Influence of forging on Tribological Characteristics of Al6061-TiO_2 composite

T. P. Bharathesh[1], C. S. Ramesh[2], R. Keshavamurthy[3], S.M.Verma[4], Saravanan[5]
[1] Professor, Mechanical Engineering, City Engineering college, Bangalore.
[2] Professor, Mechanical Engineering, PES Institute of Technology, Bangalore.
[3]Associate Professor, Mechanical Engg., Dayananda Sagar College of Engg., Bangalore.
[4]Professor, Department of OR & SQC, Royalseema University, Kurnool.
[5]Assistant Professor, Mechanical Engineering, AMC College of Engg., Bangalore

Abstract- *Al6061 matrix composite reinforced with 8wt%TiO2 particles were synthesized by stir casting technique. Cast Al6061 alloy and Al6061-8%TiO2 composites were hot forged at a temperature of 500oC. Both as cast and hot forged Al6061 alloy and Al6061-8%TiO2 composites were subjected to microstructural studies, microhardness test and friction and wear studies. Co-efficient of friction of hot forged composite reduces with addition of TiO2 in both as cast and hot forged conditions. An increase in load leads to drastic reduction in co-efficient of friction for both as cast and hot forged alloy and its composites. an increase in sliding velocity has increased the COF. Wear studies on as cast and hot forged composites have revealed that wear rate decreases with addition of TiO2 particulates in the matrix alloy at all loads and sliding velocities. It is observed that wear rate decreases with the increase in sliding distance and increases with increase in load.*

I. INTRODUCTION

Metal matrix composites (MMCs) constitute an important class of design and weight-efficient structural materials that encourage every sphere of engineering applications [1]. They can be tailored to have superior properties such as high specific strength and stiffness, increased wear resistance, enhanced high temperature performance better thermal and mechanical fatigue and creep resistance than those of monolithic alloys [2-3].

In recent years, the secondary processing of composites have been gaining impetus as these processes such as extrusion, rolling and forging have profound impact on improvement in mechanical properties, wear and corrosion resistance of the primarily processed composites.

Although abundant literature is available on primary processing and characterization of the composites, no published information is available as regards the effect of secondary process in particular the hot forging. Further, it is well known that among many secondary processes available hot forging process ensures the best mechanical properties. This is why forgings are almost always used where only the best, reproducible, statistically guaranteed and repeatable performances are required always [4].

On the other hand, TiO2 is very hard reinforcement and possess low density, high fracture toughness and excellent strength exhibits excellent wear resistance and antifrictional properties, has not gained much importance as reinforcement in aluminum alloys [5]. Further, meagre information is available in the literature as regards the mechanical, tribological or corrosion properties of metallic coated TiO2 reinforced aluminum based composites subjected to hot forging.

In the light of the above, the present investigation deals with synthesis and tribological characterization of as cast and hot forged Al6061-TiO2 composite.

II. EXPERIMENTAL METHOD

Aluminum alloy was melted in a 6kw electric resistance furnace. The melt was degassed using commercially available chlorine-based tablets (hexachloroethane). The molten metal was agitated by the use of mechanical stirrer rotating at a speed of 400 rpm to create a fine vortex.

8wt% of TiO2 (Electroless nickel coated) particles in powder form was added slowly into the vortex while continuing the stirring process. A stirring duration of 10min was adopted. The composite melt maintained at a temperature of 720ºC was then poured into preheated metallic moulds. The cast Al 6061 and Al6061-TiO2 composite was subjected to open die hot forging using 300T hydraulic hammer at Fitwell Forgings Pvt. Ltd, Tumkur, Karnataka, India. Both as cast and hot forged alloy and its composites were subjected to microstructure studies, hardness and friction and wear test. Microhardness tests were performed with a load of 100 g for duration of 10 seconds using a Vickers microhardness tester. Friction and wear behavior studies were carried out on both as cast and hot forged alloy and its composites using instrumented Pin-on Disc equipment. Pins of diameter 8mm and height 30mm were used as specimen while hardened steel disc of Rc60 was used as counter disc. The height loss of the samples was recorded at different interval of time ranging from 5 to 45 min by use Linear Variable Differential Transducer (LVDT) of accuracy 1µm. The frictional force was measured by the use of force transducer of accuracy 1N. Friction and wear studies were conducted at various loads ranging from 30 to 90N. The sliding velocities were varied from 0.2 to 0.83 m/s. The co-efficient of friction was calculated using frictional force data. The coefficient of friction was calculated using frictional load and normal load data where as wear rates were calculated from height loss data in terms of volumetric wear loss per unit load and sliding distance.

