Crack initiation in notched coarse-grained RR1000 specimens subjected to in-phase thermo-mechanical fatigue

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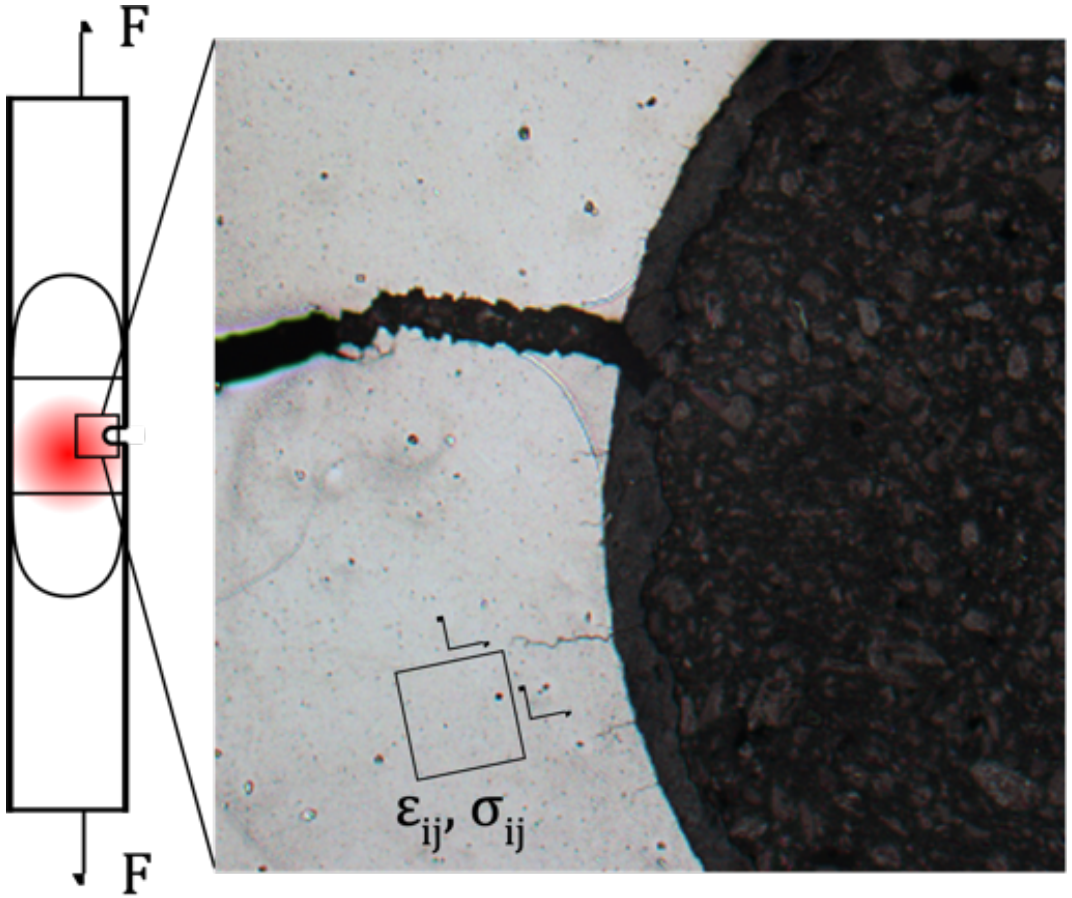
Objectives



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Outline

- Background and motivation
- Methods
- Results
- Conclusions

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DevTMF – an EU project

- Reducing aero engine emissions
  - ➢Development of light-weight and fatigue-resistant materials

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Material and load conditions

- Coarse-grained RR1000 for turbine rotors
- Thermo-mechanical load conditions

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Outcomes

- Increased understanding of fatigue crack initiation under service load conditions
- Experimental support for lifetime assessment modelling

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Methods

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Thermo-mechanical fatigue test

- 70s triangular cycle
- 400-750°C
- 240MPa, R=-1
- In-phase (IP)

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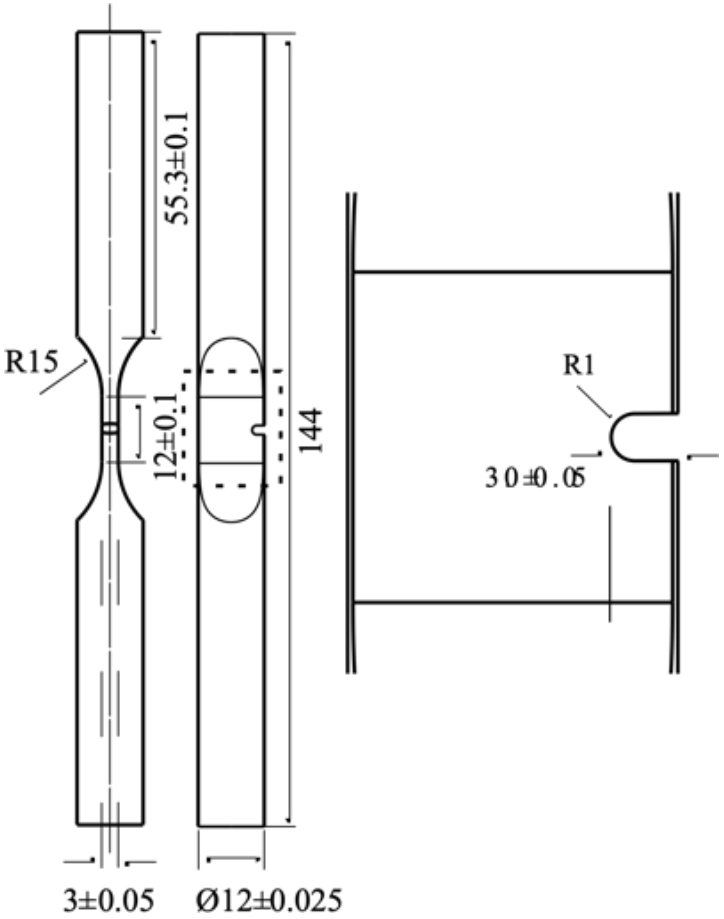
Single-edge notched (SEN) specimen



