© 2019IJSRST | Volume 6| Issue 2| Print ISSN: 2395-6011 | Online ISSN: 2395-602X
Themed Section: Science and Technology
doi : https://doi.org/10.32628/IJSRST

Effect of Heat Treatment on Corrosion Behaviour of Al6061 Alloy and its SiC Reinforced Composites

Lokesh T[*1], Mallikarjuna H M[2], U S Mallik[3]
[*1, 2]Department of Mechanical Engineering, Government Engineering College, Krishnarajapete, Karnataka, India
[3]Department of Mechanical Engineering, Siddaganga Institute of Technology, Tumkur, Karnataka, India

ABSTRACT

In the present work, Al6061 alloy with varying composition of 2% - 10wt% in steps of 2wt. % SiC particles reinforced composites were developed using conventional stir casting process. The cast composites have been subjected to solutionizing heat treatment at a temperature of 5250 ± 20C for 6 hours followed by ageing at a temperature of 1750 ± 20C for 6 hours. The Corrosion testing of Al6061-SiC composites was conducted using potentiodynamic polarization electrochemical methods. The Al6061 alloy and its composites after heat treatment process displayed low corrosion rate and high corrosion resistance when compared to that of as cast ones. As cast Al6061 composite with 10% SiC content has undergone more corrosion than any other Al6061-SiC composite. The Al6061-2%SiC composite system had low corrosion rate than rest of the composites. Based on strong interfacial bonding with matrix material and less number of micro-porosities, the heat treated alloy and composites displayed less corrosion rate and high corrosion resistance.

Keywords: Al6061, SiC, Corrosion, Heat Treatment, Electron Microscopy

I. INTRODUCTION

Aluminium and its alloys have huge applications in the area of automotive and aerospace applications as well as in Architectural applications. The development of low-density, high- strength aluminium alloys have generated much interest many industries. That is why researchers across the world have developed composite materials using organic and ceramic based materials as reinforcement [1]. Al6061 is better choice for a matrix material among the various series of aluminium alloys, because it has excellent mechanical properties, good formability and the strength of this material can be altered by doing the heat treatment [2]. Most commonly used reinforcements are SiC, Al_2O_3, graphite, TiB_2, TiC, B_4C and carbon nanotubes. The stir casting method is found to be easier and the low cost method when compared to other processing methods, particularly when discontinuous reinforcements are used [3, 4].

Particulate-reinforced Al-based MMCs find applications in various thermal environments, especially in automobile engine parts, such as drive shafts, cylinders, pistons, brake rotors and in space applications [5]. MMCs used at high temperatures should have good mechanical properties and resistance to chemical degradation in air and acid environments [6]. It is therefore essential to have a thorough understanding of the corrosion behaviour of such MMCs. Most of the authors reported the susceptibility to corrosion of aluminium based alloys and composites in NaCl solution. The pitting phenomenon is observed surrounding the secondary particles like the reinforcements in the composites where the pits are initiated in the vicinity of the ceramic reinforcements [7]. The formation of surface film controls the pitting behaviour which in turn depends on the reinforcement content in the matrix and the NaCl concentration. Saxena et al [8] studied the corrosion behaviour of aluminium alloy 6061 reinforced with graphite particles using immersion technique. The Al6061 alloy underwent significant weight loss after 36 days of immersion in HCl solution while the composite showed a minimal weight loss. Ahmad and Aleem [9] studied the corrosion properties of Al6092 alloy reinforced with SiC particles. The results obtained showed that the composites which had undergone heat treatment process showed high resistance to corrosion. The high resistance offered was attributed to the uniform dispersion of SiC particles and precipitates. Almomani et al [10] studied the corrosion behaviour of friction stir welded Al-Mg composites reinforced with SiC and graphite particles. The results showed the composite processed with high welding speed and low rotational speed displayed low corrosion rate compared to others. In case of high welding speed, the contact between the tool and the welded composite is less which helps in high rate of solidification leading formation of fine grains. These fine grains reduce the area ratio of anode and cathode in the galvanic couple produced in the composite, thus reducing the corrosion rate.