III. RESULTS AND DISCUSSIONS

3.1 Microstructure studies:

Fig.1 (a-d) shows the optical microphotographs of as cast and hot forged Al6061 alloy and Al6061-TiO2 composites. It is observed that there is homogeneity in the distribution of the reinforcement in the matrix alloy in both as cast and hot forged conditions. Further, TiO2 particles are oriented in the direction of metal flow during forging.

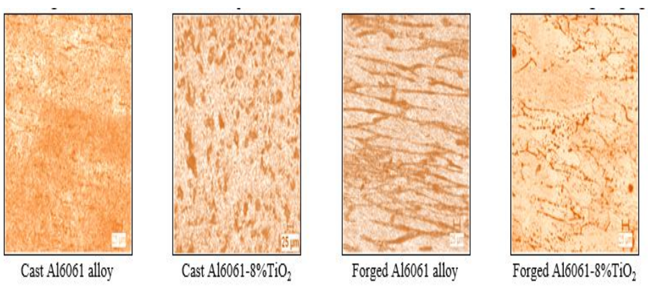

Fig.1.Optical micrographs of as cast and hot forged Al6061 alloy and Al6061-TiO2 composites

3.2 Microhardness

Fig.2 shows the variations of microhardness of forged Al6061 alloy and Al6061-TiO2 composites in as forged and heat treated conditions. It is observed that microhardness increases with addition of TiO2 particles in the matrix alloy, in both as cast and hot forged. A maximum of 20.00% improvement is noticed in as forged Al6061-8wt% TiO2 composite when compared with as forged matrix alloy. Increased microhardness with addition of TiO2 particles in matrix alloy can be attributed to higher hardness of TiO2 particles. Hard reinforcement in a soft and ductile matrix always enhances the hardness of the matrix alloy. Addition of reinforcement in matrix alloy leads to increased dislocation densities during solidification due to thermal mismatch between Al6061 alloy and TiO2 particles leading to retardation in plastic deformation [6].

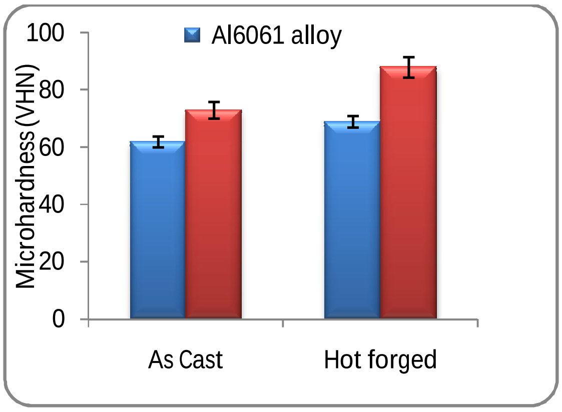

Fig.2 Variation of microhardness of Al6061 alloy and its composites

3.3 Coefficient of friction:

3.3.1 Influence of Load:

Fig.2 shows the variation of coefficient of friction of as cast and hot forged Al6061 alloy and its composites. It is observed that coefficient of friction of composites reduces with addition of TiO2 particles in both as cast and hot forged conditions. It is also observed that with increase in load a reduction in coefficient of friction is observed in both as cast and hot forged conditions for both matrix alloy and composite. However, at all the loads studied, Al6061-TiO2 composite exhibits reduced coefficient of friction when compared with matrix alloy. Further, when compared with cast matrix alloy and its composite, hot forged matrix alloy and its composites exhibited lower coefficient of friction under all the load conditions studied. The lower coefficient of friction in composite is due to antifrictional property of TiO2 particles.

