EFFECT OF SINTERING ENVIRONMENT TO THE PHYSICAL PROPERTIES OF AL/CALCINED DOLOMITE COMPOSITE

B. Johar, N.A. Rejab, N.K.Su, M.S.Talib, N.M.S.Adzali, M.H.Musa, A.R.Mohamed.
School of Materials Engineering, Universiti Malaysia Perlis, Jejawi, 02600 Arau, Perlis
e-mail: banjuraizah@unimap.edu.my

Abstract
Composites of pure aluminum with calcined dolomite powders of <65□m in size were prepared by mechanical milling. Fabrication involves the mixing of reinforcement particles with the metallic powder followed by consolidation and sintering processes. The effect of two different 'types of sintering environment to physical properties of Al/calcined dolomite composites will be presented in this paper which are nitrogen and argon gas. Materials were characterized through density, percentage of dimensional changes and hardness properties.

Keywords: Al/calcined dolomite, MMCs, powder metallurgy, sintering atmosphere.

Introduction

Aluminum (Al)-based metal matrix composites (MMCs) make up a distinct category of advanced engineering materials that provide unique advantages over conventional Al alloys. With the development of new forming methods and the use of low cost particulate material, the use of these composites is increasing in a wide variety of industries. In general, these materials exhibit good wear and erosion resistance, as well as higher stiffness, hardness and strength at a lower density when compared to the unreinforced matrix material [1]. Sintering is the process whereby green compacts are heated in a controlled atmosphere furnace to a temperature below the melting point but sufficiently high to allow bonding (fusion) of the individual particles [2]. Sintering of metals is typically conducted in a controlled atmosphere. The role of the atmosphere can include the sweeping of volatile reaction products from the furnace, the prevention of undesirable reactions and the enabling of desirable reactions [3]. Calcined dolomite produced from the dolomite, consist of a phase mixture of lime (CaO) and periclase (MgO). They have extremely high melting points, as the eutectic for the CaO-MgO binary system occurs at 2370 °C [4].

Materials and Experimental

Calcined dolomite about (< 65□m) and pure aluminium (26.18) powders are employed to process the composites.The powders were weighed and the composition as stated in table 1. The components were initially compacted at cold state in a die with the diameter of Ø12 mm with a capacity of 250 MPa. The sample then was sintered into different types of environment (Argon and Nitrogen) at 610°C for 6 hours using tube furnace. The sample then was cooled in furnace.

Table 1: Composition of Al/calcined dolomite composite

Samples name	Al (%weight)	Calcined dolomite (%weight)
A1CD	100	0
A1CD10	90	10
Al CD20	80	20
ALCD30	70	30

Percent of dimension (diameter and height) and weight changes for green compact and sintered sample was measured. It was measured by calculate the differences between final data and initial data and dividing the results with initial data. The results were presented in percentage. Average from 6 samples was taken to plot the graph. Prior to sintering and after sintering, the density of each compact and sintered sample was calculated by measuring the dry weight and volume. Density and porosity of sample was also measured and calculated using Archimedes principle as describe in ASTM standard C20-97. In this technique, the final density of materials was determined by measuring the difference in weight of a specimen when measured in air and in distilled water at room tempreature. The hardness of the composite was measured using a Vickers's microhardness tester at an applied load of 10N for an indentation period of 10 to 15 seconds. At least nine hardness values from different locations well distributed on the sample surface were measured for each sample in order to eliminate possible segregation efforts and the average of the measurement was considered to be microhardness of the sample.

Results and discussion

Dimension and weight change

Monitoring the sintering process by measuring percent changes in dimension are essential not only to determine the accuracy of manufacturing product but also to predict degree of consolidation. The relationship between both sample sintered in nitrogen and argon atmosphere indicates an expansion in diameter and height. However sample sintered in nitrogen shows upward trend as a function of weight percent of calcined dolomite as shown in Figure 1. This phenomenon is in contrast with the sample sintered in argon atmosphere as shown in Figure 2 where the dimension shows downward trend with the increment of weight percent of reinforcement although most of the dimension expand after sintering.

