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Mechanical Properties of Al6061 Based Metal Matrix Composites Reinforced with Ceramic Particulates and Effect of Age Hardening on its Tensile Characteristics

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Abstract: Aluminium materials has a huge requirement in the fields of automotive, aerospace and different engineering applications in order to meet requirements of various fields a material with good mechanical and thermal properties is developed which is metal matrix composites in which aluminium alloys is used as common matrix phases and reinforced used are different material particulates and fibers. Experimental MMC components are being developed for use in aircraft, satellites, jet engines, missiles, and space shuttle. In present study ceramic materials is used as reinforcements for MMCs such as Sic, Al2O3, B4C and TiB2. Al6061 is used as base matrix material. Metal matrix composites are fabricated using different ceramic reinforcements and Al6061 material using liquid metallurgy technique in this study stir casting method is used. Four different MMCs are produced with 10% Sic, 10%, Al2O3, 10% B4C and 10% TiB2. Mechanical properties are studied for the obtained cast composites of Al6061-10% Sic, 10%, Al2O3, 10% B4C and 10% TiB2 by conducting hardness test, tensile test and impact test. The obtained results were compared and graphically charted to characterize the different composite material.

Keywords: Metal Matrix Composites, Al6061, Ceramic materials, stir casting method.

INTRODUCTION

Aluminium material has less density than steel, with good corrosion resistance and mechanical properties, aluminium and its alloys have been widely used in various sectors such as automotive and aerospace. Aluminium metal matrix composites reinforced with ceramic particles has improved strength, high elastic modulus, impact strength and increased wear resistance, MMCs are becoming very popular as they exhibit superior strength-to-weight ratio. Al alloy based metal matrix composites are presently used in several applications such as pistons, pushrods, cylinder liners and brake discs. The manufacturing techniques of the aluminium metal matrix composites are classified into three types namely. Liquid state methods, Semisolid methods and Powder metallurgy methods

In liquid state methods, the metal matrix composites are produced by incorporating the ceramic particulates into a molten metallic matrix and casting the material in moulds. In this present study stir casting technique is used. Stir Casting is a liquid state method of producing composite materials in which preheated reinforcement materials are mixed with a molten metal by means of a stirrer, after proper mixing the liquid composite material is then casted in moulds as per required shapes.

Aluminium 6061 is a metal alloy with low density and high thermal conductivity, but it has poor wear resistance. To overcome this drawback, Al 6061 alloy is reinforced with ceramic materials so that its hardness, young's modulus and wear resistances are increased. Ceramic materials generally used to reinforce Al alloys are Si_C, Ti_C, TiB2, ZrB2, AlN, Si3N4, Al_2O_3, TiB_2 and SiO_2.

LITERATURE REVIEW

The literature survey regarding the above alloy systems and their composites are as follows.

Ravi et al. [1] conventional stir casting is an attractive processing method for produced AMCs as it is relatively inexpensive and conducive for a wide selection of materials and processing conditions. Pradeep R et.al [2] observed the study of mechanical properties of Al- Silicon Carbide Metal Matrix Composite (MMC) of Aluminium alloy of grade 7075 with addition of varying weight percentage composition such as Si_C8%+Al7075, Si_C6%+ Al7075, Si_C4%+Al7075, Si_C2%+ Al7075 by stir casting technique. The experimental result reveals that the combination of a matrix material with reinforcement SiC particles, improves mechanical properties like tensile strength, compressive strength, hardness and yield strength.

Ramesh et al. [3] investigated the mechanical properties of Al 6061-T_iB_2 in-situ composites fabricated by liquid metallurgy route using Al 6061 as the matrix material and Al-10% Ti and Al-3% B as reinforcements. The developed in-situ composites exhibited considerable improvement in the mechanical properties as compared to the base metal S.Dhinakaran [4] investigated the

Characteristic of Boron Carbide Particulate Reinforced Aluminum Metal Matrix Composites produced by stir casting technique in his studies Al 6061 was used as base material and reinforced with the varied percentages of $B4_C$. 3%, 6% and 9% with particle size of 220µm. Cocen and Onel [5] investigated evaluated the porosity content of a Si_C/Al-5%Si-0.2% Mg composite sample from the difference between the calculated density and experimentally observed density. It was reported that the composite in the as-cast condition contained some porosity, which was reduced in the extruded condition.

