Effect of Heat Treatment on Corrosion Behavior of Al 2014 based Hybrid Composite for Marine Application

Ranganatha S R[1], Shantharaja M[2]

[1]*Asst.Prof, Department of Mechanical Engineering, DBIT, Bangalore, Karnataka, India*
[2]*Asso.Prof, Department of Mechanical Engineering, UVCE, Bangalore, Karnataka, India*

ABSTRACT: This present research deals with the fabrication of Al 2014 reinforced with boron carbide and short copper coated Basalt fiber based Hybrid metal matrix composite through stir casting process and evaluate corrosion behavior in sea water for both ascast and heat treated composites by weight loss method. The corrosion characteristics of Al 2014 / B_4C/short basalt fiber based hybrid composites were experimentally assessed. The corrosion test was carried out at sea water solution for different exposure time of 48, 96, 144 and 192 hrs. The results indicated that corrosion rate of metal matrix composites was decreased with increasing the wt% of reinforcements under the corrosive atmosphere for all exposure time and also result depicted that the effect of Boron carbide on Al 2014/Short copper coated basalt fiber shows good corrosion resistance as compared to the effect of Basalt fiber and also observed heat treated composite shows better corrosion behavior as compared to ascast composites and also analyze the morphology of corrode surface by using SEM it is clearly shows heat treated composites shows less corrosive product on surface of specimen as compared to ascast composites. This corrosion analysis can be utilized to replace the conventional marine application materials with aluminium Hybrid metal matrix composites having better corrosion characteristics.

Keywords: Al2014, HAMCs, Boron carbide, Basalt fiber, sea water, Coatings, Stir casting and corrosion rate

1. INTRODUCTION:

In an aluminium metal matrix composites have been of interest as engineering materials because of their weight, specific strength and stiffness. Since it is more advantages in aerospace industries, automotive industries, sports goods industries, marine, coir manufacturing industries, textile industries and other structural applications [1-3]. Corrosion has the gradual chemical or electrochemical attack on a metal by its surroundings such that the metal is converted in to an oxide, salt or some other compound which result to loss of strength, hardness, toughness and other desirable mechanical properties which metal possesses [4]. Their corrosion behavior is an most important factor that must be considered. Most research on particulate reinforced MMCs has focused on their Manufacturing and Mechanical properties. These researches have been conducted to understand corrosion behavior and weight loss of the material. Corrosion can affect the Metal Matrix Composites in variety of ways which depends on its nature and environment conditions. Studying corrosion resistance of Aluminium based material is used for the automotive, marine and aircraft applications [5-7]. Fiber reinforced MMC's maintain good strength at high temperature, good structural rigidity, dimensional stability and light weight[8-10]. Ezhil vannan et al [11] study the corrosion behavior of Al 7075 reinforced short basalt fiber based composites, reported that there is decrease in the corrosion rate as the percentage of basalt short fiber increases in the composite. Pruthviraj R D et al study the corrosion of Al 2024 in sea water with and without Sodium Benzoate as an Inhibitor, reported that samples have higher weight loss in sea water without sodium benzoate inhibitor [12].

2. MATERIALS USED

2.1 Matrix Materials: Al2014 was used as matrix material with its compositions as shown in table 1. The main alloying element is Copper and it is second most popular of the 2000 series aluminium alloy, after 2024 aluminium alloy and also used in aircraft and automobile industry for structural components. The corrosion behavior of this alloy is poor as compared to other aluminium alloy.

2.2 Reinforcement Materials

2.2.1 Boron carbide (B_4C) second hardest material it is produced by reacting carbon with B_2O_3 in an electric arc furnace and it is widely used in bulletproof vests and abrasive in polishing and lapping applications.

2.2.2 Basalt fiber-Basalt fiber is a relative newcomer to fiber reinforced composites. The main alloying constituent is SiO_2 (53%), Al_2O_3 (12%), and has better strength characteristics as compared glass and aramid fiber and it is suitable replacement for asbestos.

3. EXPERIMENTAL WORK

3.1 Electroless deposition of copper on short Basalt fiber-

The electroless technique is used to deposit the copper on the surface of short basalt fiber the following sequence of operation along with cleaning; drying and rinsing stages are carried out.

