Informatics Control Measurement
in Economy and Environment Protection

2/2022

Informatyka Automatyka Pomiary

w gospodarce i ochronie środowiska

www.e-IAPGOS.pl

ISSN 2083-0157

Kwartalnik Naukowo-Techniczny

fot. Michał Stopel

XXXII Zjazd Dziekanów Wydziałów Elektrycznych, Elektroniki, Telekomunikacji, Automatyki i Robotyki, Cybernetyki, Mechatroniki oraz Informatyki 19-21 maja 2022 r., Politechnika Bydgoska

XXXII Congress of Deans of the Faculties of Electrical, Electronics, Telecommunications, Automatics, Robotics, Cybernetics, Mechatronics and Computer Science

The XXXII Congress of Deans of the Faculties of Electrical, Electronics, Telecommunications, Automatics, Robotics, Cybernetics, Mechatronics and Computer Science took place in Bydgoszcz between 19-21 May 2022. The congress is a cyclical undertaking, the individual editions of which were organized in various universities in Poland. The first congress was held in Silesian University of Technology in Gliwice in 1991. The Deans met for the second time in Bydgoszcz in 2003.

Dean's Reunions is a long and glorious tradition continued in many academic environments. This year, the organizer of the Congress was the Faculty of Telecommunications, Computer Science and Electrical Engineering of the Bydgoszcz University of Science and Technology named after Jan and Jędrzej Śniadecki. It is the youngest in the noble group of polytechnic schools in our country, although with 70 years of tradition. It was established 7 months ago as a result of changing the name of the UTP University of Sciences and Technology named after Jan and Jędrzej Śniadecki in Bydgoszcz. It was an undoubted honor for this young University to host such honorable guests representing renowned universities from all over the country. For years, the conventions have been a place for exchanging experiences and sharing the so-called good practices between the Authorities of individual departments. The Congress allows new members of our community to establish invaluable direct contacts. During the speeches invited guests raised the most bothersome issues in the field of science, education, organization and cooperation with the economic environment. The event was supported by L.K. Control from Bydgoszcz. Nearly 90 participants took part in the congress. During the 3 days of the congress there were 8 invited speeches. The participants had the opportunity to take part in a trip around Bydgoszcz, during which they visited the most important attractions of the city.

The next Congress of Deans will take place in the Military University of Technology in Warsaw.

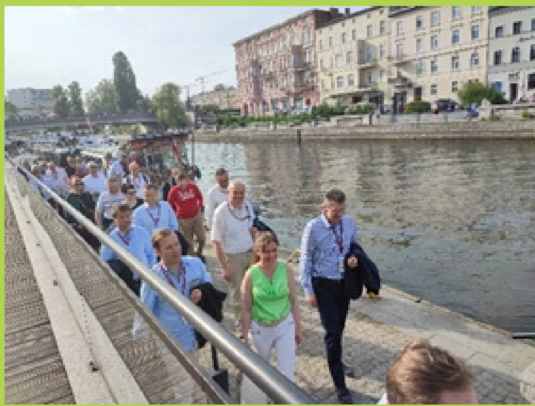

foto: arch. PBS

2/2022

kwiecień – czerwiec

Wydanie pod redakcją naukową
prof. dr hab. inż. Waldemara Wójcika

INFORMATYKA AUTOMATYKA POMIARY W GOSPODARCE i OCHRONIE ŚRODOWISKA

Informatics Control Measurement in Economy and Environment Protection

p-ISSN 2083-0157, e-ISSN 2391-6761, www.e-iapgos.pl

EDITORIAL OFFICE
REDAKCJA

Redakcja czasopisma
Informatyka, Automatyka, Pomiary w Gospodarce i Ochronie Środowiska
Katedra Elektroniki i Technik Informacyjnych
Politechnika Lubelska
ul. Nadbystrzycka 38A, 20-618 Lublin
tel. +48 81 53 84 309,
fax: +48 81 53 84 312
iapgos@pollub.pl
www.e-iapgos.pl
iapgos.pollub.pl
ph.pollub.pl/index.php/iapgos

