Fabrication of Aluminium 6082–B_4C–Aloe Vera Metal Matrix Composite with Ultrasonic Machine Using Mechanical Stirrer

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Abstract The given research deals with the study of metal matrix composite in which aluminium 6082 series was selected as the matrix and boron carbide (B_4C) along with aloe vera powder were selected as reinforcement with different weight percentages. The use of aloe vera powder helps in making a green metal matrix composite as it is organic material and biodegradable product. For the fabrication of MMC with 4% or 8% of B_4C and 8% or 4% aloe vera powder, a furnace with ultrasonicator and mechanical stirrer was used. The casting was carried at 900 °C to melt the aluminium for about an hour along with the reinforcement, and then the stirrer was rotated to mix the reinforcement properly. The spectroscopy test was carried to get the different contents of the B_4C and aloe vera powder. The reinforcements were distributed homogenously, found by the optical micrographs.

Keywords Aluminium 6082 · Boron carbide · Aloe vera powder · Casting · Optical micrographs

1 Introduction

Aluminium alloy 6082 belongs to family of 6000 series in wrought aluminium–silicon–magnesium. The most popular alloy in the series is 6082, and it is formed by extrusion and rolling process. The properties like low-density and high-hardness Al6082 are greatly preferred, and there are contents of magnesium which helps to decrease the wettability property of other material like aloe vera. These materials are used in bulletproof vests, tank armour, engine sabotage powders and other industries where high hardness is required. It is often called black diamond. Aloe vera powder is made from the aloe vera plants which is organic in nature, and there uses are vastly

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varied. In composites, it helps to decrease the wear resistance of material. It is easily available and cheap in price.

The composites are made by combining the materials which have different properties of chemical as well as physical. The composites made are far better than the base metal for almost all the cases. The composites can be formed by using different types of reinforcement materials depending upon the characteristic required. In recent days, composites are acquired quite a good place in the market due to its extraordinary properties and easily manufacturing process. The composite in which more than two or more reinforcements are used, it is termed as hybrid composite.

Raj et al. [1] have investigated on aluminium grade 6061 being reinforced with boron carbide (B_4C) with composition of 5–20% in steps of 5% volume percentage of B_4C for which stir casting technique was used. The microstructural study showed the uniform distribution of reinforcement which was carried using scanning electron microscope (SEM). Universal test machine (UTM) with 100 kN load cell was employed for tensile testing of MMC. The result from study gives the data that the hardness, yield strength and tensile strength were improved. Thangarasu et al. [2] have carried a study on the aluminium Al6082 grade which was used to make a composite using the titanium carbide (TiC). The reinforcement was used in 0, 6, 12, 18 and 24% with respect to volume fraction. The fabrication process was carried using friction stir processing (FSP) technique. For the microstructural view, optical microscope and SEM were employed. The hardness test along with tensile test was carried along with sliding wear behaviour. The study shows that the stiffness, wear resistance, etc., were enhanced by TiC. Deshpande et al. [3] have conducted the study of aluminium composite (AA7075) powder having circular shape with normal molecule size of 35 m which was chosen as lattice material. The support material utilized was pitch-based processed uncoated carbon filaments (10 μm measurement and 200-μm length). Hot squeezing was implemented for formation of powder. X-ray diffraction (XRD) technique or method was used for identifying the phase of crystals formed. Metal-coated carbon fibres were reinforced as it made the wettability property enhanced. Scanning electron microscope with the help of EDS facility was made used to check out the surface roughness. Hardness test of the composites was performed on Brinell hardness test machine. As the content of carbon fibre volume % was increased, the density of overall composites was increased. It is further reported by Authors that, at low volume, it showed quite good amount of hardness and maximum for approximate volume 20% of carbon fibre. Mohanty et al. [4] have used aluminium 7075 of cylindrical form as the matrix metal. Boron carbide of 75 μm size was used as the reinforcement in the research. They prepared a hybrid metal matrix composites by using B_4C along with coconut shell fly ash. Boron carbide was used in 0, 3, 6, 9, 12 and 15 wt.%. The process of fabrication was carried on stir casting. Stir casting being a simple and precise casting technique was implemented. Result shows that there was subsequent increment in the hardness and tensile strength for 12 wt.% of B_4C. Gireesh et al. [5], in the following research, have used aluminium 2024 as matrix and the boron carbide and graphite as the composites. For fabrication, stir casting process was involved. In this paper, the composition of boron carbide used was 5 and 10% by weight. The result from the following research shows that hardness and strength of aluminium were increased. Vardhan et al. [6], in their research, have employed aluminium A 356 as the matrix metal and the aloe vera powder as reinforcement to form a green metal matrix composite. The aloe vera has higher wettability property and contains all essential contents like magnesium (1.22%), calcium (3.58%), sodium (3.66%), %), potassium (4.06%), iron (0.1%), phosphorous (0.02%), zinc (0.02%) and copper (0.06%). The process of fabrication utilized was stir casting which is a very simple and good method of casting. The result from the paper shows that the hardness was enhanced, along with decrease in wear rate. Sankar et al. [7] investigated the microstructural and mechanical behavioural properties of copper metal matrix composite in B_4C, and crushed seashell particles were used as the reinforcement (fabrication carried using powder metallurgy). In powder form, copper is widely used in structural applications. Copper also possesses excellent electrical and thermal conductivity, and ductility, along with which it provides resistance to corrosion. B_4C comes in top three hardest known materials that also possesses excellent toughness and wear resistance. Seashells are readily available along coastal areas. By use, the following powder hardness was increased up to 5 times the native material. The use of seashell significantly improves the properties of wear resistance too. Mozammil et al. [8] have inspected the mechanical behaviour of aluminium in which copper (Cu) and titanium boride (TiB_2) have 3, 6, 9 and 12% wt.% of reinforcement. The fabrication method used was stir casting, and for testing hardness Vickers hardness test machine was used. Electron probe microscopic analysis (EPMA) was employed for checking microstructure of MMC. Thermal behaviour of MMC was also checked using differential scanning calorimetry (DSC). The result of the study shows that hardness and tensile properties were enhanced by addition of reinforcement in base metal. Sharma et al. [9] have used fly ash which is the waste left after the burning of the wood particles, and it pollutes the environment. Fly ash is one of the greatest environmental problems. In this experiment, the fly ash collected was used to enhance the property of the aluminium to certain amount. This fly ash has been reinforced with the aluminium melt. For fabricating the fly ash with aluminium melt, stir casting process has been used. For fabrication, other techniques were also used that is hot rolling, vacuum hot pressing, ball milling. The composition of fly ash used was 2, 4, 6% of weight in fixed proportion. To measure the wear and frictional force, a pin on disc set-up was used. Surface analysis of the material was performed using scanning electron microscope (SEM). As weight percentage of fly ash was increased, the wear was decreased.