Preheating $\longrightarrow$ Sensitization $\longrightarrow$ Activation $\longrightarrow$ Metallization

Basalt fibers of length 1 to 2 mm and diameter 6 µm were used in the present investigation. Initially to remove the pyrolytic acid on the surface of fiber by preheating the fiber at 500˚C for 10 to 15 minutes in muffle furnace. Then fibers were sensitized for 15 minutes with continuous stirring with help of magnetic stirrer. Then the fibers were filtered with help of filter paper and cleaned with distilled water. In order to obtain catalytic surface the sensitized fibers were activated with glacial acetic acid and stannous chloride solution. Then 40 ml/l of concentrated hydrochloric acid they were sensitized for different times with continuous stirring to get sensitized fiber. Then finally to get metalized surface on fiber by using palladium chloride solution (0.2 g/l PdCl2) and (2.5 m/l HCl) under ultrasonic agitation hence the formation of Pd sites on the fiber surface which forms the subsequent metallization activity with copper. Metallization is formed by immersion of fibers into a solution containing CuSO4-5H2O solution under agitation. The uniform thickness of copper coatings obtained at optimum parameters like temperature 450 C, time 3 minutes and with pH value of 13 it is observed by scanning electron microscope.

3.2 Fabrication of hybrid composites

The hybrid metal matrix composite of Al2014 with Boron carbide particulates of 60 Microns and short Basalt fiber of 2-3 mm length were fabricated by stir casting method in this investigation. Aluminium-2014 alloy billets were heated in a muffle furnace up to 750-800˚C. During melting aluminium alloy hexachloroethane pallets were added to remove the hydrogen. After that measured quantity preheated boron carbide and coated short basalt fiber were added at a rate of 10-30 g/min into the melt and mixed with help of stirrer at speed range 300-500 rpm for a period of 8 to 10 minutes. By the mean time the mold was preheated and chalk powder was applied to the mould. Then molten metal is poured into the mould and allowed for solidification at room temperature. The sixteen different samples of composites with varying wt% of Boron carbide particulates of 2,4,6,8 and Basalt fiber of 2, 4, 6, and 8% were casted using above procedure.

3.3 Corrosion test:

The samples were cut from as cast specimens as per ASTM G31 with diameter of 20 mm and length of 20 mm. The corrosion behavior of composites was studied by using immersion test. The Samples were floating in the 300 cm^3 of sea water for different time intervals up to 192 hours in steps of 48 hours as shown in figure 3.1 a) and b). After the specified time the samples were cleaned according to ASTM standard by using smooth emery in order to remove the heavy corrode particles on the surface of samples then washed with distilled water and acetone and air dried. The corresponding changes in the weights were noted using digital weighing machine. Corrosion rates were computed using the equation.

Corrosion rate = 22.3 W/DAT mpy

Where W is the weight loss in mg, D is density of the specimen in gm/cc, A is the area of the specimen (in^2), T is the exposure time in days.

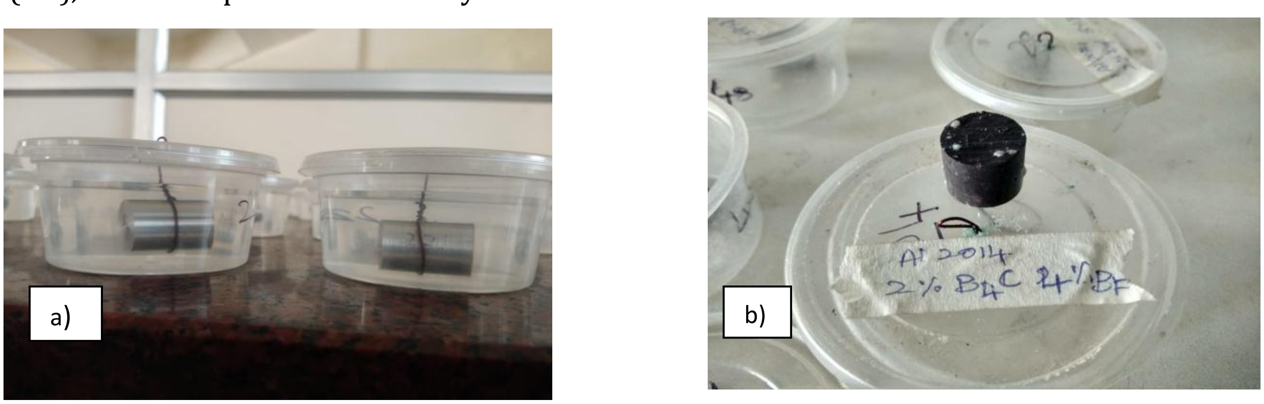
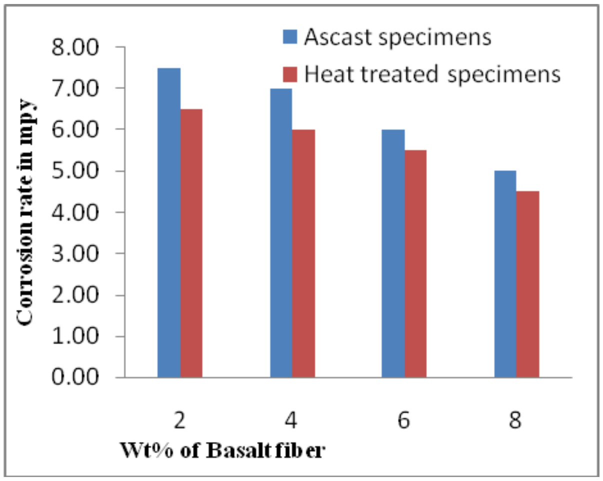


