

# Ultrasonic Stir Welding Development for Ground-Based and In Situ Fabrication and Repair for In-Space Propulsion Systems/Commercial Space Sector

## Project Manager(s)/Lead(s)

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## Sponsoring Program(s)

Space Technology Mission Directorate  
Center Innovation Fund, Tech Excellence Program,  
Center Strategic Defense Steering Group

## Project Description

The completed Center Innovation Fund (CIF) project used the upgraded Ultrasonic Stir Weld (USW) Prototype System (built in 2013/2014) to begin characterizing the weld process using 2219 aluminum (fig. 1). This work is being done in Bldg. 4755 at NASA Marshall Space Flight Center (MSFC). The capabilities of the USW system provides the means to precisely control and document individual welding parameters. The current upgraded system has the following capabilities: (1) Ability to ‘pulse’ ultrasonic (US) energy on and off and adjust parameters real-time (travel speed, spindle rpm, US amplitude, X and Z axis positions, and plunge and pin axis force; (2) Means to measure draw force; (3) Ability to record US power versus time; (4) Increasing stiffness of Z axis drive and reduce head deflection using laser technology; (5) Adding linear encoder to better control tool penetration setting; (6) Ultrasonic energy integrated into stir rod and containment plate; (7) Maximum 600 rpm; (8) Maximum Z force 15,000 lb; (9) Real-time data acquisition and logging capabilities at a minimum frequency of 10 Hz; and (10) Two separate transducer power supplies operating at 4.5 kW power.



Figure 1: USW System at MSFC.

USW is NASA owned evidenced through the following U.S. Patents: No. 7,568,608, “Ultrasonic Stir Welding Process and Apparatus,” No. 8,393,520, “Pulsed Ultrasonic Stir Welding System,” and No. 8,393,523, “Pulsed Ultrasonic Stir Welding Method.”

Welding trials were conducted as part of the CIF project. Figure 2(a) shows the effect of US energy on plunge loads. Here, US energy was integrated into the stir rod (spindle) at amplitudes ranging from 60% to 90%. Data show 33% reduction in plunge force when the ultrasonic power was run at 90% amplitude. Figure 3(b) shows the effect of traverse force reduction when US amplitude begins at 90% during the first half of the weld and is reduced to zero during the second half of the weld.

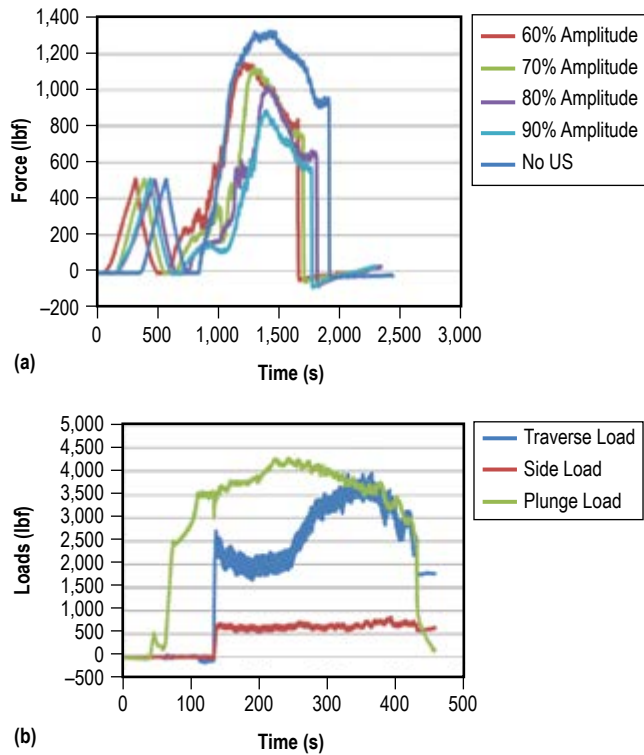


Figure 2: Data showing (a) reduced plunge forces and (b) decreased shear loads.

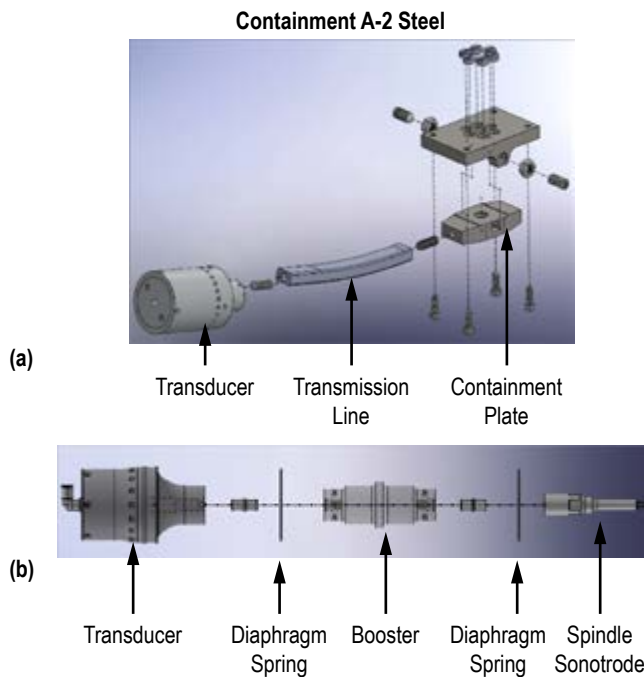


Figure 3: Ultrasonic assembly in (a) containment plate and (b) the spindle sonotrode.

### Anticipated Benefits

The results of the proposed effort are intended to produce experimental data showing the effects and benefits of high power ultrasonics technology relative to NASA interests. These can include improvements in the morphology of the weld zone; reduced welding forces, thus permitting existing machines to make larger welds or existing welds to be made with smaller machines; and faster production speeds. Increased tool life, especially when welding heat-resistant alloys, will be demonstrated. In addition, it is expected to realize higher weld mechanical properties as compared to the traditional friction stir weld properties.

### Potential Applications

All the expected benefits of ultrasonically assisted stir welding processes will have a profound impact on the NASA mission relative to ground-based and in situ welding and weld repair. Higher weld properties will provide greater margin of safety in as-welded weldments. Reduced forces will allow integration with inexpensive off-the-shelf robots allowing precision welds on both ground and in situ. Recognizing the safety of the in situ operator is paramount; ultrasonically assisted stir welding processes are solid state, meaning, there is no melting of weld material. There are no high energy beams or weld spatter that are found in the electron beam weld process.

### Notable Accomplishments

USW process characterization has commenced. In addition to the data presented in this paper, additional welding trials are being conducted using 2219 aluminum. The aluminum is being used first as it is one of the most used alloys in solid state weld development and is well within the welding engineering knowledge base.

### References

Procurement Specification No. 42004736672: "Upgrades to the Ultrasonic Stir Welding (USW) Prototype System Performance Work Statement PR 42004736672."