From the literature review, it was observed that very few attempts have been made to fabricate a hybrid composite using B4C and aloe vera as reinforcements. So in this work, hybrid composite of B_4C and aloe vera was fabricated with the help of a stir casting technique.

2 Material

Aluminium grade of 6082 with rectangular shape has dimensions breadth 8.6 cm, width 6.5 cm and length 15 cm from Hitesh Enterprises metal shop. Due to lightweight, durability, good machinability and strength, aluminium was chosen as base material. Composition of Al6082 was determined by spectroscope testing. Table 1 gives detail of the composition of the Al6082. The reinforcements taken were boron carbide having average size of 280 microns and aloe vera powder with uniform grain sizes. Due to lightweight, durability, good machinability and high strength, aluminium was chosen as base material.

2.1 Fabrication Method

Aluminium blocks were cut into small pieces having dimensions breadth 8.6 cm, width 6.5 cm and length 7 cm, and composition for reinforcement was decided on the weight percentage. Two samples for casting were prepared. One sample contained 1.5 kg aluminium, 8% B_4C and 4% aloe vera powder, and other sample contained 1.5 kg aluminium, 4% B_4C and 8% aloe vera powder. Reinforcement was wrapped into aluminium foil, and balls of 30 g were prepared. The varying weight percentages of B_4C and aloe vera powder are, i.e. 4%, 8% and 8%, 4%, respectively, shown in Table 2.

Mechanical stirrer with ultrasonic machine as shown in Fig. 1 was inducted for the fabrication of hybrid aluminium composites. Mechanical stirrer used was made up of composite which has melting point of 3000 °C and having three blades, and length of 65 cm was utilized. Cylindrical-shaped die made up of cast iron of capacity 3 kg was selected. Cylindrical-shaped die was selected for easy machining of casting, and crucible of capacity 3 kg was introduced.

Aluminium blocks which were cut were used for fabrication, and reinforcement balls were also placed into crucible. Mechanical stirrer was mounted on casting set-up, and connection was done with control panel. Cover plate was placed on

Table 1 Chemical composition of Al6082 aluminium alloy

Element	Si	Fe	Mg	Mn	Ti	Cr	Other	Al
%age	1.0333	1.086	0.746	0.6019	0.1339	0.0894	0.1331	96.251

Table 2 Different weight percentages of B_4C and aloe vera in Al6082 alloy

Sample no	B_4C (wt.%)	Aloe vera (wt.%)	Total (wt.%)
1	8	4	12
2	4	8	12

Fig. 1 Ultrasonic machine with mechanical stirrer

crucible. Connection was done, and maximum temperature limit set 900 °C. Connection switched on due to which temperature of filament started increasing gradually and preheating of the metal and reinforcement ball was done to remove the moisture. When temperature was reached at 900 °C, time was noted down and from that time metal was allowed to be kept at temperature 900 °C for melting. After one hour, metal started melting. When metal was melted completely, stirrer was brought down with the help of switch and introduced into liquid metal. Liquid melt was stirred with constant rpm for reinforcement mixing. Melt was stirred 15 min. Melt was stirred at 100 rpm for first 10 min, and at 150 rpm for last 5 min. When all reinforcement was mixed completely, stirrer was stopped and lifted up. After that, lever was pulled and liquid mixture was allowed to be poured into the die. After 10 min, die was separated and casting was taken out. Same procedure was repeated for second sample.

