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Evaluation of Properties for Al-SiC Reinforced Metal Matrix Composite for Brake Pads

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Abstract

MMC has been used in engineering application in broad way because of their mechanical and physical properties. They are broadly used in the field of automobile and aerospace because of their high strength to weight ratio, lighter weight, lower cost, and good behaviour. In present study the mechanical and wear behaviour of aluminium metal matrix composite and SiC has been discussed. Brake Pad is manufactured by route of powder metallurgy which is widely preferred because of its low cost, high volume production, ease of operation, sustainability and attractive manufacturing process. Brake pads are developed with light alloy Aluminium 2014 reinforced with SiC to augment the strength and wear resistance and explore the advantage of low density of the matrix.

Keywords: MMC; Brake pad; Powder Metallurgy.

1. Introduction

Brake pad is one of the most important parts of braking system which is mounted on a brake disc rotor on each wheel. Braking system also contains many other parts like cylinders (master cylinders, wheel cylinders, tandem cylinders) and control system which may be operated by hydraulic system or pneumatic system. In different types of breaking system varieties of materials are used for brake pads. Binders, fillers, friction modifiers and reinforcement are four important classes of ingredients into which they are often categorized. Asbestos is most frequently used brake pad material in which asbestos fibres are embedded in matrix of polymer along with other several ingredients. Many research works have been carried out for the Asbestos free brake pad materials over few years. Current trend has come out for the

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utilization of composite brake pad materials which provide more economical benefits and also preservation of environment. To develop brake pad materials for the fulfilment of requirement many factors have to be considered like stable coefficient of friction and lower wear rate at different operating speed, pressure, temperature, environmental condition etc. For the fulfilment of above requirement it is important of having appropriate combination of materials and selection of materials is not an easy task rather it is a complex process which require lot of experience. Due to carcinogenic nature of asbestos fibres use of asbestos fibres have been reduced day by day. [1] Now days MMC has been used in engineering application in broad way because of their mechanical and physical properties. They are broadly used in the field of automobile and aerospace because of their high strength to weight ratio, lighter weight, lower cost, and good behaviour. AMCs are also used because of their superior strength with appropriate toughness ductile matrix, well bonding particle matrix interface, homogenously distribution of particles etc. [2]

Recent research has been focused on the compaction method to manufacture cost effective and highly dense material through powder metallurgy method. The possibility of obtaining uniform parts and reducing tedious and expensive machining processes is the prime reason for using powder metallurgy method. [1]

Nomenclature

d	Diameter of compaction die
h	Height of compaction die
V	Total volume of compaction die
M	Total mass of compaction
m	Mass of samples
ρ	Sintered Density
BHN	Brinell Hardness Number
p	Applied force
d_i	Diameter of Indentation
D	Diameter of Indenter

2. Experimental Procedure

2.1. Raw Material And Formulation

Aluminium 2014 was used as a main raw material which is called matrix material and it is reinforced with SiC. The break pad material was developed with process starting with selection of material, weighing, mixing, compacting and sintering. Material was grouped based on different percentage of reinforcement used. In this metal matrix composite Aluminium 2014 was metal matrix and sic was reinforcement. Table 1 and 2 shows the grouping of new material.

Table 1. Formulation of SiC reinforced Aluminium brake pad materials for Sample 1

Raw materials	Percentage (%)
Aluminium 2014	80
SiC	20
Total	**100**

Table 2. Formulation of SiC reinforced Aluminium brake pad materials for Sample 2

Raw materials	Percentage (%)
Aluminium 2014	90
SiC	10
Total	**100**

The calculation of weight measuring is shown below here,

d = diameter of compaction die = 2.5cm
h = height of compaction die = 1.4cm
V = Total volume of compaction die

$$V = \pi r^2 h$$
$$= \pi \times (1.25)^2 \times 1.4$$
$$= 6.8722 cm^3$$

$$\rho = \frac{m}{V}$$

Therefore,

$$m = \rho \times V$$
$$= 2.7 gm/cm^3 \times 6.8722 cm^3$$
$$= 18.55 gm$$
$$= \text{Total mass of compaction}$$

Hence according to % of reinforcement

For Sample 1(20% reinforcement)

m for reinforcement = 3.71gm
m for matrix material = 14.84gm

For Sample 2 (10% reinforcement)

m for reinforcement = 1.86gm
m for matrix material = 16.70gm

2.2. Preparation of Material

Experimental Data

Material mixing speed = 50 rpm
Material mixing time = 30 minutes
Compacting Load = 150 KN
Sintering Temperature = 550 ^{0}C
Rate of Heating = 15^0/min
Dwell Time = 10 min
Sintering Time = 30 minutes

Two different combinations were prepared according to different volume percentage of SiC like 10% and 20% through route of powder metallurgy for the development of SiC reinforced aluminium break pad materials. Ball mill mixer was used for getting evenly distributed ingredients. The mixing process was done for getting uniform and homogeneous powder. All materials used were in powder form and powder metallurgy was used for developing brake pad materials. The powder of Aluminium 2014 (80%) and SiC (10% & 20%) was compacted in die under load of 150 kN using UTM (Universal Testing Machine) for 20 minutes. Sintering was done in Micro Wave furnace at 550^{0}C for 30 minutes.

