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Mechanical Characterization of High Density Polyethylene 6063 Aluminium

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***Abstract**: This work investigated the effects of High-Density Polyethylene (HDPE) on the mechanical properties of 6063 aluminum. This was with a view to determine the impact of the HDPE on the tensile and hardness properties of 6063 aluminum. Two separate samples of 6063 aluminum were produced and designated A and B for 0 and 5% HDPE respectively. Three test pieces were cut from each sample and prepared for tensile and hardness measurement. The micrographs of the samples were also prepared. The results obtained showed that sample B exhibited higher strength in comparison to sample A. A significant difference was also observed in the hardness in both specimens. The photomicrograph shows that there was segregation of the HDPE towards the grain boundaries thus introducing discontinuity in the grain boundaries.*

***Keywords**: 6063 Aluminum, High Density Polyethylene, Microhardness, Tensile Properties.*

I. Introduction

Aluminum is one of the most important materials that have find its broader use in the domestic and industrial sector. This versatility has been attributed to its reasonably high strength, light weight, machinability, resistant to corrosion attack, viability and affordability [3, 4]. These excellent properties serves as an impetus to its versatility [5, 6, 7].

Previous research on the improvement of mechanical properties has been focused on heat treatment, precipitation, age hardening [8] and reinforced with industrial and inorganic materials to enhanced its properties [9, 10, 11, 12].

Polyethylene (PE) is being increasingly used in many industrial and biomedical applications. Its outstanding features such as regular chain structure, combination of low cost and low energy demand for processing, excellent biocompatibility, and good mechanical properties make PE expand its application continuously [13, 14]. The superiority of PE products over metal products is attributed to their light weight, high corrosion resistance, and low costs. However, there are some drawbacks with Polyethylene including low environmental stress cracking resistance, low creep resistance, and poor compatibility with various additives which restricted its use for cretin purposes [15, 16]. Therefore, there have been many attempts to improve the properties of polyethylene by blending it with organic or inorganic materials [15 – 19].

A density of ≥0.941g/cm defines High-Density Polyethylene (HDPE). It has a low degree of branching and thus account for its strong intermolecular forces and tensile strength [2]. The mechanical properties of a material which is used to assess and determine the applicability of any material [1] is a basis for this research. To this effect, this work focuses on the study of the effects of HDPE on the mechanical properties of 6063 Aluminium.

II. Experimental Work

2.1 Mould Preparation

Plastic cylindrical pattern of diameter 20mm by 120mm length was used to prepare the sand mould. The mould was prepared using cope and drag in which prepared moulding sand was rammed round the pattern, this was to create an impression called the mould in which the melt would be poured after the withdrawal of the pattern from the sand. .

2.2 Charge Preparation, Melting and Casting

6063 Aluminium was selected to be the base metal used for the experiment. The base metal was cast without any addition and was designated A. A second casting having 95% by weight of the 6063 aluminium alloy and 5% by weight of high density polyethylene (HDPE). The aluminium alloy was melted and super-heated to a pouring temperature of 690^0C, removed from the furnace and poured into the prepared mould to form cast. The cast was designated B. The two cast were allowed to solidify in the mould to room temperature. They were subsequently knocked out, cleaned and fettled.

2.3 Metallographic Preparation

Microstructural examination of specimens was performed using daheng software driven optical microscope. Prior to this, the specimens were metallographically prepared by grinding using a series of emery papers of grit sizes ranging from 60 – 1200µm; while fine polishing was performed using polycrystalline diamond suspension of particle sizes 2.0µm with ethanol solvent. The specimens were etched with 0.5%HF solution by swabbing before observation with the optical microscope.

2.4 Mechanical properties preparation

A room temperature uniaxial tension tests were performed on round tensile samples machined from the prepared composites with average dimensions of 5 mm diameter and 30 mm gauge length. The test was performed using an software driven electronic tensiometer operated at a constant cross head speed of 1mm/s. The specimen dimension specifications and the test procedure adopted were in conformity with ASTM E8M - 91 standards [8, 10]. Four repeat tests were performed for composite composition to guarantee reliability of the data generated. The tensile properties evaluated from the stress-strain curves developed from the tension test are - the ultimate tensile strength (σ_u), the 0.2% offset yield strength (σ_y), and the strain to fracture (ε_f).

The hardness values of all cast specimens were evaluated using a Digital Rockwell Hardness Tester. Prior to the test, the specimens were polished to obtain a smooth surface. A direct load of 584.9MN (60kg) was applied on the specimens and the hardness values were recorded. Multiple hardness tests were performed on each specimen and the average value was taken as the hardness of the specimen.

III. Results And Discussion

Table 1 shows the spectrometric analysis indicating the lean alloying chemistry in the selected 6063 aluminum.

Table 1: Chemical composition of 6063 aluminum alloy

Element	% Composition	Element	% Composition	Element	% Composition
Si	0.401	**Mg**	0.501	**Ca**	0.004
Fe	0.206	**Zn**	0.006	**Al**	Bal.
Cu	0.011	**Cr**	0.003		
Mn	0.013	**Ti**	0.008		

