# Measuring Magneto-Mechanical Hysteresis during Fatigue Testing using Optically Pumped Magnetometers


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Workshop on
optically pumped magnetometers

## Abstract


The sensitivity of optically pumped magnetometers (OPM) opens new opportunities in magnetic material testing. This poster presents first results of magneto-mechanical hysteresis curves measured from a micro fatigue setup integrated into a shielded environment together with a QuSpin zero-field magnetometer QZFM. The curves were acquired from small volume specimen where the magnetic signal from single defects like cracks can be characterized by other metallographic methods.


## Methodology (Fig. 1)

Magneto-mechanical testing is commonly used for qualitative characterization of damage in in large test sites [1]. To get a more quantitative understanding, a micro fatigue test setup allowing for strain-controlled low-cycle fatigue (LCF) was integrated into a shielded environment together with an OPM covering the complete damage induced by cyclic fatigue. High-strength non-magnetic materials like ceramics and titanium alloys were used to mount the specimen inside the shielded environment while keeping all potential perturbations outside. Strain is measured optically by a real-time digital image correlation (DIC) system [2]. Coils are used to control background magnetic field $H$ in x-, y-, and z-direction.

Fig. 1

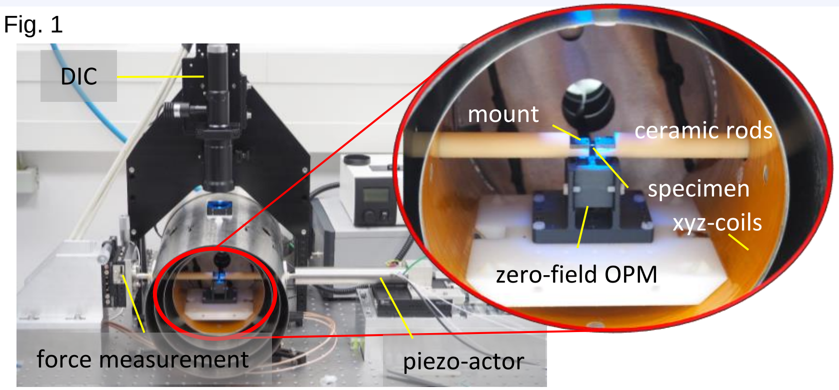
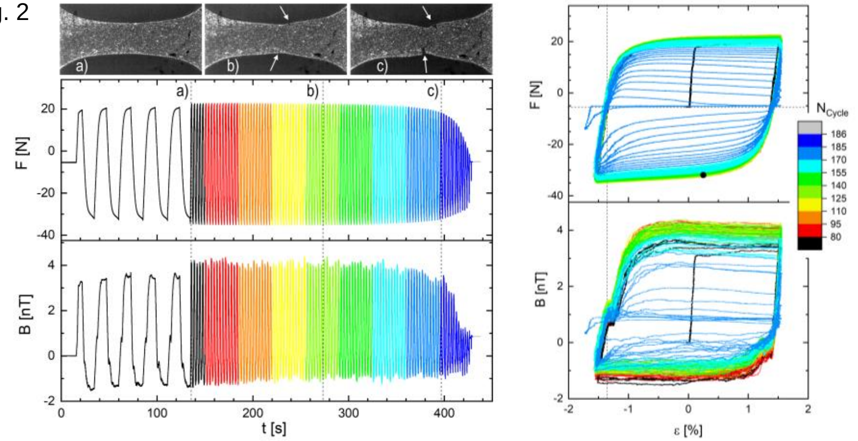



Fig. 2




## Results (Fig. 2)

Fig. 2 shows magneto-mechanical signals from a LCF experiment with a strain amplitude of $\pm$1.5 percent and 183 cycles in approximately 430 seconds. On the left, the force $F$ and the magnetic signal $B$ are drawn over time $t$ together with images from the sample together with images from the specimen made from ferritic steel with a length of about 1.5 mm. In the first 280 s, no damage is visible on the specimen surface (a). Afterwards, crack initiation occurs (arrows in images b and c) with cracks growing until the sample breaks. On the right, $F$ and $B$ are drawn over strain $\varepsilon$ with the color indicating cycle number $N_{Cycle}$ in both graphs. The final aim is to derive a quantitative measure for material damage from features like position and height of the Villari reversals in the magneto-mechanical hysteresis curves $B(\varepsilon)$ on the bottom right.

## Conclusion

The estimation of remaining lifetime of a device by damage quantification is still an unsolved problem in material science. The setup presented combines cyclic fatigue to induce damage in the material and measuring its impact on magneto-mechanical hysteresis. Based on this understanding, new non-destructive methods for lifetime-measurement might be developed in the future.

## References


[1] Guralnick, S. A.; Bao, S.; Erber, T. (2008): Piezomagnetism and fatigue: II. J. Phys. D: Appl. Phys. 41 (11), pp. 115006.

[2] Blug, A.; Regina, D. J.; Eckmann, S.; Senn, M.; Bertz, A.; Carl, D.; Eberl, C. (2019): Real-Time GPU-Based Digital Image Correlation Sensor for Marker-Free Strain-Controlled Fatigue Testing. Applied Sciences 9 (10), pp. 2025.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