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# CORROSION STUDIES ON CNT AND E-GLASS FIBER REINFORCED ALUMINIUM 7075 HYBRID COMPOSITES

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## ABSTRACT

Composite materials are manufactured from two or more materials to take advantage of desirable characteristics of the components. A composite material, in mechanics sense, is a structure with the ingredients as element transferring forces to adjacent members. The advance in design and application of composites has accelerated in the past decade especially in the aeronautics, defense and space industries. Commercial applications are also increasing as products needing challenging materials properties are increasing in demand. The majority of the composite material uses two constituents: a binder or a matrix and reinforcement. The reinforcement is stronger and stiffer, forming a sort of backbone, while the matrix keeps the reinforcement in a set place. The binder also protects the reinforcement, which may be brittle or breakable, as in the case of long glass fibers used as a conjunction with plastic to make fiber glass. Generally, composite materials have excellent corrosive resistance making them versatile in wide range of situations. In this work the specimens are fabricated using CNT and glass fiber with Aluminium7075 with the help of stir casting method. Corrosion specimens as per ASTM standards are prepared with different composition of carbon nano tubes and glass fiber. Furthermore, corrosion characteristics of composite specimens consisting of different compositions in acidic medium are studied. For all compositions of the specimen, the corrosion rates of the specimen are recorded for different normality's using weight loss method. 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.

**KEYWORDS:** Carbon Nanotubes (CNT), E-Glass fiber, carbon fiber, Aluminium 7075 alloy, Stir Casting.

**INTRODUCTION**

Conventional monolithic materials have limitations in achieving good combination of strength, stiffness, toughness and density. To overcome these shortcomings and to meet the ever increasing demand of modern day technology, composites are most promising materials of recent interest. Metal matrix composites (MMCs) possess significantly improved properties including high specific strength; specific modulus, damping capacity and good wear resistance compared to unreinforced alloys. There has been an increasing interest in composites containing low density and low cost reinforcements. Among various discontinuous dispersions used, Carbon Nano Tubes (CNTs) are one of the high strength and low density reinforcement available. Hence, composites with CNT as reinforcement are likely to exhibit high strengths for wide spread applications in automotive and small engine applications. It is therefore expected that the incorporation of E-Glass short fibers in aluminum alloy will promote yet another use of this low-cost reinforcement and, at the same time, has the potential for conserving energy intensive aluminum and thereby, reducing the cost of aluminum products.

The popular use of aluminum and its alloys in the automobile and aerospace industries gives a clear indication of the desirable properties processed by these materials. But, as technology has progressed there has been a need to fabricate materials with enhanced properties. The arena of advanced materials as made open to us limit less avenues of achieving these desired characteristics in materials. Thus to achieve specific properties selection from an array of composite materials, each tailor made to satisfy specific needs. A lot of work has been carried out in the field of E-Glass fibers reinforced aluminum matrix composites which makes it very clear that this combination is a very popular one. In recent time, commendable work has taken place in the field of Metal Matrix Composites. The results of which have shown us their tremendous capacity in enhancing the favorable properties of aluminum and its alloys. Metal matrixes with the suitable reinforcement have addressed a range of new requirements.

## EXPERIMENTATION

### 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 CNT, 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%.

### Aluminium 7075 Alloy

Figure-1 shows Al-7075 Ingots used in the experiments to prepare samples.

**Fig. 1: Al-7075 Ingots.**

### 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. Glass fibers are generally produced using melt spinning techniques. These involve melting the glass composition into a platinum crown which has small holes for the molten glass to flow. Continuous fibres can be drawn out through the holes and wound onto spindles, while short fibres may be produced by spinning the crown, which forces molten glass out through the holes centrifugally. Fibres are cut to length using mechanical means or air jets. Chopped E-Glass Fibre is as shown in Fig.2.

