Materials and Design 32 (2011) 3085–3091

Contents lists available at ScienceDirect

Materials and Design

journal homepage: www.elsevier.com/locate/matdes

Technical Report

Relationship between process parameters and mechanical properties of friction stir processed AA6063-T6 aluminum alloy

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ARTICLE INFO

Article history:
Received 23 August 2010
Accepted 22 December 2010
Available online 5 January 2011

ABSTRACT

In this investigation the surfaces of AA6063-T6 aluminum alloy were friction sir processed and the effects of process variables such as axial force, tool feed and rotational speed were studied. For certain combinations of the process variables, a maximum increase of 46.5% in the ultimate tensile strength, 133% in ductility and 33.4% in microhardness in relation to the parent material was observed. The microstructural observations revealed a defects constrained structure under an axial force of 10 kN. In addition, a mathematical model was developed to establish the relationship between the different process variables and their mechanical properties. The established model was validated through further experiments. The deviation between the developed model and experiments was within 9% for the process variables yield, tensile strengths and Vickers microhardness and for ductility, it was around 12%.

1. Introduction

AA6063 aluminum alloys are heat treatable with moderately high strength, excellent corrosion resistance and good extrudability. They are regularly used as architectural and structural members and also in automotive industries [1,2]. However, due to their low hardness and wear and abrasion resistance, the application of these materials to sliding parts is quite limited [2]. Improvement of the surface properties of the aluminum alloys can be done by a variety of processes like thermo-mechanical treatment (TMT), equal – channel angular processing (ECAP), high pressure torsion (HPT), accumulative roll bonding (ARB), etc., all of which can be used to produce a fine grain size, are complex and time consuming, e.g., during TMT a solution treatment, over-aging, reducing the thickness of plates, etc. are involved [3], with a resultant reduction in the overall economy of the process. In addition, none of these processes are capable of producing localized surface modification. Friction stir processing (FSP) is an emerging surface engineering technology based on the principles of friction stir welding (FSW), a solid state joining process invented at The Welding Institute (TWI), UK in 1991. FSP locally refines microstructures and also eliminates inherent defects in the starting material and thereby improves its strength, ductility, corrosion resistance, fatigue resistance, formability, and a host of other properties.

Friction stir processing has been successfully applied to various aluminum alloys in improving their mechanical properties [4–7]. Moreover the refined microstructure resulting from FSP has been utilized in attaining superplasticity [8,9]. However studies on establishing the relationship between the various process variables and the mechanical properties are few in number.

Regression analysis is widely used for prediction and forecasting, where its use has substantial overlap with the field of machine learning. Regression analysis is also used to understand which among the independent variables are related to the dependent variable and to explore the forms of these relationships [10]. In restricted circumstances, regression analysis can be used to infer causal relationships between the independent and dependent variables. Mathematical models developed using regression analyses have been successfully applied for various friction stir processed/welded aluminum alloys [11,12]. In this investigation, the effects of process variables during friction stir processing of AA6063-T6 alloys were studied. In addition a mathematical model was developed to establish the relationship between the different process variables and their mechanical properties. The established model was validated for further experiments.

2. Experimental

An alloy of composition (in wt.%): Cu – 0.01, Mg – 0.5, Si – 0.43, Fe – 0.2, Mn – 0.006, Ni – 0.005, Zn – 0.005, Ti – 0.014, Pb – Nil, Sn – 0.01, Al – Rest, in T6 temper condition was used as the starting material for friction stir processing.

Friction stir processing was carried out in a special purpose friction stir welding machine with the specifications as follows: maximum power – 30 hp, maximum axial force – 25 kN and a maximum spindle speed – 3000 rpm. The workpiece was firmly

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doi:10.1016/j.matdes.2010.12.049