"UGC" Approved Journal
Journal No.: 43862

INTERNATIONAL RESEARCH JOURNAL OF INDIA

ISSN 2454-8707 / IMPACT FACTOR 2.05 / VOLUME - II, ISSUE –X, JUNE 2017

COMPARATIVE ANALYSIS OF CHANGE IN MECHANICAL PROPERTIES OF ALUMINIUM ALLOY AFTER REINFORCEMENT WITH TWO DIFFERENT METAL OXIDES.

Baveet Kumar Thakur[1], Amit Sharma[2], Sandeep Salaria[3]

*Arni School of Technology, Arni University, Kathgarh, Indora, (H.P.)

E-mail: baveet2017@gmail.com

ABSTRACT:

Present work is oriented around analysis of stir casting process for production of Metal Matrix composites (MMC). Aluminium alloy Al 356 was selected for study, with two reinforcements (Aluminium oxide and magnesium oxide). With reinforcement of Al_2O and MgO in matrix of alloy the properties of Al356 alloy can be greatly improved. Two samples each with 10% and 20% reinforcement were prepared for both Al_2O & MgO as reinforcement. Comparative analysis reflects that Alumina is better participant for production of aluminium based MMC with high value of mechanical properties/parameters. Also one can choose reinforcement with desired mechanical properties.

KEYWORDS:

Al 356 alloy, stir casting, metal oxides, alumina, magnesium oxide, Metal matrix Composite (MMC), Aluminium Matrix Composite (AMC)

INTRODUCTION:

Composite materials are well known in manufacturing industry for thier high strength and stiffness, wear resistance, thermal and mechanical fatigue and creep resistance. A large scale of composites have been invented & fabricated to utilise them in various applications. [1-15] In MMC, matrix of metal or alloy & some reinforcement material is used to obtain composite. Matrix is the base material for production of composite. Aluminium and its alloys are most commanly used in the production of metal matrix composites. Different aluminium based composites have been reported by researchers. Reinforcement of aluminium alloy with hard and soft reinforcements agent such as SiC, Alumina, MgO, graphite, Si-rice husk, Frreocrome slag and many more is continue in research industry and in production in many cases. Wide use and demand of various applications composites in industry put many researchers in finding a cost effective production methods for these composites. [1-2, 16-20]

There are different methods for fabrication of composites, depending upon type of material involved and also on type of composite to be produced. Casting is commonly used method in production of MMC. Powder metallurgy is other widely used method for production of MMC. One of the obstacles in wide use of MMC in various applications is its plastic counterparts. [21-29] But MMCs are preferred in many cases due to High strength; fracture toughness and stiffness are offered

INTERNATIONAL RESEARCH JOURNAL OF INDIA
ISSN 2454-8707 / IMPACT FACTOR 2.05 / VOLUME - II, ISSUE –X, JUNE 2017

by metal matrices than those offered by their polymer counterparts. [3-5].

Commonly used matrix metals that offers good matrix for fabrication of MMCs are Titanium, Aluminium and magnesium. Modulus of reinforcements is a important parameter which decides the properties of MMC. [30-35] High modulus of reinforcement results in high strength. Operating temperature of composite is decided by frequency of its properties.[6-9] [35-39]

In this paper we have investigated comparison of properties of aluminium alloy Al 356 and its composite using alumina and magnesium oxide as reinforcement. Stir casting method was used in fabrication. Mechanical & micro structural study has been performed.

2. Materials & Methods:

2.1 Materials:

Al 356 aluminium alloy which acts as matrix was used in pure form. The detail of properties and composition of aluminium alloy Al 356 are listed below:

a) Chemical Composition

S.NO.	ELEMENT	Wt%
1	Cu	0.20
2	Mg	0.25 to 0.45
3	Mn	0.10
4	Si	6.5 to 7.5
5	Fe	0.20
6	Zn	0.10
7	Ti	0.20
8	Al	Balance*

(*Reference to the 'balance' of a composition does not guarantee this is exclusively of the element mentioned but that it predominates and others are present only in minimal quantities.)

