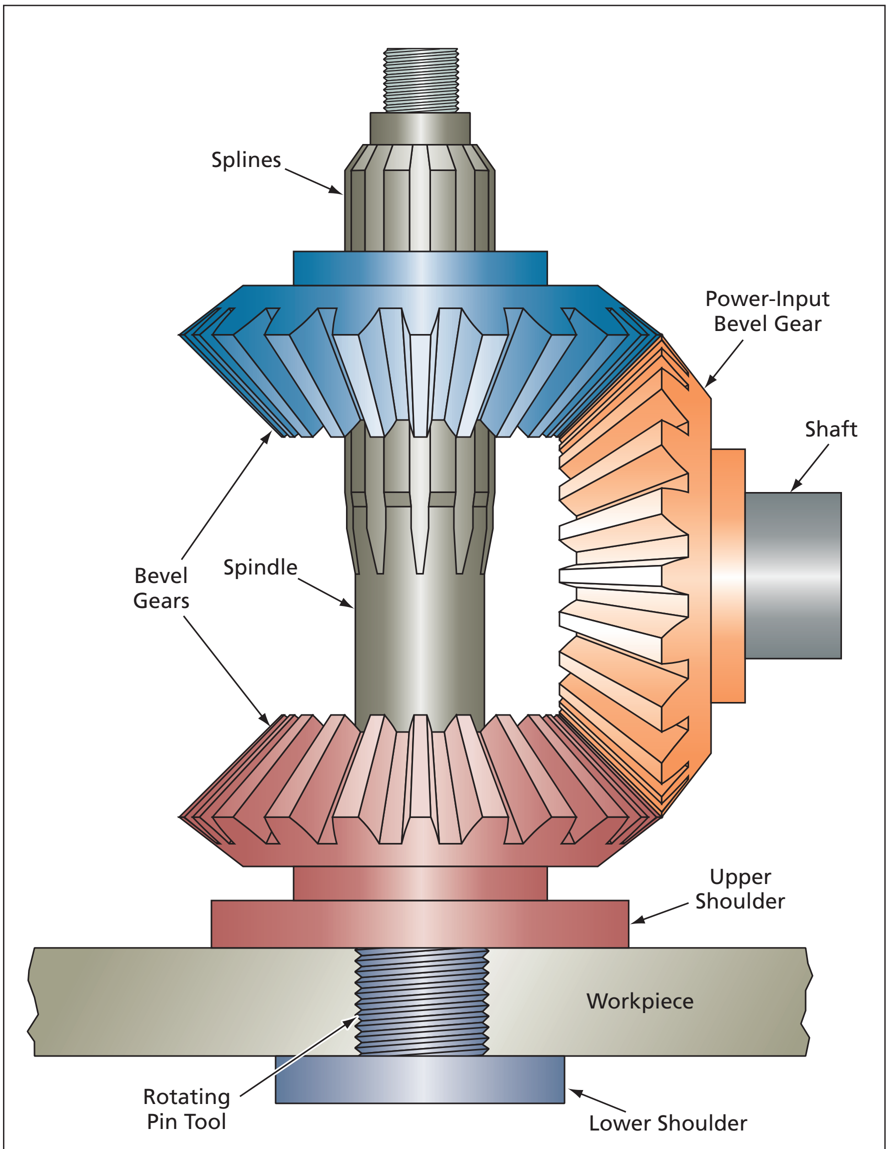
Counterrotating-Shoulder Mechanism for Friction Stir Welding

The weights and costs of fixtures for holding workpieces could be reduced.

Marshall Space Flight Center, Alabama

A counterrotating-shoulder mechanism has been proposed as an alternative to the mechanism and fixtures used in conventional friction stir welding. The mechanism would internally react most or all of the forces and torques exerted on the workpiece, making it unnecessary to react the forces and torques through massive external fixtures.

In conventional friction stir welding, a rotating pin tool is inserted into, and moved along, a weld seam. As the pin tool moves, it stirs together material from the opposite sides of the seam to form the weld. A large axial "plunge" force must be exerted upon the workpiece through and by the pin tool and a shoulder attached above the pin tool in order to maintain the pressure necessary for the process. The workpiece is secured on top of an anvil, which supports the workpiece against the axial plunge force and against the torque exerted by the pin tool and shoulder. The anvil and associated fixtures must be made heavy (and, therefore, are expensive) to keep the workpiece stationary. In addition, workpiece geometries must be limited to those that can be accommodated by the fixtures.



Counterrotating Shoulders would press on the workpiece in such a way that most of the large, localized applied welding torques and forces would be reacted within the mechanism rather than through external fixtures.

The predecessor of the proposed counterrotating-shoulder mechanism is a second-generation, "self-reacting" tool, resembling a bobbin, that makes it possible to dispense with the heavy anvil. This tool consists essentially of a rotating pin tool with opposing shoulders. Although the opposing shoulders maintain the necessary pressure without need to externally apply or react a large plunge force, the torque exerted on the workpiece remains unreacted in the absence of a substantial external fixture. Depending on the RPM and the thickness of the workpiece, the torque can be large.

The proposed mechanism (see figure) would include a spindle attached to a pin tool with a lower shoulder. The spindle would be coupled via splines to the upper one of three bevel gears in a differential drive. The middle bevel gear would be the power-input gear and would be coupled to the upper and lower bevel gears. The lower bevel gear would be attached to the upper shoulder and would slide and rotate freely over the spindle. The spindle would be fastened by its threaded upper end to an external submechanism that would exert axial tension on the spindle to load the workpiece in compression between the shoulders. By reducing or eliminating (relative to the use of a "self reacting" tool) the torque that must be reacted externally, the use of the proposed tool would reduce the tendency toward distortion or slippage of the workpiece.

