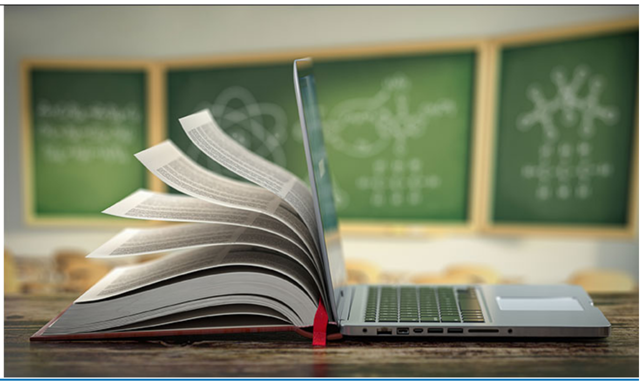
PAPER • **OPEN ACCESS**

Impact of silicon carbide reinforcement on characteristics of aluminium metal matrix composite

To cite this article: Arun Kumar Sharma *et al* 2021 *J. Phys.: Conf. Ser.* **1781** 012031



Impact of silicon carbide reinforcement on characteristics of aluminium metal matrix composite

Arun Kumar Sharma[1], R Bhandari[1] and C Pinca-Bretotean[2]

[1]Sagham University, Rajasthan 311001, Bilwara, India
[2]Politehnica University of Timisoara, Engineering and Management Department, Revolutiei str., no. 5, 331128 Hunedoara, Romania

E-mail: arunresearch88@gmail.com

Abstract. The consumption of composites has gradually raised in recent times and is incredibly likely to expand more in the future. Metal Matrix Composites (MMCs) provide an extensive range of benefits when compared with the common materials in certain conditions. Aluminum and its alloy-based composites in the current manufacturing scenario have a significant role to play in the advanced technological fields. Typically Aluminum Metal Matrix Composites (AlMMCs) used for its good strength, less density, excellent stiffness, lightweight, toughness, resistance to corrosion, fatigue, creep and wear relative to non-reinforced alloy. The AlMMCs, since their combination of the above-mentioned properties, are ideal suitable materials for many applications. Enhancement in these properties is accomplished by adequate customizing reinforcements in the base metal matrix. It is commonly used therefore in the aircraft, automobile, marine, leisure, telecommunications industries. In assessing the overall effectiveness of the composites there is a significant factor is reinforcement materials. The decision of a suitable type of reinforcement materials and volume are also important challenges within this paper the impact of different amounts of reinforcement has been studied. The silicon carbide (SiC) used as reinforcement material and Al6061used as Matrix material in AlMMCs are addressed. The effect of SiC on characteristics of AlMMCs explored in brief.

1. Introduction

Composite materials have a specific meaning of incorporating two or even more materials with various physical properties to create a new material to meet certain properties. Interests of the people in composite materials are indeed attributed as conventional materials will no longer satisfy ever more demanding requirements in numerous advanced industries so the suitable composite materials according to specific requirements developed continuously [1], [2].

Metal matrix composite (MMC) has very attractive physical and mechanical properties so it can easily become a substitute for other materials in many application areas in industries. The aluminum-based Composites (AlMMCs) are especially popular in the aerospace, automobile and sports industries because of their unique mechanical and tribological properties, reactivity between the matrix material and reinforcement material is a significant problem in the manufacture of AlMMCs. The features of the reinforcing material also decide the properties of MMCS. Few examples of reinforcement materials are boride, graphite, alumina and SiC [3].

2. Aluminum and aluminium alloys

Pure aluminum has good softness, so it is not strong. It can be drawn into wires and rolled into the foil. It is used extensively in the electronics industry, packaging industry and in the manufacturing of wires, cables. Its electrical conductivity and density are poor relative to copper, but compared with aluminum wires of similar mass and length with copper, the price of aluminum is low. Therefore, high-voltage cables in the field are mostly made of aluminum, which saves a lot of costs. Significant properties of aluminum materials include lightweight, excellent resistance toward corrosion, less density, the high ratio in between strength and weight, and good fracture toughness, due to such characteristics, aluminum has become a very economical and suitable material for use in the industrial and military fields. It is an electronegative metal, a stable oxide film is made on the aluminum surface when exposed to air, although not undergoing deep oxidation in the air, only a thin and dense oxide film is formed on its surface, this oxide film layer can potentially prevent corrosion. It can resist a variety of acidic corrosion but cannot resist alkali corrosion. Pure aluminum has no high yield strength. Furthermore, when alloying materials like Mg, Si, Cu and Mn are added to form an aluminum alloy, their strengths are improved [4], [5].