Figure: 3.1 a) experimental set up of corrosion test by immersion technique, b) corrode specimen removed from sea water solution

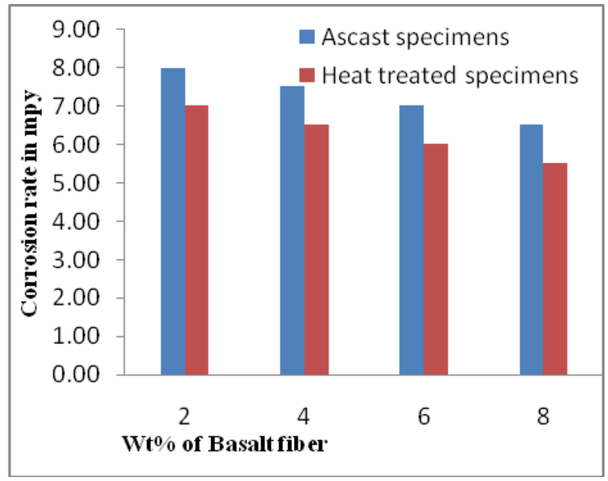
4. RESULTS AND DISCUSSION:

4.1 Corrosion Test Result for both ascast and heat treatment composites:

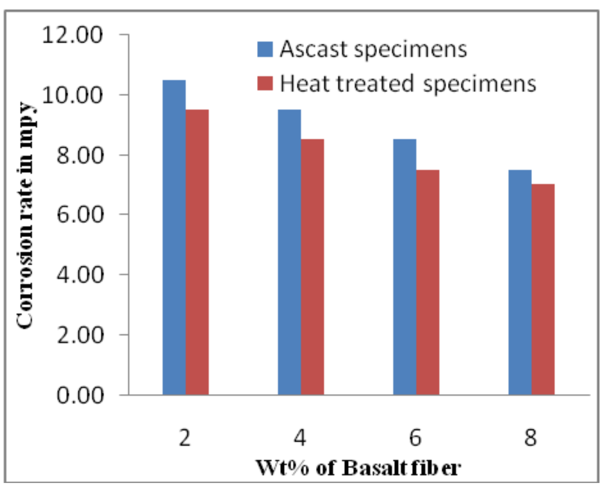
Figure shows comparison of ascast and heat treated composites in corrosion behavior.



