Charpy impact instrument. Notch depth is (0.5 mm) and notch base radius is (0.25 mm).

c) Hardness specimens: hardness specimens are a disc shape with (25 mm) diameter and (10 mm) thickness.

Six specimens were manufactured for each test, which has different resin and reinforcement percentage as shown in table 1.

**Table1.** *Structure of specimens*

| Specimens no. | 1 | 2 | 3 | 4 | 5 |
|---|---|---|---|---|---|
| Resin (wt) % | 95 | 90 | 85 | 80 | 75 |
| Fibers (wt) % | 5 | 10 | 15 | 20 | 25 |

### 2.4. Mechanical Testing

Three types of mechanical tests were used to determined the properties of composite material, and these tests are:

*2.4.1. Tensile Test*

The tensile strength test was conducted on computerized universal testing machine (HOUNSFIELD H25KS). The sample of 10 cm length was clamped into two jaws of the machine. Each end of the jaws covered 2 cm of the sample. Tensile strength was studied over the rest of 6 cm gauze length. Reading of the tensile strength test instrument for Newton force and extension was initially set to zero. The test was conducted at the constant strain rate of the order of 10 mm/min. Tensile stress was applied until the failure of the sample and load – extension curve were obtained. Each sample was tested for two times and average results have been reported.

*2.4.2. Impact Test*

Charpy impact instrument was used to determine the impact resistance of the composite materials.

*2.4.3. Hardness Test*

In this test “Brinell method” was used to measure the hardness. This test was made with a steel ball (5mm) diameter and (10 kg) exposition load, loaded on the specimens for (15 sec). The hardness number represents the diameter of impression after the load removal, which is left on surface by the ball. Universal test instrument manufactured by (Uali test company) used for this test.

### 2.5. Water Absorption Test

Water absorption test (ASTM D750 – 95) was done by the total immersion of three samples in distilled water at room temperature. The water absorption was determined by weighing the samples at regular intervals (weight gain). Sartorius balance in the range (0.0001 – 200 gm) was utilized for the weighing of the samples.

The percentage of water absorption (W%) was calculated by[7]:

$W\% = [(W_2 - W_1) / W_1] * 100\%$

Where: $W_1$ and $W_2$ are the dry and wet weight, respectively.

## 3. Results and Discussion

### 3.1. Mechanical Properties

The mechanical properties of composite materials are highly important factors in the field of using these materials, where the values of these properties should be high and acceptable. From the mechanical tests done on the HDPE resin reinforced with $FeCl_3$ filler, the results represent the values of tensile strength, tensile modulus, impact strength, and hardness with the filler reinforcement percentage:

1- Tensile strength: the resin is considered as brittle materials where its tensile strength was very low, as shown in Figure (1), but after reinforcing by filler this property is highly improved, where the filler resistances the maximum parts of loads and that leads to raise the strength of composite material. The tensile strength increases as the filler percentage addition increases, where these filler is distributed on the large area in the resin[8,9].

2- Tensile modulus: the young's modulus gives the relationship between stress and strain in a material which is the measure of the rigidity of the materials.[10] Figure (2) illustrates the relation between tensile modulus *vs.* different content of the $FeCl_3$ filler. It was clearly observed that the increasing of wt. % $FeCl_3$ filler leads to increase in the tensile modulus because of absence of voids in the composite, good mixing of the filler, and matrix[11].

3- Impact strength: the impact response in $FeCl_3$ reinforced / HDPE composite reflects failure processes involving crack initiation and growth in the resin matrix, filler breakage and pullout, delaminating, and disbanding. Figure (3) shows the value of impact strength with filler reinforcing percentage. The results shows that $FeCl_3$ filler improved the impact strength of the HDPE material approximately (41%). Higher impact strength value leads to the higher toughness properties of the material[12,13]. Also, the impact resistance continues to increase with increasing of the filler reinforcing percentage.

4- Hardness: generally the plastic materials have low hardness, as shown in Figure (4), the lowest value for HDPE resin before reinforcement. However, this hardness is greatly increased when the resin reinforced by $FeCl_3$ filler, due to the distribution of the test load on fibers which decreases the penetration of test ball onto the surface of composite material and leads to raise the hardness of this material. The hardness is increased with increasing the percentage of filler reinforcement[14,15].

### 3.2. Water Absorption

Figure (5) shows the variation of the ratio of water absorption vs. exposure time for (HDPE / $FeCl_3$) composite with different contents of the fillers. It can be noticed from the this Figure that the composites with higher filler content shows more water absorption. This is due to the higher contents of fillers in the composites that can be able to absorb more water. As the filler content increases, the formation of agglomerations increases due to the difficulties of achieving a homogeneous dispersion of filler at a high filler content. The agglomeration of the filler in composites increases the water absorption of the composites[16, 17].

