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Corrosion Resistance Characterization Of 90Al-10Cu / 4SiC Metal-Matrix Particulate Composite (MMPC) In Some Selected Media

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***Abstract*—The study ''Corrosion Resistance Characterization of 90Al-10Cu/4SiC Metal-Matrix Particulate Composite (MMPC) in some Selected Media'' has been undertaken. The work developed the MMPC which was subjected to corrosion test in several media in order to establish the corrosion resistance characteristics of the material. In the first medium which was a mixture of corrosive soil and sodium hydroxide, the composite was completely leached within the range of the exposure time of 168-840 hrs. In the second medium which was Cassava starch paste freshly extracted, the composite did not show any sign of corrosion throughout the exposure period of 168-840hrs. In the third medium which was standard salt test solution the composite only showed a weight loss of 0.10g and corrosion rate of 0.13 mpy at 168 hrs, thereafter there was no corrosion again. In the fourth medium which was rain water the composite showed some corrosion between the interval of 504-672 hrs exposure time and in the last medium which was bore-hole water some corrosion occurred at the interval of exposure time of 168-336 hrs and again occurred at the exposure time of 840 hrs. In all the media where the composite material showed some corrosion rate the value did not exceed 0.13 mpy which is far below 1-200 mpy which is the corrosion rate of usefully resistant materials. The work clearly showed that the developed 90Al-10Cu/ 4SiC metal-matrix particulate composite cannot be used in a soil environment where there is a mixture of waste from gas welding and sodium hydroxide, but it can however be used in all the other environments tested.**

Keywords—Newly developed composite; Corrosion rate; Weight loss; Characterization; Metal-matrix.

I. INTRODUCTION

Characterization of new materials is what normally follows each time a material is developed. It determines the properties of the material and by implication its areas of application. New materials are evolving on daily basis in the advanced countries, and they have a huge array of materials to choose from (Ihom, et al., 2013). The reverse is the case in the third world countries where they have to make do with what is available; often this does not always provide the best opportunity for the best material selection to be made. The development and characterization of 90Al-10Cu/4SiC Metal-Matrix Particulate Composite will provide a light but strong material that can equally withstand wear and corrosion, which may find application in several machines in the third world country like Nigeria where there is dart of engineering materials. Cassava grinding machine can use this material in place of steel which is associated with rusting and contamination of the milled cassava. The matrix of this composite is an age-hardening alloy whose strength and hardness increases on age hardening and by implication the strength of the composite will increase on age hardening. This has been demonstrated in previous works by several researchers (Ihom, 2014; Ihom, et al., 2012a). The basic structural changes or morphological changes on age hardening are brought together by the different stages of disintegration of the saturated solid solution resulting from hardening of the alloy. Since disintegration of the saturated solution is a diffusion controlled process, the degree of disintegration, type of precipitation from the solution, their dispersion, form, and other structural characteristics depends on the nature of the alloy and its chemical composition. Alfred Wilm was the first to discover an aluminium alloy which could be hardened by quenching from an elevated temperature in a similar manner to steel. In one alloy, known later as 'duralumin' this contains 4% copper, 0.5% magnesium, and a small amount of manganese. It was accidentally discovered that the hardness of quenched alloy was relatively low and subsequently increased with time. This discovery of 'age hardening' represents the only new method of hardening alloys since the quenching of steel was discovered in the second millennium BC (Cottrel, 1980; Ihom, 2014; Ihom, et al., 2012a).

Composite materials are usually classified on the basis of the physical or chemical nature of the matrix phase e.g. polymer matrix, metal matrix, and ceramic composites. According to Surappa (2003) the term 'composite' refers to a material system which is composed of a discrete constituent (the reinforcement), distributed in continuous phase (the matrix), and which derives its distinguishing characteristics from the properties of its constituent, from the geometry and architecture of the constituents and from the properties of the boundaries (interfaces) between different constituents. A composite can also be defined as a material that consists of constituents produced via a physical combination of preexisting ingredient materials to obtain a new material with unique properties when compared to the monolithic material properties. Composites combine the attribute properties of the other classes of materials while avoiding some of their drawbacks, they are light, stiff, and strong, and they can be tough. Metal matrix composites (MMCs) reinforced with ceramics or metallic particles are widely used due to their high specific modulus, strength, hardness, and wear resistance. MMCs are considered as an alternative to monolithic metallic materials or conventional alloys in a number of specialized applications. The majority of such materials are metallic matrices reinforced with high strength, high modulus and often brittle second phase in the form of fibre, particulate, whiskers, embedded in a ductile metal matrix (umewww.epf, 2012; Curran, 1998; Gupta, 2008; Matthews and Rawlings, 2005) .

