Effect of LSP treatment on the surface topography, friction and wear of Al2024

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- Experimental Procedure
- Experimental Results
  - Surface Roughness
  - Residual Stresses
  - Friction
  - Wear
  - EDX
- Conclusions

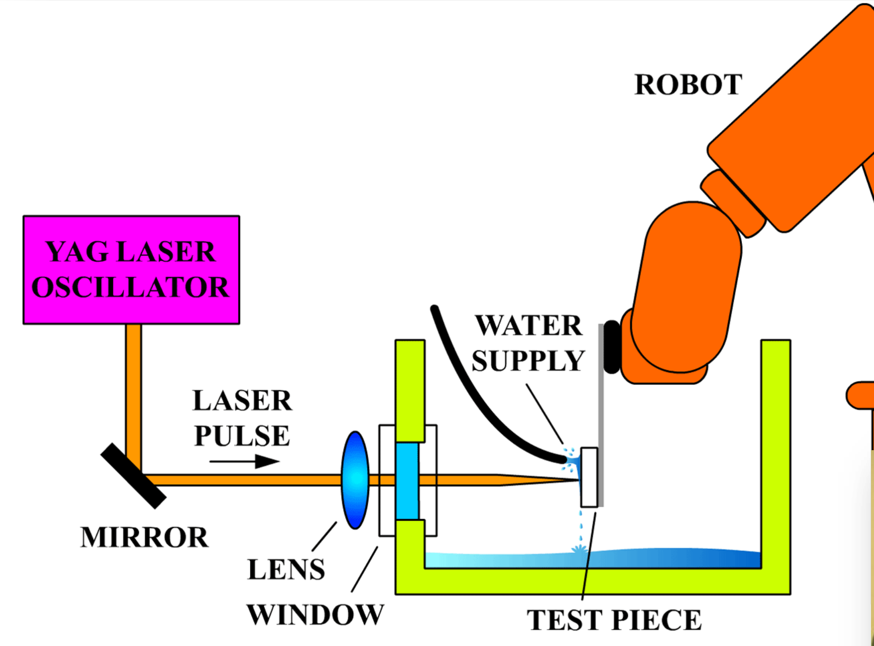
INTRODUCTION

- Laser Shock Processing (LSP) is being increasingly applied as a technique allowing the effective induction of residual stresses fields in metallic materials, allowing a high degree of surface material protection against fatigue crack propagation, abrasive wear, chemical corrosion and other failure conditions, what makes the technique specially suitable and competitive, with presently use techniques for the treatment of heavy duty components in the aeronautical, nuclear and automotive industries.

- According to the inherent difficulty for the prediction of the shock waves generation (plasma) and evolution in treated materials, the practical implementation of LSP processes needs an effective predictive assessment capability, coupled to a readily controllable experimental setup for a correct application of treatment parameters, and an associate material properties characterization capability.

- In the present communication, the effect of LSP treatment on the surface topography, friction and wear of Al2024 alloy are presented along with selected results.

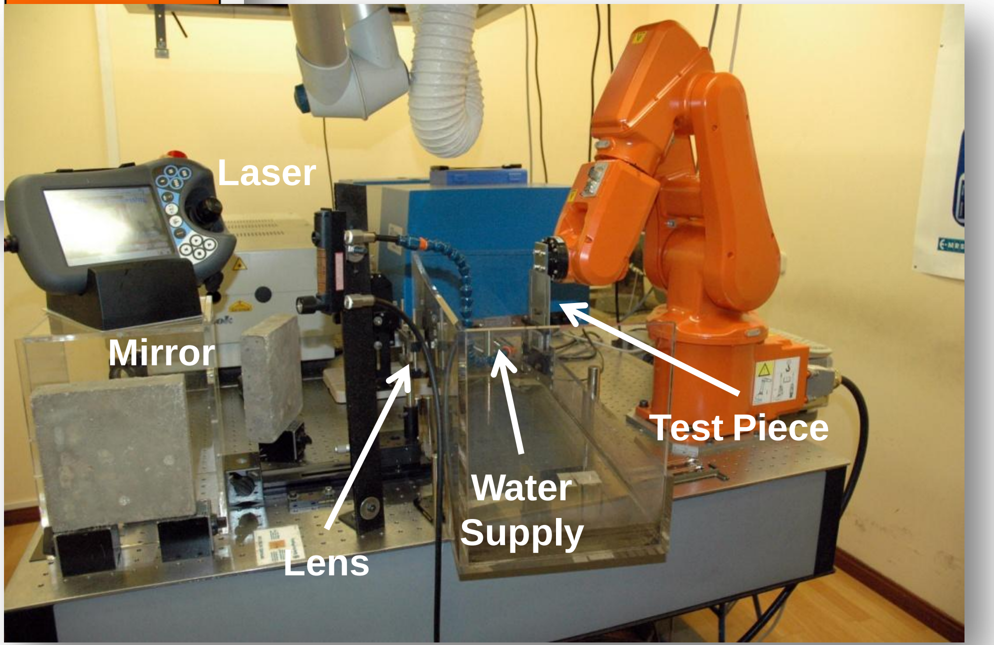
EXPERIMENTAL SETUP



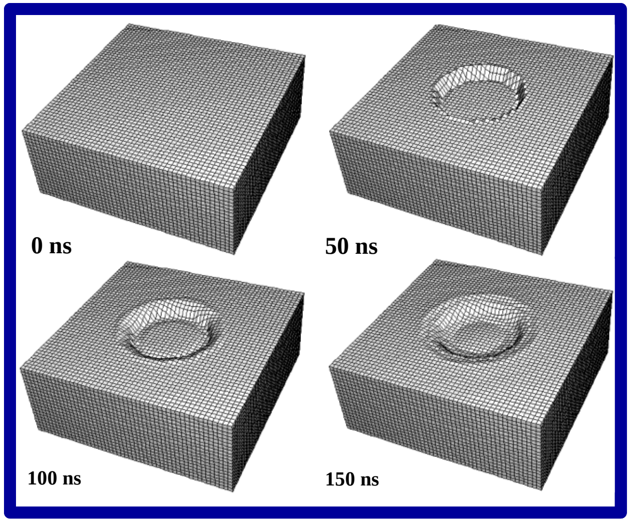
Q-SWITCHED Nd:YAG LASER

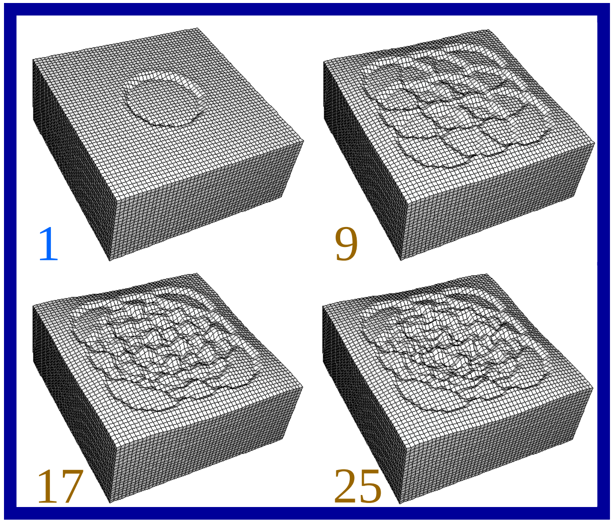
- λ = 1064 nm; E = 2.8 J/pulse
- λ = 532 nm; E = 1.4 J/pulse
- Frequency = 10 Hz

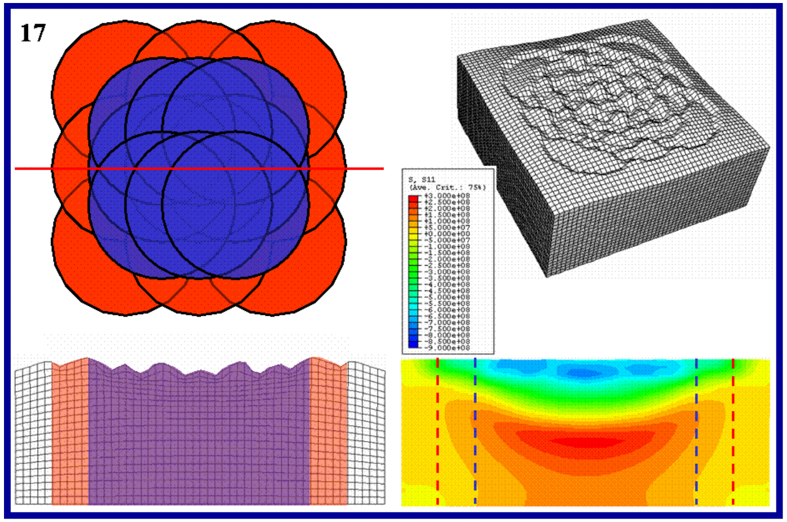
- No protecive coating
- Confining medium: Water

