Analysis of the Crack Driving Mechanism in Coarse-Grained RR1000 subjected to Thermo-Mechanical Fatigue

V. Norman[1], S. Stekovic[1], M. Whittaker[2], J. Jones[2], J. Rouse[3], S. Williams[4], B. Grant[4]

[1] Division of Engineering Materials, Linköping University, Sweden

[2] College of Engineering, Swansea University, Swansea, United Kingdom

[3] Faculty of Engineering, Nottingham University, Nottingham, United Kingdom

[4] Rolls-Royce plc., Derby, United Kingdom

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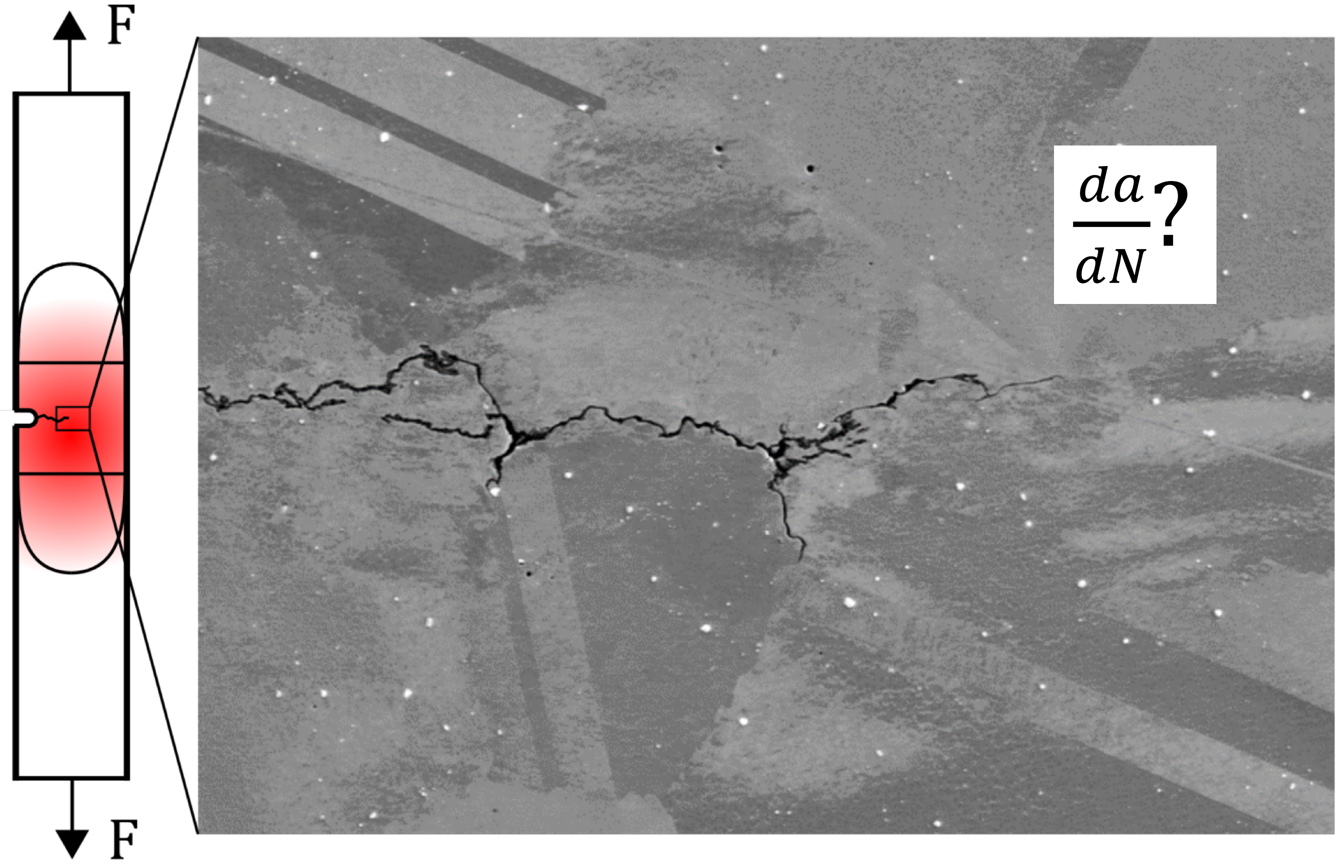
DevTMF

Clean Sky 2

Objectives

Clarify the mechanisms of thermo-mechanical fatigue (TMF) crack growth



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Outline

- Background and motivation
- Methods and results
  - Crack closure effects
  - Stress-strain state at crack tip
  - Environmental effects

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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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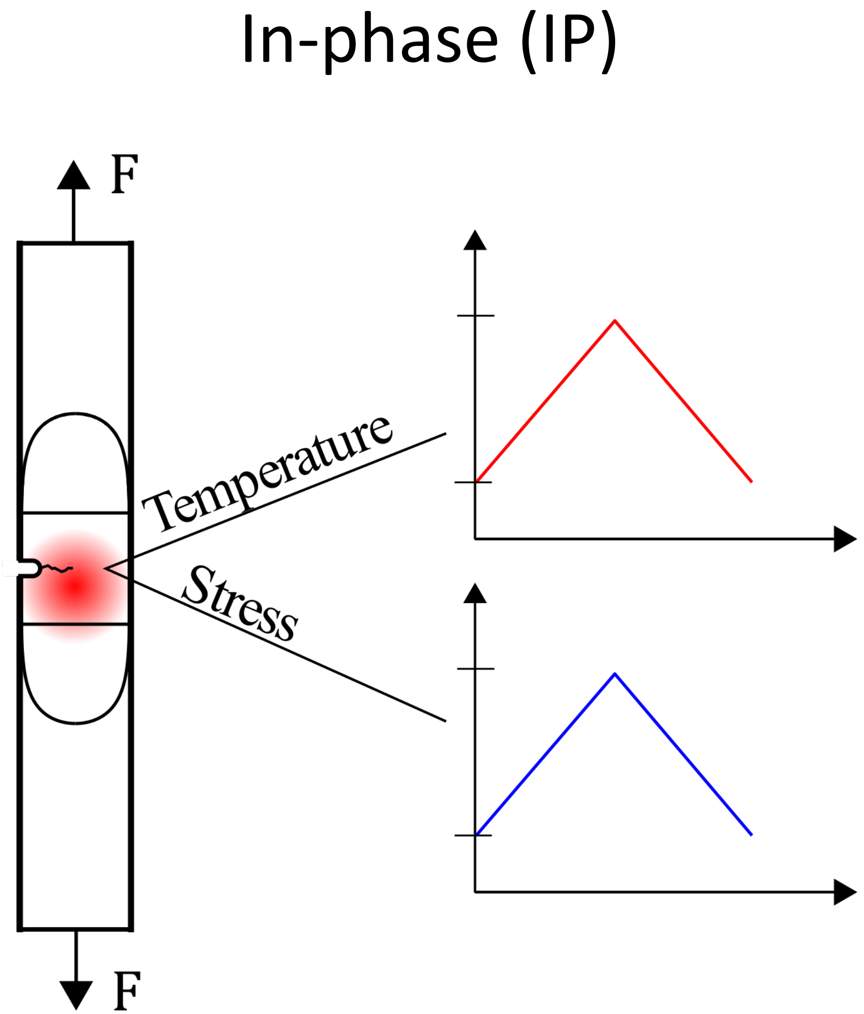

