Mechanical characterization of Titanium Alloys Linear Friction Welds

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Resume

Similar *Ti17-Ti17* LFW joints were studied. Microhardness tests were conducted to track the weld zones areas and locations. Digital Image Correlation (DIC) provided the strain field of the specimen surface. Tensile test and DIC results allowed us to identify constitutive law of the joint by fitting an isotropic hardening behavior to the weld zones. Constitutive law coefficients were mapped using the weld zones tracking. A simulation of the tensile test was performed using Z-Set. Tensile test simulations were in good accordance with the experimental results.

Keywords:
linear friction welding, mechanical characterization

1 Introduction

Linear friction welding is increasingly used in the aerospace industry. The assembly is achieved by fixing a part while the other is rubbed against with an oscillatory motion. Produced heat in the contact surface induces a material softening. A better understanding of the joints properties is required for the safe use in structural applications.

2 Aim of the Study

Simulation of a tensile test of a *Ti17* similar linear friction joint.

3 Experimental and materials

Timet produced billets of *Ti17* from which, blocks of $80mm \times 70mm \times 15mm$ have been machined using a Electrical Discharge Machine (EDM). Blocks have been used to produce LFW joints. Amplitude was 2mm and oscillation frequency was 50Hz. Forging pressure was 90MPa and the axial shortening was 3mm. Mean welding time was 2.9s. Fig.2 show specimens geometry, which have been produced from the welded blocks at *Centre des Matériaux*.

Tensile test Tensile test were carried out using a MTS 100kN standard machine. An extensometer was used to measure elongation. Test conditions are exhibited in Fig. 2.

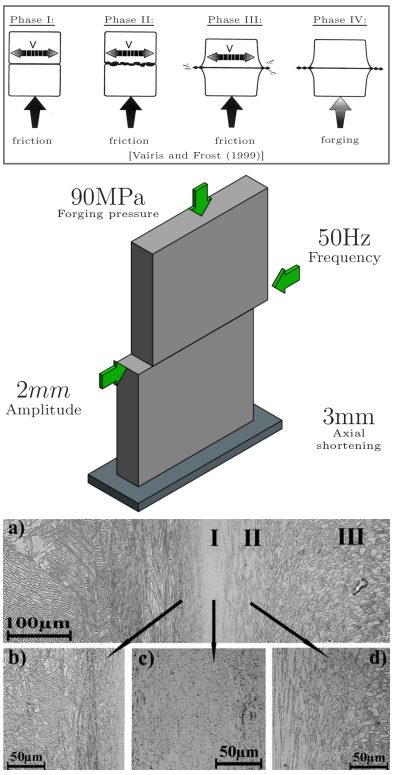

Figure 1: LFW phases and parameters. Micrograph of a weld zone in a Ti6246 LFW sample: (a) a typical LFW microstructure, (b and d) sudden onset of severe plastic deformation on both sides of the weld, (c) recrystallized grains in the weld line.) [Sorina-Müller et al. (2010)]

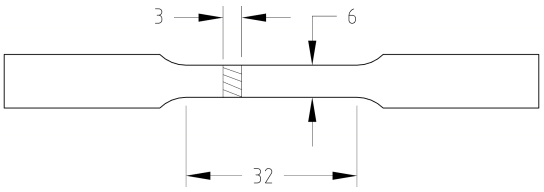

Figure 2: Tensile test specimen.

Gage length: 25mm
Section: 18mm^2
Strain rate: $10^{-3}\,s^{-1}$
Speed: 32×10^{-3} mm/s
Temp.: $23°C$
Time: $1'30''$

Microhardness Microhardness tests have been carried out in a perpendicular line to the weld with a 100µm step size, with a 500g load and a dwell period of 15s.

Digital Image Correlation Specimens were painted using matte white, an airbrush was used to set black ink speckle pattern. Two cameras of 4MP were used for the stereographic imaging. Objects-lens distance was 22cm. Lens-lens distance was 10cm. The angle was $26°18'$. For correlation values chosen for subset (SS), step size (ST) and filter size (SW) are respectivly 29, 15 and 15.

4 Results

Tensile test Joints tensile tests are analyzed and compared with the parent materials. Tensile tests done at the *Centre des Matériaux* appear in blue. Manufacturer tensile tests are plotted in gray. Tensile test curve has been compared with the parent material (PM) curve which has been provided by the manufacturer [Millet and Wies. (2015)], results are shown in Fig. 3. Localization took place in the surroundings of weld interface and the T-MAZ. Failure started in one of these two zones and then displaced to the other. Further analysis with DIC will be done to get a better understanding of failure localization. Linear friction weldings seems to represent a structural weakness in similar $Ti17$ joints.

