Periodicals of Engineering and Natural Sciences ISSN 2303-4521
Vol.6, No.2, October 2018, pp. 64~70
Available online at: http://pen.ius.edu.ba

Mechanical and Tribological Characterization Nitrided Al-7075/Al_2O_3 Metal Matrix Composites

Vitala H R[1], B P Dileep[2], A.Megalingam[3] ,Karthik K[4]
[1,4]Department of Mechanical Engineering, SJB Institute of Technology, Bengaluru, Karnataka, India.
[2]Department of Mechanical Engineering, Amrita School of Engineering, Bengaluru, Amrita Vishwa Vidyapeetham, India.
[3]Department of Mechanical Engineering,Bannari Amman Institute of Technolog,Sathyamangalam,India.

Article Info

Article history:

Received Sept 8, 2018
Revised Sept 29, 2018
Accepted Oct 16, 2018

Keyword:

Aluminium 7075
Metal Matrix Composites
Powder metallurgy
Nitriding
Wear resistance

ABSTRACT

This research is mainly intended to evaluate the effect of nitriding on the wear behaviour of Al_2O_3 reinforced aluminium-7075 metal matrix composite materials. The composites were prepared by using powder metallurgy process. The amount of Al_2O_3 in these composites was varied from 3% to 7% (by weight) in steps of 2%. Homogeneously mixed powder by using double cone mixture was compacted using hydraulic press with 60KN of load. The compaction load was optimized to get a equal density as base specimens,then the compacted specimens were sintered at 540^0 C which is 80% of melting temperature aluminium base alloy. The sintered materials were nitrided with a temperature of 520°C for 72hrs. Two different set of specimens, namely, nitrided composites and non-nitrided composites specimens were tested for their wear resistance and hardness properties. Pin-on-disc equipment was used for wear testing and microhardness testing machine was used for hardness testing. Elemental X-Ray Diffraction technique (XRD) was used to ensure the diffusion of nitrogen to the surface of composites. After all the standard tests it was observed that the nitrided composites have shown better wear resistance than the non-nitrided composites.

Corresponding Author:

First Author,
Department of Mechanical Engineering,
Amrita School of Engineering, Bengaluru,
Amrita Vishwa Vidyapeetham, India.
Email: bp_dileep@blr.amrita.edu

1. Introduction

The main elements that generate large amount of carbon dioxide are fossil fuels through burning them for obtaining energy, in which CO2 has the largest share [1]. Elimination of heavy metals like steel to make lighter vehicle is actually a major challenge in most automobile industries for hitting their emission targets and ideal fuel economy.

Vehicle dead load reduction saves energy, minimizes brake and tire wear and perhaps most welcome, it cuts down emissions to a great extent. Load of the automobile is directly linked to CO2 emissions and reduces fuel economy. Innovative materials composed of aluminium, magnesium and its alloys have allowed engineers to reduce vehicle weight without compromising strength and durability.
Aluminium and its alloys possess comparatively high strength-to-weight ratio. This material suitable for many practical applications like aerospace, automobile and space industries [3]. Aluminium 7075 reinforced with aluminium oxide composite presents increased density than that of base alloy. [4].

Surface modification is very much necessary to improve the surface hardness, wear resistance, together with low thermal and chemical stability for non ferrous materials, especially for aluminium and its alloys for the industrial and automobile applications. This can be achieved by implanting aluminium nitride (AIN) on the surface of the material to get better tribological properties along with high thermal and chemical stability [2]. Nitriding is one among the best available methods which used for surface modification [5].

This research work aims to report the effect of nitriding in Al2O3 reinforced aluminium metal matrix composite varying percentage of reinforcement. Also improvement interms of mechanical and tribological properties of the material to reduce CO2 effect specially for automobiles.

2. Fabrication Methods

2.1. Preparation of Composite

A planetary ball mill is used to blend pre mixed metal powder with different reinforcement contents which measured according to the composition of Al-7075 alloying material (Shown in the table 1). This process is carried out for 30 min at 250 rpm [6] in order to achieve homogenous mixture of powder. The blended metal powder is compacted using Split type die (Figure 1) and hydraulic compression machine. 60 KN load is applied to compress the powder [7].

Table 1. Composition of Al-7075 alloy

Material	Al	Zn	Mg	Cu	Cr	Fe	Si
Wt%	89	5.6	2.5	1.8	0.3	0.4	0.4

Figure 1. Split die for powder compaction.

