SOUTH DAKOTA SCHOOL OF MINES & TECHNOLOGY

AMP SDSM&T

Prevention of Liquation Cracking In Alloy 718 Laser Depositions Using Friction Stir Surface Processing

Research Undergraduate: Levi Lange(SDSM&T)

Faculty Advisors Dr. Michael West, Dr. Bharat Jasthi

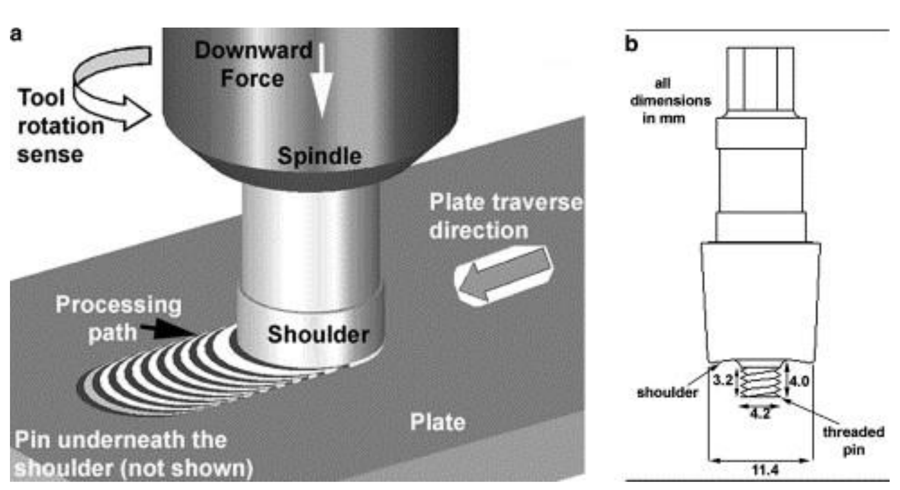
Research Experience for Undergraduates – Summer 2013

CFSP Center for Friction Stir Processing

NSF

Introduction

- The precipitation hardened 718 superalloy is composed of (55%Ni) (21%Cr) (11.15%Fe) (3.3%Mo) (5.5%Nb) (1%Cb) (.8%Cu) (1.15%Al) (< .5% Mn, Ti, Si, C, S, P, B)
- 718 Alloy's high temperature strength is developed by precipitation strengthening, small amounts of niobium combine with nickel to form the intermetallic compound Ni_3Nb or gamma prime (γ'') that inhibit slip and creep effectively at elevated temperatures.
- 718 Alloy is preferable for use in aircraft and industrial gas turbine components because of its advanced high-temperature properties.
- 718 Alloy is often used in the cast form given the cost-effectiveness, components suffer damage during service because of the severe operating conditions
- Repair of these components is often performed by welding or laser deposition (LD) processes, fusion repair of these cast superalloy components is extremely challenging because of its high susceptibility to liquation and cracking in the heat affected region (HAZ) of the weld along grain boundaries
- Friction stir processing (FSP) is performed to reduce grains size and prevent liquation during laser cladding repair



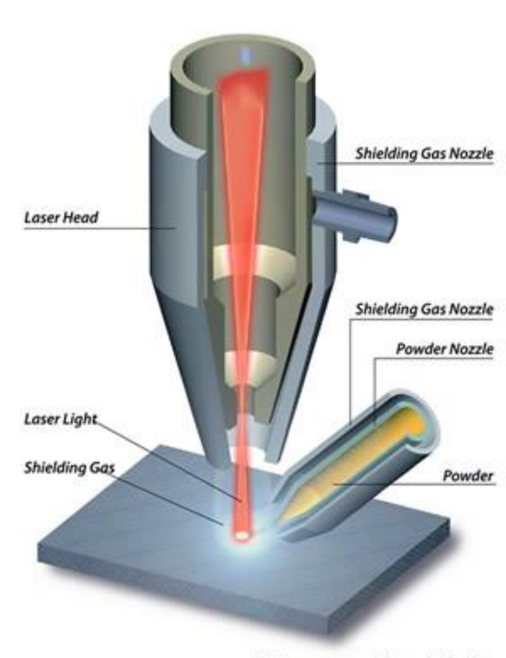


Figure 1 - Friction Stir Welding (www.sciencedirect.com) & Laser Deposition Diagrams (www.stellite.com)