The objective of this work is to develop Al6061 composites by low cost liquid metallurgy route and subject it to T6 solutionizing heat treatment. The effect of SiC content and heat treatment process on corrosion properties of Al6061 composites will be studied.

II. METHODS AND MATERIAL

The matrix material for the research study selected is Al6061 and SiC was selected as reinforcement which had density of 3.1 g/cc. The composites prepared had SiC content in the range of 2 to 10 wt%. Initially the Al6061-SiC composite were prepared using liquid metallurgy route in which Al6061 alloy ingots were charged into the graphite crucible and melted using electric resistance furnace up to a temperature of 750°C. The SiC particles of 10 to 30μm size were preheated at 600°C for a soaking period of 2 hours to improve wetness and remove moisture, the adsorbed hydroxide and other gases from the surface. The molten metal was agitated by use of mechanical stirrer rotating at a speed of 300 – 400 rpm to create fine vortex. The mechanical mixing of the matrix and the reinforcement were ensured by stirring it for 10 minutes using zirconium coated steel impeller at a speed of 300- 400 rpm before pouring it into the cavity of the pre heated finger mould split metal die at 720°C. The cast composites were subjected to T6 heat treatment cycle consisting of solutionizing at temperature of 525°C for 6 hours, quenched in hot water at 60°C followed by stabilization at room temperature for 3 hours. Finally, artificial aging was carried out at a temperature of 175°C for 6 hours followed by natural air cooling to room temperature.

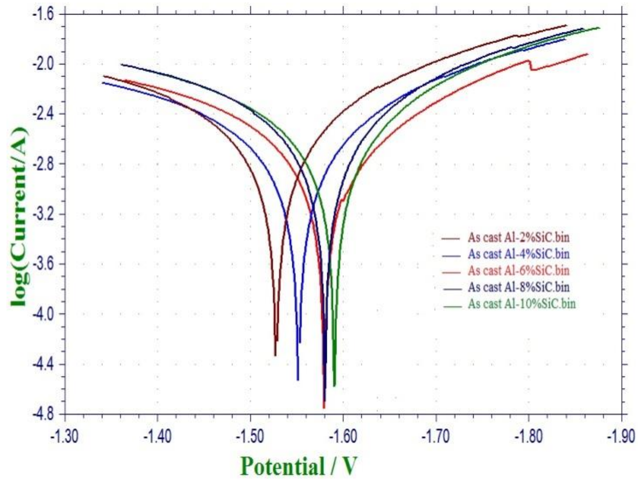
CORROSION TESTING

The Corrosion testing of Al6061-SiC composites was conducted using potentiodynamic polarization electrochemical methods. All the experiments were performed using a three-electrode corrosion cell set-up comprising the sample as the working electrode, saturated silver/silver chloride as reference electrode, and platinum as counter electrode. Working electrodes were prepared by attaching an insulated copper wire to one face of the sample using aluminium conducting tape, and cold mounting it in resin. The surfaces of the samples were wet ground with SiC as per ASTM standard, washed with distilled water, degreased with acetone and dried in air. Specimens for corrosion tests were fabricated with dimensions (1×1×0.5 cm) according to ASTM specifications for all metals used. The anodic polarization curves of the Al6061-SiC composites were obtained by sweeping a potential range from -2.5 to 3 V (vs. SCE.) with a scan rate of 5 mV/s. A linear data fitting of the standard model gives an estimate of the polarization resistance, which used to calculate the corrosion current density (I_{corr}). The microstructure of the surface of the alloy specimens after corrosion was imaged using an electron microscope and analysed.