Corrosion is defined as the destruction or deterioration of a material because of reaction with its environment (Ihom, 2004). Composites can be exposed to the surrounding environments either by edge exposure or by accidental surface damage. Selective corrosion of these reinforcements is dangerous because it removes the reinforcing components, and the damage is hidden from direct view. Selective corrosion of the matrix material is also undesirable, but it is more easily detected and produces less structural weakening. According to Fontana (1987), Corrosion of a composite material is controlled by two factors: (1) the specificity of a given corrosive towards the individual components and (2) galvanic interactions between them. The corrosivity of an environment varies from metal to metal. Fontana explained that composites reinforced with nonmetallic behave in a similar manner to composites containing metal reinforcements. However, since these inorganic solids are very resistant to most aqueous media, their selective dissolution is less likely. Also, galvanic corrosion is not likely except for those reinforcements possessing electrical conductivity such as graphite and boron. Aluminum alloy metal matrix composite has found wide area of application in engineering. The principle of lightweight-high strength composite has found application even in aerospace. Fontana (1987), stressed the need for composites to be carefully evaluated in a number of environments which might be encountered in practice. This fact has equally being pointed out by previous authors who evaluated aluminium alloy matrix composites in a number of environments (Ihom, et al., 2012b; Ihom, et al., 2013) . Ogbonna et al., (2004) , in his work evaluated aluminum based metal composite in 0.1MHCl and he discovered that as the volume fraction of the reinforcement agent alumina increased the rate of corrosion attack also increased. Asuke et al., (2009), evaluate aluminum alloy based matrix composite in 0.5MNaOH solution he highlighted in his work that one major limitation of aluminum metal composites has been corrosion in aqueous environment containing sodium hydroxide, and several researchers have carried out researches on aluminum metal composites (AMCs) details of their work can be seen in the cited literatures (Archibong and Udo, 2014; Ihom et al., 2008).

The objective of this work is to characterize the corrosion resistance of 90Al-10Cu/ 4SiC metal-matrix particulate composite (MMPC) in some selected media. The work precludes other properties characterization.

Materials and Method

Materials

The materials that were used for this work included 90Al-10Cu/ 4SiC metal-matrix particulate composite which was developed at the foundry shop of National Metallurgical Development Centre, Jos. Others were distilled water, sodium hydroxide, sodium chloride, gas welding waste dump (corrosive soil), rain water, bore-hole water, cassava starch paste, acetone, and alcohol. The last two materials were sourced locally in the Food and Chemical Engineering Laboratories of University of Uyo.

Equipment

The equipment used were electronic digital weighing balance, specimen cutter, steel brush, thread, stands, 200ml beakers, measuring cylinder, hack saw, metal file, handkerchief, vernier calipers, hand air blower, grit paper, and rinsing bath

Method

Development of the specimen

The development of the 90Al-10Cu/ 4SiC metal-matrix particulate composite took place at the National Metallurgical Development Centre, Jos Foundry section. The composite was produced using stir-cast method. In this method the matrix which was the alloy of 90% Al and 10% Cu was produced by melting in the furnace, and to this melt 4% SiC was added and fast-stirred using mechanical stirrers. The molten composite was then quickly poured into specimen moulds to solidify before removal.

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Specimen Preparation

The specimens were cut into uniform dimensions using specimen cutter and some of the equipment mentioned above. It was smoothened using files and grit paper of various sizes. The specimens were wet-polished with silicon carbide abrasive paper of grade #120. Later the coupons were degreased by dipping them in ethanol and acetone and rinsed in running tap water, and dried using air blower. The specimens were weighed and accurately recorded, and then labeled as shown in Plates 1-2.

Plate 1 Specimen on Weighing Balance

Plate 2 Labeled Specimens on Suspension Thread

Preparation of the Media

3% NaCl solution was constituted using distilled water, for 200ml of water 6g of NaCl (industrial salt) was added to obtain 3% solution. Corrosive soil was picked at the welder's waste dump site and mixed with a little quantity of sodium hydroxide it was then introduced into a 200ml beaker and distilled water was added to the 200ml mark and stirred for homogeneity. Rain water was obtained in Uyo town and filled in a beaker up to 200ml. Borehole water was obtained in the University of Uyo and filled in a beaker up to 200ml, and cassava starch was extracted from fresh cassava tubers and filled in a beaker up to 200ml. Plate 3 shows the prepared media.

