



EADS INNOVATION WORKS

**LSP to improve the fatigue resistance of highly stressed
AA7050 components**



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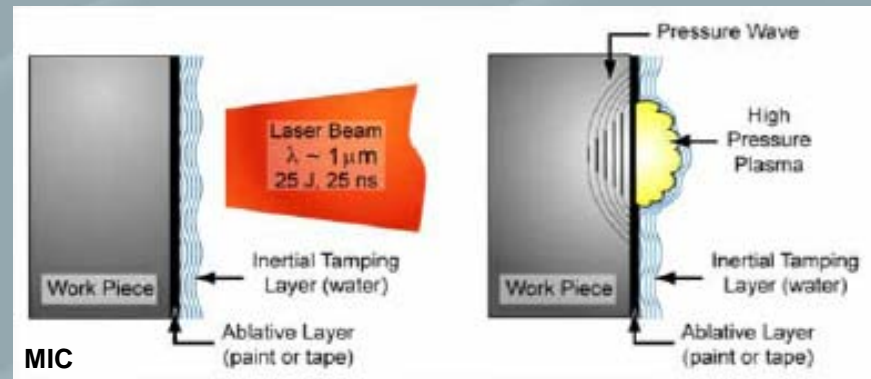
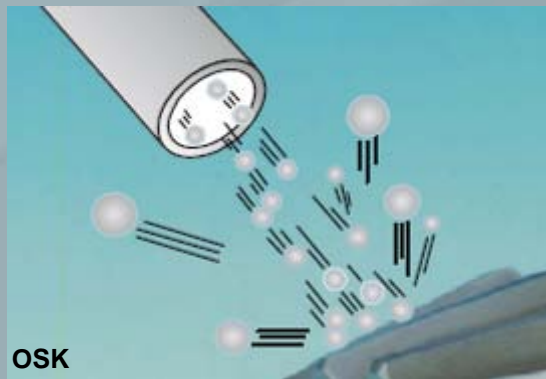
2nd International Conference on Laser Peening 2010, San Francisco

Outline

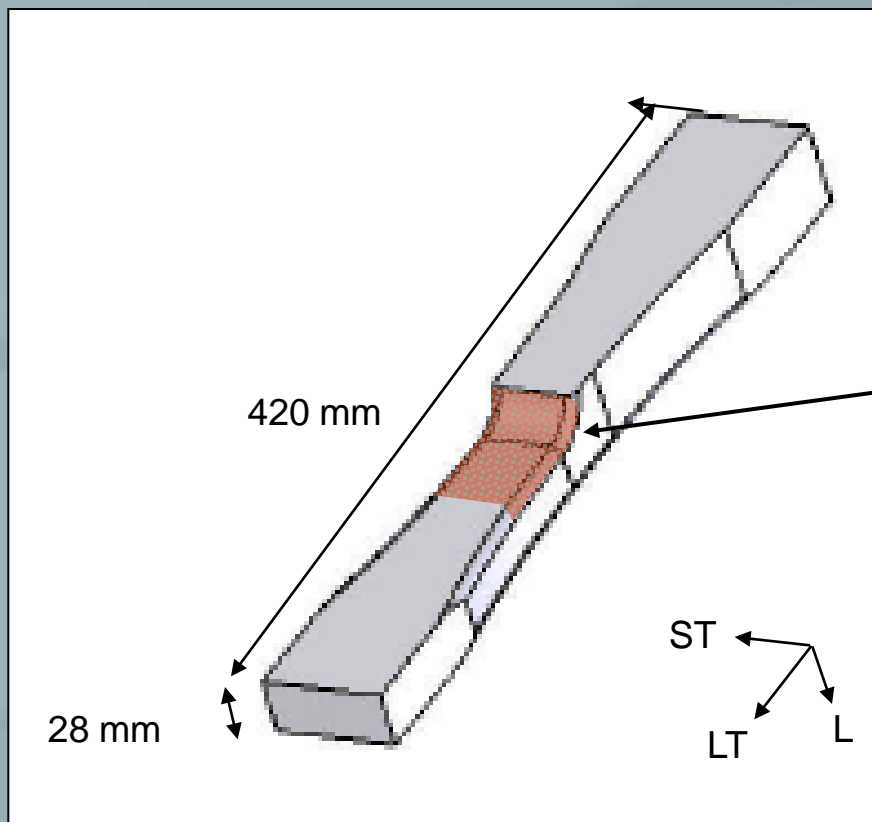
- Which kind of set-up has been chosen?
 - Specimen geometry
 - LSP parameters
- How do the LSP parameters influence the residual stress profile?
- How large is the fatigue life enhancement, esp. for SP and LSP?
- What is the reason for the fatigue life enhancement?
- Does the RS influence the crack initiation or the crack growth?
- What did we conclude?

Objective

- Improve the fatigue life of AA7050 components
- ➔ Improve the fatigue life via compressive residual stresses.
- ➔ Compare the fatigue life enhancement for different depths of the residual stresses introduced by:
 - the shot peening process,
 - the laser shock peening process.



Specimen geometry



Area treated
to introduce
residual stresses
- by shot peening (SP),
- by laser shock peening (LSP).

LSP Processing

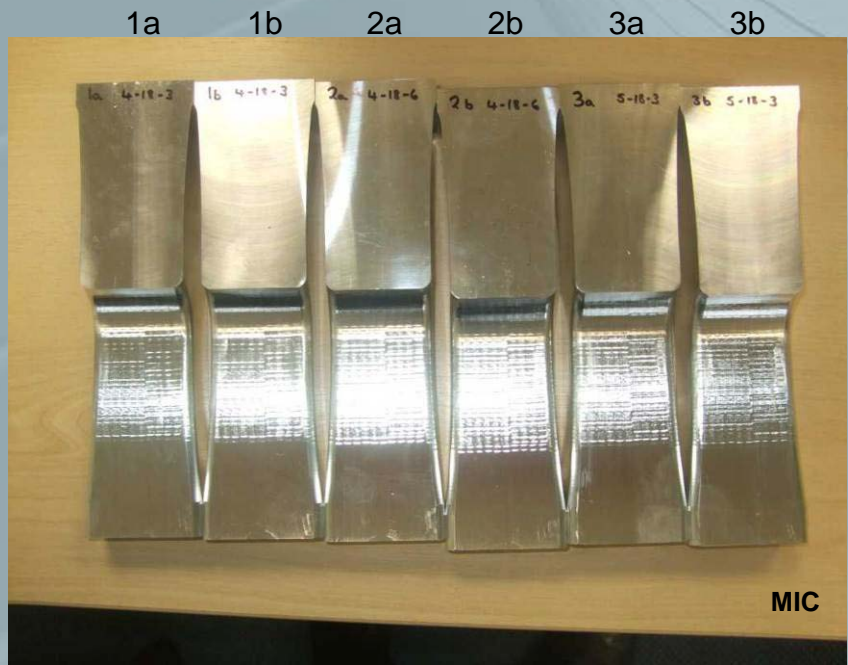
Parameters

Specimen 1a + 1b \Rightarrow 4 - 18 - 3 Pulse duration \swarrow
 Specimen 2a + 2b \Rightarrow 4 - 18 - 6
 Specimen 3a + 3b \Rightarrow 5 - 18 - 3 Number of layers \swarrow

