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Heat Treatment Effect on Mechanical Properties and SEM Analysis of AL6061/WC/B4C/TI/CR Metal Matrix Composites

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Abstract**—This project casts a hybrid Metal matrix composite (MMC) with a base ofA1606l to improve the mechanical properties of the base metal. Since aluminium has a wide applications in automotive, aerospace and aeronautics fields due to its less weight, flexibility and strength. A metal matrix Composite is the composite with a combination of a two or more metals or materials. Our project is based on mixing metals and ceramic materials withA16061. The metals and ceramic materials we choose are titanium (Ti), tungsten carbide (Wc), chromium (Cr) and boron carbide (B_4C). With the selected materials we have casted a MMC using the stir casting method. The testing are done in the machines with ASTM standards and the results of the tests are compared. We have also heat treated the samples of tensile test and the samples attested to investigate the heat treatment effect on the mechanical properties of the hybrid composites, the microstructure of the composites are analysed using the Scanning Electron Microscope (SEM) and the results are attached. The molecule and the atom bonding of the composites are analyses using the X-ray diffraction technique and they are studied.**

I. INTRODUCTION

A metal matrix composite is a composite material that are formed using the combination of two or more metals and a material. It is a composite material with at least two constituent's parts, one being a metal necessarily, and the other may be a different metal or another material such as a ceramic material or an organic compound. When at least three materials are present, it is called a hybrid composite. MMC's are made by dispersing a reinforcement material into the metal matrix. The reinforcement surface can be coated to prevent a chemical reaction with the matrix.

A. Forming Methods

- Solid state method

The powder blending and the consolidation (powder metallurgy): powder metal and discontinues reinforcements are mixed and then bonded together through a process of compaction, degassing, and thermo—mechanical treatment are the main ways of forming the metal matrix composites in a solid level materials.

- Liquid state method

In the liquid state method electro plating and electroforming are the main method. But the most commonly used and with the less cost is called as the stir casting method. In the stir casting method the metal has to be me melted in a furnace and the reinforcement materials are pre heated to al level and then they are mixed together and stirred at a high speed in order to mix up the materials and then the mixed composite materials are poured into a die and the metal is casted according to our wish.

- Semi solid state method

In the semi-solid state method the metal powder mixture is heated up to semisolid state and pressure is applied to form the composites.

- Vapor deposition method

In the vapour deposition method the material is passed through a thick cloud of vaporized material and then they are coated in it.

B. Stir Casting Method

Stir casting process is one of the least cost and common process that are used around to form or fabricate a metal matrix composite. The stir casting process is a liquid state process. This process is cheaper than compared to the other metal forming process. The steps involved are

i. The material that are of the high composition is called the base metal of the composite.

ii. The metal is first placed in a crucible and the metal is heated up to its melting point in order to melt the down the material.

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iii. The reinforcement materials are blended together and they are placed in a pre-heating furnace and the materials are heated up to a critical level.

iv. The molten metal is then transferred into the stir casting furnace and kept at the same temperature.

V. The pre heated reinforcement particles are then added into the molten metal and the stirrer is used to mix the reinforcement material in the furnace.

Vi. The composite molten metal is picked up and they are poured into the die.

vii. After few minutes the metal is removed from the die and is machined to attain the desired dimension using the electric discharge machining process.

Advantages and disadvantages in the forming process types of the fabrication are as follows,

TABLE I
CASTING METHODS

Method	Range of shape and size	Range of volume fraction	Damage to reinforcement
Stir casting	wide range of shapes :larger size: upto to 500kg	Up to 0.3	No damage
Squeeze casting	Limited by pre form shape up to 2cm height	Up to 0.5	Severe damage
Powder metallurgy	Wide range; Restricted size	Up to 0.3	Reinforcement fracture
Spray casting	Limited shape , largeshape	0.3-0.7	Damage is less compared to other methods

By comparing the above methods and its advantages and the disadvantages the method of "STIR CASTING" is selected for the fabrication of the composite materials. In the method the surface fracture is less than compared to other methods and the reinforcement mixing is done nicely than compared to that of the other methods.

II. MATERIAL SELECTION

- ALUMINUM 6061 (A1 6061)

Aluminum is remarkable for the metal's low density and for its ability to resist corrosion due to the phenomenon of passivation. Commercially pure aluminum has a tensile strength of approximately 120 MPa and can be improved 180 MPa by cold Working. The heat treatable grades can develop a tensile strength of around 570 MPa and even higher in some alloys. The wear of MMCS depends on the particular wear conditions, but there are many circumstances where Al based composites have excellent wear resistance. The coefficient of thermal expansion of aluminum alloys is affected by the nature of their constituents: example the presence of silicon and copper reduces .expansion while magnesium increases it. The chemical composition of the A1 6061 is shown in the table below.

