FABRICATION OF Al-SiC COMPOSITES THROUGH POWDER METALLURGY PROCESS AND TESTING OF PROPERTIES

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Abstract - *Powder metallurgy is a material processing technology to create new materials and parts by different metal powders as raw ingredients through the blending, compaction and sintering process. Powder metallurgy is a well-developed, cost-effective process for net-shaped fabrication of complex parts. Powder metallurgy is a value-added engineering process that provides a host of advantages over competing metal forming technologies. These advantages add up to cost-effectiveness, shape, and material flexibility, application versatility and part to part uniformity for improved product quality. This technology is highly applied in aerospace and automobile industries, for structural applications, etc. In this Research Work an attempt has been made to fabricate Al-SiC composite by powder metallurgy route as it homogenously distributes the reinforcement in the matrix with no interfacial chemical reaction and high localized residual porosity. SiC particles containing different weight fractions (10 and 20 wt. %) is used as reinforcement. Moreover, SiC as reinforcement in aluminium system improves mechanical properties of composites. After the development of material, the hardness, density and porosity of the composites have been evaluated.*

Key words: *Al-SiC, Mechanical Properties, Microstructure, compaction technique, Porosity, Heat treatment and hardness, Powder Metallurgy.*

1.INTRODUCTION

Powder metallurgy offers a world of materials to the engineer, designer, artist, crafter, and more generally the public, for a multitude of uses. Powder metallurgy is the art and science of manufacturing metal powders, consolidating them and fabricating into desired shape of the articles with little or no melting. In general, components are produced to desired dimensions by machining, casting, hot working and cold working process. But occasionally metals and non-metals cannot be mixed and impossible to fabricate components with desired properties. The aforesaid drawbacks can be overcome by a method called powder metallurgy. Many writers on powder metallurgy have referred to Wollaston's work in producing malleable platinum, published in 1829, and the process he developed for it, as the beginning of the modern renaissance in the field.

The worldwide popularity of powder metallurgy lies in the ability of this technique to manufacture complicated metal objects to exact dimensions, at very high rate, at economical prices and provide technical achievements to improve the quality. It has proved to be cost effective of producing many parts such as porous materials, composite materials, refractory materials, and special high duty alloys.

2. LITERATURE SURVEY

During last 15 years various researchers have reported the fabrication of Al-SiC composites and testing of their properties like tensile strength, hardness, wear resistance and microstructural characterization.[1] Kandavel et al. investigated that the powder metallurgy technique is widespread familiar because intricate shapes with precise sizes and shapes can be produced at high production rate in a cost effective manner.[2] Guo R Q et al. studied the conventional P/M technique can easily formulate various compositions by mixing elemental or premixed powders, consolidate and sintering of the powders.[3] Alam M T et al. studied there is need of composite materials with improved mechanical and tribological properties at minimal production cost.[4] C. Thompson et al. studied the infinite variability of mixed powders, a truly wide range of property alternatives such as machinability, formability, and weldability can be designed into the metal powder used for mechanical components.[5] Ling, et al. has investigated the effect of fabrication method on the mechanical properties of the near net shape specimens. [6] Iacoba et al. investigated that in P/M process, the combination of elemental or pre-alloyed powders are allowed to compress in a die and sintered in a furnace to bond particles. [7] Ravichandran et al. investigated that components with challenging dimension and high strength components can be easily manufactured by the P/M method.[8] F.H. Latief et al. investigated that main advantage of PM process is that it is a near net shape process and can be used for fabricating almost all shapes. [9] J. Mascarenhas et al. investigated that powder metallurgy route is green manufacturing and energy efficient manufacturing compared to casting operation.

3. EXPERIMENTAL PROCEDURE

It is indispensable to select pure metal powder and optimal processing parameters for the preparation of specimens. The specifications/ composition obtained is presented below. The aluminium metal powder and particle sizes 120 mesh (74µm). SiC powder particle sizes 320 mesh (36µm) are applied.

