EXPERIMENTAL INVESTIGATION AND ANALYSIS OF CORROSION AND HARDNESS USING AL-ALLOYS A384

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Abstract*—Aluminum alloy A384 plays a vital role in modern industry. Manufacturing of Al-alloy A384 are light weighted, high strength, good hardness, easily applicable has more useful for many industries like aerospace, marine, automobile and so on. At the centre of research and growth of these sectors this paper emphasizes the production of Al-alloy A384 using the stir-casting method. Now these samples are tested under the salt spray (Fog) test has been carried out, evaluation of the corrosion resistance of Al-alloy A384 can be done before and after corrosion, then hardness test and SEM analysis. The result of the work lead to the following conclusions: the Al-alloy A384 can be used in an environment containing sodium chloride since the corrosion rate falls within the recommended corrosion range of ≤ 0.15 mmpy for usefully resistant materials, The weight loss and the corrosion rate expressed in mmpy all agree with the physical appearance of the specimens after the exposure time of the test, The pH value of the solution to be monitored is also consistent with the test result.

***Keywords-* Stir casting method, hardness test, corrosion test, micro structural analysis.**

1. Introduction

In today's generation most automotive vehicles, submarines, aircrafts, rockets are most complex engineering structures with many components. In the construction of these type of structures it is impossible to complete avoid the corrosion. Corrosion can be defined a "deterioration of materials by chemical interaction with their environment. The term corrosion is sometimes also applied to the degradation of plastics, concrete and wood, but generally refers to metals." Understanding the corrosion rate of structure at different atmospheric conditions are key to developing reliable hardware for automotive, aerospace and marine engineering. Damage caused by corrosion fatigue may be a major structural damage factor that affects aircraft performance and life. However, the severity of degradation of aircraft components due to corrosion fatigue depends on their location in the aircraft structure.

When corrosion occurs simultaneously with fatigue, there is a synergistic effect between the two degradation processes. Damage increased. Corrosion fatigue is a serious problem for airplanes exposed to the ocean and / or polluting the air. This environment is particularly detrimental to the aircraft's corrosion fatigue properties because the chloride compounds cause damage to the passivation films covering the aluminum alloy and protect them from the atmosphere.

1.1 Corrosion And Type Of Corrosion

It is define as the deterioration of materials due to chemical interaction with their environment. The term corrosion sometimes also applies to the degradation of plastics, concrete and wood, but mostly refers to metals. Following corrosion is mostly occurred in the material.

a) Uniform Corrosion
b) Galvanic Corrosion
c) Crevice Corrosion
d) Intergranular Corrosion
e) Pitting Corrosion
f) Stress-Corrosion Cracking

Pitting Corrosion

Pitting corrosion is a localized form of cavity in the material that produces corrosion. Pitting corrosion is more dangerous than uniform erosion because it is more difficult to detect, predict and design. Corrosive products usually cover the pit. Narrow pits with the least metal loss can lead to failure of the entire engineering system. Pitting corrosion is caused by local chemical or mechanical damage to the protective oxide film. The hydration factors that can cause rupture of the passivation film are acidity, low dissolved oxygen concentration, and high concentrations of chloride. Local damage or poor protection of the protective coating is a good starting point. Other advantageous locations include non-uniformity in the metallic structure of inclusions of the components. The pitting mechanism is explained by Fontana and Greene's model.

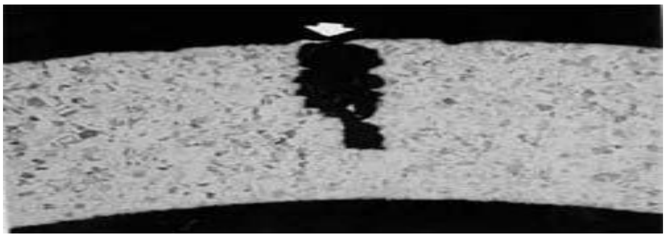

Fig: 10 Pit Growing Through The Thickness Of A Stainless Steel Tube

1.2 Corrosion Prevention Techniques

To prevent the corrosion of metals (especially steel, aluminum), we can try to prevent oxygen and water from contacting the metal. Wet areas (more moisture in the air) will corrode more than dry area. Corrosion rate are also accelerated when more ions are present in the water (ie, houses and cars rust near the ocean are much faster than inland). In an attempt to stop or at least slow down the rate of corrosion, the following techniques can be used:

a) Use non-reactive coating.
b) Use non-reactive metal coating.
c) Use sacrificial (more active) metal.
d) Using Electricity

