TREND FORECAST FOR SHORT-TERM OF SHOCK-VIBRATION PREDICTION

TIBOR KRENICKY[1], VOLODYMYR NAHORNYI[2]

[1]Technical University of Kosice, Faculty of Manufacturing Technologies with a Seat in Presov, Department of Technical Systems Design and Monitoring, Slovakia

[2]Sumy State University, Department of Computer Science, Faculty of Electronics and Information Technologies, Sumy, Ukraine

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e-mail: tibor.krenicky@tuke.sk

The short-term forecasting of vibration is considered, in which the trend of the gravitational constant is used as the initial data for forecasting. The trend is recorded throughout the entire period of maturation of the vibration at points on the earth's surface far from its epicenter.

KEYWORDS

Vibration, short-term forecasting, trend, gravitational constant, epicentre, magnitude.

1 INTRODUCTION

Forecasting earthquakes remains very relevant for humans, but the problem has not yet been resolved [Kanamori 2004]. The forecasting methods adopted in seismology, based on a comparison of the monitored parameters current values with their standard, do not lead to the desired result [Console 2003, Faenza 2003, Geller 1997, Gerstenberger 2005, Giovambattista 2000].

This problem is especially acute in short-term forecasting, the solution of which is to increase the information content of earthquake precursors that have proven themselves in practice [Nagornyi 2018].

So, based on long-term experience of forecasting, showed that as a prognostic sign it is necessary to consider not only the current value of the control parameter, but also take into account its change dynamics during the controlled object observation period [Nagornyi 2017-2020]. In other words, the observed phenomenon should not be regarded as a statically frozen picture, but should be presented as a process whose characteristics continuously change throughout the observation period [Panda 2014, 2018a,b, 2019; Mascenik 2014; Valicek 2016 and 2017, Macala 2009 and 2017, Pandova 2018, Monkova 2013, Dyadyura 2017]. Externally, this process manifests itself as trajectory (trend) of a change in time of a controlled parameter. This trend contains information necessary for decision-making, both about the current state criticality degree of seismic situation, but also about the moment of the earthquake. This forecasting method is called trend forecasting [Lonzich 2012].

The success of forecasting largely depends on the sensitivity of the precursor to changes in the seismic situation. The variation of the gravity force fully meets these requirements [Antonov 2000, Bulatova 2005, Volodichev 2001, Dobrovolskiy 2005, Levin 2001, Mikhaylov 2005, Parriskiy 1984, Starostenko 2005, Fedorov 2005, Khain 2007]. The study of gravity variations is the most important aspect of research in modern geodynamics and the most promising direction of short-term earthquake prediction.

This article discusses the results of short-term earthquake prediction obtained on the basis of these data using the methodology described in [Nagornyi 2018]. The statistics of gravity variation (gravitational constant) contains information about 7 strong earthquakes, the epicentres of which were at a distance of 4-7 thousand kilometres from the recording station [Khain 2007].

2 RESEARCH METHODOLOGY

Meanwhile, at “Binagadi” prognosis station of the ground of Scientific Research Institute on prognosis and studying of the earthquakes (Baku city) during several (2004—2006) years are permanently registered the changes of gravity before strong earthquakes, the centers of which are in the distance of tens thousands kilometers from the station of registration.

The measurements are carried out by simultaneously four high-accuracy quartz gravimeter of KV and KS type [Khain 2007].

The gravimeters are chosen so that their readings can be equal to the maximum, i.e. the graduating marks and zero-point shift in absolute values can be characterized among themselves with little difference. The statistic data show, that the gravitational signals were registered in 90% of cases, on average 8-15 days before strong earthquakes.

These data constituted a statistical series of numbers "time - gravitational signal" and were the source material for predicting earthquakes. Graphically, this series is depicted in the form of a time graph - a trend, the mathematical analysis of which allows predicting the earthquake time T_{for}.