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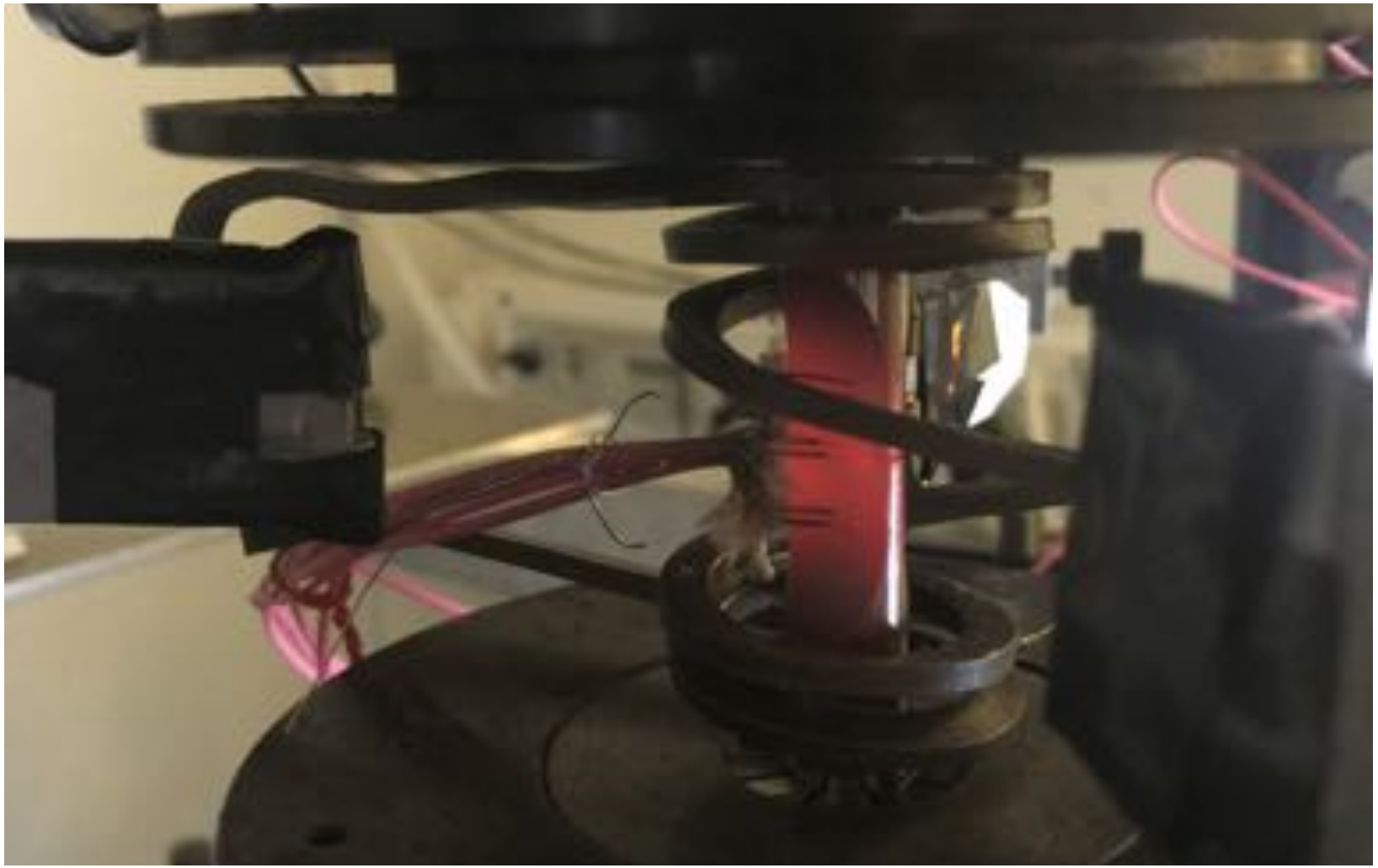