Power [GW/cm²] \nearrow

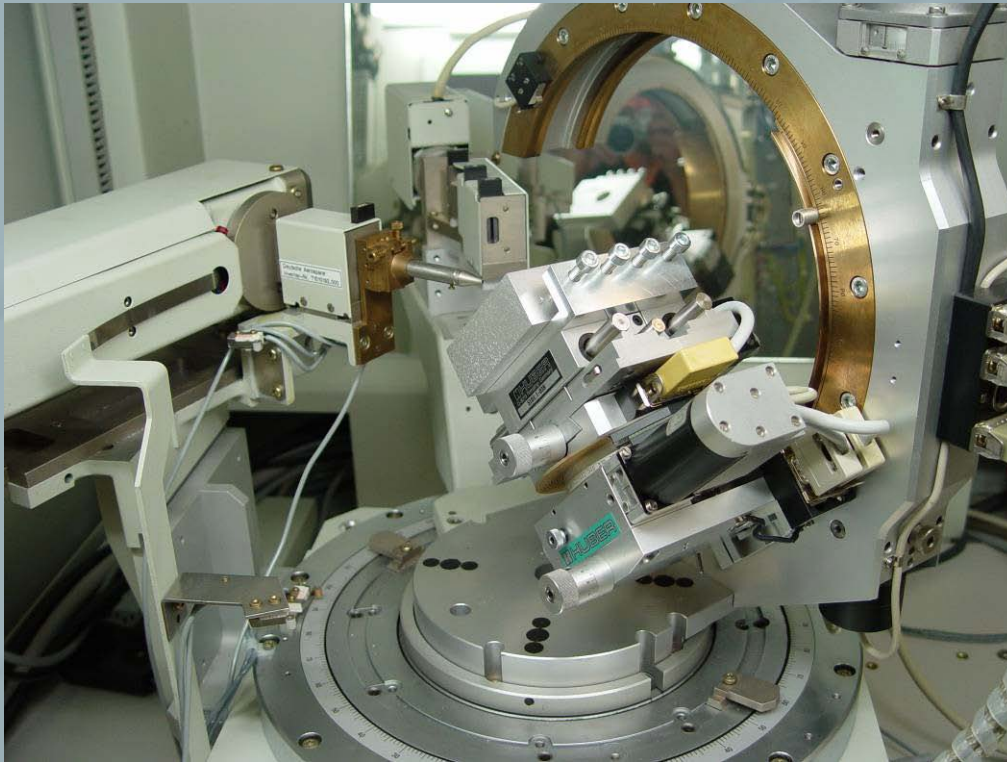


Distortion due to residual stresses (specimen 2b)



Top view of the delivered specimens

Residual stress measurement – XRD device



D5000

Euler Cradle

X-ray tube: Cu 1.5406

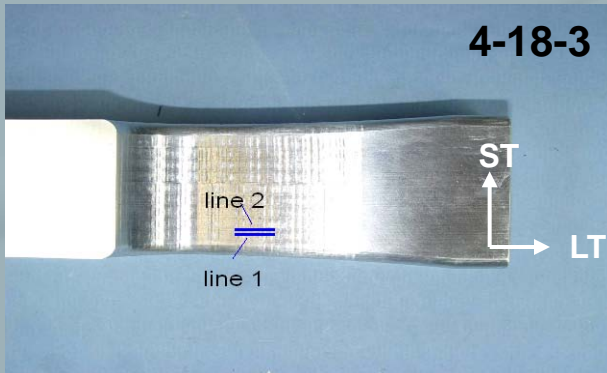
**Peak location method:
Sliding gravity.**

**Reflection Al-peak used:
[4,2,2] at 2Θ : 137.5°**

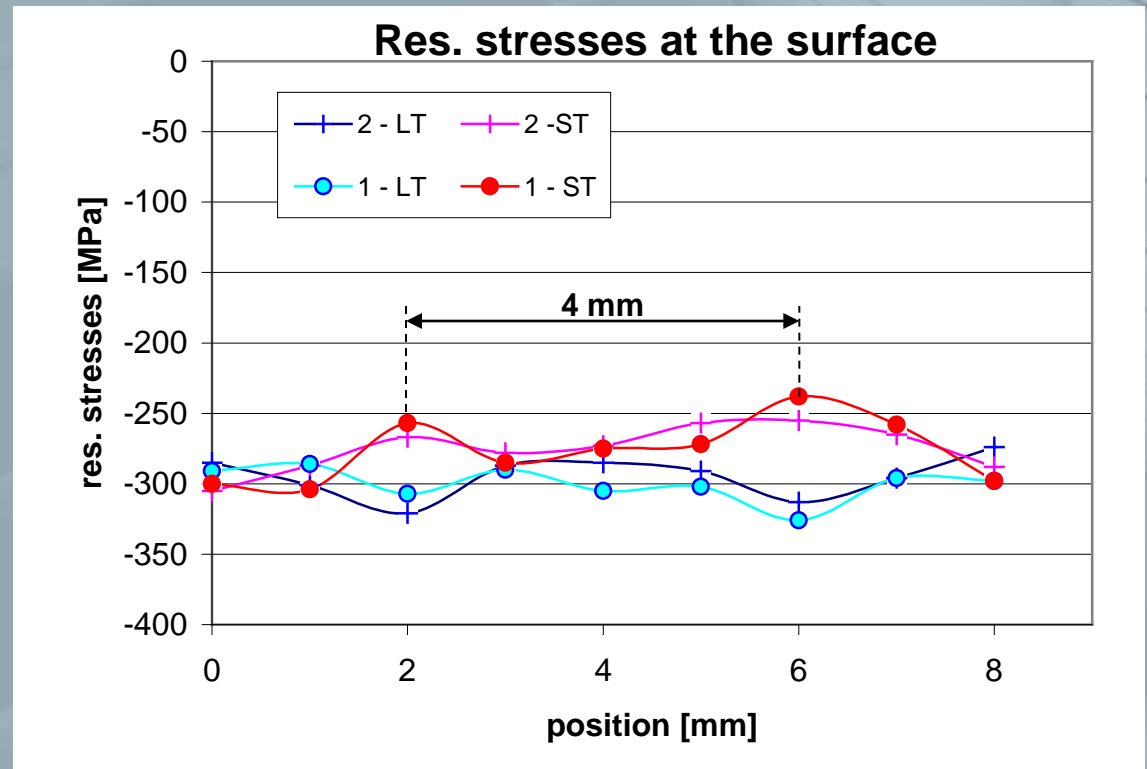
Gauge area: 2-3 mm

**Psi range: -45° ... 45°
11 steps.**

XRD results – Influence of position



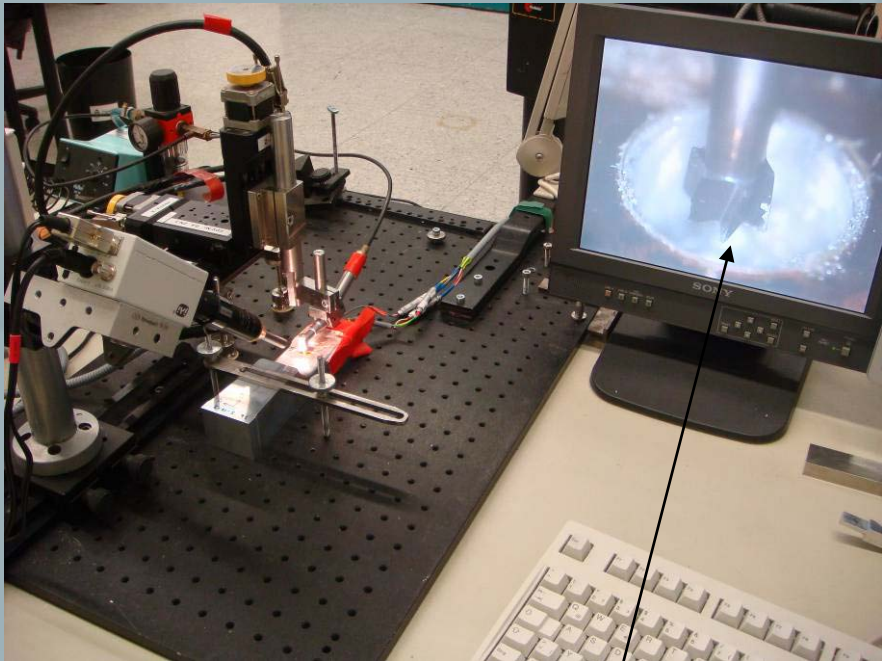
Two lines, at 1 mm distance.



