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Milling Time Effective on Microstructure and Mechanical Properties of Al-Pb Alloy Produced by Mechanical Alloying

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Abstract: ***Aluminum –lead alloys are considered as bearing materials of 21st century because of its lubricant behavior of Pb phase component. In present work, Al-Pb alloy was produced by mixing powders of (Al-10%Pb-4.5%Cu weight) using ball milling process with periods (two , six and ten hours), fine grain size , homogenous distribution of powder were achieved and noticed that a reduction of particle sizes with increasing milling time. Various testing processes were used concluded compression strength test , microstructure test included optical microscope , scanning electron microscope(SEM) , energy dispersive x-ray spectra scope (EDX) , and x-ray diffraction (XRD) . Results of this part showed that the mixing time of two hours gave the best condition as compared with other two mixing times.***

Keywords: Aluminum – lead alloy, Mechanical alloying, Milling time, microstructure.

1. Introduction

Aluminum –lead alloys are considered as bearing materials of 21st century [1]. One of the major usages for Al–Pb alloy is bearing alloys because of its lubricant behavior of Pb phase component. In general, homogeneous and disperse distribution of fine lubrication phase in Aluminum matrix is important for wear properties [2]. Al-Pb bearing alloy have been used in automobile industry, and the improving the mechanical properties of this alloy such as the strength and wear properties was done by adding some alloying element such as Copper and Magnesium. But because of the different in specific gravity and immiscibility between Al and Pb [3], which greatly increase the kinetic of lead segregation during melting and freezing [4], this lead to difficult manufacturing of this type of alloys [3]. There are different methods (rapid solidification , stir cast , rheo cast , powder metallurgy , and hot extrusion) may be used to improve microstructure homogeneity and to get finer size of Pb phase in Al –Pb alloys because the homogeneous distribution of Lead in Aluminum matrix could not be easily obtained by traditional casting processes [5].

Mechanical alloying is one of the efficient methods when it compared with the previous methods because it dependent on the mechanical forces such as compressive force, shear or impact to effect particle size reduction of bulk materials. This is sometimes referred to as mechanical alloying or ball milling which is one of the mechanical alloying methods had been used since 1970 to produce successfully new alloys bond on powder particles as a method for material synthesis [6]. Mechanical alloying (MA) is a high energy ball milling process by which constituent powders are repeatedly deformed, fractured and welded by grinding media to form a homogeneous alloyed microstructure or uniformly dispersed particulates in a matrix [7]. Wear property is better when prepared by sintering the mechanical alloyed powder (MA) of Al-Pb alloys than that of Al-Pb alloys obtained by casting and powder metallurgy, this due to fine size of pb phase and its good homogeneity in Al-Pb alloy produced by MA [2].Mechanical alloying is a complex process and hence involves optimization of a number of variables to achieve the desired product phase and/or microstructure. Some of the important parameters that have an effect on the final constitution of the powder are: type of mill, milling container, milling speed, milling time, type, size, and size distribution of the grinding medium, ball-to-powder weight ratio, extent of filling the vial, milling atmosphere process control agent, and temperature of milling. [8] Erol Feyzullahog˘lu , Nehir S_akirog in 2010, in this research a new type of Al-alloy was studied, this alloy contained lead (Pb) instead of Tin (Sn). Tin based Al- alloy are less effective than the (Pb) based aluminum alloy due to that (Pb) in Al-alloy acts as the soft phase which is homogenously spread in aluminum matrix, as they have good wear properties. Today engines deal with higher temperature thus they requires materials that have higher melting temperature and carry a soft phase instead of the classic bearing materials i.e. Cu-Sn –Pb or Al- Sn [9]. Hayder A.Hussein and Prof.Dr. Adnan N. Abood in 2010, used alloys produced by mechanical alloying method, they consisted of 10%Pb and 4.5% Cu and balanced of Al. They were produced by fraternization in a ball mill for a period of two hours. They were then pressed by various loads with the use of different sintering temperature. The study showed the sintering temperature had a significant role and was an important variable on the alloying properties. The study showed that the best results were obtained at a temperature of 450°C and pressing load of 58800 N [5]. M. Zhu , et al in 2000, studied the effect of mechanical alloying (MA) and how they improved the wear properties of Al-Pb alloys by prepared this alloy in different method (powder metallurgy , casting and mechanical alloying) . The results obtained showed that the hardness obtained from an alloy manufactured by MA was 2 to 3 times harder than that prepared by casting process .In addition, the wear properties of the Al–Pb alloys produced by MA are better than those prepared by P/M and cast method. The improvement is more obvious in the dry wear condition. The wear rate of the MA Al–Pb alloys decreases with the increasing of Pb content in the composition range of 10–18% Pb[10]. The milling time is the most important parameter. The variation of crystallite size is strongly depend on milling time ,with increasing milling time the size of particles gradually reduced as shown in Figure (1). At longer milling time, the powder was more uniform in size compared to the early stages of milling. The larger particles at longer milling times appeared to be an agglomeration of many smaller particles as shown in Figure (2) [11].

