

Influence of MgO particles on Microstructural and Mechanical Behaviour of AA7068 Metal Matrix Composites

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Abstract

Present work deals with the fabrication of AA7068 metal matrix composites reinforced with different weight percentages of MgO (0%, 1%, 2%, and 5%) produced using powder metallurgy route. A low pressure of 318 MPa was applied for compacting the composites and sintered at a temperature of 560°C for one hour. Optical microscopy was done to study the microstructural behavior. Wear test has been conducted for a sliding distance of 3 km with a sliding velocity of 1.2 m/s of load 5N, 7.5N and 10N. Vickers micro hardness test has been conducted and the maximum value of 68 VHN was obtained by adding a weight percentage of 5% MgO particles. The wear resistance has been improved by adding MgO particles in the matrix material. EDAX analysis was done to ensure the presence of MgO particles.

Keywords: compacting, sintering, powder metallurgy, SEM

I. INTRODUCTION

Aluminum matrix composites are extensively studied due to their high wear resistance, good thermal conductivity, strength and high elastic modulus, relatively low density and functionality in high temperatures [1]. AA7068 is a strongest aluminum alloy having magnesium and zinc as its major alloying elements which has better mechanical properties compared to other Aluminum alloys. It offers high strength, good workability, good machinability, high resistance to corrosion and so on [2]. Among the 7xxx series, AA7068 is famous aluminum alloy, which provides higher mechanical strength. Higher strength is required to replace heavier metals with this alloy in some applications at ambient and elevated temperatures [3]. Powder metallurgy provides better bonding of matrix and nanoparticles. MgO due its high melting point ($T_m = 2800 \text{ }^\circ\text{C}$), compressive strength, hardness and excellent thermodynamic stability is a better choice for reinforcement. The mechanical properties has been improved by the addition of MgO particles [4]. The hardness has been increased due to the addition of fine MgO particles into Zirconia Toughened Alumina (ZTA) and wear performance has been improved to 50% [5]. Increased wear loss and porosity was found with increased MgO reinforcement volume fraction [6]. Under 2N load, MgO coating showed an excellent resistance to sliding wear [7]. With ZTA, Vickers hardness increases with finer MgO particle size and gradually decreases with coarser MgO particle size [8]. The increases in magnesium oxide content up to 5% led to a decrease in the shrinkage and density [9]. With the increase of MgO the hardness of the composite specimens increases and the amount of resistance decreases [10].

In this paper, microstructural and mechanical properties of AA7068 reinforced with MgO particles, which were manufactured using powder metallurgy were reported.

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II. EXPERIMENTAL PROCEDURE

A. Preparation of Composites

The AA7068/MgO composites were produced using powder metallurgy. Table 1 shows the composition of AA7068 powders that were weighed accurately and mixed in a ball mill for 40 hours in a high energy ball mill [3]. 2% stearic acid was added to the powders to have a strong bonding [11]. A separate die and punch was made for compacting the metal powders. Cold compaction at a low pressure of 318 MPa was done using a Universal Testing Machine (UTM) to produce green compacts of size 20 mm diameter and 32 ± 2 mm height. The green compacts were sintered at 560°C for one hour in a sintering furnace (fig 4). The composites of AA7068 reinforced with MgO (0%, 1%, 2%, 5%) were produced which were shown in Fig. 3. Fig. 1 and fig 2 shows the SEM images of AA7068 and MgO powders respectively. Table II shows the average particle size of the powders analyzed from particle size analyzer.

TABLE I. COMPOSITION OF AA7068 (% BY WEIGHT)

Element	Si	Fe	Cu	Mn	Mg	Cr	Zn	Ti	Zr	Al
Content	0.12	0.15	2	0.1	3	0.05	8	0.01	0.1	Bal

