EADS INNOVATION WORKS

LSP to improve the fatigue resistance of highly stressed AA7050 components

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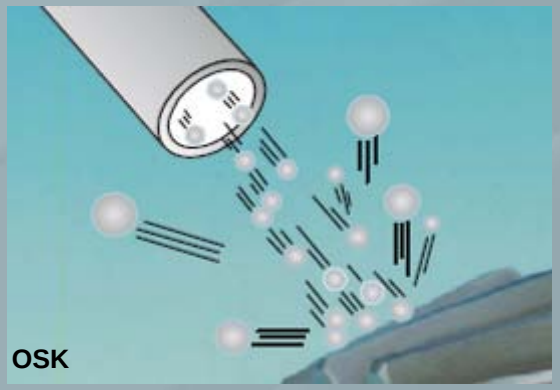
Outline

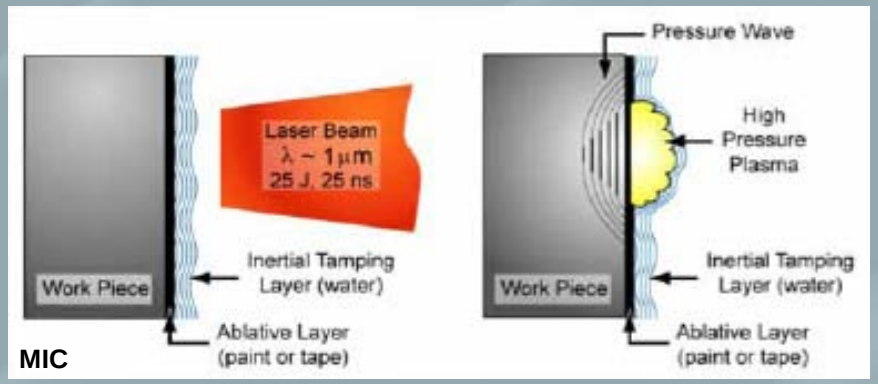
- Which kind of set-up has been chosen?
  - Specimen geometry
  - LSP parameters
- How do the LSP parameters influence the residual stress profile?
- How large is the fatigue life enhancement, esp. for SP and LSP?
- What is the reason for the fatigue life enhancement?
- Does the RS influence the crack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

Objective

- Improve the fatigue life of AA7050 components

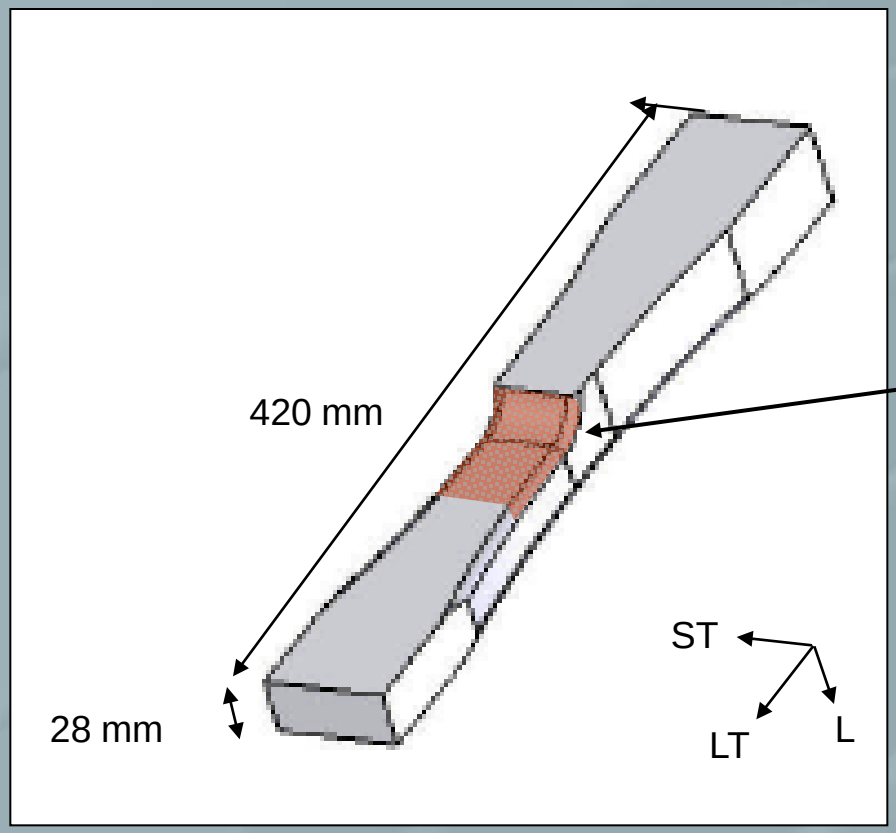
- Improve the fatigue life via compressive residual stresses.
- Compare the fatigue life enhancement for different depths of the residual stresses introduced by:
  - the shot peening process,
  - the laser shock peening process.