Microhardness Result of the microharness level are shown in Fig. 3. The welded zone seems to present the minimal microhardness level. The thermo-mechanically affected zones are highlighted by gradients of microharness. Far away from the welded zone parent material microhardness is found.

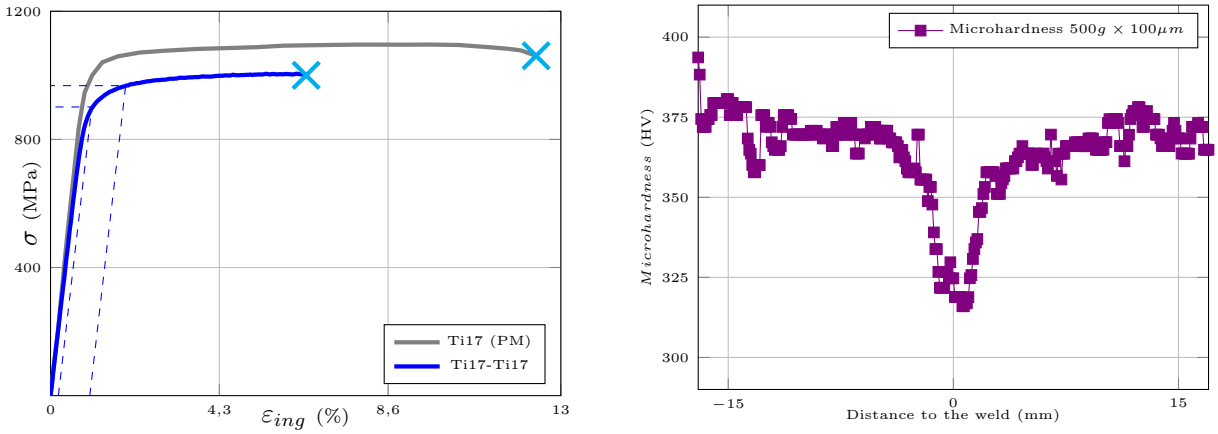

Figure 3: Tensile test curves comparison of the $Ti17$ parent material and the $Ti17 - Ti17$ similar welding. Parent material information has been provided by [Millet and Wies. (2015)]. Microhardness line perpendicular to the weld line.

DIC A discretization of the strain field on the specimen surface was used to analyze weld zones constitutive behavior. A straight line perpendicular to the weld interface was used as reference. A set of points over this line separated of $90\mu m$, allowed us to track every weld zone strain field. Figure 4 shows the strain field of the reference line for increasing macroscopic engineering stress. Material softening is once again highlighted by the increase of ductility of the weld zone.

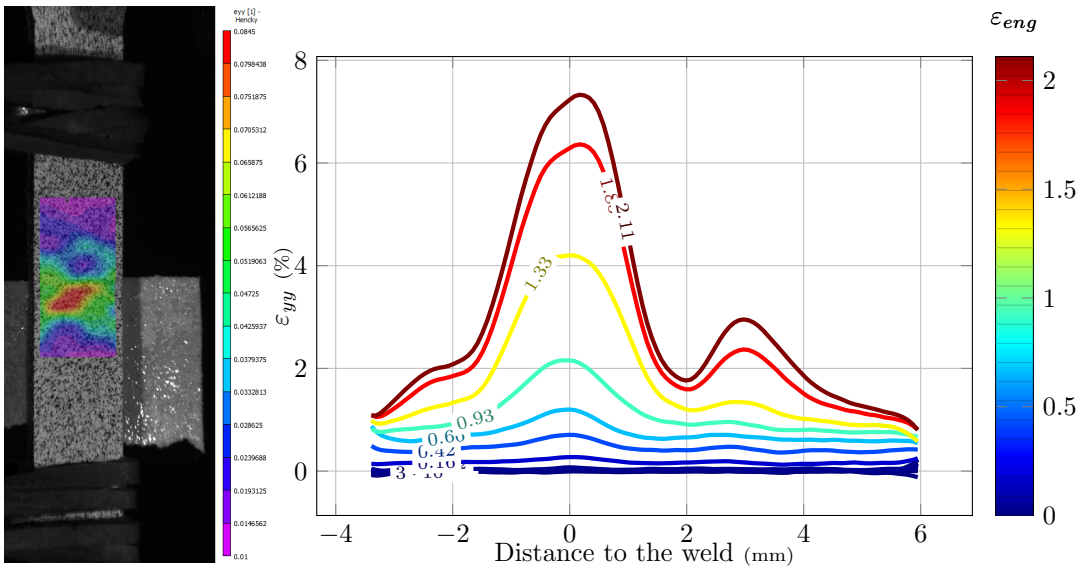

Figure 4: Strain field of a line in the specimen surface obtained by Digital Image Correlation (DIC).