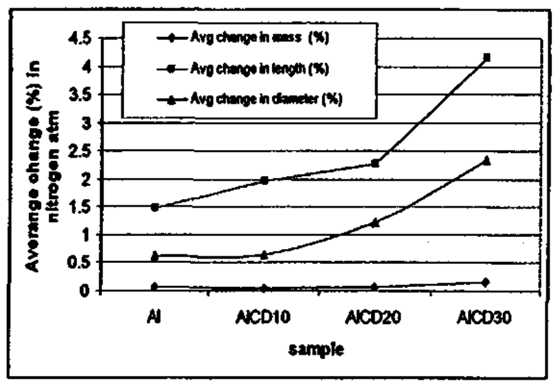

Figure 1: Average dimensional and mass changes of sample after sintered in nitrogen atmosphere in percent

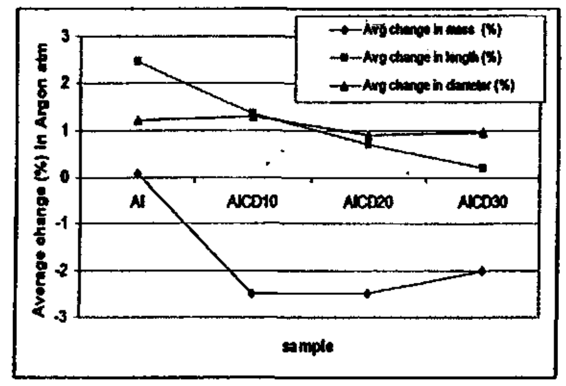

Figure 2: Average dimensional and mass changes of sample after sintered in argon atmosphere in percent

There was a slightly difference in average weight of sample sintered in nitrogen atmosphere where average percent change in mass increased with filler content. Unlike sample sintered in nitrogen, sample sintered in argon shows negative value which means that there was little lossed in weight during sintering causing weight after sintering process less than green compact sample. This result is in contrast with finding from scaffer et. al, where they find that both the argon and nitrogen sintered samples gain weight during sintering the Al alloy produce by powder metallurgy route [5]. The incorporation of 10 wt% of calcined dolomite powders into Al matrix cause the sample shrinkages after sintered. However the increment of calcined dolomite tends to increase me weight of sintered samples.

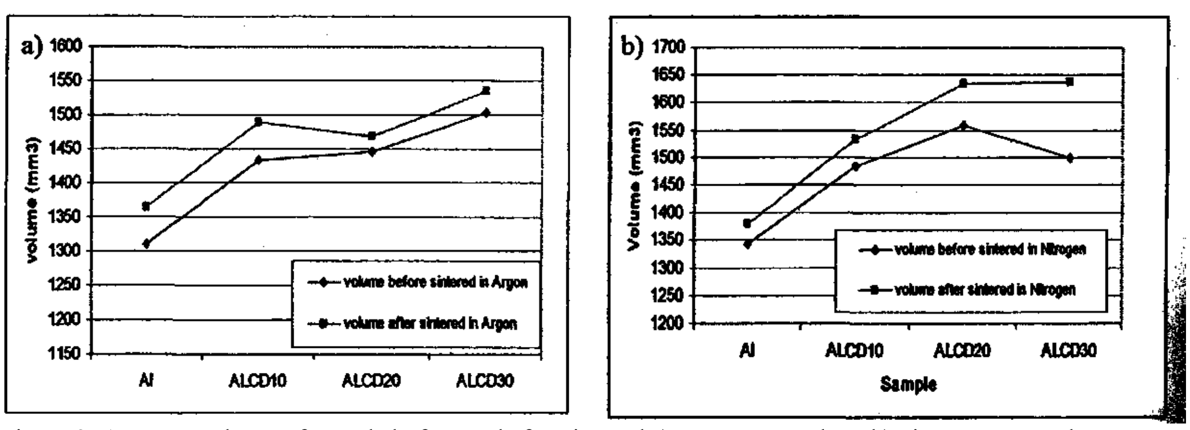

Figure 3: Average volume of sample before and after sintered a) argon atmosphere b) nitrogen atmosphere

Figure 4 shows the effect of sintering gas on average density of sample sintered in both atmospheres calculate by measuring the dry weight and volume. This figure also shows the same trends for both environments which indicate that the density of sintered sample depends on the density of green compact. Average density of green compact is higher than average density of sintered sample. Sample sintered in argon atmosphere shows average density decreased as a function of calcined dolomite content. Sample sintered in nitrogen also shows the same trend but up to 20 wt% calcined dolomite. However at 30 wt% calcined dolomite, the average density tends to increase.

