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Prediction of the parameters of magnetic field of CNC machine tools

***Abstract**. The problem of high-frequency electromagnetic field at the workplace is critical due to its effect on the operators of technological machines. For this reason, the exposure to electromagnetic fields at the workplace should be subject to regular monitoring. The paper presents the use of simple models for forecasting of magnetic fields components. This study investigates the high-frequency electromagnetic field emitted in CNC machine tools area (DMU 65 Mono Block). Experimental tests were conducted for CNC machine tool. The measurements of high-frequency magnetic field strength were performed in compliance with the method specified in the PN-T-06580-3: 2002 standard.*

Streszczenie.** Problem pola elektromagnetycznego dla wysokich częstotliwości w miejscu pracy jest krytyczny w efektach dla jego operatora. Z tego powodu ekspozycja pola elektromagnetycznego w miejscu pracy powinna być regularnie monitorowana. Artykuł prezentuje użycie modelu prostego do prognozowania oddziaływania pola magnetycznego. Niniejsze badania rozpatrują pole elektromagnetyczne wysokich częstotliwości emitowane w obszarze obrabiarki sterowanej numerycznie (DMU 65 Mono Block).Przeprowadzono testy eksperymentalne dla obrabiarki CNC. Pomiary składowej magnetycznej przeprowadzono zgodnie z normą PN-T-06580-3: 2002. (**Prognozowanie parametrów pola magnetycznego obrabiarek CNC)

Keywords: electromagnetic fields, CNC machine tools, measurement, prognosis, Simple Moving Average, Weighted- average method
Słowa kluczowe: pole elektromagnetyczne, obrabiarka sterowna numerycznie, pomiary, prognozowanie, metoda średniej ruchomej prostej, metoda średniej ruchomej ważonej

Introduction

The effect of the electromagnetic field (PEM) of high frequency on the tissue of the body is a subject of research conducted by numerous scientific centres across the world. Electromagnetic radiation causes various ailments among workers, depending on the field strength and frequency.

Operation of a technological machine in the electromagnetic field (PEM) that derives from various sources puts a machine operator in danger of harmful factors. PEM can also affect negatively operation of the machine and operating system [1, 3].

The forecast methods applied to economy were used, including the Simple Moving Average (SMAMS) and weighted- average method (WMAMS), or using the simple model of exponential smoothing. The method of the Simple Moving Average is based on a time series. Time series should be characterized by a fixed (average) level with random fluctuations. The average moving weighted method, similarly to Simple moving Average is based on a time series. The basic assumption was that the time series of deviation change should be characteristic of a fixed (average) level with random fluctuations. The premise for using the method is high random fluctuations. The action mechanizm of the method takes into consideration the phenomena of dating the information (the most recent information are of greater importance) (Fig.1, Fig.2).

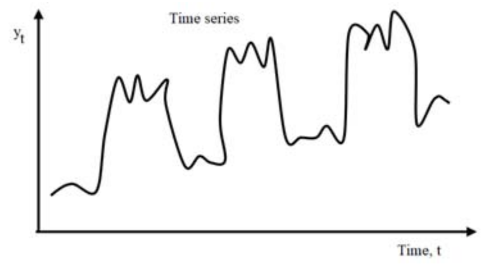

Fig.1. General form of time series and its components in typical course of time series

The basic method of electromagnetic risks assessment at workplace, used in accordance with the regulation of the Minister of Labour concerning NDN electric and magnetic fields and Polish PN-T-06580:2002 norm, is based on induction of magnetic field and that affect the operator [2, 4, 5, 6].

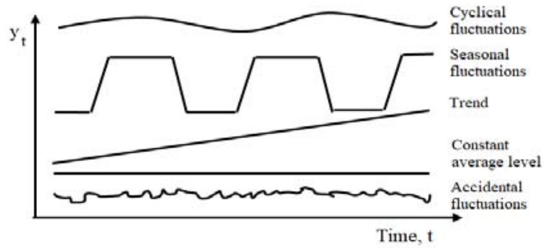

Fig.2. General form of time series and its components in time series components (random, seasonal, cyclic, trend fluctuations, fixed- average level)

On the basis of the introduced measurement and calculation results final predictions concerning an induction of the magnetic field affecting the machine tool operator [7, 8, 9].

The characteristics of the Simple Moving Average

The method of the Simple Moving Average is based on a time series. Time series should be characterized by a fixed (average) level with random fluctuations. Using Simple Moving Average requires determining the variability factor of the time series v_z, providing information on the random fluctuations values force. Low value of the variability factor of the tested variable v_z allows for the use of Simple Moving Average to construct a forecast for the next period/ quarter. The variability factor presents the formula (1) [4, 13]:

$$v_z = \frac{s}{\overline{B}} \cdot 100\% \quad (1)$$

where: s– standard deviation of a tested variable B,
$\overline{B}$– arithmetic average of the tested variable value B, (deviation).

