Abstract

Friction stir welding (FSW) is a solid state welding utilized for welded similar and dissimilar aluminum alloys which are difficult weld by traditional fusion welding processes. The current study is concerned with the study of the solid-state welding of the aluminium alloy 6061-T6 with a thickness of 4 mm. The welding tool consists of a pin with 6 mm diameter and shoulder with 16 mm diameter.

The friction stir welding (FSW) was performed at different welding speeds (20, 32 and 45) mm/min as well as, a different rotational speeds (630, 1000, and 1600) rpm while the tool tilt angle was 2^{o} with the vertical axis.

The welding process was done on a traditional milling machine. The tensile test samples for were prepared by using a Water jet machine with 3 welding line angles (45^{o}, 60^{o}, 90^{o}) with an applied load for both rotational and welding speeds. The tensile test was done to calculate the maximum tensile strength for all cases. The best welding efficiency was (86.43%) for a single pass (in the tensile test, all the failure occurs in advance side, at 90^{o} orientation welding line the most failure occurs in heat affected zone (HAZ) while at 45^{o}, 60^{o} the most failure occurs in the region between the stir zone (SZ) and thermomechanical affected zone (TMAZ)).

In this study, the Taguchi method was used to find the optimum case for all tensile tests to reduce the time and cost required when performing all tests. ANOVA analysis was also used to find the percentage contribution ratio for each factor on the maximum tensile strength, proof strength and elongation.

The optimum case (single pass) that gives higher ultimate strength was observed when using the rotational speed of 1600 rpm and a welding speed of 20 mm/min in addition to the direction of the welding line of 90^{o} with applied load.

A double pass called the friction stir processing was used for the optimum case with the same direction of the welding speed and inverse direction of the rotation speed in a clockwise direction.

It was observed that there was a significant improvement in fatigue life when using a double pass. The endurance limit of the base metal at 10^{6} cycles was (118.63 MPa) and the single pass (optimum case) was (82 MPa) while for a double pass (107 MPa). The most failure in a single pass (optimum case) occurs in stir zone (SZ) while in using double pass, the most failure at the higher level of stress occurs in SZ but at a lower level of stress the failure occurs out the welding zone very near to the supported edge.

A numerical study was done using ANSYS workbench 18. The results showed that there is a good agreement between numerical data and experimental measurements with an error not exceeding 10 % only.

The hardness was similar to what was found in the previous research in the direction and distribution and was in the stir zone for a single pass (50.6 HV0.5), while the double passes was (79.9 HV0.5).

X-ray deflection was conducted to find the residual stresses. It was observed that there was a decrease in the tensile residual stresses when using the double pass. The single pass (optimal case) was (726 MPa) while the double pass was (294) MPa.