ICAF 2023 – the 38th Conference and 31st Symposium of the International Committee on Aeronautical Fatigue and Structural Integrity

Retardation of Fatigue Cracks in Welded Structures through Laser Shock Peening

N. Kashaev [1)], S. Keller [1)], U. F. H. Suhuddin[2)], V. Ventzke [1)], B. Klusemann [2), 3)]

[1)] Department of Laser Processing and Structural Assessment,
Institute of Materials Mechanics, Helmholtz-Zentrum Hereon

[2)] Department of Solid State Materials Processing,
Institute of Materials Mechanics, Helmholtz-Zentrum Hereon

[3)] Institute of Product and Process Innovation,
Leuphana University of Lüneburg

Delft, 26.06.2023

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OUTLINE

1. Introduction and motivation
2. Laser processed Al-alloys for damage tolerant design
3. Laser processed Ti-alloys for defect tolerant design
4. Summary and outlook

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Introduction and motivation

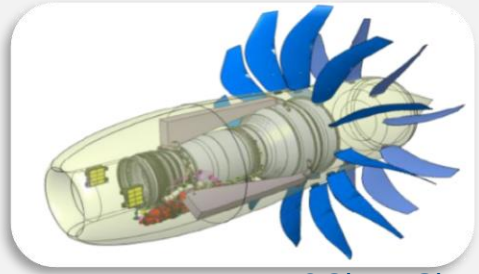
Environmental challenges and future technologies

- The goals defined by Flightpath 2050 (compared to 2000 levels)[1]:
  - 75% reduction in CO_2 emissions
  - 90% reduction in NO_x emissions
  - 65% reduction in perceived noise

→ 75% of the world fleet will be replaced by 2050

New design concepts

propulsion



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airframe

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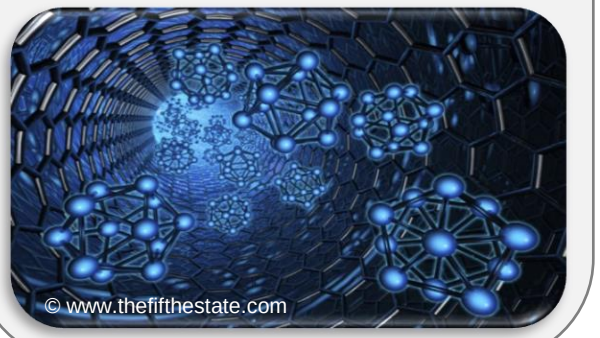
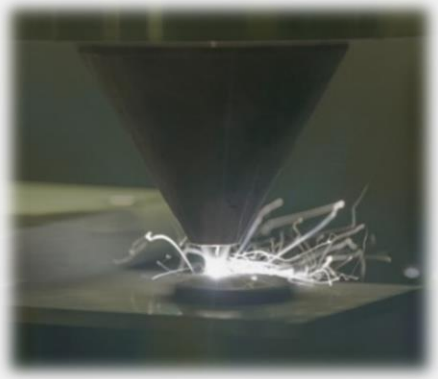
Advanced materials

- Metals:
  Al-, Ti-, Mg-, TiAl-alloys, high-entropy alloys.
- Composites and hybrid structures.



Processing technologies

Laser-based techniques for joining, additive manufacturing and residual stress engineering.



[1] "Strategic Research & Innovation Agenda. Update, Volume 1" ACARE, www.acare4europe.org, 2017.

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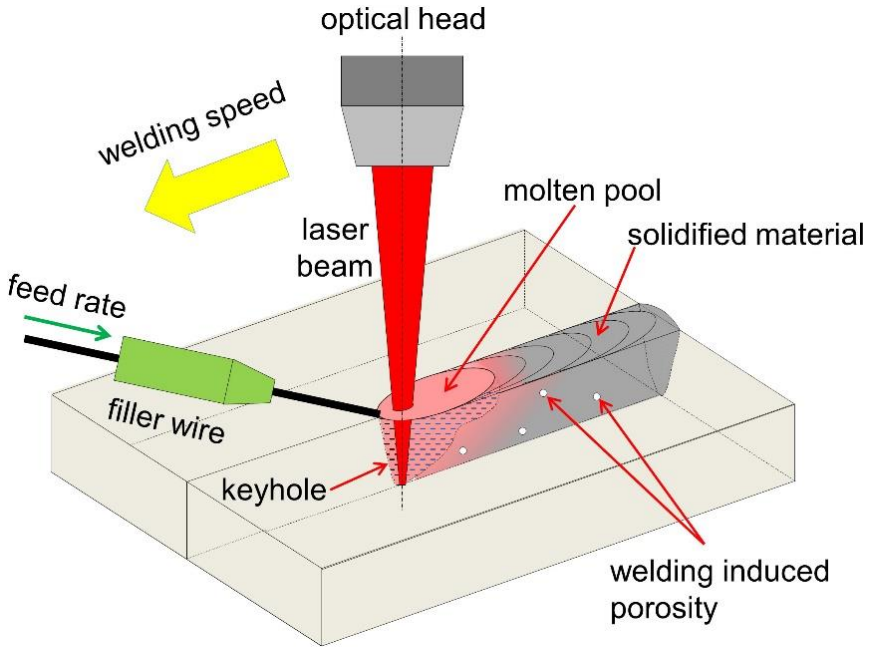
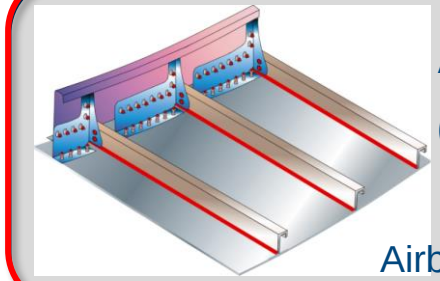
Introduction and motivation

Laser beam welding (LBW). Overview



- single step process → high productivity
- high flexibility of the process
- low heat input → low distortion
- no need for high vacuum
- non-contact technique



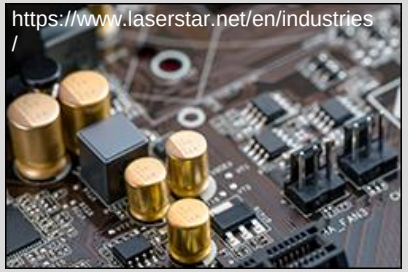
Aerospace

(airframe, turbines)

