DEVELOPMENT OF IMMERSION CORROSION TEST RIG TO STUDY EFFECT OF HIGH TEMPERATURE AND VELOCITY WATER ON CORROSION RATE OF AL-MG-SI ALLOY

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ABSTRACT

This work is focused to measure the effect of temperature, time, pH and flow rate of water on the corrosion rate of Al-Mg-Si alloy. Although these alloys show good corrosion resistance, they are more prone to pitting corrosion. Standard practice for laboratory immersion corrosion testing of metals as per ASTM G 31-72 standard is useful for pitting corrosion test. But it does not consider effect of temperature, pH and flow rate of water on corrosion rate of specimen under consideration. Hence by considering these parameters changes in the original design as given in standard practice are carried out such that chances of crevice corrosion are also minimized. To study the effect of variation in temperature and velocity of the environment, magnetic heater stirrer device is used. Results of this test are useful to find the relation of individual parameter or combination of parameters with corrosion rate of specimen in various working environments.

Keywords: Al-Mg-Si alloys, Corrosion Test, Flow Rate, Pitting corrosion, Temperature.

1 INTRODUCTION

Corrosion is the primary means by which metals deteriorate due to their chemical reaction with environment. No metal surface or metal-alloy component is totally immune to corrosion issues. Almost any aqueous environment can promote corrosion, which occurs under numerous complex conditions. When metal comes in contact with aqueous environment, corrosion becomes life limiting factor. Aluminum alloys are widely used in different industry field owing to their excellent corrosion resistance to the barrier oxide film strongly bonded to the surface. Their tendency to corrosion in the presence of halide ions limits their applications especially in sea water and atmosphere condition. As a general rule, aluminum is resistant to water solutions in the pH range of 4.5 to 8.5[1]. Alloying elements such as Zn, Cu, Mg, and Si added to aluminum to improved mechanical properties but they reduce localized corrosion resistance [2]. All aluminum alloys are attacked by water with high pH. Water containing heavy metal ions such as copper, lead, tin and nickel will lead to pitting [1]. Aluminum alloys of 5XXX and 6XXX series show good corrosion resistance, but exhibit more pitting corrosion

[3]. For a particular metal; test rig according to ASTM G31-72 standard considers variation in time and weight loss to calculate corrosion rate [4]. However; along with these parameters Corrosion rate of material also depends on flow characteristics, temperature, concentration and aeration of fluid [1]. Hence it is necessary to find relation of these parameters with corrosion rate of metal. In case of storage tanks, since the water inside is steady, simple immersion corrosion test is sufficient. However, In case of devices having motion of fluid like containers, agitators etc. fluid is unsteady and will cause change in corrosion rate of metal. Hence to study corrosion rate under these circumstances modifications in basic test rig given in ASTM G31-72 standard are done. The present apparatus is developed to study the effect of temperature, flow rate and pH of water on corrosion rate of metal in contact.

II EXPERIMENTAL

Experimental set up is developed to study the effect of temperature and flow rate of water on corrosion rate.
Standard set-up for immersion corrosion test is given in ASTM G 31-72 standard which gives the relation between corrosion rate of metal and time of exposure of metal in corrosive media by considering the mass loss during test. However modifications in the standard test rig are done to find relation between temperature, pH and flow rate of corrodent and corrosion rate of particular metal. Also with this set-up it is possible to find the combined effect of above mentioned parameters on the corrosion rate of metal.

2.1 Sample Preparation

We have taken an artificially aged Al-Mg-Si alloy AA6082 for sample experimentation. For the experiment specimen of (03*25*50) mm dimensions is selected. Sample is to be fabricated using 3mm thick sheet of required metal. For both tests the sheet of 25*50 mm^2 are required. Pieces should be cut out from sheet. These pieces should be cleaned, dried and stored in air tight bag to avoid adverse effect of dust and atmosphere.

2.2 Experimental Set-Up

The plate is kept vertical on the seats inside the bicker, as shown in fig. 01. Flow in tank is simulated with a glass bicker. Glass bicker of 2 liter capacity is used to conduct experiment. 3 seats are made inside glass bicker by using acrylic.
To obtain effect of flow and to facilitate rotation of needle, the seats are placed at a certain height from base. Magnetic needle of 24 mm length and 9 mm diameter is kept at the bottom of bicker to achieve desired flow rate by stirring action. The bicker is kept closed to prevent water from evaporation and contamination. Provisions are made on top surface to insert pH meter and temperature switch. A magnetic stirrer heater device is placed below bicker to obtain heating and stirring action simultaneously. Temperature switch is used to maintain desired temperature, and it is coupled with heater knob of magnetic stirrer heater. Manual as well as automatic control is provided to obtain and/or change desired heating rate. For testing the specimen at high pH value artificial sea water is prepared according to standard procedure [5]. Gravimetric salts used for preparation of water are shown in Table 01. pH of the prepared sea water was maintained at 8.33.

