

Analysis of fracture mechanics tests on railway axles for crack closing behaviour with regard to residual stresses

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Introduction

Motivation

- High costs caused by interval testing for defects and cracks
- Crack growth on railway axles is significantly influenced by residual stresses
- Manufacturing and assembly processes lead to the induction of residual stresses

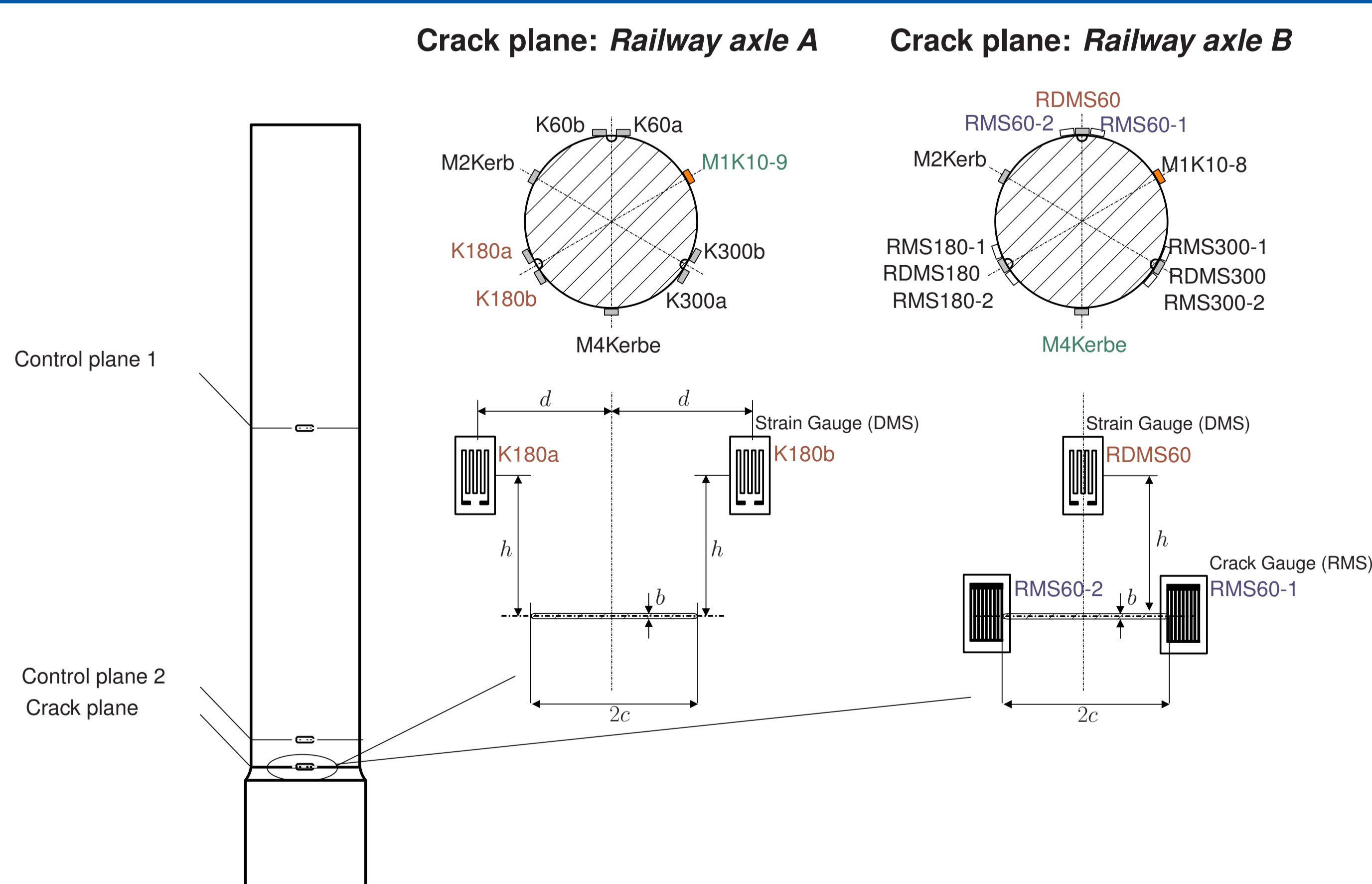
Objectives

- Determination of crack closure/crack opening stresses
- Estimation of possible production-induced residual stresses based on the crack closing stresses
- Investigation of the relationship between residual stresses and crack propagation

Procedure

- Experimental investigations with rotating bending test benches on railway axles
- Measured stresses at the crack tips are interpolated and evaluated using a B-Spline approximation
- The manufacturing induced residual stresses are determined by using the crack closing stresses