Plate 3 Media Preparation in Progress

Experimental Procedure

The washed, degreased, dried and weighed coupons were tied with the labeled thread and dipped in the media. Plate 4 shows the experimental setup of the work. Every seven (7) days one coupon was removed from each medium according to the label on it. It was washed in alcohol and water, and then scrubbed lightly using brush to remove corrosion products. It was then dried using air blower before weighing using electronic digital weighing balance. This process was repeated for 35 days and the data generated during the measurements were used in calculating the weight loss and the corrosion rate in mils per year (mpy). Plate 5 shows the specimens after exposure at various periods in their respective medium. Several precautions were taken to ensure accurate result and these included; care was taken to avoid the contamination of the specimens or alter them during specimen preparation, initial measurements were taken and subsequent measurements had fixed time throughout the period of the experiment, over scrubbing was avoided, and every specimen that was removed from the medium was never returned.

Plate 4 Experimental Setup

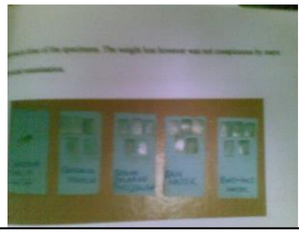

Plate 5 Specimens after Exposure at Different Periods in the Media

Results and Discussion

Results

The results of the study are presented below. Figs. 1-5 shows the effect of various media on weight loss of 90%Al-10%Cu /4% SiC Metal-Matrix Particulate Composite, while Figs. 6-9 shows the effect of various media on the corrosion rate in mpy of 90%Al-10%Cu /4% SiC Metal-Matrix Particulate Composite.

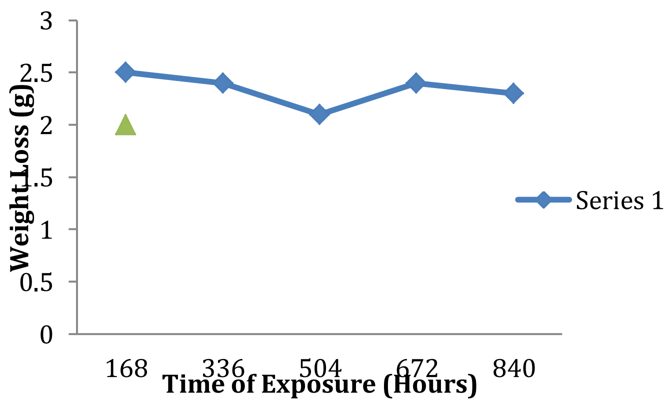

Fig.1 The Effect of Corrosive Soil with Sodium Hydroxide on Weight Loss of 90%Al-10%Cu/4% SiC Particulate Composite

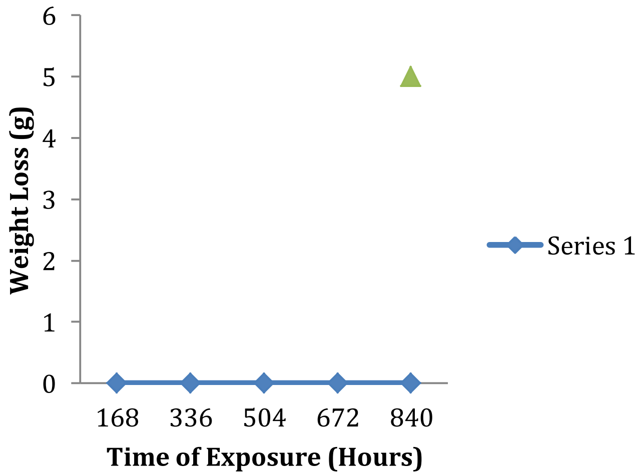

Fig.2. The Effect of Cassava Starch (paste) on Weight Loss of 90%Al-10%Cu/4% SiC Particulate Composite

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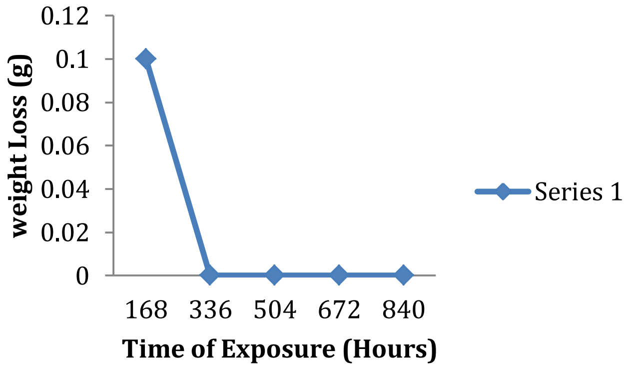

