Int. Journal of Refractory Metals and Hard Materials 54 (2016) 223–229

Contents lists available at ScienceDirect

Int. Journal of Refractory Metals and Hard Materials

journal homepage: www.elsevier.com/locate/IJRMHM

Effect of reinforcement, compact pressure and hard ceramic coating on aluminium rock dust composite performance

K. Soorya Prakash *, R. Sathiya Moorthy, P.M. Gopal, V. Kavimani

Department of Mechanical Engineering, Anna University Regional Centre, Coimbatore 641 046, Tamil Nadu, India

A R T I C L E I N F O

Article history:
Received 9 June 2015
Received in revised form 23 July 2015
Accepted 28 July 2015
Available online 1 August 2015

Keywords:
Aluminium
Rock dust
Powder metallurgy
Coating
Anodizing
Microstructure
Hardness
Wear

A B S T R A C T

Aluminium 6061T6 is reinforced with naturally available rock dust particles to fabricate low cost aluminium rock dust composite through powder metallurgy technique. Reinforcement ratio was varied from 0% to 50% whereas size of the particles was kept constant as 20 μm. Mixed powders were compacted at three different pressures from 100 to 200 MPa. Al_2O_3 ceramic coating was given over the novel composite material by Type III Sulphuric acid hard coating method. Developed composites were tested for microstructure, micro-hardness and wear resistance. SEM micrograph confirms uniform distribution of reinforcement in matrix and a fine ceramic hard coating is observed through optical microscopic images. Micro-hardness increases as reinforcement level increases up to 10%. Wear properties were analysed using pin on disc setup without lubricant and by maintaining three parameters viz load, sliding velocity and sliding distance being unchanged. It was found that composite with 10% rock dust gives better wear resistance than any other compositions. Also incrementing figure is notified for hardness and subsequently wear resisting property too when compacting pressure gets increased. Coated sample exhibits better performance than uncoated composite samples at all compositions and at different levels of compacting pressure.

1. Introduction

Mechanical and wear properties are the major elements concentrated while selecting a material for aerospace and automobile industries [1]. At present composites majorly have applications in these areas, particularly aluminium based composites because of their properties like strength to weight ratio, corrosion resistance and low cost. Even though aluminium has good strength its resistive ability to scratches and indentations are not up to the mark. To eliminate this property lag expensive hard abrasive particles like SiC, Al_2O_3 and B_4C are introduced to aluminium matrix and hence forth known as aluminium matrix composites. Several researchers tried a low cost, easily available fly ash as reinforcement and have also succeeded in their research by obtaining better properties [2]. In this study an attempt was made to introduce a low cost, easily available rock dust as it exposes equivalent properties of the above said reinforcements. The details of rock dust which are supposed to be a positive replacement for existing range of reinforcements are clearly illustrated in Table 1.

Metal matrix composites are prepared by several methods like stir casting, powder metallurgy, friction stir processing and by some severe plastic deformation processes [3–6]. Powder metallurgy is one of the commonly used methods amongst these to produce metal matrix composites owed to superior properties exhibited by PM processed materials over any other rival methodologies [7].

Hard coating over the surface will improve the surface properties of the material like wear and corrosion resistance. The type of coating material depends on the application of the core material; alumina, boron carbide, tungsten carbide and titanium based coatings are commonly used and they increase the properties significantly [8–11]. Al_2O_3 coating over the alloys increases the tribological and corrosion properties to a great extent [12]. Various methods like anodizing and spray coating are used for surface coating [12,13]. According to Dingfei Zhang et al. anodizing is an economical, efficient and environmentally friendly traditional method for such applications.

This study focuses on developing low cost composite by using naturally available rock dust as the reinforcement. Powder preparation, compaction and sintering are the three major steps of PM technique. Sintering temperature and pressure also have the influence on properties of the composites developed in PM technique, as the pressure increases density and wear rate of the composite decrease [7]. Reinforcement level and compacting pressures are also varied to produce the novel composite. In this study hard alumina coating is given over the composite by anodizing (Type III) in order to get elevated properties. The overall structure of the current study is plotted in the chart (Fig. 1).

* Corresponding author.
E-mail addresses: k_soorya@yahoo.co.in (K. Soorya Prakash), rsathiyamoorthy@ymail.com (R. Sathiya Moorthy), gopal33mech@gmail.com (P.M. Gopal), manikavi03@gmail.com (V. Kavimani).

http://dx.doi.org/10.1016/j.ijrmhm.2015.07.037
0263-4368/

Table 1
Chemical composition of rock dust.