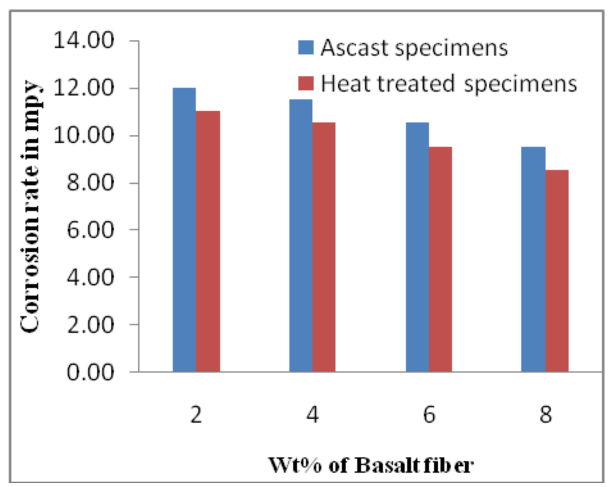
a) Exposure time 48 hrs



b) Exposure time 96 hrs

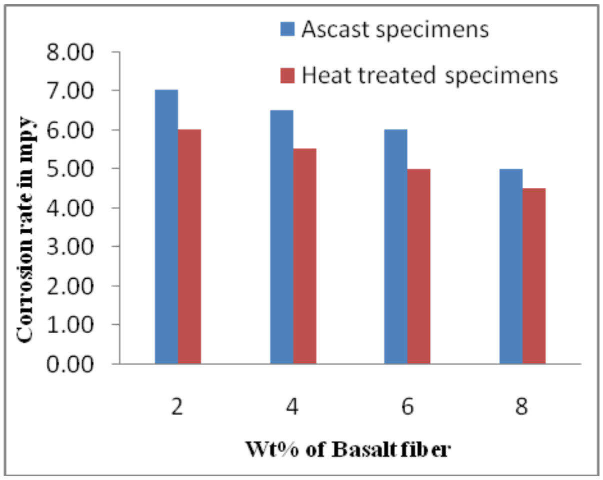


c) Exposure time 144 hrs

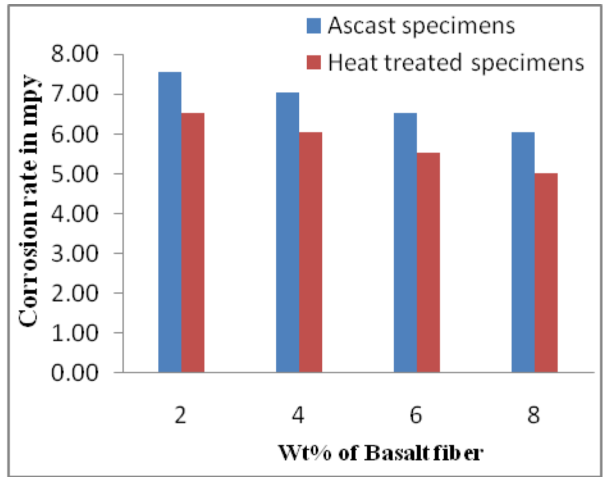


d) Exposure time 192hrs

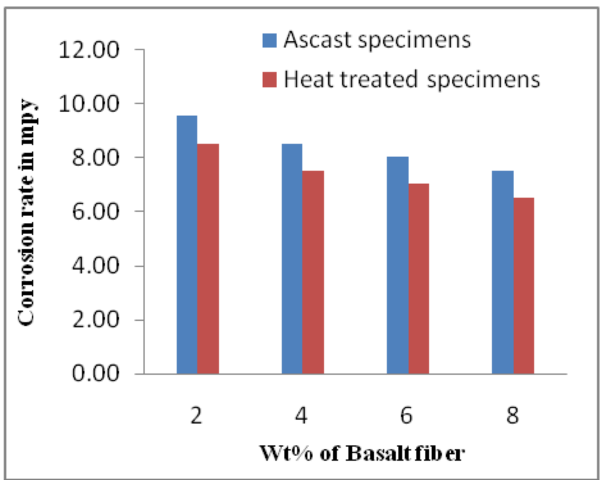
Figure: 4.1.1(a-d) the effect of copper coated short basalt fibers on corrosion rate of AL2014+2% Boron carbide based hybrid composites at as cast and heat treated specimens



