EVALUATION OF MECHANICAL PROPERTIES OF ALUMINIUM-6061, 4% GRAPHITE MMCs USING CENTRIFUGAL CASTING AND STIR CASTING

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Abstract: The present research has been focused on the utilization of large quantity of available graphite in useful manner by dispersing it into aluminum to produce Aluminum Metal Matrix Composites (AMMC). An aluminum 6061 alloy reinforced with 4wt% graphite is fabricated by stir casting. Specimens were prepared of the casting by Die casting and centrifugal casting. According to ASTM standards for various mechanical tests. The microstructural and mechanical properties of AMMC were compared with the Al 6061 alloy after experimentation. AMMC have significantly improved properties such as high tensile strength by 1.9 percent, high wear resistance by 2.33 percent, Density has been decreased by 0.95 percent and decrease in 7 percent of elongation compared to Al 6061 alloy.

Key words: Aluminum 6061, Graphite, Aluminum Metal Matrix Composite.

I. INTRODUCTION

Aluminum Metal Matrix Composites (AMMCs) have become of great interest in the lightweight fields because of their high specific strength. Aluminum based matrix composites are attractive materials in aero sector, defense and automotive field. Composite could mean almost anything if taken at face value since all materials is composed of dissimilar subunits. This module introduces basic concept of strength of advanced composite materials. MMC's are one of the important innovations in the development of advanced materials. Among various matrix materials available, Aluminum and its alloy are widely used in the fabrication of AMMC's. Al based MMC's with various reinforcement like SiC, Al_2o_3, zircon and graphite because of likely possibilities of these combinations in forming highly desirable composites. Several techniques are available for increasing the wettability of reinforced materials in molten metal. Since, the properties of Aluminum metal matrix composites are mainly based on good contact between the base and reinforcement materials. In the present investigation an effort has been made to study the microstructure and mechanical behavior Al6061- 4 wt. % of Graphite composites made-up by stir casting.

Table 1. Chemical composition of Al 6061 alloy

Al 6061	Mg	Si	Cu	Fe	Mn	Cr	Zn	Ti	Al
	0.90	0.41	0.16	0.26	0.07	0.04	0.01	0.01	Bal.

There is continuous research for suitable reinforcement material among the scientific and engineering communities. The research basically concentrates on recognizing reinforcement materials with excellent mechanical properties to satisfy various engineering applications. Graphite are found to be one such excellent reinforcing material which can improve properties of Al6061 Metal Matrix Composites significantly whose properties are tabulated in the table. Graphite can also satisfy the requirement of lightweight with good strength. Al alloys reinforced with different wt.% Graphite are likeable materials for automotive and aerospace applications due to their upgraded properties such as lightweight, high modulus and strength and high wear resistance. Various techniques have been evolved to produce these sorts of composites.

The current work has been carried out to improve the mechanical properties and microstructure growths of Al6061 alloy reinforced with 4 wt.% Graphite. The microstructure evolutions and mechanical properties of Al6061 alloy composite were studied upon at different magnification. Al6061 MMC's are commonly used in the construction of aircraft structures, such as wings and fuselages, Automotive parts, such as the chassis of the Audi A8.

Then the properties hardness, density and wear resistance along with microstructure of composite is determined.

2. Experimental Procedure

Casting is the most commonly used fabrication method in MMCs, as it is low priced and suitable for mass production of components. The preparation of metal matrix composite used in the study was done by stir casting process. In the current work, an effort is made to find out the mechanical nature of Al6061-graphite particulate composites. The composites made by Al6061 and 4 wt. % of particulates were prepared. First calculated amount of Al6061 was placed in a silicon carbide made crucible, which was placed in a furnace (electrical resistance) at an operating temperature of around 900 degree Celsius. After melting of aluminum, graphite powder is added. During addition of graphite particulates into the melt continuous stirring was carried out. Normally stirring was done for 5 minutes, after that molten Al6061-Graphite composites were poured into cast iron die. The prepared castings were machined and initially micro structural studies were done. And mechanical testing was carried out.

