

A REVIEW ON MECHANICAL PROPERTIES OFAMMCs PREPARED BY POWDER METALLURGY TECHNIQUE

S. Venkat Prasat^{#1}, V. Maduraiveeran^{#2}, S. Pon Rakesh^{#3}, K. Kavinkumar^{#4}

#1,2,3,4 Department of Mechanical Engineering, Sri Ramakrishna Engineering College,
Coimbatore – 641 022, Tamil Nadu, India.

ABSTRACT

In this review work an effort has been taken to cite the importance of powder metallurgy technique in the preparation of Aluminium metal matrix composites (AMMC). A detailed review on the influence of reinforcement particle size was carried out. The effect of size and amount of reinforcement and their mechanical properties were also studied. There was an increase in the hardness, density and tensile strength of composites with an increase in volume fraction reinforcement; however ductility was decreased. Wear tests revealed that composites offer superior wear resistance compared to the matrix alloy. In present study, the mechanical and wear behavior of AMMC has been discussed.

Key words: Aluminium metal matrix composites, Powder metallurgy, Mechanical properties

Corresponding Author: S. Venkat Prasat.

1. INTRODUCTION

Aluminum alloys reinforced with ceramic particulates have significant potential for structural applications due to their high specific strength and stiffness as well as low density [1]. These properties have made AMMC an attractive candidate for the use in weight-sensitive and stiffness-critical components in aerospace, automobile and industrial sectors [2].

AMMC are manufactured using different techniques and they can be classified into casting (liquid phase processes), semi-solid forming (liquid–solid processes) and powder metallurgy (solid-state processes) [3]. The powder metallurgy technique is widely used in the manufacture of particle MMCs. It is more cost effective than the casting methods, but it cannot be used for the production of complex shapes. Compared with powder metallurgy, liquid processing which has some advantages: high matrix–particle bonding, control of matrix structure, low cost, simplicity, a nearer net shape can be produced and there is a wide selection of materials that can be used in

this method. However, the casting process has two main problems: first, the reinforcement particles are not wetted by the liquid metal matrix, and second, the reinforcement particles tend to sink or float according to their density relative to the matrix liquid.

Recently, research has been extended to evaluate the effect of nano particles on wear resistance of aluminum and its alloys. One of the promising nano reinforcements was carbon nano tubes (CNTs) and it has high mechanical properties. Improvement of wear resistance of aluminum as a result of CNTs addition was reported in few studies. Zhou and coworkers fabricated aluminum composites reinforced with CNTs through pressure less infiltration of aluminum into CNTs-Mg-Al preformed in N₂ atmosphere at 800°C. They found that CNTs were well dispersed and embedded in the Al matrix, the friction coefficient of the composite decreased with increasing the volume fraction of CNTs, and the wear rate of the composite decreased steadily with the increase of CNTs content (from 0 to 20 vol%) [5].

2. EXPERIMENTAL PROCEDURE

Powder metallurgy comprises of pulverization of metal, milling, blending, and compaction followed by sintering. Sintering is nothing but heating the green compact to 70-90% of its melting point. Usually aluminum powder of high purity or alloyed aluminium was used as a matrix material, ceramics were used as reinforcement based on the requirement we may use single or hybrid reinforcements used. In this experiment SiC of various sizes, typically, 11, 6 and 3 μm and the aluminum powders have an average size of 50-60 μm were used. There were three different volumetric percentage of reinforcement which were dispersed in the aluminium matrix say 5, 10 and 15 vol %. Ball milling machine was used to make the powder [4]. The lubricant for this process was 1– 2 wt. % paraffin lubricant wax. Aluminium powder, reinforcement and lubricant were placed into a blender. It is mixed mechanically until a homogeneous mixture is achieved, and then the mixture was cold compacted in a tool steel die shown schematically in Fig. 1. The powders were then hydraulically pressed [5].

