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Abrasive Wear Characteristics of Composite Material (AA 7075 / SiC) Synthesized by Stir Casting

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ABSTRACT

Aluminum Metal Matrix Composites (ALMMCs) was prepared by using stir casting technique for AA 7075 aluminum alloy as a matrix reinforced with SiC particles at various percentages (3, 6, 9 and 12 wt. %) and 75µm in grain size. The prepared composite material can be used for many applications such as aerospace, automobiles and many industrial sectors. Abrasive wear test was carried out by two stages: the first stage was done by changing the emery papers at various grit sizes 180, 320, 500, and 1000µm with constant applied load 15N. While the second stage was carried out by changing the applied loads 5, 10, 15, 20 and 25N with constant emery paper at 320 µm grit size. Microstructure examination, hardness test and roughness test were performed before and after abrasive wear test. The results of this investigation showed the increasing in weight percentage of the reinforcement material leads to increase the hardness, roughness and improving the abrasive wear resistance.

Key word: composite material, AA7075, SiC, stir casting, abrasive wear.

خواص البلى الحكي لمادة مركبة (AA 7075 / SiC) مصنعة بالسباكة بالتحريك

الخلاصة

تم تحضير مادة مركبة ذات أساس معدني من الألمنيوم بأستخدام تقنية السباكة بالتحريك , المادة الأساس من سبيكة AA7075 مقواة بدقائق من كاربيد السيليكون بنسب مختلفة (3, 6, 9 and 12 wt %) وبحجم حبيبي 75µm. المادة المركبة التي تم تحضيرها يمكن أن تستخدم في الفضاء, المركبات والعديد من المجالات الصناعية. تم أجراء أختبار البلى الحكي بمرحلتين: أجريت المرحلة الأولى بتغيير أوراق التنعيم بحجم حبيبي 180, 320, 500 و1000 مايكرون وبحمل مسلط ثابت مقداره 15 نيوتن. بينما أجريت المرحلة الثانية بتغيير الأحمال المسلطة 5, 10, 15, 20 و 25 نيوتن مع تثبيت ورقة التنعيم بحجم حبيبي مقداره 320 مايكرون. تم أجراء فحص البنية المجهرية, أختبار الصلادة وأختبار الخشونة قبل وبعد أختبار البلى الحكي. أظهرت نتائج هذا البحث أن زيادة النسبة المئوية الوزنية لمادة التقوية تؤدي الى زيادة الصلادة, الخشونة وتحسين مقاومة البلى الحكي.

الكلمات الرئيسة: مادة مركبة, سبيكة الألمنيوم 7075, كاربيد السيليكون, السباكة بالتحريك، البلى الحكي.

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1. INTRODUCTION

An important alloy in industrial applications is AA7075 because of its properties such as low density, high thermal conductivity, high strength and high wear resistance, **Kaufman, 2002 and ASM**. Aluminum Metal Matrix Composites (ALMMCs) are widely manufactured by solid state as powder metallurgy or liquid state as stir casting technique, **Kumar, 2010**. Stir casting process is preferred technique because of it easy, simple and can be used for wide range of materials, **Sajjadi, et al., 2010**. A number of ceramics materials such as SiC, SiO_2, Al_2O_3, TiO_2, B_4C, and carbon are used as reinforcements of AA 7075 to produce composite materials with desirable properties, **Gangadhar, et al., 2014**. Many investigations were published in this field such as, **pryia, et al., 2016,** studied the effect of silicon carbide on the mechanical properties for AA6061 fabricated by stir casting technique. Silicon carbide was added with four different concentrations as 2.5, 5, 7.5 and 10 wt. %. The results of this work show that improving tensile strength, impact strength, hardness and wear resistance. While, **Qiyao, et al., 2017,** investigated the effect of SiC on mechanical and physical properties of two different aluminum alloys (AA356 and AA6061) produce by vacuum die casting with assisting high pressure. The results of this investigation reveal that the pores of the producing casts decrease with increasing the weight fraction of SiC. Also the tensile strength of the AA6061 / SiC and AA356 / SiC were 246MPa and 286MPa, while the elongation of AA6061 / SiC and AA356 / SiC were 6.1% and 4.3% respectively at the high pressure. Whilst, **Straffelini, et al., 1979**, indicated that the hardness of AA6061 alloy has a large effect on the dry sliding wear behavior of AA6061 / Al_2O_3 composites. The results of this work reported that the increasing of Al_2O_3 will improve the wear resistance of AA6061 alloy. The objective of this investigation is study the effect of increasing the weight fractions of SiC on the abrasive wear behavior of AA7075 alloy producing by stir casting.