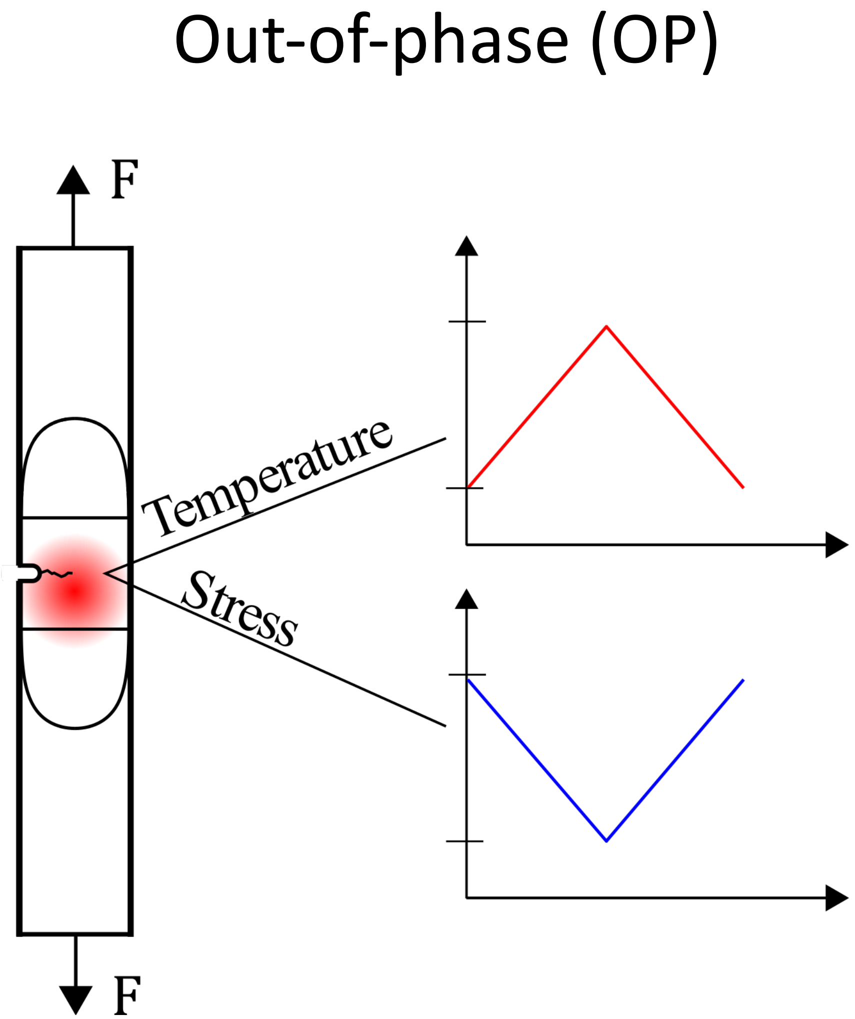

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Methods and results

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Thermo-mechanical fatigue crack propagation tests

- 70s triangular cycle
- 400-750°C
- 210-250MPa, R=0
- In-phase (IP) and out-of-phase (OP)
- Variations in the pre-crack procedure

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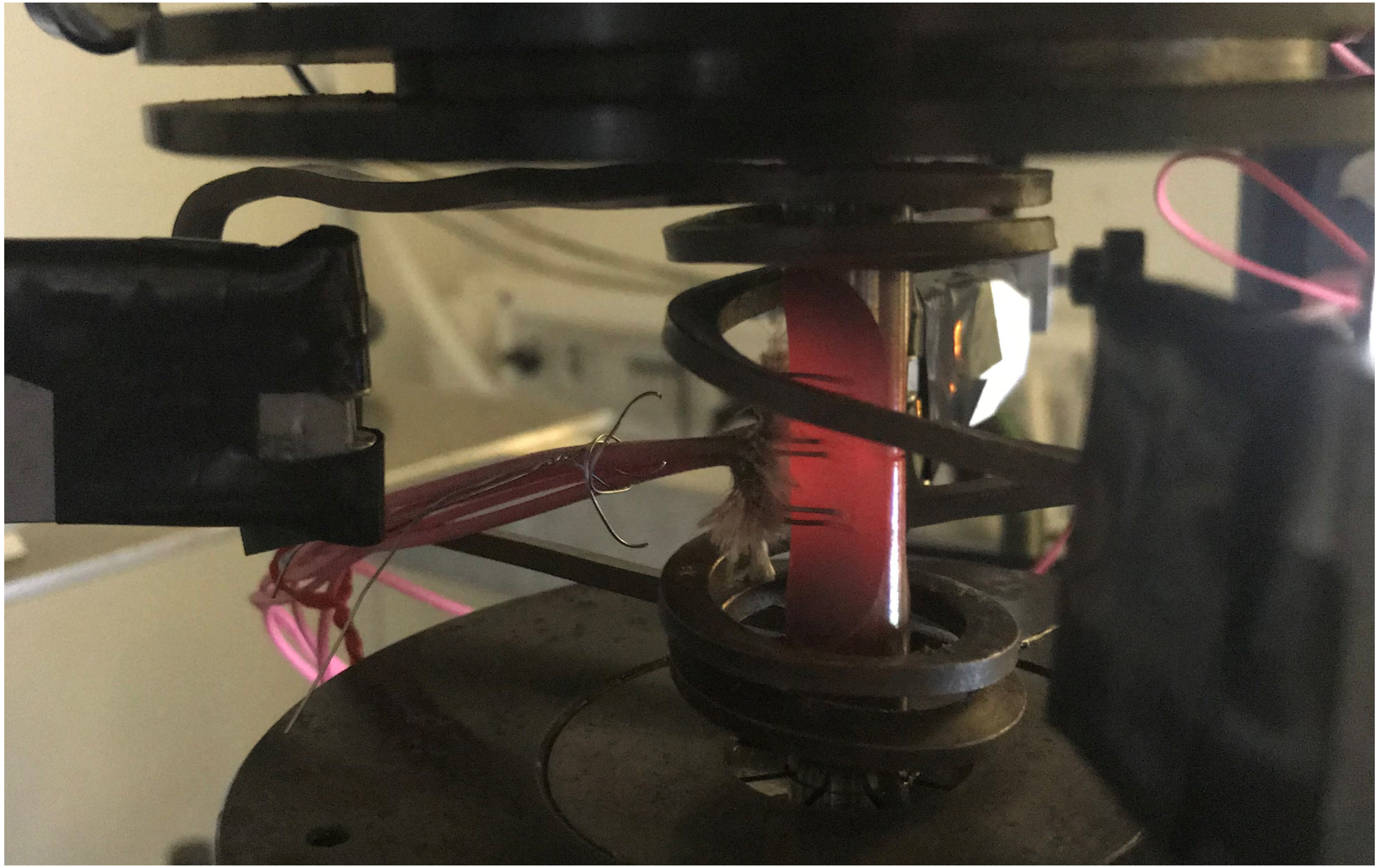