Fig.3. The Effect of Sodium Chloride (NaCl) Solution on Weight Loss of 90%Al-10%Cu/4% SiC Particulate Composite

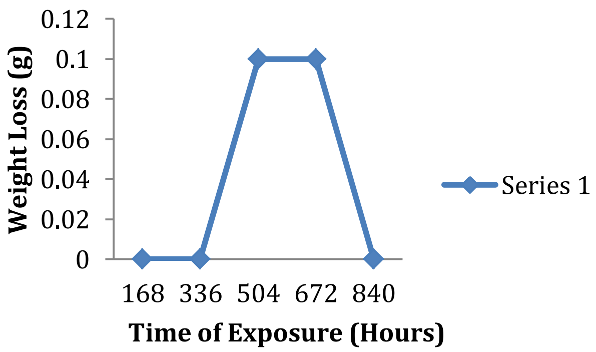

Fig.4 The Effect of Rain Water from Uyo Town on Weight Loss of 90%Al-10%Cu/4% SiC Particulate Composite

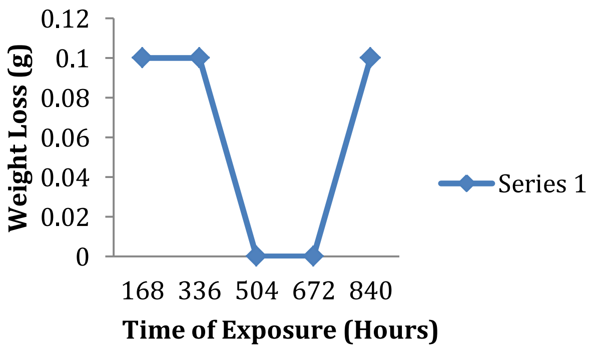

Fig.5. The Effect of Bore-Hole Water on Weight Loss of 90%Al-10%Cu/4% SiC Particulate Composite

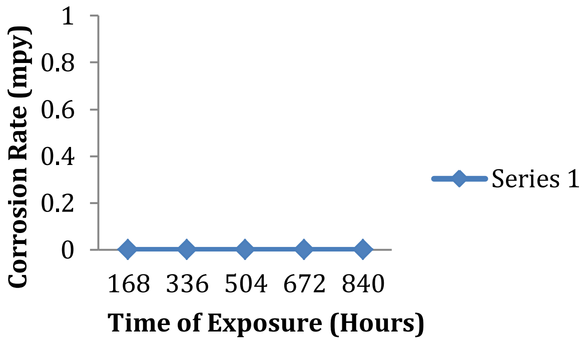

Fig.6 The Effect of Cassava Starch (paste) on Corrosion Rate of 90%Al-10%Cu/4% SiC Particulate Composite

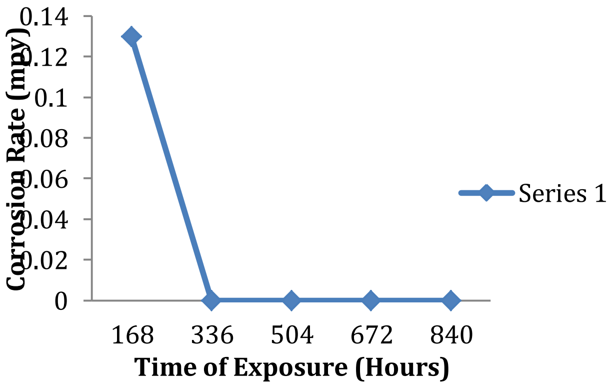

Fig.7 The Effect of Sodium Chloride (NaCl) on Corrosion Rate of 90%Al-10%Cu/4% SiC Particulate Composite

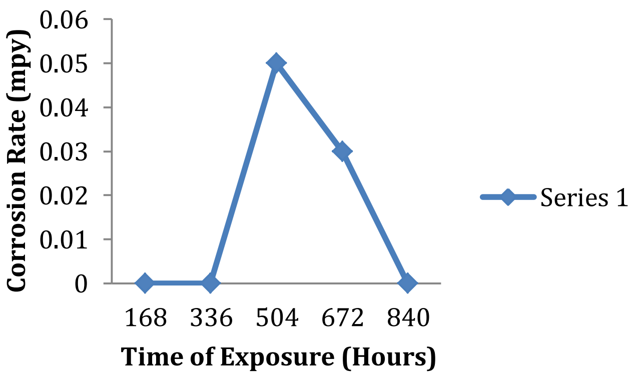

Fig.8 The Effect of Rain Water from Uyo Town on Corrosion Rate of 90%Al-10%Cu/4% SiC Particulate Composite