3.1 Pre-treatment of SiC particulates

The pre-treatment of SiC particulates is heated in vacuum condition at a temperature of 590°C in a muffle furnace as shown in Fig.1 & Fig.2 and kept at the temperature for 1 hour preceding to using it for fabrication of MMC samples.

Fig 1: Muffle Furnace

Fig 2: Heating the pellets at 590°C

3.2 Powder Metallurgy Method

The investigation specimens (Al-SiC) are made-up by using powder metallurgy technique by following steps there are Blending/Mixing, Compaction and Sintering. The objectives of our research are fabrication of Al-SiC composite using powder metallurgy technique and fabrication of Al-SiC having the ratio 9:1 and 8:2. To analyze the hardness, porosity, density, microstructure and SEM analysis of Al-SiC composite material.

3.2.1 Mixing of Powders

Without adding binders: -

Equivalent quantities of metal powders were taken by weight. The weighing was done in a very precise weighing balance. 5gm batches were prepared and composition of each sample is shown in Table 1.

Table 1: Sample preparation without binders

Sample	Al	Sic
1	90%	10%
2	80%	20%

Blending is performed in ball planetary mill which consists of two cylindrical containers made of chrome steel rotating about its axis and inside which 10 balls made up of chrome steel of sizes 10 mm. The mixing very important mainly to avoid the voids (Fig 3) using blending machine (Fig 4).

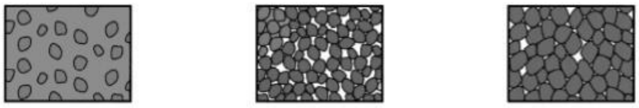

Fig 3: Mixing of powders

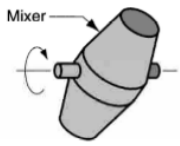

Fig 4: Blending machine

Then compaction of these samples was to done on a manually operated hydraulic press cross section die (Fig 5). Each specimen was hard pressed using pressure 100kg/cm2 for a time of 20 min, 30 min and 40 min. Then we get the green compacts. Cylindrical compacts of about 10mm diameter × 0.8mm thickness were compacted using the hydraulic press (Fig 7).

Fig 5: Die

Fig 6: Compaction using Hydraulic press

Compaction of powder metallurgy components was done by Hydraulic press (Fig 6). This press has the capability to actuate multiple levels to produce complex PM part geometries.

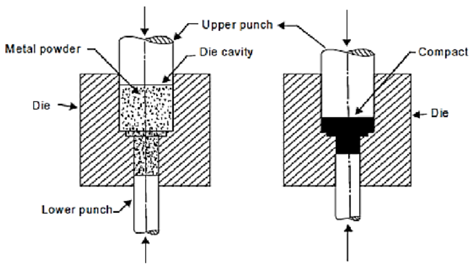

Fig 7: Compaction of powders

The green compacts of sample 1 and 2 was subjected to sintering at different sintering temperatures (462°C, 330°C, 198°C) for 45 minutes under a vacuum sintering furnace. And the particles are kept down for cooling. Heat treatment to bond the metallic particles, thereby increasing strength and hardness usually carried out at between 70% and 90% of the metal's melting point (absolute scale). Generally agreed among researchers that the primary driving force for sintering (Fig 8) is reduction of surface energy part shrinkage occurs during sintering due to pore size reduction.

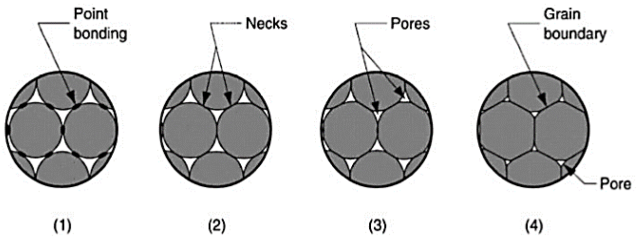

Fig 8: Sintering on a microscopic scale

The above figure shows that (1) particle bonding is initiated at contact points (2) contact points grow into "necks"; (3) the pores between particles are reduced in size; and (4) grain boundaries develop between particles in place of the necked regions.

