Tribological and mechanical properties of Al6082 reinforced with B_4C particles produced by powder metallurgy technique

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Abstract - *The present work includes the study of the behaviour of Al6082-B_4C composite developed by using powder metallurgy technique. The microstructure characterization was carried by using Scanning electron microscopy (SEM).The study revealed that the B_4C particles were uniformly distributed in the matrix and this enhanced the property of the metal matrix composites .Boron carbide reinforcement was varies from 0 to 10% along with the variation in the application of load during the compaction where it was found that increase in the weight percent of B_4C the hardness and wear property was improved .Similarly the density of the decreased with increase in amount of B_4C whereas the porosity was increased.the variation of the load also effected in the property of the AMMC's as the load increased from 12 to 18 KN the density increased by decreasing the porosity whereas the hardness and wear resistance property increased with increase in load*

Key Words: **AMMCs,Hardness ,B_4C,wear,Al 6082**

1.INTRODUCTION

Composite materials are the one of the rapidly developing in field of technology due to the advancement of the activities in the field of aerospace ,aircrafts and automobile industries .the lower specific gravity of these materials makes the property of the materials superior in their mechanical and physical properties such as density, strength and modulus than the other material such as metals .the intensive study into the fundamental properties of the composite materials in order to understand their nature and structural and physical properties ,So it has given new ways to develop composite materials with better mechanical and physical properties .metal matrix composites are the materials made up of combining two or more materials including metals ,intermettalic components or dispersed components of metal ,matrix .to achieve the optimum properties of the materials the constituting phases are altered .the relative amount ,properties geometry of the dispersed phase including the size and shape along with orientation in the matrix of constituent phase is really important.

In the field of engineering applications the materials must have better properties that are stronger, lighter and cost effective .The good weight to strength ratio in the field of automotive where improved engine performance and fuel economy is required and it becomes critical in some cases .Metal matrix composites [MMC] offers such tailored property which is required in the wide range of engineering applications[1].to obtain the optimum contribution in the the properties of the MMC's Controlling the morphology by controlling the variation of size ,shape and geometry of the dispersed phase in the matrix .Combination of the metals and ceramics develop the desirable attribute in developing the metal matrix materials. The addition of the materials with high modulus and ductile property particles leads to the material with the intermediate property between matrix alloy and ceramic reinforcement .When the reinforcement phase in the composites is included the transfer of load to them takes place .This transfer relays on the bonding between the matrix and the reinforcement phase and the fabrication method adopted [2].In the present work powder metallurgy technique is adopted to obtain Al 6082-B_4C metal matrix composite

2. FABRICATION OF MEATAL MATRIX COMPOSITE

2.1 Die design & fabrication

In order to fabricate the specimen by powder metallurgy technique its required to fabricate die. Based on calculations of pressure to be applied and specimen dimension die was designed, therefore designed die and punch assembly should have capacity has mentioned. As per the analysis made the results shows that Die design is good and it is safe for conducting.EN 24 was used has die material since it has high hardness and was fabricated as per the design shown in the figure and it was hardened such that failure of the die doesnot takes place .the die has the following parts. EN24 steel is a alloy steel which has high tensile strenght . It is used in components subject with high stress and having a large cross section.