Demir and Altinkok [6] investigated and evaluated the density and porosity of a dual-ceramic (Al_2O_3 and Si_C)-reinforced Al composite by the Archimedes principle and reported that the relative density increases with both infiltration temperature and pressure. The density of aluminium matrix composites increased with reinforcement fraction, and the density of Al 7075-Al_2O_3 composites was observed to be more as compared to that of Al 6063-SiC composites for the same reinforcement content.G. Straffelini et.al. [7] Reported that the matrix hardness has a strong influence on the dry sliding wear behavior of Al6061-Al_2O_3 composites. A. Martin et. al. [8] in the studies of tribological behavior on Al6061-Al_2O_3 composites concluded that a characteristic physical mechanism involves during the wear process.

From the above discussion it can be concluded that the not enough data is available on the mechanical properties of ceramic particulates reinforced Al6061 composites. Hence, the present studies are aimed to fabrication Al6061ccaramic reinforced composites with all the ceramic materials containing 10%'age of weight of ceramic particles in each casting and to study their density, hardness and mechanical properties the castings are to be obtained with the following compositions Al6061-10% Sic, 10%, Al_2O_3, 10% $B4_C$ and 10% TiB_2.

MATERIAL & METHODS

Base Materials used

Aluminum alloy 6061 is light weight material with density of 2.7 gm/cm3 it is a heat-treatable alloy with strength higher than 6005A. It has very good corrosion resistance and very good weld ability Aluminum 6061 has an excellent heat and electricity conductor and in relation to its weight is almost twice as good a conductor as copper.

Table 1 Chemical Composition of Al6061

Element	Si	Fe	Cu	Mn	Mg	Cr	Zn	Ti	Al
Weight %	0.62	0.23	0.22	0.03	0.84	0.22	0.10	0.1	Bal

Reinforcements used

Silicon carbide (Si_C) is a chemical compound of carbon and silicon it is produced by high temperature electro chemical reaction of sand and carbon. Silicon carbide has low density high strength and high hardness and good elastic modulus.

Aluminium oxide (Al_2O_3) is a refractory ceramic oxide also called as alumina which is synthetically produced white in colour crystalline substance. Alumina is made from bauxite, a naturally occurring ore containing variable amounts of hydrous (water-containing) aluminum oxides. Alumina has high temperature resistant good mechanical properties.

Boron carbide ($B4_C$) s an extremely hard material it is used in refractory applications because to its high melting point and thermal stability, it is also used as abrasive powders and coatings due to its extreme abrasion resistance it has high hardness and low density and it is commonly used in nuclear applications as neutron radiation absorbent.

Titanium diboride (TiB_2) Titanium diboride (TiB_2) is a known ceramic material with high strength and durability it has high melting point, hardness, strength to density ratio, and high wear resistance properties. Titanium diboride has high electrical conductivity they can be easily machined in electrical discharge machining (EDM)

Table 2 Properties of ceramic reinforcements

Properties	Silicon carbide (Si_C)	Aluminium oxide (Al_2O_3)	Boron carbide ($B4_C$)	Titanium diboride (TiB_2)
Density gm/cm^3	3.2	3.89	2.52	4.52
Melting point °C	2750	2072	2763	2970
Elastic Modulus (Gpa)	410	300	450	461.4
Hardness (HB500)	2800	1175	3100	3250

EXPERIMENTAL PROCEDURE

The aluminium 6061 based ceramics reinforced metal matrix composites are prepared using stir casting machine. Four different metal matrix composite materials were produced using different ceramic particulates. The weight percentages of Al6061 and ceramics for producing MMCs are

1. 90% of Al6061 is added with 10% Si_C
2. 90% of Al6061 is added with 10% Al_2O_3
3. 90% of Al6061 is added with 10% $B4_C$
4. 90% of Al6061 is added with 10% TiB_2

