iJRASET
International Journal For Research in
Applied Science and Engineering Technology

INTERNATIONAL JOURNAL FOR RESEARCH
IN APPLIED SCIENCE & ENGINEERING TECHNOLOGY

Volume: 11 Issue: V Month of publication: May 2023

DOI: https://doi.org/10.22214/ijraset.2023.52602

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International Journal for Research in Applied Science & Engineering Technology (IJRASET)
ISSN: 2321-9653; IC Value: 45.98; SJ Impact Factor: 7.538
Volume 11 Issue V May 2023- Available at www.ijraset.com

Evaluation of Mechanical Properties and Corrosion Behavior of Stir Cast Hybrid Composites Based on LM13 Aluminum Alloy Reinforced with Zirconium Diboride (ZrB2) and Titanium Carbide (TiC) Particles

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Abstract: In the LM13 alloy matrix, ceramic titanium carbide (TiC) and zirconium diboride (ZrB2) particles were used to create and characterise hybrid composites. TiC's weight percentage stayed constant at 5% whereas ZrB2's weight percentage was changed from 0% to 10%. The microstructure of the composites was analysed using an optical microscope after they were made using the liquid metallurgy stir casting technique. The mechanical properties of the composites, including their tensile strength, ductility, and hardness, were evaluated and compared to those of the LM13 alloy without reinforcement.

The study also investigated the dry sliding wear properties of the composites and LM13 alloy using a pin-on-disk tribometer. Researchers examined how weight loss, wear rate, and friction coefficient were affected by sliding distance and the proportion of reinforcing weight. The cracked surface of the tensile test samples and the dry sliding worn surface of the pin samples were studied using a field emission scanning electron microscope. The results showed that the hardness, tensile strength, and wear resistance of the hybrid composites increased with the weight % of ZrB2 in LM13 matrix. After a 500 m run, the sliding distance caused a reduction in the amount of wear in pin samples. The cumulative weight loss of the composites increased with the applied load throughout the wear test. When compared to the unreinforced LM13 aluminium alloy, the LM13-10ZrB2-5TiC hybrid composite shown a noticeable improvement in hardness, ultimate tensile strength, and wear resistance.

A field emission scanning electron microscope analysis of the worn surface showed that the wear process changed with increasing load, progressing from moderate abrasive wear to severe delamination. The ZrB2 and TiC particle-reinforced hybrid composites shown improved mechanical and tribological properties when compared to the TiC reinforced composite and the LM13 alloy, according to the study.

Keywords: Aluminum metal matrix, Reinforcement, Zirconium diboride (ZRB_2), Titanium carbide (TIC), Stir casting, Coating, Corrosion Resistance.

I. INTRODUCTION

The term "corrosion resistance" describes a substance's capacity to endure deterioration or damage brought on by chemical reactions, particularly oxidation, when it comes into contact with its environment. To put it another way, corrosion resistance is a material's capacity to withstand rusting, corrosion, or degradation over time. When exposed to corrosive environments like saltwater, acidic substances, or high temperatures, materials with good corrosion resistance are still able to keep their physical and chemical properties. Stainless steel, aluminium, several types of plastics, and ceramics are typical examples of corrosion-resistant materials. There are several good reasons to educate yourself on corrosion resistance.

A. Professional Interest

If you work in a field that involves materials engineering, construction, manufacturing, or any other industry where exposure to harsh or corrosive environments is a concern, understanding corrosion resistance is essential. It can help you select the right materials for your project, design effective corrosion prevention strategies, and ensure the longevity and safety of your products or structures.

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A material's ability to withstand chemical reactions with its surroundings, such as exposure to moisture, salt, or other corrosive elements, is referred to as corrosion resistance. Corrosion, surface deterioration, coating failure, galvanic corrosion, and environmental variables are a few typical issues with corrosion resistance. ZrB2 (zirconium diboride) and TiC (titanium carbide) are two materials that have been researched for their possible usage in hostile settings when it comes to corrosion reinforcing materials. Due to their great strength, hardness, and resistance to corrosion, these materials make good options for materials reinforcement in severe environments. According to these investigations, aluminium can enhance the mechanical capabilities of ZrB2 and TiC substrates while also exhibiting superior corrosion resistance. However, additional study is required to completely comprehend how aluminium behaves on these materials in a variety of challenging situations and to improve the composites' fabrication procedures.