Broader Impact

Friction stir processing is an advanced alloy processing technique that is emerging industry. It has many advantages including refining the base metal microstructure, ensuring homogeneous distribution of precipitates, and possibly eliminating detrimental phases. If these advantages can be utilized on cast components of Inconel 718 superalloys, it could save the aerospace and industrial turbine industry a lot of time, money, and resources attempting to replace these parts.

Procedures

- Friction stir processing of cast Inconel 718 (200 RPM, 2 IPM, 5000 lbf)
- Laser deposition of Inconel 718 powder on as-cast and FSP'd material at 500 W, 700 W, and 900 W
- Grinding and polishing – Up to 1200 grit, followed by 9, 6, 3, 1, 0.5 µm diamond suspension solution
- Etch – Walker's Etchant: 50ml HCl, 10ml H_2PO_3 10ml, HF, 30ml HNO_3, 50ml H_2O, 20ml $CHCO_2H$, 15g $FeCl_3$
- Micrographs taken with Nikon Epiphot 200 optical microscope
- Vicker's Hardness Testing, 1 kg load
- Vacuum tube furnace run under argon atmosphere for PWHT following AMS5383E, Section 3.5 specification: 2000 °F, 2 hours, and forced air cooling, 1750 °F, 1 hour, and forced air cooling, 1325 °F, 8 hours, furnace cool to 1150 °F at 100 °F per hour, hold 8 hours, and force air cool.

