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Study on the Properties of Al-Al_2O_3 Composite Using Synthesized Alumina from Sol Gel Technique

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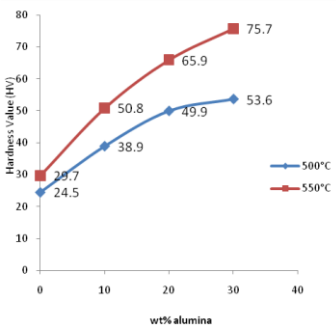
Graphical abstract



Abstract

Alumina reinforced aluminum is one of metal matrix composite (MMC) systems that can maintain its properties although at high temperature. Among various processes to produce MMC, powder metallurgy is the best method because of its efficiency dispersion of fine alumina particles. In this study, alumina powders were synthesized through sol gel method which is known as one of the ideal method to produce good properties of powders. The performances of synthesized alumina powders were then observed through the fabrication of composite. The percentage of alumina (0wt%, 10wt%, 20wt% and 30wt %) and sintering temperature (500°C and 550°C) were varied in order to observed their effects on the produced composite. Result shows that by increasing the percentage of alumina and sintering temperature, mechanical properties were increased where 30wt% alumina and 550°C sintering temperature give the optimum results. Comparison study by using 30wt% alumina and 550°C sintering temperature on the composite using synthesize and commercial alumina shows similar/comparable properties of composite.

Keywords: Ceramics; composite; alumina; sol gel; aluminum

Abstrak

Aluminium diperkuat alumina merupakan salah satu sistem komposit matrik logam (KML) yang dapat mengekalkan sifat-sifatnya walaupun pada suhu tinggi. Dari pelbagai proses untuk menghasilkan KML, metalurgi serbuk merupakan kaedah yang terbaik kerana penyerakan partikel-partikel alumina halus dengan cekap. Dalam kajian ini, serbuk alumina disintesis melalui kaedah sol gel yang diketahui sebagai satu kaedah yang baik untuk menghasilkan serbuk-serbuk dengan sifat yang baik. Keupayaan serbuk alumina yang disintesis kemudiannya dikenalpasti melalui penghasilan komposit. Peratus alumina (0% berat, 10% berat, 20% berat dan 30% berat) dan suhu pensinteran (500°C and 550°C) dipelbagaikan untuk mengenalpasti kesannya terhadap komposit yang dihasilkan. Keputusan menunjukkan dengan peningkatan peratus alumina dan suhu pensinteran, sifat-sifat mekanikal telah meningkat di mana 30% berat dan 550°C suhu pensinteran telah memberikan keputusan yang optima. Kajian perbandingan menggunakan 30% berat dan 550°C suhu pensinteran ke atas komposit menggunakan alumina yang disintesis dan alumina komersial menunjukkkan sifat-sifat komposit yang sama/sebanding.

Kata kunci: Seramik; komposit; alumina; sol gel; aluminium

1.0 INTRODUCTION

The need for composite materials has become a necessity for modern technology, due to the improved physical and mechanical properties. Metal matrix composites (MMC) have been developed in recent years, among which aluminum matrix composite have found various applications in the industry. This is due to its low density, high toughness and corrosion resistance where their major applications include aerospace, military and car industries. However, the drawback for these composites is their high production cost. It has been well established that the addition of ceramic particles to aluminum improves its strength, wear resistance. Alumina after SiC particles has made many applications in industry. Compared to SiC particles, alumina has shown better thermal stability at high temperature since undesirable phase are not produced in such materials [1].

Among various methods to fabricate MMCs, powder metallurgy method was chosen due to its advantages compared to the other method. Powder metallurgy parts can be mass produced to net shape or near net shape, eliminating or reducing the need for subsequent machining. This process also waste very little material which is about 97% of the starting powders is converted to product. Beside that through this method, products that were produced can be made with a specified level of porosity, to produce porous metal parts [2].

In this study the performance of alumina synthesized via sol gel method were observed by producing alumina-aluminum composite through powder metallurgy method where properties

obtained were compared to composite system using commercial alumina.

2.0 MATERIALS AND METHODS

Alumina powders were produced by using sol gel method. Alumina sols were prepared using aluminium isopropoxide, ALP (Merck, German) and 0.5M aluminium nitrate nonahydrate, ALN (Merck, German) aqueous sol. As-prepared sol were then undergone evaporation and drying followed by calcination at 1200 °C. Alumina powders obtained were then mixed with aluminum powder 99.9% purity (Merck, German) to produce Al-Al_2O_3 composite system using various composition of alumina (0wt%, 10wt%, 20wt% and 30wt %). The mixture were then pressed at 273MPa and sintered at two different temperatures (500 and 550 °C) to study their effect on the produced composite. Alumina powders produced were characterized using XRD and mechanical properties of the composite produced were characterized using Vickers Hardness test and wear test.

