Study of Corrosion properties of micro titanium and carbon nano tube reinforced in copper based metal matrix composites

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Abstract - **Composites material plays a prominent role in industrial sectors. The metal matrix composites play a vital role in any scenario with respect to these properties and their usage in current applications. The materials like micro titanium have good properties and hence these materials are considered and the hybrid composites are developed. In the current project work metal matrix composites was developed using copper as a matrix and carbon nanotubes and micro titanium as reinforcement. In this paper the metal matrix composites were developed using stir casting and the developed composites was subjected to corrosion test as per ASTM standards. The corrosion test was experimentally based on the concept of effects of percentage of reinforcement on corrosion duration based on normality media on corrosion rate of carbon nanotube and micro titanium in copper metal matrix and hence this present work attempts to understand the influence of corrosion on copper composites.**

keywords - **Micro titanium, Copper, Carbon nanotubes, Corrosion test, ASTM standards, Normality, Molarity.**

I. Introduction

Composites materials play a vital role in accordance with its tailor-made properties in the present modern industrial sector. Metal matrix composites are advanced materials resulting from a combination of two or more materials in which tailored properties are realized. The incorporation of several different types of fibers and reinforcements into a single matrix has led to the development of hybrid composites. The properties of hybrid composites mainly depend upon the fibre content, length of individual orientation, extent of intermingling of fibres, fibre to matrix bonding and arrangement of both the fibres.In this project the composite material developed was hybrid composite. 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. [1]

Study of corrosion behavior of such composites is very much necessary as they often come in contact with acid during cleaning, pickling, descaling, etc. Corrosion resistance of metal matrix composites depend largely on processing techniques, type of reinforcements and particulate size of the reinforcements and does not provide satisfactory results after a great deal of research. A contamination in the alloys and in homogeneity of the chemical composition adds to the corrosion damage. Chloride environment makes the aluminum alloys more prone to pitting corrosion and further inhibits the development of the compact protective layer. As a result, pitting centers are developed. As the number of pits increases, the alloy element are more cathodic than pure aluminum, further accelerating the propagation of pits and promotes depassivation.This paper focuses on the corrosion behavior of micro titanium and carbon nanotubes in copper based composites. [2-3]

II.EXPERIMENTATION

A. Materials

Reinforcements are selected and there compositions are considered based on the previous work done by the researchers. The following materials are used in this project and the same is discussed below:

1. **Carbon nanotubes**:
The carbon nanotubes are the interesting nanostructures with large potential in any application and hence they are known as carbon nanotubes. Nanotubes are categorized as single-walled nanotubes and multiwall nanotubes. Individual nanotubes naturally align themselves into ropes held together by Vander walls forces more specifically pi-stacking.

2. **Copper alloys:** Copper alloys are alloys which are having high resistance against corrosion. These alloys offer a suite of indefinitely recyclable materials providing many property combinations suited to a wide range of application that facilitate and enhance our daily lives.

3. **Micro titanium**: Micro titanium is considered because of these its high strength to weight ratio and their good mechanical properties and high melting point and hence these characteristics of micro titanium are considered as material in this project work.

The figures1 shoes the materials used in the project work

Fig1 Copper alloy, CNT, Micro titanium

B.Fabrication of specimen:

The fabrication of specimen is done by using stir casting process. Stir Casting is a liquid state method of composite materials fabrication, in which a dispersed phase (ceramic particles, short fibers) is mixed with a molten matrix metal by means of Mechanical stirring. The liquid composite material is then cast by conventional casting methods and may also be processed by convectional Metal forming technologies. The figure2 shows fabrication of specimen by stir casting

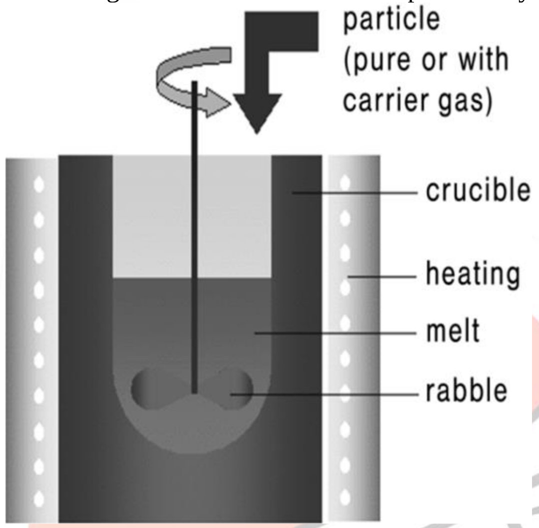

Fig 2 stir casting

C.Composition of specimen prepared:

The developed composite material composition is shown in the table1

Table 1 Composition of specimens

Compositions	Percentage of Carbon nanotubes %	Percentage of Micro titanium %	Percentage of Copper %
C	0	0	100
C1	0.5	1	98.5
C2	0.5	3	96.5
C3	0.5	5	94.5
C4	1	1	98.0
C5	1	3	96.0
C6	1	5	94.0
C7	1.5	1	97.5
C8	1.5	3	95.5
C9	1.5	5	93.5

III Testing of Composites:

1. Corrosion test:

In this paper the corrosion test is discussed based on the normality of the developed hybrid composites. The following is the discussion on the corrosion property.

The corrosion test was carried out using static immersion weight loss method as per Standards. The test specimens were machined into standards discs of 20mm diameter and 20mm thick. Before testing the specimen the surfaces was ground with silicon carbide paper of 1000 grit size. After subsequent rinsing with water and acetone the specimens were weighed accurately to a hundredth of milligram accuracy before starting the test by the weight loss method.

2. Procedure for corrosion based on normality:

The following procedure is followed for the corrosion experimentation in this project work:
1. Preparation of the acidic solutions containing sodium chloride of different normalities.
2. Immersion of the corrosion specimens in the solution for the required time.
3. Removal and cleaning of the corroded specimens.

3. Preparation of Solution:

The corrosion specimens were weighed on an electronic weighing machine accurately up to the fourth decimal place. Each of the specimens immersed in 200 ml of solution such that composites of the same composition are immersed of 0.5N, 1N & 0.5M,1M NaCl & HCl solutions for test durations of 24,48,72 and 96hours.

4. Volumetric Analysis:

The number of gram equivalents of the solute present in one liter of the solution is called normality of the solution. The chemical used were concentrated Hydrochloric acid having a normality of 0.5N NaCl and deionized water that has a normality of zero. The normal solutions required were 0.5N& 1N NaCl solution. The required volume of solution required for immersion of each specimen irrespective of its normality was fixed at 100 ml. The volumetric law of equivalents was employed to convert the 0.5N NaCl to 1N NaCl solution. The loss in weight due to corrosion was calculated and corresponding corrosion rates were calculated. 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 24 to 96 hrs. 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 drying thoroughly the specimen were weighed to determine the percentage weight loss.
The corrosion test specimen is shown in following figure3

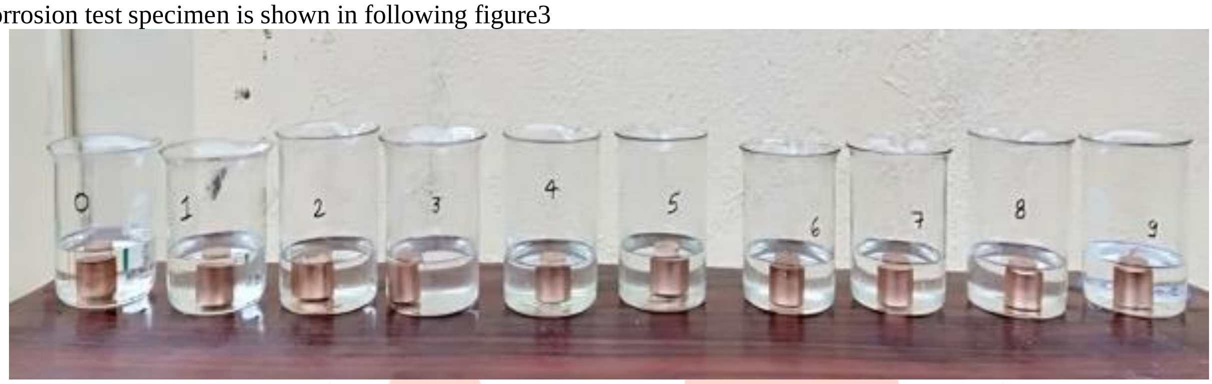

Fig 3 Corrosion test specimens

5. Corrosion rate:

Corrosion rate (mm/y) = $\frac{K\times W}{D\times A\times T}$ **(mm/y)**--------------------------------------- (1)

