LSP Influence on Mechanical Properties of Thin Dissimilar Laser Welded Joints

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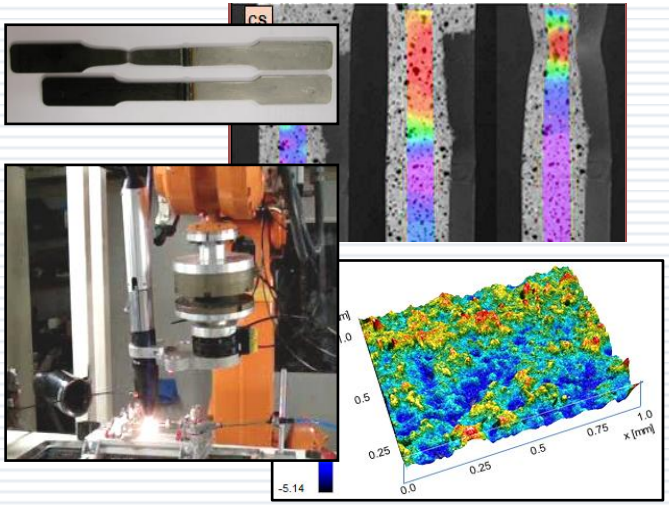

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OBJECTIVE

Assessment of laser shock processing effects on mechanical resistance of thin dissimilar laser welded joints

CONTENT

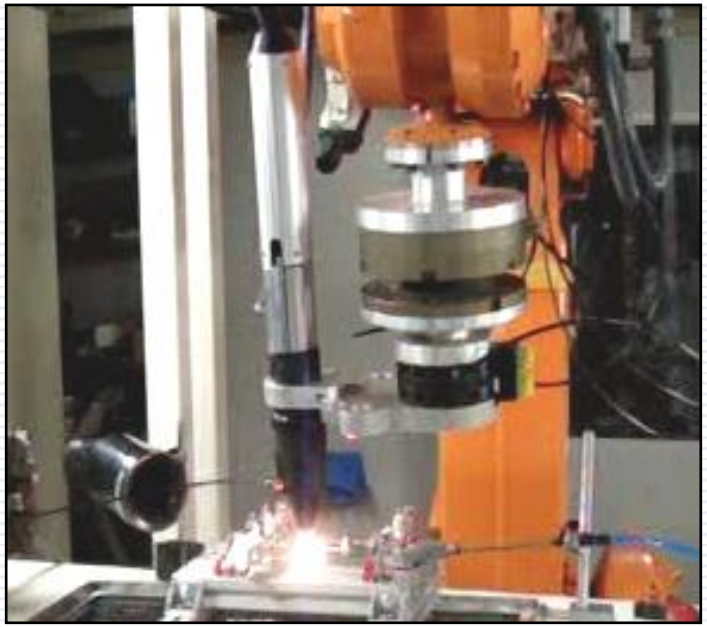
1. Experimental conditions – *LASER WELDING & LASER SHOCK PROCESSING*
2. Joint Overall and Local Mechanical Resistance
   – *COMPARISON NATIVE vs. LSP TREATED JOINT*
3. LSP effect on CS - local properties – *ROUGHNESS & RESIDUAL STRESSES*
4. Conclusions