2. EXPERIMENTAL PROCEDURE

2.1 Material Used

The metal matrix used for this investigation is AA7075. **Table.1** shows the chemical composition for AA7075 alloy while **Table.2** shows the properties of AA7075 alloy and SiC powder. SiC particles as additive powder with grain size of 75µm and varying proportions of 3, 6, 9, and 12 wt. % to produce composite materials.

Table1. Chemical Composition of AA7075 alloy (wt. %).

Element	Si	Fe	Cu	Mn	Mg	Cr	Zn	Ti	Al
Wt. %	0.38	0.51	1.6	0.33	2.5	0.15	5.5	0.22	Rem.

Table 2. Properties of AA7075 alloy and SiC.

Material	Elastic Modulus (GPa)	Density (g/ cm^3)	Poisson's ratio	Hardness(Hv) (Kgf / mm^2)	Tensile Strength (MPa)
7075 alloy	70 - 80	2.81	0.33	63	220 (T)
SiC	410	3.1	0.14	2800	3900 (C)

2.2 Stir Casting

AA7075 alloy was superheated to 800°C at the heating rate about 20°C/min. in electrical furnace. While SiC particles were preheated to 350°C for 0.5 hr. in an oven to eliminate the gases from the particles surfaces and to prevent dropping in the temperature of the molten alloy after addition of SiC particles. The preheated SiC particles were incorporated into the molten aluminum alloy. The vortex technique of the stirring of the produced composite was carried out for 15 minutes at 600rpm of stirring speed. The molten composite was poured into suitable steel mold at 750°C to manufacture wear specimens.

2.3 Hardness Test

Hardness test specimens were prepared by grinding with different grinding paper at grit size and then polished by using polishing machine to achieve smoothing surfaces like the mirror. The hardness test has been carried out by using Vicker's hardness apparatus according to ASTM E384 standard. Four readings were taken for each position in the specimen surface and then measured the average of these readings to achieve the average diameter of the indentation. Vicker's hardness number was calculating according the following formula, **Bolton, 1988**.

$$\text{V.H.N.} = 1.8544 \times \frac{F}{d_{av.}^2} \left(\frac{\text{Kgf}}{\text{mm}^2}\right) \quad (1)$$

Where: F is applied force (Kgf), d: average indentation diameter (mm).

2.4 Wear Test

Wear test was carried out in the pin-on-disc technique. Wear specimens were manufactured by using lathe machine at 2cm in length and 1cm in diameter. The disc was an alloy of hardened tool steel; the surface roughness and hardness of the disc were 1.6 Ra and 60 HRC while rotating speed at 750 rpm. The wear test was performed by changing the applied load as 5, 10, 15, 20, and 25N, also changing the grit size of emery paper as 180, 320, 500, and 1000µm. Wear test performed according to ASTM G99, the specimens were grinded and polished to obtain smooth surfaces. The specimens were weighed by sensitive electronic balance with accuracy about 0.01mg type (Mettler AE-60 made in china). The wear rate (mm^3/m) of the specimens was calculated by dividing the loss in mass (g) with the density (g/cm^3) and sliding distance (cm).

2.5 Microstructure Examination

The microstructure examination was performed by using optical microscopy. Many photomicrographs were taken for the specimens before wear test with magnification for all the specimens (250X) also photomicrographs were taken for the specimens after wear test to define the topography of the surfaces.

3. RESULTS AND DISCUTION

3.1 Microstructural Observations

Fig.1 shows the photomicrographs of the specimens with different proportions of SiC introduced into molten Al-alloy. Each of the microstructure shows the homogeneous dispersion and distribution of SiC into the molten of aluminum matrix, this is attributed to many parameters to synthesize the composites such as: 1- Rotating speed (700 rpm) for stir casting. 2- Viscosity of the molten slurry. 3- The pouring temperature. 4- Shape and size of SiC particles. 5- Cooling rate. 6- The differences of the densities between the particules and the matrix.The homogeneity of distribution due to the stirring action will improve the wettability between the particles and molten matrix. The results of this investigation agreed with, **Prabhu, 2017**.

