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Investigations on Mechanical properties of AL 8011 reinforced with micro B_4C / Red Mud by Stir Casting Method

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Abstract- Aluminium metal matrix composites are emerging as the most versatile materials for unique structural, automotive, aviation, aerospace, defense, marine applications and other structural applications. Because of their excellent interfusion of properties. The potency of Aluminium Matrix Composite can be elevated, when it is reinforced with ceramic particles, which leads the Metal Matrix to elevate their mechanical properties to the reduced weight ratio. In this research a Hybrid Metal Matrix Composite of aluminium alloy is reinforced in conjunction with Boron Carbide of grain size of <10µm and Red Mud of grain size 150µm by using stir casting technique. In which, Red Mud is one of the major dreck material extracted from the bauxite ore of the Alumina during Bayer's Process. Red Mud is contemplated as a dangerous material regarding with NBR 10004/2004, which has been treated under the room condition as a reinforcement with Aluminum Metal Matrix. The samples were casted by varying the proportions in weight percentage by stir casting route. The samples are exposed to tensile, compression, micro hardness test and the dispersion of B4C and Red Mud in the AMCs was observed in the micrographs. The results prevailed from the mechanical characterization shows the considerable elevation in strength and hardness of the Hybrid Metal Matrix Composite by reducing the weight ratio of the hybrid reinforcements.

Keywords: . Stir casting, hybrid composite, red mud, B_4C

INTRODUCTION

Stir casting is one of the best methods which is widely used worldwide for preparing particle reinforced aluminium matrix composites (PR-ALMC's)in order to produce the complex shapes easily and at a low cost. According to the type morphology and reinforcement, the AMC's are produced by different methods such as stir casting, squeeze casting, spray depositing and powder metallurgy. The above stir casting methods can be categorized under liquid stir casting and solid stir casting. In this investigation we have followed liquid stir casting method to reduce the cost. It involves the incorporation of dispersed phase into a molten metal matrix, followed by its solidification. These aluminium matrix composites are drawing more attention in aviation, aerospace, automobiles and many structural applications due to their good wear resistance with the extraordinary hardness.

Addition of reinforcement to the AMC's can increase the strength of particle reinforced aluminium matrix which imparts good mechanical properties. Addition of reinforcement to the matrix in the stir casting process is a challenging process specially where there is moisture present in the reinforcement materials. Hence the red mud is dried in hot sun for 15 hours [1]. At first B_4C is added to the AMC, where B_4C is a robust material having excellent chemical and thermal stability, High hardness and low density [2]. It is mostly used in nuclear industries due to their good capabilities of absorbing neutrons without creating long living radio nuclides. They are applicable in bullet proof vests, armor tanks, etc. Red mud is the extra ordinary wastage residue produced during the production of Alumina by Bayer's process. It is a insoluble product generated after the digestion from the sodium hydroxide at the higher temperature and the higher pressure which gives the residue of the bauxite which is known as the Red Mud.

EXPERIMENTAL PROCEDURE

The fabrication of aluminium 8011-B_4C-red mud compositions are used in this study and it was carried by stir casting method. In this, firstly the Al 8011 alloy in the form of 25mm diameter rods were placed in a clay graphite crucible. Then it is heated in muffle furnace to the desired temperature of 850 ^oC. Before the Al is melted, the B_4C of < 10µm is heated in another crucible to the temperature of 250 ^oC to remove moisture. Red mud is sieved for 150µm for second reinforcement. Then the particulates were mixed into the molten metal. The molten metal was covered with a degassing agent and with the flux to improve the quality of casting and to increase the casting speed of the aluminium 8011. The mixture was stirred by a mechanical stirrer for 5-10 min at a speed of 60 rpm. The temperature of the furnace remains constant at 850 ^oC during the addition of reinforcement particles.