Aluminum has excellent thermal conductivity, this characteristic of aluminum makes aluminum an important metal to use widely in the fields of refrigeration and heating (as heat exchangers). Due to its non-toxic properties, aluminum is also widely used in kitchenware and cookware. Because of the low density of aluminum, it is one of the lightest metal in commercial areas. Aluminum has high electric conductivity like copper and may be used for conductive purposes. Aluminum properties are also associated with its purity. The higher the pureness, the easier it can be processed like forging, rolling and drawing. Furthermore, aluminum would also have a wide potential possibility of application because of the availability of aluminum in the earth's crust and its benefits over other metal products. For example, the usage of AlMMCs to substitute traditional materials in major areas is currently being explored in the automotive sector to make automobiles lighter. Aluminum powder has a silvery-white luster. It is often mixed with other substances and used as paint. It is brushed on the surface of iron products to protect them from corrosion.

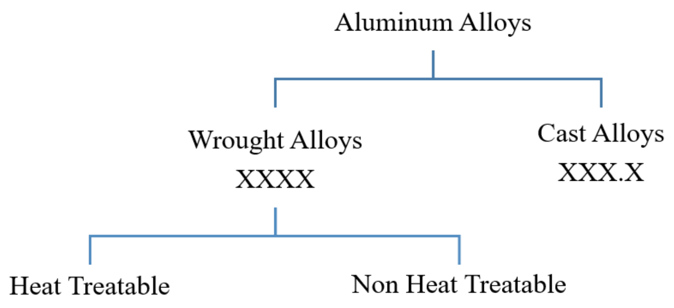


Figure 1. Types of Aluminium Alloys

Aluminum alloys may be classified into different categories, depending on the various materials properties, the capacity of the aluminum alloys to respond to mechanical and physical treatment and on the addition of major alloying element. Classification of Al alloys given in Figure1with different identification system which includes cast alloy (XXX.X) and wrought alloy system (XXXX). The classification of wrought Al alloys shown in Figure 2. Alloys in the 6xxx series consist of Si and Mg as much as in the amounts needed for development magnesium silicide (Mg_2Si), hence to make them heat treatable. Aluminum alloys divided into two parts shown in fig1. One of the main alloy in 6000 series in Al alloys represented by 6061 which have Mg and Si, and possess excellent properties which include average strength, excellent resistance towards corrosion, good weldability and oxidation effect. This is used extensively in different automotive products that need some strength and strong resistance to corrosion, such as trucks, the tower of buildings, vessels, trams, railway vehicles and furniture. Different mechanical properties of various types of Al 6061 shown in Figure 3, Figure 4 and Figure 5. Table 1 shows the chemical composition of Al6061 [6], [7].