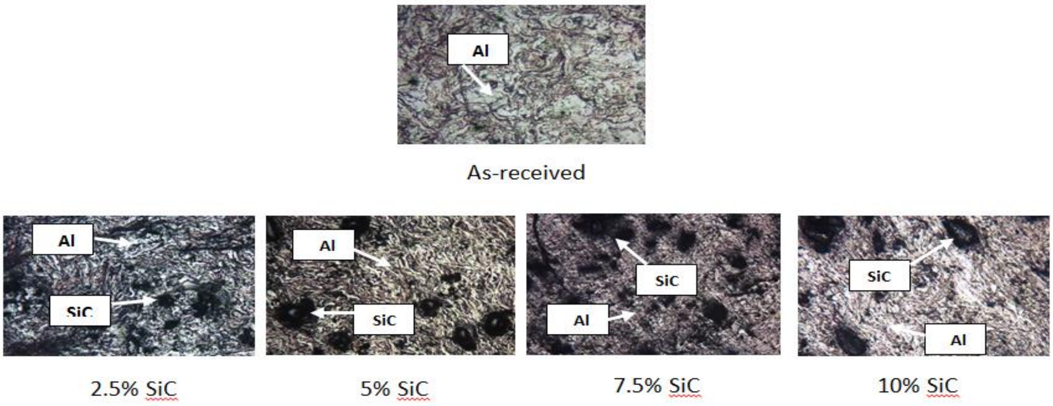

Figure 1. Photomicrographs of all the specimens for magnification (250 X).

3.2 Hardness Analysis

The hardness increases with increasing the concentration of SiC because of the strengthening mechanisms at the hard surfaces. Strengthening mechanisms lead to increase the dislocations density and causes strain hardening around SiC particles. Also created high mechanical bonding between aluminum matrix and SiC particles and no reaction occurs at the interface between aluminum matrix and SiC particles, and this is in line with, **Mohal, 2017**. **Fig.2** shows the relationship between hardness and the percentage of the ceramic particles additive. It is clearly that increasing the concentration of SiC particles leads to increase the hardness because the reinforcement ceramic particles are harder than aluminum matrix.

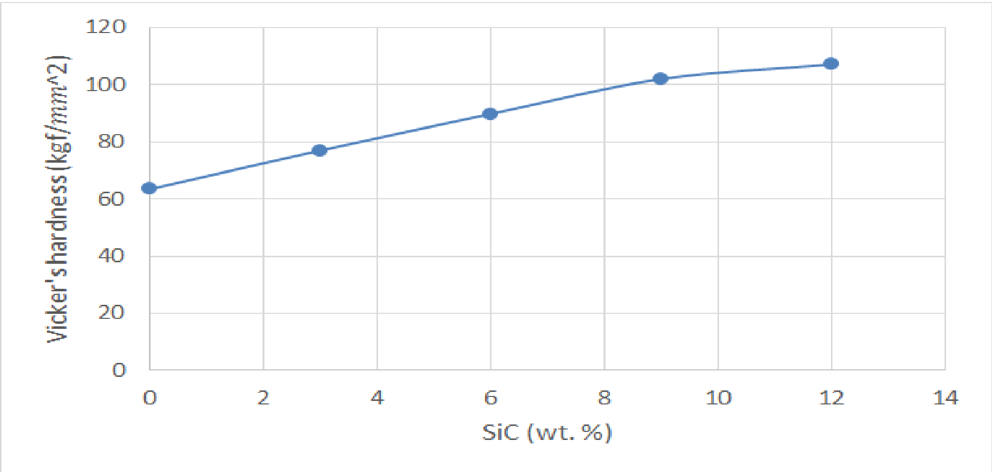

Figure 2. Show relationship between the Hardness and wt% of SiC.

3.3 Wear Characteristics

A. Changing the applied loads at constant grit size of emery paper at 500µm.

Wear rate increases with the increasing applied loads for all the specimens at constant grit size of emery paper 500µm as shown in **Fig.3.** It is clearly that wear resistance for all the specimens with different weight proportions of SiC higher than aluminum matrix. The increasing in wear resistance is attributed to the increasing of dislocations density around the SiC particles. Nonlinear curves will reduce with increasing the load which in turn rising the temperature between the pin and disc as a result of friction between them. Also increasing the weight concentrations of SiC increases the hardness and then increasing wear resistance. Increasing the load create wear debris as a result of cracking and forming cavities at the surface. Increasing the loads will break the oxide films and ploughinge those to form the debris wear, however causes delamination and abrasive wear. Increasing the applied load will increase the shear stress at the interfaces between SiC particles and aluminum matrix. Wear resistance for the composite material higher than aluminum matrix. The increasing in applied load leads to transfer from mild wear to severe wear and make more damage in the worn surfaces.

