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Effect of Zinc addition on Aluminium matrix composites utilizing powder metallurgy process

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Abstract

Metal matrix composites, made from Aluminium, utilizing powder metallurgy process, finds abundant usage in various industrial applications and are of great importance currently due to their increased usage, more so in the automobile, defense and aerospace industries. The aforementioned composites demonstrate better resistance to wear, hardness, as well as low coefficient of thermal expansion and are additionally lightweight. In the present work, aluminium metal is reinforced with composites of zinc particulate and fabricated via powder metallurgy process. In order to facilitate further usage in industrial applications, mechanical properties such as density, porosity, and hardness were measured.

Introduction

The unique properties and characteristics of composites make them highly useful, as their properties can easily be varied, by using different type of powders and mixing them, which is the main reason for its widespread usage in engineering industry. The current work involves fabricating and testing of high strength, light weight and wear resistant aluminium matrix composites. These composites have advanced mechanical and physical properties, which are formed by the combination of different metal powders which results in the development of new composites materials [1]. Metal matrix composites (MMCs) find abundant usage in automotive, aerospace and various structural applications, due to enhanced properties such as high thermal conductivity, better strength as well as high stiffness. They also exhibit low coefficient of expansion and density and exhibit high resistance to wear [2]. Matrix materials can easily be sourced from a wide array of engineering materials and its alloys. Having said that, Al alloys are preferred in most of the particle reinforced MMCs, due to their unique properties, encompassing low density, high corrosion resistance as well as good mechanical properties, bearing good isotropic mechanical properties, at quite reasonable costs [3]. Published literature data [4-10] shows that metal matrix composites are one of the most sought after metal groups in automotive applications. As far as re-enforcement goes, it is added to the base material (matrix) so as to achieve pronounced changes in mechanical and physical characteristics of the end product and provide good mechanical properties in the composites which can be easily varied with the mixing of the different types of powders which is the primary reason for its consideration in engineering usage.. The current work deals with the fabrication and testing of light in weight, wear resistant and high strength aluminium matrix composites.

Experimental Procedure

Mixing of Powders

The aluminium powder (99% pure) is mixed with zinc metal powder (R: 50-53 and S: 60-61) in a ball mill consists of a cylindrical containers which rotates so that the proper mixing of the powders can take place. The zinc powder is used as the reinforcement in the aluminium powder, which enhances its properties. The powders are first weighed and then put into the ball mill. The samples are made at different compositions and the weight of the each sample is 3 gm. The different composition of the reinforcement of zinc is performed at 3%, 4 % and 5% respectively. Grinding process has been used and works on the critical speed principle, which is defined as that speed post which the steel balls start to rotate in the same direction as that of the cylindrical device; resulting in no further grinding. The medium for grinding in this case were stainless steel balls. The milling is done approximately for 30 minutes so that proper mixing of the particles can take place.

Die compaction

The compaction of the metal powders are very important because if it (compaction) is not properly implemented, it would lead to the increase in porosity of the samples. The die and punch were designed and made up of die steel. Their dimensions are shown in the table 1 below. The punch and die were hardened post machining and after that the set up was placed on a hydraulic press. Post that compaction pressure of 400 MPa was applied for 1 minute. Compaction is necessary so that the proper binding of the particles can take place and it leads to less amount of porosity in the samples.

Table 1: Die and punch dimensions used for compaction

S. No.	Die and punch parameters	Dimension, mm
1.	Outer diameter of the die	68
2.	Inner diameter of the die	12
3.	Length of the die	110
4.	Punch diameter	11.5
5.	Length of the punch	105

Sintering

Green compacts of Aluminum zinc composites, having 3, 4 and 5 percent zinc, were sintered in a Muffle furnace at a temperature of 500° C for 60 minutes, as illustrated in figure 1. For the uninitiated, the green compacts are exposed to a high temperature, so as to facilitate proper bonding between the aluminium and zinc particles. The temperature is set in such a way that it should be below the melting point of the compacts. Post sintering the compacts were cooled slowly in a controlled temperature environment. The proper cooling additionally results in good binding of the particles.

Fig. 1. Muffle Furnace for Sintering.

Testing of properties

Density

The Al-Zn composites' density was found out by determining the volume and weight of the samples. The volume was found out by measuring the precise dimensions of the powder metal specimens. The theoretical density was also determined, by the comparison of the sum of volume (weight divided by the density) of the constituents and volume of the composite. The density variation is shown in fig 2.