**Fig. 2: Chopped E-Glass Fiber.**

**Carbon Nano Tubes**

Carbon nanotubes (CNTs) are allotropes of carbon with a cylindrical nanostructure. Nanotubes have been constructed with length-to-diameter ratio of up to 132,000,000:1, significantly larger than for any other material. These cylindrical carbon molecules have unusual properties, which are valuable for nanotechnology, electronics, optics and other fields of materials science and technology. In particular, owing to their extraordinary thermal conductivity and mechanical and electrical properties, carbon nanotubes find applications as additives to various structural materials. For instance, nanotubes form a tiny portion of the material(s) in some (primarily carbon fiber) baseball bats, golf clubs, car parts or Damascus steel.

**Fig. 3: Multi Walled Carbon Nano Tubes (MWCNT).**

**Fabrication of Composites**

Composites fabrication is one the most challenging and difficult task. Stir casting technique of liquid metallurgy was used to prepare CNT and E-glass fiber reinforced Al 7075 Hybrid composites. A stir casting setup Consist of a electrical Furnace and a stirrer assembly, which was used to synthesize the composite.

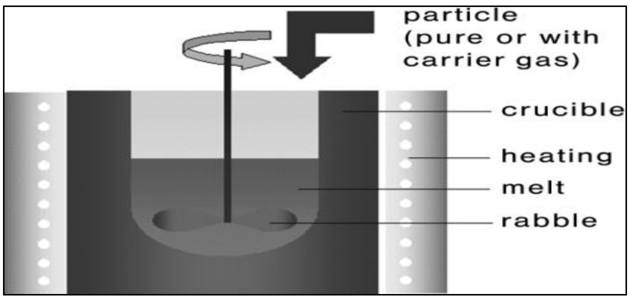



**Fig. 4: Stir casting. Setup.**

**Preheating of reinforcement and melting of alloy**

Muffle furnace was used to preheat the particulate to a temperature of $500^0$C. It was maintained at that temperature till it was introduced into the Al 7075 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 7075 alloy is of 700 – 800$^0$C. A known quantity of Al 7075 ingots were loaded into the Graphite crucible of the furnace for melting. The melt was super heated to a temperature of 800$^0$C and maintained at that temperature. The molten metal was then degassed using Hexo chloro ethane tablets for about 8min.

**Fig. 5: Crucible furnace**

**Fig. 6: Degass tablets.**

**Mixing, Stirring, casting and preparation of specimens**

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 CNT 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 Chopped E-Glass Fibre and MWCNT's. Stirring was continued until interface interactions between the particles and the matrix promoted wetting. The melt was superheated to temperature of (800$^0$C) it was poured into the preheated die. Then after few minutes the liquid metals with reinforcements are poured into the dies to get the required castings. 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. 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.

**Fig. 7: Adding reinforcent Materials.**

**Fig. 8: Pouring Molten Metal.**

**Fig. 9: Final Casted Product.**

**Fig. 10: Machining of Casted Product.**

**Composition of Specimens Prepared**

**Table 1: shows Different casting composition of Al-7075 Hybrid Composites produced.**

| Specification | E-Glass % | CNT % | AL 7075 % |
|---|---|---|---|
| C1 | 0 | 0 | 100 |
| C2 | 1 | 0.5 | 98.5 |
| C3 | 1 | 1.0 | 98 |
| C4 | 1 | 1.5 | 97.5 |
| C5 | 1 | 2.0 | 97 |
| C6 | 5 | 0.5 | 94.5 |
| C7 | 5 | 1.0 | 94 |
| C8 | 5 | 1.5 | 93.5 |
| C9 | 5 | 2.0 | 93 |

**Different casting composition of Al-7075**

## TESTING OF COMPOSITES

### 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.

**Preparation of acidic solutions**

The corrosion specimens were weighed on an electronic weighing machine accurately up to 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 HCl solution for the test duration of 48, 96, 144, 192 hours.