With binders:-

In the next stage the samples were prepared by adding binders (Ethanol and Stearic acid) along with the Al-SiC composites. Composition is given in the Table 2.

Table 2 : Sample preparation with binders

Sample	Al	SiC	Binder (Ethanol + Stearic acid)
1	90%	8%	2%
2	80%	18%	2%

And each sample is divided into three sub samples for preparing three composite material each with a mass of 1.0gm. And is mixed well and these mixtures are first compacted at a load of 100Kg/cm^2 and compacted for 5 minutes and then sintered in a muffle furnace at 590°c for 45 minutes. The sintered samples were furnace cooled and they were taken outside the furnace and its various properties like hardness, density, apparent density, porosity, and microstructure were analyzed and SEM analysis of the samples was conducted.

4. RESULTS AND DISCUSSION

4.1Hardness Testing

The Brinell hardness testing machine is used to take hardness values in "HRB" From the test reports, say sample 2 (18% reinforced) has high hardness value than sample 1 (8% reinforced). Sample 2 contains high hardness because of using high percentage of reinforcement i.e. SiC. Different materials with different percentage of reinforcement shows different hardness values (Table 3).

Table 3: Hardness values

Sample	Sl. No.	Hardness Values		
Sample 1	1A	60	58	50
	1C	47	51	55
Sample 2	2A	50	45	53
	2B	63	50	72
	2C	71	65	67

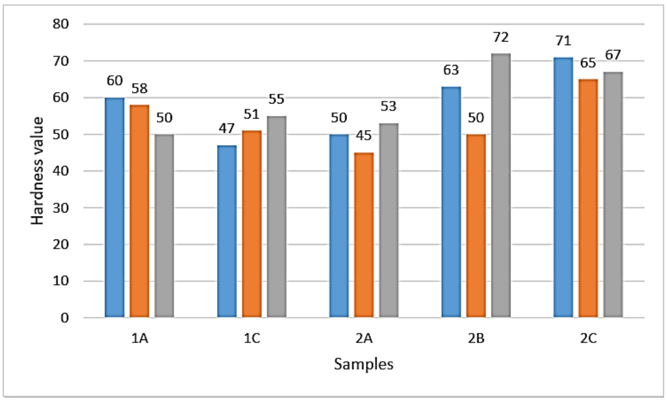

Chart 1: Hardness Vs Samples

4.2 Microstructure

The below figure (Fig 10) shows the scanning electron micrograph of the vacuum sintered Al-SiC composite with 8 and 18 wt. % of SiC at magnification of 500X and 1000X respectively. SiC particles are visible in the micrograph. The micrograph shows that the bonding has taken place between aluminum and SiC particles after vacuum sintering. Some amount of porosity is also visible in the micrographs. Particle microstructure reveals various phases, inclusions and internal porosity.

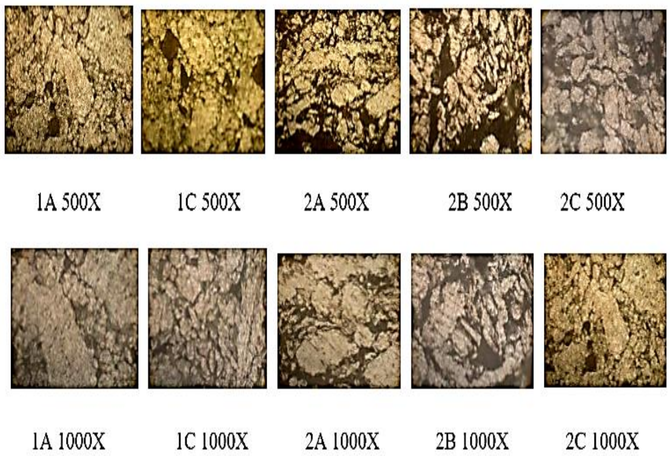

Fig 10: Microstructure of the samples

4.3 Density Testing

The theoretical density of the composites is calculated using the following relation. The theoretical density (ρth) of the samples are 0.171 g/cm2. The average actual density (ρexp) is found to be 1.404 g/cm2. The difference in density is attributed to presence of voids in the samples.