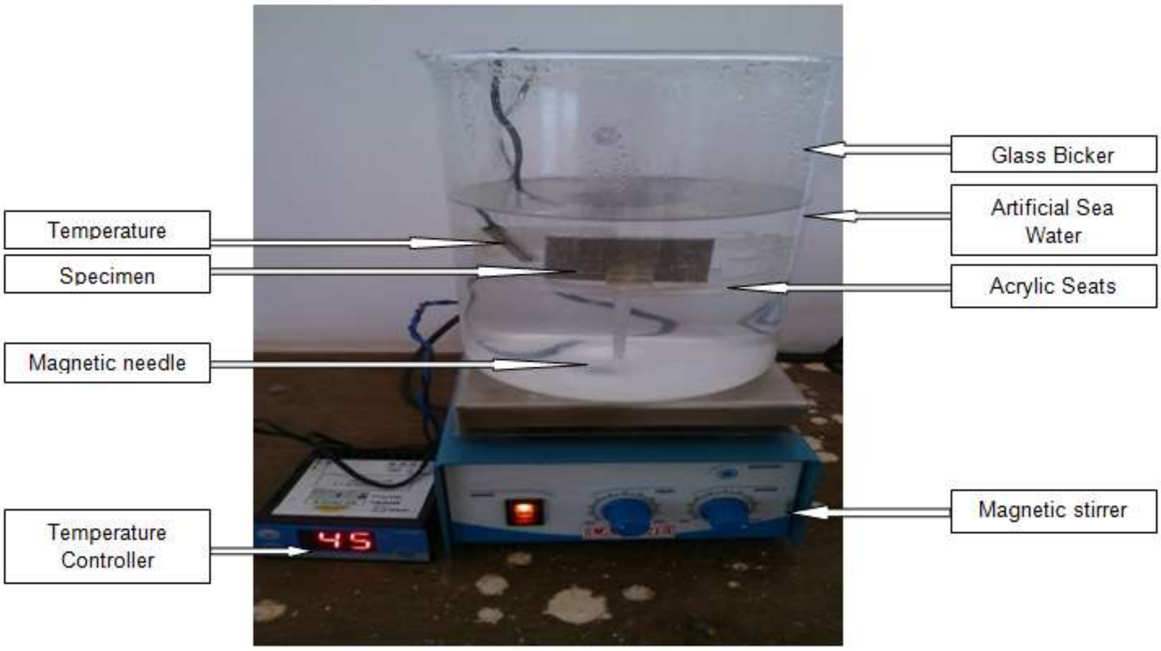

Fig. 01: Test Rig For Flow Of Water Through Tank

Table 01: Formula for 1 kg of 35.00% artificial sea water

Salt	Molecular Weight	gm/Kg of Solution
NaCl	58.44	23.926
Na_2SO_4	142.04	4.008
KCl	74.56	0.677
$NaHCO_3$	84.00	0.196
KBr	119.01	0.098
H_3BO_3	61.83	0.026
NaF	81.99	0.003

2.3 Experimental Procedure

Specimen is cleaned with acetone and its initial weight is measured. Specimen is then fixed on seats provided in bicker. Bicker is filled, with water of measured pH value, such that specimen should get completely immersed in water. Temperature probe is immersed in water. To avoid evaporation as well as contamination of water bicker is closed with top cover. Temperature is set to desired value in temperature switch and heating rate is adjusted with knob manually. Rotations of needle are set to desired value by adjusting stirring knob. After immersion for desired time period specimen is removed from bicker and cleaned with acetone to measure final weight. Difference between initial and final weight will give weight loss. By taking temperature, pH value, flow rate and time as variables; number of experiments can be performed to check effect of a particular parameter on corrosion rate. For testing we have taken temperature and flow rate as variables. Test is carried out at 4 different temperature conditions by varying water temperature viz. 30^0C, 37^0C, 44^0C, 50^0C Corrosion. Test was carried out for 72 hrs at a constant water temperature on 3 Specimens simultaneously. For checking the effect of flow rate of water on corrosion rate of specimen two sets of test were performed one at NO flow condition and other at 120rpm.