1. EXPERIMENTAL CONDITIONS – *LASER WELDING*

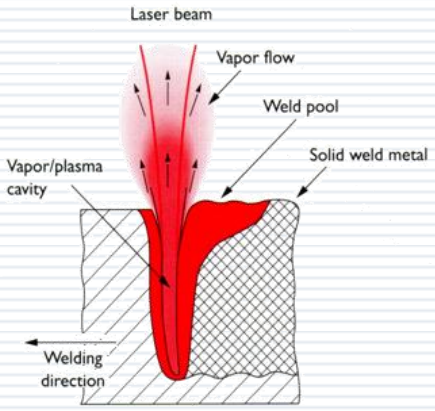
Autogenous Laser Welding

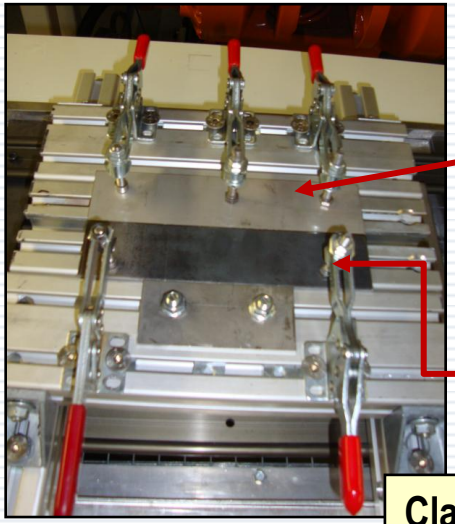
Keyhole continuum mode

- **High Penetration**
- **High speed**
- **Low distortions**



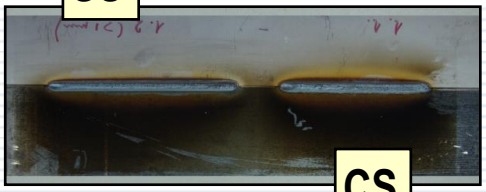
Nd:YAG laser DY 033 (3300 W)





Dissimilar joint

SS



CS

Clamping device

1. EXPERIMENTAL CONDITIONS – *LASER WELDING*

Base Materials

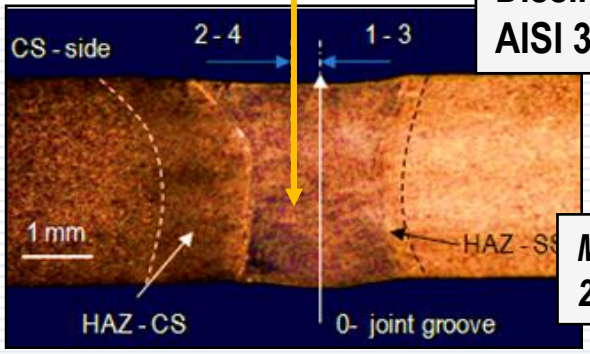
	Fe	C	Mn	Si	Cr	Cu	Ni	S	P
AISI1045	bal.	0.155	0.604	0.25	0.17	0.04	0.02	0.035	0.029
AISI 304L	bal.	0.022	1.81	0.41	18.10	0.33	9.2	0.08	0.025

Experimental matrix of welding parameters

0,5	Laser Spot Diameter, mm
3300	Laser Power, W
8	Welding speed, mm/s
1680,7	Power density (irradiance), W/cm^2
2.063	Heat Input, kJ/cm

Laser beam eccentricity

Dissimilar joints between plates of AISI 304 L & AISI1045 (200 x 300 mm)



3 mm thickness

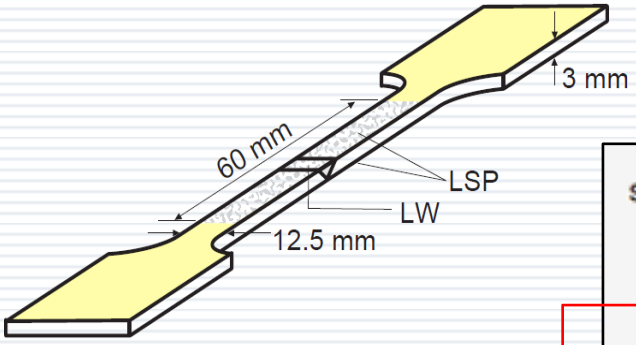
Sound, free of defects joints

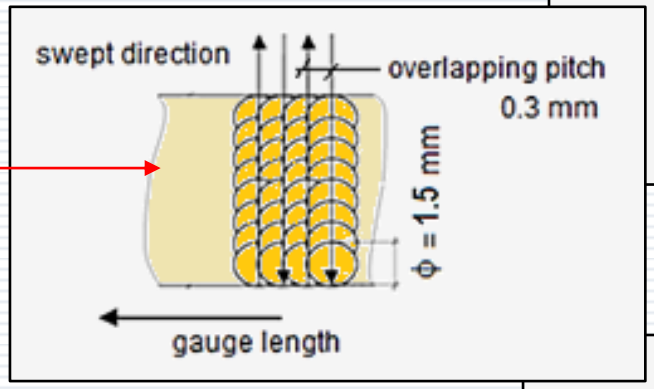
Macrostructure of a dissimilar laser welded joint: 2-4 laser beam position corresponding to LW joint.

