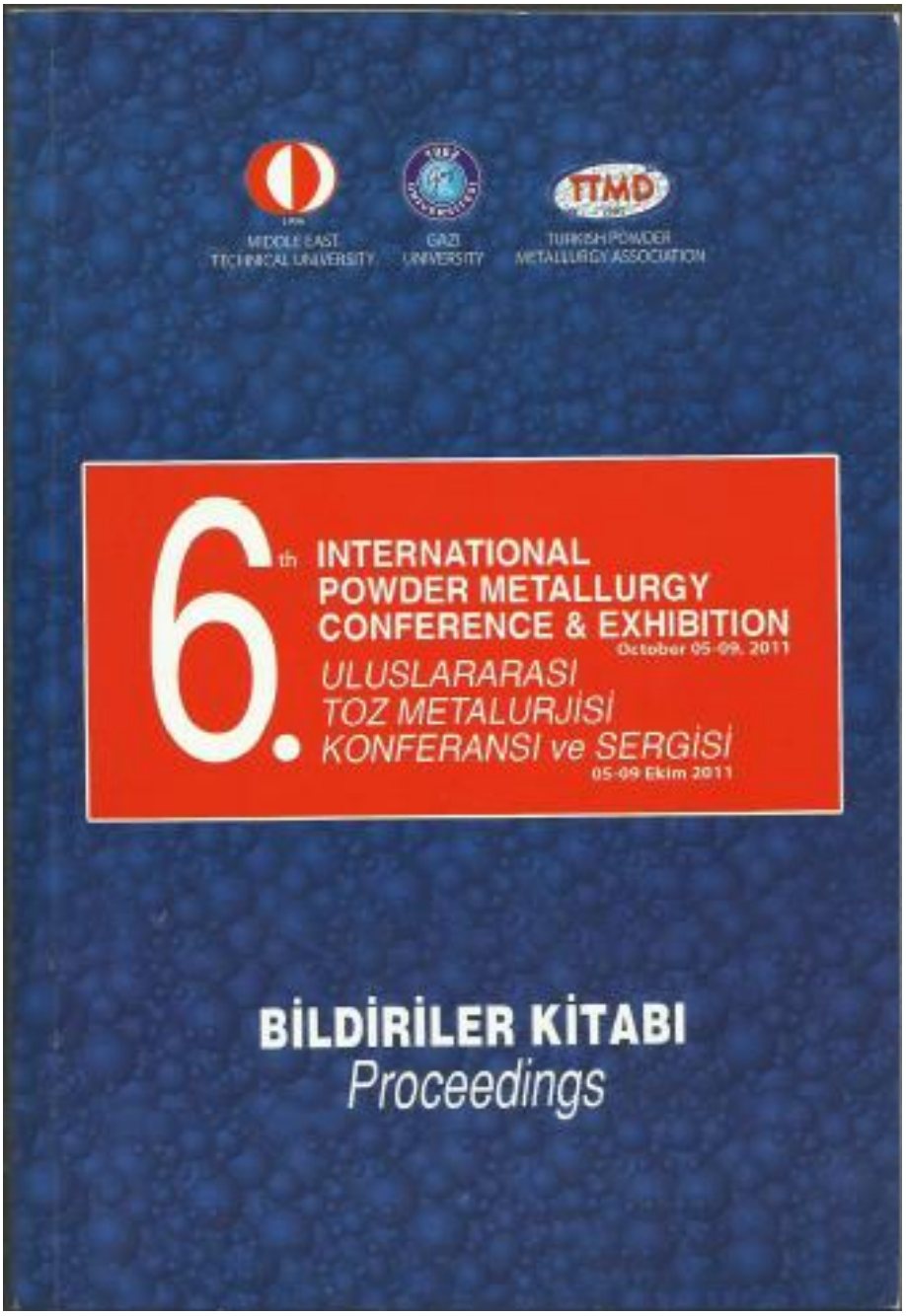

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TURKISH POWDER METALLURGY ASSOCIATION
6th INTERNATIONAL POWDER METALLURGY CONFERENCE & EXHIBITION
October 05-09, 2011
ULUSLARARASI TOZ METALURJİSİ KONFERANSI ve SERGİSİ
05-09 Ekim 2011
BİLDİRİLER KİTABI
Proceedings

6th INTERNATIONAL POWDER METALLURGY CONFERENCE

BİLDİRİLER KİTABI

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PROCEEDINGS

Publication of the communiques issued in this book is possible provided that written approval of the author and editor are taken. Giving reference is sufficient for extraction.

