Friction Pull Plug Welding in Aluminum Alloys

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Abstract:

NASA's Marshall Space Flight Center (MSFC) has recently invested much time and effort into the process development of Friction Pull Plug Welding (FPPW). FPPW, is a welding process similar to Friction Push Plug Welding in that, there is a small rotating part (plug) being spun and simultaneously pulled (forged) into a larger part. These two processes differ, in that push plug welding requires an internal reaction support, while pull plug welding reacts to the load externally. FPPW was originally conceived as a post proof repair technique for the Space Shuttle's External Tank. FPPW was easily selected as the primary weld process used to close out the termination hole on the Constellation Program's ARES I Upper Stage circumferential Self-Reacting Friction Stir Welds (SR-FSW). The versatility of FPPW allows it to also be used as a repair technique for both SR-FSW and Conventional Friction Stir Welds. To date, all MSFC led development has been concentrated on aluminum alloys (2195, 2219, and 2014). Much work has been done to fully understand and characterize the process's limitations. A heavy emphasis has been spent on plug design, to match the various weldland thicknesses and alloy combinations. This presentation will summarize these development efforts including weld parameter development, process control, parameter sensitivity studies, plug repair techniques, material properties including tensile, fracture and failure analysis.

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National Aeronautics and Space Administration

Marshall Space Flight Center • Materials and Processes Laboratory

Background

Friction Pull Plug Welding (FPPW), is a welding process similar to Friction Push Plug Welding in that there is a small rotating part (plug) being spun and simultaneously pulled (forged) into a larger part. These two processes differ in that push plug welding requires an internal reaction support while pull plug welding reacts to the load externally. FPPW was easily selected as the primary weld process used to close out the termination hole on Self-Reacting Friction Stir Welds (SR-FSW). The versatility of FPPW allows it to also be used as a post proof repair technique for both SR-FSW and Conventional Friction Stir Welds. To date, all MSFC led development has been concentrated on aluminum alloys. Much work has been done to fully understand and characterize the process's limitations. A heavy emphasis has been spent on plug design, to match the various weld thicknesses and alloy combinations.

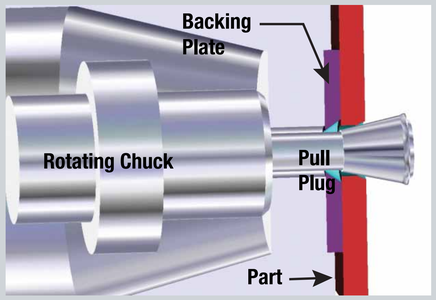
Friction Pull Plug Weld Tool

Capabilities

- Push or Pull
- High/Low Spindle Rotation
- High/Low Spindle Torque
- 5-Axis Manipulation

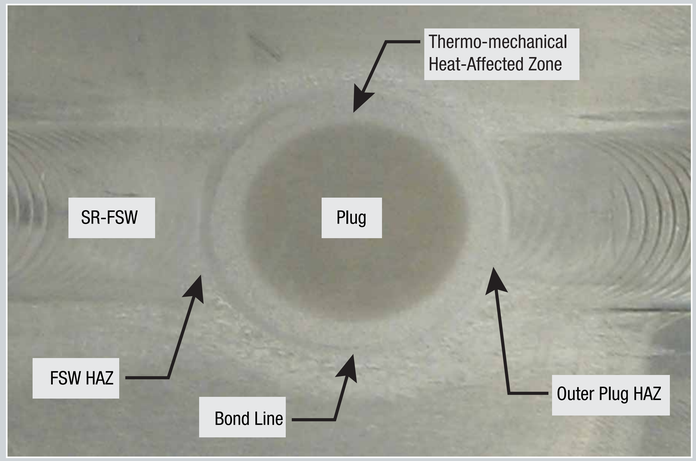
Welding Parameters

- Forging Load
- Spindle Speed
- Ram Speed

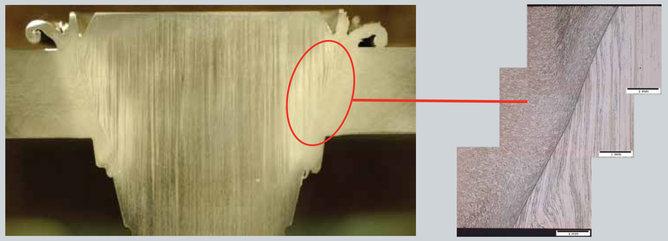


Friction Pull Plug Weld Operations

Friction Pull Plug Weld Microstructure



Cross Section of Friction Plug Weld



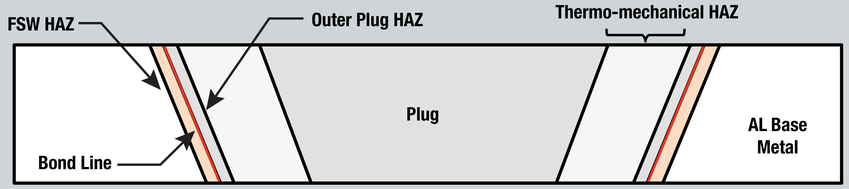
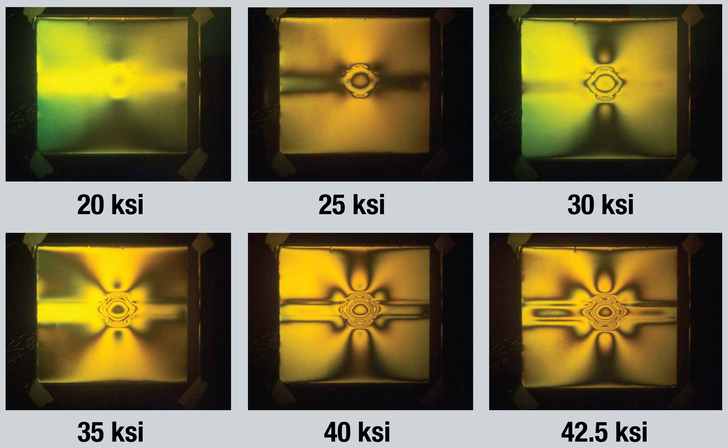
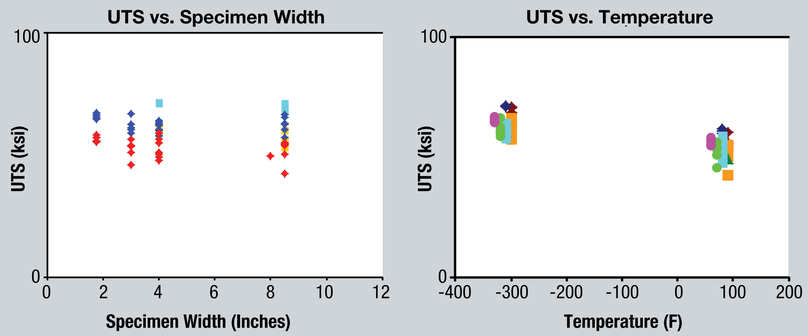


Photo Stress Analysis



Tensile Testing



Conclusion

- Viable weld process for FSW termination holes
- Viable post proof repair technique for space flight hardware
- Process strength sensitive to specimen width
- Process exhibits cryo enhancement
- Currently limited to Aluminum alloys
- Currently limited to weldlands < 0.500" thick