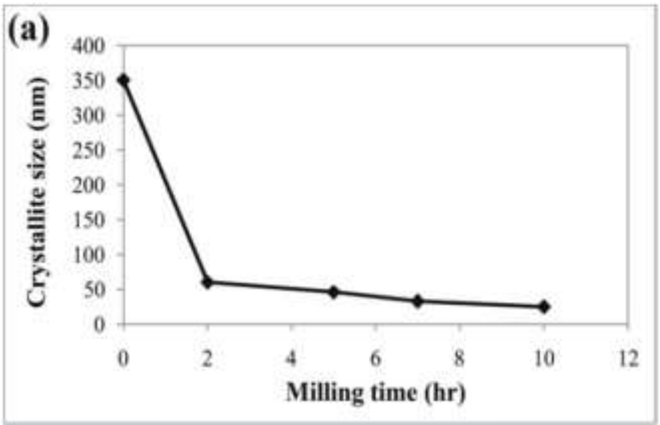

Figure 1: The variation of crystallite size [11].

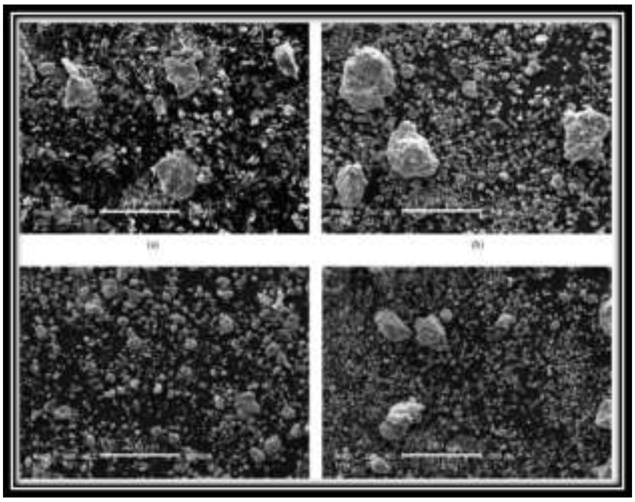

Figure 2: SEM images of powder particles after (a) 2 h, (b) 5 h, (c) 7 h and (d) 10 h of milling times [11].

2. Experimental Work

Three types of metals Al, Pb, and Cu with different particle size (Figures 3, 4 and 5) were used.

