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EFFECT OF B_4C AND SiC ON MECHANICAL AND TRIBOLOGICAL PROPERTIES OF ALUMINIUM METAL MATRIX COMPOSITES

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ABSTRACT

Aluminum Matrix Composites (AMCs) are emerging as advance engineering materials due to their strength, ductility and toughness. The aluminium matrix can be strengthened by reinforcing with hard ceramic particles like SiC,Al_2O_3, B_4C etc.In this work The aim involved in designing metal matrix composite materials is to combine the desirable attributes of metals and Ceramics.Powder metallurgy is one of the established manufactured processes which allow products of complex geometries to be produced with tailor made properties like high strength and tolerances. P/M has replaced conventional metal forming operations due to added benefits like high material utilization, low energy consumption, less material wastage and reasonable cost, because of which it is extensively used in automobile, aerospace and many other industriesIn this work Al7075-Sic and Al6082-B_4C metal matrix composites were fabricated using powder metallurgy technique Specimens were prepared by varying reinforcement content (0%, 3%, 5%, 7% and 10%) and compaction load. Mechanical properties like compressive strength, hardness, density and tribological (wear) behavior of composite was studied.Results revealed that there were significant changes in mechanical properties and enhancement of wear behavior was noticed due to incorporation of reinforcement particles.

INTRODUCTION

A composite material or composition material is basically a kind of structural material produced by mixing two or more distinct materials, where the properties obtained by mixing of these materials, are unattainable by individual materials alone. The constituents individually do not serve the required function by themselves but they did it when they were put together [1]. Composites are classified into three main categories depending on the chemical nature of matrix phase- Polymer matrix composites, Metal matrix composite and Ceramic matrix composites [2]. Metal matrix have attracted the researchers due to excellent mechanical and physical properties like high specific strength, stiffness, specific modulus, damping capacity, wear resistance and low coefficient of thermal expansion. Metals are usually reinforced to decrease or increase their properties to suit the needs of design. One of the difficult tasks for researchers today is to select material which has low weight and high strength. Aluminium is one such material. It is light weight, strong, ductile, highly corrosion resistant, and excellent conductor of heat and electricity. Also it is recyclable, odourless, long lasting and has good reflective properties. Aluminium alloys are alloys in which alluminium is predominant metal. The primary alloying elements include copper, magnesium, silicon, zinc and manganese. Aluminium alloys are mainly classified into two main categories namely casting alloys and wrought alloys and further both are subdivided into the categories heat treatable and non heat treatable. Selection of right alloy for given application requires considerations like tensile strength, density, ductility, formability, workability corrosion resistance etc. [3]. AMMC's exhibit higher strength, hardness, temperature resistance, abrasion and wear resistance etc because of which AMMC's are extensively used in space, military, automobiles, aerospace, sports, marine, transportation etc. Composites are gifted with good tribological properties due to presence of hard reinforcements. AMMC's became popular due to the improved tribological properties which replaced their monolithic counter parts mainly in automotive and aerospace sector [4]. Composites are manufactured using different techniques such as powder metallurgy, stir casting, mechanical alloying, compocasting, spray decomposition, liquid metal infiltration. Among this powder metallurgy (P/M) is one of the highly developed methods for fabricating

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composites. P/M is a material processing technology which has grown with expansion of several industries. The basic operations involved in powder metallurgy are selection of appropriate powder, mixing, compacting, sintering and post treatment process [5]. In P/M technique powder of reinforcement particles and metal matrix powder are blended for proper distribution of reinforcement particles in metal matrix. Later this blended mixture is compacted and subjected to sintering. One of the biggest benefits of P/M is its ability to shape powders directly into its final component form (net shaping) or a component near to its final form (near net shaping). P/M has succeeded in replacing other traditional methods of metal forming operations because of low energy consumption, high quality, maximum material utilization, low capital cost and its ability to fabricate complex parts economically. As a result P/M has found applications in aerospace, automotive and other manufacturing industries. Distinct properties and microstructure can be produced using P/M technique, which cannot be produced by other metal working techniques. The mechanical properties here are mainly dependent on the final density of sintered P/M alloys. It was identified that main factors responsible for the reduction of mechanical properties of P/M alloys are presence of voids or porosity in compacted performs and sintered products [6-7].