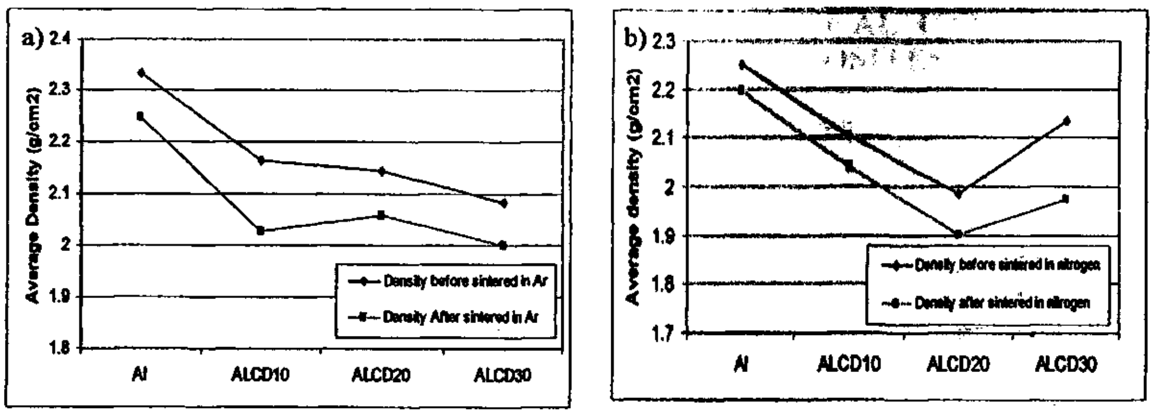

Figure 4: Average density of sample before and after sintered **a)** Argon atmosphere b) Nitrogen atmosphere calculate by measuring the dry weight and dimensions

Density and porosity

Density result measured using above method is parallel and have the same trends with the density results measured by Archimedes principle. However the average density calculated by Archimedes principle is higher compared above method. This is because the density results obtain by above method doesn't take consideration on open pore present in the sample.

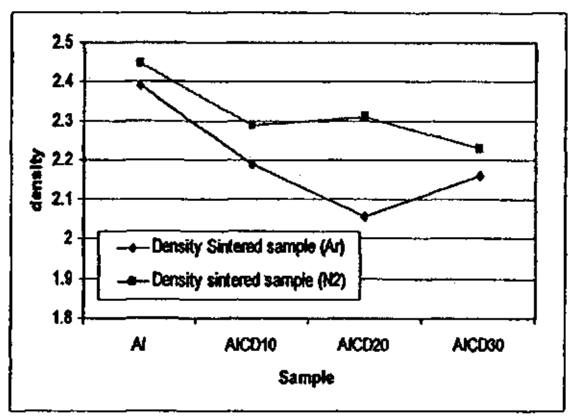

Figure 5: Comparison in average density between sample sintered in Nitrogen atmosphere and sample sintered in Argon measured using Archimedes principle

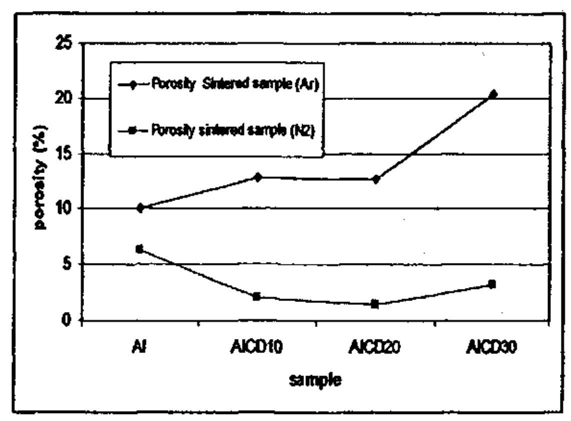

Figure 6: Comparison in average porosity beteen sample sintered in Nitrogen atmosphere and sample sintered in Argon

Hardness

Figure 7 indicates micro hardness vickers result for sample sintered in nirogen and argon atmosphere. The graphs show mat the microhardness rised steadily with weight % of filler for samples sintere in both environment. Result doesn't indicates significant or major differences between the environment. However sample sintered in nitrogen gas has higher hardness except for sample with 20 wt% filler compared to sample sintered in argon gas. Nitrogen sample has lower percent porosity compared to argon sample. Furthermore sample sintered in nitrogen has higher density providing better densification compared to argon sample. Figure 8 shows comparison of microhardness vickers value for A1CD10 which was sintered in argon, nitrogen and air atmospheres. The histograms represent that sample sintered in N_2 produced better hardness followed by Ar and air.

