Magnetic Susceptibility Imaging as a New Approach towards Characterization and Testing of Para-and Diamagnetic Materials

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Abstract. All materials interact with a magnetic field to some extent. This interaction is generally quantified by the magnetic susceptibility χ. Non-ferromagnetic materials' group comprises (besides many others) all kinds of plastics, glass, carbon and non-ferrous metals. It is legitimate to assume that there is a correlation between local χ value and local anomalies of material composition, deformation and stress, which makes it interesting to explore related sensor principles with a potential for NDT application. This contribution however concerns a novel magnetic force based sensor for laterally resolved susceptibility measurement and demonstrates the possible range of NDT applications on different non-ferromagnetic material samples.

1 Introduction

Micromagnetic materials characterization is a well-known discipline of nondestructive evaluation and testing (NDE/NDT). It is based on the interaction of magnetic domain walls (Bloch walls) with microstructure, which is similar to the interaction of dislocations with microstructure [1 – 3]. Every material interacts with a magnetic field to some extent, depending on its internal composition and structure. The interactions which define the material's behavior in a magnetic field take place on the micro- and nanometer scale and are partially quantum mechanical in nature. The magnetic susceptibility χ describes how a material interacts with a magnetic field. It is assumed that a correlation exists between micro- or electromagnetic and mechanical properties in para- and diamagnetic materials as well. There is a lack of knowledge regarding the correlation between the mechanical properties and magnetic susceptibility of non-ferromagnetic materials such as graphite, aluminum and plastics. This contribution presents an approach for magnetic susceptibility imaging and its applications in the field of NDE/NDT for non-ferromagnetic materials.

2 Experimental set-up

The novel magnetic force sensor includes a capacitive distance sensor in order to determine the deflection of a cantilever carrying a sensing magnet [4] (Fig. 1). This way, the magnetic force sensor can theoretically be used with common eddy current inspection equipment. Under the influence of the sample, the magnet is either repelled or attracted, which leads to a deflection of the cantilever. The output voltage change of the capacitive sensor electronics when approaching a material is proportional to the deflection of the cantilever. When investigating practical materials such as plastics or aluminum, the deflections are so small that the distance between sample and magnet changes to very small extent. In this case, the deflection (or voltage change) is almost proportional to the susceptibility of the material. Figure 2 depicts the diamagnetic behavior of a PVC sample. Many other non-ferromagnetic materials under test verified the efficiency of the sensor.

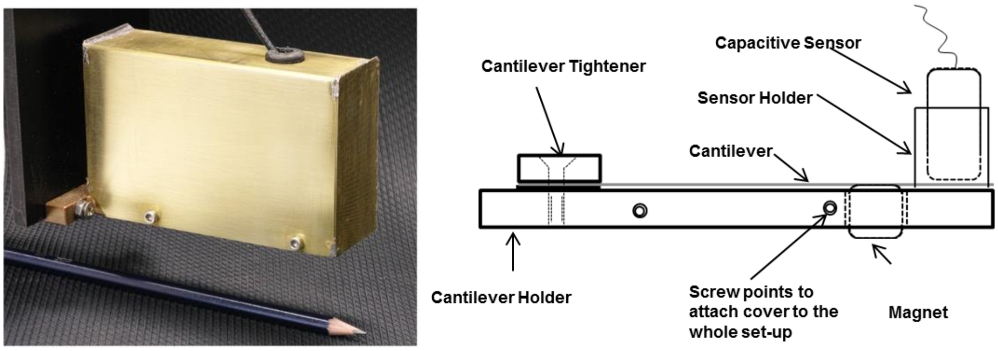

Fig. 1 Magnetic force sensor prototype (to the left) and schematic (to the right)

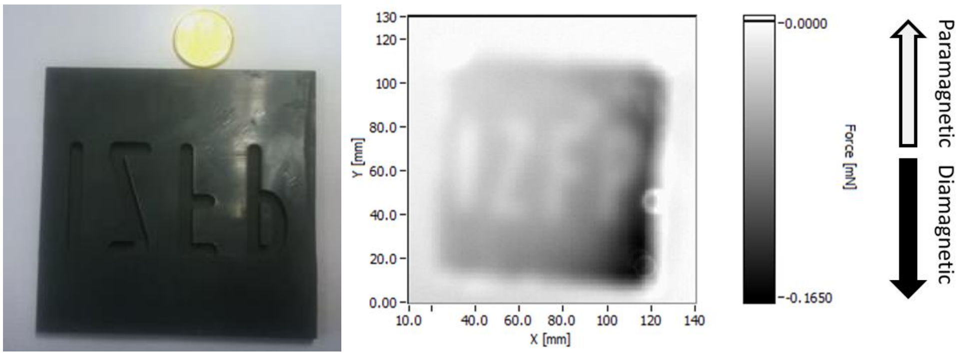

Fig. 2 Magnetic force scan of PVC plate with milled letters “IZFP”.

3 Conclusion

The principle is based on measuring the force acting upon a permanent magnet in the proximity of the material to be inspected. The sensitivity was sufficient for all kinds of plastics, metals, glass and adhesives investigated so far. Future work will focus on the improvement of lateral resolution and scanning speed, e.g. by increasing the magnetic field gradient and lowering the distance between magnet and sample. The improvement will also include the exclusion of cantilever to avoid possible vibrations. To minimize the cost, a strain gauge developed at LGEF INSA, with higher gauge factor will be used to test this principle. Possible applications are sensing and tracking of adhesives between opaque surfaces, material identification, inclusion detection and counterfeit identification.

References

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