2.2. Sintering

Sintering is the process of solidifying the compacted green solid into a solid mass of material by the application of heat to its recrystallization temperature. Sintering temperatures is kept at 550°C that is below the melting temperature of the base alloy [8]. Temperature of the furnace rises increasing from 0 to 550°C and specimens are placed in the furnace for 3 hours and cooled at room temperature in the furnace [7].

2.3. Nitriding

Gas-nitriding, a thermo-chemical process which involves the enrichment in nitrogen of a surface layer. This treatment allows to strongly increase surface properties like hardness, wear, abrasion and fatigue resistance. material was subjected to gas nitriding treatment after the machining process, for 70hours at 520oC and at a constant flow rate of 400lt/hr of ammonia [10] [11]. After 70hours the chamber is allowed to cool at room temperature and samples are removed after the chamber attains room temperature. Ammonia gas reacts with aluminium to form aluminiumnitride(AlN)under below conditions.

$$2NH_{3\,(aq)} + 2Al_{(s)} \rightarrow 2AlN_{(s)} + 3H_{2\,(g)}$$

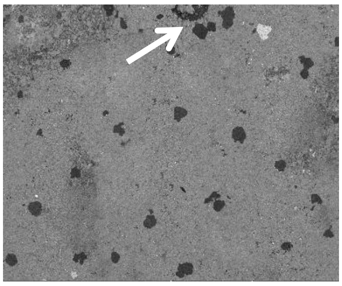
3. Experimental details

Energy-dispersive X-ray spectroscopy is used to reveal the elements which are present in the material. Figure 4 is the EDS of a nitrided Al-7075 alloy specimen. The nitrogen peak clearly represents the presence of nitrogen along with the other elements. Scanning electron microscope (SEM) is utilized for microanalysis and dispersion of reinforcement particles in matrix material. Distribution characteristics, surface texture and particle orientation in material reinforcement distribution are observed at a magnifications of 100x while grain size are investigated at 500x

Microhardness testing is a way of determine the hardness or resistance against penetration especially with low loads when surface is treated and test samples are small & thin. Microhardness test is conducted based on ASTM E92 standard by using Vickers Hardness Testing Machine. 100gms of load is applied on the specimen for a dwell time of 10 seconds. Tests are conducted at 3 different positions on the sample and average has taken. Wear is a phenomenon of removal/erosion from the surfaces of two contact bodies' in-relative motion to each other. The wear tests were conducted according to ASTM G99 standards by using Pin-on-disc wear testing machine[12,5]. The duration of each test was exactly 60 minutes to identify the amount of material lost during the test. The wear volume was calculated from the ratio of amount of weight loss to density and wear rate property was calculated using sliding distance and wear volume [12].

4. Results and Discussion

4.1. Microstructural Analysis


(a)

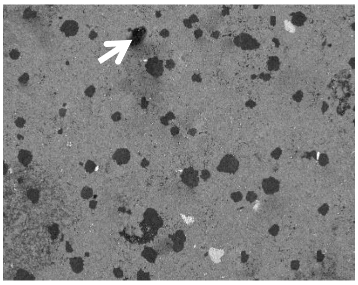

(b)

Figure 2. Dispersion of Al_2O_3 particles noticed in Al-7075 with different wt % Al_2O_3.

In addition, Figure 2(b) reveals variation in porosity content with Al2O3 in composite samples. Results reveal, increase in the amount of porosity was observed with increase in the weight fraction of Al2O3, intern improves wear resistance. Porosity increased due to increase in contact area with Al2O3 particles. This implies pore nucleation at the Al2O3 particulates locale. Effect of gas nitriding can be observed from the figure 3 which shows depth of presence of nitrogen from circumference region.

4.2. Energy dispersive X-ray spectroscopy

Main reason for employing EDS in this study is to identify presence of nitrogen content in gas nitrided specimens with different weight fraction of aluminium oxide reinforcement. Figure 4 shows identification of elements present in the samples. Nitrogen peak is clearly visible in the EDS image. Increase in oxide content was also obserfrom the analysis with increase in Al_2O_3 reinforcement. All other elements like zinc, magnesium, iron, chromium and silicon were also identified.

