Improvement the Mechanical properties of Al-Pb Alloy Prepared by Mechanical Alloying

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Abstract

Al-Pb alloys are used as bearing due to their desirable bearing properties. Improving the mechanical properties of this alloy is the main objective of this research. In present work three types of powders of Aluminum(as base metal) with 10% lead and 4.5% copper by weight mixing by mechanical alloying process using ball milling for the period two hours. Homogenous distribution of powder was achieved. Five different compacting pressures, three different sintering temperatures and various duration times through sintering step had been selected; Vickers micro hardness, compressive strength and microstructure (optic microscope, SEM and EDX) were tested to achieve an optimum condition to manufacture this alloy. Two methods were selected to enhance the obtained optimum mechanical properties; First, artificial aging process showed increasing in mechanical properties(22% for hardness and 24% for compressive strength), second, the addition of SiC powder in different percentage weight(5,10,and 15%) which increased the hardness with increasing the additive percentage reached to 44% with maximum addition , in the other hand compressive strength decreased with increasing percentage of the addition .

Keywords: AI-Pb alloy, mechanical alloying, artificial aging, SiC powder

1. Introduction

Bearing alloys are mainly based of Aluminum – Lead alloy used Pb phase as a lubricant component. Generally, homogeneous and disperse distribution of soft phase in Al matrix used as a lubricant which is enhancing wear properties.[7]. Wide variety of application for Aluminum alloys are used as bearing due to their desirable bearing properties. Steel-backed and solid aluminum bearings are employed as supporting rod to main bearings in internal combustion engines and industrial compressors. Other examples for aluminum bearing applications are in heavy tooling, such as boring mills, presses, lathes, milling machines, and grinding mills, and hydraulic pumps.[4]. Mechanical milling involves the use of compressive force with shear or impact force to effect the reduction of particle sizes of bulk materials. This is sometimes referred to as mechanical alloying or ball milling. New alloys have been successfully produced by using ball milling process for powder material particles. [5] . Unique advantages for mechanical alloying when it is applied to special alloys, such as Aluminum–Lead alloy, which have a strong tendency for sedimentation related to the high difference in the density and the mutual immiscibility of the component constituted of the systems. This structure obtained by mechanical alloying is much finer when compared with other methods such as rapid solidification, stir cast, rheo cast, and powder metallurgy (P/M). Superior properties for composite materials have been produced by ball milling.[6]. A new Al–base bearing alloys were used . In these alloys, Lead is used as the soft phase in its mixture. Wear properties improved when the soft phase in aluminum matrix spreader homogenously. Engines working at high temperatures required materials that withstand this higher temperature when compared with classic bearing materials such as Cu–Sn–Pb or Al–Sn. So Al–Pb alloys used as a solution for this problem.[1]. The mechanical alloying method was used to produce Aluminum as base metal with 10%Pb and 4.5%Cu by mixing them in a ball mill for two hours and pressed with various pressures and different sintering temperatures. The result showed that the sintering temperature is the main effective on the properties.[3]. Sn and Pb was used as a soft phase in aluminum base bearing alloys. The results indicated that Pb provides better uniformity in structure as compared to Sn for Al based alloys.[4].Authors applied the mechanical alloying process for producing Al–Pb alloy. Conclusions of this study were that the hardness, strength, and wear resistance of previous alloy were increased, almost twofold and ensures excellent high-temperature strength.[2]. X-ray diffraction and transmission electron microscopy analysis was used to study the coarsening behavior of lead phase in two alloys namely Al–10%Pb and

Al–10%Pb–4.5%Cu alloys. The results demonstrated that the coarsening rate of Pb Nano phase decreased when adding Cu to the mixture where the grain size of Pb increases with the increasing of heating temperature.[10].Researchers investigated the effect of weight fraction of SiC (5% 10% 15% 20% and 30%) on Al alloy using mechanical alloying process. Results showed that an improvement in hardness and compressive strength with 5 to 30 weight % of SiC.[8]. The hardness and wear characteristics of Al6061-SiC composites containing three different weight percentages 5%, 10%, and 15% of SiC produced by powder metallurgy method were investigated . It found that the hardness of 15% of SiC composites is more as compared to 5 and 10 % of SiC composites. The composites were shown a lower rate of wear with 15% SiC . [9]

The aim of this work is improving the mechanical properties of aluminum–lead alloy using two different methods: artificial aging process, and addition of SiC particles at different percentage weights.

