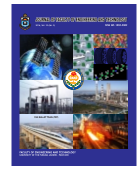
JFET 23(2) (2016) 01-07

Journal of Faculty of Engineering & Technology

journal homepage: www.pu.edu.pk/journals/index.php/jfet/index



THE EFFECT OF GLASS FIBER AND SILICA SAND NANOPARTICLES ADDITION ON ALUMINUM BASED HYBRID COMPOSITES

M.T.Z. Butt[1], T. Ahmad[1]*, M. Kamran[1], M.U. Manzoor[1]

Department of Metallurgy and Materials Engineering, CEET
University of the Punjab, Lahore, Pakistan

Abstract

Metal matrix composites are a unique class of weight efficient structural materials that are encouraging every field of engineering applications especially aerospace and automobile industries. The present study focused on the development of the silica sand nanoparticles-glass fiber reinforced aluminium based hybrid composites. Composites were developed by compocasting method using 1.5, 2.5, 3.5 and 4.5 wt. % of silica sand nanoparticles and glass fibers. Variation in tensile properties was evaluated using universal testing machine and the hardness profiles were measured using Micro Hardness Tester (HMV). A significant improvement in tensile strength and micro hardness was observed. However a decrease in impact strength was observed with increase in reinforcement. The homogenous dispersion of silica sand nanoparticles and pulling of glass fibers from the aluminium matrix was verified using Scanning Electron Microscope (SEM).

Keywords: Thal Silica Sand Nanoparticles, Glass Fiber, Aluminium Based Hybrid Composites, Mechanical Properties and Microstructure

1. Introduction

Hybrid composite has more than one reinforcements (usually two) consist of at least three components in it. Commonly one of these reinforcements is inorganic and the other one is organic in nature. They differ from traditional composites where the constituents are at the macroscopic (micrometer to millimeter) level. Mixing at the microscopic scale leads to a more homogeneous material that either shows characteristics in between the two original phases or even new properties [1]. Silica sand characteristics, based on the degree of impurity and geology of the location from where it is mined, it is usually white but frequently coloured due to impurities such as iron and could be in any colour like reddish brown silica sand [2]. It may also be characteristically transparent, semi-transparent or even translucent, then being one of the reasons to be used in glassmaking, and having a vitreous lustre. Quartz is a hard mineral owing to the strength of the bonds between the atoms and capable of scratching glass. It is also relatively inert and does not react with dilute acid. These are prized qualities in various industrial uses. Depending on how the silica deposit is formed, quartz grains may be sharp and angular, sub-angular, sub-rounded or rounded [3]. Prabhakar *et al*. [4] studied the mechanical properties of E-glass fibers and fly ash reinforced Al 7075 hybrid metal matrix composites, and proved that they have improved tensile strength and compression strength when compared to Al 7075 alloy alone. It was observed that with

* Corresponding Author: tahirengg4051@yahoo.com

the 8wt. % flay ash and 3wt. % of E-glass fibers, tensile strength became 1897.89N/mm^2. Arun *et al*. [5] studied the mechanical properties of aluminium 6061 alloy reinforced with flay ash and E-glass fibers (hybrid composite). In this study it was observed that the strength and hardness increased as compared to the Al 6061 alloy. It was also observed that with 8wt. % fly ash and 4wt. % E-glass fibers, tensile strength became 155 MPa and hardness became 105 VHN. Ramesh *et al*. [6] had fabricated frit-Al6061 alloy composites having 2 wt%, 4 wt%, 6 wt%, 8 wt% and10 wt% of frit particles using liquid metallurgy (stir cast) method. The casted composites were T6 heat treated and also machined as per test standards. An increment in wt.% addition of frit particles caused significant improvement in tensile properties, compressive strength and hardness are noticeable as the wt % of the frit particles increases.

In literature a gap about the development of silica sand nanoparticles-glass fiber aluminium based composites was observed. Therefore, this study focused to develop and characterize silica sand nanoparticles-glass fiber aluminium based hybrid composites.

