Journal of Manufacturing Engineering, 2009, Vol.4, Issue.2, pp 105-110

MECHANICAL AND TRIBOLOGICAL BEHAVIOUR OF Al7075 – Al_2O_3 COMPOSITES

***Veeresh Kumar.G.B[1], C.S.P.Rao[2], Bhagyashekar.M.S.[3] and Selvaraj.N[2]**

[1.]Don Bosco Institute of Technology, Bangalore & Research Scholar, NIT Warangal, (A.P), India.
[2]. Dept of Mech., Engg, National Institute of Technology, Warangal, (A.P), India.
[3]. Dept of Mech.Engg, Don Bosco Institute of Technology, Bangalore, India

ABSTRACT

Aluminum alloys are light and are preferred for automobile, aerospace and mineral processing industries. These materials suffer with lower strength, hence they are reinforced with hard phase material, so as to modify their properties and to tailor them for required high performance application, and such reinforced materials are popularly known as composites. The ceramic reinforcement such as Al2O3, TiC, and SiC finds much importance in these Metal Matrix Composites (MMCs) for various automotive engine components, such as cylinder blocks, pistons and piston insert rings, brake disks and calipers. Thus, the tribological and mechanical properties of Al-alloy ceramic filled MMCs are of much interest. Hence the present paper aims at presenting experimental data on the above properties. The Al7075 reinforced with Al2O3 particulate were the composites prepared by liquid metallurgy route. 2-6 wt. % of Al2O3 were dispersed in steps of 2 to obtain the castings of composites. The cast composites were carefully machined to obtain the required test specimens as per ASTM standards for density, hardness, mechanical, tribological tests and microstructural studies.

Hardness of the composites was measured using Vickers micro-hardness tester. The composites weight to volume ratio was the density. Lobo make metallurgical microscope attached with Pentax camera was used to obtain optical microphotographs. The mechanical properties were evaluated using a UTM of 20-ton capacity. Computerized pin on disc wear tester of Magnam make with EN31 counter steel disc (HRC60) was used for the evaluation of tribological properties. The microstructural studies revealed the uniform distribution of the particles in the matrix system, the measured density of the composites were found in line with that of the calculated by rule of mixtures, hardness of the composite was found to increase with increased filler content, the dispersion of Al2O3 in the Al7075 alloy confirmed the enhancement of mechanical properties and wear resistance.

Key words: *Al7075- Al_2O_3 composites, Density, Wear resistance, Mechanical properties*

1. Introduction

Aluminum alloys are most preferred materials in the automobile, aerospace and other industries owing to their lower weight, excellent thermal conductivity. Among these aluminium alloys, Al7075 were much explored and they possess higher modulus properties. Reda et al.[1], Clark et al.[2] in their studies, reported that pre-aging of Al7075 at various retrogression temperatures improves the hardness, tensile properties and electrical resistivity. Kim et al.[3] concluded that the hardness of aged Al7075 alloy increases and heat resisting property improves, further they also reported that the squeeze casting method improves the grain refinement there by reducing the wear loss when compared to that manufactured adopting non-pressurized casting methods. Bystritskii et al.[4] in an attempt of surface modification of Al7075 alloy using microsecond plasma opening lifetime of these alloys. B. Venkataraman et al.[5] reported that the removal of the mechanically mixed layer was responsible for the severe wear of the Al7075-SiC composites under dry sliding wear conditions.

Further these alloys are of much interest when they are reinforced with hard phase particle [6] and whisker reinforcements. From the literatures the most preferred particle reinforcements for the production of MMC's are the hard ceramics viz. zirconia, alumina and silicon carbide(SiC), that enhances the properties like strength, stiffness, wear and corrosion resistance, fatigue life and also elevated temperature properties. Kumar et al.[7] while developing a mathematical model for dry sliding wear behaviour of Al7075/SiC composites reported that increased SiC in base alloy reduces the wear rate of the composite by restricting the flow or deformation of the matrix material against applied load. Rupa Dasgupta et al.[8] stated that the improvement in the hardness, mechanical property and

**Corresponding Author-E-Mail:veeru232@yahoo.com*

wear resistance are attained by heat treating the composites T. J. A. Doel et al.[9] in their studies concludes that.5 and 13 µm particles SiC reinforced Al7075 exhibits improved tensile strength and lower ductility. K. Komai et al.[10] reported the superior mechanical properties of Al7075-SiC composites. The above survey reveals the availability of the meager data of Al7075-Al_2O_3 composites regarding the mechanical properties. Hence in the present paper it is aimed to fabricate the composite of Al7075 containing various % Al_2O_3 particles and to study their density, hardness, mechanical and tribological properties.