2. Experimental work

Experimental work were divided into two parts; the first one included the manufacturing of alloy and the second deals with the enhancing the mechanical properties and microstructure by two methods, artificial aging process and additive of micro SiC powder. Three types of metals Al, Pb, and Cu with different particle size (20, 25, and 95respectively) were used. 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 for two hours. The powder produced by milling was compacted by a hydraulic press (200, 250, 300, 350 and 400 MPa) to produce billets with rectangular cross section (15×15mm^2). The billets were sintered at different temperatures (450, 500 and 550 ˚C) with various soaking time (30, 45 and 60 minutes) in a tube furnace with Argon protective (2 L /minute flow rate) For improving the microstructure and mechanical properties of the alloy, aging process, and addition of SiC were selected. Al-Pb alloy recorded maximum compression strength exposed to age hardening which included heating the alloy to 500 ˚C for 1hour , quenched in water at room temperature , then age at 200 ˚C for two hours.

SiC powder with average grain size (3µm) were added to Al-Pb-Cu alloy with different weight percentages (5, 10, and 15%).The mixture were mechanically alloyed by ball milling with the same conditions. The produced powder were compacting and sintering at optimum condition that obtained. Compressive strength, Vickers micro hardness test and microstructure examination were employed to assess the alloys.

3. Results and Discussion

Powders were used had been examined by SEM method .**Figures (1-3)** showed the SEM of Al, Cu, and Pb, respectively . **Fig.4** showed the mixing of powders after two hours.