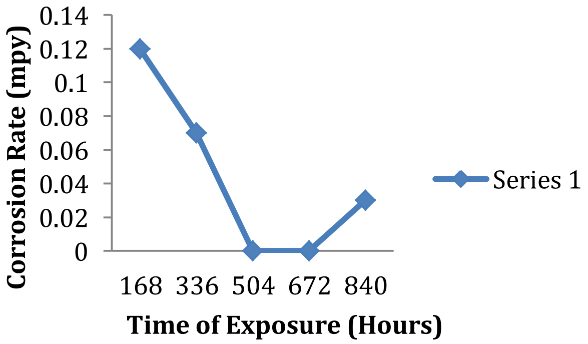

Fig.9 The Effect of Bore-hole Water on Corrosion Rate of 90%Al-10%Cu /4% SiC Particulate Composite

Discussion

Figs. 1-5 show the effect of various media on weight loss of 90%Al-10%Cu/4% SiC Particulate Composite. The curve of fig. 1 is close to the initial weight of the specimens indicating that almost all the matrix of the composite was lost in the medium. This can be seen at all the time intervals that the test was conducted. Several authors have confirmed that aluminium is a very poor material for handling caustic soda (Fontana, 1987; Ihom, et al., 2013). Physical observation revealed that the aluminum-copper alloy matrix was completely leached leaving behind a small porous mass of the reinforcement and matrix. This made it impossible for the corrosion rate in mils per year to be determined. The observation is in agreement with previous works which said aluminum and its alloys including aluminum alloy matrix composites are dissolved in an environment containing Sodium hydroxide, the corrosive soil contained sodium hydroxide (Fontana, 1987; Ihom, et al., 2012b; Asuke, et al., 2009).

Fig.2, the composite showed no weight loss in cassava starch paste. Fig.3, the composite showed a weight loss of 0.1g in sodium chloride solution at 168 hours thereafter there was no weight loss again throughout the period of the test. Fig.4, the composite showed a weight loss of 0.1g between 504 and 672 hours in rain water from Uyo town, there was no further weight loss after 672 hours of testing. In Fig.5 the composite showed weight loss between 168 to 336 hours of 0.1g and another weight loss of 0.1g at 840 hours in borehole water from the University borehole. The weight losses noticed were actually small this is in agreement with previous works (Ihom, et al., 2013; Archibong and Udo, 2014). Ihom et al (2012b), have actually revealed that aluminum alloy matrix composites are normally attacked in solutions containing chlorides and hydroxides. The break in further weight loss may be as a result of the formation of oxide coatings which inhibited further penetration of oxygen for corrosion to continue. Aluminum and Aluminum alloy is known for the formation of continuous oxide coating (Fontana, 1987; Archibong and Udo, 2014).

Figs.6-9 shows the effect of various media on the corrosion rate in mpy of 90%Al-10%Cu/4% SiC Particulate Composite. Fig.6, the composite showed no corrosion rate in cassava paste through the period of the test. In fig. 7 the composite showed an initial corrosion rate of 0.13 mpy at 168 hours in sodium chloride solution, the corrosion rate never went beyond that period (168 hours) throughout the test period. In fig. 8 the composite showed a corrosion rate of 0.05 mpy at 504 hours in rain water from Uyo town, the corrosion rate however decreased to 0 at 840 hours when the last measurement was taken. In fig. 9 the composite showed a corrosion rate of 0.12 mpy at 168 hours in borehole water, the corrosion rate decreased to 0 at 504 hours, and after 672 hours the corrosion rate started rising again. The result indicates that the rain water and the borehole water are not pure; the obvious is that they contain corrosive components (Fontana, 1987; Archibong and Udo, 2014). In fig.9, the continuation of corrosion after 672 hours indicates that there was a breakdown in the protective oxide layer of the composite (Fontana, 1987; Ihom, et al., 2008). The corrosion rate falls within the recommended corrosion range of 1-200 mpy for usefully resistant materials for all the media except for the medium containing corrosive soil and sodium hydroxide. The composite cannot be used as a container for holding NaOH solution and welding wastes or in an environment where NaOH solution is found, since it selectively dissolves the composite, leaving behind an altered residual structure (Fontana, 1987; Ihom, et al., 2012b; Ihom, et al., 2013).