Table 1: Chemical composition of Al 356 alloy

b) Mechanical Properties

Property	**Tensile strength (MPa)**	**Hardness (BHN)**	**Toughness (joule)**	**Fatigue strength (1×10^7 MPa)**	**Endurance Limit**	**Modulus of Elasticity**	**Shear strength**
Value for Al 356	230	75	6	120	56	71	120

Table 2: Mechanical properties Al 356 alloy

Journal No.: 43862

INTERNATIONAL RESEARCH JOURNAL OF INDIA

ISSN 2454-8707 / IMPACT FACTOR 2.05 / VOLUME - II, ISSUE –X, JUNE 2017

c) Thermal Properties

Property	Latent heat of fusion	Specific heat	Liquidus temperature	Solidus temperature
Value for Al 356	389kJ/kg	963 J/kg	615ºC	555ºC

Table 3 : Thermal properties Al 356 alloy

2.2 Methods:

a) Stir Casting-

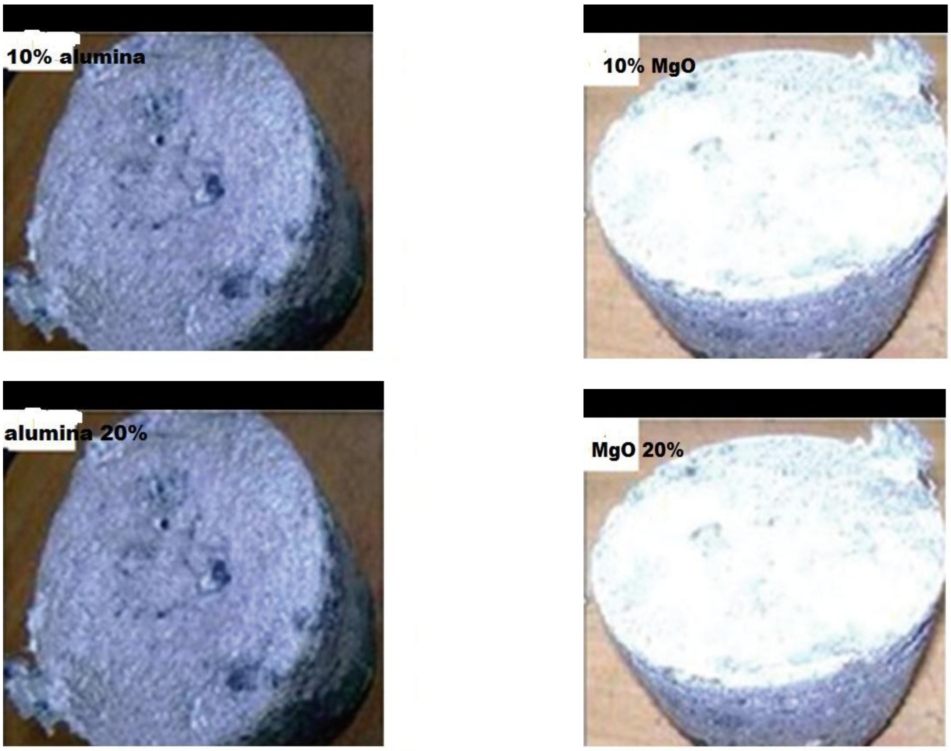
Stir casting method was used to prepare MMC. Amount of aluminium (Al 356) alloy and reinforcement (alumina (Al_2O_3) and Mgo particles) in desired quantity to produce composites having 10 and 20 volume percent of reinforcement were evaluated using charge calculations. Reinforcement material (alumina/MgO) was first preheated at a temperature of 300^0C for 5minutes to improve wettability with matrix forming alloy. The Furnace temperature was set to about maximum 700-750^{o}C in order to minimize the chemical reaction between the substances. Melting of Al 356 ingots were performed at a temperature of 750^{o}c and the liquid alloy was then allowed to cool in the furnace to a semi solid state at a temperature of about 600^0C. Reinforcement particles (pre-heated) were added to the molten alloy and stirring performed speed of 650 rpm for 10 minutes to reach mushy state. The composite slurry was then superheated to 720^0C and a second stirring performed to ensure uniform distribution of reinforcement particles using a mechanical stirrer was done. Four samples (two for alumina & two for MgO) of composite with 10 and 20 percent reinforcement were cast into prepared sand moulds. Similar sample of Al 356 without reinforcement was also prepared for comparison.

b) *Hardness Measurement [37-39]*

For hardness testing samples were prepared as per specification required for Brinell hardness Test (i.e. 10mm × 10mm × 25 mm). Samples were prepared first for testing by applying grinding and polishing. As the hardness of sample will not be uniform throughout, due to factors such as cooling rate, gravity effect, and non uniform distribution of the particles in the ingot will give different values of hardness from top to bottom. To resolve these three tests for each sample at different points on sample were performed and the average of three was taken as hardness of the sample. The value of hardness on Brinell scale for samples with alumina and MgO reinforcement is given in table 4.

