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Development of Acoustic Emission and Motor Current Based Fuzzy Logic Model for Monitoring Weld Strength and Nugget Hardness of FSW Joints

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Abstract

Friction stir welding (FSW) is a solid-state welding process that is ideally suitable for joining materials with low melting point, such as aluminium alloys. In this paper, development of a fuzzy logic model to monitor weld strength and nugget hardness of friction stir butt-welded AA6063-T6 aluminium alloy plates is presented. FSW experiments were carried out with different process parameters in vertical spindle milling machine. The generated acoustic emission (AE) and machine spindle motor current during the FSW process were acquired with the aid of data acquisition system. A fuzzy logic model based on AE signal and motor current was developed to predict the weld strength and nugget hardness. The fuzzy model accuracy was validated with experimental data. The proposed model could be used for online weld monitoring of FSW process within a range of process parameters.

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Keywords: Friction Stir Welding; Acoustic Emission; Motor Current; Fuzzy Logic.

1. Introduction

Friction Stir Welding (FSW) a solid-state welding process that is suitable for joining light materials such as aluminium and magnesium alloys. This paper presents the development and validation of fuzzy logic model to monitor the weld strength and nugget hardness of friction stir butt-welded AA6063-T6 plates, which are widely used

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to produce components in ship building, aerospace, automobile and furniture manufacturing industries. The weld tensile strength and nugget hardness are important parameters in deciding the quality of the welded joint. Since the FSW process is carried out in machine tools, monitoring of FSW process is quite complex due to non-linearity in process parameter interactions, machine tools and drives dynamics. Hence, it requires advanced sensor and soft computing techniques, such as fuzzy logic to develop monitoring systems.

Acoustic emission technique is one of the advanced evaluation tools, which has the potential application for real time monitoring of machining process. Acoustic emission is the phenomenon by which transient elastic waves are generated by rapid release of energy from localized sources within a deforming material. Acoustic emission monitoring technique has been used extensively to study various deformation and welding processes in different materials [1, 2]. AE technique is found to be a feasible approach for detecting tool profile, material flow pattern, microstructures and mechanical properties in FSW process [3]. FSW process generally produces signals that represent burst acoustic emissions, which characterizes the unsteady processes [4]. The studies revealed the frequency range considered for the friction stir welding process is between 100 kHz and 300 kHz.

As compared to AE techniques, the application of motor current measurement technique is a cost effective method for process control and machining operations. This method of non-invasive measurement increases the potential for industrial applications. In electrical monitoring methods, the stator current of an induction motor is used to monitor various kinds of machine tool and process defects. The method of spindle motor current and voltage measurements were employed for online estimation of tool wear monitoring in milling operations [5].

In order to develop an intelligent monitoring system for FSW process, the data processing is essential. Soft computing techniques are necessary for processing these data. Fuzzy logic technology is one of the artificial intelligent strategies, which is widely used because of its practical impact on dynamic process control. Fuzzy modelling was used to analyse the emitted electromagnetic radiation fundamental frequencies during the tensile failure of the FSW welds produced at different process parameters [6]. Zhang et al [7] have developed a systematic data-driven fuzzy modelling approach to model FSW behaviour relating to AA5083 aluminium alloy with micro structural features, mechanical properties and overall weld quality. It is found that the fuzzy logic approach is widely adopted for monitoring the FSW process. It is observed from the literature that the technique of weld strength and nugget hardness monitoring through acoustic emission and motor current is not yet reported. This paper presents the application of acoustic emission and motor current measurement techniques for monitoring weld tensile strength and hardness during friction stir welding of AA6063-T6 aluminium alloy plates.

2. Experimental setup

In the present work, FSW experimental setup was developed in a conventional vertical milling machine with a vertical spindle attachment to accommodate FSW tools. Automatic feed system in the milling machine is used to control the traverse speed of the work table. Since the FSW involves large forces, fixture with proper clamps was indigenously designed to prevent slipping of specimens during FSW process. Data acquisition systems (DAQ) with suitable instrumentation were integrated for acquiring the AE and motor current to monitor the process. Fig. 1 shows the AE sensor mounted on FSW fixture to measure the AE signal features during the process. R80D AE sensor from Physical Acoustic Corporation was used with a data acquisition system to acquire the AE signals during the process. AEWin® software was used to analyse the acquired AE signals. Fig. 2 represents the arragement for Hall Effect non-contact current sensor to measure the line current of main spindle motor using PCI based data acquisition sytem from National Instruments. Labview software is used to acquire and analyse the signal acquired fron the current sensor.