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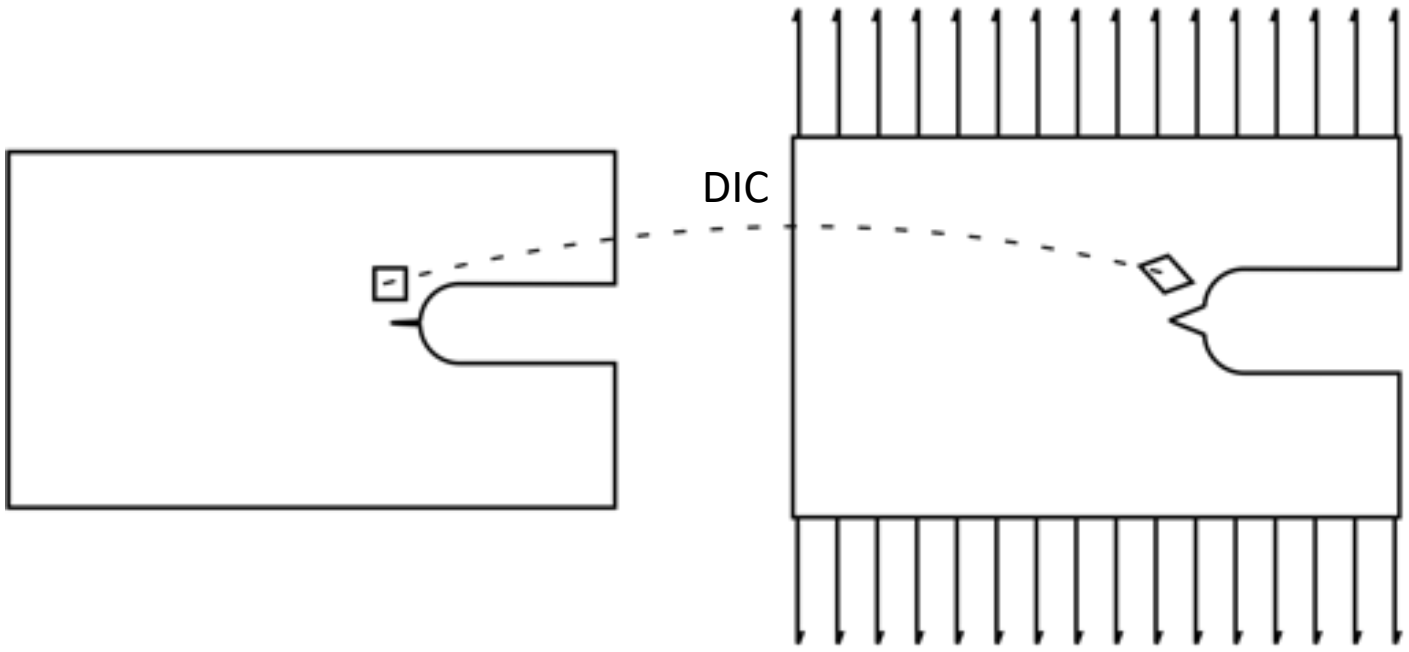
Strain field measurements

Digital image correlation (DIC)



Reference image

Image of deformed state

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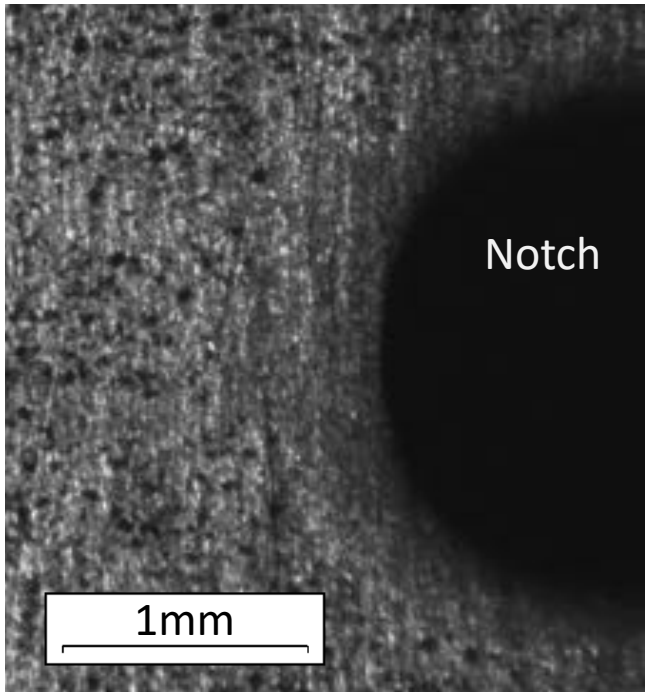
Strain field measurements

- Nikon UBS29 QXC F camera mounted at a lateral viewpoint
- LED lamp to eliminate blackbody radiation
- Open source Matlab-based DIC code
- DIC reference image taken at start of test
- Strain field averaged over several cycles



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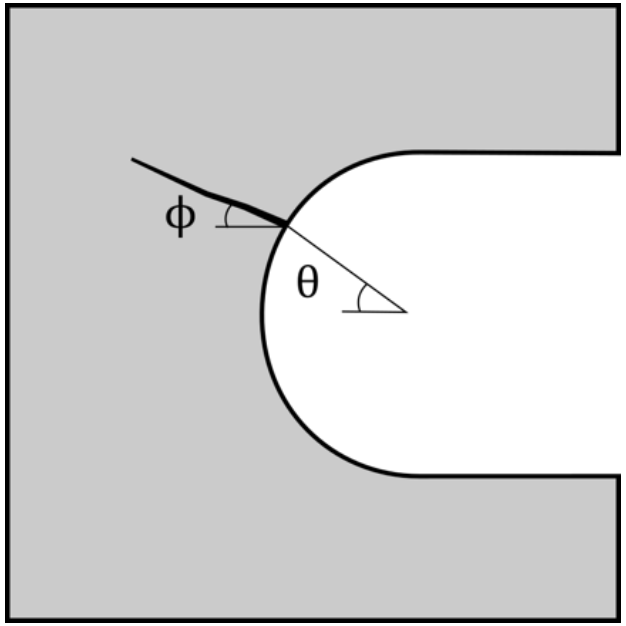
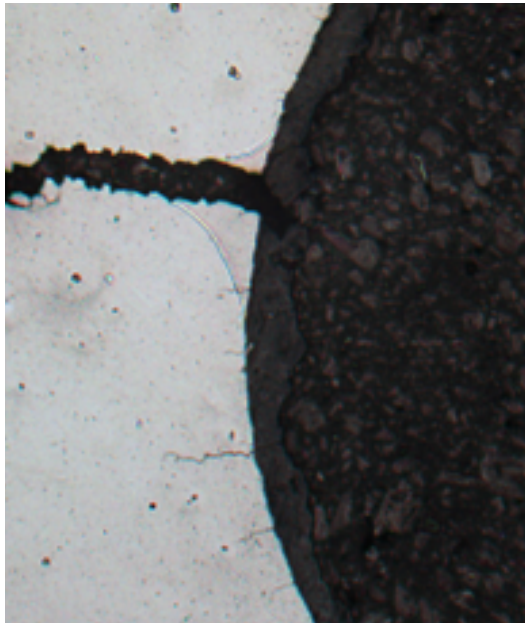
Metallography