**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.**

## RESULTS AND DISCUSSIONS

### 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.

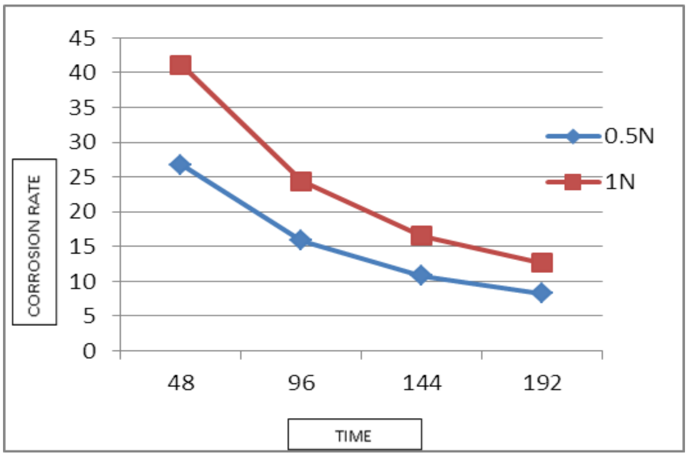
The phenomenon of gradually decreasing corrosion rate indicates a possible passivation of matrix alloy. The black film consistes of hydrogen hydroxyl chloride film, which retards the forward reaction. Which also consists of aluminium hydroxide compound. This layer protects further corrosion in acidic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

**Table 2: Corrosion rate of 1% of E-Glass and Different % of CNT in AL 7075.**

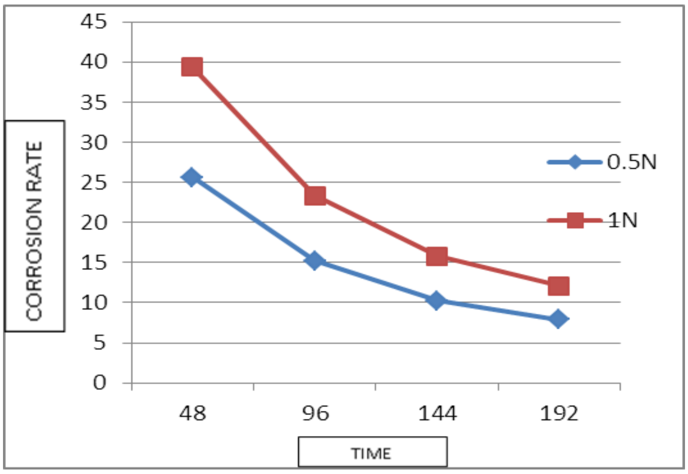
| Sl. No. | Time (Hrs) | Corrosion Rate (mpy) 1% E-Glass, 0.5% of CNT | Corrosion RATE (mpy) 1% E-Glass, 1% of CNT | Corrosion RATE (mpy) 1% E-Glass, 1.5% of CNT | Corrosion Rate (mpy) 1% E-Glass, 2% of CNT |
|---|---|---|---|---|---|
| 1 | 48 | 26.75 | 25.60 | 24.76 | 21.43 |
| 2 | 96 | 15.88 | 15.20 | 14.70 | 14.88 |
| 3 | 144 | 10.74 | 10.28 | 9.94 | 10.21 |
| 4 | 192 | 8.22 | 7.87 | 7.61 | 7.80 |
| 5 | 48 | 41.10 | 39.33 | 38.04 | 32.93 |
| 6 | 96 | 24.4 | 23.35 | 22.58 | 22.86 |
| 7 | 144 | 16.50 | 15.79 | 15.27 | 15.69 |
| 8 | 192 | 12.63 | 12.08 | 11.69 | 11.98 |

