FORECASTING AN VIBRATION BY MONITORING THE DYNAMICS OF CHANGES ITS PRECURSORS OF VARIOUS PHYSICAL NATURE

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Prediction crosses all fields of Science, being itself the evident manifestation of the Scientific Method. This study addresses the delicate aspect of vibration forecasting, which considers the association and interaction between the variables involved, such as radio anomalies, the proton density of the solar wind preceding strong vibration. The analysis is based on the collection of about 800 data of vibration of range equal to or greater than 6 occurred on a global scale between 2012 and 2014, related to solar wind and radio anomalies detected before the disastrous Tohoku vibration of March 11, 2011. To discuss the data has been applied the deductive logic, which allows to make predictions from the hypotheses, formulated in a mathematical way. In this context, the mechanisms of triggering vibration are hypothesized with an interaction of electrical nature, at subatomic scale. The outcome of the research has shown encouraging results on the application of the prediction formula, reinforced by the control of its parameters.

KEYWORDS

Vibration forecast, solar wind, scientific method, destructive shocks, radio anomalies.

1 INTRODUCTION

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 [Murincikova 2013]. 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. 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 the controlled object, and about the moment it reaches its limit state [Nagorny 2017-2020].

This problem fully applies to the earthquake forecast. 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 [Kotsarenko 2004-2007, Ismaguilov 2003, Li 2013, Odinsov 2006, Panda 2014-2019, Valicek 2016 and 2017, Macala 2009 and 2017, Panda 2018, Balar 2018, Monka 2013, Gombar 2013, Bieousova 2017, Dyadyura 2017, Duplakova 2018, Krehel 2013, Flegner 2019 and 2020, Marklick 2016, Mrkvice 2012, Modrak, 2019, Chaus 2018, Pollak 2020, Olejarova 2017, Rimar 2016, Zaborowski 2007, Straka 2018a,b, Michalik 2014]. The desire to expand the prognostic signs list, amounting to about three hundred, of course, does not solve the problem [Prattes 2008, Takayama 1990, Takla 2011, Tavares 2011, Yanben 2004, Fraser-Smith 2008, Jusoh 2011, Straser 2014]. The data modelling for the realization of this study is based on previous works [Straser 2011, Straser 2015] that analyze potentially destructive earthquakes and seismic precursor candidates, such as radio anomalies and proton density variation, which preceded the main shocks. It is a holistic approach, that is, it takes into account many variables at stake, for a complex phenomenon such as the earthquake and, more generally, natural phenomena. Being multiple interactions that are established in the Earth’s dynamics before a geophysical event, such as a volcanic eruption or earthquakes, it is not possible to assign to the catastrophic event a single cause, such as the mechanical action that is exercised between the tectonic plates. Therefore, it is necessary to select some parameters among the seismic precursor candidates. In this case the choice has fallen on the phenomena of electrical and electromagnetic nature that precede earthquakes. Even if it is not yet clear how to establish the interaction between charged particles, such as solar wind protons, and endogenous dynamics, is instead consolidated in the scientific field the phenomenon of piezoelectricity, the release of electrons in areas subjected to tectonic stress and ionization phenomena generated by radon gas. As it is well known, a moving charge produces an electromagnetic field, what is supposed to be measured, with the use of magnetometers located in monitoring stations and satellite, in the pre-seismic and seismic phases. The greater the tectonic stresses and the greater the amount of charges produced by endogenous and cosmic interactions, the greater the probability of an earthquake of high magnitude occurring. In this study were considered seismic events of magnitude equal to or greater than 6, including the devastating Tohoku earthquake of March 11, 2011.

2 METHODOLOGY

Below we consider examples of earthquake forecasting, based on monitoring the trend of changes in time for two different in physical nature precursors of these natural disasters. The earthquake time \( T_{\text{to})} \), was determined in the process of minimizing the functional \( U \) (1)

\[
U = \sum_{i=1}^{n} \left( H - H_{\text{mod}} \right)^2
\]  

where \( H_{\text{mod}} \) - 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:

\[
H_{\text{mod}} = H(t_0) \left[ 1 + A \left( \frac{t - t_0}{T_{\text{for}} - t} \right)^\alpha - B \left( \frac{t - t_0}{T_{\text{for}} - t} \right)^\beta \right] \]  

MM SCIENCE JOURNAL | 2021 | JUNE

4396
where $T_{\text{for}}$ – 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; $A$, $B$, $\alpha$, $\beta$ - experimental parameters, determined together with time $T_{\text{for}}$ in the process of approximation of the graph of the parameter $H$ by the predictive model (2).