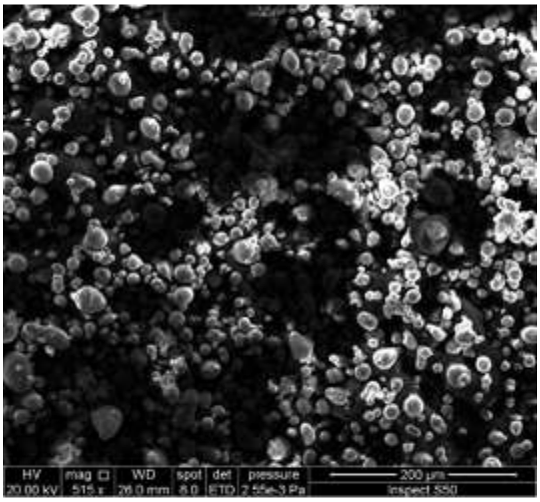

Figure 3: SEM of AL powder

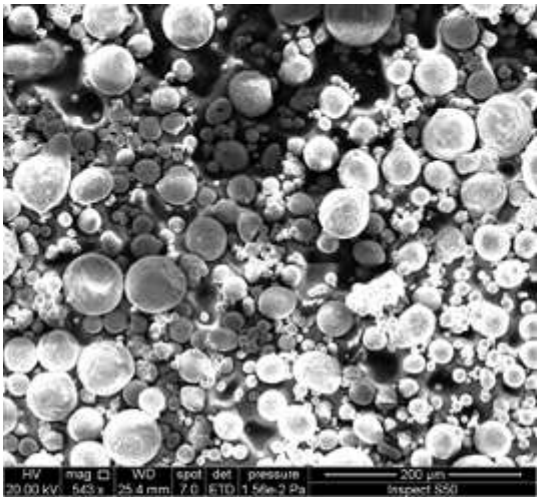

Figure 4: SEM of Cu powder

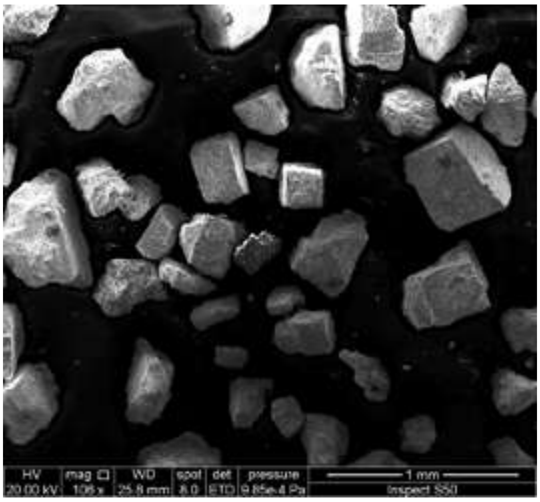

Figure 5: SEM of Pb powder

These metals were mixed together with specific weight percentage (85.5% Aluminum, 10% Lead and 4.5% Copper). Powder mixture were mixed in a stainless steel vial used hardened steel balls in a ratio of powder to steel ball (p/b)equal to (1/10) milled in a planetary mill with rotation speed 250 rpm with protective argon atmosphere, the duration of milling time are (two, six ad ten hours). The powder produced by milling was compacted by a hydraulic press at 400 MPa to produce billets with rectangular cross section (15×15mm2). The billets were sintered at (450 °C) with a soaking time 30 minutes in a tube furnace with argon protective (2 L /minute flow rate). Compression, micro hardness test and microstructure examination were employed to assess the alloy.

3. Results and Discussion

3.1 Microstructure tests

After mechanical milling, the produced mixing powder was testing by SEM, EDX and XRD to assess the powder that used to manufacture the Al-Pb alloy. Figures (6,7 and 8) show the SEM of mixing powders during 2 ,6 and 10 hours , Figures (9,10 and 11) show the EDX of mixing powder during 2 ,6 and 10 hours respectively.