OSK



MIC

Specimen geometry



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

LSP Processing

Parameters

Pulse duration

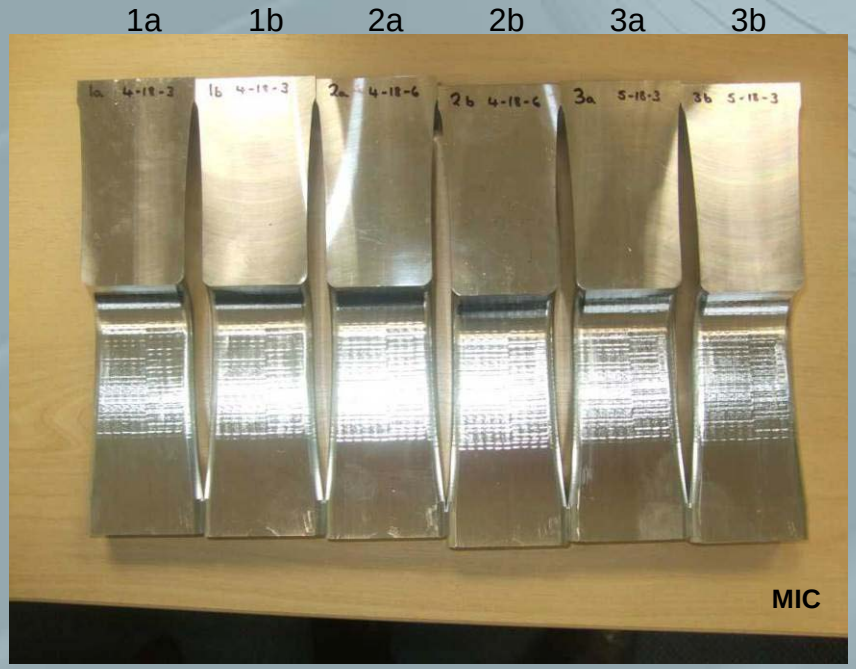
Specimen 1a + 1b ⇒ 4 – 18 – 3

Specimen 2a + 2b ⇒ 4 – 18 – 6

Specimen 3a + 3b ⇒ 5 – 18 – 3

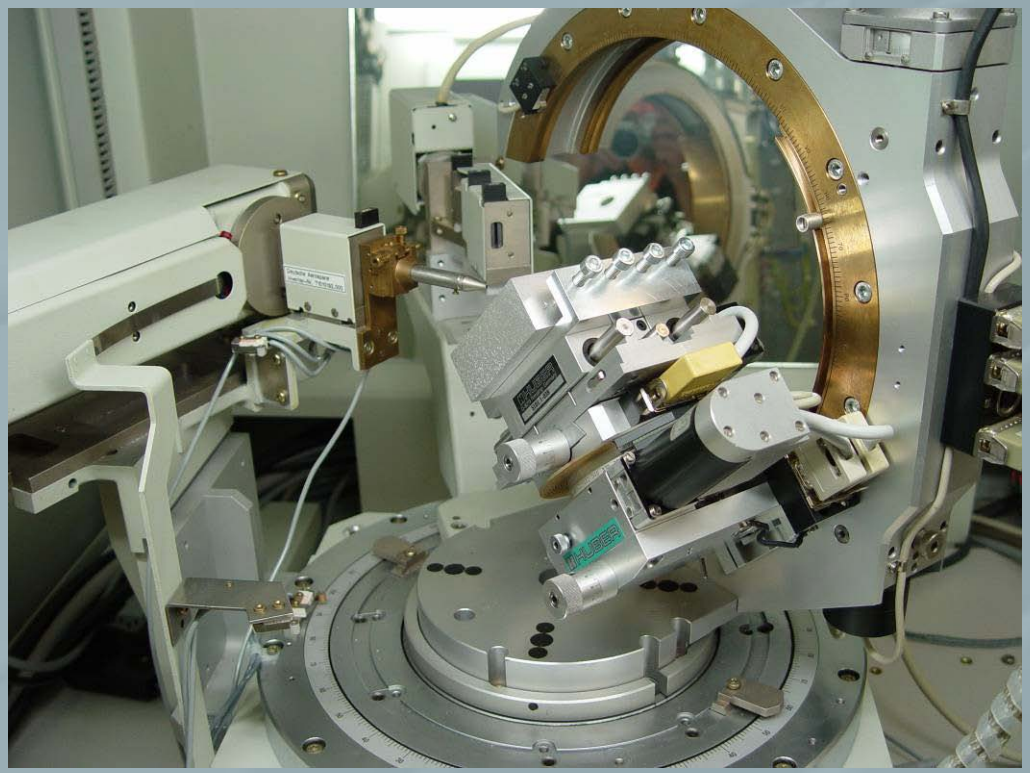
Power [GW/cm^2] Number of layers

Distortion due to residual stresses (specimen 2b)



Top view of the delivered specimens

Residual stress measurement – XRD device



D5000

Euler Craddle

X-ray tube: Cu 1.5406

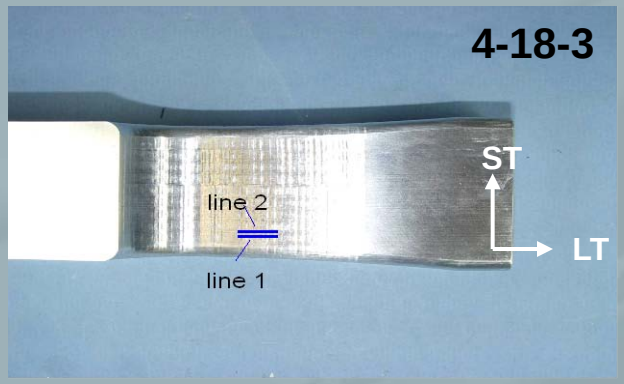
Peak location method:
Sliding gravity.

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

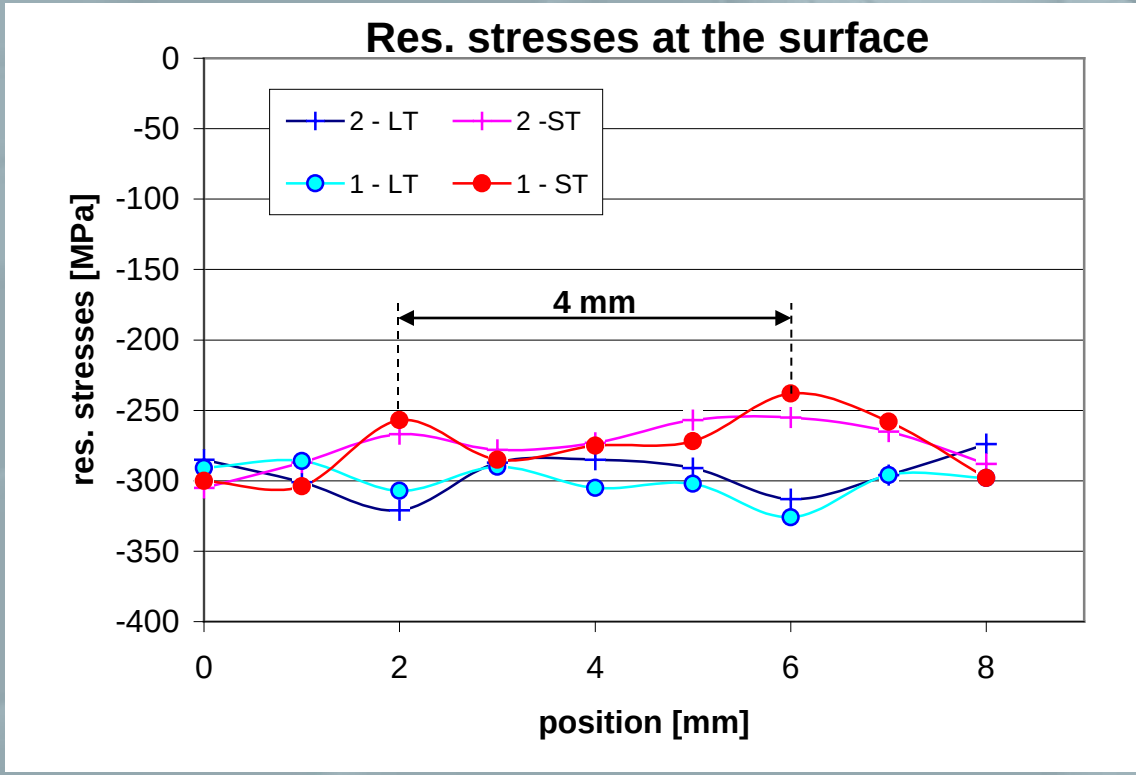
Gauge area: 2-3 mm

Psi range: -45° … 45°
11 steps.

XRD results – Influence of position



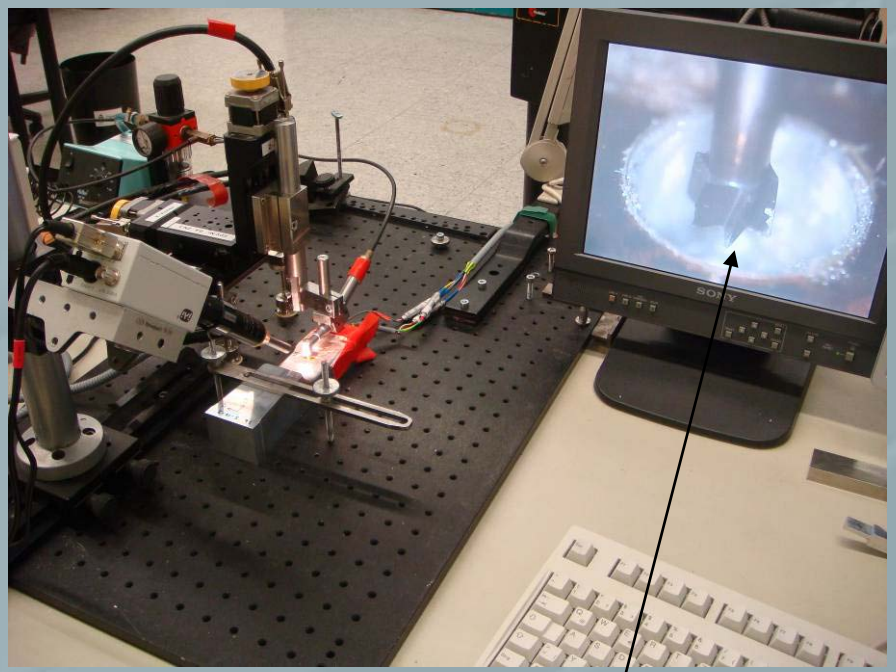
Two lines, at 1 mm distance.