The earthquake time (T_{for}), was determined in the process of minimizing the functional U (1)

$$U = \sum_{i=1}^{n} \left(H - H_{\mathrm{mod}}\right)^{2}, \qquad (1)$$

where H_{mod} - the value of the controlled parameter, calculated by the predictive model; n - the number of time series values.

The analytical expression for the predictive model is as follows:

$$H_{\mathrm{mod}} = H(t_0)\cdot\left[1 + A\cdot\left(\frac{t - t_0}{T_{for} - t}\right)^{\alpha} - B\cdot\left(\frac{t - t_0}{T_{for} - t}\right)^{\beta}\right], \qquad (2)$$

где T_{for} – earthquake time forecast; t_0, t - registration time of the controlled parameter, respectively, at the time of the initial and current measurements; $H(t_0)$ - the value of the controlled parameter, recorded during the first measurement; A, B, α, β - experimental parameters, determined together with time T_{for} in the process of approximation of the graph of the parameter H by the predictive model (2).

In [Nagornyi 2018], along with predicting the time of the onset of an earthquake, its magnitude M_{for} is also predicted. For this purpose, in [Nagornyi 2018] , based on the well-known Richter formula [Richter 1958] , the following expression was obtained.

$$M_{for} = M_{ref} + \log\frac{A_{for}}{A_{ref}}, \qquad (3)$$

where M_{for}, M_{ref} is the magnitude, respectively, of the predicted and reference earthquakes; A_{for}, A_{ref} is the magnitude of the precursor, respectively, of the predicted and reference earthquakes.

3 RESEARCH RESULTS

3.1 Forecasting earthquake timing

3.1.1 The earthquake in Indonesia on 26.12.2004 (M 9)

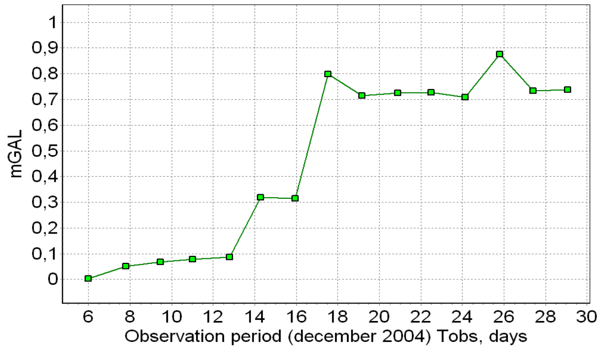

Figure 1. Variations of gravity before earthquake in Indonesia (26.12.2004)

Execution, Date	19.12.2004	21.12.2004	22.12.2004	24.12.2004
Forecast, Date	27.13.2004	29.12.2004	26.12.2004	26.12.2004
Deviation, dt, days	1.0	3.0	0.0	0.0

Table 1. Earthquake time forecast (actual date of the earthquake 26.12.2004)

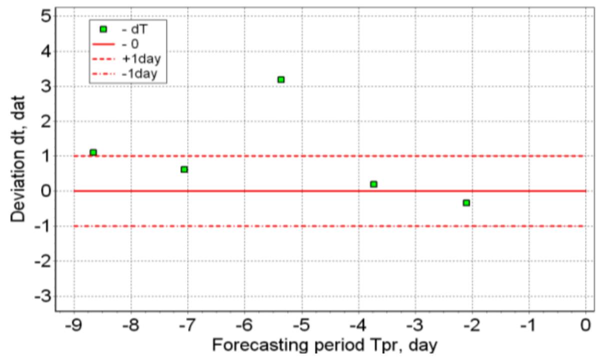

Figure 2. Forecast scatter field

3.1.2 The earthquake in Pakistan on 8.10.2005 (M 7.7)

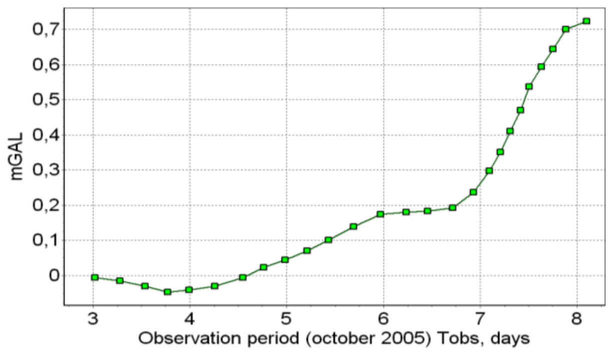

Figure 3. Variations of gravity before earthquake in Pakistan (8.10.2005)