2.3. Characterization of Brake Pad Materials

Density was measured using specific gravity which depends on the ingredients of brake pad materials. The true density of the specimen was determined by weighing the specimen on a digital weighing machine and measuring their volume by liquid displacement method.[1]

3. Result And Discussion

3.1. Density and porosity of Brake pad material

Density after sintering was carried out at the laboratory level and it is depends on ingredients of brake pad materials. Figure a shows the density difference of two different reinforced samples. The calculation of sintered density is shown below. The sintered density is measured according to Archimedes principle as shown in below

$$\text{Sintered Density of matrix}(\rho)(\text{Theoretical}) = \rho_m \text{ x \% of matrix} + \rho_R \text{ x \% of Reinforcement}$$

Hence, according to above equation,

For Sample 1(20% reinforced)

$$\rho_{Th.} = 2.7 \text{ x } 0.8 + 3.21 \text{ x } 0.2$$
$$= 2.802 \text{gm/cm}^3$$

For Sample 2(10% reinforced)

$$\rho_{Th.} = 2.7 \text{ x } 0.9 + 3.21 \text{ x } 0.1$$
$$= 2.751 \text{gm/cm}^3$$

$$\text{Sintered Density of matrix}(\rho) = \frac{\rho \text{ of fluid x weight in air}}{\text{weight in air} - \text{weight in fluid}}$$

For Sample 1(20% reinforced)

Weight in air = 17.2gm
Density of fluid = 0.9gm/cm^3
Weight in fluid = 10.80gm

Hence, according to above equation,

$$\text{Sintered Density of Matrix}(\rho) = \frac{0.9 \text{ x } 17.2}{17.2 - 10.80}$$

$$= 2.42 \text{gm/cm}^3$$

For Sample 2(10% reinforced)

Weight in air = 18.4gm
Density of fluid = $0.9 gm/cm^3$
Weight in fluid = 10.80gm
Hence, according to above equation,

$$\text{Sintered Density of matrix}(\rho) = \frac{0.9 \text{ x } 18.4}{18.4 - 10.80}$$

$= 2.18 gm/cm^3$

Fig. 1 shows the density difference between two samples

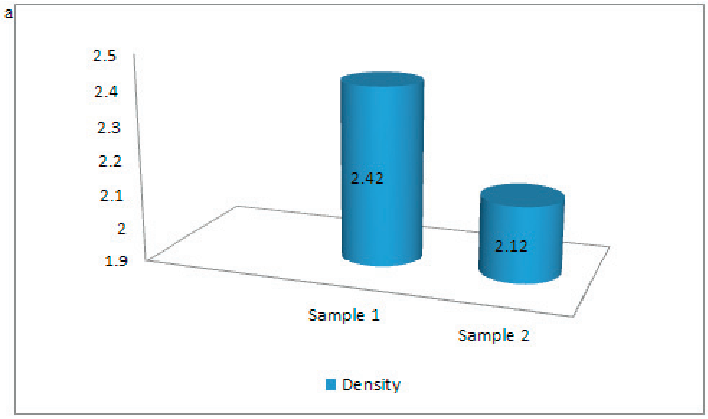


Fig. 1 Density Difference

From the above figure we can say that sample 1 has higher density than sample 2 hence, sample 1 contains better properties than sample 2
For the automotive brake pad materials porosity is playing an important role and absorbing energy and heat is a main function of porosity which is important for the effectiveness of the braking system. As far as theory is concerned higher friction coefficient and wear rate because of higher contact areas between the mating surfaces due to lower porosity. Brake pad should have a certain amount of porosity to minimize the effect of water and oil on the friction coefficient.[1]