III RESULT AND DISCUSSION

Corrosion rate test data is tabulated in table 02.Corrosion rate in table 02 is calculated from weight loss according to ASTM standard equation,

$$C.R. = \frac{8.76x\,10^4\,x\,W}{AxT\,xD}$$

Where, T is the time of exposure in hours, A is the area in cm^2, W is the mass loss in grams, D is the density in gm/cm^3.

Table 02: Effect of water temperature on corrosion rate of 6082-T6 Aluminum alloy precipitation hardened at 520^{o}C

Temperature	pH	Flow rate (RPM)	Initial weight (gms)	Final Weight (gms)	Weight Loss (gms)	Corrosion Rate (mm/year)
30	8.33	0	10.0674	10.0659	0.0015	0.054
		90	10.0982	10.0962	0.0020	0.072
37	8.33	0	10.085	10.0806	0.0044	0.158
		90	10.0590	10.051	0.0080	0.288
44	8.33	0	10.0120	10.0118	0.0122	0.438
		90	09.9484	09.9284	0.0200	0.720
50	8.33	0	10.0910	10.0851	0.0059	0.214
		90	10.0920	10.0841	0.0079	0.263

Fig. 02 gives the graph of Corrosion rate (mm/year) versus water Temperature (^{0}C) for two different flow rates of water. Corrosion rate increases nonlinearly with increase in temperature up to 44^{0}C and then drops down. For corrosion systems, increasing the temperature increases rate of oxidation reaction. However oxide film formation results into passivity which is responsible for decreasing the corrosion rate on further increasing the temperature.

Increasing the flow rate of corrodent causes increase in the rate of corrosion. Increasing the flow rate increases corrodent velocity and since mechanical action of high corrodent velocity removes passive layer; corrosion rate increases. Concentration of corrodent has strong effect on corrosion rate of metal, but not always in the direction perceived [1]. Hence more results should be obtained by varying temperature, flow rate and pH of water to obtain combined and/or individual effect of them on corrosion rate.

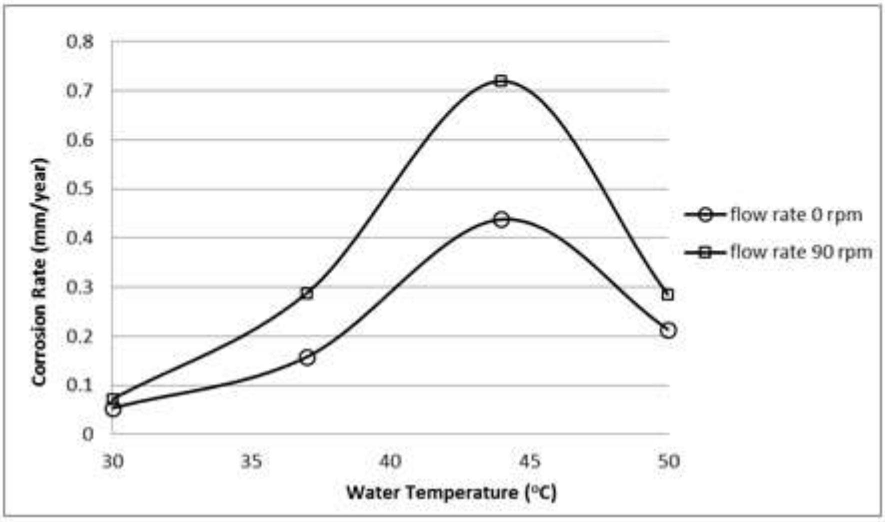

Fig. 02: Graph Of Corrosion Rate Versus Water Temperature For Precipitation Hardened 6082-T6 Al Alloy In Water Of Flow Rate 0 Rpm And 90 Rpm

IV CONCLUSION

The result of the current study leads to the following conclusions:

Corrosion rate increases at first with increasing temperature, but decreases afterwards due to passive film formation on the surface of metal.

With increasing flow rate new surface is always exposed to corrodent due to removal of ; hence increasing flow rate increases corrosion rate.

Test rig is useful to find combined or individual relation of flow rate, pH and temperature of corrodent with corrosion rate of metal.

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