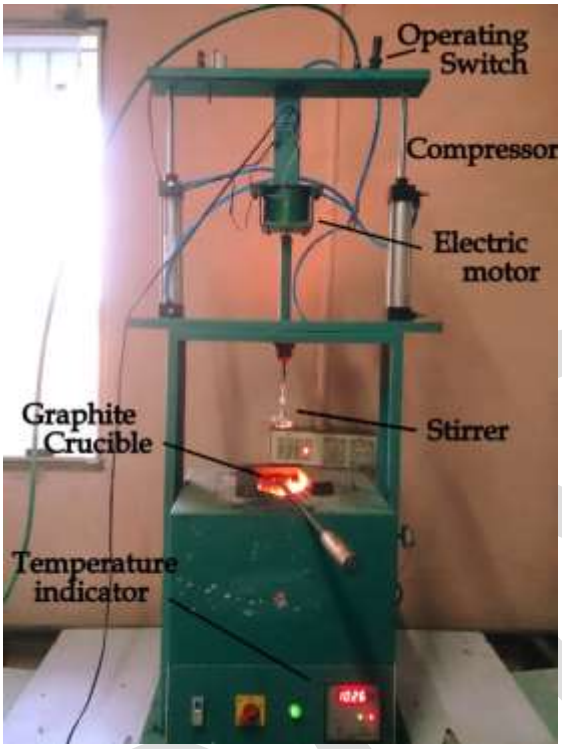


Figure 1. Stir Casting setup for fabrication of (Al8011/ B_4C/ Red Mud)

Then the molten aluminium metal matrix is poured in the preheated die for the preparation of specimen according to the ASTM standard. Same procedure is followed to fabricate AMC's with 1-5% of B_4C and red mud simultaneously. The stir casting set up used for producing composite specimen and the composite castings are shown.

Table 1. Process parameters used for Stir Casting

Parameters	Units	Value
Temperature of Melt	^oC	850
Preheated temperature of B4C Particles	^oC	250
Preheated temperature of die	^oC	400
Spindle Speed	rpm	60
Stirring time	min	10-15
Powder feed rate	g/s	0.8-1.2

EXPERIMENTAL MATERIALS

The following evaluation is associated with the characterization of mechanical properties on Al – Boron Carbide and Red Mud Metal Matrix Composite (MMC) of Aluminium alloy of grade 8011 with the addition of varying weight percentage composition of Boron Carbide and the Red Mud particles by Stir Casting Method. The properties were tested under the laboratory conditions. Variations in the properties are taken into a consideration.

For achievement of the above, a desired experimental setup was prepared to facilitate the preparation samples for the required specification, according to ASTM standards. The experiment was carried out by preparing the samples of varying percentage composition to predict the mechanical properties as well as to measure the Micro Hardness. An analyzed study of a Micro Structure had been conducted by the Optical Microscope to verify the dispersion of hybrid reinforcements.

PREPARATION OF CASTING DIE

Initially the die was made up of a low metal which can be corroded easily within a interval of time. Hence the die was surface finished by using emery papers without damaging the size of ASTM standard. After removing the rusts from the casting die, the die was made to preheated to the temperature of 400 ^{o}C for a constant time. Then clamped with two clamps vertically for the regular preparation of the samples without any voids.

Figure 2. Die used for Stir Casting

TESTS PERFORMED

- Tensile Test
- Compression Test
- Micro Hardness Test (BHN)
- Microstructure

Before initializing the testing, the samples were machined to the particular size according to the ASTM standards. Tested samples are being undergone Microstructure testing's by using De- Wintor Inverted Trinocular Metallurgical Microscope.

TENSILE TEST

The ultimate tensile strength of various compositions was measured using 5 ton capacity servo hydraulic universal testing machine. Testing of the specimens was in the parallel direction of the applied load. In a stress- strain graph the initial portion of the curve is a straight line and it represents the proportionality of varying stress to strain values according to Hooke's law. When the load is increased continuously, in which the stress of the composite is no more proportional to the strain of the following composite. UTS is the maximum stress that a specimen can bear before its fracture due to the load and its original area. All the tests were conducted according to the ASTM E8-82 standards. The tensile specimens of diameter 16 mm and gauge length 100 mm were prepared by Stir Casting method. Six specimens were tested and the average values of the ultimate tensile strength and Elongation were measured.