Fig.1(a) Experimental set-up of Stir casting

Fig. 1(b) Experimental set-up of Centrifugal casting

Fig.2(a) Al6061

Fig.2(b) Graphite Powder

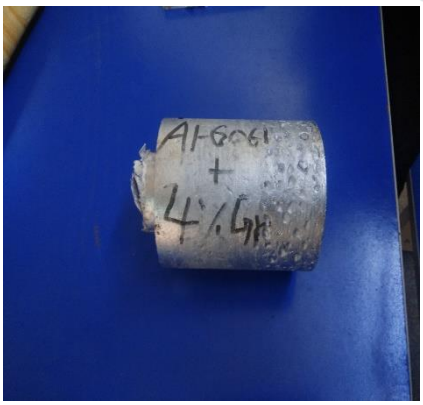


Fig.2(c) Centrifugal casting

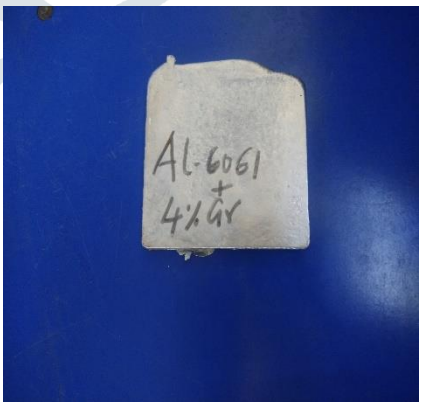
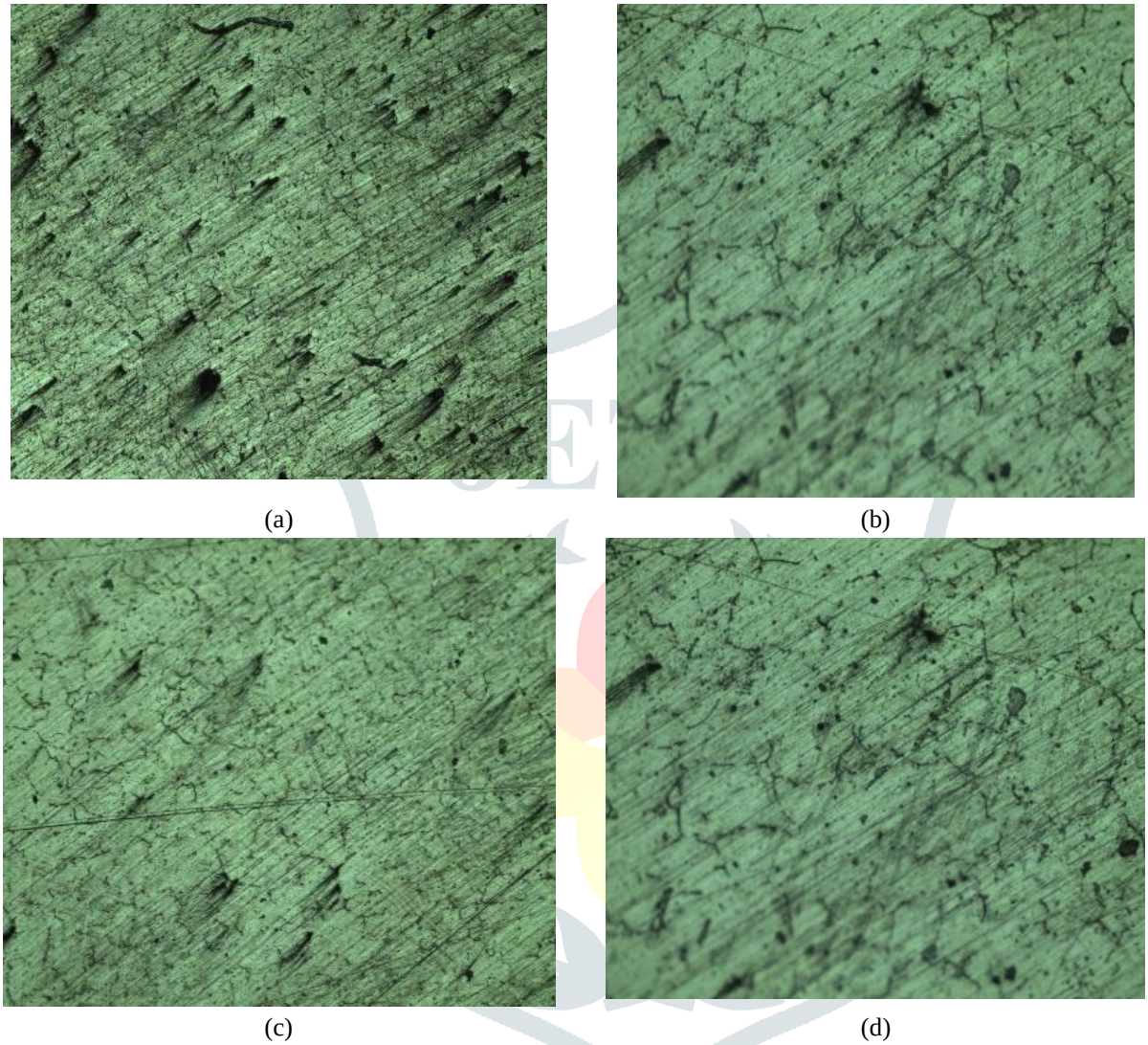