PUBLISHER
WYDAWCA

Politechnika Lubelska
ul. Nadbystrzycka 38D
20-618 Lublin
tel. +48 81 53 84 100
www.pollub.pl
ph.pollub.pl

PRINTING HOUSE – DRUKARNIA

Soft Vision Mariusz Rajski
https://www.printone.pl

nakład: 100 egzemplarzy

OTHER INFORMATION – INNE INFORMACJE

Czasopismo jest indeksowane w bazach:

DOAJ	doaj.org
BazTech	baztech.icm.edu.pl
IC Journals Master List	www.journals.indexcopernicus.com
Google Scholar	scholar.google.pl
POL-index	pbn.nauka.gov.pl
Sherpa RoMEO	www.sherpa.ac.uk
OAJI	oaji.net
SCOPUS	www.scopus.com

Czasopismo *Informatyka, Automatyka, Pomiary w Gospodarce i Ochronie Środowiska* zostało objęte finansowaniem przez Ministerstwo Nauki i Szkolnictwa Wyższego w ramach programu *Wsparcie dla czasopism naukowych* w latach 2019-2020.

Czasopismo znajduje się w wykazie czasopism naukowych opublikowanym w Komunikacie Ministra Edukacji i Nauki z dnia 1 grudnia 2021 r., Unikatowy Identyfikator Czasopisma: 200167 – z przypisaną liczbą punktów przyznawanych za publikację artykułu równą 20.

Zasady publikowania artykułów, przygotowania tekstów, zasady etyczne, procedura recenzowania, wykazy recenzentów oraz pełne teksty artykułów dostępne są na stronie internetowej czasopisma:

www.e-iapgos.pl

W celu zwiększenia oddziaływania czasopisma w środowisku naukowym redakcja zaleca:

- w artykułach publikowanych w IAPGOS cytować artykuły z renomowanych czasopism międzynarodowych (szczególnie indeksowanych w bazach Web of Science oraz Scopus) używając oficjalnych skrótów nazw czasopism,
- w artykułach publikowanych w innych czasopismach (zwłaszcza indeksowanych w bazach Web of Science oraz Scopus) cytować prace publikowane w IAPGOS – zwłaszcza posługując się numerami DOI, np.:
  Kluszczyński K. *Modelowanie – umiejętność czy sztuka?* Informatyka, Automatyka, Pomiary w Gospodarce i Ochronie Środowiska – IAPGOS, 1/2016, 4–15, https://doi.org/10.5604/20830157.1193833.

CONTENTS – SPIS TREŚCI

CONTENTS – SPIS TREŚCI

http://doi.org/10.35784/iapgos.2948

received: 08.05.2022 | revised: 10.06.2022 | accepted: 15.06.2022 | available online: 30.06.2022

DETERMINATION OF THE OPTIMAL FREQUENCY OF THE PRIMARY MEASURING TRANSDUCER OF THE THICKNESS OF DIELECTRIC COATINGS OF METAL SURFACES

Kostyantyn V. Ovchynnykov[1], Oleksandr M. Vasilevskyi[1], Volodymyr M. Sevastianov[1], Yurii A. Polievoda[2], Aliya Kalizhanova[3], Bakhyt Yeraliyeva[3]

[1]Vinnytsia National Technical University, Faculty of Intelligent Information Technology and Automation, Vinnytsia, Ukraine, [2]Vinnytsia National Agrarian University, Department of technological processes and equipment for processing and food production, Vinnytsia, Ukraine, [3]M. Kh. Dulaty Taraz Regional University, Taraz, Kazakhstan

Abstract. *The article provides an analysis of the physical processes underlying the operation of the measuring transducer, with a time based information presentation. A mathematical model is developed that describes the process of free oscillation attenuation excited in the LC-contour of primary measuring transducer, and analyzes and evaluates the influence of external factors that influence the measurement results. The ways of elimination of their influence on the results of measuring control are offered.*

Keywords: measuring, transducer, thickness, dielectric coating, metal surface, oscillation

WYZNACZANIE OPTYMALNEJ CZĘSTOTLIWOŚCI PIERWOTNYCH PRZETWORNIKÓW POMIAROWYCH DO POMIARU GRUBOŚCI POWŁOK DIELEKTRYCZNYCH NA POWIERZCHNIACH METALOWYCH

