CORROSION CHARACTERISTICS OF ALUMINIUM (AL 6063) IN 5% HCL

by

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Abstract

In this research work corrosion studies related to heat treatment have been carried out. The material considered was Al 6063. Anodic polarization was done in dilute Hydrochloric acid at 28°C. The material was heat-treated at 350°C and at 550°C. The material which was heat-treated at 550°C underwent three different cooling methods.

There were three distinct sections in the curves namely an active section, a pseudopassive section and an active section. In all the considered cases the form and the characteristic of the curves were the same. The heat treated time and temperature had some influence on the rate of corrosion of the material. But the cooling method had a clear influence on the rate of corrosion.

1.0 Introduction

As mentioned in the previous articles (1,2) , Aluminium could be considered as a suitable material in corrosion studies, due to the formation of a thin oxide layer on its surface and also due to its negative potential of -1.69 Volt (3,4,5,6,7). The rate of corrosion is minimized in certain electrolytes and therefore it could be called "passive" to corrosion (8,9,10,11,12,13). When the material is cold worked, a certain amount of stress is given to the material. According to Rohrmann (14), the stress is one of the factors to influence the rate of corrosion of metals. Therefore, to relieve the stresses in a material, heat treatment is done. In earlier invenstigations (14,15,16,17,18,19,20,21), Aluminium with different purity were taken and had undergone heat treatments. The temperature was varied between 200°C and 600°C. The heating time was varied between one hour and sixty hours. Three different cooling methods were used. The methods were quenching in water at room temperature, cooling in air (normalized) and cooling in the turned off furnace (annealed). There was very little uniformity in the obtained results. But the method of cooling had some influence on the rate of corrosion.

As AL 6063 is widely used in Sri Lanka, the intention of this study is to analyse the corrosion behaviour of this material in dilute Hydrochloric acid after undergoing heat treatment. Due to the presence of impurities in the material, Aluminium AL 6063 could corrode easily in atmospheric conditions. Today, we find that the atmosphere contains lots of impurities due to pollution. Therefore, there is a tendency for the metals to get corroded easily. In this series of experiments, I have conducted experiments in dilute HCl. Similar experiments would also be conducted in other media. The results could be very useful in the practical applications. This material is used in the hardware, in the production of Aluminium framework in various fields and in the construction of bus and lorry bodies.

2.0 Experimental Procedure

5mm thick sheet Aluminium (AL 6063) with a chemical composition of 98 - 99% AL; 0.45 - 0.9% Mg; 0.2 - 0.6% Si; 0.25% Fe; 0.1% Mn; 0.01% Cu was used. The supplied material was 20% and 50% cold worked. The degree of cold work is measured by the percent of reduction of thickness of the material during cold rolling from the original state.

To conduct the experiments rectangular pieces were cut to the size of 30mm x 20mm x 5mm (see figure 1). A portion of the samples were divided into three groups. The first group was kept in a furnace at 350°C for one hour and quenched in water at room temperature. The second group was kept in a furnace at 350°C for three hours and quenched in water at room temperature. The third group was kept in a furnace at 550°C and quenched in water at room temperature. The other portion was kept in a furnace at 550°C for one hour and underwent three different cooling methods. One part was quenched in water at room temperature, the second part was cooled in air (normalized) and the third part cooled in the turned - off furnace (annealed).

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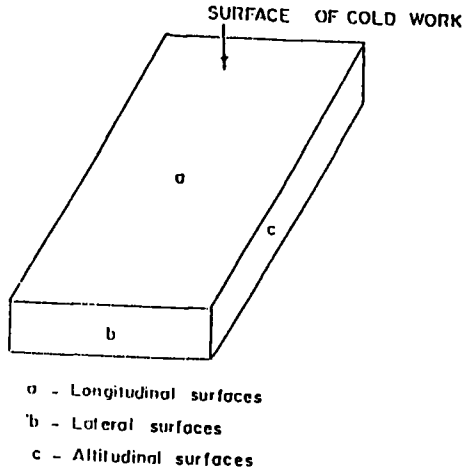

Fig. 1 - Type of Surface

All the specimens were cleaned with acetone and alcohol to remove oil and dust on the surface of the material. Electrical contact was made via an Aluminium wire attached to the back face of the specimen (22). Except for the test surface, the rest was covered with an adherent epoxy called "picein" (22) to ensure that environmental and electrical isolation were maintained. They were then cleaned once again with alcohol and then washed with distilled water, dried and kept in a desiccator.

Before the samples were placed in the corrosive media, they underwent a 4 minute polarization in 10% H_2SO_4 at 50°C by using a current density of 100 mA/cm^2. Polarization was done to remove the oxide layer. After the polarization the samples were washed with distilled water and placed in the respective electrolyte (See figure 2). Individual pieces were then coupled to a potentiostat using a conventional three - electrode technique as mentioned in (22) and (23) respectively (See figure 2). All reported potential values were referenced to a staturated calomel reference electrode.