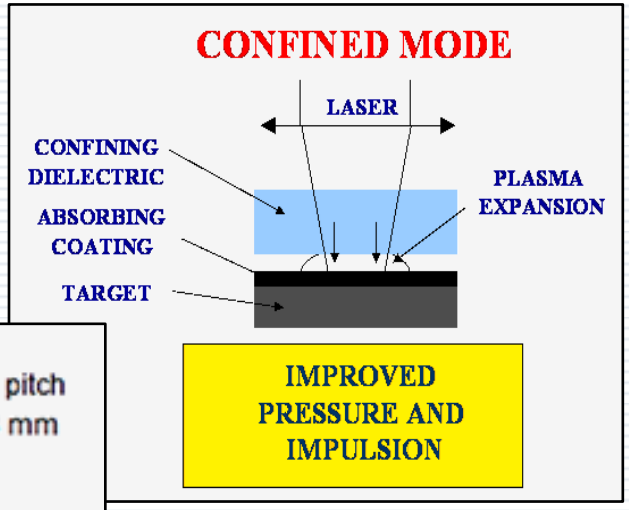
1. EXPERIMENTAL CONDITIONS – *LASER SHOCK PROCESSING*

Spectra Physics Nd:YAG Laser — ***Q-switch system***

LSP







Processing parameters

Wave length λ=1064 nm
Effective Energy = 2.8 J
Spot radius = 1.5 mm
Spot overlapping = 1600 pulses/cm^2

2. JOINT OVERALL AND LOCAL MECHANICAL PROPERTIES

Experimental stress-strain curves

Post-processing analysis – virtual extensometers

Overall dissimilar joint

BMs & Weld

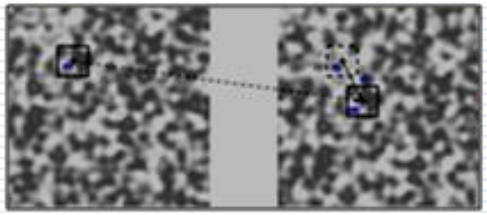
Digital Image Correlation System – VIC 2D

VIC software correlates location of random speckle patterns between two images.

The correlation is made between windows of pixels, typically 25 x 25 pixels, so measured values are averages over the window size

Image 0

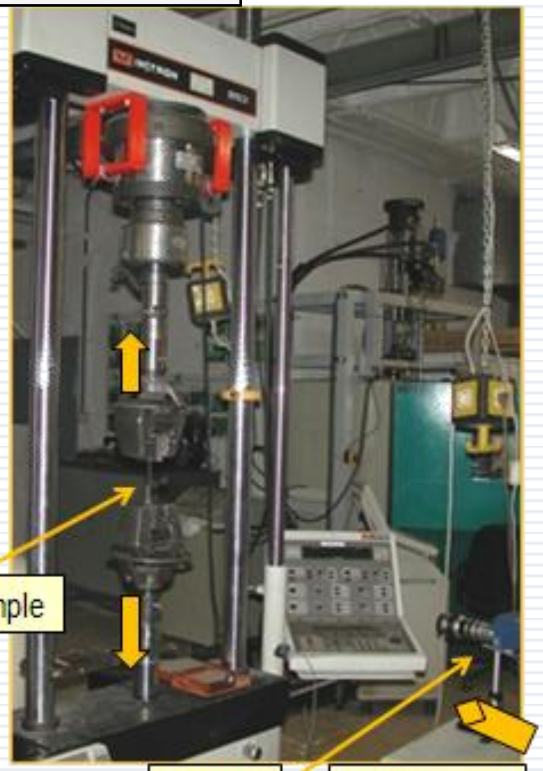
Deformed Image



2D analysis

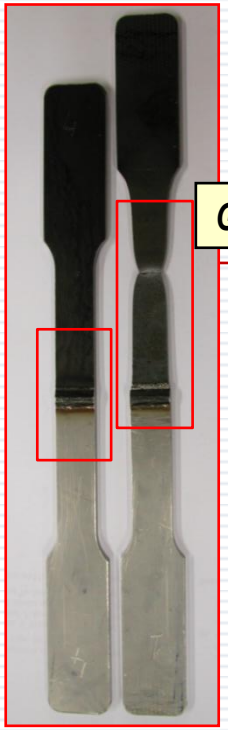
speckle patterns on the sample surface

In-plane strain/displacement measurement



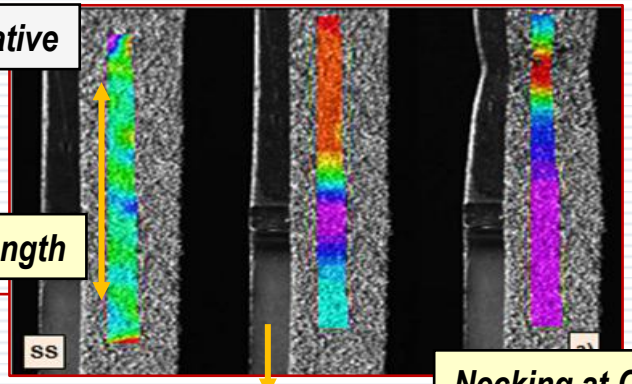
2. JOINT OVERALL AND LOCAL MECHANICAL PROPERTIES