INTERNATIONAL RESEARCH JOURNAL OF INDIA
ISSN 2454-8707 / IMPACT FACTOR 2.05 / VOLUME - II, ISSUE –X, JUNE 2017

Figure 1: Al 356/Alumina & Al 356/MgO Metal matrix composite samples.



c) *Toughness Analysis [37-39]*

Toughness of MMC was carried out on Charpy Impact Testing Machine. Samples with square cross-section of size (10 × 10 × 55) with single V-notches were prepared. Value of toughness of samples with alumina and MgO reinforcement is given in table 5.

d) *Tensile Testing*

Tension strength tests were performed on samples machined from the Al 356 alloy and the composites with dimensions of 6 mm diameter and 36 mm gauge length.

e) *Microstructure*

Metallurgical Microscope integrated with software operation was used for microstructure examination. As per requirement samples were cut in desired size and prepared for testing using Diamond polishing machine. A series of emery papers of grit sizes ranging from 400µm – 1500µm were used to prepare sample surface for examination.

"UGC" Approved Journal Journal No.: 43862

INTERNATIONAL RESEARCH JOURNAL OF INDIA

ISSN 2454-8707 / IMPACT FACTOR 2.05 / VOLUME - II, ISSUE –X, JUNE 2017

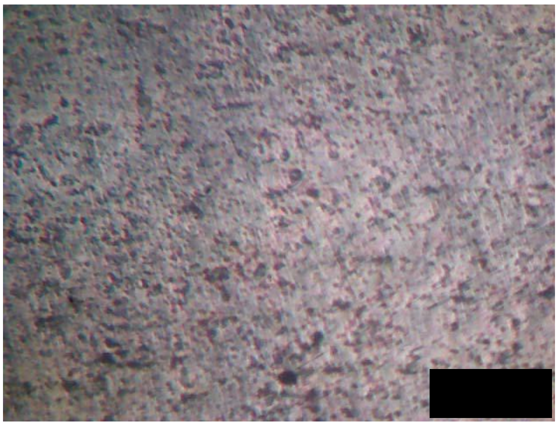


Figure 2: Micrograph of Al 356 alloy without reinforcement

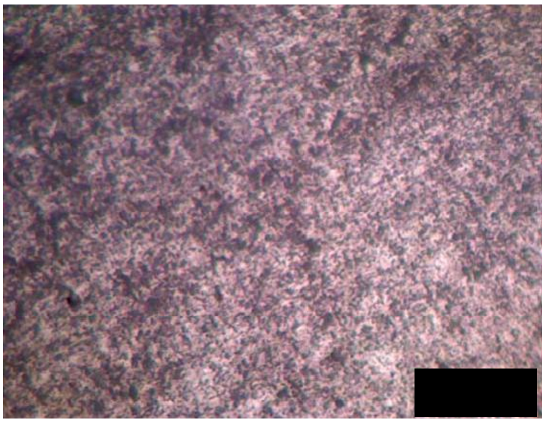


Figure 3: Micrograph of MMC (Al 356 alloy with 10 % alumina reinforcement)

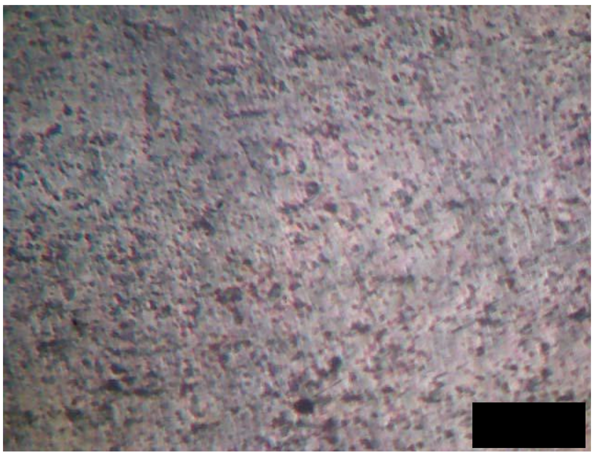


Figure 4: Micrograph of MMC (Al 356 alloy with 10 % MgO reinforcement)