Execution, Date	5.10.2005	6.10.2005	7.10.2005	8.10.2005
Forecast, Date	8.10.2005	9.10.2005	9.10.2005	9.10.2005
Deviation, dt, days	0.0	1.0	1.0	1.0

Table 2. Earthquake time forecast (actual date of the earthquake 8.10.2005)

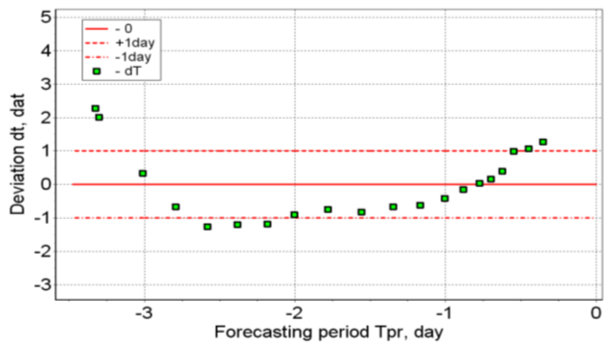

Figure 4. Forecast scatter field

3.1.3 Earthquake in Philippines on 05.02.2005 (M 7.1)

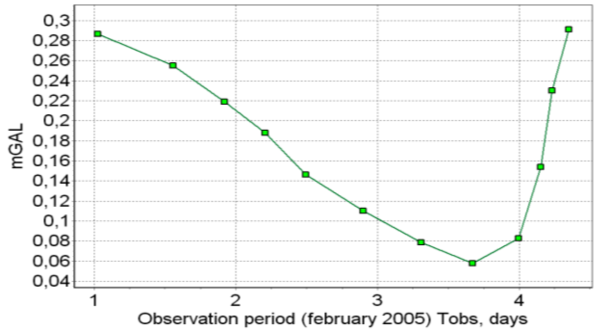

Figure 5. Variations of gravity before earthquake in Philippines (05.02.2005)

Execution, Date	1.02.2005	2.02.2005	3.02.2005	4.02.2005
Forecast, Date	5.02.2005	5.02.2005	5.02.2005	5.02.2005
Deviation, dt, days	0.0	0.0	0.0	0.0

Table 3. Earthquake time forecast (actual date of the earthquake 05.02.2005)

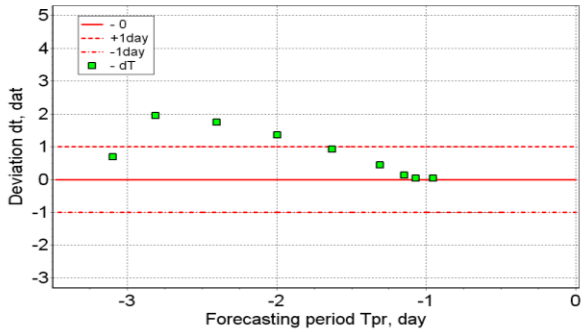

Figure 6. Forecast scatter field

3.1.4 The earthquake in South Iran on 13.03.2005 (M 6)

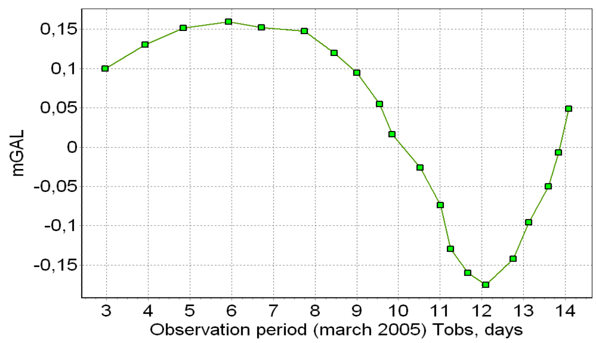

Figure 7. Variations of gravity before earthquake in South Iran on (13.03.2005)