3.0 RESULTS AND DISCUSSION

XRD analysis was done to observe phases that exist in produced powders. XRD result for synthesize alumina (Figure 1) shows that only α-alumina or corundum phase (ICDD: 00-010-00173) with hexagonal structure was exist. This is strong evidence that synthesizes alumina via sol-gel method using alkoxide raw materials and calcined at temperature 1200°C produced the α-alumina phase. Similar result was obtained by other researchers which obtained α-alumina phase 1200°C [3].

Vickers hardness results of the composite produced were tabulated in Table 1 and show in Figure 2. It shows that when percentage of alumina increases hardness value also increases. It also shows that, temperature 550°C gives higher hardness value compared to 500°C.

Table 1 Hardness value for Al-Al_2O_3 composite sintered at 500°C and 550°C

%wt Al_2O_3	Micro Vickers Hardness Value (HV)	
	500°C	550°C
0	24.5	29.7
10	38.9	50.8
20	49.9	65.9
30	53.6	75.7

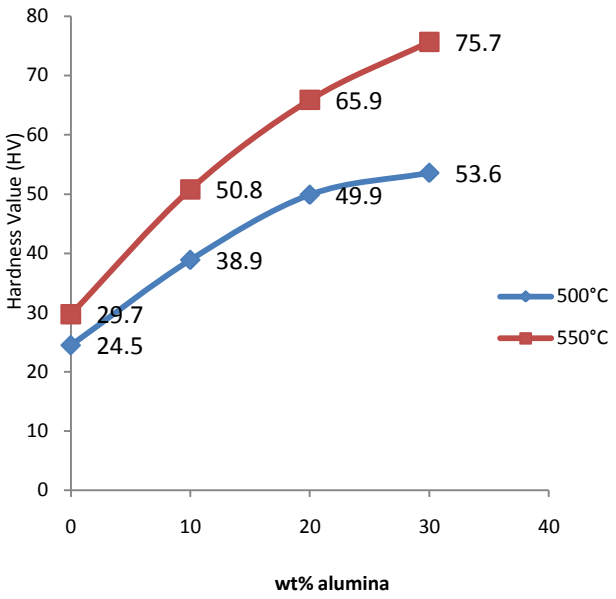


Figure 2 Hardness value of Al-Al_2O_3 composite sintered at 500°C and 550°C

The increasing of hardness value due to increasing of alumina percentage is explained by the rule of mixture that applied to composite materials as shown in equation 1 [1, 4].

$$H_c = H_m f_m + H_r f_r \qquad \text{Equation 1}$$

H_c, H_m and H_r, show the hardness of composite, matrix and reinforcement. The relationship shows that when percentage of alumina increases, hardness also increases. It was observed from these studies that by increasing in percentage of alumina from 10%wt to 20%wt, hardness increased from 38.9HV to 49.9HV.

According to Abouelmagd [6], the reinforcement increases the hardness value since they are inherently harder than matrix. As the percentage of alumina introduced to the matrix increased, the distance apart the reinforcement particles decrease. Hence the stress required for the dislocations to pass the alumina is increased, leading to the higher strength of composite materials [1].

From Figure 2, it shows that hardness value is higher at sintering temperature 550°C compared to 500°C. This is evidence that sintering temperature influenced the hardness of the composite. The increasing of the hardness may be due to the activated sintering mechanisms leading to a reduced porosity by greater mass transportation at high sintering temperature [1].

In addition, results for wear test (Table 2 and Figure 3) show that increasing in percentage of alumina and sintering temperature reduced the weight loss of Al-Al_2O_3 composite. This is again strong evidence that, by increasing of alumina percentage and sintering temperature leads to improve the mechanical properties in term of wear resistance.

