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Development of Al-SiC Compsite Material By Powder Metaullargy Route

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Abstract *— In recent year, aluminum alloy based matrix composites (MMC) are gaining importance in several aerospace and automobile applications. Aluminum has been used matrix material owing of its excellent mechanical properties coupled with good formability. Addition of SiC as reinforcement in aluminum system improves mechanical properties of composites. In the present investigation Al-SiC composite was prepared by powder metallurgy route. Powder metallurgy homogeneously distributes the reinforcement in the matrix with no internal reaction and with less porosity. SiC particles containing different weight fractions (10, 15 and 18 %) and mesh size (320) are used as reinforcement. Though Al-SiC possess superior mechanical properties, the high abrasiveness of the SiC particles obstacle the wide application. Al-SiC composite has the widest application in the aerospace industry due to high hardness and light weight material. After the development of material that specimens were tested the under the micro hardness, density and scanning electron microscopic (SEM).*

Keywords*-mmc material, al-sic composition, weight fraction of sic, compaction, sintering, x-r-d, sem analysis, micro hardness,*

I. INTRODUCTION

Attractive physical and mechanical properties can be obtained with metal matrix composite which combine metallic properties with those of ceramics. Reinforcement material in metal matrix composite material is carbides, nitrides, oxides and other element material. One of the major problems encountered in the production of metal matrix by powder metallurgy route is the agglomeration of reinforcement particles due to size difference between the powders for the matrix and the reinforced particles. To resolve this problem different methods are use e.g. ball milling or mechanical alloying technique. Mechanical Alloying or ball milling enables metallic material to coat the surface of ceramic powder particles. The constituent powder particles are repeatedly fractured and cold welded by continuous milling so that powder particles with very fine size can be obtained. The milling process largely depends on the types of ball mill and the rotation speed of the mill. Composite materials are used in the aerospace etc. The important properties are low specific gravity, high wear resistance and strength. By understanding the property, it is possible to develop the new composite reinforced material, which gives better physical and mechanical property.

II EXPERIMENTAL WORK

2.1 Purity analysis of powders

The mixtures of aluminum with 10 to 18 weights of SiC particles were prepared and ball milled in liquid atmosphere for the desire time duration with different hours. But before move to this process powder of aluminum and SiC must be pure for the good mechanical property.