B. Changing in grit size of emery paper at constant applied load 15N.

Fig.4 shows the relationships between wear rate and grit size at constant load. It has been demonstrated that increasing in grit size will decrease wear rate. It is attributed to that the particles of SiC for emery paper grit size 1000µm smoother than the particles of SiC for emery papers at grit size 320µm and 500µm respectively. The effect of increasing in grit size on wear rate for all the specimens of this work is the same for that increasing in the loads as discussed previously. The results of this investigation are agreed with, **Axen and Jacobson, 1994**.

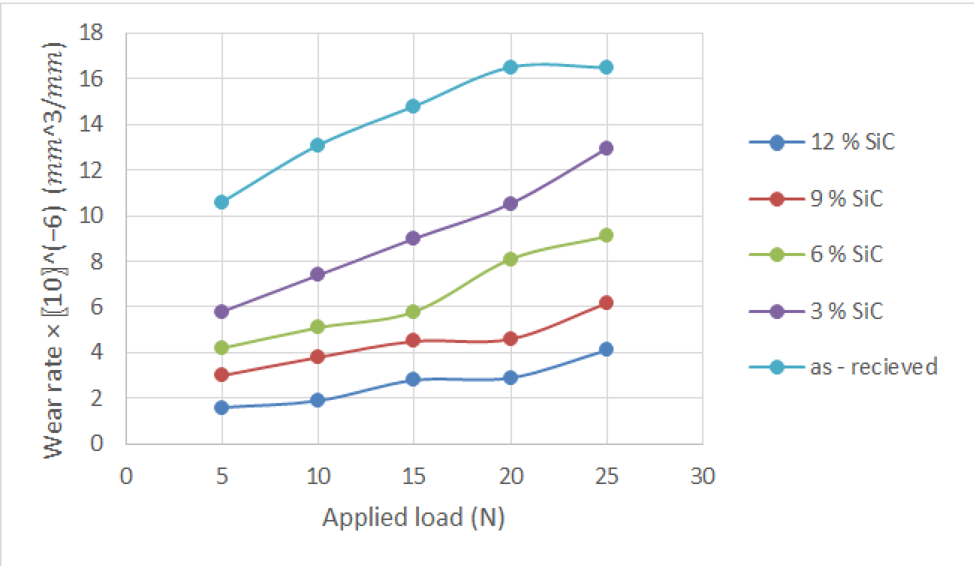

Figure 3. Show relationships between the wear rate and applied loads.

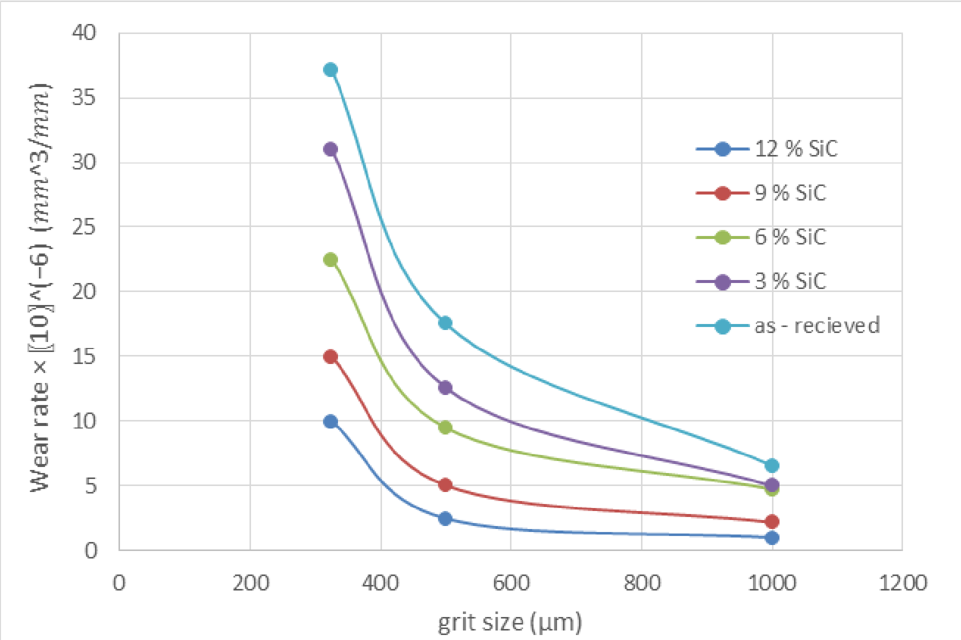

Figure 4. Show relationships between the wear rate and grit size of SiC.

