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SLIDING WEAR BEHAVIOUR OF ALUMINUM ALLOY (LM-13) REINFORCED WITH NANO-ZrO_2 MATRIX COMPOSITES

Sumod Daniel
Associate Professor,
Department of Mechanical Engineering,
Bangalore College of Engineering and Technology,
Bangalore-560099, Karnataka

Dr. G. Harish
Associate Professor,
Department of Mechanical Engineering
University College of Engineering, KR Circle,
Bangalore-560001, Karnataka

ABSTRACT

In the present investigation, aluminum alloy (LM 13) is dispersed with Nano-ZrO_2 particles by stir casting technique followed by the hot extrusion process. Particulate size dispersed varies from 50-80 nm and the amount of addiction varies from 2 to 10wt% in steps of 2%. The wear characteristics of the developed nano metal matrix composite are analyzed by pin-on-disc dry sliding wear test against hardened steel under varying loads. Nano ZrO_2 particulates have an excellent load bearing capacity under applied load in sliding process, thus enhancing the wear resistance of nano metal matrix composites. The wear resistance increases as the wt. % of reinforcement content increases in the matrix material and wear resistance decreases as the applied load increases. Wear resistance is more in nano composites as compared to the LM13 matrix material.

KEYWORDS: Wear, Aluminium-LM13, Nano Composites, Nano-ZrO2

INTRODUCTION

Metal Matrix Composites (MMCs) are engineered combinations of two or more materials (one of which is a metal) where good properties were achieved by systematic combinations of different constituents. Conventional monolithic materials have limitations in respect to achievable combinations of strength, stiffness and density. Engineered MMCs consisting of continuous or discontinuous fibers, whiskers or particles in a metal achieve combinations of very high specific strength and specific modulus. Furthermore, systematic design and synthesis procedures allow unique combinations of engineering properties in composites like high elevated temperature strength, fatigue strength, damping property, electrical and thermal conductivities, friction coefficient, wear resistance and expansion coefficient [1]. The mechanical components, which are subjected to severe wear, mainly due to sliding action, abrasive, erosion and erosion-corrosion. During the sliding action, the hard ceramic particles

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protrude the composite surface and resist wear of the material. The sliding wear resistance of the composites with respect to that of matrix material varies with the test parameters [2]. The wear rate of the composite is reported less as compared to that of the alloy. Reinforcement of hard particles in aluminium matrix protects the matrix surface against the destructive action of the abrasive during the wear process [3].

Recently, nanotechnology has attracted the attention of many material scientists. Nano-metric particulates exhibit many attractive and special properties. Recent investigations find that the incorporation of Nano-particles into the aluminum matrix could enhance the hardness, the yield and ultimate tensile strength considerably, while the ductility is retained [3-9]. The strength of composites is expected to be influenced by the dislocation density, dislocation-to-dislocation interaction and constraint of plastic flow due to the resistance offered by particles. It is reported that due to the thermal mismatch stress, there is a possibility of increased dislocation density within the matrix which leads to local stress and increasing strength of the composite [10]. Most studies so far are mainly concerned with the mechanical properties of the aluminum matrix composites reinforced with micrometric ceramic particulates. The present investigation is focused to fabricate aluminum matrix composite reinforced with varying Wt. % of nano-ZrO_2 particulates choosing stir casting technique which remains an attractive choice among all the processing routes due to its capability of bringing together the advantages of both spray processing and conventional casting. It is also predicted that the aluminium alloys demand increased globally at an average rate of 20% every year [10-15]. The composites thus obtained were hot extruded and characterized for their micro structural studies and sliding wear properties by varying the sliding speed, applied load and sliding distances. Particular emphasis is placed to study the effect of presence of nano-ZrO_2 and its increasing amount on the mechanical response of standard LM 13 alloy.

SELECTION OF MATERIAL

The matrix material selected for the development of the nano composite material is LM13 alloy. LM13 alloy is desirable because of low density, cost, corrosion resistant, good mechanical properties, easy to cast and easy to machine as a base material in the development or tailoring of nano-metal matrix composites. Table 1 shows the chemical composition of LM13 Matrix alloy. The reinforcement material used was nano-ZrO_2 particulates of size vary from 50 to 80 nm. The properties of reinforcement (ZrO_2) are shown in table 2 and ZrO_2 reinforcement material is supplied by Nano Structured and Amorphous Materials, Inc., USA.