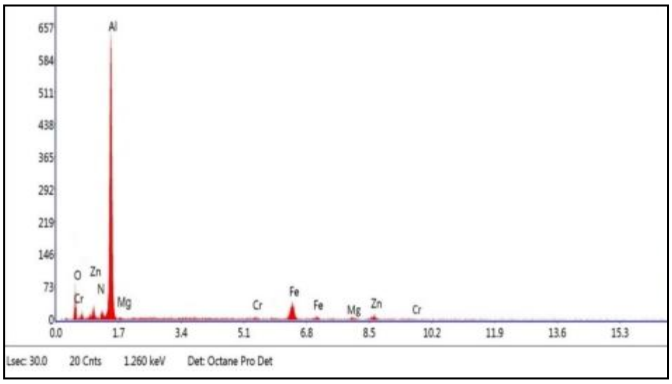


Figure 3. EDS results of Al2O3 reinforced Al-7075

4.3. Hardness

Hardness of nitrided and non-nitrided Al7075/Al2O3 composite of 0, 1, 3, 5 and 7% weight fractions samples are performed using microhardness testing machine.Hardness was carried out using 100gms for a dwell time interval of 10seconds. The hardness are then plotted on graph of microhardness (HV) vs. weight fraction of Al2O3 with respect to nitrided and non-nitrided specimens as shown in figure 5. The hardness profile showed that the hardness increases with increase in weight fraction of reinforcement material upto5wt%. At 7wt% hardness value decreased slightly. Hardness was increased by 29% when compared to base alloy and 5wt% composite. Further the nitrided samples showed even more increment in hardness than the untreated samples. 31% increase in hardness was observed in nitrided matrix material when compared with non-nitrided base alloys. 82% improvement was observed when compared to non-nitrided base alloy and nitrided Al-7075/5wt% Al2O3 composite.

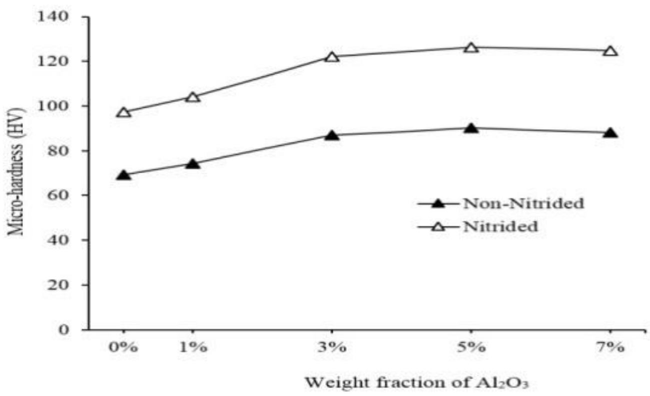


Figure 4. Hardness Profile

4.4. Wear Properties

Al-7075 samples with various weight percent of Al2O3samples are sent for analysis for dry-sliding type. Tests were performed on 10mm diameter and 20mm long cylindrical samples with the help of pin to slide against the rotating disc of En-8 steel. The wear rate and specific wear rate were monitored. All weight fraction of material, tests were conducted at 10N, 20N & 30N holding the sliding speed at 300rpm and abrading distance of 400m as even. Graphs represent that wear rate of samples of weighing fractions increased with the load applied. Figure shows decrease in wear rate of non-nitrided&nitrided composite components in the addition of Al2O3 particles compared with Al-7075 base alloy. Al2O3 particles in Al-7075 avoids the ploughing action of hard steel counterpart & boosts the wear resistance. Nitrided samples recorded improved wear resistance than non-nitrided samples shown in figure 6 and 7.

