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Influence of Graphene and Alumina on Mechanical and Microstructural Properties of AL7075 based Hybrid Composites

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Abstract

AL-7075 with particulates of reinforcement carries superior stiffness, maximum strength and better wear resistance when differentiate to unreinforced matrix alloys. They have been used for the self-propelled automotive spare parts and goods and aircraft assemblies. Aluminium Metal Matrix Hybrid Composite (ALMMHC) focus on the mainly cost and life time of the fabricated components. The requirements of industry (ALMMHC) are available in chiefly and eco-friendly and those have good specific strength and wear resistance for production applications. Aluminium alloy as a matrix material and graphene and alumina as reinforcement has good potentiality. In this study AL7075- graphene and alumina particulates castings with various volume proportions of graphene and alumina particulates were fabricated in the oxygen free argon atmosphere at stir casting methodology. At my investigation we found the increasing weight % of reinforcement graphene and alumina with there is an enhancement of specific strength of the produced hybrid composite. Pin-on-disc tester utilized for dry sliding wear behaviour of ALMMHCs at dry laboratory process.

***Keywords:** AL7075, alumina, graphene powder, stir casting methodology, tensile strength, Brinell's hardness, density, compression strength, and microstructure.*

INTRODUCTION

"Design" must be responsible for the innovation and research in all sectors of scientific point of view. As a mechanical design engineer, the major exposure is to accomplish is minimizing the price, maximizing the life span and definitive for work [1].

While approaching to the major sectors of research, metal matrix composites has specific importance in now a day's domain [2-3]. Before developing of any component choosing of matrix material plays crucial role. Standard materials allow low profits than the reinforced composite materials. These composite materials are classified into various matrix composites conforming to the region of applications. The major motives of these composites are enhancing the properties of the materials [4] which guide to high accomplish and allowable quality of materials. ALMMHC'S have some better properties namely high strength, better damping capacity, good stiffness, specific modulus; better wear behavior and low density.

Aluminum metal matrix hybrid composites are receives more interest because of having some superior properties differentiate to the remaining alloys. While seeing conforming to the strength, tribological behavior and stiffness it has significant enhancement by incorporation of reinforcements.

The selection of reinforcements is the major factor for composite material

fabrication among vast scope of materials accessible in nature. Choosing of reinforcement material should be adjustable to manufacturing process for their applications.

There are several process methods are available in fabrication process. I am choosing Stir Casting methodology [5], because of better features like simple and comfortable to operate and maintenance, high productivity etc. Most of the industries are utilizing this methodology for fabrication of the composite materials. Mechanical engineers regularly explore for advance and modern materials for better properties because standard materials do not provide the necessary properties under all working conditions **Choosing of Materials**.

Selection of Base Material

For production of aluminum metal matrix hybrid composites (ALMMHC) we prefer the matrix material as Al-7075 alloy [9] as matrix material for hybrid composite.

Selection of Reinforcement

I prefer the reinforcement materials are Graphene powder and alumina powder [6] as reinforcement material for the fabricated composite.

Matrix Material

AL7075

Al-7075 is an aluminum alloy of aluminum association, through zinc as crucial alloying element in Al-7075 alloy association. It is extremely powerful and tough in strength differentiate to other unreinforced alloys and remaining materials and has better fatigue strength, high thermal and electrical conductivity normal machinability [7], but has minor resistance to corrosion differentiate to the other unreinforced alloys [8]. It is employed for the sports goods, electronic stuff, armors, aerospace, defense and automotive industries applications.

Figure 1:*Base material Al-7075.*

For the producton of composite, AL7075 alloy was employed to the inital matrix material as show in fig.1; whereas little melting additives like Graphene powder and alumina powder were added to pure particulate forms. The chemical arrangement of AL7075 is shown in Table-1.And properties of material as shown in table-2.

Table 1: *Chemical arrangement of Aluminum 7075.*

Constituent	Cr	Cu	Fe	Mg	Mn	Si	Ti	Zn	Al
Wt.%	0.28	2	0.5	2.9	0.3	0.4	0.2	6	87

Table 2: *Properties of Al-7075.*

Property	Density	MeltingPoint	Tensilestrength	Hardness	Fatigue
Valve	2.81 cc	483^0 c	220 Mpa	147	160 Mpa

Reinforcement Materials

Graphene is an allotrope form of

carbon in the shape of a two dimensional, atomic scale, hexagonal lattice [10] in which one atom form is each vertex. It is the primary constitutional element of other allotropes, counting graphite, charcoal, carbon-nanotubes and fullerenes. It can also be considered as recognizing large aromatic molecule, the final phase of the group of plane polycyclic aromatic hydrocarbons.