Fig.2(d) Die casting

3. Results and discussion

Microstructure

Optical microscopic image of Al6061 MMC is shown in Figure 3(a) . The intense observation over a wide area revealed that the MMC contained a fairly aligned array of grains and there was a higher porosity of intragranular dislocations. Figure 3 (b), (c) and (d) shows the microstructures observed at different magnifications. It has been revealed that graphite particulates have been uniformly distributed. The uniform distribution of the reinforcement is an indispensable condition for a composite material to accomplish its performance at extreme superiority



(a) (b)

(c) (d)

Figure 3: (a) Al6061 Alloy (b)50X,(c)100X,(d)200X Al6061 reinforced with 4 wt.% Graphite at different magnifications.

Density

Here the digital density measuring setup is used and it works on the principle called Archimedes principles this process is known as water displacement. The same specimen that are used for microstructure test were used for the determine of density after the completion of microstructure test. The dimension of the specimen used for the density test are 12mm length and 10mm square face as per ASTM standard

A density meter, also known as a densimeter, is a device that measures the density. ... The wet portion comprises the density from all liquids present in the sample. The dry solids comprise solely of the density of the solids present in the sample. A density meter does not measure the specific gravity of a sample directly. Density measured are shown in table 4. Here A&B are stir casting specimens, C&D are centrifugal casting specimens.

Table. 2 Density determined

Sample No	Weight of the sample in air W1(g)	Weight of the sample in water W2(g)	Density (g/cm^3) W1/(W1-W2)
A	8.866	5.421	2.573
B	6.428	3.991	2.637
C	12.596	7.904	2.684
D	13.167	8.263	2.685

Hardness test

The Vickers test method is similar to the Brinell hardness testing method. The principle in this test is that a defined shaped indenter is pressed into the material. The indenting force is applied for a certain decided amount of time. The resulting indentation diagonals are measured and recorded. The hardness number is calculated by dividing the force by the surface area of the indentation. As mentioned previously, the principle of the Vickers test is similar to the Brinell test, but the Vickers test is performed with different forces and indenters. The square base pyramidal diamond indenter is forced under a predetermined load ranging from 1 to 129kgf into the material to be tested. After the forces have attained static or equilibrium conditions, further penetration cease, the force remains applied for a specific time (10 to 15s for normal test times) and is then removed. The resulting unrecovered indentation diagonals are measured and averaged to give the value in millimeter. These length measurements are used to calculate the Vickers hardness number (HV).

Vickers hardness test method also referred as micro hardness test method is mostly used for small parts thin section or case depth work. The Vickers method is based on optical measurement system. The micro hardness test procedure specifies a range of light loads using a diamond indenter to make an indentation which is measured and converted to a hardness value. Typically loads are very light ranging from 10gms to 1kgf, although macro Vickers can bear loads up to 30kgf or more