Post-processing analysis — **VIC-2D strain maps of native and LSP treated dissimilar joints**



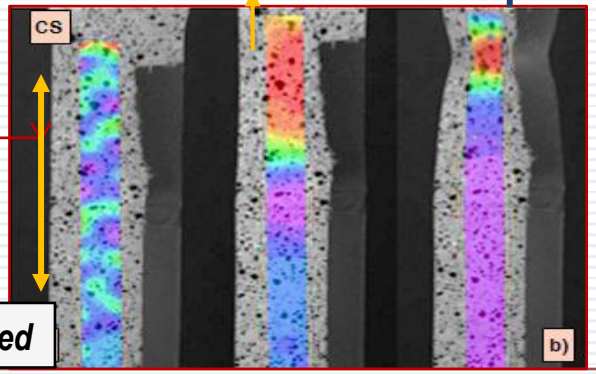
Gauge length

native

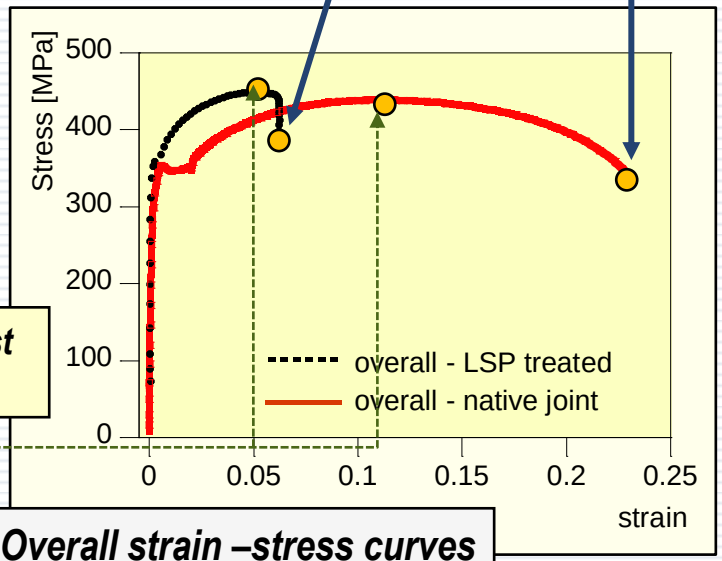


Strain localization in CS at max. load

Necking at CS just before fracture



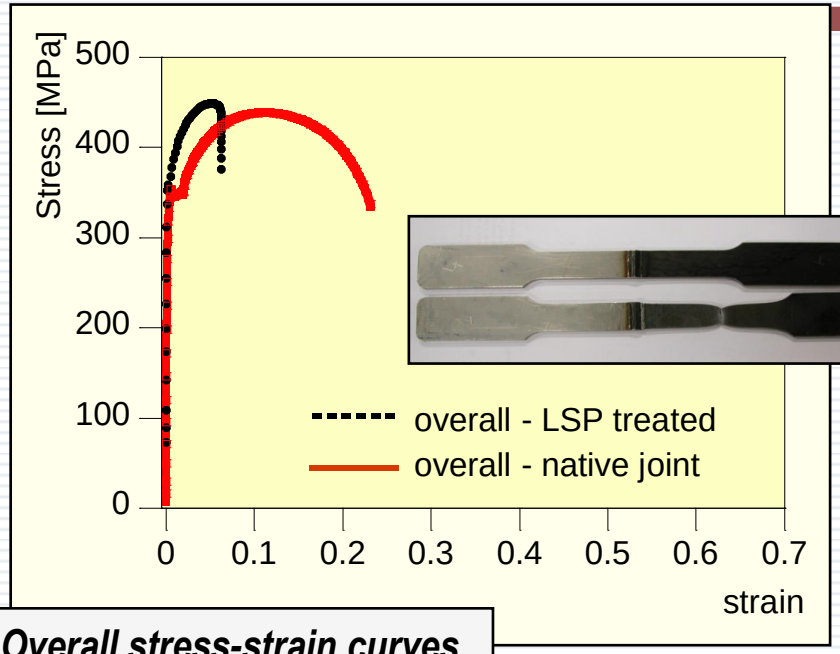
LSP treated