Graphene have so many usual belongings as shown in table-3. In portion to its width, it is about 200 times stronger over than strongest steel. It conducts electricity and heat very essentially and is usually transparent. Graphene also exhibit a nonlinear and large diamagnetism, even better than graphite, as shown in fig.2.

Figure 2: *Graphene powder.*

Aluminium oxide is a chemical combination of aluminium and oxygen with the is Al_2O_3. It is the most regularly occurring of various aluminium oxides, and specifically recognized as aluminium oxide, as shown in fig.3.

It is usually called alumina and may also called aloxide or aloxite depending on particular forms of applications. It happens usually in its crystalline polymorphic phase Al_2O_3 as the low al corundum, various of the valuable gemstones ruby and sapphire.

Al_2O_3 is important in its use to fabricate to aluminium metal, as an abrasive having to its hardness, and as a refractory material having to its high melting point.

The alumina is from the bauxite, is an ore. That is extracted from top layer of earth soil in several tropical and subtropical regions. The initial process by alumina is produced from the bauxite.

Figure 3: *Alumina powder.*

Table 3: *Belongings of reinforcements.*

Properties	Al-7075	Alumina	Graphene powder
Elastic Modulus (Gpa)	72-82	215	1000
Density (g cc-1)	2.8	3.9	1.6-2.4
Poisson's Ratio	0.33	0.2	0.17-0.2
Hardness (BHN)	140	360	-
Compressive Strength (C) (Mpa)	260	690	365

EXPRIMENTAL WORK

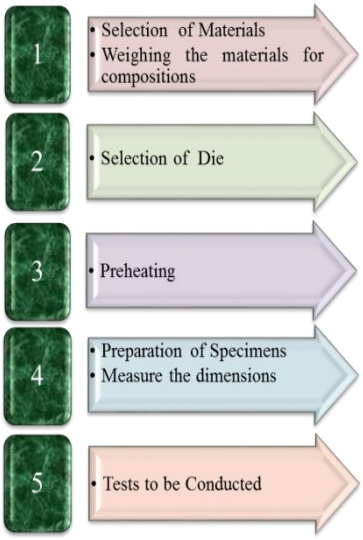

Figure 4: *Flow chart.*

Stir Casting Methodology

- The bottom flow run type of perfectly advanced and censor base Stir-Casting equipment is used to production of the ALMMHCs [11].
- At the beginning of the base material, AL7075 alloy ingots allows into the furnace of stir casting, as shown in flow chart fig.4.
- The furnace temperature was maintained at 820°C. The base material AL7075 is above 750°C temperature of matrix material to enhance at liquid stage.
- Then 10 grams of C_2Cl_6 is includes for the degasifing the molten melt, and maintains the organ nature with help of oxgen free argan gas [12].

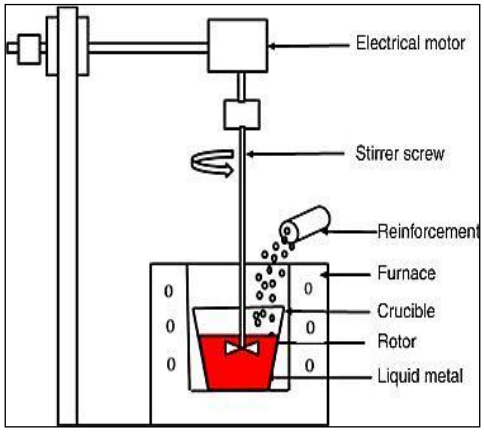

Figure 5: *Stir casting methodology.*

- Before the stirring, the reinforcement matrials is preheated up to 200°C for

50 min. The composition of composite as shown in table-4. The stirring is using by mechanical stirrer and the stirrer speed is maintained at 600 rpm and stirring time for 10 min. As shown in fig.5. and the stirrer is dipped into the furnace of molten melt. as shown in table-5.

- Operation of stirring orentation of both base material AL7075 and reinforcements are completely mixed in the stir castimg furnace as shown in fig.6. The die was preheated up to 400ºC at 1.2 hours.
- Finally the moltenmelt aluminium hybrid composite was transferred into the metallic permanent die.The die as shown n fg.7.