Table.3 Vickers hardness

Specimen	Vickers hardness number (HV)
Al 6061	107
Al 6061 + 4% Graphite	104.2

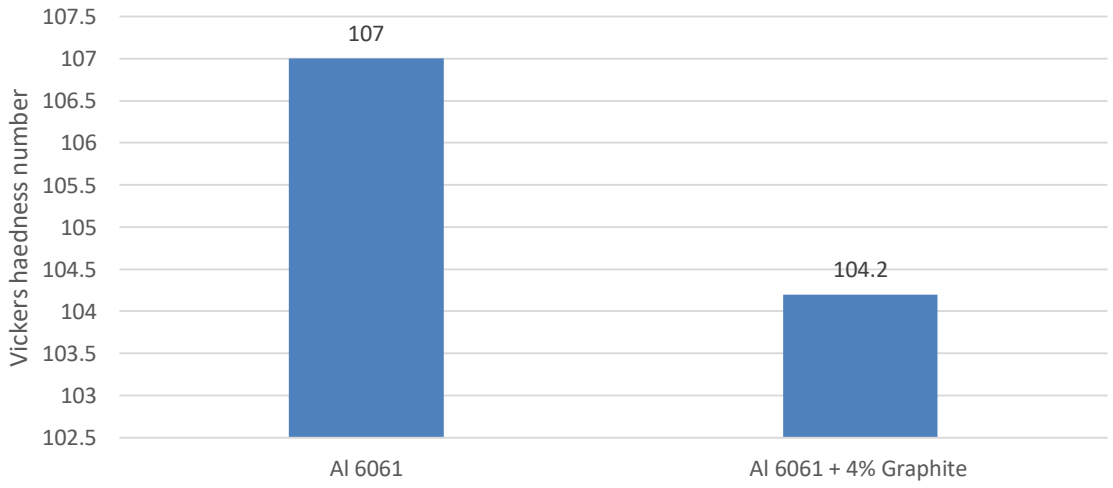


Figure 5. Hardness representation for Al6061 with 4% Graphite.

Wear test

Several standard test methods exist for different types of wear to determine the amount of material removal during a specified time period under well-defined conditions. When friction is the predominant factor causing deterioration of material and wear testing will give you data to compare material and can help you predict the lifetime of a material. It is used to test the wear rate of solid materials. The wear test specimen was prepared by turning process in a conventional lathe as per to ASTM G99 standards. From a material point of view, the test is performed to evaluate the wear property of a material so as to determine whether the material is adequate for a specific wear application. A pin-on-disc computerised wear testing machine is used to evaluate the wear properties of the Composites and are shown in Table.4. Here A&B are Die casting specimens, C&D are centrifugal casting specimens.

Table. 4 Wear rates of the AMMC's

Serial No.	Specimen	Speed(rpm)	Load(N)	Wear in microns
1	A	600	10	65.88
2	A	600	20	89.34
3	A	600	30	111.58
4	B	600	10	87.43
5	B	600	20	91.33
6	B	600	30	103.09
7	C	600	10	86.02
8	C	600	20	99.24
9	C	600	30	112.23
10	D	600	10	42.02
11	D	600	20	53.06
12	D	600	30	79.24

