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METHODOLOGY FOR GEODYNAMIC RISK DETERMINATION IN THE AREAS WITH BROACHING ENGINEERING STRUCTURES

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Summary*. Investigation of geodynamic processes influence on the safe operation of buried pipeline systems has been carried out. Possibility to obtain the information about the geodynamic zone, that is crossed by an broaching engineering structure is analyzed. Possibilities to study the geodynamic block boundaries effect on the operating of buried engineering structures are estimated. To predict the risk influence on geodynamic zone of broaching engineering structures position the complex method of calculation based on the use of methods for determining the geodynamic risk and new methods of information processing basing on the artificial neural networks, has been proposed.*

Key words*: pipeline, technology, geodynamic zone, geodynamic hazard, geological block, damage, accident risk.*

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Statement of the problem. The damage of the available broaching engineering structures can be more likely possible in the zones of high intensity geodynamic activity. The greatest intensity is in the case, when the main part of the structure is located in different blocks of the large tracks of forest, that is, when it crosses the geodynamic zone (GDZ) or is immediately within it. For the broaching engineering structures (pipelines, tunnels, highways and main lines, channels, electro – transmission lines, coal pits, etc.) the most accident risk areas are those crossed by the geodynamic zones. Breaking of strength, integrity and the engineering structures damage mostly are caused by the geodynamic factors. Flooding and marshing of territories, pollution of the surface reservoirs and water drains, as well as underground water have resulted from the geodynamic zones. The pipelines are the most injured, when the soil becomes deformed. That is why they must be of special attention being in operation under such conditions [1]. Because of this to reveal the geodeformation destruction while pipeline systems operating is the scientific problem of great importance, both theoretical and practical.

Analysis of the available results of investigation. Safe operation of the main pipeline transport has experienced different types of anomalous deformations of the earth crust effect lately. For example, it is of the direct action, when the displacements are the principle risk factor of the electric systems and municipal transport. The extend and the degree of the influence factor of highly-sufficient deformation on the oil and gas constructions have been revealed. Seal failour and the pipelines fracture (rupture) appeared to be in the zones, where current highly-intensive deformations are revealed from time to time. According to the engineering – geological control data the karst-suffosion processes and highly-intensive deformations are interrelated, which resulted in the pipelines fracture many times [2].

Of special attention is the problem of main pipelines operation and geodynamic effects relation. According to the available statistics about 80% of all accidents at these engineering structures are associated with some definite places – the areas, which are crossed by the geodynamic zones. Besides, such accidents are mostly repeated at the same areas, the twice recurrence 75 – 80%, thrice and more repeated – 95% [2, 3].

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The mentioned above can be treated as the risk factors not only for the pipelines. They break integrity and destruct the linear-broaching engineering constructions, such as railways, dams, etc. Such geodeformations are dangerous for the great-span constructions, exhibition halls, pavilions, etc.

Thus, the problem of estimation the damage risk for the broaching engineering constructions resulted from the highly-intensive geodeformations is of special importance.

Having analysed the available papers the importance of the problem is confirmed by the comparative analysis of the seismic and geodynamic risks of non-seismic territories.

It was determined, that the annual losses caused by the geodynamic phenomena, is the result of the rapid displacements of the earth surface, which is much greater than that caused by the seismic phenomena [2, 4].

Nowadays the efficient methods and technical means for the effective trassing of the geodynamic zones and estimation of the geodynamic effect degree are not available [5, 8]. The carried out analysis and investigations testify, that the problem in question can be successfully solved by the consolidation of the electromagnetic geophysical methods and the solutions in the field of the engineering diagnostics of the pipeline systems [9, 11].

The Objective of the work is to carry out estimation of the geodynamic processes effect on the stability and safe operation of the pipeline systems and to develop the method of prediction of the geodynamic risk in the zone of the broaching engineering structures.

Statement of the task. Having carried out sufficient experimental investigations of the earth crust motions at the various purpose geodynamic proving grounds, the intensive local anomalies of vertical and horizontal motions have been revealed, originated from the different type and nature fracture zones. These anomalous motions are high – amplitude (up 50 – 70 mm/years), short-term (0,1 – 1 year), space-located (0,1 – 1 km) or those of the pulsing nature with the sign-variable direction.

Application of the differencial GPS-technologies in the periodic (discret) and continuous monitoring of the displacement and deformations made possible to identify new class of the geodynamic motions in the fracture zones with the period of 30 – 60 sec, 40 – 60 sec and confirmed the motion with one year or more period. All of them as well as their conventional component are of the pulsing nature and the sign – variable direction. Having analysed the cyclic sign-variable and conventional motions, it can be concluded, that the main characteristic of the geological environment, in the fracture zones in particular, is that it is in the continuous motion. The places, where the geodynamic motions are revealed, are of the active techtonic structures (fractures) or those closely connected with them rocks and areas of the earth surface. Great displacement amplitudes have been found experimentally in these zones. For example, the natural pillar located above the tactonic breaking is characterised by the sufficient fracture. Being in the broken cracked state it can be easily damaged. That is, the engineering structures, foundations of which are grounded, will sink. At the same time the broaching engineering structures (railway embankments, pipelines) crossing the zones of tactonic fractures will cave in and sag [12, 13].