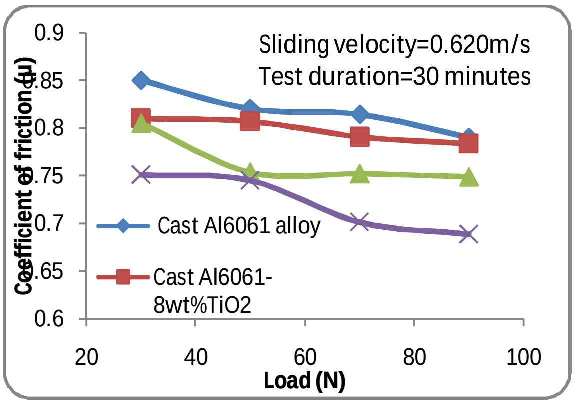

Fig.2 Variation of coefficient of friction with load

3.3.2 Influence of sliding velocity:

Fig.3 shows the variation of coefficient of friction with sliding velocity for both matrix alloy and its composite in as cast and hot forged conditions. It is observed that coefficient of friction increases with increase in sliding velocity. when compared with cast matrix alloy and its composites hot forged matrix alloy and its composites exhibits lower coefficient of friction at all the sliding velocities studied. The lower value of coefficient of friction at lower sliding velocities can be attributed to antifrictional properties of TiO2 particles.

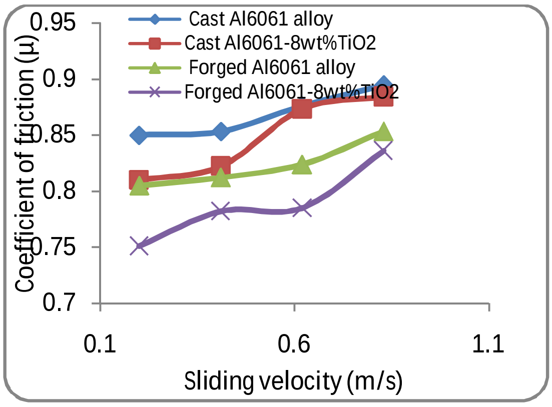

Fig.3 Variation of coefficient of friction with sliding velocity

3.4 Wear

3.4.1 Influence of Load:

Fig.4 shows the effect of addition of TiO2 particles on wear rate of Al6061 alloy in as cast and hot forged conditions. It is observed that increased in the load, and increase in the wear rate is noticed in both as cast and hot forged conditions. In all the cases studied, the wear rate of hot forged alloy and its composites are much lower than their corresponding cast alloy and its composites. Improved wear resistance may be attributed to higher hardness of forged alloy and composite when compared to cast ones. A maximum of 42% and 49% reduction is noticed in as cast and hot forged Al6061-TiO2 composites respectively when compared with cast alloy.

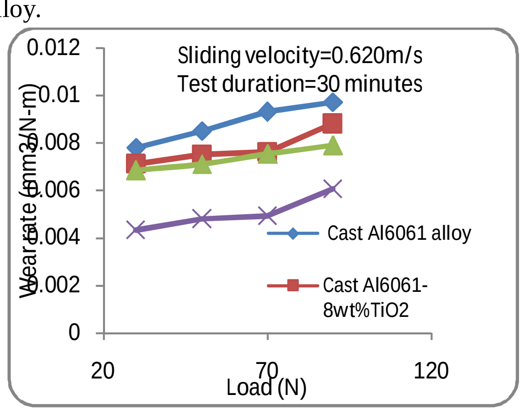

Fig.4 Variation of wear rate with load

at all the loads studied Al6061-TiO2 composite possessed lower wear rates compared to unreinforced alloy. Under identical test conditions the wear rate of hot forged alloy and its composites are significantly lower than cast ones. Increased wear rates with increased load can be attributed to the fact that at higher loads, there is a tendency for large plastic deformation which promotes the extent of wear debris formation leading to higher wear rates.