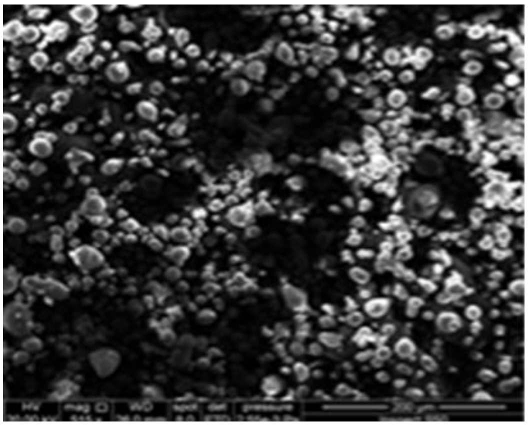


Fig.1 SEM of AL powder

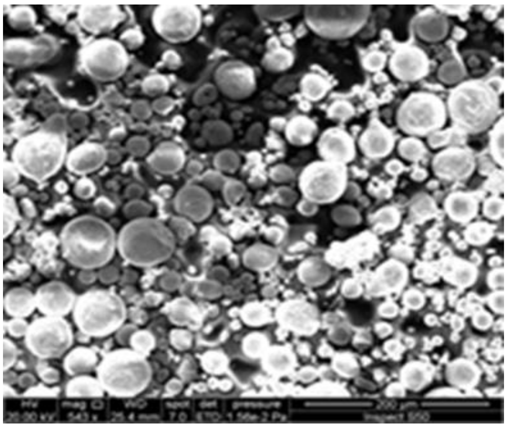


Fig. 2 SEM of Cu powder

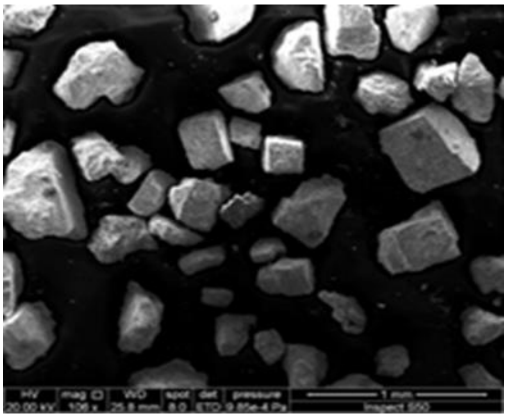


Fig. 3 SEM of Pb powder

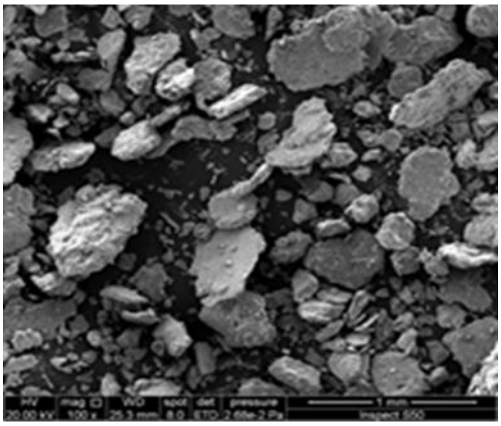


Fig. 4 SEM of alloyed powder

The results of compression test show that the higher compacted pressure registered the higher compression strength for all sintering temperature. **Fig .5**

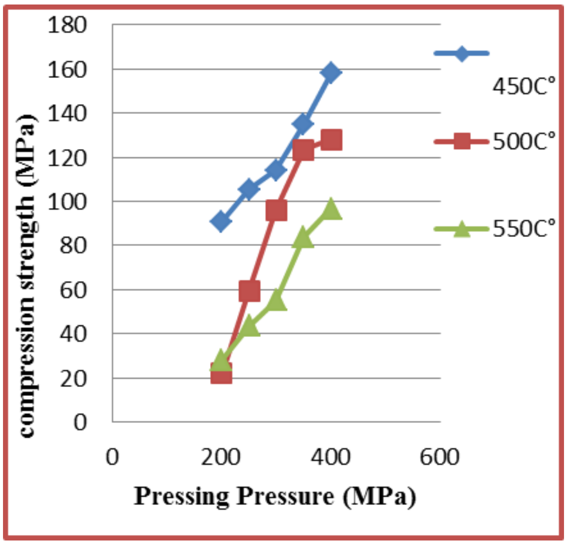


Fig .5 Compression strength verses pressing pressure in three different temperatures

This is owing to increase homogenous and consolidation between particles with increasing pressing pressure. Also it can be seen that the compressive strength decreases with increasing the temperature. This attributes to grain growth .It can conclude that the temperature of 450 °C carried out higher strength. The compressive strength rose with decreasing soaking time **Table.1** At this temperature the grain take enough time to recrystallize and subject to grain growth, so 30 minutes gives higher strength.

Table 1: Compression Strength at Different Soaking Time at 450 ˚C

Soaking time (minute)	Compression strength (MPa)
30	192
45	168
60	158

The hardness of alloys was increased with increased Pressing pressure at each temperature **Fig.6.** This could explained that the hardness values more dependent on adhesion between particles during compacting process , so with lower pressing pressure the bonding strength between grains are weakened and some porous could be noticed . As pressing pressure raised, the bonding between particles was increased and the alloy became harder. Hardness that decreased with increasing temperature, also affected by sintering time, where increased with lowering soaking time .**Table .2.**

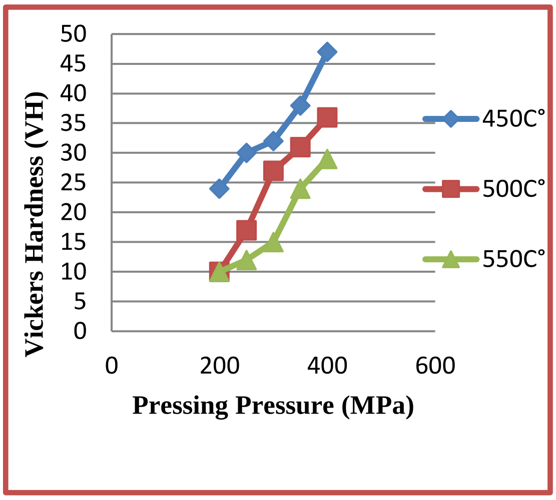


Fig.6. Micro hardness verses pressing pressure

Table.2 Micro hardness at Compacting Pressure 400 MPa and Sintering Temperature 450 °C

Soaking time (minute)	Vickers Micro hardness (HV)
30	50
45	48
60	47

The duration of soaking time 30 minute at 450 ˚C, recorded 192 MPa as compression strength and 50 HV hardness. This condition which gives an optimum results, so it can be called an optimum condition. **Fig. 7** shows the microstructure of this condition which can recognize the alloying elements (Al, Pb, and Cu) clearly.