lower shells in Airbus A318, A340, A380

Automotive

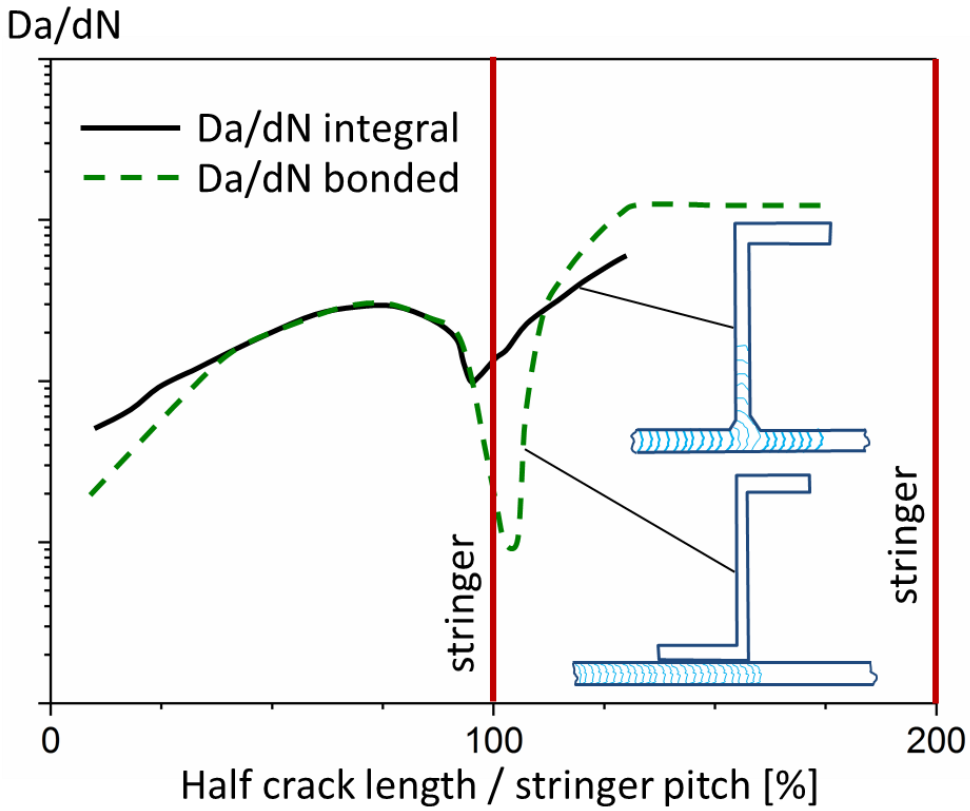
(body, power train, tailored blanks)

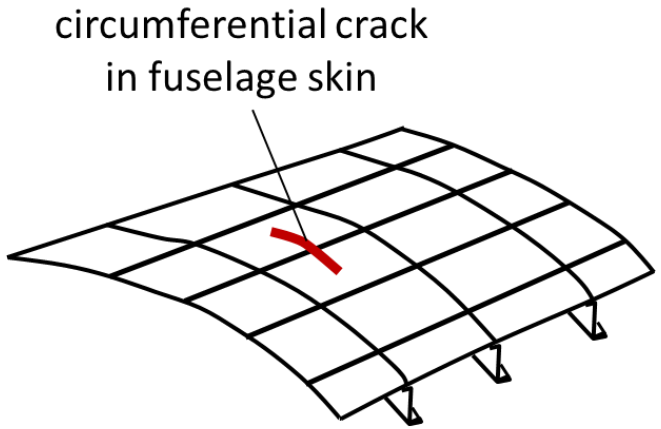


Micro technology

(cutting/welding/ drilling)

Crack scenarios in integral structures and built-up structures





➢ Inferior damage tolerance behaviour of laser welded structures

H.-J. Schmidt & B. Schmidt-Brandecker, *ECF 2010*.

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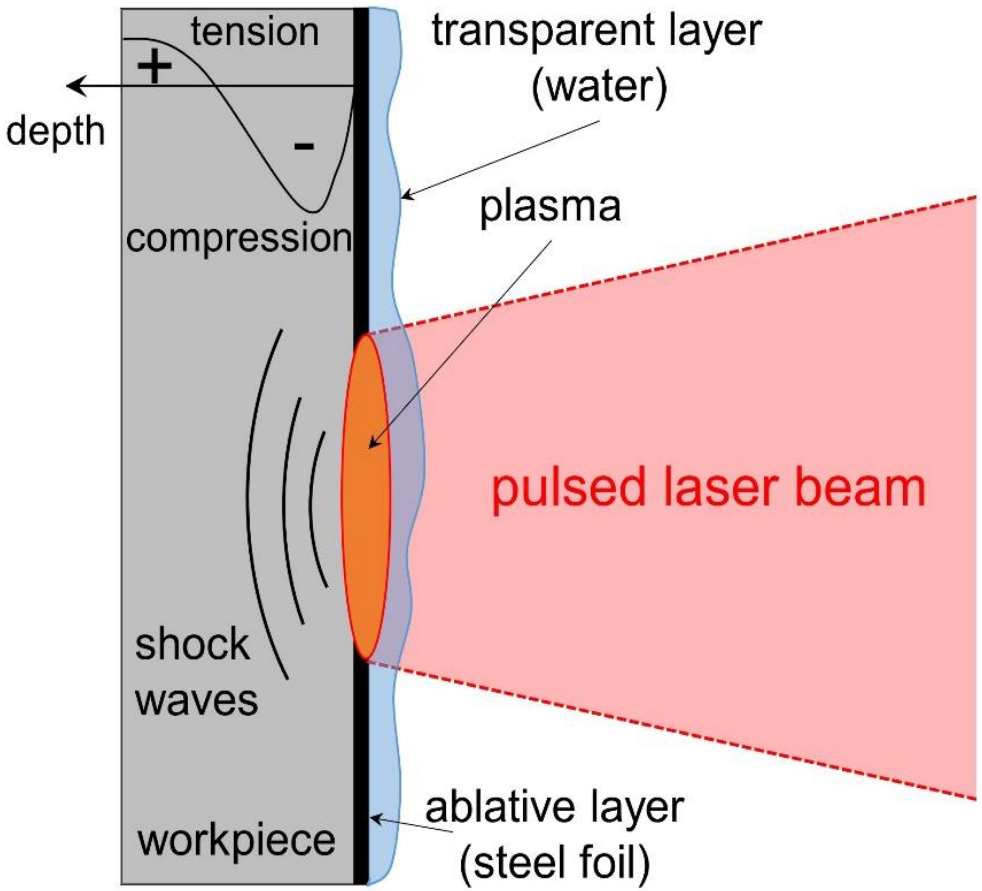
Laser shock peening for life extension and repair



- Tailored residual stress fields
- Low surface roughness
- Retardation or suppression of crack initiation
- Deceleration of crack growth

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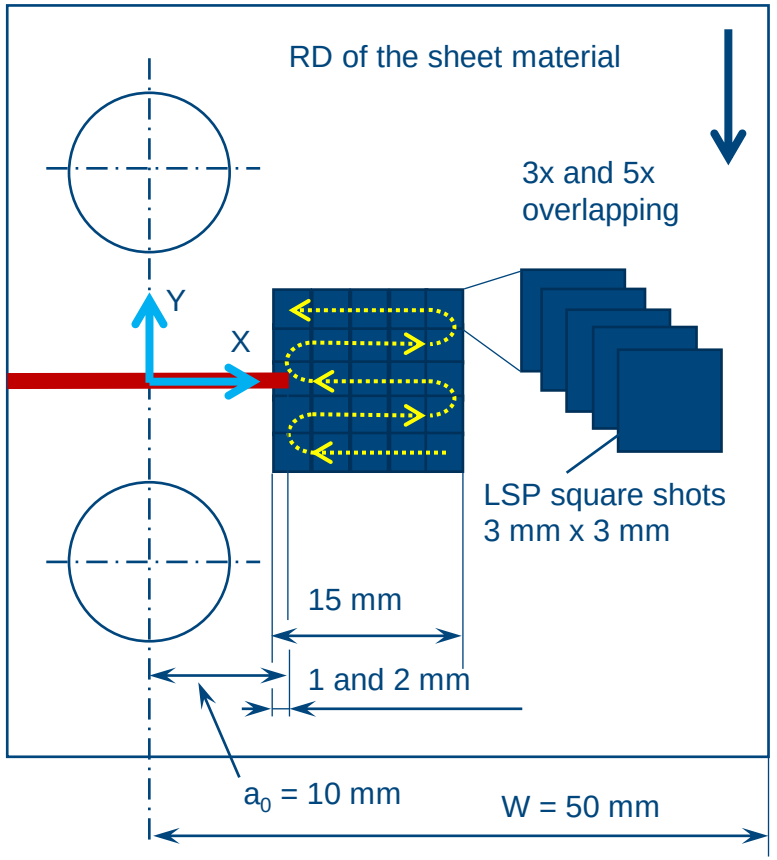
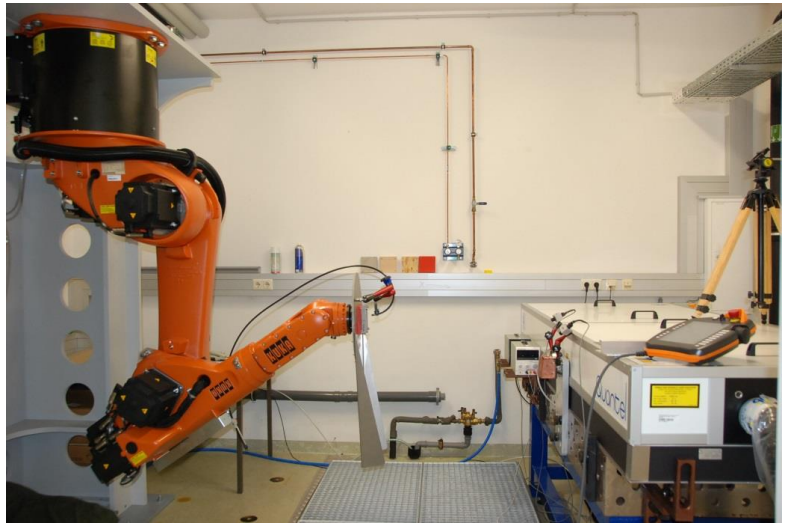
Experimental set-up for LSP at Hereon