2. Experimental Details

2.1 Materials

The chemical composition of the matrix material Al7075 and also the properties of Al7075 and the particle reinforcement Al_2O_3 are presented in the table 1 and table 2 respectively. The particle size of Al_2O_3 selected was 10–20 µm.

Table 1: Chemical composition of Al 7075 by weight percentage

Si	Cu	Mg	Fe	Cr	Zn	Ti	Mn	Al
0.5	1.2-2	2.1-2.9	0.5	0.18-0.28	5.1-6.1	0.2	0.3	Bal

Table 2: Physical properties of Al 7075 and Al_2O_3

Material	Elastic Modulus (Gpa)	Density g/cc	Poisson's Ratio	Hardness	Tensile Strength (Mpa)
Al 7075	70-80	2.8	0.33	60 (HB500)	220
Al_2O_3	375	3.89	0.22	1440 (kg/cm^2)	2600

2.2 Composite preparation

Liquid metallurgy route were adopted for the preparation of composites. Preheated Al_2O_3 particles of required quantity were introduced into the molten metal vortex that was pre-degassed and maintained at 730^{0}C. Mechanical mixing of the matrix and reinforcement were ensured by stirring the charge for about 10 minutes. The ceramic-coated steel impeller was employed for the purpose at a speed of 400 rpm. The thoroughly mixed composite were poured into the cavities of the prepared moulds at 710^{0}C and were allowed to reach the room temperature. Thus the cast composites of Al7075 containing 2-6 wt. % Al_2O_3 were obtained. These cast composites were of 20mm X 200mm in size.

2.3 Testing of composites

ASTM standards specified specimens for the measurement of density, Vickers micro-hardness, microstructure analysis; tensile strength and wear resistance were obtained after carefully machining the castings of base matrix and composites.

The density of material, ratio of weight to volume [11] was obtained by accurately measuring the weight and the volume of the composites. Shimadzu Japan make Vickers micro hardness tester served the purpose of measuring hardness of test materials. Carefully polished base matrix and its composites to mirror finish were the specimens for microstructural studies. Pentax camera attached Lobo make metallurgical microscope with maximum magnification of 1000X was adopted to obtain microphotographs. The mechanical properties were evaluated using universal testing machine of 20-ton capacity. Magnam make computerized pin on disc wear testing machine with test material as pin and high carbon EN31 steel (HRC60) as countersurface, equipped with LVDT and digital display system served to record the wear height loss in microns.

3. Results and Discussion

3.1 Composite characterizations

The densities and the microstructure of the test materials confirm its characteristics.

3.1.1 Density

The figure 1 is presented with the theoretical i.e. based on rule of mixture and experimental density values of the base matrix and its composites.

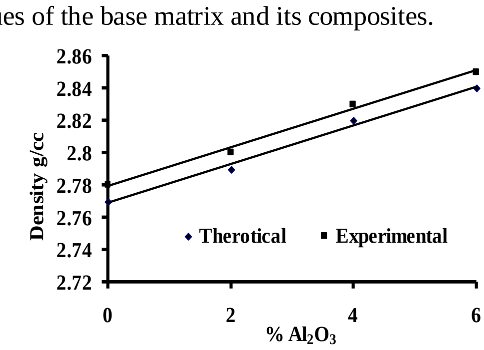

Fig.1 Comparison of theoretical and experimental density of Al7075 alloy and its Al_2O_3 composites

From the above figure it can be observed that, the density of the composites is higher than that of the base matrix alloy. Also, it can be observed that, the density of the composite increases with increased% Al_2O_3 in the base Al7075 matrix system. Further it can also be observed that, the theoretical and experimental density values are in line with each other. The above fact of increase of density of composites can be explained to the reason of higher density of the reinforcing particle Al_2O_3. The above results are in agreement with other researches with various composites containing Al_2O_3 [12, 13].