Table 4: *Designation of composites.*

Casting	AL7075 gm (%)	Al7075 (%)	Reinforcements (Graphene powder + Alumina)	Reinforcements (%)
1	800	100	0	0
2	784	98	16	2
3	768	96	32	4
4	752	94	24	6

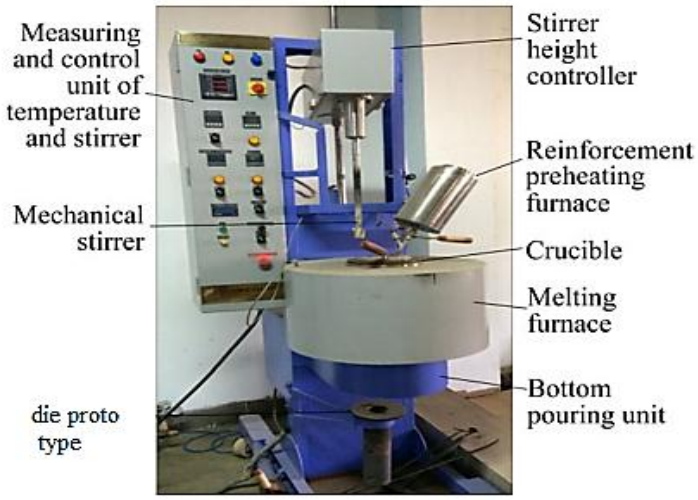

Figure 6: *Stir casting machine.*

Selection of Die

The die of two cylindrical fingers and a flat plane is as shown in Fig. 7 is for production of castings [13]. The dimensions cylindrical fingers are 200mm x 20mm. The dimensions of flat plate were 50 mm x 15mm x 100mm.

Figure 7: *Casting die.*

Table 5: *Organizing details for stir casting [14].*

Parameter	Unit	Value
Spindle speed	Rpm	600
Stirring time	Seconds	600
Stirring temperature of the molt-metal	ºC	750
Preheating of reinforcements	ºC	200
Preheating time of Reinforcements	Min	50
Preheating temperatures of die	ºC	450
Powder allow rate	g/s	2- 2.2

Tests Conducted

1. Tensile strength
2. Brineii's Hardness
3. Lower Density
4. Compression strength
5. 5 Micro-structure

RESULTS AND DISCUSSIONS

Tensile behavior of AL7075 AMMHC

Tensile nature of the hybrid composite is evaluated with as per ASTM E8 (Fig. 8.) samples utilizing universal testing machine (UTM). Tensile nature of the hybrid composite from 2w% to 6wt% is as shown in Fig8. The ultimate tensile strength of the composite is established to be enhancing with an increase in addition of reinforcement materials as shown in fig.9. Stress obtained was 143.66 MPa for 6wt% composites, as shown in fig.10 for composite.

