Experimental Report

18/12/2013

Proposal: **1-02-138** **Council:** 10/2012

Title: Effect of Friction Stir Welding Process Parameters on the Residual Stress Development in Ti-6Al-4V Welds

This proposal is a new proposal

Researh Area: Materials

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Samples: Ti

Instrument	Req. Days	All. Days	From	To
SALSA	8	3	18/05/2013	21/05/2013

Abstract:

Friction Stir Welding (FSW) is an innovative solid-state joining technique, which has been quite successful in joining Al-alloys, but has not been widely used for Ti-alloys due to the difficulty in finding a non-wearable tool material that can withstand the high stresses and temperatures (>1000˚C) during welding. There has been a growing interest in the use of FSW to join aerospace titanium structures, especially to replace other joining technologies (e.g. electron beam welding). Nonetheless, the stirring action, in addition to the transient thermal cycle, leads to the development of strong residual stresses within the weld. In this investigation, we aim to continue our previous investigations #1-02-67 and #1-02-88 by investigating the effect of process parameters mainly the rotational speed on the residual stress development in fine grained Ti-6Al-4V friction stir welds. In addition, comb specimens will be made to measure the d0-variation across the weld region. This proposed investigation is novel as the work in the literature is primarily focused on Al-alloy friction stir welds, with limited studies investigating the residual stress development in Ti-alloys friction stir we

EXPERIMENTAL REPORT

EXPERIMENT N° #1-02-138

TITLE: Influence of the Process Parameters on the Residual Stress Development in Titanium Friction Stir Welds

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LOCAL CONTACT: Thilo Pirling

Friction Stir Welding (FSW) is an innovative solid-state joining technique that utilises a non-consumable rotating tool to traverse along two rigidly clamped contacting surfaces. Heat dissipation associated with frictional sliding at the shoulder and workpiece interface, as well plastic deformation caused by the rotating and advancing tool, causes the workpiece to soften to a temperature near the respective solidus temperature. As a result, as the tool traverses and rotates, it stirs the surrounding workpiece material causing its extrusion around the tool, whilst consolidating the joint behind it.

If the FSW process parameters are correctly optimised, defect-free welds can be produced. However the low thermal conductivity of Titanium in combination with the extensive deformation experienced during welding, results in a localised region of residual stresses close to the weld region after cooling. The effect of these residual stresses can be either beneficial or detrimental, depending upon their magnitude, sign (for example a tensile or compressive stress) and distribution with respect to service induced stresses. Thus it is essential to be able to determine the residual stresses, and consider them as part of the service loads. Therefore the aim of this experiment was to help identify an optimum process parameter for FSW Titanium, which would result in the reduced development of tensile residual stresses within the weld region.

It is generally preferable to measure the residual strains in Titanium by high-energy synchrotron rather than neutron diffraction, due to the attenuation of the neutron beam caused by poor neutron scattering properties of Titanium. However this problem was overcome by using a high sampling time thus enabling better sampling statistics. Due to the thickness of the bead-on-plate weld, a biaxial stress condition could not be assumed, which meant that it was necessary to calculate the residual strain components in all three dimensions. Using collimators, a neutron beam of 1.06Å wavelength was used to diffract off the (103)α plane.

Traces were measured on the upper surface (-20mm from the mid-point thickness) and mid-thickness trace of the weld in the X-, Y- and Z- direction. Since the FSW process is essentially asymmetric, where one can make a distinction between the advancing and retreating side of the weld, traces were measured along the entire cross section of the bead-on-plate weld.

This gave a total of 72 measurement points for the entire weld (24 points in the x-direction, 24 points in the y-direction and 24 points in the z-direction). Since in the welding direction, (the x-direction) the path length was considerably smaller than in the y and z-directions, an average counting time of 30 minutes per measurement point was made to achieve an acceptable neutron count rate. However in the y and z-direction an average counting time of 60 minutes was required due to the longer path length, hence poorer diffraction statistics.

A total of 3 days of beam time was required for successful completion of the experiment. The 'hexapod' mechanism on SALSA facilitated the y and z components to be measured in a single alignment by a 90˚ rotation of the 'hexapod' enabling an efficient use of the time available.

Using a high rotational speed, it was found from previous experiments that tensile residual stresses were generated within the weld, with a maximum peak residual stress of 381 MPa in the welding direction. This peak was positioned in a location corresponding to the edge of the tool shoulder. From this proposed experiment, a weld made with a low rotational speed was analysed. It was found that the residual stresses were larger within the weld, with a maximum tensile residual stress of 438 MPa located almost at the weld centre. Therefore the residual stress development is dependent on the rotational speed of the FSW tool. A decrease in rotational speed generates high tensile residual strains within the weld region. This is because the workpiece material is not as plasticised and therefore does not flow as easily around the tool.

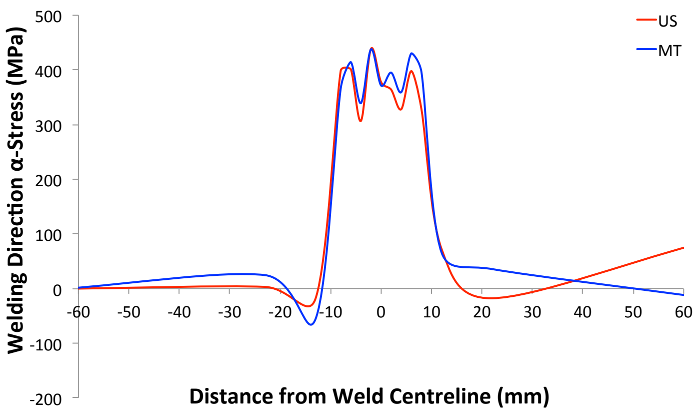

Figure 1. Residual Stress Development in the Welding Direction of a FSW made at a Low Rotational Speed

NB: The results achieved within this experiment and previous experiments using SALSA require modifying with accurate measurements of d_0, by using combs extracted from the welds.