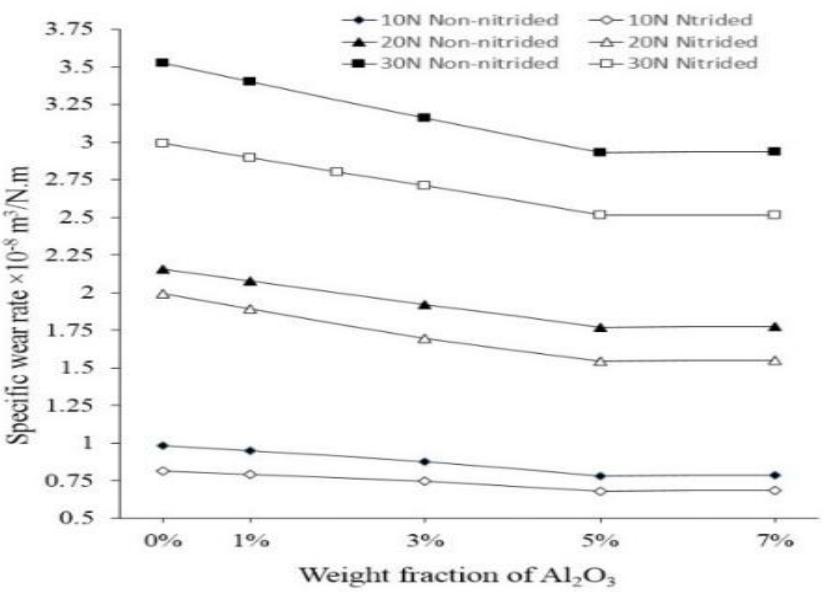


Figure 5.Plot of wear rate vs. Al2O3 weight fraction

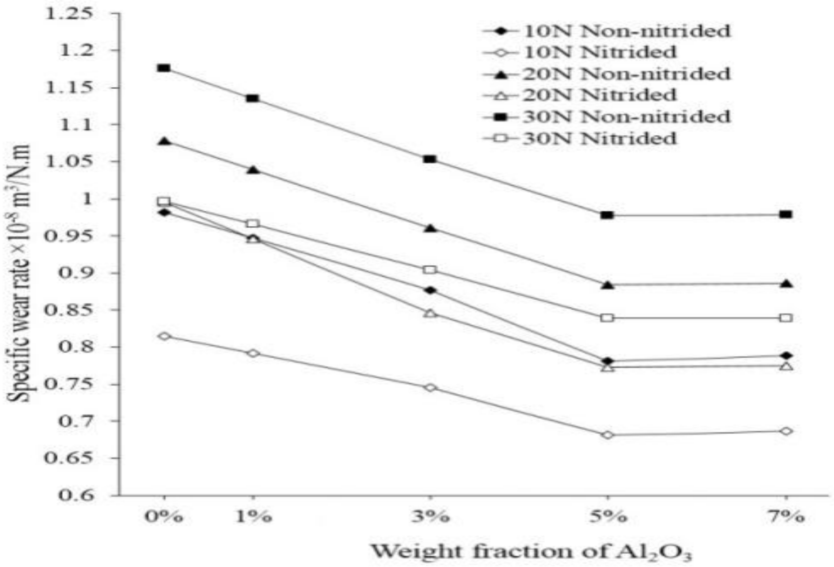


Figure 6. Plot of specific wear rate vs. Al2O3 weight fraction.

Wear analysis of samples were performed at velocity of 1.88m/s running for abrading distance of 400m for 10N, 20N & 30N. Non-nitrided samples at 30N load showed that the base alloy accounted a specific wear rate of 0.9876×10-8 mm3/N.m while samples reinforced with 5% Al2O3 recorded 0.8388×10-8 mm3/N.m, i,e wear resistance was increased by 21%. The nitrided samples under similar condition showed 18% increment between base alloy and 5% reinforced composite. While non-nitrided base alloy wascompared with nitrided 5% Al2O3 composite showed 40% increase in wearresistance.

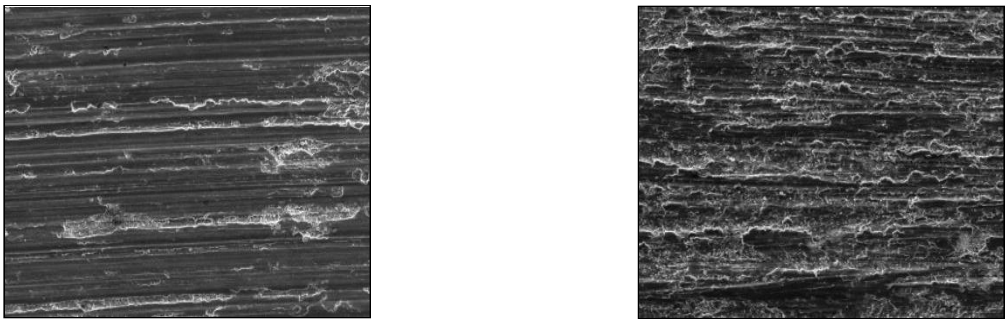

(a) (b)

Figure 7. Morphology of wear surface of Al-7075/5% Al2O3 composites (a) Non-Nitrided, (b) Nitrided

Figure 8, shows SEM micrographs indicating the morphology of wear caused under dry sliding condition. These images indicate the wear surfaces of nitrided and non nitrided samples of 5wt% Al2O3 reinforced composite samples. In 8(a) non-nitrided sample shows rough patches that are clearly visible, while nitrided composite 8(b) shows smooth surface with few delamination sites. Correspondinglynitrided 5% reinforced composite shows much smoother surface. Thus reinforcement particle andnitrided layer have plays a role in wear resistance of the materials.