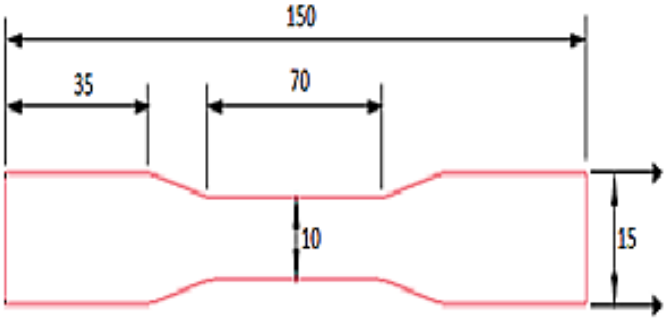

Figure 8: *ASTM E8 Specimen.*

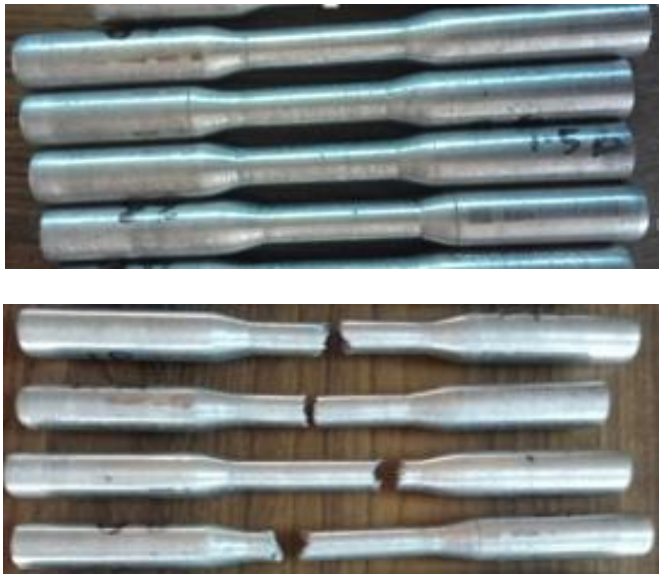

Figure 9: *Tensile specimens before and after testing.*

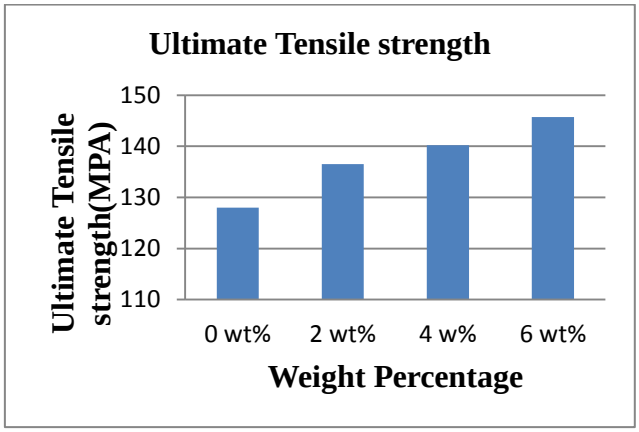

Figure 10: *Ultimate tensile strength graph of Al7075 hybrid composite.*

Hardness of Al7075 AMMHC

The Brinell's number is a hardness number based on indentation on the surface of specimen is hardness of the fabricated composite materials. The Brinell's hardness test trail is determines the hardness is evaluate the depth of indenter penetration of under a direct load differentiate to the penetration create by a preload. There are various scales, label by a single letter, that using numerous loads or indenters. The results are extracted as a dimensionless number tabulated as a respective Brinell's scales as shown in table-6. The diamond type indenter tool is utilized to make impressions on the surface of the composite material. The hardness values of composite materials are shown in graph. When testing of samples of composite materials, indentation of hardness corresponds straightly with strength. This important relation to permits economically important non-destructive testing of bulk metal deliveries with light-weight, even portable equipment, such hand held Brinell's hardness testers. In this, each sample was tested and thrice of the surface indentation was determined.

Hardness evaluations was create on several sections of the after homogenization and heat treated composite material as per ASTM E8 standards as shown in fig.11and the results are plotted Brinell's hardness no =2p/ΠD [D-sqrt (D^2-d^2)].

Table 6: *Brinell's hardness values of Al 7075 hybrid composite.*

Castings	Specimens Designations	Brinell's Hardness Number (BHN)
1	0%	147
2	2%	165
3	4%	177
4	6%	199

Figure 11: *Samples for Brinell's hardness test.*

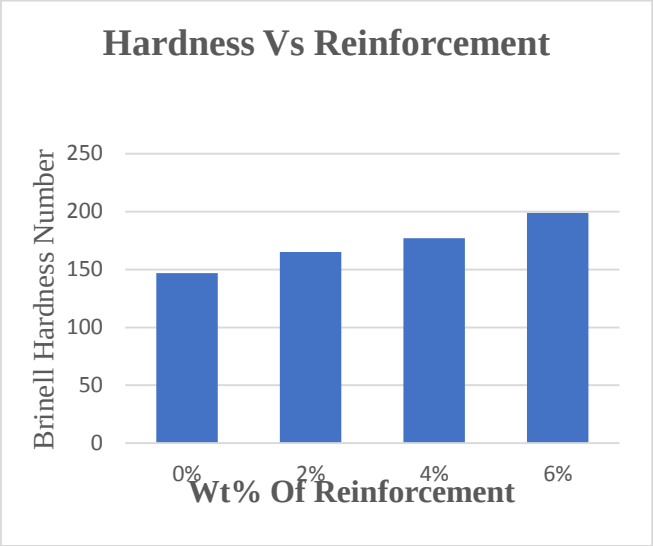

Figure 12: *Brinell hardness graph of Al 7075 hybrid composite.*

With the increase in wt% of reinforcement materials, there is an enhancement in the hardness value, as shown n fg.12.