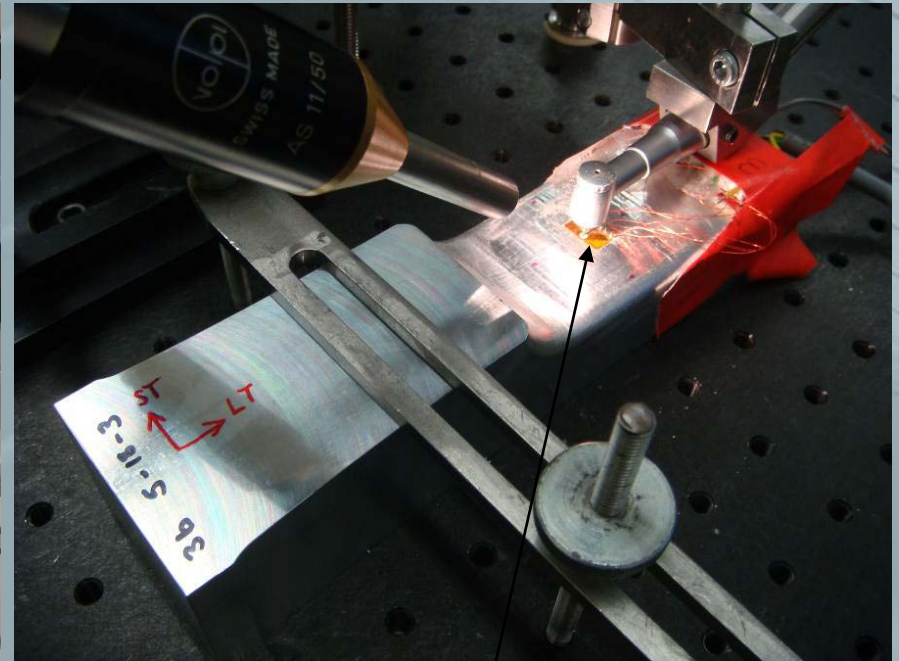
- Variations of residual stresses are correlated to the spot size.

Residual stress measurement

Incremental centre hole drilling (ICHD) – set-up

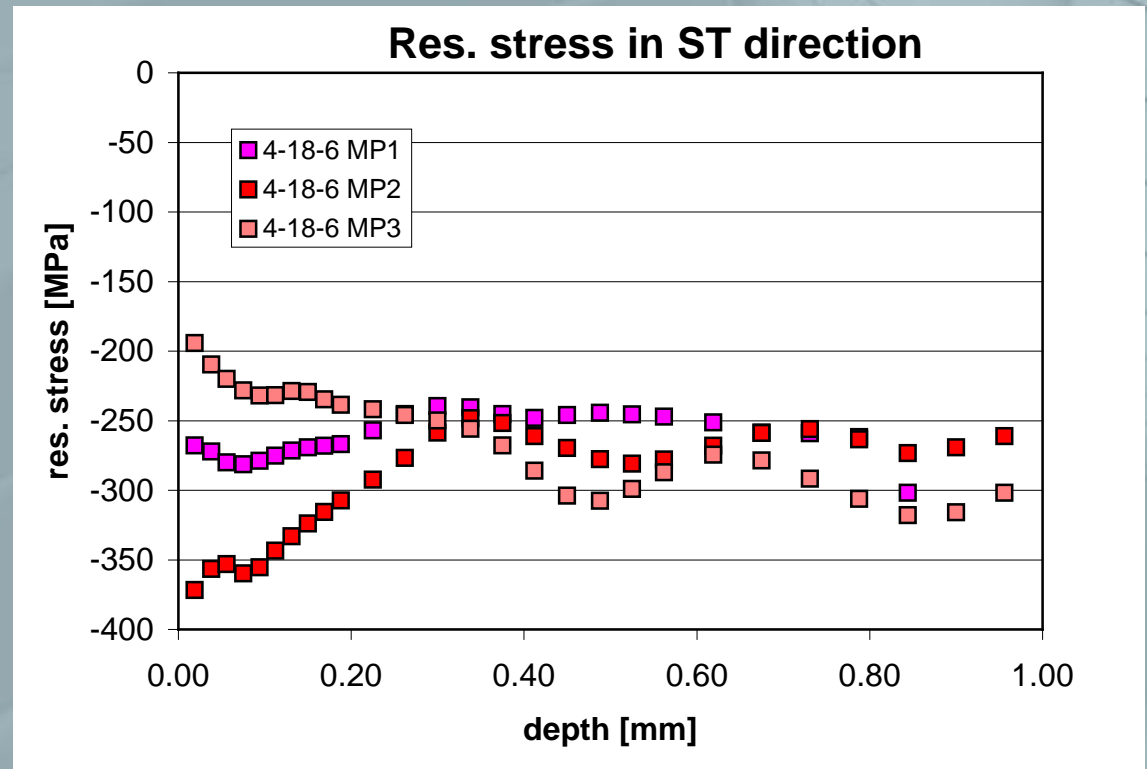
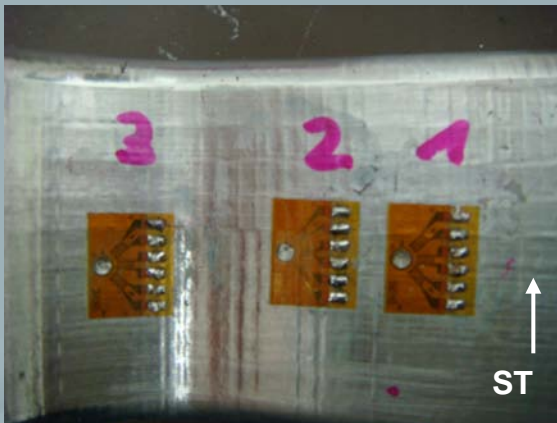


Ø 1.9 mm hole milled



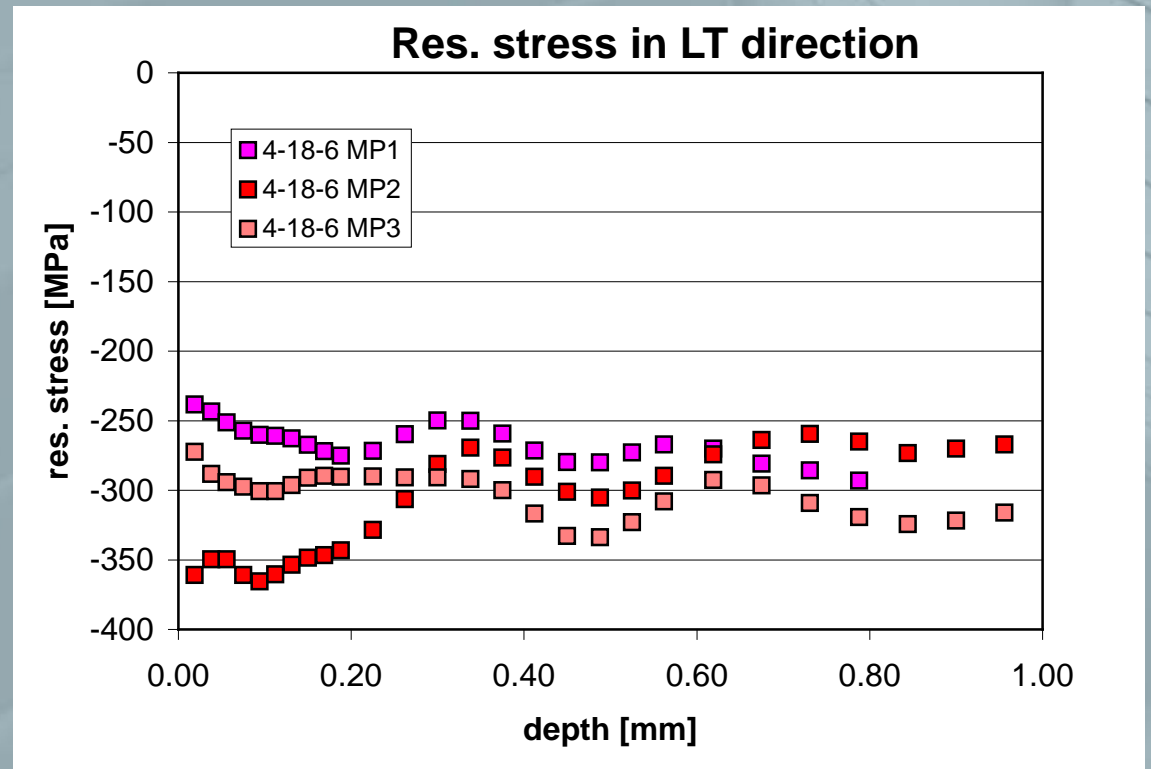
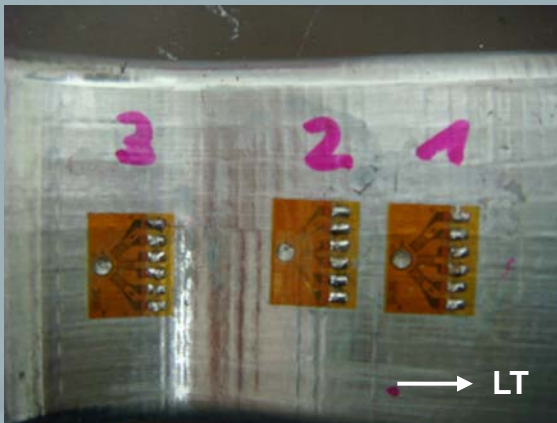
strain gauge measuring the released strains

ICHD results – Influence of position



- Large differences of the residual stress at the surface decreasing to +/- 25 MPa at a depth of 300 μ m.

