https://dx.doi.org/10.24001/ijcmes.3.6.1 ISSN: 2455-5304

Effect of Deformation on the properties of Al-4Cu-0.5Mg-2SiC Powder Metallurgy Composite

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Abstract— *The increasing demand for efficient materials in the automotive industry gave a great scope for development of metal matrix composites. In the present study, Al-4Cu-0.5Mg-2SiC composite is prepared through powder metallurgy route. The powder mixture is compacted and pressure less sintered at 550ºC for 1 hour in control atmosphere (Argon gas). The relative density of the sintered preforms is found to be 90% approximately. Sintered preforms are used as workpiece materials for deformation study at different temperatures in order to find the effect of temperature on the densification behavior. The stress strain curve is obtained during the deformation process. The effect of deformation on the hardness of the composite is studied.*
Keywords— Deformation, Workpiece, Sintering, Powder metallurgy.

I. INTRODUCTION

Aluminium being durable, lightweight, ductile, malleable metal and nonmagnetic gives a great scope over a wide range of applications. Aluminium is known for its low density and its ability to resist corrosion. Aluminium has about one-third the density and stiffness of steel which made aluminium a replacement in various applications. Aluminium and its alloys can be machined, cast, drawn and extruded. Alloying and composite preparation with the combination of aluminium metal improved the material properties for wide range of applications [1].

Aluminium metal matrix composites are gaining great scope for applications within aerospace, defense, automotive industries and various other fields. The continuous increase in demand for light weight, fuel efficiency and comfort in auto industries lead to the development of advanced materials such as metal matrix composites (MMCs). Aluminium MMCs have a great application potential in automotive engineering components i.e, braking systems, piston rods, piston pins, pistons, structural frames, valve spring caps, brake discs, disc brake caliper, brake pads, cardan shaft, engine heads etc. Axle tubes, reinforcements, blade, gear box casing, turbine, fan and compressor blades are some other significant applications in military and civil aviation for Aluminium MMCs. MMCs and alloys are extensively used over metals as they offer higher specific properties (properties/unit weight) of strength, stiffness, higher specific modulus, thermal stability, tribological properties and various other mechanical properties which enhances the product performance [1, 2].

Powder metallurgical (PM) components have better properties than components produced through conventional manufacturing processes. Production through powder metallurgy process is rapid, economical suitable for high volume production with less contamination of parts from powders. Products with high strength, wear resistance, homogenous composition with close dimensional tolerance are possible with this route [3].

PM comprises of powder mixing or blending for homogenous mixture, compaction followed by pressure less sintering. The density levels obtained after sintering are always much less than the theoretical densities. This is because of the difficulty in elimination of pores completely. Presence of such microspores is always a hinders the performance of the material. This may be because the pores may act as the sites of origination of cracks during operating conditions. Elimination of these microspores in sintered components demands for subsequent deformation processing of preforms such as forging, extrusion etc. Among these processes forging is economic and effective method to improve density with enhanced mechanical properties with homogenous structure [4].

Some limitations during hot working are oxidation, surface decarburization of billets, excess die wear, poor surface finish and induction of thermal stresses. Because of all these cold working has been gaining great importance in recent times [5-7]. In the present study the deformation study of Al-4Cu-0.5Mg-2%SiC composite is done at different temperatures. This is to evaluate the effect of temperature on deformation and the same on the hardness of the composite.

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II. EXPERIMENTAL PROCEDURE

The Al, Cu, mg and SiC powder particles are used as precursors for the preparation of composites. Powder compaction is done by using 25 Ton capacity manual pellet press. All the compositions are milled for sufficient time period to ensure homogeneous composition. Al-composite mixture is compacted in 20 mm diameter high strength tool steel die, where the punch moves freely in axial direction. The prepared green preforms are placed in stainless steel crucible which is placed inside the tube furnace. The same is then subjected to a heating cycle in the presence of continuous flowing argon gas. Preforms are sintered in a tubular furnace (Swamequip, Chennai, India). During sintering, the green compacts are heated up to 550°C at the rate 10°C/min and allowed to sinter at this temperature for 1 hour prior to furnace cooling. Flow of argon gas is maintained at a constant rate during the sintering process till the composite preforms reached room temperature. The Vickers hardness of sintered and strained performs are determined on micro Vickers hardness tester (SCHIMADZU).A load of 500g and 15 seconds of dwell time is used for each micro hardness test. An average of 6 readings for each sample are reported in the present study.