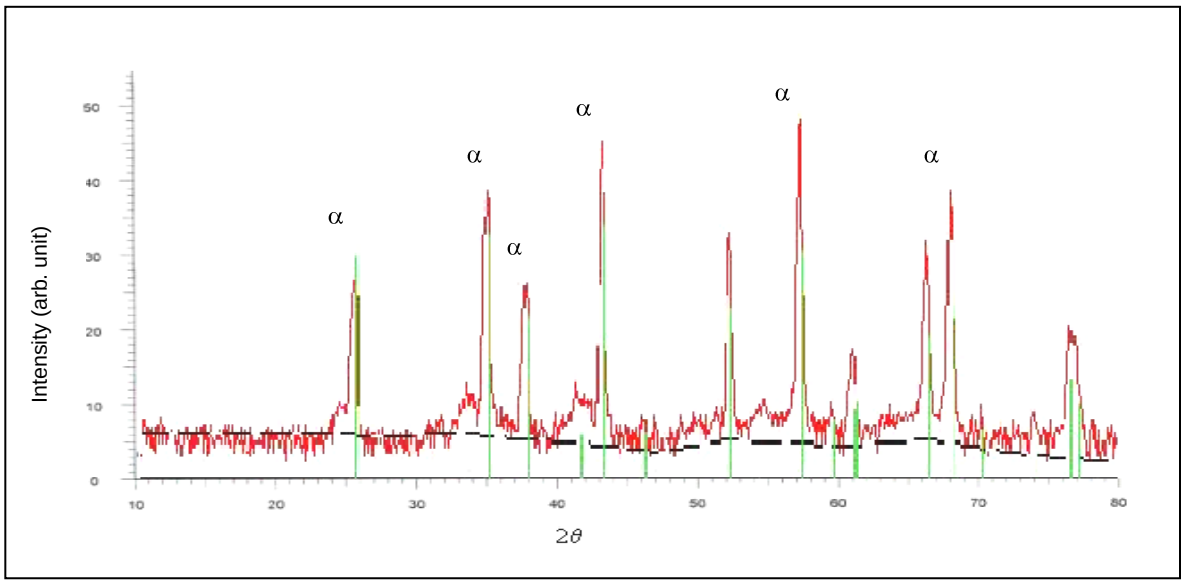


Figure 1 XRD traces show that alpha phase (ICDD: 00-010-00173) are dominantly presence in powder calcined at 1200 °C

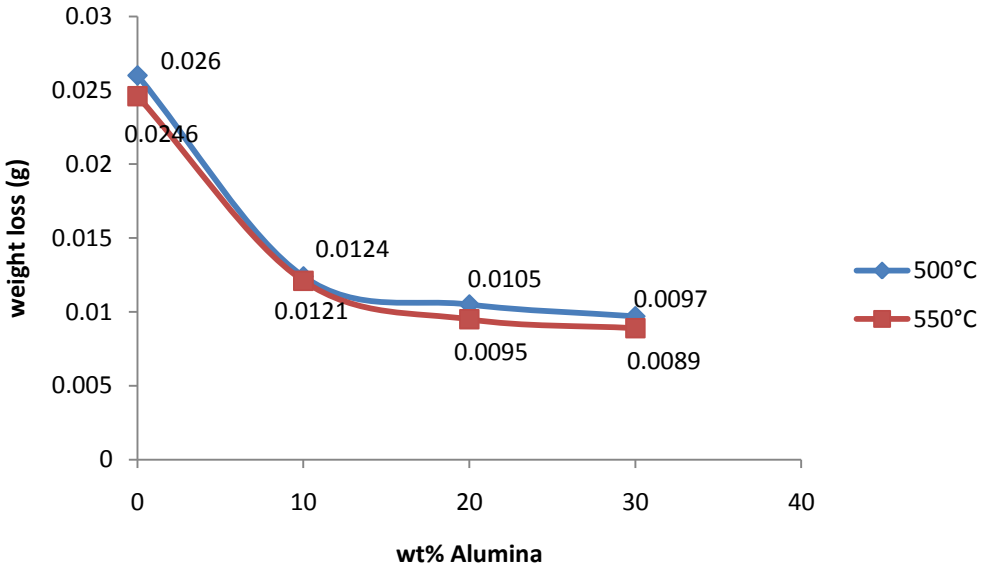


Figure 3 Weight loss of Al-Al_2O_3 composite sintered at 500°C and 550°C

Table 2 Weight loss of Al-Al_2O_3 composite sintered at 500°C and 550°C

wt% Al_2O_3	Weight loss (g)	
	500°C	550°C
0	0.0260	0.0246
10	0.0124	0.0121
20	0.0105	0.0095
30	0.0097	0.0089

As the percentage of alumina particles increase, weight loss of composite was decrease, these phenomena is due to the higher hardness of alumina compared to pure aluminum matrix. Therefore, according to the rule of mixture, increasing the percentage of alumina can justify the increasing in wear resistance. In addition, increasing in alumina percentage will increase the dispersion of alumina on the aluminum matrix particles. Better dispersion of alumina makes particles of alumina and aluminum difficult to move when pressure was imposed; hence will increase wear resistivity [1].

As for comparison, the performance of synthesize and commercial alumina on the mechanical properties (Vickers hardness and wear resistance) of the composite were determined and results were shown in Table 3. It shows that the mechanical properties of synthesize alumina in a composite system were similar/comparable to commercial alumina.

Table 3 Comparison on the performance of synthesize and commercial alumina

Reinforcement	Average Hardness value (HV)	Average Wear weight loss (g)
Synthesize alumina	75.9	0.0089
Commercial alumina	78.7	0.0084

■4.0 CONCLUSION

Alumina powders were synthesized through sol gel method and their performances were observed through the fabrication of alumina-aluminum composite system. The increasing in the percentage of alumina and sintering temperature lead to the increasing of mechanical properties. A comparison study shows that the composite using synthesizes has similar/comparable properties to the composite using commercial alumina.

Acknowledgment

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