Effects of Reinforced Particulates on Properties of Aluminium Metal Matrix Composite

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ABSTRACT
The Aluminium alloy has excellent properties such as high thermal conductivity and low density. These properties make its application wide in the field of automotive, aerospace and mineral processing industries to make their products .In spite of these properties the main drawback of aluminium alloys are poor wear resistance behavior, harness and strength. To overcome this drawback, these types of alloys are reinforced with some other materials so that its hardness, Young's modulus and abrasion wear resistance can increased to the desired limit. This paper presents an overview of different reinforced materials in Aluminium Metal Matric Composites (AMMCs) system and their effect on different properties.

Keywords: AMMCs, Wear, Hardness, Young's modulus.

I INTRODUCTION

The Composite is a material is a material made out of two or more constituent materials which are chemically and physically different. Constituent materials are the individual materials which makes the composite. There are two categories of them as matrix and reinforcement. Usually matrix material supports the reinforcement material. The constituent materials stay separately within the finished structure because they are chemically and physically different, to mix with each other. The Composites can be synthetic or naturally occurring materials. Wood is a natural composite. It is made up of cellulose fibers and a matrix of lignin. When preparing composites, normally both matrix and reinforced materials are combined and compacted. After this, the shape of the composite is set, and it won't change unless it is affected by certain conditions. The basic difference between alloys and composite are alloy is a homogenous or a heterogeneous mixture whereas composites are heterogeneous. There is at least one metal in alloy, but it is not necessary to have metals in composites. In the field of material science this is the era of composite and smart materials as the industrial demand and application. Every industry required high performance material, so that the component can perform better service at desired condition. In the category of light weight high performance material, the Aluminium matrix composites (AMCs) are widely used by several industries. The composites formed out of aluminum alloys are of wide interest owing to their high strength, fracture toughness, wear temperature application when reinforced with ceramic particle. The important reinforcement materials used in the aluminium metal matrix composites are carbon/ graphite, silicon carbide, alumina, zirconia and zircon in particulate, whisker or fibre form. Major fabrication methods used for aluminium metal matrix composites are stir casting, squeeze casting, compocasting, infiltration, spray deposition, direct melt oxidation process and powder metallurgy.

II REINFORCEMENT MATERIALS

In Aluminum matrix composites (AMCs) the ceramic reinforcements are generally oxides or carbides or borides (Al_2O_3 or SiC or TiB_2).Their microstructure, physical properties, tribological properties and others desired properties of composite depends upon their processes root of manufacturing and shape, size, chemical affinity with matrix material of reinforcement materials in composite. The Wetting of reinforcement by molten metal, an important aspect in MMC synthesis, is favored by the formation of strong chemical bonds at the interface. The presence of oxide films on the surface of molten metal and the adsorbed contaminant on the reinforcement surface generally leads to non-wetting of the reinforcement with molten metal. The lower wettability adversely affect the properties of composite. Some of the techniques to improve metal-reinforcement wettability include metallic coatings on the reinforcements, addition of reactive elements, such as magnesium, calcium or titanium, to the melt and heat treatment of particles before addition.

(a) Titanium Diboride (TiB_2):
It has superior hardness and corrosion resistance with a high melting point (>2900°C) and good oxidation resistance to 1000°C. Titanium diboride is an extremely hard ceramic compound composed of titanium and boron which has excellent resistance to mechanical erosion. TiB_2 is also a reasonable electrical conductor.

Properties:

(i) Extreme Hardness nearly as hard as diamond when its sintered.

(ii) TiB_2 is tough enough to be used as military armor and improves the fracture toughness of ceramic cutting tools and other components.
(iii) As an excellent conductor of both electricity and heat, TiB2 is valuable in electronic and specialty applications.
(iv) TiB_2 enhances thermal conductivity when used as a filler in polymeric matrices.
(v) Chemical resistance.
(vi) Titanium diboride will not react with molten, nonferrous metals including Cu, Zn and Al.
(vii) TiB_2 is used as crucibles, vacuum metallization components and electrodes for processing these materials.

Applications:

(i) Electrically conductive composites such as aluminum evaporation boats.
(ii) Additives for producing specialty ceramic composite materials.
(iii) Refractory material and antioxidant additive that is nonreactive to most molten nonferrous metals and alloys.
(iv) Thermal management materials.

