Journal of ELECTRICAL ENGINEERING, VOL 66. NO 7/s, 2015, 190 -192

INDUSTRIAL APPLICATIONS OF MAGNETOMETRY

Dušan Praslička* – Josef Blažek – Jozef Hudák* – Ivan Mikita* – Václav Moucha***

An important indicator of scientific and applied research quality is its innovative results' application in the industrial practice. The way from the basic research to a specific application is relatively complicated and it includes mainly permanent searching for a potential application and industrial partners who are disposed to go through the initial risks. That is also the case of applications of the basic research in magnetism. In the article we describe a special industrial application of magnetometry for the protection of conveyor belts against ferromagnetic objects.

Keywords: magnetometry, flux-gate magnetormeters, sensorics, trump metal detectors

1 INTRODUCTION

The Faculty of Aeronautics of the Technical University of Kosice (FA TUKE) in cooperation with the EDIS company have dealt with the applied magnetometry on the long-term basis, namely with the problems of the measurement of weak magnetic fields, mostly from the aspects of navigation, remote monitoring and detection, extremely low frequency (ELF) electromagnetic field (EMF) compatibility and ecology. To the other areas of interest belong magnetic sensors, magnetometers for research, laboratory and special industrial systems. The EDIS company which brings back to memory already the 20 years of its foundation and commercial activity on the market is one of few Slovak companies, which successfully realizes and applies basic research in magnetism. From the commercial products HFT systems for conveyor belts protection magnetometers of the VEMA series, demagnetizing devices can be mentioned.

2 HFT SYSTEMS

Among the industrial applications the most successful are HFT (from the Czech – Hlídače Feromagnetických Těles) systems assigned on the protection of conveyor belts against ferromagnetic objects.

This interesting application has its origin in the frequent presence of ferrous objects by the coal mining and stripping in the North Czech surface coal mines as a remain after the secular underground deep mining, constructions as well as technological non-discipline by the work. Occurrence of rails, tools and trump ferrous parts caused considerable problems particularly by the disrupting of expensive conveyor belts and following long-term interruption of the mining.

Fig. 1. Coal mine MUS, kilometres of conveyors **T**ransport soil and coal

Research of the HFT indicators began in 1995 in co-operation with the Department of Aviation Technical Studies of the FA TUKE, with the Faculty of Science of the University of P. J. Safarik in Kosice and with the Institute of Experimental Physics of the Slovak Academy of Sciences. Utilization of the relaxation pulse-type fluxgate magnetometers [1,2] as a result of our own research placed under the belt instead of massive frame sensing coils meant from the installation and operation point of view a considerable comparative advantage toward the competition.

Relax-type magnetometer acts as a power supply – flyback converter - with a saturated core. The energy accumulated in the core and the consequent initial current are proportional to the external field. The short measuring chain of the magnetometrs together with the well-defined uncertainties, a direct digital output with the resolution in the range of 10^{-9} T and the sampling frequency of 1kHz have been also shown to be very convenient for this demanding application.

*Technical University of Košice, Faculty of Aeronautics, Rampová 7, 041 21 Košice, Slovakia, dusan.praslicka@tuke.sk, jozef.hudak@tuke.sk, ivan.mikita@tuke.sk, vaclav.moucha@tuke.sk, ** University of Security Management in Košice, Kukučínova 17, 040 01 Košice, Slovakia, josef.blazek@vsbm.sk

ISSN 1335-3632 © 2015 FEI STU

Fig. 2. Sensor placed under the belt

Modern signal processing using effective digital filters and correlation methods by the signals extraction in the disturbed industrial environment guaranteed successful operational examinations and long-term reliable operation. Iron objects moving on belt above the sensor generate a stray field which has a special shape in time and frequency domain depending mainly on the dimension of the object.