If the amplitude of the sign-variable deformations exceeds the values of ultimate deformation of the structural elements of the construction, the breaking will be revealed, which will result in the accident consequences. If the degree of deformation is below the permissible ones, the accident consequencies depend on the fatigue effects. According to the frequencies of the found short-term geodynamic oscillations, those of about one minute and one hour oscillation periods are the most dangerous and create 500000 and 9000 loading cycles correspondingly annually. The fracture time under cyclic loadings depends on the amplitude of the variable values deformations. The cyclic loading contributes to the corrosion in dozens and hundreds times at the different purpose pipelines. In Fig. 1 the example of the tectonic thrusting scheme presenting deformation zones of the pipelines is presented.

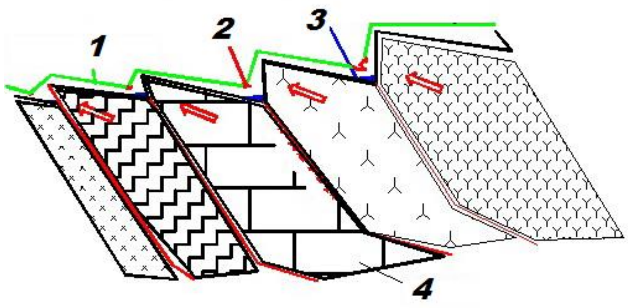


Figure 1. Tectonic scheme of thrusting with placed zones of pipelines deformation:
1 – pipeline; 2 – deformation zone; 3 – watercourses, ravines; 4 – thrusting

The portion of the accidents recurrence at the same areas of the pipelines is high enough – the twice recurrence of accidents at the same local area is 75 – 80%, the thrice and more repeated being up to 95%. The repeated accidents and pipeline fractures are caused by the factors, which contribute to the decrease of the technological fatigue properties of the pipe steel and reinforced concrete constructions. According to the results of the main pipelines inner-pipe investigations it was found, that about 70% of all defects are those of the „metal fracture“, which includes cracks, cavities, corrosion, etc. It is worth mentioning, that at the pipelines made of more plastic materials, the cracks occur only after 25 years of operation. At the same time the pipelines made of high strength materials the crack are revealed after 3 – 4 years of operation [14 – 16]. Thus, it can be assumed, that most accidents at the main pipelines are caused by the displacement of the earth surface released on the boundaries of the tactonic blocks of different hierarchy levels.

In Fig. 2 the scheme of the pipeline deformation at the fractured zones is presented. When the blocks move along the fracture surface the cylinder-shape pipeline changes into the ellipse-shape under pressing. The examples of the pipeline metal deformation under the mentioned geodynamic factors are presented in Fig. 3.

According to the carried out field investigations it was found, that most corrosion areas of the pipelines are located in the fracture zones. Besides, using the device investigation it was determined, that the outside corrosion occurs, when the plastic protective coating is damaged. In its turn, in most cases the strong plastic film coating is damaged during the rock blocks motion (broken bricks and granite or other rocks) on the fractures [14, 16].

In Fig. 4 the effect of the moving geological blocks upward the pipelines systems protective coatings is presented. Fig. 5 demonstrates the disadvantageous effects of such motions on the pipeline protective coatings state, which result in the sufficient damages.

All mentioned above testifies the need of continuous monitoring of the geodynamic processes, which occur in the earth crust. Special method and the system of the risks control for the safe operation of the buried pipeline networks being under geodynamic effects must be developed.

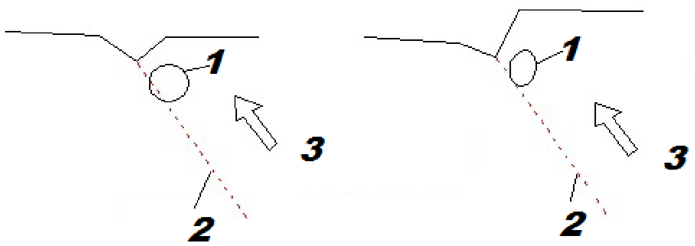


Figure 2. Deformation pipeline scheme at the fractured zone:
1 – pipeline; 2 – fracture; 3 – upward motion of the crustal block