Figure 3. Specimens which undergone Tensile Test.

HARDNESS TEST

Hardness test were conducted to find the resistance of plastic deformation of the composites under static or dynamic loads. The micro Vickers Hardness test is used in this present study to examine the hardness of the specimen. In this test the ball indenter of 0.5mm diameter is made to be tested by applying a load of 0.5 Kg for 20 seconds for each specimen. The averages of four varying positions of the specimen were considered as the highest hardness number.

Figure 4. Prepared specimens for Vickers Hardness Test

COMPRESSION TEST

Compression test was carried out using a standard 5 ton capacity universal testing machine. Compression tests were conducted on specimens of 15 mm diameter and 60 mm length machined from the casted composites, by applying the loads gradually; the corresponding strains of the following composite were measured until failure of the specimen. The tests were made according to ASTM E9 at room temperature.

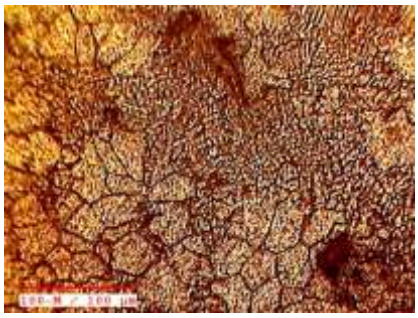
Figure 5. Specimens which were undergone for Compression Test

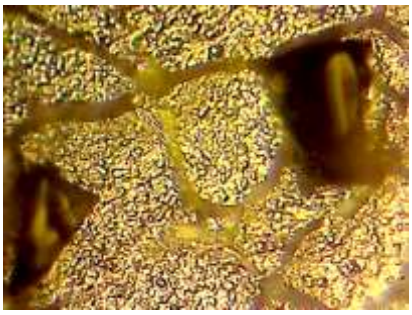
MICROSTRUCTURE

The microstructures of the varying composites are shown below for the presence of hybrid reinforcements in the Aluminium matrix composites. The Microstructure is studied by using De- Wintor Inverted Trinocular Metallurgical Microscope. The samples with the both highest and lowest value for tensile and compression strength were studied for microstructure. The OM revealed the presence of B_4C in the layer of the aluminium matrix and the Red Mud is sedimented in between the matrix which is made the composites to increase its strength.

100X HF **200X HF** **500X HF**

Figure 6. Pure Al without reinforcements

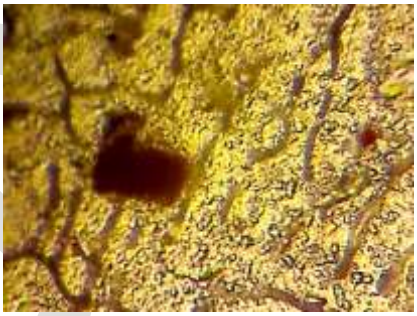




100X **HF** **200X** **HF** **500X** **HF**

Figure 7. 94% Al + 3% B_4C + 3% Red Mud





100X **HF** **200X** **HF** **500X** **HF**

Figure 8. 94% Al + 3% B_4C + 3% Red Mud

RESULT AND DISCUSSION

Table 2. Mechanical properties of Al/ Red mud and B_4C composite

Varying Wt% Composition	Tensile Strength Mpa	Hardness BHN	Yield Strength Mpa	Compression strength Mpa	Elongation %
Pure Al	65.315	37.5	57.441	66.426	18
94% Al + 5% B4C + 1% Red Mud	67.543	39.6	55.226	71.141	9.2
94% Al + 4% B4C + 2% Red Mud	71.044	36.6	46.932	61.826	12
94% Al + 3% B4C + 3% Red Mud	77.024	45.4	59.973	76.877	22
94% Al + 2% B4C + 2% Red Mud	72.038	43.7	52.613	65.164	12
94% Al + 1% B4C + 5% Red Mud	70.872	43.4	51.973	70.271	8

