Fraunhofer IPM

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

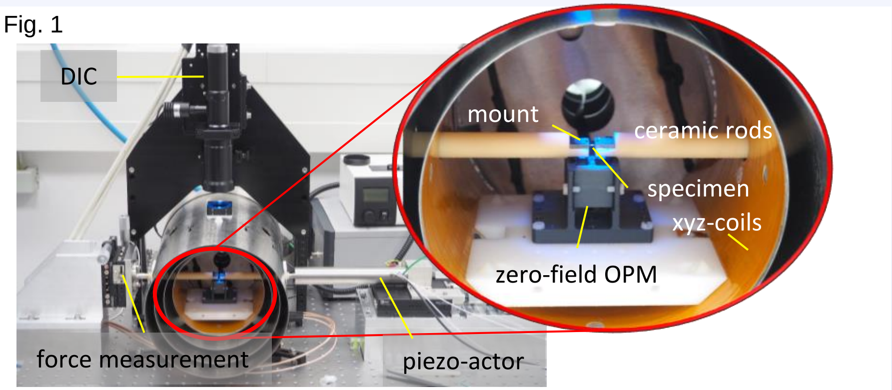
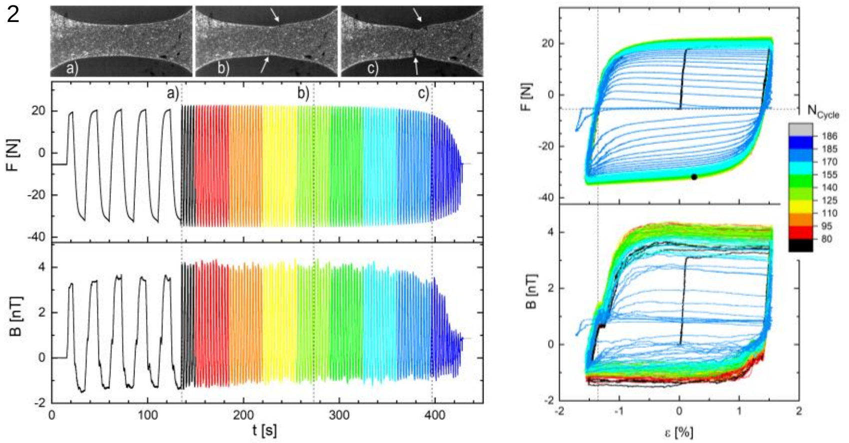


Fig. 2



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 ε 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

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Sponsors

This work was funded by Fraunhofer-Gesellschaft and by the ministry of economy of the state of Baden-Württemberg within the Fraunhofer LIGHTHOUSE PROJECT QMag – Quantum Magnetometry under Project number 005-838080/B7-aj (www.qmag.fraunhofer.de).