3.1.2 Microstructure Studies

Figure 2 and figure 3a-c are presented with the microphotographs of the cast Al7075 alloy matrix containing various wt. % Al_2O_3 respectively

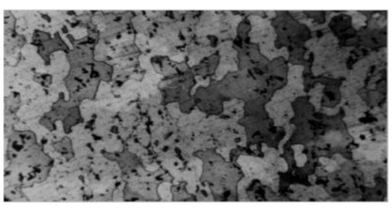

Fig 2 Microphotograph of cast alloy 200X

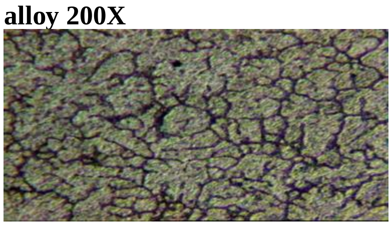

Fig 3a Microphotograph of cast Al7075-2%Al_2O_3 composite, 200X

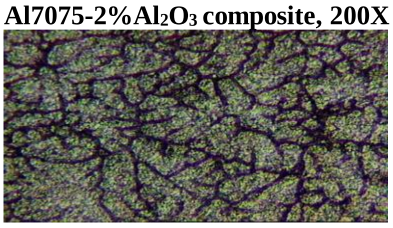

Fig 3b Microphotograph of cast Al7075-4%Al_2O_3 composite, 200X

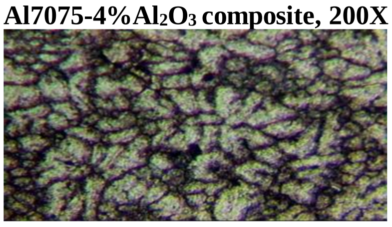

Fig. 3c Microphotograph of cast Al7075-6%Al_2O_3 composite, 200X

Form figure 2 the characteristics of Al7075 alloy can be observed. The figure 3a-c reveals the uniform distribution of Al_2O_3 in the matrix alloy. Further, the increased second phase material in the composites can be clearly identified. These figures also reveal the homogeneity of the composites.

3.2 Mechanical properties

The mechanical properties such as microhardness and tensile strength properties of cast Al7075 base matrix and its composites containing 2-6 wt.% Al2O3 are presented in the following sections.

3.2.1 Microhardness

The Vickers micro-hardness evaluated using diamond indenter for the cast matrix alloy and its composites obtained at an applied load of 100N are presented in figure 4.

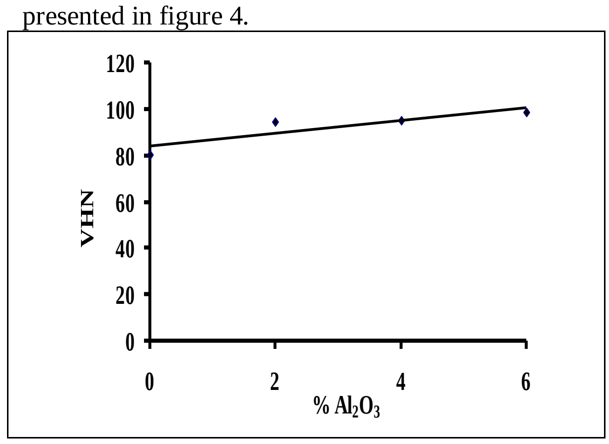

Fig. 4 Effect of Al_2O_3 on the hardness of Al7075-Al_2O_3 composites

From the figure, it can be observed that the hardness of the composite is greater than that of its cast matrix alloy. Further, it can be observed that the hardness of the composite found increased with increased Al_2O_3 content. The improvement in the hardness can be attributed to the fact that the Al_2O_3 possess higher hardness and its presence in the base matrix improves the hardness of the composite [14].

3.2.2 Tensile Properties

The tensile strength property of Al7075 alloy and its composites containing various wt.% Al_2O_3 are presented in the Figure 5.