Table 1. Chemical composition of the LM 13 Aluminium alloy

Alloy	Si	Fe	Cu	Mn	Mg	Zn	Ni	Al
Wt %	7	0.2	0.2	0.1	0.35	0.05	0.05	92.05

B. Materials

In this present study, LM13 aluminium alloy was used as basemetal matrix and its chemical compositionis shown inTable1.Two hard ceramic particles such as titanium carbide (TiC) with an average particlesize of 15-35µm and zirconiumdiboride(ZrB2) with anaverage particlesize of 25-48µm was added as reinforcements in LM13 alloy. Weight percentage of ZrB2varied from (0-10) along witha constant5wt% of TiC to produce composites. The specific details of wt% of reinforcements used inthis present work arelisted The composites consist of LM13 aluminium alloy with (0,2.5,5and 10)wt% of ZrB2 and a constant 5wt% of TiC particles were fabricated using bottom pouring type stircasting setup.

Next discussed about stir casting: The stir casting process is a relatively simple and inexpensive method of producing MMCs, and it can be used to produce a wide range of composite materials with various properties. The resulting composite material produced by stir casting can exhibit improved properties such as increased strength, stiffness, and wear resistance compared to the base metal.

After that we discussed about nickel coating on LM13 Aluminium base metal : The nickel coating on aluminum can provide several advantages, including improved wear and corrosion resistance, increased hardness, and enhanced electrical conductivity.

After that we discussed about Literature Review, Methodology, SEM analysis and Results.

(a). LM13 Aliminium base metal

(b).ZRB_2 Powder

(c).TIC Powder

II. LITERATURE REVIEW

In comparison to unreinforced alloy, particles reinforced aluminium based composites, a family of MMCs, have been discovered to have superior strength and stiffness at high temperatures, high hardness, good stability to thermal gradient, and greater wear resistance.They were appropriate for prospective applications in the automotive, aerospace, and structural sectors due to their appealing qualities [5]. Due to the wide range of applications for which LM13 aluminium alloy can be used as pistons in the automotive and aerospace industry, it is chosen as a matrix in this study. When compared to pure aluminium, its 10-12% silicon content offers greater mechanical and wear resistance [6,7]. The use of the suitable ceramic reinforcing particles and composite construction techniques can improve the various properties of the LM13 aluminium alloy. A major challenge is achieving uniform dispersion of reinforcing particles in the continuous phase of the composite, as this has a significant impact on the characteristics and casted quality.It is true that metal matrix composites (MMCs) with reinforced aluminum-based composites have better strength, stiffness, hardness, and wear resistance than unreinforced alloys.

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These qualities make them perfect for a variety of applications in the structural, aerospace, and automotive industries.A promising matrix material for this kind of composite is the LM13 aluminium alloy, which has a silicon content of 10-12% and outstanding mechanical properties. Incorporating appropriate ceramic reinforcing particles and using the right fabrication methods can further enhance the properties of LM13 alloy.

Achieving uniform dispersion of reinforcement particles in the continuous phase of the composite is crucial since it has a significant impact on the composite's properties and quality. Uneven distribution of reinforcement particles can result in defects and reduce the overall strength of the composite. Therefore, ensuring a uniform distribution of reinforcement particles is a primary concern during composite fabrication.

It is true that there are various methods used for the fabrication of particle reinforced aluminum matrix composites, including squeeze casting, powder metallurgy, stir casting, and compo casting. Among these methods, stir casting is often preferred because it is flexible, economical, and well-suited for mass production and the creation of near net shape components. Stir casting allows for the addition of higher volume fractions of reinforcement particles (up to 30%) and ensures uniform dispersion of these particles in the matrix phase. Overall, stir casting is a versatile and effective method for the fabrication of particle reinforced aluminum matrix composites.

III. METHODOLOGY

we choosing the LM13 Aluminium as base metal, adding ZRB_2 and TIC as reinforcement materials. Applying the nickel coating on LM13 aluminium base metal. Proper design of the metal component or structure to minimize contact with the corrosive environment.

A. Stir Casting Process

Metal matrix composites (MMCs) are frequently created using the stir casting process. A ceramic-reinforced MMC with outstanding mechanical qualities and great wear resistance is aluminium zirconium diboride titanium carbide (AlZrB2TiC).