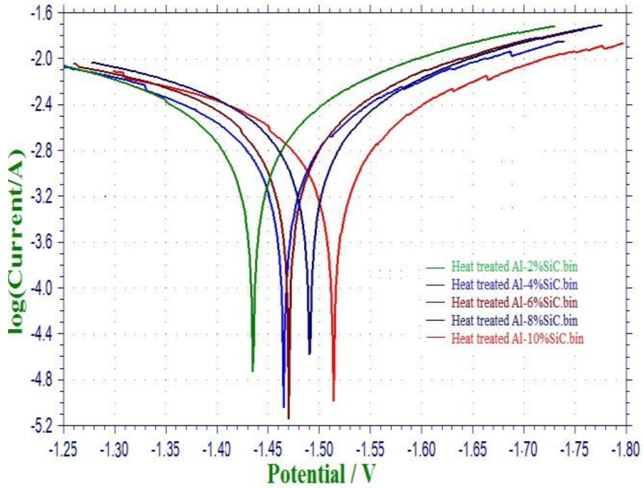
III. RESULTS AND DISCUSSION

A. Corrosion Behaviour

The Potentio-dynamic polarization curves for Al6061-SiC composite system fabricated using two different processing techniques are shown in Fig. 1. For all the composite systems the polarization curves all similar in appearance where smooth and linear changes in current are observed. Fig. 2 shows the polarization curves for Al6061-2%SiC composite system because this is one which had low corrosion rate than rest of the composites. It can be observed from the polarization curves that, out of all Al6061 composite with 2% SiC content have shown highest corrosion resistance in all the two processing conditions as revealed by the i_{corr} values (see Fig. 3). On the other hand, Al6061 composite with 10% SiC content has undergone more corrosion than any other Al6061-SiC composite processed using two different processing conditions.

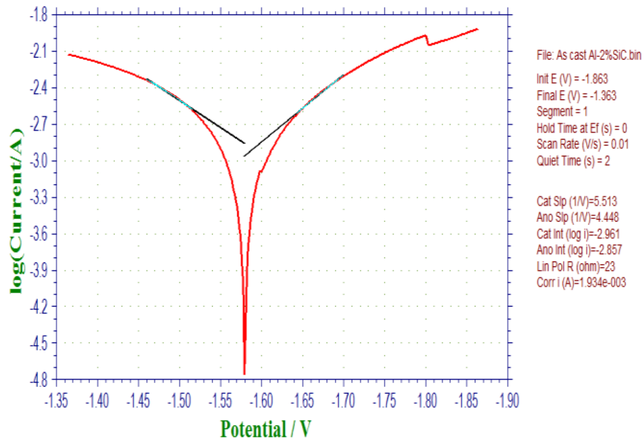


(a) As cast

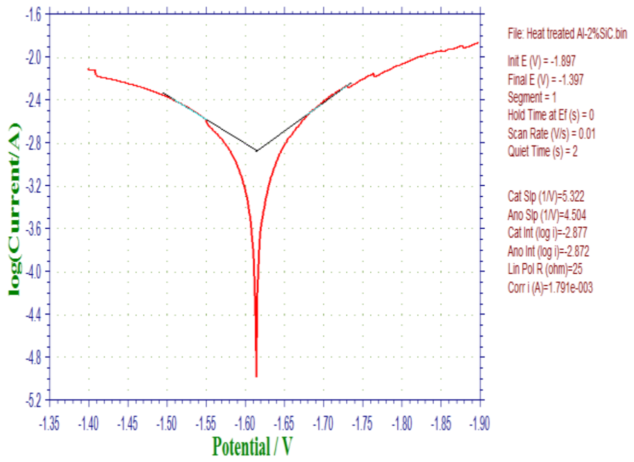


(b) Heat treated

Figure 1: Potentio dynamic polarization curves for Al6061-SiC composite system processed at different conditions.



(a) As cast



(b) Heat treated

Figure: 2 Potentio dynamic polarization curves for Al6061-2%SiC composite system processed at different conditions.

