EFFECT OF SiC ADDITION ON Al-SiC POWDER COMPACTION BEHAVIOUR

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Abstract

Uniaxial powder compaction is the most typical form of consolidation process in powder metallurgy composites where the loose powders are compressed in a die cavity by the application of pressure to prepare a solid 'green' part of relatively high density that conforms to the shape of the cavity. The density level of the part to be produced is purely controlled by the parameter such as the amount of pressure applied; ram velocity, friction between the powder and the die surfaces. An attempt has been made to investigate experimentally the powder compaction of Al-SiC metal matrix composites. The level of density and stress enhancements are investigated for various percentage combination of second phase particles without changing the other conditions like friction, ram speed and pressure.

Keywords: Compaction, Aluminium, Silicon carbide, Compressibility, Relative density

I. INTRODUCTION

Metal powder compaction has become an essential method in the manufacturing industries for their reliable and high performances as well as its economic nature. For several applications, the properties required for the material also different and high temperature strength, wear and corrosion resistance etc., need to compensate. For these purposes as well as for the fine and uniform microstructures powder forming is the best solution among the available techniques. Unique properties can be reached for the powder consolidated material is possible and here the heterogeneity problems also can be eliminated.

Powder material behavior identification is very important to identify the desired shape of the product. The powder compaction process is nothing but making of compacted sample from loose powders. To achieve the perfect compaction process as well as to get the desired shape of the compacts without any negative pass out from the industry, for the above purposes the concentration must be provided to the powder shape, size, compaction speed, die and punch displacements controls. The main aim of the powder compaction simulation is to identify the density and the stress distributions over the powder compact. The design of well-defined experiments, the constitutive model, the material parameter identification and numerical boundary value problem solving techniques are essential for the realistic error free predictions. Some of the authors are used hoop strain to find the radial stress over the inside die surface. Here, the simulation used to predict the mechanical response of the compact along the process.

To analyze the powder behavior, various forming conditions of loading, friction, boundary geometry, etc. Most of the studies are based on the pressure, density as well as yield criteria to predict the compact behavior.

A number of constitutive models for the cold compaction of powders have been proposed by researchers (1). It has been shown that a 'two-mechanism-model', such as Drucker-Prager or Mohr-Coulomb and cap models, which exhibit pressure dependent behavior, can be useful for modeling the response of powder materials. The cone-cap model based on a density- dependent Drucker-Prager criterion and a non-centered ellipse is developed by Gu et al. (2). A double-surface plasticity model is developed by Lewis and Khoei (3) for non-linear behavior of powder materials in the concept of generalized plasticity formulation. Khoei and Bakhshiani (4) developed a density-dependent endochronic theory based on coupling between deviatoric and hydrostatic behavior to simulate the compaction process of powder material. Recently, single cap plasticity with an isotropic hardening rule was developed by Khoei and Azami (5) for powder materials. Further the cap plasticity model is extended to isotropic kinematic hardening behavior of powders (6).

II. SELECTION OF THE SYSTEM

Automobile, defense as well as space industries are mainly concentrating on Al and its alloys to reduce the weight of the components at the same time they need to improve the strength thro the secondary particle additions like SiC, Fe, TiC, etc.,. Al-SiC combined composites mainly used to increase the strength at low cost. Most of the applications are using upto 20-25% SiC with Al. In this study we taken the Aluminium, 5% SiC, 10% SiC and 15% SiC over the aluminium matrix for the study to find its compressibility. The density distribution gives the clear picture about the consolidation behavior of the Al and Al-SiC powder under cold compaction.

