Effect of ageing time and temperature on corrosion behaviour of aluminium alloy 2014

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Abstract. In this paper, the effect of corrosion behaviour of aluminium alloy 2014 were studied by potentiodynamic polarization in 1 mole of NaCl solution of aged sample. The experimental testing results concluded that, corrosion resistance of Aluminium alloy 2014 degraded with the increasing the temperature (150°C & 200°C) and time of ageing. Corroded surface of the aged specimens was tested under optical microscopes for microstructures for phase analysis. Optical micrographs of corroded surfaces showed general corrosion and pitting corrosion. The corrosion resistance of lower ageing temperature and lower ageing time is higher because of its fine distribution of precipitates in matrix phase.

Index Terms—Al Alloy 2014, Ageing, Corrosion test

1. Introduction
It is generally accepted that the ageing treatment and precipitation hardening mechanism can be enhancing the corrosion behaviour of the Al-alloy because of the uniform distribution of fine precipitates, Phases and homogenization of microstructures [1-2]. The main affecting factors on microstructures of aluminum alloy are alloying element /chemical composition, ageing time (AT) and temperature. These factor can be also affect the corrosion behaviour of aluminum alloy [3-5]. Corrosion is the one of the important factor for failure of material. This reason researchers are studying corrosion properties of Aluminum (Al) alloy. Liu et al. reported that copper dissolves in the α-Al matrix that increases corrosion potential. After the T6 heat treatment of 2014 Al alloy, Al₂Cu phase forms which has cathodic nature relative to the α-Al solution. As a result, it increases driving force for pitting corrosion [6]. All results shown in different researchers into the field of corrosion behaviour of aluminium alloy [7-10].

2. Material and Experimental
2.1. Material
The Alloy 2014 was purchased from Perfect Metal Work Bangalore. Alloy were extruded rod of 12 mm diameter and its chemical composition is listed in Table 1.

| Elements | Al | Cu | Mn | Si | Mg | Fe |
|----------|----|----|----|----|----|----|
| Weight % | Balance | 5.17 | 1.04 | 1.76 | 0.63 | 0.34 |
2.2. Ageing treatment
This alloy rod was machined into 12 mm diameter and 10 mm length for corrosion samples. These samples are used for Heat treatment process. First, we did solution treatment (ST) of all samples at 545°C for three hours and subsequent quenched in water medium in room temperature and then ageing was done at two temperature (150°C & 200°C) for 4, 8, 12, 16 and 24 hrs. The corrosion behavior of alloys was explored foe as received and after ageing treatment samples. For microstructural analysis, specimens were first belt grinded and polished with different grade of emery papers (microgrits 220 to 1200) and finally with cloth polishing in alumina paste. After cloth polishing samples were etched with Keller’s reagent for 30 seconds and washed. The metallographic study was carried out on Zeiss microscope.

2.3. Corrosion test
Corrosion tests were carried out on Versa stat 3 corrosion testing machine shown in Fig. 1. All the sample were cleaned in ethanol before the corrosion test. These cleaned sample were attached in the flat cell and the was filled with 250ml of electrolyte solution. Concentration of NaCl electrolyte was 1 mole/litre. After filling electrolyte solution in flat cell, working electrode, counter electrode and reference electrode were connected respectively with the corrosion testing sample, platinum mesh electrode and reference electrode tube. The potentiodynamic polarization test were performed with 1 mV/s scan rate. Open circuit potentials of the Al Alloy 2014 were tested in ranging from -900 mV to -300 mV with a 1 mV/s of scan rate. After corrosion test corrode surface structure study was carried out on Zeiss microscope.

2.4. Hardness Test
Hardness test of as received sample, and (4, 8, 12, 16, 20 & 24 hrs.) aged samples are tested in Shimadzu Micro Vickers hardness test machine in 1Kgf load. Each sample have 5 hardness reading and the average of these are presented in graphical from in Fig. 2.

3. Results and Discussion

3.1. Metallographic Investigation
Microstructures of Al Alloy 2014 in as received, ST and aged conditions were taken in 500X magnification have been shown in Fig. [3-4]. In Fig. 3 we can see the elongated grain structures in of as received sample, due to the extruded condition. After ST the elongated grains were converted into uniform grains that are shown in Fig. 3-ST. The phases present in microstructures are of two colours, one is brighter and another phase slightly darker. These are because of alloying elements existing in
matrix phase. The brighter phases mainly contain aluminium rich phase and the slight dark phases contain intermetallic phases which reacts easily to etchant. During the ageing treatment process the effect on the microstructures of the sample observed that the ageing temperature and time increases the size of precipitates.

