New Sensors Based on the Magnetostrictive Delay Line Technique

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This presentation refers to the recent advances concerning sensors based on the magnetostrictive delay line (MDL) technique. Three sensors are presented, namely a flexible length position sensor, a tensile stress or plastic deformation sensor and a blood coagulation sensor.

Position sensors to be used in pneumatic pistons suffer from low sensitivity, high cost and flexibility in length [2]. Targeting the development of such position sensors [2] we have developed our latest version of position sensor, which is illustrated in Figure 1. Two parallel conductors including the MDL, transmit pulsed current thus inducing pulsed eddy currents on conductive disks, firmly set parallel and on top of the conductor – MDL arrangement. The pulsed eddy currents generate elastic pulses at each MDL-conductive disk intersection. Hence, a train of voltage pulses is induced at the search coil output. The amplitude of the individual pulsed voltage outputs depends on the biasing field at the above mentioned MDL-conductive disk intersection, thus allowing for measurement of the distribution of the magnetic biasing field at each intersection. A contactless moving permanent magnet parallel to the conductors-MDL arrangement causes change in the biasing field at the neighboring intersections of conducting disks and MDL. The sensing element can be produced in the form of long tapes thus allowing for the development of flexible or variable length position sensors dependent on the given request. A laser interferometer has been used as the comparison instrument for the calibration of the MDL position sensor. Both magnetic tape and MDL sensor have been used to measure the static displacement of different permanent magnets. All tested magnets were Nd-Fe-B cylinders in various sizes and various distances from the MDL. The typical sensitivity and uncertainty of the position sensor have been determined to be better than 1μm/m and 5μm/m respectively, using a 24 bit dc ADC. Permanent magnets (probably in the form of disks) may be fixed above the conductive disks to allow monotonic decrease of the generated elastic pulse amplitude with respect to moving magnet displacement. The conductive disks may also be soft magnets to combine both requirements of low resistivity for eddy current generation and high coercive field for polarising the MDL.

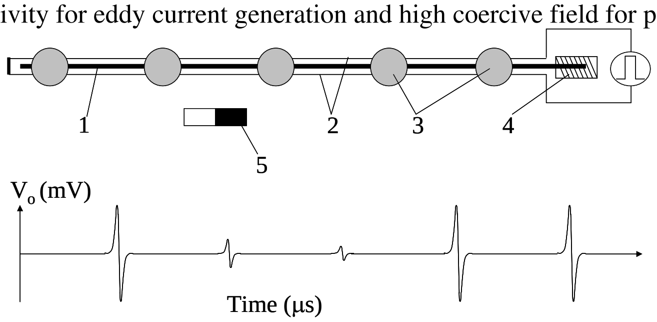

Figure 1. The schematic of the sensor (1) MDL, (2) pulsed current conductors parallel to the MDL, (3) conducting disks, (4) search coil, (5) moving permanent magnet. The sequence of voltage output pulses illustrates the response of the search coil for a possible position of the permanent magnet between two conductive disks.

The second sensor refers to non destructive testing of the magnetic permeability of ferromagnetic surfaces. The method is based on the arrangement shown in Figure 2. A balanced set-up of pulsed current excitation conductors is symmetrical around the MDL that is therefore free from any stresses, even if the pulsed current I_e is transmitted (in the same direction) in the two conductors [3]. In the absence of any other magnetic bodies in the neighborhood of the MDL, there is no magnetic flux in the delay line and consequently no pulsed voltage output is detected. Contrary, the presence of a ferromagnetic specimen at any side of the MDL and conductors balanced structure will destroy the symmetry due to partial flux closure through that specimen. This will cause an elastic excitation of the MDL and result in a pulsed voltage output of the search coil. The detected peak voltage V_o depends on the permeability of ferromagnetic specimen, distance from the pulsed-current conductors, as well as on the lift-off distance between MDL and the specimen being thus under the test. For a minimum distance between MDL and pulsed current conductors equal to 0.1 mm and a minimum lift-off distance between MDL and ferromagnetic specimen equal to 0.2 mm, the obtained maximum MDL output V_o was around 50 mV, corresponding to a reference high-permeability ribbon. Maintaining these distances at the amplitude allows estimating of the magnetic permeability at a small area of the magnetic specimen at the MDL-conductors location. Experiments were performed using Armco and electric steels after a mechanical treatment. The plastic deformation of the samples was evaluated by an "Instron" stress machine and the permeability was determined by a home-made hysteresis-meter. The MDL measurements showed monotonic dependence of the MDL output V_o on the plastic deformation or on the material permeability (Figure 3). Thus, the designed sensor can be used for scanning that may result in measuring the distribution of plastic deformation at the tested specimen surface, which is often an indication of the plastic deformation of the whole material.