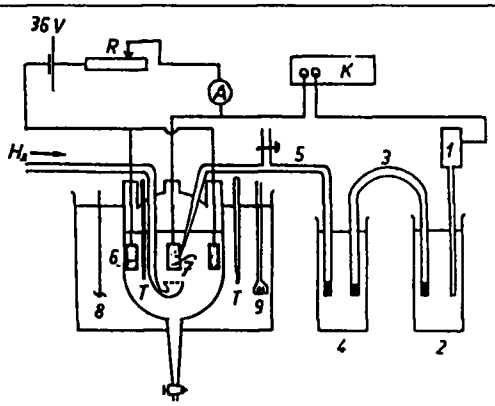

Fig. 2 - K - Potentiostat; 1 - Calomel electrode; 2 - Beaker with saturated KCl solution; 3 - Brige with saturated KCl solution; 4 - Beaker with the electrolyte; 5 - Bridge with the electrolyte ; 6 - Cathode (Pt); 7 - Anode (Al); 8 - Rotor; 9 - Heater; T - Thermometer

The test solution was deaerated with H_2 for about one hour before the sample immersion. Deaeration with H_2 continued throughout the experiment. All testing were continued at laboratory temperature at 28°C. Prior to anodic polarization the material was kept for about 30 minutes in the respective electrolyte, to reach an average steady - state free corrosion potential V_{SCE}. At least two anodic polarization curves were generated for each condition. As they were very similar, only one reading was taken for each condition to plot the graphs. The rate of polarization was 2 V/h for all the conducted experiments.

3.0 Experimental Results and Discussion

Figure 3,4,5 and 6 show anodic polarization curves for Aluminium (AL 6063) in 5% HCL at 28°C after undergoing heat treatment. The figures 3 and 4 are very similar, except for the rate of corrosion at high current densities. The characteristics of the curves in both figures are very similar. The V_{SCE} potential value vary between -1.025 Volt and -0.975 Volt. The V_{SCE} potential value for 20% and 50% cold worked material is nearly the same. With the increase in heat treatment temperature, the V_{SCE} potential value shifted to greater negative values. When a cold worked material is heat treated, the grains begin to rearrange and with the increase in temperature, diffusion of impurities into the grains of the material could take place. Due to the diffusion of impurities, the V_{SCE} potential value could shift to greater negative values as seen in figures 3 and 4. All three curves in both the figures exhibit an active nose for low current densities prior to the formation of the pseudopassive film. In this section of the curves the current density increases rapidly when compared to the change in potential. In the region of pseudopassivation the potential increases faster than the increase in current causing a flat section of the curve. By a current density of about 0.25mA/cm^2 and a potential of about -0.875 Volt activation of the pseudopassive film takes place causing pitting corrosion. With the start of pitting corrosion the current density increases very rapidly compared to the change in potential. This section of the curves are very similar to the first part of the curves. Once the pitting corrosion starts, acceleration of the corrosion reaction takes place. Due to the presence of impurities on the surface of the material this reaction could be further accelerated. The rate of corrosion of the material after the pitting potential is higher in figure 3 compared with figure 4. As mentioned in (1) the impurities on the surface of the material, could have effected this change in the corrosion rate.

By keeping the 350°C heat treated material in the furnace for three hours, and water quenching at room temperature, the V_{SCE} potential value was shifted towards a greater negative potential value (see figure 5). The V_{SCE} potential value was about -1.020 Volt. The reason could be explained as due to more impurities diffusing into the grains of the

material as a result of heat treatment time. Except for this difference, the form and the other characteristics of the three curves are very similar to the curves in the figures 3 and 4.

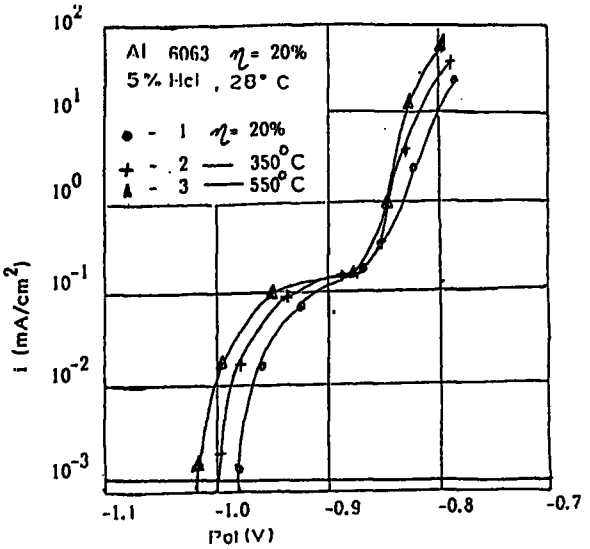

Fig. 3 Anodic polarization curves for the three conditions as mentioned in the figure