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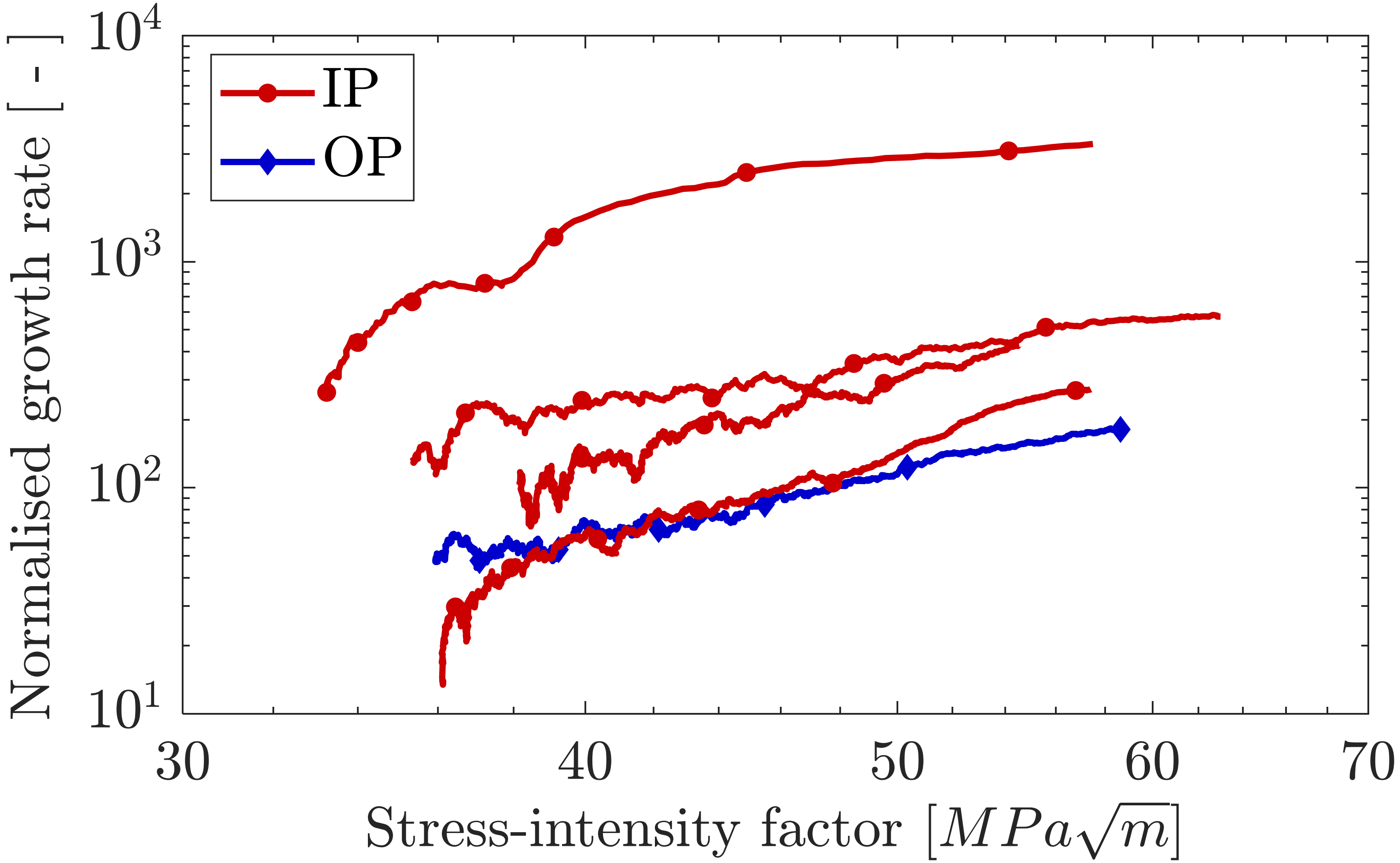

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Crack closure effects

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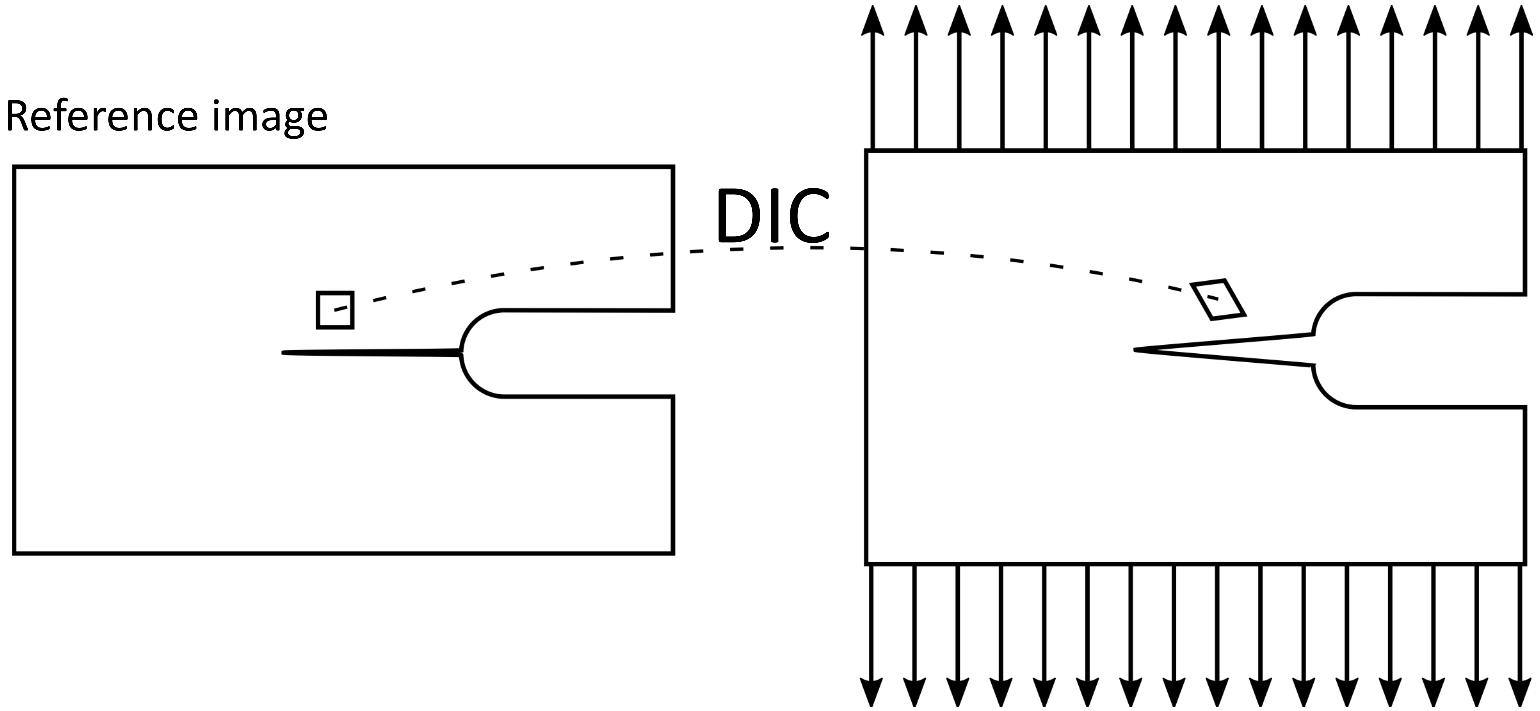
Digital image correlation (DIC)



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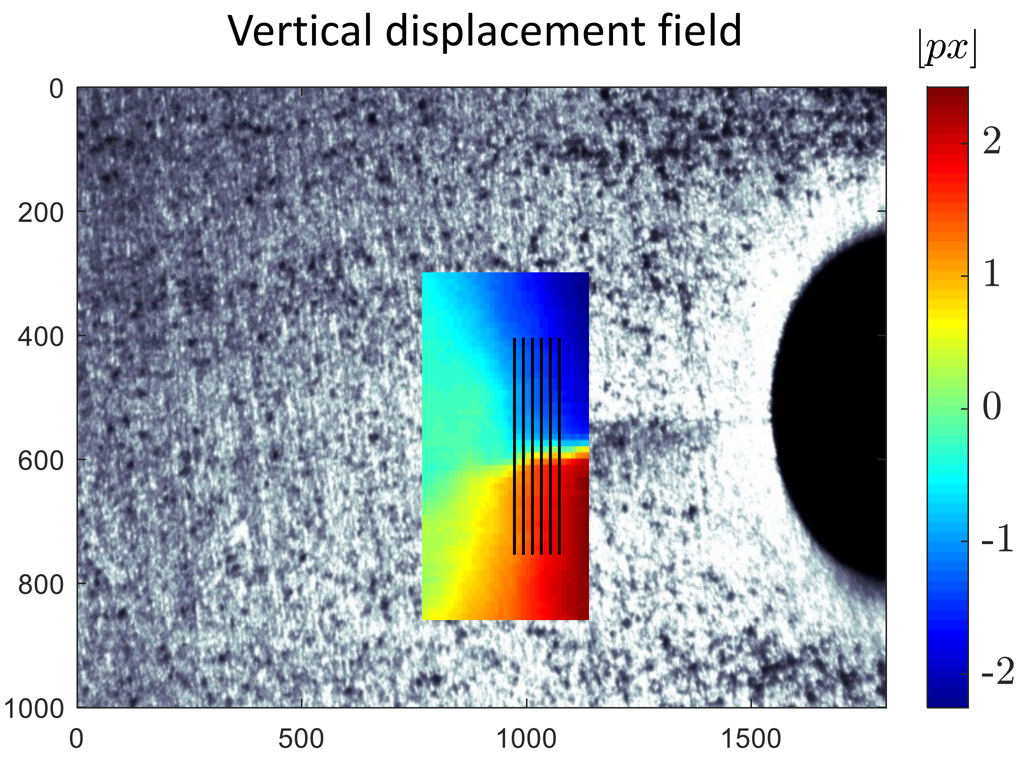