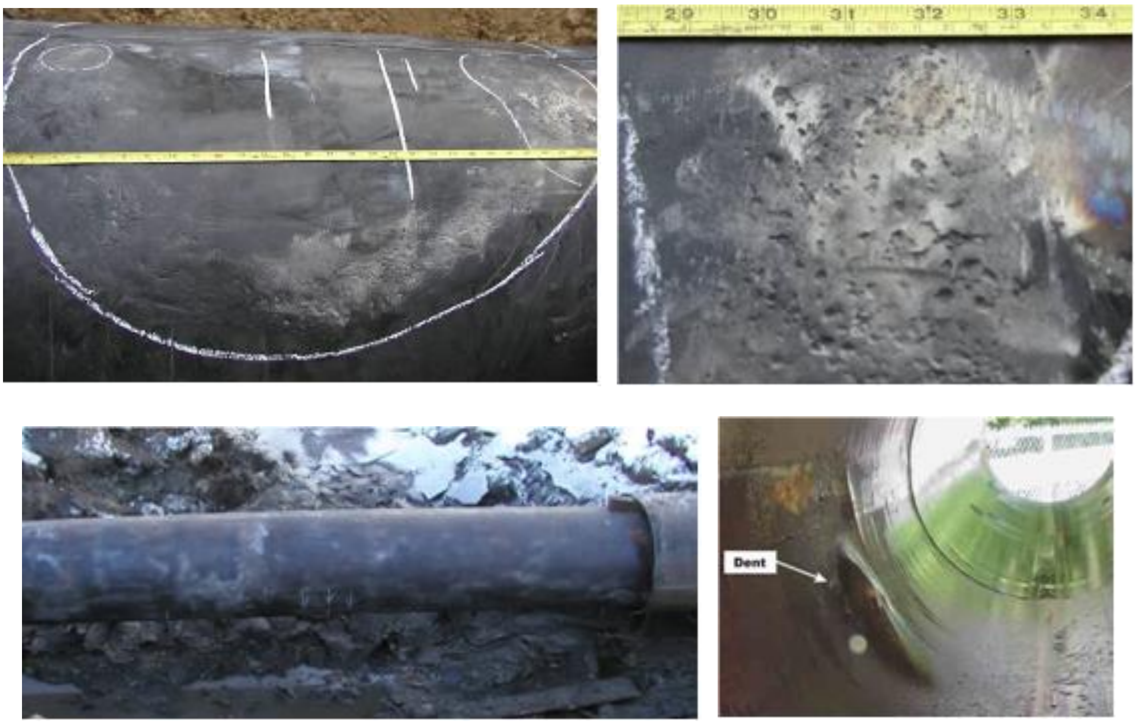


Figure 3. Examples of pipeline walls deformation

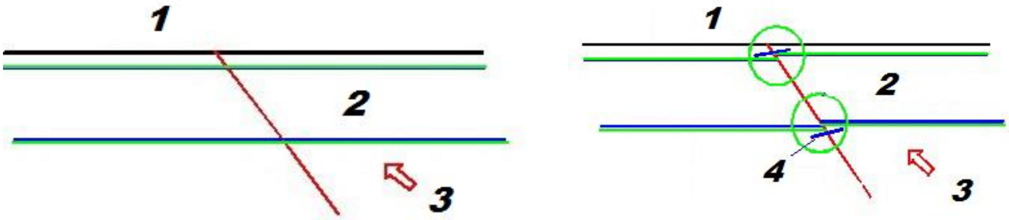


Figure 4. Zones of pipeline coating damages due to geological blocks upward motion on:
1 – coating; 2 – pipeline; 3 – fracture; 4 – protective coating

Figure 5. Examples of pipeline coating damages

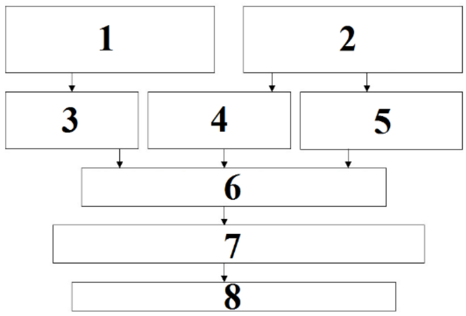
The results of investigations. To describe the hazard of the geological processes and phenomena reveal different methods of the risks estimation have been developed and are applied nowadays [17 – 19]. All these methods are developed basing on the geological investigations of rocks characteristics, practical experience and are specified by the calculations of some certain accidents.

The most known is the approach, which is based on the results of the geodynamic entrails division into types. In the papers on the geodynamic entrails division it is shown, that the earth crust can be treated as the hierarchy system of interrelated blocks, the boundaries of which are the zones of high geodynamic risk for different engineering structures. In the paper [22] the estimation of the geodynamic risk is based on the variation of the earth surface deformation degree in the engineering construction areas and deals with calculation of certain accidents. In fact, boundaries of the geodynamic active blocks are multiple and it is impossible to predict where at their crossing with the engineering structures the accident can occur. Besides, in the mountain area covered with the broaching engineering structures it is very difficult to identify the block boundaries, which is caused by the difficult area relief.

The method of investigation of the block boundaries effect on the conditions of the buried engineering operation can be presented as the block-scheme (Fig. 6).

Geodynamically hazardous zones are considered to be the boundaries of the geodynamically active blocks of the earth crust and the places of their crossing. According to the [23] the geodynamically active blockes and their boundaries are devided into the ranks. The boundaries of every rank have their own affecting area, which icreases with the rank growth. It is considered, that when the engineering structure gets into the area of the geodynamically active block boundaries effect the construction is under geodynamic risk. In this case any construction being on the block boundaries is under the hazard and the accident risk is likely to grow. The map of geodynamic risk of the separate territory is presented in Fig. 7.

In the quantitative assessment of the geodynamic risk, which arises caused by the geodynamic hazardous zone, the risk is treated as that, which can likely result in some losses.