The sintered composite preforms of different compositions and aspect ratios are used as raw materials for deformation study. Six samples of each composition and each aspect ratio are used for deformation. This is to evaluate the effect of compositional changes on the deformation behavior during the process of deformation. Deformation process is progressed upto an evolution of visual crack on the bulge, which is considered to be finally densified preform. To evaluate the effect of temperature, temperature during deformation process is varied. Deformation of composite preforms are performed in a 40Ton hydraulic press(SVS hydraulics, Hyderabad, India) at three different temperatures, 25°C (room temperature), 400°C and 500°C. The dimensional measurements are noted down after each deformation step to calculate the strain behavior.

III. RESULTS AND DISCUSSION

The hardness of the preforms are shown in fig. 1 and are measured at 500g load for 15 seconds of dwell time. Hardness of pure Al sintered preform is measured to be 25.6Hv. The effect of alloying with the addition of 4wt% Cu to the Al matrix the hardness of Al-4Cu sintered preform resulted to be 36Hv which recorded to have an increase of 40% when compared to pure Al preform. This increase in the hardness is because of the secondary phase precipitates Al_2Cu phase. Precipitation hardening is the cause for the increase in the hardness. Further addition of 0.5wt% Magnesium further to the Al-4Cu matrix increased the hardness to 49Hv which is about an increase of 100% when compared to pure Al preform. The hardness of the Al-4Cu-0.5Mg-2% SiC are 49.9Hv.

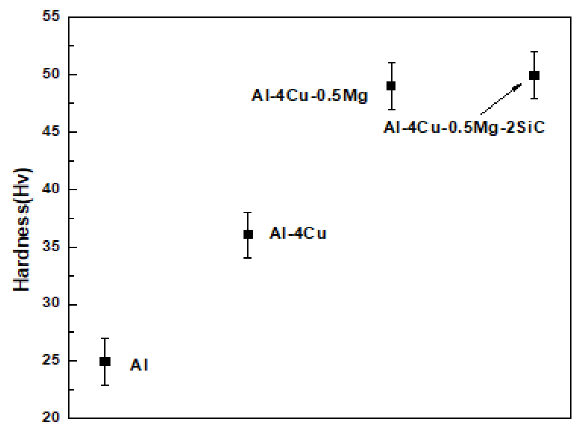

Fig. 1: Hardness of the alloy and composites

The optical micrograph of the sintered composite if shown in the fig. 2. The image shows that SiC particles distributed along the grain boundaries. The grain size of the composite varies between 10-20µm. The pores are along the grain boundaries which coexist with the SiC particles. The relationship between the stresses applied and the strains measured are shown in the fig. 3 at three different temperatures of deformation. Different temperatures are used during deformation process to evaluate the effect of temperature on deformation. Composites deformed at 25 °C required higher stress levels than composites deformed at elevated temperatures. This is due to the basic phenomena effect that cold working requires high load to deform, while working at high temperatures the material are require lower stress levels. When compared to composites deformed at 25 °C composites deformed at 400 and 500 °C are deformed at lower stress levels. The strains measured for the composites deformed at higher temperatures are higher than the composites deformed at 25 °C.

