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Research Article

Mechanical Properties of AA7075- nano-B_4C Metal Matrix Composites Prepared by Powder Metallurgy

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Abstract

Powder metallurgy prepared composites are preferred over composites made of other liquid manufacturing techniques, due to its unique advantages such as near-net shape. Metal matrix composites with reinforcement in its nano size exhibit enhanced Mechanical properties. In the present work, the effect of nano -B_4C over the Mechanicalproperties of AA 7075composites is elaborated. The nanocomposites produced by powder metallurgy were tested for hardness, compression, and density. The results obtained exhibits increased compression strength, density and hardness of composites in comparison with the micro reinforcement.

I. Introduction

Synthesizing Aluminum based metal matrix composites (AMC's) dates back to ages, due to its imperative capabilities like corrosion resistance, low density, high wear resistance, thermal conductivity and increased strength[1,2].

Metal Matrix Composites(MMCs) having ceramic reinforcement demonstrate considerable advancement in properties, when compared with pure metals and alloys. MMC's edges over other classes of composites by demonstrating properties like matrix ductility & matrixtoughness and high modulus and strength of the reinforcements [3]. The mentionedoutstanding properties of suchcomposites make them viable for suitable for applications likeaerospace, automotive industries and military warfares [4].

Major disadvantages of MMC's are improper wetting, improper bonding between the interface of matrix and reinforcement, in the conventional process like stir casting and squeeze cating, involving the liquid molten metal.Hence Powder metallurgy is preferred by manyresearchers to eradicatesuch limitations and improve the mechanical characteristics.

Powder metallurgy isundoubtedly one of the superior methods to fabricate composites and nano-composites to the near-net shape. MMC's with at least one of the constituent (usually reinforcement) in nano scale (<100nm) can be called as Metal Matrix Nano-composites (MMNCs). Reinforcement in nano-refinement enable MMNCs to exhibit outstanding properties.

II. Materials and methods

Aluminum Alloy 7075 powder is chosen as base metal and boron carbide in nano scale(APS<100nm) is used as reinforcement. Composites are prepared with different proportion of reinforcement (2.5%, 5%, 7.5% and 10%) and also for set of sintering temperatures (450ºC, 500ºC, 550ºC and 600ºC).

Base metal and reinforcement powders are initially blended in ball milling process and then it is compacted in a compaction machine under a constant compaction pressure of 60 kN.

Die design

To preparethe nano-composites specimens by using Powder Metallurgy [P/M] technique, it is essential to design and produce a metallic die, which has enough strength to withstand the load during compaction. Reference parameters for die design were specimen dimensions and the compaction pressure, which is to be applied on each specimen. A solid block of D2 material was bored at the centre and the inner cavity of formed die is subjected to finishing operations to get very high smooth surface. Polishing of inner cavity is done to facilitate easy removal of specimens.

A circular base plate having same diameter as of die, is prepared to place it below the die. A plunger is provided for compaction purpose. Constructional details of die assembly are shown in below figures.

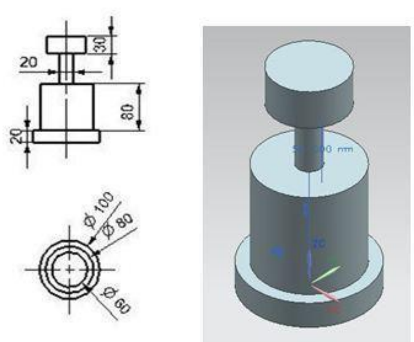

Figure 1: Die design and model

Blending of the powder

The AA7075 powder having a particle size of around 50 microns was used as a matrix, for blending with the reinforcement nano B_4C.Reinforcement was blended with the matrix in five proportions to study its effects i.e., 0%,2.5%,5%,7.5%and10% .The properly weighed proportions of matrix and reinforcement was blended using ball milling process. The planetary ball mill was run for 2 hours without the presence of balls for thorough mixing of composites.

Preparation of green compacts

The compaction of mixed composite powder is performed by uniaxial compression testing machine of maximum capacity 60 kN.The die is filled with the calculated weight of blended powder, which is calculated by taking density of AA7075 and nano B_4C into consideration. The green compacts obtained were subjected to sintering process for densification.

Sintering

The green compacts obtained after compressing the mixture of powders are having low strength and therefore, they are sintered at different sintering temperatures i.e 450ºC, 500ºC,550ºC and 600ºC below the melting temperature of AA7075. Furnace Temperature starts increasing from 0 to respective sintering temperatures at the rate of 5ºC/ min. It takes approximately twoand half hours to reach sintering temperatures and compacts are held for 2 hours & cooled to room temperature. The sintered specimens thus obtained are harder and denser compared to green compact.

