MAGNETIC SENSORS

1. Introduction

Magnetic sensors differ from most other sensors in that they do not directly measure the physical property of interest. Conventional sensors detect a physical property (temperature, pressure, strain, light, etc.) directly while magnetic sensors detect changes in magnetic fields that have been created or modified, and from them derive information on properties of interest (e.g. direction, rotation, force, electrical current, and angle). There are many ways of detection magnetic field changes, such as optical sensors based on magneto-optical materials, Hall effect sensors, SQUIDS and variety of other devices. Important point is that magnetic sensors provide accurate and reliable data without physical contact (due to presence of magnetic field).

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2.Magnetic sensors based on magnetostrictive materials

Joule magnetostriction is one of several manifestations of coupling between magnetic and elastic degrees of freedom. Other effects are:
Villari effect, Δ E effect, Wiedemann effect, Matteuci effect, magnetovolume (Barret) effect and Nagaoka-Honda effect. All these effect may be used in magnetic sensors.

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2.1 Torque sensors

Magnetostrictive noncontact torquemeters have been developed based on the principle that the torque applied to a shaft generates stresses of opposite sign $+\tau$ and $-\tau$ oriented at $\pm\pi/4$ from the shaft axis. If the shaft is magnetostrictive or has a magnetostrictive amorphous ribbon bonded onto it, the magnetic properties along the directions $+\tau$ and $-\tau$ will change. These properties can be measured either with a set of perpendicular coils or through a single Hall effect or similar magnetic field sensor. Another class of noncontact torquemeters relies on the changes in permeability exhibited by a magnetostrictive material subjected to torsional stresses.
The perspective materials for torque sensors applications are metal-bonded cobalt ferrite composites because of their attractive mechanical properties.

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2.2 Deformation sensors

Transverse-field annealed magnetostrictive ribbons or wires make very sensitive strain gauges. The sensors respond to the changes in permeability of the ribbon, which by virtue of the magnetomechanical coupling depends on the state of the strain in the material.

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2.3 Position sensors

A position detector can be accomplished with a magnetostrictive material employed as an acoustic waveguide. Such a device consists of a permanent magnet which is connected to the target and rides along the length of the waveguide and an emitter/receiver head which sends and receives either an acoustic or current pulse down the waveguide. The magnet interacts with the magnetostrictive waveguide and locally changes its material properties. These material property changes can be detected using ΔE or Wiedemann effects.

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2.4 Force sensors

These sensors are based on Villari effect. The sensor consists of two magnetostrictive elements, one surrounded by an excitation coil and the other surrounded by a pick-up coil, and two rigid and plates. In one operation mode, an ac voltage is applied to the excitation coil which generates a magnetic flux in the sensor and a corresponding voltage in the sensing coil. As a force is applied, the magnetostriction in the elements produces a change in the magnetic flux which is detected as a proportional voltage change in the pick-up coil. In a second operation mode at constant flux, the excitation voltage is allowed to change in order to maintain a constant pick-up coil output voltage. The change in excitation voltage is then related to the change in applied force.

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2.5 Pressure sensors

Magnetostrictive membrane-type pressure sensors are based on a micromembrane coated with a magnetostrictive thin-film and magneto-optical interrogation. A pressure difference across the diaphragm causes deflection and thus stress in the magnetostrictive layer. This leads to a change in the magnetic properties of the thin film, which can be detected using the magneto-optical Kerr effect. For sensing applications, soft-magnetic, Fe-based magnetostrictive alloys are most interesting.

Surface

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2.6 Magnetostrictive magnetometers

If the magnetostriction of a given material is known as a function of magnetic field, the problem of measuring magnetic field reduces into one of measuring length. The length can be measured with a laser interferometer, optic fiber, strain gauge, capacitor or with other calibrated material (e.g. piezoelectric compound).

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2.7 Current sensors

Non-contact current sensors have to be sensitive to small changes in the induced magnetic field. For this a cobalt-coated microcantilever is usually used as the detector element. Other methods are based on application of the optical Faraday effect. For this purpose Ce:YIG single crystals are utilized.

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2. Magnetic sensors based on giant magnetoresistance

Magnetoresistance (especially anisotropic magnetoresistance in NiFe), has been used in magnetic field sensors for some time. Recently giant magnetoresistance (GMR) has been discovered in multilayers and granular magnetic materials. This has ultimately led on to the spin-valve sensors, which is the prime device for current drive heads in the magnetic recording industry. GMR is also observed in Spin-dependent Tunneling (SDT) structures. In SDT structures the conduction is due to quantum tunneling through the insulator layer separating two magnetic layers.
A magnetic field sensor based on GMR effect can directly detect a magnetic field and any changes of this field. It means that it can be used in variety of magnetic sensors to detect such parameters as displacement ,torque, position, current and many others.

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3. Magnetic sensors based on giant magnetoimpedance

Giant magnetoimpedance (GMI) is defined as the change of the impedance response of a conducting soft ferromagnet, subjected to an ac current of small amplitude, when a dc magnetic field is applied. GMI is observed in amorphous and nanocrystalline wires, ribbons and films with high magnetic permeability. Most technological applications results from the field dependence of the impedance. Sensors based on GMI are employed mainly in technologies such as car traffic monitoring, quality control of steels, vibrational detection of earthquakes or biomagnetic sensors. Other application of GMI include current, position, liquid level or pressure sensors. It has to be mentioned that the stress dependence of GMI can be applied to estimate the saturation magnetostriction constant of negative magnetostriction samples.

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4. Other sensors

4.1Magnetic sensors in biomedical and biological applications

It has been proposed that the high sensitivity of GMR sensors to small magnetic fields could be employed for detection of biomolecules that have been tagged with magnetic labels. GMR sensors are favored over competing optical detection schemes due to their higher sensitivity, compact size, and easy integrability with existing semiconductor electronics.

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4.2 Tilt inductive sensors

Magnetic fluids are used in sensors to determine inclinations. The operation of inclinometers is based on the inductive detection of the magnetic fluids. The tilt sensors are also built in which a permanent magnet having a surface coated with a magnetic fluid is housed in a space inside a nonmagnetic case and is freely movable, and a magnetic sensing element is disposed outside a bottom portion of the case. When the case is tilted, the permanent magnet is moved and the magnetic sensing element detects the changes and a tilt of the case.

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