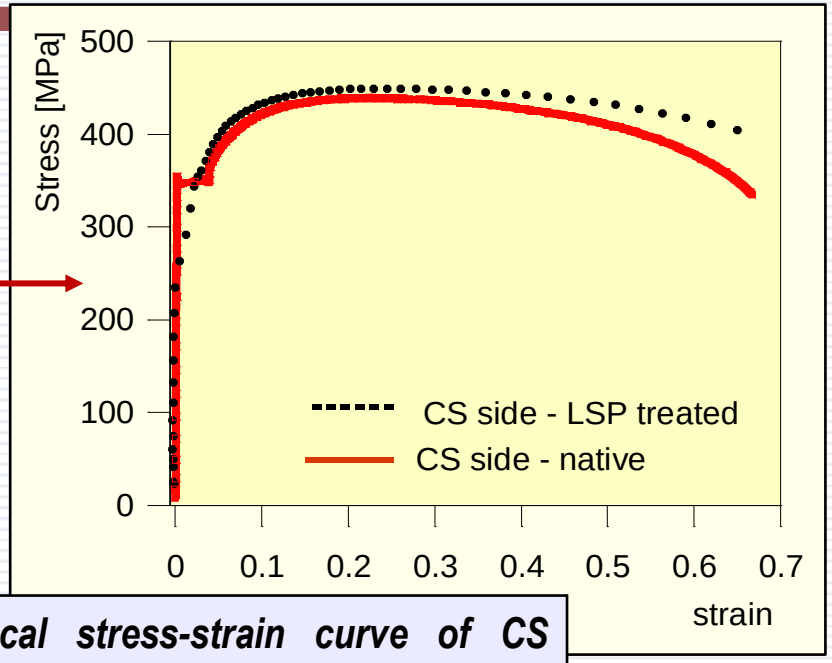
Overall strain –stress curves of the dissimilar joint

CS is the mechanical fusible of the joint rather than SS-HAZ

2. JOINT OVERALL AND LOCAL MECHANICAL PROPERTIES



Overall stress-strain curves



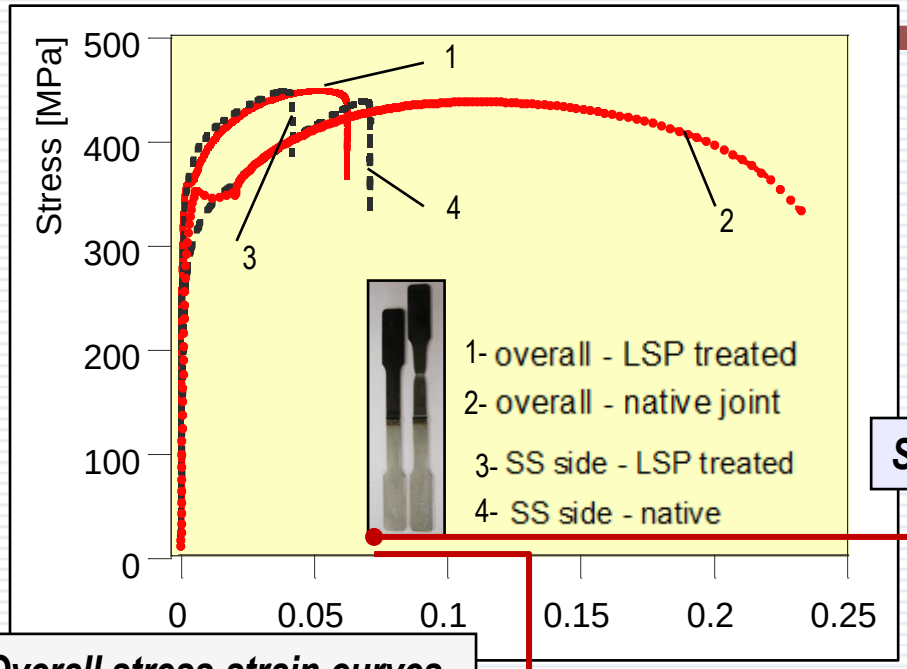
Local stress-strain curve of CS with and without LSP treatment