The steps in the stir casting procedure for an MMC made of aluminium and reinforced with ZrB2 and TiC are as follows:

1) *Preparing the Materials:* The ceramic powders of TiC, ZrB2, and aluminium base metal are measured out and combined in the specified ratios. To produce a homogeneous combination, the powders are then ball-milled.
2) *Melting:* Using either an electric resistance furnace or a gas-fired furnace, the combined powder is then put into a crucible and melted. Usually, the temperature is kept between 700 and 800 °C.
3) *Stirring:* When the molten mixture is ready, stirring is started with an impeller or stirrer. Typically, the stirring speed is maintained between 500 and 1000 rpm.

- *Ceramic powder addition:* The ceramic powders (ZrB2 and TiC) are gradually added to the molten aluminum base metal while stirring continues. The addition of the ceramic powders is typically done in small increments to ensure uniform dispersion.
- *Degassing:* After the ceramic powders are added and mixed thoroughly, the molten mixture is subjected to a degassing process. This step is essential to remove any trapped gases or impurities in the molten metal, which can negatively affect the properties of the final composite.
- *Casting:* After the degassing step, the molten mixture is poured into a preheated mold. The mold can be made of sand, graphite, or steel, depending on the required shape and size of the final product.
- *Cooling and Solidification:* Once the molten mixture is poured into the mold, it is allowed to cool and solidify. The cooling rate can be controlled by adjusting the mold temperature or using water cooling.
- *Post-processing:* After solidification, the MMC is removed from the mold and undergoes further post-processing steps such as machining, polishing, and heat treatment, depending on the desired final properties.

Overall, the stir casting process for aluminum-based MMCs reinforced with ZrB2 and TiC involves the preparation of the material, melting, stirring, ceramic powder addition, degassing, casting, cooling, and post-processing steps.

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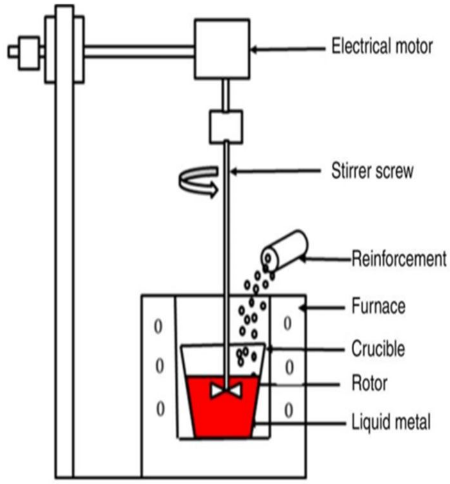


Fig.:Stir casting

B. Coating

An aluminium substrate is covered with a layer of nickel by the process of nickel coating. This procedure is frequently used to increase aluminum's electrical conductivity, corrosion resistance, and wear resistance. The nickel coating can be applied in a number of ways, including dipping, to the aluminium substrate.
The required coating thickness and qualities, as well as the dimensions and shape of the aluminium substrate, all have a role in the coating process selection.
A nickel coating on aluminium can have a number of advantages, including better wear resistance, enhanced corrosion resistance, and increased electrical conductivity.

