Gimballed Shoulders for Friction Stir Welding
Digging of edges of shoulders into workpieces would be reduced or eliminated.

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In a proposed improvement of tooling for friction stir welding, gimballed shoulders would supplant shoulders that, heretofore, have been fixedly aligned with pins. The proposal is especially relevant to self-reacting friction stir welding.

Some definitions of terms, recapitulated from related prior NASA Tech Briefs articles, are prerequisite to a meaningful description of the proposed improvement. In friction stir welding, one uses a tool that includes (1) a rotating shoulder on top (or front) of the workpiece and (2) a pin that rotatess with the shoulder and protrudes from the shoulder into the depth of the workpiece. In conventional friction stir welding, the main axial force exerted by the tool on the workpiece is reacted through a ridged backing anvil under (behind) the workpiece. When conventional friction stir welding is augmented with an auto-adjustable pin-tool (APT) capability, the depth of penetration of the pin into the workpiece is varied in real time by a position- or force-control system that extends or retracts the pin as needed to obtain the desired effect.

In self-reacting (also known as self-reacted) friction stir welding as practiced heretofore, there are two shoulders: one on top (or front) and one on the bottom (or back) of the workpiece. In this case, a threaded shaft protrudes from the tip of the pin to beyond the back surface of the workpiece. The back shoulder is held axially in place against tension by a nut on the threaded shaft. Both shoulders rotate with the pin and remain aligned coaxially with the pin. The main axial force exerted on the workpiece by the tool and front shoulder is reacted through the back shoulder and the threaded shaft into the friction-stir-welding machine head, so that a backing anvil is no longer needed. A key transmits torque between the bottom shoulder and the threaded shoulder. Since friction stir welding is commonly done with shoulders that are rotatable and protrude from the shoulder into the workpiece, a pin that rotates with the shoulder on top (or front) of the workpiece and tool that includes (1) a rotating shoulder on top (or front) of the workpiece and (2) a pin that rotates with the shoulder and protrudes from the shoulder into the workpiece are prerequisite to a meaningful description of the proposed improvement, which is especially relevant to self-reacting friction stir welding.

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shaft, so that the bottom shoulder rotates with the shaft. This concludes the prerequisite definitions of terms.

One consequence of the fixed alignment of the shoulders with the pin is that if the thickness of the workpiece or the slope of either surface of the workpiece varies as the tool moves along the workpiece, then the leading or trailing edge(s) of one or both shoulder(s) tend to dig into the workpiece, generating excessive flashing along the weld. The proposed improvement would be a simple, relatively inexpensive means of preventing or reducing such digging. The gimballeding of either or both shoulder(s) would enable the tool to better adapt to curvatures and other local variations in the slopes of workpiece surfaces, without need for a complex, expensive shoulder-angle control system.

The figure depicts a representative tool for self-reacting friction stir welding incorporating the proposed improvement. [In this case, the bottom shoulder (only) would be gimballed. Optionally, both shoulders or the top shoulder (only) could be gimballed.] The shaft would be terminated in a ball, from which indexing pins would protrude radially at angular intervals of 90° in a plane perpendicular to the pin/shaft axis. The indexing pins would define gimbal axes. The bottom shoulder would contain slots that would loosely engage the indexing pins. The configuration of the indexing pins and slots would be such that the bottom shoulder would be forced to rotate with the pin and shaft and the pins would hold the back (bottom) shoulder axially in place against tension, yet the looseness of the pin/slot engagement would allow limited rotation of the bottom shoulder about the gimbal axes to accommodate local variations in the slope of the lower surface of the workpiece.

This work was done by Robert Carter and Kirby Lawless of Marshall Space Flight Center. This invention is owned by NASA, and a patent application has been filed. For further information, contact Sammy Nabors, MSFC Commercialization Assistance Lead, at sammy.a.nabors@nasa.gov. Refer to MFS-32115-1.