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Experimental Measurements of Load Distributions on Friction Stir Weld Pin Tools

BACKGROUND

Inherent to the FSW process are the significant loads exerted by the pin tool on the workpiece. Understanding these forces and their implications on the pin are essential to proper tool development.

Recent work has also shown that forces generated while welding are related to tool geometry. Some research has been done to measure the total lateral and thrust loads for several tool geometries while welding various aluminums. Other research has focused on characterizing forces by the tool pin independently of the shoulder. However, little work has been done to understand force distributions along an FSW pin tool.

OBJECTIVE

This study will investigate a method to experimentally measure the force distribution on a friction stir weld pin tool. By understanding the forces experienced by the tool pin and shoulder while welding, stresses can be analyzed and tool designs modified to minimize cracks and fractures and maximize tool longevity.

EXPERIMENT

Method

To determine the force distribution on the tool in the x-direction, a designed experiment was used. The experiment measured x-forces on a dynamometer while friction stir welding with varying tool geometries. For example, a number of welds were made at several tool lengths with a constant pin *diameter*. Welds were then processed at several pin diameters with a constant pin *length*. In all cases, shoulder diameter and concavity were held constant. A function of force per unit length on the pin was obtained.

Materials

Welds were processed on 6061-T6 aluminum-alloy plate, with tools made from heat treated H13 tool steel. For a pin diameter of 0.250 in., the pin length varied from 0.0711 to 0.280 in. For a pin length of 0.250 in., the diameter varied from 0.206 to 0.30 in. Figure 1 shows the tool pin geometries that were used.

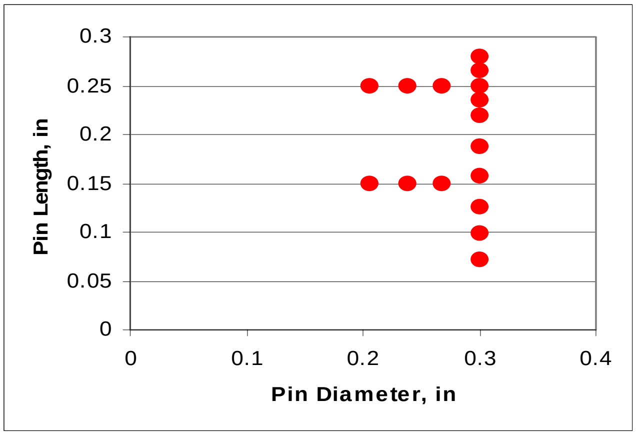

Figure 1 Tool pin sizes

In addition, the pins were a smooth cylinder, containing no flats, threads, tapers or other welding enhancement designs. The tool shoulder was kept constant at 1 inch in diameter and an 8° concave cavity.

Welding Procedure and Conditions

Welding parameters were primarily 650 rpm spindle speed, a feed rate of 8 inches per minute and a head tilt of 3 degrees.

The average force for each pin geometry was then found. Forces were then interpolated to obtain a function that provides a force value at all locations along the profile of the tool. Force distributions were then generated.

RESULTS SUMMARY

Figure 2 shows the x-forces obtained for the various pin lengths, with +/- one standard deviation of error. Force generally increased with pin length; however unexpected variation occurred at lengths of 0.25, 0.265 and 0.28. Therefore, two force curves were developed using the high and low data sets, therefore providing the highest and lowest possible force distribution. See Figure 4.

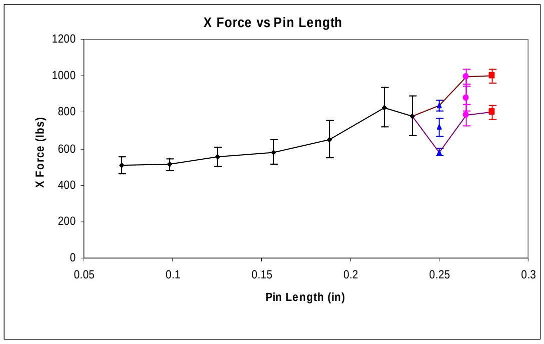

Figure 2 X-force as a function of pin length

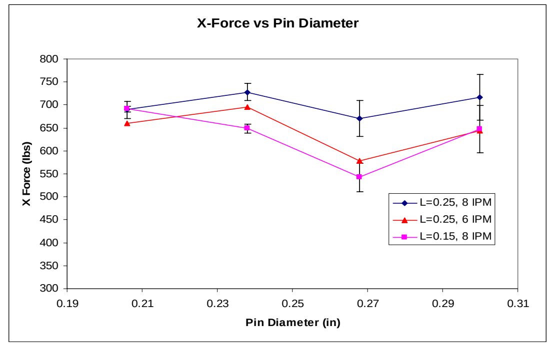

Figure 3 X-force as a function of pin diameter

The results of x-force as a function of pin diameter are shown in Figure 3. It was anticipated that the force would increase with pin diameter; however the results did not support this hypothesis. X-force did not prove to be a strong function of pin diameter, as the greatest variation in force between the smallest and largest diameter pin was less than 7%. Method of varying pin diameter does not appear to work well for estimating force distribution along diameter of pin.

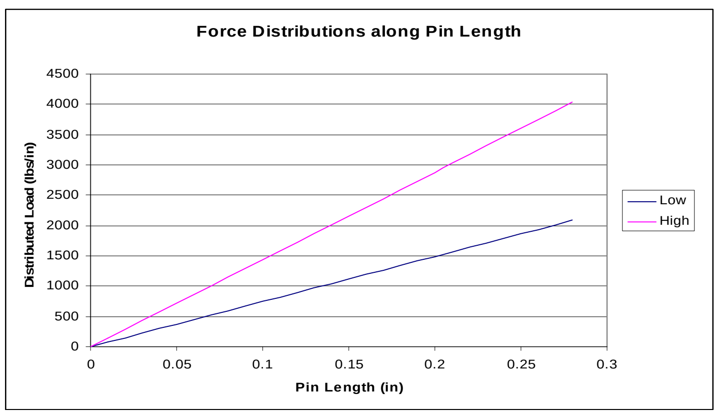

Figure 4 Force distributions along pin length