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Experimental Investigation of Mechanical Properties on Synthesized AA 6061 Reinforced with B_4C

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Abstract

Aluminium metrics based aluminium alloys have numerous applications in the field of modern technology. The aluminium alloys having three platforms of industrial applications which are widely used in electronics goods, ground transportation such as automobile, aerospace engineering and marine as well as military purposes. Aluminium alloys having low density, lightweight, excellent malleability and high strength are the key potency of these alloys. At present, the aluminium alloys are the capability to full fill the current demand of the modern industry. To enhance the mechanical properties of this aluminium alloys can be developed by reinforcing with ceramics such as SiC, MgO, Gr and so on are used to achieve the desirable properties of the materials. The present works investigated on Al 6061/B_4C composites have been synthesized with different weight percentages of B4C (0, 1, 5, and 15%) along with varied particulate sizes of 50, 100 and 150 µm were used. The cast composites were produced via stir casting method and the addition of B_4C particles in the base matrix has been analysis by SEM. The mechanical property such as Vickers hardness and UTS has been studied and the values of ultimate tensile strength have been optimized using the Taguchi method.

Keywords: Aluminum alloys • Aluminium matrix composites • Vickers hardness and ultimate tensile strength • Taguchi method

Introduction

Aluminium Matrix Composites (AMCs) are better to replace conventional materials in several applications especially in the automotive and air craft industries. AMCs are aluminium alloys reinforcing with ceramics and these developed low cost composites provide enhanced strength, high thermal stability and wear resistance over the monolithic alloy. Metal matrix composites are manufactured by adding solid particles based ceramics which are used as reinforcement to aluminium matrix material. Metal matrix comprising malleable feature and ceramics having hard-hitting behaviour combine together after that develops a material to achieve desirable class of composites strength [1]. AMCs have applications in resistance to high refractoriness; electronic components, structural corrosion and tribological significance are constantly developing. To highlight the control that reinforcing particle volume or weight percentage has to exert on the mechanical properties of AMCs have been influenced distinctly. AMCs having various advantages resembling high speed automated machinery, seals, bearings, high quality performance bicycle components, valve constituent parts, turbine exertions, brake parts, optical and laser tackle and semiconductor industrialized equipments. The six series, magnesium based matrix alloys such as the fabricated AMCs has been used in various applications due to its exceptional mechanical properties such as malleability, weld ability, ductility and ease of availability. Thus the reasons especially 6xxx series alloys has been broadly explored by many researchers. In this study, highlighting on the synthesize aluminium matrix composites via stir casting method by adding B_4C up to 15% by weight fraction [2].

Experimental Procedure

Selection of aluminium matrix and reinforcement

AA 6061 matrix was chosen as dispersion phase of these AMCs which has a variety of applications in military armour and aerospace structural parts. The chemical composition of AA 6061 shown in Table 1.

Element	Mg	Si	Fe	Cu	Cr	Zn	Ti	Mn	Aluminium
(Wt. %)	0.92	0.68	0.5	0.17	0.07	0.19	0.12	0.1	Balance

Table 1. Chemical composition of AA 6061.

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AA 6061 as base matrix the discontinuous reinforcement of B4C particulates with different particles sizes of 50, 100 and 150 µm were used. The wt. fraction i.e. percentage of reinforcement of boron carbide is varied from 1 to 15% as shown in Table. 2.

Composite specimens Type	Reinforcement
Specimen A	Al 6061-1% B4C
Specimen B	Al 6061-5% B4C
Specimen C	Al 6061-15% B4C

Table 2. The prepared specimens with different compositions.

Synthesis of Al 6061/B4C composites by stir casting process

The liquid state process as stir casting method is inexpensive and straight forward. The prominent uniqueness is the main reason this method. In this system, an electric furnace was used in which molten metal AA 6061 was melted up to 700°C temperature and preheated boron carbide particles were added into the slurry and mixed. Thereafter, the temperature was increased to completely liquid form and mixing was continued with the help of automated stirrer about 5 minutes at a standard stirring speed about 350 rpm [3]. The molten metal was then poured into a mould. The molten materials were cool down and allow to solidifying it and then machined to standard sizes of samples were synthesized for further assessment.

Results and Discussion

Material characterizations

Material characterization has been studied via SEM analysis. The cast specimens were polished with fine abrasive basics to improve the resolution. The assessment results reveal that uniform distribution of particles in the (base matrix) AA 6061 and the aluminium particles shows lighter and clear image of microstructure as compare to respite of particles manners in the composites as shown in Figure 1
(a). Al 6061/B_4C-15% microstructures with 50 µm and Al 6061/B_4C with reinforcement represented a mixture of material particles were dispersed completely and found to be a fine and coarse grains arrangement of particles along with dendrite outlines has been shown in Figure 1 (b). Furthermore, the microstructure of Al 6061/B_4C-15% at 100 µm the bright coarse grains have been detected at this level of magnification of SEM analysis as shown in Figure 1 (c). The material characterization of Al 6061/B_4C-15% at 150 µm in which the atoms arrangement of particles has been highlighted in a regular pattern with the colour effect of high ratio by wt. % reinforcement has been found in this microstructures study as shown in Figure 1 (d).