Where, W=W1-W2 weight loss due to corrosion in the static immersion corrosion test in grams.
If W1 = weight of the specimen before the conduction of the test in grams.
W2 = weight of the specimen after the conduction of the test in grams.
D = density of the composite in g/cm3
A = Surface area of the specimen exposed to corrosion in square inch.
A =2 x π x R (Rah) 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 of Corrosion rate

A. Corrosion rate based on normality at 0.5N

The observation on corrosion rate is a function of the exposure on static immersion rate. The observation table provides us the better understanding and the corrosion rate based on normality at 0.5N & 1N is discussed below:
The table 2 shows the corrosion rate based on normality at 0.5 N,

Table 2 Corrosion rate at 0.5 N

Normality (N)	**Time Hrs**	**Corrosion rate(mm/y)**									
		C0	**C1**	**C2**	**C3**	**C4**	**C5**	**C6**	**C7**	**C8**	**C9**

0.5	24	0.00923	0.00659	0.00527	0.00516	0.00395	0.00211	0.00211	0.00188	O.00116	0.00102
	48	0.00822	0.0065	0.00527	0.00515	0.00395	0.0211	0.0021	0.00153	0.0011	0.00101
	72	0.00711	0.00625	0.00526	0.00511	0.00394	0.00211	0.00204	0.00133	0.00104	0.00101
	96	0.00639	0.00639	0.00521	0.00508	0.00393	0.00211	0.00208	0.01111	0.00101	0.001

The table 2 illustrates the corrosion rate with respect to normality at 0.5N and at 24,48,72,96 hrs respectively. Similarly the corrosion variation based on 1N is mentioned below:

B.Corrosion rate based on normality at 1N

Table 3Corrosion rate at 1N

Normality (N)	Time Hrs	Corrosion rate(mm/y)									
		C0	**C1**	**C2**	**C3**	**C4**	**C5**	**C6**	**C7**	**C8**	**C9**
1	24	0.0105	0.0098	0.00851	0.00621	0.00511	0.00386	0.0031	0.00256	O.00211	0.00111
	48	0.00911	0.0082	0.00711	0.00634	0.00522	0.0312	0.00308	0.00278	0.00118	0.0011
	72	0.00812	0.00713	0.00623	0.00541	0.00323	0.00253	0.0022	0.00196	0.00123	0.0011
	96	0.00716	0.00638	0.00546	0.0051	0.00302	0.00225	0.0021	0.0157	0.00108	0.00103

From the table 2 & table 3 shows the corrosion rate variation at 0.5N & 1N. In this relation the below graphical representation based on normality is discussed in following below graphs in the section results and discussions.

V Results & Discussions

The effect of corrosion rate based on normality and graphical variations of above tabulated results can be discussed in the following graphs.

A. Corrosion rate based on normality at 0.5N

1. **Corrosion rate 0.5N Nail 24 hrs ageing condition**

The following graphs show the variation in corrosion rate at 0.5N Nail 24hrs ageing condition:

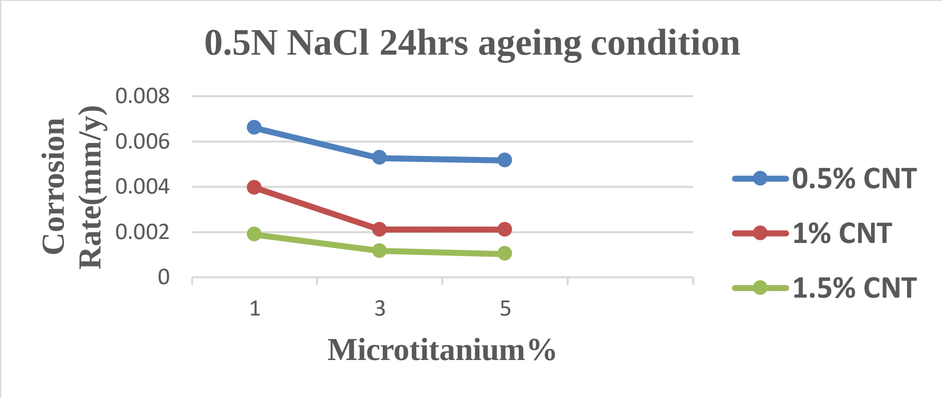

Fig 4Corrosion rate vs. percentage of micro titanium at 0.5N 24 hrs.