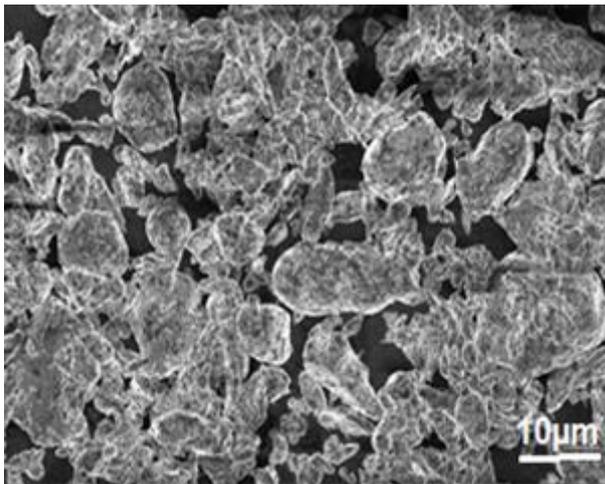


Fig.1 SEM image of AA7068 powders

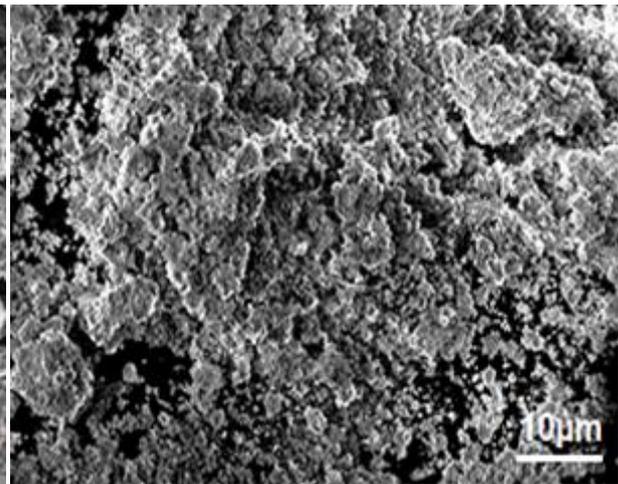


Fig. 2. SEM image of MgO powders

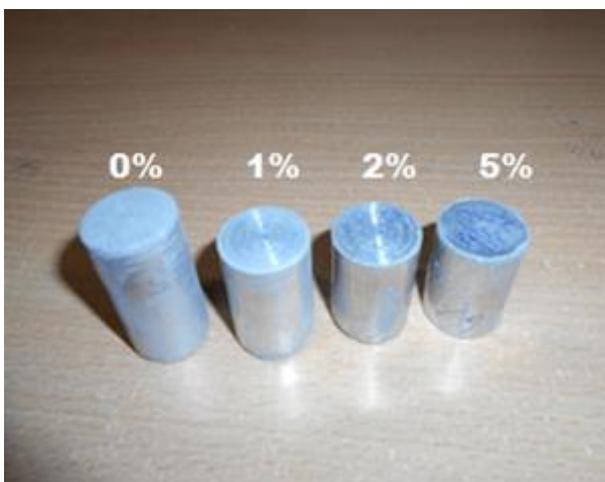


Fig. 3. Compacted samples of AA7068 reinforced with MgO (0%, 1%, 2%, 5%)



Fig. 4. Sintering furnace



Fig. 5. Pin-on-disc wear testing machine



Fig. 6. Vickers microhardness tester

B. Hardness Test

The hardness were measured using Vickers micro-hardness tester. The test was conducted on polished sample of AA7068 and its composites. The test was carried at ten different locations and the averages were reported in table III. The Vickers microhardness tester was shown in the Figure 6.

TABLE II. AVERAGE PARTICLE SIZE

Powder	Average Particle size (μm)
AA7068	1.785
MgO	3.619

C. Wear Test

The sintered samples were extruded to 10 mm diameter and 30 mm height for testing purpose. Wear tests were carried out using DUCOM TR 20-LE pin-on-disc wear testing machine. A sample size of 10 mm diameter and 30 mm height was used for testing. Initially the pin masses were weighed using Shimadzu electronic weighing machine ATY 224 model with an accuracy of 0.0001g. All tests were conducted at room temperature (26°C). The experiments were conducted at a load of 5N, 7.5N, 10N at a sliding velocity of 1.2 m/s at six sliding distances for a total of 3 km. The exact mass was measured after every sliding distance of 500 m after the wear test.