INTERNATIONAL RESEARCH JOURNAL OF INDIA
ISSN 2454-8707 / IMPACT FACTOR 2.05 / VOLUME - II, ISSUE –X, JUNE 2017

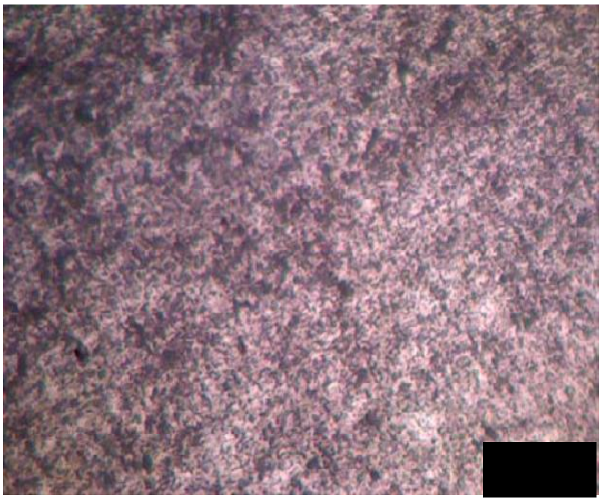


Figure 5: Micrograph of MMC (Al 356 alloy with 20 % alumina reinforcement)

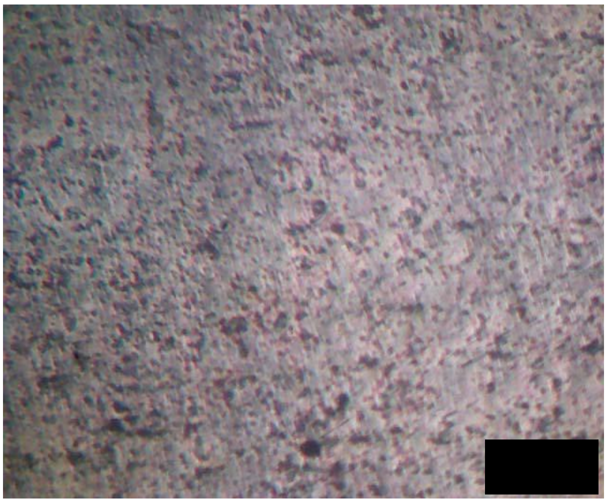


Figure 6: Micrograph of MMC (Al 356 alloy with 20 % MgO reinforcement)

Paste of Alumina powder was applied on sample to attain fine polishing, with valvet cloth replacing emery paper on polishing machine. Etching was done using Nital (solution of Methanol & Nitric acid) solution to explore surface of sample.

3 Results and Discussion:

31 Microstructure Examination:

Figure 2-6 shows micrographs of samples of Al_2O_3 and MgO reinforced Al356 composites with 10 & 20 percent reinforcement. From microstructure examination it is clear that there is full dispersion of particulates as desired in both cases (alumina & MgO). Samples were observed under microscope at different magnifications (up to 1000) in order to select best one. Microstructure examination confirms good efficiency of production procedure.

INTERNATIONAL RESEARCH JOURNAL OF INDIA
ISSN 2454-8707 / IMPACT FACTOR 2.05 / VOLUME - II, ISSUE –X, JUNE 2017

3.2 Hardness measurements:

With Load applied 100 Kgf, Diameter of ball 2.5mm, testing time 30 seconds [37-39], we have obtained an increase in hardness with increasing percentage of reinforcement. In case of alumina increase in hardness is more as compared to MgO reinforced MMC. This reflects more efficiency of alumina for production of MMC with high value of harness. Also alumina is known for high hardness of particles, which let it to be used as abrasive. So with increasing percentage of reinforcement, alumina contributes more towards increasing hardness of MMC.

S.No.	Reinforcement/ wt%	Hardness (BHN)
1	Without reinforcement	75.33
2	Alumina 10%,	94.5
3	MgO 10%,	92
4	Alumina 20 %	114.5
5	MgO 20%	111.5

Table 4: Hardness testing results of Al 356-Alumina/MgO MMC.