Standard deviation presents the formula (2):

$$s = \sqrt{\frac{1}{n-1}\sum_{t=1}^{n}\left(B_t - \overline{B}\right)^2} \quad (2)$$

whereas the average arithmetic $\overline{B}$ of a tested variable from the following equation (3):

(3) $$\overline{B}=\frac{1}{n}\sum_{t=1}^{n}B_t$$

where: n – the number of quarters, B_t – subsequent values of the tested variable B „deviation" in particular quarters of a considered period.

A forecast B_t^* for the period / quarter t using the Simple Moving Average may be determined from the following relation (4).

(4) $$B_t^*=\frac{1}{k}\sum_{i=t-k}^{t-1}B_i$$

where: k – smoothing constant, B_i – subsequent values of the tested variable B in the particular quarters of a considered period of time t.

The forecast horizon is usually short and because of that the method is used to draw a short-term prognosis. The prognosis acceptability assessment is done on the basis of an average squared prognosis error ex post $s*$ (5).

(5) $$s^*=\sqrt{\frac{1}{n-k}\sum_{i=k+1}^{n}(B_i-B_t^*)^2}$$

where: k – smoothing constant, B_i – real value of a tested variable B in the period/ quarter t, B_t^* –prognosis for a period/ quarter t.

Weighted Moving Average method Specification

The average moving weighted method, similarly to Simple moving Average is based on a time series. The basic assumption was that the time series of deviation change should be characteristic of a fixed (average) level with random fluctuations. The premise for using the method is high random fluctuations. The action mechanism of the method takes into consideration the phenomena of dating the information (the most recent information are of greater importance). The average moving method takes prognosis in the following form (6) [4, 5]:

(6) $$B_t^*=\sum_{i=t-k}^{t-1}w_{i-t+k+1}\cdot B_i$$

where: k – smoothing constant, B_i – the the tested variable B „deviation" in subsequent quarters of a considered time period t, w_i – weighs given to particular observations.

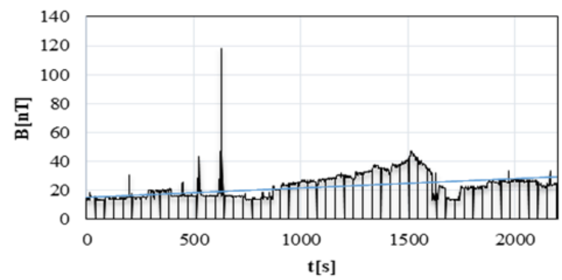

Fig.3. The results of measurements of the induction of magnetic field in the workplace of the operator (DMU 65 Mono Block)

Measuring system

Experimental tests were conducted for CNC machine tool. The measurements of high-frequency magnetic field strength were performed in compliance with the method specified in the PN-T-06580-3: 2002 standard [10, 11, 12, 13]. Research of spatial distribution of the electromagnetic field in the surrounding area of CNC machine operator were made using the electromagnetic field meter ESM-100 by Maschek. The measurements were performed at the workplace of the CNC machine operator at a height of 1.4 m corresponding to the height of the chest in an adult person. The results of the induction of magnetic field strength obtained at the DMU 65 Mono Block workplace are shown in Fig. 3.

