SYMPOSIUM ON BUILDING BLOCKS FOR FUTURE SPACE EXPLORATION AND DEVELOPMENT (D3)
Novel Concepts and Technologies for Enable Future Building Blocks in Space Exploration and Development (3)

Author: Dr. Tracie Prater
United Launch Alliance LLC (ULA), United States, tracie.j.prater@gmail.com

WELDING IN SPACE: A COMPARATIVE EVALUATION OF CANDIDATE WELDING TECHNOLOGIES AND LESSONS LEARNED FROM ON-ORBIT EXPERIMENTS

Abstract

An in-space welding capability is an essential supporting technology for the success of the long-duration, deep space missions being considered by government space agencies and commercial ventures. Welding offers several advantages over mechanical fasteners and adhesives: weight reduction, improved mechanical properties, reduced stress concentrations, and enhanced rigidity. This paper identifies current technologies used for aerospace welding and evaluates their suitability for in-space applications. The candidate welding processes considered are Gas Metal Arc Welding (GMAW), Plasma Arc Welding (PAW), Gas Tungsten Arc Welding (GTAW), Electron Beam Welding (EBW), brazing, and Friction Stir Welding (FSW). Each process is assessed based on the following criteria: safety, compatibility of the process with common materials and joint designs used in space structures, joint and surface preparation requirements, weight/portability of equipment needed to perform a weld, the degree to which certain environments (microgravity, vacuum, large thermal variations) can compromise the process's functionality, ability to reliably produce a hermetic seal, and operational modes (because of concerns about astronaut safety and spacesuit dexterity, some welding techniques may need to be teleoperated). Historically the Russians have the most experience with in-space welding, having demonstrated teleoperated EBW on-orbit as early as 1969. A manual electron beam tool, developed by the Paton Welding Institute (PWI) of the Ukraine, was tested on Salyut 7 in 1984. From 1985-1990, an EBW unit on MIR was used for a variety of experiments, including assembly of a truss structure for solar cells. US research into on-orbit welding is less broad, consisting of experiments on metal melting, brazing, and sphere forming using EBW conducted on SkyLab in the 1970s. NASA and PWI developed the In Space Welding Experiment, an EBW experiment to be conducted in the space shuttle's cargo bay, but this experiment was never flown. This paper will examine lessons learned from previous experiments spanning the course of four decades and propose a strategic path forward for in-space welding research. Since work in the area of space welding tapered in the 1990s, a new welding technology (friction stir welding) has emerged. FSW has proven to be highly compatible with aerospace alloys, is not dependent on gravity, and does not require shielding gas. While FSW is currently used in many aerospace applications, the high forces and large equipment it currently requires may render it unsuitable for in-space applications. This paper includes a general concept for a mobile friction stir welding unit for in-space structural repair/refurbishment.