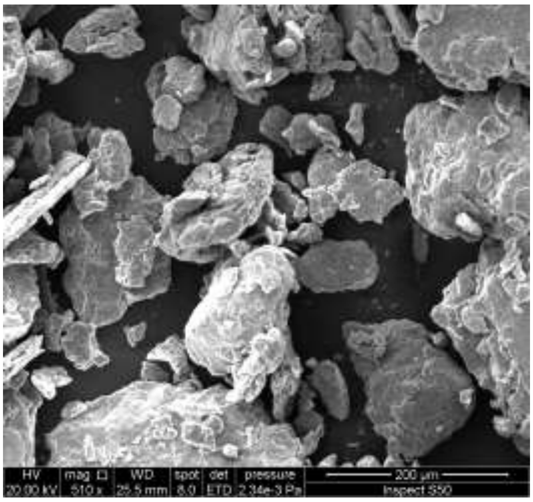

Figure 6: SEM of mixing powder for 2 hours

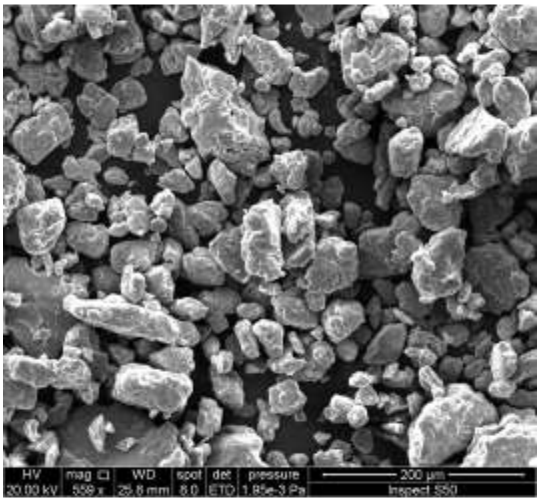

Figure 7: SEM of mixing powder for 6 hours

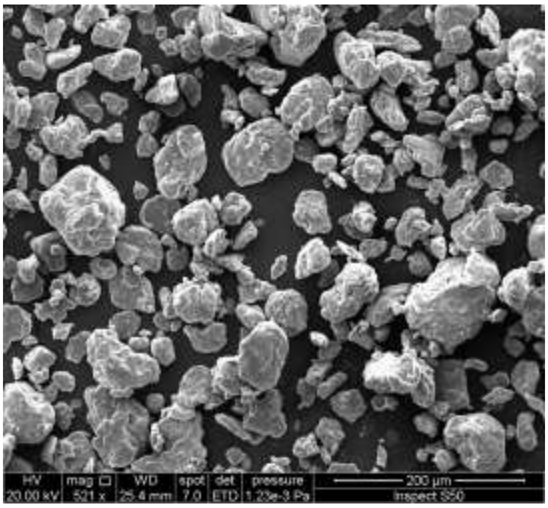

Figure 8: SEM of mixing powder for 10 hours

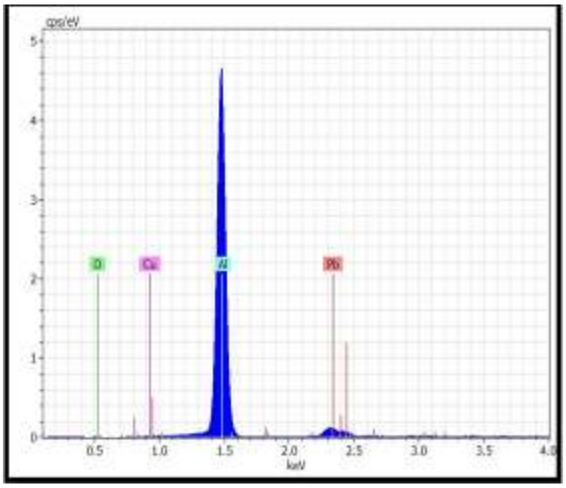

Figure 9: EDX of mixing powder for 2 hours

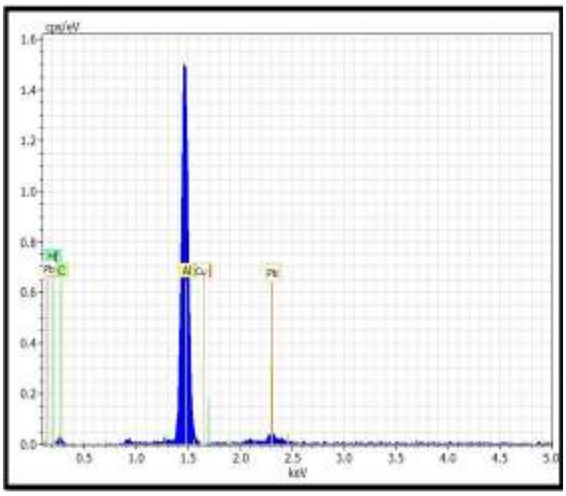

Figure 10: EDX of mixing powder for 6 hours

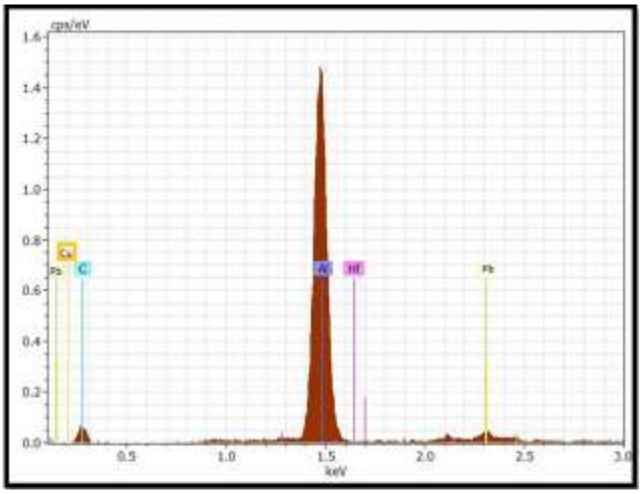

Figure 11: EDX of mixing powder for 10 hours

From Figures (6,7and 8) , it be noticed that the particle size reduced with increased the mixing time due to impact force from steel balls in ball milling, furthermore the particles shapes were changed from rounded and circular shape of aluminum and copper particles and rectangular shape of lead particles, all the particles shape were deformed because of the effect of different forces from ball milling on powders which lead to fracture the particles and cold weld between them. So where the time of milling increased the particle size decrease and homogenous between particles increased, this was obviously shown in previous figures. In the other hand , it can be seen from Figures (10 and 11) the presence of carbon element as contaminate as a result of milling for long times, while in Figure (9) the carbon element was not appearance, so the longtime of milling although it give fine grain size and homogenous distribution for particles , but a new elements was appeared that have bad effective on produced alloy after compacting step, carbon was act as insulating particles between compacting particles, this event leaded to negative results of produced alloy .