3.2. Hardness

In Fig. 2 illustrated that result of ageing treatment process on hardness of Al-alloy. This figure, we could easily interpret that, initially hardness value (Hv) increases as the time increases (upto 8 hrs) but beyond this time, Hardness (Hv) decrease. This may be due to the uniformed distribution of fine precipitate in the matrix phase (upto 8 hrs). Increasing the time of ageing these fine precipitates are increase in size and degrade the properties of hardness. Increasing the temperature of ageing process increases the precipitate’s kinematics due to this samples aged at higher temperature has lower hardness in compare to the samples aged at lower temperature. From hardness testing results we know that the maximum hardness was 154 Hv at 150°C and 8 hrs. of ageing time.

3.3. Potentiodynamic polarization

The Fig. [5-6] shows the Potentiodynamic polarization curves of Al Alloy 2014 of two different ageing temperature in 1 mole/litre of NaCl electrolyte solution. Potentiodynamic polarization test curves shows similar trend for all samples. The cathodic branches in the polarization curves showing the Tafel behavior and by applying Tafal exploration method we get the values of I_{corr} and V_{corr}, which are shown in table 2. Comparison of potentiodynamic polarization curve in 1mole of NaCl electrolyte solution on same ageing time with respect to 150°C and 200°C ageing temperature are shown in Fig. [7-10]. In all curves as the temperature and time increases the current density increases and potential voltage decreases. The corrosion rate is directly proportional to current density.

Table 2 Effect on the current and potential voltage on Ageing time/ temperature

| S No | Ageing time/Temp | Current (A) | Potential (V) |
|------|------------------|-------------|---------------|
| 1    | 4/150            | 6.805       | -628.519      |
| 2    | 8/150            | 11.703      | -637.844      |
| 3    | 12/150           | 12.119      | -660.784      |
| 4    | 24/150           | 22.617      | -612.119      |
| 5    | 4/200            | 9.189       | -617.745      |
| 6    | 8/200            | 18.235      | -652.528      |
| 7    | 12/200           | 19.068      | -612.527      |
| 8    | 24/200           | 26.174      | -642.299      |
3.4. Corrosion result
All potentiodynamic polarization test samples were evidently shown in damaged on the surface all sample. This clearly shown to a certain extent of corrosion occurs.

In the variation of corrosion behavior of Al Alloy 2014 with different ageing temperature and time have been explained by the graph in Fig. 11. By comparing the corrosion rate with respect to time and temperature, we can see that the lower temperature of ageing as well as lower aging time shows lower corrosion rates. Boag et al also reported that the current density (Icorr) increases with ageing time and it increases the corrosion rate. Corrosion rate of the aged sample were high due to the presence of intermetallic phases and increases in precipitate size [10].

After corrosion test micrographs of the worn-out surface have been taken of As received and samples were aged at 150°C (8 hrs., 16 hrs. and 24 hrs., respectively) and they are shown in Fig. 12. These worn-out surfaces clearly show the pattern of the corrosion. Initially corrosion was started in the form of pits and when the ageing time was increased pitting corrosion was converted into the intergranular corrosion. Weilong et al. also reported that corrosion morphology changeover into pitting to intergranular corrosion was found in Al Alloy 2014 [11-13].

3.5. Tensile Test
Figure 13 shows the comparison between ultimate tensile strength of as received, ST and aged samples. This graph shows that the maximum Ultimate tensile strength first increase and then decreases due to over ageing. Tensile testing result shows that the maximum Ultimate tensile stress reaches to 573 MPa and Yield strength 528 MPa values at 150°C and 8 hrs of aged sample. Samples aged at higher ageing
temperature (200°C), attains higher strength then as received samples but they get slight lower UTS than the samples aged at lower temperature (150°C).

Figure 11. Effect of ageing time on the corrosion rate.

Figure 12. Macrographs of worn out surface after corrosion tests.

Figure 13. Tensile stress of aluminium alloy aged samples

4. Summery
1. Corrosion damage start with pitting corrosion and proceeds to convert into intergranular corrosion as ageing time increases.
2. Lower ageing temperature 150°C resulted lower corrosion rate as compare to higher ageing temperature.
3. In hardness testing result, the maximum hardness value of 154Hv was found at 150°C and 8 hrs. of ageing time.
4. In Tensile testing result the maximum Ultimate tensile strength of 575.13 MPa, Yield strength 530.77 MPa and elongation (%) of 10.26 values were found at 150°C and 8 hrs. of ageing time.

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