STUDIES ON THE CORROSION BEHAVIOUR OF ALUMINIUM 2014/ ALBITE METAL MATRIX COMPOSITES

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Abstract:

Metal matrix composites containing aluminium alloys as matrix are of special interest in the present research field due to their decreased density and improved mechanical and corrosion resistance properties. Aerospace, automobile and marine industries are in need of these materials which are less prone to corrosion. Hence the need of composite materials is there in present industrial requirements because of improved resistance to corrosion. Aluminium and albite are mixed to get composite materials by the process of liquid metallurgy and vortex. Various corrosion tests were carried on composites in order to test their feasibility in different engineering applications. Static weight loss (SWL) corrosion test and potentiodynamic polarization were conducted on the composite materials mentioned above in hydrochloric acid medium. The results obtained confirms these composite materials possess better corrosion resistance properties from the matrix alloy.

Key words: Aluminium, Albite, Matrix, Composites, Vortex.

I. Introduction

In the recent research scenario, composite materials find application in huge quantities in different engineering fields which involve aerospace, aircraft, two and four-wheeler, marine industry etc. Extensive usage of composite materials in engineering field is due to the good properties like improved ultimate strength, density and hardness. They also exhibit increased corrosion resistance. The improvement in these properties is due to the usage of newest expertise and numerous production approaches which has increased the requirement of these materials. Usage of composite materials was originated at aerospace industry during 70s. From the last thirty years the development of these materials leads to the application in engineering fields. Presently automobile sector is getting good benefits from improved properties of these materials. Hence composite materials are of attraction for many engineering industries.

Much of research has not been done on the composite materials made up of aluminium 2014 alloy. But other aluminium alloys reinforced with albite particulates have been studied with respect to various mechanical properties. Batluri Tilak Chandra\textsuperscript{1} et al studied the effect of cold quenching on mechanical properties of Al 7075-albite particulate composite. They subjected the composites manufactured by them to artificial ageing by heat treatment at 470\textdegree C for two hours and quenched in ice then again heated to 120\textdegree C for 6 hours. Then UTS, Compression and hardness tests were conducted on the materials. Finally, they report that the above mention properties were significantly improved when compared with matrix. Mechanical properties of Metal matrix composites like aluminium 6061-albite metal composite prepared by Campo casting method were developed by A Ramesh and K H W Seah\textsuperscript{2}. They studied UTS, hardness and young’s modulus of the composites manufactured by them. They report that the above-mentioned properties were improved when compared with the values of matrix alloy. Anjum Anwar Shaik\textsuperscript{3} et al studied the mechanical
properties of LM 26 alloy reinforced with albite particulates. They manufactured copper chill by the chill casting method. In their research paper they have studied the properties like tensile strength, compressive strength, and hardness these properties have increased with increase in weight percentage of albite in LM6 matrix alloy giving rise to improved microstructure of composite. Regarding corrosion characterization of composite materials containing aluminium 2014 and albite as reinforcement no work has been done so far.

II. Experimental details

II. a. Materials selected

The materials used in the present research work are aluminium 2014 as alloy matrix and albite particulates as reinforcement. Aluminium 2014 is a commercially available alloy in the present industries and it costs around Rs 270 per Kg in the polished plate form. Its composition is given in the table 1 below. Figure 1 shows the purchased alloy.

Table 1: Composition of Aluminium 2014 alloy

<table>
<thead>
<tr>
<th>Element</th>
<th>Copper</th>
<th>Silicon</th>
<th>Magnesium</th>
<th>Chromium</th>
<th>Manganese</th>
<th>Aluminium</th>
</tr>
</thead>
<tbody>
<tr>
<td>Percent</td>
<td>4.4</td>
<td>0.8</td>
<td>0.5</td>
<td>0.1</td>
<td>0.6</td>
<td>Balance</td>
</tr>
</tbody>
</table>

The alloy is rich in copper content. The reinforcement used is albite. Its chemical formula is NaAlSi₃O₈. Its structure is tectosilicate and has pure white colour. It will be in triclinic crystal system. It finds application as a gemstone, it is semi-precious. Geologists identifies it as an important rock forming mineral and it will used by them for various purpose. The mineral is also used in industry for the manufacture of glass and ceramics. Its hardness is 6-6.5 in Moh’s scale. Its specific gravity is 2.6-2.65. It is also available commercially. It is subjected to pulverization and particulates of 50-80µM were taken and added to molten alloy. Figure 2 given above shows the crystal of albite.