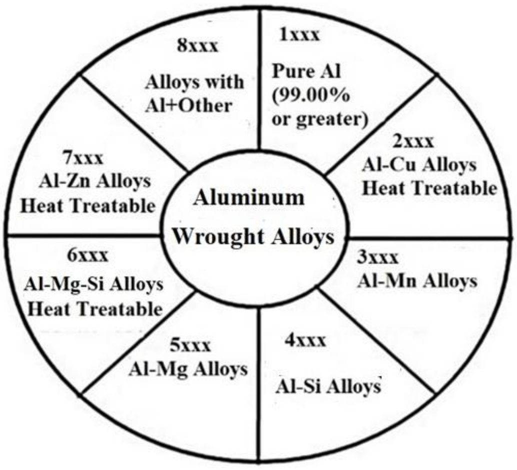


Figure 2. Types of Wrought Al Alloys

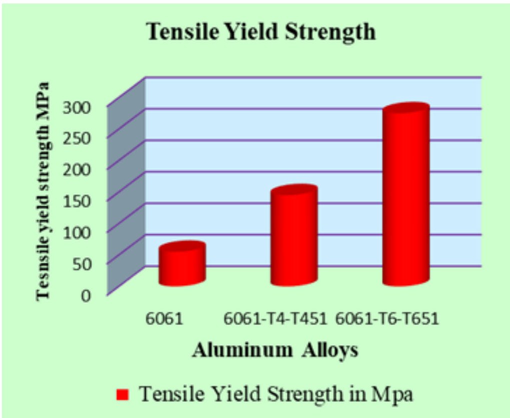


Figure 3. Tensile Yield strength of Al6061

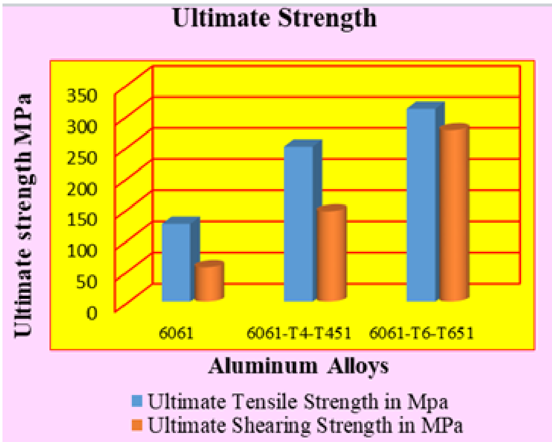


Figure 4. Ultimate Tensile and Shear Strength of Al6061

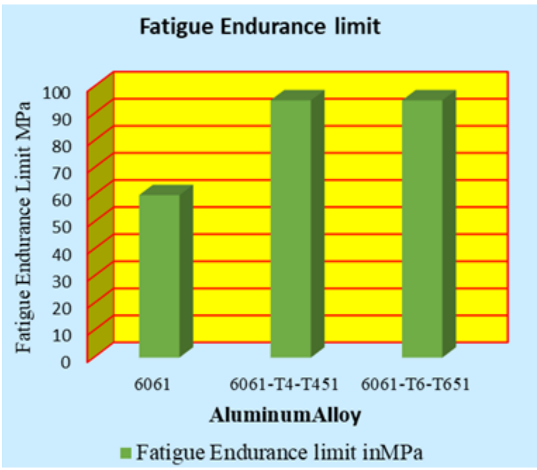


Figure 5. Fatigue Endurance Limit of Al6061

AlMMC materials will continue to expand with the development in technology not only in conventional applications such as aeronautics, shipping, telecommunications and building but also in new fields.

Table 1. Chemical Composition of Al6061

Elements	Si	Cu	Zn	Fe	Mn	Mg	Cr	Ti	Others	Al
W_t (%)	0.04-0.08	0.1-0.4	0.09	0.07	0.15	0.8-0.12	0.04-0.35	0.15	0.15	Remaining

Aluminum has good thermal conductivity than iron. Aluminum is commonly used in industry to make various heat exchangers and heat dissipation materials, cookers used in households are also made of aluminum. Compared with iron, it is also less susceptible to rust, extending its service life. The efficient and cost-effective method in the manufacture of Aluminum MMCs is liquid state systems. It has been reported that stir casting is the most economical process of all the production techniques considered [8].

3. Reinforcing materials

Reinforcement materials can significantly improve certain properties of the base metal /alloys such as high thermal conductivity, heat resistance, wear resistance, low thermal expansion.

The structure and properties of the reinforcement materials do not change and degrade significantly during use and the fabrication of MMCs and should have good chemical compatibility in between reinforcing and matrix material without serious interfacial reaction. The design of composite materials must consider the relationship between the arrangement of reinforcing materials and the direction of stress application [9].

SiC is extremely hard, strong material and has outstanding thermal shock resistance which maintains their strength at very high temperatures with no loss of strength. SiC is an exceptional abrasive material and has excellent mechanical properties. SiC has low density, good strength and high hardness, therefore used in a wide array of high-performance applications. Structural and wear applications also continue to develop when SiC particles are used as reinforcements. Silicon carbide is one of the commonly used structural ceramics, used as an attractive wear resistance practitioner rather than tungsten carbide in many of its complex design forms. When compared to silicon nitride, the raw materials used to obtain silicon carbide are cheaper and the cost of the resulting products is lower than that of tungsten carbide [10].

4. Literature Review (SiC/Al6061)

4.1 Mechanical Properties

A study of scientific literature related to mechanical properties of AlMMCs, made by Al6061 reinforced with SiC discussed [11-19].

Laxmi et al. (2017) Investigated, AlMMCs, manufactured by the stir casting technique, matrix material Al 6061, reinforced with a weight fraction of 10, 15, 20 percentage of Silicon carbide (SiC). A brief microstructural examination was performed on the electron microscope scanning (SEM). The test findings indicate that the hardness value of the composites is increased with the rise in reinforcement from 10 to 15 % [11].

