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Study of Corrosion Properties of SIC and E-GLASS reinforced al-3003 Hybrid MMC.

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Abstract: Composite materials play a vital role at the present modern industrial sectors. Preparations of metal-matrix composites are light weighted, high strength, extremely hard materials which were useful for every industrious area like aerospace, motor vehicle industries, mechanical tools manufacturing industries due to its advantageous properties like light in weight, flexibility, hardness, simplicity and easily applicable and so on. At the centre of research and growth of these sectors this paper emphasizes the production of metal-matrix Al-SiC & E-Glass composites using the stir-casting method and prepared sample of varying percentile compositions of SiC & E-Glasss with aluminium The aim of the current investigation is to study the static immersion corrosion behavior of SiC particulates and E-glass fibers reinforced Al-3003 hybrid MMCs in 0.25,0.5,0.75 and 1 normality of NaCl solution at ambient temperatures. The effect of the different composition of SiC particulates and E-glass fibers on the corrosion behavior of Al-3003 hybrid metal matrix composites (MMCs) were studied. The static immersion corrosion tests of Al/SiC/E-glass MMCs in NaCl aqueous solution at ambient temperature, have better corrosion resistance than the pure Al matrix. Increasing the volume fraction of the SiC particulates and E-glass fibers reduces the corrosion rate of the Al/SiC/E-glass MMCs. In contrast, the Al/SiC/E-glass hybrid composites exhibited higher corrosion resistance than the pure Al matrix.

Keywords: E-Glass fiber, Silicon carbide, Aluminium 3003 alloy,Stir Casting.

I. INTRODUCTION

Metal Matrix composites (MMCs) are made of a continuous metallic matrix and one or more discontinuous reinforcing phases. The reinforcing phase may be in the form of fibers, whiskers or particles. In particular, Particle – reinforced aluminium alloys have the potential to be used in the wide range of engineering applications due to their higher stiffness and strength when compared with conventional aluminum alloys. For these composite materials, silicon carbide (SiC), a commercially pure material, has become the main type of reinforcement used. And most of the research work carried out on aluminium based composite materials involved in silicon carbide as its reinforcing material. Hence forth it is essential to look for the possibilities of fabricating aluminium based composite materials using alternative materials such as E – glass.

Metal matrix composites are produced economically by stir casting techniques, with substantial increase in the stiffness, hardness and strength to weight ratio of cast MMCs; but however there is reduction in ductility. It has been observed that some improvements in strength and ductility can be achieved with the application of plastic forming processes i.e. forging of the cast composites. The forged MMCs in general have better mechanical properties compared to cast MMCs, such as it improves density, hardness and tensile strength etc. The forging process also avoids the use of secondary operation like machining.

II. EXPERIMENTATION

A. Materials

Reinforcement's compositions are selected based on the previous work done by many researchers. In many literatures authors have mentioned the reinforcement percentage should be less than 10% for E-Glass and 2% for SiC, if it is more than 10% reinforcement will not mix with the casting properly and there is a chance of agglomeration of particles. So, in the present study reinforcement compositions are limited to above mentioned wt%.

1) Aluminium 3003 Alloy

Figure-1 shows Al-3003 Ingots used in the experiments to prepare samples.

Fig.-1 Al-3003 Ingots

2) E-Glass Fibre

E-Glass or electrical grade glass was originally developed for standoff insulators for electrical wiring. It was later found to have excellent fiber forming capabilities and is now used almost exclusively as the reinforcing phase in the material commonly known as fiber glass.

Fig.2 Chopped E-Glass Fiber

3) Silicon Carbide

Silicon carbide is the only chemical compound of carbon and silicon. It was originally produced by a high temperature electro – chemical reaction of sand and carbon. Silicon carbide is an excellent abrasive and has been produced and made into grinding wheels and other abrasive products for over one hundred years. Today the material has been developed into a high quality technical grade ceramic with very good mechanical properties. It is used in abrasives, refractories, ceramics and numerous high performance applications. The material can also be made an electrical conductor and has applications in resistance heating, flam igniters abd electronic components. Structural and wear applications are constantly developing.

Fig.3 Silicon carbide

B. Fabrication Of Test Specimen

The microstructure of any material is a complex function of the casting process, subsequent cooling rates. Therefore composites fabrication is one the most challenging and difficult task. Stir casting technique of liquid metallurgy was used to prepare Al 3003 Hybrid composites.