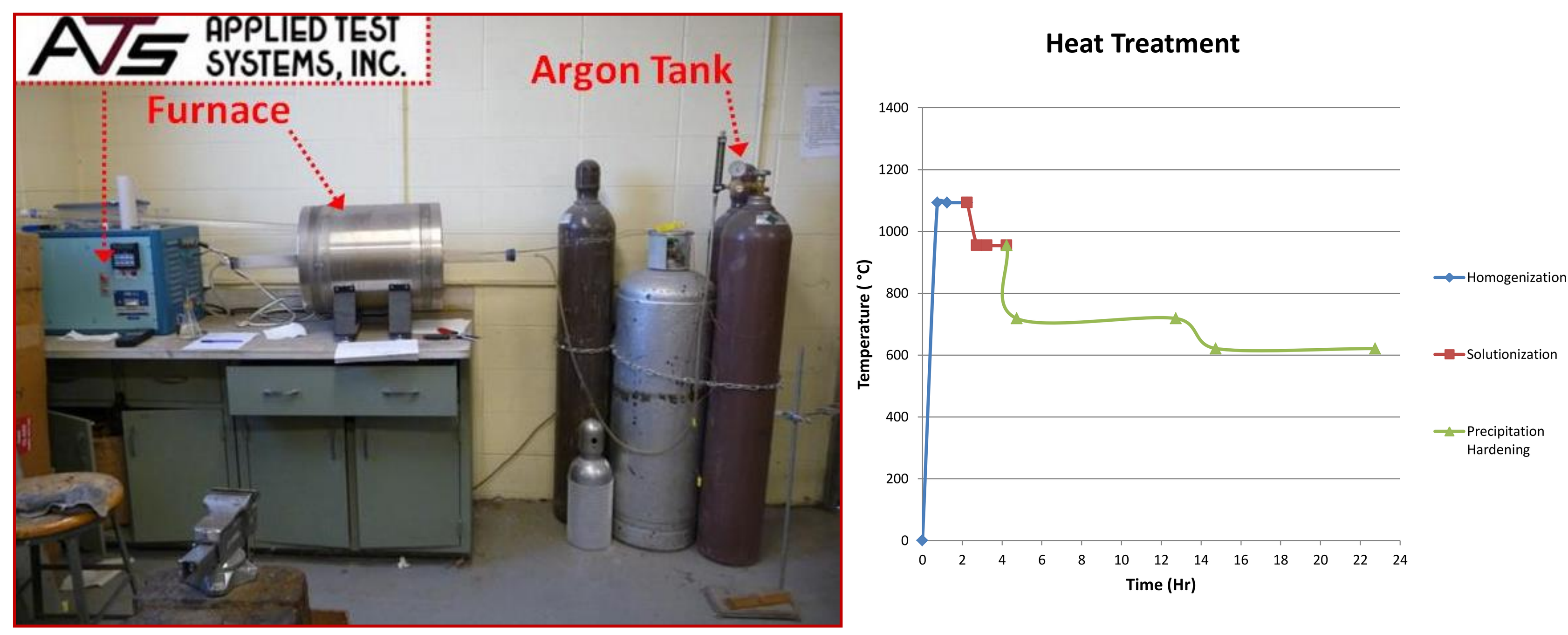


Figure 2 – Post weld heat treatment performed using ATS tube furnace

Results

- Deposition is affected by varying heat input

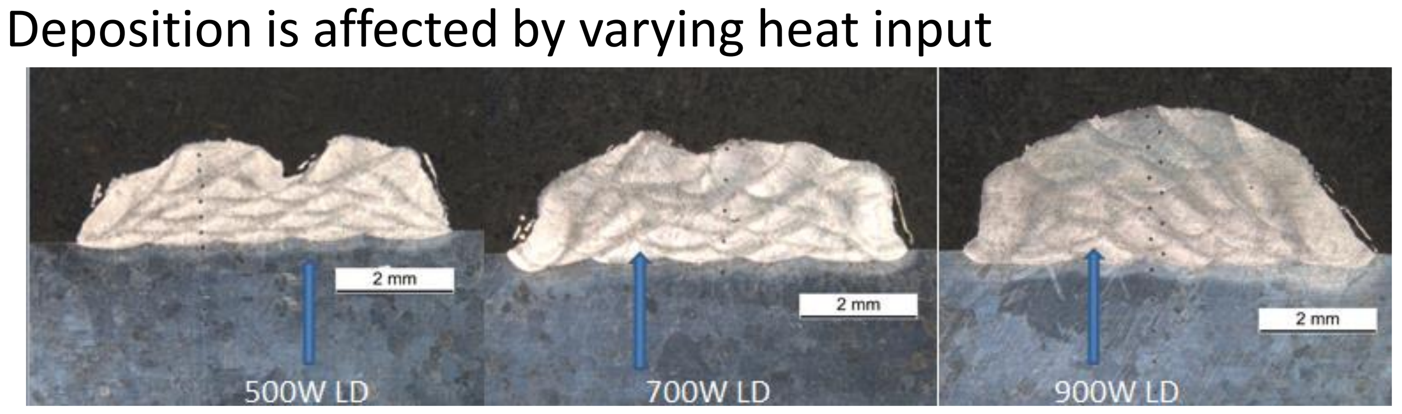


Figure 3 – 718 Alloy Laser Depositions

- Friction Stir Processing greatly reduced grain size