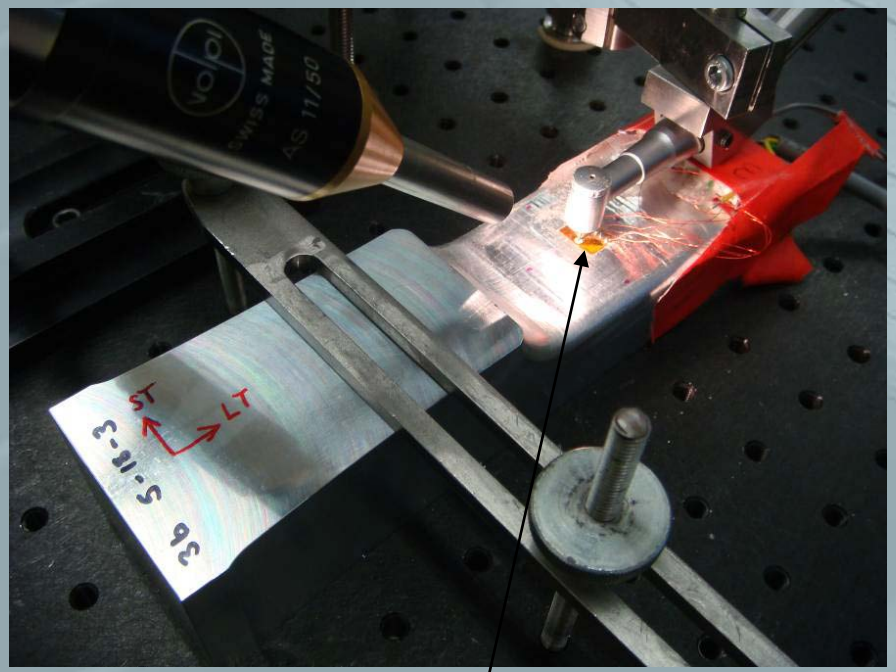


- **Variations of residual stresses are correlated to the spot size.**

Residual stress measurement

Incremental centre hole drilling (ICHD) – set-up

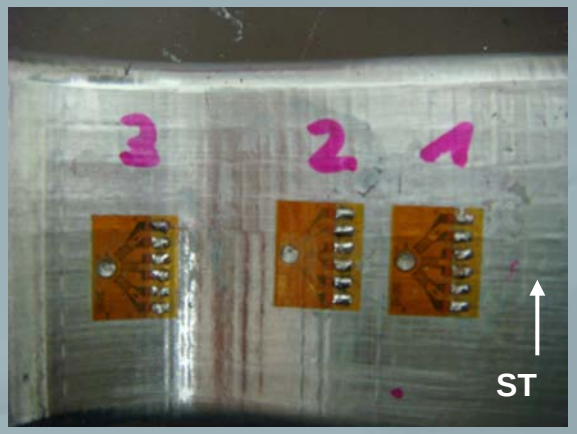


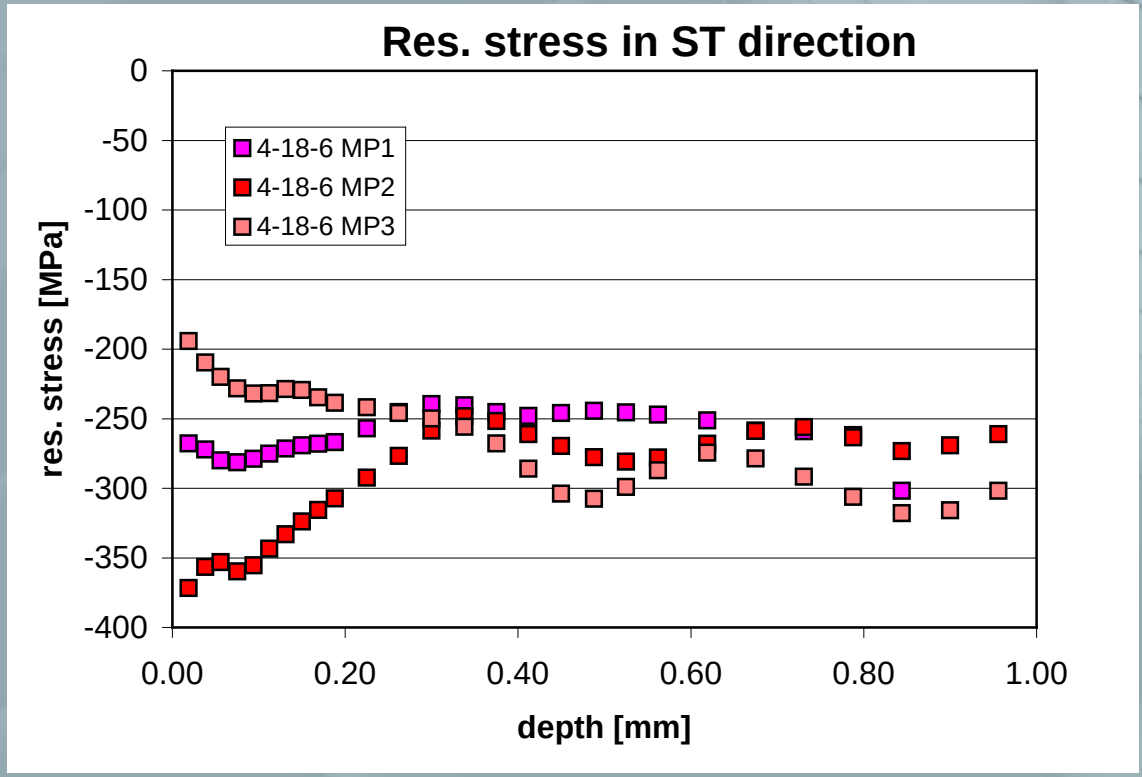


Ø 1.9 mm hole milled

strain gauge measuring the released strains

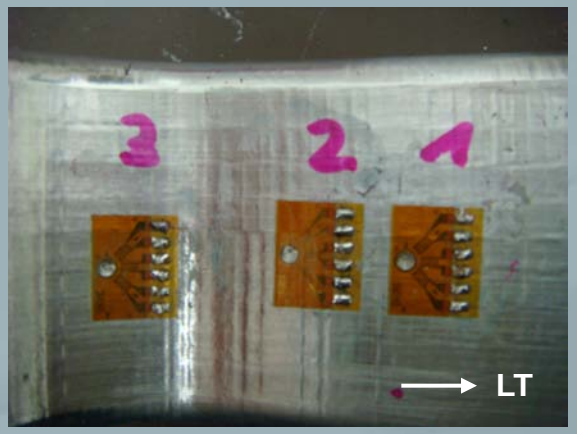
ICHD results – Influence of position

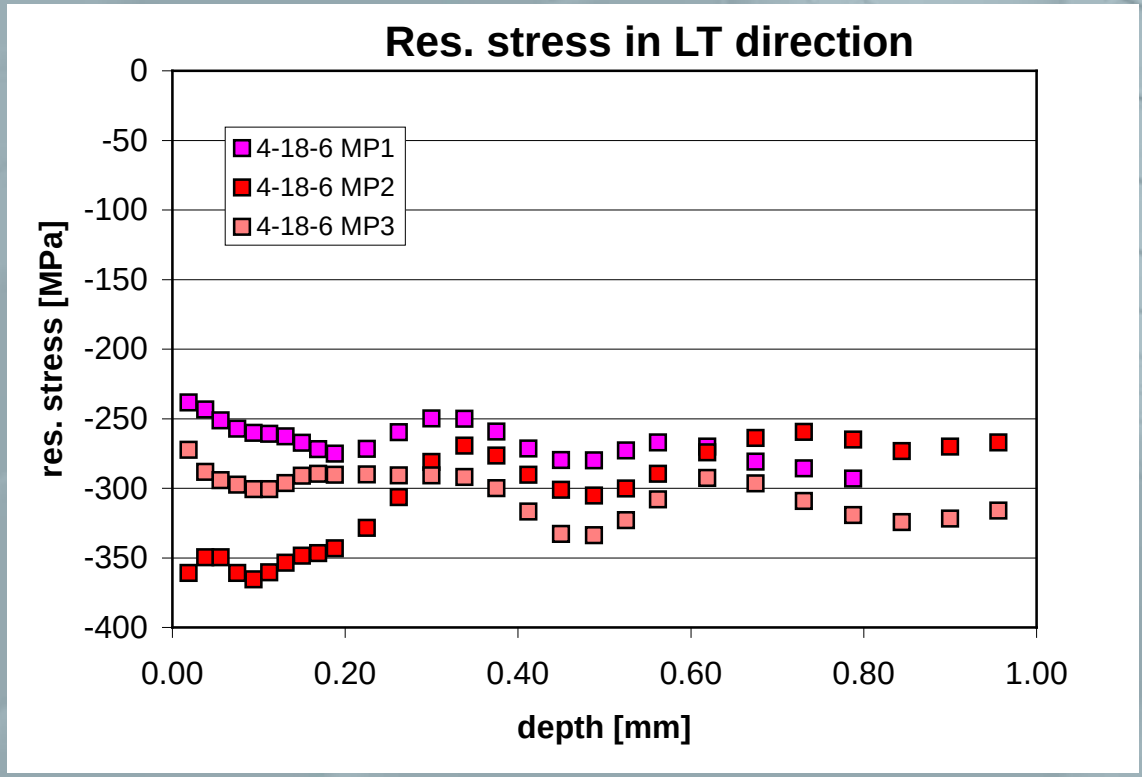




- **Large differences of the residual stress at the surface decreasing to +/- 25 MPa at a depth of 300 µm.**