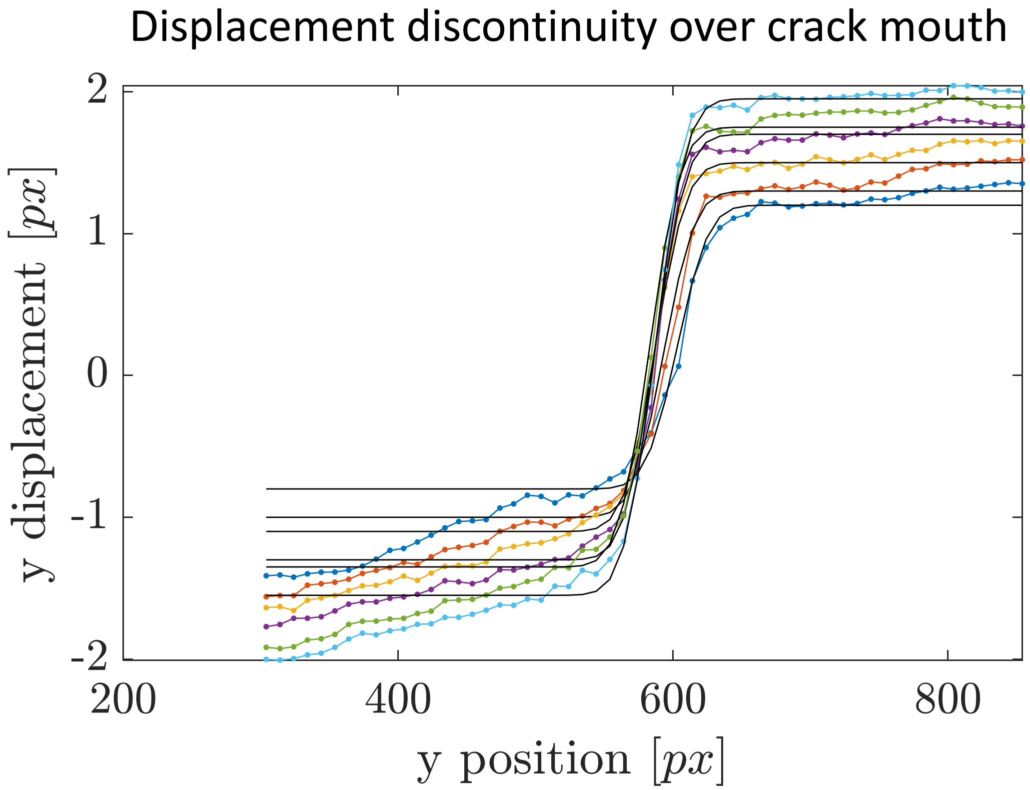

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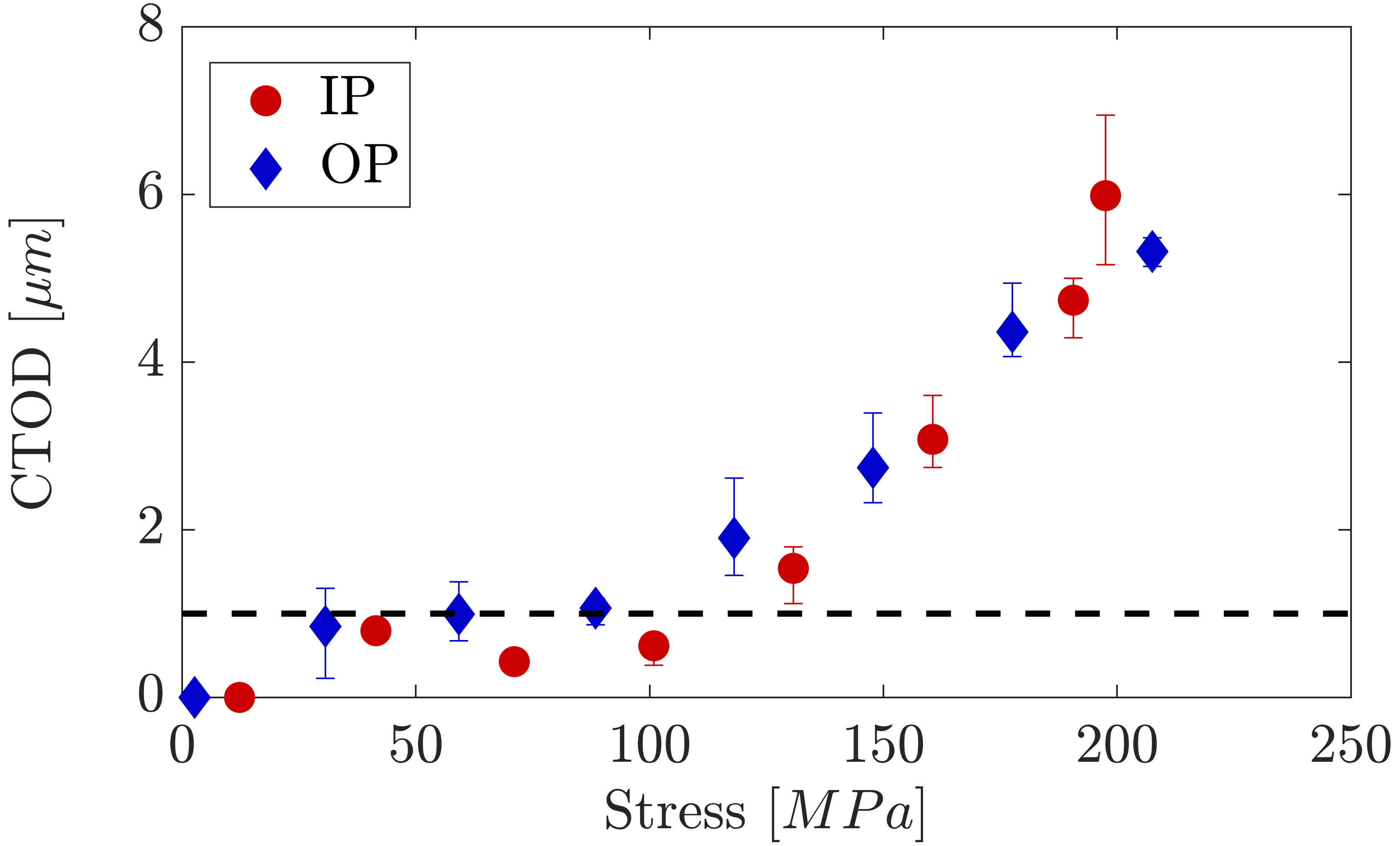
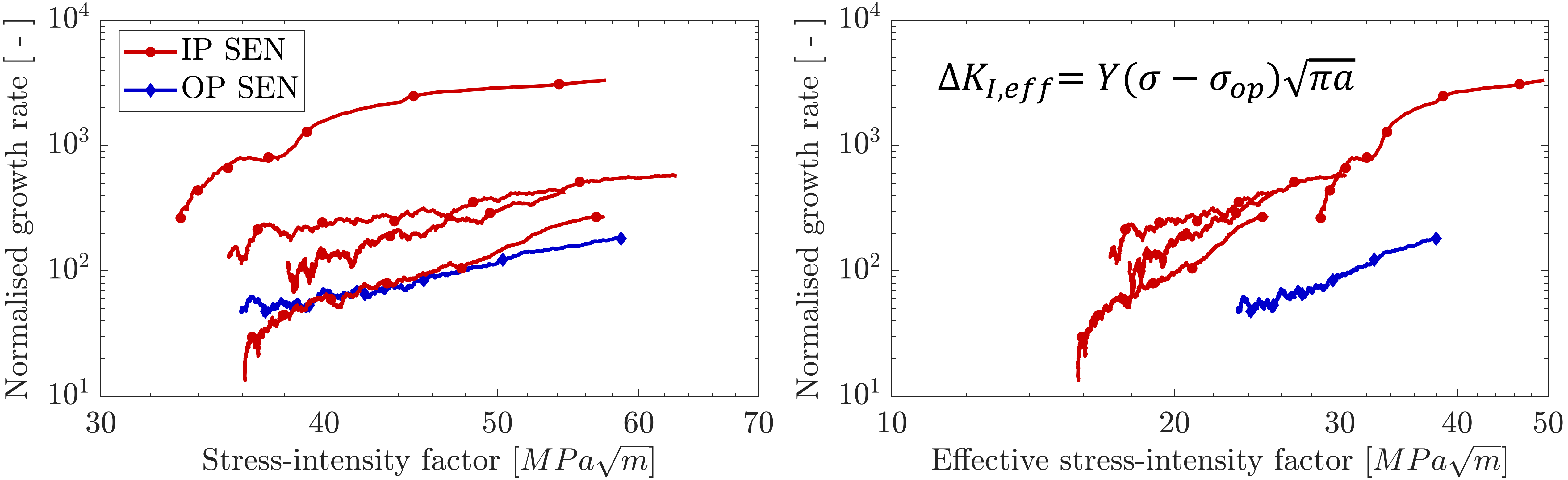
Crack-tip-opening displacement (CTOD)