2. Corrosion rate 0.5N Nacl 48hrs ageing conditions

The following graphs show the variation in corrosion rate at 0.5N Nacl 48hrs ageing condition:

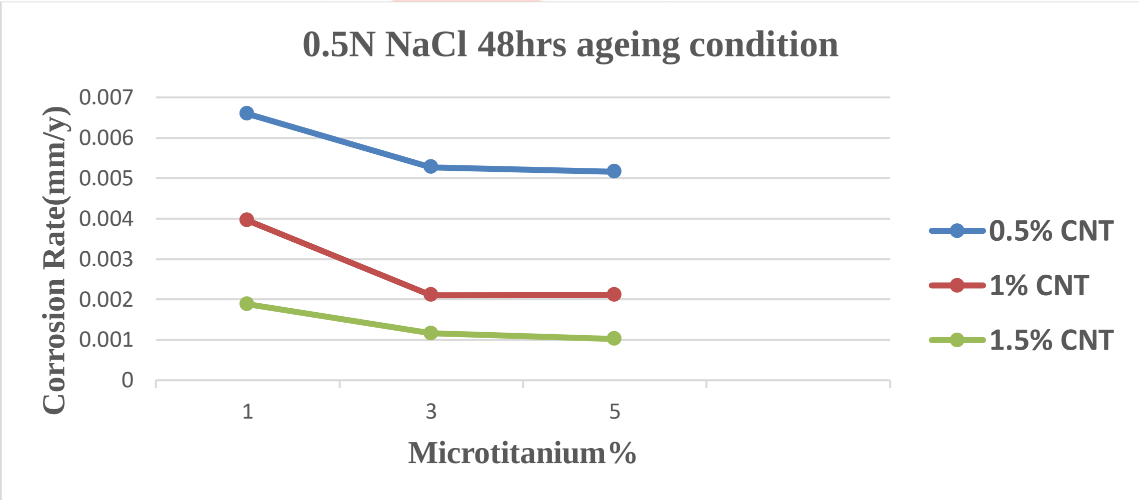

Fig 5 Corrosion rate vs. percentage of micro titanium at 0.5N 48 hrs

3. Corrosion rate 0.5N Nacl 72hrs ageing conditions

The following graphs show the variation in corrosion rate at 0.5N Nacl 72hrs ageing condition:

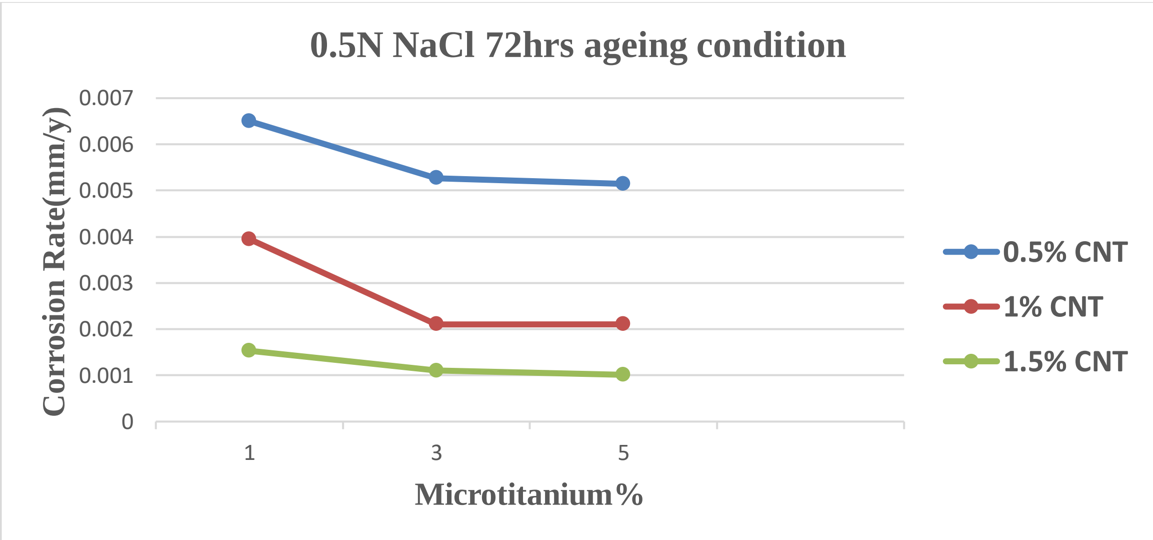

Fig 6 Corrosion rate vs. percentage of micro titanium at 0.5N 48 hrs

4. Corrosion rate 0.5N Nacl 96hrs ageing conditions
The following graphs show the variation in corrosion rate at 0.5N Nacl 96hrs ageing condition:

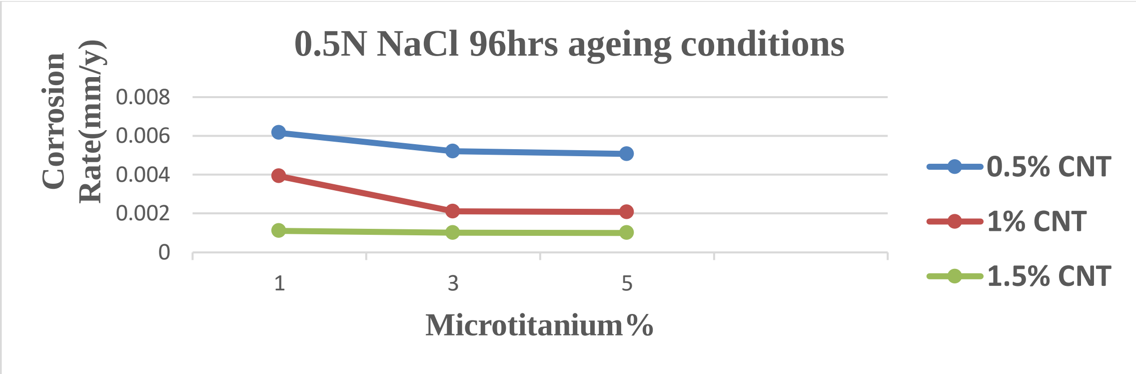

Fig7 Corrosion rate vs. percentage of micro titanium at 0.5N 96 hrs

From the table and graph the corrosion rate based normality at 0.5N, 24, 48, 72,96hrs as the following observations.
1.The effect of CNT and micro titanium on corrosion rate, as seen in above graph, the corrosion rate decrease as the percentage of micro titanium increases from 1%, 3%, and 5% and 0.5%, 1.0% and 1.5% CNT in CNT and micro titanium hybrid reinforced Copper based MMC.
2. At 0.5N and 96hrs, the corrosion rate increased this is because of amount of reinforcements in MMC.