(b) 2.2 Silicon Carbide (SiC):

The aluminium-SiC composite system finds potential applications as structural elements in the automotive and aerospace industries. These composites possess unique properties such as improved strength, modulus and wear resistance and good resistance to corrosion. But several drawbacks of these materials such as low temperature, ductility and poor toughness hinder their wide range of application. The causes for the remarkable drop in ductility and toughness of the composite are believed to be related to the structure at the interface region and the processing factors. The major problems encountered during the fabrication of SiC-reinforced aluminium matrix composites are the reactivity of SiC with molten aluminium at higher processing temperatures and the poor wettability of SiC at lower processing temperature (900-1000 K). The reaction between SiC and liquid aluminium during processing causes significant degradation in the properties of the composites [1-2]. In order to prevent the degradation of SiC (particles, whiskers or fibres) and improve wettability, various treatments and coatings have been attempted. The metallic coatings given to SiC are copper [3-4], nickel [4-6], antimony [5] and silver [4]. Investigation by Moon and Lee [4] has shown that the wettability of copper-, nickel- and silver-coated SiC fibre with aluminium is better than as received fibre, copper and silver coatings being between metallic thin film and the liquid aluminium.The influence of various ceramic coatings as a possible barrier against degradation of SiC particles with aluminium, has been understood. more effective. The driving force for wetting has been considered to be increased by the interfacial reaction. In silicon carbide-reinforced aluminium metal matrix composites, SiC is thermodynamically unstable in molten aluminium at around temperatures exceeding 1000 K [7]. The SiC reacts with molten aluminium [8, 9] to form Al4C3 and rejecting metallic silicon. These reaction products have also been observed to cover SiCp by Lee *et al.* [10]. However, the above reaction can be suppressed by having a matrix alloy containing a higher silicon content and maintaining the proper melt temperature [11].

(c) Alumina (Al_2O_3):

The alumina-reinforced aluminium metal matrix composites find wide application next to carbon and silicon carbide-reinforced composites in the areas of automotive and aerospace industries. Al-Al_2O_3 metal matrix composites possess high elevated-temperature strength, wear resistance, damping properties, electrical conductivity, thermal conductivity and coefficient of thermal expansion. The alumina can be in the form of particulates, whiskers and fibres. The alumina in a pure aluminium matrix is considered to be the ideal dispersoid with no chemical reactions. But, when aluminium alloys are used as the matrix, the Al_2O_3 reacts with alloying elements such as magnesium. The other major problem is its lower wettability below 900K [12]. In order to enhance its wettability, metallic coatings such as nickel [13, 14], cobalt [15, 18] and palladium [17] have been applied to alumina. MgO-coated alumina particles [18] have been found to improve the properties of composites compared to as received ones. The deposition of nickel on alumina is made by nickel ions from a solution under hydrogen pressure in the presence of ammonia as a complexing agent. Cobalt coating increases its wettability during processing. The evaluation of tensile properties and fracture behavior of cobalt-coated Al_2O_3 fibre-reinforced 2024 Al alloy composites has shown improved properties compared to that with uncoated fibres.

III PROPERTIES AND REINFORCEMENT MATERIALS

G. B. Veeresh et. al.[22], they prepare two composite Al6061-SiC and Al7075-Al_2O_3 with varying wt % of particles from 2 to 6 by using vortex stir casting and investigated mechanical and found increased to 60-97VHN & 80-109VHN respectively. The tensile strength of composite increased 68% & 24% increased respectively. Conclusion of their finding is Al6061-SiC exhibit superior mechanical and tribological properties due to Sic reinforcement. **Do-Suck Han, et.l[38],** they studied the wettability of SiC in Al alloys. According to them wetting of silicon carbide (SiC) or wettability of SiC to aluminum and aluminum alloys is an important phenomenon in processing of SiC reinforced aluminum metal matrix composites. Many parameters affect the wettability such as free silicon in silicon carbide, wetting angle and kinetics of SiC. **M. Kobashi and T. Choh[41],**

they made a study to find the wettability and the reaction for silicon carbide particle and aluminum alloy system. They found that silicon carbide particles did not incorporate into the liquid aluminum immediately. This indicates that the silicon carbide particles gradually wetted by liquid aluminum. Thus the incorporation time represents duration, which is necessary for full particulate wetting. The incorporation time can be shortened by alloying magnesium and titanium. **G. G. Sozhamannan & S. Balasivanandha Prabu[32],** evaluated of interface bonding strength of Al/Si carbide at different temp. The aluminum/silicon carbide specimens were prepared at different processing temperature with constant holding time through melt joining process. They found that the interface bond strength increased with increase in processing temp. Due to increase in concentration of Si at the interface which minimizes the formation of Al_4C_3 at the SiC surface as a result the wettability of SiC become uniform in composite as depicted in fig.1.

Fig 1: Al/SiC interface bonding.

- Tensile strength of Al/SiC specimen

Materials	Temperature (°C)	Tensile strength (MPa)
6061 Al/SiC	700	0.241
6061 Al/SiC	750	0.352
6061 Al/SiC	800	0.41

T.V. Christy et.al.[23], prepared Al6061-TiB_2 (12%wt)composite using the in-situ salt-metal reaction process and compare the mechanical properties and the microstructure of Al 6061 alloy & composite. The hardness, tensile strength and young's modulus of composite increased but ductility of the composite was found to be slightly lower than that of the aluminium 6061 alloy.