To test the corrosion behaviour the media selected was 0.025, 0.05 and 0.1 molar hydrochloric acid (HCl) solutions. Different concentrated solutions of the acid were prepared using research grade HCl in triple distilled water.

Composites Preparation

The liquid metallurgy route using vortex technique used by Krupakara was employed to prepare the composites. The alloy was heated slightly above the melting point in a ceramic crucible and a mechanical stirrer is introduced into it to create a vortex. Pre heated but uncoated albite particulates are added in to the vortex in which the albite concentration is varied from 3 to 9 weight percentage at incremental difference of 3% by well mixing. The same procedure is followed for casting of matrix.
Specimen Preparation:
Cylindrical shaped specimens of matrix and composite with size 20cm x 20cm and rectangular shape specimens having 20mm x 10mm x 1mm dimension is subjected to SWL corrosion test and potentio dynamic polarization test by standard metallographic procedure. Dimensions of all specimens were determined from vernier gauge. All specimen were machined from castings as per ASTM standards.

Corrosion Test:
Weight loss technique is used to determine the corrosion rate of specimens at room temperature. The method involves immersing the accurately weighed specimens in various concentration of HCl solutions for different time intervals like 24, 48, 72 and 96 hours. The weight lost by the specimen is obtained and this loss of weight is converted into corrosion rate by substituting the values in the formula

\[
\begin{align*}
\text{Corrosion rate in mpy} & = \frac{534W}{DAT} \\
W & = \text{Loss of weight in grams} \\
D & = \text{Specimen density in gm/cc} \\
A & = \text{Area of the specimen in inch}^2 \\
T & = \text{Time of exposure in hours}
\end{align*}
\]

By applying current through the electrolyte, the potential of the electrode can be changed at a selected rate by using potentio dynamic polarization technique. It is one of the best techniques for finding the corrosion resistance by polarization testing method for wide variety of functions.

For potentio dynamic polarization test was carried out using electrochemical work station CHI 608E series model developed by CH instruments USA. It has arrangement for connecting the cell with reference electrode, counter electrode and also to connect to the prepared specimen as working electrode.

Beaker with 100 cm³ capacity is used to carry out electrochemical investigations. This can be used to place cell containing a counter electrode, reference electrode and specimen holder. Reference electrode used in these studies is silver electrode, counter electrode used is platinum electrode and composite and alloy specimen prepared for studies will be working electrode. Specimen of 1cm² area is used to study the corrosive nature of the environment. The results in the form of Tafel plots were obtained from the personal computer attached to the work station. Figure 3 shows the electrochemical work station developed by CH Instruments USA. Stress corrosion test is carried out in a stainless-steel autoclave shown in Figure 4. All the above tests were conducted using different concentrated solutions of HCl at various temperature and exposure times.

![Fig 3: Electrochemical workstation](image1)

![Fig 4: stainless steel autoclave.](image2)

Results and discussion
From the results obtained by SWL corrosion test, graph 1, 2 and 3 is drawn with the help of MS excel where X axis shows the time of exposure and Y axis shows rate of corrosion.
We can understand from the above graphs that, in different concentration of HCl like 0.025, 0.05 and in 0.1M HCl, the corrosion rate diminishes with addition of reinforcement particulates. Matrix alloy possess higher corrosion rate than the composite materials containing albite. Aluminium 2014 is not exhibiting sufficient corrosion resistance in all the three concentrated solutions of HCl. The ceramic nature of albite introduces chemical inertness and hence it is unaffected during SWL corrosion tests. The inert nature of reinforced albite particulates will not affect electrochemically the corrosion mechanism of the composites. Hence corrosion resistance increases with the increase of albite content in the composite materials. Many researchers have reported same type of results where different aluminium alloys and ceramic particulates used as reinforcements.
Graphs 4-6 are the Tafel plots for the matrix alloy and composite materials obtained after conducting potentiodynamic polarization test using electrochemical work station.