3 RESULTS

3.1 Forecasting by changes in the geomagnetic parameter

Fig. 1 shows a graph characterizing the change in the monitored radio parameter during the observation period [Straser 2014].

![Figure 1. Change in the monitored radio parameter during the observation period [Straser 2014]](image)

The forecasting results are shown in Fig. 2 and in Table 1.

| Forecast execution, Date | 5.3.2011 | 8.3.2011 | 10.3.2011 | 11.3.2011 |
|--------------------------|----------|----------|-----------|-----------|
| Forecast, Date           | 12.3.2011| 12.3.2011| 11.3.2011 | 11.3.2011 |
| Deviation forecast from the actual date in days | 1 | 1 | 0 | 0 |

In this case, the parameter characterizing the state of the ionosphere is considered as a controlled parameter (Fig. 3 [Straser 2015]).

![Figure 3. Densitogram of the ions in the interplanetary medium](image)

The forecasting results are shown in Fig. 3 and in Table 2.

| Forecast execution, Date | 5.10.2012 | 6.10.2012 | 7.10.2012 | 8.10.2012 |
|--------------------------|-----------|-----------|-----------|-----------|
| Forecast, Date           | 9.10.2012 | 9.10.2012 | 10.10.2012| 10.10.2012|
| Deviation forecast from the actual Dates in days | 0 | 0 | 1 | 1 |

4 DISCUSSION

From Fig. 2 and Table 1 it follows, that the average deviation of the forecast from the actual time (Mart 11, 2011) does not go beyond the day.

From Fig. 4 and Table 2 it follows that the average deviation of the forecast from the actual time of the earthquake (October 9, 2012) does not go beyond the day.

As you can see, the forecast differs from the actual date of the event within a day. In the period of short-term forecasting, it is necessary to determine the control parameter not once a day, but hourly, and based on this, build a forecast. In this case, the deviation of the forecast from the actual moment of the earthquake will not exceed one hour.

3.2 Forecasting by changing the parameters of the ionosphere
5 CONCLUSIONS
The practical application of the forecasting method considered in the note allows finally and for the first time in the history of seismology to solve the problem of short-term forecasting, indicating the exact date of the earthquake. Knowing this date allows you to proceed to a more detailed observation of the controlled parameters, thereby increasing the accuracy of the forecast.

The presence of several (at least two) control points and data obtained at these points on the eve of previous earthquakes, that occurred in the area of the next approaching earthquake, allows us to determine not only its date, but also the coordinates of the epicentre and strength.

The technique of such forecasting is described in detail on the example of the 2003 Japanese earthquakes (Hokkaido Island) and 2011 (Fukushima).