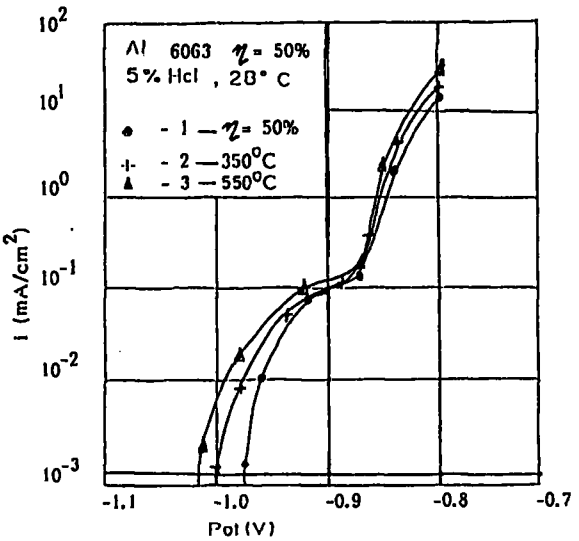

Fig. 4 Anodic polarization curves for the three conditions as mentioned in the figure

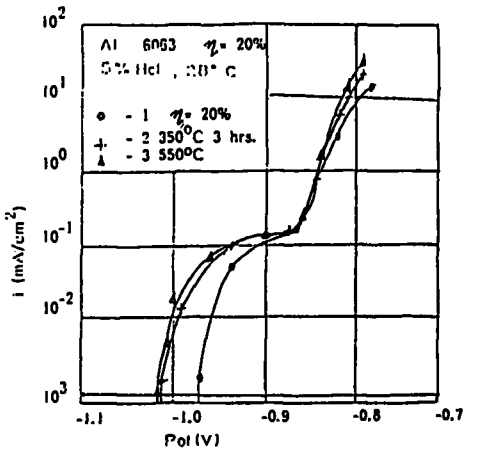

Fig. 5 Anodic polarization curves for the three conditions as mentioned in the figure

In figure 6 , a comparison is made between 20% cold worked material and heat treated material. After the material was heat treated at 550°C for one hour, they underwent three cooling methods as mentioned earlier. All four curves have very similar characteristics. The V_{SCE} potential value vary between -1.075 Volt and -0.975 Volt. With the method of cooling, the V_{SCE} potential value shifted to greater negative values. For 20% cold worked material the V_{SCE} potential value was -0.975 Volt, for water quenched material the V_{SCE} potential value was -1.025 Volt, for normalized material the V_{SCE} potential value was -1.045 Volt and for annealed material the V_{SCE} potential value was -1.075 Volt. When compared to 20% cold worked and water quenched material the normalized and annealed material the impurities had time to diffuse into the grains of the material in the cooling process. This could shift the V_{SCE} potential value to a greater negative potential value.

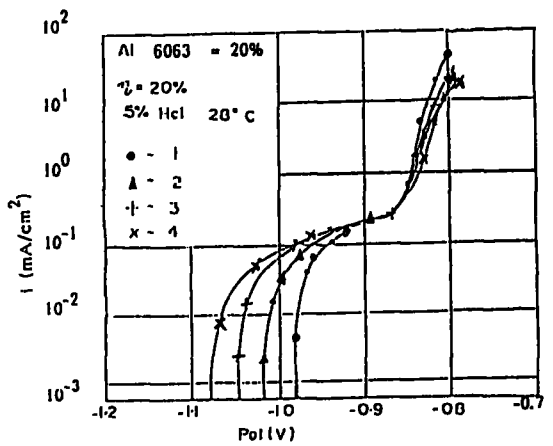

Fig. 6 Anodic polarization curves for the following conditions : 1. 20% cold worked material; 2. heat treated at 550°C and water quenched; 3. heat treated at 550°C and normalized; 4. heat treated at 550°C and annealed.

All four curves exhibit an active nose for low current densities prior to the formation of the pseudopassive film. In this section of the curves the current density increases rapidly when compared to the change in potential. In the region of pseudopasivation the potential increases faster than the increase in current causing a flat section of the curve. By a current density of about 0.25 mA/cm^2 and a potential of about -0.870 Volt, activation of the pseudopassive film takes place causing pitting corrosion. With the beginning of pitting corrosion the current density increases very rapidly compared with the change in potential. This section of the curves are very similar to the first part of the curves. But, when we compare the first part of the curves and the third part of the curves, there is a difference in the character of the rate of corrosion as shown in figure 6. In the first part of the curves the rate of corrosion decreased with the cooling method. Once again the influence of the impurities are very clear. In 20% cold worked material the impurities were on the surface of the material and therefore these influence the rate of corrosion. In annealed specimens the impurities were diffused into the grains of the material causing a lesser corrosion rate. But once the pitting corrosion starts the method of heat treatment or the degree of cold work has little influence on the rate of corrosion. Whether the impurities are on the surface of the material or inside the grains of the material, the impurities will influence the rate of corrosion once the pitting corrosion starts (1,24). Metallographic investigations of the material showed that there was uniform pitting corrosion on the surface of the material.

4.0 Conclusion

The degree of cold work or the heat treatment temperature or the method of cooling did not change the pattern of the anodic polarization curves. The heat treatment temperature and the method of cooling had some influence on the V_{SCE} potential value. The method of cooling also influenced the rate of corrosion before the pseudopassivation started. But once the pitting corrosion starts, activation takes place and the rate of corrosion increased very rapidly. In this section of the curves the impurities also would have influenced the rate of corrosion

5.0 References

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