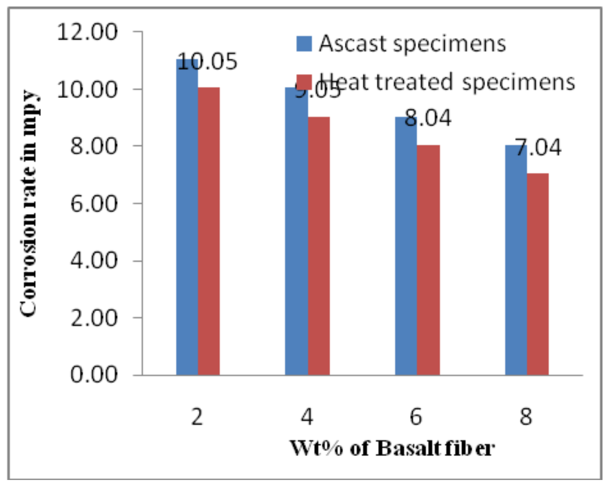
a) Exposure time 48 hrs



b) Exposure time 96 hrs

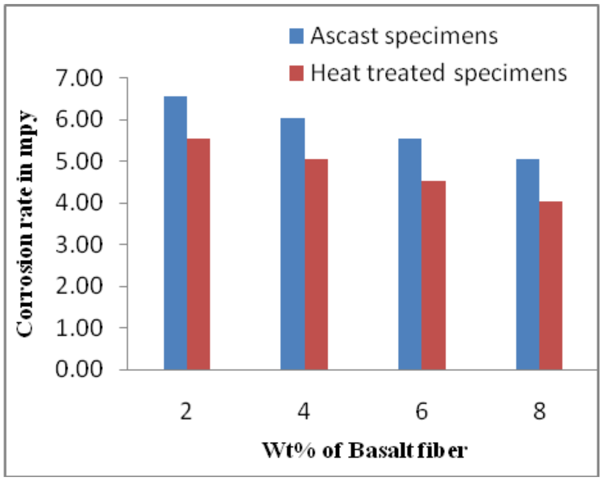


c) Exposure time 144 hrs

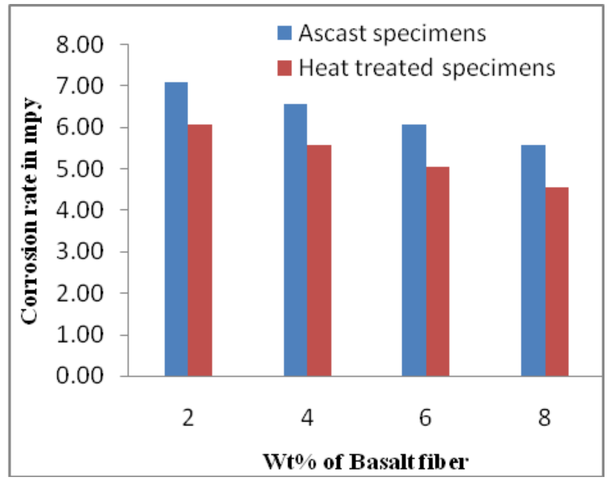


d) Exposure time 192hrs

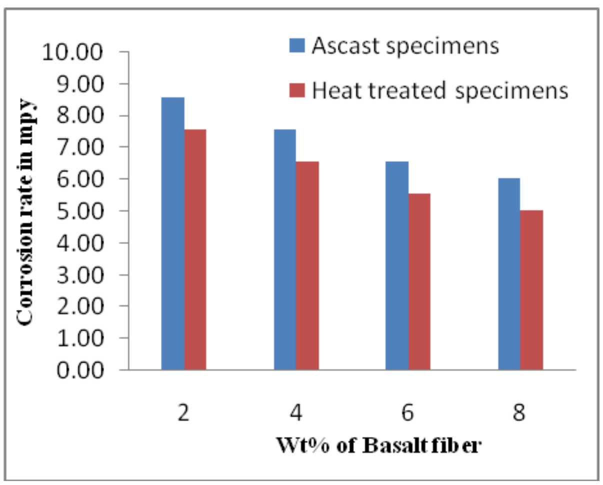
Figure: 4.1.2(a-d) the effect of copper coated short basalt fibers on corrosion rate of AL2014+4% Boron carbide based hybrid composites at as cast and heat treated specimens