MATERIAL AND METHOD

Al7075 and Al6082 were chosen as base matrix and SiC and B_4C particulates were chosen as reinforcement phase. Table 2.1 gives chemical composition of Al7075 and Al6082 . Powder metallurgy technique was employed for fabrication of specimens. Die was designed and fabricated based on the required dimensions of the specimens to be tested. . Powders are mixed thoroughly and calculations are made to find the amount of powder required for preparing Al7075-Sic and Al 6082-B_4C metal matrix composites . Specimens were prepared by compaction process where large loads are applied to the powder mix. Uni-axial compression testing machine (CTM) is used for preparation of green compacts. Specimens are prepared for different combinations of loads and five different combination of varying reinforcement content (0%, 3%, 5%, 7%, and 10%). Sintering is carried at constant temperature of 560^0 C approximately for three hours and specimens were cooled in the furnace itself for 24 hours. Tests were conducted on prepared specimen

Fabrication of Meatal Matrix Composite

The fabrication processed involved mainly three steps ie, the blending or mixing of the powders using ball milling process and the compaction process followed by the sintering process In ball milling powder mixture is blended where it is subjected to high energy collision between the ball. Clean the inner surface of the ball milling chamber through with brush so that no previous material is present in it. Pour the premixed powder of into the chamber of 20 steel balls and allow to run for 1 hour and remove the blended powder.The compaction of the powder is done by using Uniaxial compression testing machine of maximum capacity 200 tonnes.The die is filled with the blended powder and the weight of the powder is calculated for required size of the green compact , powder is poured into die cavity and the variable load is applied to obtain the green compacts

Figure1. Die filled with powder for compaction

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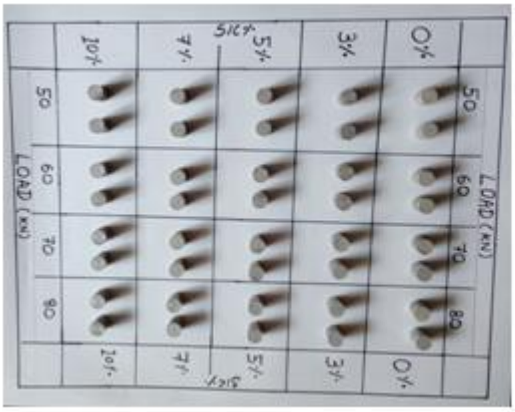
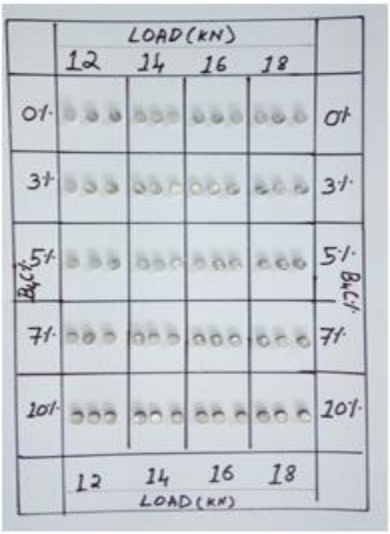
Figure 2. Specimens kept inside sintering furnanace

The green compacts obtained by pressing of die are of lesser strength therefore they are sintered at 520-560 ^{o}C below its melting temperature of Al6082 and Al7075. Temperature of furnace starts increasing from 0 to 520^{0}c at the rate of 3^{0}C/ min. It takes approximately 2 and a half hours to reach 520^{0}C and compacts are held for 2 hours & cooled to room temperature. In this time period and at this temperature bonding between powders takes place by inter diffusion and this provides necessary strength for specimen. The sintered specimen is harder and denser than the previous one. The sintered specimens are subjected to further study.



(a)



(b)

Figure 3..compacted and sintered specimen of (a)Al7075-Sic and (b) Al6082- B_4C composit

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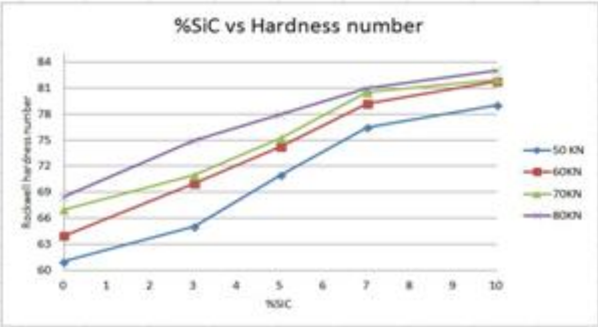
RESULTS AND DISCUSSIONS

Hardness test

Hardness test here was performed on Rockwell hardness tester. Each specimen is subjected to hardness test with 2.5 mm ball indenter, 100kgf load and 20 seconds of dwell time. Experiments are conducted for varying wt. fraction of silicon carbide and boron carbide reinforcement (0%, 3%, 5%, 7% and 10%) and by varying (load applied to prepare green compacts).



