Data on the corrosion resistance as-received, annealed and quenched 1060 aluminum alloy in dilute H$_2$SO$_4$ and HCl acid concentrations

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Abstract: The effect of annealing and quenching heat treatment processes on the corrosion resistance of 1060 aluminum alloy was studied by weight loss method in 0.5, 1, 1.5 and 2M H$_2$SO$_4$ and HCl acid media. Alteration of the microstructural constituents of the alloy significantly influenced its corrosion resistance. Data obtained confirmed that quenched aluminum depicted the highest corrosion resistance with highest corrosion rate value of 0.00149 mm/y and 0.02151 mm/y from 2 M H$_2$SO$_4$ and HCl solution. Annealed aluminum exhibited the lowest corrosion resistance with optimal corrosion rates of 0.00768 mm/y and 0.02792 mm/y. Corrosion resistance of as-received aluminum was observed to be intermediate between the values obtained for quenched and annealed aluminum alloy. Annealed AL1060 exhibited the highest standard deviation value in H$_2$SO$_4$ while quenched AL1060 exhibited the highest values in HCl solution. Mean values generally increased with increase in acid solution for the as-received, annealed and quenched AL1060. Statistical data from analysis of variance (ANOVA) shows acid concentration is the statistically relevance sources of variation influence the the corrosion behaviour of as-received, annealed and quenched AL1060 in H$_2$SO$_4$ and HCl solution. The statistical relevance values for acid concentration obtained in H$_2$SO$_4$ solution 83.40%, 97.04% and 89.29% while the corresponding values in HCl solution are 97.94%, 99.29% and 96.07%. The values for exposure time were calculated to be statistically irrelevant in both acids.

1. INTRODUCTION

Aluminium is an important structural engineering alloy whose application is only behind ferrous alloys as a result of their light weight, relatively high strength and excellent corrosion resistance properties. Their corrosion resistance is due to the initiation and growth of inert, impenetrable protective oxide layer on their surface. The application and production of aluminium has exponential increase in recent years with extensive application as the material of construction for heat exchangers, electrical wires, automotive radiators, aircraft parts, marine components, consumer devices, sports equipment etc. [1-3]. Heat treatment is indispensible in the final fabrication and production of aluminium to meet specific property requirements [4-6]. Aluminium alloys are highly reactive metals and vulnerable to corrosion due to its amphoteric nature wherewith it can sometimes undergo accelerated degradation in the presence of threshold concentrations of salts, acids or bases. Alteration of their metallurgical and microstructure properties in high temperature applications significantly influences their corrosion resistance [7, 8]. Several factors are responsible for the corrosion resistance properties of aluminum alloys in aqueous environments such as surface properties of the material, the nature, the temperature, pH and the composition of the electrolyte [9-11]. Previous research has shown that corrosion resistance of aluminum is strongly by the heat treatment [12-14]. This research focuses on the effect of annealing and quenching heat treatment processes on the corrosion resistance of 1060 aluminum alloy in dilute concentrations of H$_2$SO$_4$ and HCl acid solution.
2. MATERIAL AND METHODS

As-received 1060 aluminum alloy (AL1060) rod with average length and diameter of 10 mm x 12 mm was machined into three sets of four 4 test specimens with HSS parting tool on a lathe machine. The Al1060 samples were metallographically prepared using emery papers of 80, 120, 220, 800 and 1000 grits. One set of four Al1060 samples were heat treated by annealing in a muffle furnace above the transformation range to 425°C before slowly cooled to 260°C and then gradually to room temperature. Another set of four Al1060 samples were heat treated by quenching at a temperature of 425°C in the muffle furnace after which the samples are removed and immediately quenched in distilled water. 0.5M, 1M, 1.5M and 2M of H2SO4 and HCl solution at 150 mL were prepared by dilution of analar grade of both acids (98% H2SO4 and 37% HCl) with distilled H2O. Weight measured AL1060 samples were separately and fully immersed in 200 mL of the prepared acid solutions for 480 h at ambient temperature of 25°C. The AL1060 samples were weighed every 24 h with Ohaus analytical weighing balance. Tabulated results of as-received, annealed and quenched AL1060 corrosion rate values at each acid concentration are shown from Tables 1 to 3. Corrosion rate was calculated from the equation below;

\[ R = \left( \frac{0.076W}{DAT} \right) \]  

(1)

W is the weight loss in grams, D is the density in g/cm², A is the area in cm², and T is the time of exposure in hours. W was calculated from the difference between the initial weight of AL1060 (kept constant for 480 h) and every final weight taken at 24 h interval for a total of 480 h.