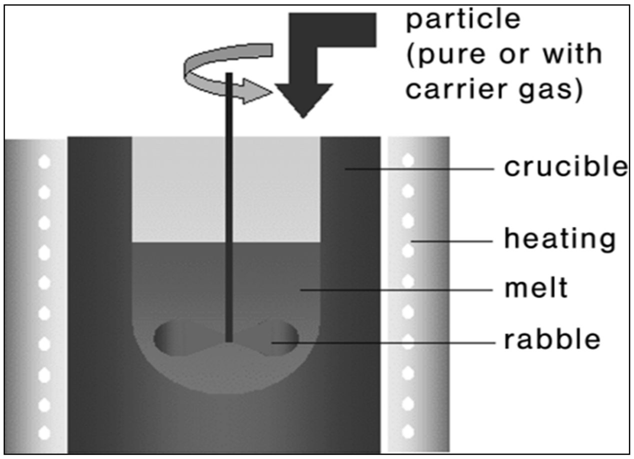


Fig.4 Graphical representation of stir casting.

1) *Preheating of reinforcement & melting of Matrix alloy:* Muffle furnace, shown in Figure 8 was used to preheat the particulate to a temperature of 500^0C. It was maintained at that temperature till it was introduced into the Al-3003 alloy melt. The preheating of reinforcement is necessary in order to reduce the temperature gradient and to improve wetting between the molten metal and the particulate reinforcement. The melting range of Al 3003 alloy is of 700 – 800^0C. A known quantity of Al 3003 ingots were loaded into the Graphite crucible of the furnace for melting. The melt was super heated to a temperature of 800^0C and maintained at that temperature. The molten metal was then degassed using Hexo chloro ethane tablets for about 8min. Figure 6 and Figure 7 indicates loading Al 3003 in to furnaces with crucible and Molten Metal respectively.

Fig.5 Molten Fig.6 degas tablet Fig.7Adding
Metal, Degasifier reinforcent Materials

2) *Mixing and Stirring and preparation of specimen:* Alumina coated stainless steel impeller was used to stir the molten metal to create a vortex. The impeller was of centrifugal type with 3 blades welded at 45^0 inclination and 120^0 apart. The stirrer was rotated at a speed of 300 – 400 rpm and a vertex was created in the melt. The depth of immersion of the impeller was approximately one third of the height of the molten metal. From the bottom of the crucible. The preheated particulates of SiC and short E-Glass fiber were introduced into the vortex at the rate of 120gm/min. Figure 7 shows the process of adding reinforcent material SiC and Chopped E-Glass Fibre. Stirring was continued until interface interactions between the particles and the matrix promoted wetting. The melt was superheated to temperature of (800^0C) it was poured into the preheated die.

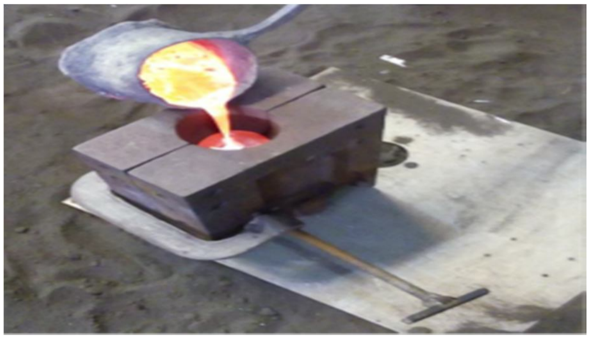


Fig.8 Pouring

Then after few minutes of stirring as shown in Figure 8, the liquid metals with reinforcements are poured into the dies to get the required castings. The pouring into the dies of ASTM Mould Box is as shown in the Figure 8. The dies were pre heated and were coated with additives to ease the process of removing the castings. The dies were coated with a mixture of china clay, water and sodium silicate to prevent iron contamination. Fig.9 shows the process of removing the casting after cooling the casted Al3003 hybrid composite with SiC and E-glass. After solidification the required casts are obtained which are sent for proof machining on a centre lathe to remove the scaling from the surface as shown in Figure 10.

Fig9. Final Casted Product

Fig.10 Machining

3) *Composition of Specimens Prepared:* Table 2 Different casting composition of Al-3003 Hybrid Composites produced as part of this research work.