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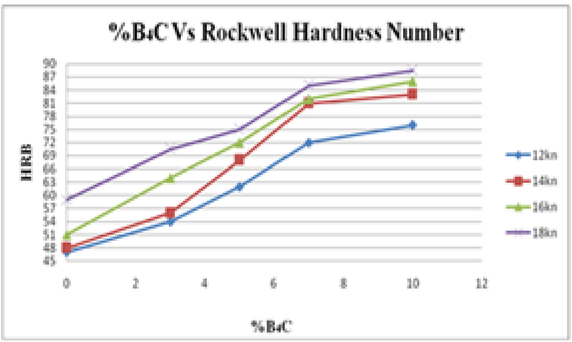

(b)

Figure.4 Hardness of prepared composite with respect to increased wt% of (a) SiC and (b) B4Ccontent and compaction load.

Figure4(a) shows variation in hardness of prepared composite with respect to increased wt% of SiC content and compaction load. Improved hardness of the prepared composite (Al7075/SiCp) was noticed with increase in the wt% of SiC content. The increased hardness can be because of presence of silicon carbide reinforcement particles which are basically very hard. The uniform distribution of SiC in the formed composites is also responsible for increasing hardness of the Al7075/SiC composite [8]. Another reason for increased hardness is increased density of the composites. The density of base material (Al7075) is 2.81 g/cc, whereas the density of SiC is 3.21 g/cc. incorporation of SiCreinforcement in Al7075 matrix increases density of the composite which intern increases hardness of the Al7075/SiC composite. It is seen that the hardness increases. with the increase in the reinforcement percentage of B_4C added to the matrix materials,this may be due to variation in the microstructure of the composites. Al of the matrix, the MMCs hardness was found to be greater, and the addition of B_4C particles increases the hardness of Al6082. The value of the hardness also increases functionally with increase in the application of the load during the fabrication process as shown in the table. In previous works it was found that the effect of the weight % of the B4C particles was influenced by two factors: load carrying capacity of the matrix phase and the inhibit dislocation movement. It is observed that hardness values increases with increasing wt% of boron carbide particles also the hardness value increases by increasing the load applied during fabrication of MMC's.

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Density measurements

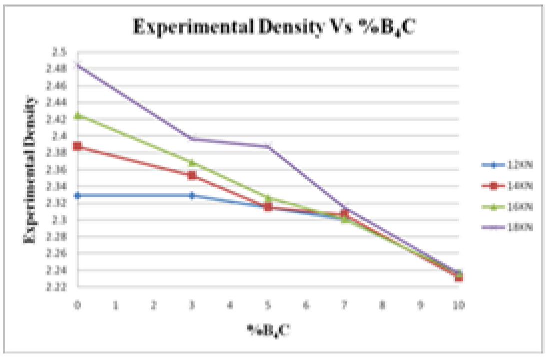

Figure .5.Variation in experimental density with varying %B_4C for different compaction loads

The theoretical density (ρ_t) of sintered specimens was calculated by rule of mixtures. Calculation of experimental density is done by basic formula using mass and volume relations. From the figure 3.2, it can be noticed that the theoretical density of reinforced Al7075 is increasing linearly with increase in the amount of SiC reinforcement. In this work theoretical density was maximum for 10%SiC/Al7075 for all the loads that is specimen prepared by using different loads. Figure shows that experimental density increases with increasing SiC content. The reason behind increased theoretical as well as experimental density is attributed to addition of reinforcement particles SiC which has high density compared to base metal Al70752 .It can be observed that the density is decreasing with the increase in boron carbide reinforcement .This can be summarized as the density of Al is 2.71g/cm^3 and that of B_4C is 2.52 g/cm^3 .Since the density of the boron carbide is lesser than that of Al the combined density also decreases .The increase in weight percentage of B_4C decreases density because of its lower density factor .the maximum theoretical density was obtained by only Al whereas the least dense composite was 10% B_4C about 2.6808 g/cm^3 .The figure 5.1 shows the variation of theoretical density of Al6082-B_4C with respect to the weight % of the compositesThe Experimental density versus %B_4C is as shown in the figure 7.2 the experimental density also shows similar charecteristics of theoretical density where it decreases with respect to the increase in reinforcement content .But the density varies with increase in the load of compaction this is due to the the clustering of the B_4C when the load is increased .The above observation reveals that the desinfication is due to the brittle property of the B_4C and also the powder sliding during the compaction with some amount of fragmentation occurring during the process.