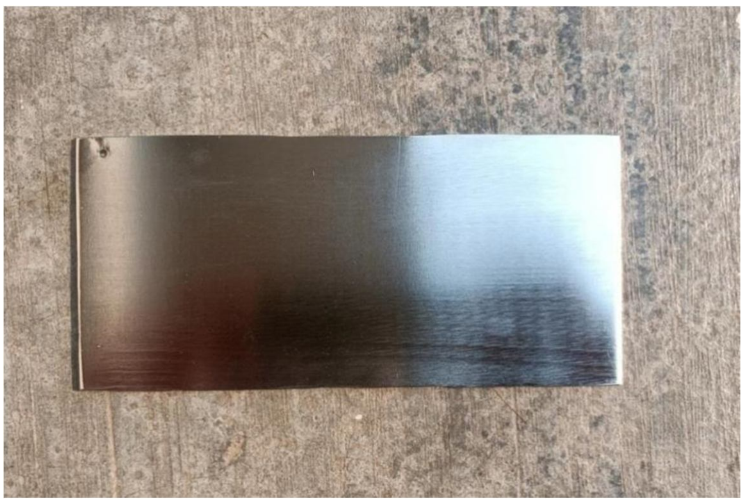


Fig: Nickel Coating

C. Corrosion Testing

Corrosion testing is crucial for figuring out how materials behave in simulated service situations and can help to guarantee that they will last for the anticipated design life. Corrosion testing can be used to compare various materials, gauge a material's behaviour in highly corrosive environments, and anticipate a material's resistance to corrosion. Producers can learn whether coating operations are being carried out according to specifications with the use of corrosion testing. To ensure that the materials used in industrial applications adhere to quality standards, testing is necessary. In order to analyse the discharge of waste form components into solution during waste form deterioration, the passage outlines corrosion testing techniques. For many materials, including metals and oxide materials like glasses, various corrosion test methodologies have been devised.

However, the mass loss by itself is unable to separate the proportional contributions of localised or intergranular corrosion from generalised corrosion. Prior to being weighed in accordance with ASTM G31, the corrosion products from reacted specimens are removed. To comprehend the corrosion mechanism, more investigations are thus required. To find pitting and identify corrosion products, microscopic investigations of reacted specimens can be carried out. Due to its higher performance compared to single reinforced MMCs, hybrid metal matrix composites (HMMCs) are gaining a lot of attention from researchers. Due to their ability to combine the best qualities of the matrix material and reinforced constituents, HMMCs have the potential to satisfy the requirements of many advanced engineering sectors. Hybrid aluminum-based matrix composites have received a lot of attention in research that examine how varied reinforcement quantities affect mechanical and tribological properties. For instance, Kumar AA2618-based hybrid composites with different weight ratios of AlN, Si3N4, and ZrB2 reinforcing particles were created using a stir casting process. Jeyaprakasam created hybrid AA6061 matrix composites with TiC and graphite particles using a similar procedure. The researchers discovered that when the volume fraction of soft graphite particles in the matrix decreased, the hardness of the composites increased. Additionally, as the weight % of TiC and graphite particles increased, the rate of wear in the composites reduced. Overall, it appears that HMMCs have the potential to significantly improve the performance of metal matrix composites and may find widespread use in advanced engineering fields.

IV. CONCLUSION

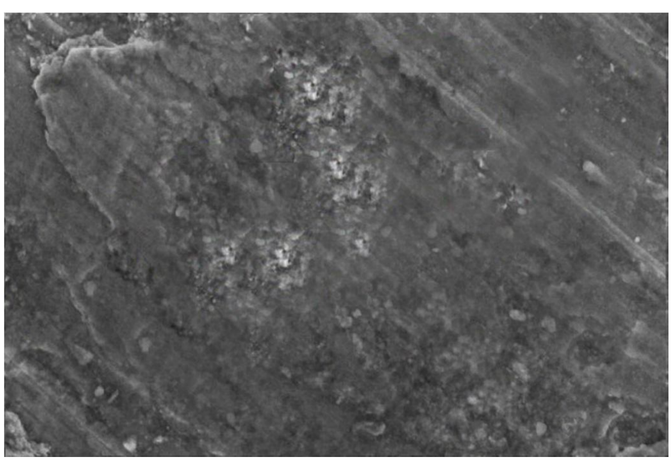
Using the stir casting method, TiC and ZrB2 particles were added in various weight percentages to create LM13 aluminium alloy based hybrid composites. The reinforced particles were efficiently disseminated throughout the matrix and refined the alloy grains, according to the microstructural examination. The composites' ductility reduced as reinforcement particles were added, but their hardness and ultimate tensile strength significantly increased. The tribological behaviour of the composites was also assessed, and it was discovered that the coefficient of friction was lower than that of the unreinforced alloy and that the amount of sliding wear decreased with increasing weight percentage of reinforcements. It was discovered that the composites fracture process involved both ductile ripping of the matrix and brittle fracture of the reinforced particles. The worn surface analysis showed that the wear process changed at higher loads from mild abrasive wear to severe delamination. The superior mechanical and tribological characteristics of the hybrid composites made them appropriate for a variety of applications.

V. RESULTS

A. Microstructure Analysis

1) SEM Analysis

Following potentiodynamic tests, the specimens underwent Scanning Electron Microscopy (SEM) analysis, which showed that the composites' surface displayed substantial pitting. The interface of the grain boundaries was where pitting was most prevalent. The sample with the most prominent surface 45 pitting was sample A, which included 5 wt% RHA and 5 wt% ESA. The degree of pitting and corrosion increased along with the proportion of RHA. It has been noted by other researchers that Metal Matrix Composites (MMCs) corrosion frequently starts at a physical or chemical heterogeneity, such as a reinforcement/matrix interface, a defect, an intermetallic, a mechanically damaged region, a grain boundary, or an inclusion.



