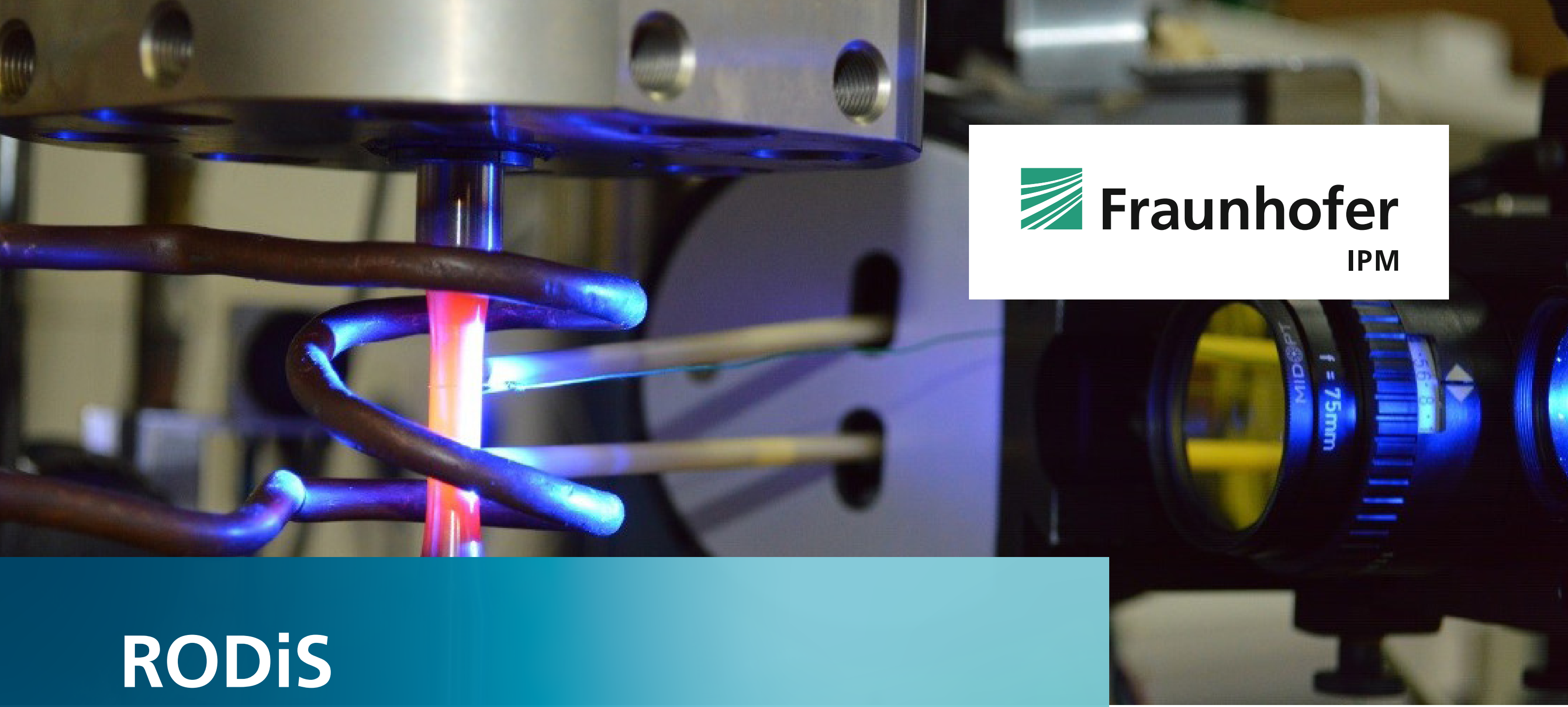

Optically strain-controlled fatigue test at 1000 °C: RODiS allows both integral strain measurements, as with mechanical extensometers, and full-field DIC measurements within one single sensor.

Fraunhofer IPM

RODiS

Real-time image correlation for optical strain measurement in material and component testing

Digital image correlation (DIC) is a well-established image processing method used in materials research to measure strain and displacement of samples under load at sub-pixel level. Due to the high computational load, the correlation runs slowly on conventional processors, which makes it impossible to adhere to the recommendations of relevant standards such as ASTM E606 regarding strain control or ASTM E647 on the measurement of fatigue crack growth rates. The optical measurement system RODiS (Real-time Optical Displacement Sensor) from Fraunhofer IPM uses graphics processing units (GPU) to meet the requirements of material and component testing.

Many parameters in material sciences can be attributed to changes in length or displacements. This applies to strain as well as crack contours and the opening and closing behavior of cracks in materials, and to gap variations between rotors and stators in machines. FE models are also used to simulate the displacement of surfaces that act as easily accessible measuring points. When designing structural components, strain and displacement measurements enable hypotheses to be tested during experiments under operational conditions.

Fraunhofer IPM's RODiS optical measurement system allows many of these parameters to be recorded using a single sensor. Customized measuring points can be set within a camera image, either as individual points or for full-field mapping.

State-of-the-art cameras resolve the microstructure of a workpiece surface while recording more than 1500 images per second. Simultaneously, graphics cards evaluate up to 200,000 DIC subsets per second. This enables the system to use the microstructure on metallic surfaces as correlation pattern in a marker-free manner. Therefore, a surface treatment with speckle paint is not required.

Figure 2 demonstrates this using the example of a biaxial strain measurement for crack propagation testing on cruciform specimen for biaxial material testing on axes A and B. The camera image of the sample surface shows the microstructure as seen under a microscope. The four measuring points are superimposed to measure integral strain with a base length of 10 mm. This enables integral strain to be controlled according to ASTM E606, as illustrated in figure 3.