3. RESULTS AND DISCUSSION

3.1 Coupon measurement

Data for corrosion rate of as-received, annealed and quenched AL1060 from H2SO4 and HCl solutions are presented from Tables 1-3. AL1060 corroded progressively with increase in concentration of both acids. AL1060 is an amphoteric metal, as a result changes in the surface characteristics of the alloy causes spontaneous reaction which implies breakdown of the protective oxide. The protective oxide in AL1060 had limited effect in the presence of higher concentrations of H2SO4 and HCl. Generally, the corrosion rate values for as-received, annealed and quenched AL1060 in HCl are relatively higher than the values obtained in H2SO4 due to the higher reactivity and smaller size of Cl⁻ ions. Annealed AL1060 specimens showed higher susceptibility to corrosion than the as-received specimens from observation of its corrosion rate values which are higher, while quenched Al 1060 showed the highest corrosion resistance compared to the as-received and annealed AL1060 due to its lower corrosion rate values. The influence of exposure time on 1060AL is quite varied as in some cases the corrosion rate decreased and vice versa.

Table 1. Data for as-received AL1060 corrosion rate in 0.5M, 1M, 1.5M and 2M of H2SO4 and HCl solution

| Acid Conc. (M) | 0.5M H2SO4 | 1M H2SO4 | 1.5M H2SO4 | 2M H2SO4 | 0.5M HCl | 1M HCl | 1.5M HCl | 2M HCl |
|---------------|------------|-----------|------------|----------|----------|--------|----------|--------|
| Exp. Time (h) |            |           |            |          |          |        |          |        |
| 24            | 0.00065    | 0.00078   | 0.01320    | 0.00200  | 0.00204  | 0.01190| 0.02033  |        |
| 48            | 0.00063    | 0.00058   | 0.00738    | 0.00128  | 0.00122  | 0.00133| 0.00714  | 0.01660|
| 72            | 0.00049    | 0.00055   | 0.00544    | 0.00164  | 0.00099  | 0.00253| 0.00615  | 0.01782|
| 96            | 0.00064    | 0.00045   | 0.00419    | 0.00156  | 0.00087  | 0.00282| 0.00625  | 0.01860|
| 120           | 0.00065    | 0.00055   | 0.00356    | 0.00143  | 0.00079  | 0.00297| 0.00591  | 0.02080|
| 144           | 0.00073    | 0.00063   | 0.00331    | 0.00132  | 0.00077  | 0.00325| 0.00647  | 0.02258|
| 168           | 0.00076    | 0.00059   | 0.00306    | 0.00156  | 0.00081  | 0.00339| 0.00624  | 0.02443|
| 192           | 0.00083    | 0.00058   | 0.00277    | 0.00167  | 0.00078  | 0.00335| 0.00689  | 0.02594|
Table 2. Data for annealed AL1060 corrosion rate in 0.5M, 1M, 1.5M and 2M of H$_2$SO$_4$ and HCl solution