Specification	SiC %	E-Glass %	AL 3003 %
C1	0	0	100
C2	2	1	95
C3	2	3	95
C4	2	5	93
C5	4	1	95
C6	4	3	93
C7	4	5	91
C8	6	1	93
C9	6	3	91
C10	6	5	89
C11	8	1	91
C12	8	3	89
C13	8	5	87

Table- 1: Different casting composition of Al-3003

III. TESTING OF COMPOSITES

A. Corrosion Test

The corrosion test was carried out using static immersion weight loss method as per standards. The test specimens were machined into standard discs of 20mm diameter and 20mm thick. Before testing the specimen the surfaces were ground with silicon carbide paper of 1000 grit size and polished in steps of 1.5 to 3 micron diamond paste to obtain a mirror surface finish. After subsequent rinsing with water and acetone and specimens were weighed accurately to a hundredth of milligram accuracy before starting the test by the weight loss method

B. Preparation of acidic solutions

The corrosion specimen were weighed on an electronic weighing machine accurately upto the third decimal place. Each of the specimens was immersed in 200ml of acidic solution such that composites of the different compositions are immersed in 0.5N and 1N NaCl solution for the test duration of 24,48,72,96 hours

C. Volumetric Analysis

The corrosion procedures as per ASTM were carried out with all percentage specimens and the uniform dispersion of reinforcements was studied by optical microscope. The corrodent used was Hydrochloric acid solution . The corrosion tests were conducted using conventional weight loss method similar to ASTM-G67-80 test standards. The tests were conducted on all types of specimens of the exposure time was varied from 48 to 192 hours, in steps of 48 hours. The cradles containing the measured specimens were kept inside the glass, which contains the corrodant. According to ASTM standards a ratio of 50ml of hydrochloric acid to $1mm^2$ of the surface area was maintained. After the corrosion test the specimen were immersed in acetone solution for 10 minutes and gently cleaned with a soft brush to remove adhered scales. After drying thoroughly the specimen were weighed to determine the percentage weight loss.

Fig.11 Specimen for Corrosion test.

Fig 12: Specimen during Corrosion

Fig 13: Specimen after Corrosion

Corrosion rate = $\frac{534 \times W}{D \times A \times T}$

Where W=W_1-W_2 weight loss due to corrosion in the static immersion corrosion test in grams.
If W_1 = weight of the specimen before the conduction of the test in grams.
W_2 = weight of the specimen after the conduction of the test in grams.
D = density of the composite in g/cm^3
A = Surface area of the specimen exposed to corrosion in square inch.
=2 x π x R(R+h) in square inch.
Where R = cross sectional radius of the specimen.
h = height of the specimen.
T = time in hours for which the corrosion test is conducted

IV. OBSERVATION TABLE

A. *Effect of exposure time on corrosion rate*

The corrosion rate was measurement as a function of exposure time in the static immersion test as shown. The observed trends in all the cases exhibit a decrease in corrosion rate with increase in test duration. It is clear from the tables and graphs that the corrosion resistance of the composites increases with exposure time.

The phenomenon of gradually decreasing corrosion rate indicates a possible passivation of matrix alloy. The black film consistes of hydrogen hydroxyl chloride film, which retards the forward reaction. Which also consists of aluminium hydroxide compound. This layer protects further corrosion in acidic medium. But exact chemical nature of such protective film is still not established.

SL No	TIME (HRS)	CORROSION RATE (mpy) 2%SiC, 1% of E-Glass	CORROSION RATE (mpy) 2%SiC, 3% of E-Glass	CORROSION RATE (mpy) 2%SiC, 5% of E-Glass	CORROSION RATE (mpy) 4%SiC, 1% of E-Glass
1	24	25.34	24.5	23.9	22.53
2	48	12.67	12.4	11.8	11.15
3	72	8.34	8.26	7.89	7.42
4	96	6.25	5.91	5.91	5.56

Table-1: Corrosion rate of Different % of SiC and E-Glass with Al-3003 in 0.25 Normality

