Determination of the Heat Input at the Tool/Workpiece Interface during Friction Stir Welding

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Objective

Determine the heat input magnitude and distribution along the tool/workpiece interface through a detailed analysis of FSW tools.

Background

Friction Stir Welding (FSW) is a solid-state joining process by which an interface-free union of two workpieces is formed. It has increased in popularity over the last decade and numerous researchers have attempted to model the process different ways. However, there has not been a study specifically dedicated to determining the heat input at the tool/workpiece interface. Using mathematical relations, heat conduction modeling of FSW tools, and actual experimental temperature measurements of FSW tools, an in-depth study of the heat input at the interface will be performed. It is felt that a greater understanding of the heat input at the interface, specifically its quantity and distribution, can thus be obtained.

Experimental Approach

In general, the approach will be to produce a numerical model of an FSW tool, apply a heat input along the tool/workpiece interface, and then analyze the temperature contours within the tool. FLUENT commercial software will be used to perform the numerical heat conduction analysis. Experiments will be run concurrently where thermocouples, mounted within the tool, will record temperatures during the weld. Tool temperatures are transmitted to the data acquisition system using and RF telemetry system. Infrared Imaging will also be used throughout the weld to determine the surface temperature of the tool (Figure 1). The numerical and experimental results will be compared and the heat input in the numerical model will then be adjusted until an agreement is reached, thus characterizing the heat input at the interface.