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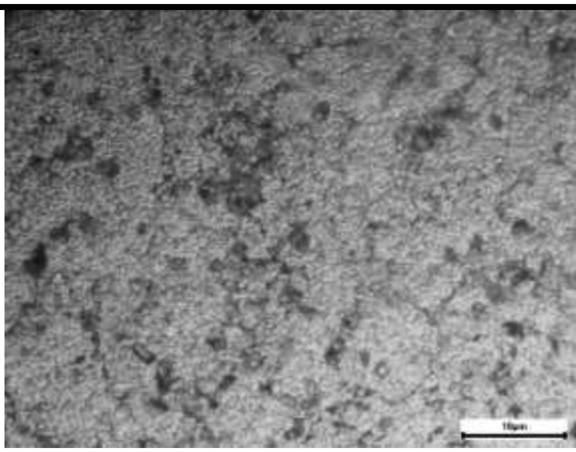

Fig. 2: Optical microscope image of the composite

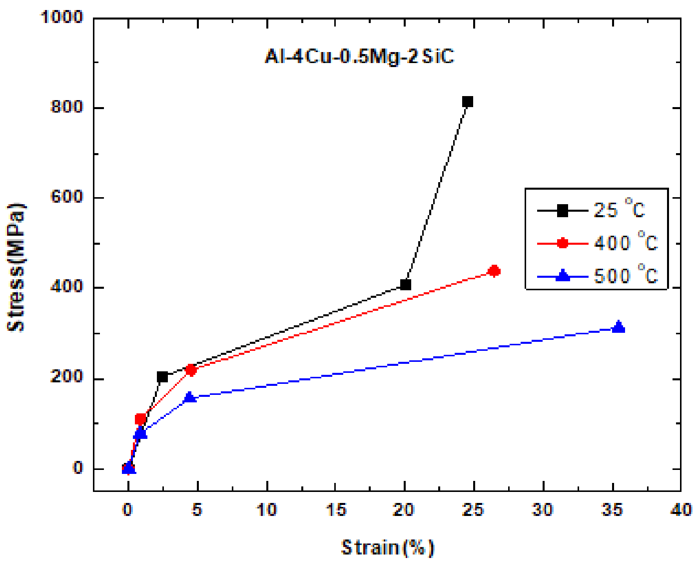

Fig. 3: Stress strain curve of composite deformed at different temperatures

The hardness of the composite increased with the extent of deformation. In the present study, the extent of deformation is the measured strain after deformation process. The composites deformed at 25 ºC appeared to have high hardness than the composites deformed at higher temperatures. This is because of the recrystallization and the increase in the ductility of the composites upon working at high temperatures. Inspite of high extent of strain the composites deformed at 400 and 500 ºC appeared to have low hardness when compared to composites deformed at 25 ºC.

IV. CONCLUSIONS

Based on the above work the following conclusions are drawn,

- The hardness of the composite increased with a alloying and with the addition of SiC particles.
- The SiC particles added to the alloy matrix are along the grain boundaries in the sintered composite.
- The composites deformed at lower temperature requires higher loads to deform than the composites deformed at higher temperatures.
- The composites deformed at lower temperatures appeared to have high hardness upon comparison with composites deformed at high temperatures.

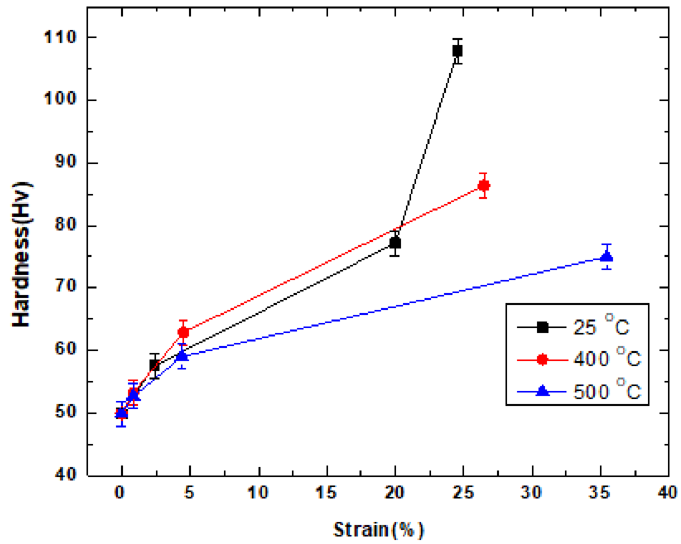

Fig. 4: Effect of strain on the hardness of the composite during deformation

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