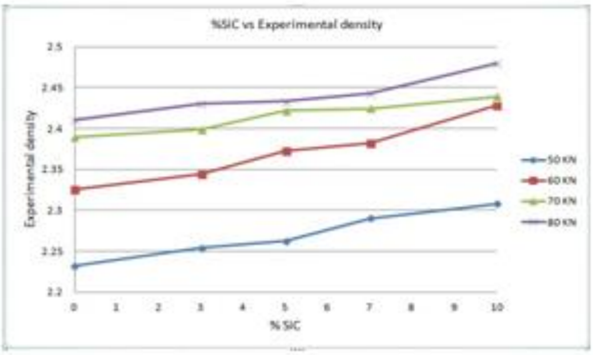

Figure.6 Variation in experimental density with varying %SiC for different compaction loads

Wear test

Wear tests (dry sliding) were conducted on “pin-on-disc wear tester” for 3%, 5% S, and 7%reinforecement particles ($B_4C$and SiC)in aluminium matrix . EN31 is counter disc material**.** Before initiating the test, the surface of disk is to be cleaned thoroughly with acetone. Wear tests were performed by using “Design of Experiments” approach. Taguchi technique is being employed for optimization of best condition

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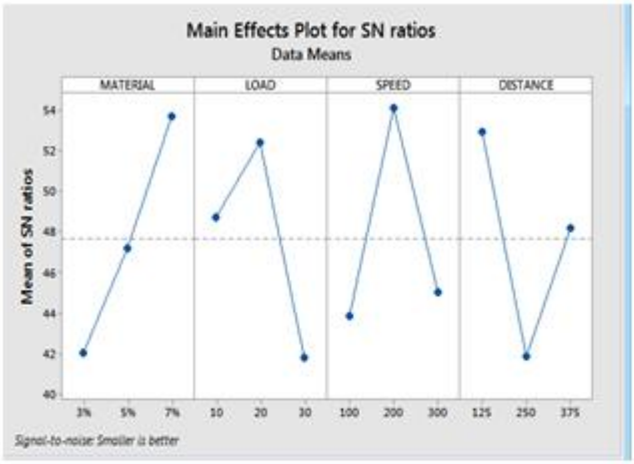
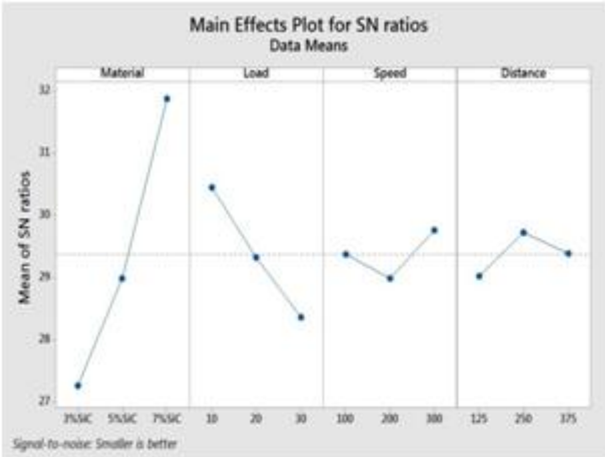


(a)



(b)

Figure.7 Wear response plot for S/N ratio of test specimens of (a).Al7075-SiC (b) Al6082- B_4C

Wear analysis was studied using Minitab software (version 17) to find out the predominant factors which are responsible for wear. Response table for S/N ratios and rankings were found out using the software. "Smaller the better "was chosen as characteristic type. From Taguchi analysis it is inferred that SiCreinforcement content is the most predominating factor responsible for wear rate. Next dominating factor on wear behavior was applied load, which is followed by sliding speed. It is found that in this test sliding speed has least importance on wear rate. From table we observe that Al7075 with 7% SiC, 10 N load, 300speeds, and 250 m distance has least wear.Sinmilarly in case of B_4C the material of the component is primary factor that play important role in wearing of the specimen next important role is played by speed followed by load on pan, the distance traversed by the specimen shows least effect on the wearing of the component. From the plots of S/N ratio we can observe that for material condition 3, speed of rotating disc 200rpm, the traversing distance of 250m and pan loading of 20N shows the least wear.