(a) Mixed reinforcement

International Journal for Research in Applied Science & Engineering Technology (IJRASET)
ISSN: 2321-9653; IC Value: 45.98; SJ Impact Factor: 7.538
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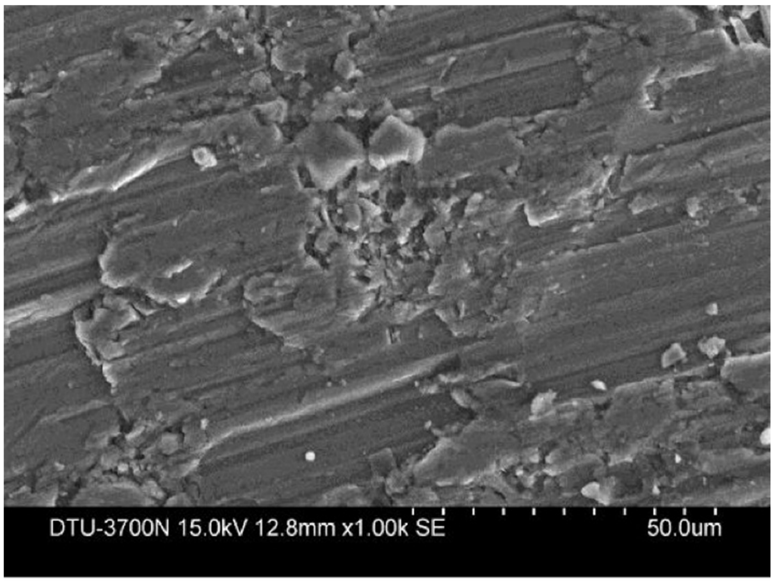
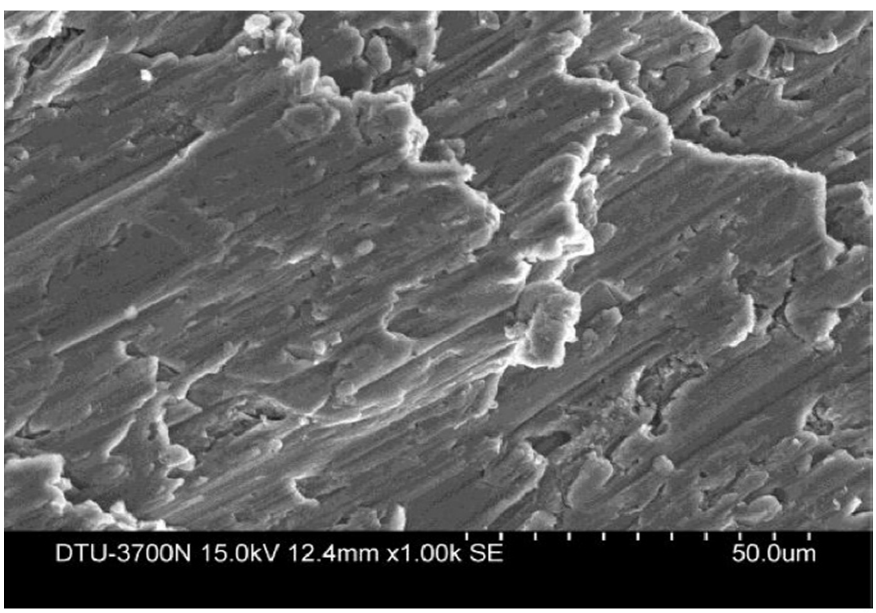
Corrosion Actions In Fig. 4, the polarisation plots of the A356 base alloy are labelled. According to the figures, the corrosion potential (Ecorr) of the A356 base material is -334 mV. Fig. 5 shows the results of the potentiodynamic analysis performed on the specimens with reinforcement. According to the Tafel plots, the protective surface oxide coatings become increasingly discontinuous as the amount of RHA in the composites rises. As a result, sample B (A356 + 10% RHA) has a higher level of discontinuity than the other samples.