III. Results And Discussions

Density measurement

Density of prepared composite was measured by Archimedes's principle and itwas seen that density of prepared compositesgoes decreasingwith the increase in nano boron carbide weight fraction. This can be attributed to the variation of density of AA7075 and B_4C. As the density of the nano boron carbide is lesser compared to AA7075,net density decreases with the increase in weight fraction of B_4C .The figure 2 shows the variation of theoretical and experimental density of composites with respect to weight percentage of nano B_4C reinforcements.

Table 1: Theoretical density and experimental density results

Wt. % of Nano B_4C	Density(g/cc)				
	Theoretical	**450°C**	**500°C**	**550°C**	**600°C**
0%	2.7	2.41	2.434	2.453	2.481
2.5%	2.69	2.54	2.499	2.483	2.431
5%	2.69	2.53	2.487	2.469	2.412
7.5%	2.68	2.478	2.484	2.47	2.411
10%	2.671	2.504	2.541	2.442	2.384

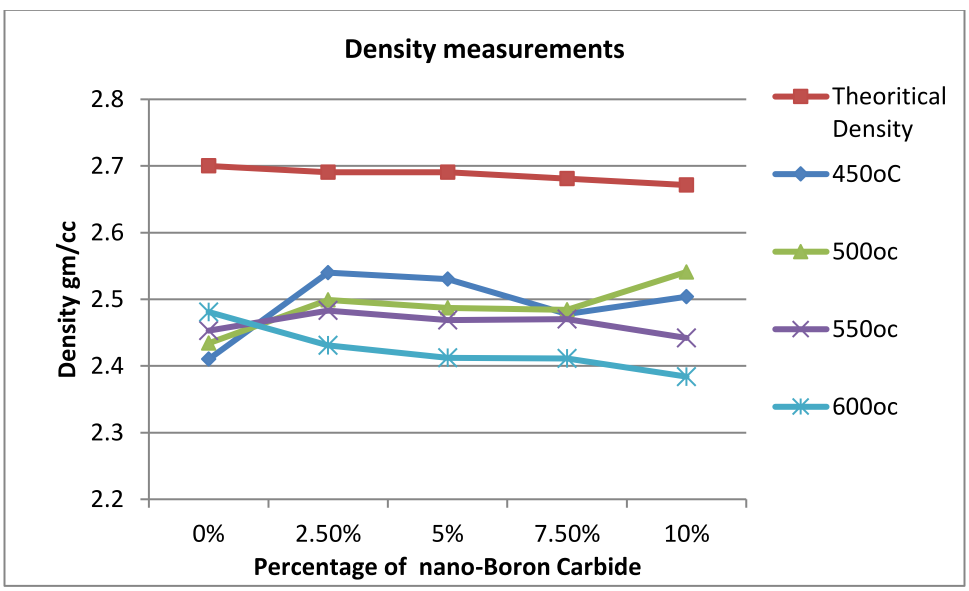

Figure 2: Theoretical andExperimental density values for different weight fraction of nano B_4C and sintering temperatures.

Compression Test

Compaction test for prepared specimen was conducted using bliss UTM with crosshead speed of 0.5mm/min.

Table 2 : Compression strength of composites for different weight fraction of nano B_4C and sintering temperatures.

Wt% of Nano B_4C	Compression strength (Mpa)			
	450°C	**500°C**	**550°C**	**600°C**
0%	178.5	181	182.3	183
2.5%	219	223	231	238
5%	236	241	253	264
7.5%	266	274	281	288
10%	294	299	304	311