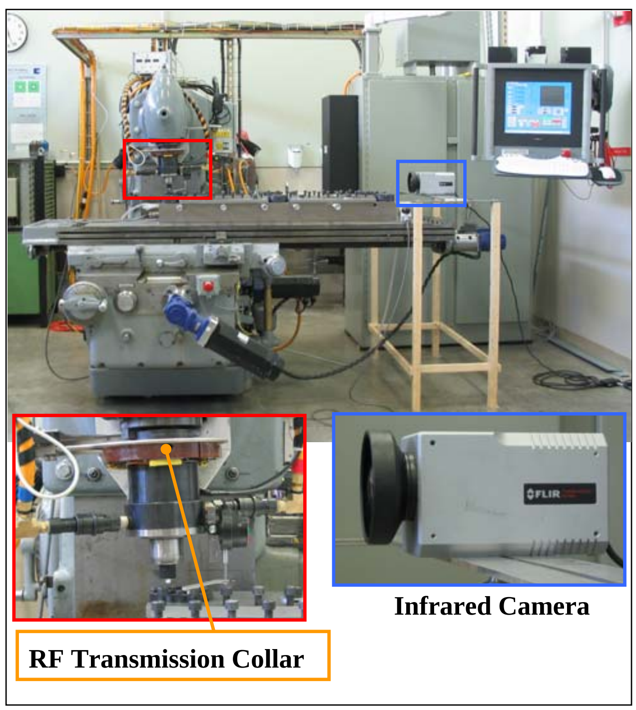

Figure 1—FSW facilities at BYU with temperature sensing equipment

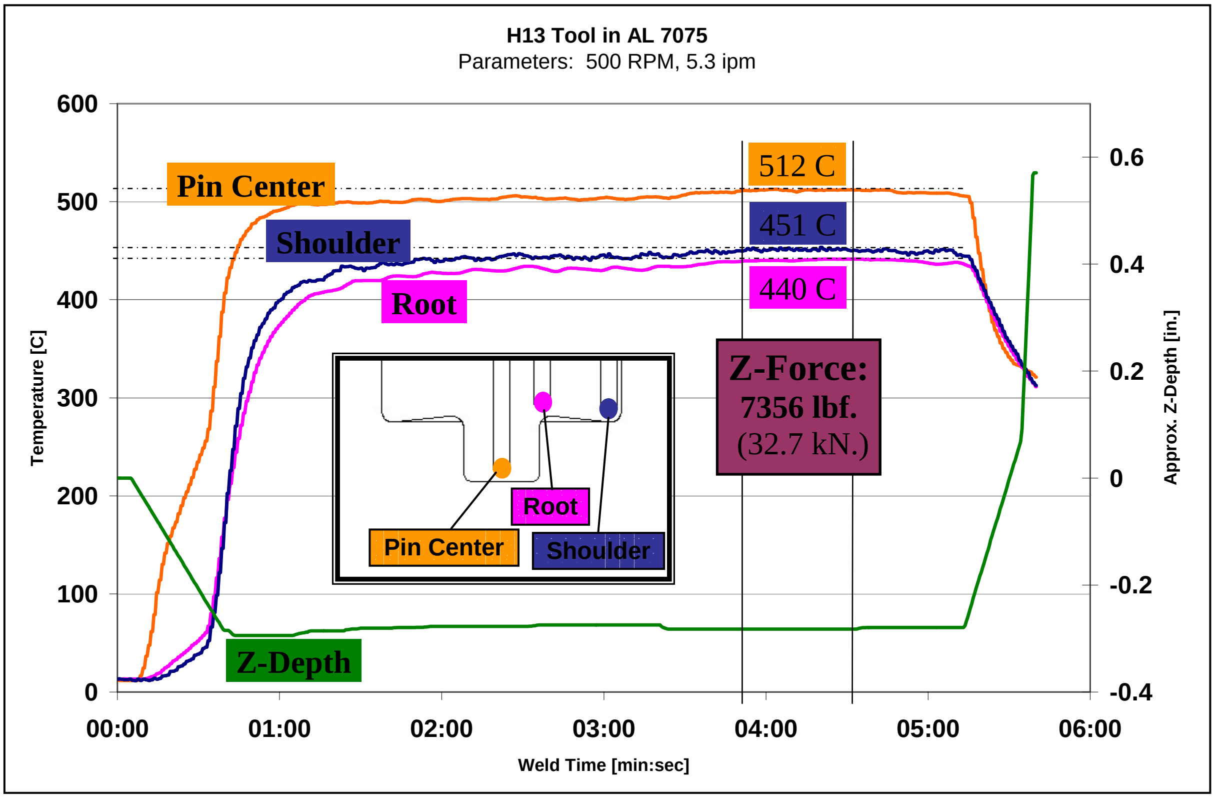

Figure 2—Plot of tool temperature and approximate tool depth versus time for a weld in 7075 Aluminum

Preliminary Results/Discussion

<u>Experimental</u>

A typical plot showing tool temperatures and tool depth throughout a weld is shown in Figure 2 above. The inset picture shows the locations of three thermocouples, each of which is within 0.050 in. (1.27 mm.) of the tool/workpiece interface. Tool temperature (left) and approximate tool depth (right) are plotted versus weld time. As can be seen in the plot, as the tool is plunges into the workpiece (decreasing tool depth) the tool temperatures raise over time and then level out, reaching a final plateau near the end of the weld. Average values for the temperatures and z-force were taken for this last plateau and are displayed on the plot. It can be noted that small fluctuations in tool depth affect tool temperature. It is interesting that the temperature at pin center is considerably higher than the temperatures at the other two locations. This result is consistent between welds. Current efforts are focusing on obtaining temperature data and analyzing the infrared images to confirm tool surface temperatures at a number of different weld parameters.

<u>Numerical</u>

Although much work is still to be done by way of numerical modeling, initial results show the method to be very promising. One numerical prediction, which correlates with the parameters used to obtain the plot shown in Figure 2, gave the following temperatures: **Pin Center: 521 C**; **Root: 457 C**; **Shoulder: 479 C**. It is interesting here that although the temperatures are higher than those shown in Figure 2, the trend showing the Pin Center as the hottest, followed by the Shoulder and then the Root as the coldest is exhibited in both the numerical and experimental results. Further work will need to be done to adjust the numerical heat input until the numerical and experimental results agree.