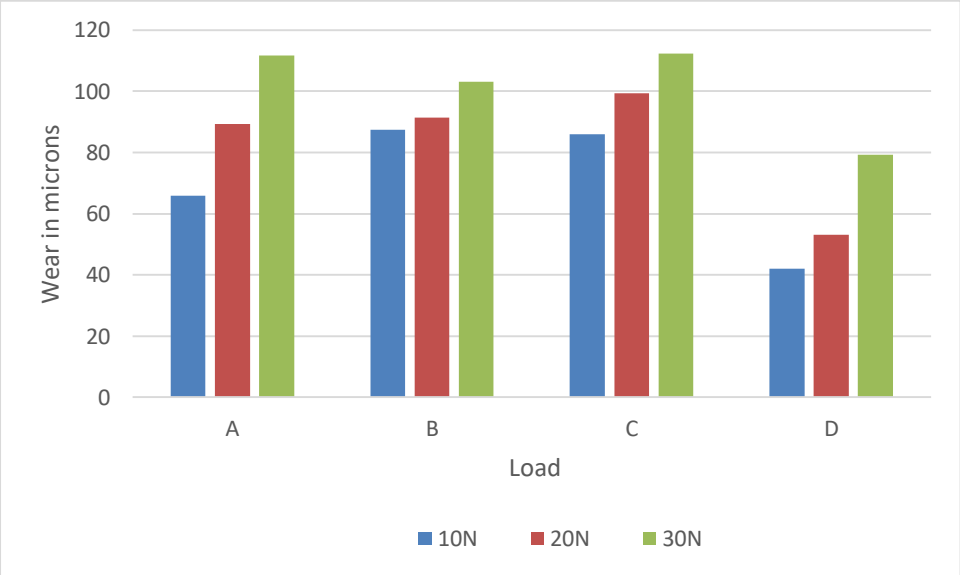


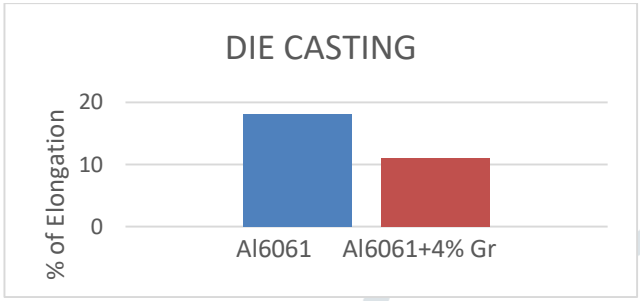
Figure 6. The variation of wear with varying load for Al6061 reinforced with 4wt.% Graphite.

Tensile Test

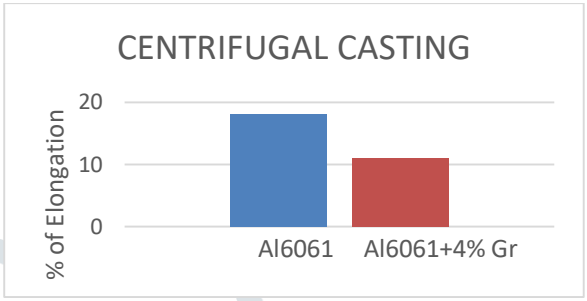
Tensile properties like ultimate tensile, yield strength and % of elongation is evaluated by conducting tensile test. The tensile test specimens were loaded in the computerized universal testing machine. During test the load and displacement are noted to plot the results as shown in fig 2 and 3. The effect of graphite particles addition has enhanced the ultimate tensile strength and yield strength, whereas % of elongation has been decreased when compared to standard Al6061 alloy.

Table.5 Tensile Test Results

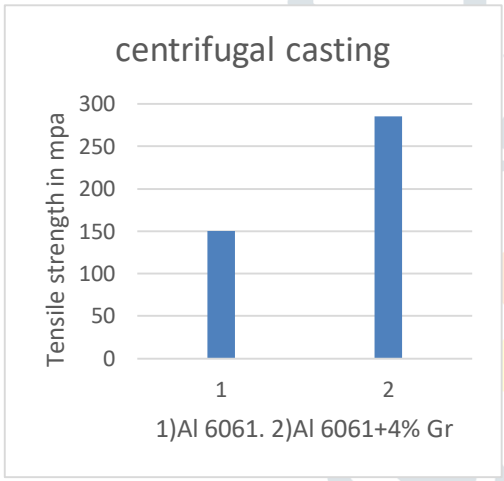
Material	Tensile Strength(Mpa)	Yield Stress(Mpa)	% of Elongation
Al6061	150	83	18
Al6061+4%Graphite (Centrifugal casting)	285.64	123.74	11
Al6061+4%Graphite (Die casting)	187.11	110	11.20



(a)



(b)



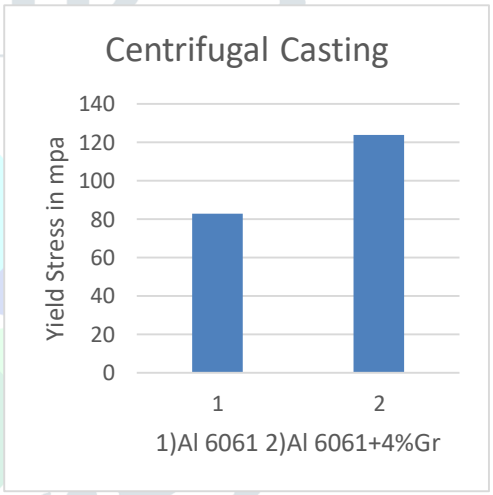


Figure 7(a),(b),(c),(d). Tensile results of die casting and centrifugal casting specimens.

4. Conclusion

The present study shows the improvement of mechanical properties due to microstructural transformation in Al6061 after casting. Present work thus concludes that:

- The variation in density with different method of fabrication is observed. The density of composite specimens is lower as compared to those of the Al6061 alloy.
- The effect of graphite particles addition has enhanced the ultimate tensile strength and yield strength, whereas % of elongation has been decreased.
- Graphite decrease hardness in little amount but improves machining.

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