Figures (12, 13 and 14) show XRD of mixing powder for 2, 6 and 10 hours respectively. These three Figures confirm the above interpretation. From Figure (12), it can be seen not formation any oxides or any new elements presence, but in Figures (13 and 14) the oxides formation and presence of carbon content as a result of long time of mixing.

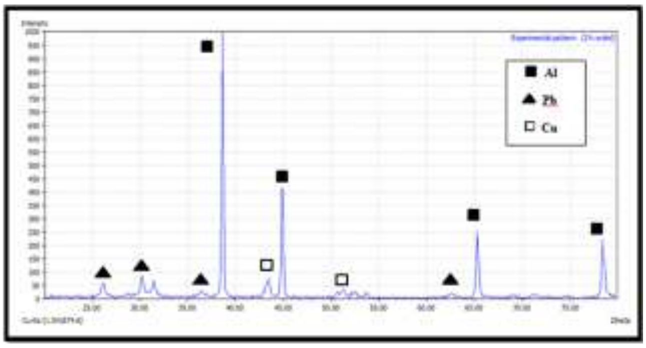

Figure 12: XRD for mixing powder at 2 hours

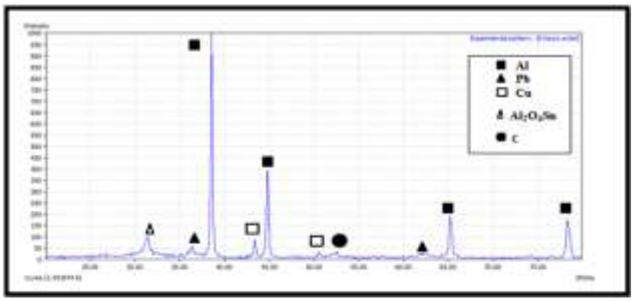

Figure 13: XRD for mixing powder at 6 hours

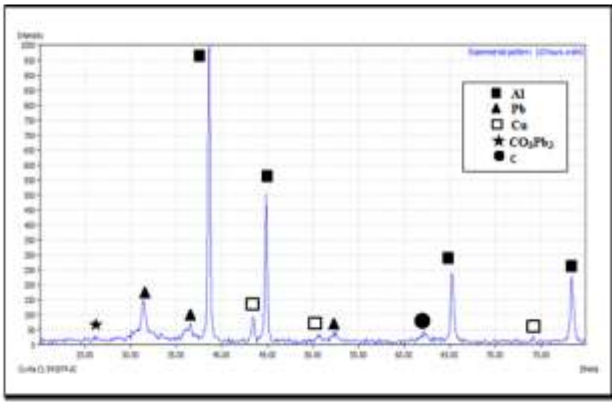

Figure 14: XRD for mixing powder at 10 hours

3.2 Mechanical Properties of alloy

The compression strength of produced Al- Pb alloy are listed in table 1

Table 1: Compression Strength of Al-Pb Alloy at Different Milling Time

Milling Time (hours)	2	6	10
Compression Strength (MPa)	191	102	65

From Table (1), it can be noticed that the compression strength of produced alloy was reduced with increasing the milling time because of formation oxides and carbon content from contacted the powder with balls and jar for long time, carbon caused slipping the atoms of alloy and reduced the adhesion forces between the particles, this led to decrease the strength of the alloy on the contrary of the other authors in this field who obtained high mechanical properties with longer milling time, one of the important reasons that in present work had not been used any addition on mixing during milling such as methanol or stearic acid as a process control agent (PCA) which was used to prevent powders from sticking to the balls and the jar wall. From results above ,two hours duration acts the best choice to produce Al –Pb alloy without any additions, which is saving time and power consumed for using long milling time and in the same time getting the reasonable mechanical properties which are better than achieved from casting and powder metallurgy.

3. Conclusion

1) Mechanical alloying is considered as an attractive method used to produce Al-Pb alloy.

2) Milling time is one of important parameters effective on mechanical alloying method.
3) Mixing the powders along two hours by mechanical alloying process gave accepting results and these results were better than other researches that used p/m, and stir cast methods.
4) Increasing milling time decrease the particle size of powders, but in the other hand carbon content and other oxides are contaminate with alloys and had bad effective on mechanical properties of alloy.
5) Additions known as (PCA) such as methanol and stearic acid must be used for long time duration of milling.

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