DIC and Tensile Test comparison Strain field over the reference line and microhardness profiles are plotted in Fig. 5. The increase of ductility seems to be coupled with the decrease of microharness.

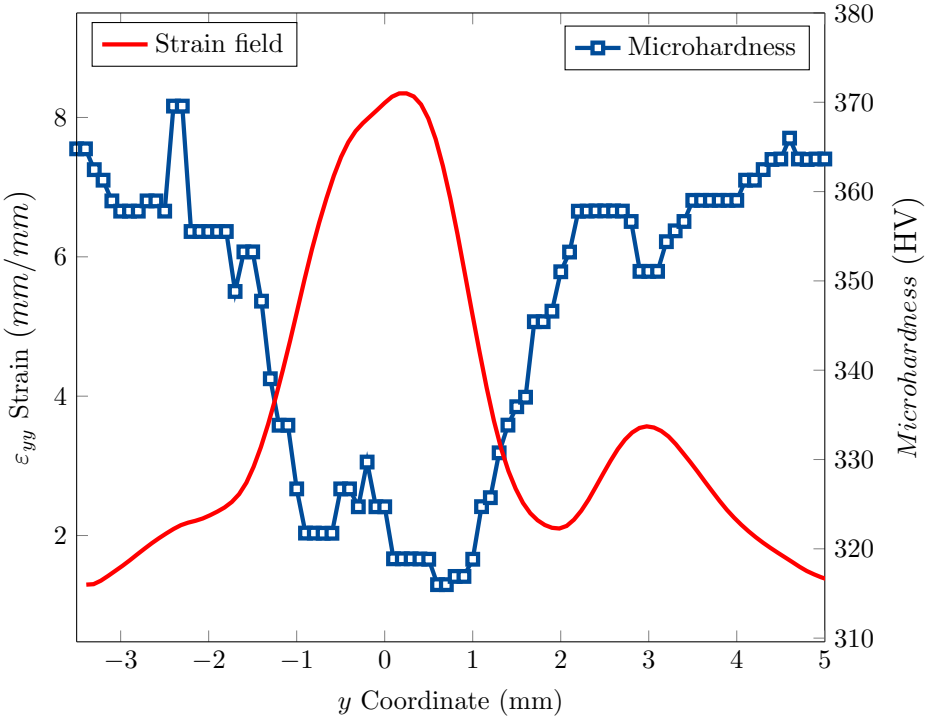

Figure 5: Comparison of Microhardness profile and Strain Field along a line perpendicular to the weld.

Constitutive behavior identification and Simulation Using the macroscopic force of the tensile test and the strain field of the discretization, an isotropic hardening behavior was fitted to every point in the reference line. A tensile test simulation was launched using a map of isotropic hardening parameters using the weld line as reference. Results are shown in Figure 6.

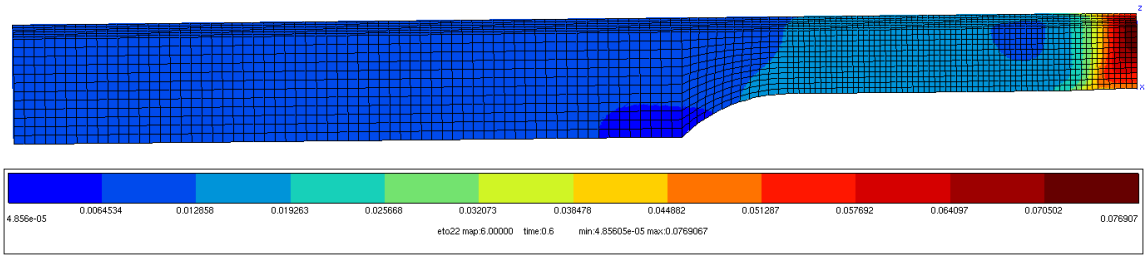

Figure 6: Similar *Ti17-Ti17* LFW joint tensile test simulation.

5 Conclusions

Mechanical characteristics of similar an dissimilar linear friction welding joints depend on the welding parameters such as frequency, amplitude and forging pressure. In this work, tensile test has been performed for a similar *Ti17-Ti17* linear friction welding joint. The following observations were made:

(1) *Ti17-Ti17* similar joint is weaker than the parent material: its ultimate tensile strength is reduced by 10% and its ductility by about a half.

(2) A 13% microharness decrease is provoked by Linear friction welding, in *Ti17-Ti17* similar joints.

(3) Ductility of the weld zone is higher than the parent material.

References

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