EFFECTS OF DIFFERENT PROCESS CONTROL AGENT ON CHARACTERISTICS OF MECHANICALLY MILLED Al2024 POWDERS

A. Canakci[1a], S. Ozkaya[1], F. Erdemir[1], T. Varol[1]

1. Metallurgical and Materials Eng. Dept., Karadeniz Technical University, Trabzon, Turkey.
a Corresponding author (aykut@ktu.edu.tr)

ABSTRACT: In this study, the effect of different process control agents (PCA) on particle size, particle morphology and particle hardness produced mechanical milling method was investigated. To evaluate the effects of PCA with increasing milling time, powders have been successfully milled from 0.5h up to 16h. Methanol and stearic acid were used as process control agents to investigate the effect on milled powder properties. The particle size of alloy powders was determined by laser particle size analyzer and the milled powders were characterized by SEM. Microhardness values were obtained for different milling time show that the hardness of powders increase with increasing milling time. The results show that both methanol and stearic acid have different effects on the morphology, particle size and structural behavior of the as milled Al2024 powders. Moreover, it was observed that methanol is earlier than stearic acid for steady state in ductile-ductile milling system.

I. INTRODUCTION

Process variables in MM technique such as milling time, milling speed, ball to powder weight ratio and process control agents (PCAs) have a significant role on the final structure and morphology of the powders [Suryanarayana, 2001; Canakci et al. 2011]. With cold welding, the particles will not be bonded together for interdiffusion while too much cold welding will cause an increase in particle size. Therefore, the balance between cold welding and fracturing is important for succesfull MM process [Lu and Zhang, 1999]. The balance between these two mechanisms can be controlled by addition of a surface additive, called as PCA, which inhibits cold welding. The type of PCA also plays an important role in the balance [Zhang et al. 1999; Zhu et al. 2010]. There are several kinds of PCAs, for example methanol, stearic acid, hexane, cyclohexane, polyethylene are most common used process control agents in MM process [Juarez et al. 2007]. By adding PCA, particle size can be decreased as a result of inhibited welding during collisions and increased fracturing process [Pilar et al. 2007].

The aim of this work is to investigate the effect of different process control agents on very fine graded Al2024 powders produced by MM technique.

2. EXPERIMENTAL PROCEDURE

Gas atomized Al2024 powders, with the average particle size of 56 μm were choosen as starting material.The chemical composition of alloy is (in weight percent) of 4.850% Cu, 1.310% Mg, 0.667% Mn, 0.254% Fe, 0.110% Si, 0.079% Zn, 0.033% Cr, 0.008% Ti and balance Al. The milling process was carried out in a planetary ball-mill (Retsch PM 200) at room temperature using tungsten carbide bowl and high argon atmosphere. Alloy was milled up to 16 h with the following parameters; ball to powder charge ratio; 10:1(wt),ball diameter ;10mm, milling speed 400rpm.A total of %2 (wt) of stearic acid or methanol were added to the different

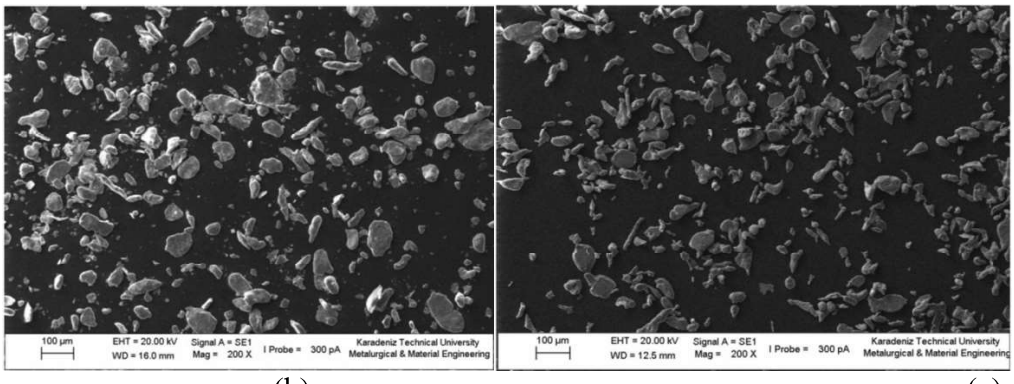
bowls as PCA. To prevent overheating, ball milling experiments were stopped (every 1h) and then resumed when the temperature of the bowl decreased to room temperature. The milled alloy powders were taken out at regular interwals of 0,5 ,1,2,6,10 and 16h for investigating it's properties. The powder sizes of alloys were obtained lazer particle size analyzer (Malvern, model 'Mastersizer Hydro 2000e'), characterization of powders were obtained by scanning electron microscopy. Therefore, the hardness of milled alloys were determined using vickers measurement $HV_{0,1.}$