C. Surface Topography

In this investigation, the surface topography of all the specimens was examined by optical microscopy (OM). Increasing the concentration of SiC into aluminum matrix leads to improve wear resistance for many reasons mentioned previously. The variation in wear resistance is considered as a result in changing the applied load and grit size of emery paper, which rises the heat temperature of friction between the rubbing surface (the pin of composite material and the rotating disc) and forming oxidation layer, which fragments and making grooves at the worn surfaces. These grooves are finer for the composite material with high concentration of SiC (12 wt. %) for wear test either changing the load or grit size of emery paper that increases the hardness, which in turn make the grooves finer.

While the low grit size at 320µm make the grooves more deeper than for 500µm and 1000µm because of SiC particle for emery paper at grit size 320µm larger than in emery papers at 500µm and 1000µm. While increasing the applied load will increase the depth of grooves, therefore the size of fragments is larger. **Fig. 5(A and B)** shows the surface topography of the chosen specimens tested by wear technique; this is in line with, **Pramila, et al., 1992**.

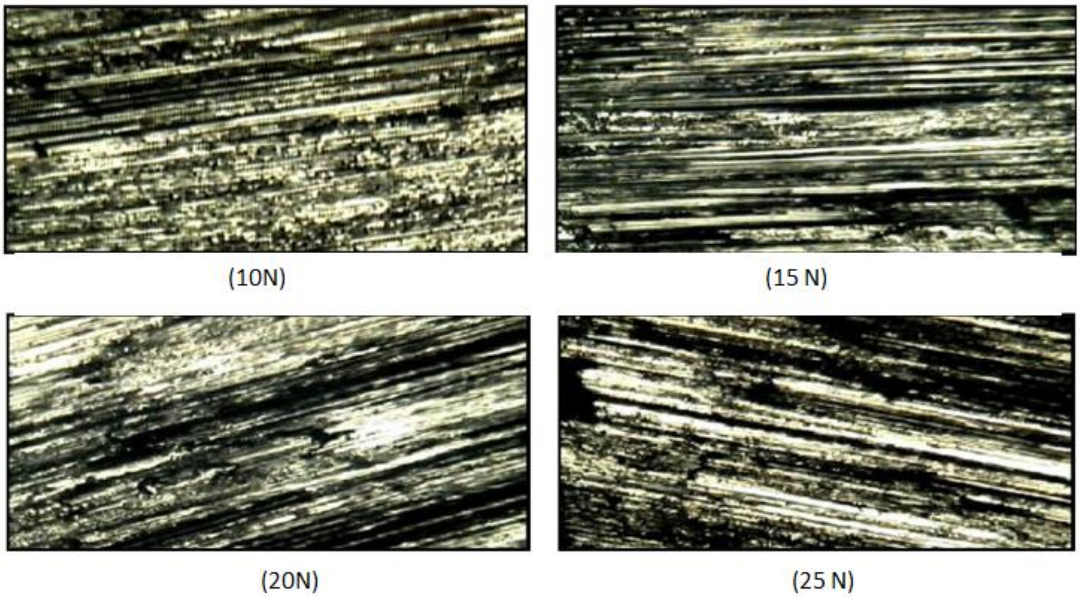

Figure 5A. Photomicrographs show surface topography of the specimens with 12 wt.% SiC for different loads.