Density of Al7075 AMMHC

The density of Al7075 alloy metal matrix hybrid composite was evaluated was carried to estimate the percentage of porosity of the produced hybrid composites and in order to study the effect reinforcement influence the wt% portions of grapheme and alumna powder of the densities of the fabricated hybrid composites. This was attained by differentiation of experimental results to theoretical results of composite material densities of each composition specimen's proportion weight percentage grapheme and alumna powder reinforced metal matrix hybrid composites utilizing standard methodologies. The experimental density (***ρ***EXT) of fabricated composite was tabulated by dividing the measured weight of the hybrid composite samples by its calculated volume. The density tester as show in fig.13. The theoretical density (***ρ***T) of fabricated composite was obtained by the method of rule of mixtures as shown in table-7. The density specimens as shown in fg.14.

Figure 13: *Density tester.*

The percent porosity of fabricated composite was evaluated by using the given relations:

$$\% \text{ Porosity} = \frac{\rho T - \rho EXT}{\rho T} * 100$$

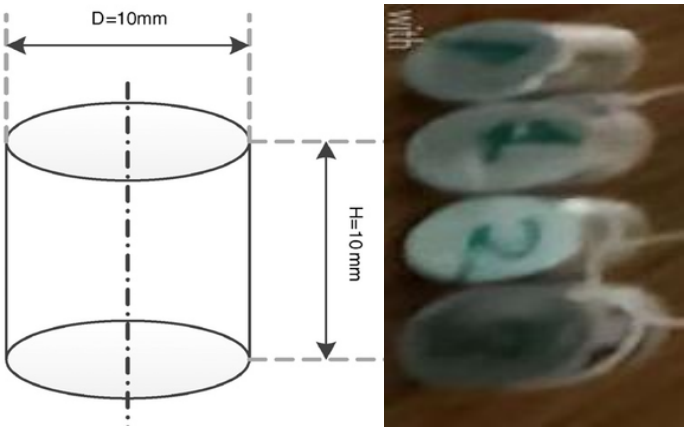

Figure 14: *Density specimens.*

Table 7: *Density values of Al 7075 hybrid composite.*

Samples Designations	Theoretical Density (ρT)	Experimental Density (ρEXT)	% Porosity
0%	2.87	2.81	2.0
2%	2.76	2.70	2.1
4%	2.50	2.45	2.0
6%	2.48	2.43	2.0

Compression Behavior of Al7075 AMMHC

The compressive strength is the scope of a material or construction to withstand loads trending to reduce size, as opposed to tensile strength which withstands loads are tending to stretched. In other words, compressive strength resists compression, whereas tensile strength resists tension. In the evaluation of strength of materials, compressive strength, shear strength and tensile strength can be analyses independently.

Compressive strength of the fabricate hybrid composite is determined with ASTM E8 samples using universal testing machine (UTM) as shown in fig.15. Compressive strength of the hybrid composite compositions of 0 % to 6 % is as shown in fig.16 and fig.17.