Execution, Date	10.03.2005	11.03.2005	12.03.2005	13.03.2005
Forecast, Date	13.03.2005	12.03.2005	13.03.2005	13.03.2005
Deviation, dt, days	0.0	-1.0	0.0	0.0

Table 4. Earthquake time forecast (actual date of the earthquake 8.10.2005)

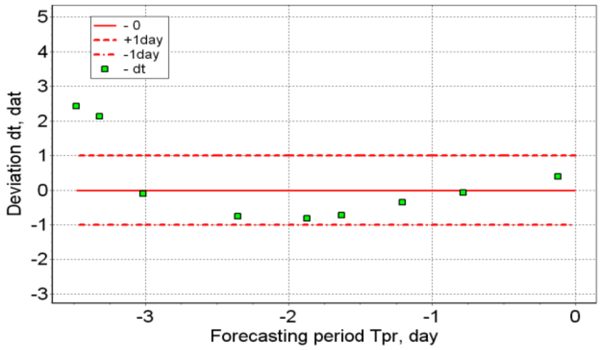

Figure 8. Forecast scatter field

3.1.5 Earthquake in Indonesia on 27.05.2006 (M6.3)

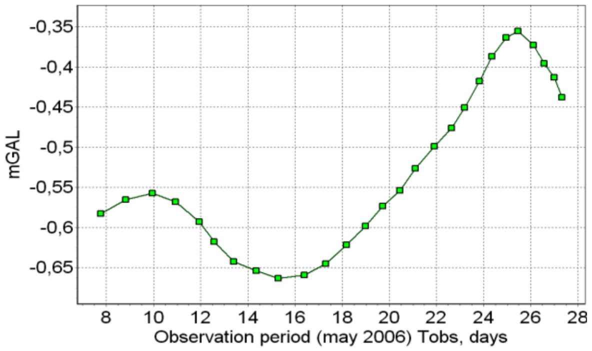

Figure 9. Variations of gravity before earthquake in Indonesia on 27.05.2006

Execution, Date	23.05.2006	24.05.2006	25.05.2006	26.05.2006
Forecast, Date	28.05.2006	27.05.2006	27.05.2006	27.05.2006
Deviation, dt, days	1.0	0.0	0.0	1.0

Table 5. Earthquake time forecast (actual date of the earthquake 27.05.2006)