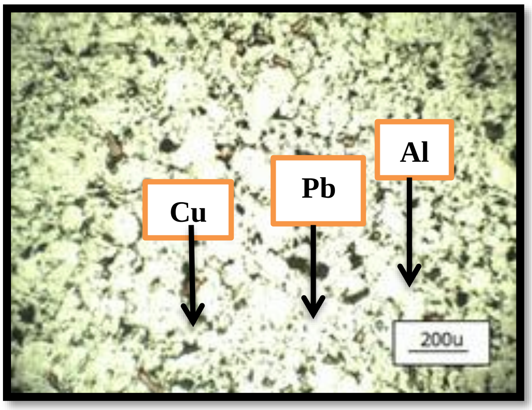
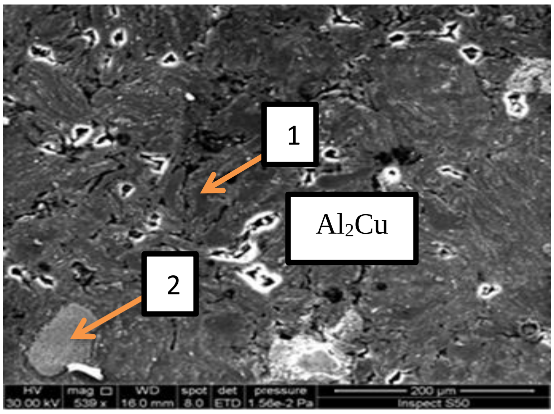
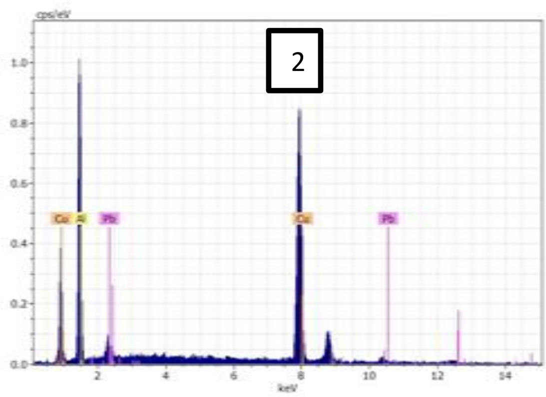


Fig.7. Microstructure of Al-Pb-Cu alloy at optimum condition

SEM and EDX of AL-Pb –Cu alloy **Fig. 8** indicate, that the formation of a hard intermetallic compound (Al_2Cu) which may the reason of enhancing mechanical properties.





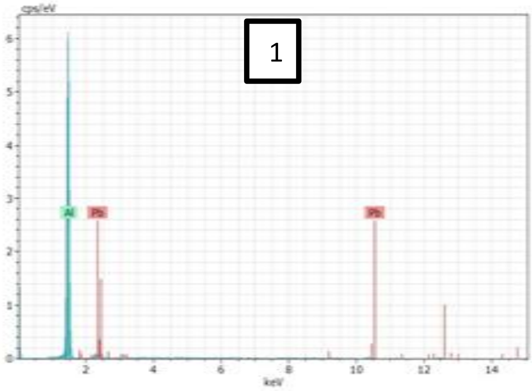


Fig.8. SEM & EDX for alloy at optimum condition

After aging process which is the first method of improving the mechanical properties , the micro hardness and compression strength of the alloy are 61HV and 238 MPa respectively , so the values of improving percentages calculated from the following formula

$$\frac{new\ value - old\ value}{old\ value} \times 100\% \qquad (1)$$

The microstructure can be seen from **Fig. 9**, we can see homogenous distribution phases, and fine grains which may relate to enhance the mechanical properties.