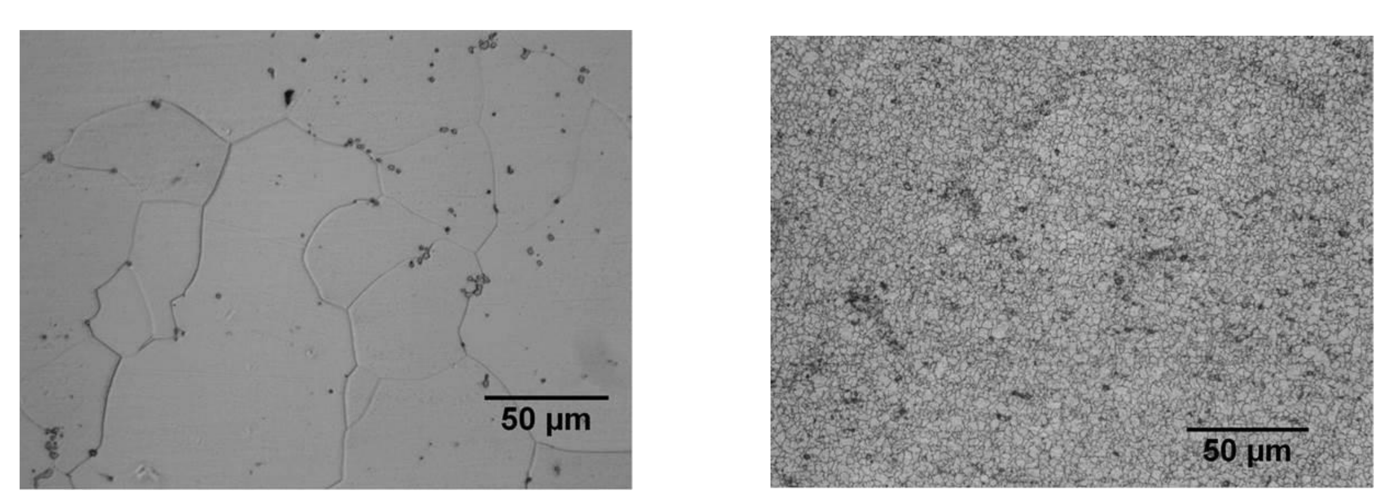


Figure 4 – 718 Alloy Parent, 718 Alloy FSP (respectively)

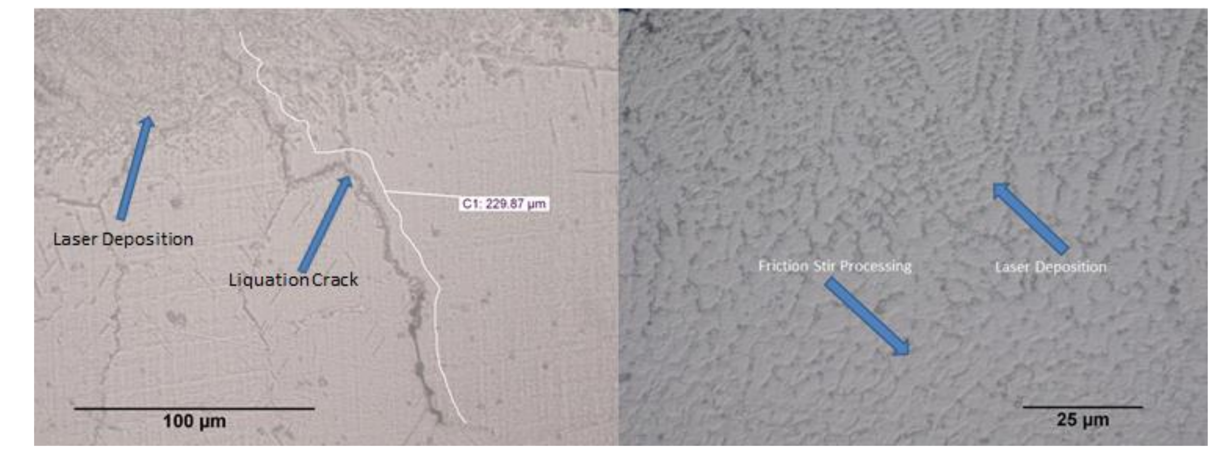


Figure 5 – 718 Alloy Parent, 718 Alloy FSP (respectively) showing liquation cracking in the parent material and no cracking in the FSP