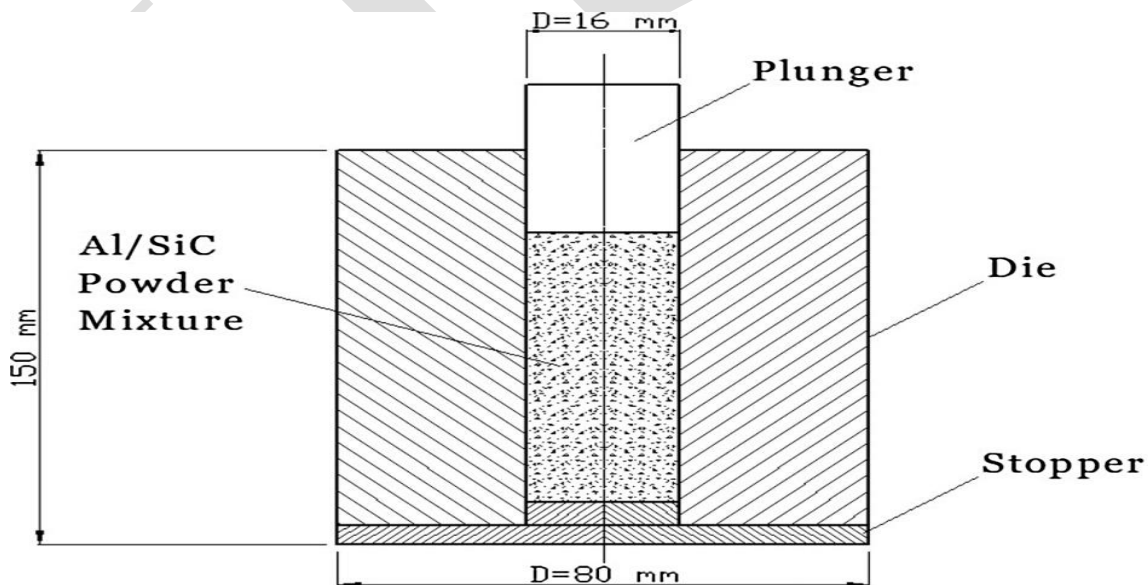


Figure1: A schematic illustration of the cold compaction die used for preparation of Al/SiC composites

At the end of compaction, green compact was made. Press of capacity about 400-500 kN was used. The compaction pressure was about 400 MPa. The Al/SiC composites produced from the cold compaction (green compact) were subjected to sintering at 590 °C for 2 hours. The process was performed under inert gas atmosphere. After sintering, AMMCs were subjected to hot extrusion. The final AMMCs samples had cylindrical shape of 8 mm dia and about 12 mm length. The samples were subjected to micro structure and mechanical tests.

3. RESULTS & DISCUSSION

3.1. Behavior of Al/SiC AMMC reinforced with micron sized particulates

Microstructural characteristics of Al/SiC composites

Fig. 2 shows SEM micrographs AMMCs having different sizes of the SiC reinforcement with a constant volume fraction of 10 vol. %. Even though some clustering of reinforcement particulates could be observed, the distribution of SiC generally appeared to be fairly homogeneous throughout the Al matrix. It shows typical optical micrographs of AMMCs having a constant SiC particulates size of 11 μm but with different volume fractions of the SiC particulates. It has been observed that increasing the volume fraction of reinforcement increases the agglomerations of the SiC particulates. Many researchers revealed such observations. The agglomerations size of reinforcement was found varying between 10 and 35 μm [5].

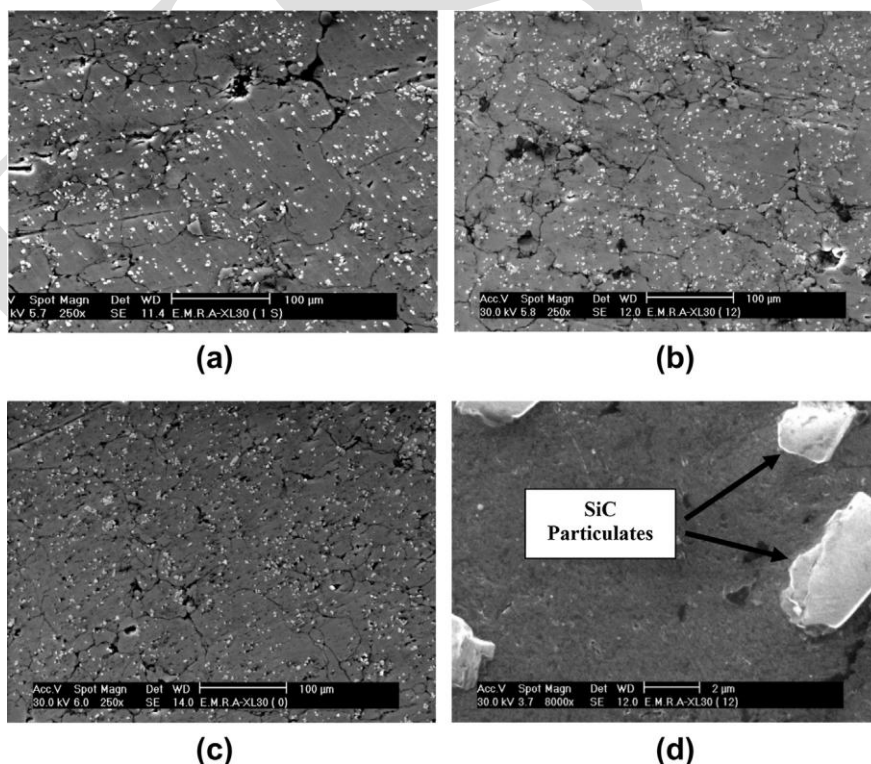


Figure 2 SEM micrographs of Al/10 wt.% SiC composites reinforced with SiC particulates have size of (a) 11 μm ; (b) 6 μm ; (c) 3 μm ;