The weight loss, and the corrosion rate expressed in mpy all agree with the physical appearance of the specimens after the exposure time of the test. See Plate 5.

Conclusion

Corrosion resistance characterization of 90%Al-10%Cu/4% SiC metal-matrix particulate composite has been carried out and the following conclusions have been drawn from the work

i. The developed composite cannot be used in an environment where there is sodium hydroxide and welding waste from gas welding
ii. The developed composite can be used in a machine for grinding cassava to avoid rust contamination associated with mild steel which is commonly used in Nigeria.
iii. The developed composite can also be used as a container for rain water and borehole water from university of Uyo and for sodium chloride because the corrosion rate is within the range of 1-200 mpy for usefully resistant materials.

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References

Archibong , M.S. and Udo, I.D. (2014). Determination of Corrosion Resistance of 90Al-10Cu/ 4SiC Particulate Composite in Some Media, B.ENG Degree Submitted to the Department of Mechanical Engineering, University of Uyo, Uyo-Nigeria

Asuke, F., Yaro, S.A., and Oloche, O.B. (2009). Propargyl as Corrosion Inhibitor for

Al-5%Si-15%SiC Composite in 0.5MNaOH, Proc. Of the NMS, 85-94

Cottrel, A. (1980). An Introduction to metallurgy, 2nd Edition. Edward Arnolds Publishers Ltd, Cambridge.

Curran, G. (1998). Metal matrix composites, the future. Materials World, 6(1): 21-23.

Fontana, M.G. (1987). Corrosion Engineering, 2nd Reprint, McGraw-Hill Book Company NewYork,

Gupta, M. (2008). “Recycling of Aluminum Based Composite using Disintegrated Melt Deposition Technique,” National University of Singapore, Engineering Research, 23 (1):19-24

Http:/umewww.epf/ch/people/cayron/Fichiers/thesebook-hap.2pdf.

Ihom, A.P. (2004). Impact Assessment of Corrosion on Foundry Equipment at NMDC, Jos, Foundryshop J. of Sc. And Tech. 1(1): 70-71

Ihom, A.P., Ayeni, A.F., and Mbaya, E.I. 2008. Assessment of the Corrosion Behaviour of selected Materials in synthetic Brake Fluid, International journal of Materials and Metallurgical Engineering 3(1): 39-43

Ihom, P.A., Nyior, G. B, Anbua, E.E., Ogbodo, J.N. (2012a). The Effect of Ageing Time on Some Mechanical Properties of Aluminum/0.5% Glass Reinforced Particulate Composite, Journal of Minerals and Materials Characterization and Engineering, 11: 919-923 doi:10.4236/jmmce.2012.119090

Ihom, A.P., Nyior, G. B., Nor, I.J., Segun, S., Ogbodo, J. (2012b). Evaluation of the Corrosion Resistance of Aluminum Alloy Matrix/ 2.5% Particulate Glass Reinforced Composite in Various Media, International Journal of Science and Technology, 1 (10): 560-569

Ihom, P. A., Ayeni, F., Mohammed, S., and Ola, S. (2013). The Inhibitive Potential of Arecaceae Extract on the Corrosivity of Aluminium based Matrix Composite and Medium Carbon Steel in Different Media Leonardo Electronic Journal of Practices and Technologies ISSN 1583-1078, 22: 1-14

Ihom, P.A. (2014). Role of Age Hardening Heat Treatment on the Hardness Values of 93.95 Al-5Zn-1.05Sn/5Al_2O_3-SiO_2 Particulate Composite Aceh Int. J. Sci. Technol., 3(2): 61-66 doi: 10.13170/AIJST.0302.02

Mathews, F.L. and Rawlings, R.D. (2005). Composite Materials: Engineering and Science Fourth Reprint Woodhead publishing limited Cambridge England.

Ogbonna, A.I., Asoegwu, S.N. and Okebanama, P.C.(2004). Corrosion Susceptibility of Squeeze Cast Aluminium Based Metal Composites, J. Sc. And Tech. 1(1): 62-63

Suprappa, M. K. (2003). Aluminum Matrix Composites: Challenges and Opportunities, Sadhana, 28 (1-2): 319-334. doi:10.1007/BF02717141