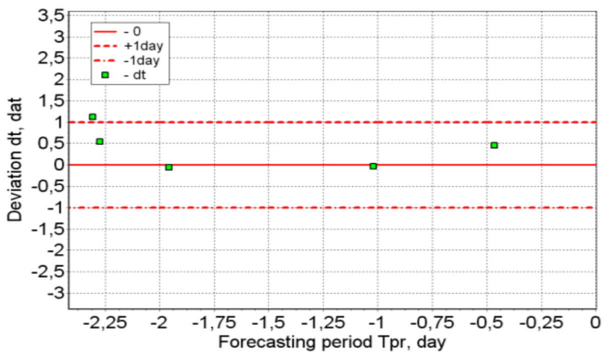

Figure 10. Forecast scatter field

3.1.6 Earthquake in the Kuriles on 15.11.2006 (M 8.3)

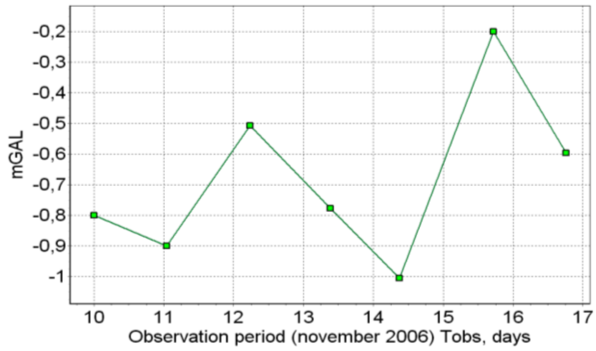

Figure 11. Variations of gravity before earthquake in Indonesia on 15.11.2006

Execution, Date	12.11.2006	13.11.2006	14.11.2006	15.11.2006
Forecast, Date	14.11.2006	15.11.2006	15.11.2006	16.11.2006
Deviation, dt, days	-1.0	0.0	0.0	1.0

Table 6 Earthquake time forecast (actual date of the earthquake 15.11.2006)

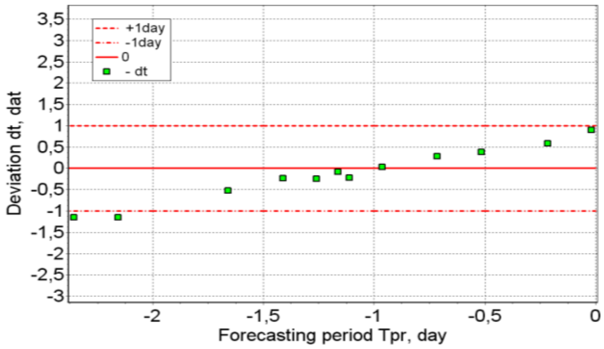

Figure 12. Forecast scatter field

3.1.7 Earthquake in Taiwan on 26.12.2006 (M 7.4)

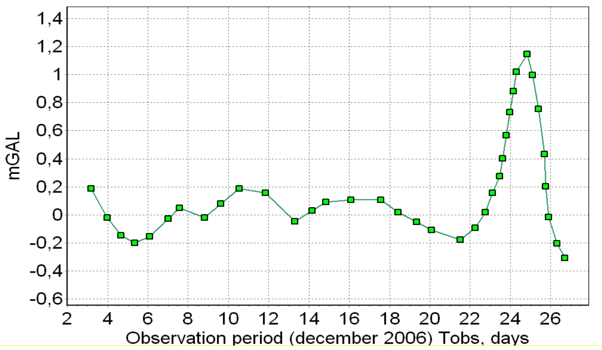

Figure 13. Variations of gravity before earthquake in Indonesia on *26.12.2006*

Execution, Date	23.12.2006	24.12.2006	25.12.2006	26.12.2006
Forecast, Date	26.12.2006	26.12.2006	26.12.2006	27.12.2006
Deviation, dt, days	0.0	0.0	0.0	1.0

Table 7. Earthquake time forecast (actual date of the earthquake 26.12.2006)

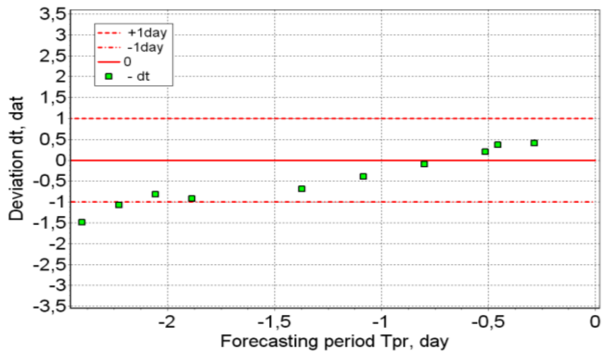

Figure 14. Forecast scatter field

3.2 Predicting magnitude

In [Khain 2007] the correlation between the magnitude of an earthquake and its precursor, the value of the gravitational constant, is shown and explained (Fig. 15).