Material	Hardness (BHN)	Tensile Strength (Mpa)	Young's Modulus (Gpa)	% Elongation
Al-6061	62.8	134.8	79.8	8.0
Al-TiB2	88.6	173.6	94.2	7.0

David L Mc Danels[43], examined mechanical properties and stress-strain behavior for several fabricated aluminum matrix composites containing up to 40 vol. % discontinuous silicon carbide whisker, nodule or particulate reinforcement. The four types of aluminum matrices are used: 6061, 2024/2124, 7075 and 5083. Silicon carbide reinforced into the matrix material in a form of discontinuous, whisker, nodule and particulate. They found that the modulus of elasticity increased with increasing reinforcement content. When the factors influencing strength are considered, the effect of the matrix type is found to be the most important. The SiC/Al composites with as 2024/2124 or 7075 Al, has higher strengths but lower ductility. Composites with a 6061 Al matrix showed good strength and higher ductility. **E.E.S. Moraes, M.L.A. Graça & C.A.A. Cairo,** In their studies the wettability of SiC by aluminium alloys was investigated under argon and vacuum atmosphere. They found that the contact angle was no measure in tests with argon atmosphere because the argon doesn't prevent the formation of the film oxide at the surface of aluminium alloys. The silicon contents decreases the contact angle

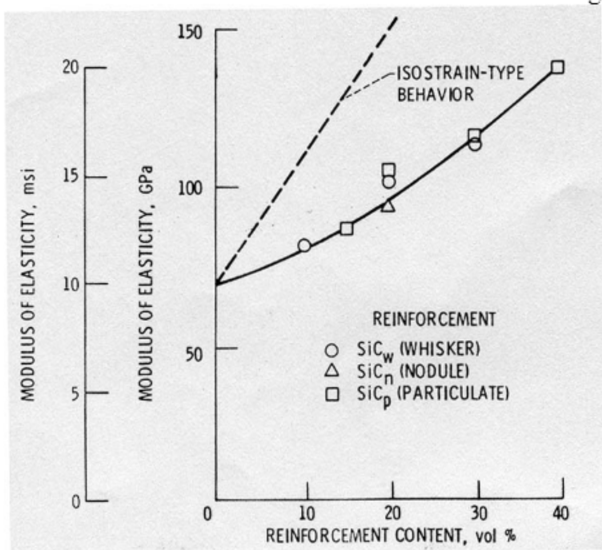

Fig 2(a): Effect of aluminum matrix alloy on elasticity behavior of composites with 20 vol% SiCw reinforcement.

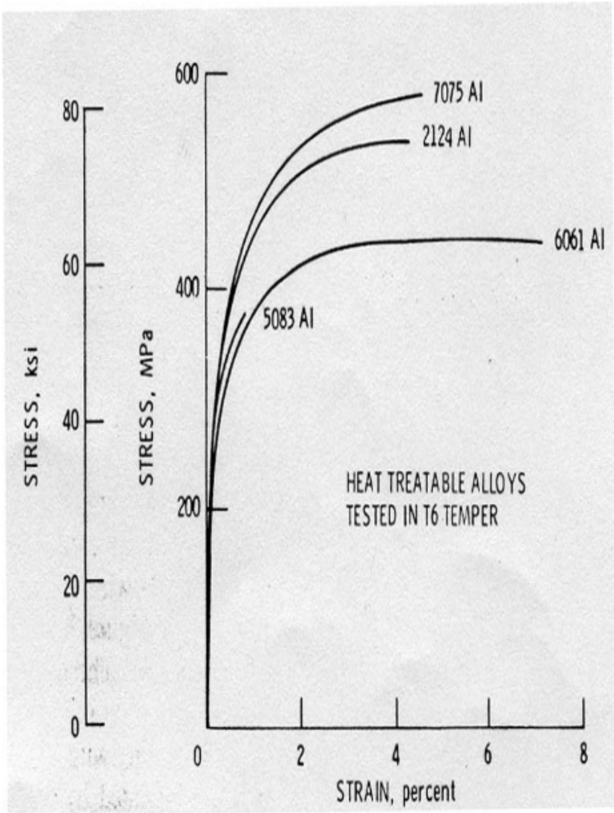

Fig 2(b): Effect of aluminum matrix alloy on stress-strain behavior of composites with 20 vol% SiCw reinforcement.