III. EXPERIMENTAL INVESTIGATION

A. Material characterization

Aluminium powder with an average particle size of -38 to +106 ìm mixed with silicon carbide powder of particle size +180 ìm have been used in this research work. Table 1 provides the characterization of Al and SiC powders. An weighed Al and Al-SiC powders were taken in a stainless steel pot with the powder mix to porcelain ball (10−15 mm diameter) ratio of 1:1 by weight. The pot was very securely tightened and then fixed on the pot mill for blending operation. The mill was operated for a period of 20 h to obtain a homogeneous powder blend. But, after an interval of 1 h, nearly 100 g of powder mix was taken out for the measurement of flow rate and apparent density and returned back to the pot as soon as the aforesaid measurements were carried out. Once the value obtained for flow rate and apparent density became quite consistent, the blending operation was terminated. Thus, the most ideal time for Al-SiC composition was found to be 19−20 h.

The powder materials where grained to the specific particle size with irregular morphology as seen in the SEM images of the loose powders shown in the fig. 1-2. The image of Al particle gives the clear picture about the suitability of the powder for the compaction thro its non circular in shape with high surface area to pick the secondary particles. The apparent relative density of the particle materials are 2.67size had been chosen as shown in table 1 and SiC taken as 180 mixture is about 40%.

Table 1. Sieve Analysis of aluminium powder

Sieve number (μm)	wt.% retained
+106	0.26
+90	2.54
+75	14.73
+63	17.58
+53	24.86
+45	12.33
+38	6.27
-38	21.42

Table 2. Characteristics of the powders.

characteristics	Quantity
Apparent Density	1.030 g cm?3
Flow rate, S (by Hall flow meter)	32.00 (50 g?1)
Compressibility at a pressure of 300MPa	2.344 g cm?3
SiC particle size	180 μm

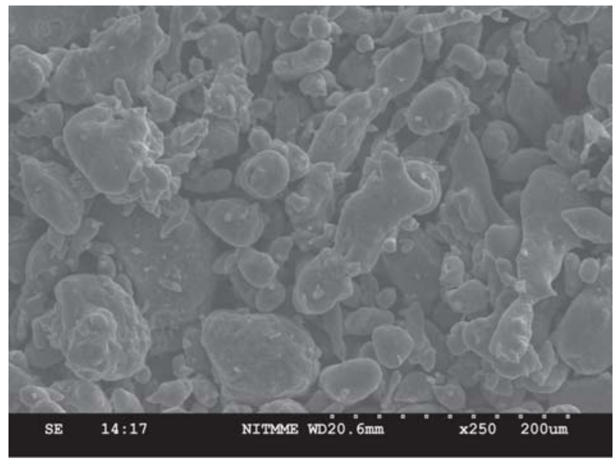


Fig. 1. SEM image of the Aluminium loose powder as used for the compaction .

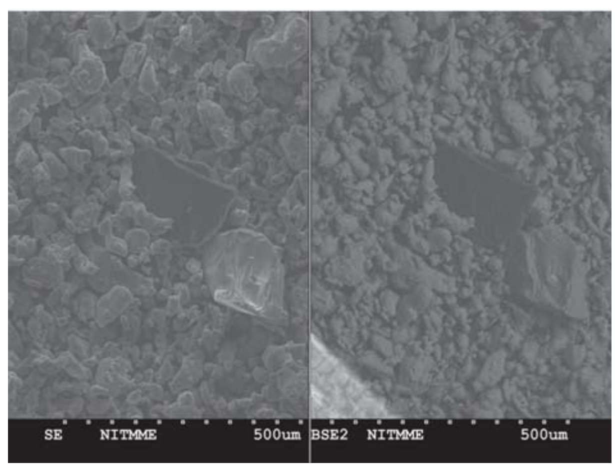


Fig. 2. SEM image of the blended Al-SiC powders (SE-Scanning electron image, BSE-Back scattered electron image).

B. Experiment proceedure

The loose powder mixtures of Al and Al-SiC was compacted through a cylindrical die and punch assembly (Fig. 3 (a)). A hydraulic press of 100 ton capacity was used (Fig. 3 (b)) for the compaction of powders. Cylindrical samples for investigations were prepared as follows: 50g of Al/Al-SiC powder was poured into the die cavity, then the Al/Al-SiC performs were produced by transferring the axial load from the testing machine to the powder inside the die via the punch.