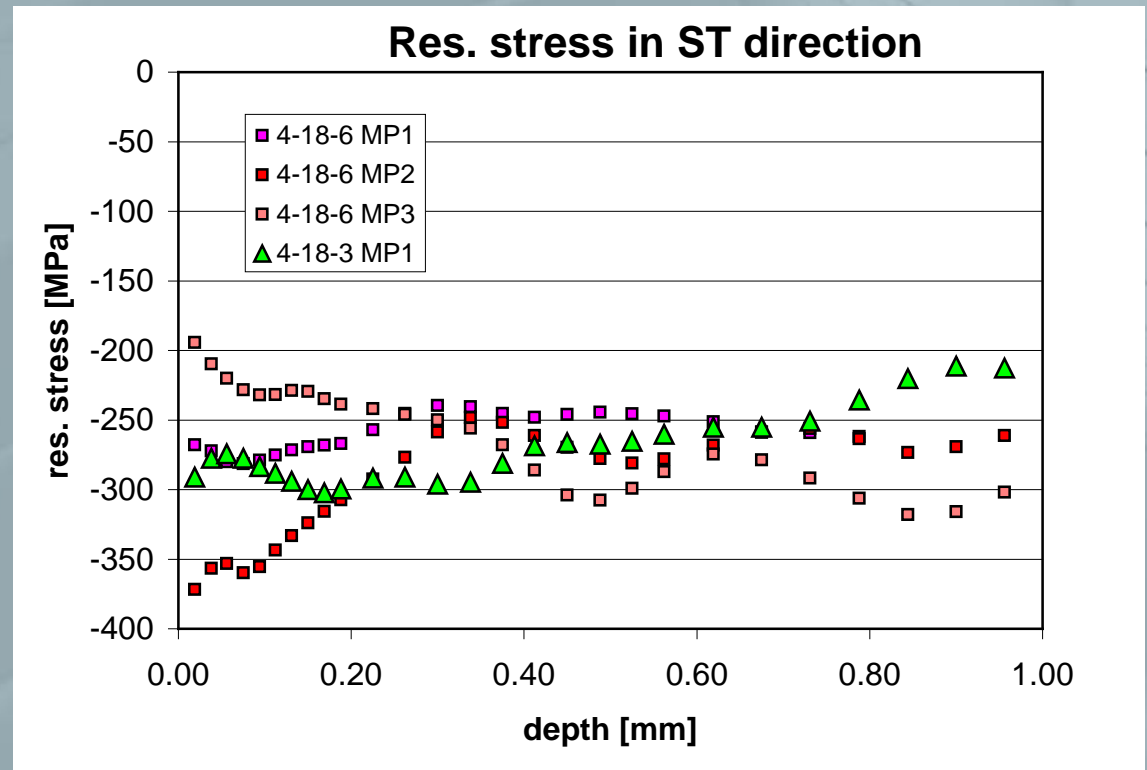
ICHD results – Influence of position



- Large differences of the residual stress at the surface decreasing to +/- 25 MPa at a depth of 300 μm .

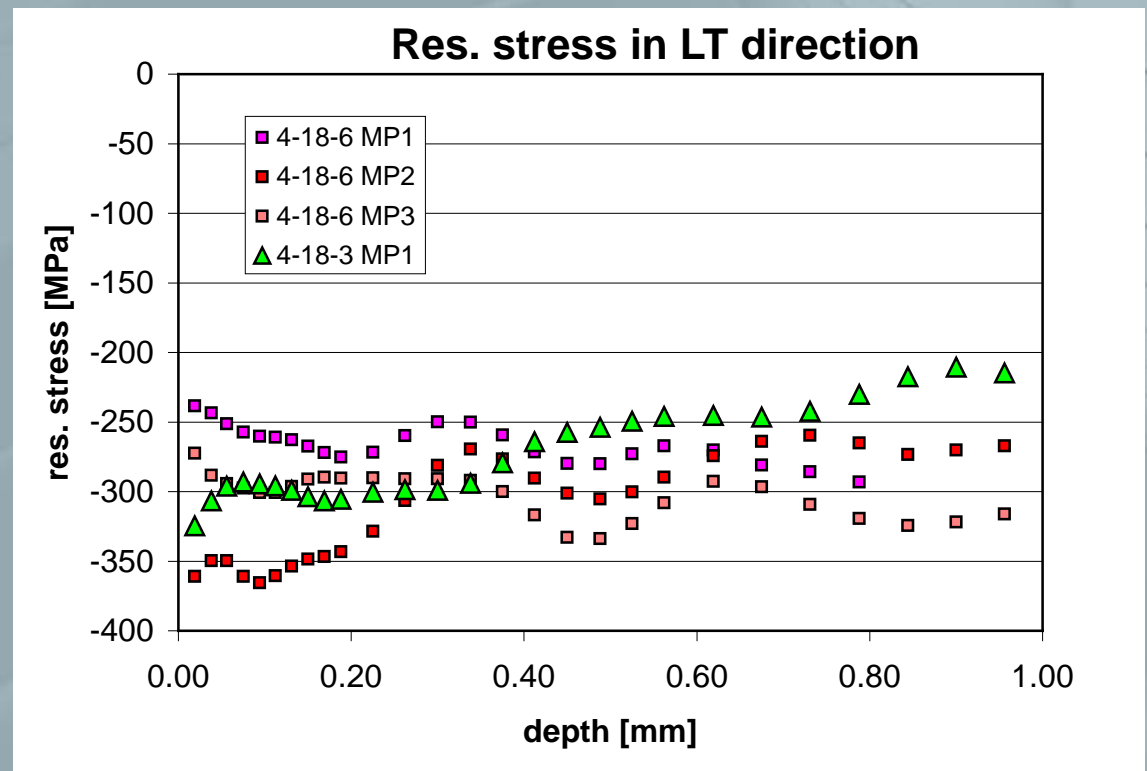
ICHD results – Influence of number of layers

- Reduction of number of layers appears to have no influence on the residual stress at the surface.
- Reduction of number of layers leads to a faster decrease of the compressive stresses with increasing depth.



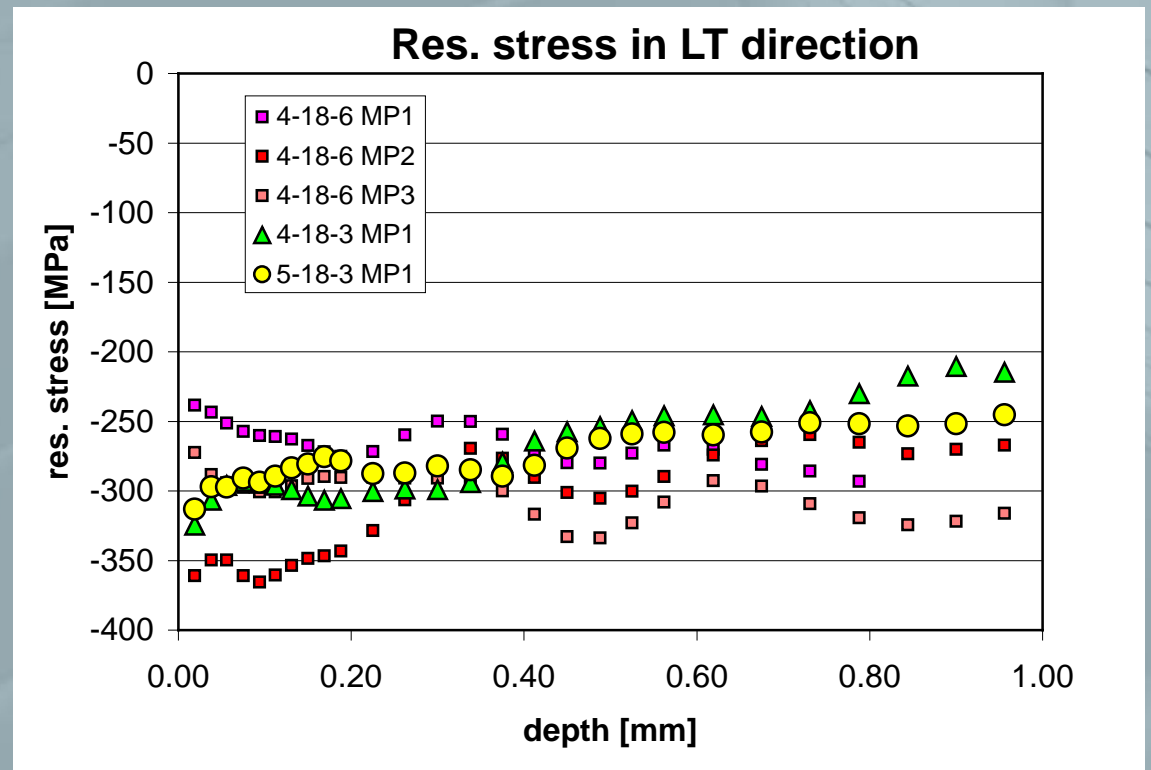
ICHD results – Influence of number of layers

- Reduction of number of layers appears to have no influence on the residual stress at the surface.
- Reduction of number of layers leads to a faster decrease of the compressive stresses with increasing depth.