The difference between argon and nitrogen atmospheres on pore evolution is readily apparent in Figure 9. Bom samples have a similar pore structure when the sintering temperature is first attained. However sample sintered in argon gas shows high porosity compared to sample sintered in nitrogen. Besides porosity, there is very little difference in the other microstructural features between the nitrogen and argon sintered samples.

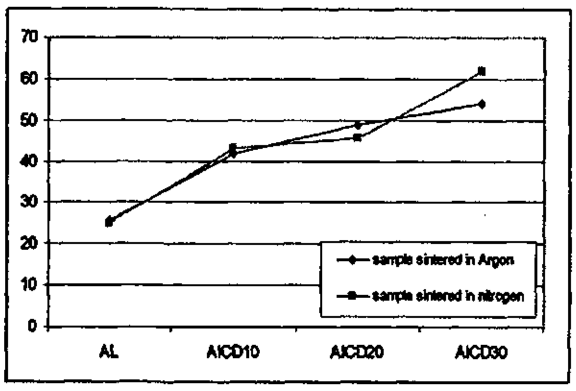

Figure 7: Difference in microhardness between sample sintered in Nitrogen atmosphere and sample sintered in Argon

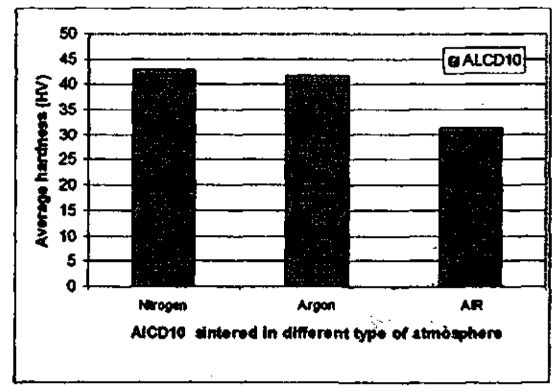

Figure 8: Average hardness HV for sample A1CD10 sintered in 3 different type of atmosphere.

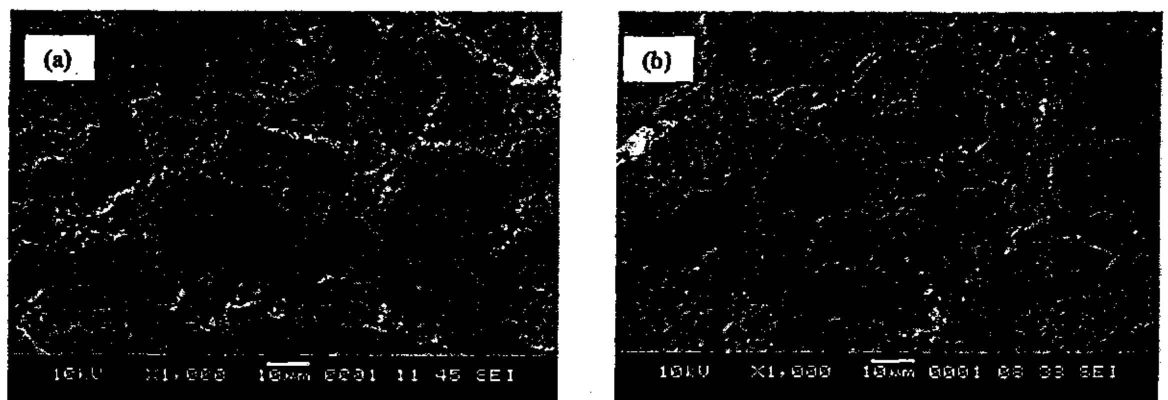

Figure 9: Micrograph of composite Al with 30 wt% of calcined dolomite sintered in (a) nitrogen and (b) argon Atmosphere

Conclusion

Sample sintered in nitrogen gives nearly linear expansion in dimension with the increment of calcined dolomite content in contrast with sample sintered in argon gas. Although after sintering in nitrogen it gain weight unlike the other sample, but the density was higher than the sample in argon. Furthermore it gives lower porosity and high densification compared to sample sintered in argon gas. Lower porosity and better densification in nitrogen atmosphere provide better hardness for aluminum reinforced calcined dolomite sintered in nitrogen compared to sample sintered in argon. This indicates that the atmosphere plays an active role in the sintering of aluminium and that it is not simply inert.

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