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Modeling and analyzing the effects of heat treatment on the characteristics of magnesium alloy joint welded by the tungsten-arc inert gas welding

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ABSTRACT

The objective of this paper is to present the mathematical models for modeling and analysis of the effects of heat treatment on the characteristics of magnesium alloy joint welded by the tungsten-arc inert gas (TIG) welding. The process of heat treatment adopts the tempering process with varying processing parameters, including tempering temperature and tempering time. The microstructure and mechanical properties of the welded joint are considered in the characteristic evaluation and explored by experiment. An experimental plan of the face-centered central composite design (CCD) based on the response surface methodology (RSM) has been employed to carry out the experimental study. The results of analysis of variance (ANOVA) and comparisons of experimental data show that the mathematical models of the value of the maximum tensile strength and elongation are fairly well fitted with the experimental values with a 95% confidence interval. In the tempering process, the microstructure of welded joint in the weld bead displays two main microstructures of hcp-α-phase Mg and bcc-β-phase $Mg_{17}Al_{12}$. Results show that the average size and proportion of α-phase Mg grains decreases with the increase of the tempering time and temperature. But, the increase of the tempering time and temperature promote increasing the average size and proportion of β-phase $Mg_{17}Al_{12}$ grains. An increase in both the high value of tempering temperature and tempering time leads to an increase of the maximum tensile strength. The values of the elongation increase with increasing in both the value of tempering temperature and tempering time.

1. Introduction

Magnesium alloys have gradually used for lightweight structural and functional parts in the bike, automotive and electronic industries because of their high specific strength, light specific weight, excellent damping capacity, recyclability, and ability to shield electromagnetic shocks [1]. Magnesium alloys have the potential to replace aluminum alloy and steel in many structural applications since it is 35% and 77% less dense than aluminum alloy and steel, respectively [2–5]. However, the lightweight structural and functional parts of magnesium alloys may be joined using mechanical fasteners as well as a variety of welding methods including tungsten-arc inert gas (TIG), metal-arc inert gas (MIG), plasma arc, electron, laser friction, adhesive, explosion, stud, ultrasonic and resistance spot welding [6]. The magnesium alloy joint welded by the welding process presents lots of relevant welding defects in practice. The process reveals low welding speeds, large heat affected zone (HAZ) and fusion zone (FZ), high solidification shrinkages, variations in microstructures and properties, evaporative loss of alloying elements, high residual welding stress, and distortion of welded joints. Sun et al. [7] studied the microstructures and mechanical properties of the resistance spot welded magnesium alloy joints. Wang et al. [8] investigated the effect of welding time on the microstructure and tensile shear load in resistance spot welded joints of AZ31 magnesium alloy. The effects of welding parameters on the characteristics of the welded joint proved the variations in microstructures to influence its mechanical properties. Furthermore the rapidly solidified process of molten materials in the FZ causes the residual welding stress in the weld bead, thus resulting in the degradation of mechanical properties of the welded joints [9–11].

For eliminating the residual stress induced by manufacture process, the tempering process is one of the well-known methods to relief stress. In alloys materials containing second phase constituents and non-uniform solute atom distributions, the microstructure becomes quite complicated with grains oriented with varying tempering processing parameters. Liu and Dong [12] made use of optical microscopy (OM) and scanning electron microscopy (SEM) to examine the microstructure and fracture of AZ31 magnesium alloy joint welded by the automatic gas tungsten-arc filler

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