ICHD results – Influence of energy

- Up to a depth of 1.0 mm the increase of energy does not show too much benefits.

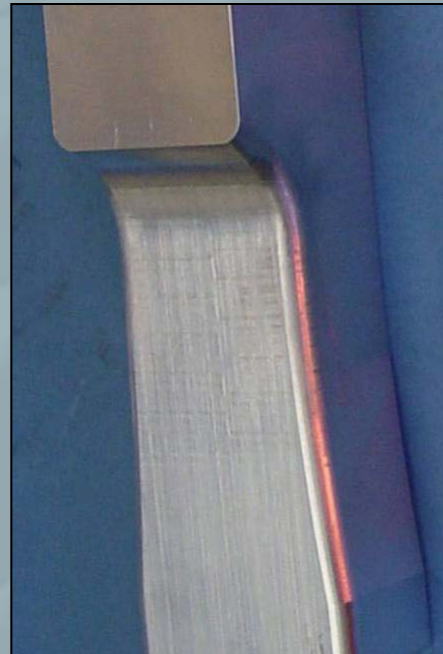


Let's go for: 4 – 18 – 3

LSP Processing

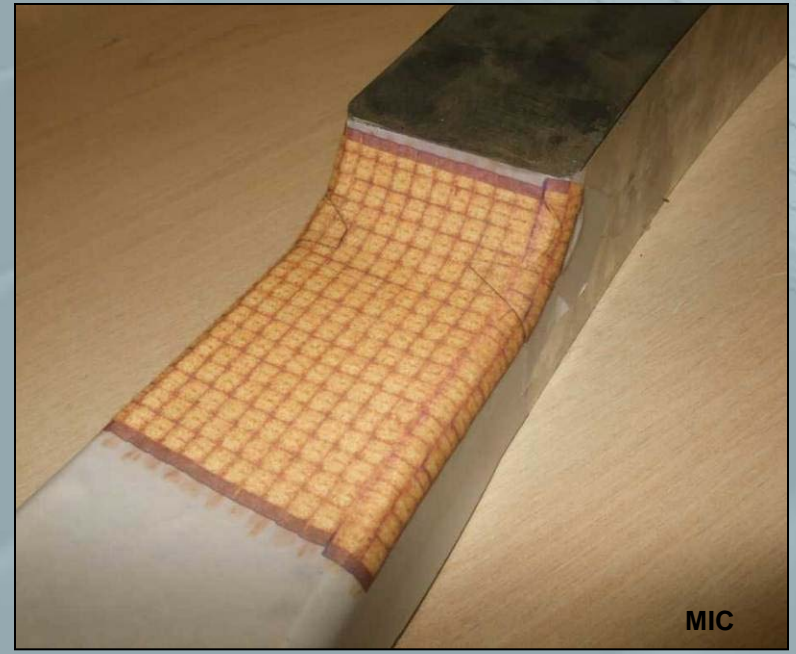
„first approach“: 50% off-set

check after two layers result for three layers



„final pattern“: 30% off-set

check after two layers

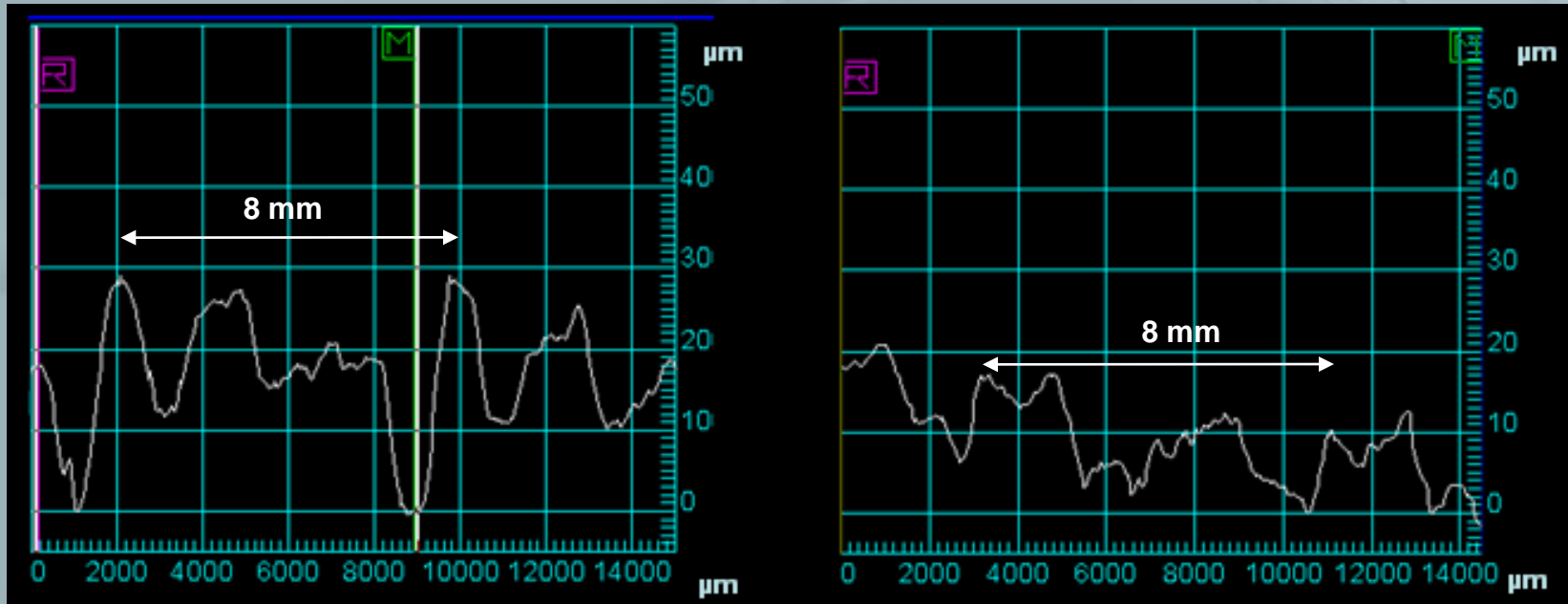


 **Let's go for the final pattern.**

LSP Processing – Roughness

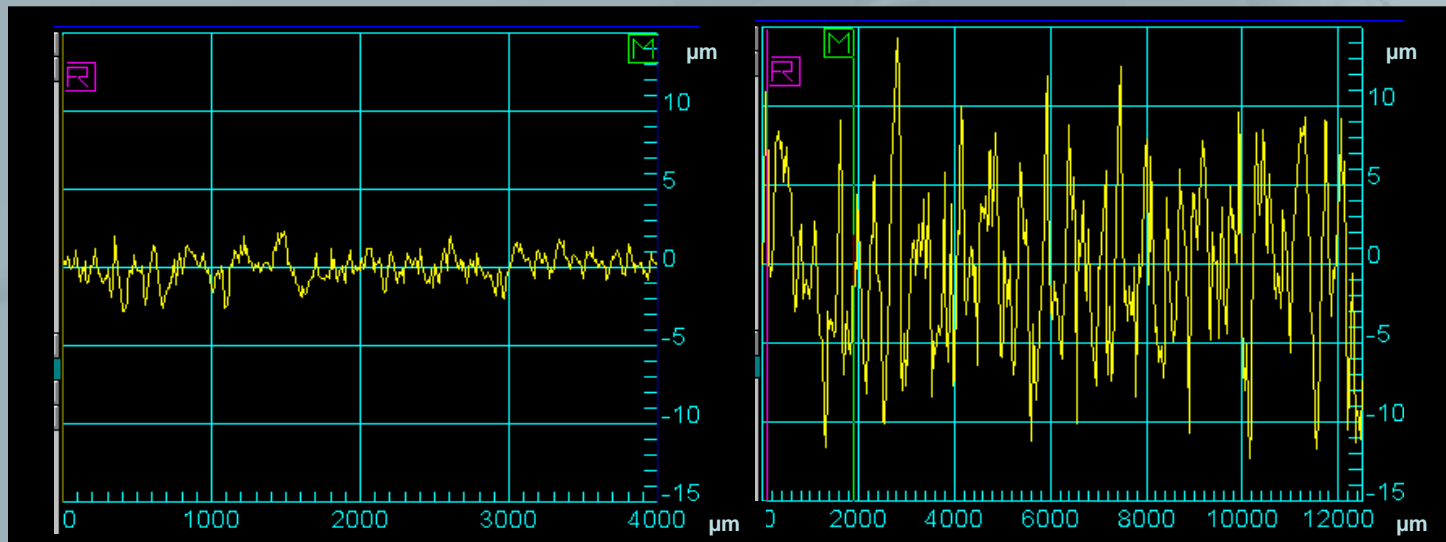
„first approach“

„final pattern“