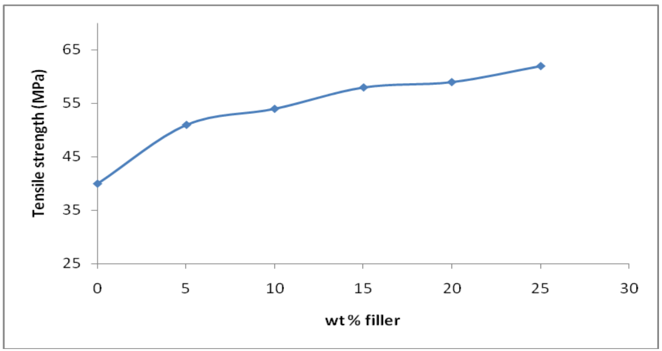


**Fig1**. *Tensile strength as a function of content for samples.*

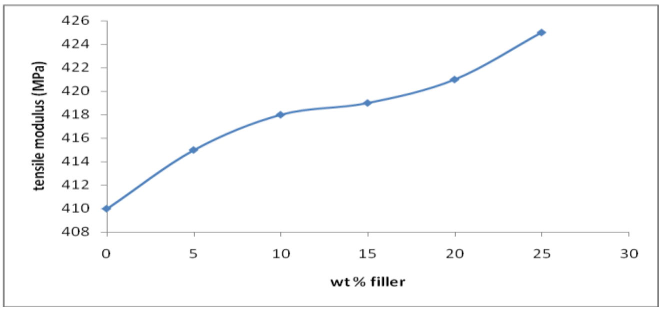


**Fig.2**. *tensile modulus vs. different Filler $FeCl_3$ filler content for samples.*

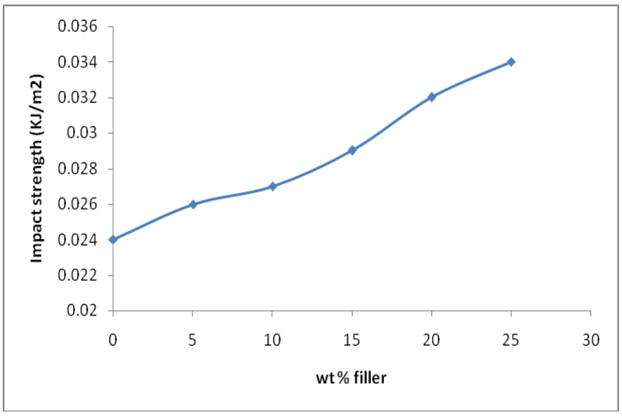


**Fig3**. *Impact strength as a function of filler content for samples.*

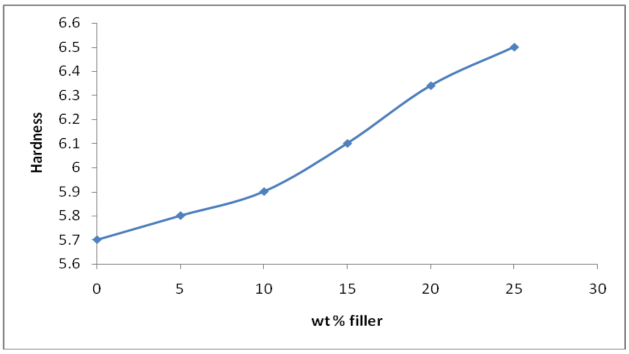


**Fig.4**. *hardness as a function of filler content for samples.*

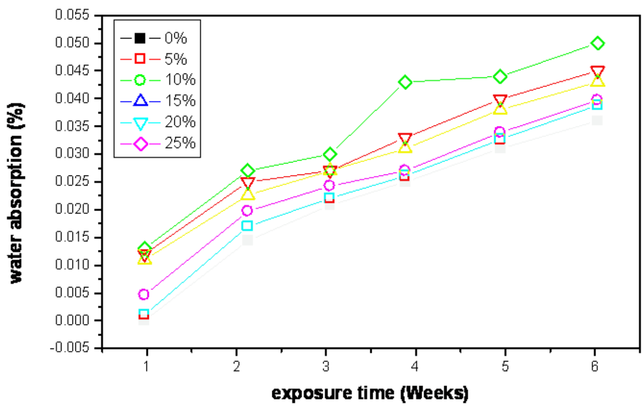


**Fig5**. *Effect of exposure time on the water absorption of (HDPE / $FeCl_3$) composites with different filler content.*

## 4. Conclusions

From this study it is demonstrated that the filler concentration affects composite mechanical properties and water absorption. Therefore the following conclusions can be drawn:

- The tensile strength and hardness on the (HDPE / $FeCl_3$) composite were increased by (55% and 14 %) respectively to the HDPE material.
- The results of the impact strength test showed that FeCl3 filler improves the impact strength of the HDPE material approximately (41%). Higher impact strength value leads to the higher toughness properties of the material.
- The percentage water absorption increases with increasing filler concentration.

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