The required quantities of Aluminium 6061 alloy is melted in the Inconel crucible of stir casting machine as shown in figure 1 the alloy melted completely at 800 ^{0}C. Slag was removed from the molten metal by adding hexachloro ethane (degassing) tablet, once the alloy is melted the preheated ceramic particulate Si_C is poured in the Inconel crucible in required quantities which contains molten Al60601 alloy, silicon carbide is preheated till 250 0C using muffle furnace as shown in figure 2. the stirring processes is started using mechanical stirrer, stirring is done at a speed of 250 rpm for 10 mins. The molten metal was poured in the preheated cast iron mould (preheat temperature 400 ^{0}C) as shown in figure 3 and MMCs are produced in round bars as shown in figure 4. The same process is repeated for producing other three metal matrix composites.

Fig. 1 shows stir casting machine

Fig. 2 shows Muffle furnace

Fig. 3 Cast iron mould

Fig. 4 Casted metal matrix composite materials

RESULTS AND DISCUSSION

Hardness test

To evaluate the hardness properties of produced metal matrix composites Rockwell hardness testing machine is used, the results of the Rockwell hardness tests are obtained for both the base alloy and the composites.

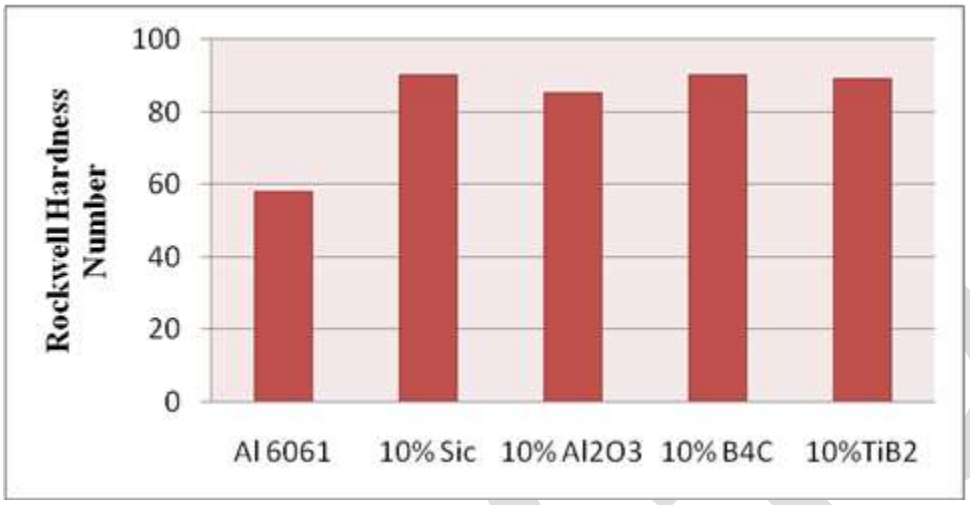

Fig. 5: Hardness tests of composite materials

From figure. 5 it is seen that the hardness of metal matrix composites is more when compared to base Al6061alloy and it is observed that the composites reinforced with silicon carbide (Sic), and boron carbide ($B4_C$) and Titanium diboride (TiB_2) has more hardness compared to aluminium oxide (Al_2O_3).

Tensile test

The tensile test determines the ability of a material to withstand loads before elongation the testing is conducted using Tensometer testing machine the metal matrix composites were machines as the required dimensions for the test. Ultimate tensile strength is calculated as it is the maximum stress that a material can with stand under tensile loading.