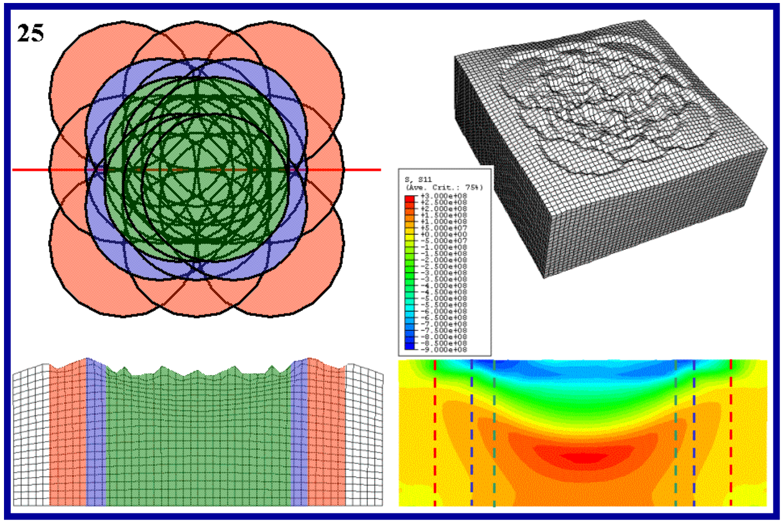


EXPERIMENTAL PROCEDURE









EXPERIMENTAL PROCEDURE

Material: Al2024-T351

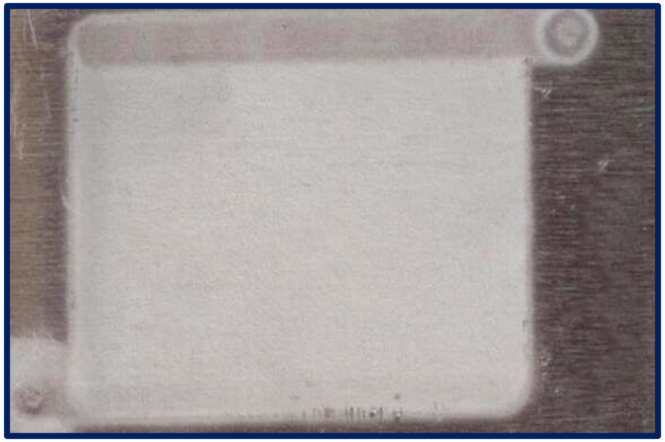
Composition (%)								
Al	**Cr**	**Cu**	**Fe**	**Mg**	**Mn**	**Si**	**Ti**	**Zn**
90.7 - 94.7	0.10	3.8 - 4.9	0.50	1.2 - 1.8	0.3 - 0.9	0.50	0.15	0.25

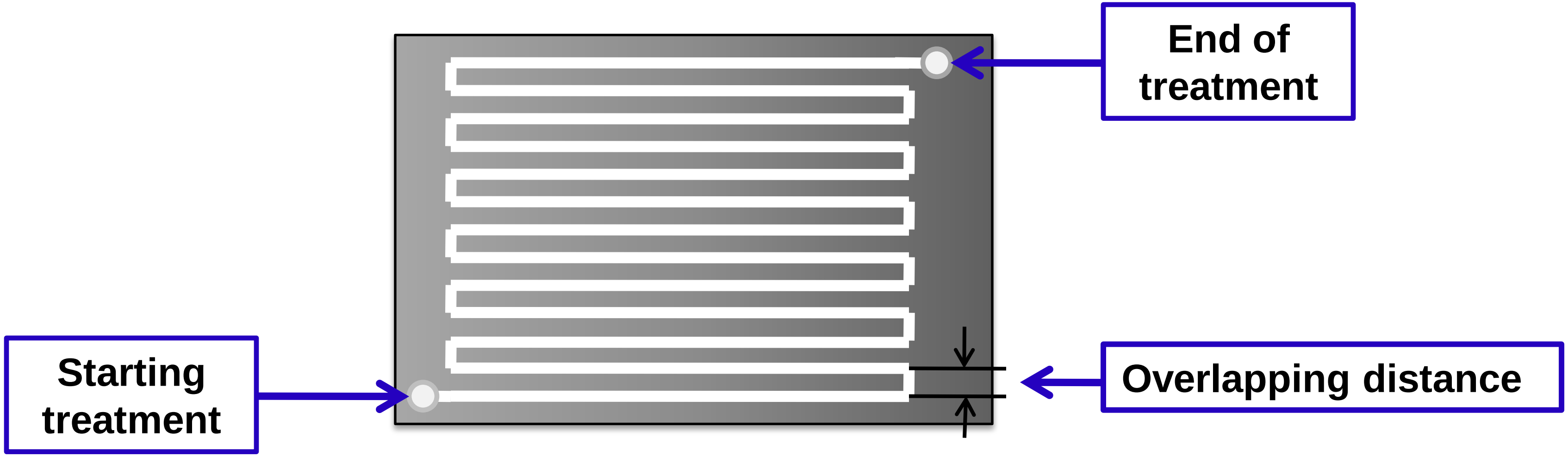
Mechanical Properties	
Vickers Hardness	137
Ultimate Tensile Strenghth	469 MPa
Tensile Yeild Strength	324 MPa
Elongation at Break	20 %
Modulus of Elasticity	73.1 GPa

Al2024 Microestructure (Optical microscopy)

EXPERIMENTAL PROCEDURE

Treated samples: Al2024-T351



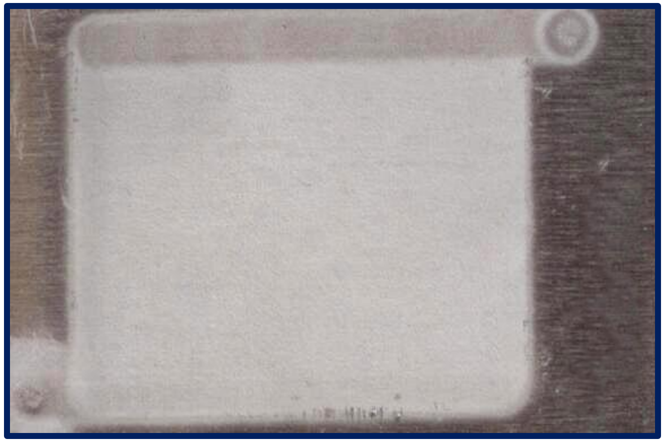


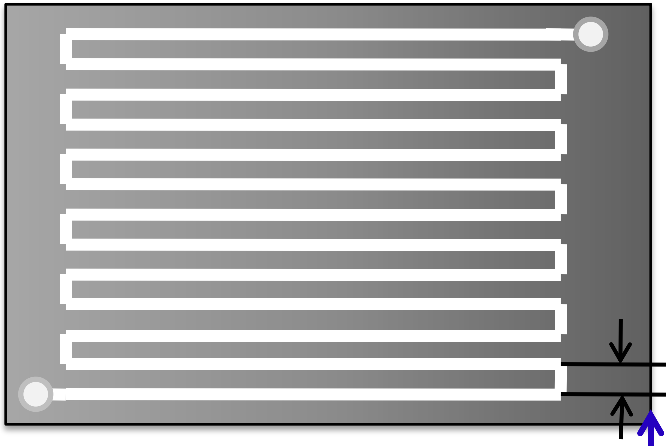
End of treatment

Starting treatment

Overlapping distance

EXPERIMENTAL PROCEDURE





Overlapping distance

Overlapping distance (mm)	Equivalent overlapping density (pulses/cm^2)
0.40	625
0.33	900
0.25	1600
0.20	2500

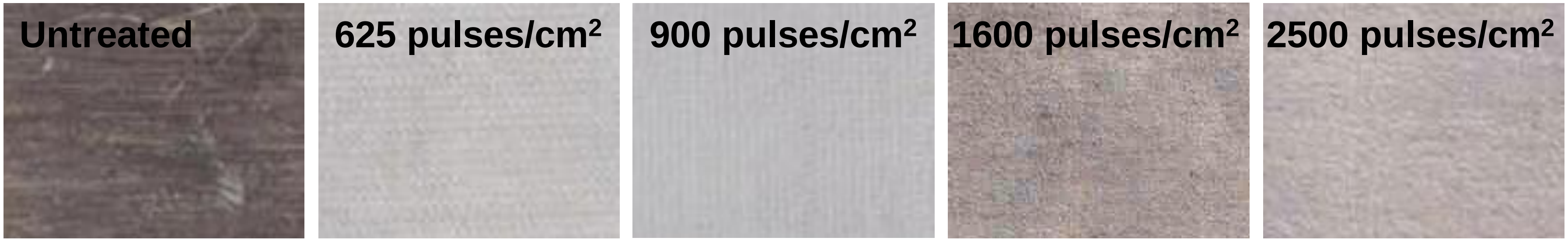
Relation between overlapping distance and equivalent number of pulses per unit surface corresponding to the defined treating.