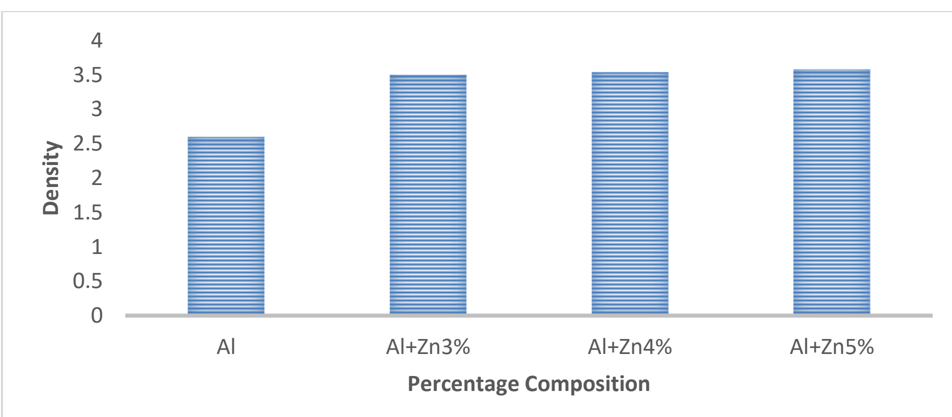

Fig 2: Comparison of density with the varying percentage composition of Al-Zn in Al

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Porosity testing

The porosity of Al-Zn composites are illustrated in Fig. 3, which demonstrates that Al-Zn composites porosity increases with increment in wt. % of Zinc particles and it is attributed to the increment in the percentage of the coarser component (Zn particles). Porosity of 3, 4 and 5 wt. % Al-Zn samples are 0.037, 0.039 and 0.042 respectively.

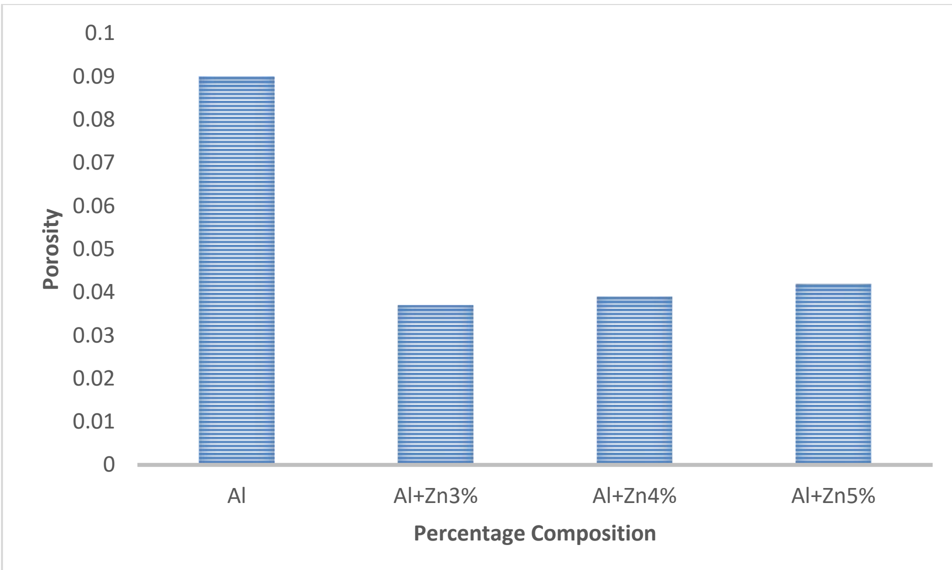

Fig 3: Comparison of porosity with the varying percentage composition of Al-Zn in Al

Rockwell hardness test

Rockwell hardness of Al- Zn composites increase with an increment in % by wt. of Zn, which can be attributed to the fact that the zinc is harder than pure aluminium. The Rockwell hardness of Al-Zn composites are represented in Fig.4 below. It exhibits Rockwell hardness of 3, 4 and 5 wt. % Al-Zn samples as 35 HRB, 40 HRB and 55 HRB respectively.