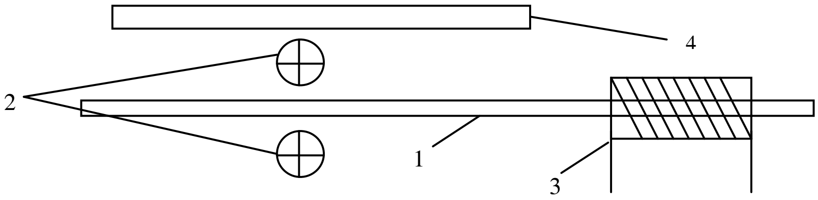

Figure 2. The testing device. (1) Magnetostrictive delay line (MDL); (2) Pulsed current conductors; (3) Receiving coil; (4) Specimen under the test.

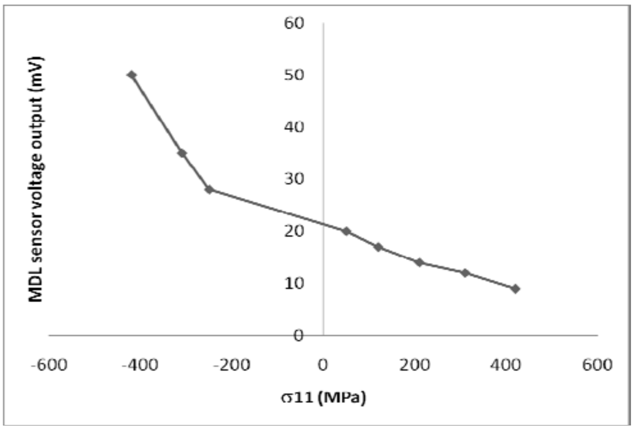

Figure 3. Dependence of the MDL output on the σ_{11} stress tensor component.

The coagulation-sensing element is an MDL, having the shape of an acoustic waveguide with rectangular cross section area can be made of FeSiB amorphous ribbons, offering high magneto-mechanical coupling factor and the smallest possible hysteresis. An excitation and a search coil are set around the MDL at the two ends of it. The output MDL signal is strongly affected by the pressure or coagulated liquid on top of the MDL. A typical dependence of the MDL pulsed-voltage output on the time of a blood drop set on top of the MDL between the two coils is illustrated in Figure 4.

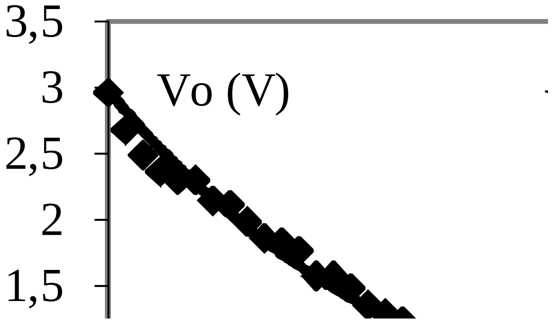

Figure 4. MDL output dependence on the time of a blood drop on the MDL surface.

[1] Reininger T, Welker F. and von Zeppelin M., *Sensors and Actuators A: Physical*, 129, 270 (2006)
[2] Hristoforou E., Dimitropoulos P.D. and Petrou J., *Sensors and Actuators A: Physical,* 132, 112 (2006)
[3] Hristoforou E., Kosmas, K., Int. J of Appl. Electromagnetics, 25, 287 (2007)