EXPERIMENTAL RESULTS

- **Material: Aluminium 2024 T3, as received, without polished.**

- **Pulses**
  - **Diameter = 1.5 mm**
  - **τ = 9 ns**
  - **Energy per pulse = 2.8 J/pulse**

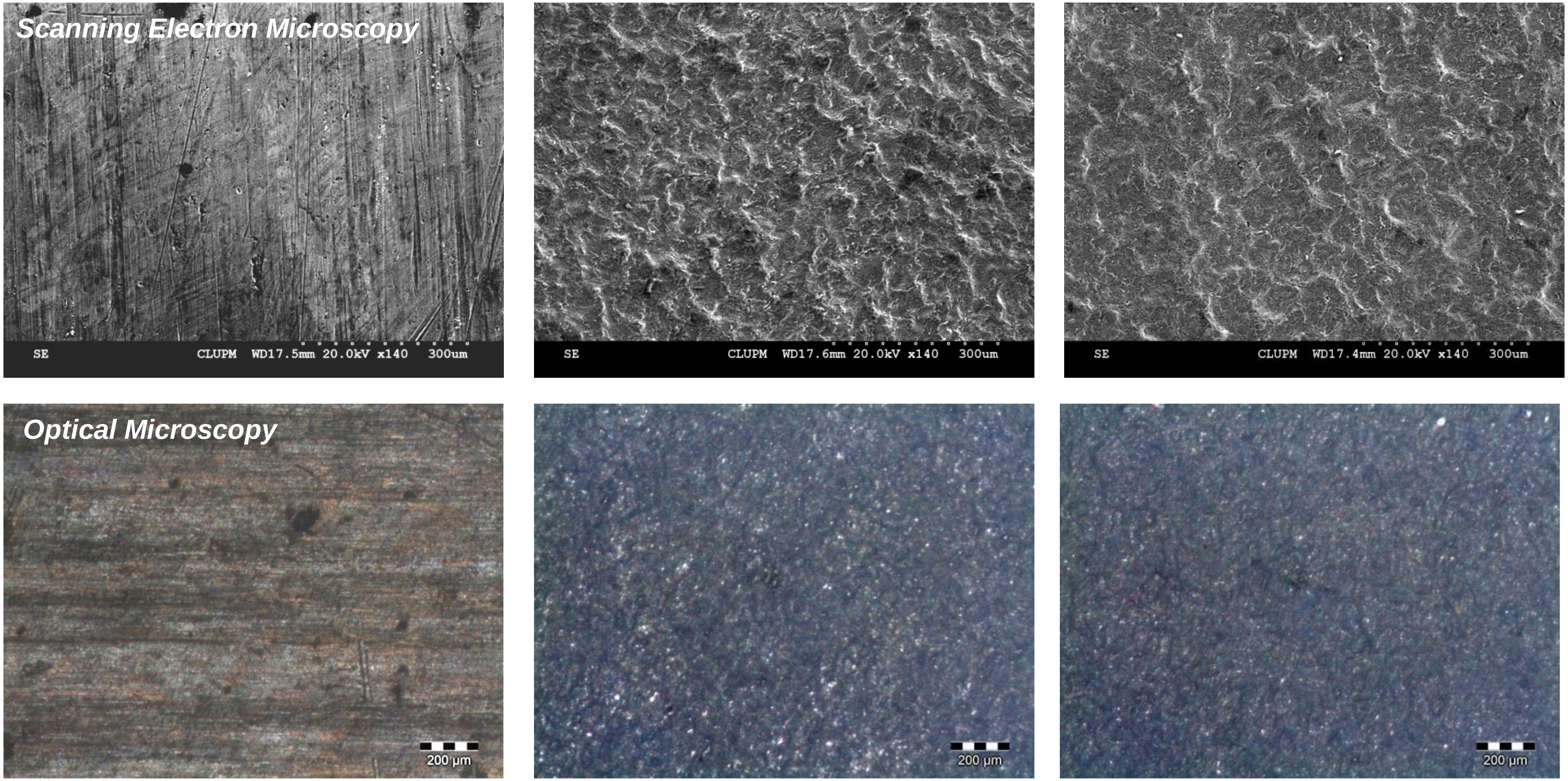
- **Treated area: 45 x 50 mm^2; 625, 900, 1600 and 2500 pulses/cm^2.**



Optic microscopy: Al2024-T351

EXPERIMENTAL RESULTS

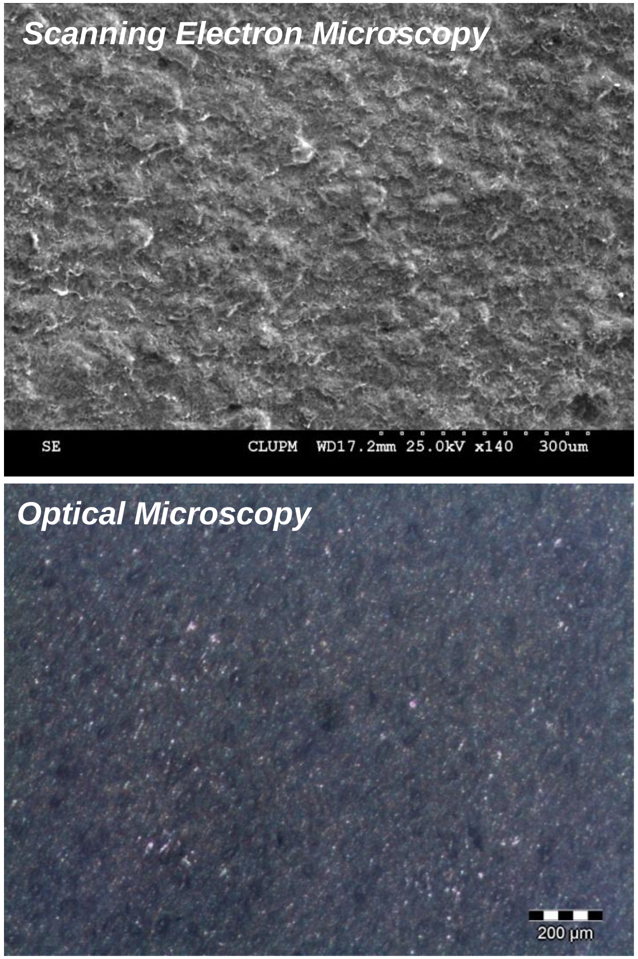
Surface Roughness (Microscopy): Al2024-T351



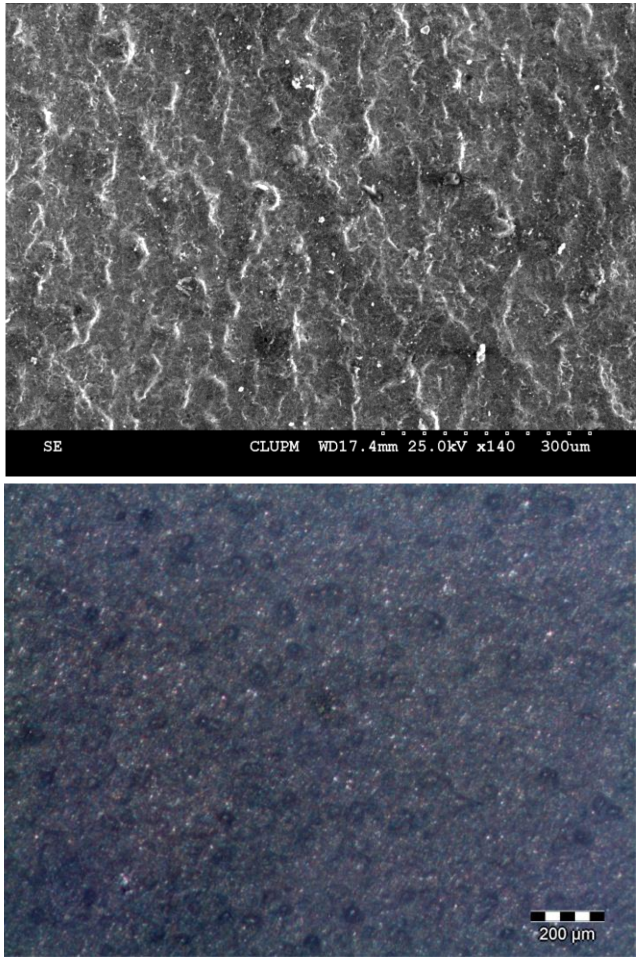
No Treatment **625 pulses/cm^2** **900 pulses/cm^2**