C(T)50, AA2024 T3, thickness = 2 mm

N. Kashaev et al.: *Int. J. Fatigue* 98 (2017) 223-233



Q-switched Nd:YAG-laser, 3 J, 10 ns,
3 mm x 3 mm square spot, Al-foil **3.3 GW/cm²**

Specimen identification	Numbers of LSP layers	Distance of LSP patterns before the crack tip
BM	-	-
LSP 5x -1	5	1 mm
LSP 3x -2	3	2 mm
LSP 5x -2	5	2 mm

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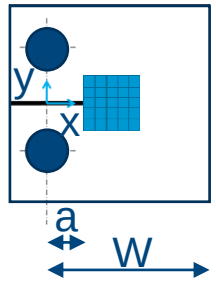
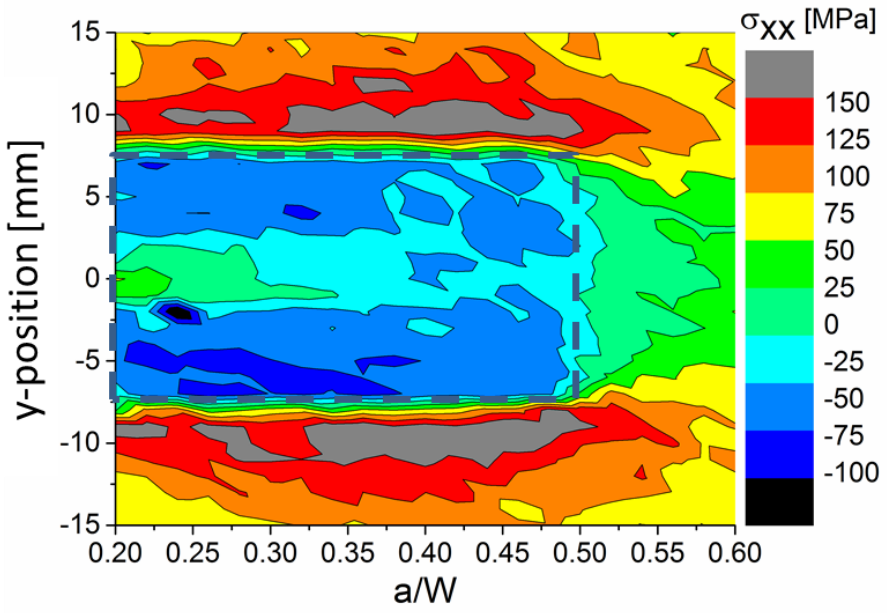
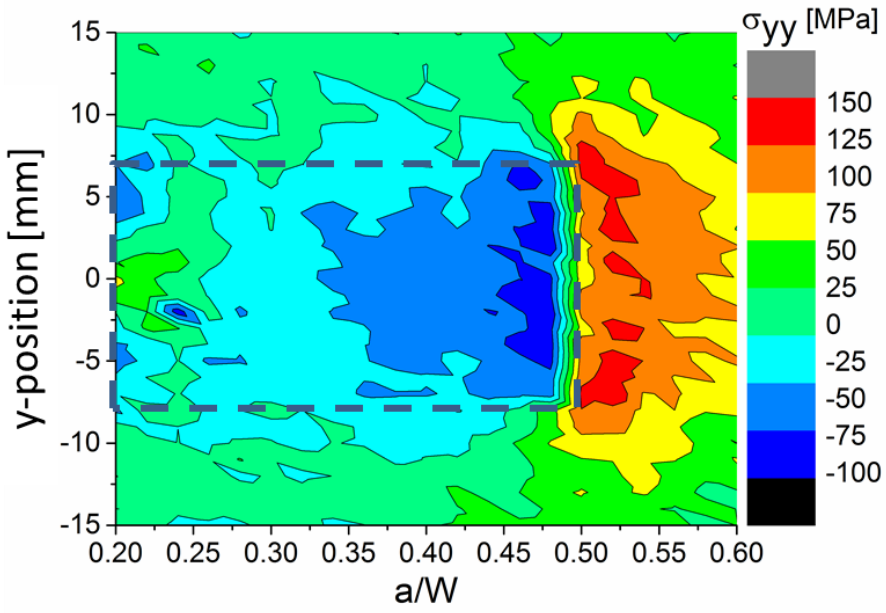
Residual stress analysis using synchrotron radiation