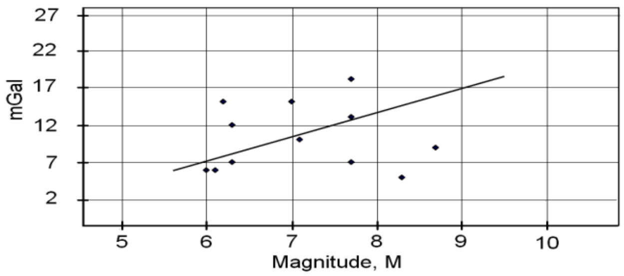

Figure 15. The graph of the magnitude from the period of quasi-wave variation Δg.

Fig. 16 shows the summary information on the change in the trends of the gravitational constant registered in Indonesia in 2004 - 2006 on the eve of the next strong earthquake.

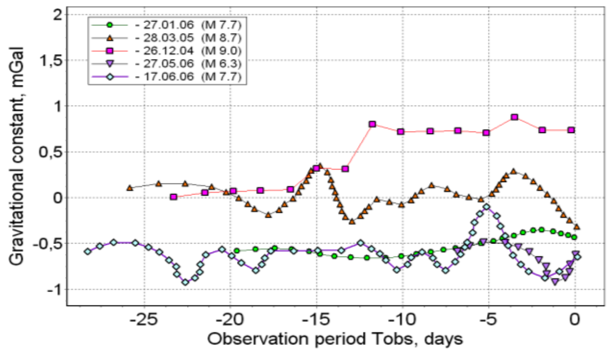

Figure 16. Changes in the trends of the gravitational constant on the eve of the earthquakes in Indonesia in 2004 - 06 years

Fig. 17 presents the forecast of the strength of the earthquake (M 8.7), which occurred in Indonesia on March 28, 2005. In this case, an earthquake with a force of 9 magnitudes recorded in Indonesia on December 26, 2004 was considered as a reference one (formula 3).

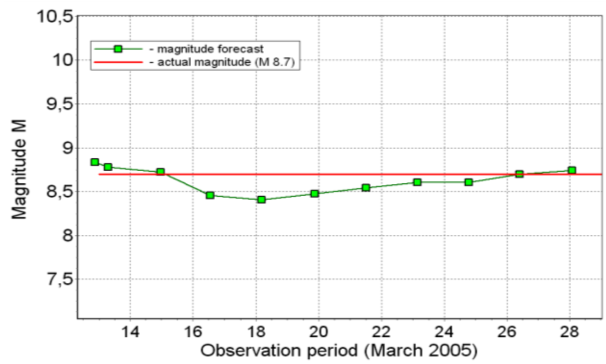

Figure 17. Comparison of actual and forecasted magnitudes (Indonesia, March 28, 2005)

4. THE RESULTS DISCUSSION

The prediction results show that the prediction scatter field, as a rule, is within ± 1 day. Moreover, as we approach the date of the earthquake (Tab. 1-7), the scattering tends to zero.
Comparison of the actual and predicted magnitudes (Fig. 17) indicates their insignificant (0.2 magnitude) differences.

5. CONCLUSIONS

The statistics, significant in volume, clearly show that the combination of trend forecasting with the use of gravitational constant variations as input data is an effective means of short-term earthquake forecasting.
In this case, not only the time of the earthquake is reliably predicted, but also its strength.
To solve the forecasting problem in full, it is required to indicate the epicentre of the earthquake. The considered forecasting technique also solves a similar problem.
In this case, the initial data on the variation of the gravitational constant should be synchronously recorded in at least 2-3 observation stations spatially spaced across the globe.

