Modeling of Friction Stir Welding of AL7075 Using Neural Networks

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ABSTRACT

Friction stir welding (FSW) is a solid state welding process, which is used for the welding of aluminum alloys. It is important to note that the mechanical properties of the FSW process depend on various process parameters, such as spindle speed, feed rate and shoulder depth. Two different tool materials, such as High speed steel (HSS) and H13 are considered for the welding of Al 7075. The present paper deals with the modeling of FSW process using neural networks. A three layered feed forward neural network (NN) has been used to model the FSW of aluminum alloys. It is important to note that the connection weights and bias values of the NN are optimized with the help of a binary coded genetic algorithm (GA). The training of the NN with the help of GA is a time consuming process. Hence, offline training has been provided to optimize the connection weights and bias values of the neural network. Once, the training is over, the GA trained neural network will be used for online prediction of the mechanical properties of FSW process at different operating conditions.

Keywords: Feed Rate, Friction Stir Welding, Genetic Algorithm, Neural Networks, Spindle Speed

INTRODUCTION

The friction stir welding was invented by The Welding Institute, UK in 1991 (Thomas et al., 1991). It is a solid state welding and was initially utilized for joining of aluminum alloys (Ozarpa et al., 2005). In FSW, a rotating shouldered tool plunges into the butt plates and locally plasticizes the joint region during its movement along the joint line. In this process, heat is originally derived from the friction between the welding tool (including the shoulder and the probe) and the material to be welded. The heat generated causes the material to soften at a temperature less than its melting point temperature and joining of the plates take place. Friction stir welding can be used for joining of many types of materials and metals, if suitable tool materials and their designs for the work pieces are identified. In FSW process, the tool axis is typically tilted by a few degrees (2° or 3°) from the vertical in order to facilitate consolidation of the weld. The process has been used for manufacture of butt welds, overlap welds, T-sections and corner welds. It is to be noted that for each of these geometries, specific tool designs are required.

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Moreover, the microstructural changes in friction stir welding were studied by Nelson et al. (2003). The authors observed a pancake microstructure with unrecrystallized regions consisting of rod-like or bar-like shaped sub regions in the parent material. Ericson and Sandstorm (2003) concluded that the fatigue strength of FS welded Al-Mg-Si alloy 6082 was higher than that of MIG-plus and TIG welds of the same material, to the narrower geometry of the joints.

In FSW heat is generated by a combination of friction and plastic dissipation during plastic deformation of the metal. Early experimental studies showed that the majority of the heat generation occurs at the shoulder/work piece interface (Tang et al., 1998). A thermal model (Song & Kovacevic, 2003) for FSW was developed utilizing multiphysics finite element package. For modeling this problem, a fixed tool approach was employed by moving the work piece towards the tool. The tool tilt angle was assumed to be zero. It was observed that the aluminum alloy had temperature dependent yield strength. In Elangovan and Balasubramanian (2007), the authors studied the influence of pin profile and rotational speed of the tool of FSW welding on AA2219 aluminum alloys. Five different tool pin profiles, such as straight cylindrical, tapered cylindrical, threaded cylindrical, triangular and square were used to fabricate the joints. It was observed that square tool pin produces mechanically sound and defect free welds compared to other tool pin profiles.

Later on, statistical regression analysis models based on design of experiments (Montgomery, 2001) were developed to study the influence of various process parameters on the quality of the FSW joint. Full-factorial design of experiments was used by Jayaraman et al. (2009) to analyze the effect of rotational and traverse speeds and axial tool force on the tensile strength of the FSW joint. Lakshiminarayanan et al. (2008) utilized the Taguchi method to optimize the FSW process parameters using a tensile test specimen. Moreover, a complete review of Taguchi optimization of process parameters in friction stir welding was explained in Nourani, Milani, and Nannacopoulos (2011). It is important to note that response surface methodology was also used to model the fusion welding process (Gunaraj & Murugan, 1999), and allows the development of an empirical methodology. Moreover, genetic algorithm (Nandan et al., 2007; Tutum & Hattel, 2010) was used for the optimization of the process parameters after utilizing the regression equations obtained from the statistical modeling methods.

Instead of developing analytical or empirical models, recently, some researchers had used soft computing (Pratihar, 2008) based approaches (that is, neural networks, fuzzy logic, genetic algorithm, and their different combinations) to model the welding process. Okuyucu et al. (2007) presented the possibility of the use of neural networks for the calculation of the mechanical properties of friction stir welding, after incorporating the process parameters, such as rotational speed and welding speed. A four layer neural network model was developed by Yousif et al. (2008) to predict the characteristics of friction stir welding. Weld speed and tool rotation speed were considered as inputs and tensile strength, yield strength and elongation were treated as outputs. Simulated annealing-based optimization strategy was used to train the neural network. In Lakshiminarayanan and Balasubramaniyan (2009), the authors compared the prediction capability of response surface methodology (RSM) and artificial neural networks (ANN) in predicting the tensile strength of the aluminum alloys. This model utilized the welding speed, rotational speed and axial force as inputs and tensile strength of the joint as output. Moreover, the architecture of the ANN can be tuned with the help of a genetic algorithm (Atharifar, 2010; Tansel et al., 2010) to optimize the process parameters in friction stir spot welding.

In the present paper, process modeling of FSW has been carried out with the help of a genetic algorithm trained neural networks. Two different tool materials, such as HSS and H13 are used for the friction stir welding of AL 7075 aluminum alloy. Three inputs,
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