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Technical Report

Developing an empirical relationship to predict the corrosion rate of friction stir welded AZ61A magnesium alloy under salt fog environment

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ABSTRACT

Magnesium (Mg) alloys shows the lowest density among other engineering metallic materials. As a consequence, this light alloy has a promising future. However, these alloys have great affinity for oxygen and other chemical oxidizing agents. The limitation of low corrosion resistance restricts their practical applications. Extruded Mg alloy plates of 6 mm thick of AZ61A grade were butt welded using friction stir welding (FSW) process. Corrosion behavior of the welds was evaluated by conducting salt fog test in NaCl solution at different chloride ion concentrations, pH value and spraying time. Also an attempt was made to develop an empirical relationship to predict the corrosion rate of friction stir welded AZ61A magnesium alloy. Three factors and a central composite design were used to minimize the number of experimental conditions. Response surface method was used to develop their relationship. The developed relationship can be effectively used to predict the corrosion rate of friction stir weld AZ61A magnesium alloy at 95% confidence level.

1. Introduction

Magnesium (Mg) alloys are one of those light weight metallic alloys currently being investigated, because of its low density (1.74 g/cm^3) and high mechanical stiffness [1]. The mechanical benefits of magnesium, however, are contrasted by a high corrosion rate as compared to aluminum or steel. Because of magnesium's electrochemical potential, as illustrated in the galvanic series, it corrodes easily in the presence of sea water. The high corrosion property of magnesium has relegated the alloy to use in areas unexposed to the atmosphere, including car seat and electronic boxes. The demand for the use of magnesium alloys as structural materials in automobile industry, electronic products, vibrating plates of vibrating test machines, automotive wheels, etc., have increased in recent years [2]. The use of magnesium alloys in automotives reduces the total weight of the component up to 20% and at the same time this will substantially reduce the fuel consumption and the CO_2 emissions.

Conventional fusion welding of Mg alloys resulted in much solidification related problems such as porosity, hot cracking, alloy segregation and partial melting zone. Hence, the applications of Mg alloys in structural members were still limited. However, a recent innovation of friction stir welding (FSW) process eliminated the above said problems. FSW is a solid state, autogenously process and hence there was no melting and solidification. Though the mechanical properties and micro structural characteristics of FSW joints of Mg alloys are the topic of many researchers, the corrosion properties of these joints have not yet been fully explored.

In a buffer chloride solution, the corrosion rate of magnesium and its alloys did not depend on their purity or the content of the major alloying, but solely on the pH of the solution [3]. A serious limitation for the potential use of several magnesium alloys is their susceptibility to corrosion. Magnesium alloys, especially those with high purity, have good resistance to atmospheric corrosion. However, the susceptibility to corrosion in chloride containing environments is a serious concern [4].

The thickness of the oxide film formed on the surface of the specimen is quite increased with the increase in pH. The corrosion rate of AZ91 is high in acidic solution as compared to that in neutral and highly alkaline solutions. In extruded magnesium alloy the pitting corrosion is more at lower pH [5]. Alloying magnesium with aluminum in general improves the corrosion resistance [6].

In the initial stages of the corrosion attack, the cathodic reactions could involve both reductions of oxygen and water. The oxygen reduction occurred preferentially in the periphery of the electrolyte droplets on the surface, which led to alkaline conditions and an increase in CO_2 deposition in these areas. After a long exposure time, a thickened layer of corrosion products were

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