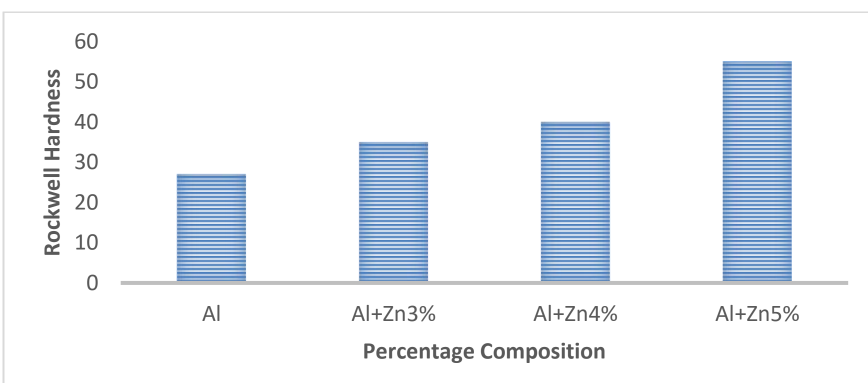

Fig 4: Comparison of Rockwell Hardness with the varying percentage composition of Al-Zn in Al

Wear Test

In wear process, we witness an interaction amongst different surfaces and, to be precise, it encompasses the deformation and removal of material from a surface due to mechanical action of the objects in contact via motion. Standard specimen of 1/8” x 1/2” x 5”, as per ASTM D790; is placed between the jaws and height is adjusted, w.r.t the wear disc using height adjustment block. The wear test of the samples has been performed at 20 N and a speed of 400 rpm. The wear in the sample is found by measuring the difference in the weights of the samples before and after the wear. The plot shows the wear of different samples at the different reinforcement’s compositions. The plot shows that the wear decreases when the reinforcement percentage increases till 4% and increases further increases the composition becomes 5 %.

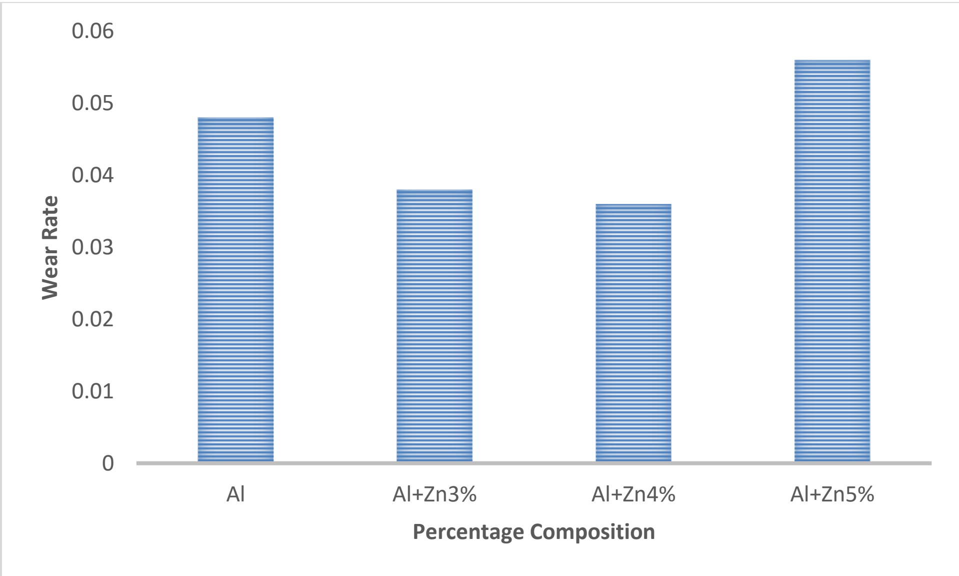

Fig 5: Wear variation with the varying percentage composition of Al-Zn in Al

Conclusions

In the work at hand, Al-Zn composites have been fabricated successfully via powder metallurgy method and the (mechanical) properties such as porosity, density as well Rockwell hardness, tested. The density of the compacts is found to increase with the increase in composition percentage of zinc reinforcement. The porosity of the samples starts increasing with the increase in the weight percentage of Zinc particles in aluminium. This is because the zinc particles and pure aluminium particles have different particle sizes. The Rockwell hardness of Al-Zn composites increases with the increment in the weight percentage of Zinc particles as zinc is slightly harder than the Aluminum. The wear test is also performed and the results reveal that wear decreases with the addition of zinc as a reinforcement till 4% but on further addition of zinc the wear rate increases rapidly.

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