ICHD results – Influence of position

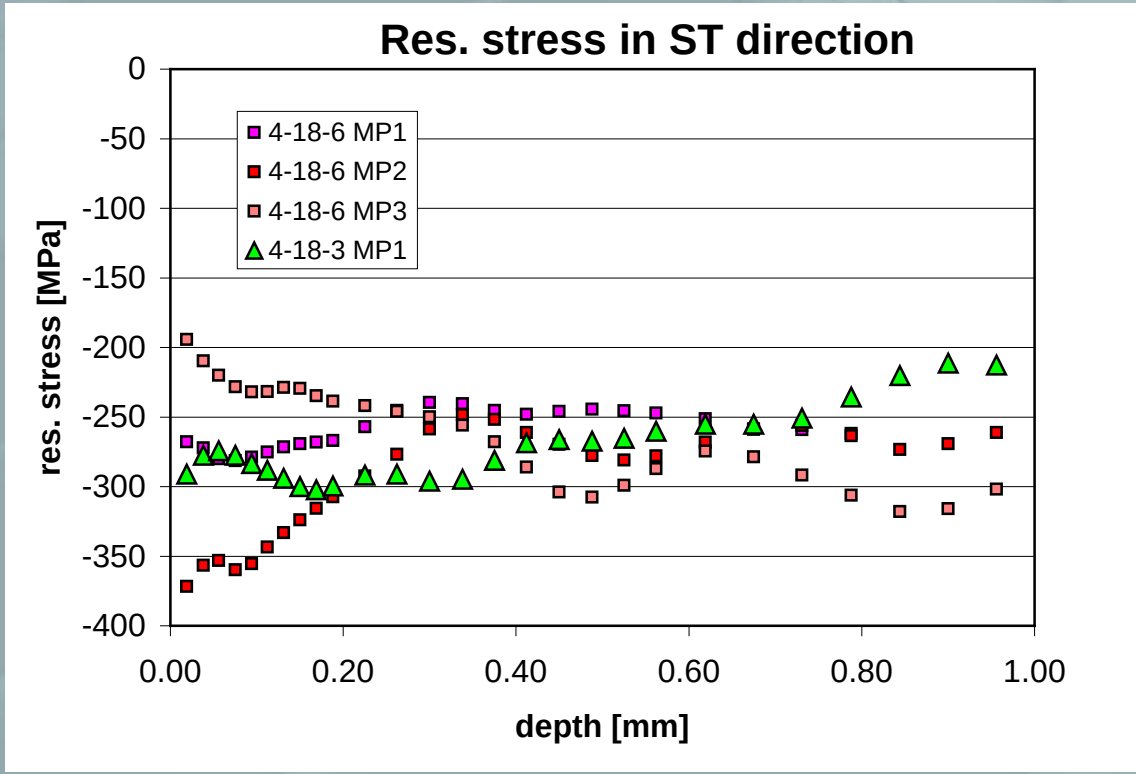




- **Large differences of the residual stress at the surface decreasing to +/- 25 MPa at a depth of 300 µm.**

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.**



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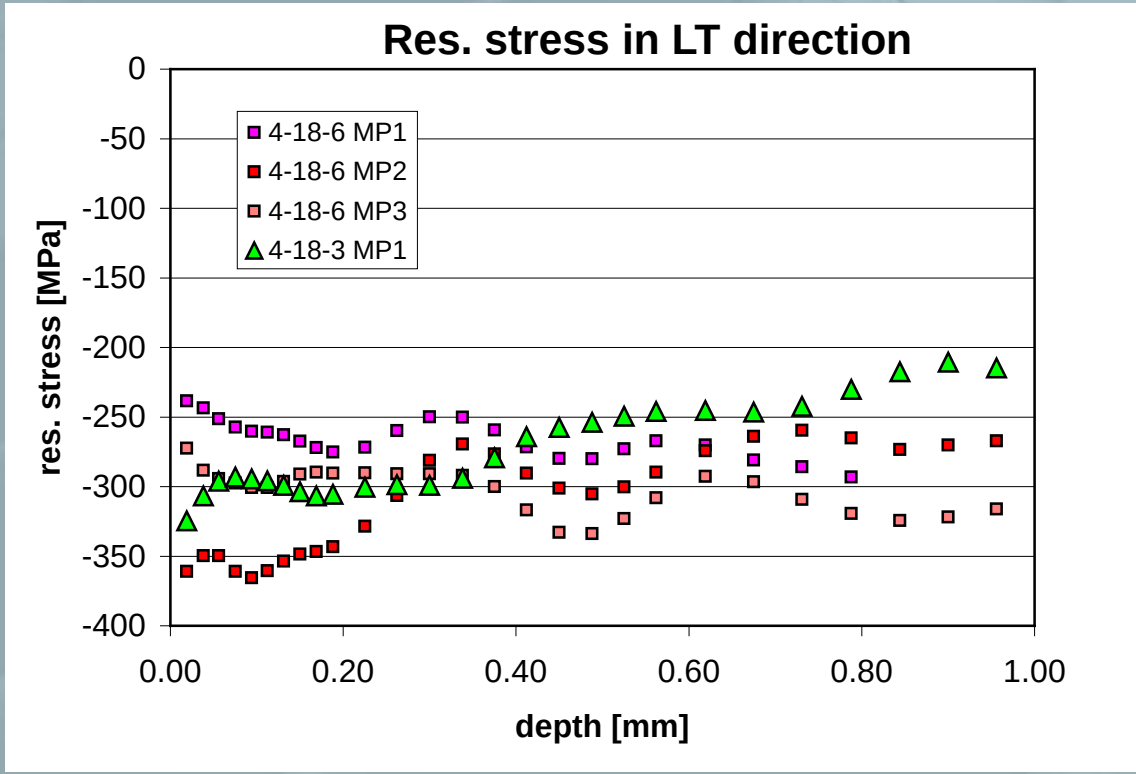
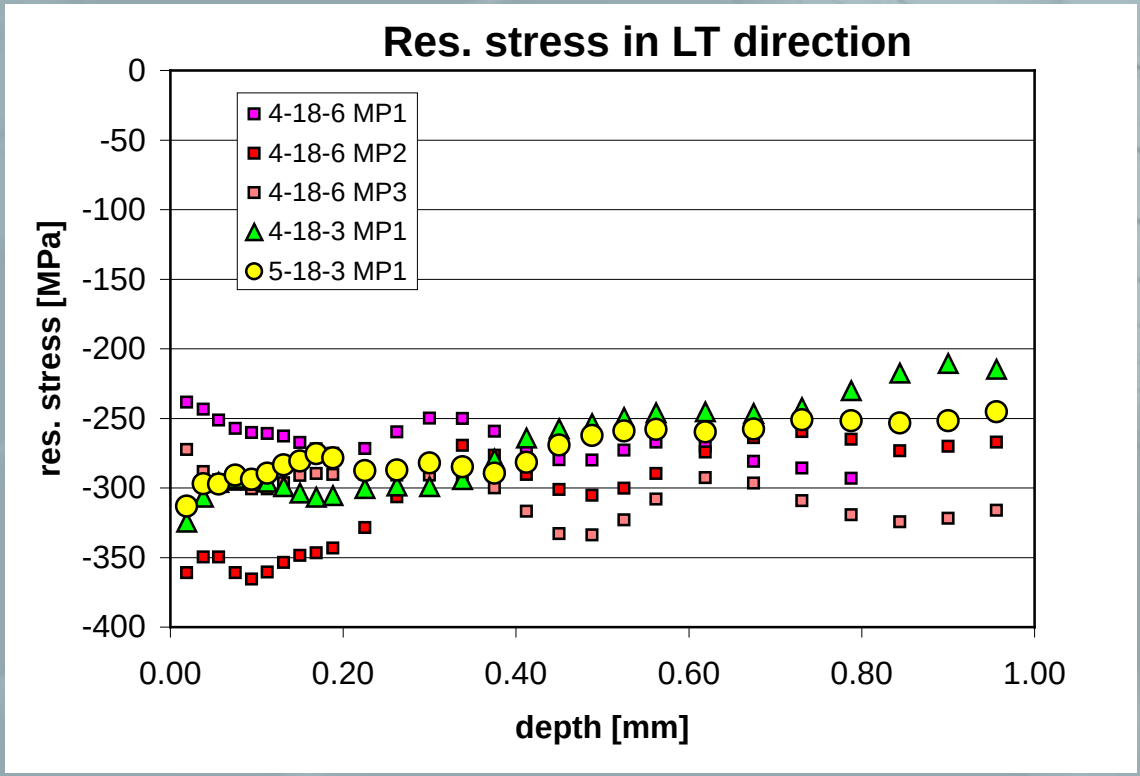


