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Compacting Characteristics of Aluminum-10 wt % Fly Ash-Lead Metal Matrix Composites

S. Pichi Reddy[1,*], B. Ramana[1] and A. Chennakesava Reddy[2]

[1]Department of Mechanical Engineering,
L.B. Reddy College of Engineering, Mylavaram-521230, India
[2]Department of Mechanical Engineering, JNTUH Hyderabad, India
**Corresponding Author E-mail: seelamspr@yahoo.co.in*

Abstract

Aluminum-10 wt % Fly Ash and 0, 5, 10, 15 and 20 wt% lead powder mixtures were prepared and compacted in the pressure range from 200MPa to 400MPa. The effects of compaction pressure and % lead content on the green properties were determined. It was found that the ejection pressure, green density and % spring back increased while % true porosity decreased with increasing compaction pressure. For a fixed compaction pressure increasing the lead content was found to decrease ejection pressure and % true porosity. The green density increased with increasing lead content and the % spring back increased upto 10 wt % lead and thereafter decreased.

Introduction

Aluminum alloys get more and more importance as the structural materials in wide branch of industrial, automotive and aerospace applications. They exhibit low density, excellent corrosion resistance, good thermal and electrical conductivity. In tribological applications, however aluminum alloys have been limited by substandard stiffness, strength and wear resistance. In order to improve strength and tribological properties, hard ceramic reinforcements such as Al_2O_3 and SiC were introduced as the second phase in aluminum metal matrix composites (MMCs)[1,2]. Consequently, MMCs have superior stiffness, strength and wear resistance compared to unreinforced alloys.

Fly ash, the particulate waste material formed as a result of coal combustion in thermal power plants has been tried as a reinforcing material in aluminum by various researchers [3-8]. The addition of fly ash into aluminum matrix decreases the energy content, cost and weight of the component by improving selected properties. Additions of fly ash can make automotive castings lighter, leading to further energy saving during the use of cars and trucks by means of reduced fuel consumptions [3]. The addition of fly ash decreases the density and coefficient of thermal expansions and increases the hardness and wear resistances of the components [4-8]. Hence Fly Ash has been chosen as the reinforcing material.

Progress in the area of engineering and other large number of other branches of technology is associated with the increase of speeds and loads in friction system. In many cases, the technical or economic parameters of conventional bearing alloys are not suitable for these applications. In recent years, interest has been increasing in the antifriction alloys based on aluminum because of their advantages, such as the low specific mass, high strength to weight ratio, low cost and high corrosion resistance. The materials based on aluminum are characterized by high anti friction properties and are therefore regarded as a promising replacement of tin bronzes. Bimetallic bearings with a layer of aluminum alloy containing upto 20% Sn are used extensively in car construction. There are tendencies to increase the tin content further, but this increases the consumption of this difficulty available and expensive material. However Pb [9-17] has been tried as a substitute for Sn by various research workers because of its low modulus of elasticity, hardness and cost as compared to those of Sn.

The aluminum lead antifriction materials have been attracting special interest in recent years. However, the production of these materials by the methods of casting technique is associated with insurmountable difficulties owing to a wide immiscibility gap even at high temperature and large difference in specific gravity. These difficulties can be over come by the method of powder metallurgy. Aluminum lead, aluminum fly ash composites have been successfully produced by powder metallurgy technique [13-19]. Hence powder metallurgy method is chosen to prepare aluminum, Fly Ash and lead compacts. From the powder metallurgical characteristics of aluminum fly ash composites it is observed that 10 wt% fly ash composites have minimum spring back [20], however the hardness was found to increase slightly up to 10 wt % fly ash, beyond which it decreased[18]. Hence the present investigation deals with the determination of various compacting properties of Al-10 wt% Fly Ash with 0, 5, 10, 15 and 20 wt% of lead.

Experimental Procedure

Materials Used

The materials used during the present investigation constitute powders of Al (99% pure), lead (99.5 % pure) and Fly Ash. Aluminum powder was supplied by M/s. S.D.Fine Chem.Ltd., Mumbai, India. Lead powder was supplied by M/s Loba Chemicals, Mumbai, India. Fly Ash was collected from Dr. Narla Tata Rao Thermal Power Station, Ibrahimpatnam, Krishna District, Andhra Pradesh, India. The chemical analysis of Fly Ash is given in Table 1.

Table 1: Chemical Composition of Fly Ash (Wt. %).