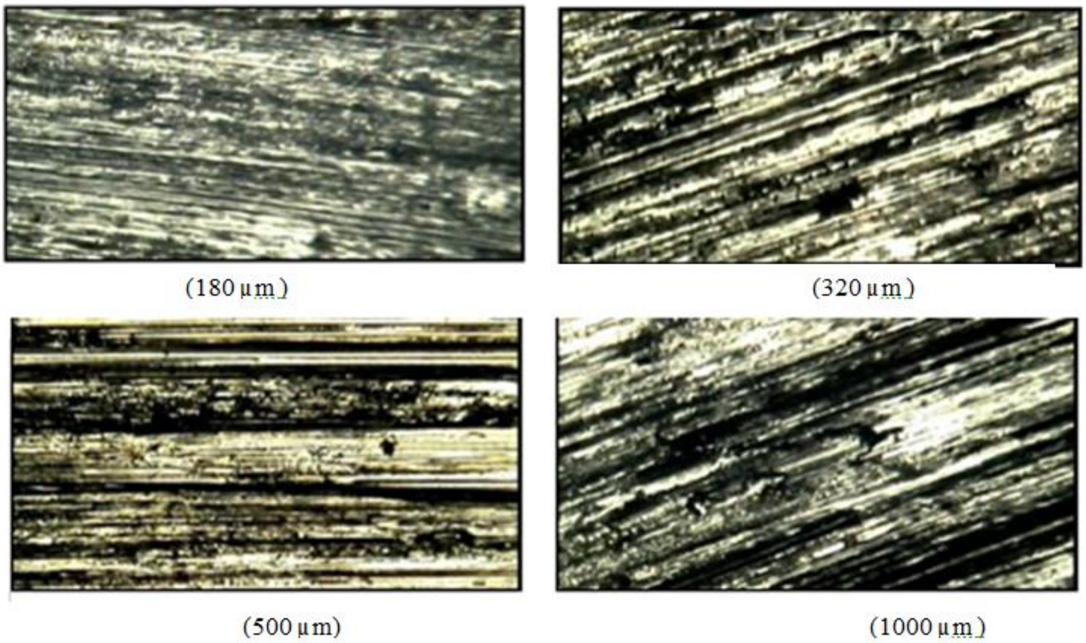

Figure 5B. Photomicrographs show surface topography of the specimens with 12 wt.% SiC for different grit size.

CONCLUSIONS

1- Increasing grit size of SiC particles leads to improve the hardness and wear resistance.
2- Wear rate decreases with increasing the grit size of emery paper.
3- Wear debris with increasing the applied loads larger than with increasing of grit size for emery paper.

REFERENCES

- -ASM Handbook of Composites, Volume 21.
- Axen, Jacobson, 1994, *Transition in the Abrasive Wear Resistance of Fiber and Particle Reinforced Aluminum*, Wear, pp. 1-7.
- Bolton W., 1988, *Engineering Materials Technology*, Butter worth Heinemann Oxford.
- Gilbert Kaufman, 2002, *Properties of Aluminum Alloys; Tensile Creep and Fatigue Data at High and Low Temperature*, ASM International.
- Gangadhar, Umashankar and V. Auradi, 2014, *Tensile and Dry Sliding Wear Behavior of Al 7075- Al_2O_3 Glass Composites*, IOSRD International Journal of Engineering, Vol.1, Issue.1, pp. 16-20.
- Pramila, Ramesh, Surappa, 1992, *Dry Sliding Wear of A 356- Al-SiC Composites*, Wear 157, pp. 295 – 304.
- Svi Pryia R., Yogeshwaran R., Syed Mohammed K, Bharathvaj S, 2016, *Investigation on Mechanical Properties of Aluminum 6061 Reinforced with SiC and Al_2O_3*, International Conference on Explorations and Innovations in Engineering and Technology, ICEIET.
- Qiyao Hu, Haidong Zhao, Fangdong Li, 2017, *Microstructures and Properties of SiC Particles Reinforced Aluminum Matrix Composites Fabricated by Vacuum-Assisted High Pressure die Casting*, Materials Science and Engineering, A680, pp. 270-277.
- Ram Prabhu, 2017, *Processing and Properties Evaluation of Functionally Continuous Graded 7075 Al Alloy / SiC Composites*, Archives Civil and Mechanical Engineering, pp. 20-31.
- Sachin Mohal, 2017, *Microstructure Investigation of Aluminum – Silicon Carbide Particulate Metal Matrix Composite Fabricated by Stir Casting*, International Journal for Innovative Research in Science and Technology, Vol.3, Issue.11, pp. 26-30.
- Sajjadi SA, Ezatpour HR, Beygi H, 2010, *Microstructure and mechanical properties of Al-Al_2O_3 Micro and Nano Composites Fabricated by Stir Casting*, In: Proceedings of 14th national conference on Materials Science and Engineering.
- Straffelini, F. Bonollo, A. Tiziani, 1979, *Influence of Matrix Hardness on the Sliding Behavior of 20 Vol% Al2O3 – Particulate Reinforced 6061 Al Metal Matrix Composite*, Wear 211, pp. 192-197.
- Veeresh Kumar, C.S.P. Rao, N. Selvaraj, M.S.Bhagyashkar, 2010, *Studies on Al 6061 – SiC and Al 7075 – Al_2O_3 Metal Matrix Composites*, Journal of Minerals and Materials Characterization and Engineering, Vol.9, No.1, pp. 43-55.