5. Conclusion

Addition of Al_2O_3 reinforcement to the aluminium alloymatrixenhances the wear resistance property of the composites. Nitriding surface treatment process greatly improves the wear resistance to a next level. Results revealed that, hardness and density increased with increase in incorporation of Al_2O_3. Nitrided samples showed increase surface hardness in comparison to untreated composites. Increasing hardness on the surface of the material, resulting wear resistance so that this kind of material can be used for light weight components, instead of using heavy materials for tribological applications. Therefore, avoiding heavy materials, automatically CO_2 will be reduced especially for automobiles and moving componenats. The presence of AIN and nitrogen is claimed to be a primary cause for the increase in hardness and wear resistance of aAl_2O_3 reinforced Al-7075 metal matrix composite materials.

6. References

[1] P. Krishnakumar, K. Prakash Marimuthu, K. Rameshkumar, K. I. Ramachandran, "Finite element simulation of effect of residual stresses during orthogonal machining using ALE approach, "*Int. J. Machining and Machinability of Materials*", 14, 2013, pp. 213-229.

[2] Enes Akca, Ali Gürsel, Gökhan Yıldız "Effects of Cooling Rate on Strength and Microstructure of Powder Metallurgy Superalloys" *Periodicals of Engineering and Natural Sciences*, vol. 5, pp. 15-27, 2017

[3] E. Akca and A. Gursel, "A Review on Superalloys and IN718 Nickel-Based INCONEL Superalloy," *Periodicals of Engineering and Natural Sciences*, vol. 3, pp. 15-27, 2015

[4] Elma Kicukov and Ali Gursel, "Ultrasonic welding of dissimilar materials: A review," *Periodicals of Engineering and Natural Sciences*, Vol. 3, No. 1, pp. 28-36, 2015.

[5] V. Ravikimar, B. P. Dileep, and H. R. Vital," Tribological and mechanical characterization of Al-Ni-SiC metal matrix composites", *AIP Conference Proceedings* ,1859 (2017), 020020.

[6] Dileep BP, B R Sridhar,"A Investigation on Mechanical and Metallurgical Properties of Steel EN24 and SiC MMCs",*International Journal of Mechanical and Production Engineering Research and Development (IJMPERD)* ISSN(P): 2249-6890; ISSN(E): 2249-8001 Vol. 8, Issue 2, Apr 2018, 189-194

[7] V. Ravi Kumar, B. P. Dileep, S. Mohan Kumar, and M. V. Phanibhushana, " Effect of metal coatings

on mechanical properties of aluminium alloy", *AIP Conference Proceedings,* 1859 (2017), 020037-1 – 020037-6.

[8] Anuj Bisht, Supreeth Gaddam, Lailesh Kumar, B. P. Dileep, Satyam Suwas, "Precipitation Behavior of IN718 After Surface Mechanical Attrition Treatment (SMAT) and Its Effect on Wear Properties",*The Journal of The Minerals, Metals & Materials Society (TMS) JOM,* vol. 70, no. 10, PP 1-10,oct 2018.

[9] E. Bayraktar, D. Katundi, "Development of a new aluminium matrix composite reinforced with iron oxide (Fe3O4)", *Journal of Achievements in Materials and Manufacturing Engineering,* vol. 38, no 1, jan 2010.

[10] Asif M, Chandra K and Misra P S, "Development of Aluminium Based Hybrid Metal Matrix Composites for Heavy Duty Applications", *Journal of Minerals & Materials Characterization & Engineering,* vol. 10, no. 14 ,pp. 1337- 1344, 2011.

[11] E. Bayraktar, J. Masounave, R. Caplain, C. Bathias, "Manufacturing and damage mechanisms in metal matrix composites, *"International Journal of Materials, Mechanics and Manufacturing",* vol. 3, no. 1, feb 2015.

[12] A. Włodarczyk-Fligier, M. Adamiak, L.A. Dobrzański, "Corrosion resistance of the sintered composite materials with the EN AW-AlCu4Mg1(a) alloy matrix reinforced with ceramic particles", *Journal of Achievements in Materials and Manufacturing Engineering,* vol. 42, no.1-2, Sep-Oct 2010.