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Microstructural and Hardness Behavior of AL/B_4C/h-BN Hybrid Composites Prepared By Powder Metallurgy Method

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Abstract: The proceedings of this presentations enables us to explore the effect of B_4C and h-BN particles on Aluminum based metal matrix composites (AL MMCS).The composites were fabricated with different reinforcement percentages of h-BN and B_4C in aluminum using powder metallurgy technique. To obtain homogenous mixture between the powders, for small duration of milling, attrition mill is adopted. The powders were then compacted to optimal compaction pressure and sintered under nitrogen atmosphere. The prepared composites were polished and etched for micro structural analysis. Also determine the Brinell's and Vicker's hardness numbers. Results reveal that there is good improvement of results in composites than base metal.

Keywords: mmcs; microsturecture; hardness; sintering; inert atmosphere.

I. INTRODUCTION

In today's scenario industries are seeking the advanced applications of metal matrix composites because of their superior mechanically inherent properties. Metallic matrix composite erections are great interest in automotive engine parts, military, aeronautical and other applications. These composites offer excellent combination of mechanical properties that enhances the workability. The metal matrix can be reinforced by numerous reinforcements with variety of types like graphite, SiC, Al_2O_3, TiO, MgO, SiO_2, B_4C, TiC, WC, h-BN and C in the form of particulates, whiskery structures or fibrous matter. In this paper powder metallurgy route was used to prepare the composite materials though various techniques are available because, it has many advantages such as we can produce near net shapes components and also we can use this method to produce high melting point components with high accuracy and god surface finish. In this PM technique we can produce specific properties like microstructure, strength, hardness and other mechanical properties also for specific applications and also utilize full amount of raw material and there is no material waste during the process.

II. LITERATURE REVIEW

Boron carbide (B_4C) is extreme hard reinforcement material component with significantly excellent hardness, impeccable corrosion resistance, numerous mechanical properties, which makes it is a desirable reinforcement material for enormous engineering requisite and its related applications. [1,2]. Hexagonally bonded boron nitride (h-BN) particle also an effectual reinforcement for aluminum metal composites specially for tribological applications in automobiles and other because it makes the composites as the most toughest and self-lubricant in nature.The support provided by these h-BN particles improves the machinability and wear resistance of Al-B_4C composites when embeds into the base composite metal. The synthesized hybrid aluminum based composites encompassing B_4C and h-BN particles having great benefit compared to other combination of reinforcements. A K Bodukuri et al [3], Investigated on hardness values of metal matrix composites by varying the compositions of B4C and SiC reinforcements in Aluminum metal matrix composites and conclude that hardness values are higher compared to the base metal aluminum and alloys. The effect of addition of molybdenum trioxide on strength coefficient, hardness, density and thermal conductivity was studied by B.Stalin et al, [4] result reveals that addition of parentage of MoO_3 increase the strength coefficient, hardness and density and decrease the strain hardening index during cold upset process. Cunguang Chen et al [5] observed that due to the distinct high relative density, more significantly distributed grain refinement and the presence of meagerly distributed hard particulates (nano-Al2O3) and inter metallic phases (Al2Cu) in the matrix showed the best mechanical performance, including the Brinell hardness, compressive strength and fracture strain.Amar E Nasser et al [6] investigated that Reinforcement of titanium dioxide with aluminum was effect on mechanical properties like tensile strength, hardness, density which were increased with increasing of titanium dioxide. Also decreasing of ductility and enhancing of wear resistance of composite. K. Kanthavel, K.R. Sumesh, P. Saravanakumar [7] proposed that the characteristic features of the combinations of Al+ 5% Al2O3, Al+ 5% Al2O3 + 5% MoS2 and Al +5% Al2O3 + 10% MoS2, reveals that further addition of 10% MoS2 in the hybrid composite does not help to improve the already existent tribological property. Ehsan Ghasali et al, [8] says that Microwave sintering produce Al/B4C metal matrix composite at a sintering temperature which is either at 850˚C or more. By increase the weight percentage of B4C micro hardness and compressive strength values increased.

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Use of Microwave heating produces Al/B4C composites and saves the energy proportions. Maho Yamaguchi et al, [9] Aluminum/boron nitride nano tube (BNNT) composites were prepared by the process of spark plasma sintering (SPS). The Boron nitride nano tubes were found in the grain boundaries in Plasma Sintering samples at room temperature containing about 3.0 wt% Boron nitride nano tubes (300MPa) became one and another half times higher than that of free High pressed torsion /Al compact (200MPa). Madhuri deshpande et al [10] studies on AL7075 alloy MMCs and discussed that there is good bonding exist between the reinforcement and alloys even high volume fractions of reinforcements also uniform distribution of the carbon fibers.

S. Ozkaya, A. Canakci [11] investigated the unreinforced Al-Cu-Mg alloy shows 15 wt% B4C composites produced with 25 hr milling time. The hardness of the hot pressed composites was higher than that of the hot pressed nano composites incured by using the globally identified conventional powder metallurgy and 10 wt% of B4C nano composites produced with 6hr milling time gives the highest tensile strength. Sener karabulut et al [12], also proposed his theory on Al6061 alloy reinforced with 5-20 wt% B4C produced using a powder metallurgy method. The highest tensile and transverse rupture strengths are for Al6061/5 wt% B4C were estimated successfully.