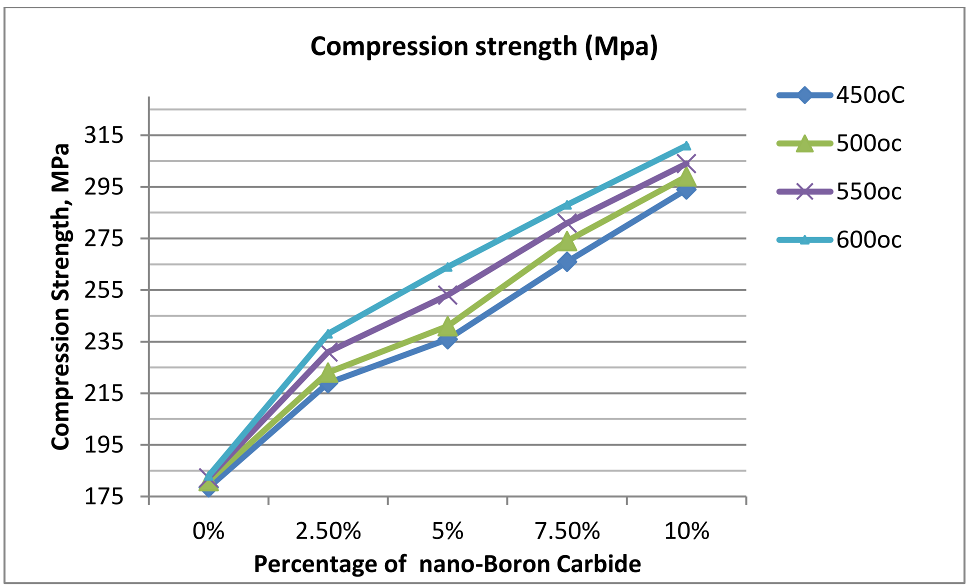

Figure 3: Compression strength with respect to Wt % of B4C and sintering temperatures

Fig. 3. indicates the variation of ultimatecompressive strength with the variation in nano-B_4C reinforcement volume. Compressive strength is found to increase, due to theincrease in weight percentage of nano B_4C ceramic particles, imposing abarrier to the movement of dislocation. The harder nano-B_4C particles provides resistance for the propagation of crack and this will result in the change of the crack growth plane. Thenano-B_4C particles applyexcess resistance on plasticdeformationof composites , that will end up in increased compressive strength.

Hardness test

Hardness test was conducted using Rockwell hardness testing machine. Instrument has diamond indentation. Initially to eliminate the effect of dust specimen is polished by emery paper & oil etched load of 100 Kgf is applied.

Test is conducted at 4 different positions on the same sample and average is taken same procedure is repeated for different samples and hardness value is calculated.

Table3 : Hardness value of composites for different weight fraction of nano B_4C and sintering temperatures.

Wt% of Nano B_4C	**Rockwell hardness number**			
	450°C	**500°C**	**550°C**	**600°C**
0%	61	63	65	66
2.5%	77	89	94	98
5%	87	93	103	121
7.5%	95	108	126	133
10%	101	114	124	145

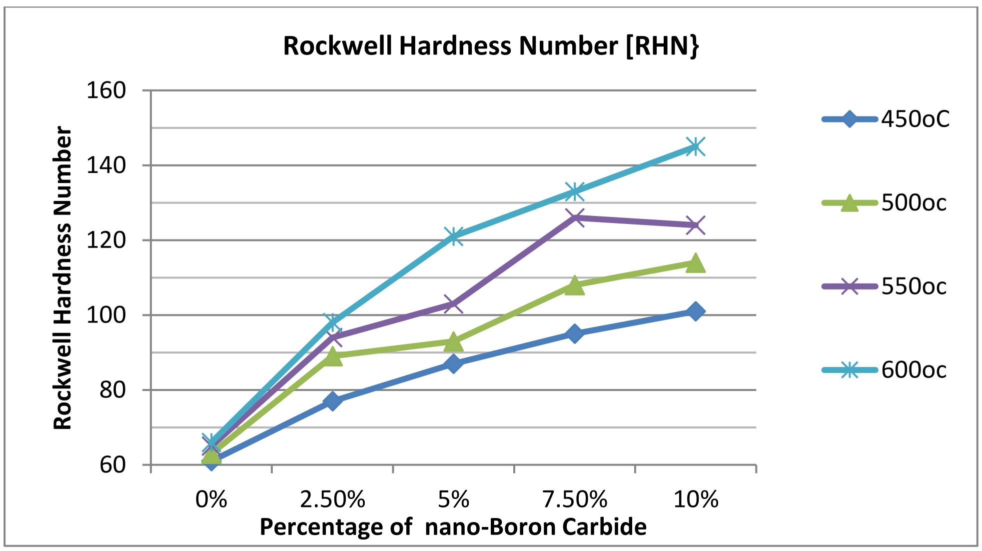

Figure 4: Rockwell Hardness Number with respect to Wt % of B_4C

The results of the hardness tests of the composites are presented in Fig. 4. The hardness values of 2.5, 5, 7.5 and 10 vol% of nano B_4C are much higher compared to base alloy. hardness of the composites is increased, due to increased strain energy. The presence of nano-B_4C particles acts as a barrier to the motion of dislocations and hence possess higher hardness .

