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Effect of Compaction Pressure on Aluminium With 5% of Silicon Carbide Composite through Powder Metallurgy

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Abstract - This work is to investigate the compaction conditions of Aluminium Matrix Composite (AMC) by Powder metallurgy technique where pure aluminium powder is the base metal and weight percentage 5% SiC particulate is the reinforcement with material. The compaction pressure required for producing green compacts was optimized and relation between pressure and densities was established. The green density, sintered density, porosity, and micro Vickers hardness measurement was performed on fabricated Al-SiCp composites of 5% of SiC under different compacting pressure. From the experiment it is observed that 5% of SiC has an optimized pressure of 445 MPa, which was used for producing green compacts. The green density of Al-SiCp composites increases with increases in compaction pressure and porosity decrease with increases in compaction pressure.

***Key Words*:** Aluminium Matrix composite, Pure Aluminium Powder, Silicon carbide particulates (SiC), Powder Metallurgy, Sintering, Densities, Micro Vickers Hardness.

1. INTRODUCTION

The demand for light weight, high strength materials in technologically advanced industries supported by the advances in the field of material science. Due to their light-weight and high strength, aluminium based metal matrix composites (MMCs) have been extensively used for automotive, aerospace and military applications [1]. The reinforcement of silicon carbide (SiC), boron carbide (B4C) and aluminium oxide (Al2O3) in MMCs have significant advantage over conventional materials. The mechanical properties of the matrix can significantly improve by Nano-particle reinforcements which effectively promoting the particle hardening mechanisms than micron size particles [2]. The addition of lower volume fraction of nano-particles can significantly improved MMNCs properties and their performance at elevated temperatures [3]. Therefore Al nano SiC composites have seen most wide spread applications because of their good forming characteristics and the availability of comparatively low cost, high volume production methods. There are various methods available for fabrication of Al matrix nano-composites such as infiltration [4], squeeze casting [5], mechanical alloying [6], powder metallurgy [7], ball milling [8], and stir casting [9]. Powder metallurgy is one of the best technique because, it is relatively inexpensive, and offers a wide variety of material and processing conditions. Powder metallurgy (PM) is a widely used fabrication method for producing metal matrix composites. This involves three major stages: blending of the metal and ceramic powders, pressing or cold compaction, and sintering. The last two steps are often combined in hot pressing. Although PM allows producing components with complex geometries in bulk, there are some disadvantages associated with conventional powder metallurgy such as porosity and segregation of the reinforcing particles between the metal matrix particles. This often leads to degradation of the mechanical properties. These problems become more important when the difference in particle size between the reinforcement and the matrix alloy powders is large or when the volume fraction of the reinforcement is high [9].

2. EXPERIMENTAL PROCEDURE

In present work powder metallurgy technique was used for fabrication of metal matrix composites, 95% of Al and 5% of SiC in weight percentage where mechanically mixed by using Ball mill. The mixed powders were compacted in a closed die. Compaction of the mixed materials was carried out using a die for the required shape and size in a universal testing machine. Then the compacted sample is heated in a tubular furnace at controlled atmosphere, which is usually known as sintering. In this process, bonding of powder particles will takes place to form the final shape and size.

2.1 Mixing of powders

The Aluminum and SiC powders were weighed individually and mixtures were prepared. The Ball mill was run at 500 rpm for 10 minutes. The powder becomes hot during milling therefore it is allowed to cool for 10 minutes then it is taken out of the vials and stored in plastic containers.

2.2 Compacting

Compaction enables the forming of mixed metal powders into required shapes with sufficient strength to withstand untill sintering is completed. Here the compaction is done without the application of heat. In this process, loose powder is shaped in a cylindrical die as shown in Figure 1, using a mechanical or hydraulic press giving rise to densification as shown in figure 2. The mechanisms of densification depend on the material and structural characteristics of powder particles. In single die compaction, powders close to the punch and die walls experience much better force than in centre. This results in green density variation across the sample length. This non-uniformity can result in non-uniformity in properties of sintered part.

Fig-1: Cylindrical die

Fig-2: Universal Testing Machine (UTM)

2.3 Green Compact

The green compacts have been produced at different pressures using Universal Testing Machine (UTM).

Fig-3: Prepared Green compacts

The Figure 3 (a) shows the Green compacts prepared at 5%, of SiC at varying loads.

2.4 Sintering

It is the process of consolidating either loose aggregate of powder or a green compact of the desired composition under controlled conditions of temperature and time.

Fig-4: Tubular furnace

The green compact specimens were sintered using a tubular furnace as shown in Figure 4. The temperature was set to 600ºC with a heating rate of 5ºC/min. At this temperature, a holding time of 20 minutes was maintained. Then the specimens were allowed to cool in the furnace in order to reach the room temperature. The green compacts prepared by applying different loads have been sintered at 600˚C using tubular furnace as shown in figure 5.

Fig-5: Sintered Specimens

3. RESULTS AND DISCUSSION

3.1 Compacting Pressure for Green Compact

The combination of 5% of SiC in weight percentage is reinforced with pure aluminium to produce AMC. The green compacts have been produced by applying pressure, using UTM.