2. Materials and Methods

The silica sand used in this research was taken from Thal desert Punjab Province of Pakistan. Thal silica sand was beneficiated as discussed by Tahir *et al.* [7] and the chemical composition of Thal-Silica sand nanoparticles is given in Table 1.

Table 1. Chemical Composition of Thal Silica Sand Nanoparticles

Compound	SiO_2	Al_2O_3	K_2O	CaO	TiO_2	Cr_2O_3	Fe_2O_3	MnO
Wt.%	95.52	1.71	0.52	1.30	0.44	0.23	0.56	0.11

E-glass fibers were selected for the reinforcement in aluminium matrix along with silica nanoparticles for the production of hybrid composites. Glass fibers are available in continuous sheets form in the markets. Sheet of boron free glass were cut down in small chunks of length of one inch and used in different weight percentages like 1.5wt.%, 2.5wt.%, 3.5wt.% and 4.5wt,% as a reinforcement along with same wt.% ratio of silica nanoparticles in aluminium matrix for the production of hybrid composite as shown in Table 2.

Table 2. Composition of Aluminium based hybrid Composites

Composites	Reinforcement content (wt.%)	
	Silica Sand Nanoparticles	Glass Fiber
1.5 SG	1.5	1.5
2.5 SG	2.5	2.5
3.5 SG	3.5	3.5
4.5 SG	4.5	4.5

Commercially available 99% pure aluminium metal was used to develop hybrid composite. Aluminium metal was in the shape of ingot that was cut into small pieces with the help of electric hacksaw HS 160. During cutting of aluminum metal water was continuously flowing between the blade of hacksaw and metal to prevent metal and blade from heating and increase the life of blade. Aluminum metal was cut in four different parts of appropriate weight for four casting of different composition of silica sand nanoparticles and Glass fibers. Mould was prepared using a mixture of river sand and molasses. Molasses was thoroughly mixed with sand in particular ratio 8 wt.% for strong binding. After the complete mixing of molasses with river sand, mixture was slow heated for about 5-10 minutes to gain strong binding between molasses and river sand. The mould was prepared in moulding box using cope and drag. First sand was poured in the drag with pattern and rammed and then the cope was filled with the sand. Gating systems for mould was also provided during the making of cope part of the mould. Gating system consist of in-gate, sprue well, sprue, pouring cups and runner. Mould was preheated before the casting to evaporate all moisture. Melting of aluminium metal was done in a pit furnace and mixing of reinforcements such as silica nanoparticles and glass fibers was done in four different batches, to make four different castings having different percentage (wt.%) compositions of reinforcements. Aluminium was melted upto 720^{o}C for appropriate mixing of reinforcements such as silica nanoparticles and glass fibers. Flux and degasser (hexachloroethene) were also used during melting, each 5wt.% of metal in every castings. Tensile test of the all four composites were performed using the "Shimadzu universal testing machine" having load capacity of 1000 KN and the tests were performed at room temperature according to ASTM standards E 8-03. Samples of charpy impact test were made according to the dimension of ASTM standard E23. The apparatus consist of a pendulum of known mass and the length that is dropped from a known height to notched specimen. Micro hardness test was performed at all four samples using Rockwell scale. Five tests were performed for each sample and the average of these values was considered as the micro hardness of the samples. The fractured surfaces of the tensile samples were studied using Scanning Electron Microscope.

3. Results and Discussion

3.1 Tensile strength of Aluminum based hybrid Composites

Increasing wt.% content of silica nanoparticles and glass fiber increased the tensile strength of the composite as highlighted in Figure 1. During the tensile test the fibers are pulled out from matrix, pulling of fibers from matrix delay the fracture mechanism as shown in Figure 2. The fibers provide ductility to composite as compared to silica sand nanoparticles. Although, the silica nanoparticles increased the brittleness of the composite but in this case of the hybrid composite, they support ductility of the composite, making interlocking and filling the porous sides of the composite. Stress-strain graphs showed pulling and delaying behaviour of hybrid composites because the curve is moving in zigzag manner.