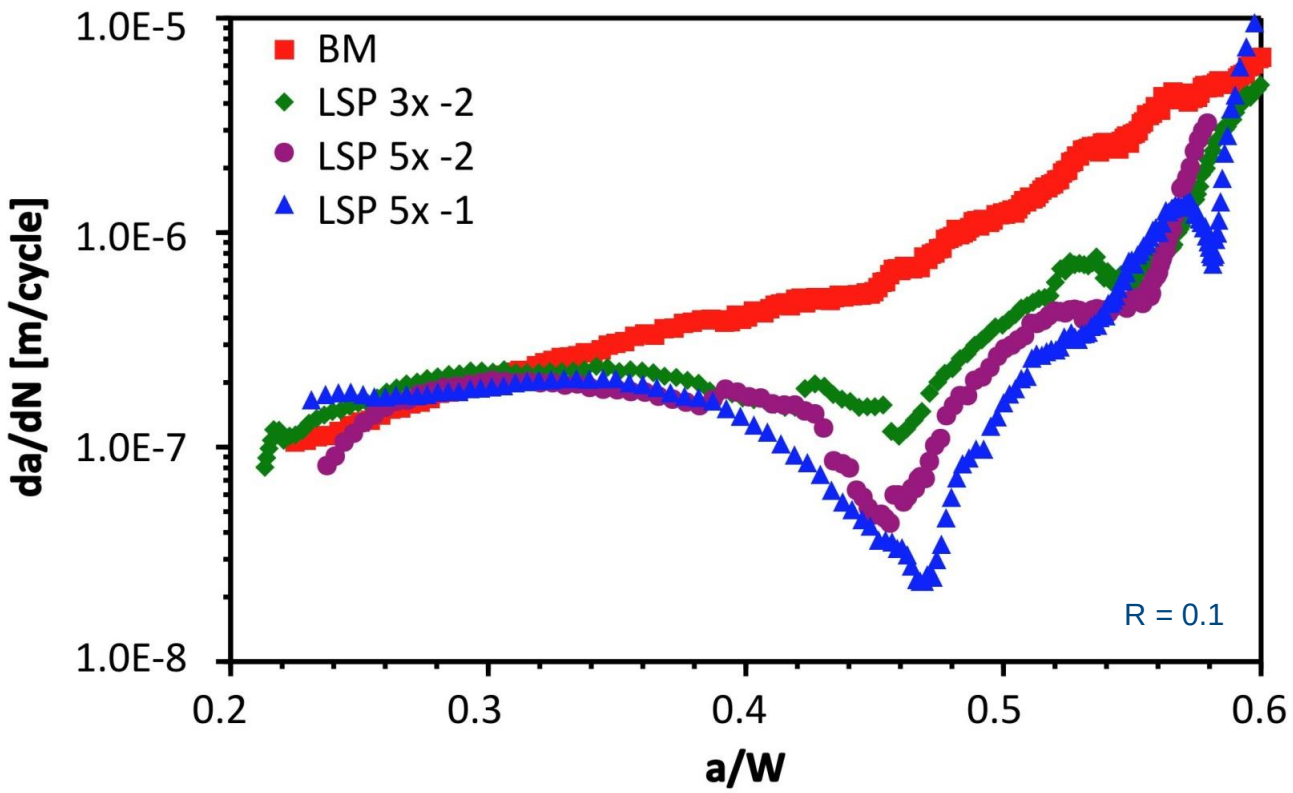


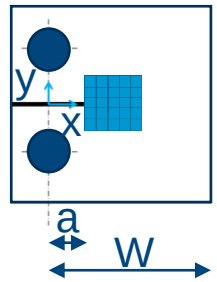


- Generation of through-the-thickness compressive residual stresses is possible by using the LSP treatment!

N. Kashaev et al.: *Int. J. Fatigue* 98 (2017) 223-233

Fatigue crack propagation





- Significant retardation in the FCP when the crack propagates through the LSP-treated area with high compressive through-the-thickness residual stresses!

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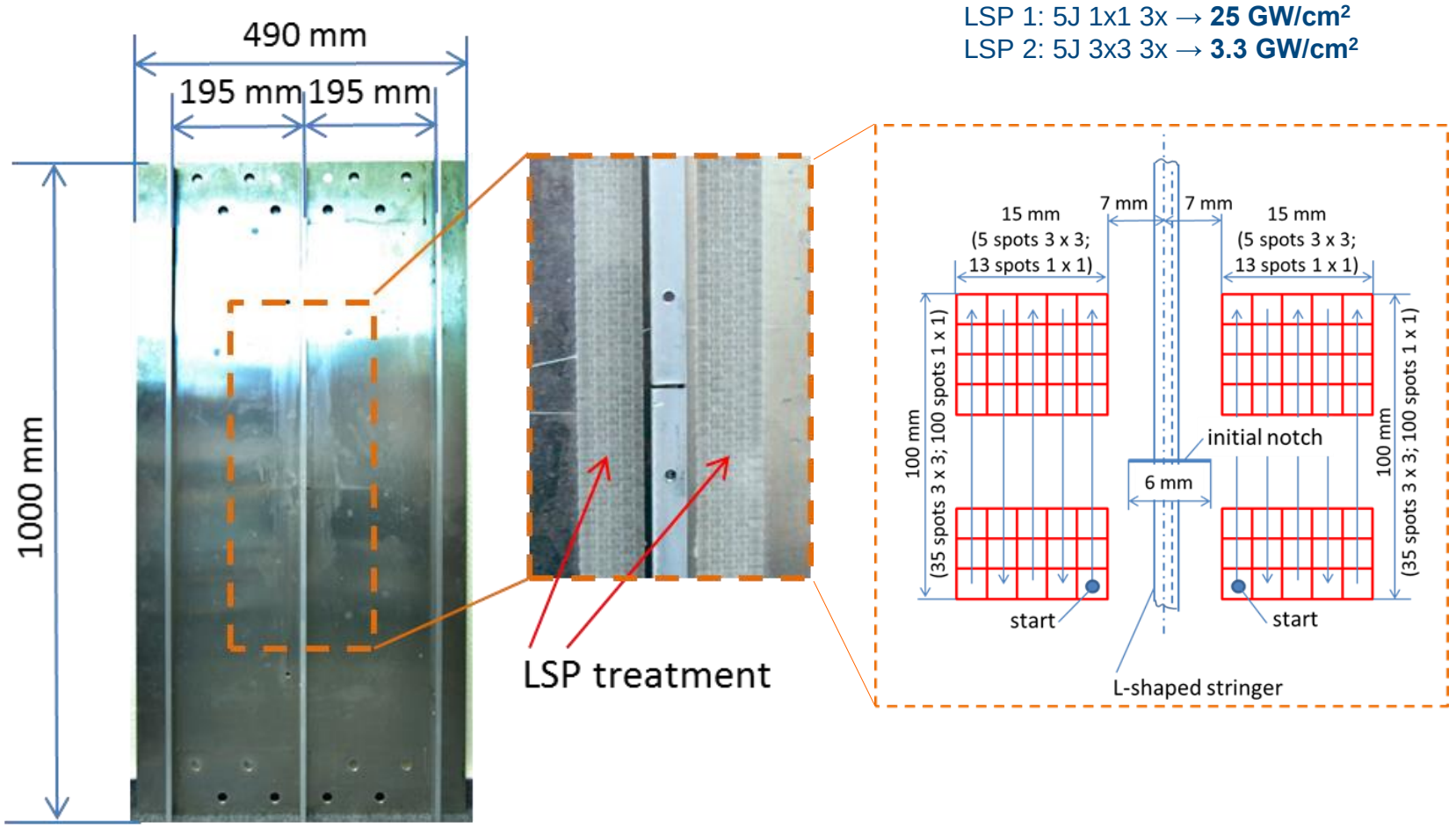
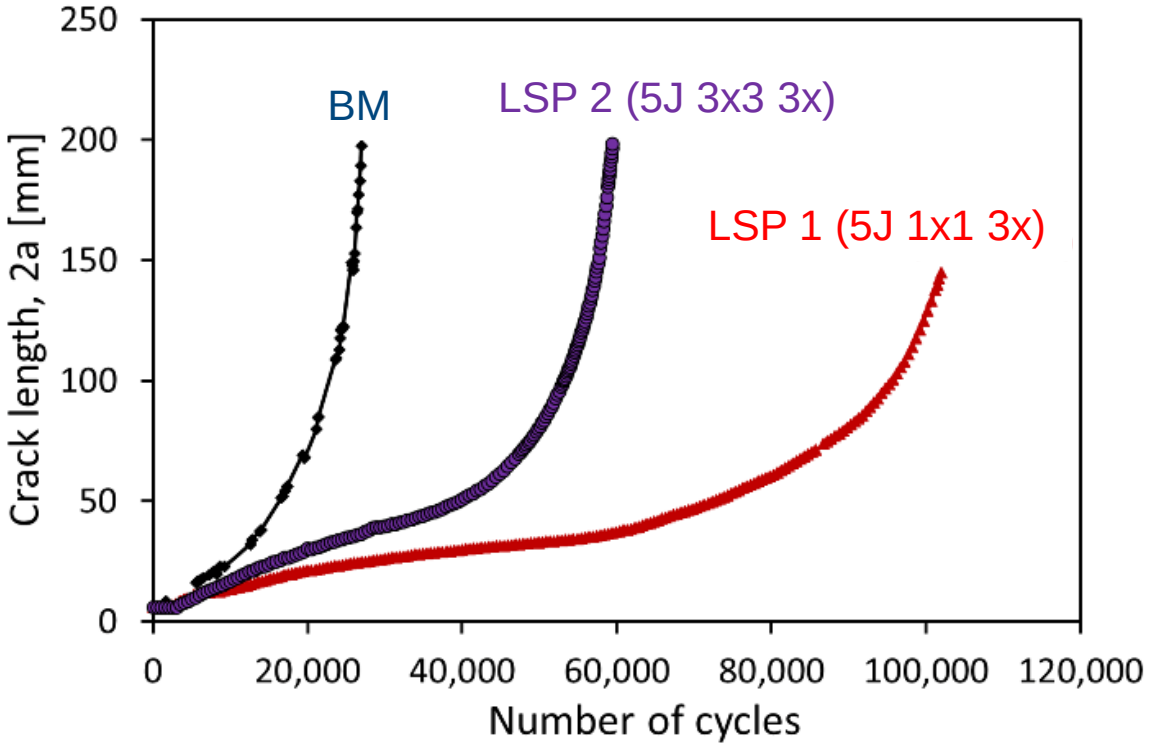
LSP-treatment of welded AA2024-AA7050 3-stringer panels