A.P.Kumbhar et al. (2018) conducted research in which the effects of the Sic reinforcement on the characteristics of the metal matrix composite investigated. Al 6061 taken as matrix material and with different weight % (0.3, 6 and 9) of SiC as reinforcement, stir casting process was used to prepare composite material. The conclusions obtained that The Al 6061 matrix with Sic boosts mechanical properties. Tensile strength, the compressive strength of composite improves with the weight percentage of SiC [12].

N. S.Patel et al. (2018) investigated AlMMCs fabricated by the stir casting process in which Sic nanomaterial in different weight fractions (0, 5, 15%) used as reinforcement material and al6061 as a matrix. Hardness, density, performance, ultimate strength increase by the increase in silicon carbide reinforcement particles. The elongation percentage decreases with growing silicon carbide enhancement particles [13].

A Q Wang et al. (2018) study powder-metallurgy method to fabricate AlMMC in which Al 6061 reinforced by 35% vol. SiC particles of varying sizes. The reinforcement is of SiC, particles size (7.5 μm, 25 μm, 15 μm, 40 μm) and Al6061 powders of 10 μm mean particle size is used as matrix material. The analysis found that the coefficient of thermal expansion (CTE) of AlMMC has improved, the SiC particles spread more evenly in the matrix, but the tensile strength has been decreased with increase in the size of SiC particle. SiC particles spread more evenly in the matrix by raising the particle size [14].

Y. Hu et al. (2019) analyzed the mechanical characteristics of SiCp/6061Al composites with a broad variety of SiC weight percentages (0-30 percent), during T6 treatments and composites were effectively prepared by means of hot-press sintering, tensile testing conducted at room temperatures, 100°c and 200°C. Further examination was rendered with an optical microscope and SEM of the microstructure. The findings indicate that a significant improvement in tensile strength and an apparent decrease in elongation is the effect of T6 treatment for mechanical characteristics of composites. As the increases in temperature, the tensile strength of T6-treated samples improved and the material has a peak elongation at 100°C [15].

N. Kumar et al. (2019) have studied the impact of SiC content on aluminum alloy Al 6061 through experimental analysis. Composites are developed using the stir casting process with a differing weight percentage (0, 1, 2, 3 and 5) of SiC material. The Al 6061/Sic composite density was increased when SiC material was enhanced. The mechanical properties of manufactured specimens were examined through hardness and tensile testing. Up to 5 % of SiC particles also enhanced the stiffness and tensile strength greatly. The density of the material has been enhanced by incorporated SiC particles. Adding Sic material increases the performance of the processed Al6061/SiC composite. At the 5% reinforcement, the density of the composite Al6061/SiC was increased by 1.4 %. The hardness of the composite Al6061/SiC has improved considerably to 45 HRB. With 5 % SiC, the hardness level of the processed composite was increased by 12.5%. For Al 6061/5wt maximum SiC composite tensile strength has been raised to 288 MPa [16].

M. K. Pal et al. (2019) studied AlMMC for which the stir casting process has been used to prepare aluminum 6061 composites consisting of different volumetric percentages of Silicon Carbide (SiC) (0%, 5%, 10%, 15%, 20% and 25%). In the present research, silicon carbide (SiC) reinforced AlMMCs have been examined including microstructure and mechanical properties. The findings revealed that the improvement of the hardness and tensile strength observed when the weight percentage of SiC improved in the Aluminum6061 matrix, nevertheless limited the elongation of SiC reinforced AlMMC to 25%. The highest hardness and tensile strength were measured at 25% SiC. The result shows, in the microstructures, SiC particle clustering and uniform dispersion in the Al6061 matrix is observed, the compressive strength of a material is improved because of the inclusion of SiC particles. Since SiC is harder in comparison to the Al 6061 matrix, the mechanical properties of composites (tensile strength and hardness) [17].

S. Sivananthan et al. (2020) studied AlMMcs, for which stir casting process used, to make AlMMCs, Al 6061 alloy reinforced by SiC particle, the Weight percentage of the SiC particles ranged from 0 to 4. The findings showed that the compression strength, hardness and tensile strength of the samples improved by increasing the weight percentage of the SiC particles in 6061 aluminum alloy. Furthermore, the ductility of aluminum 6061 alloys is decreased with the increment in weight percentage of SIC from 0 to 4 in matrix. Compression strength Hardness and tensile strength improved by up to 12 %, 25 % and 25.6 % respectively compared to 6061 aluminum alloys. This aluminum carbide reinforced metal matrix composites offer superior mechanical characteristics relative to aluminum alloy [18].