Secondary cracks in the notch

- Measurement of secondary crack deviation angle
- Electron backscatter diffraction (EBSD)





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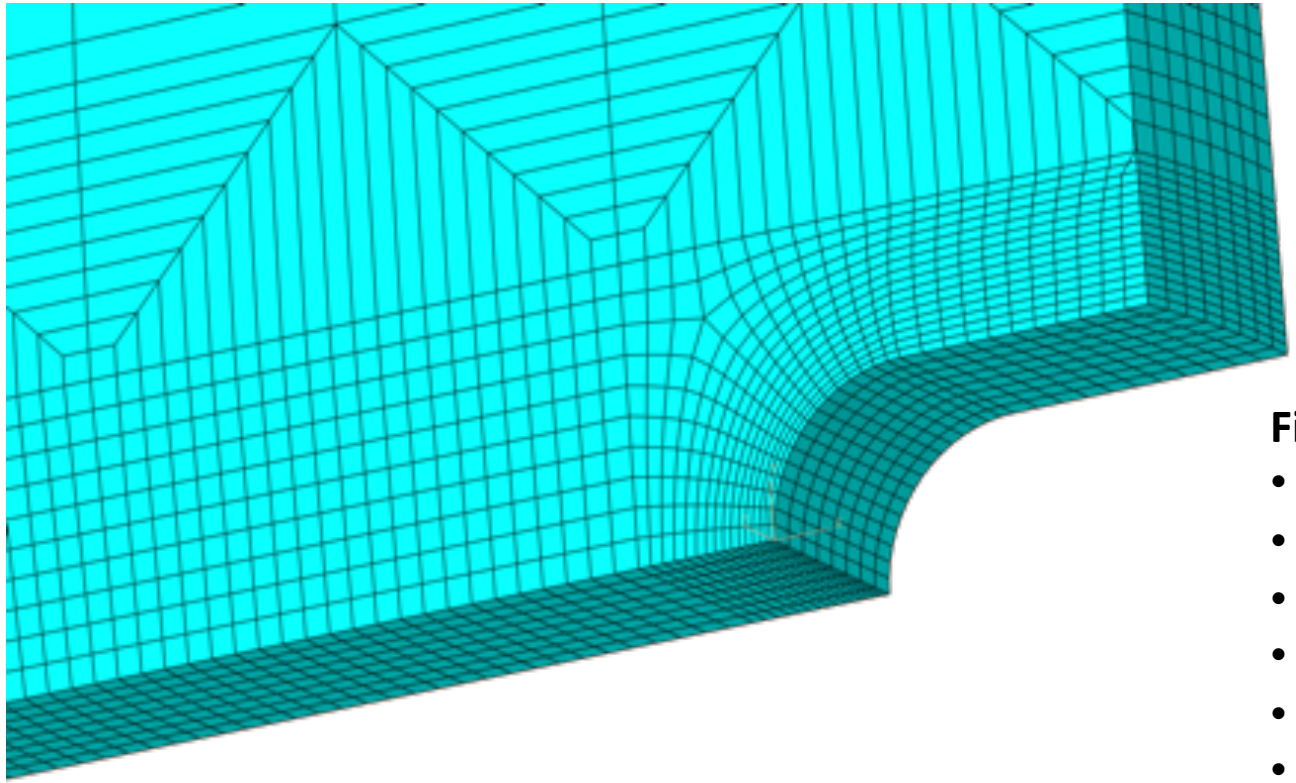
Finite element modelling



Finite element model

- Abaqus CAE 6.12
- Elastic-perfect plastic material model
- Material data from tensile tests
- Uniform temperature
- Specimen symmetry exploited
- Uniform displacement at grip ends
- Brick elements with reduced integration