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Baskı Tarihi - Issue Date:
28.02.2012

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ISBN 978-605-61038-7-2

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THE EFFECT OF PROCESS PARAMETERS ON MECHANICAL AND DRY WEAR BEHAVIOUR OF ALUMINIUM COMPOSITE

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ABSTRACT

Al_2O_3 particle-reinforced Aluminium composites were prepared by powder metallurgy (PM) method under different temperatures and times. Wear behaviour of Al-Al_2O_3 reinforced composites were tested under dry conditions using a pin-on-disc wear rig. Pure Al of average particle size of 45 µm was reinforced with 10wt. %Al_2O_3 with average particle sizes of 20 and 3 µm. SEM examination showed a nearly uniform distribution of the Al_2O_3 particles within the matrix. Improvements of hardness in comparison to matrix for 550°C, 610°C were achieved at about 44.52%, 50%, respectively. These improvements were reached up to 62.6% at 120 min sintering time. Moreover, the wear rate of the composites increased with increasing all applied loads, but wear rate decreased with increasing particle size.

Keywords: Al matrix Al_2O_3 particle, metal matrix composite, powder metallurgy, wear

1. INTRODUCTION

Metal matrix composites (MMCs) are relatively new class of advanced engineering materials characterized by higher stiffness and hardness, lighter weight and greater wear resistance than those of conventional materials [1]. The reinforcing particles in the MMCs protect the matrix surface against destructive action of abrasive wear. In producing MMCs; thus, C, SiC, TiC, B and Al_2O_3 in the form of continuous fibres, chopped fibres or whiskers and particulates have been used as reinforcement materials, whereas, aluminium, magnesium, titanium and their alloys have been used as matrix alloys [2]. The most commonly employed MMCs consists of aluminium alloy reinforced with hard ceramic particles, as stated above. The MMCs can be produced through a number of routes including casting and powder metallurgy (PM) including mechanical alloying (MA) [3-9, 10-13]. Some of the difficulties of producing the MMCs using conventional casting method is to obtain non-uniform microstructures and particle clustering [14, 15]. The PM routes like densification of mixtures of metal and ceramic powders or of composite powders made by mechanical processing, followed by pressure and sintering. The PM is simple method and exhibit excellent finished performance [16, 17]. MMCs, therefore, have been used for the automobile components such as engine piston, brake drums, cylinder blocks, drive shaft, but they are also used in structural applications such as helicopter parts, rotor vanes in compressors in aerospace industry [4, 18, and 19]. There have been a number of studies on the fabrication of Al matrix composites. However, there are a few reports on wear behaviour of Al_2O_3/Al composites with the effect of particle sizes at lower stress [2, 6, 15-16]. The purpose of the current study, therefore, is to produce MMCs with different particle sizes by PM method, evaluate the effect of particle sizes and load on the dry wear behaviour of MMCs.

2. EXPERIMENTAL PROCEDURE

2.1. Materials

Pure aluminium (Al) was fabricated by powder metallurgy as an unreinforced material. In order to produce Al_2O_3-Al based composites, commercial aluminium powders with an average particle size of 45 µm with 99.5% purity and various particle sizes of Al_2O_3 powders have been provided from Akyol Turkish Company in Istanbul. For manufacturing MMCs, the average particle sizes of 22 µm, 3 µm was evaluated, hereafter denoted as 22 µm- Al_2O_3/

Al composite, 3 μm-Al_2O_3/Al composite containing 10 weight fractions of Al_2O_3 particles. The mixtures of alloyed powders were uniaxially cold compacted using a cylindrical die of 6.5 mm diameter and 20 mm height at a pressure of 650 MPa. The compacts were then sintered in a pipe type of furnace under a control of argon gas. The mixed powders were sintered at 550°C, 610°C for 45 min and 120 min. A similar subsequent experiment was conducted for the development of Al powder specimens-only for comparison purposes.