Streszczenie. *Artykuł zawiera analizę procesów fizycznych leżących u podstaw pracy przetwornika pomiarowego wraz z prezentacją informacji w czasie. Opracowano model matematyczny opisujący proces tłumienia drgań swobodnych wzbudzanych w obwodzie LC głównego przetwornika pomiarowego, analizujący i oceniający wpływ czynników zewnętrznych na wyniki pomiarów. Proponowane są sposoby wyeliminowania ich wpływu na wyniki kontroli pomiarów.*

Słowa kluczowe: pomiar, przetwornik, grubość, powłoka dielektryczna, powierzchnia metalu, oscylacja

Introduction

The basic principles of construction of measuring transducers, based on the excitation method in the electrically conductive basis of the measuring object of vortex currents, are described in [4, 5, 24]. The process of energy transfer in a oscillatory circuit can be of a different nature. Depending on the ratio of the active and characteristic (wave) contour resistance, the periodic (oscillatory) process can turn into aperiodic. But regardless of the nature of the transient process in the circuit, the time constant remains unchanged for certain parameters [14].

Since in a real oscillatory circuit, due to losses of accumulated energy for heating, free oscillations will always be attenuating; the main characteristic of the oscillatory circuit is the damping decrement, which is directly proportional to the active contour resistance and inversely proportional to the contour circuit's wavelength and its Q factor. The greater the active resistance of the contour, the smaller the time of attenuation of excited free fluctuations in it. The main energy losses in the circuit occur mainly in the active resistance of the coil, so the decay of the attenuation and the quality of the circuit will be determined by the quality factor of the coil of inductance [23, 26].

The equivalent circuit of the measuring transducer is shown in Fig. 1.

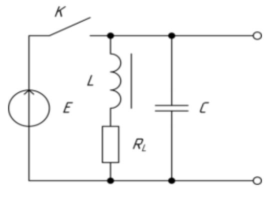

Fig 1. Equivalent circuit of the measuring transducer

1. Formulation of the problem

The change in the duration of the transition process in the circuit when applying the active component of the resistance in the form of a metal base of the object to be measured will depend on many factors. To increase the accuracy of measurement of such a time interval, it is necessary to ensure the maximum amplitude of the change in the damping time of free oscillations of the isolated circuit and the circuit that interacts with the object of measurement. One of the parameters that can be changed in a wide range without changing the hardware properties of the measuring transducer is the frequency of oscillations in the circuit. Therefore, the task of determining the optimal value of the oscillation circuit frequency is relevant, at which the maximum accuracy of measuring the attenuation time of free oscillations in the circuit can be achieved

2. Theoretical research

The total resistance of the inductor Z_{lss} coil will be determined as [25]:

$$Z_{lss} = Z_0 + Z_{md} = Z_0 + 2\pi f M\Psi(\beta,\gamma), \quad (1)$$

where Z_{lss} – the resistance of the coil; Z_0 – complete resistance in the absence of electromagnetic field conductive material; Z_{md} – additional resistance (introduced), which occurs when the coil of the conductive material appears; M – coefficient of co-induction (interaction) of a coil of inductance and conductive material; $\Psi(\beta,\gamma)$ – a function of flow coupling for a coil located normal to a flat conduct or plate with certain dimensions, conductivity and other parameters of the conductive material; β, γ – generalized parameters that characterize the geometrical and physical properties of the metal base of the control object.

The co-induction coefficient M is a functional dependence of the distance ℓ between the end of the core of the coil and the surface of the conductive material [6], which is described by the expression:

$$M = M_0 e^{-\frac{6l}{d_e}} \quad (2)$$

where M_0 – the coefficient of co-induction between the coil inductance and its mirror image at zero gap between the ends of their rods; d_e – equivalent diameter of the coil of inductance. For the convenience of calculations, the equivalent diameter value is taken to be equal to the average diameter of the coil. The value of the coefficient M_0 is determined from the ratio:

$$M_0 = \frac{e_1}{\frac{\Delta i_2}{\Delta t}} \quad (3)$$

where e_1 – the electromotive force of interinvitation, which arises in the first circuit with a uniform change in current at 1 amperes per second in the second circuit; i_2 – the current flowing along the second contour, with the first and second contours being inductively connected.