B.Corrosion rate based on normality at 1N

1. **Corrosion rate 1N NaCl 24 hrs ageing condition**

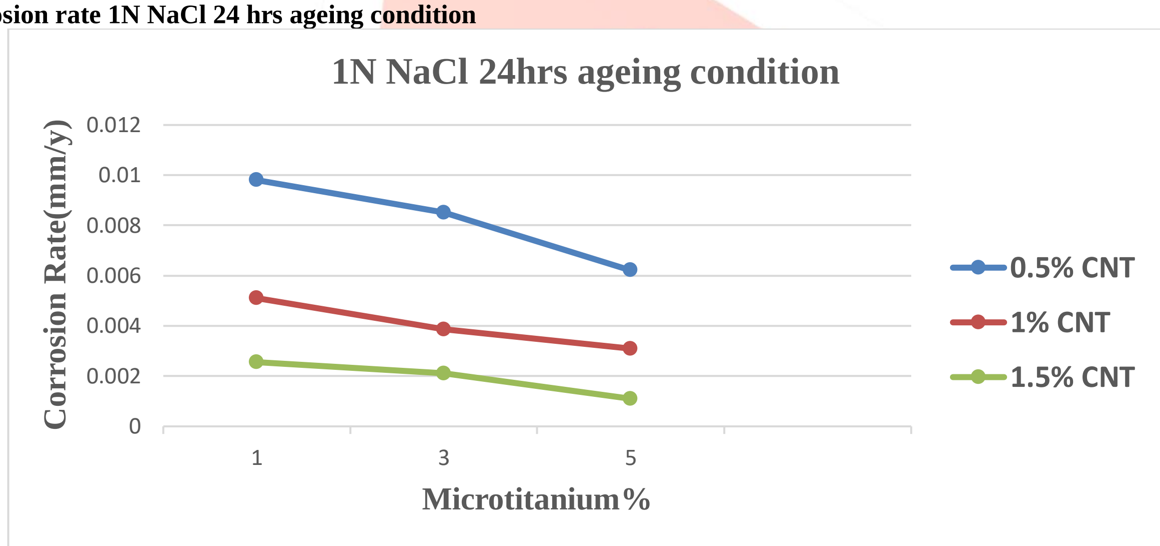

Fig 8Corrosion rate vs. percentage of micro titanium at 1N, 24 hrs.

2. Corrosion rate 1N NaCl 48 hrs ageing condition

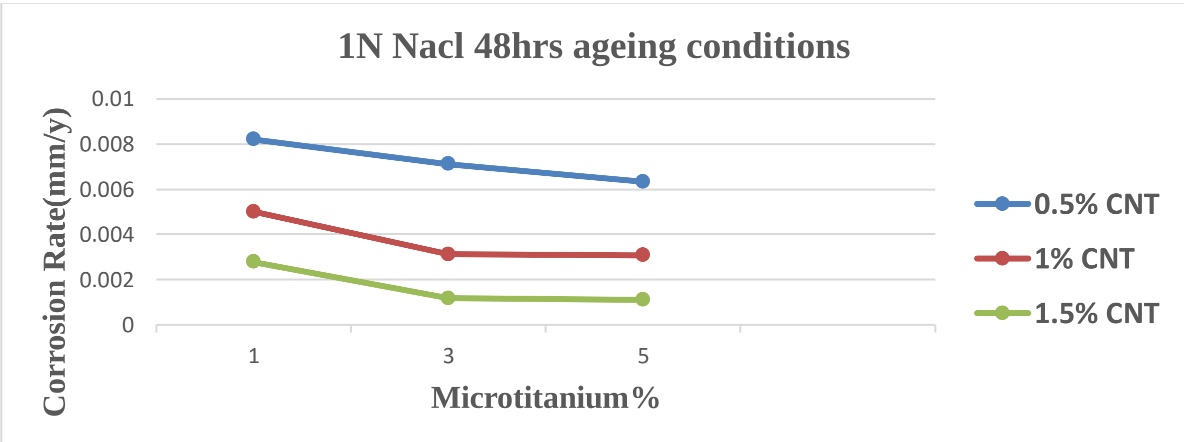

Fig 9Corrosion rate vs. percentage of micro titanium at 1N 48 hrs.