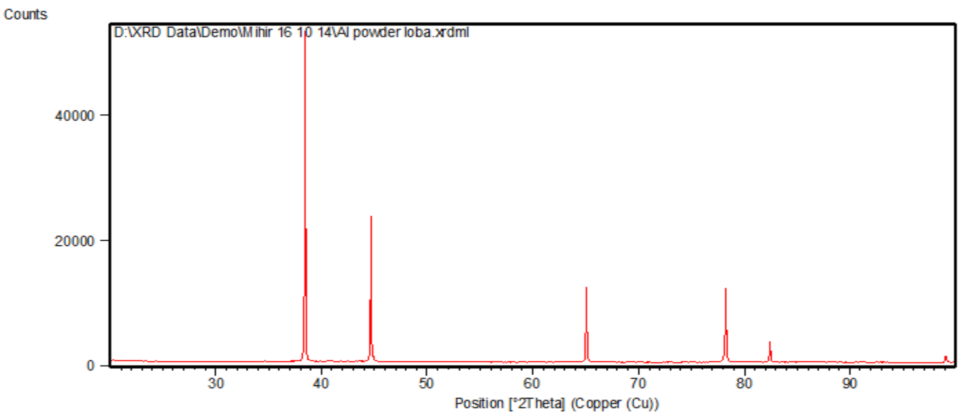


Figure 1 X-R-D of Aluminum Powder

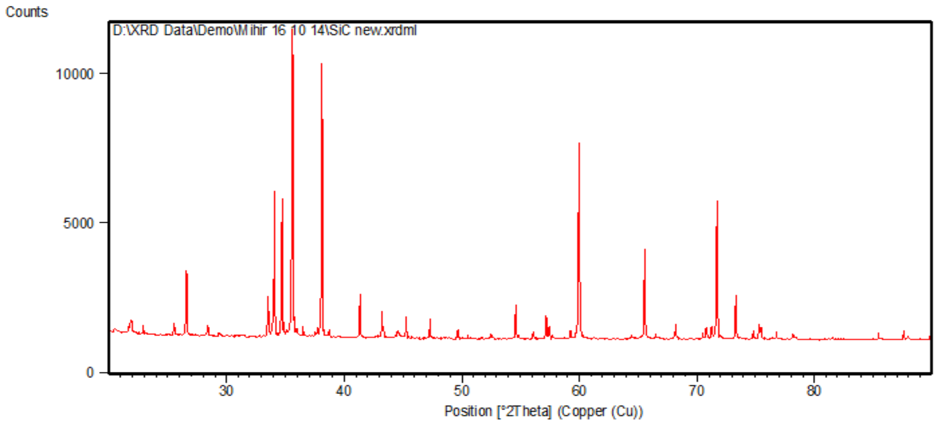


Figure 2 X-R-D of SiC Powder

Powder samples were taken for X-R-D test for the purity. The result of the test shows that the aluminum powder has been 98.5% pure and silicon carbide powder has been 97% pure. The above result shoes that powder has good property for the composition. After the X-R-D test the purity was been prove depend on the highest peak value that shown in above figure 1 and 2.

2.2 Fabrication of Al-SiC composite through metallurgy process

Standard samples of Al-SiC composite with 10, 15 and 18 % of SiC were fabricated through powder metallurgy in following process.

2.2.1Mixing of powders

The aluminum and SiC powders of particular size range obtained after purity analysis were weighted individual and mixtures of six different compositions (viz 10, 15 and 18 weight % of SiC) were prepared. Figure 8 shows the scanning electron micrograph of the aluminum and SiC particulates used in the development of specimens. The shape of the Al was round and thin while SiC particulates was sharp and long at 400X.The mixture were put in the plastic container and mixing was done manually for one hour for proper mixing.

2.2.2 Mechanical Alloying

Mechanical alloying results in mixing at molecular level. The SiC particles get embedded into Al powder particles and Al-SiC composite is obtained. The powder hand mixer was transfer in to the planetary ball mill that contains the tungsten carbide (WC) ball with different ball diameter. In order to minimize the extreme tendency to get it self-welded and also to prevent the oxidation form the atmosphere the 2 % weight of toluene was been added to the mixer. The mill was run at 400 rpm for 8 hours. The powders becomes hot during milling therefore it allowed to coll for every 15 min of one cycle.SEM of after the 4 hour and 8 hour is shown in figure 3.

Figure 3 Planetary Ball Mill

2.2.3 Cold Isostatic Compaction

Cold isostatic compaction process results in better and more uniform properties as compared to die compaction because of uniform application of pressure from all direction and absence of wall friction. The elemental and the composite powders developed under this investigation were pressed in single- action die compaction mode on a 100 ton capacity hydraulic press of M/s. Lawrence & Mayo (India) Pvt. Ltd., Mumbai bearing the model no. LM-17-510 to get green compacts. The Fig. 5 shows the pictorial view of the hydraulic press. The maximum capacity of this press was 25 ton. The compaction was done on 10 ton load with constant loading of 2 min/load. For die compaction of Al-SiC composite a die set-up consist 1.5 % of zinc sterate) to reduce the friction between the punch and the die wall. The diameter of the punch was 15mm.The All-SiC composite powder of weight amount of 1.2gm was been added inside the punch and pressing was done on desirable load. After the compaction the 15mm diameter and 3.28(approx.…) that shown in figure 4.at different weight fraction of SiC (10, 15, and 18) three each specimens were prepared.

Figure 4 Cold compaction uniaxial Press

2.2.4 Sintering

The green compacts produced from Al powder, Al-SiC composite powder were subjected to sintering at different sintering temperatures for 60 min under a vacuum of 10^{-2} torr in a resistance heating type tubular furnace as shown in Figure 7.The temperature during the course of sintering was controlled to $\pm$ 3 °C using a microprocessor- based PID type temperature programmer/controller model WEST 2050, Germany supplied by Toshniwal Brothers (Mumbai) Pvt. Ltd., Mumbai.