Sl No	TIME (HRS)	CORROSION RATE (mpy) 4%SiC, 3% of E-Glass	CORROSION RATE (mpy) 4%SiC, 5% of E-Glass	CORROSION RATE (mpy) 6%SiC, 1% of E-Glass	CORROSION RATE (mpy) 6%SiC, 3% of E-Glass
1	24	22.24	21.12	19.71	19.43
2	48	11.01	10.45	9.75	9.62
3	72	7.33	6.96	6.5	6.40
4	96	5.5	5.2	4.87	4.8

Table-2: Corrosion rate of Different % of SiC and E-Glass with Al-3003 in 0.25 Normality

Sl No	TIME (HRS)	CORROSION RATE (mpy) 6%SiC, 5% of E-Glass	CORROSION RATE (mpy) 8%SiC, 1% of E-Glass	CORROSION RATE (mpy) 8%SiC, 3% of E-Glass	CORROSION RATE (mpy) 8%SiC, 5% of E-Glass
1	24	18.30	16.89	14	13.8
2	48	9.06	8.36	8.22	6.83
3	72	6.03	5.57	5.47	4.55
4	96	4.38	4.17	3.48	3.41

Table-3: Corrosion rate of Different % of SiC and E-Glass with Al-3003 in 0.25Normality

SL No	TIME (HRS)	CORROSION RATE (mpy) 2%SiC, 1% of E-Glass	CORROSION RATE (mpy) 2%SiC, 3% of E-Glass	CORROSION RATE (mpy) 2%SiC, 5% of E-Glass	CORROSION RATE (mpy) 4%SiC, 1% of E-Glass
1	24	42.09	39.2	38.1	41.81
2	48	20.77	19.3	18.8	20.63
3	72	13.83	12.9	12.5	13.74
4	96	10.37	9.67	9.39	10.30

Table-4: Corrosion rate of Different % of SiC and E-Glass with Al-3003 in 1 Normality

SL No	TIME (HRS)	CORROSION RATE (mpy) 2%SiC, 1% of E-Glass	CORROSION RATE (mpy) 2%SiC, 3% of E-Glass	CORROSION RATE (mpy) 2%SiC, 5% of E-Glass	CORROSION RATE (mpy) 4%SiC, 1% of E-Glass
1	24	38.99	37.86	40.96	37.29
2	48	19.24	18.68	20.21	18.4
3	72	12.81	12.44	13.46	12.25
4	96	9.60	9.32	10.09	9.19

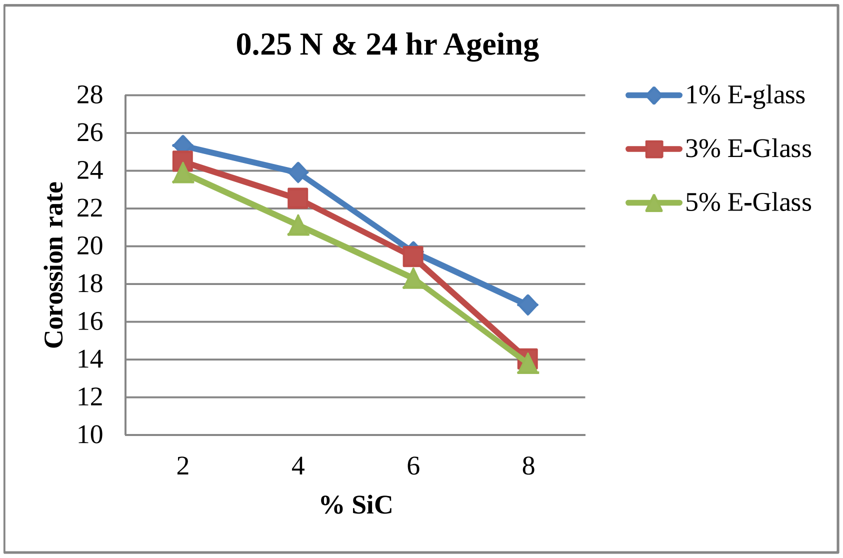
Table-5: Corrosion rate of Different % of SiC and E-Glass with Al-3003 in 1 Normality

SL No	TIME (HRS)	CORROSION RATE (mpy) 2%SiC, 1% of E-Glass	CORROSION RATE (mpy) 2%SiC, 3% of E-Glass	CORROSION RATE (mpy) 2%SiC, 5% of E-Glass	CORROSION RATE (mpy) 4%SiC, 1% of E-Glass
1	24	36.16	39.5	36.73	35.8
2	48	17.84	19.51	18.12	17.7
3	72	11.88	13.00	12.07	11.7
4	96	8.91	9.74	9.05	8.8