The value of the co-induction coefficient M_0 is determined experimentally under the following conditions: two coils of inductance L and L' having identical electrical, physical and geometric parameters, connecting the cores one of them is connected to the generator of the sinusoidal voltage through the resistor *R1* (Fig. 2), which satisfies the condition:

$$R1 >> \sqrt{R_L^2 + (L \cdot \omega)^2} \tag{4}$$

where R_L – the active resistance of the inductance coil, L – the inductance of the input coil, ω – the angular frequency of the sinusoidal voltage. Another coil is connected to a voltmeter. The resistor *R2* with a nominal resistance of about 10^3 Ohm for the load of the inductor L' is connected.

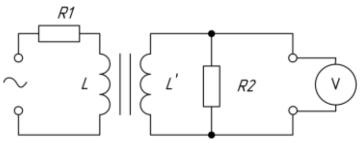

Fig. 2. Schematic diagram of the installation to determine the coefficient of co-induction between the coil and its mirror image

Using the scheme (Fig. 2), the expression for determining the coefficient of interinduction (3) can be rewritten as follows

$$M_0 = \frac{e_2 R1}{2\pi f U_0} \tag{5}$$

where e_2 – the electromotive force occurring in the second coil; *R1* – the resistance, which specifies the current in the coil of the inductance; f – the frequency of the generator signal; U_0 – the amplitude value of the sinusoidal voltage of the generator. During the change of current Δt in the first circuit, the period of sinusoidal voltage e_1 was taken.

For a non-ferromagnetic plane conductor plate, the flow-coupling function $\Psi(\beta,\gamma)$ has the form

$$\Psi(\beta,\gamma) = -j\frac{2\beta^2 + th\frac{\gamma}{4}\sqrt{9+j4\beta^2}}{3\sqrt{9+j4\beta^2} + (9+j2\beta^2)th\frac{\gamma}{4}\sqrt{9+j4\beta^2}} \tag{6}$$

where $\beta = \frac{d_e}{2}\sqrt{2\pi f\mu\sigma}$; $\gamma = \frac{4h}{d_e}$; μ – the magnetic permeability of the plate; σ – specific electrical conductivity of the material of the plate; h – the thickness of the plate.

Substituting the equation (1), (3) and (6) in expression (1), we obtain the dependence for the complete resistance of the oscillatory circuit

$$Z_{вт} = Z_0 - j2\pi f M_0 e^{-\frac{6l}{d_e}} \frac{2\beta^2 + th(\frac{\gamma}{4}\sqrt{9+j4\beta^2})}{\sqrt[3]{9+j4\beta^2} + (9+j2\beta^2)th(\frac{\gamma}{4}\sqrt{9+j4\beta^2})} \tag{7}$$

To ensure the maximum sensitivity of the measuring transducer, it is necessary that the conductive object of a certain size, when approaching the inductance coil, contributes the maximum value of the full resistance to the contour. Since the circuit works in a resonant mode, the reactive component of the introduced resistance can be neglected [1, 27].

The expression for determining the time constant of free-fluctuation attenuation in the contour is written as follows [14]

$$\tau_k = \frac{2L}{Z_0 + Z_{вн}} = \frac{2L}{R_L + R_{вн}} \tag{8}$$

Performing the substitution in expression (8) of the above relations, we obtain an equation that describes the dependence of the time of attenuation of free oscillations excited in the LC-contour from the distance of the end of the core of the inductance coil to the conductive material of the control object's basis [2, 13].

$$\tau_k = \left[-2L\frac{K}{R_L}\left(9+54P+81P^2+4\beta^4P^2\right)\right] \times \\ \times \left(\begin{array}{l} -9K - 54KP - 81KP^2 - 4K\beta^4P^2 + 4Y\beta^2P^2\frac{K}{R_L} + 6Y\beta^2\sqrt{\frac{2K}{R_L} - 18} + \\ +4Y\beta^4P\sqrt{\frac{2K}{R_L} + 18} + 18\beta^2P\sqrt{\frac{2K}{R_L} - 18} \end{array}\right)^{-1} \tag{9}$$

where $K = R_L\sqrt{81+16\beta^4}$; $P = th\left(\frac{1}{4}\gamma\right)$; $Y = \pi f M_0 e^{-\frac{6l}{d_e}}$.