Figure 5 Vacuum sintering furnace

The heating rate during sintering cycle was maintained at 6-7 0C per minute. The green compacts produced from elemental Al-SiC pallet were sintered at temperatures of 450 ˚C, 500 ˚C, 550 ˙C and 600 ˚ C for optimizing sintering temperature. Optimization temperature were found based on the density difference of pallet before density of pallet before sintering and density after sintering and also based on hardness. The optimum temperature was at 600˙C and holding time 1.30 min. Density of specimens must be improved after the sintering and that shown in table 1.

2.2.5 Re-Pressing

After sintering the density was not widely increased due to the present of SiC particles to the Al composition. Due to that for improving the density the repressing of the pallet was done on the single acting axial press with 14 ton load and 2 min of holding time. Due to high load the mechanical bonding was been produce and the density improvement to be possible.

2.3 Testing of properties

In order to evaluate the properties of the Al-SiC composite the micro hardness, density, and microstructure were determined.

2.3.1 Micro hardness

Vickers micro hardness measurements were performed on polished flate specimens according to ASTM E-384-11 with indenting load of 100gms and dwell time 10 sec. The average micro hardness data given in this paper resulted from three mesurments.The position of indention chosen randomly. The micro hardness test gives a good indication on the strength of the material. As the SiC increase from 10 to 18 % hardness `also increased. The results are shown in below Figure 6.

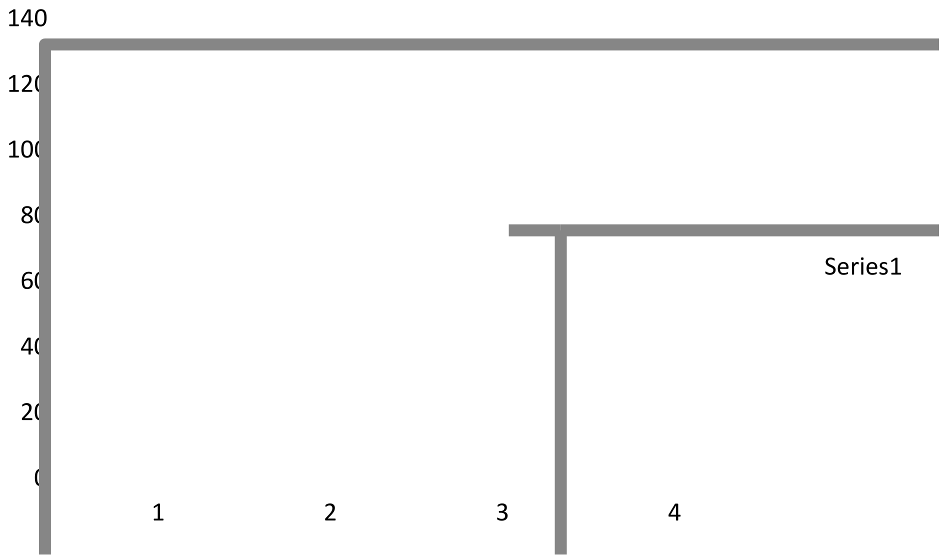


Figure 6 Micro hardness-Weight % SiC

2.3.2 Density

After the pressing the composite powder the green density has been generated and that density calculated as per the standard norms. After sintering density of specimens increased with respect to the % ratio and that depends on the sintering temperature and holding time. Due to sintering process the porosity of specimen was removing and that increased the strength of components. The density table is given below.

Al-Sic composition material	Theoretical Density	Green Density	Sintering density	Re-Press density
Al-10 %SiC	2.7435	84.81%	86.97%	91.51%
Al-15% SiC	2.7662	80.92%	82.38%	87.33%
Al-18 % SiC	2.7794	81.93%	83.97%	88.97%

Table 1 Density data at different levels

2.3.3 Microstructure

The purpose of the microstructure examination was to investigate grain size and shape morphology and distribution of the silicon carbide particles**.** The micrographs show that the aluminum and SiC particles are not propyl bonded in green stage. Figure 9 shows the morphology shape of the Al and SiC particles. That shows that the aluminum are in round and thin shape while SiC are sharp and long.After the 4 hour milling with 10% of SiC weight that shown in figure 10 that shoes that the bonding has been done between the Al-SiC particulate due to high energy ball milling. More broad bonding and reduction in the size of the particle had been shown in figure 11.

