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# CORROSION AND CORROSION INHIBITION OF SOME MAGNESIUM ALLOYS OF TECHNOLOGICAL IMPORTANCE IN AQUEOUS SOLUTIONS

**By**

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# ***Summary***

Magnesium and magnesium alloys have great interest structural materials for automobile, aircrafts and electronic products due to their properties like high strength to weight ratio, low cost of production, ease of machinability, high damping capacity, castability, weldability and recyclability. Magnesium alloys have great heat transfer property, ability to shield electromagnetic interference and radio frequency interference, making them promising materials for electronic applications. The corrosion resistance of Mg alloys is highly related to their composition, microstructures and ambient medium. These alloys are sensitive to sulphate ion concentration and pH of environments.

The present work represents a systematic and detailed investigation concerning the corrosion and passivation behavior of pure Mg, Mg-Al, Mg-Zn, Mg-Al-Zn and Mg-Al-Zn-Mn alloys in aqueous sulphate solutions of different pH, 3, 7 and 12. Also, the inhibition of the corrosion process in acidic sulphate solution was considered. The use of some urea derivatives (urea, thiourea, semicarbazide, thiosemicarbazide) and water soluble polymers (polyacrylamide, polyvinylpyrollidone and their blends) as environmentally safe corrosion inhibitors for magnesium alloys was also investigated.

The work presented in this thesis is divided into three chapters. *Chapter I* is subdivided into two sections. The first one is an introduction reviewing the relevant literature, and the second summarizes the aim of the whole investigation.

*Chapter II* is devoted to the experimental part. It includes specification of the electrodes and chemicals beside the details of the

electrochemical cell and measuring systems. It describes also details of the electrode pretreatment, polarization and impedance techniques.

The experimental data are presented and discussed in *chapter III* where, they are divided into four main parts. In the first part the electrochemical behavior of Mg, Mg-Al and Mg-Zn alloys in naturally aerated stagnant aqueous sulfate solutions covering the acidic, neutral and basic media were described. The obtained results show that in acidic sulfate solutions of pH=3, a continuous corrosion is taking place until the steady state is reached. In neutral sulfate solutions, a passive film develops on the metal surface. In basic sulfate solutions at pH=12 a corrosion/passivation process occurs. The electrochemical impedance data were analyzed using an equivalent circuit model. The results of the DC measurements are consistent with those of the EIS, investigations.

The second part presents the electrochemical behavior of Mg-Al-Zn and Mg-Al-Zn-Mn alloys in naturally aerated stagnant aqueous sulfate solutions of different pH. It is aimed at the study of the effect of alloying elements Zn and Zn plus Mn. The results show that the presence of Zn and Mn together has improved the electrochemical properties of Mg-Al alloys. The results show also that in acidic sulfate solutions of pH=3, a continuous corrosion is taking place. The calculated values of the corrosion current density, $i_{corr}$, of the Mg-Al-Zn-Mn alloy show higher current density in acidic solution that is more than 6 times that measured in neutral solutions and much more than 75 times that obtained for the basic solutions. The investigated alloys have lowest corrosion rate in basic solution due to formation of a barrier layer of $Mg(OH)_2$ which is insoluble in basic solutions and partially soluble in neutral media. The impedance data were fitted to theoretical data according to the proposed equivalent circuit model which describes the electrode/electrolyte interface.

The third part directed towards the investigation of the corrosion inhibition process in acidic sulphate solutions. In this respect different urea derivatives (such as urea, thiourea, semicarbazide and thiosemicarbazide) and some water soluble polymers (such as polyacrylamide and polyvinylpyrollidone) were used as environmentally safe inhibitors. This part is subdivided into two sections.

In the first section, the effect of different urea derivatives on the inhibition of corrosion of Mg-Al, Mg-Al-Zn and Mg-Al-Zn-Mn alloys were investigated. Thiosemicarbazide was found to be the best of the investigated urea derivatives as corrosion inhibitor for all alloys in acidic sulphate solutions. The inhibition efficiency has its maximum value of 81.6% in 10 mM of thiosemicarbazide for Mg-Al-Zn-Mn. The corrosion inhibition process is based on the adsorption of the inhibitor molecule on the alloy surface. The calculated values for the adsorption of urea and its derivatives on the surface of Mg-Al, Mg-Al-Zn and Mg-Al-Zn-Mn alloys reveals a physical adsorption of the inhibitor on the alloy surface. The resistance and the relative thickness of the adsorbed layer were also investigated.

In the second section, the effect of some water soluble polymers on corrosion inhibition of Mg-Al, Mg-Al-Zn and Mg-Al-Zn-Mn alloys in acidic sulphate solutions was investigated. A critical concentration of polyvinylpyrollidone of 0.2 mM was found to suitable for the corrosion inhibition process. An efficiency of more than 96% was obtained. The activation energy of the corrosion process occurring at the surface of Mg or Mg-alloys in aqueous solutions is less than 40 kJ $mol^{-1}$ indicating diffusion controlled one electron transfer electrode process. Finally, the calculated value for adsorption process was found to obey the Langmuir adsorption process and the calculated values for the adsorption found to be less than -40 kJ/mol, which indicates physical adsorption and there is no chemical interaction between the inhibitor molecules and the electrode surface.

The fourth part presents the quantum chemical calculations which used to study the effect of the molecular structure of the investigated inhibitors on their inhibition efficiency. From this study we find a correlation between the experimental results obtained from (Tafel polarization and electrochemical impedance spectroscopy, EIS techniques) and the theoretical calculations.