1.3Corrosion Monitoring Techniques

The easiest and longest way to estimate corrosion losses in plants and equipment is weight loss analysis. Weighed samples (samples) of the metal or alloy under consideration are introduced into the process and removed after a reasonable interval of time. Then clean all corrosive products and weigh again. Use appropriate conversion equations to convert weight loss to total thickness loss or average corrosion rate.

a) Weight Loss Coupons (A Weighted Sample)
b) Electrical Resistance Monitoring (ER)
c) Hydrogen Monitoring

2.Literature Review

Ajay Singh et al, Studied the behavior of an aluminum cast alloy (6063) with an alumina (Al 2 O 3) composite prepared by a stirring casting technique. Various mechanical tests have been performed at AMMC, such as tensile testing, hardness testing, impact testing (fracture). With the increase of the amount of rebar, the mechanical properties of the composites increase in value [1].

B. Babu and SK Karthikeyan et al, In this study emphasize the preparation of Al-SiC matrix composites by using the stirring casting method and the samples with different percentages of SiCp-10% were prepared with aluminum and the samples were tested in hardness test, corrosion test And SEM analysis. The corrosion resistance of aluminum alloy matrix / 10% SiC reinforced composite in various media was evaluated [2].

J.A.Moreto and O.C.Gamboni et al. In this paper, the open circuit potential, dynamic polarization and salt spray test of two kinds of aluminum alloy corrosion resistance. The results show that AA2198-T851 alloy and AA2524-T3 alloy have higher corrosion resistance. Corrosion is one of the main contents of this research work. AA2198-T851 replaces AA2524-T3 alloy [3].

3. Methodology

The methodology adopted to carry out the project is as follows:

- Material selection
- Composite fabrication (Stir Casting)
- Mechanical testing.

3.1 Material composition of Al-alloy A384

Sr. No	1	2	3	4	5	6	7	8	9	10
Composition	Si	Fe	Cu	Mg	Mn	Ni	Zn	Sn	Other	Al
Wt %	10.5-12	1.3	3-4.5	0.1	0.5	0.5	3	0.35	0.05	Balance

4. Experimental Procedure

4.1 Specimen Preparation

The pure ingots of Aluminium were taken and they are melted in furnace. The furnace is of oil type and the ingots got melted in the burning of the furnace. The ingots gets into a liquid state at the temperature of 650-750^0 C. The die is prepared for pouring the molt. There preliminary works must be done before pouring the casting. The die is made up of sand by placing a pattern. Since the molt is about 700^{0}C the molt starts burst, this produces blow holes and other improper casting. The die must be filled with a lubricating material to avoid sticking of the casting to the die. The vent for gas release is kept to avoid blow hole formation inside the casting.

Fig. Preparation of aluminium metal molt

The specimen prepared as per the ASTM B117 standard. The specimen is 100×100×10 mm respectively.

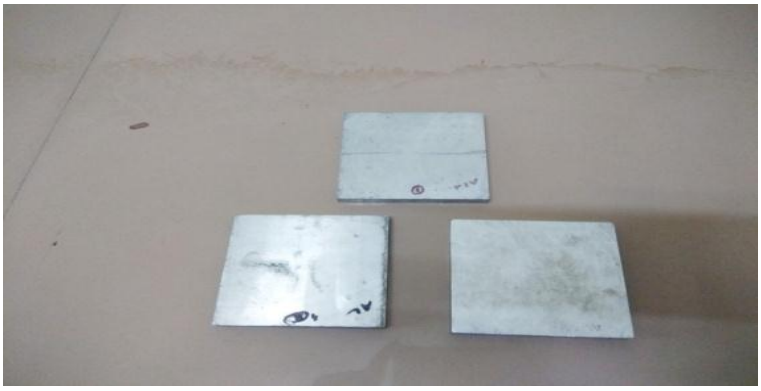

Fig. Specimens as per ASTM B117 Standard

4.2 Machining Process

The Machining process is done in order to remove the excess and unwanted material. The machining process includes all the vertical milling machine works. The casting is machined to the desired shapes shown in above fig. This process includes surface finish, surface grinding, facing, operations.

