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MAGNETIC NOISE MEASUREMENT FOR VACQUIER TYPE FLUXGATE SENSOR WITH DOUBLE EXCITATION

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This paper presents a Vacquier type fluxgate sensor noise measurement and the constructive principle of our sensor. The sensor contains two cores made by amorphous wires and permits two kinds of excitation modes: excitation by coils and “direct” excitation (excitation current flowing through the cores). In both excitation modes we used the same frequency. We obtained a sensor’s noise reduction from 500 pT (pp) to 30 pT (pp) in 0 – 10 Hz frequency range.

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Keywords: Fluxgate sensor, Amorphous wires, Noise reduction

1. Introduction

The Vacquier type magnetic field sensors are used in many applications, but especially in those for which low magnetic field measurements are required. Recent studies are concentrating on increasing the performance [1,2] concerning miniaturization, power consumption, noise level and design [3,4] of this kind of sensors. The physical characteristics of the Vacquier type sensor containing magnetic amorphous wires obtained in our institute are presented.

2. Experimental

This work presents a functional fluxgate sensor with double excitation (Fig. 1) produced in our department, having the following physical characteristics: overall sensor length of 40 mm, maximum diameter of 10 mm, pick-up coil with 600 windings, calibration coil with 240 windings (coil constant – 24 μT/mA), two exciting coils with 80 windings for each (coil’s constant – 4 mT/A). The two cores of the sensor made of two pieces of $Co_{68.18}Fe_{4.32}Si_{12.5}B_{15}$ amorphous wire with 30 mm in length and 130μm in diameter have thin copper leads soldered at the ends. The ohmic resistance of the two cores connected in series is 9 Ω.

The block diagram of the magnetometric channel is represented in Fig. 2. The frequency of the exciting current flowing through the coil was 15,6 kHz (obtained using a quartz oscillator) and the amplitude was 1.2 A(pp) (equivalent exciting field is 4.8 mT(pp)).The current flowing through the cores (in the case of “direct” excitation method) has the frequency 15.6 kHz and an amplitude of 50 mA(pp). The phase difference between the two currents was 15 μs.

The signals from the pick-up coils are amplified (fifty times) with an amplifier having symmetrical input and a 5.6 nF capacitor connected in parallel, detected by using a synchronous detector (driving on the second harmonic) and finally integrated (using a dc amplifier). Between the magnetometric channel and data acquisition system a low pass filter (cut off frequency 10 Hz) was inserted. To reduce the influence of the external magnetic disturbances the sensor was placed inside a five layers Permalloy shield.

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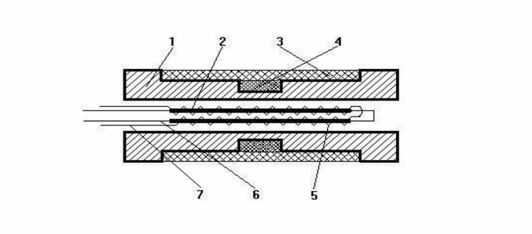

Fig. 1. Basic details of sensor (cross section): 1 - support; 2 – core; 3 – calibration coil; 4 – pick up coil; 5 – excitation coil; 6, 7 – terminals for excitation current.

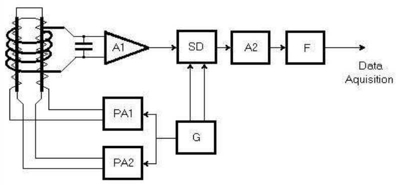

Fig. 2. Block diagram of electronic circuit: A1 – amplifier; SD – synchronous detector; A2 – dc amplifier; F – filter; G – generator; PA1,PA2 power amplifier.

3. Results and discussions

In Fig. 3 is represented the output signal of the magnetometric channel for 2 nT(pp) (square shape) external applied field in the case of classical excitation (excitation by coil), 1.2 A(pp) current flowing trough the exciting coils and zero current through the cores. As it can be observed the measured signal at the output of the magnetometric channel is affected by a noise level of 500 pT(pp). The output signal of the sensor in the case of simultaneous excitation, by coils with a current of 1.2 A(pp) and by passing a current of 50 mA(pp) trough the wires core is represented in Fig. 4. In this case the value of the square shape applied magnetic field was 1 nT.

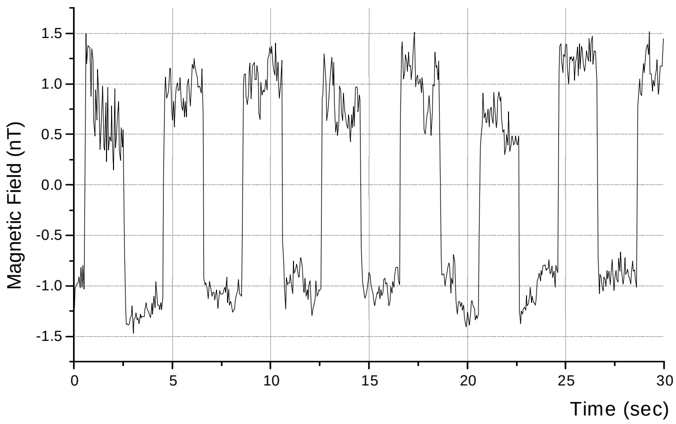

Fig. 3. The output signal of the magnetometric channel for 2 nT(pp) (square shape) external applied field in the case of classical excitation (excitation by coil), 1.2 A(pp) current flowing trough the exciting coils and zero current through the cores.