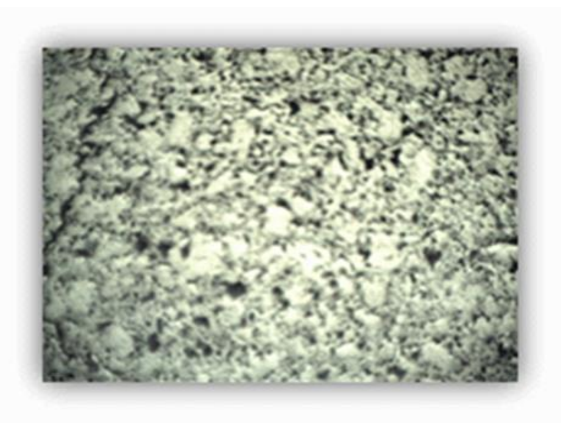


Fig.9. Microstructure of alloy after aging process

Fig. 10 showed the SEM of SiC powder that added to constitutes for improving the mechanical properties.

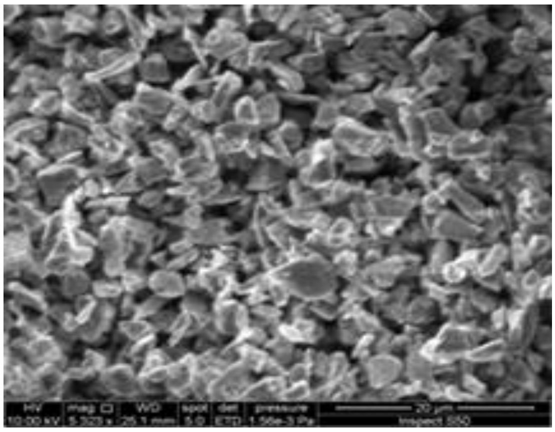


Fig. 10. SEM of SiC powder

The results showed that the micro hardness increased with increasing the percentage of addition as shown in **Fig.11**, and the maximum addition of SiC powder indicate 72 HV, that is mean the percentage of improvement of micro hardness is 44%.

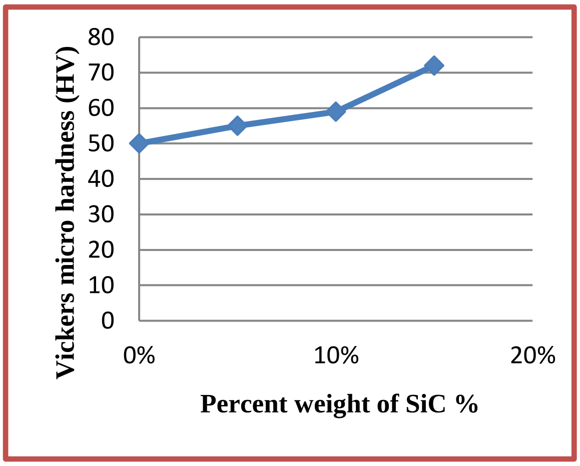


Fig.11 Micro hardness verses percent weight of SiC powder

The results of compression strength for produced alloy is showed that the increasing of percentage of SiC powder associating with lowering down in compression strength as shown in **Fig .12** This is due to the particle shape of SiC powder was not spherical or rounded as shown in **Fig. 10**, and the particles have sharp edges. These sharp edges which caused stress concentration, leading to reduce the strength.

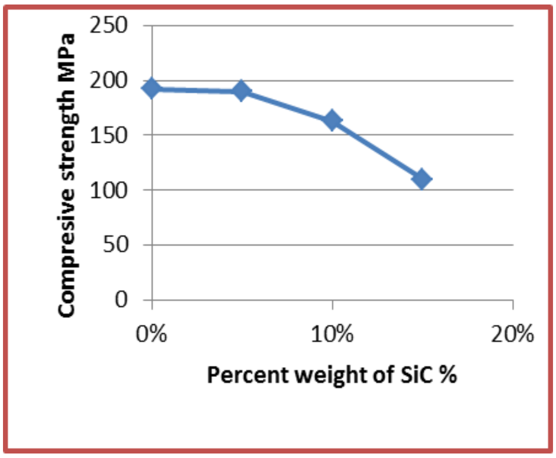


Fig.12. Compressive strength verses percentage weight of SiC powder

Fig.13 showed the SEM of the produced alloy with 15% SiC powder additive. The SiC particles indicated in figure through the main matrix alloy.