4.3 Testing the Specimen

After the machining process the final product is our specimen. The specimen is used for the tests. The test is conducted to find the properties of the specimen manufactured. In this work, hardness test, surface roughness, surface morphology and corrosion testing.
The commonly done tests are as follows.

a) Corrosion test
b) Brinell hardness test
c) Scanning Electron Microscope (SEM) test

a) Corrosion Testing by Salt Spray Test

The salt spray test is a standardized test method used to check corrosion resistance of coated samples. Salt spray test is an accelerated corrosion test that produces a corrosive attack to the coated samples in order to predict its suitability in use as a protective finish. The appearance of corrosion products (oxides) is evaluated after a period of time. Test duration depends on the corrosion resistance of the coating; the more corrosion resistant the coating is, the longer the period in testing without showing signs of corrosion. Salt spray testing is popular because it is cheap, quick, well standardized and reasonably repeatable. There is, however, only a weak correlation between the duration in salt spray test and the expected life of a coating (especially on hot dip galvanized steel where drying cycles are important for durability), since corrosion is a very complicated process and can be influenced by many external
factors. Nevertheless, salt spray test is widely used in the industrial sector for the evaluation of corrosion resistance of finished surfaces or parts.

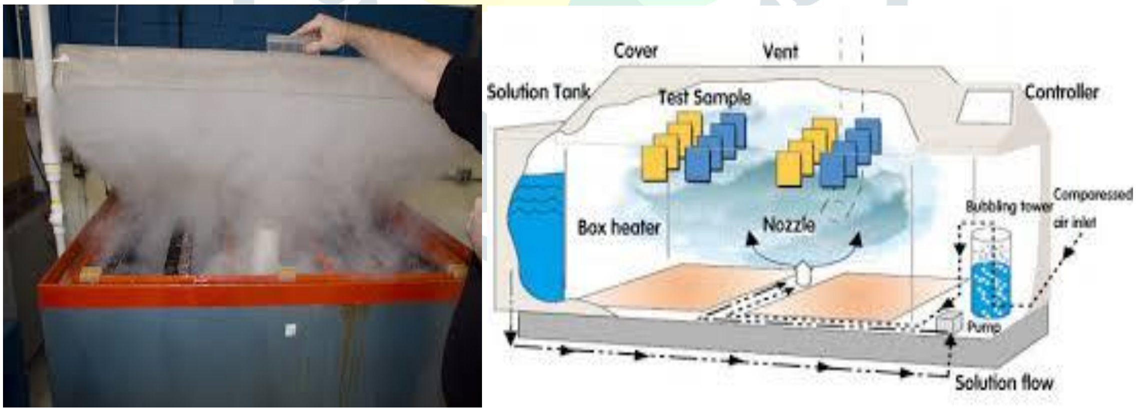

Fig: Salt Spray Chamber End Its Internal Arrangement

- **Weight Loss And Corrosion Rate**

The weight loss is calculated by finding the difference between the initial and final weights of each specimens after each immersion cycle given in equation (1) and, as given in equation (2), in millimeters per year Calculate the corrosion rate.

$$\mathbf{W = W_i - W_f} \quad \text{---------------} \ (1)$$

Where,
W_i = Initial weight (g)
W_f = Final weight (g).
W = Weight loss (g).

Corrosion Rate

$$\mathbf{CPR\ (mmpy) = 8600W/(D \times A \times T)} \quad \text{------------}(2)$$

Where,

W: Weight loss (Mg) after exposure time T (H)
D: Density of metal (G/Cm^3)
A: Area of the specimen (Cm^2)
T: Time of exposure in hours

b) Hardness Testing

Hardness is the property of a material to resist permanent indentation. Because there are several methods of measuring hardness, the hardness of a material is always specified in terms of the particular test that was used to measure this property. Rockwell, Vickers, or Brinell are some of the methods of testing. Brinell hardness testing is the most common method for hardness testing. In Brinell tests, a hard, spherical indenter is forced into the surface of the metal to be tested. The diameter of the hardened steel (or tungsten carbide) indenter is ranges from 5-10mm. Standard loads range between 500 and 3000 Kg; during a test, the load is maintained constant for a specified time (between 10 and 30 seconds). Here we used 5mm indenter ball diameter of the hardened steel, the 750 Kg load is maintained constant for a 10 seconds. Then indentation on the specimen is measured by hand microscope. The Brinell hardness test shall be carried out over Brinell hardness tester. Two samples of Al/Sic- MMC's for different sizes and weight fraction of SiC particles shall be prepared. After test and hardness value on dial, the Brinell hardness values with reference to scale HRB shall be taken for all samples.