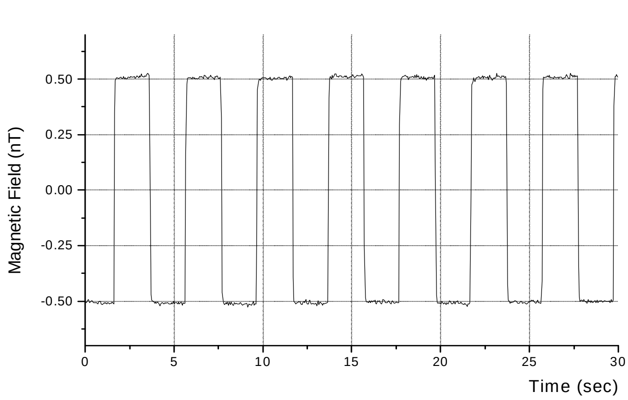

Fig. 4. The output signal of the sensor in the case of simultaneous excitation, by coils with a current of 1.2 A(pp) and by passing a current of 50 mA(pp) trough the wires.

One can observe that the noise affecting the measured signal is much less than in the absence of the "direct" excitation. In order to estimate the noise, the output signal of the magnetometric channel without the applied magnetic field, is represented in Fig. 5. The estimated noise level is 30 pT (pp). This noise is associated with the specific material noise and also with the electronic noise. Since the electronic noise is relative high (equivalent to 20 pT (pp)) the Spectral Power Density estimation usually applied for noise characterization of the flux-gate sensor is less relevant.

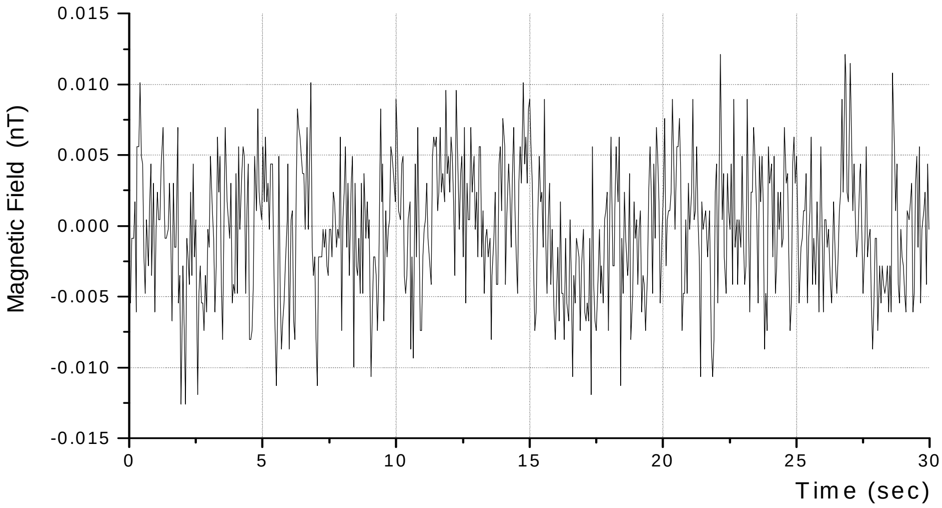

Fig. 5. The output signal of the magnetometric channel without the applied magnetic field.

By applying an a.c. current directly through the wires' core, one can observe the reduction of the noise and of the sensitivity, proportionally to the value of current. For instance, for a intensity of the current of 50 mA (pp), the reduction of the noise is 20%. Over this value, the level of the noise remains constant and only the sensitivity is reduced. The decrease of the noise is proportional with the increase of excitation current applied through the wire up to values as high as 50 mA (pp). Wire excitation signals of different frequencies compared to the coil excitation ones (i.e. coil excitation signal of 10 kHz) do not lead to the reduction of the noise level. The phase difference between the two signals is difficult to be evaluated but one can appreciate that it should be as low as possible.

The results obtained by us are in agreement with those recently published by R. Koch and J. Rosen [5] that report high performances concerning the sensors' sensitivity when applying a d.c. current through the wires core.

On the other hand, by changing the amorphous wires core with Permalloy core, no modification of either the noise or sensitivity in the case of wire excitation, has been found. One should mention that the residual noise obtained in such sensors that use amorphous magnetic wires is less compared with the case when Permalloys cores are used.

This behaviour can be explained taking into account the particularities of the $Co_{68.18}Fe_{4.32}Si_{12.5}B_{15}$ amorphous magnetic wires with close to zero magnetostriction, that present a specific magnetic domain structure. This domain structure is formed by a central axially magnetized monodomain core region and an outer shell with magnetic domains circumferentially magnetized [6]. The axial magnetic field produced by the excitation through the coils, determines switching of the magnetization in the central monodomenic core region, fact that may explain the relative high sensitivity of the sensors with amorphous magnetic wires cores. The magnetic moments from the outer shell region of the wires are perturbed by the excitation magnetic field in a random way, out of the easy axis of magnetization. This gives rise to the appearance of a high noise effect. By applying through the magnetic wires of a d.c. or a.c. current with the same frequency as that one applied through the coil, one can produce a circumferential magnetic field that may lead to circumferential magnetization blocking in the outer shell region. That also reduces the influence of the axial magnetic field on the magnetization processes in the outer shell region and implicitly reduces also the noise level. The absence of such a magnetic domain structure in Permalloy cores may explain the reduced sensitivity of the sensors with Permalloys cores, the higher level of noise and the fact that the noise cannot be reduced by wires excitation.

4. Conclusions

We present in this paper a new type of flux gate sensor using $Co_{68.18}Fe_{4.32}Si_{12.5}B_{15}$ amorphous wires with close to zero magnetostriction. A double excitation mode of the sensor, one through the coils wounded on the two wires cores and one by passing an a.c. current of the same frequency through the magnetic wires, is presented. In this way, the noise level of the magnetometric chanel is reduced by more than one order. An explanation of this phenomenon based on the domain structure specific to the used amorphous magnetic wires, is done.

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