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Results

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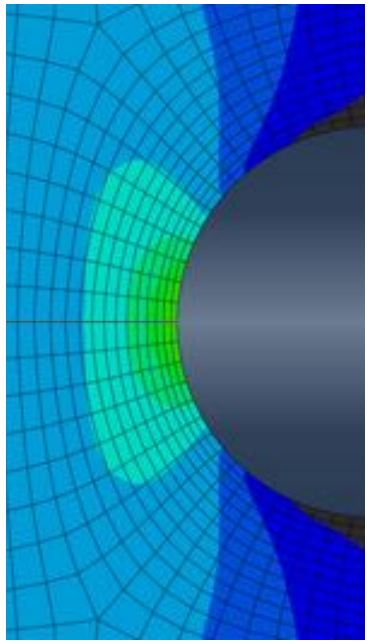
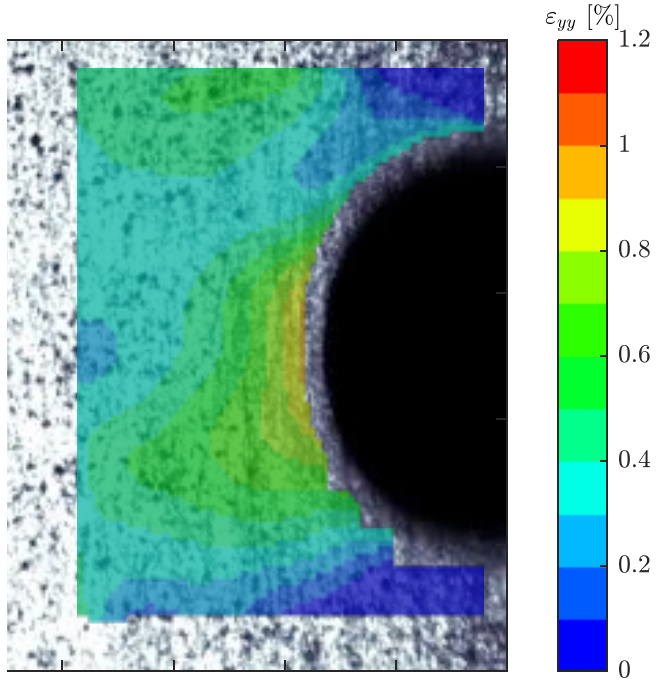
Vertical strain component at peak tensile load (240MPa)





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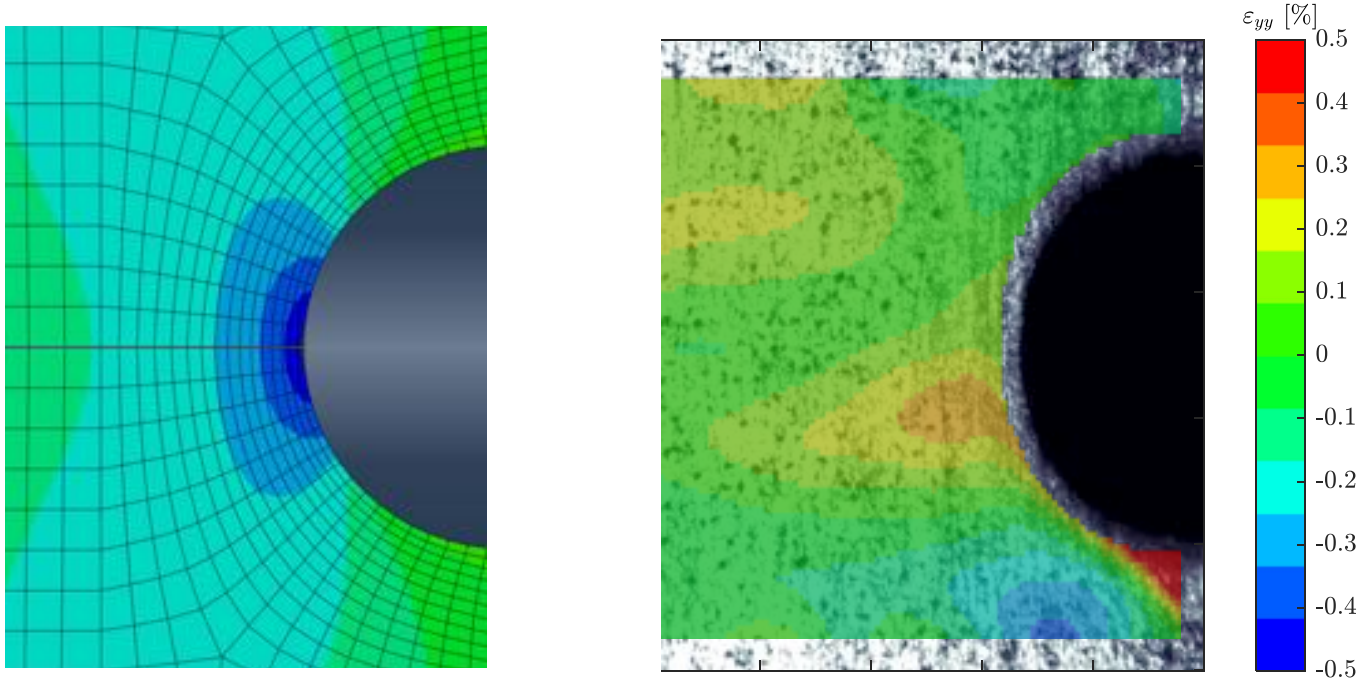
Vertical strain component at peak compressive load (-240MPa)



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- Significant ratchetting effect
  - Non-symmetric creep and hardening due to the IP cycle