3. RESULTS AND DISCUSSION

3.1. Particle Morphology

The morphologies of the milled Al2024 wt-%2 PCA powders are shown in Fig1. The milling duration changes from 0,5h up to 10 h. When examine the figures, it can be seen that, the effect of methanol on powders starts in early stages of milling. Thus, rapidly changing in powder morphology was obtained. The powder morphology after 0,5h milling time (Fig.1a) was flake, but after 10h it converted into equiaxial morphology it is because of after 10h powders reach to the steady state. That rapidly changing in powder morphology have an important influence on the powder size that, powder size was decreased quickly [Pilar et al. 2008; Long et al. 2010; Nouri et al. 2010]. On the other hand, stearic acid presented too much lubricant characteristic and powders could not reach to the enough work hardening to be fractured. As indicated in Fig.1 (1h) after 10h milling time, while methanol proceeded through equiaxed morphology, stearic acid has mostly flake shape. When powder morphologies are examined, it can be seen that there is almost no change on powders lubricated with methanol. In other words these powders reach steady state after 10h. But then, the alloy powders lubricated with stearic acid starts fracturing after 10h and at 16h it still continues fracturing.

In conclusion, when compared stearic acid and methanol, methanol is more effective on fracturing and also it gains %40 time, to reach to steady state.



(b) (c)