Test setup



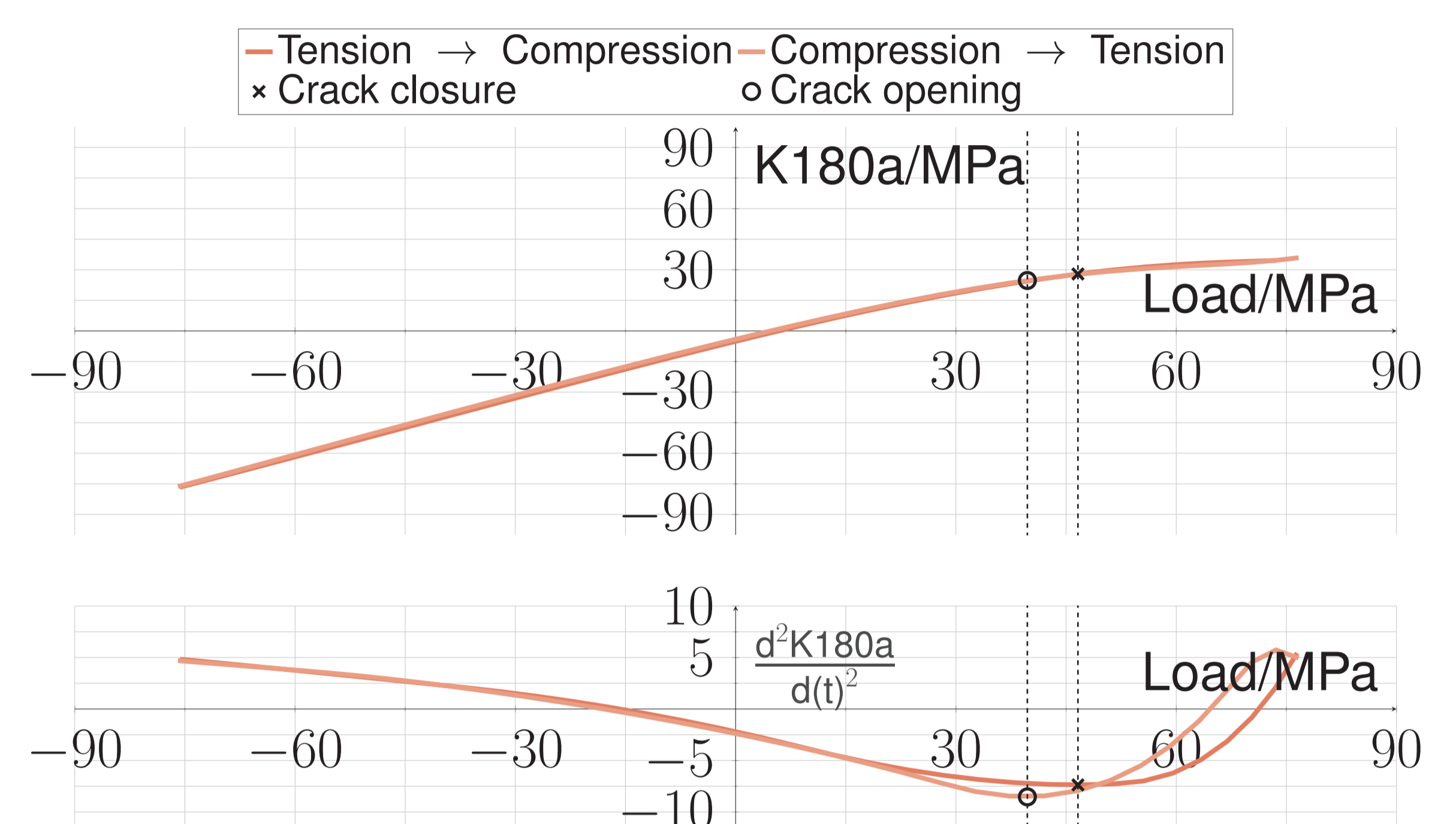
Railway axle A

- Optical crack length monitoring (camera system)
- Two strain gauges at each crack - strain gauge above each crack tip (K180a, K180b)
- Strain gauge for measuring the applied load, offset by 180° from the starting notch (M1K10-9)

Railway axle B

- crack length monitoring by using crack detection gauge (RMS60-1, RMS60-2)
- A strain gauge centered over notch/ crack (RDMS60)
- strain gauge for measuring the applied load offset by 180° from the starting notch (M4Kerbe)