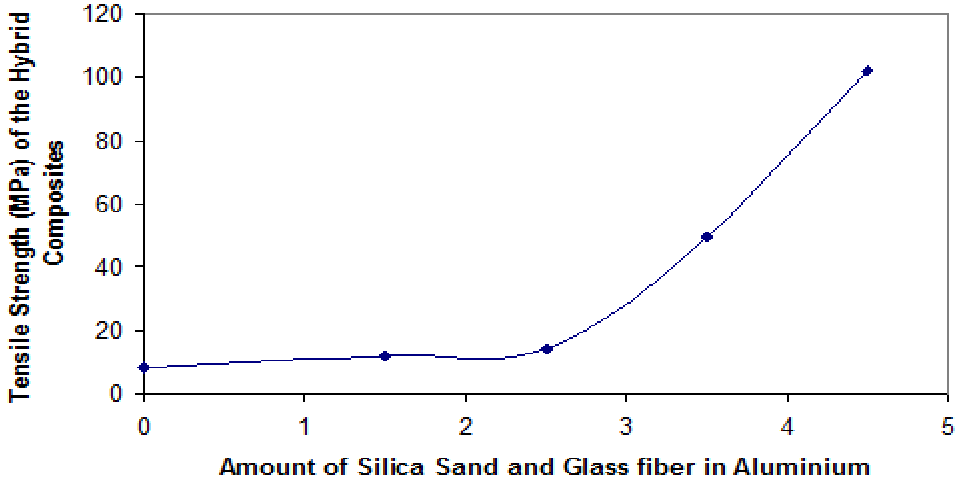


Figure 1. Tensile Strength of the Aluminium based Hybrid Composites

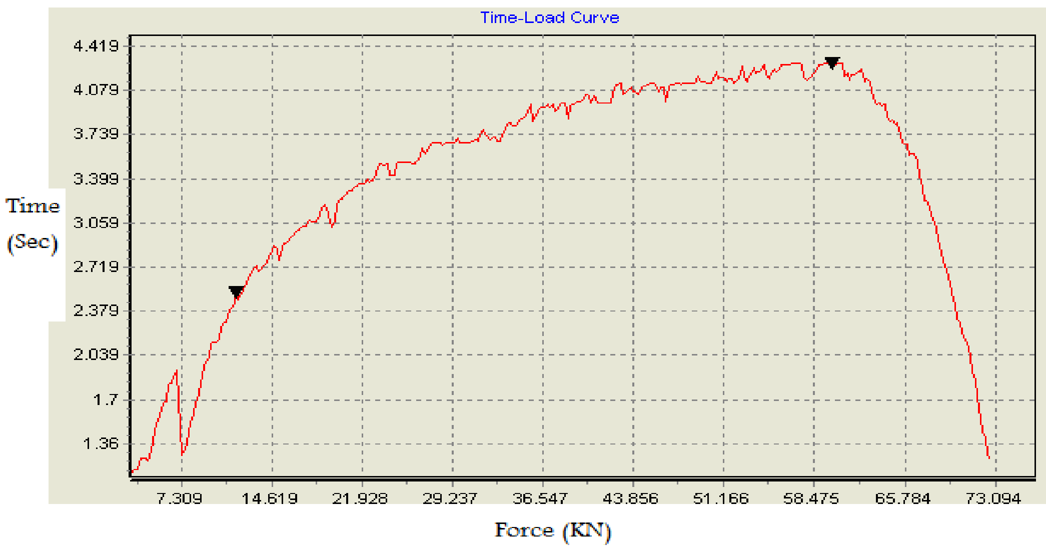


Figure 2. Stress-Strain Curve of Aluminium based Hybrid Composites

3.2 Impact Strength of Aluminium based Hybrid Composites

Increasing the silica nanoparticles and glass fibers contents in aluminium decreased the impact strength of hybrid composites by increasing the ductility. Increasing trend of impact strength was studied by Manoj *et al*. [8] with increase in weight percentage of SiC. Gurwinder *et al*. [9] also prepared aluminium based composites reinforced with SiC, Al_2O_3 and C particle by squeeze casting and increasing trend of impact strength was observed. In our study fibers play an important parts to enhance ductility by completely dispersed in aluminium matrix. The fibers create linkage between matrixes and reduced the properties generated by silica sand nanoparticles in aluminium.