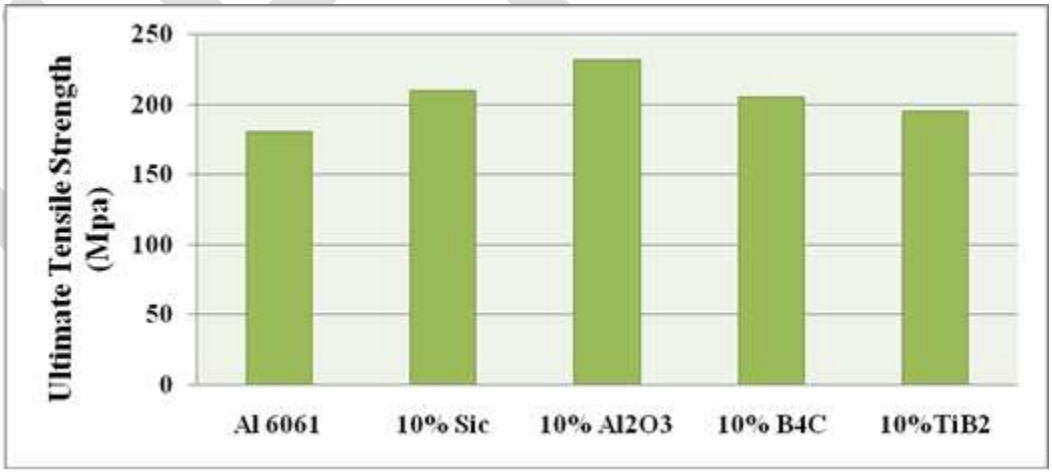

Fig. 6: Ultimate tensile strength of composite materials

From figure 6, it is clear that the tensile strength increased from 180 MPa of Al6061 to 212 Mpa in Al6061+10% Si_C MMC, the ultimate tensile strength of MMCs reinforced with 10%, Al_2O_3, 10% $B4_C$ and 10% TiB_2 is more than the base Al6061 alloy and it is observed that the ultimate tensile strength of composite reinforced with aluminium oxide (Al_2O_3) is more that the other ceramics reinforced MMCs.

Impact test

The impact test is conducted using Charpy impact test, it is a standardized high strain-rate test which determines the amount of energy absorbed by a material during fracture. The test specimens were machines as per the required dimensions.

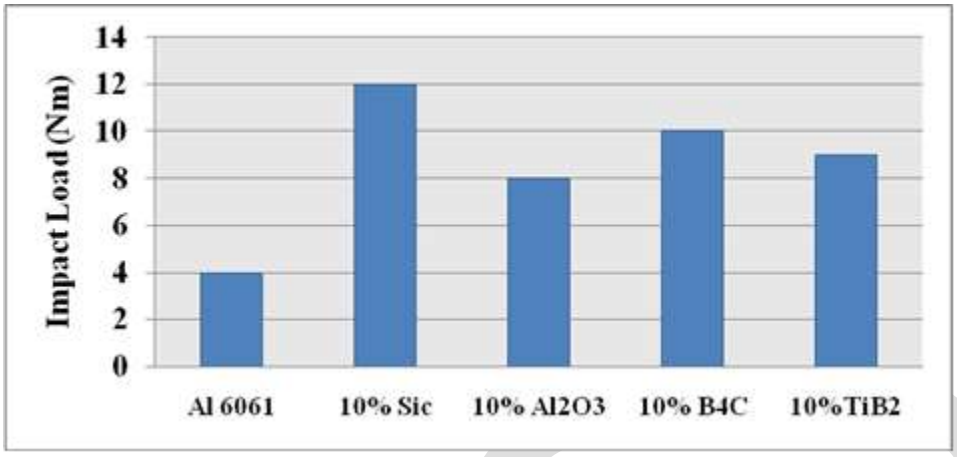

Fig. 7: Impact tests of composite materials

Figure 7 shows that the metal matrix composites reinforced with ceramic particulates has more impact resistance strength than the base Al6061 alloy, composite which is reinforced with ceramic aluminium oxide (Al_2O_3) has more impact strength than the other composites which are reinforced with silicon carbide (Sic), and boron carbide ($B4_C$) and Titanium diboride (TiB_2).

Age Hardening

Age hardening is done by solutionizing the samples at 525 0C for 10 hours and then cooled in water after cooling the specimens were artificially aged at 1650C for 8 hours and Effect of age hardening on the tensile strength of Al 6061 Metal matrix composites reinforced with ceramics is studied.