III. RESULTS AND DISCUSSION

A. Microstructural analysis

Fig. 3 shows the samples after cold compaction. After compaction the samples were sintered at 560°C in a sintering furnace for 1 hour. The samples were polished and grinded before conducting the optical microscopy. The surface of the samples were ground by using 600,800 and 1200 grit abrasive paper and polished using diamond paste. Fig. 7 shows the optical micrographs of AA7068 reinforced with MgO at (a) 0% (b) 1% (c) 2% and (d) 5%. MgO particles were uniformly distributed in the matrix. Fig. 7(a) shows more porosity present in the AA7068 sample without reinforcement, with more number of fine and spherical shape of pores. This is due to the application of low applied pressure (318 MPa) which coincides with Amin et al [3]. Fig. 7(b) shows excellent bonding between the AA7068 particles and MgO particles with very less pore holes and a very high density. This is due to fine particles of MgO mixed with the matrix material. Smaller the grain size improves the hardness, toughness and reduces wear rate [12]. Fig. 7(c) shows the particles are uniformly distributed, but having few non-uniform larger cavities which is due to poor pressing which goes parallel with Amin et al [3]. Fig. 7(d) shows that the particles with homogeneous

distribution, but few non-uniform large shaped pores due to poor pressing. Porosity is more because aggregation of MgO nanoparticles is less probable in powder metallurgy. Formation of porosity is highly probable in sintering method compared to other methods [4].