1 – investigation and analysis of the geodynamic condition on the territory; 2 – investigation and analysis of the characteristics of buried engineering facilities and factors affecting on their accident risk; 3 – investigation of the block structure characteristics; 4 – investigation of the spatial distribution of accidents; 5 – investigation of the spatial distribution of engineering objects; 6 – analysis of the dependences between the position of engineering facilities, accidents and the boundaries of geodynamic blocks; 7 – impact assessment of block boundaries on buried engineering facilities operating conditions; 8 – reliability estimation of received results

Figure 6. Methodology of investigation the block boundaries influence on buried engineering facilities operating conditions

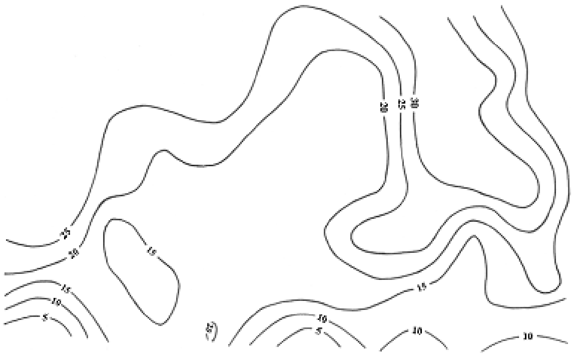


Figure 7. Map of geodynamic hazard of certain area

As it was mentioned above there are some available methods for determining the accident losses, but they are very difficult to be used for the estimation of the geodynamic risk in the zone of the broaching engineering constructions, because they are based on the calculation of certain accidents. As the processes, which are revealed on the block boundaries, are not investigated enough, it is wrong to treat every broaching engineering structure on these boundaries as the sophisticated accident.

Due to the mentioned above the development of new method of the losses estimation (geodynamic risk) is up-to-time and it would be less dependable on the fact, if the structure is in the hazard or safe block boundary. It should be based on the results of measuring the real values of the geodynamic activity in the area, that is, only losses resulted from the active or hazardous zones must be taken into account.

Generally speaking, the estimation of the geodynamic risk is a special type of the design – research activity contributed to the population safety as well as different facilities and environment within the territories subjected to the hazardous geological and engineering-geological process by providing the preventive engineering-technological and other measures to decrease the disadvantageous consequences and to prevent the natural accidents, caused by the processes.

While estimating the geodynamic risk it is worth taking into account all possible cases of activisation of the available and new geological hazards under the natural and industrial disaster factors, as well as their disadvantageous consequences within the facilities being estimated and the nearby territories.

Prediction of the geodynamic hazards development estimation of effects and risk losses caused by these hazards, as well as the verification of the final estimation of the risk must be based on the analyses of all available information and data on the cases of their arise and disadvantageous consiquences similar in nature.

The results of the estimation of the geodynamic risk must specify numerically all possible physical, economic and social losses during the given time, which arise, when the estimated broaching engineering constructions are affected by some geological hazards (differentiated risk) and the whole complex of these hazards (integral risk) under different methods of taking measures to prevent natural accidents.

Not less than two options of the predictable natural emergency procedures development are recommended to be analysed with the most possible maximum losses (risks).

The main results of the geodynamic risk estimation are proposed to be presented as corresponding risk maps (Fig. 7), which are compiled in the same or smaller scale than the maps schemes of the main design documentation for the construction of engineering facilities and the tables of geodynamic risk, which specify all initial data used for its estimation, as well as intermediate and final results of estimation of all procedures of the natural emergency situations and the options of their prediction.

The maps and tables must be provided by the specifications containing the characteristic of the initial data, short description of the method of prediction of the geodynamic hazards and risks as well as critical analysis of all assumptions and available uncertainties in the final estimation of possible losses.

Available map of the geodynamic risk makes possible to make decisions to control this risk taking advantage of the protective engineering measures.

Recommendations as to the choice of the protective engineering measures for the raising of ecological safety of the available and constructed buried broaching engineering facilities are based on the information on the dependence of the geodynamical hazardous zone on the level of the geodynamic risk.

Taking into account the principles of the decision making on the risks control (principle of normalizing-principle of acceptable risk, interpreting – „advantages disadvantages“ (the losses must not exceed the expenditures for the preventive measures and optimization of the optimal expedient resources application) for the buried broaching pipeline systems, the following preventive measures can be proposed.

Table 1

Recommendation as to the choice of the preventive engineering measures under known and unknown location of the geodynamic hazard zone

Location of the geodynamic zone is known	Location of the geodynamic zone is not known
PREVENTIVE MEASURES	
1. Improvement of the structure reliability of the pipelines in the places, where they are crossed by the geodynamic hazardous zone (choice of the pipes material, their laying in special boxes, connection of joints by the flexible clutch, if it is possible, etc.).	1. Improvement of the structure reliability of pipelines in the zones, where the dangerous situations are likely to arise.
2. Passing round the geodynamical hazardous zone or the pipe laying with the minimum crossings with the geodynamic hazardous zone.	2. The change of the pipeline laying trajectory around the zones, where the dangerous situations are likely to arise.

Taking into account the mentioned above the prediction of the geodynamic hazard degree in the zone of the engineering structures broaching is worth being carried out taking into account the geodynamic risk in the area, which will make possible to decrease the human factor effect, and the level of risk will make possible to plan properly the procedure of repairing and recovering.

Geodynamic risk is closely connected with the industrial facility (pipelines in particular), geological conditions of the pipeline laying, its technical condition and is the numerical characteristic of the geodynamic hazard and is treated as the group of the risk factors natural by origin.

One of the factors of the geodynamic risk degree growth is the broaching engineering structures on the boundaries of the geodynamic active blocks, which contributes to increase of the accidents.