| Acid Conc. (M) | Exp. Time (h) | 0.5M H$_2$SO$_4$ | 1M H$_2$SO$_4$ | 1.5M H$_2$SO$_4$ | 2M H$_2$SO$_4$ | 0.5M HCl | 1M HCl | 1.5M HCl | 2M HCl |
|---------------|--------------|------------------|---------------|-----------------|---------------|----------|--------|----------|--------|
| 24            | 0.00244      | 0.00195          | 0.00305       | 0.07163         | 0.00413       | 0.00762  | 0.01686 | 0.00726  |
| 48            | 0.00180      | 0.00195          | 0.00203       | 0.03628         | 0.00257       | 0.00425  | 0.01318 | 0.00727  |
| 72            | 0.00158      | 0.00161          | 0.00218       | 0.02521         | 0.00204       | 0.00347  | 0.01300 | 0.02004  |
| 96            | 0.00136      | 0.00125          | 0.00178       | 0.01901         | 0.00164       | 0.00304  | 0.01252 | 0.02554  |
| 120           | 0.00148      | 0.00140          | 0.00197       | 0.01567         | 0.00143       | 0.00290  | 0.01224 | 0.02789  |
| 144           | 0.00138      | 0.00138          | 0.00192       | 0.01357         | 0.00142       | 0.00310  | 0.01279 | 0.02835  |
| 168           | 0.00132      | 0.00127          | 0.00209       | 0.01198         | 0.00131       | 0.00311  | 0.01287 | 0.02770  |
| 192           | 0.00137      | 0.00140          | 0.00226       | 0.01095         | 0.00145       | 0.00336  | 0.01348 | 0.02954  |
| 216           | 0.00141      | 0.00151          | 0.00239       | 0.01014         | 0.00156       | 0.00356  | 0.01395 | 0.03098  |
| 240           | 0.00152      | 0.00171          | 0.00269       | 0.00976         | 0.00159       | 0.00384  | 0.01424 | 0.03066  |
| 264           | 0.00160      | 0.00172          | 0.00291       | 0.00933         | 0.00161       | 0.00397  | 0.01424 | 0.02964  |
| 288           | 0.00168      | 0.00183          | 0.00310       | 0.00883         | 0.00169       | 0.00421  | 0.01446 | 0.03101  |
| 312           | 0.00182      | 0.00196          | 0.00334       | 0.00870         | 0.00178       | 0.00453  | 0.01451 | 0.03186  |
| 336           | 0.00191      | 0.00196          | 0.00352       | 0.00838         | 0.00181       | 0.00468  | 0.01468 | 0.03245  |
| 360           | 0.00191      | 0.00202          | 0.00349       | 0.00810         | 0.00193       | 0.00483  | 0.01467 | 0.03341  |
| 384           | 0.00204      | 0.00224          | 0.00385       | 0.00811         | 0.00198       | 0.00516  | 0.01470 | 0.03450  |
| 408           | 0.00210      | 0.00217          | 0.00388       | 0.00782         | 0.00195       | 0.00529  | 0.01462 | 0.03280  |
| 432           | 0.00222      | 0.00225          | 0.00394       | 0.00772         | 0.00188       | 0.00546  | 0.01449 | 0.03101  |
| 456           | 0.00220      | 0.00228          | 0.00406       | 0.00750         | 0.00180       | 0.00551  | 0.01431 | 0.02938  |
| 480           | 0.00237      | 0.00275          | 0.00396       | 0.00768         | 0.00173       | 0.00561  | 0.01429 | 0.02792  |

Table 3. Data for quenched AL1060 corrosion rate in 0.5M, 1M, 1.5M and 2M of H$_2$SO$_4$ and HCl solution

| Acid Conc. (M) | Exp. Time (h) | 0.5M H$_2$SO$_4$ | 1M H$_2$SO$_4$ | 1.5M H$_2$SO$_4$ | 2M H$_2$SO$_4$ | 0.5M HCl | 1M HCl | 1.5M HCl | 2M HCl |
|---------------|--------------|------------------|---------------|-----------------|---------------|----------|--------|----------|--------|
| 24            | 0.00166      | 0.00177          | 0.00186       | 0.00285         | 0.00108       | 0.00529  | 0.01953 | 0.12754  |
| 48            | 0.00073      | 0.00087          | 0.00131       | 0.00180         | 0.00057       | 0.00313  | 0.01266 | 0.08942  |
| 72            | 0.00096      | 0.00143          | 0.00111       | 0.00170         | 0.00125       | 0.00291  | 0.00954 | 0.07051  |
| 96            | 0.00087      | 0.00117          | 0.00091       | 0.00164         | 0.00109       | 0.00234  | 0.00937 | 0.06018  |
| 120           | 0.00095      | 0.00112          | 0.00111       | 0.00156         | 0.00102       | 0.00206  | 0.00834 | 0.05258  |
| 144           | 0.00107      | 0.00107          | 0.00126       | 0.00165         | 0.00088       | 0.00201  | 0.00798 | 0.04695  |
| 168           | 0.00095      | 0.00109          | 0.00116       | 0.00147         | 0.00097       | 0.00315  | 0.00700 | 0.04275  |
| 192           | 0.00097      | 0.00112          | 0.00119       | 0.00149         | 0.00107       | 0.00415  | 0.00633 | 0.03974  |
| 216           | 0.00098      | 0.00114          | 0.00121       | 0.00151         | 0.00103       | 0.00493  | 0.00580 | 0.03740  |
240 | 0.00100 | 0.00107 | 0.00121 | 0.00152 | 0.00111 | 0.00535 | 0.00521 | 0.03506  
264 | 0.00101 | 0.00104 | 0.00121 | 0.00146 | 0.00101 | 0.00495 | 0.00558 | 0.03320  
288 | 0.00098 | 0.00109 | 0.00116 | 0.00143 | 0.00094 | 0.00485 | 0.00558 | 0.03234  
312 | 0.00094 | 0.00108 | 0.00121 | 0.00143 | 0.00096 | 0.00451 | 0.00581 | 0.02996  
336 | 0.00088 | 0.00110 | 0.00118 | 0.00146 | 0.00095 | 0.00424 | 0.00588 | 0.02860  
360 | 0.00084 | 0.00111 | 0.00113 | 0.00140 | 0.00096 | 0.00405 | 0.00593 | 0.02714  
384 | 0.00079 | 0.00110 | 0.00125 | 0.00140 | 0.00097 | 0.00387 | 0.00608 | 0.02603  
408 | 0.00075 | 0.00105 | 0.00120 | 0.00141 | 0.00097 | 0.00364 | 0.00615 | 0.02494  
432 | 0.00071 | 0.00100 | 0.00115 | 0.00139 | 0.00092 | 0.00344 | 0.00630 | 0.02385  
456 | 0.00068 | 0.00096 | 0.00120 | 0.00138 | 0.00088 | 0.00327 | 0.00613 | 0.02261  
480 | 0.00065 | 0.00092 | 0.00125 | 0.00149 | 0.00084 | 0.00313 | 0.00642 | 0.02151  