III. EXPERIMENTAL WORK

In this experimental work Powder metallurgy process was used to prepare the samples. This process consists of mainly four steps which were powder characterization, blending or mixing, compaction and sintering.

Materials used in the present work

Pure aluminum with above 99 percentage of purity used as base metal and boron carbide and boron nitride were used as reinforcement. These reinforcement material have different properties and which gives different material properties and full fill the all the requirements of mechanical properties especially automobile engine applications. Boron carbide enhances the mechanical strength and hardness and boron nitride act as solid lubricant and improve the tribological properties. Zinc stearate was used as lubricant during compaction process and acetone also used to clean the die for each sample preparation. Nitrogen gas was used in sintering process to create the inert atmosphere in order to reduce the oxidation effect during the process.

Blending

Blending is a process of mixing of powders, to achieve homogenous mixture in this work attrition milling equipment (shown in fig 3(a), fig 3(b)) was used to mix the powders and it was attached to drilling machine. Attrition apparatus consists of a cylindrical compartment in which a circular cross sectional shaft with impellers is placed along with it. When the shaft starts its revolution, impeller agitates the steel balls to and fro, which in turn taps, vibrates the powder placed in the vial by which the powder particles get cold welded and uniform distribution is achieved, Speed was maintained at 200rpm, and it was carried for a time of 2 hrs to overcome any errors in milling speed and ball to charge ratio was maintained to a range of 5:1, 50% of Vial space is left empty for free motion of balls and powders.

Fig 3 (a) mixing of powder set up

Fig 3.(b) attrition mill

Compacting

After mixing of the powder, universal testing machine with a maximum capacity of 40 ton was used for compacting the powder. A 20mm diameter sample was prepared by applying the uniaxial compaction load gradually and zinc stearate and acetone were used for easy detachment of greenish compact specimen sample and punch and die.15 grams of powder was used to consolidate the powder in to the cylindrical sample. Optimal Compaction pressure employed during consolidation of powder up to 150MPa for the samples which reduces the porosity.

Sintering

The prepared green compact samples did not have enough strength, to improve the strength of the green sample go for sintering process. It consists of electric furnace (Fig 3(c)) with a facility to vary temperature and inert gas arrngment. In Sintering process green compacts which was prepared by compaction heated at a temperature of 580^0c employed. The heating rate employed in this process is 30C/min. Sintering atmosphere employed here is nitrogen, that gets first purified from moisture content, if any impuritical substances in gas it passes through brass chips and calcium pellets to purify the gas, before entering the furnace. The gas from the exit is passed through a vessel of water, to verify the gas flow. Sintering time employed was 3 hours. After completion of sintering process samples were cooled in the furnace itself to the room temperature, them the samples taken out from the furnace and the mechanical tests for characterization.

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Fig 3 (C) Electric Furnace with inert gas set up

Composition of composite materials fabricated in this work

The following six different combinations aluminum, boron carbide and boron nitride were used to fabricate the samples show in table 3.1. In this work by using powder metallurgy method, below table shows the weight percentage of different combination of composites.

Table 3.1 compositions of composites

Composite Sample	Composition		
	Aluminum	h-BN	B4C
C1	100	0	0
C2	95	5	0
C3	90	10	0
C4	90	2	8
C5	90	5	5
C6	90	6	4

IV. RESULTS AND DISCUSSIONS

Microstructural and hardness values were determined by using microscope, vicker and brinell hardness tester. There test were primary concerns for all the mechanical and other properties. The grain size analysis was done according to the ASTM E112 standerd. Hardness values for Vickers and brinell were determined by taking the three different impressions and average of that was considered for hardness evalution.

A. Metallographic studies:

The sintered sample particulates were first roughly grounded, then polished for smoothness on emery papers, followed by disc polish procedure with implementation of diamond paste post which it is etched with Keller's reagent prepared from 95ml distilled water, 2.5ml HNO_3, 1.5ml hcl, 1.0ml HF in par with the standard ingredients. Then these sample particulates were inspected and scrutinized under a metallographic microscope. Following figures shows the microstructures images of the samples (fig 4.1 to 4.6)