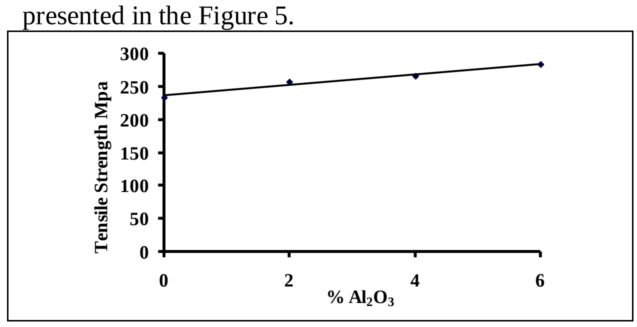

Fig. 5 Variation in tensile strength of Al7075 with increasing wt. % of Al_2O_3

From the figure it can be observed that, the composite's tensile strength is greater then that of the base matrix. Further it can be observed that, the increased wt.% Al_2O_3 resulted in increased tensile strength properties of the composites. The observed improvement in tensile strength of the composites may be attributed to the fact that the filler Al_2O_3 possess higher strength and imparts the improved strength to the composites [8-10].

3.2.3 Elongation Property

Figure 6 is presented with variations of % elongation of Al7075 base matrix and the composite as a function of wt.% Al_2O

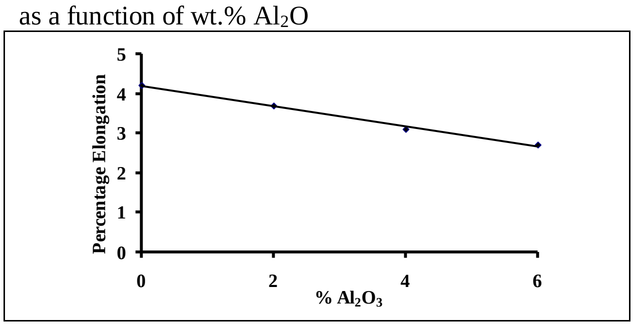

Fig. 6 Variation in the % elongation with wt.% of Al_2O_3 in Al7075

From figure it can be observed that, the % elongation of the Al7075-Al_2O_3 composite is lower in its value than that of the base matrix. Also it can be observed from the figure that, the addition of Al_2O_3 contributes in reducing the % elongation. The % reduction in elongation is found greater for the composites. From the above trend it can be concluded that, the dispersions of Al_2O_3 in the base matrix Al7075 reduces the ductility [15].

3.3 Tribological properties

The cast pins of 10mm diameter and 25mm length were the specimen for the tribological test. The height loss experienced by the specimen as a function of material parameter (filler content) and the test parameters (sliding time) for various applied load (10-50 N in steps of 10) and various speed (100-500 rpm in steps of 100) for the base alloy and its composites are presented in figure 7 a-e and figure 8 a-e.

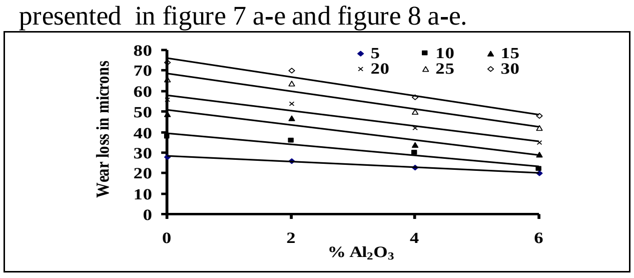

Fig. 7 a Wear loss of Al7075 alloy and its composites under while sliding at 100 rpm and an applied load of 10N

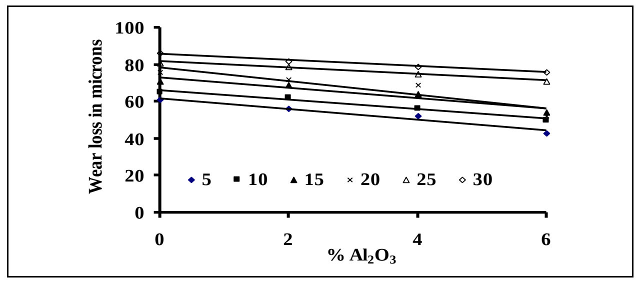

Fig. 7 b Wear loss of Al7075 alloy and its composites under while sliding at 200 rpm and an applied load of 10N