Graph 4: Representation of Tafel plot for composites and matrix in 0.025M HCl

Graph 5: Representation of Tafel plot for composites and matrix in 0.05M HCl

Graph 5: Representation of Tafel plot for composites and matrix in 0.1M HCl
Table 2: Corrosion potential, corrosion current and corrosion rates in hydrochloric acid

<table>
<thead>
<tr>
<th>Percentage of albite in Al2014</th>
<th>Concentration of HCl</th>
<th>E corrosion</th>
<th>I corrosion</th>
<th>C.R</th>
</tr>
</thead>
<tbody>
<tr>
<td>0</td>
<td>0.025 M</td>
<td>-0.475</td>
<td>2.424 x10^-7</td>
<td>1.514</td>
</tr>
<tr>
<td>3</td>
<td>-0.415</td>
<td>2.012 x10^-7</td>
<td>1.314</td>
<td></td>
</tr>
<tr>
<td>6</td>
<td>-0.389</td>
<td>1.954 x10^-7</td>
<td>1.103</td>
<td></td>
</tr>
<tr>
<td>9</td>
<td>-0.487</td>
<td>1.554 x10^-7</td>
<td>0.864</td>
<td></td>
</tr>
<tr>
<td>0</td>
<td>0.05 M</td>
<td>-0.699</td>
<td>3.978 x10^-7</td>
<td>3.414</td>
</tr>
<tr>
<td>3</td>
<td>-0.502</td>
<td>2.901 x10^-7</td>
<td>2.214</td>
<td></td>
</tr>
<tr>
<td>6</td>
<td>-0.467</td>
<td>2.762 x10^-7</td>
<td>1.903</td>
<td></td>
</tr>
<tr>
<td>9</td>
<td>-0.228</td>
<td>1.151 x10^-7</td>
<td>0.834</td>
<td></td>
</tr>
<tr>
<td>0</td>
<td>0.1 M</td>
<td>-0.699</td>
<td>4.978 x10^-7</td>
<td>4.414</td>
</tr>
<tr>
<td>3</td>
<td>-0.502</td>
<td>3.901 x10^-7</td>
<td>3.214</td>
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<td>1.834</td>
<td></td>
</tr>
</tbody>
</table>

The results of the potentiodynamic polarization tests are given in the table 2. With the results obtained it is very clear that with increase in amount of albite as a reinforcement in the specimen reduces the rate of corrosion in all the three different concentration of HCl.

Tafel polarization plots given above show that the anodic and cathodic curves of both matrix and composites are proportional to each other, however cathodic curve of composites is somewhat moved to the more positive side which is attributed to the reduction of hydrogen gas liberation. Corrosion rate of matrix and hybrid composites is influenced by the concentration of corrosion medium. With increase in concentration of HCl the rate of corrosion of matrix and hybrid composites also increases. The corrosion current developed and hydrogen gas evolution were found to be directly proportional to each other. Concentration of the corrosion medium and area exposed will play an important role in the chemical reaction taking place during the exposure. As the reinforcement content increases, the rate of corrosion decreases. This is because of the chemical inert nature of the reinforcement particulates, which are ceramic in nature. Exposure of active-matrix surface in the composites is reduced due to the presence of albite particulates added as reinforcement. Several researchers who have performed potentiodynamic polarization test for different aluminium alloys reinforced with various ceramic particulates. Report of same type of results and explanation13-20.

Conclusions
Specimens of Aluminium 2014 reinforced with albite particulates were prepared by the process of liquid melt metallurgy using vortex method. Specimens were machined from castings as per ASTM standards. Specimens were subjected to static weight loss corrosion test by immersing them in corrodenent media and potentiodynamic polarization test using electrochemical workstation. In both the
tests the composite materials exhibited improved resistance to corrosion in all the three concentrated solutions of HCl.

References


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