- Max. roughness R_t alleviated by new pattern.
- Max. roughness R_t pushed below 15 μm .

Roughness profile of reference specimens

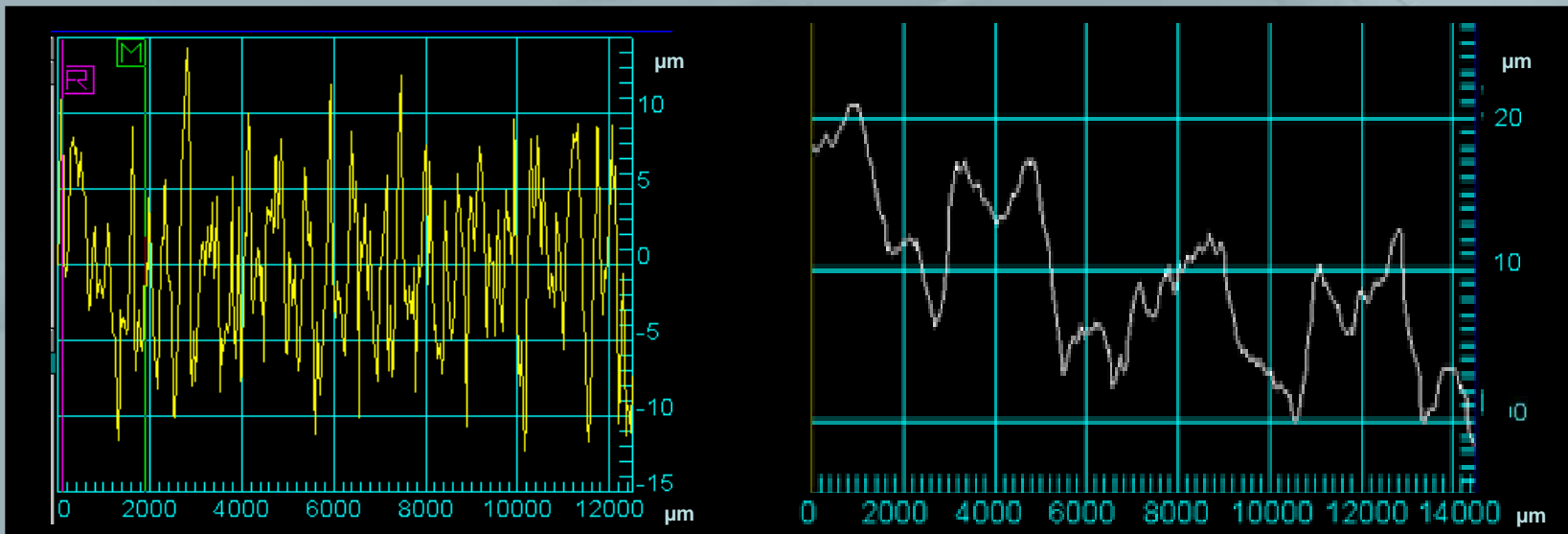


Milled surface

Shot peened surface

- Roughness typical for a milled surface: $R_a=0.6 \mu\text{m}$.
- Roughness increased due to shot peening.

Roughness profile for SP and LSP treatments



Shot peened surface

Laser shock peened surface

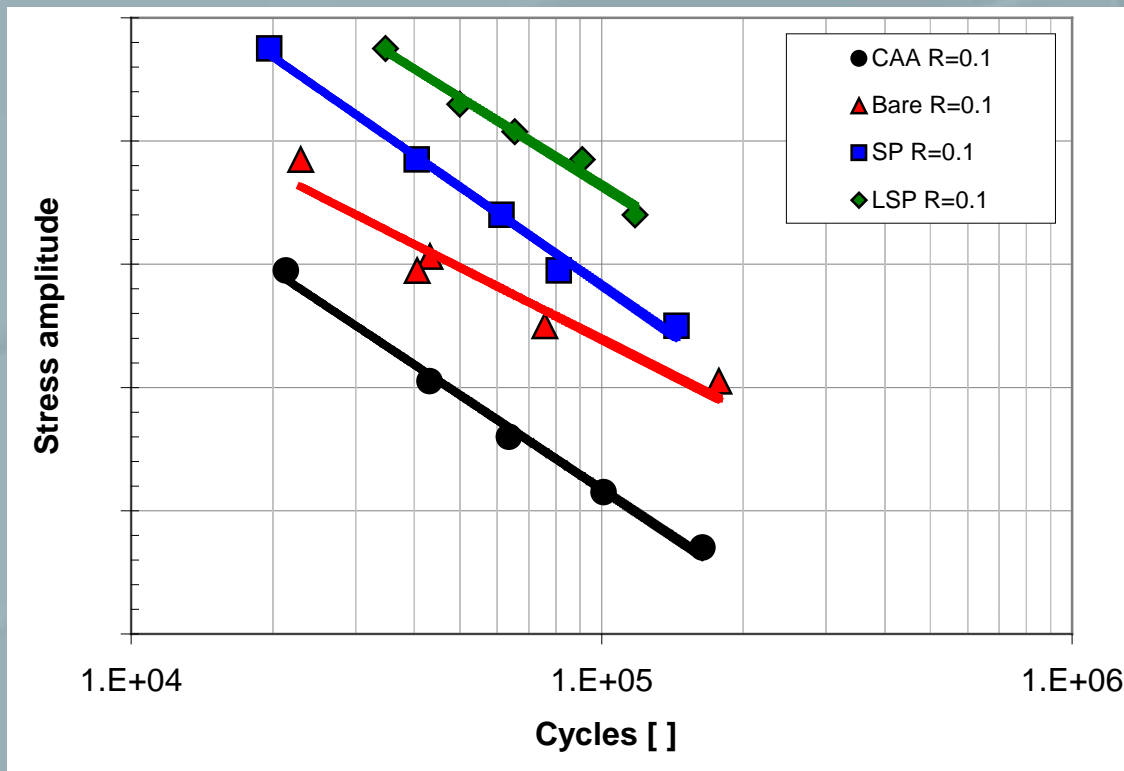
- Max. roughness R_t after SP treatment is larger than after LSP treatment.
- SP surface appears to obtain rather sharp edges.