3. Experimental research

The analysis of equation (9) shows that the dependence of the decay time of free oscillations excited in the circuit from the distance l of the end of the inductor coil to the conductive basis of the control object has a nonlinear character. At the same time, the transformation function (9) has a plot with an approximate linear character, and if using elements of the oscillatory circuit with optimal parameters it is possible to create a measuring transformer with a transformation function that is close to linear in a definite range of variation of the distance from the end of the coil to electrical conductive basis of the object of control.

To conduct research, we will address the following characteristics of the object of measurement control [13, 15, 20]:

- thickness of dielectric coating ℓ, μm: 10 – 200;
- metal base material: steel grades 040A10, 1449-1HR, 1HR, 2HR, DC01, DD13;
- specific electrical conductivity of the base material σ, Sm/m: 6.8×10^6;

  The following parameters of inductance coils of the primary measuring transducer (L1, L2, L3) are used for the analysis:
- coil inductance is $122\cdot10^{-3}$ mH, $520\cdot10^{-3}$ mH, $1000\cdot10^{-3}$ mH;
- active resistance of coils 2.0 Ohm, 3.7 Ohm, 4.6 Ohm;
- the equivalent diameter of the coils is 7 mm, 8 mm, 9 mm.

For each coil, the value of the coefficient of interinduction M_0 was determined experimentally. To do this, an experimental installation was used, the principal scheme of which is shown in Fig. 2. The research was carried out in the frequency range of the generator of sinusoidal voltage from 5 kHz to 50 kHz. The averaged values of the experimental results for coils with different parameters in the form of the dependence of the coefficient of co-induction of the coil and its mirror image of the frequency of the supply voltage are given in Fig. 3. Significant change in the coefficient of interinduction is observed when the frequency of the supply voltage varies from 5 kHz to 50 kHz, so the theoretical study determined the average value of the M_0 coefficient from the specified frequency range of the supply voltage.

To determine the M_0 coefficient, the amplitude value of the voltage in the second circuit was determined from the results of the experiment (Fig. 2). The results are shown in Table 1.

Table 1. Amplitude values of the voltage in the second circuit when changing the frequency of the supply voltage from 5 kHz to 50 kHz

f, kHz	5	10	15	20	25
e_2(*L*1), mV	25.0	25.0	30	32.5	35.0
e_2 (*L*2), mV	22.5	22.7	25.9	27.5	30.0
e_2 (*L*3), mV	21.3	22.1	24.8	27.0	29.0
f, kHz	30	35	40	45	50
e_2(*L*1), mV	40.0	40.5	41.1	41.4	41.7
e_2 (*L*2), mV	35.0	35.2	35.8	36.1	36.3
e_2 (*L*3), mV	32.0	32.2	32.7	32.9	33.1

The graph of the change of the coefficient of interconnection M_0 from the frequency of the supply voltage is presented in Fig. 3.

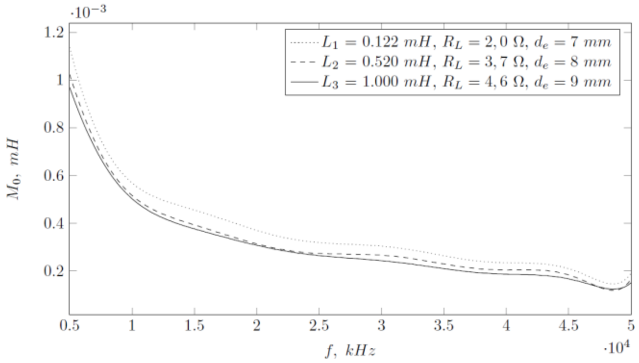

Fig. 3. Dependence of the co-induction coefficient of the coil and its mirror image on the frequency of the supply voltage

For theoretical studies, the mean value was chosen for the value of the co-induction coefficient. According to the results of the experiment, the following values of the coefficients of interinvitation were obtained [15, 22]:

- for L1, the coefficient of interinvection M_0 = 0.40 mH;
- for L2, the coefficient of interinvection M_0 = 0.36 mH;
- for L3, the coefficient of interinvection M_0 = 0.34 mH.