Compacted cylindrical specimens where 26.11 mm diameter, height 30 to 32 mm. and compacted with the help of 100 tons capacity fully instrumented uniaxial die compaction hydraulic press. In the experimental set up the upper and lower punch movements are computed accurately at different loaded conditions. The fill height kept nearly constant for all the experiments. The axial displacement of the punch is keenly observed and recorded. The weight of the each specimen was measured thro the electronic weighing machine to calculate the relative density. The recorded results were used and drawn the relative density graphs with related to the punch movement as well as load given (Fig. 4 and 5). Specimens with bulk relative densities varying from 75% to 92% were compacted at pressures ranging from 410 MPa to 485 MPa. (Fig. 6 and 7).

(a)

(b)

Fig. 3. (a) and (b). Photographs of the die set which used for the compaction and the UTM

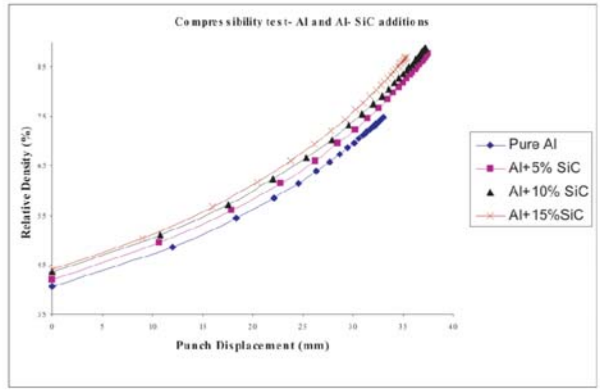


Fig. 4. Density-Displacement curves

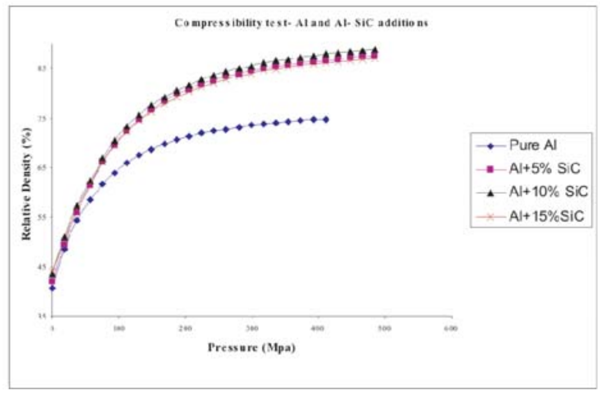


Fig. 5. Pressure-Density compaction curve

Fig. 6. Specimen samples of Al and Al-SiC samples before sintering.

The distribution of the primary secondary particle examination is also very important to get the idea about the mixing efficiency as well as the equalized particle distributions. Fig 7 and 8 gives clear picture about these examinations. These macroscopic views give better picture over the distribution of secondary particles and confirming non-accumulation of the secondary particles. So the perfect mixing of metal matrix composite is ensured thro this study.

Many authors were doing the microstructure examinations over the composites after the sintering only. But here the microstructural views of the non-sintered composite also important for our consolidation behavior studies.

In order to characterize the SiC distribution, the sample surface was polished and etched with the classical Keller reagent (0.05%HF-1.5%HCl- 2.5%HNO3 -H20; reaction time 5s). The distribution of SiC particles in the composites was determined by optical microscopy using an Olympus B061 optical microscope. Finding the grain shapes, orientations and distribution, this is not an easy task in the case of composite materials. During compaction of MMCs, large deformations are imposed on the material and the distribution of the presence of non-shearable hard particles. As a consequence, SiC fraction influences the distribution pattern of the material.

Fig. 9 and 10 gives the microscopic examination of the Al and Al-SiC respectively. Here we are able to look out the voids and secondary particles for the evaluations. SiC particles are placed perfectly and neighborhood Al particles are capturing SiC perfectly. So we can come to the conclusion that the consolidation of the composite was good. With the smaller Al particle size, the SiC particles were "pushed" and packed in the interstices between the smaller Al particles, yielding a more clustered macrostructure.