Fatigue test program

1. **Bare**: No surface protection (bare condition – milled surface)
2. **CAA**: Aircraft condition: Chromic Acid Anodizing (CAA)
3. **SP**: Shot Peening – Alodine
4. **LSP**: Laser Shock Peening – Alodine

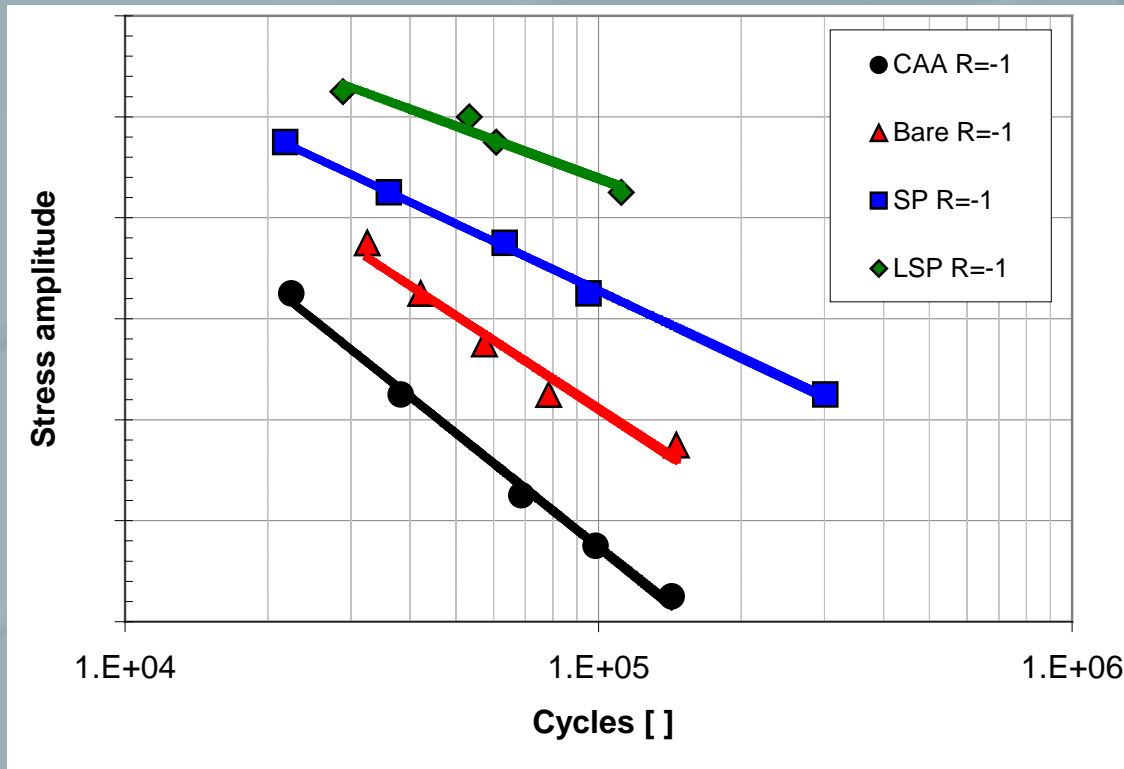
| | R-ratios | | |
|--------------------|----------|----|----|
| | 0.1 | -1 | -3 |
| <u>Bare</u> | 5 | 5 | 5 |
| <u>CAA</u> | 5 | 5 | 5 |
| <u>SP</u> | 5 | 5 | 5 |
| <u>LSP</u> | 5 | 5 | 5 |

Fatigue results – R = 0.1



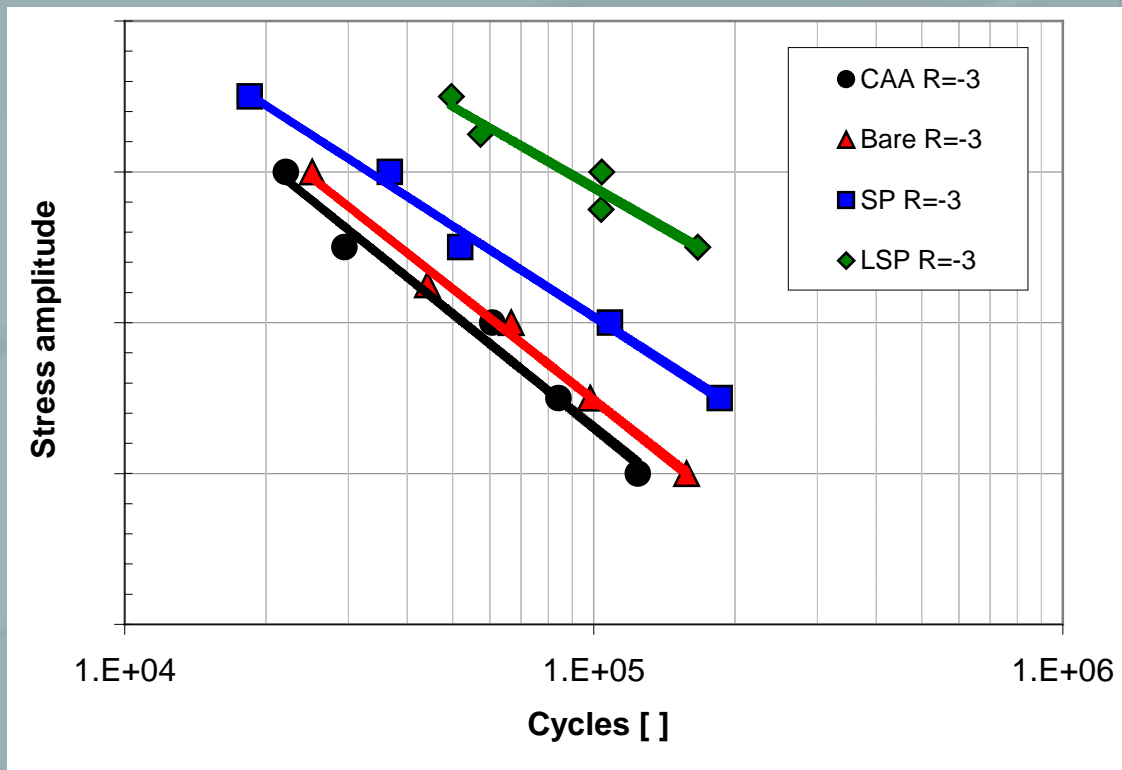
- Between 10% and 20% larger stresses can be born for SP.
- Between 25% and 35% larger stresses can be born for LSP.

Fatigue results – R = -1



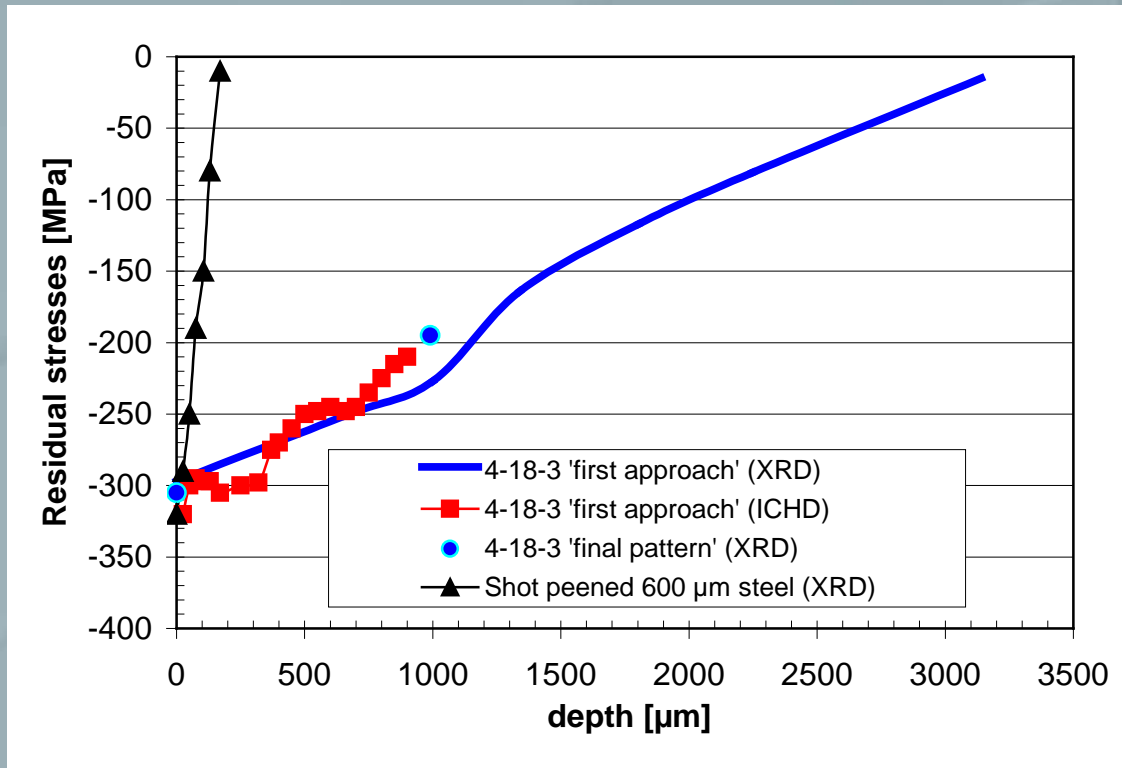
- Around 15% larger stresses can be born for SP.
- Around 30% larger stresses can be born for LSP.