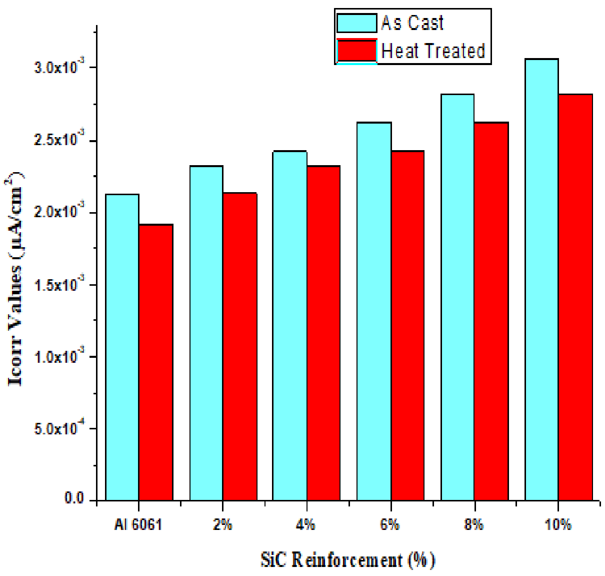
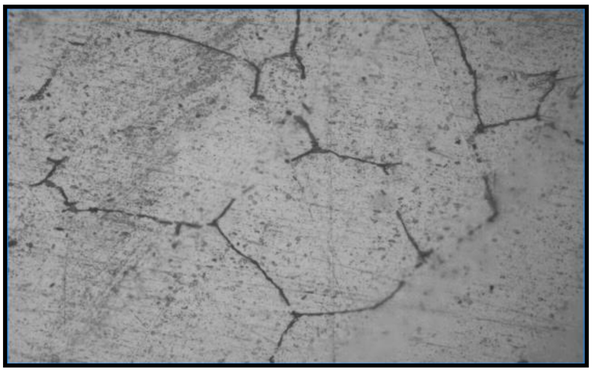


Figure: 3 I_{corr} values for all the Al6061-SiC composite systems processed under different processing condition.

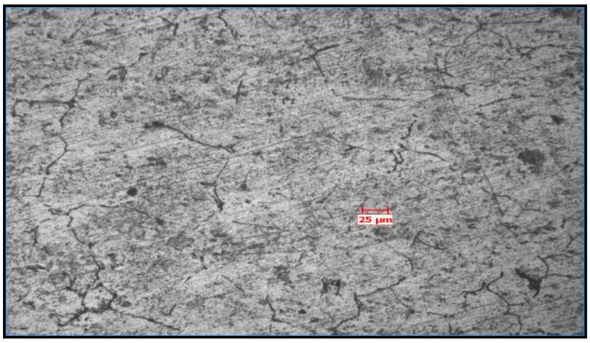
Overall heat treated composites displayed better corrosion resistance when compared to that of as cast composites. The decrease in corrosion resistance of as cast composites can be attributed to presence of micro porosities and clusters of SiC particles. Further SiC particles act as cathode in these composites which shifts the anodic potential of Al6061 alloy towards cathodic side leading to higher corrosion rate in as cast conditions as compared to that of heat treated ones. This is because the depth of penetration and interfacial bonding is very high in case of heat treated composites [10, 11].

B. Corroded Surface Analysis

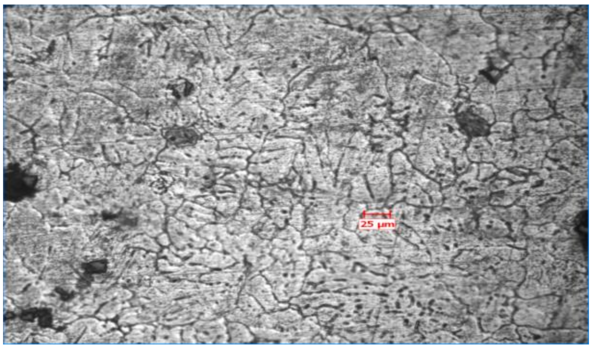
In order to understand the degradation of Al6061 alloy and composites after corrosion, optical microscopy studies were conducted. Fig. 4 and 5 shows the optical micrographs of Al6061 alloy and Al6061-SiC composite before and after subjected to corrosion in 3.5% NaCl solution. It can be observed from Fig. 4 that the microstructure of the all materials is clean and the grain boundaries are clearly visible with SiC particles located in them. Fig. 5 shows the optical micrographs of all materials after corrosion testing. It can be observed that including Al6061 alloy, the composites suffered corrosion at the grain boundaries and at the matrix -reinforcement interface. Due to adsorption of Cl^{-}, the high energy areas like grain boundaries and Al6061-SiC interface are more prone to corrosion. As observed in optical micrographs, the corrosion is seen as dark or black coloured regions mainly at the grain boundaries and around the reinforcements.