According to the figures, the corrosion potentials for samples A, B, and C are, respectively, -267.93 mV, -250.37 mV, and -324.03 mV. The sample B showed the most positive potential among the three different reinforcement percentages examined, followed by the sample A with the second-highest potential, and the sample C with the least positive potential.

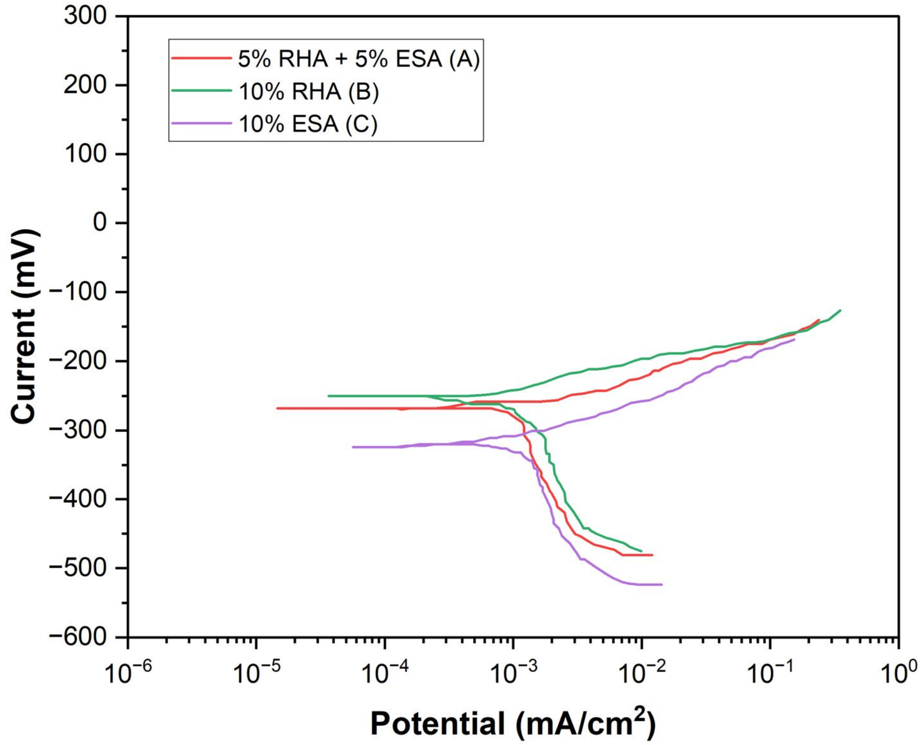


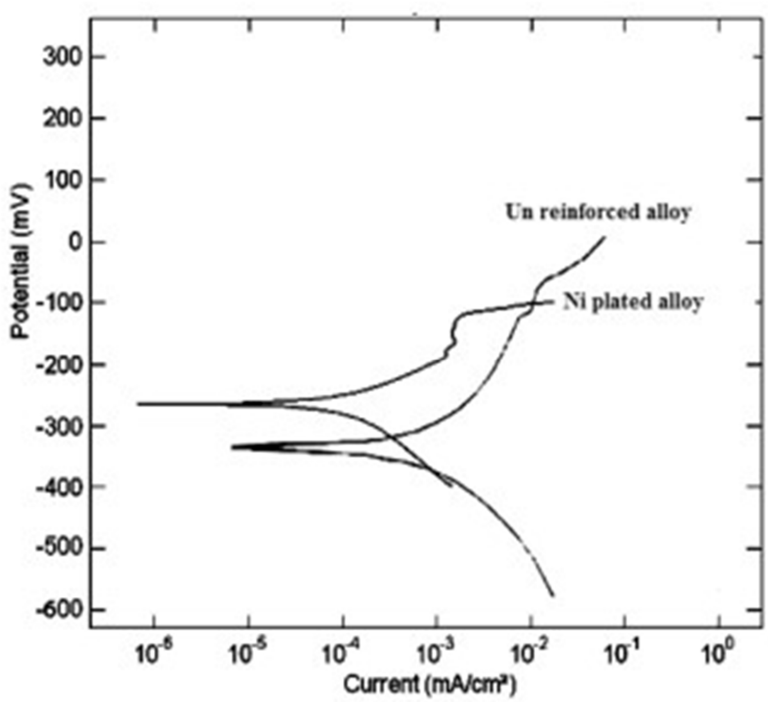
(b). SEM images of sample 1 (Low flyash content) after wear test.