SiO_2	Fe_2O_3	Al_2O_3	TiO_2	Mn	CaO	MgO	Na_2O	K_2O	P	SO_4	LOI
61.75	1.06	27.79	0.95	0.14	4.36	0.73	0.15	0.64	0.83	0.98	0.52

Mixing of Powders
Powder mixture compositions consisting of Al-10 wt % Fly Ash with 0,5,10,15 and 20 wt % lead are prepared using a mixing chamber fixed and rotated eccentrically in a lathe chuck at 32 rpm for one hour with change in direction every five minutes to ensure proper mixing.

Preparation of Compacts
An electronic universal testing machine of 40 Ton capacity is used for compaction. The compacts have been prepared by conventional powder metallurgy technique using single action die compaction. The compacts were prepared at three compacting pressures 200, 300 and 400 MPa by applying the calculated maximum compacting load. Silicone fluid spray is used as a die wall lubricant.

Results and Discussions
Compaction Characteristics
The microphotographs of Aluminum-10 wt% Fly Ash-0% Lead compacted at 200, 300 and 400MPa compacting pressures are shown in Fig. 1, 2, and 3 respectively. These Figures show uniform distribution of fly ash particles in aluminum matrix. It can also be observed that, as the compaction pressure increases the deformation of the aluminum particles increases which increases the area of contact.

Ejection Pressure
The ejection pressure P_e is calculated from ejection load F_e using the equation

Ejection Pressure $P_e = F_e/(\pi d_g l_g)$ MPa, where d_g and l_g are diameter and length of the green compacts.

The effect of compaction pressure on ejection pressure is shown in Fig.4. It reveals that ejection pressure increases with increase in compaction pressure. The reason is that with the increase in compaction pressure more penetration of the material into the micro irregularities present in the die wall is taking place which requires high forces for ejecting out the compact. Secondly with the increase in compaction pressure the effective area of contact between the die wall and compact is increasing hence the increase in ejection pressure.

The effect of lead content on ejection pressure is shown in Fig.5. The ejection pressure is decreasing with the addition of lead content. This is due to the lubricating properties of lead which reduces the friction between the die wall and the compact and hence reduces ejection pressure.

Green Density

The green density ρ_g is obtained from: $\rho_g = 4000W_g / (\pi d_g^2 l_g)$ Kgm^{-3}x 10^3 , where W_g is the weight of the green compact in grams.

Fig.6 shows the effect of compaction pressure on the green density of different composites. It can be concluded that the green density increases with increasing compacting pressure. This is due to the reason that as the compaction pressure increases the particles are more closely packed. Further densification results due to increasing deformation with increasing compaction pressure as evident from the microphotographs shown in Figs. 1,2and3. The rate of increase in density is more at the lower compaction pressure as compared with high compaction pressure.

The effect of lead content on green density is shown in Fig.7. It is evident that the green density increases linearly with the increase in lead content. It is because of reduction in inter-particle friction giving better packing due to easy flow of particles and higher specific gravity of lead.

True Porosity

The true porosity is calculated from the green density ρ_g and theoretical density ρ_{th} of different compositions using the equation: % True Porosity = $[\ 1-(\ \rho_g / \rho_{th})]$ x 100.

% True Porosity versus compaction pressure and wt % of lead are represented in Figs.8 and 9 respectively. With the increase in compaction pressure the % porosity is decreasing because of good packing of particles obtained by deformation and cold welding of particles at higher pressure. This is well supported by the micro photographs shown in Figs. 1,2 and 3. Comparison of these photographs reveals that the porosity is more for the compacts made at lower compaction pressure.

The effect of lead content on % porosity shown in Fig.9 indicates that the porosity decreases with increase in lead content. This can be attributed to the relative softness and lubricating properties of the lead which gives better packing.

Spring Back

The % spring back is calculated from die diameter d_d using the equation:

$$\%\ \text{Spring Back} = [\ (d_g - d_d) / d_d\ ] \times 100.$$

The effect of compaction pressure on spring back shown in Fig.10 indicates that the % spring back increases with increase in compaction pressure linearly. The effect of lead content on spring back shown in Fig.11 indicates that it increases with increase in lead content upto 10 % considerably and thereafter it has little influence showing optimum at 10%.

It is reported that spring back will be greater the higher the yield stress, the lower the elastic modulus and the greater the plastic strain. The increase in spring back with increase in compaction pressure may be assigned to higher plastic strain.

