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The Effect of Ball Milling & Reinforcement Percentage on Sintered Samples of Aluminium Alloy Metal Matrix Composites

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Abstract

SiC, Al_2O_3 and Graphene are the major reinforcement in aluminium-based composites, which have been developing rapidly in recent years. This paper focuses on the effect of ball milling & reinforcement percentage on mechanical properties of aluminium alloy metal matrix composites. The average particle size of matrix metal is 10 microns and reinforcements used are SiC, Al_2O_3 and Graphene of particle size 10 microns and 10 Nano microns. Sintering temperature of 550 °C and time in the range of 10-15 min was used to sinter the compacts. It has been concluded that as the fine particle size resulted in good compact densities at 650 Mpa of compaction pressure. The green compact has cracked and failed because of two factors such as reinforcement percentage and rate of heating. Based on the findings, the reinforcement percentage is optimized to wt 10% or less than wt 10%.

Keywords:Metal Matrix Composites AA 2900 , Microwave Sintering,Graphene, Al_2O_3, SiC;

1. Introduction

Metal Matrix Composites with Ceramic reinforcements are attaining good physical properties to increase the insufficiencies of light aluminium alloy composites like temperature resistance, stiffness, tensile strength and more often wear resistance. Among various reinforcements such as SiC, graphite and alumina, SiC upholds good thermal and chemical stability during synthesis and good strength at severe service conditions. Mohanasundaram, et al. [1] have developed Al-SiCp composites by powder metallurgy route and identified a significant improvement in tensile properties and wear resistance with increasing content of second phase. The effect of fabrication method on the mechanical properties of the near net shape specimens was investigated by Ling, et al. [2].

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The cold welding of the Aluminium metal matrix with the die walls are also being studied and resolved in the research work. The poor mechanical properties of Aluminium Metal Matrix Composites produced by the other methods are attributed to the weak bonding between adjacent particles and to internal porosity. At higher volume portions, the strength of interfacial bonds, initiation and growth of voids and particle cracking all play an important role in controlling the mechanical properties. Sintering parameters, such as rate of sintering or rate of heating the samples and moisture can also impact the sinterability. Pieczonka et al. [3] have also testified that increased concentration of magnesium on the oxide surface film of the powder particles film supports sintering of aluminium by reduction of Al_2O_3. Likewise increasing the shear stresses existing during solid state consolidation processes can advance the particle–matrix interface strength due to added operative break-up of the oxide barrier. The mechanical properties of the powder metallurgy (PM) parts are comparable to wrought or cast alloy. However, sintering of aluminium and its alloys is tough due to the presence of the balanced aluminium oxide layer covering the powder confining the atomic diffusion between each particle. The compact is said to have ‘‘poor sinterability’’ as the powders are uncertainly bonded with each other. Poor sinterability results in low sintered density and poor mechanical properties [4]. Thus a careful control of the bonding at the matrix-reinforcement interface is one of the major problems to be solved with aluminium base matrix composites [5]. Especially Microwave sintering technique is adapted to sinter the powder compacted MMC samples. Most metals possess penetrating depths of micrometer order, so the direct heating remains superficial, using the metal powders of the same order might enhance to use Microwave in the heating process [6]. In Conventional sintering heat is generated from the heating source and the samples are heated up by conduction, radiation & Convection. Moreover in Microwave Sintering the materials themselves absorb the microwave and convert them to heat inside their body [7, 8]. The research work presented in this paper focuses on understanding the microwave sintering behavior of SiC, Al_2O_3 and Graphene particle reinforced aluminium alloy composite by powder processing and the influence of various process parameters on the obtaining a good compact sample for testing. Hence the Aluminium alloy compacted samples are sintered in microwave furnace. The rate of heating and reinforcement’s percentage is studied on the green compact which clearly shows the outcome of a good compact for testing.

2. Experimental Details

2.1. Powders

The matrix material used in this research work is AA2900 alloy which is alloyed with copper. Reinforcement SiC, Al_2O_3 and Graphene of particle size 10 microns in case of SiC and Al_2O_3 and 10 Nano microns in case of Graphene. It was reported that particle size of Aluminium alloy and reinforcement particles have a substantial effect on the hardness, microstructure and fracture toughness of the composite. Relatively non uniform microstructure was obtained when the reinforcement particle size was smaller than the matrix particle size [9]. Hence in the present work both matrix and SiC of equal size particle size of 10 microns is chosen.

2.2 Powder Blending

The weighed powder is mixed in a high energy ball mill from VB Ceramics Inc. Chennai. Since the particle size of matrix and the reinforcements are 10 microns which is sufficient for compaction ball milling was focused only on mixing rather than running it for hours to further break particles to attain fine grains. The ball milling time was 20 min for all the reinforcement composition.

2.3. Compaction

Compaction of the powders has been carried out in a standard die-setup. Compaction was carried out in a universal testing machine with a capacity of 100 tons. Uni-axial pressing was carried out at 650 Mpa compacting pressures. Zinc stearate mixed with acetone was used for die wall lubrication and no lubricant was used in the powder mixture since it was noticed that powder with mixed lubricant did not help in gaining preferred green compact density. Die was manufactured from ASTM D2 high carbon steel, hardened, tempered and Carbide inserted. Punch and die were ground to close tolerances.