during heating, because affects the fluidity positively. The magnesium increases the driving force for wetting, reactions consumes the oxygen present on surface of the metal enhancing the wetting. **A. Sreenivasan. et.al[24],** they prepared Al6061-TiB_2 (5,10,15%wt) composite using combo stir casting technique and microstructure and wear characteristics of TiB_2 reinforced aluminium metal matrix composites (MMCs) was examined. The result showed that the wear rate was decreased with increase in TiB_2 content in the Al/TiB_2MMC specimens as depicted in fig.3. **L.Lu et.al[45],** the composite of Al/TiB_2/B_2O_3 prepared by in situ process exhibit yield and ultimate stress increased with increase of TiB_2 in composite. When the percentage of TiB_2 in composite is 15% the yield and ultimate stress increased 53% and 44% respectively as compare to its unreinforced. **ZHU He-guo, WANG Heng-zhi et.al[46],** the composites prepared by exothermic dispersion reaction in Al-TiO_2-B_2O_3 system noticed that when the B_2O_3/TiO_2 mole ratio is below 1, the reaction products are composed of particle-like α-Al_2O_3, TiB_2 and rod-like Al_3Ti. The α-Al_2O_3 crystallites, resulting from the reaction between Al and TiO_2 or B_2O_3, are segregated at the grain boundaries due to a lower wettability with the matrix.When the B_2O_3/TiO_2 mole ratio is around 1, the Al_3Ti phase almost disappears in the composites, and the distribution of α-Al_2O_3 particulates is improved evidently. **M.D. Kulkarni, et.l[44],** examined the role of percentage volume of SiCp on the tensile properties and fracture behavior of Al 7075 Al alloys at various test temperatures. They found that as the percentage of SiC increases the yield strength, ultimate strength and young's modulus of composite increases. **Alakesh Manna & B. Bhattacharayya[33],** In this research, machinability of LM6Mg15SiC-Al-metal matrix composite was investigated during turning using a rhombic uncoated carbide tool CCGX-09-T3-04 Al-H 10 type inserts. Their finding was the cutting speed, feed and depth of cut having equal influence on the surface roughness characteristics, i.e. R*a* and R*t*. High speed, low feed rate and low depth of cut were recommended for achieving better surface finish during turning of Al/SiC−MMC using CCGX-09-T3-04-Al-H 10 type insert. The cutting speed zones between 60 m/min to 150m/min were recommended for machining of Al/SiC−MMC. The research work findings also provide useful economic machining solution by utilizing fixed rhombic tooling during processing of Al/SiC−MMC, which is otherwise usually machined by costly Polycrystalline Diamond (PCD) tools. **N. Muthukrishnan & M. Murugan & K. Prahlada Rao[31],** invested machinability of fabricated aluminum metal matrix composite (A356/SiC/10p) during continuous turning of composite rods using medium grade polycrystalline diamond (PCD 1500) inserts. The composite was prepared by stir casting. They found that higher cutting speeds result in relatively easier removal of the hard SiC particles, resulting in better surface finish. The steady low values of Ra and Rz at a cutting speed of 400 m/min over the entire tool life span makes high speed finishing of MMC possible. **Metin Kök[34],** investigated the effects of cutting speed, size and volume fraction of particle on the surface roughness in turning of 2024Al alloy composites reinforced with Al_2O_3 particles. Particle sizes of 16 and 66 μm, 7.3 and 23.3 vol.% Al2O3 particles. The plan of experiments, based on Taguchi method, was performed machining with different cutting speeds using coated carbide tools K10 and TP30. They found that the surface roughness value of the K10 tool was higher than that of the TP30 tool. The surface roughness increased with an increase in the cutting speed while it decreased with increasing the size and volume fraction of particles for both tools in all cutting conditions. The dependency of the surface roughness on the cutting speed was smaller when the particle size was smaller. **N. Muthukrishnan & M. Murugan & K. Prahlada Rao[31],** studied the machinability of Al/SiC composite containing 15%wt of SiC in turning using different grades of poly crystalline diamond (PCD) inserts. The material was provided by Defense Materials and Research Laboratory (DMRL), Hyderabad, India. The material was turned by using PCD inserts of three different grades given below:-

Specification of the cutting tool (PCD insert):-

- Insert PCD (grades 1300,1500, & 1600)
- Substrate (for PCD) Tungsten Carbide , Type CNMA 1204
- Nose Radius 0.8 mm, Shank size 25*25 mm , Product name Diapax.

In their study it was observed that the 1600 grade PCD inserts performed better surface finish and less specific power consumption closely followed by the 1500 grade. **Yahiya Altunpak & Mustafa Ay & Serdar Aslan[35]**, In this work, the influence of cutting parameters on cutting force and surface roughness in drilling of Al/20%SiC/5%Gr and l/20%SiC/10%Gr was investigated. The composite was fabricated by vortex method. The drilling tests are conducted with diamond-like carboncoated cutting tools. The results indicate that inclusion of graphite as an additional reinforcement in Al/SiCp reinforced composite reduces the cutting force. The feed rate is the main factor influencing the cutting force in both composites. The surface roughness value is proportional with the increase in feed rate while inversely proportional with cutting speed in both composites. For all cutting conditions, Al/20%SiC/10%Gr composite has lower surface roughness values than Al/20%SiC/5%Gr composite. **Ay Mustafa & Tanju[25],** In this study, an experimental investigation on surface roughness, cutting temperature and cutting forces in turning of Al7075 – T651 alloy using diamond like carbon (DLC) coated cutting tools was presented. In order to optimize the experimental results, Taguchi optimization method was employed. The optimal values of cutting parameter were as below:-

- The surface roughness values were between 0.8 to 3.6 μm.
- The optimum cutting force value was reached at f = 0.20 mm/rev, V = 150 m/min and d =1.5 mm.
- The optimum heat generation value was reached at f = 0.15 mm/rev, V =
- 150 m/min and d = 0.75 mm.

