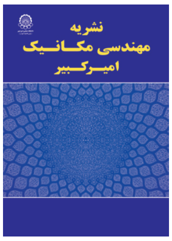

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Investigating the Shear Strength of Friction Stir Lap Welded 7075 Aluminum Alloy

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ABSTRACT: Creating melt joints in aluminum is an obstacle in introducing this metal into structures. This is due to the fact that fusion welding methods of aluminum leaves mechanical and metallurgical defects in the final produced parts. Friction stir welding is a non-melting replacement fabrication method, which creates welded joints from a semi-solid material state. In this paper, friction stir lap welding of 7075 aluminum alloy is studied both numerically and experimentally with the aim of investigating the shear strength of the welded joint. The shear strength which is calculated by the simulation is maximum 14 to 15 % lower to the acquired experimental results, which shows that the simulation process can appropriately be utilized to predict the shear strength of the welded joints for different cases. In addition, the results show that the maximum shear strength is equal to 165 Mpa which is obtained for a case in which the rotational speed is 1250 rpm, the linear speed is 50 mm/min and the tilt angle is set to 3˚.

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1- Introduction

During the fusion welding of aluminum alloys, the weld quality is strongly affected by defects such as porosity, slag inclusions, solidification cracks, undesirable chemical reactions, segregation of particles during solidification etc. [1-3]. To avoid these defects, friction stir welding (FSW) is introduced as a solid state joining process in which the base material does not melt during the process. This joining technique is energy efficient, environment friendly and versatile. The process mechanics is governed by the action of a specially designed rotating tool which is inserted into the adjoining edges of the sheets to be welded with a proper tilt angle, and then moved all along the joint. The process of conducting FSW in lap joint configuration is called friction stir lap welding (FSLW) [4].

According to previous studies, finite element method is successfully used to simulate the FSW. On the other hand, the FSW process consists of several highly coupled and non-linear physical phenomena such as large plastic deformation, material flow transportation, mechanical stirring of the tool, tool- work piece surface interaction, dynamic structural evolution, heat generation from friction and plastic deformation. In addition, in this process the thermal and mechanical behaviors of the tool and the workpiece are mutually dependent and coupled together [5]. These phenomena turn the simulation of FSW into a tough task. There are two approaches to simulate this process; first, by means of analytical models which use a moving heat flux instead of the welding tool and second, by taking advantage of thermo-mechanical finite element modeling [6].

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The first studies in the modeling of friction stir welding were carried out by Song and Kovacevic [7] and Chao et al. [8]. In these researches, a numerical model, which takes the frictional forces and plastic deformation into account, has been utilized in order to extract the heat generation during the welding process.

Few papers have directly dealt with the modeling of the thermo-mechanical stresses in FSW. Dong et al. [9] have developed several models to separately deal with the heat transfer, material flow and plastic flow in FSW. Chen and Kovacevic [10] have presented a three-dimensional coupled thermo-mechanical model based on finite element analysis. They have used ANSYS software to investigate the thermal history of the friction stir welded zone in AA6061-T6. In their model, they have considered the heat source to be frictional while the work hardening of the base material is not included. A vital step in modeling FSW is to introduce the deformation and the shape of the pin (tool) into the simulations. Mandal et al. [11] have used ABAQUS finite element package to present a three-dimensional model to study the thermal phenomena of FSW in aluminum alloy 2024. In their model they have considered the effect of effect of the shape of the tool. Assidi et al. [12] have developed a numerical simulation based on the Euler-Lagrange analysis using Forge3 software.

Buffa et al. [6, 13, 14] and Sadeghi et al. [15] have presented thermodynamic modeling of friction stir welding process in DEFORM3D software; to calculate the residual stresses in the process. Their analysis has been based on explicit Lagrangian simulation of the process. This technique reduces the simulation time. In addition, the stirring process and the large deformation of the elements can be properly simulated in DEFORM3D.

In this paper, a three-dimensional model based on a finite element method (FEM) is proposed to study the thermal effect and evolution of the shear stresses in the friction stir welded joints of 7075 aluminum alloy. In the simulations the mechanical interaction of the tool are included into simulations and the stirring process in modeled in a way to correctly simulate the physical process. In order to do so, the FSW is simulated in DEFORM3D and the resulted thermal history is imported into ABAQUS to find the shear strength of the welded joint. The numerical results are verified by experimental results. After validation, the FE model is used to study the effect of the process parameters on the shear strength of the specimen.

2- Experimental Procedure

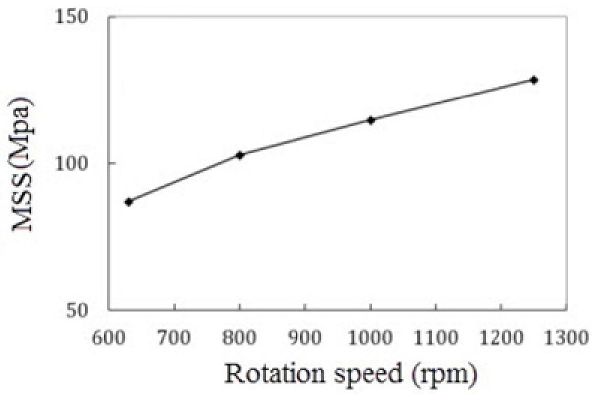
The 7075-O aluminum plate of 3mm thickness has been used in this study. The dimensions of workpiece were 150×80×3 mm^3. The tool was made of H13 having a shoulder of 16 mm diameter and a pin of 5.6 mm height. The thread pin had the large and small diameters of 6 mm and 4.8 mm, respectively. After the welding process, the welded specimens have been tested by an Instron-5502 tensile machine at a strain rate of 10^{-3} 1/s in order to find the effect of process parameters on the shear strength of the welded joints.

3- Finite Element Simulation

To model the FSW process, the commercial FE analysis software DEFORM3D™ has been used. After simulating the welding process, the temperature history of all nodes is exported to ABAQUS. In this software, the process is divided into three phases, welding stage, cooling stage and the shear tensile stage.

4- Results and Discussion

Fig. 1 shows the effect of rotation speed and linear transverse speed of the tool on the maximum shear strength (MSS) of the welded joint. As it can be seen in this figure, increasing the rotational speed and decreasing the linear speed of the tool, increase the MSS. This is due to the fact that increasing rotational speed and decreasing the transverse speed of the tool decrease the residual stresses which in turn increases the MSS of the weld.



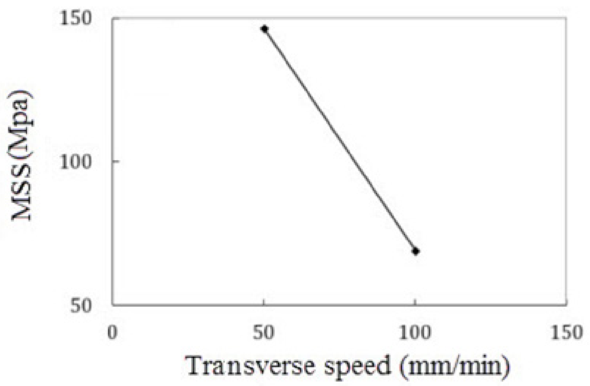


Figure 1. The effect of rotational and linear transverse speed of the tool on the maximum shear strength of the welded specimen

5- Conclusions

In this paper, friction stir welding of aluminum alloy 7075 is studied by means of both finite element analysis and experimental procedure. The results show that increasing rotational speed and decreasing the transverse speed of the tool, decrease the maximum shear strength of the welded specimen.

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