Integrated Process Improvement using Laser and Friction Stir Processing for Nickel Alloys used in Fossil Energy Power Plant Applications

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Objective

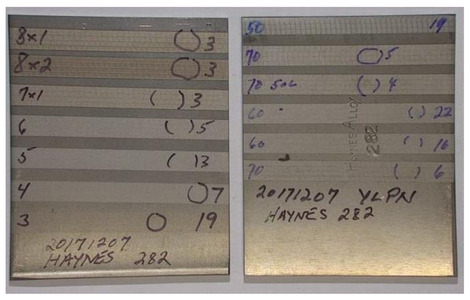
This project will investigate and demonstrate an integrated approach using both Laser Processing (LP) and Friction Stir Welding and Processing (FSW/P) to join, repair, and return-to-service Nickel alloy castings and wrought fabrications (such as hot gas path components in gas turbine applications).

Background

- Challenges exist in conventional fabrication and repair of Ni alloy components. Fabrication challenges include the time and cost of diffusion bonding(DB), the surface preparation needed for DB (and for later application of thermal barrier coatings), the difficulty with hot cracking and liquation cracking when fusion welding is used in fabrication; and for large, expensive Ni alloy castings, near surface casting defects can influence casting integrity and performance.
- Challenges also exist in repair and return-to-service environments. In-service degradation of TBCs requires stripping/ cleaning of the TBC prior to recoating. Laser based processes may prove to be outstanding in this role of surface preparation. Crack or damage repair also represents a problem for Ni alloys when repaired using conventional fusion welding due to Ni alloy propensity to develop hot and liquation cracking after welding.
- Recent technological advancements in laser and friction stir welding and processing (FSW&P) 0ffer potential solutions to some of the challenges in the fabrication of components like the transition duct.

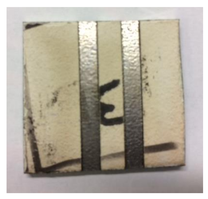
Laser Processing

Laser Cleaning of Haynes 282

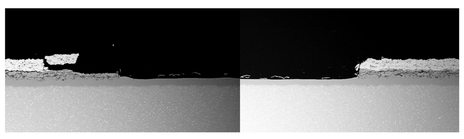


Laser cleaning efforts needed for removal of pre-oxidation layer prior to diffusion bonding or friction stir welding. Contact Angles of 3-6 degrees were obtained in 1 quick pass

Laser Stripping of Metallic/Ceramic Coatings

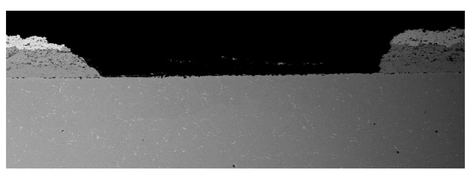


Ceramic TBC layer removal



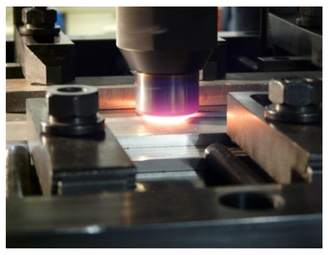
Ceramic and bond coat layer removal

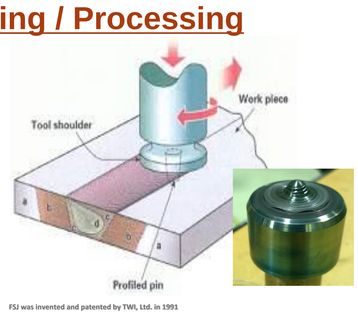
Segment from service run gas turbine vane



Clean/Rapid removal of TBC and bond coat demonstrated, < 1 hr process as opposed to 8 hours of chemical stripping, hence environmentally friendly

Friction Stir Welding / Processing

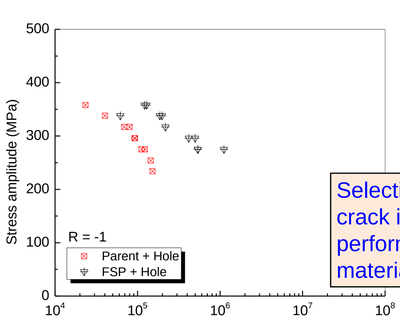


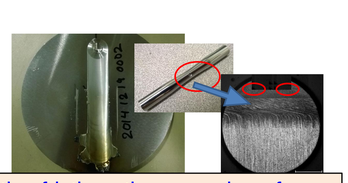


FSJ was invented and patented by TWI, Ltd. in 1991

Potential Advantages of Friction Stir Welding from other material systems

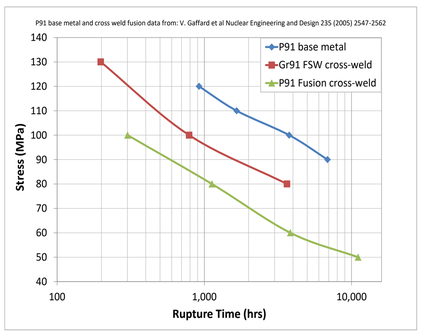
Improvement in fatigue performance in med-C steel





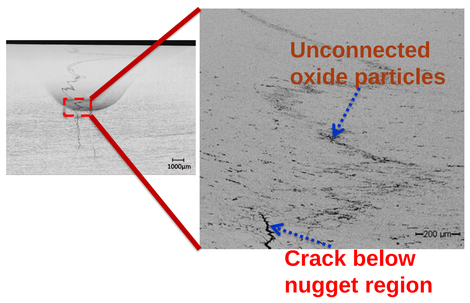
Selective friction stir processing of crack initiation site, improved fatigue performance by 4x over the parent material in a SAE 1538 steel

Improvement in creep performance in P91 steels



Weld Strength Reduction Factor (WSRF) raised by more than 20% over fusion welded equivalents after FSW. FSW allows for very low heat input and a customizable thermomechanical processing of the HAZ.