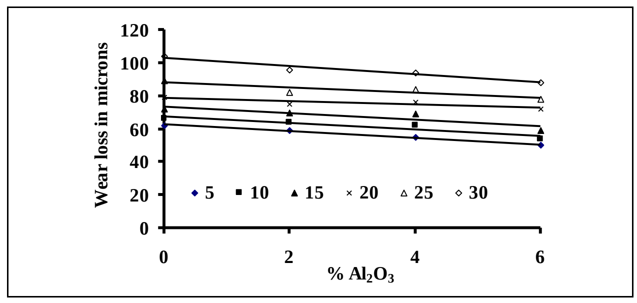

Fig .7 c Wear loss of Al7075 alloy and its composites under while sliding at 300 rpm and an applied load of 10N

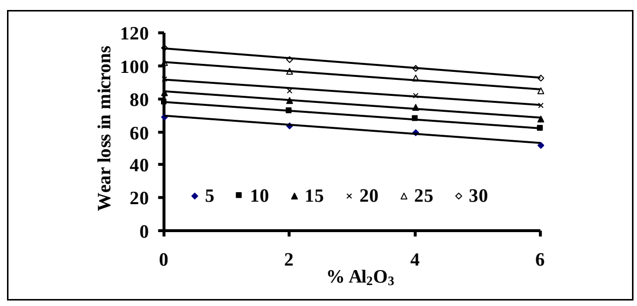

Fig .7d Wear loss of Al7075 alloy and its composites under while sliding at 400 rpm and an applied load of 10N

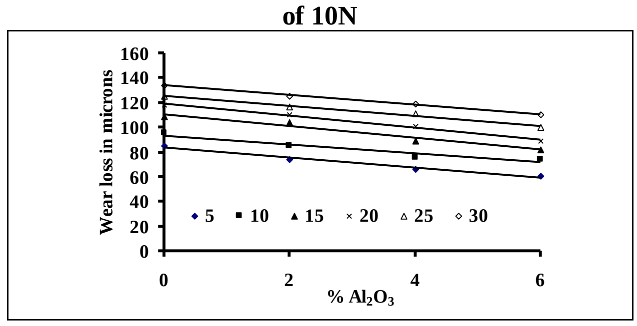

Fig .7e Wear loss of Al7075 alloy and its composites under while sliding at 500 rpm and an applied load of 10N

Figures 7a-e presents the variation of wear loss of the Al7075 alloy and its composites under an applied constant load of 10N and at various sliding speeds, for sliding time up to 30 minutes. Further figure 8a-e presents the variation of wear loss of the Al7075 alloy and its composites under a constant sliding speed of 100rpm up to 30 minutes duration and for various applied loads 10N to 50N.

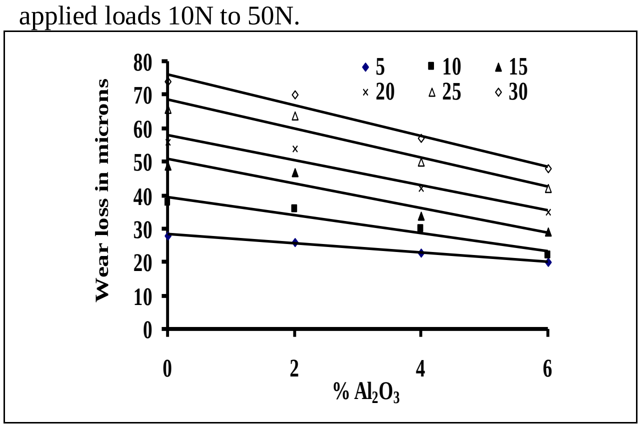

Fig. 8 a Wear loss of Al7075 alloy and its composites under while sliding at 100 rpm and an applied load of 10N

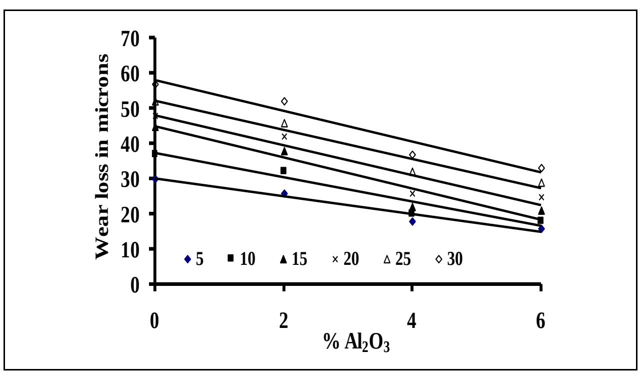

Fig. 8 b Wear loss of Al7075 alloy and its composites under while sliding at 100 rpm and an applied load of 20N