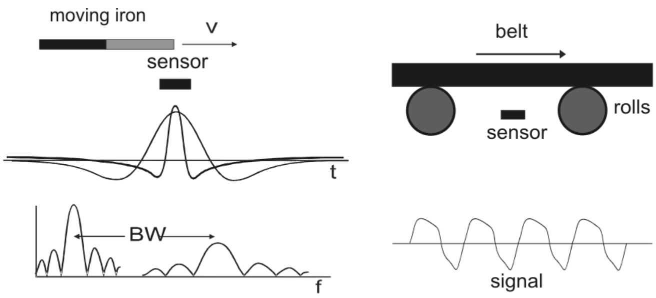

Fig. 3. Moving ferromagnetic object and generated stray field (left) and stray fields from rolls (right)

The stray field in Fig.3 (left) sensed by the sensor is the carrier of the useful information about the presence of the moving ferromagnetic object and in the time domain and could be calculated as:

$$B_R = \frac{JS}{4\pi}\left\{\frac{vt - l/2}{\left[(vt-l/2)^2 + d^2\right]^{\frac{3}{2}}} - \frac{vt + l/2}{\left[(vt+l/2)^2 + d^2\right]^{\frac{3}{2}}}\right\}, \quad (1)$$

where B_R is stray induction in the place of the sensor, S is the cross-section and l is the length of the object, J represents magnetic polarisation of the object, d corresponds to the distance from the sensor and v is the speed of the object. Spectral analysis of the equation (1) gives us information about the expected bandwidth of the signal. In practice the bandwidth of the signal produced by the iron objects with the length of 0.1 – 2 m, considering the speed of the belt 5 m/s, the distance up to the 1 m from the sensor can be expected in the range from 1 to 20 Hz. Sure, this signal in the industrial environment is almost hidden in the interferences. The periodic interference in Fig. 3 (right) is produced by the moving ferromagnetic part of the conveyor construction – iron belt rolls and holders. They are strong because sources are too close to the sensors but the frequency is correlated to the speed of the belt, and thus can be almost fully removed by the adaptive comb filter. The data processing for the extraction of the useful signal can be then formulated as:

$$b_i = \sum_{k=0}^{M} a_{i-k} h_k W_k\,, \quad (2)$$

where b_i is the output signal, h_k are FIR coefficients of bandpass filter and W_k are Blackmann window coefficients. Then we use a simple comb filter for the suppression of the periodic interferences:

$$c_i = \frac{1}{2}\left(b_i - b_{i-L}\right), \quad (3)$$

where c_i is the output of this second stage. Transfer function is shown in next Fig. 4. Although the impulse response of such a filter is not ideal it doesn't very matter in our case whereas we are searching for almost single processes in time.

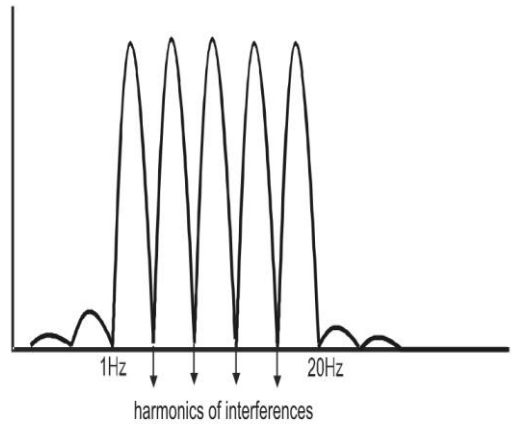

Fig. 4. Adaptive selective comb FIR filter for selection of signal from interferences

Random interferences are another problem that could disqualify such a system in practice. False identifications interrupt the coal mining and can cause subsequent financial losses. They have an origin in the switching megawatt motors, lights, alarms, random vibrations of construction and so on. For the low-frequency region, unfortunately, there is insufficient legislation for the EMC interference in the industry. As wideband, they lie in the frequency range of our interest for the identification of ferromagnetic objects. The only solution lies in the correlation analysis using at least two sensors at a defined distance that excludes these mostly distant interferences.