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REFERENCES

[Antonov 2000] Antonov Y.V., Slusarev S.V. et al. Possible reasons of temporary changes of vertical gradient of gravity. Geophysics, 2000, No. 4, pp. 45-51. (in Russian)
[Bulatova 2005] Bulatova N.P. Latitudinal distribution of seismicity of the Earth depending on location of the Sun and Moon. Volcanology and seismology, 2005, No. 2, pp. 57-58. (in Russian)
[Console 2003] Console, R. et al. Re-fining earthquake clustering models. Geophys. Res., 2003, Vol. 108, No. B10., pp. 2468–2477. ISSN 2169-9356.
[Dobrovolskiy 2005] Dobrovolskiy I.L. Gravitational precursors of tectonic earthquake. Physics of the Earth, 2005, No. 4, pp. 23-28. ISSN 0022-3743. (in Russian)
[Faenza 2003] Faenza, L. et al. A non-parametric hazard model to characterize the spatio-temporal occurrence of large earthquakes: An application to the Italian catalogue. Geophys. J. Int., 2003, Vol.155, No. 2., pp. 521–531. ISSN 0956-540X
[Fedorov 2005] Fedorov V.M. Chronological structure and possibility of volcanic activity in connection with tidal deformation of lithosphere. Volcanology and seismology, 2005, No. 1, pp. 44–50. (in Russian)
[Geller 1997] Geller, R.J. et al. Earthquakes cannot be predicted. Science, 1997, Vol. 275, No. 5306., pp. 1616–1617. ISSN 0036-8075.
[Gerstenberger 2005] Gerstenberger, M.C. et al. Real-time forecasts of tomorrow's earthquakes in California. Nature, 2005, No. 435, pp. 328-331. ISSN 1476-4687.
[Giovambattista 2000] Giovambattista, R. and Tyupkin Y. Spatial and temporal distribution of seismicity before the Umbria-Marche September 26, 1997 earthquakes. J. Seismol., 2000, No. 4, pp. 589-598. ISSN 1383-4649.
[Kanamori 2004] Kanamori, H. and Brodsky, E.E. The physics of earthquakes. Rep. Prog. Phys., 2004, Vol. 67, No. 8., pp. 1429–1496. ISSN 0034-4885.
[Khain 2007] Khain V.E. and Khalilov E.N. Gravitational effects before strong distant earthquakes. Bulletin of the International