**Table 3: Corrosion rate of 5% of E-Glass and Different % of CNT in AL 7075.**

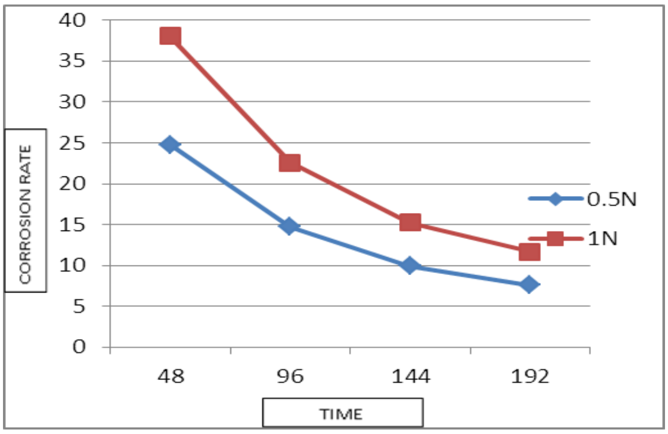
| Sl. No. | Time (Hrs) | Corrosion Rate (mpy) 5% E-Glass, 0.5% of CNT | Corrosion Rate (mpy) 5% E-Glass, 1% of CNT | Corrosion Rate (mpy) 5% E-Glass, 1.5% of CNT | Corrosion Rate (mpy) 5% E-Glass, 2% of CNT |
|---|---|---|---|---|---|
| 1 | 48 | 20.49 | 20.16 | 19.84 | 19.28 |
| 2 | 96 | 14.23 | 14.60 | 13.77 | 13.96 |
| 3 | 144 | 9.76 | 9.73 | 9.45 | 9.30 |
| 4 | 192 | 7.46 | 7.56 | 7.22 | 7.23 |
| 5 | 48 | 31.48 | 30.97 | 30.48 | 29.62 |
| 6 | 96 | 21.86 | 22.43 | 21.16 | 21.45 |
| 7 | 144 | 15.00 | 14.95 | 14.52 | 14.29 |
| 8 | 192 | 20.49 | 11.62 | 11.09 | 11.11 |