ICHD results – Influence of energy

- **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

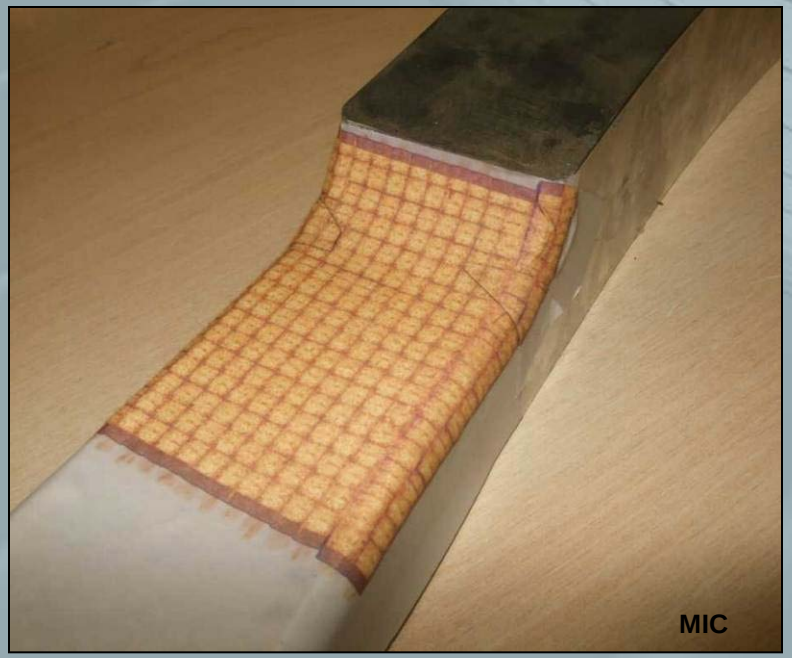
„first approach“: 50% off-set

„final pattern“: 30% off-set

check after two layers

result for three layers

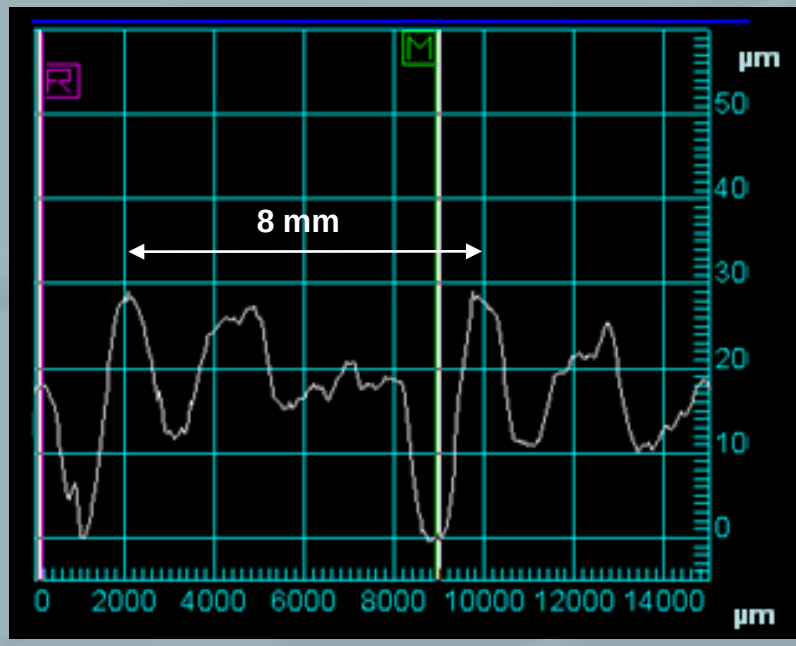
check after two layers



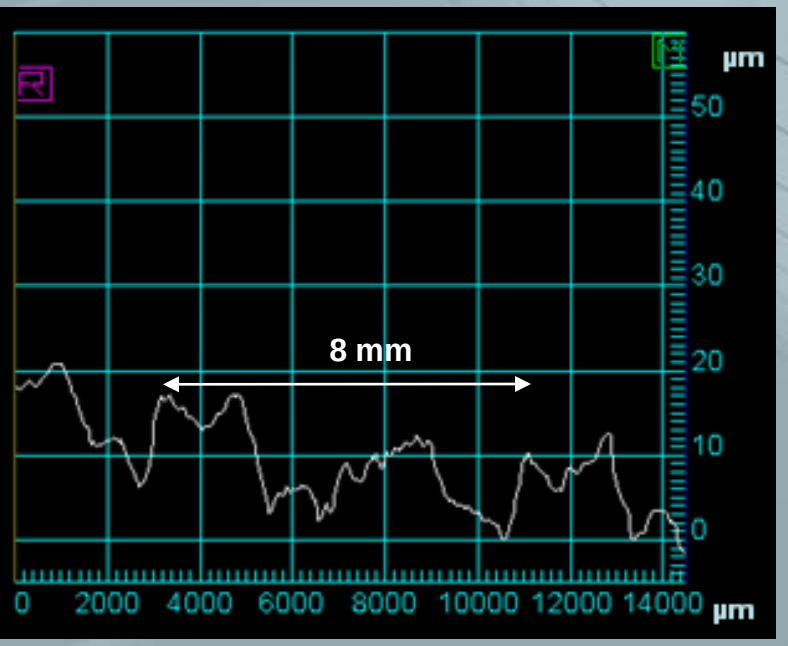
☞ **Let’s go for the final pattern.**

LSP Processing – Roughness

„first approach“

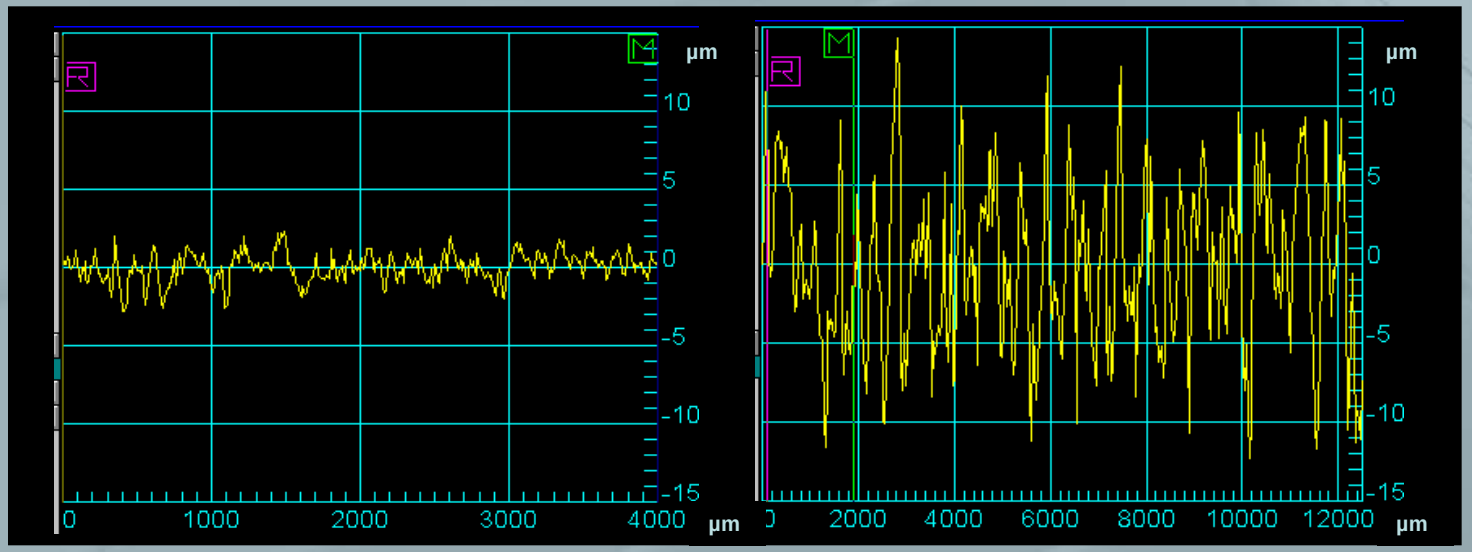


„final pattern“