EXPERIMENTAL RESULTS

Surface Roughness (Microscopy): Al2024-T351



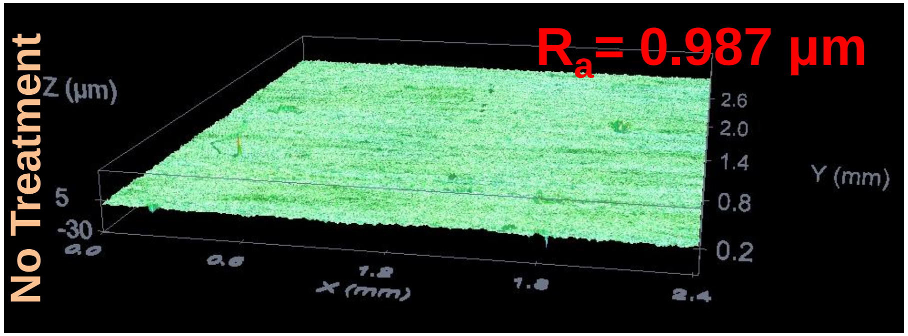
1600 pulses/cm^2

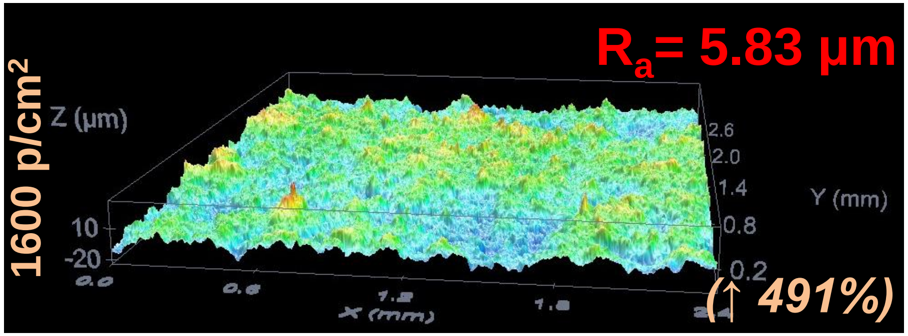


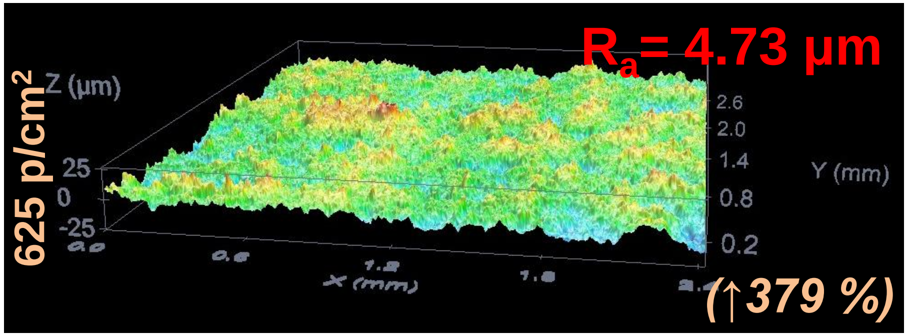
2500 pulses/cm^2

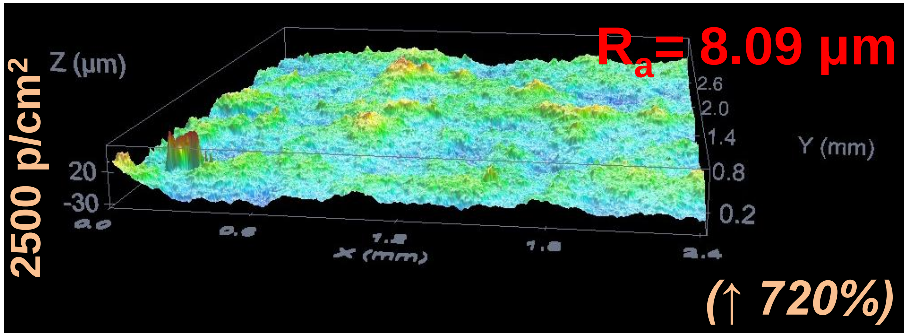
EXPERIMENTAL RESULTS

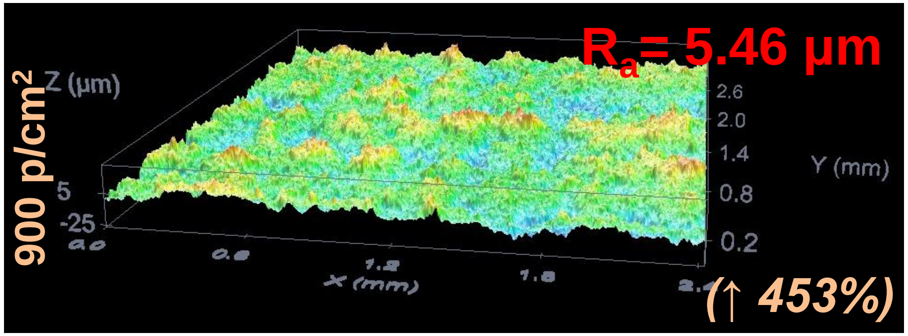
Surface Roughness (Topographic Confocal Microscopy): Al2024-T351







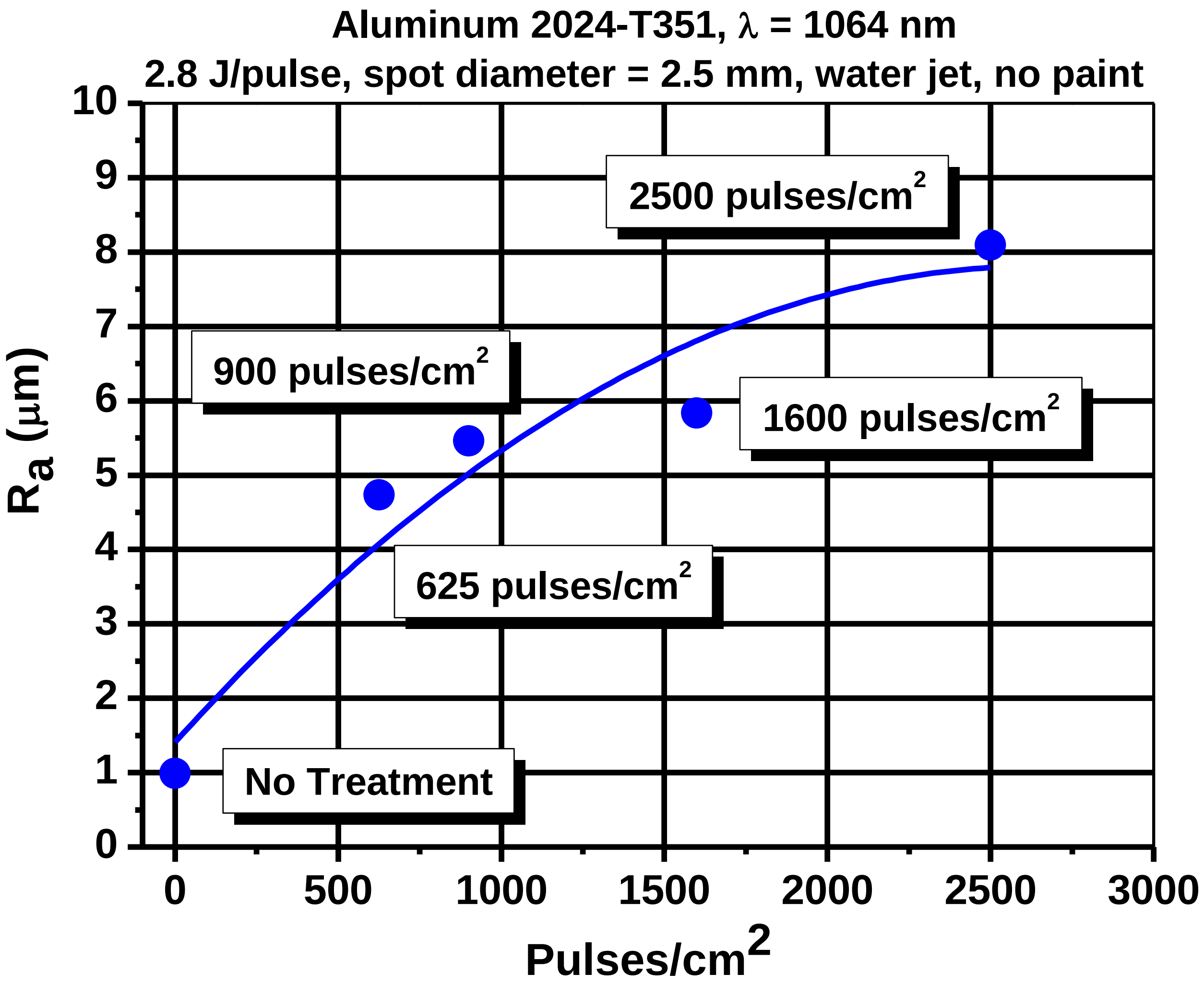




R_a is the average of the absolute values of the profile heights measured from a mean line averaged over the profile.