V. Anandakrishnan & A. Mahamani [36], They investigated flank wear, cutting force, and surface roughness in the machining of Al-6061–TiB_2 in situ metal matrix composites produced by flux-assisted synthesis. Their finding was higher TiB_2 reinforcement ratio produces higher tool wear, surface roughness and minimizes the cutting forces. The machinability of in situ MMC is better from traditional MMC, because of the presence of fine and uniformly distributed reinforcement, which reduces flank wear. The rate of flank wear, cutting force, and surface roughness were high when machining with a higher depth of cut. An increase in feed rate increases the flank wear, cutting force and surface roughness. The hardness of the composite also increased with increase of the ratio of TiB2 in composite. **Chen Tijun, Li Jian and Hao Yuan[28],** The Al3Ti intermetallic reinforced with pure Al, Al-13Si and Al-17Cu matrix composites were prepared by casting method. Their microstructures and dry sliding wear behaviors at room temperature and 100°C were particularly investigated. The Al-Cu matrix composite had the best wear resistance, while the pure Al matrix composite showed the worst for the same Ti content. The wear resistance for pure Al matrix composite increases with increasing Ti or Al_3Ti content. **Rajesh Kumar Bhushan & Sudhir Kumar & S. Das[30],** investigated the influence of cutting speed, depth of cut, and feed rate on surface roughness during machining of 7075 Al alloy and 10 wt.% SiC (particle size 20–40 μm) particulate metal-matrix composites. The composite was prepared by Stir casting process. The experiments were conducted on a CNC Turning Machine using tungsten carbide and polycrystalline diamond (PCD) inserts. For optimum surface roughness they recommended that turning operation on Al alloy composite by carbide insert should be carried out at cutting speed within the range of 180 to 220 m/min, feed rate within range of 0.1 to 0.3 mm/rev, and DOC within range of 0.5 to 1.5 mm. For minimum flank wear in the carbide insert, machining should be carried out at cutting speed of less than 200 m/min, feed rate of 0.1 mm/rev. and DOC 0.5 mm. Based on the results of surface roughness in the work piece and flank wear in the tool, it is recommended that turning operation on Al alloy composite by PCD insert should be carried out at cutting speed higher than 220 m/min but at a feed rate of less than 0.2 mm/rev and DOC less than 1.0 mm. **E. Uhlmann • et.al[26],** They Analysed the tool wear and residual stress of CVD diamond coated cemented carbide tools in the machining of aluminium silicon alloys. The materials were aluminium silicon alloys G-$AlSi_9Cu_4Mg$ and G-$AlSi_{17}Cu_4Mg$, with 9 and 17% silicon respectively. The turning tests were carried out on a CNC Lathe Type 180 C-U. The tools are EMT100 substrates (6% cobalt) and EMT210 (10% cobalt). They found that EMT100 substrates (6% cobalt) consistently had higher tool lifetimes than the EMT210 (10% cobalt) substrates because those coatings deposited on the tungsten carbide substrates with 10% cobalt exhibited tensile stresses, while those on substrates with 6% cobalt possessed compressive stresses. The compressive residual stresses in CVD diamond coated tools allow better film adhesion and thus longer tool lifetimes to be achieved. **Gül Tosun[27],** They analysed process parameters for surface roughness in drilling of 2124 Aluminum–SiCp composite containing 17 vol.% SiC particulate reinforced material provided by Aerospace Metal Composites Limited (UK). The experimental studies were conducted under varying spindle speed, feed rate, drill type, point angle of drill, and heat treatment. The settings of drilling parameters were determined by using Taguchi experimental design method. The experimental parameters and their values are Drill type HSS, TiN, carbide , Drill point angle (°) 90, 118, 130, Heat treatment as-received, peak age, overage, Feed rate (mm/rev) 0.08, 0.16 ,Spindle speed (rpm) 260, 1330. They found that the optimal drilling performance for the surface roughness was obtained at 0.16 mm/rev feed rate, 260 rev/min spindle speed, 130° drill point angle, carbide drill type, and as-received heat treatment settings.