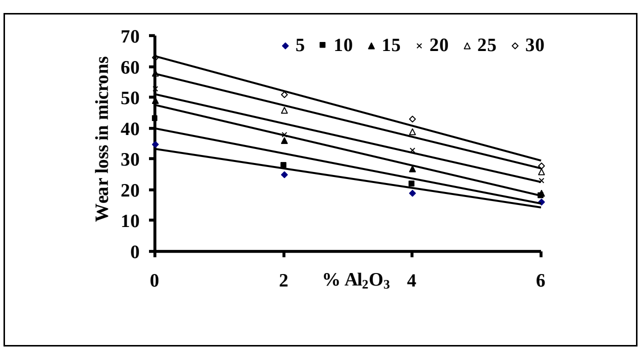

Fig. 8 c Wear loss of Al7075 alloy and its composites under while sliding at 100 rpm and an applied load of 30N

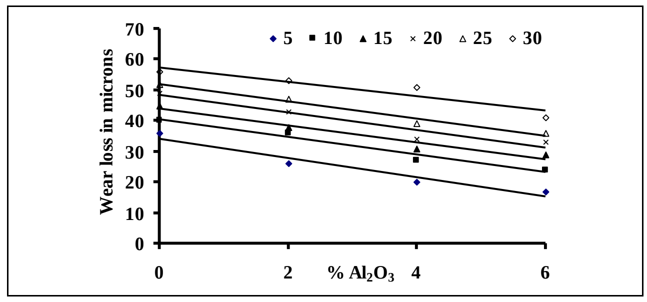

Fig 8 d Wear loss of Al7075 alloy and its composites under while sliding at 100 rpm and an applied load of 40N

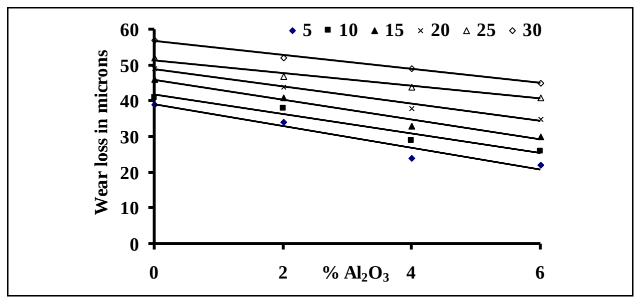

Fig. 8 e Wear loss of Al7075 alloy and its composites under while sliding at 100 rpm and an applied load of 50N

From figure 7a, it can be observed that, the wear height loss experienced by the composites are lesser than that of the base alloy also it can be found that the wear height loss for the composites decreases as a function of filler content. Further, it can also be observed from the figure that, for given filler content, the composites wear height loss increases with increased sliding duration. From figures 7b-e, it can be observed that the trend of wear loss of the base alloy and composites are more or less same as compared to the trend of figure 7a. From the above discussions, it can be concluded that irrespective of sliding speed the composites containing Al_2O_3 exhibits decreased wear loss and hence exhibits improved wear resistance. Figure 8, reflects all the features of figure 7 reflecting the improved wear resistance of the composites. From the above discussions it can be concluded that, the presence of Al_2O_3 in the composite is to reduce the wear loss and hence contributes in improving the wear resistance. The highest wear resistance is exhibited by the composite containing higher Al_2O_3 contents. The improvement of the wear resistance can be attributed to the fact that the filler improves the hardness of the composites thus further contributing to the improvement of the wear resistance of the composites [16].

4. Conclusion

The significant conclusions of the studies undertaken on Al7075-Al_2O_3 composites are summarized as follows.

I) Al7075-Al_2O_3 composites were prepared successfully using liquid metallurgy techniques.

II) The experimental and theoretical densities of the composites are found in agreement to each other. The densities of the composites containing higher Al_2O_3 particulates are found higher.

III) The microstructural studies revealed the uniform distribution of the particles in the matrix system.

IV) Microhardness of the composites found increased with increased Al_2O_3 content.

V) The tensile strength properties of the composites found increased with increased reinforcement content.

VI) The percentage elongation of the composites found decreased with increased % reinforcement contents.