The choice of the optimum frequency of the measuring transducer was carried out provided that the primary sensitivity of the primary measuring transducer was maximized in the range of the change in the thickness of the dielectric coating from 0 μm to 200 μm. To ensure maximum sensitivity in the absence of external perturbing factors, it is necessary to ensure the maximum value of the introduced resistance when changing the thickness of the coating by 1%, and accordingly the maximum value of the increase in the time of attenuation of excited free oscillations. To determine the optimal frequency value, we obtain the following dependence [10, 21]

$$\delta(\mathrm{f}) = \tau_k(\mathrm{f},\mathrm{l}) - \tau_k(\mathrm{f},(\mathrm{l}\cdot 1.01)) \tag{10}$$

and a definite argument of the function at which it acquires the maximum value [11, 16].

Theoretically, the values of the optimal frequency were determined for different thicknesses of the basis of the control object h (0.18 mm, 0.22 mm, 0.36 mm) [8] at various values of the parameters of the inductance coils of the measuring transducer [3, 9, 12, 17–19]:

- inductance of coils L1 – $122\cdot10^{-3}$ mH, L2 – $520\cdot10^{-3}$ mH, L3 – $1000\cdot10^{-3}$ mH;
- active resistance of coils R1 – 2.0 Ohm, R2 – 3.7 Ohm, R3 – 4.6 Ohm;
- the equivalent diameter of the coils $d1_e$ – 7 mm, $d2_e$ – 8 mm, $d3_e$ – 9 mm.

For conducting theoretical investigations, the magnetic permeability of the base material (steel grade 040A10, 1449-1HR, 1HR, 2HR, DC01, DD13[20]) was taken into account as 600 objects by known practical studies [7, 23], which determine the physical and chemical properties of steel for annealing temperature in the range of 0–200°C set the initial and maximum permeability respectively μ_i = 400 and μ_m = 650. Specific electrical conductivity of the material of the basis of the object of control was determined on the basis of the known value of the specific resistance ρ of the 08КП alloy at a temperature of 20°C $\rho = 147\times10^{-9}$ Ω·m and assumed to be equal to 6.8×10^6 cm/m.

4. Conclusions

The given data of theoretical studies testify that the optimum frequency of the oscillatory circuit of the measuring transducer depends on the parameters of the inductance coil of the measuring transducer. So, for an inductor of a primary converter of $122\cdot10^{-3}$ mH, the frequency from the range 170 - 400 kHz can be considered optimal. As the inductance increases to $1000\cdot10^{-3}$ mH, the optimal frequency will increase, and the optimal value will be within the range of 340–750 kHz. At the same time, the absolute value of the gain of the decay time of oscillations also depends on the parameters of the inductance of the oscillatory circuit and increases with increasing its inductance. So, when using the inductance L1 = $122\cdot10^{-3}$ mH, with an equivalent diameter of the coil of 7 mm, the absolute value of the gain of the oscillation decay time is 260 μs. With an increase in inductance to L3 = $1000\cdot10^{-3}$ mH, this gain will be 720 μs.

Obviously, for the control of objects with different thickness of the metal base, it is advisable to use one type of inductance at different frequency values, since the change in the increase in the oscillation decay time for the range of change in the thickness of the base 0.18–0.36 mm for one inductance will be: for L1 $122\cdot10^{-3}$ mH – 4%; for L2 $520\cdot10^{-3}$ mH – 3%; for L2 $1000\cdot10^{-3}$ mH – 3%. At the same time, the difference in the attenuation time for different inductances at the same frequency (350 kHz) at best would be 55% for L1 and L2, in the worst case for L1 and L3 at the same frequency would be 68%.

References

[1] Azarov O. D., Dudnyk O. V., Kaduk O. V., Smolarz A., Burlibay A.: Method of correcting of the tracking ADC with weight redundancy conversion characteristic. Proc. of SPIE 9816, 2015, 98161V.