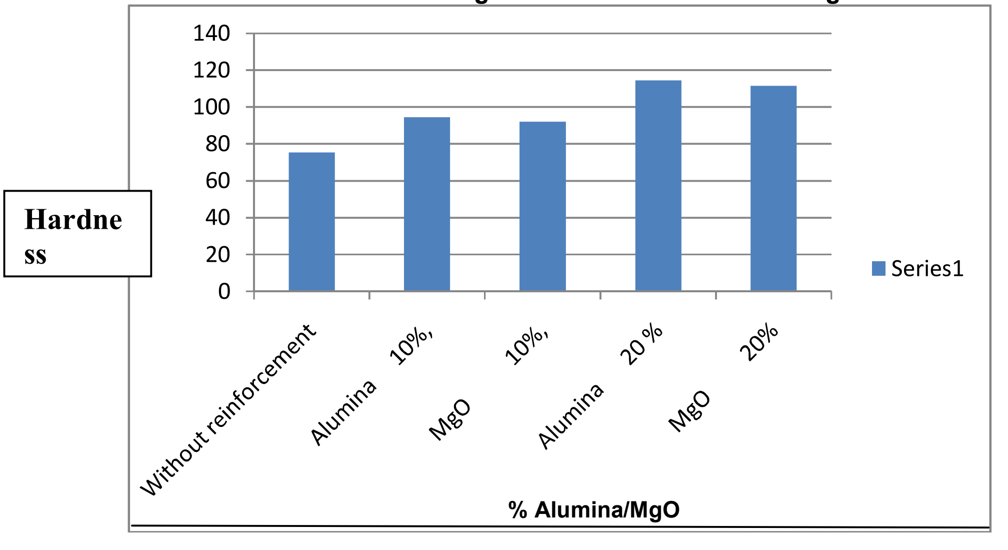


Figure 7: Hardness Vs percentage reinforcement

3.3 Toughness measurement:

S.No.	Reinforcement/ wt%	Toughness (Joule)
1	Without reinforcement	6.16
2	Alumina 10%,	11.16
3	MgO 10%,	10.20
4	Alumina 20 %	14.10
5	MgO 20%	11.80

Table 5: Toughness testing results of Al 356-Alumina/MgO MMC

Increase in toughness with increasing percentage of reinforcement observed in both cases Again as in case of hardness measurement, alumina shows high values of toughness with increasing

INTERNATIONAL RESEARCH JOURNAL OF INDIA
ISSN 2454-8707 / IMPACT FACTOR 2.05 / VOLUME - II, ISSUE –X, JUNE 2017

percentage as compared to MgO. Increase in toughness i.e. energy absorbed with increasing percentage of reinforcement is due to fact that alumina particles acts as brittle material so requires more energy for plastic deformation. In case of MgO same behavior observed, but to less extent.

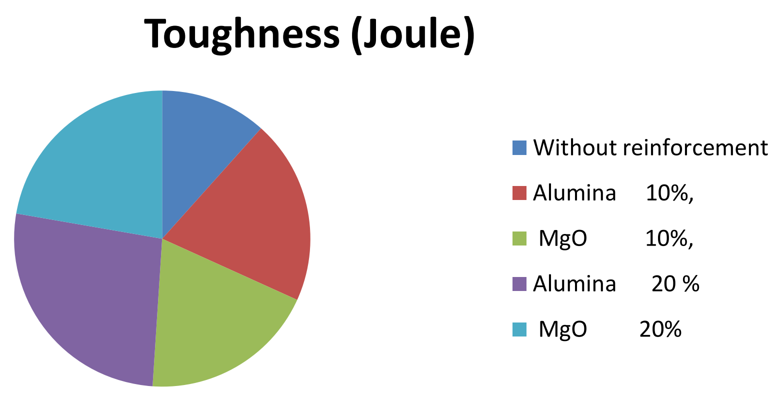


Figure 8: Toughness Vs percentage reinforcement

3.4 Tensile Testing

S.No.	Reinforcement (wt%)	Tensile strength (MPa)
1	Without reinforcement	232.23
2	Alumina 10%,	284.96
3	MgO 10%,	281.4
4	Alumina 20 %	318.22
5	MgO 20%	316.5

Table 6: Tensile strength testing results of Al 356-Alumina/MgO MMC

It is observed that tensile strength increases with increasing percentage of alumina/MgO reinforcement. Here alumina contributes more towards tensile strength with increasing percentage in MMC. Difference in tensile strength for alumina & MgO is shows same pattern as for difference in data of hardness & toughness [36-39].