M. Dhanashekar et al. (2020) write a research paper which provides information on the mechanical properties and the wear characteristics of composites, SiC reinforced AA6061 produced through powder metallurgy method. The findings of the study show that the composite has improved in hardness and compressive strength with the improved quantity of reinforcement. There was a homogeneous distribution of particles of reinforcement material in the composites. With an improvement in the SiC the wear rate of composites decreases. The composite microstructure shows uniform particle distribution, a clear relationship between both the matrix and reinforcing particles. With increasing weight percentage of the SiC particles, compression strength, hardness and density of the composites improved [19].

4.2 Tribological, Physical and Thermal Properties

An investigation related to thermal, tribological and physical properties of AlMMCs, fabricated through Al6061 alloy reinforced by SiC discussed [20-23].

S. Mohal (2017) has done an investigation on the manufacturing of AlMMCs by a double stir casting technique. As matrix Al6061 and as reinforcement sic with 5, 10 and 15 weight percent used. Results show that a relatively homogeneous distribution of SiC particle within the alloy matrix of 6061Al observed. Subsequently, a small volume of Mg lower than 1% of the overall weight is applied to increase the wettability. The addition of Mg was found to limit the creation of Al_4C_3 at interfaces [20].

P. V. Trinh et al. (2018) investigated the AlMMCs which developed by the use of spark plasma sintering method, oxidizing-silicon carbide particle 10% by weight added in Al6061at 1200°C,1300°C and 1400°C. The findings showed that the interfacial binding intensity between Al6061 and oxidized SiCp was improved. For the composite comprising oxidized SiCp, the hardness by 75%, the ultimate tensile strength by 26 % and elongation by 32% are improved respectively. The coefficient of friction and specific wear levels for composites oxidized by SiCp/Al6061, respectively, have been lowered by 7 and 17 %. This improved hardness and strength of AlMMCs [21].

R. Zare et al. (2019) studied the impact of SiC particle weight percentage on the physical and thermal characteristics of Al6061/SiCp composite. SiC used as reinforcement material, 6061 as matrix and powder metallurgy as fabrication process used. The reduction of the CTE, by the increase of the reinforcement material was seen in experiments. Thermal conductivity was shown to decrease due to the increase in crystalline defects on the phase borders, as the SiC content of the composite in samples was raised [22].

S. Sarapureet al. (2020) did a statistical study of the corrosion behavior, by using a Taguchi method, of AlMMc, for the fabrication, the Stir casting technique was adopted in which Al6061 reinforced by SiC with 0 percent, 2 percent and 4 percent weight. Through means of a design experimental approach, by using Taguchi technique, the corrosion properties of the AlMMCs were analyzed statistically. The findings of the research indicate that greater resistance to corrosion was obtained in the composite materials compared to monolithic 6061 alloys. Studies have shown a significant reduction in the rate of corrosion and loss in weight per unit area with an increase in time. AlMMCs compared with monolithic unreinforced matrix alloy demonstrated greater corrosion resistance [23].

5. Conclusions

In this article, the mechanical, as well as tribological characteristics of AlMMCs which developed by various methods of adding different reinforcement, are presented. To conclude this study, the experimental evidence addressed the effects of the reinforcement on microstructure and mechanical characteristics of AlMMCs.

Following results found through study:

- The stir casting process is the most commonly used process to make AlMMCs.
- AlMMCs which made through Al6061 as matrix and Sic As reinforcement, with the increment in Sic weight percentage hardness, Tensile strength compressive strength and corrosion resistance improved and wear level reduced.

- Homogeneous distribution of Sic in Al6061can be obtained by Powder metallurgy process.

Within this study, the key developments and findings reveal that aluminum MMCs have better characteristics and lower thermal expansion coefficients relative to unreinforced aluminum alloy. The properties of reinforced AlMMCs are better, due to the distribution of reinforced materials in the matrix as well as their non-homogeneous existence, the analysis of the efficient and economic processes of the manufacturing of AlMMCs remains important. AlMMCs fabrication may be made economical by choosing correct fabrication methods.