Correlation analysis then requires precise knowledge of the belt speed.

The block scheme of the HFT system is in Fig. 6. Hardware of the HFT system fulfils the requirements for the signal measuring and processing. It consists of the Wafer industrial single board computer, two channel simultaneous relaxation 18-bit magnetometer with the sampling frequency of 1 kHz in the range of ±100 000 nT, a proximity switch as a tachometer SP14, two relaxation sensors and switching power supply 24 V / 5 V, ±12 V.

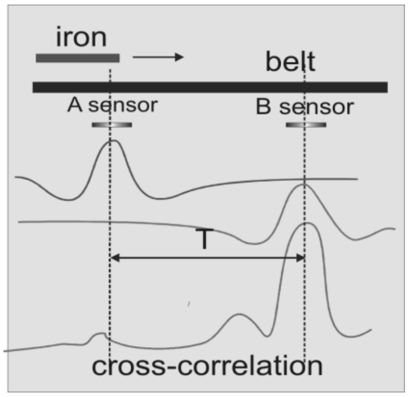

Fig. 5. Cross-correlation between two channels of the system excludes random distant interferences

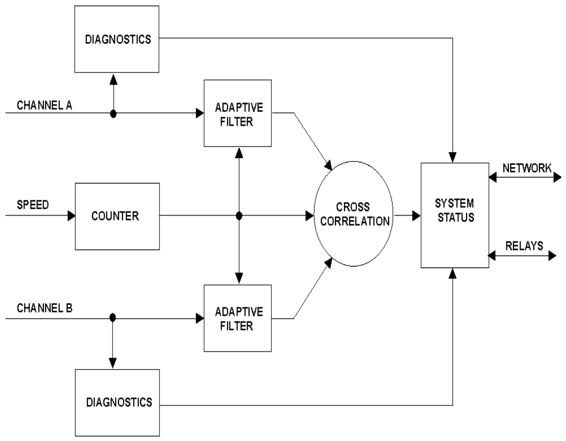

Fig. 6. Block scheme of the HFT system

The software implements all the requirements for the data acquisition, system settings and diagnostics, processing and evaluation of the signals in the real-time and automatic system configuration for optimal performance. Full auto-diagnostic, network communication and operating records are also included.

5 CONCLUSIONS

Many HFT systems have been in operation for 15 years whereby the number of its applications exceeds 60 in the North Czech coal regions and Třinec Iron and Steel Works. Systems have been continuously developed according to the customers' requirements and nowadays they represent modern industrial automatic machines with the network control.

Fig. 7. HFT system installed on the KK1300 excavator, SD Bílina

Nevertheless, there are still many challenges for further research and development, such as:

- development of new materials for ferroprobes, characterized by the increased sensitivity, noise reduction and extending of the measuring range,
- utilization of four-channel and multichannel systems,
- research and development of magnetometers based on the amorphous microwires,
- and finally looking for new applications and customers.

Acknowledgement

This work was supported by the APVV 0266-10 project, Scientific Grant Agency of the MESRaS SR and SAS under contract No VEGA 1/0286/13 and Cultural and Educational Grant Agency of the MESRaS SR under contract No KEGA 028 TUKE-4/2013.

REFERENCES

[1]. PRASLIČKA, D.: - Relax - Type Magnetometer Using Amorphous Ribbon Core. In IEEE Transaction on Magnetics. Vol. 30 (1994), No. 2, P. 934-935. ISSN 0018-9464.

[2]. MARCIN, J. – KLINDA, A. – ŠVEC. P. – PRASLIČKA, D. – BLAŽEK, J. – KOVÁČ, J. – ŠVEC, P. – ŠKORVÁNEK, I.: Melt-Spun FE-CO-B-CU Alloys With High Magnetic Flux Density For Relax-Type Magnetometers. In IEEE Transaction on Magnetics, Vol. 46, No. 2 (2010), P. 416-419. ISSN 0018-9464.

Received 30 November 2015