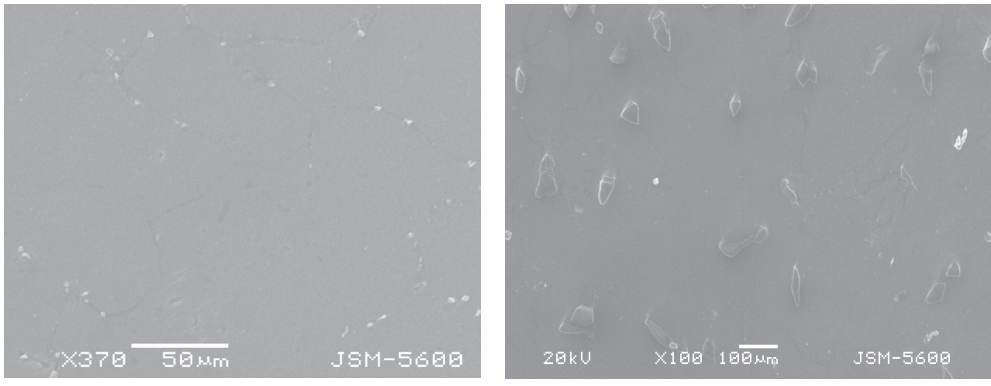
Hardness's of composites and matrix were measured by Vickers hardness method by applying 30kgf load after polishing to a 3 μm finish. Five samples were averaged at least.

A pin-on-disc type of apparatus was employed to evaluate the wear characteristics of MMCs and matrix. The counter surface material,which was heat-treated to give a surface hardness of 59-63 HRC. The composite bars were in the form of cylindrical shapes. The pin was then mounted in a steel holder in the wear machine so that it was held firmly perpendicular to that of flat surface of the rotating counter disc when tested. The samples were loaded against the hardened steel disc with the help of a cantilever mechanism. In the tests; normal load on the pin was variable at a constant sliding speed of 1 m s^{-1}.

3. RESULTS AND DISCUSSION

3.1 Microstructure

Fig.1 shows the SEM micrographs of pure Al matrix and its composites reinforced with a 10 wt. % of Al_2O_3 composites with various particle sizes. Grain boundary can be seen in the pure Al matrix (Fig.1a). The darker region in the microstructure is essentially Al_2O_3 particles. The distributions of Al_2O_3 particles in these composites seem to be uniform. With the increment in the amount of particles, the size of α-Al phase or grain boundary decreases progressively. There are no agglomerations and porosity in this micrograph because of increased the pressure (see Fig.1b). Grain growth during sintering changes the configuration of the grain boundaries relative to pores and thus may markedly influence the shrinkage rate. The addition of Al_2O_3 particles will increase the sintering rate if they increase diffusion rates, but they may also increase sintering rates by impeding grain-boundary movement. The grain growth might proceed via solid-state atomic diffusion. The relatively homogenous microstructure leads to the highest hardness in Fig.2.



a) C_1 b) C_3

Fig.1. Typical SEM micrographs of pure Aluminium matrix and its 10wt. % Al_2O_3 reinforced Al composite, sintered at 550°C for 45 min. a) Pure aluminium (C_1), b) 20 μm-10wt. % Al_2O_3/Al composite, indicating distributions of Al_2O_3 particles in the matrix (C_3).

3.2 Hardness of The Composite

Hardness's of composites produced at different temperatures and times were measured by taking at least 5 samples. The results showed that hardness increased with increasing temperature, as shown in Fig.2. This 600°C temperature promotes additional particle to particle bonding and more complete alloying because of higher diffusion rates. On the other hand, it is necessary to reduce the oxides of these elements in order to promote bonding of particles. However, sintering time is found to be more effective than that of the because of mechanism of neck formation and neck growth of powders (Table 1).

Moreover, the hardness of the MMCs increased with increasing the size of particles (Fig.2). The achievement of wettability of these materials decreased for 3μm-Al_2O_3 reinforced composite than that of the 20μm-reinforced composite although the degree of liquid phase formation increases with temperature.

Table 1. The results of hardness of metal matrix composite.

	Sintering times			
	45min		120min	
Material's type	Hardness at 550°C(HB1)	Hardness at 610°C(HB1)	Hardness at 550°C(HB1)	Hardness at 610°C(HB1)
Al matrix (C1)	26.5	28	30	31.3
Al-3μm-10wt.% Al_2O_3 reinforced MMCs (C2)	31.8	32.1	35.2	36.5
Al-20μm-10wt.% Al_2O_3 reinforced MMCs (C3)	38.3	42	46	50.9