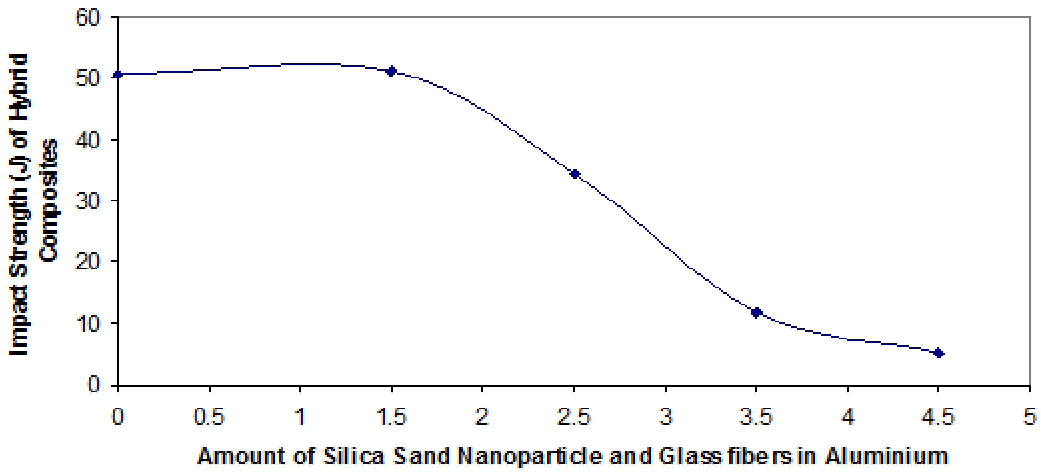


Figure 3. Impact Strength of Aluminium based Hybrid Composites

3.3 Micro Hardness of Aluminium based Hybrid Composites

Results of micro hardness of hybrid composites showed that hardness increased with the increase of silica nanoparticles in the aluminium metal because silica nanoparticles homogenously diffused in to the aluminum matrix along with glass fibers to make harder the hybrid composites. Some of silica sand nanoparticles also come on surface during the casting of the hybrid composites and caused to improve the surface hardness of the composites. The results of improved hardness of the hybrid composites are presented in Figure 4.