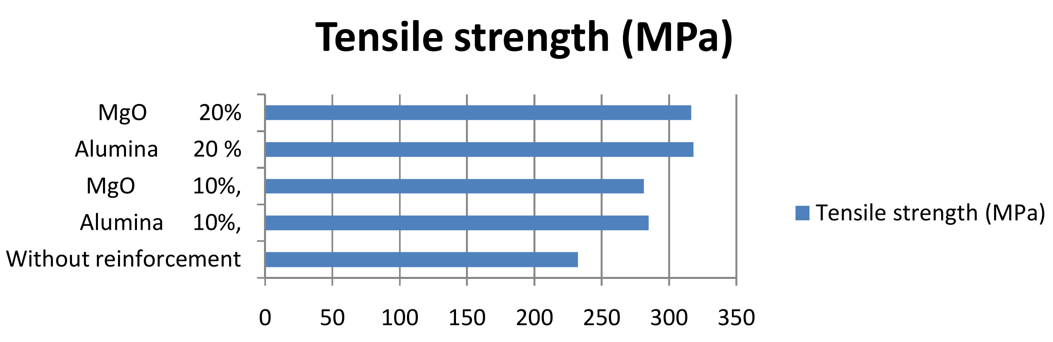


Figure 9: Tensile strength Vs percentage reinforcement

INTERNATIONAL RESEARCH JOURNAL OF INDIA
ISSN 2454-8707 / IMPACT FACTOR 2.05 / VOLUME - II, ISSUE –X, JUNE 2017

From stress-strain behavior for all samples with and without reinforcement we observed that sample without reinforcement shows largest plastic strain and also show least resistance to plastic deformation due to relatively lower flow stress in comparison with the MMC.

CONCLUSIONS:

From overall study and results of characterization we concluded that, addition of reinforcement particles in Al 356 alloy results in composite that have hardness greater than Al 356 alloy. Hardness of MMC increases more with increase in percentage in case of alumina as compared to MgO reinforcement. So one can easily choose reinforcement for production of MMC with desired hardness range. With increasing percentage of alumina amount of energy absorbed by MMC material increases more as compared to MgO case. Study of tensile strength behavior confirms that alumina reinforcement increases strength of Al 356 alloy. Again alumina shows high effect on this mechanical property. Microstructure study confirms formation of reinforcement particulate in MMC. This show feasibility of production technique. Overall we conclude that alumina is better participant for production of aluminium based MMC with high value of mechanical properties/parameters. Also one can choose reinforcement with desired mechanical properties.

Acknowledgement: After all mighty God, I want to thanks Mr Amit Sharma (Assistant Professor), Mr Sandeep Salaria(Assistant Professor) and all other staff members of department of mechanical engineering, workshop staff, Arni University for their help during my thesis work.

INTERNATIONAL RESEARCH JOURNAL OF INDIA
ISSN 2454-8707 / IMPACT FACTOR 2.05 / VOLUME - II, ISSUE –X, JUNE 2017

REFERENCES:

[1] Fitzer E and Heine M, 1988, in Fibre Reinforcements for Composite Materials, *Composite Materials Series,* volume 2, (editor AR Bunsell), (Elsevier, Amsterdam), 73-148.

[2] Adamson, M. J. (1980). "Thermal Expansion and Swelling of Cured Epoxy Resin used in Graphite/Epoxy Composite Materials," *Journal of Material Science, 15, 1736-1745.*

[3] Atzori B, Quaresimin M and Trattenero G, 1994, in Proc *2nd International Seminar Experimental Techniques and Design in Composite Materials* (editor MS Found) Sheffield, Sept 1994, (Sheffield Academic Press, Sheffield, UK), 193-211.

[4] L. T. Drzal, 'The Effect of Polymeric Matrix Mechanical Properties on the Fiber-Matrix Interfacial Shear Strength', *Materials Science and Engineering*, A126, 1990, pp. 289-293.