Joint elongation is mostly provided by CS

LSP preserves CS high ductility

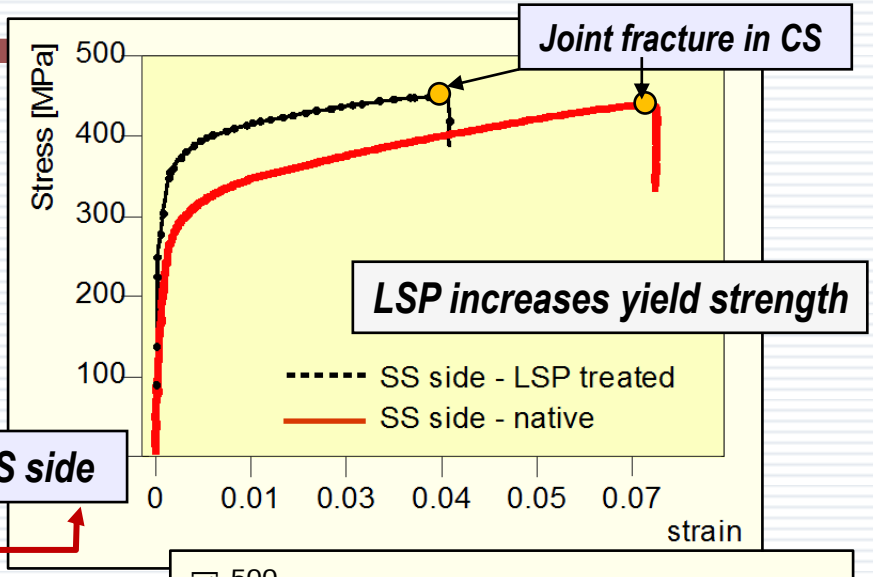
Residual stresses change yielding initiation