Microstructural features

Fig shows 0%, 3%,5% and 7% SiC particles in Al7075 matrix alloy. SEM analysis revealed that there was near to uniform distribution of SiC particles in Al7075 matrix alloy. Among SiC particles there was no proper evidence of porosity, when they particleswere close to each other. It is known that with increase in reinforcement content there will be increase in porosity, but in microstructure images no porosity was seen which may be due to high compaction load applied while preparing the specimens.The study shows a cross section of the particles of B_4C and details of the microstructures of different interfaces, the interface between the aluminum powder, There is no indication that the individual craking or samples of each layer and interfaces

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with a loss of coherence. B_4 ceramic phase of Al-under bright and dark gray micro-structures. With a change in the composition, microstructure layer is transferred to the stepwise addition of % B4C. Details MMC microstructures in a variety of interfaces can be seen

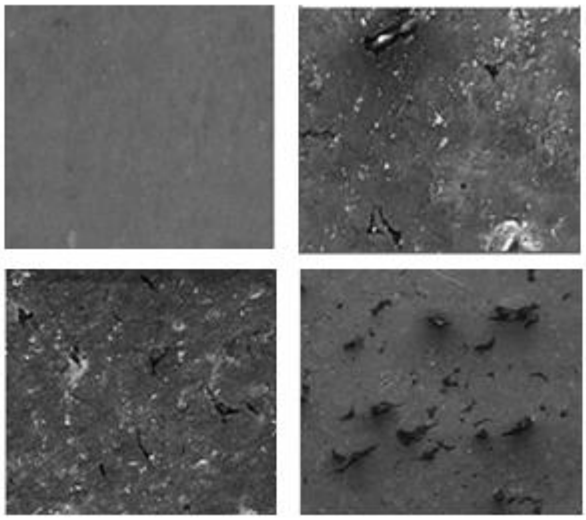

Fig..8 Microstructure observations 0% SiC, 3% SiC,5% SiC and 7% SiC reinforced with Al7075alloy by SEM

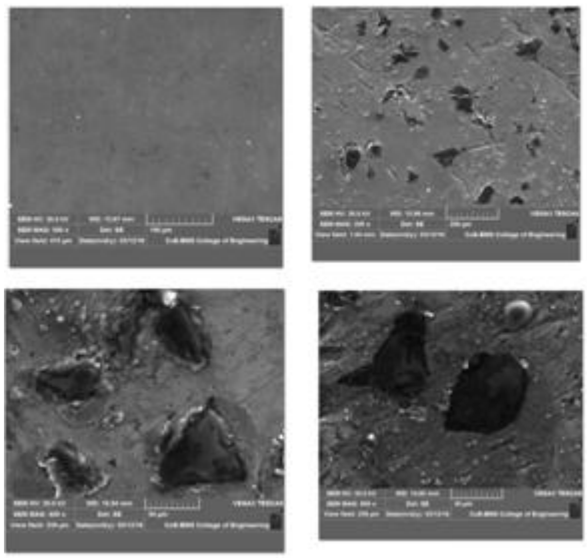

Figure.9 Microstructure observations 0% SiC, 3% SiC,5% SiC and 7% B_4C reinforced with Al6082 alloy by SEM

CONCLUSION

The powder metallurgy route was adopted for the production of Al 7075-SiC and Al6082-B_4C composites .The percentage of boron carbide and silicon carbide was varied from 0 to 10% in the matrix also the variation of compaction load was done to produce the composites .the specimens were sintered at 520^{o}C-560^{o}C and were characterized for different physical and mechanical properties and the following conclusions were made:

1) Al7075-SiC and Al6082- B_4C composites were successfully fabricated by employing powder metallurgy (P/M) technique.
2) Hardness test results revealed that with increase in reinforcement content (from 0% to 10%), the hardness of fabricated composite increased when compared to base 7075 and 6082 alloy matrix for all combination of compaction loads.
3) Density studies revealed there was increase in theoretical density with increase in %SiC content from 0% to 10%. Also for different combination of compaction load (50KN to 80KN) experimental density

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increased with increase in load and % SiC content.The theoretical and experimental densities decreases with increase in the weight percentage of B_4C but the experimental density was increased with increase incompacion load (12 KN to18KN) but the porosity of material increased with decrease in the density

4) Wear results showed that addition of wt% SiC increased wear resistance significantly. From Taguchi analysis it was found that least wear was noticed at 7% SiC, 10N load, 300 rpm speed and 250 m distance. Hence increment in content of reinforcement leads to improved wear resistance.The wear property is directly related with hardness therefore the composites with better hardness value showed the better wear resistance .The Al6082 showed least wear resistance than the reinforcement composite
5) Overall we can conclude that Al7075/SiC and Al6082-B_4C showcase better tribological and mechanical properties than conventional monolithic metals

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