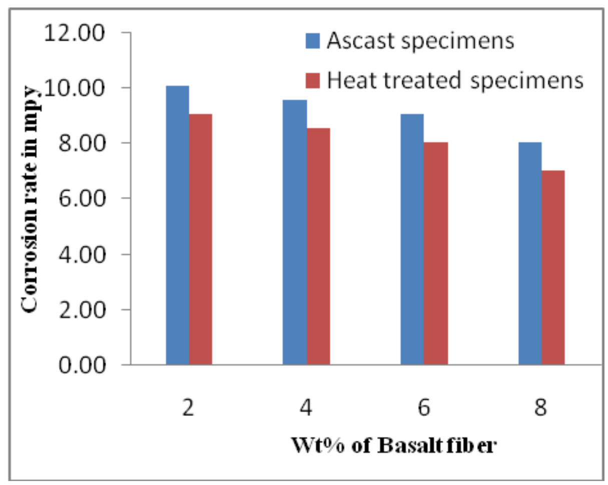
a) Exposure time 48 hrs



b) Exposure time 96 hrs

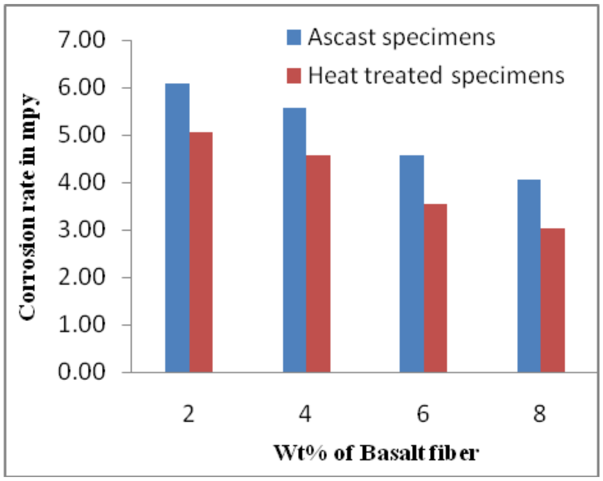


c) Exposure time 144 hrs

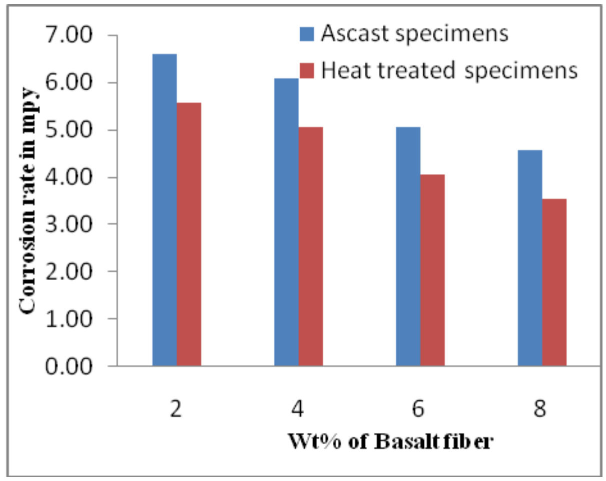


d) Exposure time 192 hrs

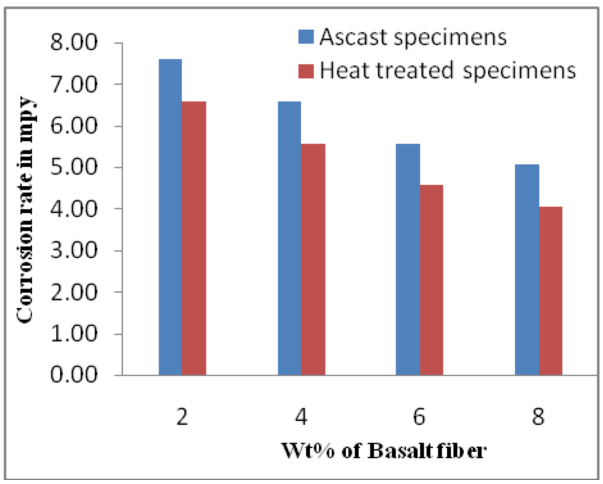
Figure: 4.1.3 (a-d) the effect of copper coated short basalt fibers on corrosion rate of AL2014+6% Boron carbide based hybrid composites at as cast and heat treated specimens



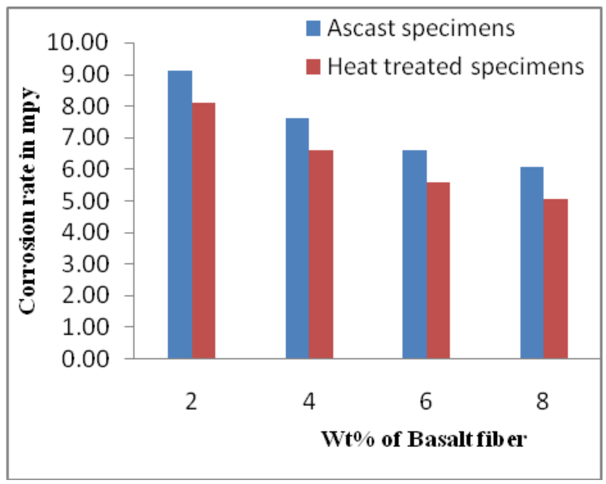
a) Exposure time 48 hrs



b) Exposure time 96 hrs



c) Exposure time144 hrs



d) Exposure time 196 hrs

Figure 4.1.4 (a-d) the effect of copper coated short basalt fibers on corrosion rate of AL2014+8% Boron carbide based hybrid composites at as cast and heat treated specimens