2. JOINT OVERALL AND LOCAL MECHANICAL PROPERTIES



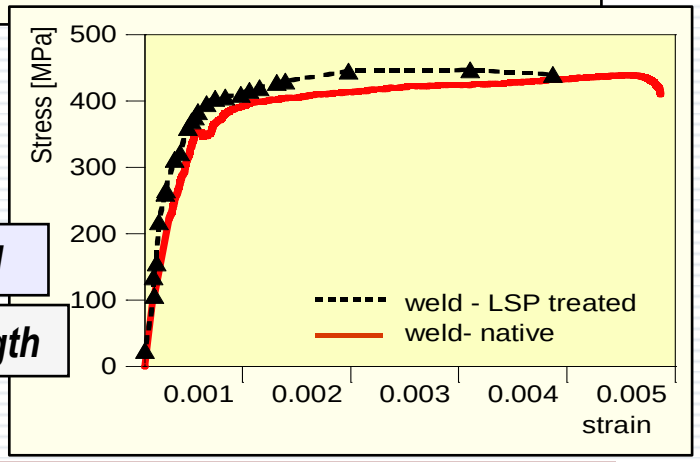
Overall stress-strain curves

SS side

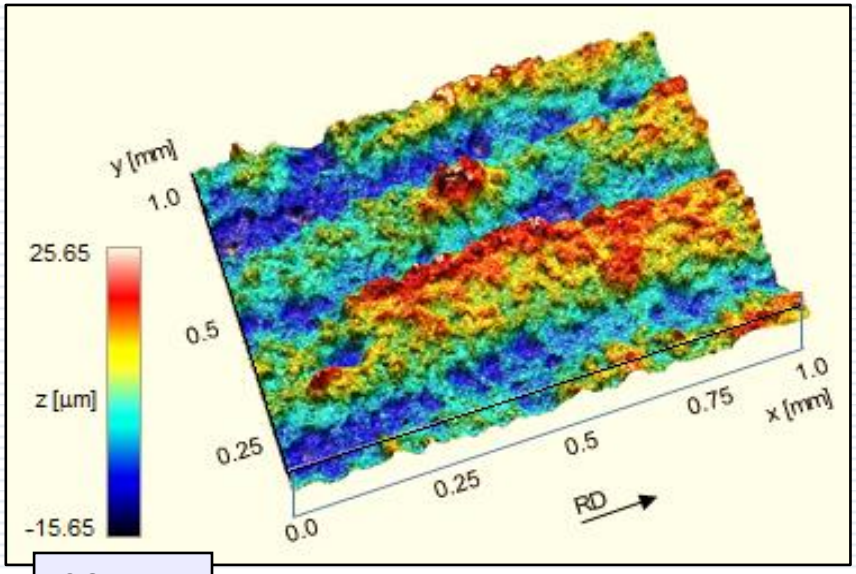


weld ≅ un-deformed

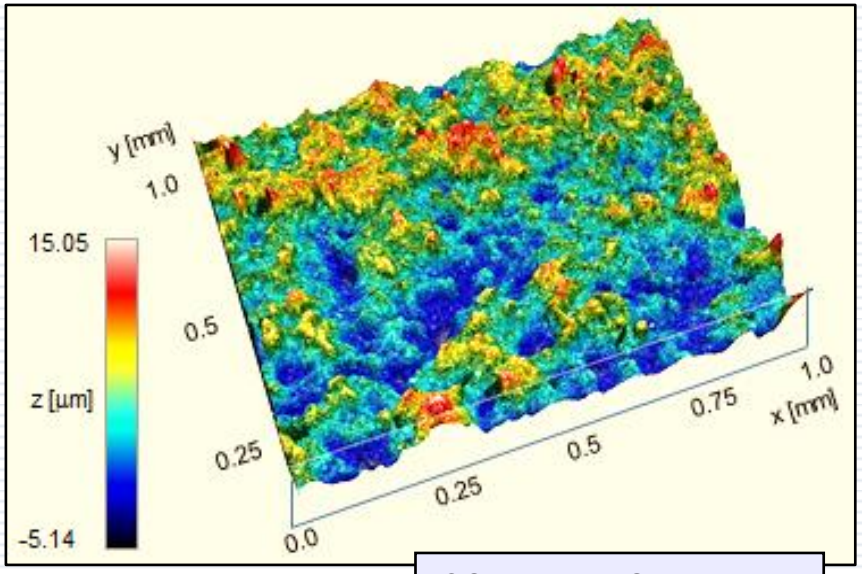
LSP preserves yield strength



3. LSP EFFECT ON CS - LOCAL PROPERTIES
(CS - side ROUGHNESS)



CS side



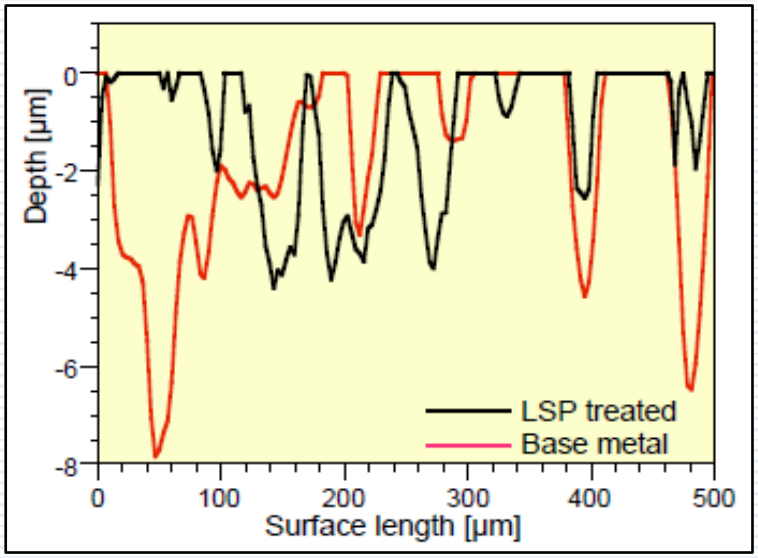
CS side – LSP treated

Roughness is slightly decreased by LSP

Processing parameters

Spot overlapping = 1600 pulses/cm²

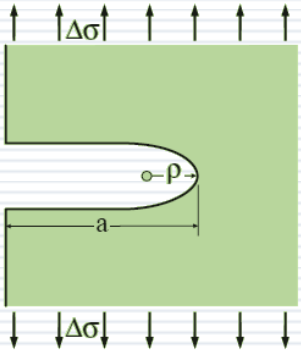
3. LSP EFFECT ON CS - LOCAL PROPERTIES
(CS - side ROUGHNESS)



Depth of surface cavities and irregularities

Fatigue limit prediction:

Macroscopic notch models [1] can explain the fatigue strength improvement induced by LSP on the basis of roughness changes



