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Corrosion - Fatigue Characteristics of 4043 Aluminium Alloy

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Abstract: The paper provides the information of corrosion - fatigue characteristics of aluminium alloy 4043 (AA4043). Casted aluminium alloy 4043 was used for tensile and fatigue test with and without corrosion. The ultimate tensile strength obtained from tensile test and was used to conduct fatigue test on rotating bending fatigue testing machine as per RR Moore rotating bending fatigue test for un-corroded specimens for different stress values and compared the results with that of corroded specimens. The S-N curves were plotted. It is found that the corroded specimen became weak due to formation of oxides on its surface which resulted in early failure.
Keywords: Aluminium Alloy 4043, Corrosion- fatigue test, Weight loss method, Rotating bending type fatigue test

I. INTRODUCTION

Corrosion is a phenomena in which pure metal is modified into irreversible form to its hydroxide, sulphide or oxide. It is the slow destruction of metal by electrochemical reaction (1). Study on effect of grain width during corrosion for various alloy highlight the compound interrelation between grain width, processing rate, environment relating that both structural & chemical changes influence the corrosion susceptibility (2).

Some metal-environment combination irrespective of the electrochemical modification or solute alteration, the grain refinement will lead to lower corrosion rates. Alloy of aluminum, silicon and magnesium provides resistance to corrosion when dipped in sample sea water for about 40-45 days. In partial desert areas, the lakes have high concentration of salt in its environment and it is common in several places on universe (3-10).

Aluminum is used more when compared to steel in aerospace and automobile sector due to its light weight and reduced cost. These parts are exposed to different loading and climatic conditions, i.e they are subjected to corrosion and fatigue at a time. This gives rise to interest in evaluating fatigue characteristics to the scientists. Fatigue crack usually start on surface of the materials and its behavior depends strongly on the mechanical and geometrical properties. Let us consider a crack on surface, it widens if the tensile stresses are applied and contracts with the compressive stresses. The compressive stress is favorable since it reduces crack opening. The surface roughness and stress concentration factor also influence the fatigue characteristics of a material (11-15).

A fatigue check allows us to assess the material's ability to sustain cyclic loading. The material is chosen for fatigue testing applications to meet or exceed duty loads. Fatigue test consists of applying tensile and compressive loads, twisting, bending or merging of these loads continuously. Very limited research is done on fatigue properties of materials and it is essential to understand properties of fatigue of a material and plot the results on S-N curves (stress v/s no of cycles to failure) by conducting tests on un-notched polished specimen and the fatigue crack can originate in a classical way through localized slip on surface of the specimen. The fatigue test results on aluminum alloy castings are in complement with the steel and cast iron where the fatigue crack initiated from casting defect and deep study has not been done on effects of heat treatment (16).

II. EXPERIMENTATION

AA4043 is obtained in the form of a cylindrical rod of 16mm diameter through casting process and it is subjected to machining process to the required shape as per tensile and fatigue test confirming to ASTM standards (ASTM D1141-98 to prepare salt solution, ASTM E8/E8M-13a for tensile test, RR Moore rotating bending fatigue test for fatigue test). Firstly, tensile test is conducted on three un-corroded specimens to find out its ultimate tensile strength and using this ultimate strength, fatigue test is conducted on un-corroded and corroded specimens.

The salt solution is prepared as per ASTM D1141-98. The test specimens were dipped in the salt solution and allowed them to corrode for 17 days and the amount of corrosion on each specimen is found out by weight loss method. To perform a fatigue test, the test sample is placed in rotating bending fatigue testing machine and loaded under the pre-calculated bending stress and tested till failure.

Fig 1: Universal Testing Machine

Fig 2: Rotating Bending fatigue testing machine

Fig 3: Tensile test specimen

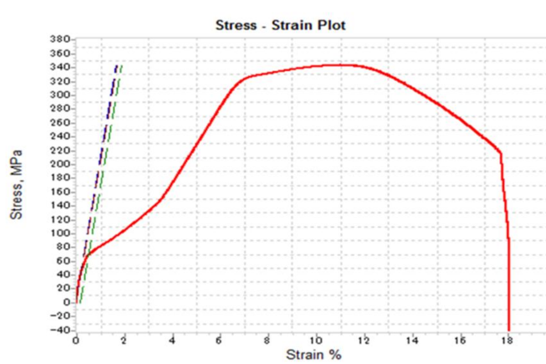

Fig 4: Stress v/s Strain plot

Fig 5: Fatigue test specimens

Fig 6: Sample corrosion specimens

Fig 7: Specimens dipped in salt solution

The tensile test was conducted on Universal Testing Machine as shown in Fig.1 as per ASTM E8/E8M-13a standards. Test is conducted on three specimens and average of the three is considered for further calculations. The average ultimate tensile stress obtained is 345.42 MPa.