4.2 Effect of Boron carbide and short copper Basalt fiber on corrosion rate at heat treatment condition:

The Effect of Boron carbide and short copper Basalt fiber content on the corrosion behavior of Al 2014 based hybrid composites for different exposure time at heat treated condition is shown in Fig .4.1.1(a-d) to Fig 4.1.4(a-d),

It is observed from Figure.4.1.1 (a-d) to Figure 4.1.4(a-d) that there is progress in corrosion resistance of specimens subjected to heat treatment. Heat treatment has a reflective influence on the corrosion resistance of the Hybrid composites the lowest material loss was observed at heat treated conditions as compared to as cast and also observed from the Figures that the corrosion rate of the composites Decreases with the increase in reinforcement content. The addition of boron carbide shows 10 to 15% better corrosion rate as compared to addition of basalt fiber this may be due to boron carbide more hardened material as compared to basalt fiber and also noted that the heat treated composites shows 8 to 14% better corrosion as compared to as cast composites.

4.3 Effect of exposure time on corrosion rate with heat treatment

Figure.4.1.1 to figure.4.1.4 shows a corrosion rate of Boron carbide/Basalt fiber reinforced Al2014 based Hybrid composites plotted against the exposure time of 48hrs, 96hrs, 148hrs and 192hrs. It is clearly observed from the figure that the corrosion rate of the composites increases with the increase in exposure time and also observed from figure that there subjected to a higher exposure time at which there is an abrupt increase in the corrosion rate of all composition hybrid composites. When the exposure time is low, the corrosion rate is quite small; it can be considered that it is quite natural for the effect of corrosion rate with respect to exposure time.

4.4 surface morphology using SEM

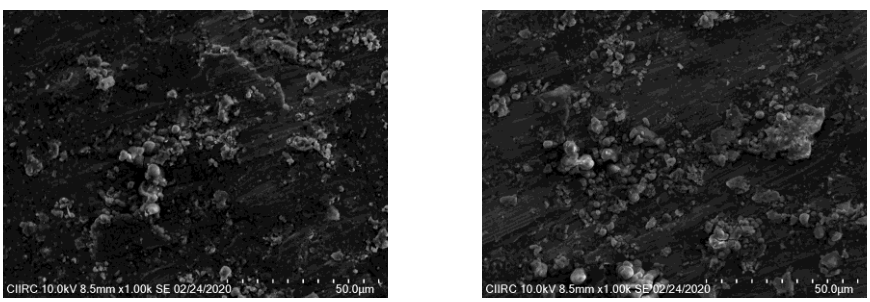


Figure 4.4.1: corrode surface of ascast composites

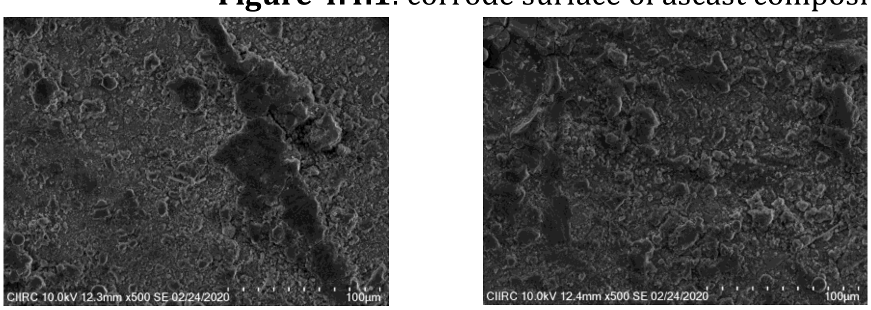


Figure 4.4.2: corrode surface of heat treated composites

The corrode surface morphology was analyzed in more detail using SEM as shown in figure 4.4.1 and 4.4.2. The study was successfully indicates that the less corrosion rate observed in heat treated composites as compared to ascast composites. The surface morphologies of Al2014/copper coated short basalt fiber/Boron carbide based hybrid composites immersed in sea water solution for 48, 96,144 and 192hrs. Figure 4.4.1 and 4.4.2 shows corrode surface of both ascast and heat treated composites at maximum of 192 hrs of immersion time and observed large corrosion pit, many peeling layers and more white corrosion products in ascast composites and observed heat treated composites shows small corrosion pit and low white corrosion product as compared to ascast composites this might be due to at heat treated condition there is an strong intermolecular bonding between particulates and matrix material hence the surface are more hardened in nature and are not more react with sea water solution.