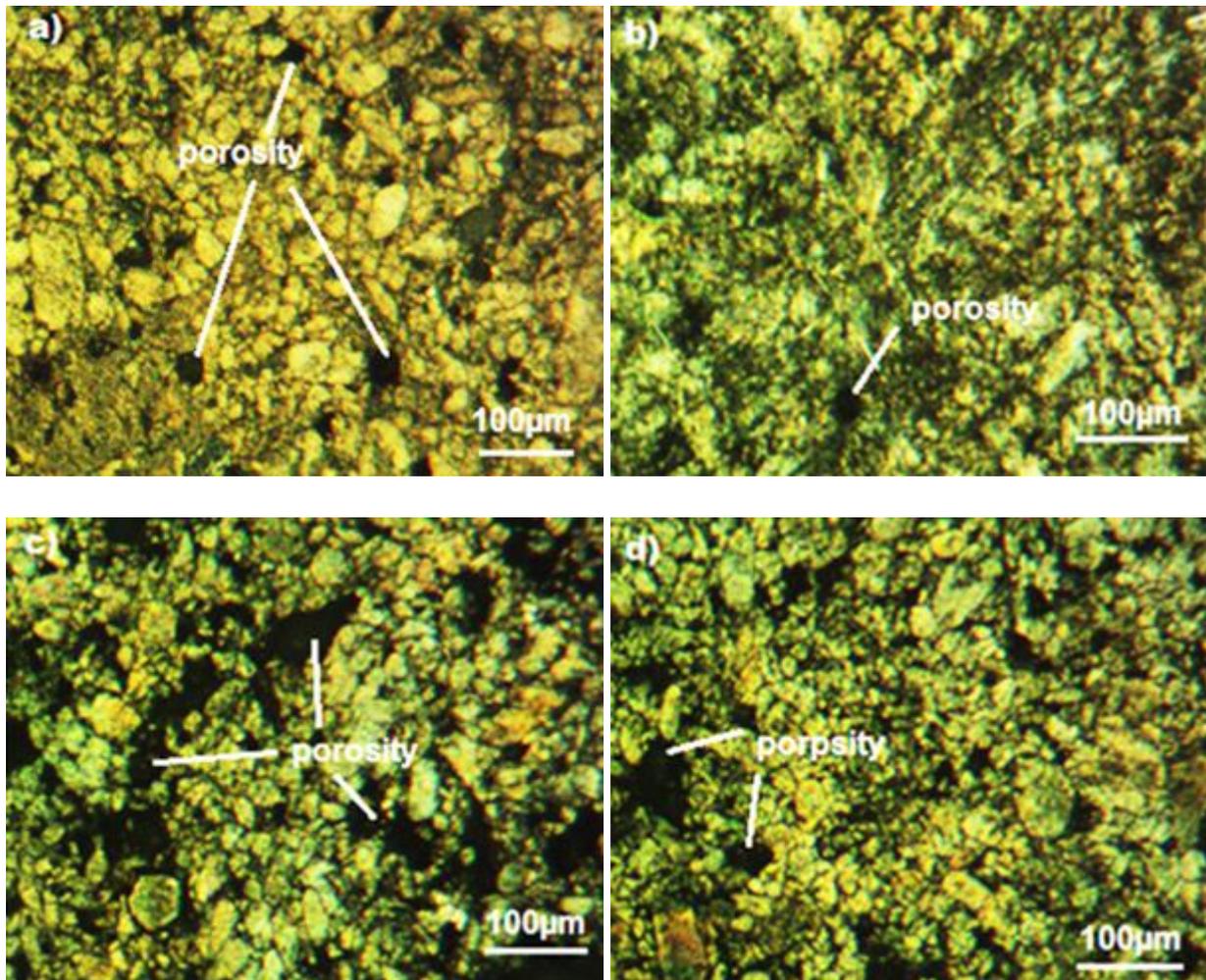


Fig. 7: Optical Micrographs of AA7068 reinforced with MgO (a) 0% (b) 1% (c) 2% and (d) 5%

B. Wear behavior

Fig 8. shows the graph of sliding distance against wear rate plotted for AA7068/MgO composites. The wear rate increases with increasing sliding distance, while as the MgO weight fraction increases, wear rate decreases. The wear rate was found to be maximum for AA7068 without reinforcement and found to be minimum for the maximum percentage of the addition of MgO particles. As the load increases, wear rate also increases. The wear rate for 10 N load is more compared to 7.5 N load and similarly wear rate for 7.5 N load is more compared to 5 N load.

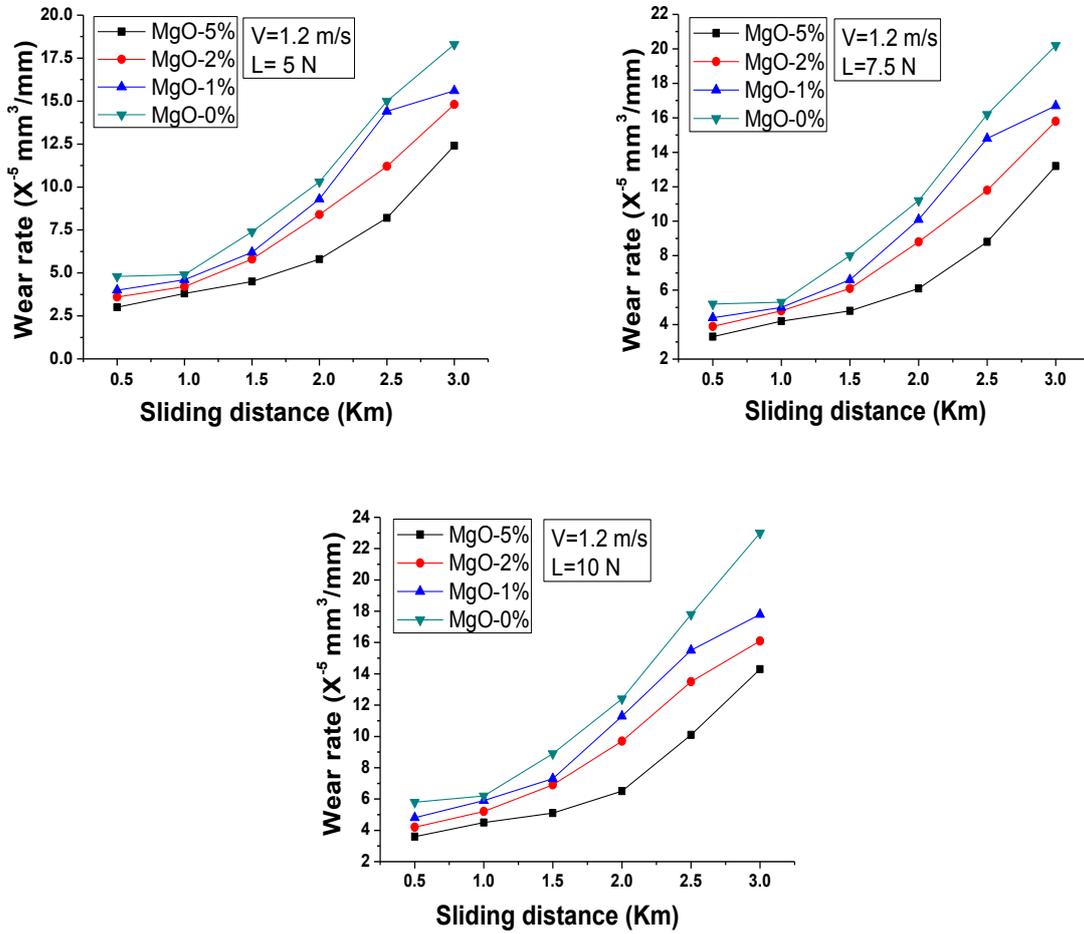
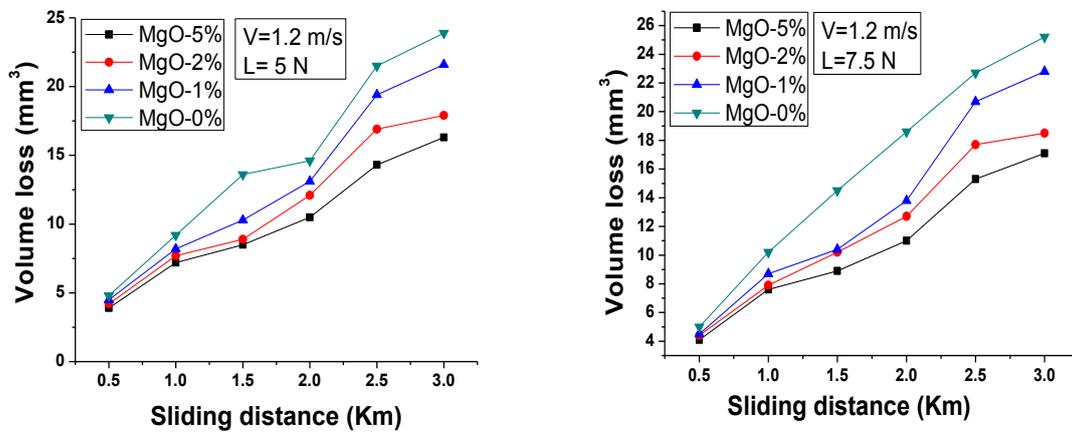