3.1 Micrograph

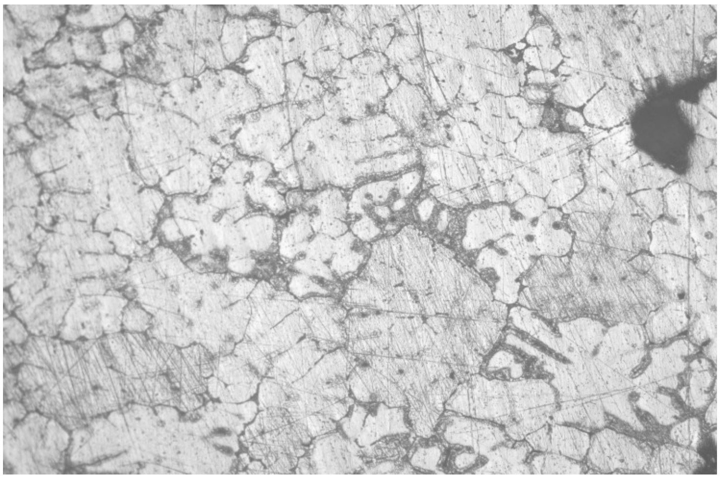

Figure 1: Micrograph of sample A (as cast) 6063 aluminium X100

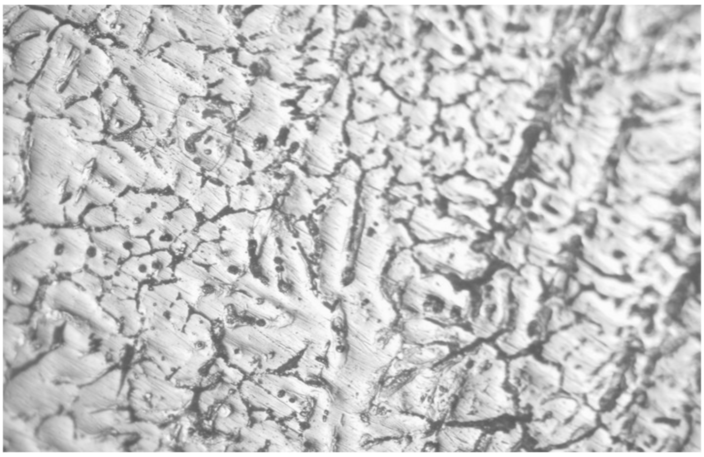

Figure 2: Micrograph of sample B (aluminium 6063 with 5% HDPE) X100

Daheng software driven metallurgical microscope was used to view and capture the microstructures of the samples. From the photomicrograph, it was observed as shown in Figure 1 that the sample with 5% HDPE have clear and continuous network of grain boundaries. The silicon strand is also visible and evenly distributed in the micrograph. The reason for this continuous network could be attribute to the high density of the polyethylene used in the experiment, thus resulting in the close-packed bond relationship among the grains. The HDPE added was seen to segregate along the grain boundaries thereby disorganizing the initial structure. The microstructure of sample B (Figure 2) however, shows thickened grain boundaries alongside cracks promoting discontinuity among the colonies.

3.2 Hardness

Table 1: Microhardness result of selected samples

Label	I	II	III	IV	Average
Sample A	101.2	100.2	103.3	105.7	102.6
Sample B	112.9	108.1	115.1	115.6	112.93

Four samples were selected for microhardness analysis at room temperature and the results are as shown in Table 2. From the table, it was observed that when a load of 584.9MN (60kg) was applied on the samples over a period of 10 seconds, sample B exhibited a high average hardness of 112.193HV while sample A recorded average hardness of 102.60HV. The higher values recorded in sample B may be due to it thickened grain boundaries and the discontinuity in the microstructure.

3.3 Tensile Results

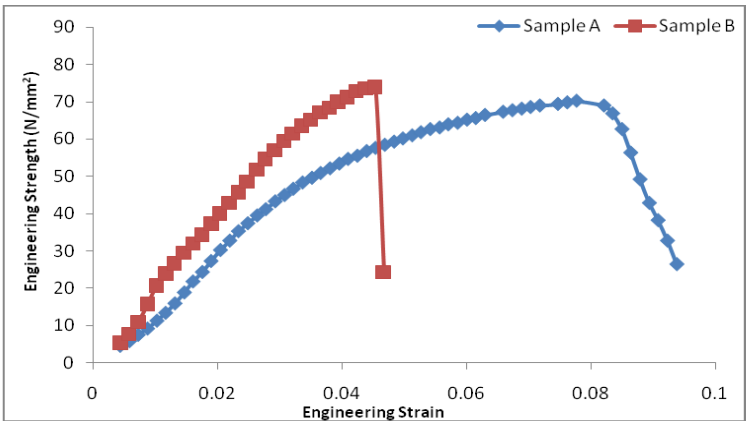

Figure 3: Variation of Strength to Strain at regular strain rate

Table 3: summary of tensile properties

Label	Eng. UTS (N/mm^2)	0.2% Proof Strength	Peak Displacement (%)	strain to fracture (%)
Sample A	70.2	57.6	7.77	9.67
Sample B	73.9	57.0	4.53	4.67

A uniaxial tensile test was conducted using an electronic tensiometer at a regular strain rate. Figure 3 shows the super-imposed plots of the two samples, the results confirm that samples sample B (with 5% HDPE) exhibited high ultimate tensile strength (UTS) in comparison with sample A which serves as the control in this experiment. The tensile plots show that the addition of HDPE into aluminum results in the significant improvement in the ultimate tensile strength (UTS) with a peak value of about 74.0N/mm^2, the ductility of the material is however observed to have been reduced by about 42%. This thus indicate that despite the remarkable increase in the hardness and strength of sample B (with 5% HDPE), its failure under tensile loading is sudden when compare with the displacement exhibited in sample A.

IV. Conclusion

In an attempt to study the effect of HDPE in Al matrix, the possibility of entrapping high density polyethylene (HDPE) in aluminum by casting without allowing vaporization of the HDPE is feasible.

In this experiment, microscope, microhardness tester and electronic tensiometer was used to characterize the cast. From the results, it was observed that when a high density polyethylene (HDPE) is entrapped in Al matrix, a positive and significant increment in the hardness and strength is enhanced, though at the expense of its ductility.

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