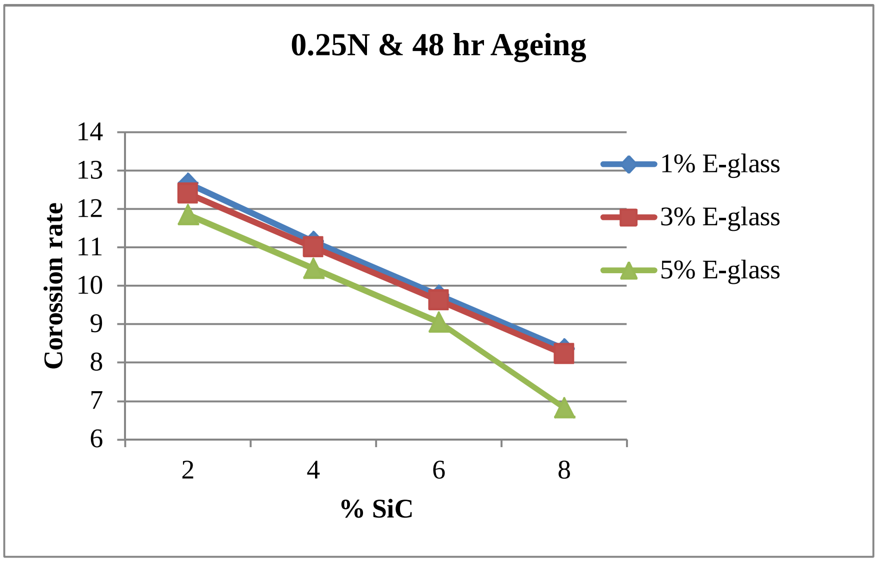
Table-6: Corrosion rate of Different % of SiC and E-Glass with Al-3003 in 1 Normality

V. RESULTS AND DISCUSSIONS

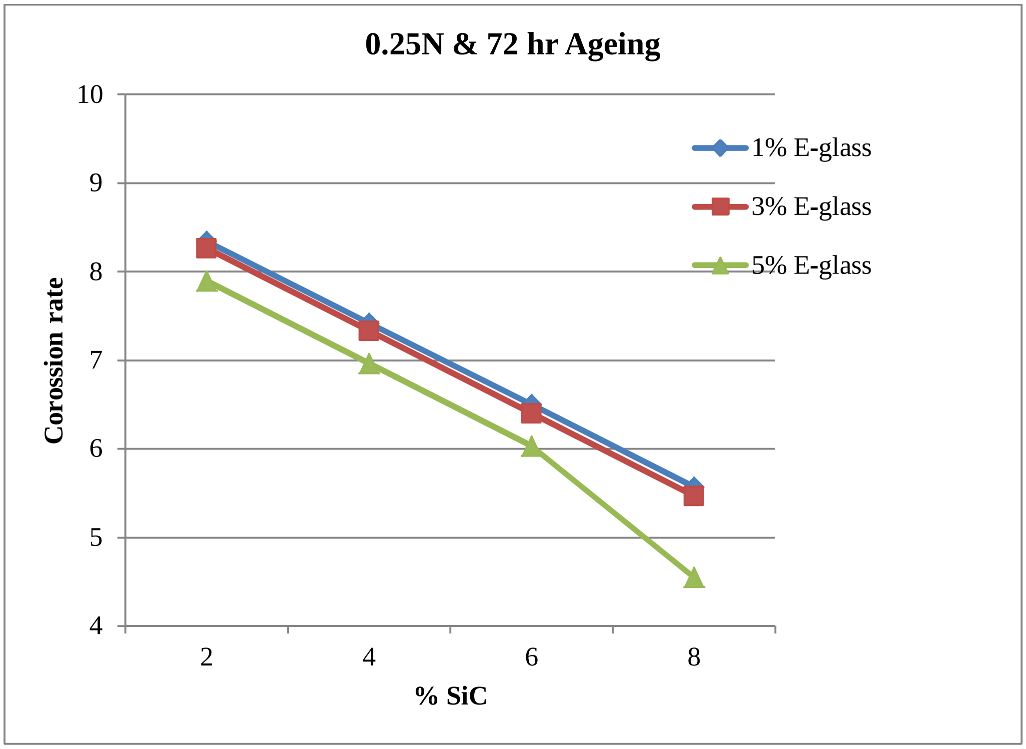
Below graph shows the corrosion rate of specimen in different composition of SiC & E-glass fiber