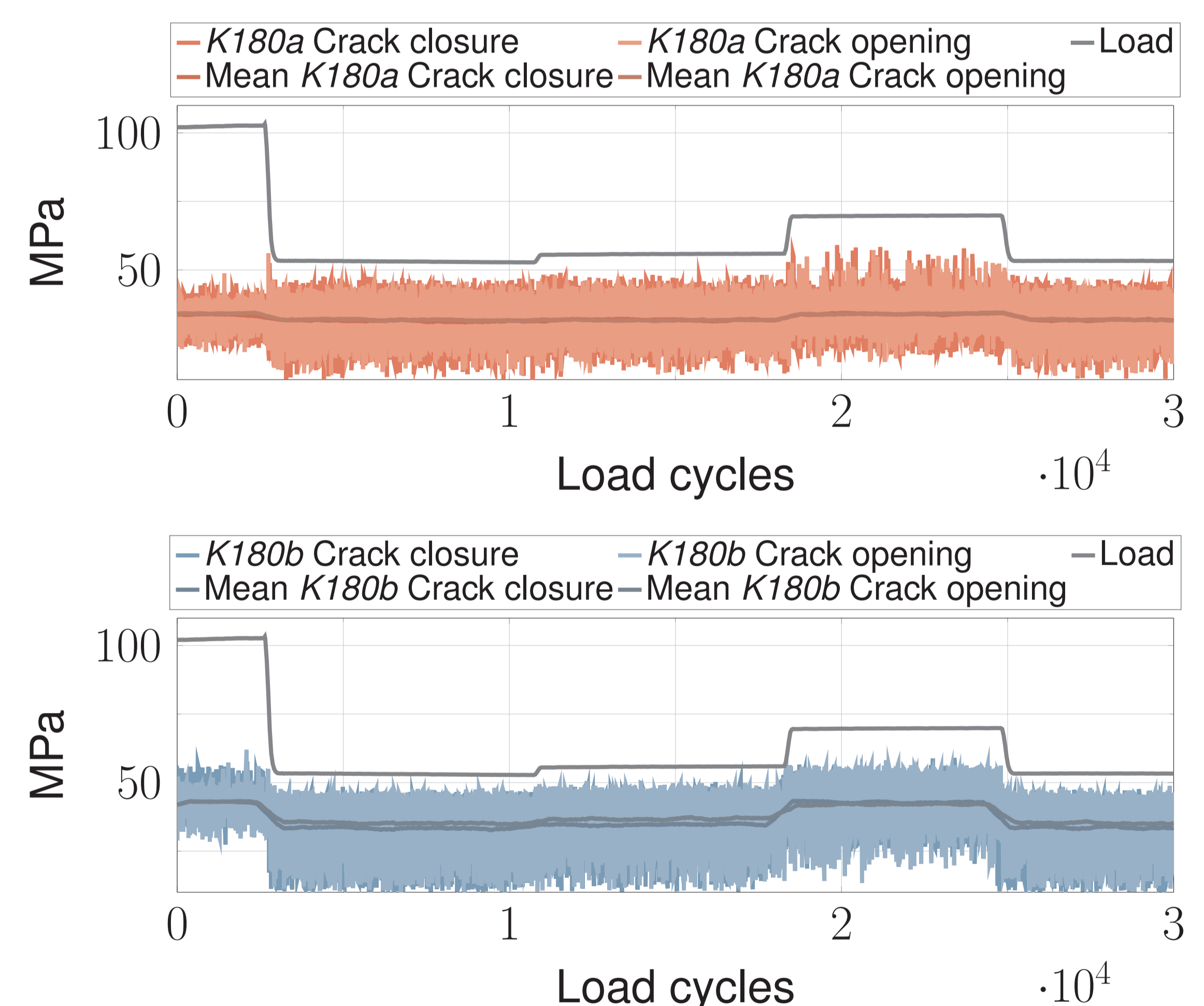
Crack closing / crack opening stresses



- Periodic evaluation of the measured stresses
- The data of a single oscillation were interpolated using a B-Spline
- Based on the fully parameterized B-Spline-function, the maximum curvature could be determined in the 2nd derivative
- The maximum curvature defined the points of crack opening and crack closing

Results

Crack opening & closing stresses



- Crack closing mechanisms of plasticity induced crack closing were observed under variable load
- Crack closing and crack opening stress can be assumed to be the same [1]
- The manufacturing induced residual stresses are compressive residual stresses

References

- [1] H. A. Richard, M. Sander
Fatigue Crack Growth
Springer, Berlin; Springer International Publishing, 2016.