2.2 Machining of Casting

Casting obtained had dimension of 13 cm in length and diameter of 7.8 cm. Turning operation was performed on casting with depth of cut of 1.5 mm, and porous part of casting was removed from casting with parting operation. Facing operation was also performed on casting to make the face surface smooth. After performing above-mentioned operation, final dimension of casting was obtained. Final dimension of casting having length 9 cm and diameter 7.5 cm was cut into circular discs having diameter of 7.5 cm and thickness 5.6 mm. Six such discs were cut from each cylindrical casting, and those circular discs were proceeded for further testing.

2.3 Microstructure

The study of microstructure constituent of the composites is done through optical micrograph equipment. The mixing of reinforcement in the composites can be verified through the optical microscope. For the optical micrograph, various processes are taken under consideration. First step involves cutting of the samples into small pieces so that it can be mounted on the Bakelite with some resin. Second step involves the grinding of the sample being mounted with different grit papers, varying in nature to make the scratches remove and wash them with soapy water. In the third step, polishing of sample has been done with polishing machine to remove the scratches left in second step. Fourth step involves etching of the polished surface. This was done to remove the thin layers which were produced during the grinding and polishing work. Final step involves the taking of image with optical micrograph with different zooming lens [10–16] (Fig. 2).

3 Result and Discussion

Figure 3 shows the micrographs obtained from optical microscope which shows that the mixing of the reinforcement was proper and in uniform manner. Figure 3a, b shows the reinforcement B4C and aloe vera used 8% and 4% by wt. %, respectively, with different zooming lens of 100X and 200X. Similarly, Fig. 3c, d shows the reinforcement B_4C and aloe vera used 4% and 8% by wt.%, respectively.

Fig. 2 Polished surface of samples

The fabrication of green hybrid metal matrix composites based on aluminium 6082 with ultrasonic machine using mechanical stirrer has been done. The test from micrograph shows the fair enough distribution of the reinforcement in the composite prepared.

4 Conclusion

In this study, a hybrid aluminium composite was fabricated using the ultrasonic-assisted stir casting technique. Two aluminium composites with 4 wt% B_4C, 8 wt% aloe vera and 8 wt% B_4C, and 4 wt% aloe vera were prepared.

To inspect the distribution of the reinforcement particles, optical microscopic images at 100X and 200X magnifications were obtained. The optical microscopic images present the equal distribution of the reinforcement in the aluminium matrix.

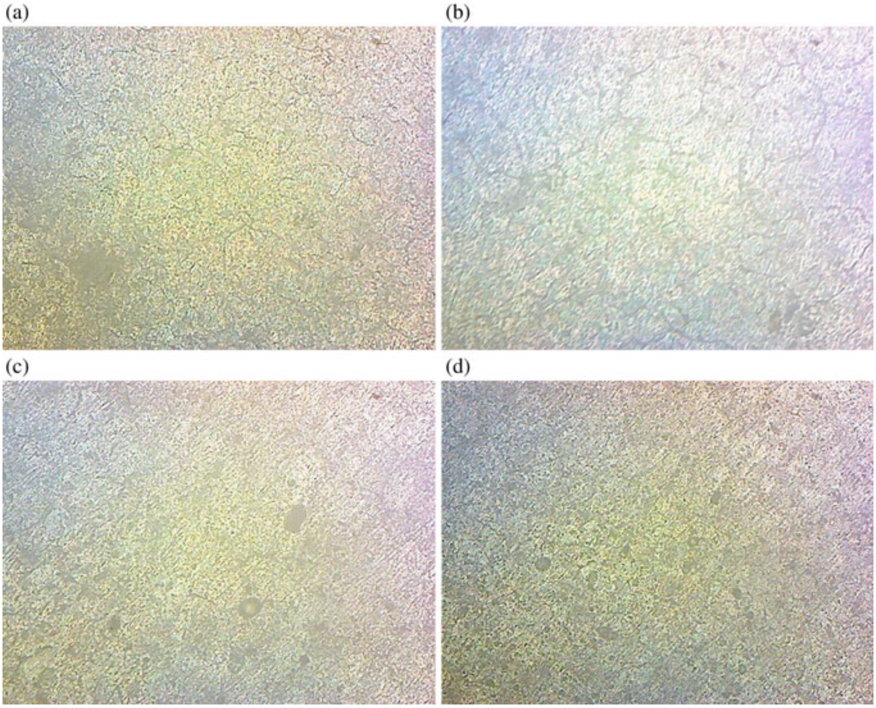

Fig. 3 Optical micrograph of Al6082 reinforced with: **a** 8% B_4C and 4% aloe vera with 100X zooming lens; **b** 200X zooming lens; **c** 4% B_4C and 8% aloe vera with 100X zooming lens; and **d** 200X zooming lens

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