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

Roughness profile of reference specimens

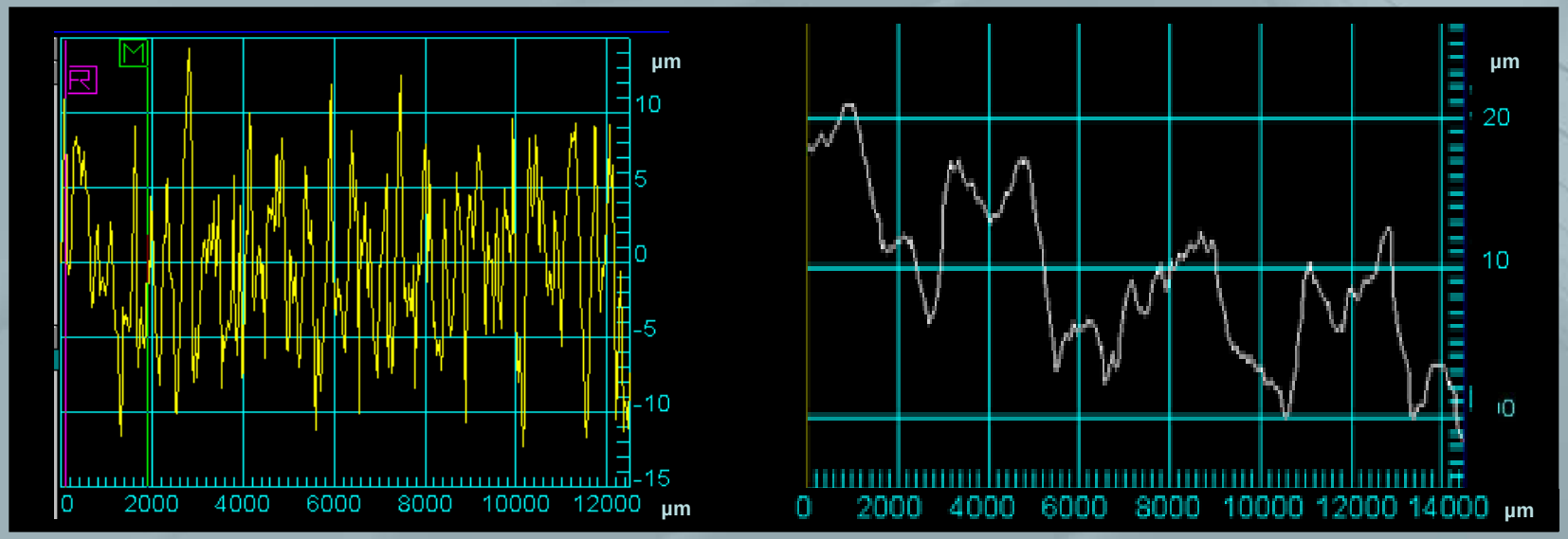


Milled surface

Shot peened surface

- **Roughness typical for a milled surface: Ra=0.6 µm.**
- **Roughness increased due to shot peening.**

Roughness profile for SP and LSP treatments



Shot peened surface

Laser shock peened surface

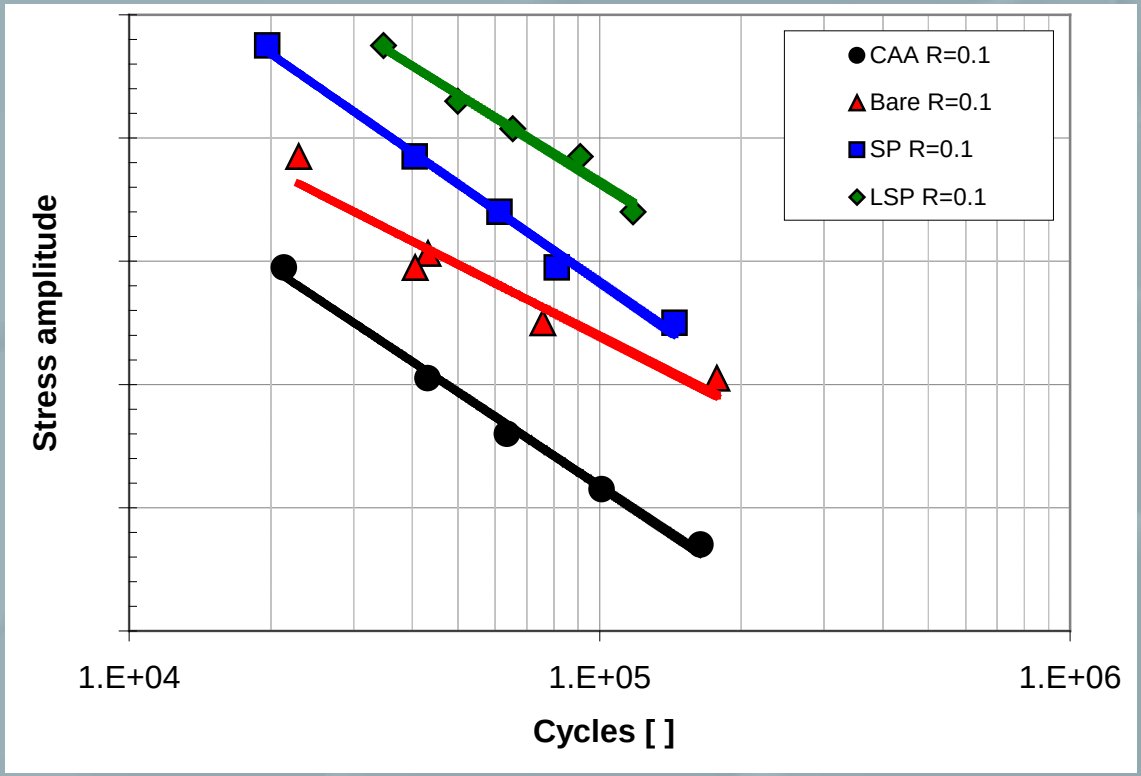
- **Max. roughness R_t after SP treatment is larger than after LSP treatment.**
- **SP surface appears to obtain rather sharp edges.**