VII) The wear height loss of the composites decreased clearly indicating the increased wear.

The reinforcement Al_2O_3 profoundly improves the wear resistance of al-alloys. Al7075-6 wt.% Al_2O_3 composite exhibits superior wear resistance among the composites tested.

References

1. *Y. Reda, R. Abdel-Karim and I. Elmahallawi "Improvements in mechanical and stress corrosion cracking properties in Al-alloy 7075 via retrogression and reaging" Materials Science and Engineering: A, 485, 468-475, 2008.*
2. *R. Clark, Jr, B. Coughran, I. Traina, A. Hernandez, T. Scheck, C. Etuk, J. Peters, E.W. Lee, J. Ogren and O.S. Es-Said "On the correlation of mechanical and physical properties of 7075-T6 Al alloy Engineering Failure Analysis", 12, 520-526, 2005*
3. *S. W. Kim, D. Y. Kim, W. G. Kim and K. D. Woo "The study on characteristics of heat treatment of the direct squeeze cast 7075 wrought Al alloy" Materials Science and Engineering A, 304-306, 721-726, 2001.*
4. *V. Bystritskii, E. Garate, J. Earthman, A. Kharlov, E. Lavernia and X. Peng "Fatigue properties of 2024-T3, 7075-T6 aluminum alloys modified using plasma-enhanced ion beams Theoretical and Applied Fracture Mechanics", 32, 47-53, 1999.*
5. *B. Venkataraman, G. Sundararajan "Correlation between the characteristics of the mechanically mixed layer and wear behaviour of aluminium, Al-7075 alloy and Al-MMCs" Wear, 245, 22-38, 2000.*
6. *T. Miyajima, Y. Iwai, "Effects of reinforcements on sliding wear behavior of aluminum matrix composites", Wear 255, 606–616, 2003.*
7. *S. Kumar, V. Balasubramanian, "Developing a mathematical model to evaluate wear rate of AA7075/SiCp powder metallurgy composites", Wear, 264, 1026-1034, 2008.*
8. *Rupa Dasgupta and Humaira Meenai "SiC particulate dispersed composites of an Al–Zn–Mg–Cu alloy: Property comparison with parent alloy" Materials Characterization, 54, 438-445, 2005*
.9. *T. J. A. Doel and P. Bowen "Tensile properties of particulate-reinforced metal matrix composites", Composites Part A: Applied Science and Manufacturing, 27, 655-665, 1996.*
10. *K. Komai, K. Minoshima and H. Ryoson, "Tensile and fatigue fracture behavior and water-environment effects in a SiC-whisker/7075-aluminum composite", Composites Science and Technology, 46, 59-66, 1993.*
11. *M.D. Bermudeza, G. Martinez-Nicolas, F.J. Carrion, I. Martinez-Mateo, J.A. Rodriguez, E.J. Herrera, "Dry and lubricated wear resistance of mechanically-alloyed aluminium-base sintered composites", Wear 248, 178–186, 2001.*
12. *M.R. Rosenberger, C.E. Schvezov, E. Forlerer, "Wear of different aluminum matrix composites under conditions that generate a mechanically mixed layer", Wear 259, 590–601, 2005.*
13. *L.J. Yang "A test methodology for the determination of wear coefficient" Wear 259, 1453–1461, 2005.*
14. *J.M. Wu, Z.Z. Li, "Contributions of the particulate reinforcement to dry sliding wear resistance of rapidly solidified Al-Ti alloys", Wear 244, 147–153, 2000.*
15. *M.D. Bermudez, G. Martinez-Nicolas, F.J. Carri0n, I. Martinez-Mateo, J.A. Rodriguez, E.J. Herrera, "Dry and lubricated wear resistance of mechanically-alloyed aluminum-base sintered composites", Wear 248, 178–186, 2001.*
16. *L.J. Yang, "Wear coefficient equation for aluminium based matrix compo Al_2O_3 sites against steel disc", Wear 255, 879–892, 2003.*

Acknowledgements

The authors express their thanks to the Management, Wayanamac Education Trust, Bangalore and to Dr K. Muralidhara, Principal, DBIT, Dr.C.R.Rajashekar, Professor and Head, Mechanical Engineering, DBIT and also to the staff of Mechanical Engineering Department, DBIT for their support and encouragement during the research studies.