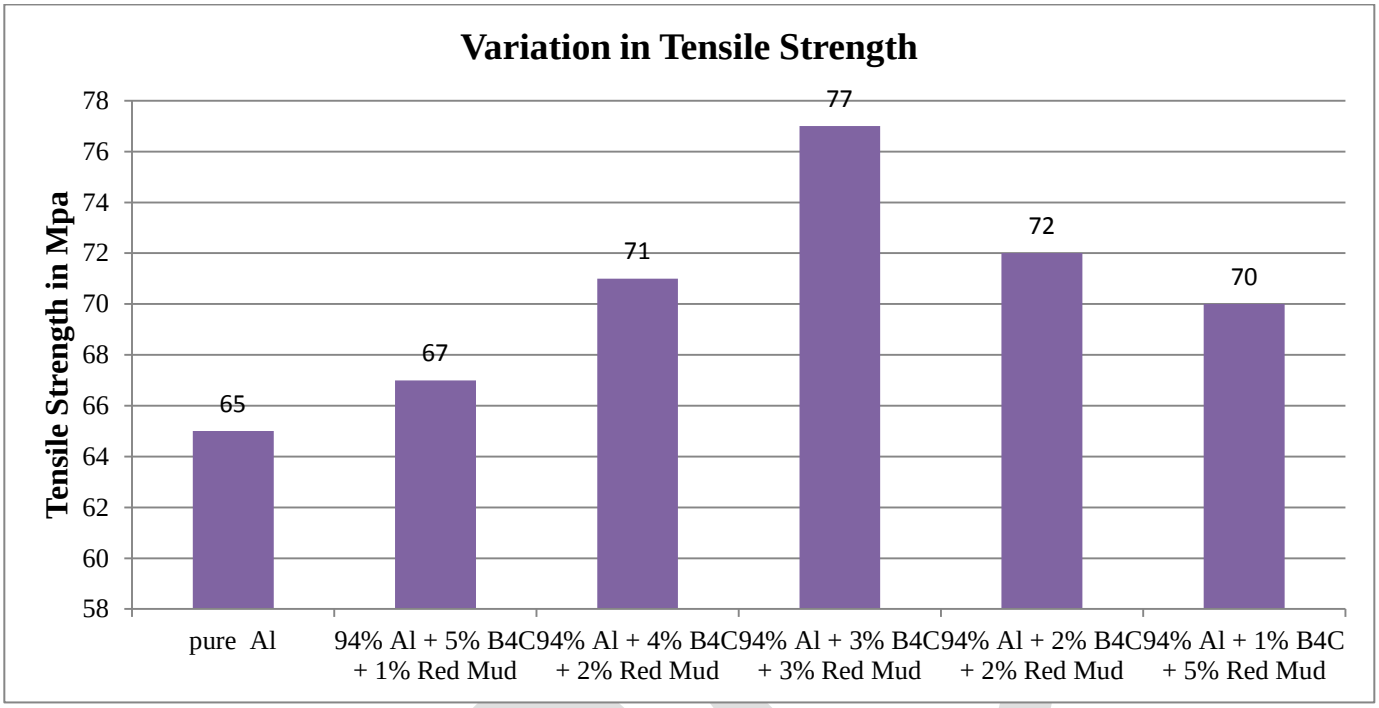


Fig.9 graph shows the variation in tensile strength from 5-1% of B_4C and 1-5% Red mud composite