Porosity can be calculated using following equation

$$\text{Porosity} = \frac{\rho_{Th} - \rho_{exp}}{\rho_{Th}} \text{ x } 100$$

For sample 1(20% reinforced)

$$\text{Porosity} = \frac{2.802 - 2.42}{2.802} \text{ x } 100$$

= 14%

For Sample 2(10% reinforced)

$$Porosity = \frac{2.751 - 2.18}{2.751} \times 100$$

= 21%

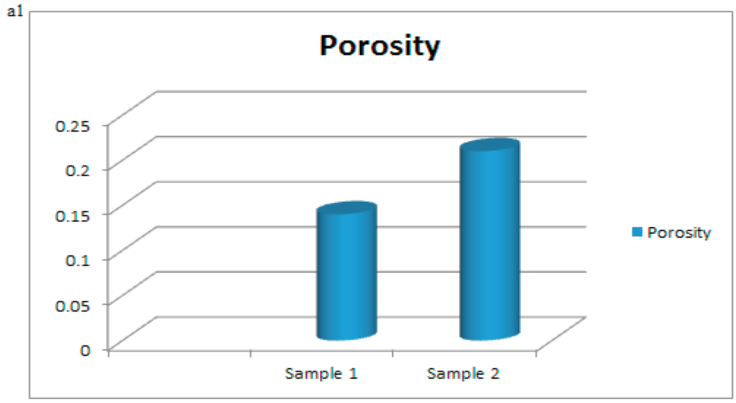


Fig. 2 Porosity

From the figure 2 we can say that with reduction in % reinforcement porosity increases

3.2. Hardness of the Brake pad Materials

The Brinell hardness number can be given by following equation

$$BHN = \frac{2p}{\pi D\left(D - (D^2 - d^2)^{\frac{1}{2}}\right)}$$

From the above equation the calculation of brinell hardness values is shown below

For Sample 1(20% Reinforced)

p = Applied Force = 500kgf
d = Diameter of Indentation = 3.33mm
D = Diameter of indenter = 5mm

Therefore,
BHN = 50
For Sample 2(10% Reinforced)

p = Applied Force = 500kgf
d = Diameter of Indentation = 3.86mm
D = Diameter of indenter = 5mm
Therefore, BHN = 35

Figure 3 shows the Brinell hardness values for two different reinforced brake pad materials

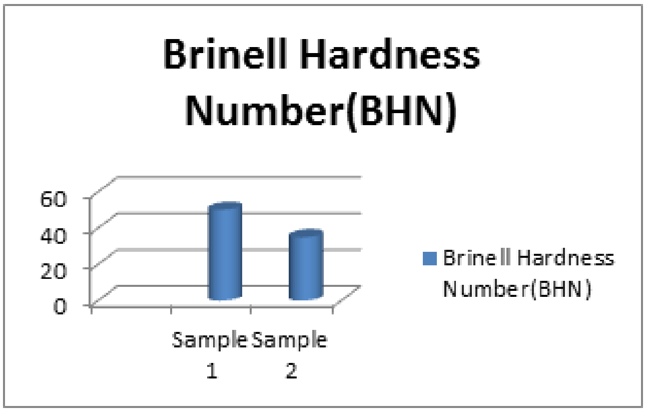
b


Fig. 3 Brinell Hardness Number

From figure 3 we can say that sample 1(20% reinforced) has high hardness value than sample 2(10% reinforced). Sample 1 contains high hardness because of using high percentage of reinforcement i.e. SiC. Sample 1 is brittle in nature because of high hardness value while sample 2 is ductile in nature because of low hardness value which shows higher wear, porosity and low density. Different percentage of reinforced material shows different value of hardness.

3.3. Wear Testing

Wear is a most common phenomenon of brake pad materials. Wear testing was done with the help of abrasive sheet of grid size 80 of 25cm length. Wear was measured for different length of abrasive sheet like 100cm to 500cm. Both samples were abraded for a distance of 100cm to 500cm with each pass of 25 cm made on a fresh abrasive surface. Then abrasion was measured using digital weighing machine where difference in weight between two consecutive distances shows a wear rate. [3]. Table 3 show the wear rate of two different reinforced samples

