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Finite Element Simulation of the Trailing Heat Sink's Effect on Welding-Induced Distortion of Al 3105

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ABSTRACT: There are several ways to reduce the distortion caused by welding, one of which is to use a new method called a trailing heat sink. In this research, the effect of trailing heat sinks on the reduction of distortion caused by aluminum welding has been investigated. In this study, first, 2 mm thick wrought aluminum alloy 3105 was welded by tungsten-inert gas arc welding method without a trailing cooling source. In the next step, a cooling source of argon gas was installed and used to quickly cool the welding line. Then the heat transfer and thermal stresses caused by welding were simulated using the 3D finite element method with and without considering the effect of the applied cooling source. In the next step, the effects of the diameter and flow rate of cooling gas on temperature distribution and distortion caused by welding were analyzed. It was found that the use of a trailing cooling source creates tensile stresses, and tensile plastic strains and compensates for the compressive strains of the heated area. The trailing cooling source reduced the amount of distortion caused by welding by about 30% and increased the hardness in the heat-affected zone by 10%.

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1- Introduction

Aluminum is a light metal with a high strength-to-weight ratio. Exceptional ductility, good corrosion resistance in chemical environments, and good welding capability have made it suitable for use in aerospace and residential industries [1, 2]. The use of arc welding causes distortion and loss of hardness and local strength in aluminum parts. Therefore, it is important to predict and reduce the amount of distortion in the design stage. In recent years, a new method called welding with a trailing heat sink has been developed. In this method, a cooling source such as water, argon gas, or liquid nitrogen is used, and the welding site is cooled immediately after the connection, which reduces the distortion in the part [3-6]. This study explored the effects of using a trailing cooling source on welding distortion and its variables on welding distortion.

2- Methodology

Experiments were performed on 3105 aluminum alloy specimens. The reference specimens were prepared with a length of 250, a width of 40 mm, and a thickness of 2 mm. Before welding, they were cleaned with acetone and sandpaper. The process used was autogenous Tungsten Inert Gas (TIG) welding, and the specimens were welded in a single pass without beveling and using a designed fixture. The study employed a tungsten electrode with a diameter of 2.4 mm. Behind the welding heat source, a trailing cooling source of argon gas with a temperature of 10°C was used at a certain distance behind the arc. The information and variables used in the experiment are given in Table 1. Voltage, current, welding speed, and nozzle-to-sample distance were 40 volts, 70 amps, 6 mm/s, and 5 mm in all tests, respectively. Welding specimens were cut from the middle and perpendicular to the welding line, and after mounting and sanding, macro metallography was done to obtain the size of the weld pool. After measuring the weld pool width of the metallographic specimens, hardness was measured with a force of 50g and a load duration of 20s. Fig. 1 shows how the trailing heat sink was applied. Three-dimensional finite modeling was performed in two thermal and mechanical stages. Solid70 and Surf152 elements were used for heat transfer solution and Solid45 and Contac52 elements for mechanical analysis. Three heat transfer coefficients were used in the research. It was 1100 W/m^2. K for the part below the fixture, 30 W/m^2. K for the upper surface, 15 W/m^2. K for the lower surface of the part, which had less open airflow. The ambient temperature of the part was also considered to be 27°C.

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Table 1. Experimental variables used in the welding operation.

Welding sample	1	2	3	4
Effective diameter of cooling source (mm)	-	29	20	29
Volumetric flow rate (l/m)	-	12	12	8

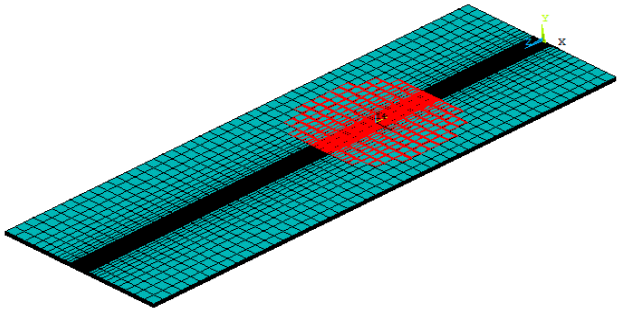

Fig. 1. The training heat sink applied

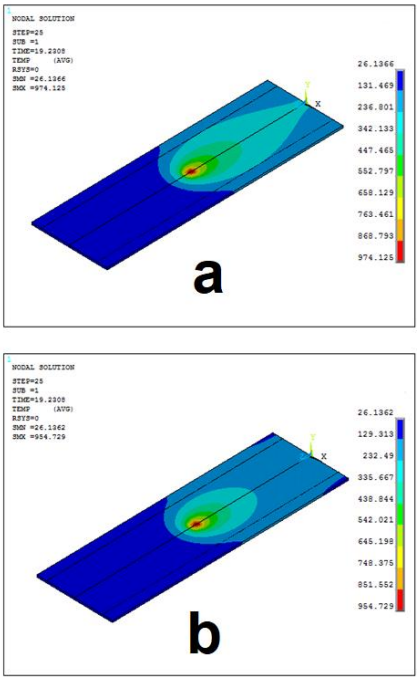

Fig. 2. Temperature distribution across the specimen (a) without and (b) with a trailing heat sink

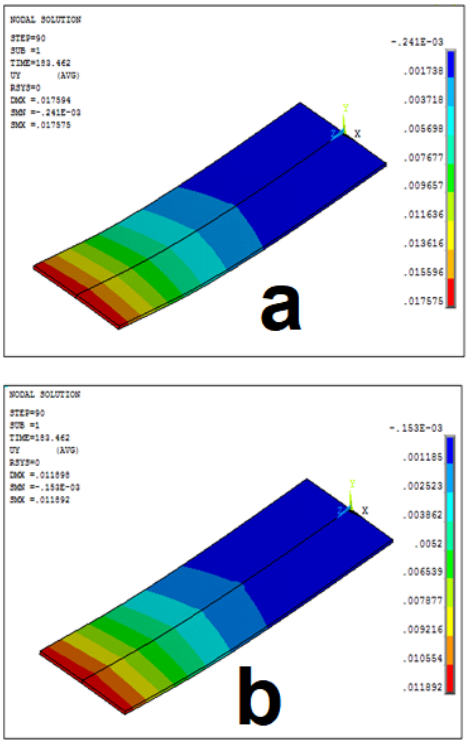

Fig. 3. Distortion of the specimen (a) without and (b) with a trailing heat sink

3- Results and Discussion

In this study, the width of the weld pool was used as a criterion for simulation validation. The results as depicted in Fig. 2 show that the application of a sequential cooling source reduced the temperature by 20°C so that 974°C in conventional welding was reduced to 954°C in welding with a cooling source. Fig. 3 shows the distortion created by the welding temperature gradient in the *y* direction of the part. The greatest distortion was in this direction, and the application of a cooling source behind the arc remarkably reduced distortion from 17.5 mm to 11.8 mm, which can be ascribed to the sudden and sharp drop in temperature. Due to the restraint applied in this regard, there was little distortion before the restraint was removed. But, as soon as the fixture was removed, plastic deformation began to form in this direction.

4- Conclusions

This study used the finite element method to estimate distortion due to welding of 3105 aluminum alloy with and without using a trailing heat sink. The results showed that the use of a cooling source of argon gas behind the moving arc reduced the maximum temperature and distortion.

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