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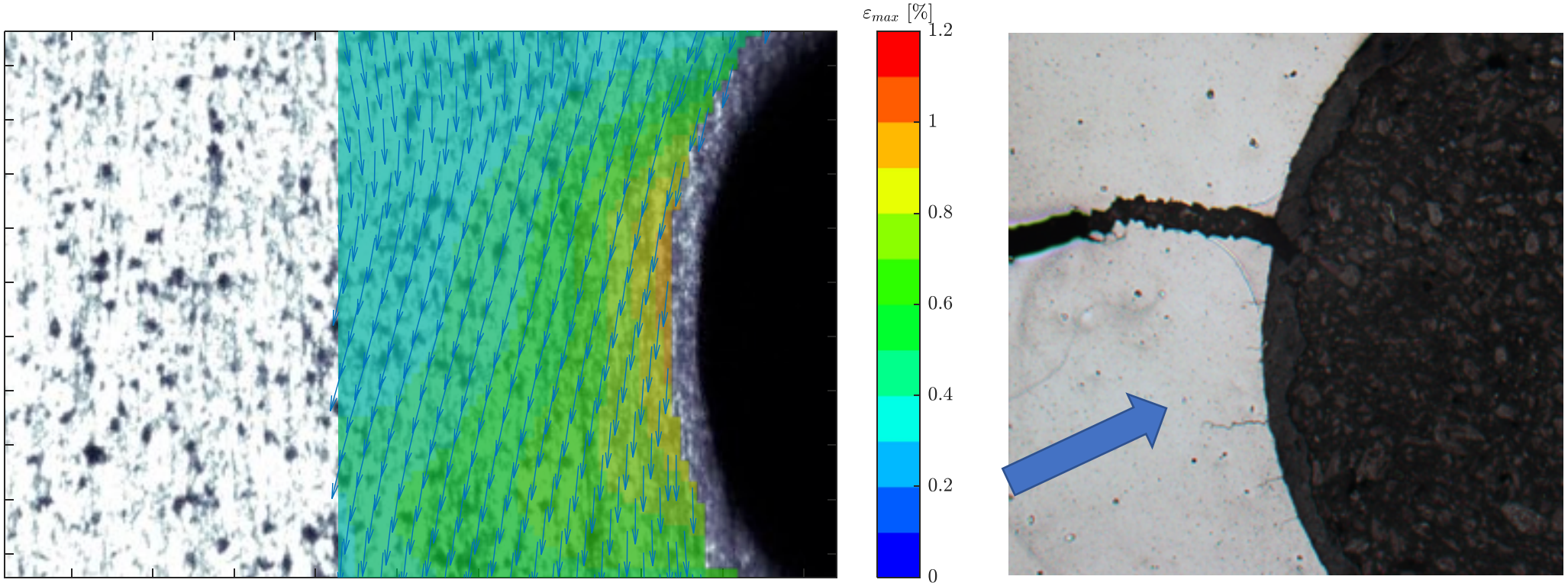
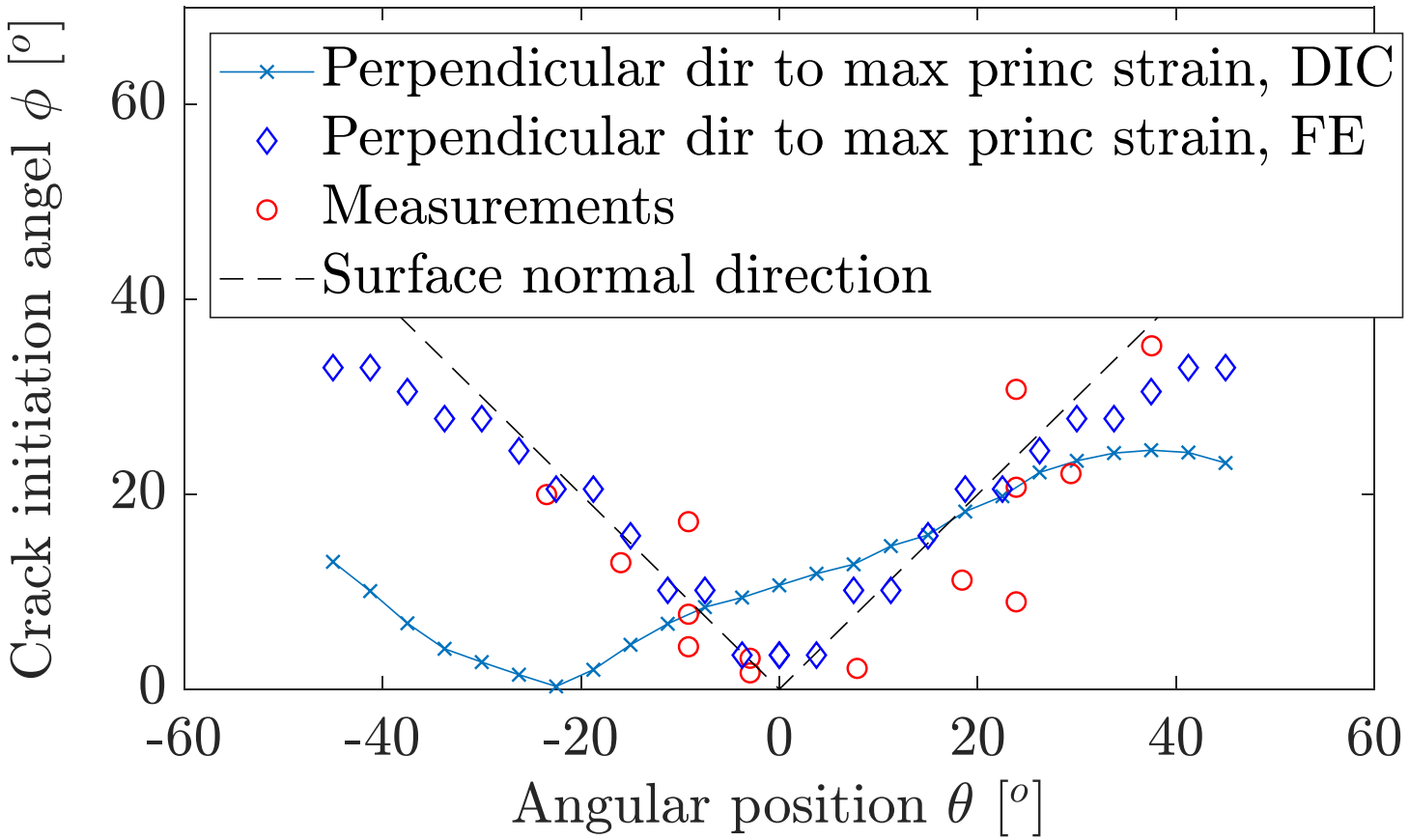
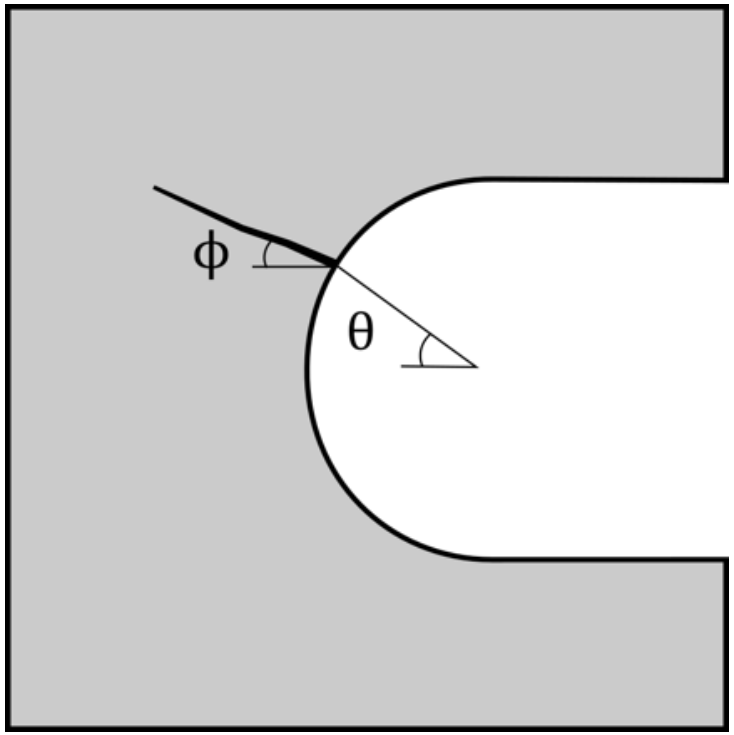
Maximum principal strain and principal direction