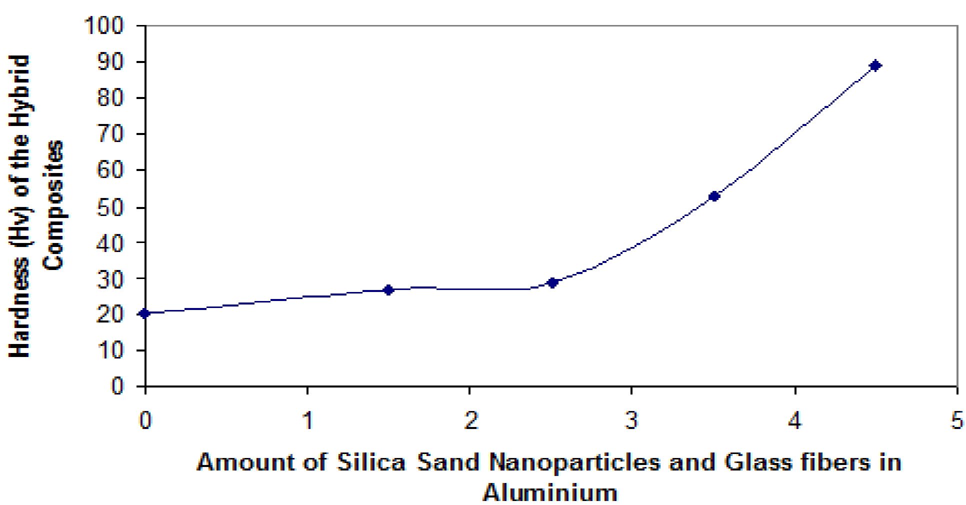


Figure 4. Hardness (HV) of Aluminium based Hybrid Composites

3.4 SEM Analysis of Tensile fracture specimen of Hybrid Composites

Micrographs of the hybrid composites showed that fibers are completely dispersed in aluminium matrix and during testing, these fibers are pulled out from matrix and due to fibers composites take some time to fracture. Pulling of fibers from the matrix in vertical directions is shown in Figure 5(a) where the fibers are first pulled out and then fractured.

The pulling of fibers from matrix in horizontal direction is shown in Figure 5 (b, c) during this mechanism fibers make the composites ductile whereas the silica sand nanoparticles provides the brittleness. Some where this both ductile and brittle behaviour balanced each other and in this way the aluminium based hybrid composites are behaving different than other composites. In Figure 5(c) the breaking mechanism of fibers are clearly observed and some fibers are indicated.