References

[1] Sharma A K, Bhandari R, Aherwar A and Rimašauskienė R 2020 *Matrix materials used in composites A comprehensive study*, Materials Today: Proceedings, Elsevier, **21** 1559-1562
[2] Pinca-Bretotean C, Lemle L D and Szabo A 2019 Ecological Composites Materials for Brake Pads Using Shells as Filler Material, *Materiale Plastice* **56** 588-591
[3] Sharma A K, Bhandari R, Aherwar A, Rimašauskienė R and Pinca-Bretotean C 2020 A study of advancement in application opportunities of aluminum metal matrix composites, *Materials Today: Proceedings* **26** 2419-2424
[4] Totten G E and MacKenzie D S 2003 *Handbook of aluminum, Physical Metallurgy and Processes Vol 1,* First Edition, Marcel Dekkern, New York ,USA
[5] Sharma A K Bhandari R and Aherwar A 2018 Mechanical Aspects Of Metallic, Biomaterials in Human Hip Replacement, *International Journal of Research and Analytical Reviews* **5** 363-8
[6] Benedyk J C 2010 *Aluminum alloys for lightweight automotive structures, Materials Design and Manufacturing for Lightweight Vehicles*, Elsevier, 79-113
[7] Sankaran K K and Mishra R S 2017 *Metallurgy and Design of Alloys with Hierarchical Microstructures*, First Edition, Elsevier
[8] Sharma A K, Bhandari R, Aherwar A and Pinca-Bretotean C 2020 A study of fabrication methods of aluminum based composites focused on stir casting process, *Materials Today: Proceedings* **27** 1608-12
[9] Kainer K U 2006 *Metal Matrix Composites, Custom made Materials for Automotive and Aerospace Engineering*, First Edition,Wiley-VCH
[10] Davis R F 2017 *Reference Module in Materials Science and Materials Engineering*, Elsevier
[11] Lakshmi and Kumar S 2017 Fabrication and Testing of Aluminium 6061 Alloy & Silicon Carbide Metal Matrix Composites, *International Research Journal of Engineering and Technology* **4** 2207-2211
[12] Kumbhar A P, Vyavahare R T and Kulkarni S G 2018 Vibrational response and mechanical properties characterization of aluminium alloy 6061/Sic composite, *AIP Conference Proceedings* **1966** 020036
[13] Patel N S, Patel A D, Ranjan R K and Rai V 2018 *Studies on Properties of Al–SiC Metal Matrix Composite Material for Making IC Engine Valves*, Proceedings of the World Congress on Engineering **2**
[14] Wang A Q, Tian H W and Xie J P 2018 Properties investigation and microstructures characterization of SiCp/6061Al composites produced by PM route, *IOP Conf. Ser: Mater. Sci. Eng*. **292** 012055
[15] Hu Y, Wu T, Guo Y, Wang W, Song M, Qian L, Zhao H and Wang M 2019 Effects of T6 Treatment, Tensile Temperature, and Mass Fraction of SiC on the Mechanical Properties of SiCp/6061Al Composites, *Materials MDPI* **12** 1602
[16] Kumar M N, Maurya M, Kumar S A, Dwivedi S P, Kumar A and Chauhan S 2020 Investigation of mechanical properties of Al 6061/SiC composite prepared through stir casting technique, *Materials Today: Proceedings* **25** 755-758
[17] Pal M K, Vikram A and Bajaj V 2019 Enhanced microstructure and mechanical properties of

sic particle reinforced aluminium alloy composite materials, *Acta Metallurgica Slovaca* **25** 253-58

[18] Sivananthan S, Ravi K and Samson Jerold S C 2020 Effect of SiC particles reinforcement on mechanical properties of aluminium 6061 alloy processed using stir casting route, *Materials Today: Proceedings* **21** 968-70

[19] Dhanashekar M, Loganathan P, Ayyanar S, Mohan S R and Sathish T 2020 Mechanical and wear behaviour of AA6061/SiC composites fabricated by powder metallurgy method, *Materials Today: Proceedings* **21** 1008-12

[20] Mohal S 2017 Microstructural Investigation of Aluminium-Silicon Carbide Particulate Metal Matrix Composite Fabricated by Stir Casting, *International Journal for Innovative Research in Science & Technology* **3** 26-30

[21] Van Trinh P, Lee J, Minh P N, Phuong D D and Hong S H 2018 Effect of oxidation of SiC particles on mechanical properties and wear behavior of SiCp/Al6061 composites*, Journal of Alloys and Compounds* **769** 282-92

[22] Zare R, Sharifi H, Saeri M R and Tayebi M 2019 Investigating the effect of SiC particles on the physical and thermal properties of Al6061/SiCp composite, *Journal of Alloys and Compounds* **801** 520-8

[23] Sarapure S, Shivakumar B P and Hanamantraygouda M B 2020 Investigation of Corrosion Behavior of SiC-Reinforced Al 6061/SiC Metal Matrix Composites Using Taguchi Technique*, Journal of Bio and Tribo Corrosion* **6** 31