Orientation of secondary cracks





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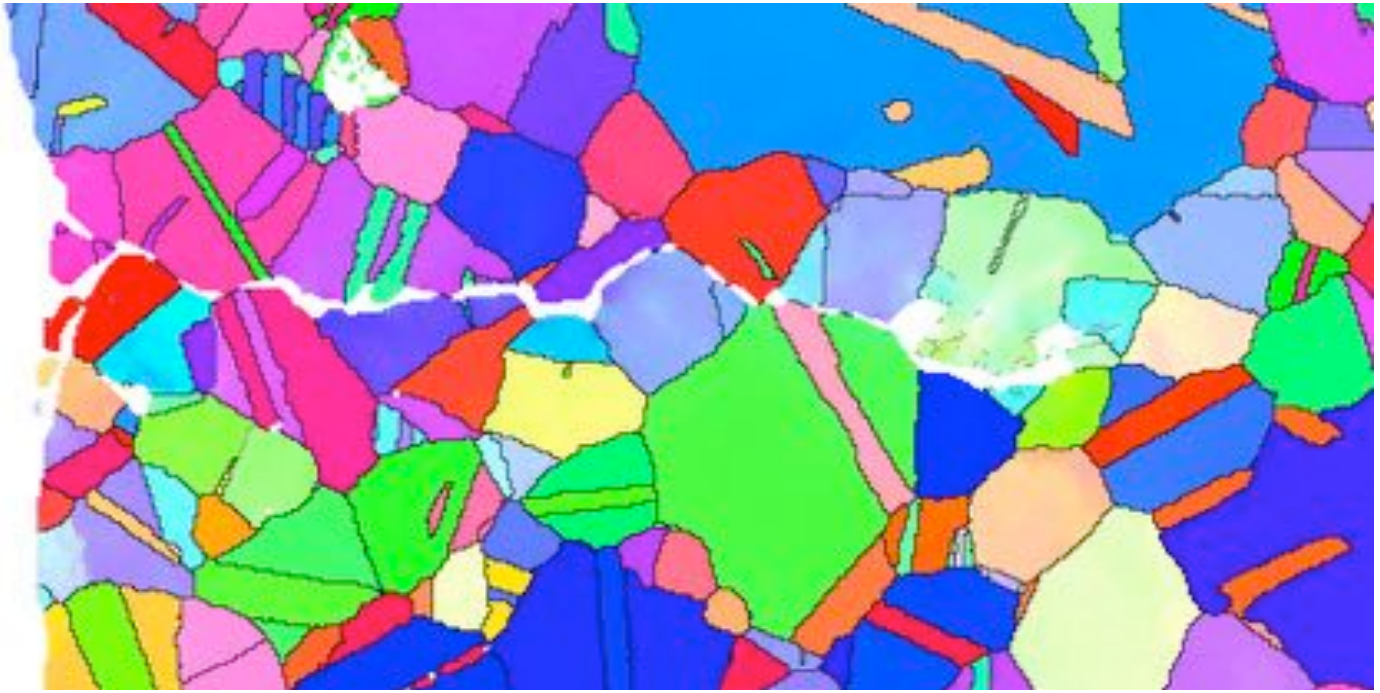
Secondary crack path morphology