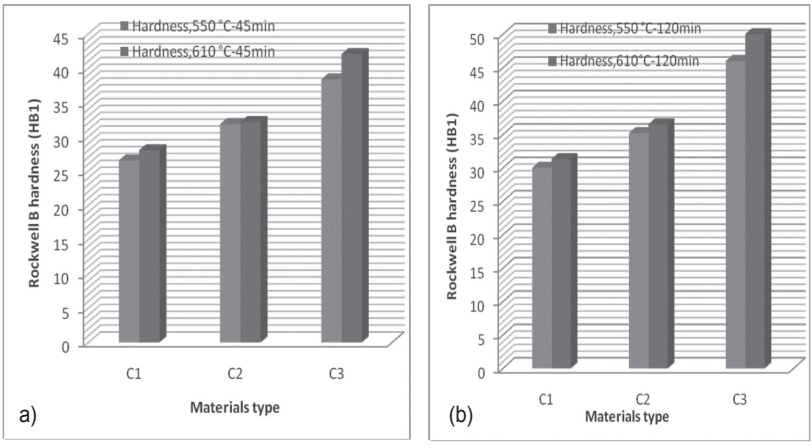


Fig.2. Variation of hardness as a function of type of materials for Al matrix and its 10wt. % Al_2O_3 reinforced Al composite.
a) Sintering time of 45min,
b) Sintering time of 120min

3.3. Wear Behaviour

The average volumetric wear rate of Al/Al_2O_3 reinforced composites are determined, and are illustrated graphically in Fig.3 as a function of different load. It is found that the wear loss of the composites increase sharply with all applied for both materials. The composite shows a lower wear rate than that of the matrix at lower loads due to increased hardness of the samples (see Table 1). This is a good agreement with previous studies on wear of metal matrix composite by Lim et al. [13], and Kumar et al. [17]. Furthermore, lower sizes of particles in the MMCs give the highest wear loss because small SiC particles in the composite are more easily pulled-out from the matrix, compare with higher sizes of particles. As the Al_2O_3 particles size increases from 3 μm to 20 μm in a fixed sliding distance, the composite's wear rate tested at an average load decreases to 52%. On the worn surfaces, reddish-brown coloured transfer layers are observed by naked eye. This layer may be contained constituents from the counter face like Fe, Si and Cr, which is Fe rich layer. It acts as a solid lubricant and prevents direct contact between the composites and counter face during wear testing [23, 25]. However, there

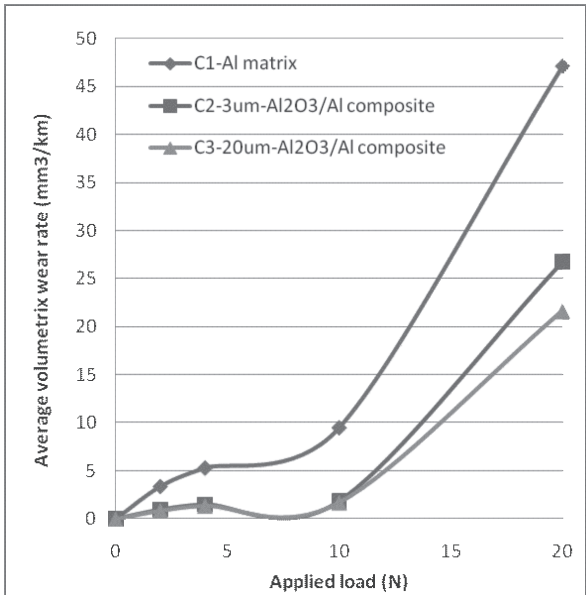


Fig.3. Variation of average volumetric wear rate as a function of applied load for 10wt. % Al_2O_3 reinforced Al composite, sintered at 550°C and 45 min.

are more conflicting reports on these issues. For example, some researcher's show that the wear resistance of Al_2O_3 or SiCp reinforced composites increases with increasing particle sizes and/or volume fraction of particles [21-24]. On the contrary, other people report that the smaller sizes of particles lead to the more wear resistant composites [26, 27].

4. CONCLUSIONS

The effects of particle size, applied load on the mechanical and dry wear behaviour of composites were investigated.

1. Aluminium composites containing various particle sizes with 10wt. % Al_2O_3 particles were produced successfully using PM method. SEM observation of the microstructure showed that homogenous distributions of Al_2O_3 particles in the pure matrix seemed to be dominant.
2. Hardness of the composite sintered at 550°C increased with increasing the size of particle in the matrix, average hardness increased by approximately % 44.5 compared to unreinforced matrixes.
3. It was found that the composite's wear rate decreased to 52% as the Al_2O_3 particle size increased from 3 μm to 20 μm in a fixed distance.

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