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# Magnetic non-destructive materials characterization of non-ferromagnetic materials using magnetic susceptibility

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## Abstract

All materials interact with an external magnetic field to some extent quantified by the magnetic susceptibility  $\chi$ . There is a correlation between local  $\chi$  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 modification over the magnetic force based sensor for laterally resolved susceptibility measurement and demonstrates the possible range of NDT applications on different non-ferromagnetic material samples. This sensor however eliminates the use of cantilever to avoid possible vibrations in the industrial environment.

**Keywords:** non-destructive testing, magnetic force, magnetic susceptibility, paramagnetism, diamagnetism

## 1. Introduction

Micromagnetic materials characterization is a well-known field of non-destructive 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  $\chi$  describes how a material interacts with an external magnetic field. It has been verified before that a correlation exists between micro- or electromagnetic and mechanical properties in para- and diamagnetic materials as well [4]. Previously, a magnetic force sensor developed [4][5] has shown promising potential in characterizing the materials like composites, plastics and many other non-ferromagnetic materials. Since, luxury car makers and aerospace industry are using more and more composites in manufacturing, it becomes very important to have a method to control the quality check, e.g., adhesion between two composites. However, one major drawback of this approach [4] was the use of cantilever which is not very useful when it comes to industrial test conditions which are more prone to vibrations. Hence, a new modification is proposed in this contribution in which the experimental set-up is changed entirely and a diaphragm is used instead of a cantilever. This system shows more stability and is less prone to vibrations. As an added advantage, the cost of the entire set-up is also reduced.

## 2. Experimental set-up and results

Previously, a capacitive distance sensor was used in order to determine the deflection of a cantilever carrying a sensing magnet [4]. In the new proposed method, the authors use a plastic film thick enough to hold the sensing magnet with one layer of reflector on top for the laser sensor to sense the displacement (Figure 1). The sheet used to hold the sensing magnet is PVDF in order to be strong enough to hold the magnet and at the same time thin enough to sense some stretching due to the force on the magnet when exposed to the material under test. The thickness of the diaphragm used in this set-up is 500 microns. The laser sensor used in this method is an MTI instruments device whose resolution is 0.5  $\mu\text{m}/\text{mV}$ . The output voltage change of the laser sensor electronics when the sensing magnet is approaching a material is proportional to the displacement of the magnet. 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. The output

of the laser sensor is calibrated in terms of force. Figure 2 depicts the initial results with aluminium and graphite sample over varied distances. Many other non-ferromagnetic materials characterization will be presented in the extended version of this article to verify the efficiency of the sensor.

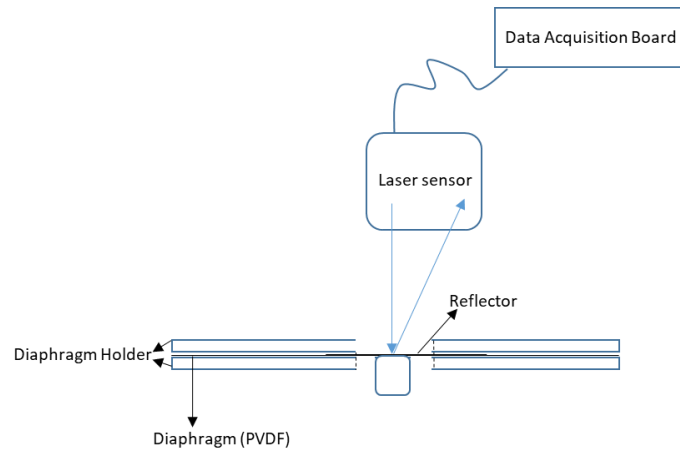


Figure 1: Experimental set-up schematic

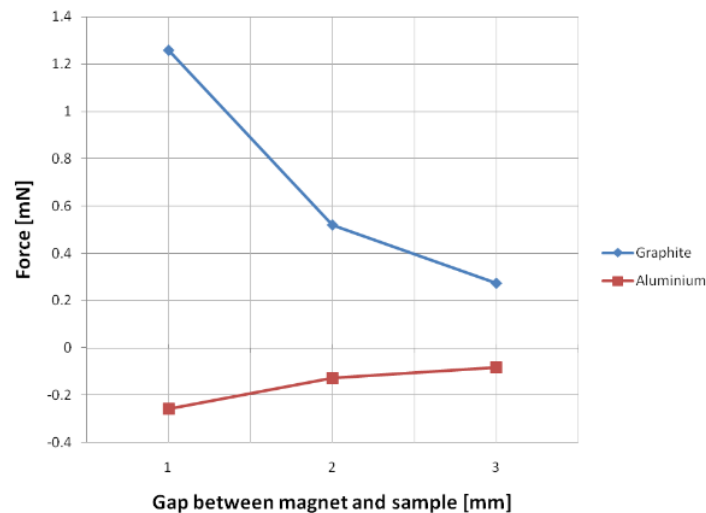


Figure 2: Initial results

### 3. Conclusions

In this study a new experimental set-up is proposed for the characterization of the non-ferromagnetic materials non-destructively. A diaphragm is used to avoid any vibrations which are a major possibility in the industrial testing conditions. Additionally, the cost of the sensor is also reduced to make it easily available for the industry. In the extended version of the article, many different non-ferromagnetic materials will be characterized and imaged as per their magnetic susceptibility.

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