Fig 8. Wear rate Vs sliding distance of AA7068 reinforced with MgO particles



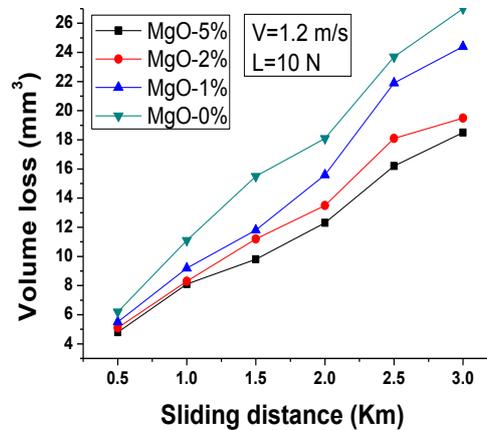


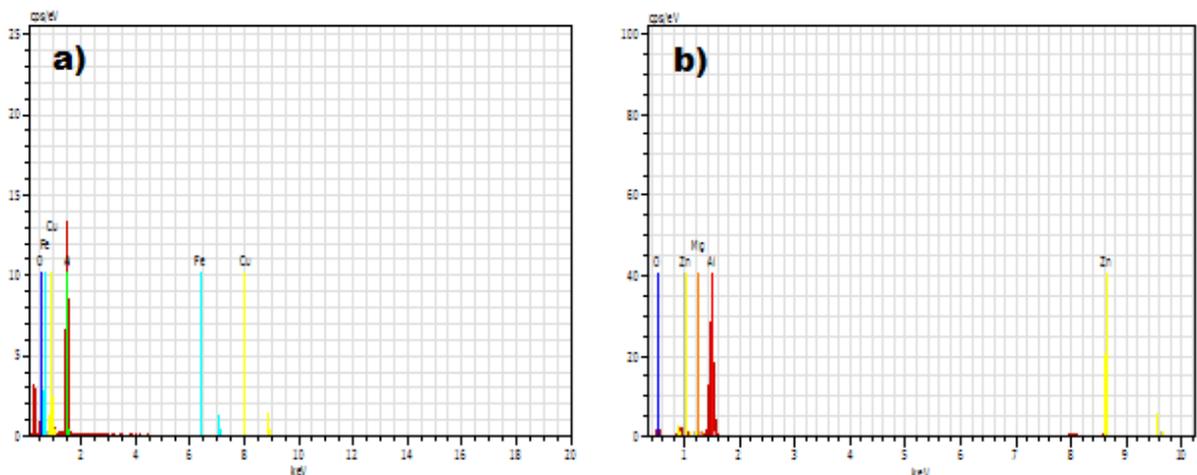
Fig 9. Volume loss Vs sliding distance of AA7068 reinforced with MgO particle