[5] Comparison of Microstructure and Mechanical Properties of A356/SiC Metal Matrix Composites Produced by Two Different Melting Routes Hindawi Publishing Corporation *"International Journal of Manufacturing Engineering"* Volume 2014, Article ID 747865, 13 pages. doi.org/10.1155/2014/747865.

[6] T. A. Khalifa and T. S. Mahmoud, *Elevated Temperature Mechanical Properties of Al alloy AA6063/SiCp MMCs*, Proceedings of the World Congress on Engineering 2009 Vol II WCE 2009, July 1 – 3, London, U.K, ISBN: 978 -988 -18210-1-0.

[7] D. Hull, *An Introduction to Composite Materials*, Cambridge University Press, Cambridge, UK (1981).

[8] Sheng C. H. and Springer G. S., "Moisture Absorption and Desorption of Composite Materials", *Journal of Composite Materials,* Vol. 10, 1976, pp.2-20.

[9] Madhukar, M. S and Drzal, L. T, *Journal of Composite Materials,*1991, 25, 932.

[10] Madhukar, M. S and Drzal, L. T, *Journal of Composite Materials,*1991, 25, 958.

[11] Madhukar, M. S and Drzal, L. T, *Journal of Composite Materials,*1992, 26**,** 936.

[12] H. Li, A. C. Rosario, S. V. Davis, T. Glass, T. V. Holland, R. M. Davis, J. J. Lesko, J. S. Riffle, and J. Florio, *J. Advanced Materials*, July, p. 55 (1997).

[13] Janssens, W., Doxsee, L. E., Jr. and Verpoest, I., "*Influence of the fiber-matrix interface on the moisture absorption Characteristics of Aramid-Epoxy Composites*", SAMPE, 1989.

[14] H. L. Cox, *British Journal of Applied Physics*, Vol.3, 1952.

[15] S. Subramanian, "Effect of Fiber/Matrix Interphase on the Long Term Behavior of Cross-Ply Laminates," *Dissertation, Department of Engineering Science and Mechanics, Virginia Polytechnic Institute & State University*, January, 1994.

[16] Liu, X. H., Moran, P. M., and Shih, C. F., "*The Mechanics of Compressive Kinking in Uni-directional Fiber Reinforced Ductile Matrix Composites*," *Composites Part B,* Vol. 27B, 1996, pp. 553-560.

[17] Drzal, L. T., Rich, M. J., and Lloyd, P. F., "Adhesion of Graphite Fibers toEpoxy

INTERNATIONAL RESEARCH JOURNAL OF INDIA

ISSN 2454-8707 / IMPACT FACTOR 2.05 / VOLUME - II, ISSUE –X, JUNE 2017

Matrices:1. *The Role of Fiber Surface Treatment*," J. Adh., Vol. 16, 30 (1982).

[18] Ghorbel, I., and Valentin, V. (1993). "Hydrothermal Effects on the Physio-Chemical Properties of Pure and Glass Reinforced Polyester and Vinylester Resins," *Polymer Composites, August,* Vol.14, No.4, 324-334.

[19] Rosen, B. W., "Mechanics of Composite Strengthening in Fiber Composite Materials," *American Society of Metals Seminar, 1965, PP. 37-75.*

[20] J. J. Lesko, R. E. Swain, J. M. Cartwright, J. W. Chen, K. L. Reifsnider, D. A. Dillard, and J. P. Wightman, "Interphases Developed from Fiber Sizings and Their Chemical- Structural Relationship to Composite Performance", *Journal of Adhesion*, Vol. 45, 43, (1994).

[21] T. S. Grant and W. L. Bradely, "In situ Observations in SEM of Degradation of Graphite/Epoxy Composite Materials Due to Seawater Immersion," *Journal of Composite Materials,* 1995, Vol. 29, No. 7, pp. 852-867.

[22] S. Wilson and A.T. Alpas, "Effect of Temperature on the Sliding Wear Performance of Aluminium Alloys and Aluminium Matrix Composites", *Wear*, 196 (1996) 270-278.

[23] Zuhailawati, H.; Samayamutthirian, P. and Mohd Haizu, C. H. (2007). Fabrication of Low Cost Aluminium Matrix Composite Reinforced With Silica Sand, "*Journal of Physical Sciences"* 18(1), 47-55.