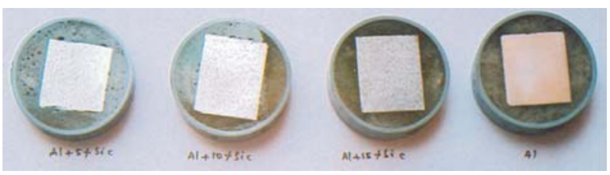
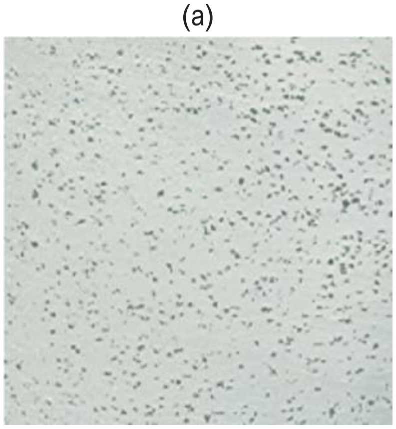


Fig. 7. Photograph of the polished specimen for the micro-structural studies.

(a)



(b)

(c)

Fig. 8. (a) Al + 5% SiC specimen- SiC particle size 180 microns- macrostructure (b) Al + 10% SiC specimen- SiC particle size 180 microns- macrostructure (c) Al + 15% SiC specimen- SiC particle size 180 microns- macrostructure.

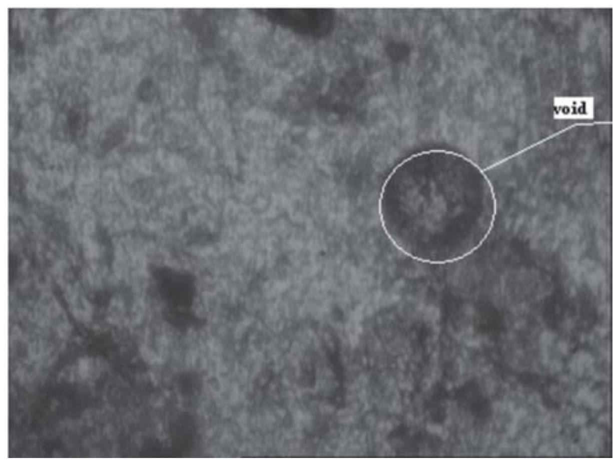
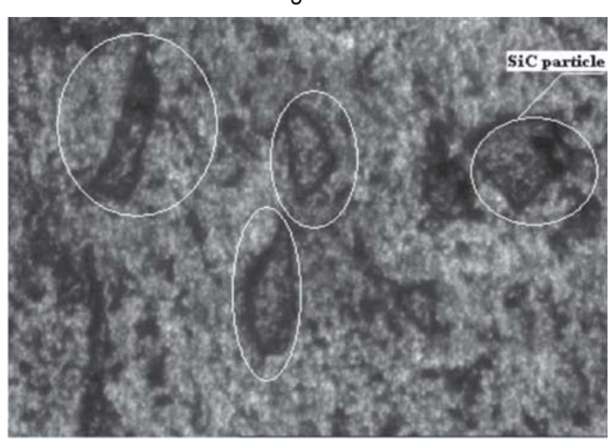


Fig. 9. Microstructure of Al compact before sintering at 400 magnification.



. 10. Microstructure of Al and SiC compact before sintering at 100 magnification level

IV. CONCLUSION

The powder compaction process experimentation is critical due to non availability of proper machines, to include its nonlinear behavior. Here experimental arrangements had been made to get accurate measurements and plotted the graphs. From this experiment we were observed that the lower density compacts are having high density behavior. The effect of friction on the density gradients behavior is predicted by the practical one. Higher friction coefficient leads to larger pressure difference along the die wall and leads to higher density gradient.

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