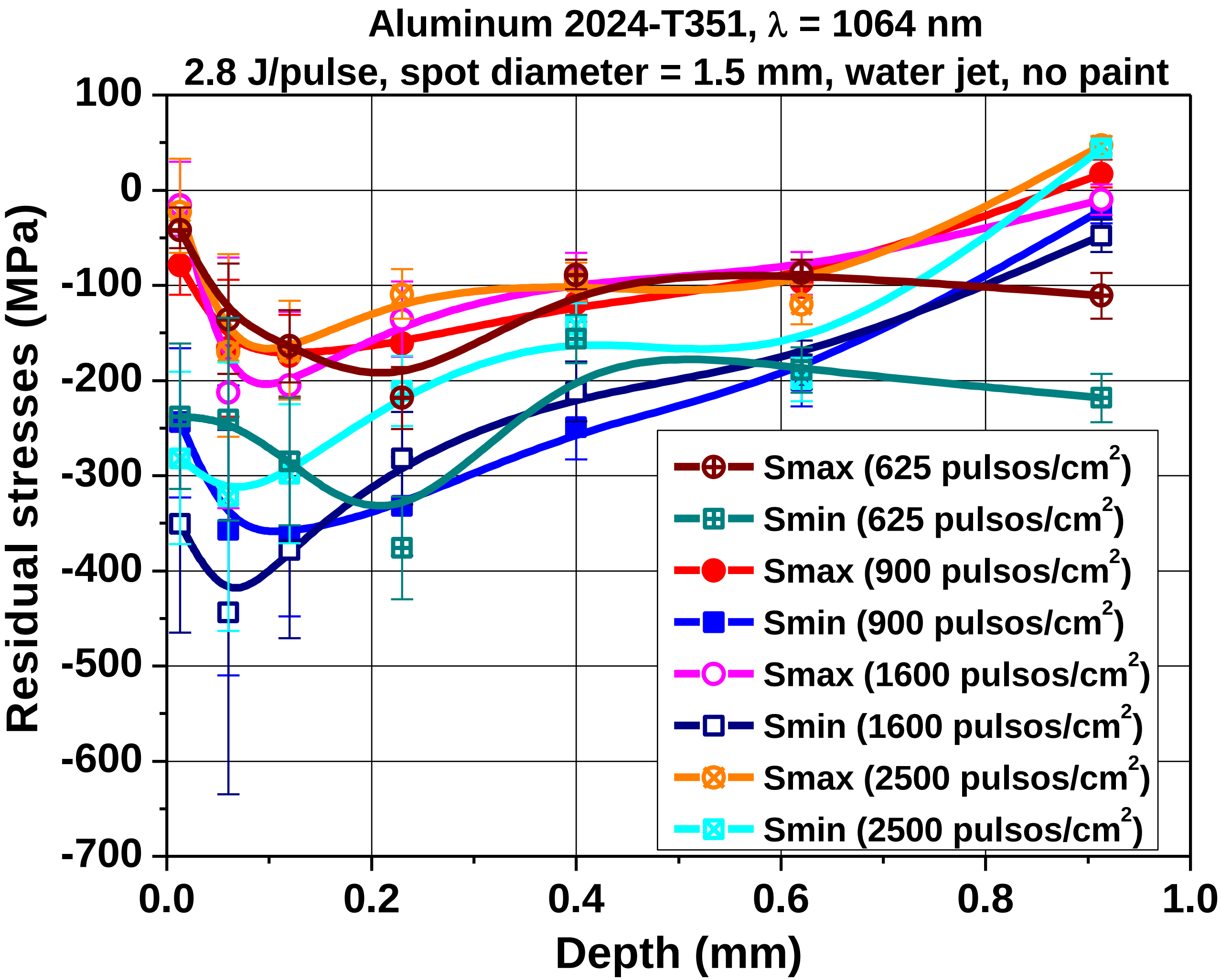
EXPERIMENTAL RESULTS

Surface Roughness (Topographic Confocal microscopy): Al2024-T351



EXPERIMENTAL RESULTS

Residual Stress Distribution (According to ASTM E837-08)



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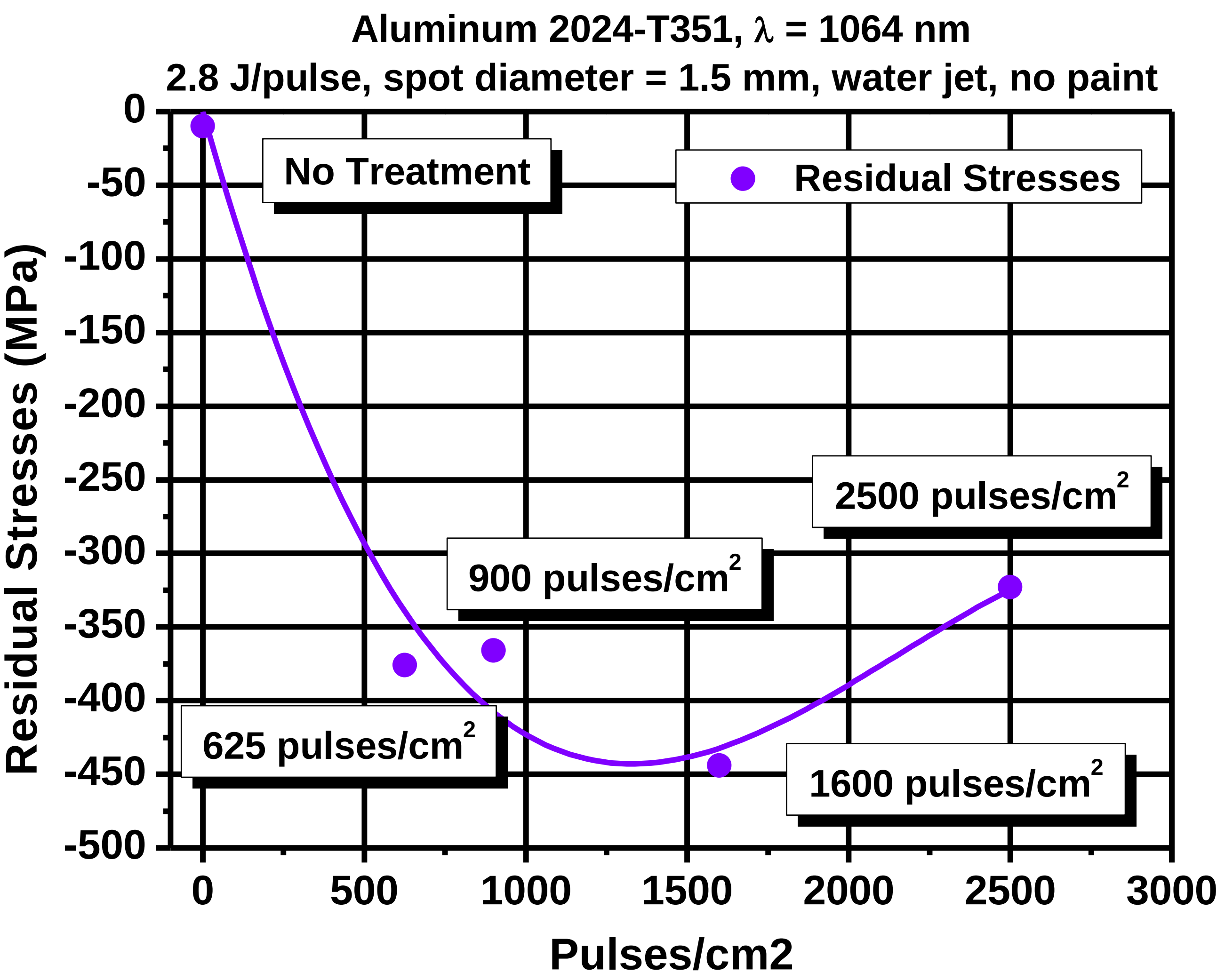
EXPERIMENTAL RESULTS