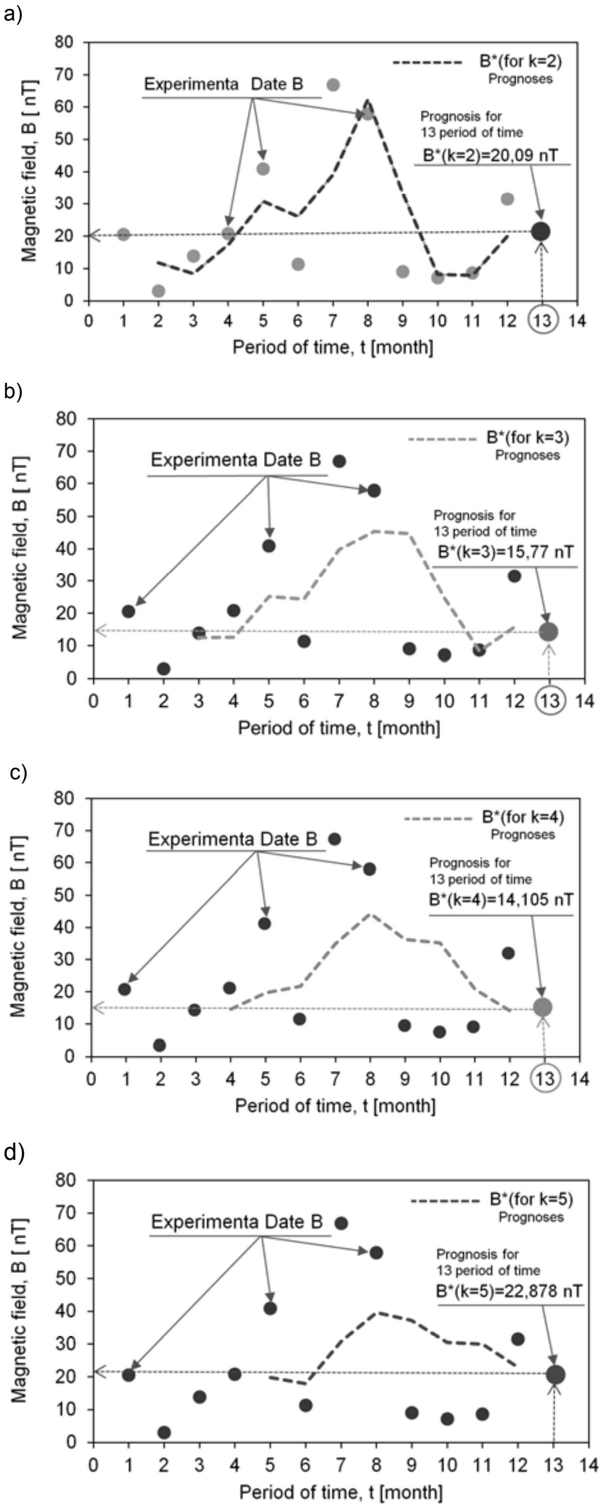

Fig.4 The results of measurements of the induction of magnetic field in the workplace of the operator (DMU 65 Mono Block): a) soothing constant k=2, b) soothing constant k=3, c) soothing constant k=4, d) soothing constant k=5

Fig. 4 shows a comparison of the workplace of the operator in the time function and the forecasts using simple moving average method according to a classical model.

On the basis of the performed stimulation, it seems that the modified weighted model may be adopted to foresee using time series with a trend, with a satisfactory accuracy.

Three weight sets were taken into consideration in the conducted research show in table. 1

The modified model of a simple moving average the prognosis is constructed as an arithmetic average of the deviation values from three previous months (t-1, t-2, t-3), plus the difference in the value of the first and third, starting from the end, recorded result.

Table I. Weight set coefficients for Weighted Moving Average Method Specification

	w_1	w_2	w_3
Weight Set I	0,7	0,2	0,1
Weight Set II	0,6	0,3	0,1
Weight Set III	0,5	0,3	0,2
Weight Set IV	0,4	0,3	0,3

Table II. Value of the induction of magnetic field prognoses *B** obtained by Simple Moving (SMAMS) and Weighted Moving Average method Specification (WMAMS)

Prognosis of magnetic field, *B** [nT]				
	B*(for k=2)	B*(for k=3)	B*(for k=4)	B*(for k=5)
SMAMS	20,09	15,77	14,105	22,878
	Weight Set I	Weight Set II	Weight Set III	Weight Set IV
WMAMS	24,545	22,245	19,800	17,355

Table I and Table II show the results of CNC machine tool axis squareness deviation prognosis calculations using Simple moving average and weighted utilizing classical models.

The effect of model accuracy improvement is the improvement in the correlation between expired forecasts and the experimental results.

Conclusions

The method proposed in the work allows to predict the value of the measured field based on the analytical model without performing time-consuming measurements. The prognostics model was built based on the time series for which regression functions were determined and the moving average and the weighted average for forecasting were used. It allows to predict the value of the magnetic field and its parameters, which in turn will allow the employee to take protective steps and enable preventive control activities and minimize the negative impact of the field on the environment.

The production process presented in the work allows for making short-term prognosis without conducting research trials. The presented characteristics show that the most accurate prognosis is obtained by Simple moving average for the series with slight periodic variations for conducted experiments. In the case of the magnetic component, the most accurate prognosis was used for soothing constant k = 4. For the magnetic component, the best forecasting results were obtained during the prediction of results by the weighted average method and the third weight set.

Including weight sets allows modelling the impact (significance) of obtained experimental results and their shares in the prepared prognosis.

The most accurate prognosis for the *B** field (obtained from SMAMS) was 14,105 nT. It will also minimize the disturbances of machines and devices found in the environment, especially the data transmission of measurement and control probes of machine tools, the operation of the machine control system and the cooperating devices.

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