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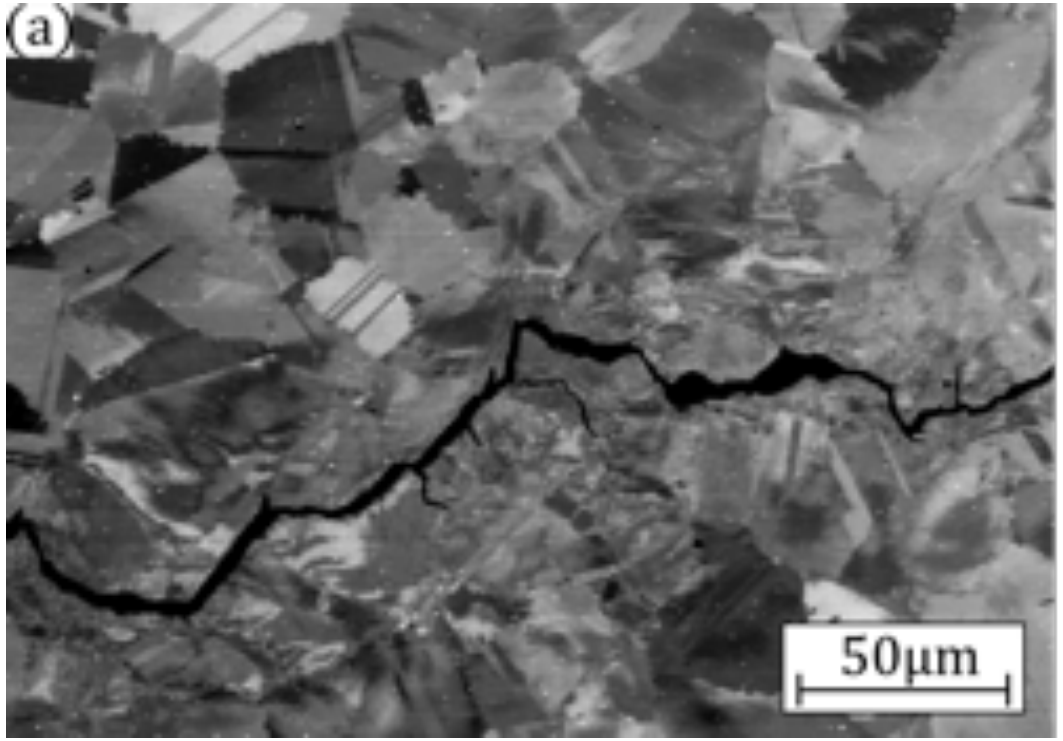
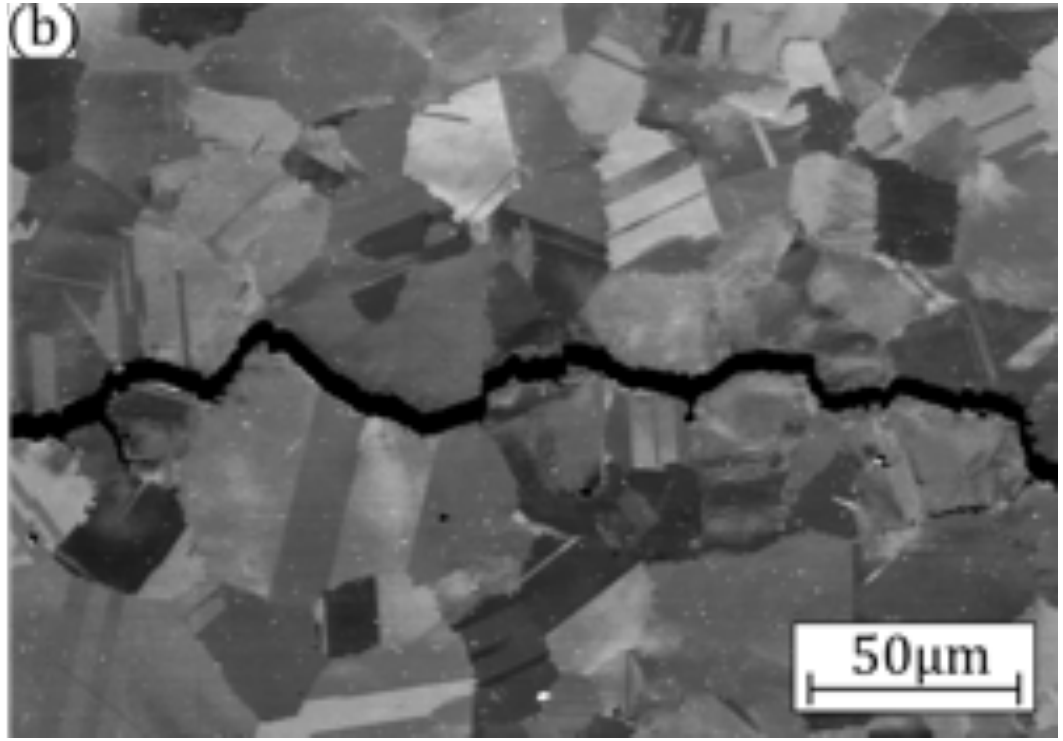
Primary crack path morphology



Out-of-phase



In-phase

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- Generally, IP loading seems to induce intergranular growth
  - Both small and long cracks

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Concluding remarks

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Conclusions

- IP cycling results in ratchetting effect in the notch
- Cracks are initiated perpendicular to the modelled maximum principal strain direction
- Secondary cracks grow intergranularly, in agreement with the primary crack growth

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