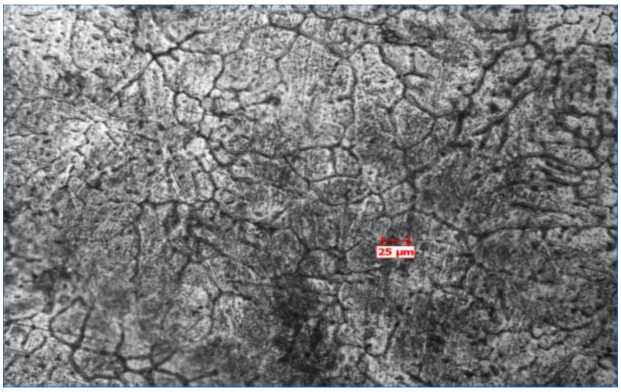
(a) Al6061 alloy



(b) Al6061-2%SiC

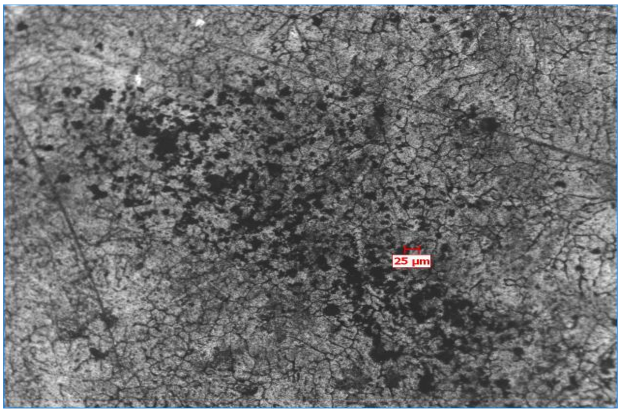


(c) Al6061-6%SiC

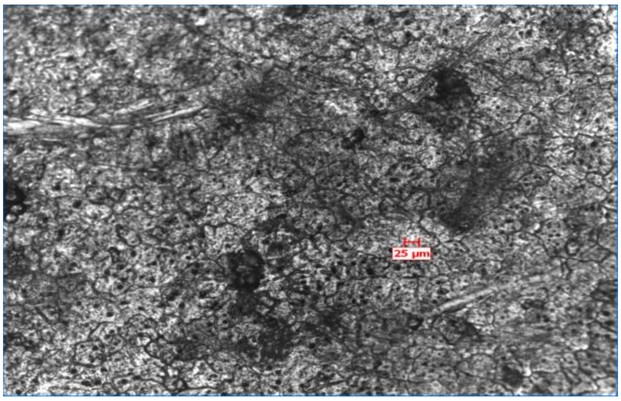


(d) Al6061-8%SiC

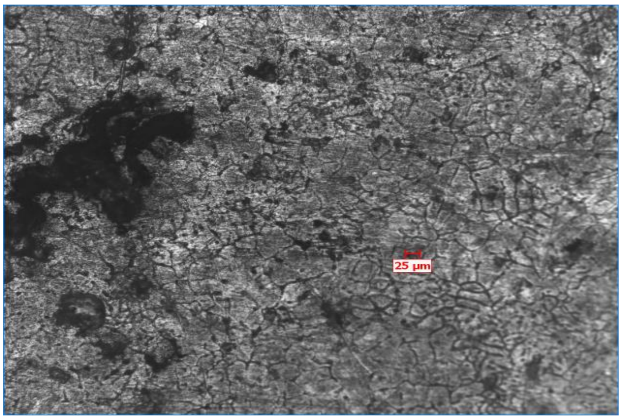
Figure: 4 Optical micrographs of Heat treated materials before corrosion.