[24] Froyen, L. and Verlinden, B. (July, 2013). Aluminium Matrix Composites Materials "*Training in Aluminium Application Technologies* (TALAT)" European Aluminium Association, Belgium.

[25] K K Alaneme, M.O. Bodunrin, Mechanical behaviour of alumina reinforced AA 6063 Metal matrix composite developed by two step-stir casting process. *"Bulletin of engineering, Tome VI (Year 2013)"*, FASCICULE, ISSN-2067-3809.

[26] Ghorbel, I., and Valentin, V. (1993). "Hydrothermal Effects on the Physio-Chemical Properties of Pure and Glass Reinforced Polyester and Vinylester Resins," *Polymer Composites, August,* Vol.14, No.4, 324-334.

[27] N. Altinkok, I. Ozsert and F. Findik, "Dry Sliding Behaviour of Al_2O_3/SiC Particle Reinforced *Aluminium Based MMCs Fabricated by Stir Casting Method", 124 (2013) 11-19*

[28] Sudarshan and M.K. Surappa, "Synthesis of Fly ash Particle Reinforced A356 Al Composites and their Characterization", *Mater. Sci. & Engg.,*480 (2008) 117-124.

[29] S. Natarajan., R. Narayanasamy., S.P. Kumaresh Babu., G. Dinesh., B. Anil Kumar., K. Sivaprasad., "Sliding Wear Behavior of Al 6063/TiB_2 in Situ Composites at Elevated Temperatures, *Mater. & Dsg.,*30 (2009) 2521-2531.

[30] S. Kumar, "Effect of Reinforcement Size, and Volume Fraction on the Abrasive Wear of AA7075 Al/SiCp P/M composites-A Statistical Analysis", Tribol. Inter., 43 (2010) 414-422.

[31] H.N. Reddappa, K.R. Suresh, H.B. Niranjan and K.G. Satyanarayana, "Dry Sliding Friction and Wear Behaviour of Aluminium/Beryl Composite", *Inter. J. App. Engg. Rsch*., 2 (2011) 502-511.

INTERNATIONAL RESEARCH JOURNAL OF INDIA
ISSN 2454-8707 / IMPACT FACTOR 2.05 / VOLUME - II, ISSUE –X, JUNE 2017

[32] Lakhvir Singh, Baljinder Ram and Amandeep Singh, "Optimization of Process Parameter for Stir Casted Aluminium Metal Matrix Composite using Taguchi Method", *Inter. J. Rsch.in Engg.& Techno.,*2 (2013) 378-382.

[33]. Balasivanandha Prabu. Karunamoorthy. S. L., "Influence of Stirring Time on Distribution of Particles in Cast Metal matrix Composite", *J. Mater.Process. Techno.,* 171 (2008) 208-273.

[34] Bijay Kumar Show, Dipak Kumar Mondal, Joydeep Maity,'' Dry Sliding Wear Behavior of Aluminum-Based Metal Matrix Composites with Single (Al_2O_3) and Hybrid (Al_2O_3 + SiC)'', Metallogr. Microstruct. Anal. 3 (2014) 11-29.

[35] S.K. Chaudhury, C.S. Sivaramakrishnan and S.C. Panigrahi, "A new spray forming technique for the preparation of aluminium rutile (TiO2), ex situ particle composite", *J. Mater. Proces.Technol.,* 145 (2004) 385-390.

[36] Barekar, N.; Tzamtzis, S., Dhindaw, B. K.; Patel, J.; Hari Babu, N. and Fan Z. (2009). Processing of Aluminium-Graphite Particulate Metal Matrix Composites by Advanced Shear Technology. *"Journal of Materials Engineering and Performance"* 1-11. DOI: 10.1007/s11665-009-9362-5.

[37] Martín, M.A. Martínez, J. Llorca ,"Wear of SiC-reinforced Al-matrix composites in the temperature range 20–200°C", 193 (1996) 169–179.

[38] Microstructural and Mechanical behaviour of Aluminium Matrix Composites reinforced with coated SiC particles fabricated by Stir Casting. "*Applied Mechanics and Materials"* Vols. 766-767 (2015) pp 301-307, doi:10.4028/www.scientific.net/AMM.766-767.301.

[39] G. Gray, and G. M. Savage, "Advanced Thermoplastic Composite Materials," *Metals and Materials,* Vol. 5, 513, (September 1989).