Academy of Sciences (Russian section), 2007, No. 2, pp. 45–52. (in Russian)
[Levin 2001] Levin B.V. Is the Earth core the conductor of seismic activity? The Earth and the Universe, 2001, No. 3, pp. 12-19. (in Russian)
[Lonzich 2012] Lonzich P.A. , Eliseev S.V. Trend prognosis and control of system of quality. Systems. Methods. Technologies, 2012, No. 4(16), National Research Irkutsk State Technical University, Irkutsk, Russia, pp. 29-35. (in Russian)
[Mikhaylov 2005] Mikhaylov V.O. et al. Researching of the possibility of finding out and studying of variations of gravity of geodynamic origin on modern satellite gravimetric data. Physics of the Earth, 2005, No. 3, pp. 18-32. ISSN 0022-3743. (in Russian)
[Nagornyi 2018] Nagornyi, V. Earthquake forecasting by the results of the seismic signal trend analysis. Geofizicheskiy Zhurnal, 2018, Vol. 40, No. 6, pp. 159–176. ISSN 0203-3100. (in Russian)
[Nagornyi 2018] Nagornyi, V. Method of forecasting the time of the next earthquake. Registration number of the application: u 2018 00119, Date of submission: 30.01.2018. (in Ukrainian)
[Nagornyi 2018] Nagornyi, V. Method for predicting the strength of the expected earthquake. Application registration number: u 2018 01307, Date of submission: 12.02.2018. (in Ukrainian)
[Nagornyi 2017] Nagornyi, V. Method of long-term forecasting of the coordinates of the epicenter of the next earthquake. Registration number of the application: u 2017 11548, Date of submission: 27.11.2017. (in Ukrainian)
[Nagornyi 2020] Nahornyi V., et al. To the question of verification of forecasting methods of earthquakes. In: XIV International Scientific Conference "Monitoring of Geological Processes and Ecological Condition of the Environment", 10–13 November 2020, Kyiv, Ukraine. (in Russian)
[Nagornyi 2020] Nagornyi V., Pigulevsky P. et al. On the development of a method for short-term forecasting of earthquakes based on fluctuations in the water level in wells / Structure, material composition, properties, modern geodynamics and seismicity of platform territories and adjacent regions. In: Materials of the XXII All-Russian scientific and practical conference Shchukin Voronezh with international participation, September 22-25, 2020. Voronezh, Voronezh State University Publishing House, pp. 247-252. (in Russian)
[Parriskiy 1984] Parriskiy N.N. About irregular changes of the speed of rotation of the Earth and their possible connection with the deformations of the Earth and changes of gravity. In: The problems of widening and pulsation of the Earth. Science, 1984, pp. 84–93.
[Richter 1958] Richter Ch. F. Elementary seismology. San Francisco, and Bailey Bros. & Swinfen Ltd., London, 1958, 768 p.
[Starostenko 2005] Starostenko V.I. et al. The disastrous earthquake of 26 December 2004 near the shores of Sumatra: reasons, consequences, lessons. Geophysical journal, 2005, Vol. 27, No. 6, pp. 940–961. (in Russian)
[Volodichev 2001] Volodichev N.N. et al. Correlation of appearance of big series of earthquakes with the time of phases of new moon and full moon. Volcanology and seismology, 2001, No. 1, pp. 60-67. (in Russian)
[Macala 2009] Macala, J., Pandova, I., Panda, A. Clinoptilolite as a mineral usable for cleaning of exhaust gases. Mineral resources management, 2009, Vol. 25, No. 4, pp. 23-32. ISSN 0860-0953.
[Macala 2017] Macala, J., Pandova, I., Panda, A. Zeolite as a prospective material for the purification of automobile exhaust gases. Mineral resources management, 2017, Vol. 33, No. 1, pp. 125-138. ISSN 0860-0953.
[Mascenik 2014] Mascenik, J., Pavlenko, S. Determining the Exact Value of the Shape Deviations of the Experimental Measurements. Applied Mechanics and Materials, 2014, Vol. 624, pp. 339-343.
[Panda 2014] Panda, A., Duplak, J. Comparison of theory and practice in analytical expression of cutting tools durability for potential use at manufacturing of bearings. Applied Mechanics and Materials, 2014, Vol. 616, pp. 300-307. ISSN 1662-7482.
[Panda 2018a] Panda, A., Dobransky, J., Jancik, M., Pandova, I., Kacalova, M. Advantages and effectiveness of the powder metallurgy in manufacturing technologies. Metalurgija, 2018. Vol. 57, No. 4, pp. 353-356. ISSN 0543-5846.
[Panda 2018b] Panda, A., Olejarova, S., Valicek, J., Harnicarova, M. Monitoring of the condition of turning machine bearing housing through vibrations. International Journal of Advanced Manufacturing Technology, 2018, Vol. 97, No. 1-4, pp. 401-411. ISSN 0268-3768.
[Panda 2019] Panda, A., et al. Development of the method for predicting the resource of mechanical systems. International Journal of Advanced Manufacturing Technology, 2019, Vol. 105, No. 1-4, pp. 1563-1571. ISSN 0268-3768.
[Pandova 2018] Pandova, I., et al. Use of sorption of copper cations by clinoptilolite for wastewater treatment. International Journal of Environmental Research and Public Health, 2018, Vol. 15, No. 7, pp. 1-12. ISSN 1661-7827.
[Valicek 2016] Valicek, J., et al. A new approach for the determination of technological parameters for hydroabrasive cutting of materials. Materialwissenschaft und Werkstofftechnik, 2016, Vol. 47, No. 5-6, pp. 462-471. ISSN 0933-5137.
[Valicek 2017] Valicek, J., et al. Identification of Upper and Lower Level Yield strength in Materials. Materials, 2017, Vol. 10, No. 9, pp. 1-20. ISSN 1996-1944.

CONTACTS:

Assoc. Prof. RNDr. Tibor Krenicky, PhD.
Technical University of Kosice
Faculty of Manufacturing Technologies with a seat in Presov
Sturova 31, 080 001 Presov, Slovakia
e-mail: tibor.krenicky@tuke.sk