When the broaching engineering structures cross the geodynamic zone, the geodynamic risk can be estimated according to the formula [24]:

$$R = P \cdot V; \tag{1}$$

where P – probability of the disadvantageous geodynamic event; V – affecting of the engineering structure, when the disadvantageous geodynamic event occurs, is found according to the formula:

$$V = U / S; \tag{2}$$

where U – losses caused by the disadvantageous geodynamic event; S – total cost of the engineering construction.

Block scheme of the proposed methodology for the risk determination (Fig. 8).

The estimation of U losses, which are caused by the location of the engineering structure in the geodynamic zone, is performed according to the formula:

$$U = \rho_1 \cdot U_C \cdot l_1; \tag{3}$$

where ρ_1 – specific density of accidents caused by the geodynamic hazardous zones; U_C – average value of losses of one accident under the investigation; l_1 – the length of the engineering structure area, which crosses geodynamic hazardous zone.

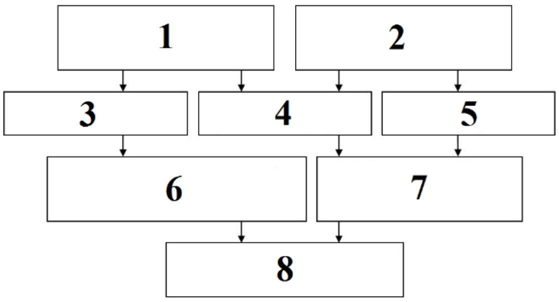
Specific density of accidents is found from the expression:

$$\rho_1 = \rho - \rho_0; \tag{4}$$

where

$$\rho = N / L_1; \tag{5}$$

where N – general number of accidents arose in the geodynamic hazardous zones; L_1 – total length of the pipeline areas crossed by the geodynamic hazardous zones.



1 – investigation and analysis of the geodynamic condition; 2 – investigation and analysis of the characteristics of buried engineering facilities and factors affecting their accident risk; 3 – construction of an analytical model for determining the probability of negative geodynamic event occurrence; 4 – determination of the specific density of accidents; 5 – damage assessment from 1 accident; 6 – determination of the probability of dangerous geodynamic event occurrence; 7 – assessment of geodynamical damage; 8 – assessment of geodynamic risk

Figure 8. Block scheme of the methodology for geodynamic risk determination

Specific density of the accidents ρ_0, which occur outside the geodynamic hazardous zones, is found due to the expression:

$$\rho_0 = N_0 / L_0; \tag{6}$$

where N_0 – general number of accidents occured outside the geodynamic hazardous zones; L_0 – general length of the pipeline without taking into account l_1.

The amount of average losses U_C caused by the *i*- accident at the broaching engineering structures and ecological component of these losses can be estimated according to the available methods of estimation the losses caused by the accidents at the engineering structures.

To build the map of the geodynamic risks the length of the engineering structure part crossed by the geodynamical dangerous zone is assumed to be equal 1 m.

According to the available methods the identification of the probability of the dangerous situation arising with the purpose to find the broaching engineering constructions within the geohazardous boundaries the Buffon task solution is used:

$$P_{GEO} = \sum_{i=1}^{n} \left(\frac{h_{GEOi}}{H_i + h_{GEOi}} + \frac{2L}{\pi\left(H_i + h_{GEOi}\right)} \right); \quad (7)$$

where n – number of the block boundary systems on the calculation model; h_{GEOi} – width of the *i* – system block boundary; H_i – distance between the parallelly oriented boundaries of the *i* – system blocks; L – length of the buried engineering construction or its part.

On the contrary to the conventional approach identification of the probability of the disadvantageous geodynamic event P is proposed to be carried out using the data obtained from the stationary monitoring system together with the application of artificial neural networks, because the determination of the possibility is very complex labour-consuming and multiple task, especialy in the area, where geodynamic hazardous zones have not been studied earlier. In our case the output of the neural network will be in the range 0…1, with the 0,01 pitch.

Conclusions. Having taken into account the mentioned above, we can conclude, that the method in question for finding the geodynamic risk and the system of continuous monitoring will make possible to solve the problems, which deal with:

– application of the systematic approach to the control of the industrial safety of the broaching engineering structures;

– taking advantage of the latest efficient methods to control the industrial safety of the broaching engineering structures, which are based on the real estimation of safety conditions which do not depend on the skills and deligence of the workers;

– introducing of criteria of the quantitive and qualitative estimation of the industrial safety of the broaching engineering networks, of the permittable and real accident risks;

– monitoring of the industrial safely state in real time, analysing the real accident risks due to the variable data, revealing of the broaching engineering structure accident risks in the proper time, effective planning and control of the taken measures directed on the decreasing of the accident risks to the permittable degrees taking into account available financial, material and human resources;

– communicating support of the complex system of the safety control of the broaching engineering networks operation.