Elements	O	Na	Mg	Al	Si	K	Ca	Fe
Weight %	51.57	2.96	1.34	8.51	24.34	1.45	5.21	4.61

2. Materials and methods

2.1. MMC production

Al6061 was taken as a base metal and rock dust as reinforcement. Rock dust is collected from quarries and its chemical composition is given in Table 1 and the EDAX pattern is shown on Fig. 2. In this work powder metallurgy technique was used for composite fabrication in which rock dust of 20 μm (average) is reinforced with aluminium by different weight ratios (100:0, 90:10, 80:20, 70:30, 60:40, 50:50). Size distribution of rock dust particles is identified through particle size analyser and the same is depicted in Fig. 3. As the first step of powder metallurgy technique, rock dust was mixed with aluminium metal powder using a ball mill for around 5 h. The mixed powder is compacted by the vertical hydraulic press under three different loads of 100, 150 and 200 MPa. Compacted green components are sintered using a muffle furnace for 2 h besides maintaining the temperature at 550 °C. The specimens developed for varying weight ratio are as shown in Fig. 4.

2.2. Coating

Hard coating over the components is a widely used technique in order to improve the surface properties. Anodizing is a coating process that develops an aluminium oxide layer over the aluminium that prevents the material from environmental effects. In the present study the same technique is adopted and the novel aluminium rock dust composite is coated with aluminium oxide by anodizing and the thickness of coating is maintained with slight deviations and within 15–20 μm. Type III Sulphuric acid hard coat anodization method is used and 15 V, 25 A current is passed for 50 min to achieve aluminium oxide coating over the novel composite.

3. Material characterization

3.1. Density

Density of the composite was found using Archimedes principle. It was observed that the composite with higher reinforcement ratio gives lower density due to the lower density value of the reinforcement.

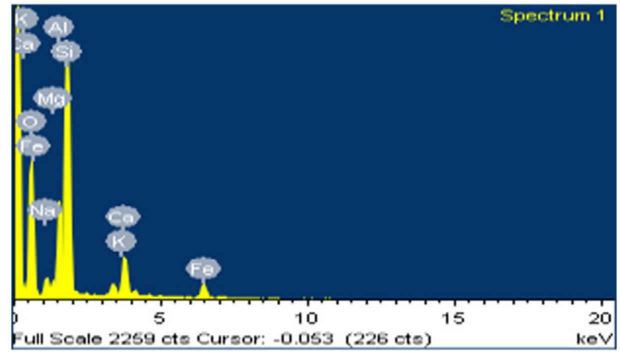

Fig. 2. EDAX pattern of rock dust.

It is well known that the density of the component decreases as the compaction pressure increases because of the reduction in porosity.

3.2. Micro-hardness

Hardness of both the coated and uncoated composites was experimented in Vickers hardness setup made by Mitutoyo, Japan. A diamond ball under the load of 0.5 kg was used for measuring micro-hardness.

3.2.1. Effect of reinforcement

Addition of reinforcement alters the hardness of the composite. Furthermore decrease or increase in the hardness of the MMC depends on the reinforcement type, level and of course their size. Headed by this formulation, in this study hardness of the MMC increases till 10% rock dust addition, further increase in reinforcement decreases the hardness as shown in the graph represented in Fig. 5. This is due to the unhealthy bonding between the metal and reinforcement when it exceeds 10% at all compacting pressures as shown in Fig. 5(a–b). Micro-hardness increases as more amount of reinforcement is added and uniformly distributed [14]. Maximum hardness of 59.1 HV was exhibited for 10% addition of the reinforcement at 200 MPa compacting pressure which is around 38% more than the base metal. Micro-hardness of each composition is listed in Table 2 and the same is illustrated in the form of graphs indicated in Fig. 5(a–c).

3.2.2. Effect of compacting pressure

Compaction pressure plays a significant role in property amalgamation of the material. As stated by previous researchers, hardness

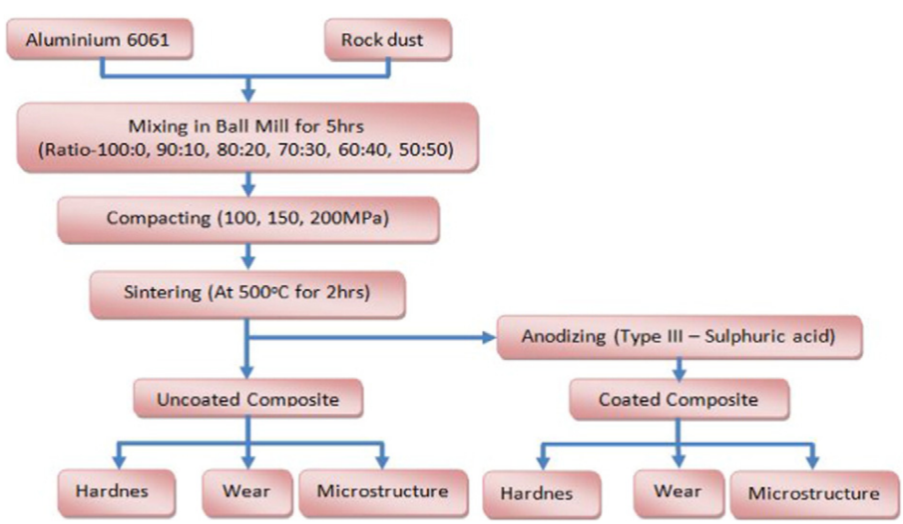

Fig. 1. Composite development and characterization chart.