To begin a weld, the spindle would be inserted through a hole in the workpiece or run-on tab at the beginning of the seam and fastened to the loading submechanism. Rotation and axial loading would be increased gradually from zero and, after a time to be determined by trial and error, translation along the weld seam would be increased gradually from zero to a steady weld speed. The weld would be ended by running the mechanism off the workpiece or, if the lower shoulder were detachable, by detaching the lower shoulder from the spindle and pulling the pin tool out.

This work was done by Arthur C. Nunes, Jr., of Marshall Space Flight Center. Further information is contained in a TSP (see page 1).

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-31648-1.

Strain Gauges Indicate Differential-CTE-Induced Failures

Failures are indicated by changes in slopes of strain versus temperature.

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A method of detecting mechanical failure induced by variation in temperature at an adhesive bond between two materials that have different coefficients of thermal expansion (CTEs) involves monitoring of strain-gauge readings. This method can be regarded as an exploitation of the prior observation that the readings of strain gauges commonly used in tensile and compressive testing of material specimens include features indicative of incremental failures in the specimens. In this method, one or more strain gauges are bonded to either or both of the two materials near the bond between the materials. (The adhesive used to bond the strain gauges would not ordinarily be the same as the one used to bond the two materials). Then strain-gauge readings are recorded as the temperature of the materials is varied through a range of interest. Any significant discontinuity in the slope of the resulting strain-versus-temperature curve(s) is taken to be a qualitative indication of a failure of the bond between the two materials and/or a failure within one of the materials in the vicinity of the bond.

The method has been demonstrated in experiments on specimens consisting of polyacrylonitrile-fiber/epoxy-matrix laminated composite plates bonded by epoxy to smaller plates made, variously, of aluminum, titanium, and a low-CTE nickel/iron alloy. In preparation for each experiment, strain gauges were bonded, by use of cryogenic-rated adhesives, to the composite plate near the corners of the metal plate (see Figure 1). In each experiment, strain-gauge and temperature readings were taken as the specimen was cooled from room temperature to 20 K. The specimens were then returned to room temperature and ultrasonically inspected for damage in the bond region.

No failure events were detectable in the strain-gauge readings from the composite/titanium and composite/low-thermal-expansion-alloy specimens, and ultrasonic inspection of these specimens revealed no damage. However, failure events were seen in the strain-gauge readings from the composite/aluminum specimens (see Figure 2), and ultrasonic inspection confirmed that there was damage in the bond regions of these specimens.

This work was done by Brian Harris of Goddard Space Flight Center. Further information is contained in a TSP (see page 1).
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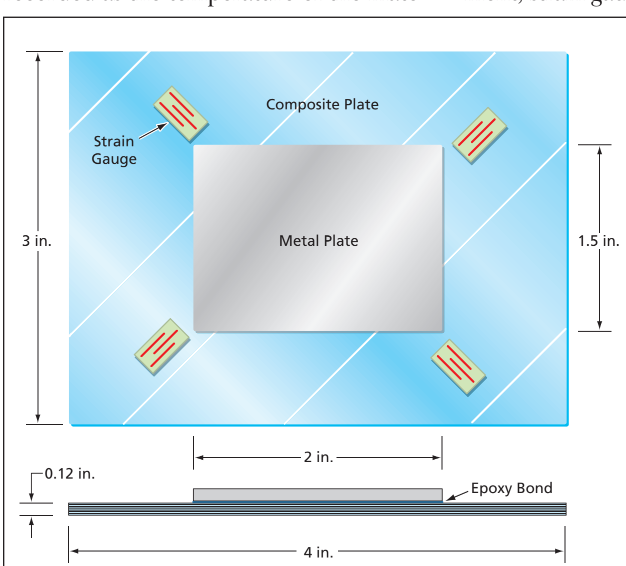

Figure 1. **Strain Gauges Were Bonded** to the composite plate near the corners of the metal plate because differential-thermal-expansion-induced stresses were expected to be large at these locations.

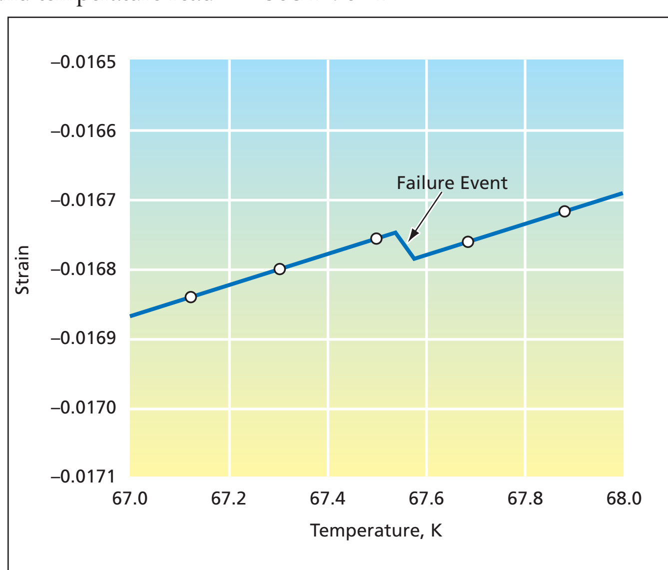

Figure 2. **Part of the Strain-Versus Temperature Curve** from one specimen includes a slope discontinuity indicative of a failure in the metal/composite bond region.