References

1. Guidelines for Constructing Natural Gas and Liquid Hydrocarbon Pipelines Through Areas Prone To Landslide and Subsidence Hazards (PRCI L52292e), http://prci.org.
2. Geodinamika. Osnovy kinematicheskoy geodezii: monografiia. S.P. Voytenko, I.L. Uchitel, V.N. Yaroshenko, B.B. Kapochkin. Odessa: Astroprint, 2007, 264 p. [In Russian].
3. Kuzmin Yu.O. Sovremennaya anomalnaya geodinamika aseysmichnyh razlomnih zon. Yu.O. Kuzmin, Elektronnyi nauchno-informatsionnyi zhurnal „Vestnik otdeleniya nauk o Zemle RAN“, 2002, no. 1(20), 27 p., URL:http://www.scgis.ru/russian/cp1251/h_dgggms/1-2002/scpub-13.pdf. [In Russian].

4. Kasyanova N.A. Sovremennaya anomalnaya geodinamika nedr i ee vliyanie na obekty neftegazovogo kompleksa, N.A. Kasyanova, Yu.O. Kuzmin. M.: Geoinformmark, 1996. 56 p. [In Russian].
5. Iavorskyi A.V. Pidkhody do vyiavlennia vytokiv hazu z liniinoi chastyny mahistralnykh hazoprovodiv v zonakh heodynamichnoho ryzyku. Andrii Yavorskyi, Oleh Karpash, Ihor Rybitskyi. Rozvidka ta rozrobka naftovykh i hazovykh rodovyshch, 2011, no. 1, pp. 113 – 119. [In Ukrainian].
6. Vashchyshak S.P. Analiz ryzykiv bezpechnoi ekspluatatsii inzhenernykh sporud znachnoi dovzhyny ta pidkhody do yii otsinky. S.P. Vashchyshak, P.M. Raiter, A.V. Yavorskyi. Rozvidka ta rozrobka naftovykh i hazovykh rodovyshch, 2011, no. 2, pp. 54 – 58. [In Ukrainian].
7. Diagnosticheskoe obespechenie bezavariynoy raboty magistralnyh truboprovodov pri nalichii geodinamicheskoy aktivnosti. Yavorskiy A.V., Vaschishak S.P., Rayter P.N., Ryibitskiy I.V. „Nadezhnost i bezopasnost magistralnogo truboprovodnogo transporta“: materialy VII Mezhdunarodnoy nauchno-tehnicheskoi konferentsii (Novopolotsk, 22 – 25 noyabrya 2011 g.). Novopolotsk: PGU, 2011, pp. 157 – 158. [In Russian].
8. Orhanizatsiia pidhotovky personalu hazotransportnykh kompanii dlia poshuku vytokiv ta vyznachennia vtrat pryrodnoho hazu. Yavorskyi A.V., Karpash O.M., Karpash M.O., Rybitskyi I.V. Shosta Mizhnarodna naukovo-tekhnichna konferentsiia i vystavka „Suchasni prylady, materialy i tekhnolohii dlia neruinivnoho kontroliu i tekhnichnoi diahnostyky mashynobudivnoho i naftohazopromyslovoho obladnannia“: Zbirnyk tez dopovidei (29.11 – 2.12.2011). Ivano-Frankivsk: IFNTUOG. 2011, pp. 171 – 176. [In Ukrainian].
9. Mobilnaya sistema monitoringa geodinamicheskoy aktivnosti v zone proleganiya magistralnyh neftegazoprovodov. A.V. Yavorskyi, S.P. Vaschyshak, I.V. Rybitskyi, P.M. Raiter. Nauchni izvestiya (Scientific Proceedings), 2011, no. 1 (121), pp. 89 – 92. [In Russian].
10. Remote monitoring system of main gas pipeline linear part sections position and condition. Andrii Yavorskyi, Oleg Karpash, Sergii Vaschyschak, Ihor Rybitskyi. Wiertnictwo, Nafta, Gaz (Drilling, Oil, Gas), 2011, no. 1 – 2, vol. 28, pp. 469 – 473.