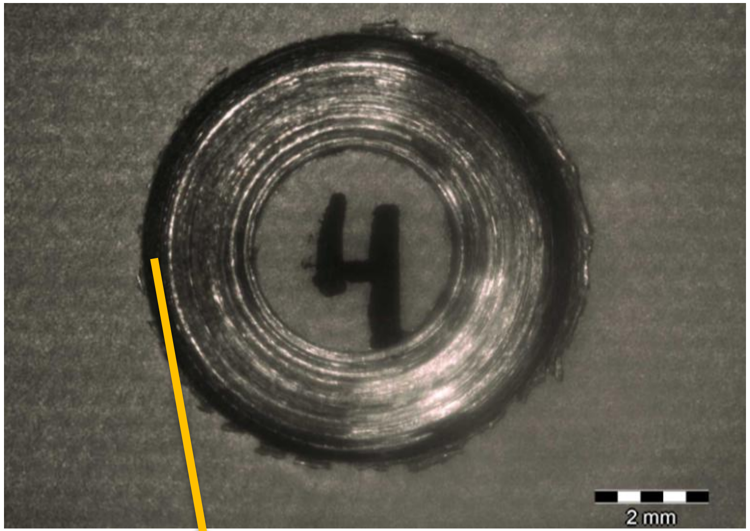
Maximum Compressive Residual Stress (According to ASTM E837-08)

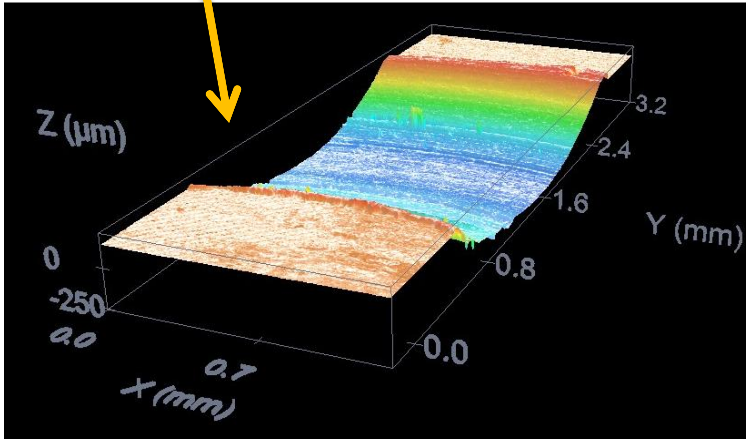


EXPERIMENTAL RESULTS

Friction and Wear

Pin	SS AISI 52100	Tungsten Carbide (WC)
Speed (rpm)	300	300
Speed (m/s)	0.0785	0.0785
Normal Force (N)	**30**	**20**
Sliding distance (m)	1000	1000
Revolutions	63700	63700
Track Radio (mm)	2.5	2.5
Pin Diameter (mm)	3	3