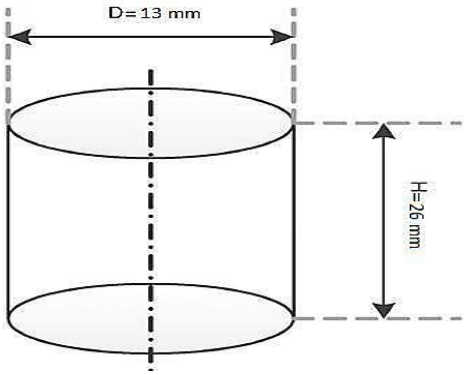

Figure 15: *Dimensions of compression test specimen.*

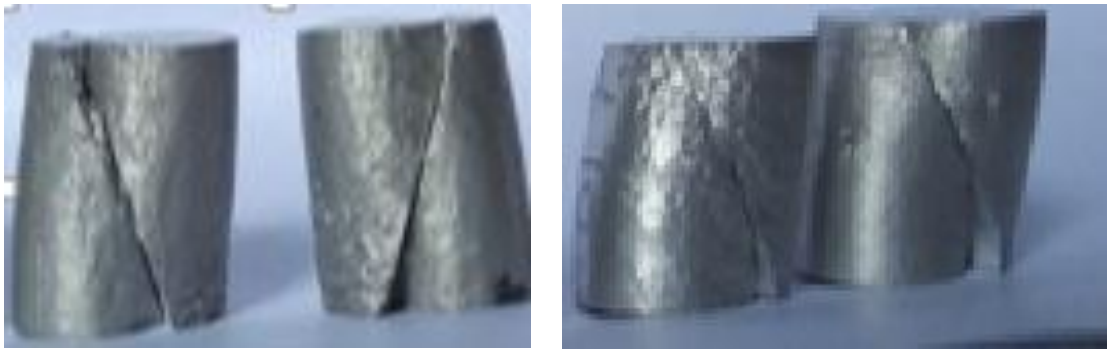

Figure 16: *Compression specimens after testing.*

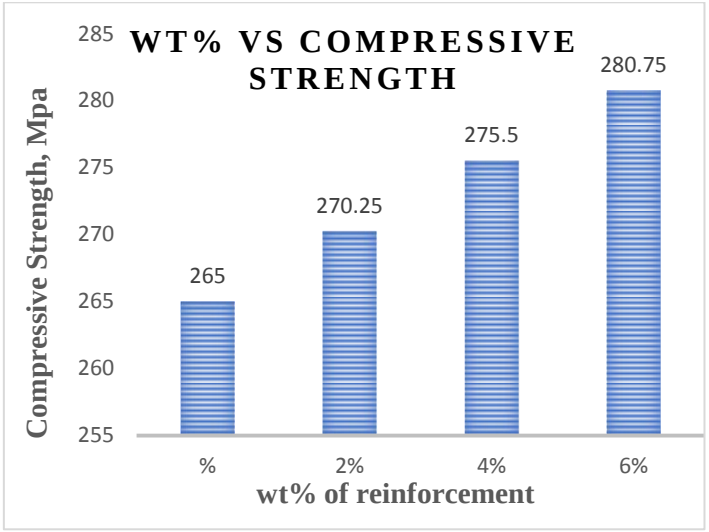

Figure 17: *Brinell's hardness graph of Al 7075 hybrid composite.*

MICROSTRUCTURE

When a smoothly polished flat sample reveals traces of its microstructure, it is normal to capture the images using microphotography. Most experienced microstructure evaluation involves costly high powered consumption instruments: optical microscope, X-rays diffraction, electron microscope. Some of the involving preparations of the composite material specimens are dimensioning, microtome, polishing, etching, vapor-deposition etc. A computerized inverted Trinocular metallurgical microscope with all accessories to analyses the surface microstructure captures was used to analysis the microstructure of the fabricated hybrid composites[15]. The micro structure of several metal matrix hybrid composites are given below as shown in Fig. 18 to Fig. 21.