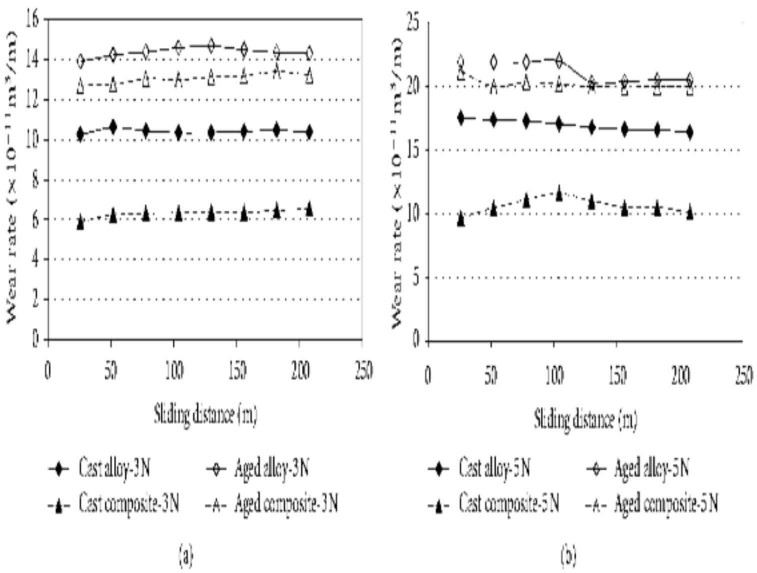

Fig 3 (a) wear rate behavior between cast and aged conditions for 7075 alloy system (a) alloy (b) composite.

IV CONCLUSION

The properties of aluminuim metal matrix composite depend upon the various parameters such as process rout, temperature, alloys elements of matrix materials, types of reinforcement materials with their shape, size, wettibility, wt and volume percentage and reaction during composite preparation. The various results show that composite materials always exhibit superior properties than the conventional material and have great potential in various fields of applications. The stir casting process for making the composite is most popular amongst the researcher but the composite made by in-situ and other process exhibits superior properties than this process. The most of the researcher used SiC and Al_2O_3 as reinforcement material

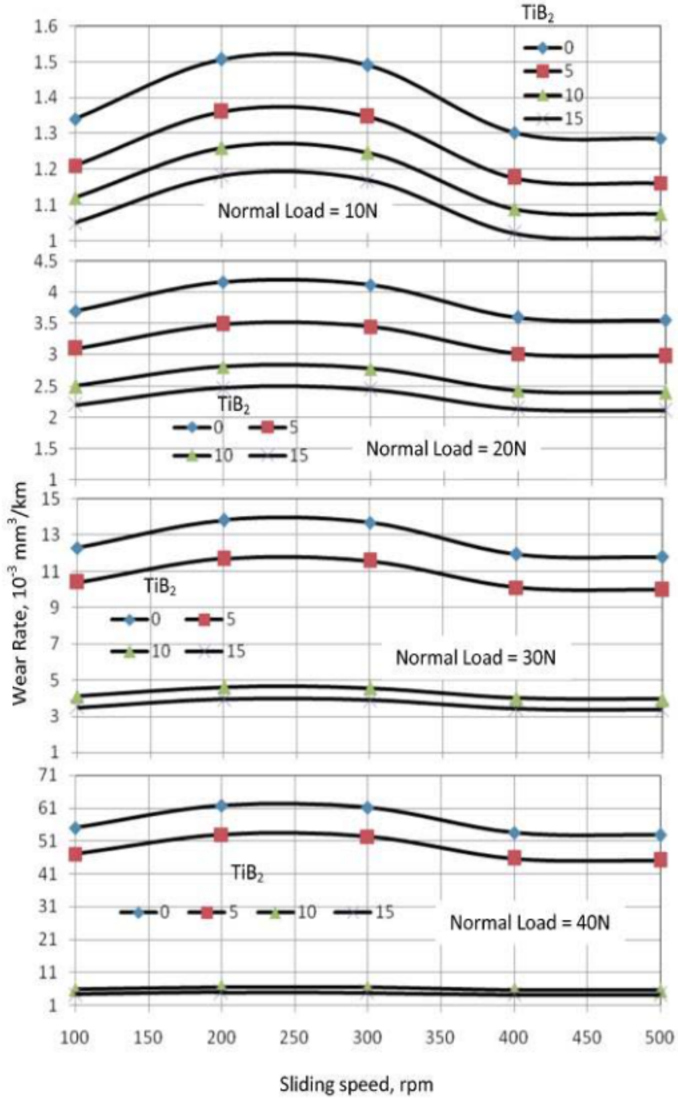

Fig 3 (b) Wear rate of Al matrix and Al/TiB_2 MMCs as the function of sliding speed for different normal load.

and result shows these materials are very reactive with aluminium and high affinity to temperature and their percentage volume in matrix material. The TiB_2 does not react with aluminium and composite exhibit superior properties than the SiC and Al_2O_3.The selection of composite required lot of attention for a particular application because cost of composite material and their manufacturing cost are very high and make the component expensive.

REFERENCES

[1] P. K. ROHATGI, S. RAY, R. ASTHANA and C. NARENDRANATH, *Mater. Sci. Eng. A* 162 (1993) 163.

[2] A. MORTENSON, in ÔÔProceedings of the Conference on Mechanical and Physical Behaviour of Metallic and Ceramic CompositesÕÕ, edited by S. I. Anderson, H. Lilhot and O. B.Pederson (Ris+ National Laboratory, Ris+, Denmark, 1981) pp. 41.

[3] O. SHIRAISHI, K. YOSHIDA K. AKAMATTU and Y.TANABE, in Proceedings of the 76th Conference of Japan Institute of Light MetalsÕÕ (Japan Institute of Light Metals,Tokyo, 1989) p. 185.