Fatigue results – R = -3



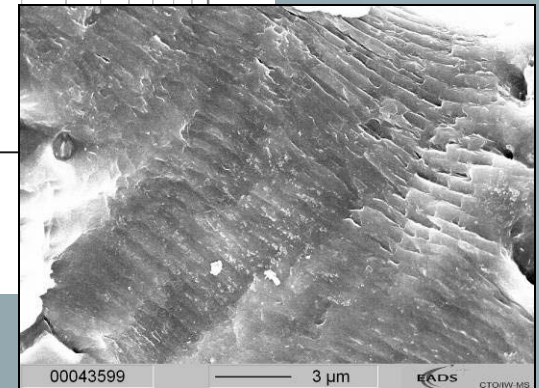
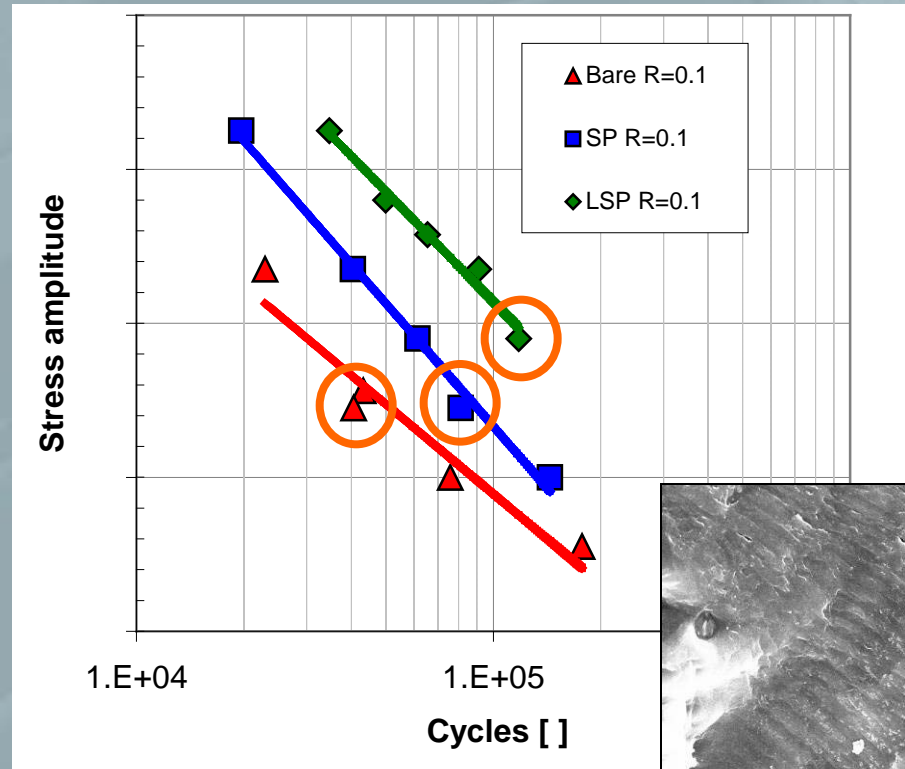
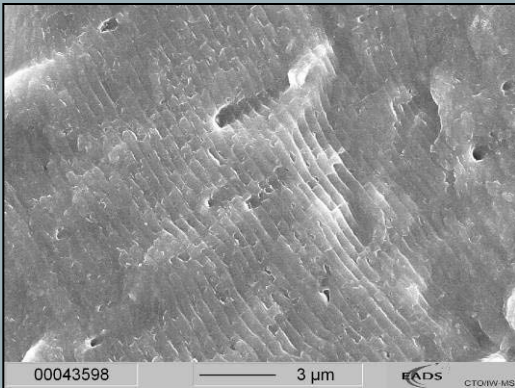
- Around 5% larger stresses can be born for SP.
- Around 15% larger stresses can be born for LSP.

Residual stress profiles – Comparison of treatments



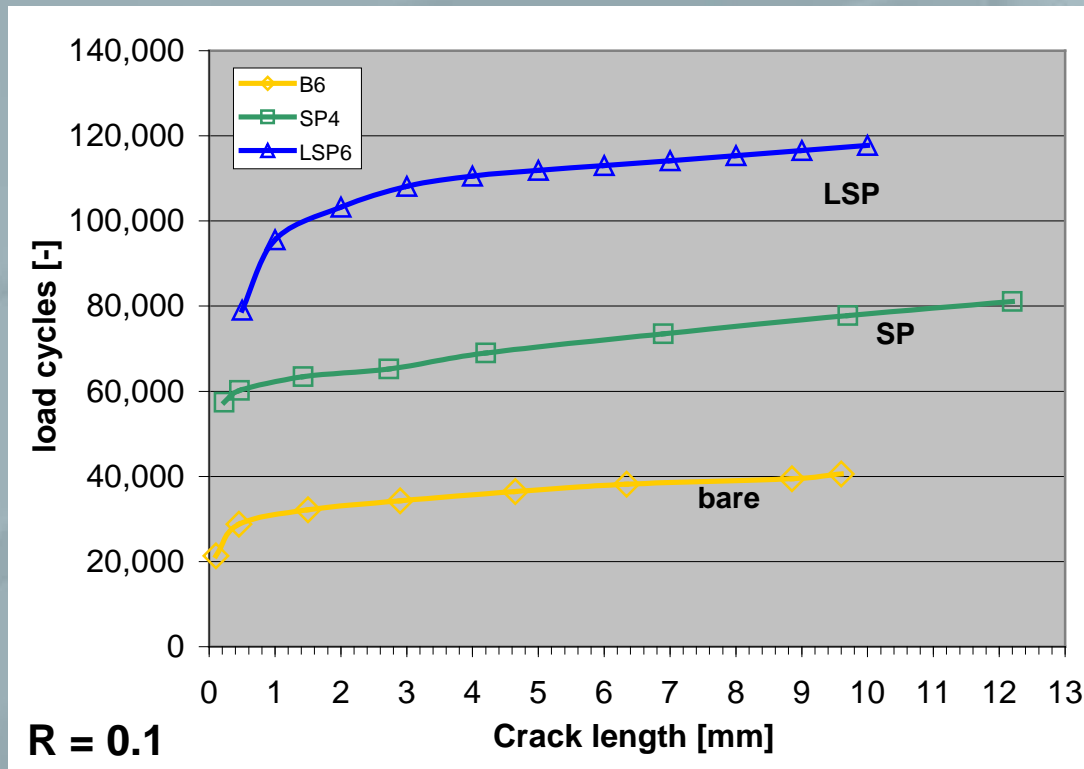
- The compressive residual stresses (RS) reach much deeper in case of the LSP than for the SP treatment.
- “Final pattern” leads to comparable RS as the “first approach”.

Impact of RS on crack initiation, or crack growth, or both?



Analysis of striations.

LSP: Impact of RS on crack initiation AND crack growth



- Crack initiation delayed due to the LSP and SP treatment.
- In case of LSP, retarded crack growth up to a crack length of ca. 4 mm.

Conclusions

- Laser shock peening provides residual stress profiles with compressive residual stresses which are of comparable magnitude as for shot peening, but they reach much deeper into the material.
- Variations of the residual stresses at the surface of the material are leveled out at depths of about 0.3 mm.
- The number of LSP layers and the energy increase the depth of the compressive residual stress regime.
- The roughness of the LSP treated surface is lower than for SP (600 μm steel shots, 0.2 – 0.24 mmA), and free of sharp edges.

cont. Conclusions

- SP specimens are able to bear between 10 % and 20 % larger stresses compared to milled specimens for the tensile fatigue loading with $R = 0.1$.
- LSP specimens are able to bear between 25 % and 35 % larger stresses for $R = 0.1$.
- Even in case of prevailing compressive fatigue loading with $R = -3$, SP and LSP provide a benefit of 5 % and 15 %.
- LSP and SP delay the crack initiation in the same way due to the same level of compressive residual stresses at the surface.
- LSP retards the crack growth up to a crack length which is in the same order as the depth of the compressive residual stress regime.

**Thank you very much
for your attention!**

Questions?