3.4.2 Influence of sliding velocity:

Fig.5 shows the dependence of wear rates of as cast and hot forged Al 6061 matrix alloy and Al6061- TiO2 composite on sliding velocity. With an increase in sliding velocity there is an increase in wear rate for both matrix alloy and its composite in both as cast and hot forged conditions. However, at all the sliding velocities studied, the wear rates of the composites were much lower when compared with the matrix alloy and reduced with addition of TiO2 particles. This can be attributed to enhancement in hardness of the composites as discussed earlier. Increase in hardness results in improvement of wear and seizure resistance of materials. Further, increased wear rate with increased sliding speed is due to high strain rate subsurface deformation. The increased rate of subsurface deformation increases the contact area by fracture and fragmentation of asperities. Therefore this leads to enhanced delamination contributing to enhanced wear rate [7].

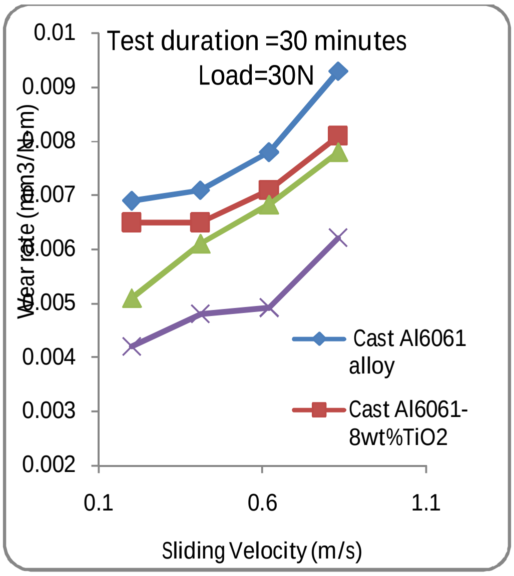

Fig.5 Variation of wear rate with sliding velocity

IV. CONCLUSION

Co-efficient of friction reduces with addition of the TiO2 particles in matrix alloy under both as cast and hot forged conditions. However, a significant reduction in coefficient of friction is observed after hot forging. Wear rate of composite was lower than matrix alloy in both as cast and hot forged conditions. Addition of hard reinforcement leads to reduced wear rate. Hot forged composite possess the lowest wear rates when compared with cast ones.

REFERENCES

[1] R.L.Deuis, C. Subramanian, and J.M. Yellup. "Abrasive wear of aluminium composites- a review". Wear 201, 1-2, (1996), 132-144.

[2] D.L. Mc Danels. "Analysis of stress- strain, fracture, and ductility behaviour of aluminium matrix composites containing discontinuous silicon carbide reinforcement", Metallurgical and Materials Transactions A, 16, (1985), 1105-1115.

[3] B. Ralph, H.Y Yuen, and W.B. Lee. "The processing of metal matrix composites an overview". Journal of Material Processing Technology, 63, (1997), 339-353.

[4] G.Durrant and V.D. Scott, "The effect of forging on properties and microstructure saffil fibre reinforced Aluminum". Composite Science & Technology 49 (1993) 153-164.

[5] CS Ramesh, AR Khan, N Ravikumar, P Savanprabhu "Prediction of wear coefficient of Al6061–TiO2 composites" Wear 259 (1), 602-608.

[6] V.V Ganesh, C.K.Lee and M. Guptha, "Enhancing the Tensile Modulus and Strength of an Aluminum" Material Science Engineering, A, 333 (1-2) (2002), 193-198.

[7] A.A. Hamid, P.K. Ghosh, S.C. Jain and S. Ray, "The influence of porosity and particles content on dry sliding wear of cast in situ Al(Ti)–Al2O3(TiO2) composite. Wear 265 (2008) 14–26.