Table 1: Chemical composition of LM13 matrix alloy

Elements	**Zn**	**Mg**	**Si**	**Ni**	**Fe**	**Mn**	**Al**
Wt.%	0.5	1.4	12	1.5	1.0	0.5	Bal

Table 2: Properties of the synthesized nano ZrO_2 reinforcement

Property	Value
Density	8.2 gm/cm^3
Melting Point	1860˚c
UTS	428 MPa
VHN	151
Young's modulus	97 GPa

DEVELOPMENT OF THE NANO METAL MATRIX COMPOSITE

The LM13-ZrO_2 nano composite materials were fabricated by stir casting technique followed by the hot extrusion process by varying the percentage of reinforcement from 0 wt.% to 10 wt.% in steps of 2 wt.%. This method is the most economical to fabricate composite materials. The known quantity of LM13 alloy was melted to a desired superheating temperature of 735^{0}C in the alumina crucible. To achieve higher particle content in the cast composite the melt temperature is maintained with the partially solid range of the alloy which is called compact processing [16]. This involves heating of the LM13 alloy in an alumina crucible up to 735^{0}C using the electrical resistance furnace with a temperature controlling device was used for melting. After melting, the required quantity of reinforcement particulates were preheated to around 350^{0}C then added into the molten metal and stirred continuously by using mechanical stirrer. The vortex is created to get a uniform distribution of nano ZrO_2 reinforcement particulates in the Al (LM13) alloy matrix. The matrix mixture was poured into the mould at a pouring temperature of 780^{o}C and was allowed to cool at atmospheric conditions. The AFS mould of size 245x160x35 mm was prepared using silica sand with 8% bentonite as binder and 6% moisture and dried in an air furnace. The castings were taken out from the mould and the castings were tested to know the common casting defects using an ultrasonic flaw detector. Then the castings were cut to required shape and size for testing.

TESTING OF THE NANO METAL MATRIX COMPOSITE

The sliding wear tests were carried out on LM13 alloy and its nano composites as per ASTM standards. The specimens were prepared from the developed nano composites. The sliding wear test was conducted in Pin-on-Disc wear testing machine with data acquisition system, which was used to evaluate the wear behaviour of the nano composite, against the hardened ground steel disc (En-32) having hardness 60 HRC and surface roughness (Ra) 0.5 µm. It is versatile equipment designed to study wear under sliding condition only. Sliding generally occurs between a stationary pin and a rotating disc. The disc rotates with the help of a D.C. motor; having speed range 0-1000 rev/min with wear track diameter of 50 mm -120 mm. The load is to be applied on pin (specimen) by dead weight through pulley string arrangement. The system has a maximum loading capacity of 200N. The specimens under tests were fixed to the collect. The collect along with the specimen (Pin) is positioned at a particular track diameter. This track diameter is to be changed after each test, i.e., a fresh track is to be selected for each specimen. During the experiment the specimens remain fixed and disc rotates. The load is applied through a dead weight loading system to press the pin against the disc. Frictional force arises at the contact can be read out from the controller. The speed of the disc or motor rpm can be varied through the controller. Each set of tests was carried out for a period of 30 minutes and at an interval of 5 minutes, wear rate and frictional force were noted down. The load was increased further and the test was carried for 20-60N in steps of 20. After each 30 minutes run the test pieces were removed from the machine and weighted accurately to determine the loss in weight.

RESULTS AND DISCUSSIONS

SLIDING WEAR:

Figure 1 show the effect of reinforcement and sliding distance on wear in volume loss of LM 13 alloy and LM13 / nano ZrO_2 metal matrix composites at constant applied load of 10N and sliding speed of 300 rpm. It can be seen that as the sliding distance increases, the wear of both the LM13 / nano ZrO_2 metal matrix composites as well as the matrix material increases. The wear of the matrix material is more than that of the composites for all sliding distances. Further, as the percentage of reinforcement increases, the wear of the LM13 / nano ZrO_2 metal matrix composite decreases. Further, as the percentage of reinforcement increases, the wear rate of the LM13 / nano ZrO_2 metal matrix composite decreases.