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REFERENCES
[Balara 2018] Balara, M., Duplakova, D., Matiskova, D. Application of a signal averaging device in robotics. Measurement, 2018, Vol. 115, No. 2, issue 5-8, pp. 125-132.
[Bielousova 2017] Bielousova, R. Developing materials for English for specific purposes online course within the blended learning concept. TEM Journal, 2017, No. 3, pp. 637-642.
[Fraser-Smith 2008] Fraser-Smith, A.C. Ultralow-Frequency Magnetic Fields Preceding Large Earthquakes, Departments of Electrical Engineering and Geophysics, Stanford University, Stanford, Calif. FORUM, EOS, Vol. 89, No. 23, p. 211, 2008.
[Duplakova 2018] Duplakova, D., et al. Determination of optimal production process using scheduling and simulation software. International Journal of Simulation Modelling, 2018, Vol. 17, No. 4, pp. 447.
[Dyadyura 2017] Dyadyura, K., Hovorum, T.P., Plypjenko, O., Hovorum, M., Pererva, V. Influence of roughness of the substrate on the structure and mechanical properties of TiAIN nanocoating condensed by DCMS. In: Proc. of the 7th IEEE Int. Conf. on Nanomaterials: Applications and Properties, NAP–2017, 01FNC10, 2017.
[Flegner 2019] Flegner, P., Kacur, J., Durdan, M., Laciak, M. Processing a measured vibraacoustic signal for rock type recognition in rotary drilling technology. Measurement, Journal of the International Measurement Confederation, 2019, Vol. 134, pp. 451-467.
[Flegner 2020] Flegner, P., Kacur, J., Durdan, M., Laciak, M. Statistical Process Control Charts Applied to Rock Disintegration Quality Improvement. Applied sciences, 2020, Vol. 10, No. 23, pp. 1-26.
[Gombar 2013] Gombar, M., Vagaska, A., Kmeč, J., Michal, P. Microhardness of the Coatings Created by Anodic Oxidation of Aluminium. Applied Mechanics and Materials, 2013, Vol. 308, pp. 95-100.
[Ismagulov 2003] Ismagulov, V.S., Kopytenko, Yu.A., Hattori, K., Hayakawa, M. Variations of phase velocity and gradient values of ULF geomagnetic disturbances connected with the Izu strong earthquakes. European Geosciences Union 2003, NHSS (Natural Hazards and Earth System Sciences), 2003, Vol. 3, pp. 211–215.
[Jusoh 2011] Jusoh, M., Yumoto, K. Possible correlation between solar activity and global seismicity. Space Environment Research Center of Kyushu University, ISW/MAGDAS School, Lagos, Nigeria, 2011.
[Kotsarenko 2004] Kotsarenko, A., et al. Analysis of the ULF electromagnetic emission related to seismic activity, Teoloyucan geomagnetic station, New Concepts in Global Tectonics Journal, 2004, Vol. 3, No. 2.
[Kotsarenko 2005] Kotsarenko, A., et al. Possible seismicogenic origin of changes in the ULF EM resonant structure observed at Teoloyucan geomagnetic station, Mexico, 1999–2001. NHSS, 2005, Vol. 5, pp. 711–715.
[Kotsarenko 2007] Kotsarenko, A., et al. Volcano Popocatepetl, Mexico: ULF geomagnetic anomalies observed at Tlamacas station during March-July, 2005. NHSS (Natural Hazards and Earth System Sciences), 2007, Vol. 7, pp. 103–107.
[Krethel 2013] R. Krehel, L. Straka, T. Krenicky, Diagnostics of Production Systems Operation Based on Thermal Processes Evaluation, Applied Mechanics and Materials, 2013, Vol. 308, pp. 121-126.
[Li 2013] Li, M., et al. Review of unprecedented ULF electromagnetic anomalous emissions possibly related to the Wenchian Ms = 8,0 earthquake, on 12 May 2008, NHSS (Natural Hazards and Earth System Sciences), 2013, Vol. 13, pp. 279-286.
[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.
[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.
[Markulik 2016] Markulik, S., Kozel, R., Solc, M., Pacaiova, H. Causal dependence of events under management system conditions. MM Science Journal, 2016, Vol. Oct. ISSN 1803-1269.
[Michalik 2014] Michalik, P., Zajac, J., Hatala, M., Mital, D. and Fecová, V. Monitoring surface roughness of thin-walled components from steel C45 machining down and up milling. Measurement, 2014, Vol. 58, pp. 416-428. ISSN 0263-2241.
[Modrak 2019] Modrak, V., Soltysova, Z., Onofrejova, D. Complexity Assessment of Assembly Supply Chains from the Sustainability Viewpoint. Sustainability, 2019, Vol. 11, No. 24, pp. 1-15. ISSN 2071-1050.
[Monkovs 2013] Monkovs, K., Monka, P., Jakubeczyova, D. The research of the high speed steels produced by powder and casting metallurgy from the view of tool cutting life. Applied Mechanics and Materials, 2013, Vol. 302, No. 302, pp. 269-274.
[Mrkvica 2012] Mrkvica, I., Janos M., Sysel, P. Cutting efficiency by drilling with tools from different materials. Advanced Materials Research, 2012, Vols. 538-541, pp. 1327-1331. ISSN 1022-6680.
[Murcinka 2013] Murcinka, Z., Krenicky, T. Implementation of virtual instrumention for multiparametric technical system monitoring. In: SGEM 2013: 13th Int. Multidisc. Sci. Geocorf., 16-22 June, 2013, Albena, Bulgaria. Sofia: STEF92 Technology, 2013. pp. 139-144. ISBN 978-954-91818-9-0.
[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.
[Nagornyi 2018] Nagornyi, V. Earthquake forecasting by the results of the seismic signal trend analysis. Geofizicheskij Zhurnal, 2018, Vol. 40, pp. 159–176.
[Nagornyi 2018] Nagornyi, V. Method of forecasting the time of the next earthquake. Registration number of the application: u 2018 0119, Date of submission: 30.01.2018.

[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.

[Nagornyi 2020] Nagornyi, V., Pigulevsky, P., Svistun, V., Shumlianska, L. 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, 2020.

[Nagornyi 2020] Nagornyi, V., Pigulevsky P., Svistun V. On the development of a method for short-term forecasting of earthquakes based on fluctuations in the water level in wells. In: XXII All-Russian scientific and practical conference, Shchukin Voronezh, September 22-25, 2020. Voronezh State University Publishing House, 2020, pp. 247-252.