11. Mobilnyi monitorynh heodynamichnoi aktyvnosti dlia zabezpechennia bezpechnoi ekspluatatsii truboprovidnykh system. Yavorskyi A.V., Tahar Aifa, Raiter P.M. at all. Shosta Mizhnarodna naukovo-tekhnichna konferentsiia i vystavka „Suchasni prylady, materialy i tekhnolohii dlia neruinivnoho kontroliu i tekhnichnoi diahnostyky mashynobudivnoho i naftohazopromyslovoho obladnannia“: Zbirnyk tez dopovidei (29.11 – 2.12.2011.). Ivano-Frankivsk: IFNTUOG, 2011, pp. 185 – 191. [In Ukrainian].
12. Zaynullin R.S. Mehanika katastrof. Obespechenie rabotosposobnosti oborudovaniya v usloviyah mehanohimicheskoy povrezhdaemosti. R.S. Zaynullin. Ufa: Mezhdunarodnyiy institut bezopasnosti slozhnyih tehnicheskih sistem (MIB STS), 1997, 408 p. [In Russian].
13. Raschet i obespechenie prochnosti truboprovodov v slozhnyih inzhenerno-geologicheskih usloviyah. A.M. Shammazov, R.M. Zaripov, V.A. Chichelov, G.E. Korobkov. M.: Inter, 2005, 264 p. [In Russian].
14. Glikman A.G. Geoekologicheskie faktory avariynosti neftegazoprovodov i nasosnyh stantsiy. A.G. Glikman, URL:http://www.newgeophys.spb.ru. [In Russian].
15. Otsenka raspredeleniya defektov magistralnyh gazoprovodov na osnove strukturnogo geodinamicheskogo kartirovaniya i morfometricheskogo analiza, Asadullin M.Z., Kasyanova N.A., Selyukov E.I. i dr. Materialyi Mezhdunarodnoy nauchno-tehnicheskoy konferentsii „Truboprovodnyiy transport segodnya i zavtra“ (Ufa, 27 – 29.11.2002). Ufa, 2002, pp. 128 – 130. [In Russian].
16. Kuzmin Yu.O. Sovremennaya geodinamika i otsenka geodinamicheskogo riska pri nedropolzovanii, Yu.O. Kuzmin. M.: Agentstvo ekologicheskih novostey, 1999, 220 p. [In Russian].
17. Anikeev A.V. Izuchenie karstovo-suffozionnyih provalov na modelyah iz termoplasticheskih materialov, A.V. Anikeev. Geoekologiya. Inzhenernaya geologiya. Gidrogeologiya. Geokriologiya, 2008, no. 5, pp. 420 – 435. ISSN 0869-7803. [In Russian].
18. Koff G.L. Seysmicheskiy risk (vidy, otsenka, upravlenie), G.L. Koff, E.V. Ryumin. Institut litosfery okrainnyh i vnutrennih morey RAN. M.: POLTEKS, 2003, 108 p. ISBN 5-87413-033-0. [In Russian].
19. Ekzogennyie geologicheskie opasnosti. Tematicheskiy tom. Pod red. V.M. Kutepova, A.I. Sheko. M.: KRUK, 2002, 348 p. [In Russian].
20. Petuhova M.V. Sovershenstvovanie sistemy otsenki i upravleniya riskami v sektore roznichnogo kreditovaniya: avtoref. diss. kand. ekon. nauk: spets. 08.00.10, M.V. Petuhova. Novosibirsk, 2012, 22 p. [In Russian].
21. Batugina I.M. Geodinamika nedr. Metodicheskie ukazaniya, I.M. Batugina, I.M. Petuhov. L.: VNIMI, 1990, 118 p. [In Russian].
22. Kuzmin Yu.O. Otsenka geodinamicheskogo riska obektov neftegazovogo kompleksa, Yu.O. Kuzmin. Fundamentalnyiy bazis novyh tehnologiy neftyanoy i gazovoy promyshlennosti. M.: Nauka, 2000, pp. 334 – 344. [In Russian].
23. Petuhov I.M. Geodinamika nedr, I.M. Petuhov, I.M. Batugina. M.: Nedra, 1996, 120 p. [In Russian].