Density of the Al/SiC composites

The actual density of AMMCs with the different volume fraction of SiC is illustrated in Fig. 3. The AMMCs exhibited densities higher than the pure aluminium. It has been observed that there is a difference in actual and theoretical densities. The actual densities are 97-98% of theoretical densities the (6 μm) reinforced AMMCs contain 5, 10, and 15 vol. % of SiC particulates exhibited densities which are very close to the aluminium matrix. The Al matrix alloy had a density of 2.685 g/cm^3 . It has been also observed that increasing the volume fraction of reinforcement particle increases the density of the composites. It was reported by many investigators that the reinforcements enhance the density and strength of the AMMCs. Moreover the increase in particulate volume fraction increased the density of the composites. This density increment is due to the higher density of the reinforcement. So it is essential to choose the proper percentage of reinforcement presence. The reinforcement particulate size also influences the density of the composites.

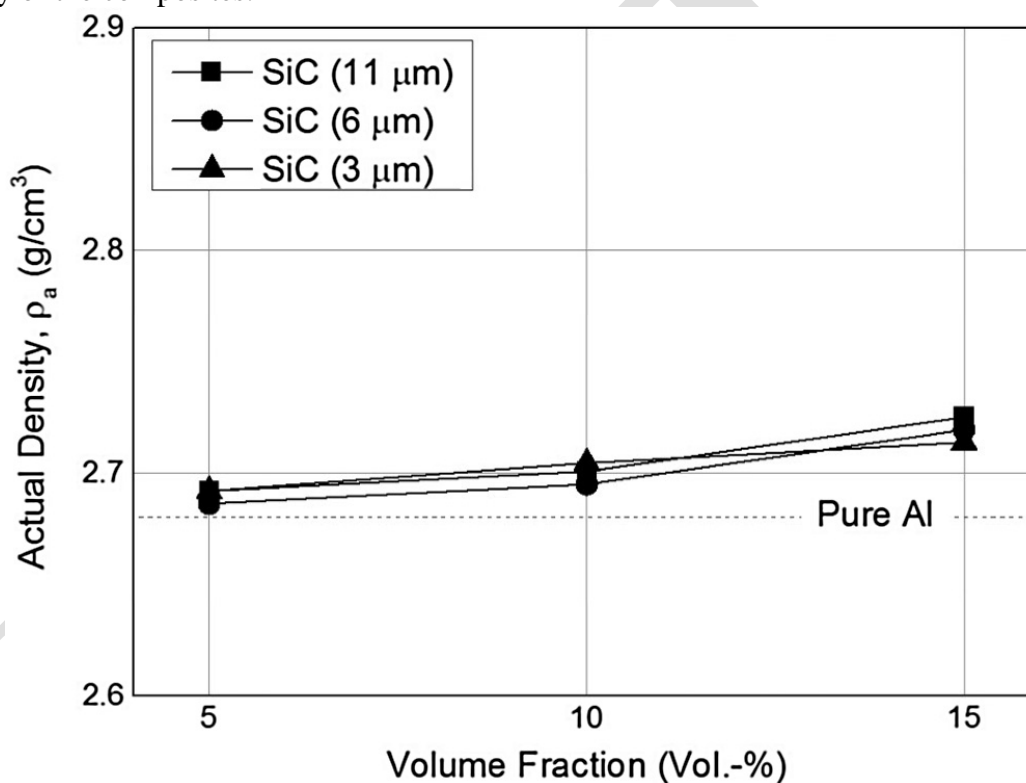


Figure 3 Density of AMMC at various Vol.% of reinforcements and particulate size

Corrosion behavior of Al/SiC Composite

The major problem in usage of metallic components is corrosion and nowadays many researches are conducted to control the factors responsible for corrosion. One of the important method to avoid corrosion is addition of reinforcement. Some results have shown that the presence of reinforcement reduces the pitting of AMMCs. For example, Feng et al. [6] examined the corrosion behavior of composite due to the vol. % presence of reinforcement. Candan [7] studied the effect of particle size on corrosion behavior. It has been observed that the corrosion reduces with an increase in the percentage of reinforcement and reduction in

reinforcement particle size. Figure 4 displays the results of tests which were carried out with different combinations of reinforcement and exposure time. The combination of high reinforcement content, small reinforcement particle size and short exposure time gave the best result. Corrosion is a very important parameter for assessing composite as a structural material [14].