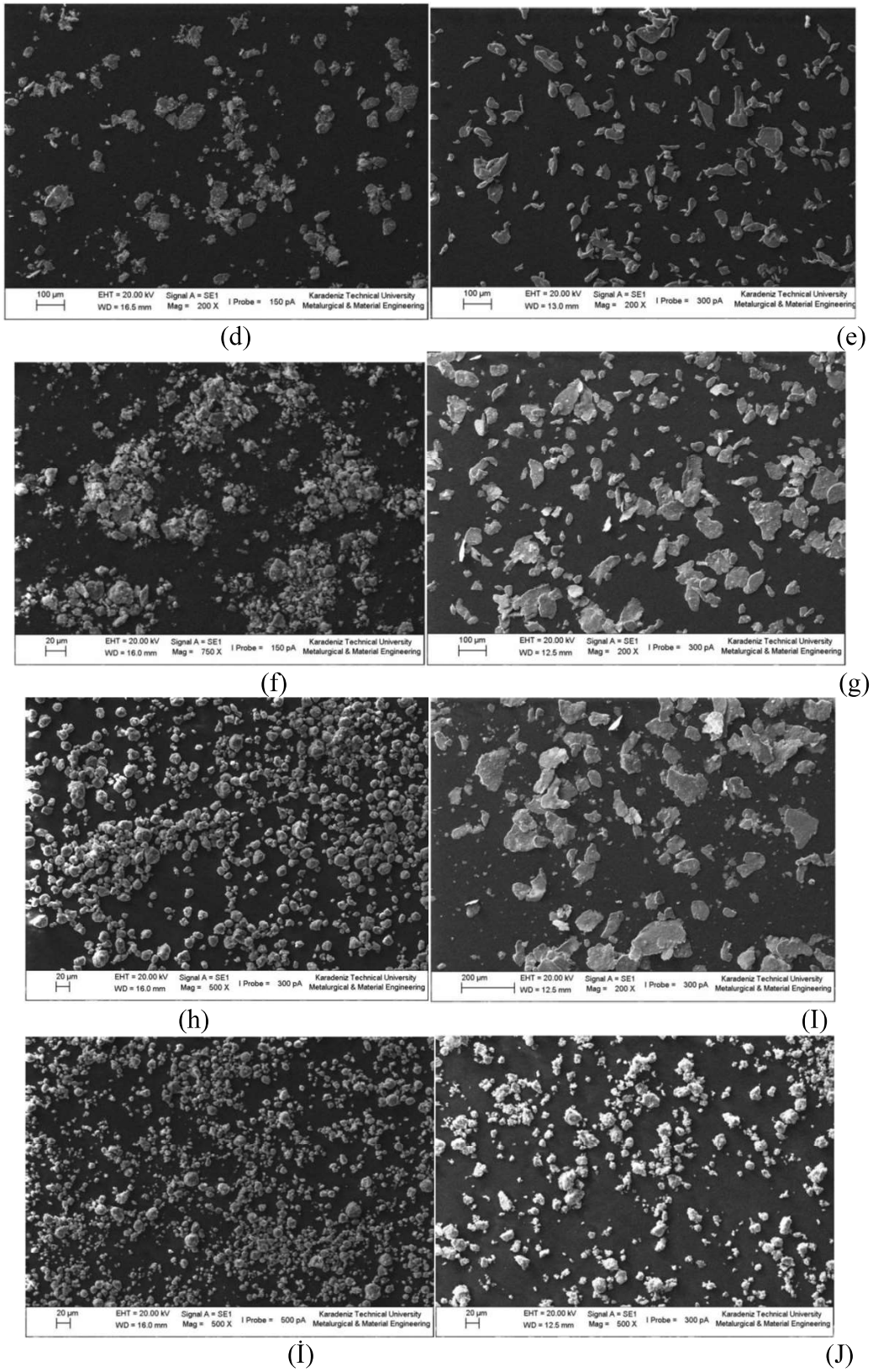


Fig. 1: Powders milled with different process control agent and milling time; (a) Methanol-0.5h, (b) Stearic asid-0.5h, (c) Methanol-1h, (d) Stearic asid-1h, (e) Methanol-6h, (f) Stearic asid-6h, (g) Methanol-10h, (h) Stearic asid-10h, ı) Methanol-16h, (i) Stearic asid-16h.

3.2. Particle Size

Fig.2 shows the measurement of the particle sizes of Al2024 powders for different types of PCA after different MM duration. As shown in figure a large difference in particle size can be observed only for a short MM duration. Up to two hours, while particle size of powder used stearic acid has an increase, particle size has decreased with used to methanol. This may be attributed to the amount of stearic acid is not enough up to two hours to balance between the cold welding and fracturing. The size of the aluminum particles is range from 15-45 µm. In the early stages of ball milling for stearic acid, the coarse particles were soft, and tendency to cold welding and form large particles was high. Thus after 2h of ball milling, powder with stearic acid starts fracturing up to 16h. As it can be seen from the Fig. 2, both stearic acid and methanol comes to steady state that, they are not going on fracturing anymore. When compared these additives, methanol is more effective than stearic acid in this proccess that methanol reaches steady state %40 earlier than stearic acid.