N. Kashaev et al.: *MATEC Web. Conf.* 165 (2018) 18001

FCP-test results of welded 3-stringer AA2024-AA7050 panels



Servo-hydraulic machine:
$f \leq 5$ Hz, $R_F = 0.1$

- An increase of up to 200-400% in fatigue life could be obtained by local treatment via laser shock peening

N. Kashaev et al.: *MATEC Web. Conf.* 165 (2018) 18001

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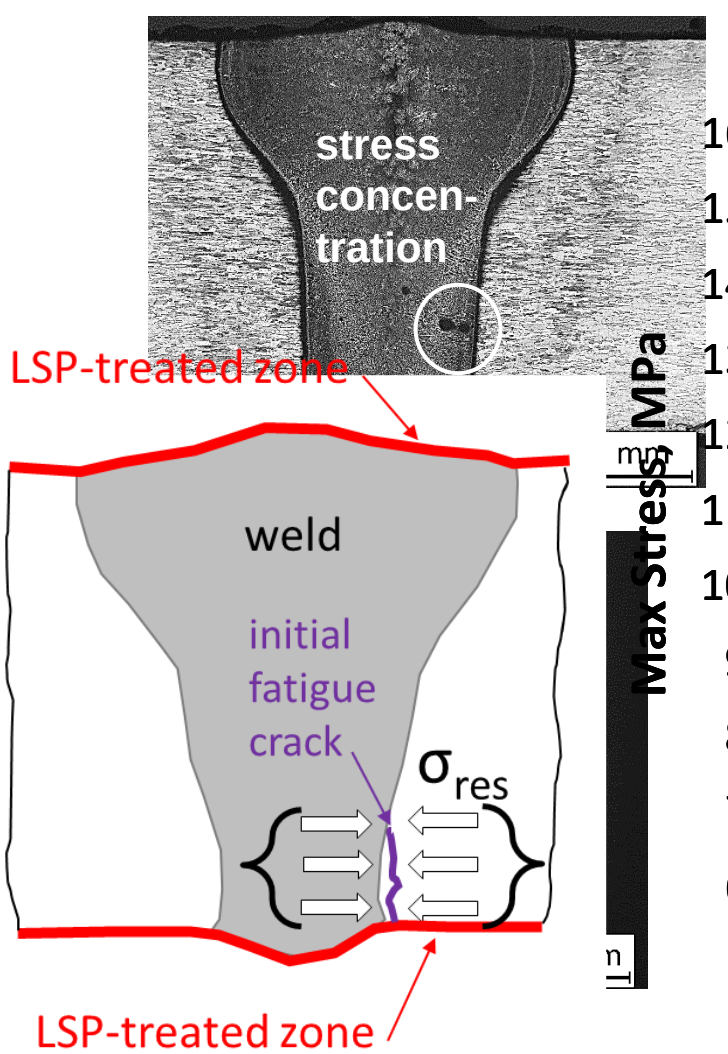
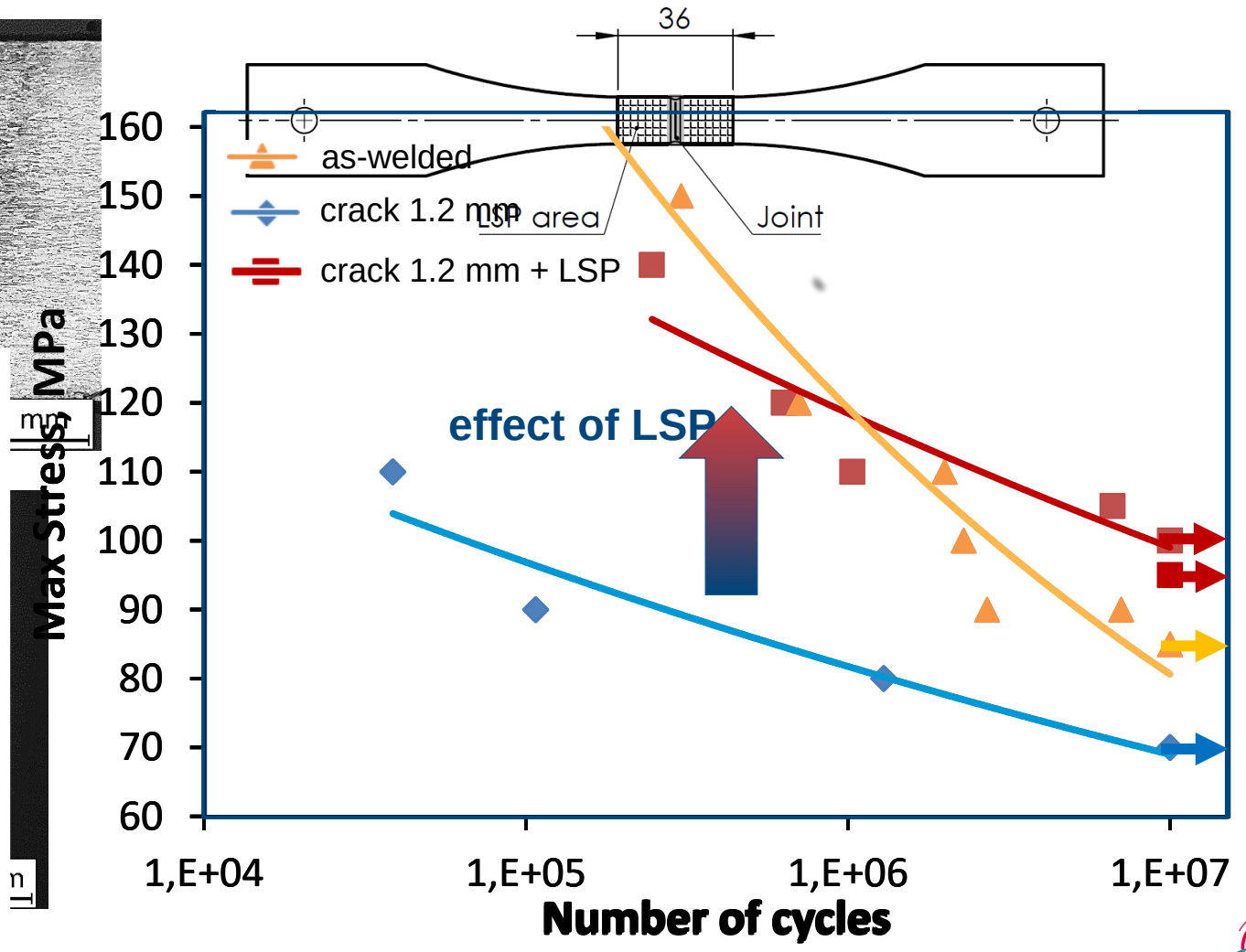
LSP for welds repair – application for laser welded AA6056 with surface fatigue cracks