CONTENTS	SPECIFICATION
Capacity	Up to 650 HBW
Ball size	5mm and10mm
Load capacity	(750,1000,3000) kg
Uncertainty	± 2%

Fig. Hardness testing machine and specification

c) Surface morphology test using SEM

Scanning electron microscopy (SEM) uses focused high-energy electron beams to generate a variety of signals on the surface of solid samples. The signals from the electronic sample interaction show information about the sample, including the external morphology (texture) of the material that constitutes the sample, the chemical composition, and the crystal structure and orientation. In most applications, the data is collected on selected areas of the surface of the sample and a two-dimensional image showing the spatial variation of these properties is generated. Regions ranging in width from about 1 cm to 5 microns can be imaged in scan mode using conventional SEM techniques (magnification ranging from 20X to about 30,000X with a spatial resolution of 50 to 100 nm). The SEM is also capable of performing selected spot positions on samples; this method is particularly useful for qualitative or semi-quantitative determination of chemical composition (using EDS), crystal structure and crystal orientation (using EBSD). The design and function of the SEM is very similar to that of the EPMA, with the ability to overlap between the two instruments.

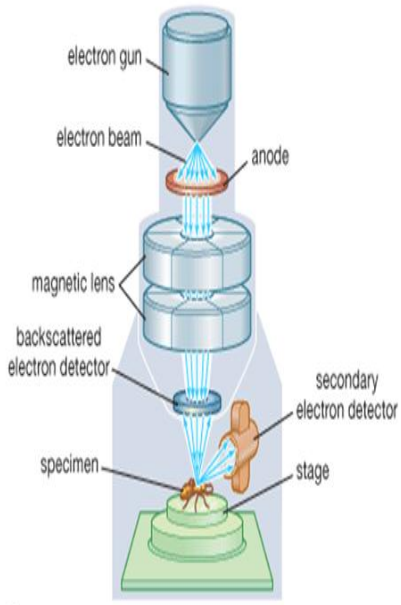

Fig: Schematic View of the Operation o f SEM

5. Results and Discussions

5.1 Corrosion result using weight loss method.

The result of the work lead to the following conclusions: the Al-alloy A384 can be used in an environment containing sodium chloride since the corrosion rate falls within the recommended corrosion range of ≤ 0.15 mmpy for usefully resistant materials

Specimen 1	$W = W_i - W_f$
	= 265-262
	= 3g
Specimen 2	$W = W_i - W_f$
	= 264-260
	= 4g
Specimen 3	$W = W_i - W_f$
	= 267-265
	= 2g

Specimen 1	CPR (mmpy) = 8600W/(D×A×T)
	= 8600×0.003/(2.7×100×18)
	= 0.005308 mm/year
Specimen 2	CPR (mmpy) = 8600W/(D×A×T)
	= 8600×0.004/(2.7×100×18)
	= 0.007078 mm/year
Specimen 3	CPR (mmpy) = 8600W/(D×A×T)
	= 8600×0.002/(2.7×100×18)
	= 0.003539 mm/year

Table : Weight loss calculation and Corrosion rate calculations

5.2 Hardness test result

CONTENTS	SPECIMEN – 1	SPECIMEN - 2	SPECIMEN - 3	SPECIMEN - 4
SAMPLE ID	Al- alloy (A384) (without corrosion)	Al- alloy (A384) (with corrosion)	Al- alloy (A384) (with corrosion)	Al- alloy(A384) (with corrosion)
HARDNESS VALUE	95 BHN	93 BHN	91 BHN	94 BHN
INDENTOR	5.0 mm ball	5.0 mm ball	5.0 mm ball	5.0 mm ball
LOAD APPLIED	750 kg	750 kg	750 kg	750 kg