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Stress-strain state at crack tip

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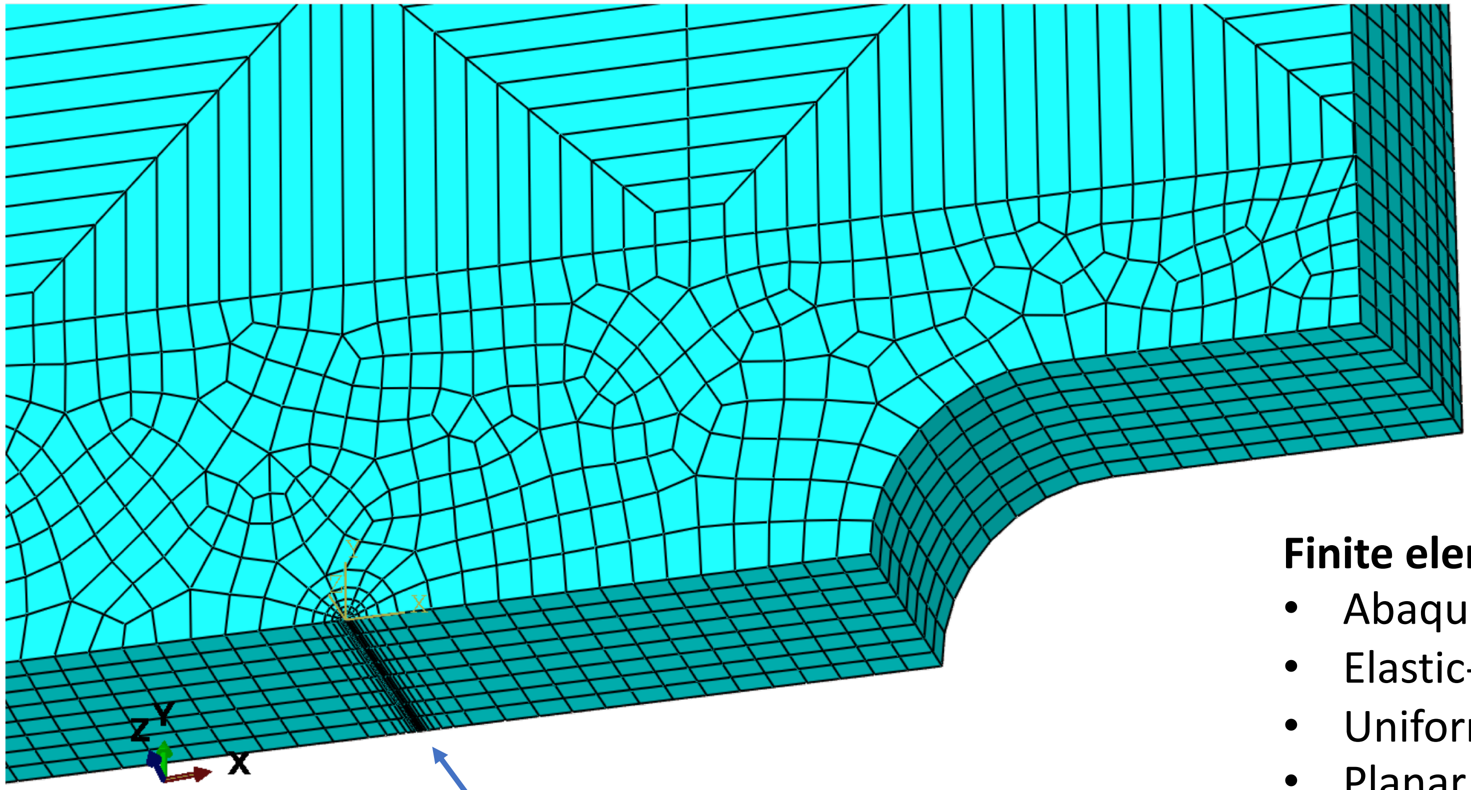

Crack front

Finite element model

- Abaqus CAE 6.12
- Elastic-ideally plastic material model
- Uniform temperature
- Planar crack
- Brick elements with reduced integration
- 10µm element size at crack tip

