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

A. Blug[1], P. Koss[1], A. Durmaz[2], G. Laskin[1], A. Bertz[1], F. Kühnemann[1], and T. Straub[2]

[1]Fraunhofer Institute for Physical Measurement Techniques IPM, Germany
[2]Fraunhofer Institute for Mechanics of Materials IWM, Germany

Magnetic and magneto-mechanical testing are commonly used for qualitative characterization of damage in devices [1] and in large test sites [2]. This presentation reports first results obtained with an optically pumped zero-field magnetometer (OPM) in combination with a micro fatigue setup. The small sample volume of about 1 mm³ allows metallographic characterization of specific material defects occurring during the fatigue process and linking them to features in the magnetic signal.

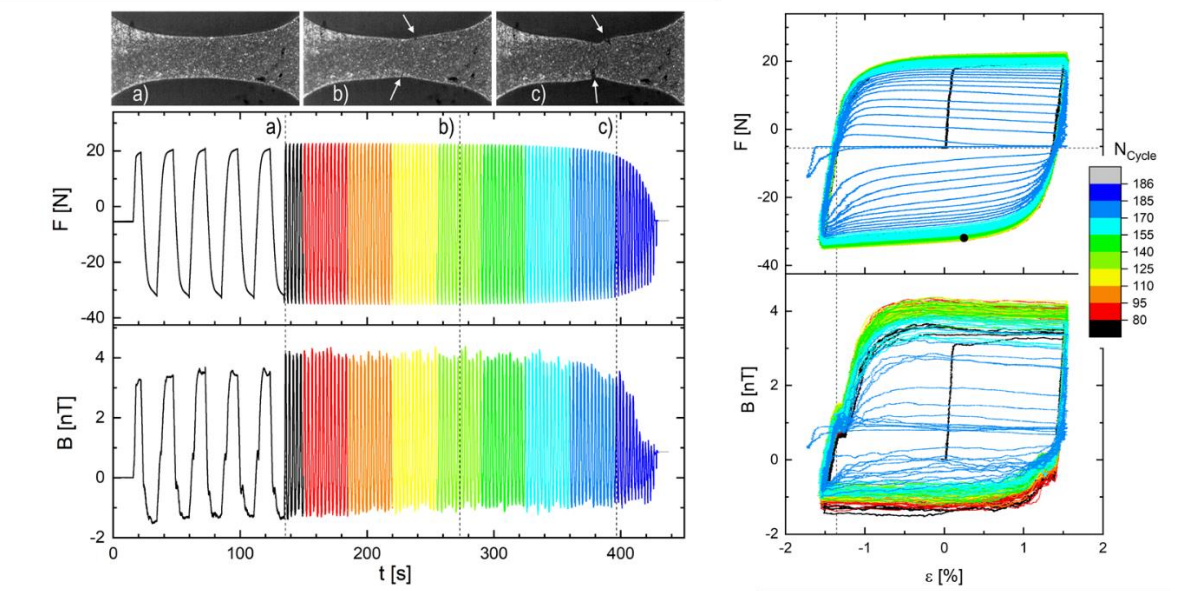

Figure 1: Magneto-mechanical curves from a strain-controlled low-cycle fatigue experiment.

Figure 1 shows magneto-mechanical signals of a low-cycle (LCF) fatigue experiment with a strain amplitude of ±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 sample (a). Afterwards, crack initiation occurs (arrows in 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.

[1] Wolter, B.; Gabi, Y.; Conrad, C. (2019): Nondestructive Testing with 3MA—An Overview of Principles and Applications. In: Applied Sciences 9 (6), pp. 1068.

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