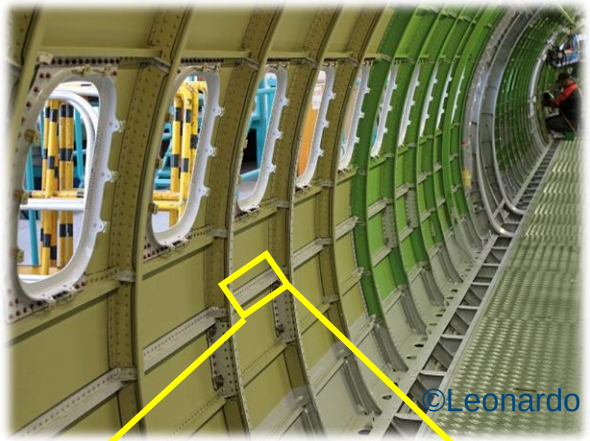
P = 3.25 kW (CO_2); v = 2.0 m/min; argon

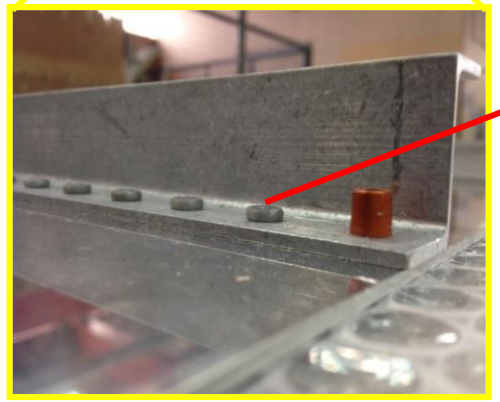


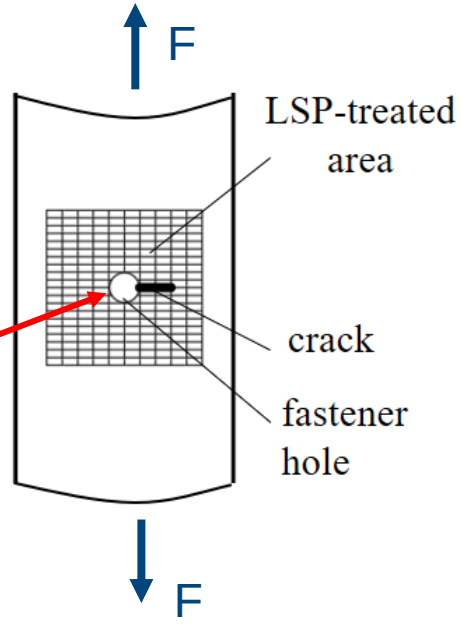


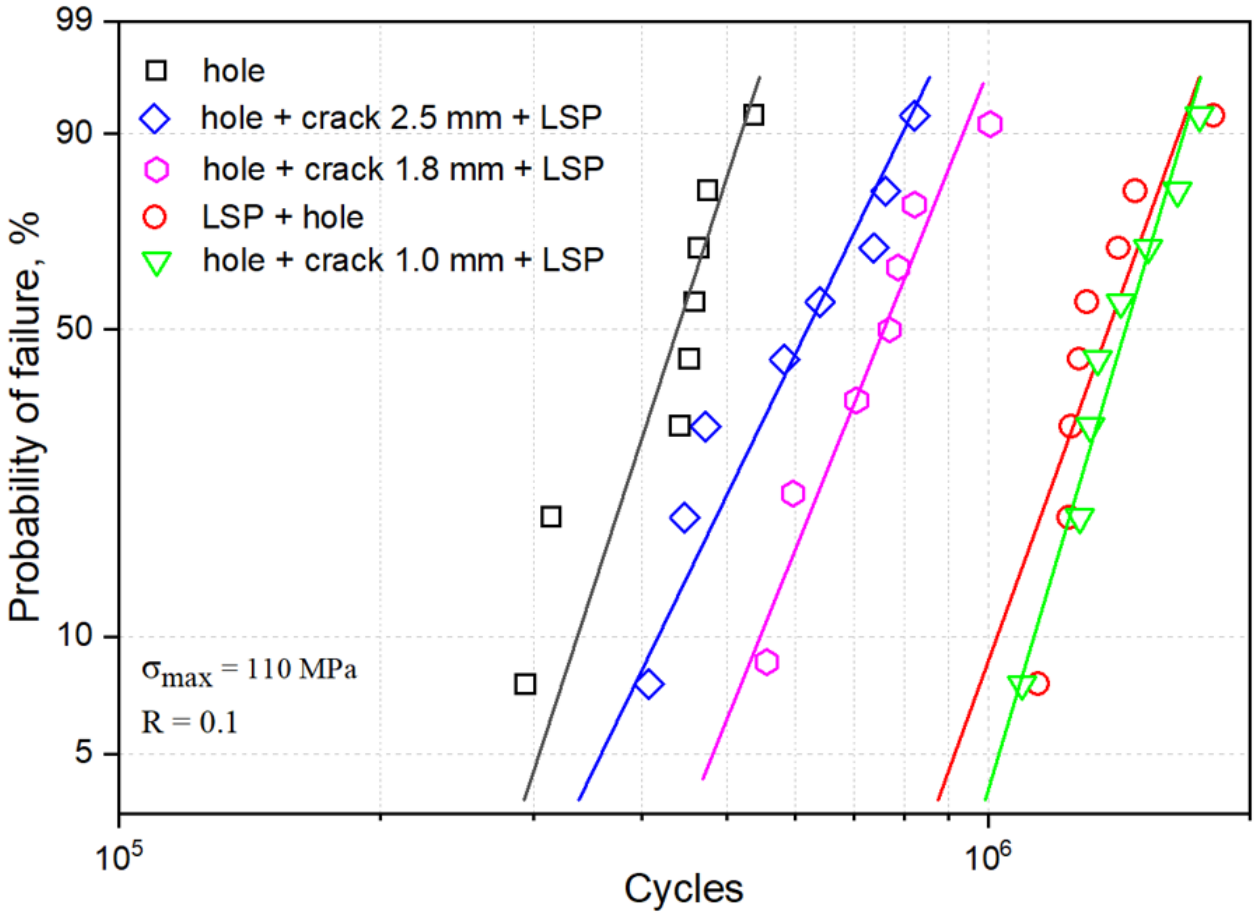
N. Kashaev et al.: *Fatigue. Fract. Eng. Mater. Struct*. 2020

