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Study on Fiber Laser Welding of AA6061-T6 Samples through Numerical Simulation and Experiments

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Abstract

A three-dimensional finite element model based on thermo-elastic-plastic model is applied to simulate the temperature and residual stress of aluminum alloy joint weld during fiber laser welding. Transient temperature, residual stress field, and joint distribution are studied, and the influence of laser power influence and welding speed is analyzed. A laser welding system can automatically preheat and weld in the seal cavity full of nitrogen. The laser welding system welds 2 mm thick 6061-T6 joints with processing parameters determined by simulation. The appearance of the weld bead of the joint is smooth and continuous. The welded joint specimens can be used for low-cycle tensile-tensile fatigue tests. The fracture of fatigue test is located in the HAZ of the welded joint. Result provides support for research and technology optimization of fiber laser welding.

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1. Introduction

Aluminum alloy has been used in aircraft fields given that it is light weight and has high strength and good corrosion resistance. Aluminum alloy has been used in the fields of auto parts to realize the lightweight of automobiles in recent years [1, 2]. The weld bead and HAZ of the weldments are the weakest parts of aluminum alloy because the material has a tendency to form intergranular cracks under residual tensile stress, and stress concentration caused by welding deformation easily forms the crack source [3, 4]. Therefore, adopting effective welding methods and optimizing the process parameters of aluminum alloy are necessary to improve weldment properties.

Fiber laser welding machine using fiber with the rotation of the mirror makes beam transmission easier compared with CO_2 welding. Fiber transmission ensures that the quality of the laser beam is close to the diffraction limit and

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has a theoretically minimum possible focus size compared with the high power Nd: YAG laser. Thus, the laser beam can have a small focus size and can achieve high power density [5].

However, the highly focused energy during the welding with fiber laser tends to cause excessively high-temperature gradients and stress gradients, which largely increase the risk of welding crack and decrease the welding quality and precision to a large extent. Numerical simulation method can be used to study the welding temperature field and stress field and predict the welding joint stress distribution. The method has been widely used in the areas of research and design of welding. The temperature fields of the laser welding process were simulated with FEA software, such as ANSYS, ABAQUS, and MSC.Marc et al. [6–8]. Studies [9, 10], simulations, and experiments have been conducted on aluminum alloy sheet laser welding and TIG welding. The characteristics of the residual stress distribution of the welding process were studied. The results show that welding quality is not controlled by just one single parameter but through a series of laser processing parameters, which is a complex process. The analysis of welding temperature field and stress field in laser welding can optimize welding processing parameters. The relative research is rare.

This paper uses the software Simufact.welding to simulate the 6061-T6 aluminum alloy sheet butt joint of fiber laser welding process, and the temperature field and residual stress field are obtained. The influence of laser power and welding speed on welding quality was studied. Welding experiments have been conducted in one special welding system, which can realize rapid and complete welding in a preheating sealed chamber that is filled with nitrogen. The experimental results verified the accuracy of the simulation.

Nomenclature

T	time nodes in the welding process
HAZ	heat-affected zone
FEA	finite element analysis

2. Thermal-mechanical coupling model of fiber laser welding

2.1. Geometric model

The establishment of three-dimensional solid models is the base of the entire coupling numerical simulation of the process of fiber laser welding. Simufact.welding does not have the function of three-dimensional modeling; thus, the entity model is completed in the three-dimensional software UG NX, as shown in Fig.1. The welded plate is 6061-T6 aluminum alloy, the specification is 220 mm × 40 mm×2 mm, and the fixture material is 45 steel.

2.2 Mesh division

The solid model is imported in HyperMesh software for meshing. Irregular shell element must be adjusted and optimized to ensure that the final division of the unit is a hexahedron. The model then needs to be tested about the continuity of the mesh. The weld bead and HAZ adopt a relatively dense grid and the regions far away from the weld bead, and HAZ uses a sparse grid. All parts are divided into a good grid and the BDF format output. 2D shell element must be deleted in the export conversion process. The mesh models of the welding specimen and fixture are imported in Simufact.welding software, as shown in Fig.2.

2.3 Heat source model

A laser heat source model with a constant heat source on the surface of a cylinder is used in the simulation [11]. The heat source model has the cylinder as the constant source. Surface heat distribution meets the mathematical model of Gaussian function in Simufact.welding definition. Welding mode laser welding can input laser energy. Welding speed and other related parameters are defined as heat energy input and distribution.