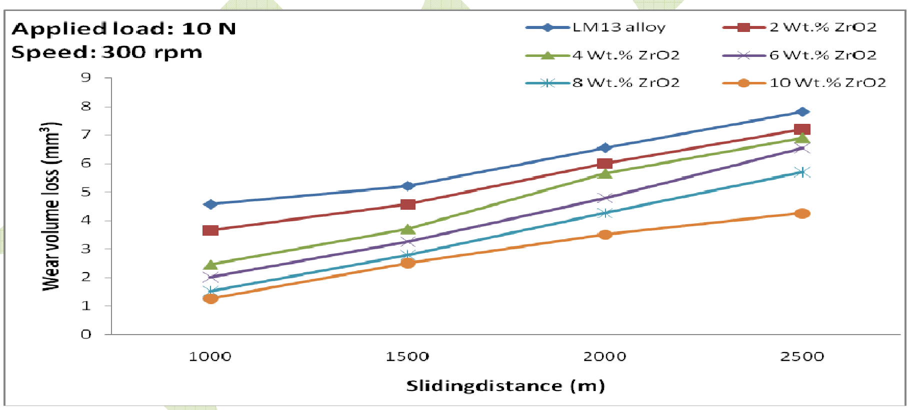

Figure 1: Effect of reinforcement and sliding distance on wear in volume loss of LM 13 alloy and LM13 / nano ZrO_2 composites at constant applied load of 10 N and sliding speed of 300 rpm.

Figure 2 shows the effect of reinforcement and sliding distance on wear in volume loss of LM 13 alloy and LM13 / nano ZrO_2 metal matrix composites at constant applied load of 30 N and sliding speed of 300 rpm. It can be seen that as the sliding distance increases, the wear of both the LM13 / nano ZrO_2 metal matrix composites as well as the matrix material increases. The wear of the matrix material is more than that of the composites for all sliding distances. Further, as the percentage of reinforcement increases, the wear of the LM13 / nano ZrO_2 metal matrix composite decreases. Further, as the percentage of reinforcement increases, the wear rate of the LM13 / nano ZrO_2 metal matrix composite decreases. It can be seen that as the applied increases, the wear of both the LM13 / nano ZrO_2 metal matrix composites as well as the LM13 matrix material increases. The wear of the matrix material is more than that of the nano composites for different applied loads.

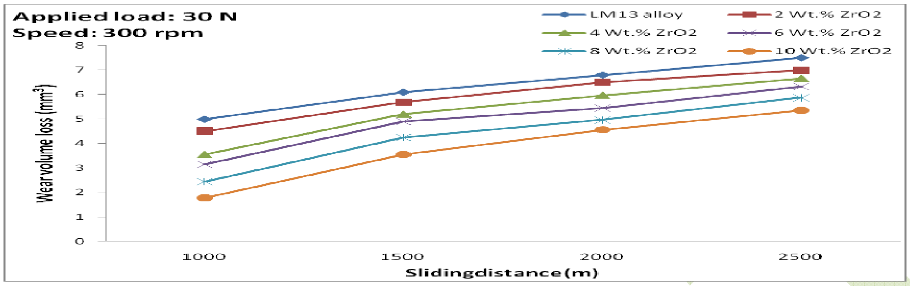

Figure 2: Effect of reinforcement and sliding distance on wear in volume loss of LM 13 alloy and LM13 / nano ZrO_2 composites at constant applied load of 30 N and sliding speed of 300 rpm.

WEAR MECHANISM:

Figure 3 and 4 shows the SEM photograph of the worn surfaces of the LM13 matrix alloy as well as LM13-ZrO_2 Nano Metal Matrix Composites (NMMCs) indicating the wear mechanism. It is observed that the worn surface of the matrix alloy is completely smooth and flat and containing wear tracks in the direction of sliding [17]. In addition, the signature of intense plastic flow is seen in the worn surface of NMMCs with 8 Wt.%.