Stress corrosion crack repair in 304 SS via FSW

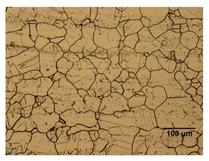


Cracks in the processed volume successfully repaired. No volumetric defects forms during repair operations

FSW of Ni-base alloys: Previous Results

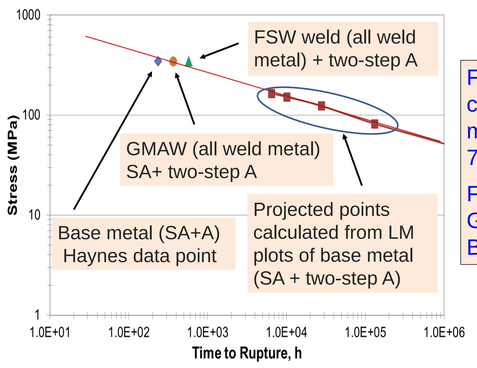
Defect-free welds were produced with W-Re-4%Hf-C convex tool.

As-Received Haynes 282



FSW Nugget

Refined microstructures in FSW nugget

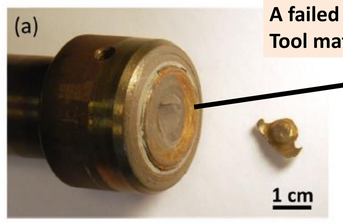


FSW weld metal had longer creep-rupture life than base metal and GMAW at 760°C/345 MPa

FSW + A = 576 hours
GMAW SA + A = 365 hours
Base metal SA + A = 238 hours

Challenges with FSW / P of Ni-alloys

Tool wear is the major challenge with welding of Ni alloys using FSW.



A failed FSW tool,
Tool material : PCBN + W-Re with W-Re

Both reaction-based and mechanical tool wear was noted.

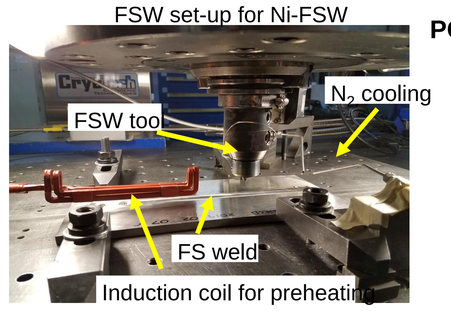
Tool wear in WC-Co and PCBN-based tools noted while welding various Nickel alloys.

Pre-heating of the plates eliminated tool wear in Haynes 230.

Processing approaches

Developing the Advanced Manufacturing Process for joining Ni-based alloys using FSW (induction preheat, closed loop temperature control, in-process defect detection etc).

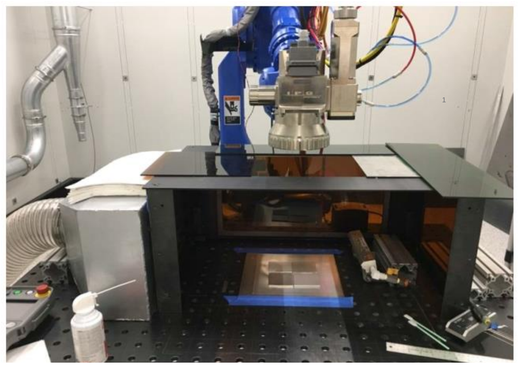
FSW set-up for Ni-FSW



PCBN Q-60 tool

Induction heating will be used to reduce the process loads and subsequent tool wear during FSW

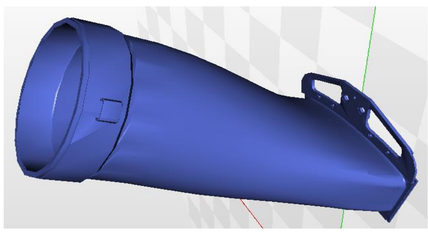
Developing Laser cleaning/ Stripping Process for Ni-based alloys and Coatings



Cleaning Setup with IPG 2DHP Scanner

Anticipated Project Outcome

- The purpose of this project is to develop solutions to the challenges encountered in fabrication, repair and return to service of Ni alloy components in extreme service environments found in fossil energy applications
- The techniques developed will be applied to materials and geometries relevant to fossil energy systems including gas turbine transition duct materials and Ni alloy castings



- It is anticipated that significant cost savings are possible using new advanced manufacturing techniques: Laser stripping reduces coating removal time by >50% compared to chemical stripping. Friction stir welding will reduce component manufacturing by > 25% compared to diffusion bonding.

Acknowledgement

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