(c). SEM images of sample 3 (High flyash content)

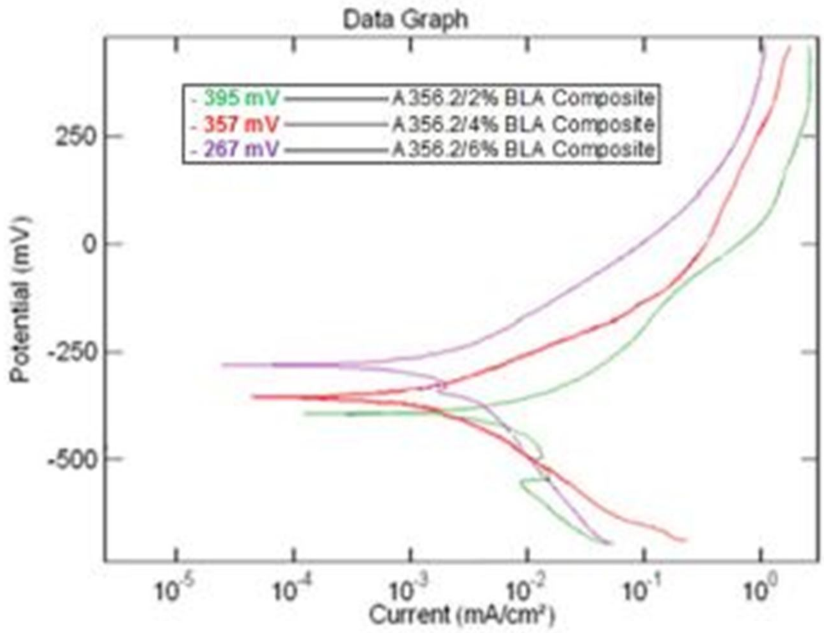
VI. GRAPHS





Base alloy

A. New Composite Reinforcement Corossion



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REFERENCES

[1] J.J. Moses, I. Dinaharan, S.J. Sekhar, Prediction of influence of process parameters on tensile strength of AA6061/TiC aluminum matrix composites produced using stir casting, Trans. Nonferrous Met. Soc. China (English Ed. 26 (2016) 1498–1511. doi:10.1016/S1003-6326(16)64256-5.
[2] V. Kumar, C.S.P. Rao, N. Selvaraj, Mechanical and Tribological Behavior of ParticulateReinforced Aluminum Metal Matrix Composites – a review, J. Miner. Mater. Charact. Eng. 10 (2011) 59–91. doi:10.4236/jmmce.2011.101005.
[3] K. Kalaiselvan, N. Murugan, S. Parameswaran, Production and characterization of AA6061-B4C stir cast composite, Mater. Dies. 32 (2011) 4004–4009. doi:10.1016/j.matdes.2011.03.018.
[4] K. Ravi Kumar, K. Kiran, V.S. Sreebalaji, Micro structural characteristics and mechanical behaviour of aluminium matrix composites reinforced with titanium carbide, J. Alloys Compd. 723 (2017) 795–801. doi:10.1016/j.jallcom.2017.06.309.
[5] D. Yadav, R. Bauri, Nickel particle embedded aluminium matrix composite with high ductility, Mater. Lett. 64 (6) (2010) 664–667.
[6] M. Rahsepar, H. Jarahimoghadam, The influence of multipass friction stir processing on the corrosion behavior and mechanical properties of zirconreinforced Al metal matrix composites, Mater. Sci. Eng., A 671 (2016) 214–220.
[7] S.B. Prabu, L. Karunamoorthy, S. Kathiresan, B. Mohan, Influence of stirring speed and stirring time on distribution of particles in cast metal matrix composite, J. Mater. Process. Technol. 171 (2) (2006) 268–273.
[8] Perez R J, Zhang J, Gungor M N, and Lavernia E J, Metall Trans A 24 (1993) 701.
[9] Zhang Y, Ma N, Wang H, Le Y, and Li X, Mater Des 28 (2007) 628.
[10] M. Esmaily, N. Mortazavi, J.E. Svensson, M. Halvarsson, A.E.W. Jarfors, M. Wess´en, R. Arrabal, L.G. Johansson, On the microstructure and corrosion behavior of AZ91/SiC composites produced by rheocasting, Mater. Chem. Phys. 180 (2016) 29–37.