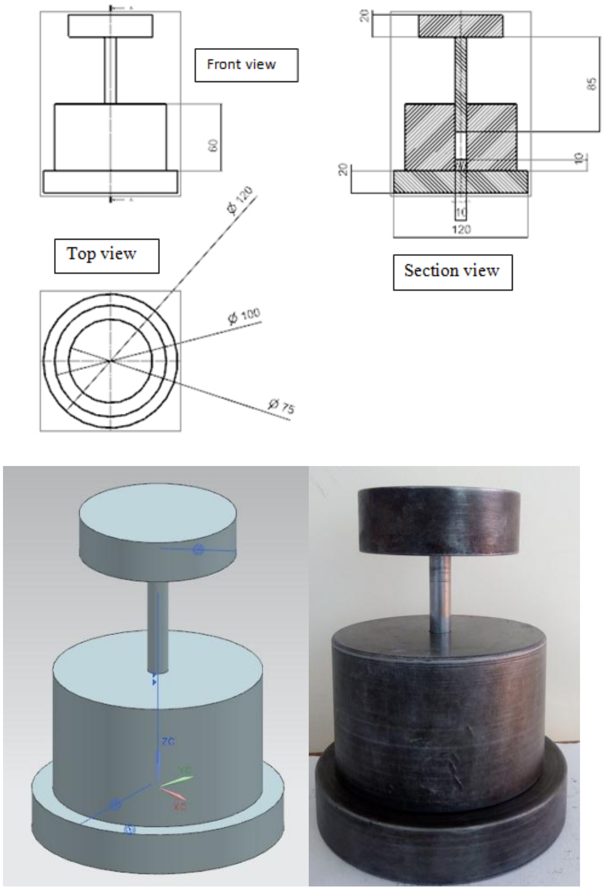

Figure 1 (a) Different views of the die (b) Assembly view

The die was fabricated as per the dimension required it was designed such that the cavity was about the diameter 10 mm for which the size of the specimen was prepared and the punch was about 120mm length which helped for the easily removal of the compacted composites after compaction the total die design is as shown in the above figure .It is made up of total six parts as mentioned above .The die is mounted on the bottom plate of dia 120mm ,die is about 100 mm in dia and length of 80mm with cavity of dia10 mm a small but piece is used at the bottom of the plate as a support inside the die cavity , the top plate was fixed with the punch of length 120mm and dia 10 mm .the whole assembly of die was used to compacting the powders

2.2 Blending of the powder

The Al6082 Powder was obtained from SERENA INC, Banglore .The mesh size of 300-325 ie,about 44-50 microns of AL6082 was used for mixing with B_4C which was purchased from SPEEDFAM(INDIA) PVT.LTD ,Mumbai. The total 5 were blended ie,0%,3%,5%,7%and 10% of B_4C in wt% of Al6082.The require weight of Al6082 and B4C were measured using the high precision weighing machine and are blended using ball milling .The Weighed AL6082 and B4C powders are pre mixed using lathe machine as shown in the figure .The Powder are put into the steel box with 25 hot rolled steel balls of about 10 mm diameter and is fixed to the lathe machine and is rotated at 90 for 2 hours for every 10 minutes the direction of the rotation is changed so that thorough mixing of powder ocurrs.This remixed powder is blended using Ball milling

2.3 Preparation of green compacts

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 ,ie, 2.12g of powder is poured into die cavity and the load varying from 12 KN to 18 KN is applied by using punch as shown in the figure to obtain the green compact. The cylindrical specimen of diameter 10mm and length 10mm was pressed by using 2.12 g of powder Four different ie,.12KN 14KN 16KN and 18KN by using five different percentage of reinforcement was used for compaction ie, 0%,3%,5%,7% and 10% B_4C.then the specimen were sintered to improve their strength and are used for further studies

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Figure 2.Uniaxial compression testing machine with die under compaction

2.4 Sintering

The green compacts obtained by pressing of die are of lesser strength therefore they are sintered at 520^{0}C below its melting temperature of Al6082. 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.

Figure 2: Specimens inside the furnace

3. RESULTS AND DISCUSSIONS.

3.1 Density measurement

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 fraction of B_4C decreases the 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 7.1 shows the variation of theoretical density of composites with respect to the weight % of the composites

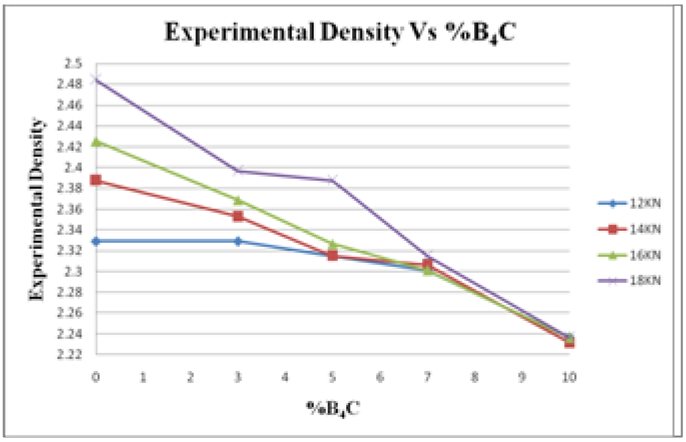

Figure 3: Experimental density values with respect to Wt% of B_4C

3.2 Porosity

The porosity increase with the percentage of B_4C this is cause due to the clustering the boron carbide powder increases with increase in weight percent .Increase in the porosity can be related to the clustering of B_4C powder that increase with increase in percentage of B_4C and. As the load increased the density of the composites increased while the porosity value decreased where as the density decreases with increase in the weight percentage of B_4C.