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

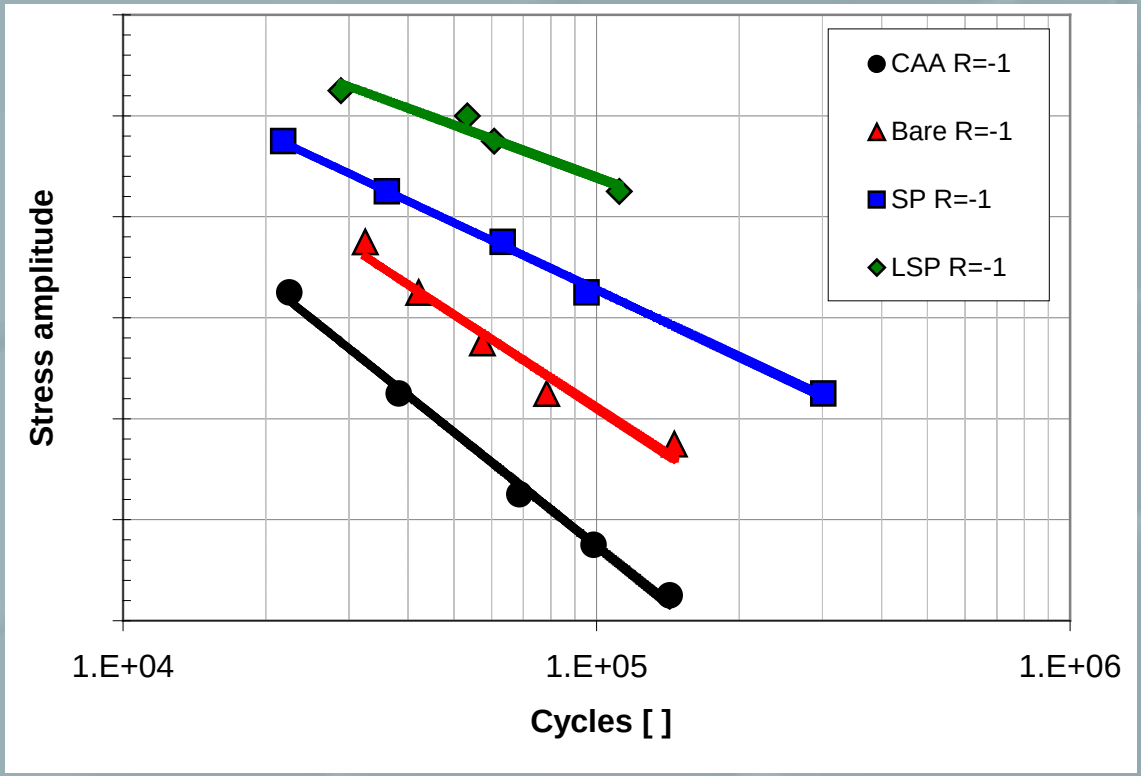
	R-ratios		
	0.1	**-1**	**-3**
Bare	*5*	*5*	*5*
CAA	*5*	*5*	*5*
SP	*5*	*5*	*5*
LSP	*5*	*5*	*5*

Fatigue results – R = 0.1



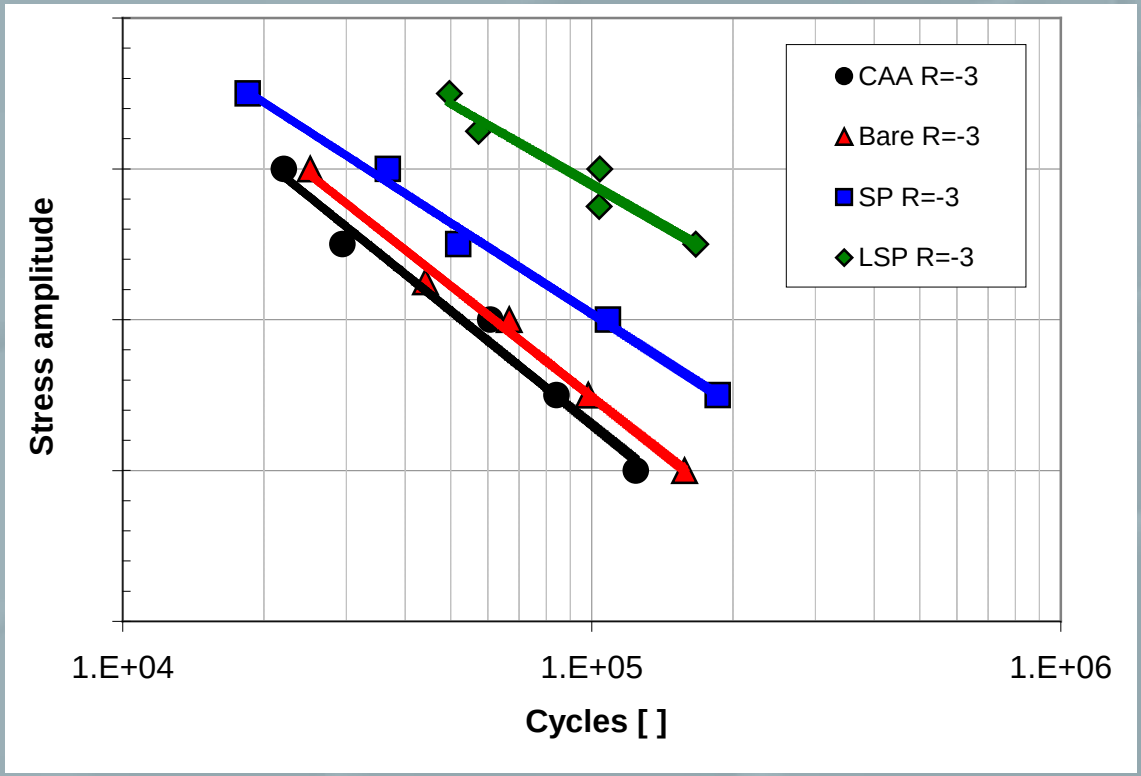
- **Between 10% and 20% larger stresses can be born for SP.**
- **Between 25% and 35% larger stresses can be born for LSP.**

Fatigue results – R = -1



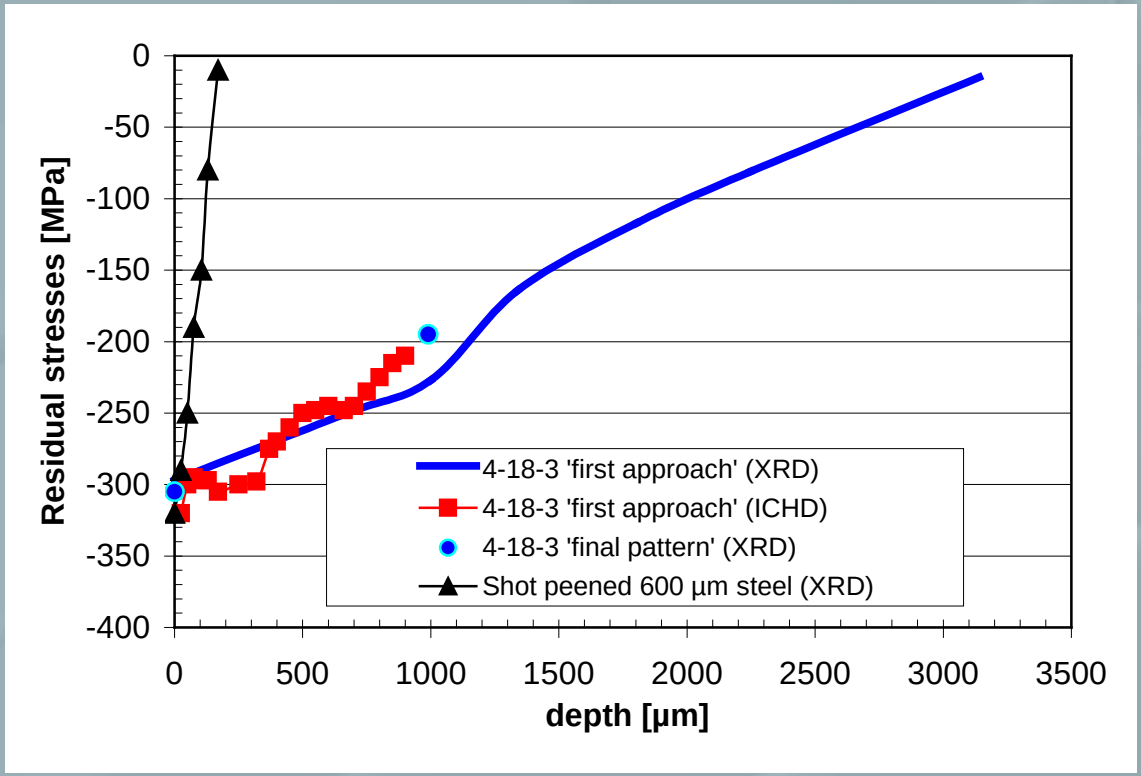
- **Around 15% larger stresses can be born for SP.**
- **Around 30% larger stresses can be born for LSP.**