$$\textbf{Theoretical density, } \rho th = \frac{1}{\frac{Wal}{\rho al}+\frac{Wsic}{\rho sic}}$$

Where,

WAl - Weight fraction of matrix
WSiC – Weight fraction of reinforcement
ρth - Theoretical density
ρAl - Density of matrix
ρSiC – Density of reinforcement

4.4 Porosity Testing

Porosity is the Ratio of volume of the pores (empty spaces) in the powder in bulk volume. The porosity of isostatically pressed Al-SiC composites in sintered conditions were analyzed. Due to the increase (8 to 18%) in percentage of coarser component (SiC) porosity decreases. In sample 2 while adding more SiC particles the porosity decreases by 7%. For the prepared samples the porosity has been found to be decreasing.

$$\textbf{Porosity} = \frac{\rho th-\rho exp}{\rho th} \times 100$$

$$\textbf{Experimental density, } \rho exp = \frac{Mass}{Volume}$$

Where,
ρth – Theoretical density
ρexp – Experimental density

Table 4: Porosity values

Samples	Porosity values
Samples 1	91%
Samples 2	84%

4.5 SEM Analysis

The morphology of sintered samples having 8 and 18 weight percentage of silicon carbide after sintering was made with Scanning Electron Microscopy (Fig 11). In this sintered samples it is observed that silicon carbide particles enclosed by melted aluminium particles and also compared with 8% weight of silicon carbide more number of voids is observed in the samples of 18% weight of silicon carbide.

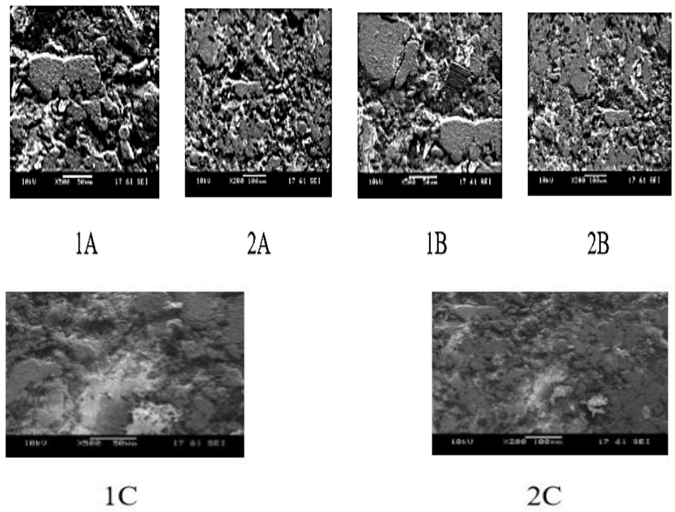

Fig 11: SEM analysis

5. CONCLUSION

Through this research work we had fabricated Al-SiC composites using Aluminium and Silicon Carbide metal powders. And the analysis of the mechanical and physical properties of the fabricated samples were done. From the test results it can be concluded as that the strength of the Al- SiC composite increases with the increase in reinforcement i.e SiC metal powder and hence the samples acquire high porosity, density and hardness. So, from the result and discussion we can conclude that: Sample 2 (18% Reinforced) has higher hardness than Sample 1 (8% Reinforced) because of high density. When reinforcement increases porosity decreases. Hardness value of sample 2 is greater than sample 1 density of sample 2 is greater than sample 1. From the detailed literature survey, it was concluded that, powder metallurgy route is the easiest route to synthesis the metal matrix composites with hard and soft reinforcements when compared with the other manufacturing. From the study it has been observed that composites synthesized through powder metallurgy method provided improved mechanical and tribological properties. The mechanical properties of the Al-SiC composites are improved as the silicon carbide particles obtain higher volume fractions in the composites.

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