Comparison of Friction Stir Welded MA956 Superalloy with and without Post Weld Heat Treatment

Faculty Advisors Dr. Michael West, Dr. Bharat Jasthi
Research Undergraduate: Katie Strader (UT Knoxville)
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Background

- The research conducted on FSW MA956 ODS superalloy is used to portray the growing importance of using solid-state welding techniques as opposed to conventional arc welding techniques and how the friction stir weld responds to post weld heat treatments (PWHT). Dispersed yttria particles enhance creep resistance at high temperatures. These ODS particles are lost through conventional welding techniques involving melting, so FSW has a great impact on the future of ODS alloys.
- For our experiment, the best weld produced on the MA956 superalloy was performed at 600 RPM, 0.5 IPM under an argon atmosphere in order to decrease the likelihood of oxidization.

Objective

- To see how FSW and heat treatments affect the microstructure and properties of the oxide dispersion strengthened (ODS) superalloy MA 956.

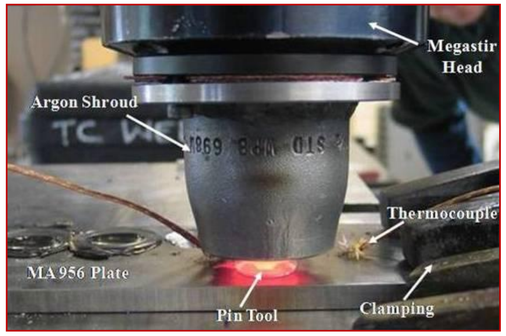

Figure 1 - Friction Stir Welding of MA956 using W-Re pin tool

Introduction

- The oxide dispersion strengthened (ODS) INCOLOY® MA956 superalloy is composed of (Fe) (20%Cr) (4.5%Al) (0.5%Ti) (0.5%Y2O3) (in wt %) and is provided by Los Alamos National Laboratory.
- This ODS superalloy is produced by dispersing fine Y_2O_3 (yttrium oxide) particles into a ferritic matrix by a mechanical alloying (MA) technique, such as ball milling.
- MA956 is preferable for use in nuclear reactors, advanced energy conversion systems, high-temperature shields, and other high-temperature applications.
- A PWHT is performed in order to study the effects of annealing on the properties and microstructure of FSW MA956.

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

Broader Impact

- Friction Stir Welding (FSW) is a solid-state welding process - no melting occurs - so the ODS alloy microstructure can retain 80-90% of the parent-material properties. FSW produces a much stronger and safer weld joint than conventional arc welding for applications involving high temperature and radiation and no hazardous fumes are emitted. With no fumes, the FSW process is safer and does not require costly safety equipment, whereas conventional arc welding uses costly filler metal, consumables, and shielding gas.

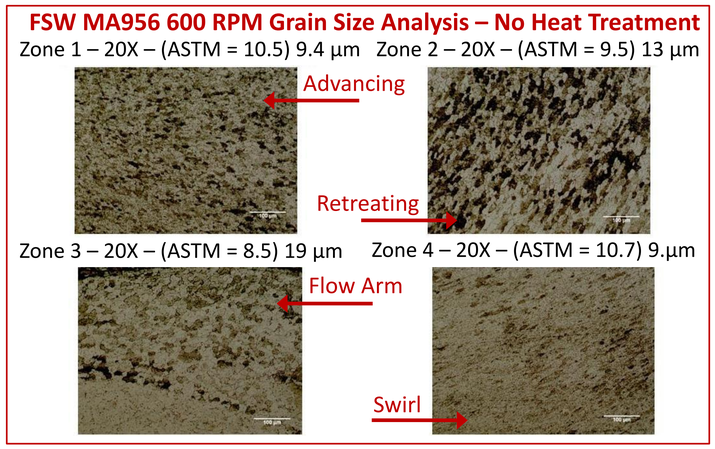

Figure 3 – Grain size analysis using ASTM line-intercept method

Procedures

- MA956 ODS superalloy undergoes solid-state FSW process
- Grinding and polishing – Up to 1200 grit, followed by 3 µm, 1 µm polycrystalline solution, then 1 µm colloidal silica
- Electrolytic Etch – 30% HCl and 70% Ethanol
- Micrographs taken with Nikon Epiphot 200 optical microscope
- Vicker's Hardness Testing, 500 g load
- Vaccum tube furnace run under argon atmosphere for PWHT at 1000°C and 1300°C – both temperatures run for 1 and 5 hours

Results

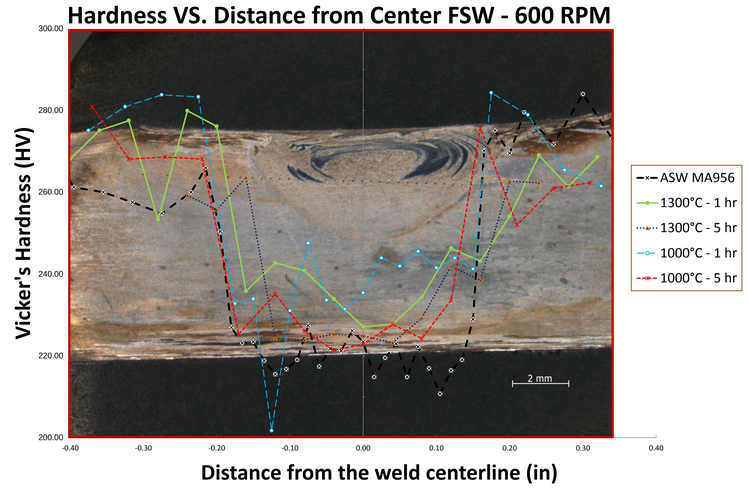

Figure 4 – FSW region of MA956 at 6.25X magnification showing Vicker's hardness values across the nugget.

- (Figure 4) At different PWHT temperatures and times, the hardness values have very similar hardness results.

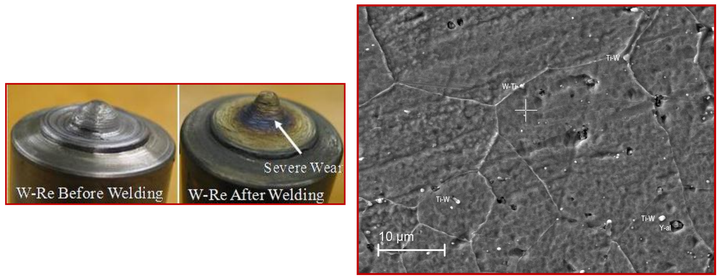

Figure 5 – Higher rotational speed (900 RPM – left) results in severe wear of pin tool. The 600 RPM SEM micrograph shows significant pin tool wear particles present in the flow arm region of weld nugget.

Conclusions

- FSW is successful in making a strong weld in MA956.
- The hardness values in the FSW region of MA956 do not show significant change when the PWHT has been performed. This is significant because it shows the strength in the FSW region can be retained at high temperatures for long periods of time.
- The SEM micrographs showed that pin tool wear occurs at 600 RPM in the flow arm zone of the weld nugget.

Future Work

- Further grain size analysis on PWHT samples is necessary to determine grain growth.
- TEM analysis to study particles in stir zone and particle stability after PWHT

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