Fig 9. shows the graph of sliding distance against volume loss plotted for AA7068/MgO composites. The wear curves shows that the volume losses of all produced composites decreases with increasing MgO weight fraction and increases with increasing sliding distance. The volume loss was found to be maximum for AA7068 without reinforcement and found to be minimum for the maximum percentage of addition of MgO particles. As the load increases, the volume loss also increases. The volume loss for 10N load is maximum compared to the volume loss for load of 5N and 7.5N.

There is a good agreement between the hardness values given in table III and the wear behavior of the composites. The wear resistance of the composites increases with increase in their hardness values.

C. EDAX

Fig. 10. Illustrates the EDAX pattern for AA7068 reinforced with MgO a) 0% b) 1% c) 2% and d) 5%. The EDAX pattern in fig. 10 (b), 6(c) and 6(d) confirms the presence of magnesium oxide particles.



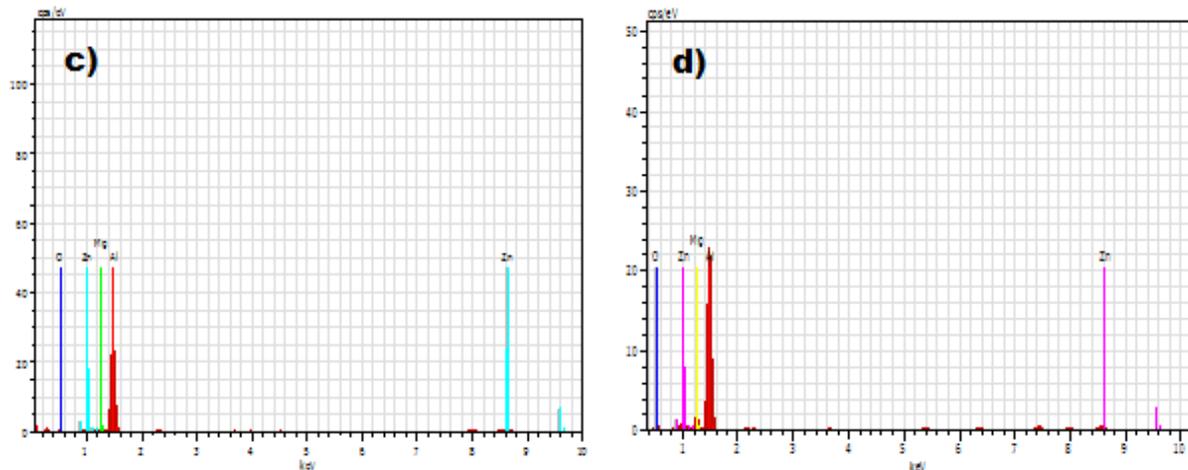


Fig 10. EDAX pattern for AA7068 reinforced with MgO a) 0% b) 1% c) 2% and d) 5%

E. Hardness Test

The hardness test was conducted using Vickers micro hardness tester. The hardness values of AA7068/MgO composites were given in the table III.

TABLE III. VICKERS HARDNESS NUMBER

Composite	Hardness(VHN)
AA7068	33
AA7068 + 1% MgO	48
AA7068 + 2% MgO	56
AA7068 + 5% MgO	68

As the weight fraction of MgO increases, the hardness also increases and was found to be a maximum of 68 for 5% MgO, because of the homogeneous distribution of MgO particles and due to the decrease in grain size of the particles [12].

IV. CONCLUSION

1. AA7068/MgO composites can be produced successfully using powder metallurgy.
2. The optical micrographs showed that the particles were mixed with homogeneous dispersion.
3. The Vickers microhardness number has been increased to a maximum of 68 VHN for an addition of 5% MgO particles.
4. The wear resistance has been improved by adding MgO particles in AA7068 matrix material.

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