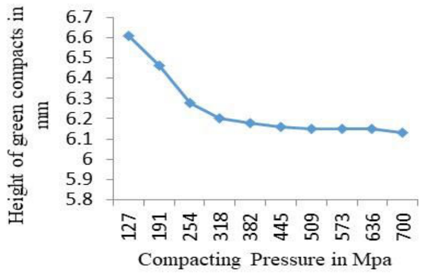

Fig-6.1: Compacting Pressure for Green Compact

The Figure 6.1 shows the optimization of compacting pressure for green compact which are produced at different pressure. It is observed that 5% of SiC has an optimized pressure of 445 MPa, which was used for producing further green compacts.

3.2 Green Density Measurement

The densities for the samples were measured by using Archimedes principle. Each cylindrical sample was weighed in air (Wa), then suspended in distilled water and weighed again (Ww). The experimental density was calculated using Eqn. (1).

$$\delta e = [Wa/(Wa - Ww)]^{*} \delta w \quad (1)$$

where δe is the experimental density, Wa is the mass of the cylindrical sample in air, Ww is the mass in distilled water, and δw is the density of distilled water. The sample was weighed using a balance with an accuracy of 0.005mg.

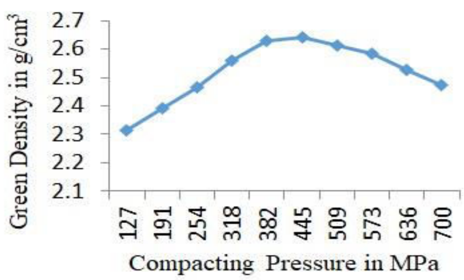

Fig- 6.2: Green Density of Samples at Different Pressure

From the Figure 6.2, it shows that at low compacting pressure the density of the green compact is low and on increasing the compacting pressure the density of green compacts also increases until it reaches the optimized compacting pressure. On further increasing the compacting pressure, the green density of samples decreases. For the optimized compacting pressure of 5% SiC reinforced with pure aluminium samples, the green density where found to be 2.642 g/cm3.

3.3 Sintered Density Measurement

The method used for the determination of sintered density is similar to those which have already been described for the determination of green density.

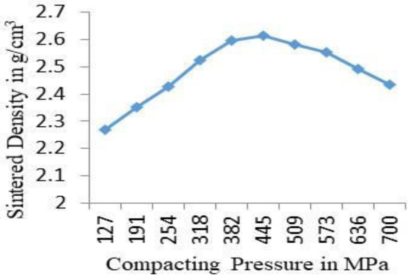

Fig- 6.3: Sintered Density of Samples at Different Pressure.

From the Figure 6.3, it shows that at low compacting pressure the density of the sintered samples is low and on increasing the compacting pressure the density of sintered samples also increases until it reaches the optimized compacting pressure. For the optimized compacting pressure of 5% SiC reinforced with pure aluminium samples, the sintered density was found to be 2.613 g/cm3.

3.4 Porosity Measurement

It is very difficult to produce P / M parts without any porosity remaining after sintering. The total porosity present in the sintered part may be calculated from the following relationship is shown in Eqn. (2)

$$P = 1 - \frac{P_p}{P_s} \qquad (2)$$

Where P = Frictional porosity, P_p = the density of the sintered sample and P_s = the density of slid material.

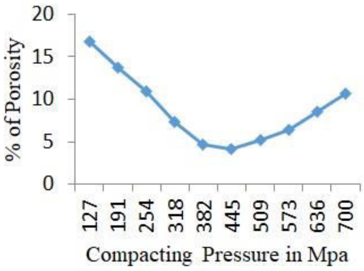

Fig-6.4: Percentage of Porosity in Sintered Samples

From the Figure 6.4, it shows that at low compacting pressure the porosity of the sintered samples is high and on increasing the compacting pressure the porosity of sintered samples also decreases until it reaches the optimized compacting pressure. When increased the porosity level of the composites the experimental densities were reduced and vice versa.

3.5 Micro Hardness Measurement

The micro Vickers hardness of powder metal Al-SiCp composites increases with increase in compacting pressure. This is because the mechanical alloying involves severe deformation of the aluminum powders and embedding of the SiC particles uniformly into the aluminum matrix.

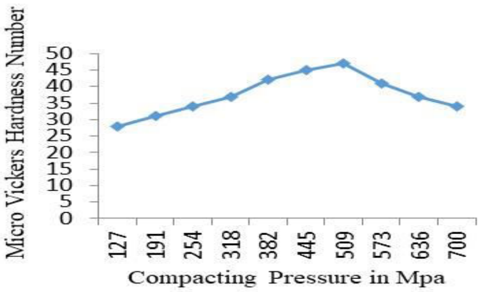

Fig-6.5: Micro Vickers Hardness Numbers of Sintered Samples.

The values shown in the graph are average of the five readings for each composition of the composite and the scatter of the actual hardness values about the average was limited to within ± 5 % of the average hardness values for the Al-SiCp composite samples. A relatively high variation in the hardness values measured at different positions on the samples made by PM process may be due to the presence of porosity.

4. CONCLUSION

The Powder metallurgy technique was used to produce the Al-SiCp composite where pure aluminium powder is the base metal and weight percentage of 5% SiC particulate is the reinforcement. From the experiment, it shows that the height of green compact decreases on increasing pressure and remains constant after attains the compacting pressure. The density of green compacts also increases until it reaches the optimized compacting pressure. The density of sintered samples also increases until it reaches the optimized compacting pressure. . When the porosity level of the composites increases the experimental densities were reduced and vice versa. The micro Vickers hardness of powder metal Al-SiCp composites increases until it reaches the optimized compacting pressure.

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