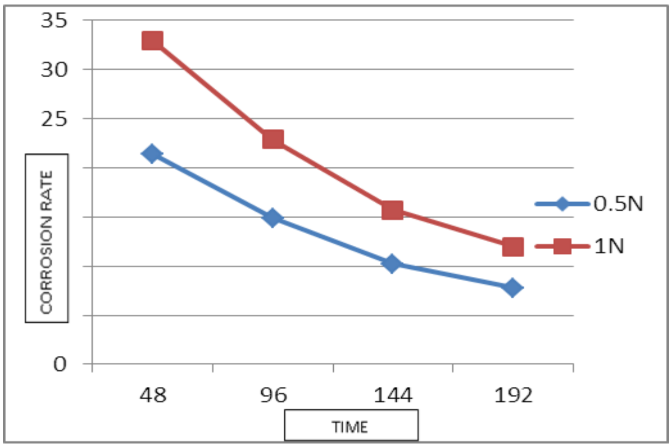

**Graph 1: corrosion rate Vs time of 1% E-glass, 0.5% CNT and AL 7075 is 98.5%.**



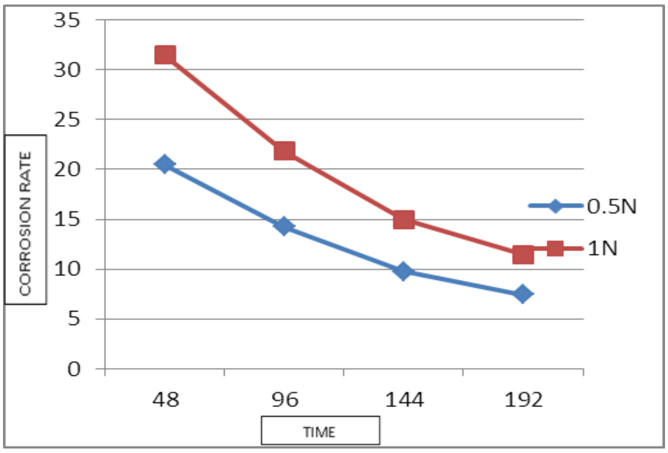

**Graph 2: corrosion rate Vs time of 1% E-glass, 1% CNT and AL 7075 is 98%.**



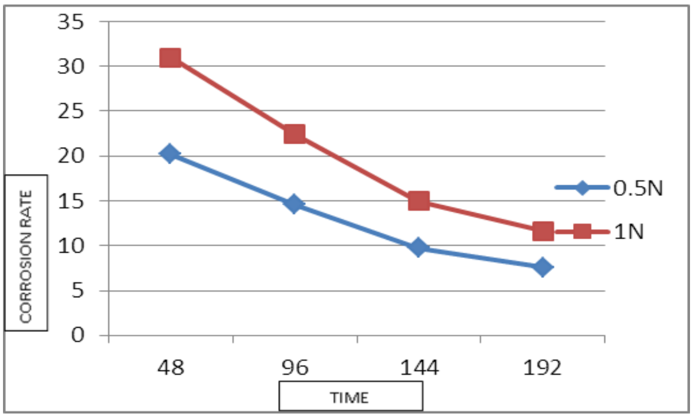

**Graph 3: corrosion rate Vs time of 1% E-glass, 1.5% CNT and AL 7075 is 97.5%.**



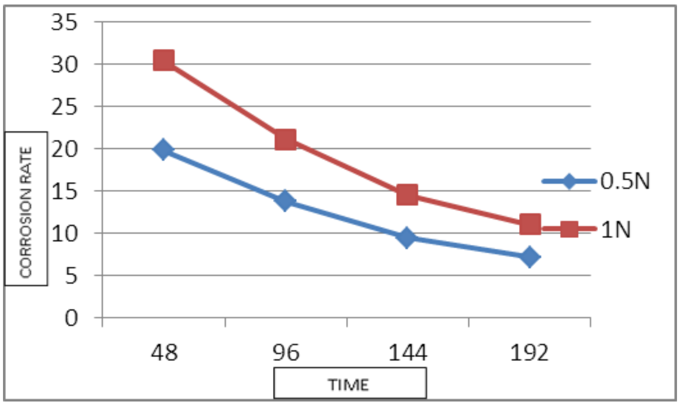

**Graph 4: corrosion rate Vs time of 1% E-glass, 2% CNT and AL 7075 is 97%.**



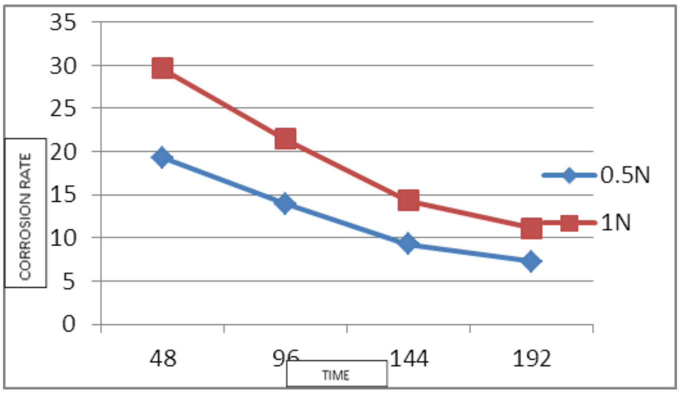

**Graph 5: corrosion rate Vs time of 5% E-glass, 0.5% CNT and AL 7075 is 94.5%.**




**Graph 6: corrosion rate Vs time of 5% E-glass, 1% CNT and AL 7075 is 94%.**




**Graph 7: corrosion rate Vs time of 5% E-glass, 1.5% CNT and AL 7075 is 93.5%.**




**Graph 8: corrosion rate Vs time of 5% E-glass, 2% CNT and AL 7075 is 93%.**

## CONCLUSIONS

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

- 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.
- 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.
- The corrosion rate 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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