[4] K. W. MOON and D. J. LEE, *J. Korean Inst. Met. Mater*. 30 (1992) 432.

[5] A. BARDAL, *J. Mater. Sci*. 28 (1993) 2699.

[6] M. CHAKRABORTY, in Surface and Interfaces in Cast Al/SiCp MMCÕÕ, Second Annual Project Report submitted to CSIR-India, (1997) p. 12.

[7] D. J. LLYOD, H. P. LAGACE and A. D. MC LEOD, in Proceedings of the International Conference on Composite MaterialsÕÕ, ICCM-III, edited by H. Ishida (Elsevier Applied Science, London, 1980) p. 359.

[8] D. J. LLYOD and I. JIN, *Metall. ¹rans*. 19A (1988) 3107.

[9] R. WARREN and C. H. ANDERSON, *Composites* 15 (1984)101.

[10] J. C. LEE, JUNG. III LEE and Ho. In. LEE, *Scripta Mater*.35 (1996) 721.

[11] L. SALVO, G. L. ESPERANCE, M. SUERY and J . G. LEGOUX, *Mater. Sci. Eng*. A177 (1994) 173.

[12] A. MUNITZ, M. METZGER and R. MEHRABIAN, *Metall.¹rans*. 10A (1979) 1491.

[13] L. V. RAMANATHAN and P. C. R. NUNES, in Proceedings of the Conference on Control of Interfaces in Metal andCeramic CompositesÕÕ edited by R. Y. Lin and S. G. Fishman (TMS, Warrendale, PA 1994) p. 333.

[14] B. S. KANG, B. S. CHUN, C. W. WON and H. Y. SOHN,*J. Mater. Sci*. 30 (1995) 3883.

[15] K. H. BAIK, G. C. LEE and S. AHN, in Proceedings of the Conference on Light Materials for Transportation SystemÕÕ, edited by N. J. Kim (Pohang University of Science and Technology, Pohang, Korea, 1993) p. 773.

[16] K. H. BAIK, S. AHN, E. S. LEE and G. C. LEE, *J. Korean Inst. Metall. Mater*. 34 (1996) 85.

[17] R. RAJ, A. PEARCE and C. M. KENNEFICK, *Acta Metall.Mater*. 39 (1991) 3187.

[18] J. SINGH, S. K. GOEL, U. N. S. MATHUR and M. L.KAPOOR, in Proceedings of the Conference on Advances in Composite Materials, edited by P. Ramakrishnan (Oxford & IBH, New Delhi, India, 1991) p. 281.

[19] I. N. Fridlyander, V. G. Sister,1 O. E. Grushko, V. V. Berstenev, L. M. Sheveleva, and L. A. Ivanova1, "ALUMINUM ALLOYS: Promising Materials In The Automotive Industry", Metal Science and Heat Treatment Vol. 44, 2002,pp9-10.

[20] R. Deaquino-Laraa,b, I. Estrada-Guela, G. Hinojosa-Ruizc, R. Flores-Camposa,d, J.M. Herrera-Ramíreza, R. Martínez-Sáncheza, "Synthesis Of Aluminum Alloy 7075-Graphite Composites By Milling Processes Andhot Extrusion", Journal of Alloys and Compounds, 509S(2011),pp284-289.

[21] M. K. Surappa, "Aluminium Matrix Composites: Challenges And Opportunities", Sadhana Vol. 28, Parts 1 & 2, February/April 2003, pp. 319–334.

[22] G. B. Veeresh Kumar, C. S. P. Rao, N. Selvaraj,, M. S. Bhagyashekar3, " Studies On Al6061-SiC and Al7075-Al2O3 Metal Matrix Composites", Journal of Minerals & Materials Characterization & Engineering, Vol. 9, No.1, 2010, pp.43-55.

[23] T.V. Christy, N. Murugan and S. Kumar, "A Comparative Study on the Microstructures and Mechanical Properties of Al 6061 Alloy and the MMC Al 6061/TiB2/12P", Journal of Minerals & Materials Characterization & Engineering, Vol. 9, No.1, 2010, pp.57-65.

[24] A. Sreenivasan, S. Paul Vizhian, N.D. Shivakumar,M. Muniraju,M. Raguraman, " A Study Of Microstructure And Wear Behaviour Of Tib_2/Al Metal Matrix Composites", Latin

American Journal of Solids and Structures, vol.8 no.1, 2011.pp48-56.

[25] Ay Mustafa1, and Karagol Tanju, "Investigation Of The Machinability Of The Al 7075 Alloy"Using DLC Coated Cutting Tools", Scientific Research and Essays Vol. 6(1), Jan. 2011, pp. 44-51.

[26] E. Uhlmann , W. Reimers , F. Byrne ,M. Klaus, "Analysis Of Tool Wear And Residual Stress Of CVD Diamond Coated Cemented Carbide Tools In The Machining Of Aluminium Silicon Alloys", Prod. Eng. Res. Devel. 2010,Vol 4,pp203–209.