TABLE II
AL COMPOSITION

ELEMENTS	Si	Cu	Mg	Fe	Mn	Al
PERCENTAGE	0.63	0.32	1.08	1.72	0.52	Rem

- TITANIUM (Ti)

Titanium metal is a strong material when reinforced with aluminium composite they possess heavy strength for the composite. Since the aluminium is lighter and this titanium composite gives the strength to that of the aluminium composite and increase the hardness of the material. The tensile strength of the titanium metal is 250 MPa as it has a density of 4.56g/cm3 and it is used in the aerospace materials. The mechanical properties of the titanium are shown in the table below.

TABLE III
TITANIUM PROPERTIES

MATERIALS	DENSITY g/CM^3	TENSILE STERNGTH	HARDNESS (Rockwell)	MELTING POINT °C
Titanium	4.56	2.50	34	1608

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- BORONCARBIDE

Boron Carbide particulate reinforced aluminium composites possess a unique combination of high specific strength, high elastic modulus, good wear resistance and good thermal stability than the corresponding non-reinforced matrix alloy system. A limited research work has been reported on AMCs reinforced with B4C due to higher raw material cost and poor wetting. B4C is a robust material having excellent chemical and thermal stability, high hardness and low density (2.52 g/cm3) and it is used for manufacturing bullet proof vests. armor tank, etc. Hence, B4C reinforced aluminium matrix composite has gained more attraction with low cost casting route. The mechanical properties of the boron carbide are shown in the table below,

TABLE IV
BORON CARBIDE PROPERTIES

MATERIALS	DENSITY g/CM³	TENSILE STERNGTH	HARDNESS (Rockwell)	MELTING POINT °C
Boron carbide	2.52	569	30	2763

- TUNGSTEN CARBIDE

As we know the tungsten carbide is the stronger material, with a melting point of' 2830^{0}cand with the highest tensile strength when the material is mixed with the aluminium the properties of the materials are shared with that of the aluminium and this will give the composite the high melting point and the tensile strength. As the density of the material is concerned the density of the material is 15.6g/cm^{3}.With a highest density of the selected materials so the mixing of the material takes some time but the mixture will be strong enough than anything due to the high density. The mechanical properties of the material tungsten carbide are shown in the table below,

TABLE IV
TUNGSTEN CARBIDE PROPERTIES

MATERIALS	DENSITY g/CM³	TENSILE STERNGTH	HARDNESS (Rockwell)	MELTING POINT °C
Tungsten carbide	15.6	344	60	2830

III. FABRICATION METHOD

Aluminium alloys was melted in a graphite crucible inside a high temperature furnace for a temperature for about 600 to 650°C until the aluminium is melted. The reinforcing materials such as titanium and boron carbide are mixed and are preheated at a temperature of 450^{0}c in a pre-heater furnace for 15 to 20 min. then the aluminium is lifted off from the furnace and placed in the stir-casting furnace and the pre heated reinforce materials are then mixed with the aluminum alloy where the temperature of the furnace is maintained at a temperature of 760°C. The mechanical stirrer is inserted into the crucible and the composition is stirred at a rpm of400 for 10mins until the materials are mixed the molten aluminum is poured in the die. The same process is repeated with the composition of tungsten carbide and chromium. The same process is done for both the compositions. The compositions that we have choose to cast are shown below.

i. 1000grA16061pure.
ii. 1000grA16061+10%wt Ti+5%wt B_4C.
iii 1000grA16061+10%wtWC+3%wtCr.

IV. MECHANICAL TESTS

There are several tests taken to determine the mechanical properties of the hybrid composites. The test taken are the

- Tensile test
- Hardness(Rockwell)
- Charpy test(impact test)
- X-ray diffraction
- Scanning electron microscopy.

A. Tensile Test

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Fig. 1 Tensile Strength Specimen

The tensile test is done on the pure al 6061 and the other two hybrid composite with three different specimens. The test specimens were heat treated before testing to determine the heat treatment effect on the mechanical properties of the composite materials. There are about three specimens taken from each composition. The specimens were heat treated with different treatment methods such as “annealing” and “quenching”. The specimens were tested with the universal testing machine, to determine the point of break, elongation etc.

B. Impact Test (Charpy)

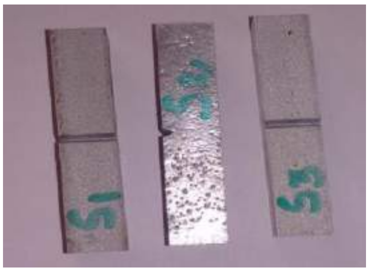


Fig. 2 Impact Strength Specimen

The impact test is taken the Charpy test method as per the ASTM dimensions. The test is taken for all the composition. The impact test results are compared between the pure al 6061 and the hybrid composites.