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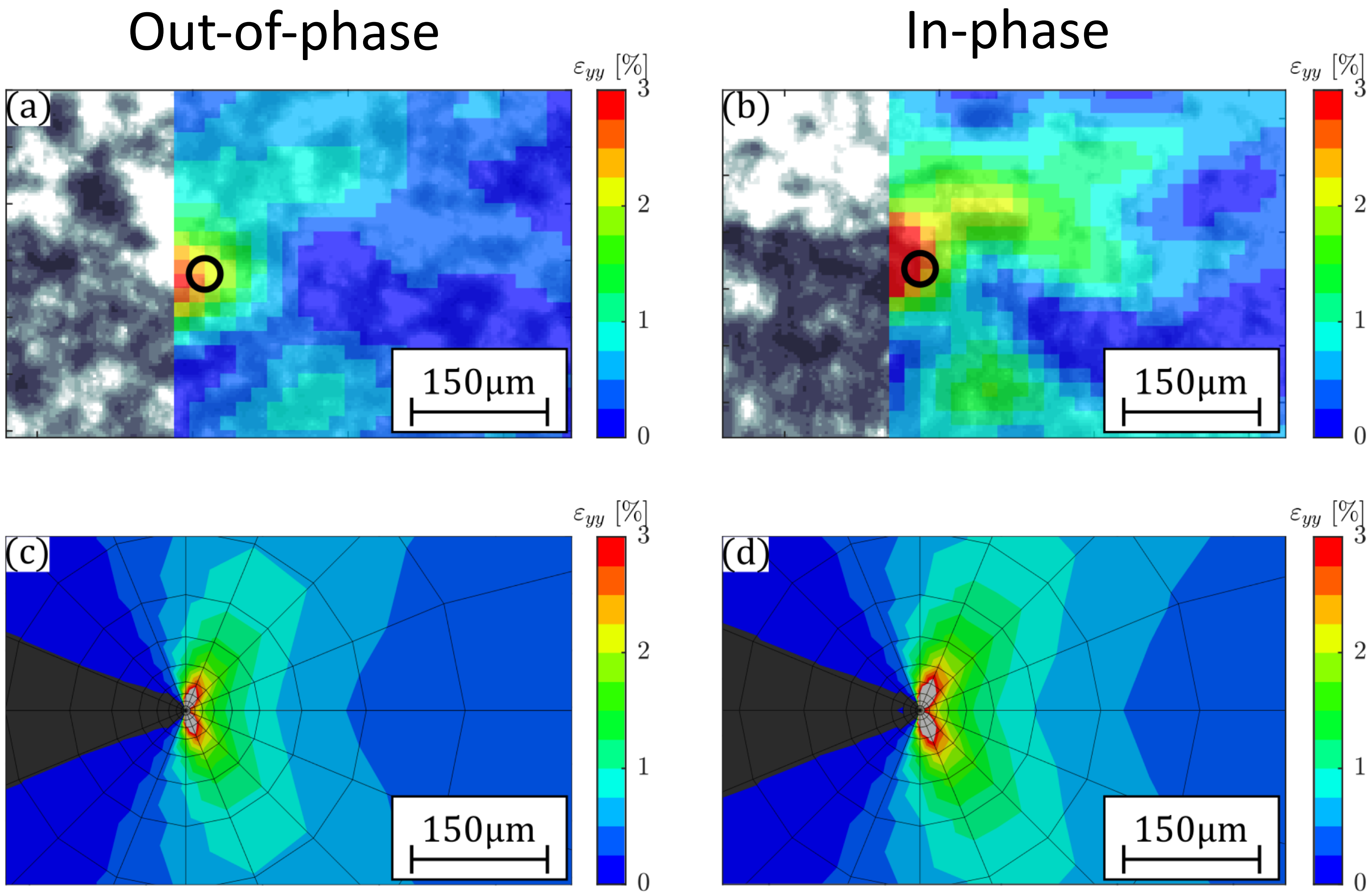

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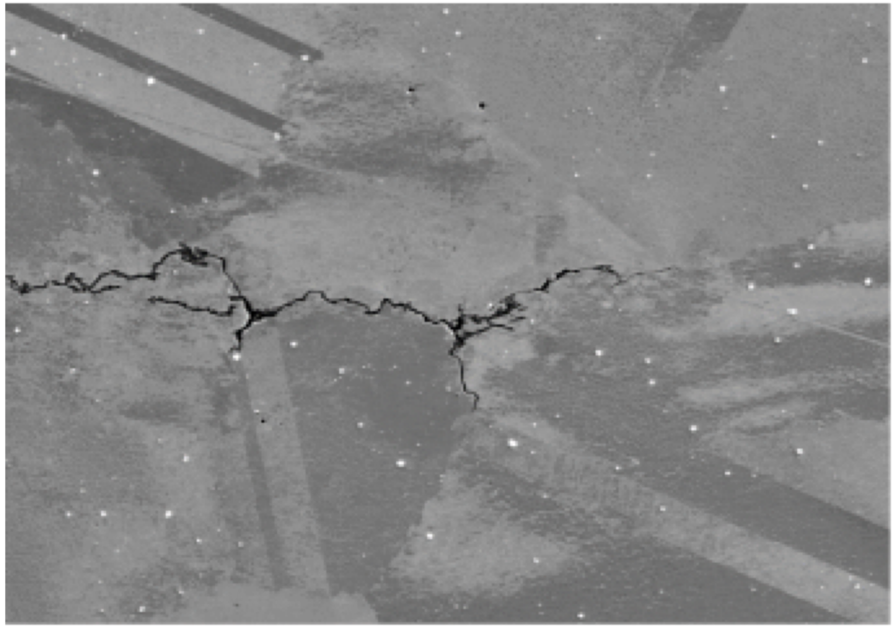