LSP for repair – Application for riveted joints





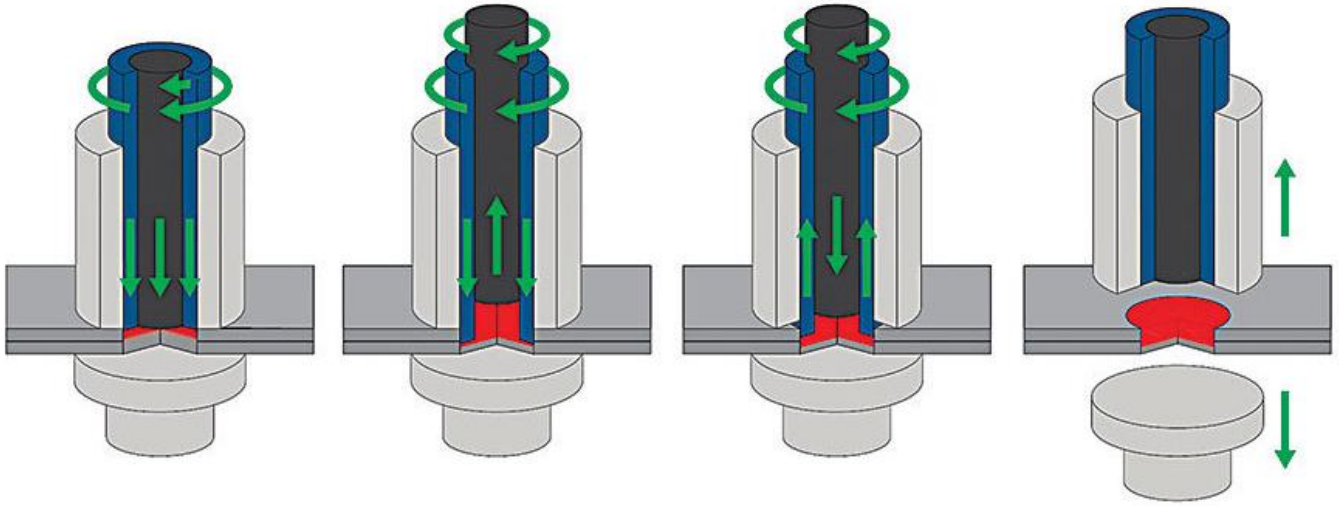


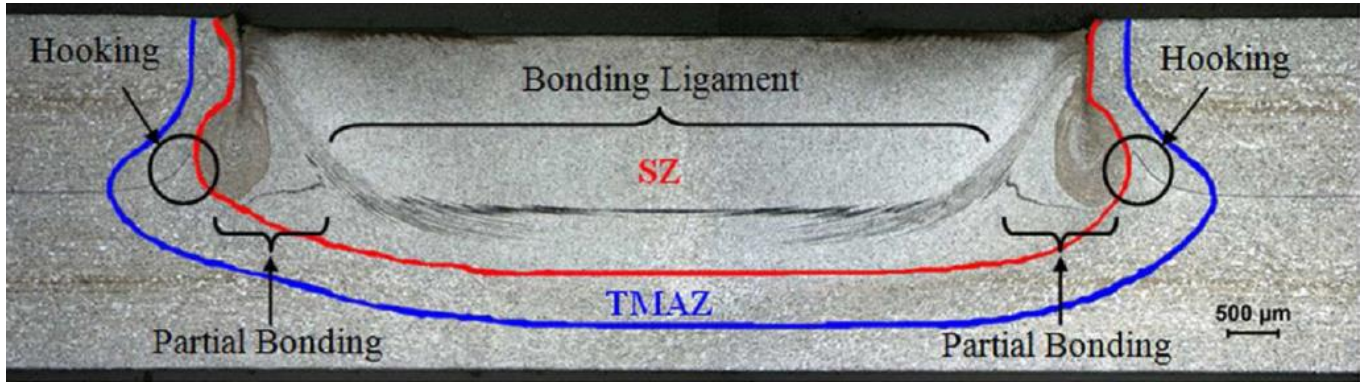


- Fatigue life increase of pre-cracked and LSP-treated specimens with a rivet hole by factor 1.5 - 3.3 compared to untreated crack-free specimens

R. Sikhamov et al.: *Metals*. 2020

Fatigue Life Extension of Refill Friction Stir Spot-Welded Joints





- fatigue strength of the refill FSSW joints is only 15% of the ultimate lap shear strength