2.4. Sintering

Sintering was carried out for some samples at 550 ^{o}C for 15 min in Microwave sintering furnace at a rate of heating up to 10 ^{o}C per minute, the specimens after the sintering time was allowed to cool up to 250 ^{o}C inside the furnace to avoid atmospheric contamination and sudden cooling. And then to room temperature.

3. Experimental Plan

Aluminium alloy powder (AA-2900) with the grain size of 10 microns manufactured by gas atomization process was used for the experimentation. Ceramic reinforcements of SiC, Al_2O_3 and Graphene with the grain size of 10 Microns and 10 Nano microns were used in MMC's samples. All the AA-2900 with SiC, Al_2O_3 and Graphene are mixed in Ball mill to obtain a homogeneous mixture without mixing lubricants for 15 min. The mixed composites are loaded in the compaction die which is coated with Zinc stearate mixed with spirit to provide die wall lubrication and to avoid cold welding of AA-2900 particles with the die walls. Compaction pressure used was 650 Mpa. Experiments were carried for three different reinforcement percentages i.e. 10%, 15%, 20% for which Microwave sintering method is followed. The rate of heating in microwave sintering is assumed as 10 ^{o}C per minute. The densities of the compact are studied and the influence of rate of heating and the reinforcement percentages are compared.

4. Results and Discussion

4.1 Ball Milling

The AA 2900 alloyed with copper and with various reinforcements such as SiC, Al_2O_3 and Graphene is mixed using ball milling. The ball mill used for this experimentation is high energy planetary ball mill. The purpose behind doing ball milling is to attain just the homogeneous mixing rather preferring for break of matrix and reinforcements to fine grains. Each composition was ball milled for 20 min of time at revolution per minute of 150 RPM. The AA 2900 reinforced with SiC faced a difficulty in ball milling because of high hardness of SiC which is abrasive in nature. The ball mill jar and balls used was manufactured from a material Tungsten carbide which is comparatively less hard than SiC. The SiC reinforced AA 2900 mixture damaged the Balls and jar which is shown in Fig 1.

Fig. 1 Balls worn out after AA 2900 With SiC ball milled.

4.2 Hardness

Micro hardness measurement on microwave sintered samples is carried out. The densification rate is strongly subjected to the diffusion of ions between sample particles, and the grain growth rate is mostly resulted by the grain boundary diffusion. Dube et al. have found that the intense microwave field concentrates around samples during microwave sintering [10]. This is also one of the factor for which the hardness of the microwave sintered samples are enhanced. The sintered samples which are subjected to microwave are prepared for hardness testing in Brinell hardness machine. The steal ball of size 10 mm is used to create an indentation on the samples. The hardness measuring experiments was carried out in two stages. The hardness was measured on samples on the same day when it was sintered the hardness values are shown in table 1.

Table 1.hardness measured on the same day of sintering.

Metal Matrix	Reinforcement	Weight %	Indundation dia in mm	Brinell Number
AA 2900	SiC	15	2.8	37.13791
AA 2900	SiC	20	2.7	40.22754
AA 2900	SiC	10	2.9	34.35811
AA 2900	Al2O3	15	2.9	34.35811
AA 2900	Al2O3	20	2.8	37.13791
AA 2900	Al2O3	10	3	31.84713

The same samples which are sintered were measured for hardness after 2 months. It was observed that the components broke to pieces. But in case of Graphene reinforced AA 2900 MMC the Weight percentage chose was 10%, 15%, 20%, because of which the components broke. The reason behind the Graphene reinforced MMC failure is, the number of Graphene particle has exceeded the number of matrix metal particles. The Brinell harness is measured using the standard load of 250 Kg. As a result the reinforcement has become the matrix and the matrix has become the reinforcement as considering the factor number of particle shown in Fig 2 & Fig 3. El-Sayed M. Sherif et al. has found that less than Wt 3% of Graphene Nano platelets would fetch better mechanical properties rather going for higher percentages of Graphene Nano platelets [10]. And the failure components reinforced with SiC and Al_2O_3 are shown in Fig 4 & Fig 5.

Fig. 2 Graphene wt. 10%

Fig. 3 Graphene wt. 15%

Fig. 4 Crack observed in SiC wt. 20%

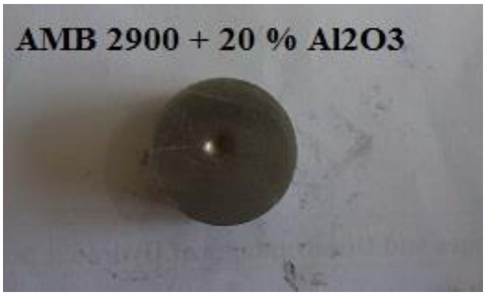

Fig. 5 Crack observed in Al_2O_3 wt. 20%

5. Conclusion

The experiments were carried out on MMC's with AA2900 matrix reinforced with SiC, Al_2O_3 and Graphene using three different reinforcement percentages i.e. 10%, 15%, and 20%. It was observed that the hardness measuring was possible on the same day when it was sintered. The samples reinforced with SiC, Al2O3 were again subjected to hardness measurement after 2 months during which the sample broke. This is because of the reinforcement percentage, rate of heating in microwave furnace and aging. SEM and EDAX studies will help us to find the carbide formation in the samples considering the rate of heating factor. 2 ^{o}C rate of heating which is almost equal to conventional type will overcome this issue. Considering Graphene as reinforcement it's viable to go with equal to wt 1% or less to get good compact for sintering and to get improved mechanical properties.

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