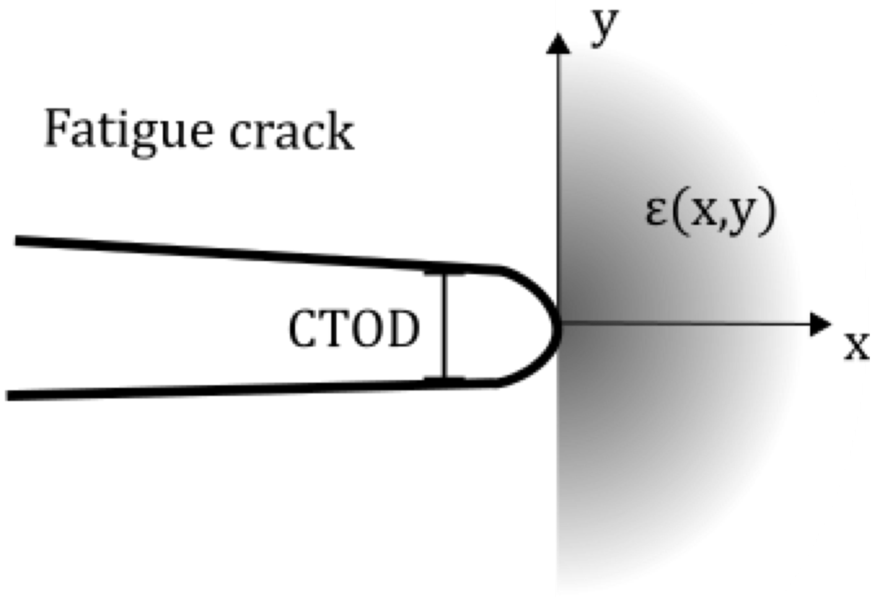

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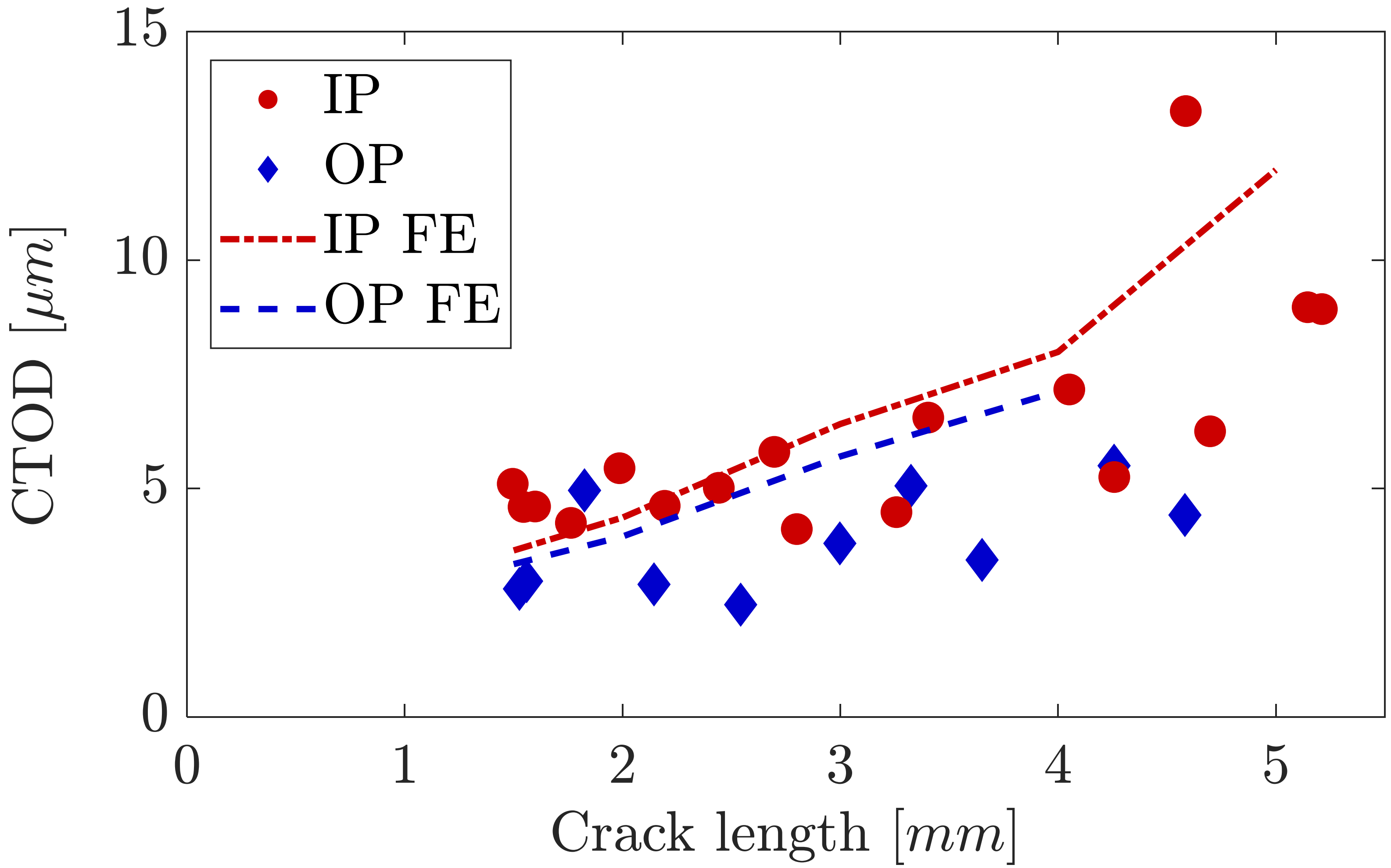

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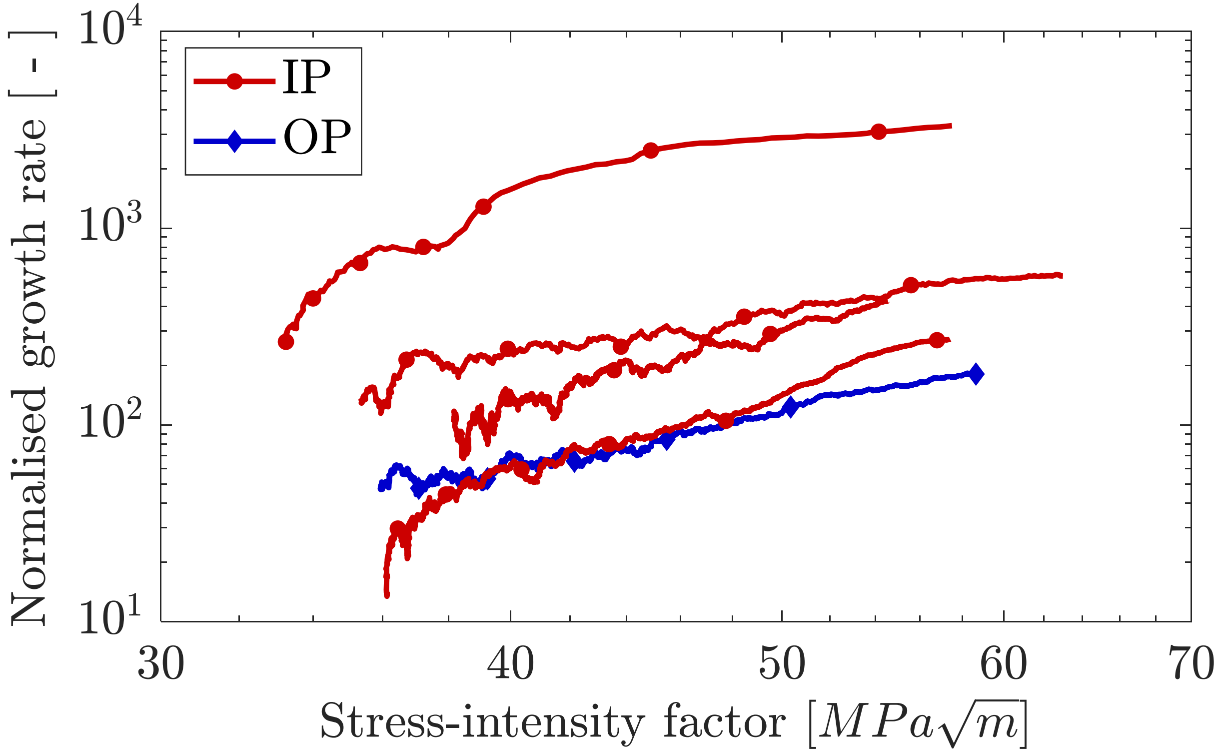
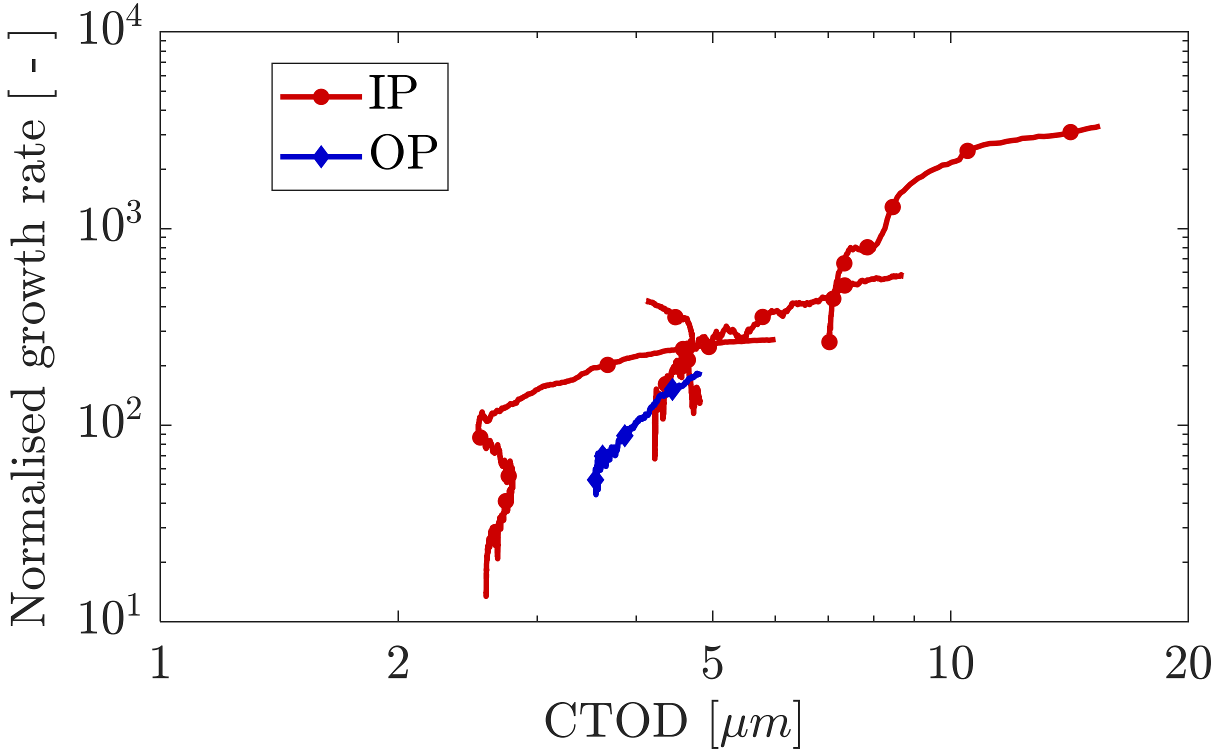
Clean Sky 2