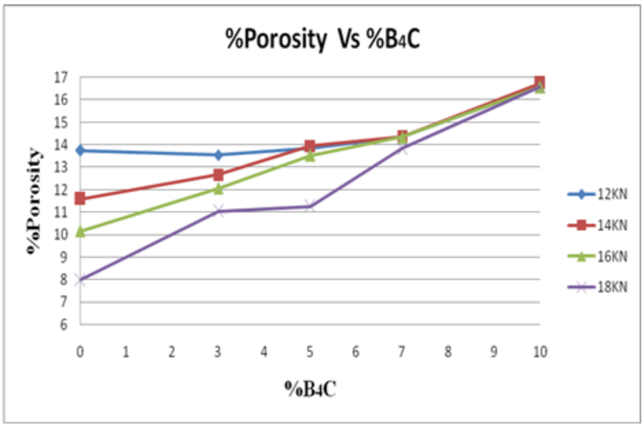

Figure 4: Percentage Porosity with respect to Wt% of B_4C

3.3 Hardness Test

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 B_4C 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

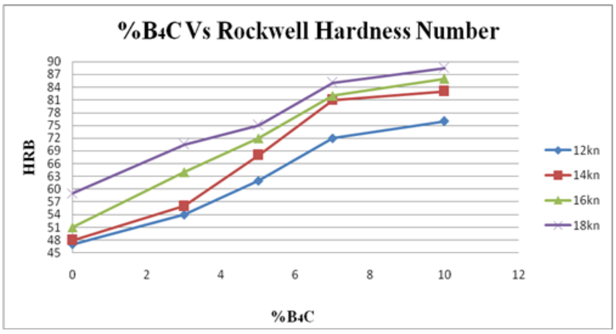

Figure 5: Rockwell hardness number for different Wt% of B_4C and loads

3.4 Wear test

The wear test result was carried out according to astm G99 standards and the results were tabulated as shown below. The graph shows that the decreasing in wear rate occurs with increase in weight fraction of B_4C also the weight loss of composites is decreases as applied load is increased .The I wear resistance property directly related to the hardness of material hardness is more wear resistance. Hence as the % of B4C increases the hardness value increases thus decreasing the weight loss the maximum weight loss was observe in the 0% B4C composite processed at 12KN load ie, 0.0936grams whereas the minimum weight loss occurred at 10% B4C processed at 18KN load ie, 0.0001 grams for wear test carried at same conditions

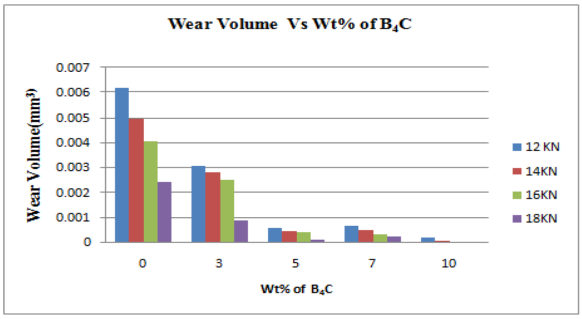

Figure 6: Weight loss Vs different Wt% of B_4C and loads

3.5 Taguchi technique for wear analysis

The wear behaviors of components are determined by conducting different set of experiments. The parameters chosen are speed of the rotating disc, Pan loading, material combination; wear distance traversed by the specimen. The experiments were performed based on the levels and factors chosen for orthogonal array. In experiments conducted an L9 orthogonal array was chosen. The condition of wear factors are material with three different levels and load and three different speed levels and different abrading distance. The results for the experiments conducted are as shown in the tables below.

Level	Material	Load	Speed	Distance
1	42.04	48.76	43.85	48.51
2	49.46	54.67	47.47	41.89
3	47.08	35.16	47.27	48.19
Delta	7.42	19.51	3.63	6.62
Rank	2	1	4	3

Signal to noise: Smaller is better

Material 1- Al6082-3%B_4C, 2 Al6082-5%B_4C, 3- Al6082-7%B_4C

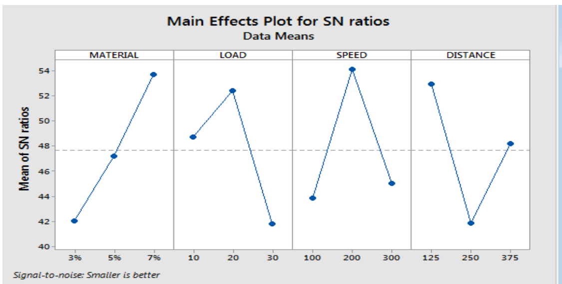

Figure 7: Wear response plot for Signal to Noise ratio of test specimens

Wear parameters were analyzed using the software Minitab version 17 to find out predominant parameters that control the wear. The parameters selected were speed of the rotating disc, Pan loading, material combination; wear distance traversed by the specimen based on the plots of signal to noise ratio and the ranked components on those values for each parameter. From the analysis of the wear parameters based on the results from Taguchi technique it concludes that 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.