5. Conclusions:

The following conclusions can be drawn from the Experimental investigation of corrosion behavior of Al2014 reinforced with boron carbide and short basalt fiber based hybrid composites at heat treated conditions

- The stir-cast experimental set up could be successfully adopted in the preparation of Al 2014/B_4C/basalt fiber based hybrid composites.
- The corrosion rate is dominated by exposure time. With the increases in the weight percentage of reinforcements there is a decrease in the corrosion rate this may be due to the presence of hard ceramic particles.
- Maximum weight of 8% boron carbide and 8% short basalt fiber shows minimum corrosion rate of the composites and also observed that the addition of boron carbide shows 10 to 15% better corrosion behavior as compared to the addition of short basalt fiber for all exposure time.
- Heat treated composites shows marked improvement in corrosion behavior of 8 to 14% as compared to as cast composites.
- Corrode Surface morphology was done by using SEM clearly shows heat treated composites shows small corrosion pit and low white corrosion product as compared to ascast composites.

6. References:

1. Ravichandran, M., Anandakrishnan, V.: Optimization of powder metallurgy parameters to attain maximum strength coefficient in Al-10 wt% MoO3 composites, Journal of Materials Research, 30, 2380-2387 (2015).
2. Veeresh Kumar, GB, Rao, CSP, Selvaraj, N.: Studies on mechanical and dry sliding wear of Al6061-SiC composites, Composite Part B, 43, 1185-1191 (2012).

3. Mohanavel, V., Rajan, K., Arul, S., Senthil, PV: Mechanical behaviour of hybrid composite (AA6351+Al2O3+Gr) fabricated by stir casting method, Materials Today Proceedings, 4(2PA) 3093-3101 (2017).
4. R. U. Evans (1963) An introduction to metallic corrosion, published by Edward Arnold publishers, London
5. Baradeswaran, A., Elaya Perumal, A., Davim, JP.: Effect of B4C on mechanical properties and tribological behaviour of AA6061-B4C composites, Journal of the Balkan Tribological Association, 19(2), 230-239 (2013).
6. Mohanavel, V., Rajan, K., Senthilkumar, KR.: Study on mechanical properties of AA6351 alloy reinforced with titanium diboride (TiB2) composite by in situ casting method, Applied Mechanics and Materials, 787, 583-587 (2015).
7. Nataraja, G., Sudhakara, A., Pruthviraj, RD., Ramesha, S.: Weight loss corrosion studies of aluminium alloy and silicon carbide particulate composites, International Journal of Engineering Science and Research Technology, 4(4), 538-541 (2015).
8. Padro, A., Mercino, M.C., Viejo, F., "Influence of reinforcement proportion and matrix composition on pitting corrosion behavior of cast aluminium matrix composites". Corros. Sci. Vol.47 (2005), pp. 1750–1764.
9. Oguzie, E.E., "Corrosion inhibition of aluminum in acidic and alkaline media by Sansevieria trisfasciata extract". Corros. Sci. Vol.49 (2007), pp. 1527–1539.
10. Rehim, S.S.A., Hamdi, H.H., Mohammed, A.A., "Corrosion and corrosion inhibition of Al and some alloys in sulfate solutions containing halide ions investigated by an impedance technique". Appl. Surf. Sci. Vol. 187(2002), pp. 279–290.
11. Ezhil Vannan * a, Paul Vizhian." Corrosion Characteristics of Basalt Short Fiber Reinforced with Al-7075 Metal Matrix Composites". Jordan Journal of Mechanical and Industrial Engineering. Volume 9 Number 2, April.2015 ISSN 1995-6665 Pages 121 – 128.
12. Pruthviraj R D," Corrosion Studies of AA2024 in Sea Water using Sodium Benzoate as an Inhibitor" Journal of Material Science & Engineering. Volume 5 • Issue 2, ISSN: 2169-0022 JME, an open access journal pp 2-4.