5.3 Surface morphology result

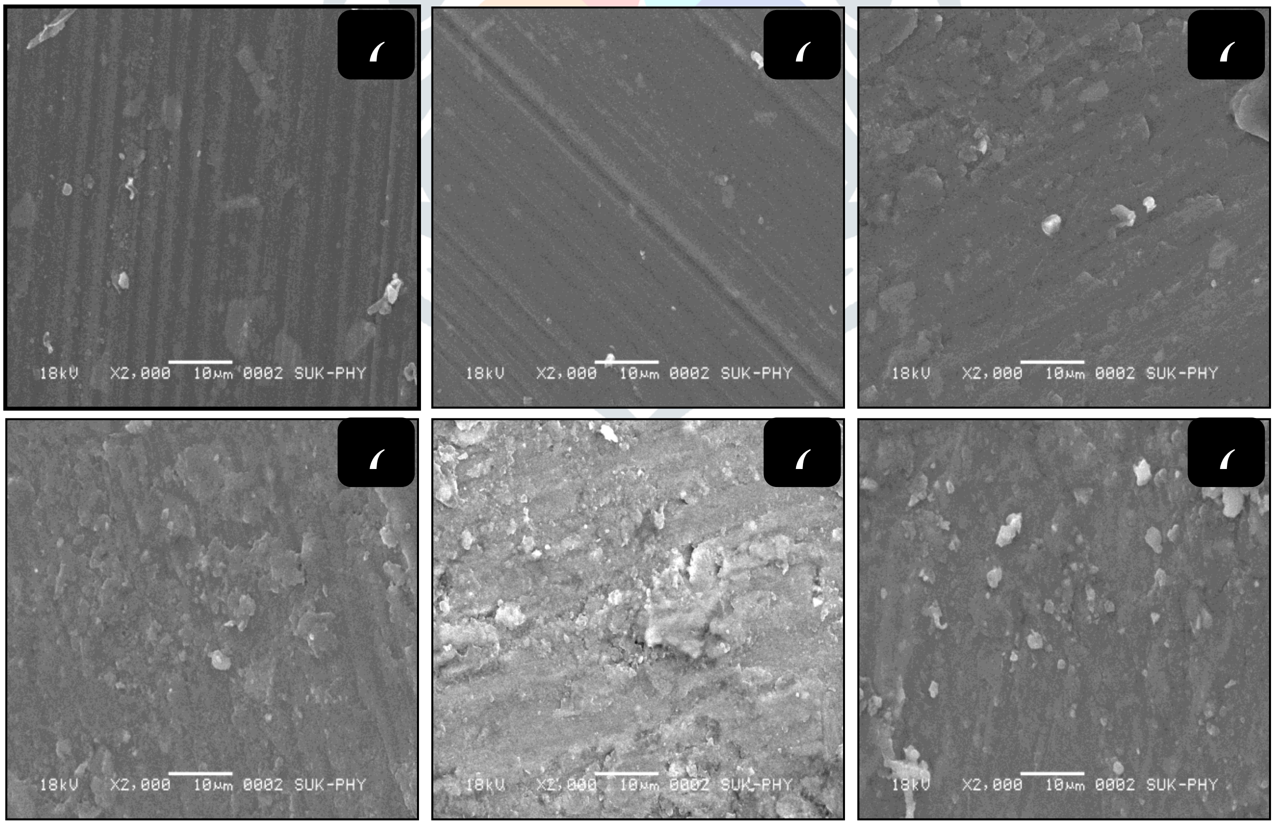

Fig: SEM Images of (A, B, C) Before Corrosion Test and (D, E F) After Corrosion Study of the Sample, Where (A) is Taken from One Corner, (B) is from Middle and (C) is from Other Corner of the Same Sample.

It is observed that corrosion test does not significantly affect the corner sites. The surface morphology of the corner samples is seen to be smooth and after corrosion study not drastic change have been observed (Fig. a, d and c, f). But at the middle of the sample sudden change in surface morphology have been observed (Fig. b and e) after the corrosion test. Smooth surface of aluminum get converted into rough one. This could be attributed to the such as concentration may be high at the center of salt solution during corrosion test or it may be any invisible casting defects at these portion.

6. Conclusion

- For Al-alloy A384 has average hardness around 92.66 BHN, which is good comparatively as that of same Al-alloy family i.e Al-alloy 6061.
- Al-alloy A384 has the average corrosion rate is about 0.005308 millimeter per year and this corrosion rate is less as that of Al-alloy 6061.
- The surface morphology of Al-alloy (A384) is studied and it is observed that sample surface morphology will not change at initial time period but less effect has been observed when surface is exposed to longer time period.
- Both weight loss and corrosion rate in millimeter per year are consistent with the substantial form of the sample after the test infection time.

Future scope of the work

- Both weight loss and corrosion rate in millimeter per year are consistent with the substantial form of the sample after the test infection time.
- Different corrosive medium can be used and their effect on Al-alloy A384 can be investigated.
- One can used to conduct the hardness and corrosion test by adding reinforcement on Al-alloy (A384)
- One can analyze the corrosion behavior of sample by varying time duration.
- Surface morphology can be studied by using TEM and XRD.

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