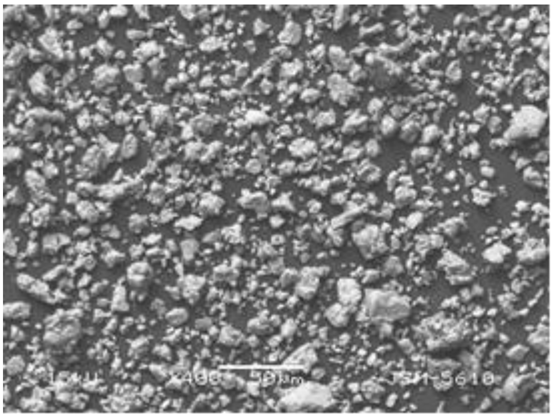
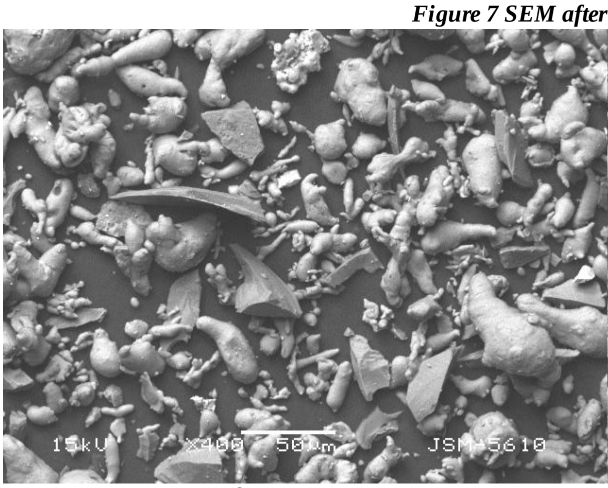


Figure 7 SEM after 8 hour ball milling



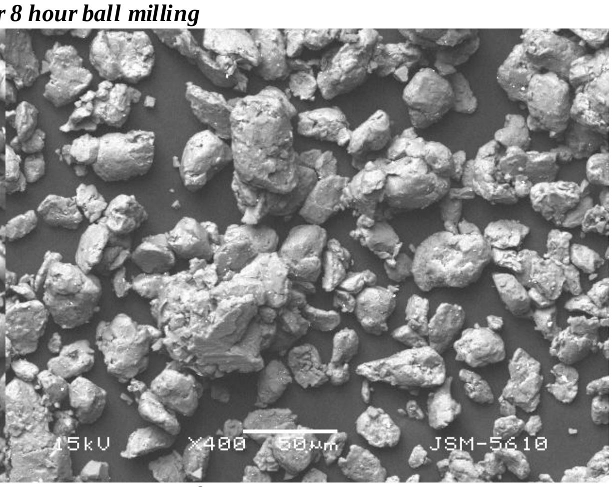


Fig 8 SEM data of hand mixing Al-SiC powder ***Figure 9 SEM after 4 hour milling***

III CONCLUSIONS

1. Mechanical alloying of aluminum and silicon carbide powders for 8 hours of milling results in fine homogeneous powder structure.SEM studies of ball milled powders at intermediate stages reveal that due to impact of WC balls, the cold welding ,fracturing and re-welding of powders particles take place and SiC particles get embedded in the particles.
2. During isostatic compaction due to high load application different particles get to each other and mechanical bonding has been taken place it call green density of the specimens.
3. Cold isostatic compaction followed the sintering at 600C with holding time 1.30 min has been successfully used to produce the Al-SiC composite.
4. Micro hardness and Density of Al-SiC composite increase with increase the weight % of SiC (10, 15, 18) and 125 hv the high value at 18 % of SiC.
5. The incesing in density was 2 to 3 % after the sintering st 600˙C.But after the repressing the increased density was 5 to 6% of the base density.
6. Scanning electron micrograph of powder metal Al-SiC show the proper distribution of the Al-SiC particles and also show that the reduction of the particle size after the 8 hour of milling.

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