3.2 Statistical data

The mean and standard deviation for as-received, annealed and quenched AL1060 from H$_2$SO$_4$ and HCl solution are shown in Table 4. The standard deviation values increased with concentration for the three set of AL1060 which shows the amount of variation of corrosion rate values with respect to exposure time increased with acid concentration. The standard deviation values from HCl solution were generally higher than the values in H$_2$SO$_4$ solution. Annealed AL1060 exhibited the highest standard deviation value in H$_2$SO$_4$ while quenched AL1060 exhibited the highest values in HCl solution. Mean values generally increased with increase in acid solution for the as-received, annealed and quenched AL1060.

Table 4. Mean and standard deviation of corrosion rate values for as-received, annealed and quenched AL1060 in H$_2$SO$_4$ and HCl solution

| Acid Solution | H$_2$SO$_4$ |  |  | HCl |  |  |  |  |
|---------------|------------|----|----|----|----|----|----|----|
| Conc. (M)      | 0.5 | 1 | 1.5 | 2 | 0.5 | 1 | 1.5 | 2 |
| SD            | 0.00010 | 0.00023 | 0.00027 | 0.00047 | 0.00028 | 0.00093 | 0.0014 | 0.0056 |
| Mean          | 0.00074 | 0.00075 | 0.0034 | 0.0018 | 0.00096 | 0.0034 | 0.0076 | 0.026 |
| ANNEALED      | H$_2$SO$_4$ |  |  | HCl |  |  |  |  |
| Conc. (M)      | 0.5 | 1 | 1.5 | 2 | 0.5 | 1 | 1.5 | 2 |
| SD            | 0.00036 | 0.00040 | 0.0008 | 0.021 | 0.00060 | 0.0012 | 0.0010 | 0.0076 |
| Mean          | 0.0018 | 0.0018 | 0.0029 | 0.015 | 0.0019 | 0.0044 | 0.014 | 0.027 |
| QUENCHED      | H$_2$SO$_4$ |  |  | HCl |  |  |  |  |
| Conc. (M)      | 0.5 | 1 | 1.5 | 2 | 0.5 | 1 | 1.5 | 2 |
| SD            | 0.00021 | 0.00019 | 0.0002 | 0.0003 | 0.00014 | 0.0011 | 0.0033 | 0.026 |
| Mean          | 0.0009 | 0.0011 | 0.0012 | 0.002 | 0.0010 | 0.0038 | 0.008 | 0.044 |