[27] Gül Tosun,, "Statistical analysis of process parameters in drilling of AL/SICP metal matrix composite", Int J Adv Manuf Technol ,Vol.55, 2011,pp477–485.

[28] Chen Tijun, Li Jian and Hao Yuan, "Casting Fabrication Of In Situ Al3Ti-Al Composites And Their Wear Behaviors", Research & Development, Vol.6,Nov.2009,pp319-327.

[29] N. Muthukrishnan & M. Murugan & K. Prahlada Rao, "An Investigation On The Machinability Of Al-Sic Metal Matrix Composites Using Pcd Inserts", Int J Adv Manuf Technol ,Vol.38,2008,pp447–454.

[30] Rajesh Kumar Bhushan & Sudhir Kumar & S. Das, "Effect Of Machining Parameters On Surface Roughness And Tool Wear For 7075 Al Alloy Sic Composite", Int J Adv Manuf Technol,Vol.50,2010,pp459–469.

[31] N. Muthukrishnan & M. Murugan & K. Prahlada Rao," Machinability Issues In Turning Of Al-Sic (10p) Metal Matrix Composites", Int J Adv Manuf Technol ,Vol.39, 2008, pp211–218.

[32] G. G.Sozhamannan & S. Balasivanandha Prabu, "Evaluation Of Interface Bonding Strength Of Aluminum/Silicon Carbide",Int J Adv Manuf Technol,Vol.44,2009, pp385–388.

[33] Alakesh Manna,B. Bhattacharayya, "Influence Of Machining Parameters On The Machinabilityof Particulate Reinforced Al/Sic–MMC", Int J Adv Manuf Technol, Vol.25,2005,pp 850–856.

[34] Metin Kök, "Modelling The Effect Of Surface Roughness Factors", Int J Adv Manuf Technol,Vol.55,2011,pp911–920.

[35] Yahya Altunpak & Mustafa Ay & Serdar Aslan, "Drilling Of A Hybrid Al/Sic/Gr Metal", Int J Adv Manuf Technol, Sept.2011,Vol.10,pp1-5.

[36] V. Anandakrishnan & A. Mahamani, "Investigations Of Flank Wear, Cutting Force, And Surface Roughness In The Machining Of Al-6061–Tib2 In Situ Metal Matrix Composites Produced By Flux-Assisted Synthesis", Int J Adv Manuf Technol,Vol.55,2011,pp65–73.

[37] M.D. Kulkarni, P.S. Robi,R.C. Prasad, P.Ramakrishnan, "Deformation and Fracture Behavior of Cast and extruded 7075Al-SiCp Composites at Room and Elevated Temperatures", Materials Transactions, JIM, Vol37, No.3, 1996,pp.223-229.

[38] Do-Suck Han, H.Jones, H.V. Atkinson ,"The Wettability of Silicon Carbide by Liquid Aluminium: The Effect of Free Silicon in the Carbide and of Magnesium, Silicon and Copper Alloy Additions to the Aluminum", Journal of Materials Science, 1993, pp.2654-2658.

[39] V.Laurent,C.Rado, N. Eustathopoulos "Wetting Kinetics and Bonding of Al and Al Alloys on α - SiC",Materials Science and engineering, A205, 1996,pp.1-8.

[40] S.-Y. OH,J.A.Cornie, K.C. Russell, "Wetting of Ceramic Particulates with Liquid Aluminum Alloys",Metallurgical Transactions A, vol 20A, March 1989,pp. 527-541.

[41] M.Kobashi, T.Choh ,"The Wettability and the Reaction for SiC particle/Al Alloy System", Journal of Materials Science, 1993, pp. 684-690.

[42] T.Choh, T.Oki,"Wettability of SiC to aluminum and aluminum alloys",Materials Science and Technology, 1987, vol 3 pp 378-385.

[43] David L.McDanels,"Analysis of stress-strain, fracture and ductility behavior of Aluminum matrix composites containing discontinuous silicon carbide reinforcement" A Metallurgical and Materials Transactions, 1985, vol. 16A, pp1105-1115.

[44] M.D. Kulkarni", P.S. Robi,R.C. Prasad, Ramakrishnan "Deformation and Fracture Behavior of Cast and extruded 7075Al-SiCp Composites at Room and Elevated Temperatures",Materials Transactions, JIM, Vol37, No.3, 1996,pp.223-229.

[45] Lu L, Lai M.O, Su Y, Teo H.L & Feng C.F "In sit iB2 reinforced Al alloy composites.", Ssripta Materialia,*Vol.45,*2001,pp1017-1023.

[46] ZHU He-guo, WANG Heng-zhi, GE Liang-qi,CHEN Shi, WU Shen-qing, " Formation of composites fabricated by exothermic dispersion reaction in Al-TiO2-B2O3 system." Trans. Nonferrous Met. Soc. China vol.17,2007,pp590-594.

[47] www.metalsupplieronline.com