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

Figure 4 and 5 shows the cumulative wear rate for sample 1 and sample 2

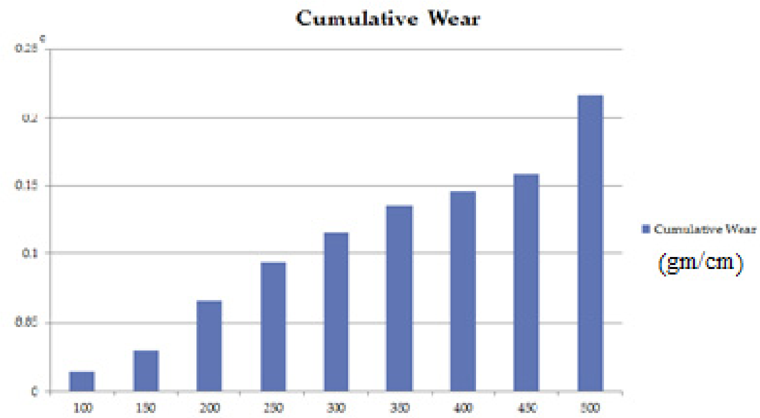


Fig. 4 Cumulative wear rate for sample 1

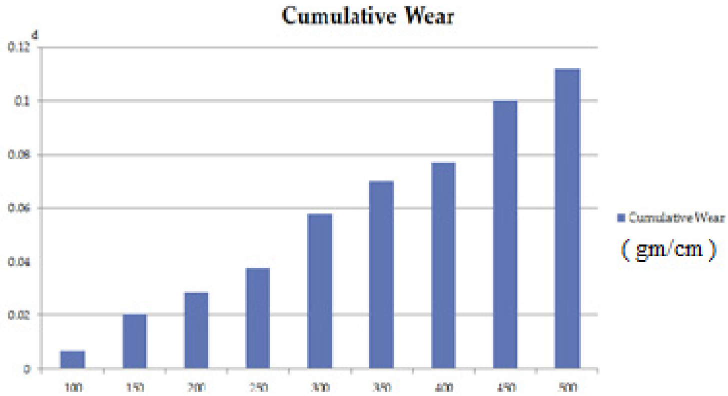


Fig. 5 Cumulative Wear rate for sample 2

Fig 4 and 5 shows the graph of Brinell hardness number v/s over all wear rate

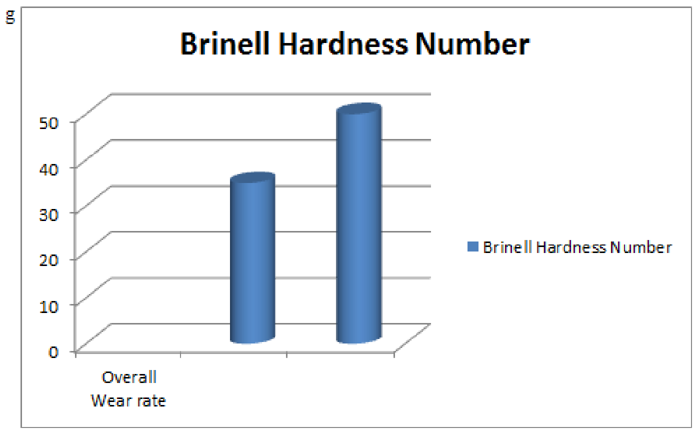


Fig. 6 BHN v/s overall wear rate

From the figure 6 we can say that with increase in BHN overall wear rate is also increases

3.4. Surface Morphology

The microscope which has 400X magnification was used to analyze the surface morphology of both samples i.e. sample 1(20% reinforced) and sample 2 (10% reinforced). Sample 1(as in figure e) and sample 2 (as in figure f) shows that Aluminium 2014 properly clumps with the SiC reinforcement.

Figure e and f shows surface morphology of sample 1 and 2

Fig. 7 Surface Morphology for Sample 1

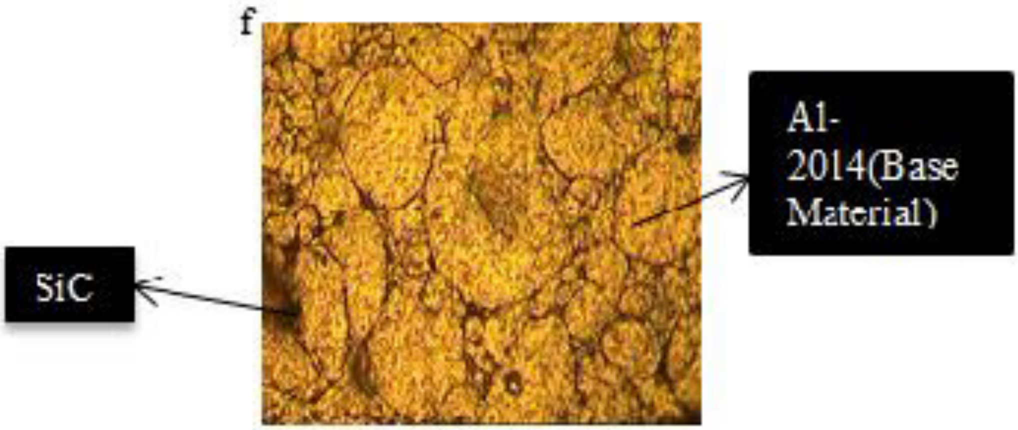


Fig. 8 Surface Morphology for Sample 2

4. Conclusion

From the result and discussion part we can conclude that:

1. Because of lower density of Sample 1(20% Reinforced) has higher wear rate i.e. 48% than Sample 2(10% Reinforced)
2. Sample 1(20% Reinforced) has higher hardness i.e. 30% than Sample 2(10% Reinforced) because of high density.
3. With decreasing with reinforcement porosity is increases by 7%
4. With increase in BHN overall wear rate is also increases by 48%
5. The hardness value obtain is too lower than the pure aluminium specimen because of less sintering time and compaction pressure.

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