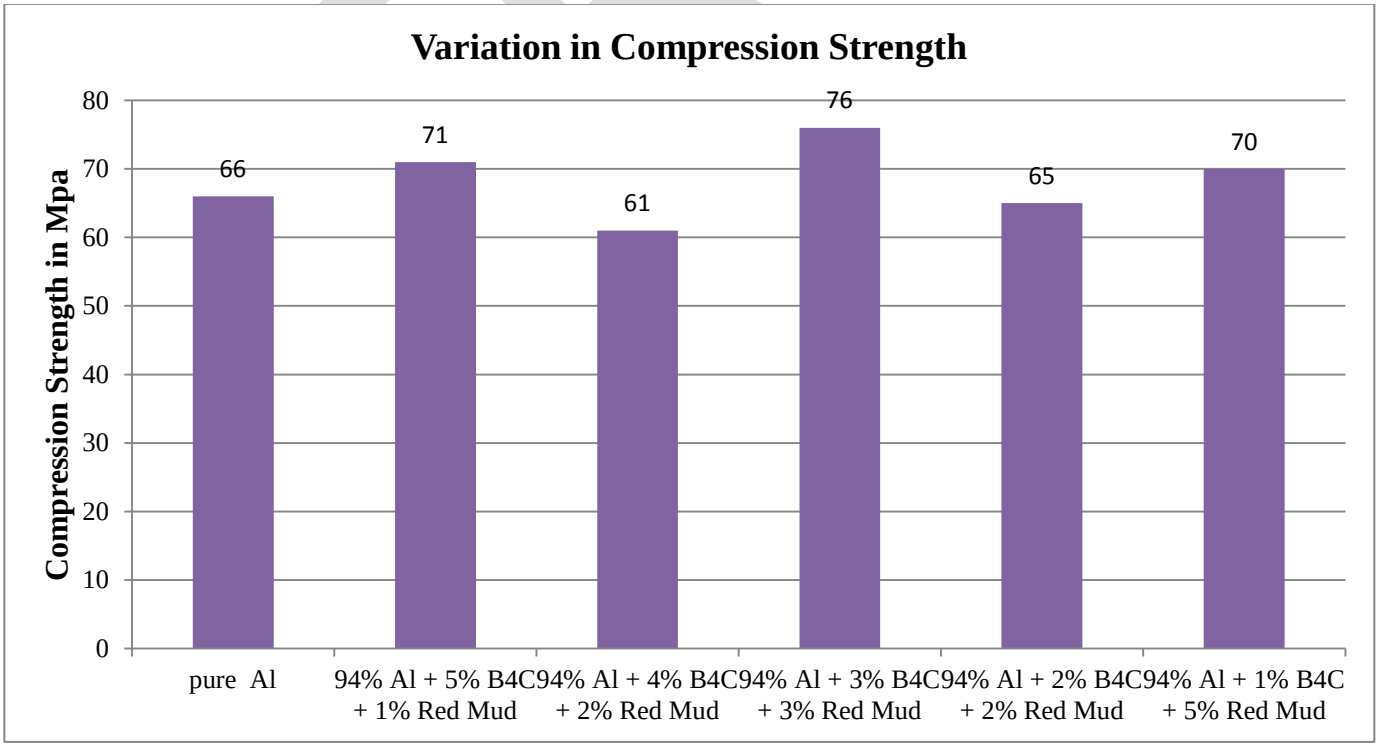


Fig.10 graph shows the variation in Compression strength from 5-1% of B_4C and 1-5% Red mud composite