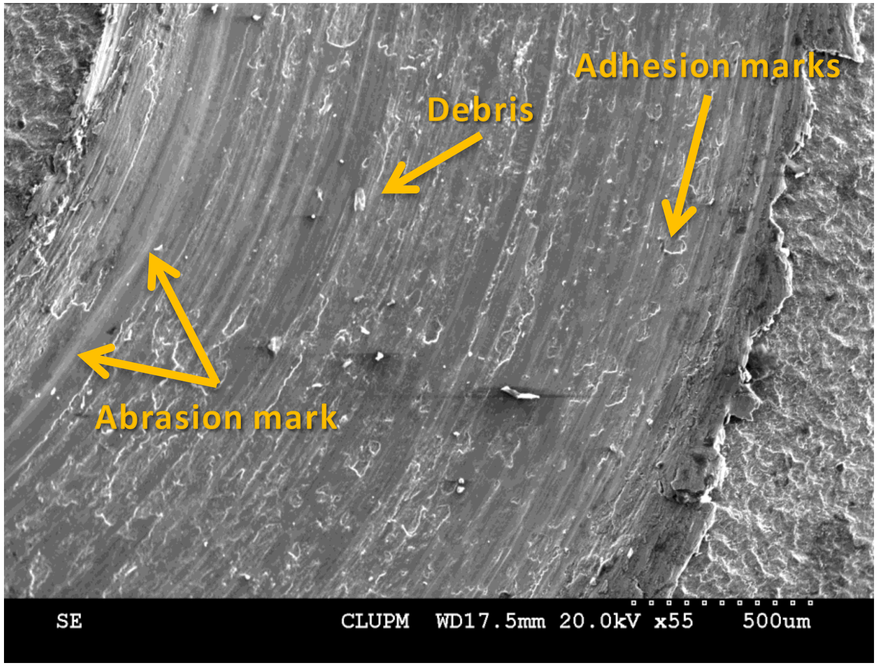


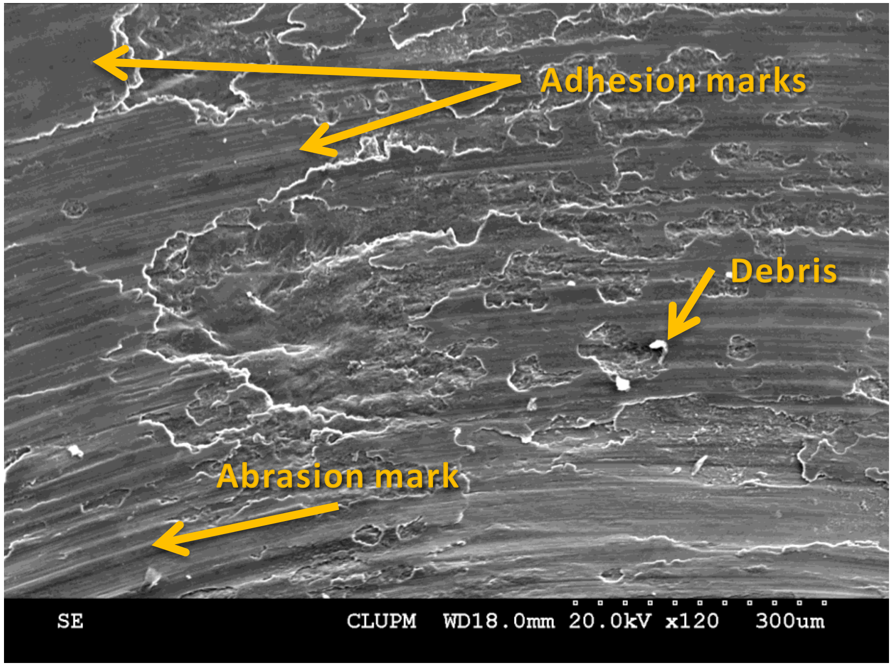


Pin-on-disk tribometer

EXPERIMENTAL RESULTS

Friction and Wear: SEM images of wear scar

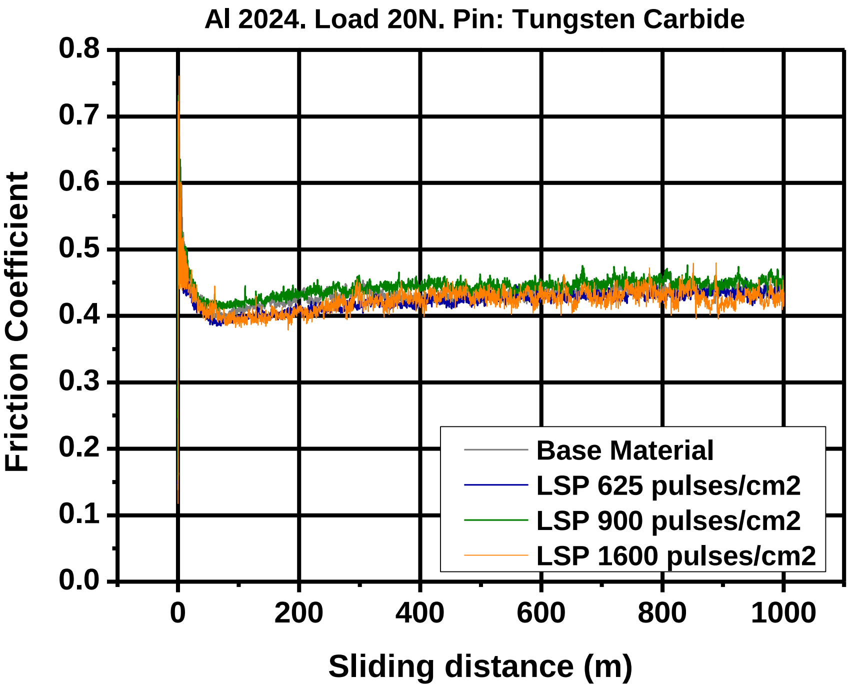




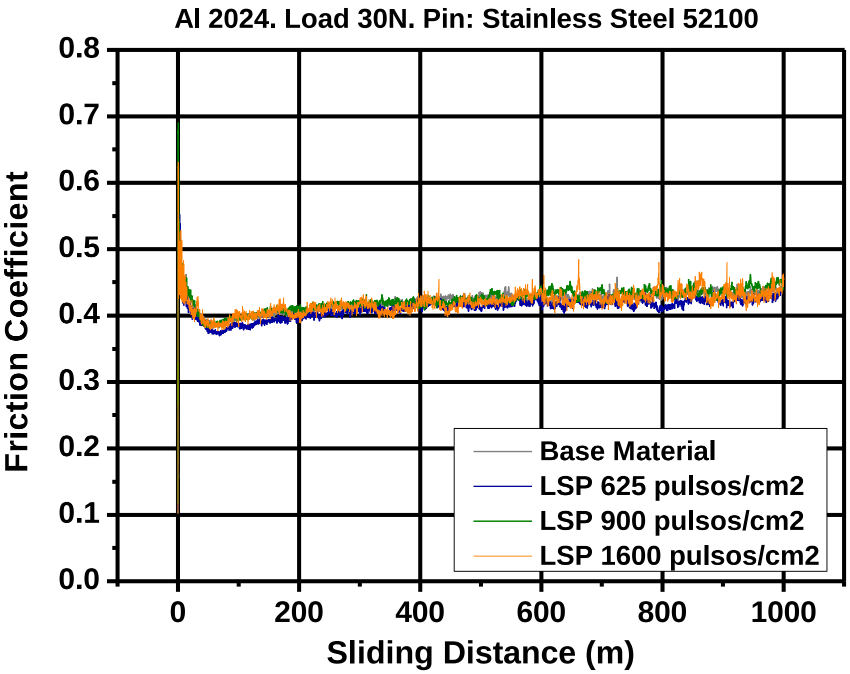
- From SEM images similar wear marks can be observed in both, untreated and LSP treated specimen.
- The wear scar shows the presence of adhesive wear caused by relative motion, direct contact and plastic deformation between two bodies.
- Also debris is observed. It is suggested that after reaching the maximum value of the coefficient of friction, adhesive wear starts, creating wear debris and material transfer from one surface to another.
- Abrasion marks are made by solid particles in the friction zone.

EXPERIMENTAL RESULTS

Friction (According to ASTM G99-04)



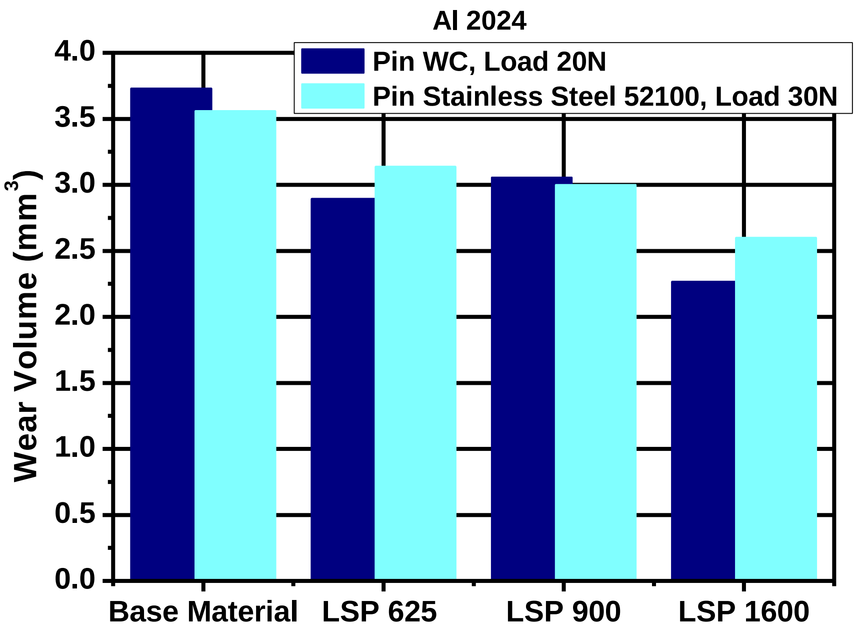
Load 20N. Pin: Tungsten Carbide

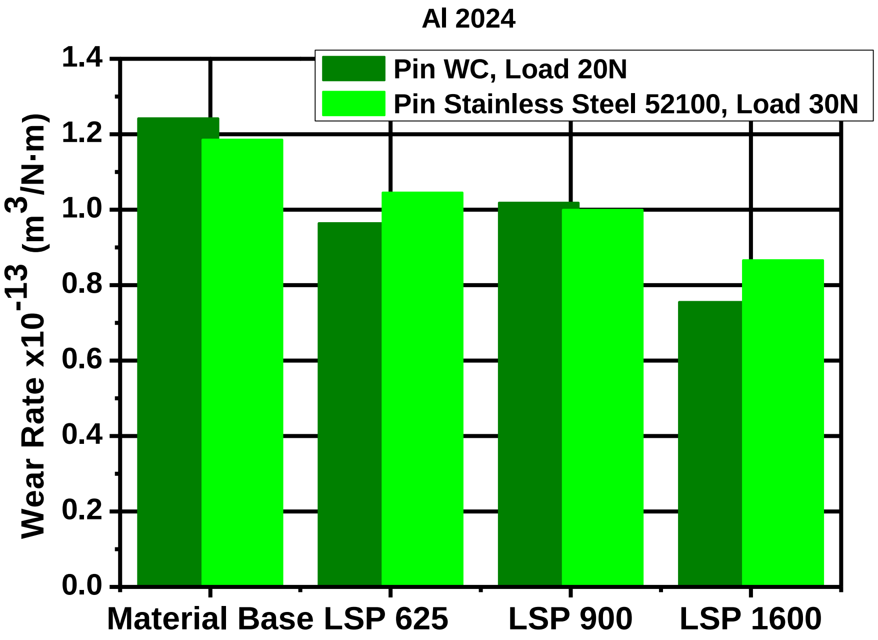


Load 30N. Pin: Stainless Steel 52100

EXPERIMENTAL RESULTS

Wear Resistance (According to ASTM G99-04)





Pin WC and *20N*:
- With *LSP625* the worn volume is ***22 %*** less than BM.
- With *LSP900* the worn volume is ***18 %*** less.than BM.
- With *LSP1600* the worn volume is ***39 %*** less than BM.

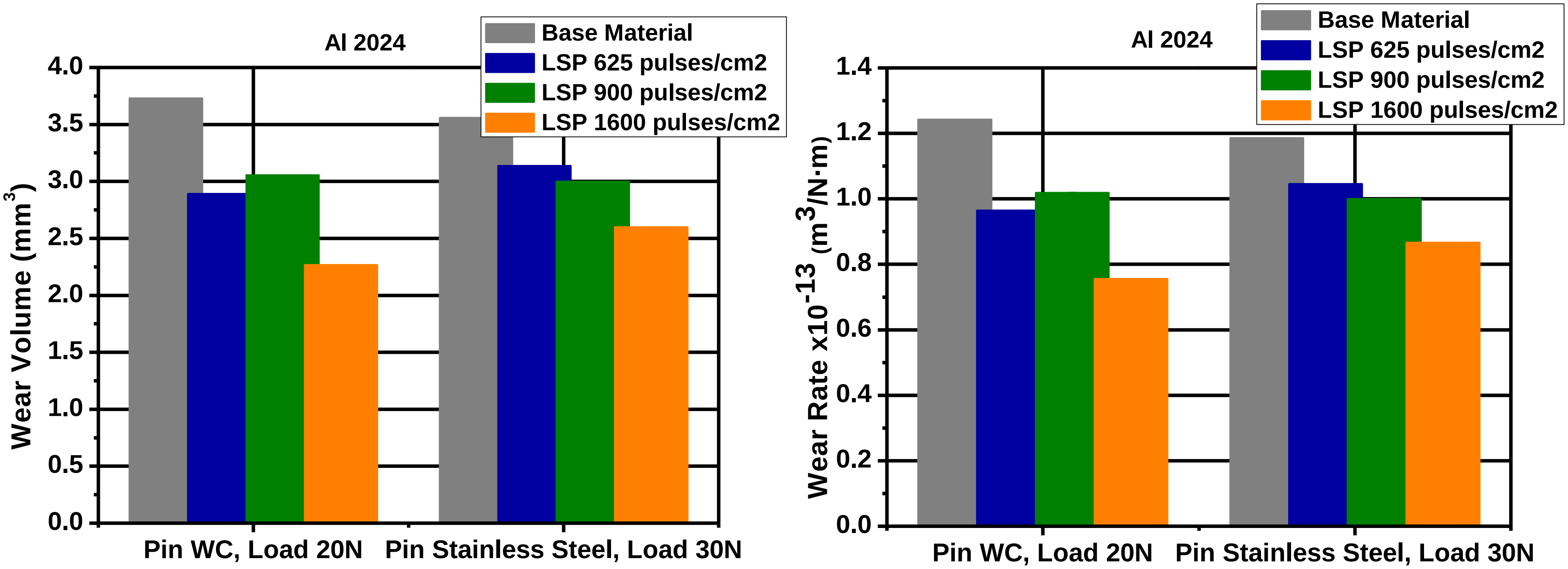
Pin AISI 52100 and 30N
- With *LSP625* the worn volume is ***12 %*** less than BM.
- With *LSP900* the worn volume is ***16 %*** less than BM.
- With *LSP1600* the worn volume is ***27 %*** less than BM.