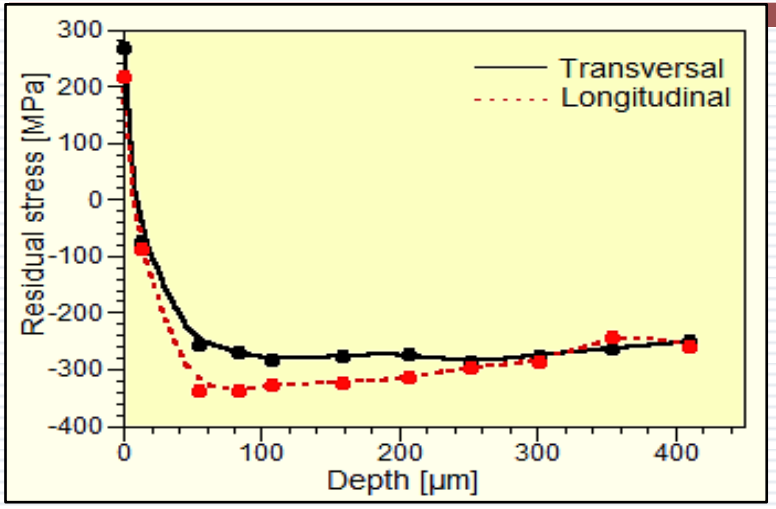
$$\Delta\sigma_f = \frac{0.435 R_m}{\sqrt{\frac{a}{\rho} - \frac{1}{2}}}$$

[1] Barsom, J.M. and McNicol, R. C. *Effect of stress concentration on fatigue-crack initiation in HY-130 Steel, ASTM-STP 559*, ASTM, Philadelphia (USA), 1974.

$\Delta\sigma_f$ is proportional to tensile strength R_m but it decreases with the notch aspect ratio a/ρ

LSP decreases the aspect ratio a/ρ of roughness profile, then LSP would improve fatigue strength

3. LSP EFFECT ON CS - LOCAL PROPERTIES
(CS - side RESIDUAL STRESSES)

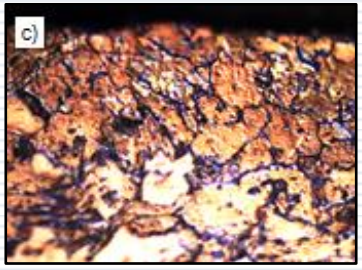


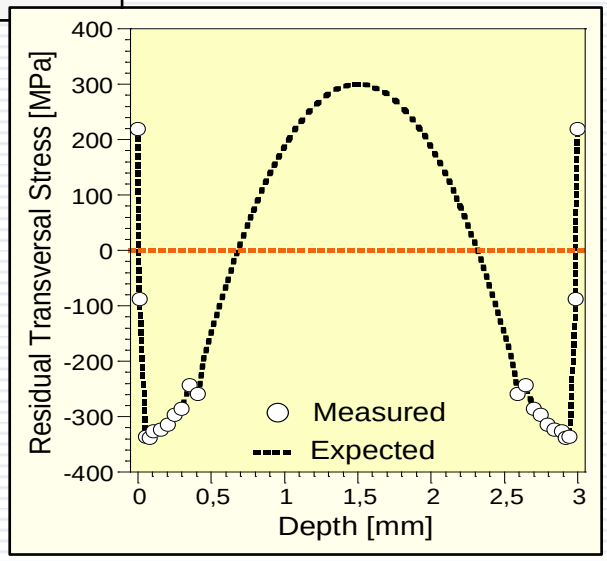
LSP effects:

Microstructure changes

Hardening

Surface residual stresses (DRX measurements)





Surface residual stresses in CS might induce:

- **Short crack arresting when propagating from surface**
- **Significant tensile residual stresses at the middle of the plate to balance the near-surface compressive residual stresses**

4. CONCLUSIONS

- *VIC method was proved efficient for assessing the overall mechanical resistance of the dissimilar joint and of base metals, CS and SS, native and LSP treated showing the difference in yield between the weld and the base materials*
- *CS acts as a mechanical fusible of the joint, protecting the SS side joint; LSP is locally increasing its resistance.*
- *LSP treatment slightly improves the surface roughness of the joint CS-side and induces a superficial compressive residual stress field which delays/arrest fatigue cracking from the joint surface*

THANK YOU !

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