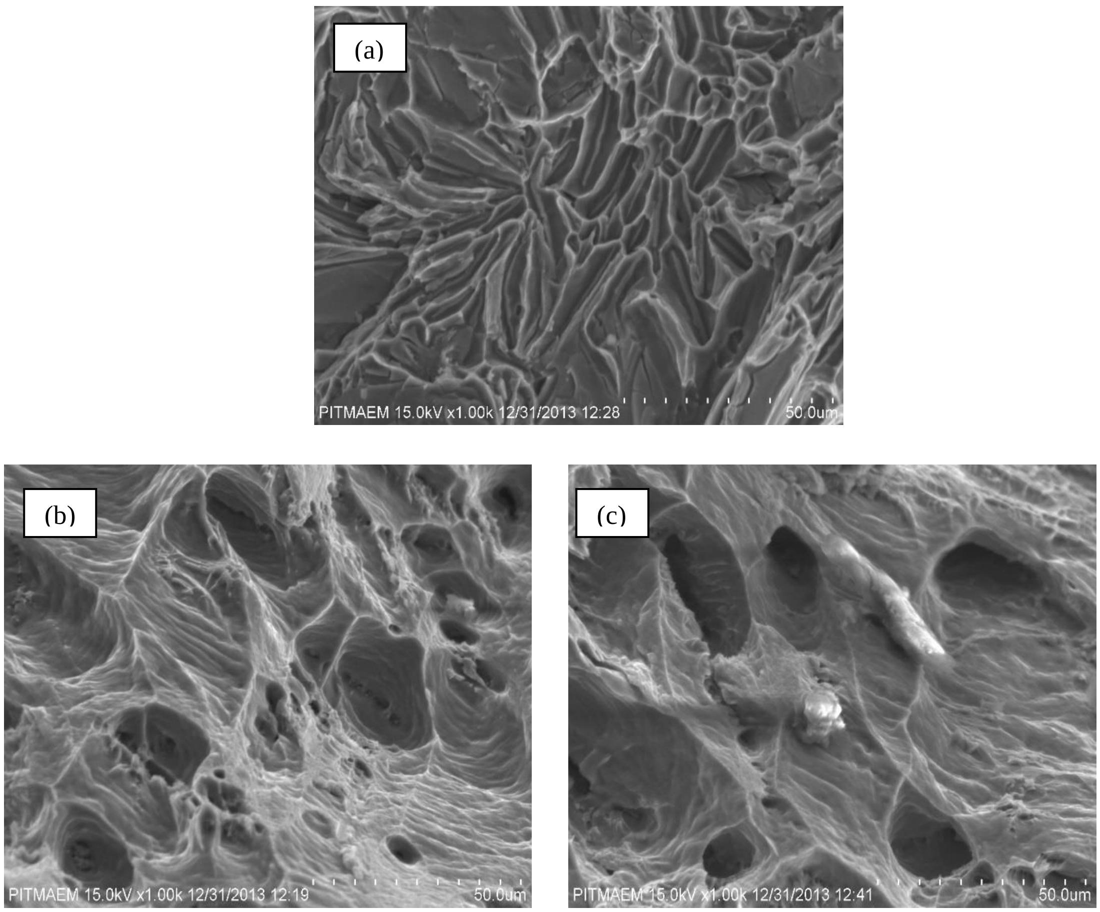


Figure 5 (a, b, c). Fractured Tensile specimen of Aluminium based Hybrid Composites

4. Conclusion

Aluminium based Thal Silica sand nanoparticles-glass fibers hybrid composites were successfully by compocasting method (liquid metallurgy method). The reinforcement of short glass fiber and silica sand nanoparticles improved both the Tensile strength and hardness of the hybrid composite upto 102.00 MPa and 88.93 HV respectively. However a decrease in impact strength from 51.25 to 11.95 J was observed. The SEM analysis showed the pulling of fibers from aluminum matrix in vertical and horizontal direction and this mechanism provides the ductile behavior to aluminum based hybrid composites. Glass fibers provide ductile behavior to the matrix where the silica sand nanoparticles support to brittleness and this mechanism balanced each other and improved the properties of aluminum based hybrid composites.

Acknowledgments

The authors would like to thank the University of the Punjab Lahore for providing necessary supports in completing this research. This research is funded by Higher Education Commission of Pakistan (HEC) under the StartUp Research Program 2013.

References

[1] G. Kickelbick (Editor), Hybrid Materials: Synthesis, Characterization, and Applications, Wiley, ISBN 978-3-527-31299-3, (2007) pp. 153-299.

[2] T. Ahmad "The Development of Silica Nanoparticles from Sand Mines as Reinforcement for Iron based Metal Matrix Composites", PhD thesis, Department of Mechanical Engineering, Universiti Teknologi Petronas, (2012) pp. 5-60.

[3] M. Sundararajan, S. Ramaswamy, P. Raghavan, "Evaluation for the Beneficiability of White Silica Sands from the Overburden of Lignite Mine", Journal of Minerals & Materials Characterization & Engineering, 8 (9) 2009 pp. 701-713.

[4] P. Kammer, H.K. Shivanand, S. Kumar, "Experimental Studies on mechanical studies of E-glass short fibers & fly ash reinforced Al 7075 hybrid metal matrix composites", international journal of mechanical and industrial engineering (IJMIE), 1 (4) (2012) pp. 111-115.

[5] M.B. Arun Kumar, R.P. Swamy, "Evolution of mechanical properties of Al6061, fly ash and E-glass fiber reinforced hybrid metal matrix composites", ARPN journal of engineering and applied sciences, 6,(5) (2011) pp. 40-44.

[6] S. N. Prashant, M. Nagaral, V. Auradi, Preparation and Evaluation of Mechanical and Wear Properties of Ali6061 Reinforced with Graphite and SiC Particulate Metal Matrix Composites, International Journal of Mechanical Engineering and Robotics Research, 1(3) (2012) pp.106-112.

[7] T. Ahmad, R. Ahmad, M. Kamran, B.A. Wahjiodi, Effect of Thal Silica Sand nanoparticles and glass fiber reinforcements on epoxy-based hybrid Composite, Iranian Polymer Journal, 24(1) (2015) pp. 21-27.

[8] M. Singla, D.D. Dwivedi, L. Singh, V. Chawla, Development of Aluminium Based Silicon Carbide Particulate Metal Matrix Composite**,** Journal of Minerals & Materials Characterization & Engineering, 8(6) (2009) pp 455-467.

[10] G. Singh, C.S. Kalra, Fabrication and Characterization of Al-based hybrid Composites Reinforced with SiC, Al_2O_3 and C particles by Squeeze Casting, C.S./ Mechanica Confab, 3(1) (2014) pp. 1-14.