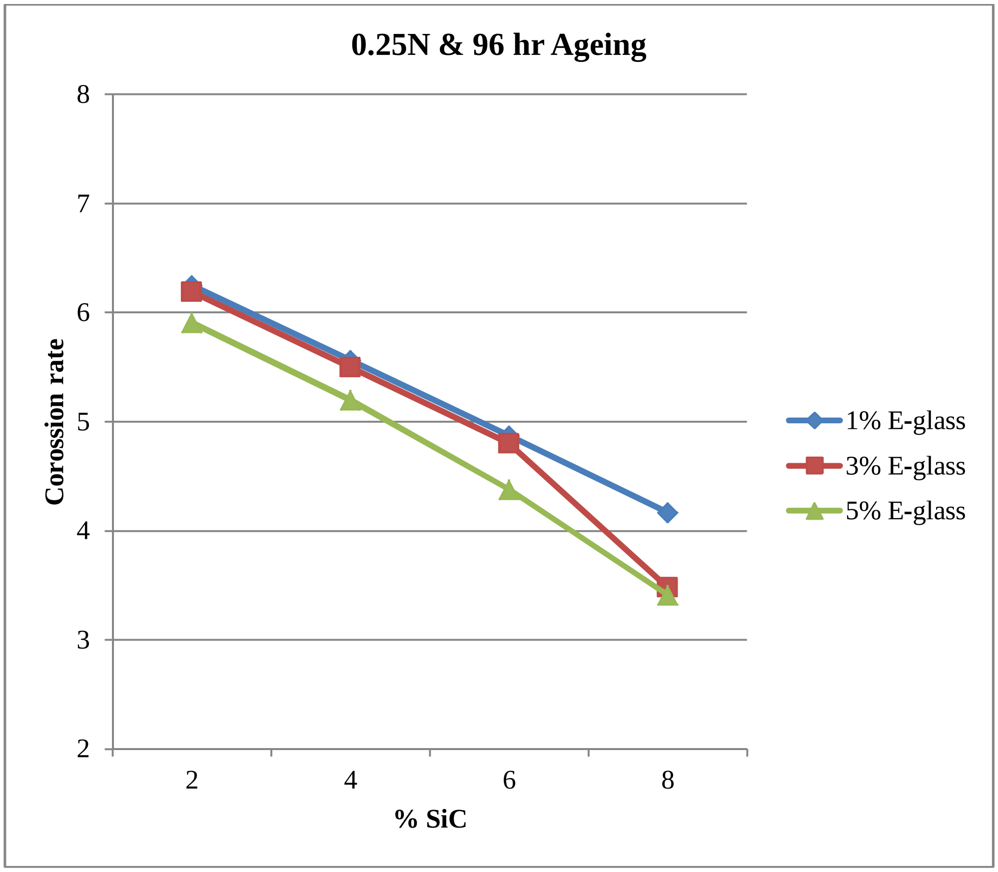
Graph-1: corrosion rate Vs % of SiC



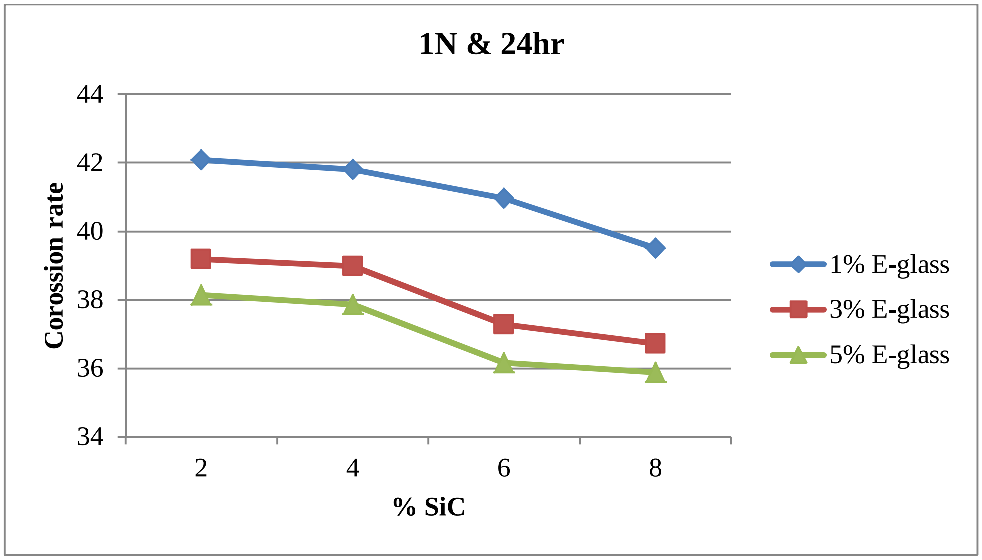
Graph-2:corrosion rate Vs % of SiC



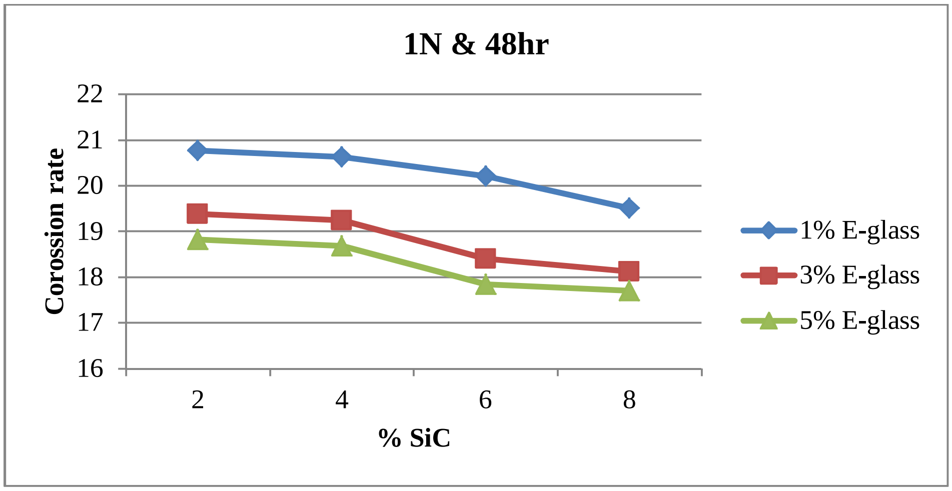
Graph-3: corrosion rate Vs % of SiC



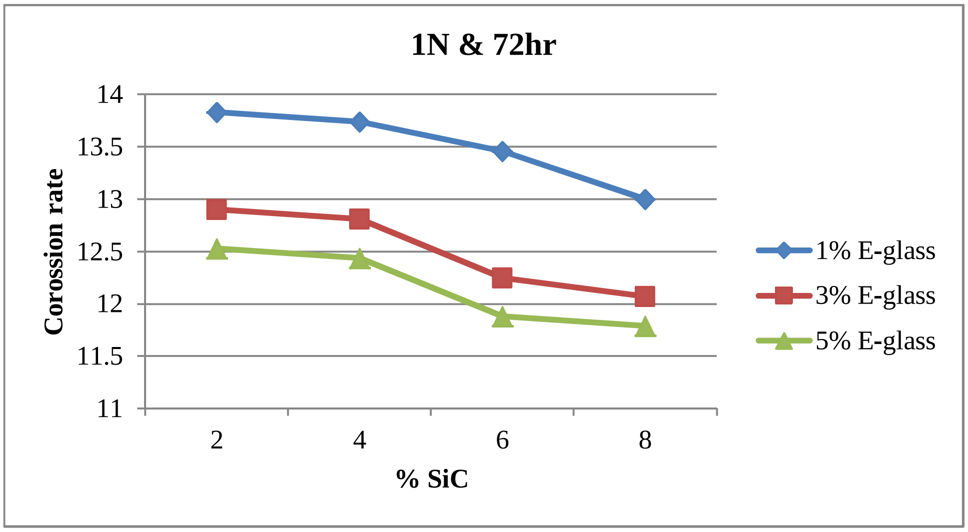
Graph-4: corrosion rate Vs % of SiC



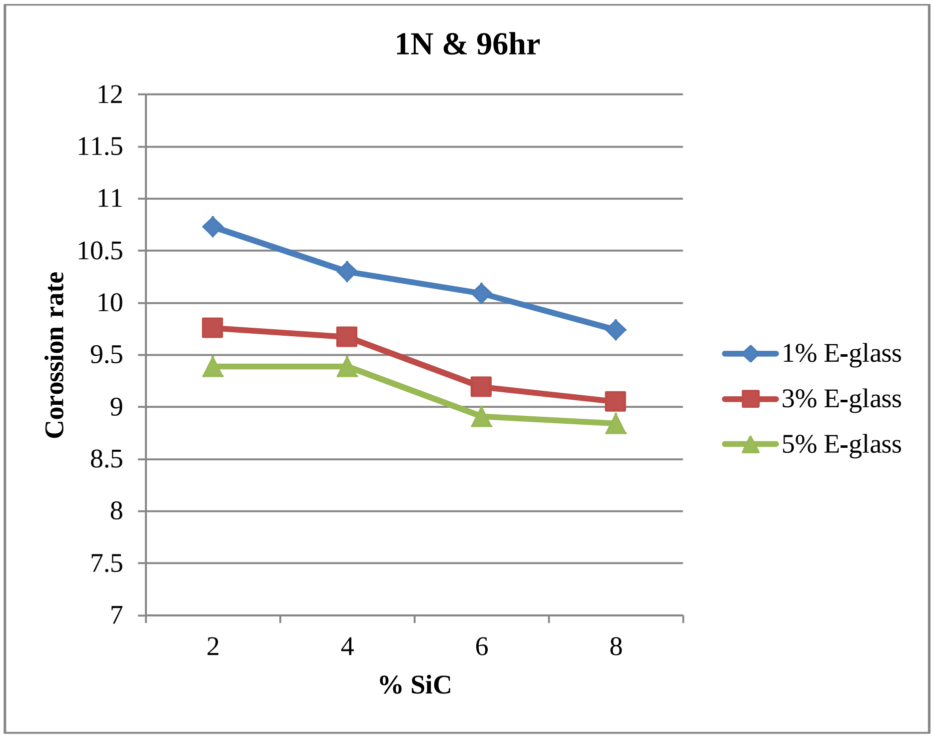
Graph-5: corrosion rate Vs % of SiC



Graph-6: corrosion rate Vs % of SiC



Graph-7: corrosion rate Vs % of SiC



Graph-8: corrosion rate Vs % of SiC

A. *Effect of exposure time on corrosion rate*

The corrosion rate was measurement as a function of exposure time in the static immersion test as shown. The observed trends in all the cases exhibit a decrease in corrosion rate with increase in test duration. It is clear from the tables and graphs that the corrosion resistance of the composites increases with exposure time.

B. *Effect of Normality on corrosion rate*