R. C. Brzostek et al. *Fatigue Fract. Eng. Mater. Struct*. 41 (2018) 1208-1223

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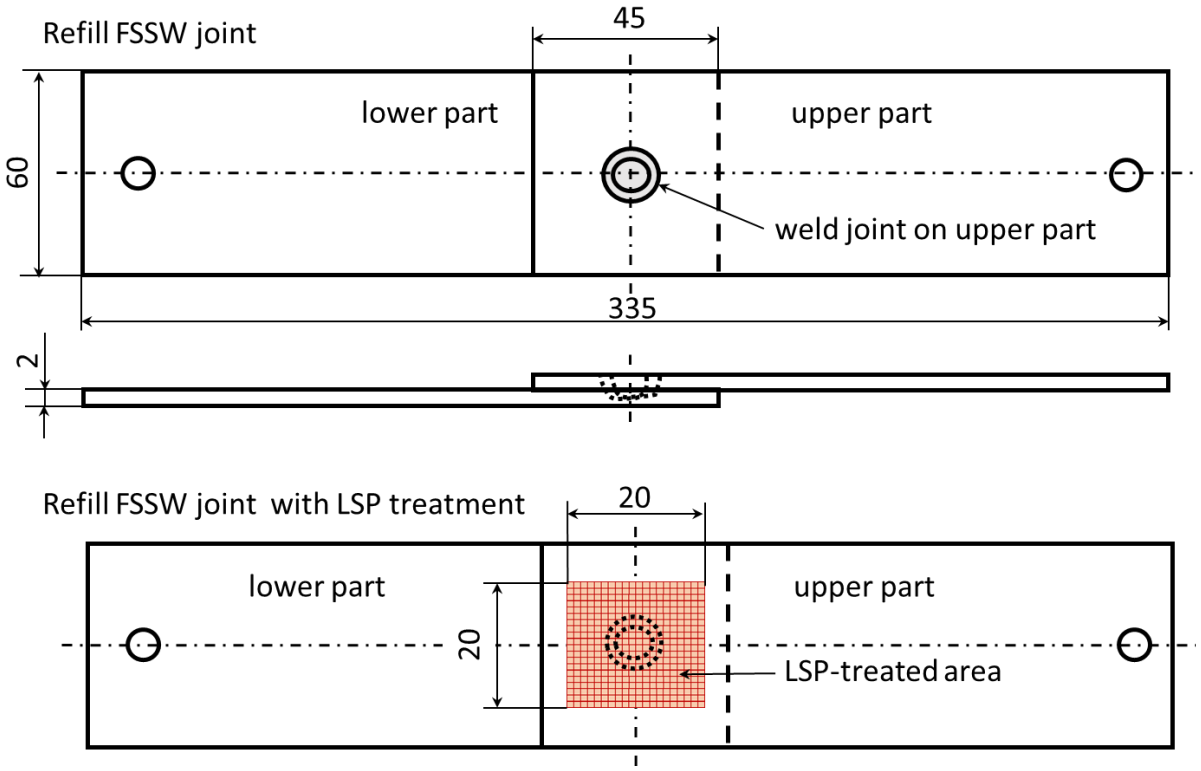
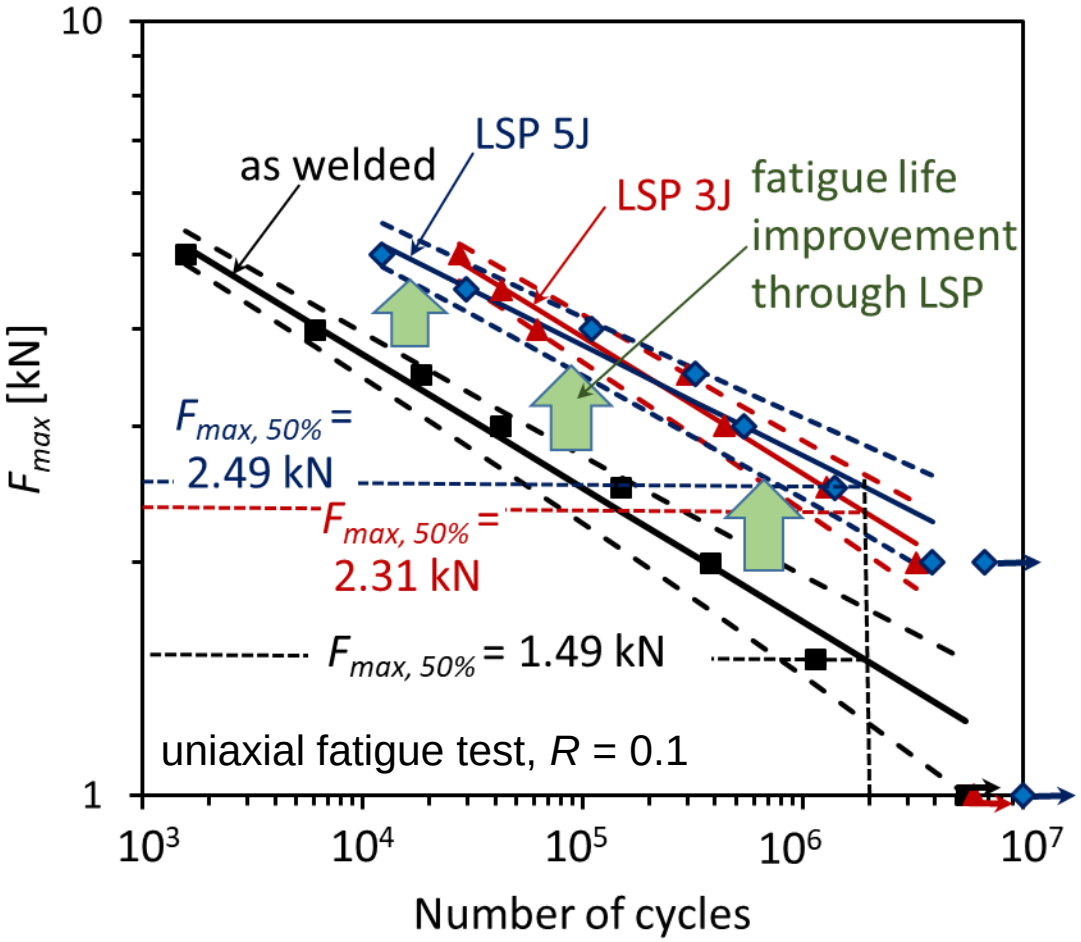
Fatigue Life Extension of Refill Friction Stir Spot-Welded Joints





- LSP represents a promising post-processing technique to increase the service life of refill FSSW joints without adding weight to the structure, thus making this innovative joining technique a competitive replacement for classical riveting

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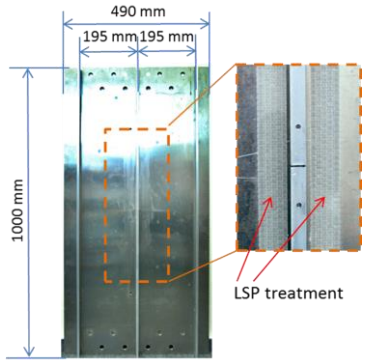
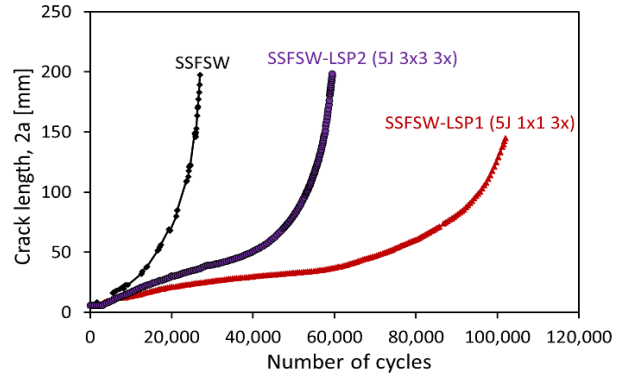
Summary and Outlook

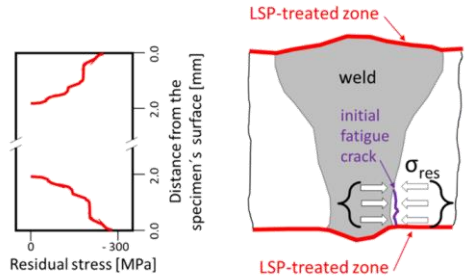
Retardation of Fatigue Cracks in Welded Structures through Laser Shock Peening

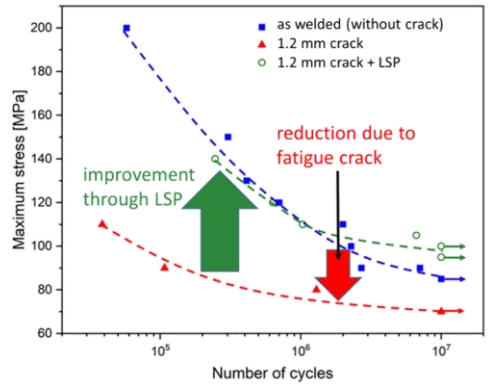
- An increase of up to 200-400% in fatigue life could be obtained by local treatment via laser shock peening



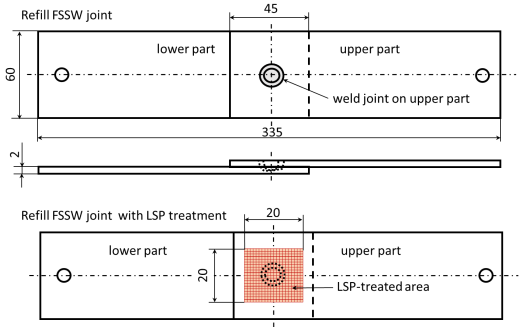


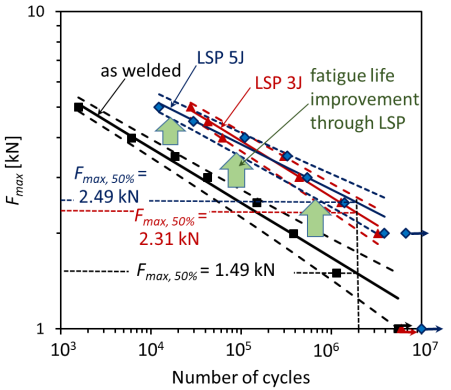
- Laser shock peening can be applied as an repair and/or a prophylactic residual stress engineering approach to extend the fatigue life of critical structures in ageing aircrafts





- The positive effect of laser shock peening is also demonstrated for riveted and refill FSSWed joints





Thank you very much for your attention!