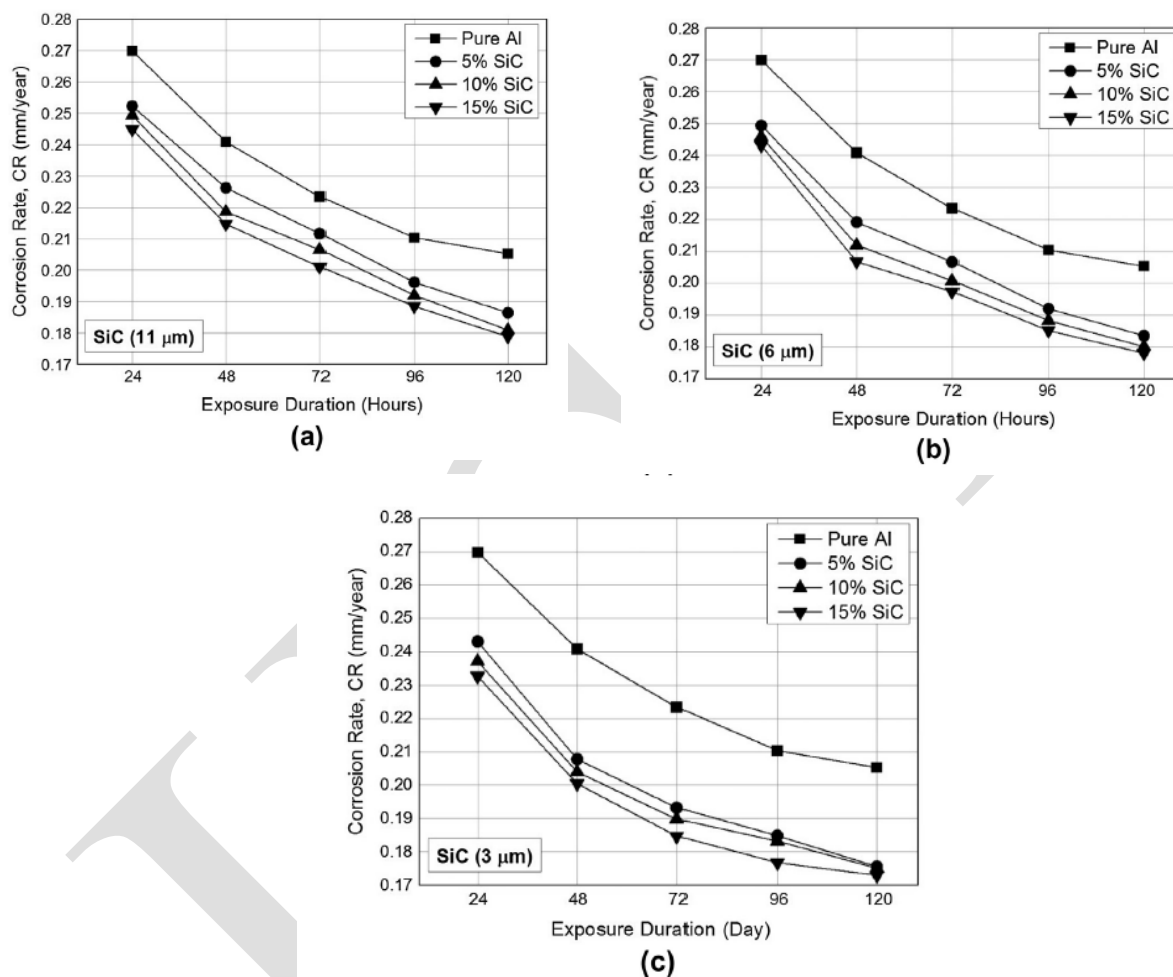


Figure 4 Corrosion behavior of AMMC at various combinations

Hardness behavior of Al/SiC Composite

Ceramics are generally harder in nature. So, an increase in the amount of ceramics present in the AMMCs causes a corresponding increase in the value of hardness but at the same time it reduces the ductility of the composite. The comparison of two samples (20% and 10% reinforced) is shown in Figure 5 [8]. Sample No.1 has higher hardness compared to Sample No.2 because of higher percentage of SiC reinforcement. Sample No.1 is brittle in nature because of high hardness value whereas sample No.2 is ductile in nature because of low hardness value. The sample No.2 also shows higher wear, porosity and low density. Different percentage of

reinforced material shows different value of hardness [8]. The addition of SiC particulates increases the of tensile strength of the composite by around 20% [9].