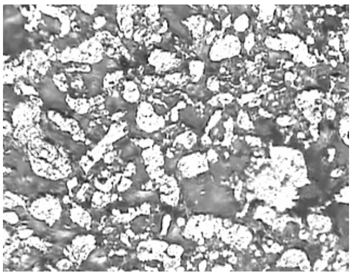

Figure 1: Microphotograph of Al-10%FA-200MP at 400X

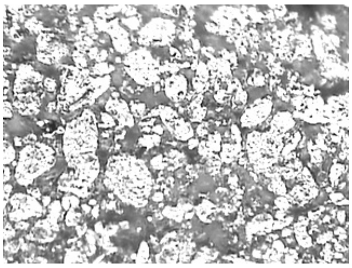

Figure 2: Microphotograph of Al-10%FA-300MPat 400X

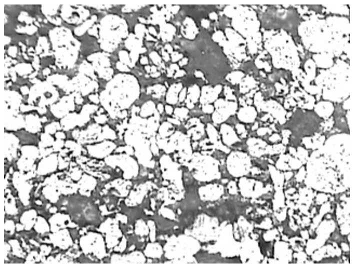

Figure 3: Microphotograph of Al-10%FA400MPa at 400X

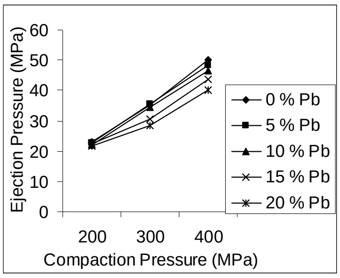

Figure 4: Effect of Compaction Pressure on Ejection Pressure.

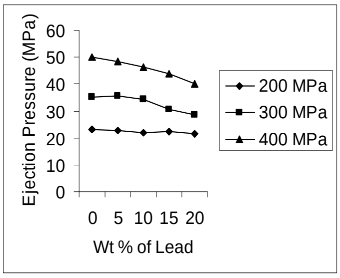

Figure 5: Effect of Lead content on Ejection Pressure.

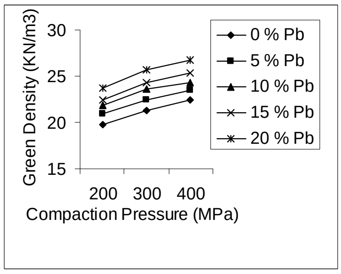

Figure 6: Effect of Compaction Pressure on Green Density

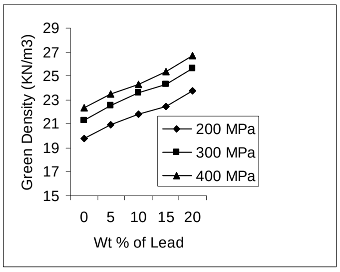

Figure 7: Effect of Lead content on Green Density.

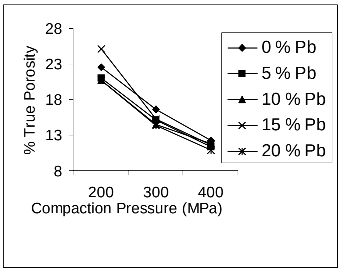

Figure 8: Effect of Compaction Pressure on % True Porosity.

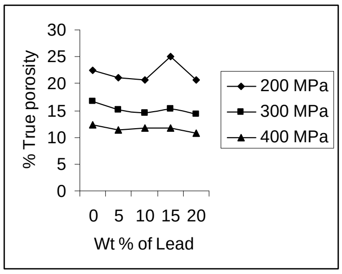

Figure 9: Effect of Lead content on % True Porosity.

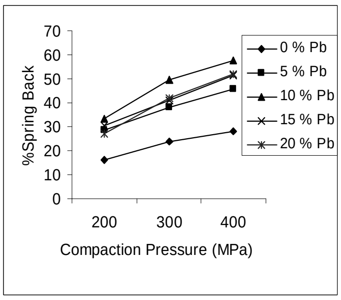

Figure 10: Effect of Compaction Pressure on % Spring Back..

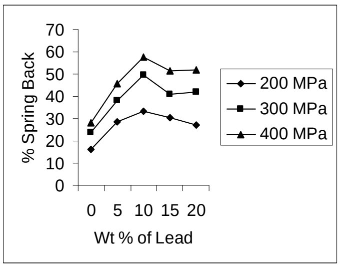

Figure 11: Effect of Lead content on % Spring Back.

Conclusions

1. Aluminum-Fly Ash-Lead composites are prepared by conventional powder metallurgy technique using single action die compaction.
2. The ejection pressure increases with the increasing compaction pressure and decreases with increasing lead content.
3. With increase in compaction pressure and lead content, the green density of the compacts increases.
4. The % porosity of the compacts decreases with increasing compaction pressure and increasing lead content.
5. The % spring back increases with increasing compaction pressure whereas % spring back increases upto 10% lead considerably and thereafter it has little influence.

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