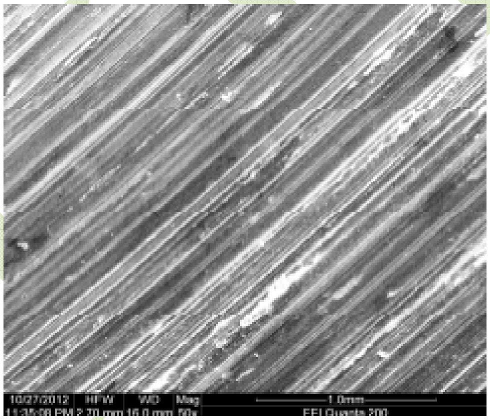

Figure 3: SEM micrograph of worn surface of matrix alloy (LM 13)

Figure 4: SEM micrograph of worn surface of NMMCs (8 Wt. % ZrO_2)

CONCLUSIONS

The LM13-ZrO_2 nano metal matrix composite materials have been fabricated by stir casting method followed by extrusion process. Pin-on-disc dry sliding wear characterization of developed NMMCs reveals improved wear resistance with increasing Wt. % of ZrO_2. Nano ZrO_2 particulates have an excellent load bearing capacity under applied load in sliding process, thus enhancing the wear resistance of NMMCs. The wear resistance increases as the wt. % of reinforcement content increases in the matrix material and wear resistance decreases as the applied load increases. Wear resistance is more in nano composites as compared to the matrix material. The SEM photograph of the worn surface of NMMC with 8 Wt.% ZrO_2 was found to be rough, in contrast to the worn surface of matrix alloy, which is completely smooth and flat.

REFERENCES

[1]. K.Upadhya, *"composite materials for aerospace applications, developments in ceramic and metal matrix composites", Kamaleshwar Upadhya, ed.., warrendale, PA: TMS publications, 1992, pp. 3-24.*

[2]. Greg Fisher, "*Composite: Engineering the ultimate material", Am. Ceram. Soc, Bull. Vol. 63 (2), pp. 360-364.*

[3]. T.G.Nieh, K.R. Forbes, T.C. Chou and J. Wadsworth, "*Microstructure and deformation properties of an Al2O3-Ni3Al composite from room temp to 14000C", High performance Composites for the 1990's Eds.*

[4]. C. Y. H. Lim, D.K. Leo, J.J.S. Ang, M. Gupta, '*Wear of magnesium composites reinforced with nano-sized alumina particulates', Wear., 259 (2005) 620-625.*

[5]. Joel Hemanth, "*Development and property evaluation of aluminium alloy reinforced with nano-ZrO2 NMMCs", Material Science and Engg A, 507,(2009) 110-113.*

[6]. R. A. Saravanan, M.K. Surappa, "*Fabrication and characterization of. Al-SiCp particle Composite", Mater. Sci. Engg.A, 108 (2000) 276-285.*

[7]. S.F. Hassan, J. Gupta., J. *Mater. Sci. 37 (2002) 2467-2477.*

[8]. A. Singh, A.P. Tsai, "*Quasicrystal strengthened Mg-Zn-Y alloys by extrusion", Scripta Mater. 49 (2003) 417-426.*

[9]. A.G. Guy, "*Elements of Physical Metallurgy" Addision-Wesley, USA, 1967, 78-85.*

[10]. P.K. Rohatgi, "*Metal-matrix Composites", J. Defence Sci. vol.43, No.4, (1993) 323-349.*

[11]. A.I. Nuesbaum, *"New Applications for Aluminium Based Metal Matrix Composites",*

Light Metal Age, 53 (1997) 54-58.

[12]. A.T.Alpas, J. Zhang, "*Wear rate transitions in cast Al-Si alloys reinforced with SiC particles", Scripta Metall. 26 (1992) 505-509.*

[13]. A.T. Alpas, J. Zhang, "*Wear regimes and transitions in Al2O3 particulate-reinforced aluminium alloys", Mater. Sci. Eng. A 161 (1993) 273-284.*

[14]. Y.M. Pan, M.E. Fine, H.S. Gheng, *Scripta Metall, 24 (1990) 1341.*

[15]. A.T. Alpas, J. Zhang, "*Effect of microstructure (particulate size and volume fraction) and counterface material on the sliding wear resistance of particulate-reinforced aluminium matrix composites", Metall. Trans. 25A (1994) 969-983.*

[16]. M. Roy, B. Venkataraman, V. Bhanuprasad, Y.R. Mahajan, G. Sundararajan, *Metall. Trans. 23A (1992) 2833.*

[17]. R.E. Reed Hill, "*Physical Metallurgy Principles", 2nd Edn., D.Van Nostrand Company, UK, 1964, 56-69.*