DevTMF





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Environmental effects

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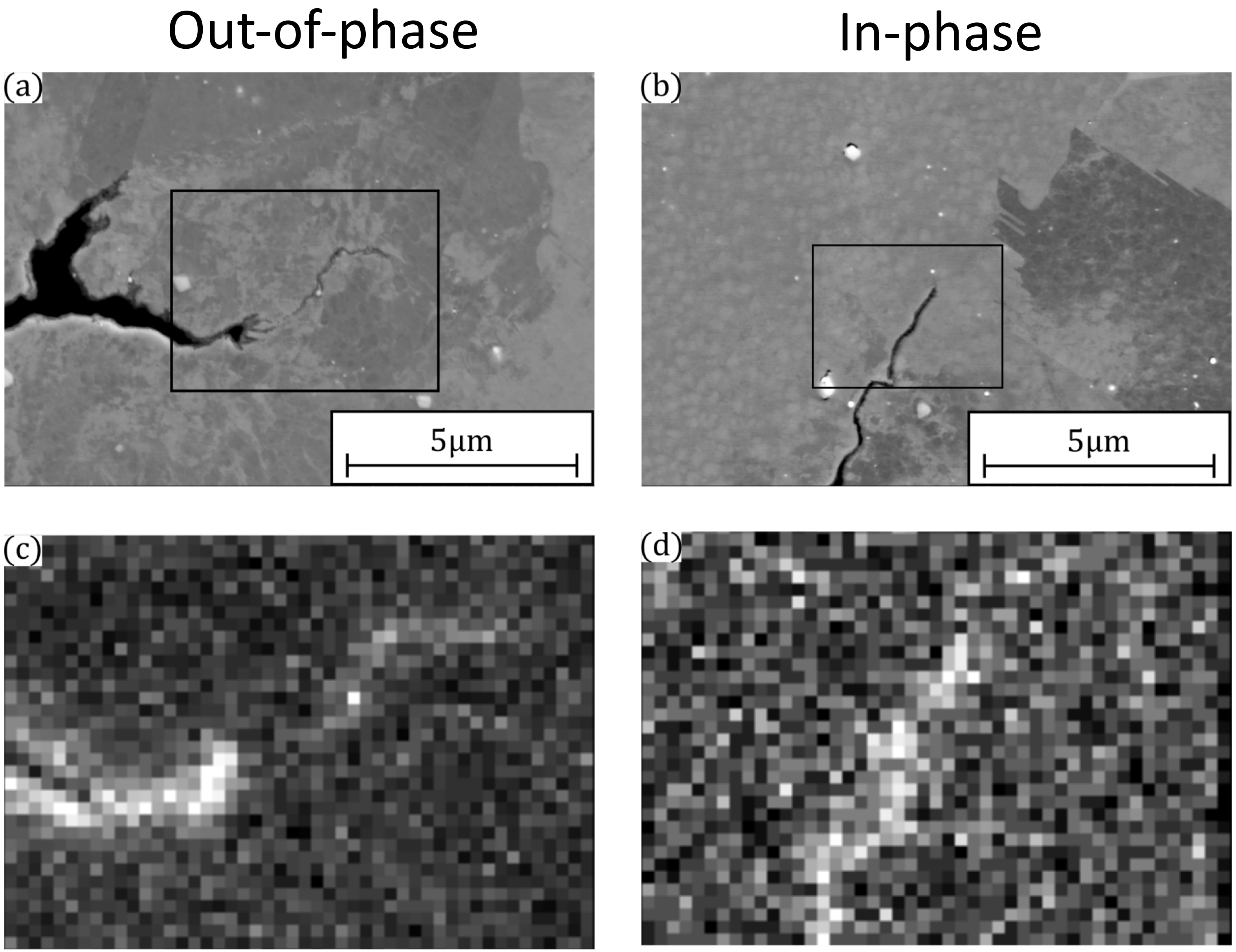

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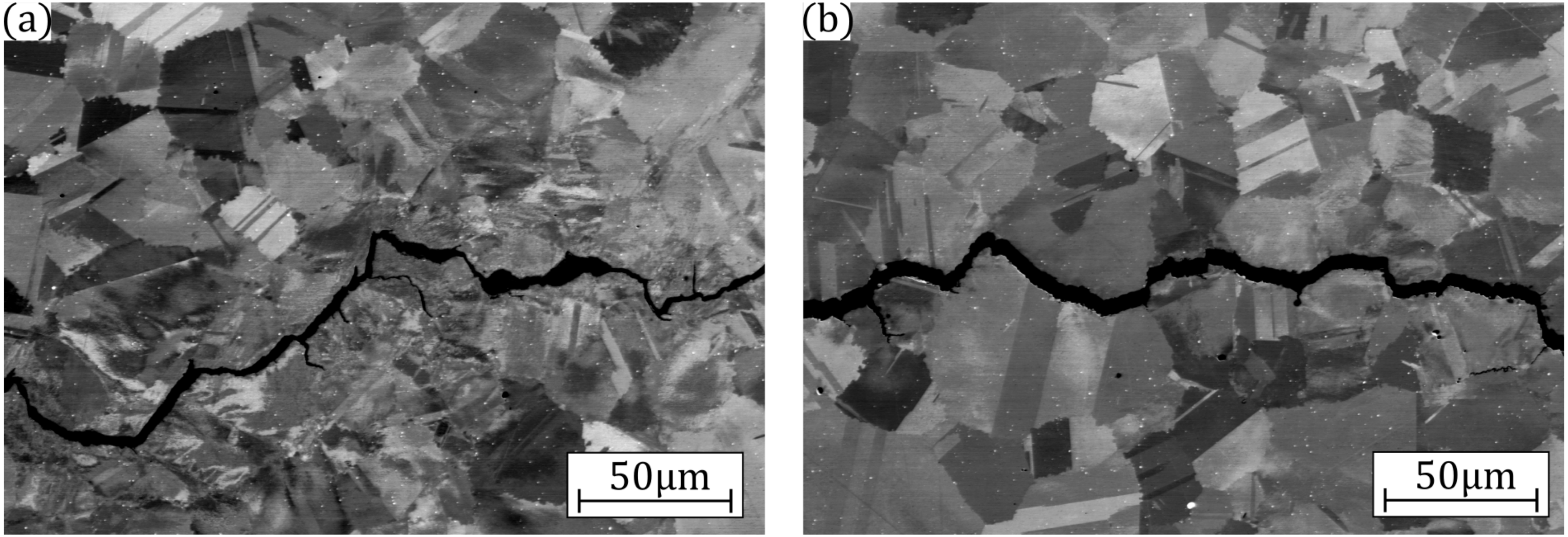
Out-of-phase In-phase



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- Crack morphology indicates influence of oxygen
- However, grain boundary sliding occurs despite absence of oxygen at high temperatures in Ni-base superalloys [1-4]

[1] Mat. Sc. Eng. A (2009) 510-511 301-306
[2] Exp. Mech. (2012) 52:4 405-416
[3] Mat. Sc. Eng. A (2014) 605 127-136
[4] Exp. Mech. (2015) 55:1 53-63

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Concluding remarks

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Conclusions

- Growth rate is governed by the **mechanical conditions at the crack tip**, rather than environmental effects.
- IP growth rate is higher than OP due to the **temperature dependence of the yield strength**

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