C. Hardness Test (Rockwell)

Fig. 3 Hardness Strength Specimen

Hardness test are taken for the samples of all compositions and these hardness are compared with the hardness of the al6061. Here the hardness test is taken from the “Rockwell hardness” methods.

D. XRD Analysis

The X-ray diffraction is a technique that is used to identify the materials composition and the materials crystal structure and crystallography. Here in the X-ray diffraction method a beam of X-ray is made to fall into the materials and this X-ray penetrates the material and the report form a series of graphs with different profiles these profiles shows a series of peaks, these peaks indicates the crystallite size and the lateral strain on the material.

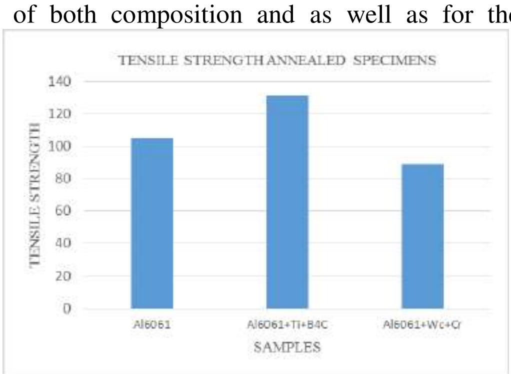
E. SEM Analysis

The scanning electron microscopy is a method that is used to view the microstructure of the material. In this method a strong beam of electron is projected into the material and this electron beam is used examine the materials inner microstructure. The result of the beam is viewed in the computer and the microstructure of the material is identified.

V. RESULT DISCUSSION

A. Tensile Test

The tensile test of the materials are tested using the universal testing machine with a capacity of 10 KN the materials are placed in the jaws of the machine are a load is applied this load makes an elongation in the material this elongation of the material is noted and the yield strength and the point of breaking are noted. This process is done for the material of both composition and as well as for the pure Al6061.



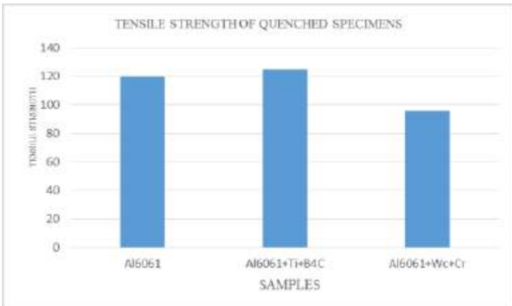


Fig. 4 Tensile strength of annealed and quenched specimens bar chart

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TABLE V
TENSILE STRENGTH OF ANNEALED SPECIMEN

S.No	Composition	Yield stress N/mm2	Tensile strength N/mm2
1	Al6061	120.124	133.073
2	Al6061+Ti+B4C	89.161	112.386
3	Al6061+Wc+Cr	114.222	142.885

TABLE VI
TENSILE STRENGTH OF QUENCHED SPECIMEN

S. N O	Composition	Yield stress N/mm2	Tensile strength N/mm2
1	Al6061	83.4 6	119.476
2	Al6061+Ti+B 4C	76.076	95.839
3	Al6061+Wc+Cr	71.23	124.660

B. *Impact Test (Charpy)*

Impact test is done on the impact testing machine with the charpy method according to the ASTM dimensions and standard's. The specimen is placed in the charpy test machine and the pendulum is fixed in the stand. The pendulum is released and they are made to strike the specimen. The energy absorbed be the material during its breakage is noted in the pointer and the calculation is done. The results obtained by the charpy test are calculated and they are displayed in the table.

TABLE VII
IMPACT TEST RESULTS

S.NO	SAMPLES	TOUGHNESS(Mpa)
1	S1	29
2	S2	38
3	S3	37

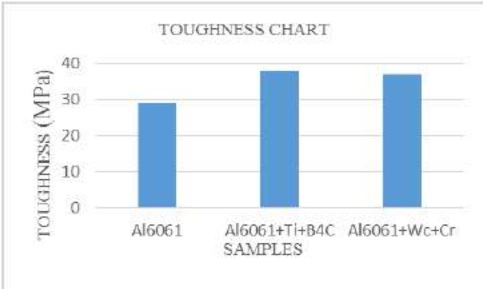

Fig. 5 Toughness in bar chart

C. *Hardness Test (Rockwell)*

The hardness of the material is calculated by the results obtained by the hardness scale of the machine. The specimen is placed in the vice and the tester is made to touch the surface of the material. This will show the hardness of the material in the scale attached to the machine. The process is done for three trails and the average value of the material is calculated and the calculated value is tabulated and the graph is drawn.

