



### Ultrasonic Low-Friction Containment Plate for Thermal and Ultrasonic Stir Weld Processes

Marshall Space Flight Center, Alabama

The thermal stir welding (TSW) process is finding applications in fabrication of space vehicles. In this process, workpieces to be joined by TSW are drawn, by heavy forces, between “containment plates,” past the TSW tool that then causes joining of the separate plates. It is believed that the TSW process would be significantly improved by reducing the draw force, and that this could be achieved by reducing the friction forces between the workpieces and containment plates.

Based on use of high-power ultrasonics in metal forming processes, where friction reduction in drawing dies has

been achieved, it is believed that ultrasonic vibrations of the containment plates could achieve similar friction reduction in the TSW process. By applying ultrasonic vibrations to the containment plates in a longitudinal vibration mode, as well as by mounting and holding the containment plates in a specific manner such as to permit the plates to acoustically float, friction between the metal parts and the containment plates is greatly reduced, and so is the drawing force.

The concept was to bring in the ultrasonics from the sides of the plates, permitting the ultrasonic hardware to be

placed to the side, away from the equipment that contains the thermal stir welding and that applies clamping forces to the plates.

Tests demonstrated that one of the major objectives of applying ultrasonics to the thermal stir system, that of reducing draw force friction, should be achievable on a scaled-up system.

*This work was done by Karl Graff and Matt Short of the Edison Welding Institute for Marshall Space Flight Center. For more information, contact Sammy Nabors, MSFC Commercialization Assistance Lead, at sammy.a.nabors@nasa.gov. Refer to MFS-32900-1.*

### High-Powered, Ultrasonically Assisted Thermal Stir Welding

**This method has the potential to increase the longevity of hardware in the auto industry, especially in bearing wear.**

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This method is a solid-state weld process capable of joining metallic alloys without melting. The weld workpieces to be joined by thermal stir welding (TSW) are drawn, by heavy forces, between containment plates past the TSW stir tool that then causes joining of the weld workpiece.

TSW is similar to friction stir welding (FSW) in that material is heated into a plastic state (not melted) and stirred using a stir rod. The FSW pin tool is an integrated geometrical structure consisting of a large-diameter shoulder, and a smaller-diameter stir pin protruding from the shoulder. When the pin is plunged into a weld workpiece, the shoulder spins on the surface of the weld workpiece, thus inducing frictional heat into the part. The pin stirs the fraying surfaces of the weld joint, thus joining the weld workpiece into one structure. The shoulder and stir pin of the FSW pin tool must rotate together at a desired rotational speed. The induced frictional energy control and stir pin control of the

pin tool cannot be de-coupled. The two work as one integrated unit.

TSW, on the other hand, de-couples the heating and stirring of FSW, and allows for independent control of each process element. A uniquely designed induction coil heats the weld workpiece to a desired temperature, and once heated, the part moves into a stir rod whose RPM is also independently controlled. As the weld workpiece moves into the stir rod, the piece is positioned, or sandwiched, between upper and lower containment plates. The plate squeezes together, thus compressing the upper and lower surfaces of the weld workpiece. This compressive force, also called consolidation force, consolidates the plastic material within the weld nugget material as it is being stirred by the stir rod. The stir rod is positioned through the center of the top containment plate and protrudes midway through the opposite lower containment plate where it is mechanically captured. The upper and lower contain-

ment plates are separated by a distance equal to the thickness of the material being welded.

The TSW process can be significantly improved by reducing the draw forces. This can be achieved by reducing the friction forces between the weld workpieces and the containment plates. High-power ultrasonic (HPU) vibrations of the containment plates achieve friction reduction in the TSW process. Furthermore, integration of the HPU energy into the TSW stir rod can increase tool life of the stir rod, and can reduce shear forces to which the stir rod is subjected during the welding process.

TSW has been used to successfully join 0.500-in ( $\approx$ 13-mm) thick commercially pure (CP) titanium, titanium 6AL-4V, and titanium 6AL-4V ELI in weld joint lengths up to 9 ft ( $\approx$ 2.75-m) long. In addition, the TSW process was used to fabricate a sub-scale hexagonally shaped gun turret component for the U.S. Navy. The turret is comprised of six 0.5000-in ( $\approx$ 13-mm) thick angled welds. Each an-

gled weld joint was prepared by machining the mating surfaces to 120°. The angled weld joint was then fixtured using an upper and lower containment plate of the same geometry of the angled weld joint. The weld joint was then stirred by the stir rod as it and the upper and lower

containment plates traverse through the angled joint prep.

*This work was done by Robert (Jeff) Ding for Marshall Space Flight Center. For more information, contact Sammy Nabors, MSFC Commercialization Assistance Lead, at sammy.a.nabors@nasa.gov.*

*This invention is owned by NASA, and a patent application has been filed. Inquiries concerning nonexclusive or exclusive license for its commercial development should be addressed to the Patent Counsel, Marshall Space Flight Center. Refer to MFS-32895-1.*

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## Next-Generation MKIII Lightweight HUT/Hatch Assembly

**Applications for general aviation include the insulation around fuel tanks, especially wing-located tanks.**

*Lyndon B. Johnson Space Center, Houston, Texas*

The MK III (H-1) carbon-graphite/epoxy Hard Upper Torso (HUT)/Hatch assembly was designed, fabricated, and tested in the early 1990s. The spacesuit represented an 8.3 psi ( $\approx 58$  kPa) technology demonstrator model of a zero pre-breathe suit. The basic torso shell, brief, and hip areas of the suit were composed of a carbon-graphite/epoxy composite lay-up. In its current configuration, the suit weighs approximately 120 lb ( $\approx 54$  kg). However, since future planetary suits will be designed to operate at 0.26 bar ( $\approx 26$  kPa), it was felt that the suit's re-designed weight could be reduced to 79 lb ( $\approx 35$  kg) with the incorporation of lightweight structural materials.

Many robust, lightweight structures based on the technologies of advanced honeycomb materials, revolutionary new composite laminates, metal matrix composites, and recent breakthroughs

in fullerene fillers and nanotechnology lend themselves well to applications requiring materials that are both light and strong.

The major problem involves the reduction in weight of the HUT/Hatch assembly for use in lunar and/or planetary applications, while at the same time maintaining a robust structural design. The technical objective is to research, design, and develop manufacturing methods that support fabrication of a lightweight HUT/Hatch assembly using advanced material and geometric redesign as necessary. Additionally, the lightweight HUT/Hatch assembly will interface directly with current MK III hardware.

Using the new operating pressure and current MK III (H-1) interfaces as a starting block, it is planned to maximize HUT/Hatch assembly weight reduction

through material selection and geometric redesign. A hard upper torso shell structure with rear-entry closure and corresponding hatch will be fabricated. The lightweight HUT/Hatch assembly will retrofit and interface with existing MK III (H-1) hardware elements, providing NASA with immediate "plug-and-play" capability.

NASA crewmembers will have a lightweight, robust, life-support system that will minimize fatigue during extraterrestrial surface sojourns. Its unique feature is the utilization of a new and innovative family of materials used by the aerospace industry, which at the time of this reporting has not been used for the proposed application.

*This work was done by Mike McCarthy and Ralph Toscano of Air-Lock, Inc. for Johnson Space Center. Further information is contained in a TSP (see page 1). MSC-23941-1*