ANOVA data showing the statistical influence of acid concentration and exposure time on the corrosion rate value of AL1060 in H$_2$SO$_4$ and HCl solution are shown in Tables 5 and 6. The statistical relevance is the percentage significance of each source of variation relevance to the corrosion rate output. The mean square ratio is the calculated significance factor which must be greater than the theoretical significance factor (threshold factor) the statistical relevance value to be acceptable. The statistical relevance value in Table 5 shows H$_2$SO$_4$ concentration is the only statistically relevant source of variation important in the resulting corrosion rate output for as-received, annealed and quenched AL1060 with values of 83.40%, 97.04% and 89.29%. The corresponding values for exposure time are generally below 5%. However, the value of mean square ratio for the heat treated and as-received AL1060 are lower than the theoretical significance factor which showsexposure time is statistically irrelevant in the corrosion value output of the alloy. The results obtained for as-received, annealed and quenched AL1060 in HCl solution shown in Table 6 is generally similar to the values obtained in Table 5 with HCl solution being the only statistically relevant factor with values of 97.94%, 99.29% and 96.07%. The corresponding values for exposure
time were generally below 2% while the values for mean square ratio for exposure time is below the theoretical significance factor.

Table 5 ANOVA data for as-received, annealed and quenched AL1060 corrosion in H₂SO₄ solution

| Source of Variation | Sum of Squares | Degree of Freedom | Mean Square | Mean Square Ratio (F) | Theoretical Significance Factor | Statistical Relevance (%) |
|---------------------|----------------|-------------------|-------------|-----------------------|-------------------------------|---------------------------|
| H₂SO₄ Conc.         | 0.000017       | 3                 | 0.00000555  | 67.40                 | 2.81                          | 83.40                      |
| Exp. Time           | 0.000001       | 10                | 0.00000008  | 1.03                  | 2.05                          | 4.23                       |
| Residual            | 0.000002       | 30                | 0.00000008  |                       |                               |                           |
| Total               | 0.000020       | 43                |             |                       |                               |                           |

Annealed

| Source of Variation | Sum of Squares | Degree of Freedom | Mean Square | Mean Square Ratio (F) | Theoretical Significance Factor | Statistical Relevance (%) |
|---------------------|----------------|-------------------|-------------|-----------------------|-------------------------------|---------------------------|
| H₂SO₄ Conc.         | 0.0002984      | 3                 | 0.00009947  | 341.89                | 2.81                          | 97.04                      |
| Exp. Time           | 0.000004       | 10                | 0.00000004  | 0.13                  | 2.05                          | 0.12                       |
| Residual            | 0.0000087      | 30                | 0.00000029  |                       |                               |                           |
| Total               | 0.0003075      | 43                |             |                       |                               |                           |

Quenched

| Source of Variation | Sum of Squares | Degree of Freedom | Mean Square | Mean Square Ratio (F) | Theoretical Significance Factor | Statistical Relevance (%) |
|---------------------|----------------|-------------------|-------------|-----------------------|-------------------------------|---------------------------|
| H₂SO₄ Conc.         | 0.0000021      | 3                 | 0.00000689  | 136.99                | 2.81                          | 89.29                      |
| Exp. Time           | 0.000001      | 10                | 0.00000010  | 1.93                  | 2.05                          | 4.19                       |
| Residual            | 0.0000002     | 30                | 0.00000005  |                       |                               |                           |
| Total               | 0.0000023     | 43                |             |                       |                               |                           |

Table 6 ANOVA data for as-received, annealed and quenched AL1060 corrosion in HCl solution

| Source of Variation | Sum of Squares | Degree of Freedom | Mean Square | Mean Square Ratio (F) | Theoretical Significance Factor | Statistical Relevance (%) |
|---------------------|----------------|-------------------|-------------|-----------------------|-------------------------------|---------------------------|
| HCl Conc.           | 0.0059         | 3                 | 0.0020      | 549.79                | 2.81                          | 97.94                      |
| Exp. Time           | 0.000002      | 10                | 0.000002    | 0.47                  | 2.05                          | 0.28                       |
| Residual            | 0.000011      | 30                | 0.000004    |                       |                               |                           |
| Total               | 0.000060      | 43                |             |                       |                               |                           |

Annealed

| Source of Variation | Sum of Squares | Degree of Freedom | Mean Square | Mean Square Ratio (F) | Theoretical Significance Factor | Statistical Relevance (%) |
|---------------------|----------------|-------------------|-------------|-----------------------|-------------------------------|---------------------------|
| HCl Conc.           | 0.00584        | 3                 | 0.0019      | 2053.66               | 2.81                          | 99.29                      |
| Exp. Time           | 0.0000011     | 10                | 0.0000013   | 1.38                  | 2.05                          | 0.22                       |
| Residual            | 0.0000003     | 30                | 0.000009    |                       |                               |                           |
| Total               | 0.0000588     | 43                |             |                       |                               |                           |