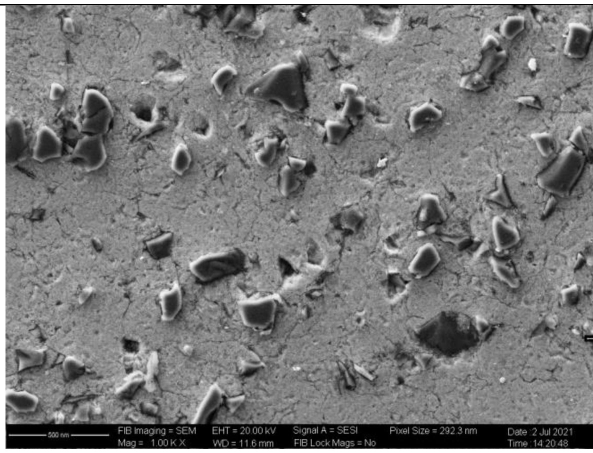	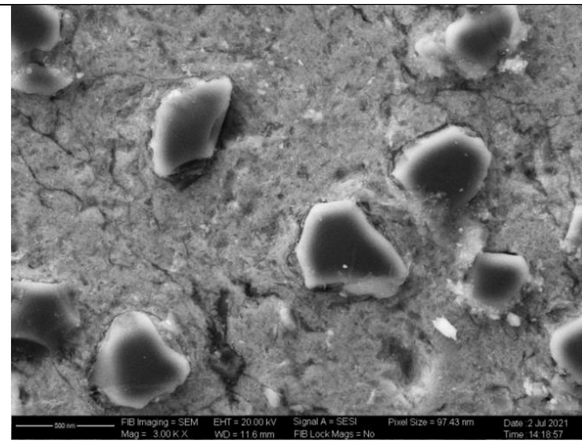
Fig.5a. FESEM image of AA7075-2.5% nano B_4C composite	Fig.5b. FESEM image of AA7075- 5% nano B_4C composite
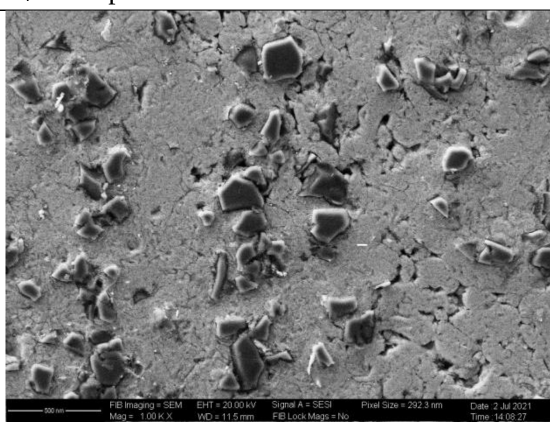	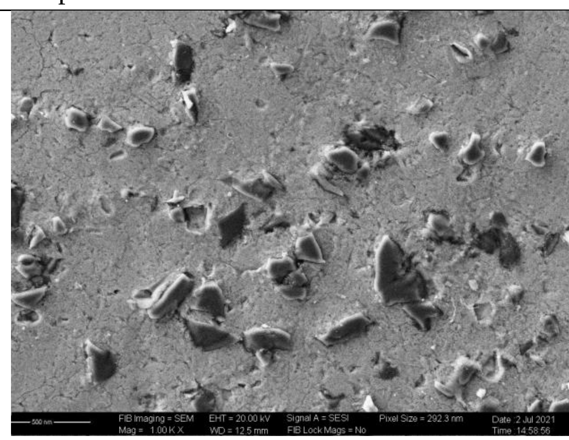
Fig.5a. FESEM image of AA7075-7.5% nano B_4C composite	Fig.5a. FESEM image of AA7075-10 % nano B_4C composite

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FESEM images of prepared composites

FESEM micrograph of AA7075-nano B_4C MMC's with 2.5,5, 7.5 and 10 wt. %of nano B_4C particles are as shown in Figure 5a,5b,5c & 5d. The AA7075 matrix particles wasobserved to be uniformly distributed except for AA7075 –2.5 wt.% nano B_4C, in which void regions are found in the matrix, probably because of lower weight percentage of nano B_4C . Higher weight percentage exhibit reasonably uniform dispersion with no regions without the presence of nano reinforcement. This is due to the densification of particulate and matrix at higher sintering temperatures. Nano-B_4C particles, due to compaction process was found attached to the dendrite boundaries.

At distributed locations, a small magnitude of clustering and agglomeration of nano reinforcement particles was indicative,leading toformation of regions with variation of particulate density. The island regions formation can be attributed to the nano size of the reinforcement particle, which can adversely affect mechanical characteristics by nucleating cracks at the surface.

IV. Conclusions

AA7075– nano B_4C composites was fabricated by powder metallurgytechnique , The hardness of prepared composites was observed to increasewith the increasing weight fraction of nano-particulates, due to the effect of increase in ceramic phase .. The nano-B_4C particles present tend toblock the movement of dislocations and hence possessincreased hardness value in comparison with the zero reinforcement composite. The compression values are indicative of rise with the nano B_4C particle volume increase, which indicate improved Mechanical characteristics of the composite.

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