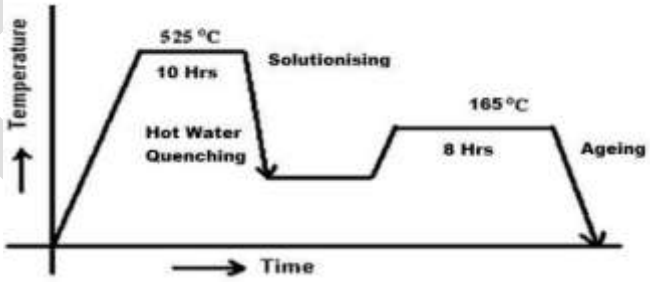

Fig. 8: Diagram representing age hardening process

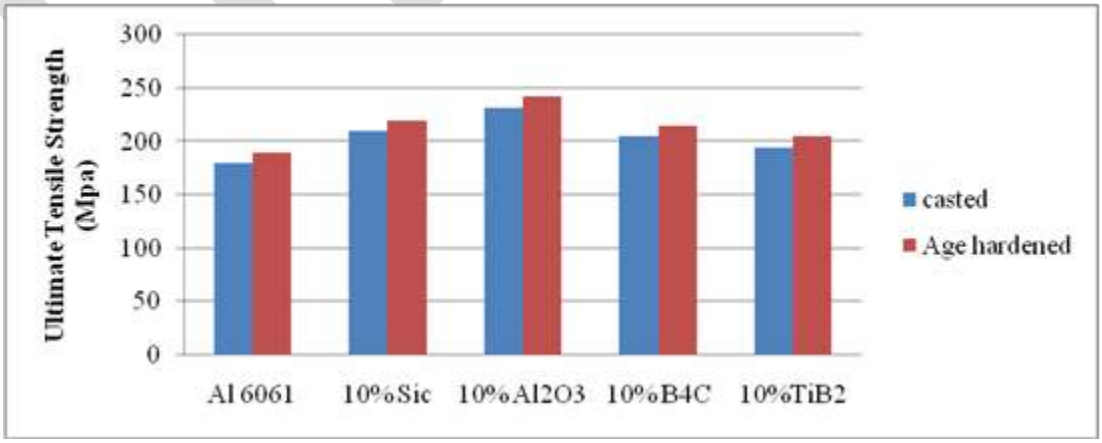

Fig. 9: Comparison of ultimate tensile strength of casted MMCs and MMCs after age hardening

From figure 9 it is observed that the age hardening of metal matrix composites has increased the ultimate tensile strength of MMCs. The strain to fracture was less affected by the volume fraction of ceramic reinforcements and ageing treatment.

CONCLUSION

Al6061 based ceramics reinforced metal matrix composites have been successfully fabricated using stir casting machine with different types of ceramic particulates. The mechanical properties such as hardness, tensile and impact strength of composites are studied. Following conclusions can be drawn from this study

1. Liquid metallurgy techniques were successfully adopted in the preparation of Al6061-10% Sic, Al6061-10%, Al_2O_3, Al6061- 10% $B4_C$ and Al6061-10% TiB_2. Metal matrix composites.
2. Hardness test study revealed that the hardness of ceramic reinforced metal matrix composites is more that the base Al6061 alloy. Al6061-10% Sic, and Al6061- 10% $B4_C$ composite materials exhibits more hardness than other reinforced composites.
3. Tensile test results shows that the Al6061-10%, Al_2O_3 MMC material has good ultimate tensile strength property when compared to other ceramic reinforced MMCs.
4. This present study reveals that the impact strength of ceramic reinforced metal matrix composites is more that the base Al6061 alloy. Highest impact strength is seen in composite reinforced with silicon carbide (Sic).
5. The age hardening process has increased the tensile strength of the metal matrix composites.

Future studies can be carried out on processing and evaluation mechanical properties of different aluminium alloy combinations with reinforcements like AlN, BN, $MgAl_2O_4$ and Graphite. Tribological studies and other mechanical properties evaluation of the above produced MMCs can also be investigated.

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