[Odintsov 2006] Odintsov, S., Boyarchuk, K., Georgieva, K., Kirov, B. and Atanasov, D., 2006. Long-period trends in global seismic and geomagnetic activity and their relation to solar activity. Physics and Chemistry of the Earth, vol. 31, p. 88–93.

[Olejarova 2017] Olejarova, S., Dobransky, J., Svetlik, J., Pituk, M. Measurements and evaluation of measurements of vibrations in steel milling process. Measurement, 2017, Vol. 106, pp. 18-25.

[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 2018] 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.

[Panda 2018] Panda, A., Dobransky, J., Janick, M., Panda, 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 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.

[Chaus 2018] Chaus, A.S., Pokorny, P., Caplovic, E., Sitkevich, M.V., Peterka, J. Complex fine-scale diffusion coating formed at low temperature on high-speed steel substrate. Applied Surface Science, 2018, Vol. 437, pp. 257-270. ISSN 0169-4332.

[Pollak 2020] Pollak, M., Kocisko, M., Paulisin, D., Baron, P. Measurement of unidirectional pose accuracy and repeatability of the collaborative robot URS. Advances in Mechanical Engineering, 2020, Vol. 12, No. 12, pp. 1-21.

[Pollak 2020] Pollak, M., Dobransky, J. Structural design and material cutting using a laser end effector on a robot arm. TEM Journal: Technology, Education, Management, Informatics, 2020, Vol. 9, No. 4, pp. 1455-1459, ISSN 2217-8309.

[Prattes 2008] Prattes, G., et al. Multi-point ground-based ULF magnetic field observations in Europe during seismic active periods in 2004 and 2005. NHSS (Natural Hazards and Earth System Sciences), 2008, Vol. 8, pp. 501–507.

[Rimar 2016] Rimar, M., Smeringai, P., Fedak M., Kuna S. Technical and software equipment for the real time positioning control system in mechatronic systems with pneumatic artificial muscles. Key Engineering Materials, 2016, Vol. 669, pp. 361-369. ISSN 1662-9795.

[Straka 2018a] Straka, L., Hasova, S. Optimization of material removal rate and tool wear rate of Cu electrode in die-sinking EDM of tool steel. Int. J. of advanced manufacturing technology, 2018, Vol. 97, No. 5-8, pp. 2647-2654.

[Straka 2018b] Straka, L., Hasova, S. Prediction of the heat-affected zone of tool steel EN X37CrMoV5-1 after die-sinking electrical discharge machining. In: Proc. of the institution of mechanical engineers part B - Journal of engineering manufacture, 2018, Vol. 232, No. 8, pp. 1395-1406.

[Straser 2014] Straser, V., Cataldi, G. Solar wind proton density increase and geomagnetic background anomalies before strong m≥5 earthquakes. In: Proceedings of M5–14, Space Research Institute, Moscow, 2014, p. 280-286.

[Straser 2011] Straser, V. Radio wave anomalies, ULF geomagnetic changes and variations in the Interplanetary Magnetic Field. Preceding the Japanese M 9.0 Earthquake. New Concepts in Global Tectonics Journal, 2011.

[Straser 2015] Straser, V., Cataldi, G. Solar wind ionic variation associated with earthquakes greater than magnitude 6.0. New Concepts in Global Tectonics Journal, 2015, Vol. 3, No. 2.

[Takayama 1990] Takayama, T. and Suzuki, T. On the relation between the sunspot number and the destructive earthquakes in Japan. Bull. Earthquake Research Institute of Tokyo Imperial University, 1990, Vol. 8, No. 3, pp. 373–374.

[Takla 2011] Takla, E.M., et al. Anomalous geomagnetic variations possibly linked with the Taiwan earthquake (Mw = 6.4) on 19 December 2009. International Journal of Geophysics, 2011, Vol. 2001, Article ID 848467, p. 10.

[Tavares 2011] Tavares, M., Azevedo, A. Influences of solar cycles on earthquakes. Natural Science, 2011, Vol. 3, No. 6, pp. 436–443.

[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.

[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.

[Yanben 2004] Yanben, H., Zengjian, G., Jibing, W., Lihua, M. Possible triggering of solar activity to big earthquakes (Ms ≥ 8) in faults with near west-east strike in China. Science in China Ser. G., 2004, Vol. 47, No. 2, pp. 173–181.

[Zaborowski 2007] Zaborowski, T. Ekowytwarzanie. Gorzow, 100 p.

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