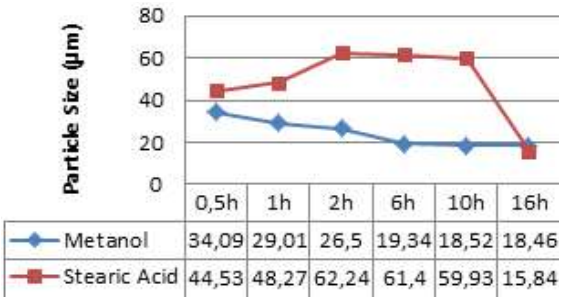


Fig.2 : The change of particle size with increasing milling time

3.3. Microhardness

Figure 3 shows the Vickers hardness of milled powders as a function of milling time and different process control agents. As known, plastic deformation rate and work hardening rate increase with increasing milling time. The hardness of alloy shows a decidedly upward trend with increasing milling time. In addition, for a given milling time, the hardness of alloy powder milled with methanol higher than that of the powder milled with stearic acid. The reason for difference in hardness can be explained the powders with methanol start fracturing at the beginning of milling. Thus, that powder has more work hardening.

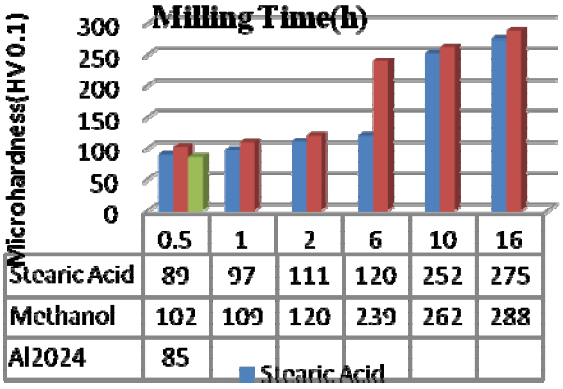


Fig. 3: The change of microhardness with increasing milling time

4. CONCLUSIONS

1) The powder sizes increased with increasing milling time in both lubricating additives, but the powders with methanol started fracturing in earlier periods of milling and reached steady state earlier than stearic acid.

2) The hardness of powders was increased with increasing milling time and it was shown that, powders with methanol have bigger hardness values than stearic acid.

3) Solid lubricators have more efficiency than liquids owing to the that, powders with stearic acid starts fracturing later than methanol.

REFERENCES

Suryanarayana, C., 2001. Mechanical alloying and milling Progress in Materials Science 46, 1.

Canakci, A.,Varol, T., Nazik, C., 2011. The effect of amount of methanol on the properties of Al-Al_2O_3 composite powders,International 6th Powder Metallurgy proceedings book.

Lu, L., Zhang, Y.F., 1999. Influence of process control agent on interdiffusion between Al and Mg during mechanical alloying, Journal of Alloys and Compounds, 290, 279.

Zhang, Y.F., Lu, L., Yap, S.M., 1999. Prediction of the amount of PCA for mechanical milling, Journal of Materials Processing Technology 89-90, 260.

Zhu, S.G., Wu, C.X., Luo ,Y.L., 2010, ,Effects of stearic acid on synthesis of nanocomposite WC-MgO powders by mechanical alloying, Journal of Materials Science 45, 1817.

Juarez, R., Sunol, J.J., Berlanga, R., Bonastre, J., Escoda, L., 2007. The effects of process control agents on mechanical alloying behavior of a Fe–Zr based alloy, Journal of Alloys and Compounds 434-435, 472.

Pilar, M., Sunol, J.J., Bonastre, J., Escoda L., 2007. Influence of process control agents in the development of a metastable Fe–Zr based alloy, Journal of Non-Crystalline Solids 353, 848.

Pilar, M., Escoda, L., Sunol, J.J. and Greneche, J.M., 2008. Magnetic study and thermal analysis of a metastable Fe-Zr-based alloy: Influence of process control agents, Journal of Magnetism and Magnetic Materials 320, 823.

Long, B.D., Zuhailawati, H., Umemoto, M., Todaka, Y. and Othman, R., 2010. Effect of ethanol on the formation and properties of a Cu–NbC composite, Journal of Alloys and Compounds 503, 228.

Nouri, A., Hodgson, P.D. and Wen, C.E., 2010. Effect of process control agent on the porous structure and mechanical properties of a biomedical Ti–Sn–Nb alloy produced by powder metallurgy, Acta Biomaterialia 6, 1630.