Fast, contactless and marker-free

The combination of fast, high-resolution cameras and graphics processing units (GPU) enables RODiS to measure metallic surfaces at measurement rates of up to 1500 Hz using a marker-free method, with no need for speckle paint treatment. The optical RODiS system also uses a contactless approach to take measurements in environments where tactile systems are not applicable, such as pressurized containers, machines or even inside shields or thermal insulation. This makes it easier to provide experimental proof of the behavior of materials or components under real operating conditions.

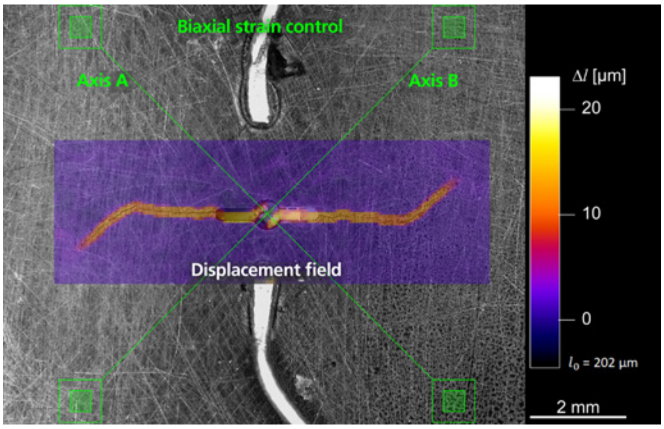

Fig. 2: Camera image with superimposed integral strain and full-field image correlation measurement. Green: Biaxial integral strain measurement with a base length l_0 of 10 mm for uni- or biaxial strain control along the A and B axes of cruciform specimen. Color scale: Full-field analysis to evaluate crack contour, crack length and crack opening/closing.

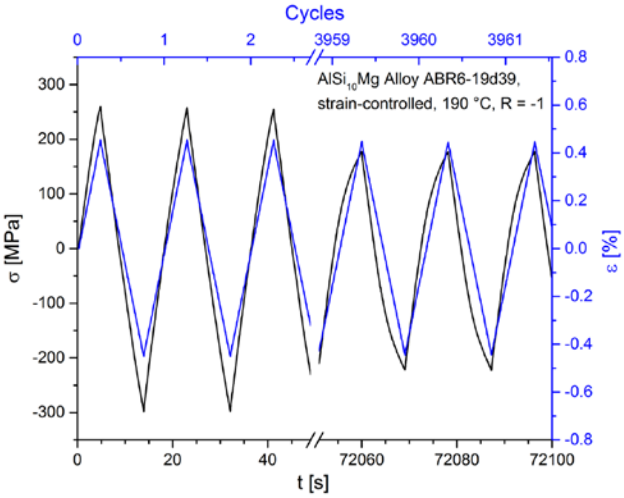

Fig. 3: Optically strain-controlled fatigue trial according to ASTM E606 with strain measurement rates of up to 1500 Hz – close to mechanical extensometers

The colored measuring area in the center shows the full-field evaluation, with approximately 10,000 measuring points at the time of maximum strain. The S-shaped contour of the biaxially grown crack is clearly recognizable. The displacement field is suitable for analyzing crack length, crack contour and the opening and closing behavior. It can be directly compared to a fracture-mechanical FE model of the specimen. Figure 4 shows a comparison between the results of a crack length measurement in the displacement field and measurements taken using the alternating current potential drop (ACPD) method. The agreement is well within boundaries defined by ASTM E647.

The measurement accuracy meets the requirements of accuracy class 0.5 according to DIN ISO 9513. Turning points in cycle frequencies up to 10 Hz are sufficiently resolved for strain-controlled trials with triangular strain signal shape according to ASTM E606. Just like with mechanical extensometers, the analog strain signal can be directly passed to the test station's PID controller. Other parameters, such as force, distance and temperature are synchronously recorded as analog signals.

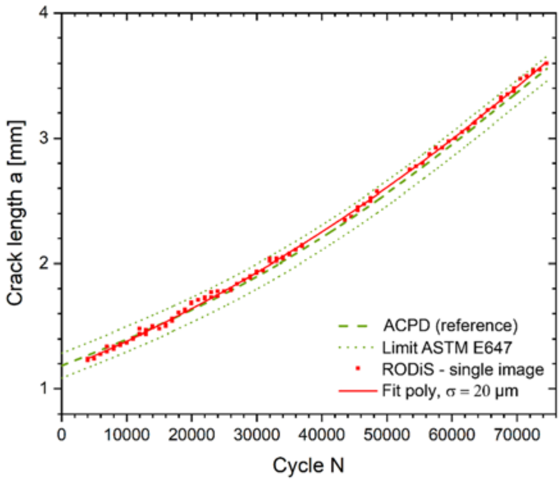

Fig. 4: Crack growth curve according to ASTM E647 in comparison to measurements taken using the alternating current potential drop (ACPD) method

Technical data

Examples of adjustable measurement rates of integral strain and image fields. The integral strain is displayed as a 10 V analog signal.

Resolution [px]	Image field [mm²]	Measurement rate [Hz]	Notes
2560 x 880	12.8 × 4.4	1500	max. meas. rate, e.g. for cylindrical specimen
2560 x 1280	12.8 × 6.4	1000	e.g. notched flat sample
1600 x 1540	8.0 × 7.7	850	biaxial strain control with l_0 = 10 mm
2560 x 1916	12.8 × 9.6	690	max. field-of-view

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