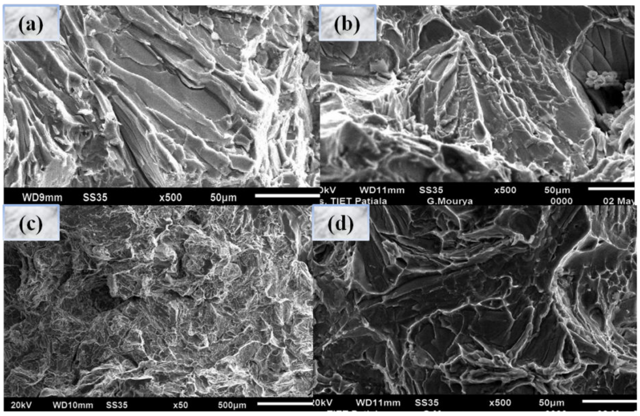

Figure 1. (a-d) Shows SEM micrographs of AA 6061 reinforced with weight percentage of B4C of composites (a) unreinforced AA 6061 (b) Al 6061/15%B_4C at 50 µm (c) Al 6061/15%B_4C at 100 µm and (d) Al 6061/15% B4C at 150 µm.

Mechanical testing

The mechanical tests were carried out on the various specimens according to ASTM E8 and ASTM E384 standard were prepared for ultimate tensile strength and Micro Vickers hardness testing [4].

Micro Vickers hardness Test: Micro hardness test was conducted on the polished surface of the Al 6061/B_4C based composite. As per standard procedure the 50 kg applied load and dwell times of 15 s was used. All the developed samples were prepared and analyzed with different compositions of reinforcement and particle sizes. The higher side values of hardness number can be consider in this study as drawn in Table 3 and the Vickers hardness values of Al 6061/B_4C-(1 to15%) composites while shown in Figure 2.

Materials	Vickers hardness
Al + 1% B_4C	61.2
Al + 5% B_4C	67.3
Al + 15% B_4C	79.5

Table 3. Vickers hardness of B4C reinforced AMCs.

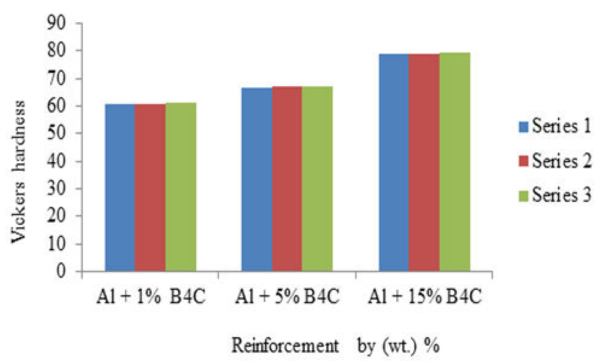

Figure 2. The graphical representation of reinforcement verses Vickers hardness.

From this results it was observed that the higher value percentage that was 15% of reinforcement with 150 µm particle size attain higher strength about 79.50 HV.

Ultimate tensile strength test: The Ultimate Tensile Strength (UTS) test was performed in which the strength has been increased with the increase of reinforcement accordingly. The maximum value of UTS has been achieved about 137.7 MPa. The word orthogonal means balanced. To synthesize the best composition of most desirable design variables of AMCs can be achieved by Taguchi method. L9 orthogonal array the suitable design of experiment technique is used to analyse tensile strength of specimens in which factors (particle size and percentage of reinforcement) are already selected in design. The ANOVA study estimates all the values such as degree of freedom, sum of squares, variance, F-Ratio, pure sum and then percentage of contribution has been measured at last with help of Taugchi software. The expected result at optimum condition is 134.943 at level 3 will be identified in this examination [5].

The optimal value with respect to the different percentage of reinforcement varies from 117.633 to 134.033 equal to 134.30 MPa at level 3 and particle sizes varied from 124.7 to126.666 equal to 127.1 MPa at level 2 as shown in this Figure 3. However, the orthogonal array represented the values having range from 117.0 to 134.70 MPa. The confirmation tests were carried out by selecting the set of variables as shown in Table. 6 and the level of confidence are taken as 95%. The best value is 134.943 MPa. It is expected result at optimum condition. From the analysis, error was 0.618% possibly it's due to multiphase microstructure or impurities of the cast composites.

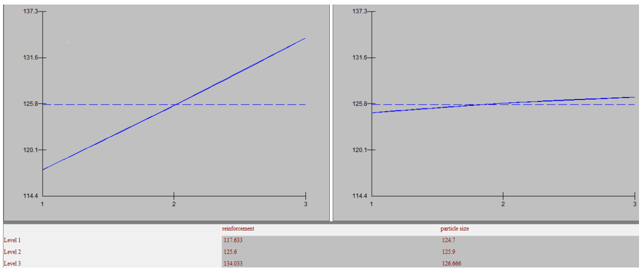

Figure 3. The graph of main effects of interaction between two factors.

Conclusion

From the attempt, the synthesis of Al 6061/B_4C based composites were developed. The Vickers micro hardness and UTS tests were carried out. As the increased sizes of particles have been reinforcement by weight along with percentage the mechanical properties of cast composites were increased steadily. On basis of this, following points are summarized as follows. The weight fraction of boron carbide up to 15% were reinforced into AA 6061 base matrix composites and synthesized efficiently by stir casting method. The SEM examined that fine and coarse grains arrangement of atoms has been found that led to displace in consistent behaviour in this analysis of prepared and inspected samples. Moreover, the homogeneous dispersion of particles with dirt-free microstructures was obtained. The Vickers micro-hardness shows that the gradual increase of the hardness value with respect to the increase of reinforcement of B4C. Al 6061/15%B4C composites with 150 µm particles size has the maximum value has been achieved up to 79.50 HV. The tensile test shows that the Al 6061/15%B4C composites 150 µm particles size had maximum tensile strength of 134.7 MPa. The optimal values means the best value within the parameters has been achieved at optimum condition equal to 134.943 at level 3. The overall contribution of reinforcement about 82.70%, the particle in relation to 9.11% and the rest of the estimated value was error. From the fairly accurate results, the overall development of mechanical properties such as hardness and ultimate tensile strength were increased up to 19.75% and 20.70% respectively were recorded from the aluminium based cast composites as compared to unreinforced and non-heat treated.

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