TABLE VIII
HARDNESS TEST RESULTS

Sl.no	Composition	Observed values, HRB			Average, HRB
1	Pure Al 6061	30	31	30	31
2	Al6061+Ti+B4C	85	86	80	84
3	Al6061+Wc+Cr	78	75	80	78

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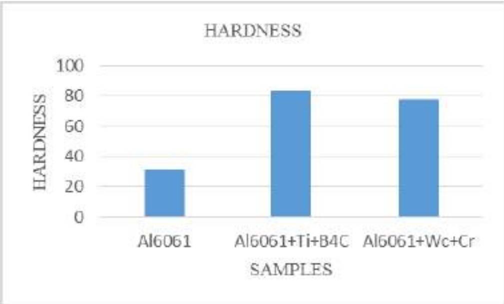

Fig. 6 Hardness in bar chart

D. XRD Analysis

The XRD analysis for the specimens are done in the x ray diffraction machine by passing through a beam of xray in to the specimen and by identifying the amount of the diffraction light emitted the graphs are drawn with the peaks in them this shows the crystallite size and the lattice strain of the structure, the crystallite size and the lattice strain of the specimens are calculated by the Scherer equation shown below, $DP = 0.94\ \lambda / \beta 0.5 \cos\theta$

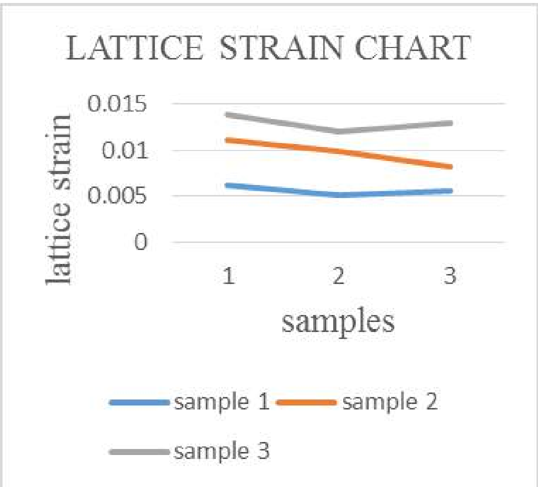

Fig. 7 Lattice strain chart

E. SEM Analysis

The SEM analysis results shows the crystal bonding between the base material and the reinforcemnts shown in the SEM images, the SEM images of these specimens are shown below,

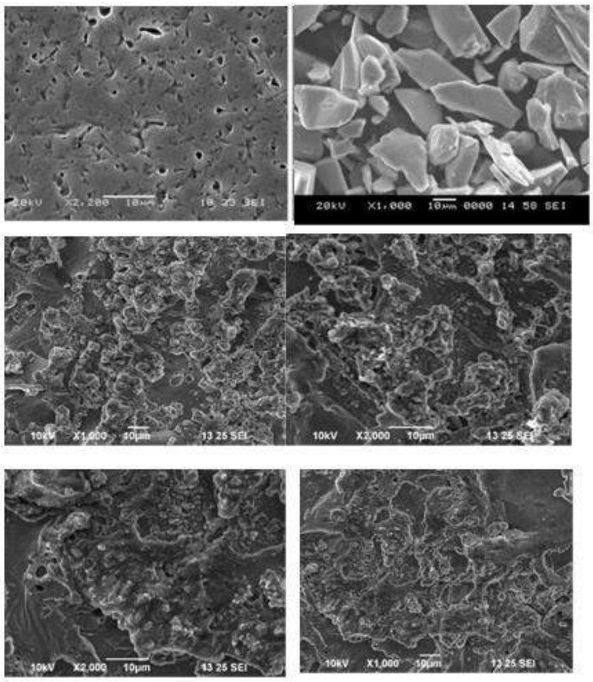

Fig. 8 SEM analysis of samples

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VI. CONCLUSION

The significant conclusion of the studies are followed below,

1. The hybrid composite with the composition of al6061+Ti+B4C and al6061+Wc+Cr are prepared by the stir casting process.
2. The mechanical properties of the cast composite materials are tested.
3. As far as we studied the heat treatment process have changed the physical and the chemical properties of the materials.
4. The tensile strength values of the heat treated specimen vary as the heat treatment process alters the grain structure of the material.
5. The lattice strain of the material is identified using the XRD testing and this shows the sample 2 have the least strain and have the highest of hardness values.
6. The SEM analysis shows the bonding of the reinforcement materials with that of the base material. And by this analysis we can be sure that the bonding between the materials is very good in this method than the other methods.

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