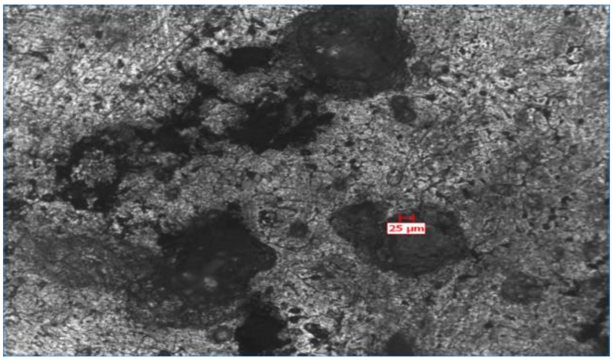
(a) Al6061 alloy



(b) Al6061-2%SiC



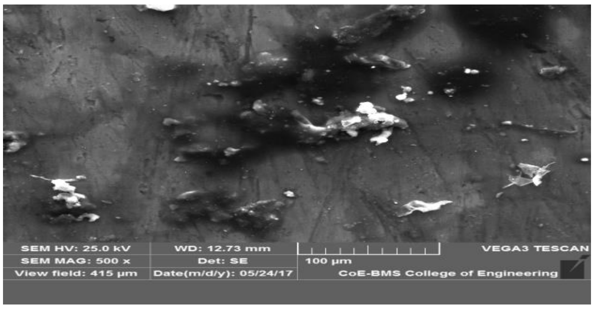
(c) Al6061-6%SiC



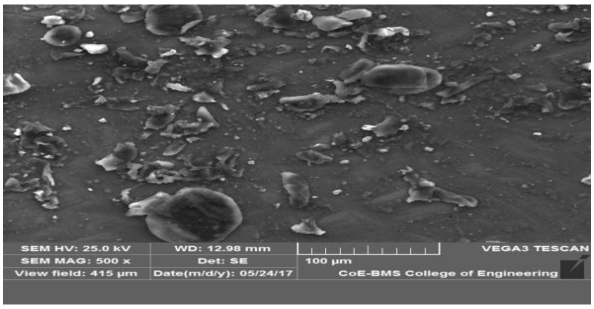
(d) Al6061-8%SiC

Figure: 5 Optical micrographs of Heat treated materials after corrosion.

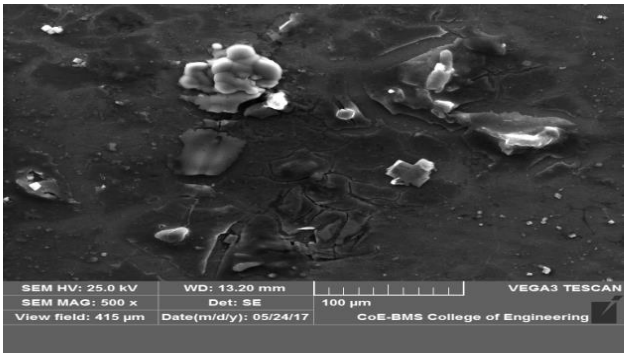
In case of Al6061 alloy shown in Fig. 5 (a), the intermetallics like $CuAl_2$ and Mg_2Si are possible sites for corrosion attack along with the grain boundaries. These intermetallics are highly conductive at room temperature and enhance corrosion rate in the alloy. The presence of micron sized pits near SiC particles in Al6061-SiC composite induces galvanic corrosion within the Al6061 matrix. The localized corrosion attack at the SiC and Al6061 interface lead to pit formation. Heat treatment process imparts strong interfacial bonding with matrix material along and decreases the number of micro porosities. This is why we have observed high corrosion resistance in heat treated composites which are well supported by the SEM micrographs presented in the Fig. 6 (b), (c) and (d). The heat treated Al6061 and its composites have good bonding with matrix and reinforcement with almost negligible porosity. With high dense composites and low surface pores the adherence of passive layer will be strong thereby enhancing the corrosion resistance [12].