Brinell Hardness Number(BHN)

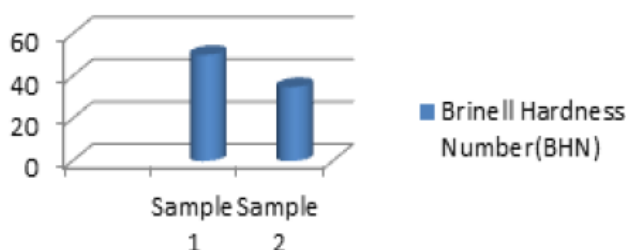


Figure 5 Hardness behavior of AMMC at various combinations.

Wear tests on Al/SiC Composite

Wear testing is one of the important mechanical test in material science. Here the testing was conducted with two samples, one with 20% reinforcement and other with 10% reinforcement. Wear test was carried with the help of abrasive sheet of 80 (grit size). The parameter taken into considerations was length of abrasive paper. The samples are abraded along the length of the abrasive paper, say 100 cm. Then the amount of abrasive wear loss was measured using digital weighing machine. It has been observed that sample 2 (10% reinforcement) is highly abraded when compared with sample 1 (20% reinforcement). The amount & size of the reinforcement determine the wear properties of AMMCs [10].

Table 3. Wear Rate of Sample 1(20% reinforced) and Sample 2(10% reinforced)

Length(cm)	Wear Rate(gm./cm)	Wear Rate(gm./cm)
	Sample 1	Sample 2
100	0.0137	0.0067
150	0.0298	0.0207
200	0.0658	0.0285
250	0.0938	0.0376
300	0.1158	0.0576
350	0.1358	0.0700
400	0.1458	0.0766
450	0.1588	0.1001
500	0.2158	0.1119

Table 1 Wear test on AMMCs

3.2 Behavior of Al/TiO₂ AMMC reinforced with nano sized particulates

The hardness of Al matrix reinforced with different amounts of nano particle was conducted by researchers [11]. From Fig 6, it can be seen that the hardness of AMMCs increases with an increase in the amount of nano particles [12]. The maximum hardness of 82BHN was obtained in the sample containing 4.5 vol. % of nano particles. This may be due to the presence of nano particles, which hindered the movement of matrix dislocation in the composite leading to increased strength and hardness [13]. The addition of nano particles did not influence the ductility but in contrast strength and hardness are clearly influenced by the effect of the volume fraction of nano-particles [15].

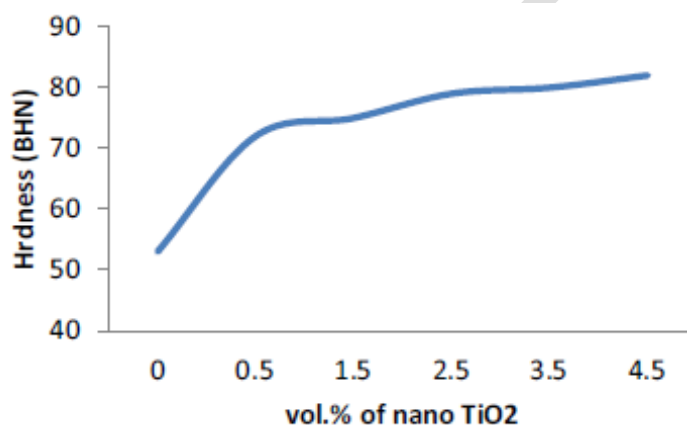


Figure 6 Hardness of AMMCs at various combinations.

CONCLUSION

1. The density of the AMMC increases with increase of volumetric percentage of reinforcement and the size of the reinforcement.
2. During corrosion test, the weight loss of the composites increased with increasing particle size as well as exposure time. Corrosion is a very important parameter for assessing composite as a structural material.
3. The hardness of the composite increases with an increase in the volumetric percentage of reinforcement, which in turn increase the brittleness.
4. The size of the reinforcement also influences the wear properties of the composites.
5. It has been also observed that increasing the volume fraction of reinforcement increases the agglomerations of the reinforcement particulates.
6. Powder Metallurgy can be utilized to obtain uniform distribution of particulates in comparison to Stir casting technique. Powder metallurgy can be used for low density particulates.

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