It is observed that , the corrosion rate is maximum for 1N which corresponds to NaCl environment. As normality value increases corresponding to NaCl medium the corrosion rate decreases rate also increase. The corrosion rate in the 0.5N of corrosion media are also observed to be less than that of 1N. The corrosion rate of each specimen increases with the concentration of NaCl as expected. In fact, the corrosion attack has a stronger tendency to penetrate more deeply as the concentration of the NaCl solution from 0.25 to 01N.

VI. CONCLUSIONS

A. The corrosion resistance increases with increase in duration of time. The improvement in corrosion resistance due to this factor is attributed to a protective layer formed on the surface of the material which gradually builds up and reaches a steady state with time.

B. The Corrosion resistance was also found to improve with increase in E-glass concentration, probably since they act as physical barriers to the corrosion process, as well as the aluminium intermetallic compounds at the matrix, restricting pit formation and propogation there in.

C. The composite specimens showed better corrosion /pitting resistance than the unre-enforced matrix alloy, also it is seen that corrosion rate increase with increase in normality of the solution

D. The e glass content in aluminium alloys place a significant role in the corrosion resisitance of the material. Incrase in the percentage of addition will be advantageous to reduce the density and increase in the strength of the alloy, and thus the corrosion resisitance is ther-by significantly reduced.

E. The corrosion resistance of the composites was higher than that of the corresponding matrix alloy, which may be due to dislocation density and porosity of MMC’s

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