Pin WC and 20N
- *LSP625* offers ***22 %*** more wear resistant than BM.
- *LSP900* offers ***18 %*** more wear resistant than BM.
- *LSP1600* offers ***39 %*** more wear resistant than BM.

Pin AISI 52100 and 30N
- *LSP625* offers ***12 %*** more wear resistant than BM.
- *LSP900* offers ***16 %*** more wear resistant than BM.
- *LSP1600* offers ***27 %*** more wear resistant than BM.

EXPERIMENTAL RESULTS

Wear Resistance (According to ASTM G99-04)

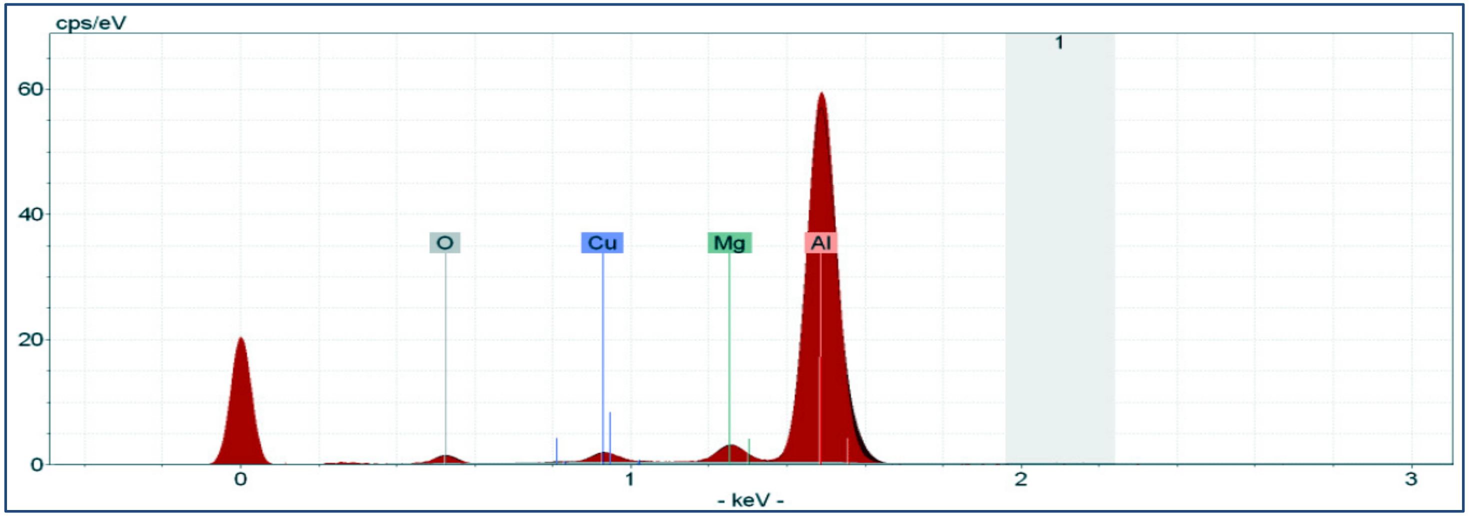


- **Not significant differences between two pins.**
- **The specimen treated with 1600 pulses/cm^2 is the most resistant wear, and is consistent with the residual stress distribution: this treatment (1600 p/cm^2) has the maximum value of compressive residual stress.**

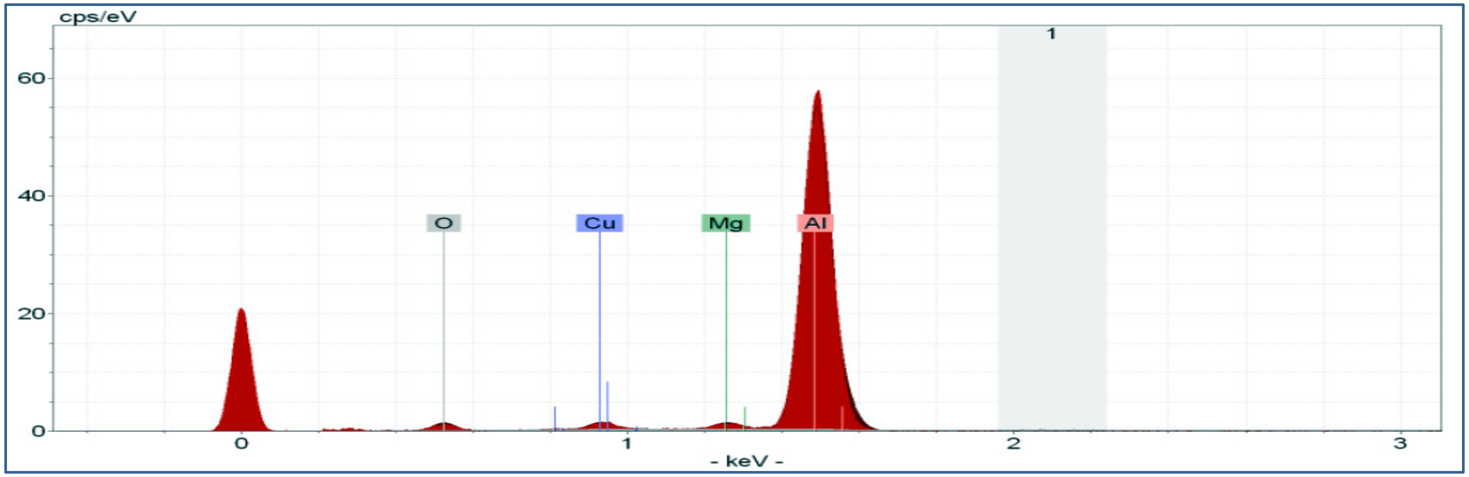
EXPERIMENTAL RESULTS

Energy Dispersive X-Ray (EDX)

Al 2024, Not Treated



Al 2024, Treated



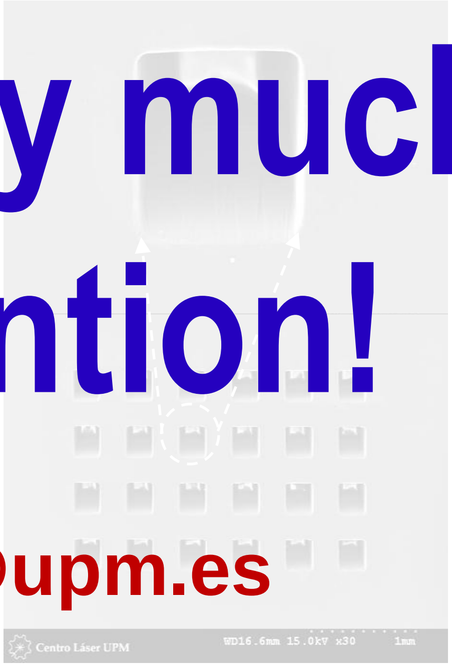
CONCLUSIONS

- In the context of this work, the surface modifications made in Aluminium 2024 have been characterized with different techniques. The roughness rises with the pulses density.

- The wear resistance has been measured. It has shown that the LSP treatment has improved the wear resistance due to the compressive residual stresses.

- Observing the SEM images obtained of the wear marks, it is seen that are similar in all cases. This leads to the conclusion that the mechanisms of wear are the same for the base material, and the material treated with shock waves generated by laser.

- An analytical analysis of the chemical composition in surface over treated and untreated samples, suggested that there are not significant difference.



Thank you very much for your attention!

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