3.6 Microstructure studies

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 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

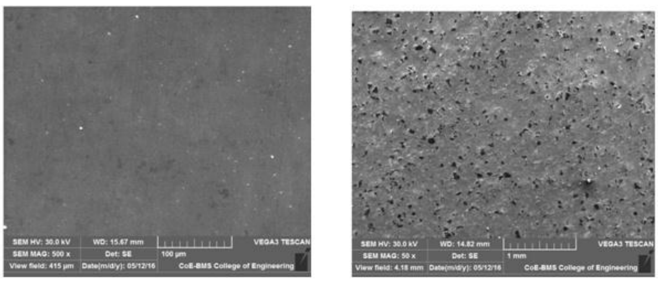

Figure 8:(a) SEM micrographs of pure Al6082 (b) the B_4C particles light gray in Al phase

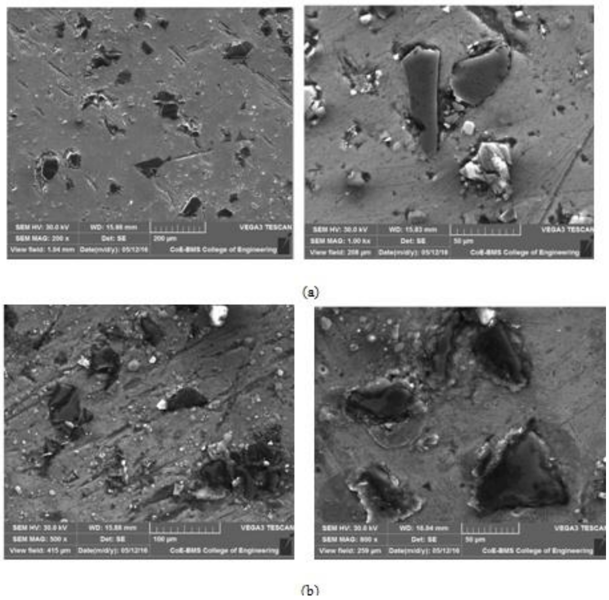

Figure 9 :(a) SEM micrographs of sample with 3% B_4C (b) SEM micrographs of sample with 5% B_4C composites

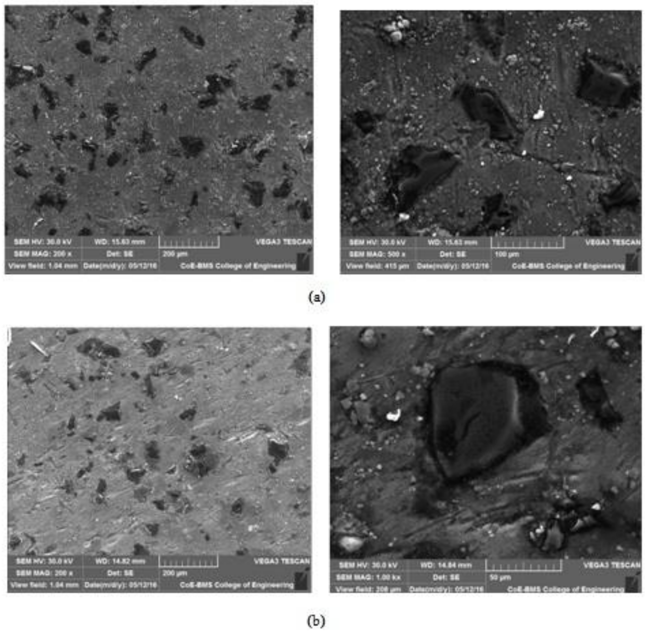

Figure 10: (a) SEM micrographs of sample with 7% B_4C (b) SEM micrographs of sample with 10% B4C composites

4. CONCLUSION

The powder metallurgy route was adopted for the production of Al6082-B_4C composites .The percentage of boron carbide was varies 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°C and were characterized for different physical and mechanical properties and the following conclusions were made:

1. Fabrication of Al6082-B_4C composites were done by Powder metallurgy technique successfully
2. The theoretical and experimental densities decreases with increase in the weight percentage of B_4C but the experimental density was increased with increase in load from 12 KN to18KN but the porosity of material increased with decrease in the density
3. The increase in wt percentage of B_4C and the load increased the hardness of the composites The maximum hardness value was found with the specimen of 10% wt of B_4C for 18 KN load applied where as the minimum hardness was showed by the pure Al at 12 KN load
4. 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 composites

From all the observations we can conclude that the properties of Al6082 gets better with increase in the weight percent of B_4C reinforcement .Therefore the incorporation of B_4C in Al6082 yields better results than pure Al6082 material

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