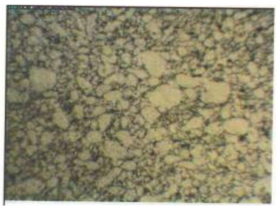


Fig 4.1 Sample C1

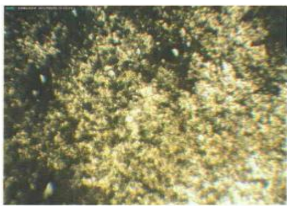


Fig 4.2 Sample C2

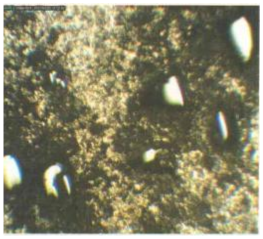


Fig 4.3 Sample C3

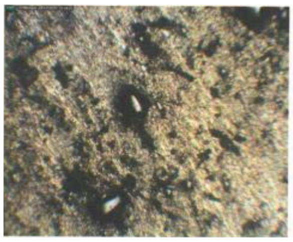


Fig 4.4 Sample C4

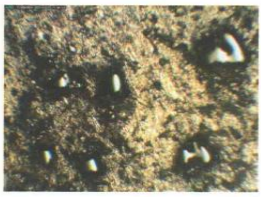


Fig 4.5 Sample C5

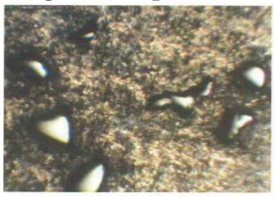


Fig 4.6 Sample C 6

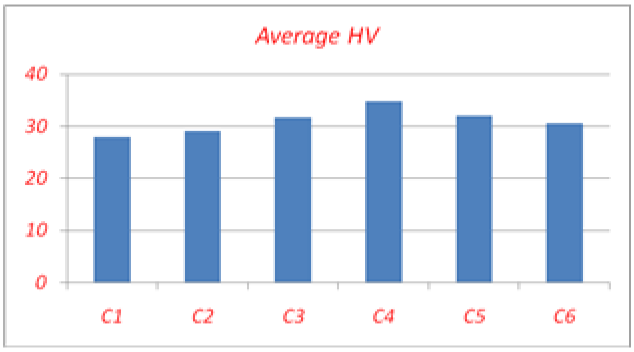
Above figures shows the microstures of all samples from C1 to C6 and it is shows that mixing and sintering were done properly and distribution of reinforcements were also done uniformly.

B. Vickers Hardness

Vickers hardness test facilitates an accurate, more precise, rapid and economic way of persuading the resistances to indentation, penetration, embed or plastic deformation of the surface content of the material. For this test, the samples are highly polished to achieve great surface finish. Then the sample is placed in the vickers hardness setup and hardness values were measured by using the diamond indentor and the load applied was 1 kgs according to the IS 1501:2002. Three different impressions were taken from different areas and tabulated in the table 4.1 along with the average value and graphs (graph 4.1) were plotted for different samples average hardness's for different combination of six composites.

Table 4.1 vickers hardness table

Sample	impression 1	impression 2	impression 3	Average HV
C1	28.1	27.9	27.6	27.87
C2	29.2	29	29	29.07
C3	32.2	31.7	31.1	31.67
C4	35.1	34.8	34.5	34.8
C5	32.2	31.9	31.7	31.93
C6	31.5	31.2	28.7	30.46



Graph 4.1 shows compositions V/S Average vicker's hardness values

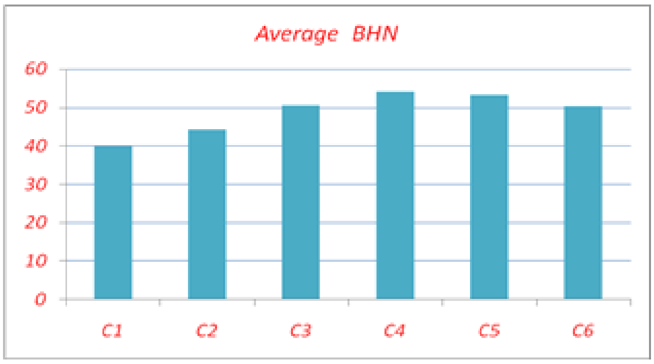
As we see that if we find the hardness value of pure aluminum we got the hardness very less, as we go on adding the compositions of HBN and B_4C the hardness value goes on increasing.

C. Brinell hardness:

Brinell's Hardness Testing is one of the foremost procedures for testing hardness; this test was conducted on numerous parts from least in size to high in size and weight. This varying test force as well as ball size allows testing of various metals.. Hardness values was measured by using 5 mm ball indentor and the load applied was 250 kgs according to IS 1500:2005. Three different impressions were taken from different areas and tabulated in the table 4.2 along with the average value and graphs (graph 4.2) were plotted for different samples average hardness's for different combination of six composites.

Table 4.2 Brinell hardness table

Sample	impression 1	impression 2	impression 3	Average BHN
C1	40.2	39.6	39.9	39.9
C2	44	44.4	44.4	44.27
C3	51.4	51	49.2	50.53
C4	54.3	53.8	54.3	54.13
C5	53.8	53	52.6	53.13
C6	51.9	51.4	47.5	50.27



Graph 4.2 shows compositions V/S Average brinell hardness values.

The hardness value of composites improved compared to the pure aluminum in all the six combinations.

V. CONCLUSIONS

- From the microstructural investigation it was found that there is uniform distribution of reinfoecement in the base luminium
- For all the composites and also the average grain size number lies between 5 to 6 for all the composites which shows the reinforcement in the base metal imparts uniform distribution in the metalographic structure and there is no aggromiration and sedimentations formed in the composites.
- From the hardness value observation there was a significant influence of the h-BN and B4C in all the cases.
- For pure aluminium we found that very less hardness and as addition of boron nitride the hard ness value increased gradually but addition of boron carbide it was found to be maximum of 34.8HV and 54.13 BHN.

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