Fatigue results – R = -3



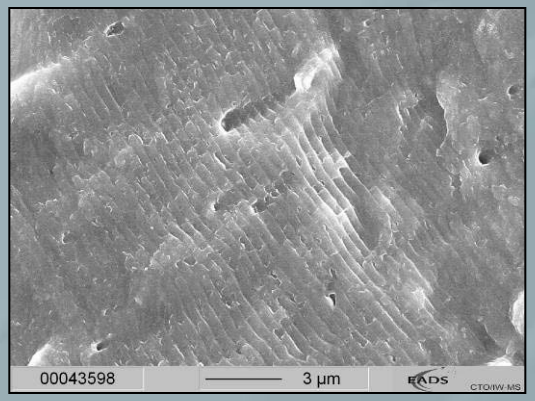
- **Around 5% larger stresses can be born for SP.**
- **Around 15% larger stresses can be born for LSP.**

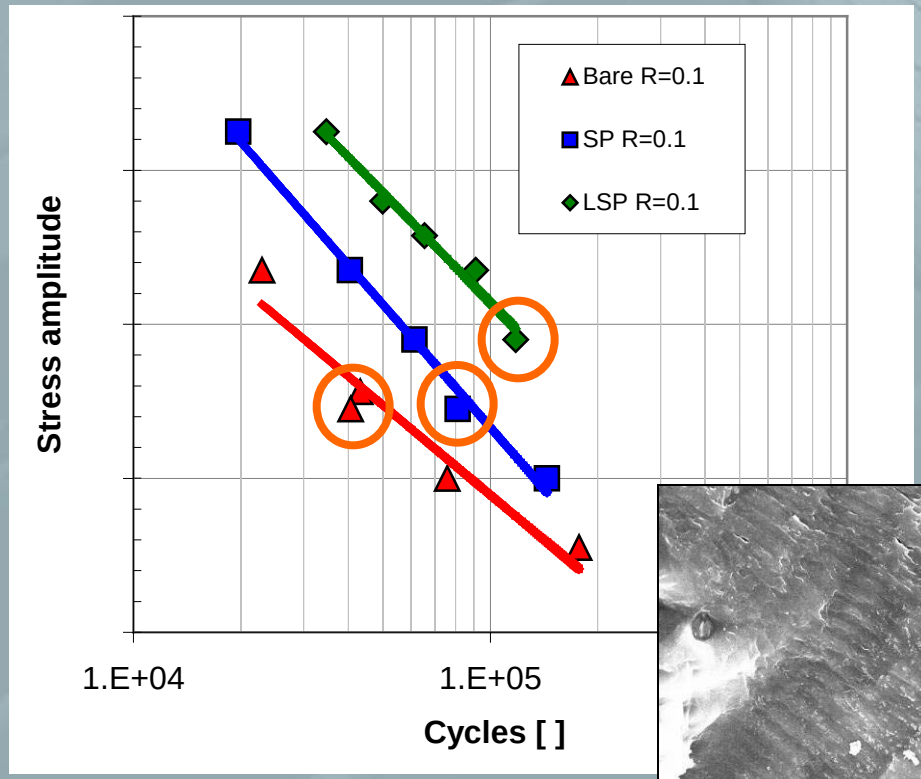
Residual stress profiles – Comparison of treatments

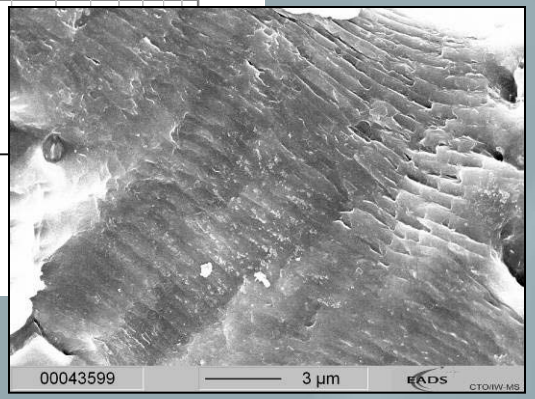


- **The compressive residual stresses (RS) reach much deeper in case of the LSP than for the SP treatment.**
- **“Final pattern” leads to comparable RS as the “first approach”.**

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

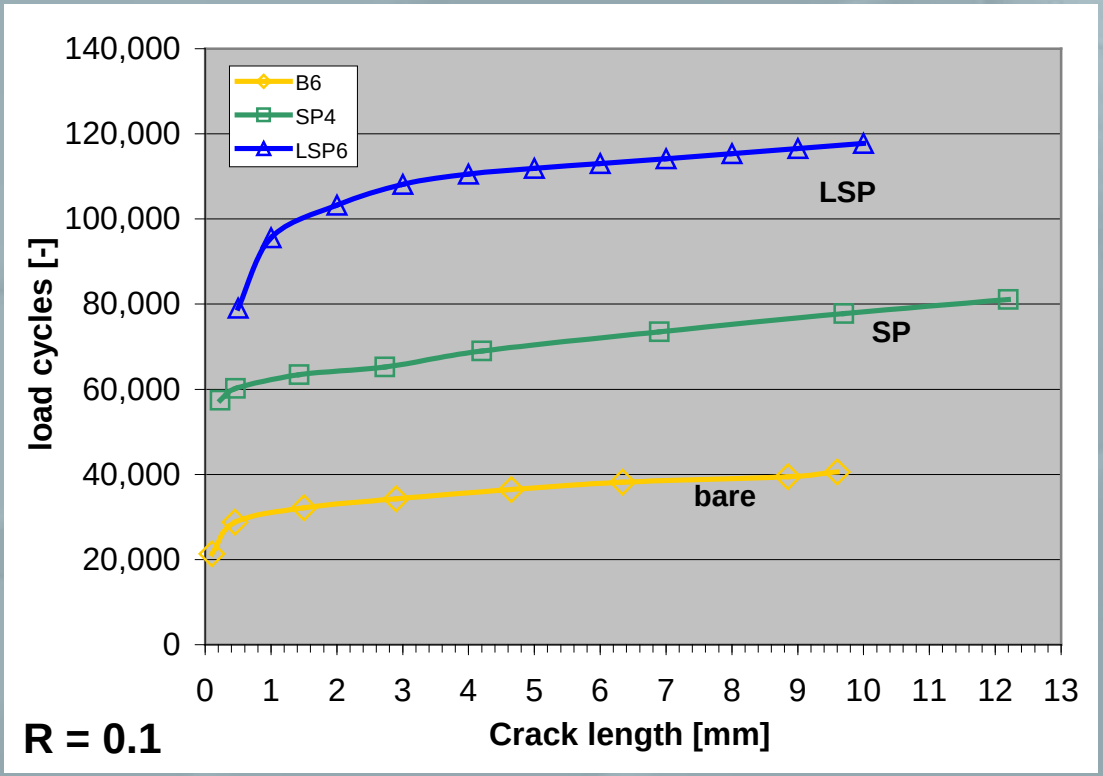






☞ **Analysis of striations.**

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.

EADS

Thank you very much for your attention!

Questions?