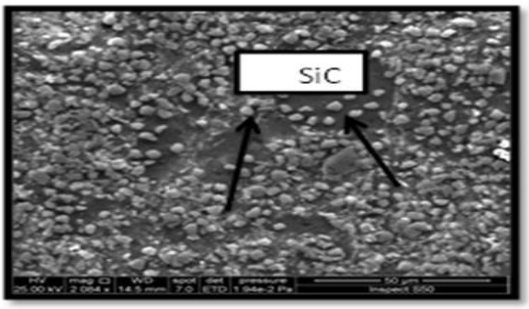


Fig.13. SEM for alloy at 15 % SiC powder

4. Conclusion

From present work, the main conclusions obtained as following:

1- Mechanical alloying technique produces homogenous and uniform distribution of Pb particles in aluminum matrix, so it is considered that the mechanical alloying technique is an alternative and most effective method to produce Al-Pb base bearing alloys.

2- The effect of compacted pressure on mechanical properties is more important, at compacted pressure increase, the mechanical properties increased too.

3- Although of significant of compacting pressure but sintering temperature is most effective parameters on mechanical properties of produced alloy. It was obviously, lowering the duration time of sintering gives better mechanical properties.

4- Artificial aging process enhanced the mechanical properties of Al-Pb alloy (compressive strength and micro hardness) 24% and 22% respectively percentage of the enhancement, this enhancement will lead to improving wear properties.

5- Addition of SiC powder in different percentages raised the micro hardness, the maximum additive led to 44% enhancement.

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تحسين الخواص الميكانيكية لسبيكة المنيوم- رصاص محضرة بطريقة الخلط الميكانيكي

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الخلاصة :

تستخدم سبيكة المنيوم-رصاص كسبيكة محامل نسبة لخواصها المرغوبة لهذا الغرض .الهدف الرئيسي من هذا البحث هو تحسين خواص هذه السبيكة . في البحث استخدمت ثلاثة انواع من المساحيق تضمنت (المنيوم كعنصر رئيسي مع 10% رصاص و 4.5% نحاس كنسب وزنية) , خلطت بطريقة الخلط الميكانيكي باستخدام كرات فولاذية واستمرت عملية الخلط لمدة ساعتين . نتج عن هذه العملية توزيع متجانس للمساحيق المستخدمة . استخدمت خمس قيم ضغوط مختلفة لكبس المسحوق الناتج تبعها تحميص القطع الناتجة عن الكبس بثلاث درجات حرارية مختلفة ولفترات زمنية مختلفة اثناء عملية التحميص .تم اجراء الفحوصات المختبرية متضمنة فحص صلادة فيكرز , مقاومة الانضغاط . والفحص المجهري لاختبار القطع الناتجة واختيار الظروف المثلى لانتاج هذه السبيكة . الجزء الثاني من البحث تضمن عمليات تحسين خواص السبيكة الناتجة باستخدام طريقتين : الطريقة الاولى هي معاملة حرارية (التعتيق الاصطناعي) واظهرت نتائجها زيادة ملحوظة في الخواص الميكانيكية حيث ازدادت الصلادة بنسبة 22% , ومقاومة الانضغاط بنسبة 24% . الطريقة الثانية تضمنت اضافة دقائق كاربيد السليكون باوزان مختلفة (5 , 10 , 15 %) ادت الاضافة الى زيادة الصلادة بزيادة نسبة الاضافة وصولا الى 44% زيادة بنسبة الصلادة مع اعلى نسبة اضافة , من الجهة الاخرى فان مقاومة الانضغاط تناقصت مع زيادة نسبة الاضافة .

الكلمات المفتاحية : سبيكة المنيوم-رصاص ، الخلط الميكانيكي ، التعتيق الاصطناعي ، مسحوق كاربيد السليكون