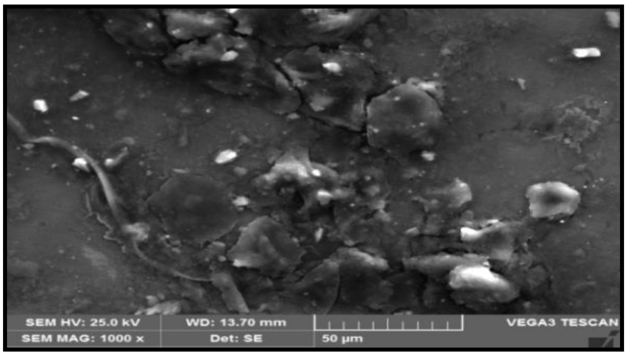
(a) Al6061 alloy



(b) Al6061-2%SiC



(b) Al6061-6%SiC



(d) Al6061-8%SiC

Figure: 6 SEM micrographs of Heat treated materials after corrosion.

IV. CONCLUSION

An attempt was made to develop Al6061 alloy and SiC reinforced composites using stir casting method. The effect of heat treatment and varying SiC content on corrosion behaviour of Al6061 composites was studied. Based on the corrosion testing following concluding remarks were made

- The Al6061-2%SiC composite system had low corrosion rate than rest of the composites.
- The As cast Al6061 composite with 10% SiC content has undergone more corrosion than any other Al6061-SiC composite processed using two different processing conditions.
- The heat treated alloy and composites displayed less corrosion rate and high corrosion resistance.
- The high corrosion resistance in heat treated Al6061-SiC composites is due to strong interfacial bonding with matrix material and less number of micro-porosities.

REFERENCES

[1] ASM Handbook, *Composites. ASM International*, Vol 21, pp1029-1032, 2001.
[2] M K Surappa, Sadhana, Vol 28, pp319-334. 2003.

[3] Lokesh T, U. S. Mallik, Effect of ECAP process on the Microstructure and Mechanical Properties of Al6061-Gr Composites, *Materials today Proceedings, Elsevier,* Vol 5, pp2453-2461, 2018.

[4] M.A. Taha, Practicalization of cast metal matrix composites (MMCCs), *Materials and Design* Vol 22, pp 431-441, 2001

[5] S. Elomari, R. Boukhili, D.J. Lloyd, Thermal expansion studies of prestrained Al2O3/Al metal matrix composites, Compos. Sci. Technol. 44, 1873. 1996.

[6] S.C. Sharma, Effect of aging on oxidation behaviour of aluminum–albite composites at high temperatures, J. Mater. Engng Perf. 9, 344–349, 2000.

[7] Lokesh T, Mallikarjuna H M, U S Mallik, Effect of Heat Treatment on Corrosion behaviour of Al6061 alloy and its graphite reinforced composites, International Journal of Emerging Technologies and Innovative Research, Voume 6, Issue 3, pp 226-230, 2019.

[8] M. Saxena, A.K. Jha, G.S Upadhyaya, Corrosion behaviour of sintered 6061 alloy-graphite particle composites, *Journal of Materials Science*, Vol28, pp4053-4058, 1993.

[9] M. Almomani, A.M. Hassan, T. Qasim, A. Ghaithan, Effect of process parameters on corrosion rate of friction stir welded aluminium SiC–Gr hybrid composites, *Corrosion Engineering, Science and Technology*, Vol 48, pp346-353, 2013.

[10] [8]. Z. Ahmad, B.J.A. Aleem, The mechanical properties and localized corrosion of Al 6092 composite in arabia seawater, *Materials and Manufacturing Processes*, Vol18, pp643-651, 2003.

[11] X. Wang, G. Chen, W. Yang, Q. Guo, G. Wu, D. Jiang, Effect of Magnesium Content on the Corrosion Behaviors of Grf/Al Composite, *Metallurgical and Materials Transactions* A 41, pp3458-3462, 2010.

[12] M. Rahsepar, H. Jarahimoghadam, The influence of multipass friction stir processing on the corrosion behaviour and mechanical properties of zircon-reinforced Al metal matrix composites, *Materials Science & Engineering A* 671, pp214–220, 2016.