Quenched

| Source of Variation | Sum of Squares | Degree of Freedom | Mean Square | Mean Square Ratio (F) | Theoretical Significance Factor | Statistical Relevance (%) |
|---------------------|----------------|-------------------|-------------|-----------------------|-------------------------------|---------------------------|
| HCl Conc.           | 0.0049         | 3                 | 0.001630    | 345.72                | 2.81                          | 96.07                      |
| Exp. Time           | 0.000006      | 10                | 0.000006    | 1.24                  | 2.05                          | 1.15                       |
| Residual            | 0.000014      | 30                | 0.000005    |                       |                               |                           |
| Total               | 0.00051       | 43                |             |                       |                               |                           |
4. CONCLUSION

Data obtained from electrochemical corrosion behaviour of as-received, quenched and annealed 1060 aluminium alloy showed that the quenched alloy generally had the highest corrosion resistance. The as-received aluminium specimens exhibited a lower corrosion resistance than the quenched specimens though the corrosion rates from HCl solution are generally higher than values obtained from H$_2$SO$_4$. Annealed aluminium alloy had the highest corrosion rate. The standard deviation values for the heat treated and as-received alloy increased with acid concentration while the standard deviation values for HCl solution were generally higher than the values in H$_2$SO$_4$ solution with respect to exposure time. Statistical data from ANOVA acid concentration is the dominant source of variation statistically relevant for the resulting corrosion rate value with respect to exposure time for the heat treated and as-received Al alloy.

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REFERENCES

[1]. Birbilis N and Muster T 2011. Corrosion of aluminum alloys. Corrosion mechanisms in theory and practice, 3rd Ed., CRC Press, pp. 705-736.

[2]. Davis JR 1999. Corrosion of aluminum and aluminum alloys, ASM International, Materials Park, Ohio, USA.

[3]. Makanjuola O, Kayode O, John O, Samuel O 2013. Inhibition of aluminium in HCl by amine modified epoxy resin. Journal of Materials. http://dx.doi.org/10.1155/2013/479728

[4]. Loto RT 2018. Investigation of the localized corrosion resistance of 4044 aluminum alloy in acid chloride and neutral chloride solutions. J Fail Anal Prev. 18:905–911. https://doi.org/10.1007/s11668-018-0474-9.

[5]. Loto RT and Adeleke A 2016. Corrosion of aluminum alloy metal matrix composites in neutral chloride solutions. J Fail Anal Prev. 16(5):874–885. https://doi.org/10.1007/s11668-016-0157-3.

[6]. Rajan TV, Sharma CP and Sharma A 1988. Heat treatment principles techniques, Rajkarnal Electric Press. India, pp. 142-149.

[7]. Loto RT and Igbogbo EA 2016. Corrosion behaviour of heat treated 1060 aluminium in dilute acid solutions. Rev. Tec. Fac. Ing. Univ. 39:35 - 40.

[8]. Garrigues L, Pebere N and Dabosi F 1996. An investigation of the corrosion inhibition of pure aluminium in neutral and acidic chloride solutions. Electrochimica Acta. 41(7-8):1209–1215.

[9]. Lampeas N and Koutsoukos PG 1994. The importance of the solution pH in electrochemical studies of aluminum in aqueous media containing chloride. Corros. Sci. 36(6):1011-1025.

[10]. Van Gheem E, Vereecken J and Le Pen C 2002. Influence of different anions on the behaviour of aluminium in aqueous solutions. J Appl. Electrochem. 32:1193-1200.

[11]. Andreatta F, Terry H and De Wit JH 2004. Corrosion behaviour of different tempers of AA7075 aluminium alloy. Electrochim. Acta. 49(17-18):2851-2682.

[12]. Berrada S, El Boujdaini M and Ghali EJ 1992. Electrochemical behavior of aluminum alloys 2024 AND 7075 in a saline environment. J. Appl. Electrochem. 22:1065-1070.

[13]. Wloka J, Hack, T and Virtanen S 2007. Influence of temper and surface condition on the exfoliation behaviour of high strength Al–Zn–Mg–Cu alloys. Corros. Sci. 49(3):1437-1449.

[14]. Ambat R, Prasad RK, Dwarakadasa ES 1995. The influence of aging at 180 °C on the corrosion behaviour of a ternary Al1.5Li0.1Zr alloy. Corros. Sci. 37(8):1253-1265.