[2] Azarov O. D., Murashchenko O. G., Chernyak O. I., Smolarz A., Kashaganova G.: Method of glitch reduction in DAC with weight redundancy. Proc. of SPIE 9816, 2015, 98161T.

[3] Bereziuk O. V., Lemeshev M. S., Bogachuk V. V., Duk M.: Means for measuring relative humidity of municipal solid wastes based on the microcontroller Arduino UNO R3. Proc. of SPIE 10808, 2018, 108083G [http://doi.org/10.1117/12.2501557].

[4] Cathey J.: Electric Machines. McGraw-Hill, 2001.

[5] Fitzgerald A. E., Kingsley C. Jr., Umans S. D.: Electric Machinery. McGraw-Hill, 2005.

[6] Grover F. W.: Inductance Calculations. Dover Publications, 2009.

[7] Hechler O., Axmann G., Donnay B.: The right choice of steel. Sections.arcelormittal.com (11.01.2019).

[8] ISO 6892-1:2016 Metallic materials - Tensile testing - Part 1: Method of test at room temperature, 2016.

[9] Kozlov L. G., Bogachuk V. V., Bilichenko V. V. et al.: Determining of the optimal parameters for a mechatronic hydraulic drive. Proc. of SPIE 10808, 2018, 1080861 [http://doi.org/10.1117/12.2501528].

[10] Kvyetnyy R. N., Sofina O. Yu., Lozun A. V. et al.: Modification of fractal coding algorithm by a combination of modern technologies and parallel computations. Proc. of SPIE 9816, 2015, 98161R.

[11] Obertyukh R. R., Slabkyi A. V., Marushchak M. V. et al.: Dynamic and mathematical models of the hydraulic-pulse device for deformation strengthening of materials. Proc. of SPIE 10808, 2018, 108084Y [http://doi.org/10.1117/12.2501519].

[12] Ogorodnikov V. A., Zyska T., Sundetov S.S.: The physical model of motor vehicle destruction under shock loading for analysis of road traffic accident. Proc. of SPIE 10808, 2018, 108086C [http://doi.org/10.1117/12.2501621].

[13] Osadchuk V. S., Osadchuk A. V.: The magneticreactive effect in transistors for construction transducers of magnetic field. Electronics and Electrical Engineering 3(109), 2011, 119-122.

[14] Pain H. J.: The physics of vibrations and waves. John Wiley & Sons, 2005.

[15] Pavlov S. V., Kozhemiako V. P., Kolesnik P. F. et al.: Physical principles of biomedical optics: monograph. VNTU, Vinnytsya 2010.

[16] Polishchuk L. K., Kozlov L. G., Piontkevych O. V. et al.: Study of the dynamic stability of the conveyor belt adaptive drive. Proc. of SPIE 10808, 2018, 1080862 [http://doi.org/10.1117/12.2501535].

[17] Semenov A., Osadchuk O., Semenova O., Bisikalo O., Vasilevskyi O., Voznyak O.: Signal Statistic and Informational Parameters of Deterministic Chaos Transistor Oscillators for Infocommunication Systems. International Scientific-Practical Conference Problems of Infocommunications – Science and Technology (PIC S&T), 2018.