The individual ultimate stress values for three samples are as tabulated below

TABLE-I:
TENSILE TEST RESULTS

Sample Number	Ultimate tensile stress (N/mm^2)
Sample 1	344.55MPa
Sample 2	421.3 MPa
Sample 3	270.4 MPa

From Soderberg equation

$$\frac{K_{tf} x\, \sigma_a}{ABC\ x\ \sigma_{en}} + \frac{\sigma_m}{\sigma_{yp}} = \frac{1}{N}$$

For completely reversed loading $\sigma_m = 0$

$$\frac{K_{tf} x\, \sigma_a}{ABC\ x\ \sigma_{en}} = \frac{1}{N}$$

Load factor, A = 1
Size correction factor, B = 1

Surface finish factor, C = 0.9

Factor of safety, N = 2 (assumed)

σ_{en} =1/3 X 345.41 MPa

σ_{en} =115.14 MPa
K_{tf} = 0.3

$$\frac{K_{tf} x\, \sigma_a}{0.9\ x\ \sigma_{en}} = \frac{1}{N}$$

$$\frac{0.3\ x\ \sigma_a}{0.9\ x\ 115.14} = \frac{1}{2}$$

σ_a = 172.71 MPa

From which the force to be applied is obtained i.e,
F = 86.80 N
Which yield the mass to
m = 8.84kg
8.5 kg was applied due to unavailability of 0.34 kg combination set. Corresponding to this value of load, the stress amplitude was 165.90MPa. This value is considered the maximum. Further four different stresses were applied in the decreasing order for different specimens (Table 3). Each specimen was rotated till it fails and number of cycles were recorded.

A. Sample corrosion test

A sample corrosion test is carried out to find the corrosiveness of the salt water. Five small specimens of 16 mm diameter and thickness 5mm (Fig.6) are kept in salt solution for 17 days and allowed to corrode and the mass of the specimens is noted before and after corrosion. Test results are shown in Table II. Actual test specimens are also dipped in salt water for 17 days to corrode the same (Fig.7)

B. Fatigue testing of Corroded and un-corroded specimens

Two set of specimens (corroded and un –corroded) are tested in rotating bending fatigue testing machine for different loads. The test results are tabulated and are shown in Table III and graph 1.

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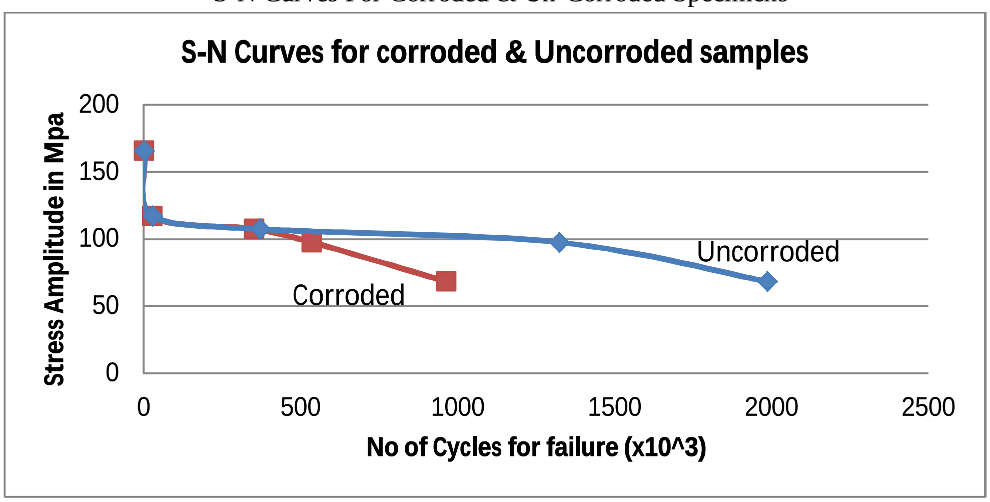
TABLE -II
sample corrosion test results

Trial no	Mass of the Specimen (g)		
	Before Corrosion	After Corrosion (After Scrubbing)	Mass of powder
1	2.14	2.13	0.01
2	2.22	2.20	0.02
3	2.30	2.28	0.02
4	2.25	2.24	0.01
5	2.05	2.04	0.01

TABLE III
Fatigue Test Results For Corroded And Un-Corroded Specimen

Trial no	Stress Amplitude (MPa)	Percentage of Ultimate tensile stress	No. of Cycles required for Un-corroded Specimen to fail ($x10^3$)	No of Cycles required for Corroded Specimen to fail($x10^3$)
1	165.9	48	27	05
2	117.13	34	39	16
3	107.4	31	372	352
4	97.6	28	1323	536
5	68.3	20	1886	965

GRAPH I
S-N Curves For Corroded & Un-Corroded Specimens



III. CONCLUSION

Fatigue test was conducted for both corroded and un-corroded specimens. It was found that the corroded specimens lost their fatigue strength and hence failed at minimum number of cycles compared to un-corroded specimens.

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