3**. Corrosion rate 1N NaCl 72 hrs ageing condition**

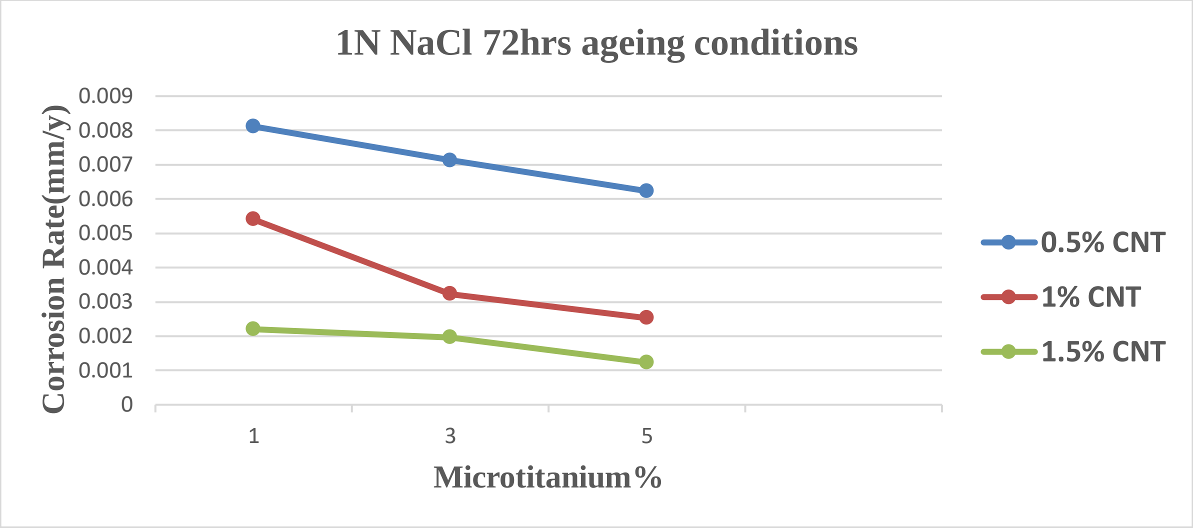

Fig 10Corrosion rate vs. percentage of micro titanium at 1N 72 hrs.

4. Corrosion rate 1N NaCl 96 hrs ageing condition

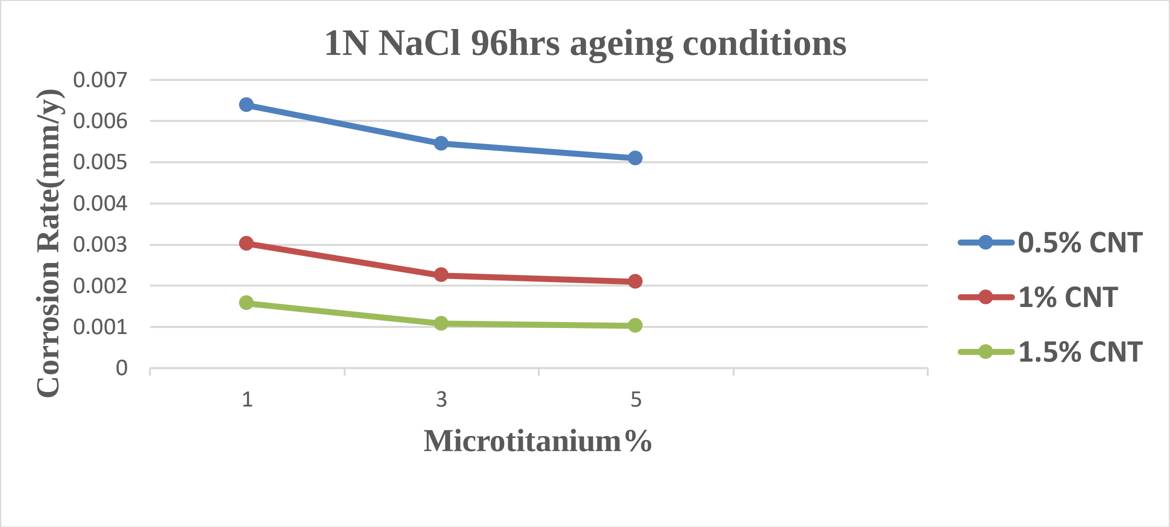

Fig11 Corrosion rate vs. percentage of micro titanium at 1N 96 hrs.

From the table and graph the corrosion rate based normality at 1N, 24, 48, 72,96hrs as the following observations.
1.The effect of CNT and micro titanium on corrosion rate, as seen in above graph, the corrosion rate decrease as the percentage of micro titanium increases from 1%, 3%, and 5% and 0.5%, 1.0% and 1.5% CNT in CNT and micro titanium hybrid reinforced Copper based MMC.

VI CONCLUSIONS

At room temperature, the CNT and micro titanium reinforced Copper composites exhibited better corrosion resistance than the pure copper matrix in NaCl aqueous solution
1. Increasing the composition of the CNT and micro titanium particulates increased the corrosion resistance of the CNT and micro titanium Reinforced Copper composites.
2. The corrosion resistance increases with increase in duration of time. The improvement in corrosion resistance is 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.
3. The Corrosion resistance was also found to improve with increase in micro titanium concentration, probably since they act as physical barriers to the corrosion process, as well as the Copper inter metallic compounds at the matrix, restricting pit formation and propagation.
4.The composite specimens showed better corrosion /pitting resistance than the unreinforced matrix alloy, also it is seen that corrosion rate increase with increase in normality and molarity of the solution.

5. The micro titanium content in Copper alloys plays a significant role in the corrosion resistance of the material. Increase in the percentage of addition will be advantageous to reduce the density and increase in the strength of the alloy, and thus the corrosion resistance is there-by significantly reduced.
6. 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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