[18] Trishch R., Nechuiviter O., Dyadyura K., Vasilevskyi O., Tsykhanovska I., Yakovlev M.: Qualimetric method of assessing risks of low quality products. MM Science Journal 2021(4), 2021, 4769–4774.
[19] Vasilevskyi O. M., Kulakov P. I., Dudatiev I. A. et al.: Vibration diagnostic system for evaluation of state interconnected electrical motors mechanical parameters. Proc. of SPIE 10445, 2017, 104456C [http://doi.org/10.1117/12.2280993].
[20] Vasilevskyi O. M.: Calibration method to assess the accuracy of measurement devices using the theory of uncertainty. International Journal of Metrology and Quality Engineering 5, 2014, 403.
[21] Vasilevskyi O., Kulakov P., Kompanets D. et al.: A new approach to assessing the dynamic uncertainty of measuring devices. Proc. of SPIE 10808, 2018, 108082E [http://doi.org/10.1117/12.2501578].
[22] Vassilenko S. V., Teixeira J.P., Pavlov S.: Energy harvesting: an interesting topic for education programs in engineering specialities. Proc. of Internet, Education, Science IES-2016, 2016, 149-156.
[23] Vedmitskyi Y. G., Kukharchuk V. V., Hraniak V. F.: New non-system physical quantities for vibration monitoring of transient processes at hydropower facilities, integral vibratory accelerations. Przeglad Elektrotechniczny 93(3), 69-72, 2017.
[24] Webster J. G., Eren H.: Measurements, instrumentation and sensors handbook: Spatial, mechanical, thermal and radiation measurement. CRC press, 2014.
[25] Wojcik W., Kisala P.: The method for the recovery of the apodization function of the fiber Bragg gratings on the basis of its spectra. Przeglad Elektrotechniczny 86(10), 2010, 127-130.
[26] Wojcik W.: Application of fibre-optic flame monitoring systems to diagnostics of combustion process in power boilers. Bulletin of the Polish Academy of Sciences-Technical Sciences 56 (2), 2008, 177-195.
[27] Wójcik W., Vasilevskyi O., Didych V. et al.: Method of evaluating the level of confidence based on metrological risks for determining the coverage factor in the concept of uncertainty. Proc. of SPIE 10808, 2018, 108082C [http://doi.org/10.1117/12.2501576].

Ph.D. Kostyantyn Ovchynnykov
e-mail: ovkos1980@gmail.com

Ph.D., associate professor of Department of Automation and Intelligent Information Technologies, Vinnytsia National Technical University. Research Interests: measurement of geometrical sizes of dielectric coatings on conducting bases with the use of conversion
of measuring information in tin intervals, software of measuring equipment.

http://orcid.org/0000-0003-4685-1137

Prof. Oleksandr Vasilevskyi
e-mail: o.vasilevskyi@gmail.com

Doctor of Technical Sciences, professor, Professor of the Department of Metrology and Industrial Automatcs, as well as Professor of the Department of Computer Science of the Vinnitsa National Technical University. Academician of the Academy of Metrology of Ukraine, an official representative from Ukraine in the IMEKO. Author of more than 200 publications, including 3 monographs, 3 collective monographs, 16 textbooks, 5 patents for inventions of Ukraine, more than 100 scientific articles in peer-reviewed journals, 24 of them in the Scopus scientometric databases and Web of Science.

http://orcid.org/0000-0002-8618-0377

Ph.D. Volodymyr Sevastianov
e-mail: sevastiyanov.vladimir@vntu.edu.ua

Ph.D., associate professor of Department of Automation and Intelligent Information Technologies, Acting Dean of the Faculty of Intelligent Information Technology and Automation Vinnytsia National Technical University. Research Interests: information-measurement and control systems, software engineering, computer science & education, Industry 4.0, Internet of Things.

http://orcid.org/0000-0001-8385-7146

Ph.D. Yurii Polievoda
e-mail: vinyura36@gmail.com

Candidate of Technical Sciences, associate professor of the Department of technological processes and equipment for processing and food production, Vinnytsia National Agrarian University. Author of more than 86 publications, including 3 textbooks, 33 patents for inventions and more than 51 scientific articles in professional journals, of which 9 are in scientometric databases Scopus and Web of Science.

http://orcid.org/0000-0002-2485-0611

Ph.D. Aliya Kalizhanova
e-mail: kalizhanova_aliya@mail.ru

Candidate of physical and mathematical sciences, professor, University of Power Engineering and Telecommunications, the chief researcher of the Institute of Information and Computational Technologies of the Ministry of Education and Science CS of the Republic of Kazakhstan. Scientific interests of the leader: mathematical modeling of systems, models of transport systems network analysis, optimization methods, technologies for developing sensor systems for signals receive-transmit, mathematical modeling of Bragg fiber gratings.

http://orcid.org/0000-0002-5979-9756

M.Sc. Bakhyt Yeraliyeva
e-mail: yeraliyevabakhyt81@gmail.com

Senior lecturer of the Information Systems Department, Faculty of Information Technology, M. Kh. Dulaty Taraz Regional University, Taraz, Kazakhstan.
Research interests: Information technologies, fiber-optic technologies, microprocessor systems.

http://orcid.org/0000-0002-8680-7694