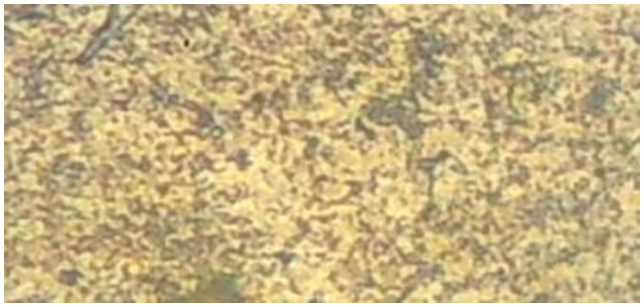

Figure 18: *Micro Structure of Al-7075.*

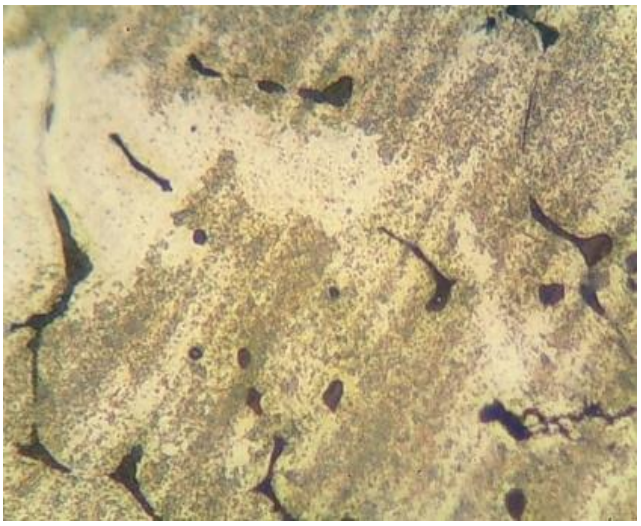

Figure 19: *Micro structure of AMMHC 2wt%.*

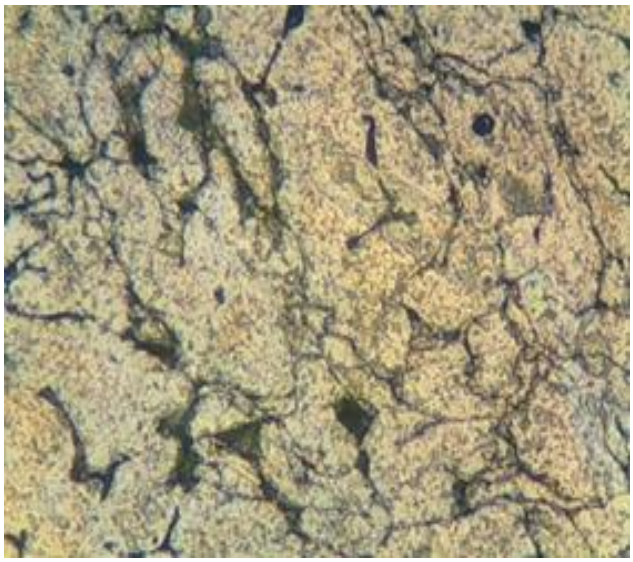

Figure 20: *Micro structure of AMMHC 4wt%.*

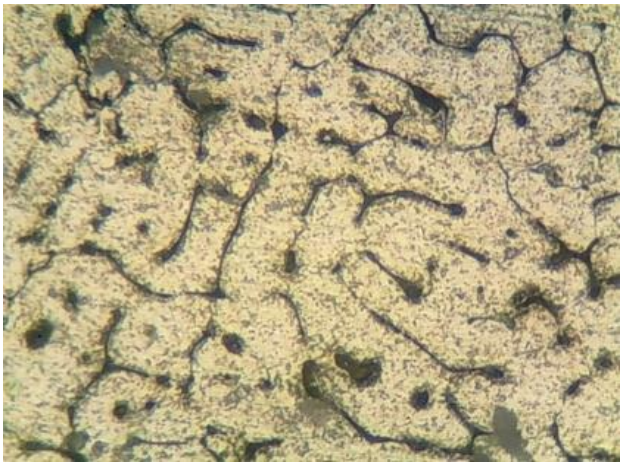

Figure 21: *Micro structure of AMMHC 6wt%.*

CONCLUSION

Investigating the effect of Graphene and Alumina wt% on the mechanical and microstructural behaviour of Al7075 alloy based hybrid composite containing with various portions of 0wt%, 2wt%, 4wt%, and 6wt% are evaluated to find mechanical, metallurgical and microstructural properties such as tensile strength, hardness, density, compression strength, and micro structure of fabricated hybrid composites (AMMHC).

We have concluded that the reinforcing with Graphene and Alumina has the following results:

- The tensile strength of the fabricated composites gradually increases enhancing the reinforcement composition of produced AL-7075 composite. The maximum tensile strength occurs at 6wt% of reinforcement such as 3wt% of Graphene and 3wt% of Alumna is 146Mpa.
- The Brinell's hardness of the fabricated composites gradually increases enhancing the reinforcement composition of produced AL-7075 composite.
- The Density of the fabricated Al7075 hybrid composite gradually decreases for all 2wt%, 4wt% and 6wt% reinforcement of Graphene and Alumina increasing compositions while there as lite significant variations in porosity.
- AL-7075 Hybrid composite containing 2wt%, 4wt% and 6wt% reinforcement of Graphene and Alumina increasing compositions the compressive strength value in gradually increase. The maximum compressive strength occurs at 6wt% of reinforcement such as 3wt% of Graphene and 3wt% of Alumna is 280.7Mpa.
- Observations from microstructure:
  Uniform mixing reinforcements Graphene and Alumina of 2wt% of reinforcement, 4wt% of reinforcement and 6wt% of reinforcement occurs n produced AL-7075 composite.

Hence, we can conclude that:

The optimum percentages of reinforcement are Graphene and Alumina in Al-7075 as 6wt% reinforcements such as 3wt% of Graphene and 3wt% of Alumna are good mechanical, metallurgical properties.

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