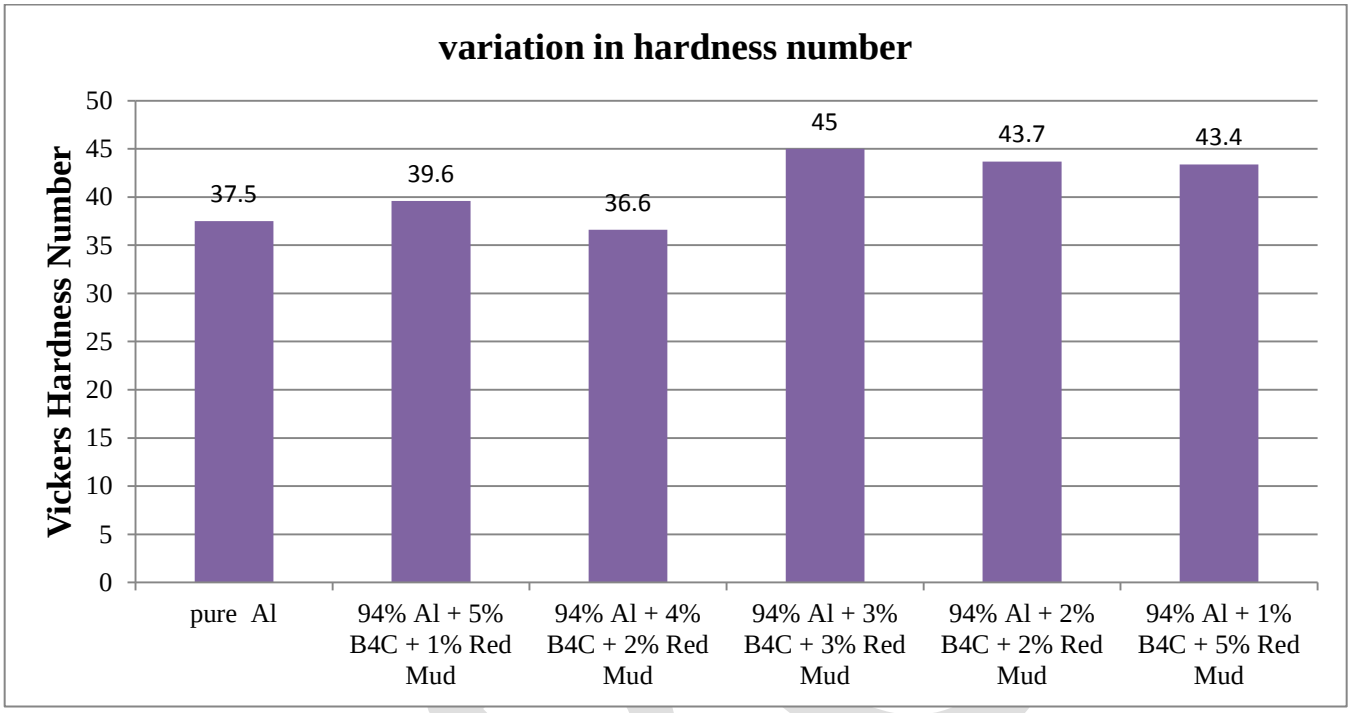


Fig.11 graph shows the variation in Hardness Number from 5-1% of B_4C and 1-5% Red mud composite

It has been observed that at 94% Al + 3%B_4C + 3% Red Mud, there is a considerable increased values in almost all the mechanical properties of the following hybrid composite.

CONCLUSION

Red mud is the waste generated product from alumina plant which can be successfully used as a reinforcing material to produce the particle reinforced aluminium matrix composites (PR-ALMC's) component to be used in the casting environment. It can be successfully used in the place of conventional aluminium intensive materials, and also by saving the usage of about 10 percent of matrix material could be achieved.

There is a good dispersion of red mud in aluminium matrix which improves the hardness of the matrix material of the hybrid composite. The effect is increase in interfacial area between the matrix material and the red mud particles leading to increase in strength appreciably. From this study that the oxide phases like Al2O3, Fe2O3, TiO2 etc. have been dispersed uniformly in the interfacial areas of the aluminium matrix thus strengthening the result.

The general conclusion which is revealed from the present work is that by the combination of a matrix material with reinforcement such as B_4C and Red mud particles, it improves mechanical properties like tensile, compression strength, hardness and yield strength. The microstructure studies also indicate the presence of Aluminium dendrite structure with the fine inter metallic particles of B_4C and Red mud reinforced in between interfacial areas of the matrix.

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