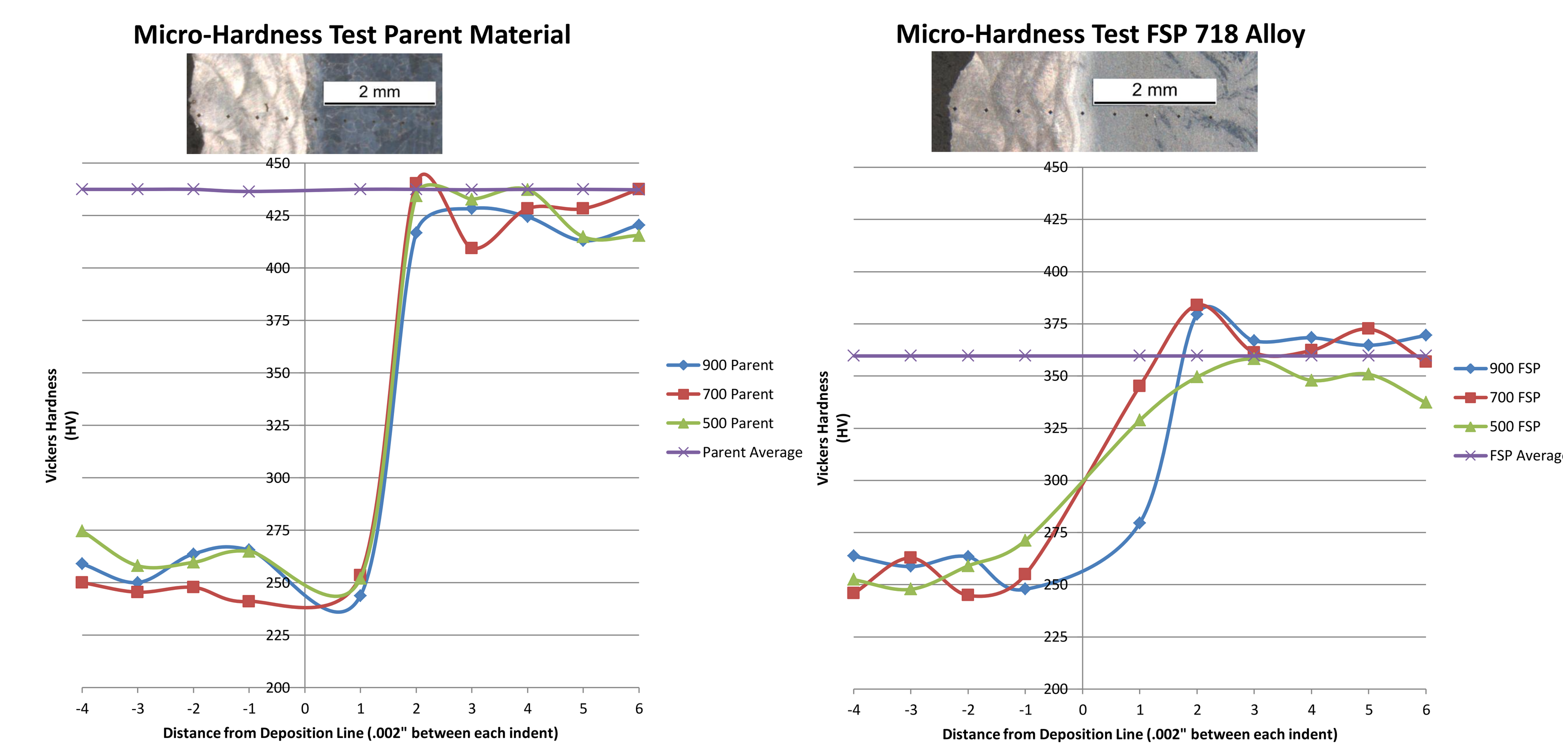


Figure 6 – 718 Alloy Vickers Hardness Pre Heat Treatment

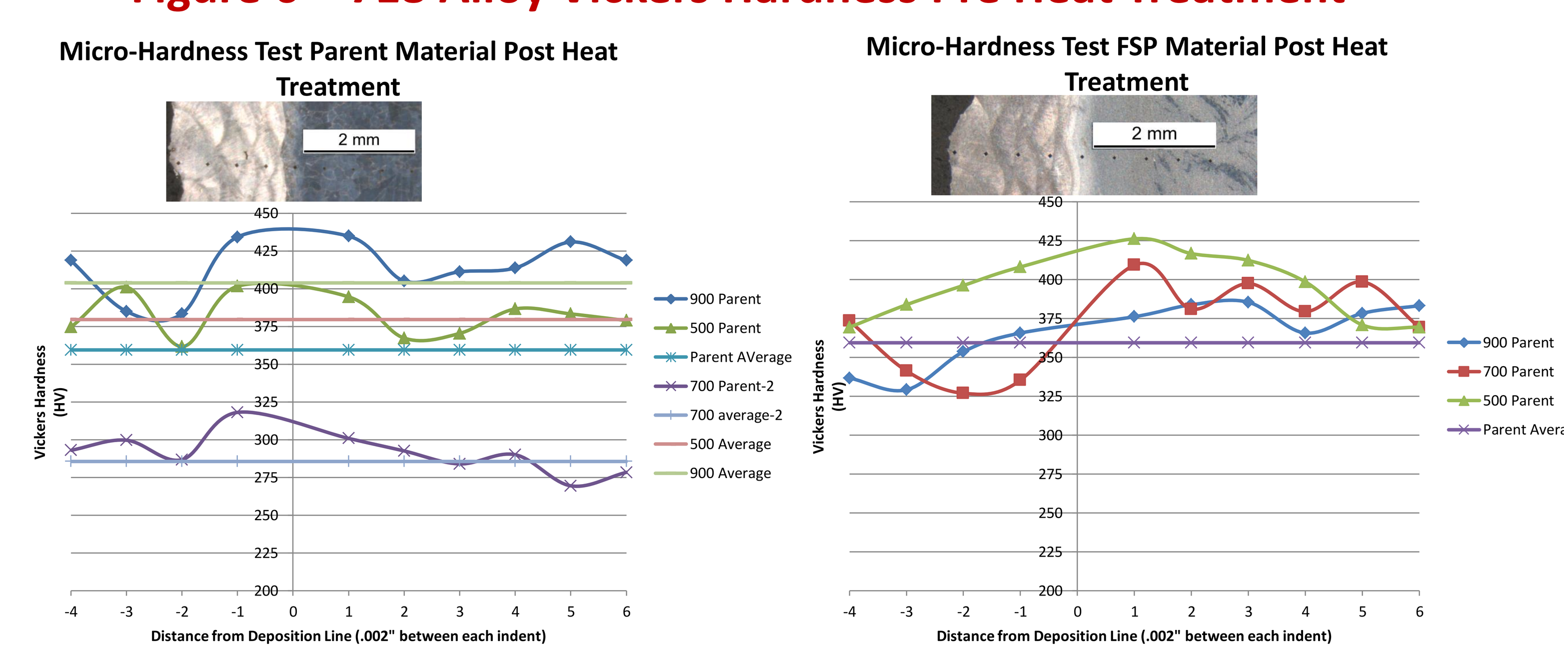


Figure 7 – 718 Alloy Vickers Hardness Post Weld Heat Treatment

Conclusions

- FSW is successful in reducing grain size to prevent liquation cracking.
- The hardness values in the laser deposition region of 718 alloy show significant increase when the PWHT has been performed. This is significant because it shows the strength in the LD region can be recovered after treatment.

Future Work

- Further grain size analysis on PWHT samples is necessary to determine grain growth.
- Further Mechanical and Microstructural characterization to see if this would be an applicable repair technique.

Special Thanks to Todd Curtis, Josh Hammel, James Tomich (SDSM&T AMP) -NSF I/UCRC Center for Friction Stir Processing Award ENG-0934383, NSF REU Back to the Future Award DMR-1157074