Список використаної літератури

1. Guidelines for Constructing Natural Gas and Liquid Hydrocarbon Pipelines Through Areas Prone To Landslide and Subsidence Hazards (PRCI L52292e), [Електронний ресурс]. Режим доступа: http://prci.org.
2. Геодинамика. Основы кинематической геодезии: монография [Текст] / С.П. Войтенко, И.Л. Учитель, В.Н. Ярошенко, Б.Б. Капочкин. – Одесса: Астропринт, 2007. – 264 с.
3. Кузьмин, Ю.О. Современная аномальная геодинамика асейсмичных разломных зон [Электронный ресурс] / Ю.О. Кузьмин // Электронный научно-информационный журнал «Вестник отделения наук о Земле РАН». – 2002. – № 1(20). – 27 с. Режим доступу: URL:http://www.scgis.ru/russian/cp1251/h_dgggms/1-2002/scpub-13.pdf.
4. Касьянова, Н.А. Современная аномальная геодинамика недр и ее влияние на объекты нефтегазового комплекса [Текст] / Н.А. Касьянова, Ю.О. Кузьмин. – М.: Геоинформмарк. – 1996. – 56 с.
5. Яворський, А.В. Підходи до виявлення витоків газу з лінійної частини магістральних газопроводів у зонах геодинамічного ризику [Текст] / Андрій Яворський, Олег Карпаш, Ігор Рибіцький // Розвідка та розробка нафтових і газових родовищ. – 2011. – № 1. – С. 113 – 119.
6. Ващишак, С.П. Аналіз ризиків безпечної експлуатації інженерних споруд значної довжини та підходи до її оцінки [Текст] / С.П. Ващишак, П.М. Райтер, А.В. Яворський // Розвідка та розробка нафтових і газових родовищ. – 2011. – № 2. – С. 54 – 58.
7. Диагностическое обеспечение безаварийной работы магистральных трубопроводов при наличии геодинамической активности [Текст] / А.В. Яворский, С.П. Ващишак, П.Н. Райтер, И.В. Рыбицкий // «Надежность и безопасность магистрального трубопроводного транспорта»: материалы VII Международной научно-технической конференции (Новополоцк, 22 – 25 ноября 2011 г.). – Новополоцк: ПГУ. – 2011. – С. 157 – 158.
8. Організація підготовки персоналу газотранспортних компаній для пошуку витоків та визначення втрат природного газу [Текст] / А.В. Яворський, О.М. Карпаш, М.О. Карпаш, І.В. Рибіцький // Шоста Міжнародна науково-технічна конференція і виставка «Сучасні прилади, матеріали і технології для неруйнівного контролю і технічної діагностики машинобудівного і нафтогазопромислового обладнання»: Збірник тез доповідей (29 листопада – 2 грудня 2011 р.). – Івано-Франківськ: ІФНТУНГ. – 2011. – С. 171 – 176.
9. Мобильная система мониторинга геодинамической активности в зоне пролегания магистральных нефтегазопроводов [Текст] / A.V. Yavorskyi, S.P. Vaschyshak, I.V. Rybitskyi, P.M. Raiter // Научни известия (Scientific Proceedings). – 2011. – № 1 (121). – С. 89 – 92.
10. Remote monitoring system of main gas pipeline linear part sections position and condition. Andrii Yavorskyi, Oleg Karpash, Sergii Vaschyschak, Ihor Rybitskyi. Wiertnictwo, Nafta, Gaz (Drilling, Oil, Gas), 2011, no. 1 – 2, vol. 28, pp. 469 – 473.
11. Мобільний моніторинг геодинамічної активності для забезпечення безпечної експлуатації трубопровідних систем [Текст] / А.В. Яворський, Aifa Tahar, П.М. Райтер та ін. // Шоста Міжнародна науково-технічна конференція і виставка «Сучасні прилади, матеріали і технології для неруйнівного контролю і технічної діагностики машинобудівного і нафтогазопромислового обладнання»: Збірник тез доповідей (29 листопада – 2 грудня 2011 р.). – Івано-Франківськ: ІФНТУНГ. – 2011. – С. 185 – 191.
12. Зайнуллин, Р.С. Механика катастроф. Обеспечение работоспособности оборудования в условиях механохимической повреждаемости [Текст] / Р.С. Зайнуллин. – Уфа: Международный институт безопасности сложных технических систем (МИБ СТС). – 1997. – 408 с.
13. Расчет и обеспечение прочности трубопроводов в сложных инженерно-геологических условиях [Текст] / А.М. Шаммазов, Р.М. Зарипов, В.А. Чичелов, Г.Е. Коробков. – М.: Интер. – 2005. – 264 с.
14. Гликман, А.Г. Геоэкологические факторы аварийности нефтегазопроводов и насосных станций [Електронний ресурс]. Режим доступа: URL:http://www.newgeophys.spb.ru.
15. Оценка распределения дефектов магистральных газопроводов на основе структурного геодинамического картирования и морфометрического анализа [Текст] / М.З. Асадуллин, Н.А. Касьянова, Е.И. Селюков и др. // Материалы Международной научно-технической конференции «Трубопроводный транспорт сегодня и завтра» (Уфа, 27 – 29 ноября 2002 г.). – Уфа. – 2002. – С. 128 – 130.
16. Кузьмин, Ю.О. Современная геодинамика и оценка геодинамического риска при недропользовании [Текст] / Ю.О. Кузьмин. – М.: Агентство экологических новостей. – 1999. – 220 с.
17. Аникеев, А.В. Изучение карстово-суффозионных провалов на моделях из термопластических материалов [Текст] / А.В. Аникеев // Геоэкология. Инженерная геология. Гидрогеология. Геокриология. – 2008. – № 5. – С. 420 – 435.

18. Кофф, Г.Л. Сейсмический риск (виды, оценка, управление) [Текст] / Г.Л. Кофф, Е.В. Рюмин // Ин-т литосферы окраинных и внутренних морей РАН. – М. : ПОЛТЕКС, 2003. – 108 с.
19. Экзогенные геологические опасности. Тематический том; [Текст] / под ред. В.М. Кутепова, А.И. Шеко. – М. : КРУК, 2002. – 348 с.
20. Петухова, М.В. Совершенствование системы оценки и управления рисками в секторе розничного кредитования: автореф. дисс. … канд. экон. наук: спец. 08.00.10 [Текст] / М.В. Петухова. – Новосибирск, 2012. – 22 с.
21. Батугина, И.М. Геодинамика недр. Методические указания [Текст] / И.М. Батугина, И.М. Петухов. – Л. : ВНИМИ, 1990. – 118 с.
22. Кузьмин, Ю.О. Оценка геодинамического риска объектов нефтегазового комплекса [Текст] / Ю.О. Кузьмин // Фундаментальный базис новых технологий нефтяной и газовой промышленности. – М.: Наука, 2000. – С. 334 – 344.
23. Петухов, И.М. Геодинамика недр [Текст] / И.М. Петухов, И.М. Батугина. – М.: Недра, 1996. – 120 с.

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РОЗРОБЛЕННЯ МЕТОДИКИ ВИЗНАЧЕННЯ ГЕОДИНАМІЧНОГО РИЗИКУ В МІСЦЯХ ПРОЛЯГАННЯ ПРОТЯЖНИХ ІНЖЕНЕРНИХ СПОРУД

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Резюме. *Проведено дослідження впливу геодинамічних процесів на безпечну роботу підземних трубопровідних систем. Проаналізовано можливість отримання інформації про геодинамічну зону, що перетинається протяжною інженерною конструкцією. Оцінено можливості для вивчення впливу границі геодинамічних блоків на експлуатацію підземних інженерних споруд. Для прогнозування ризику впливу геодинамічної зони на положення протяжних інженерних споруд запропоновано використати комплексний метод розрахунку, який базується на використанні методів визначення геодинамічного ризику, а також нових методах опрацювання інформації на основі штучних нейронних мереж.*

Ключові слова: *трубопровід, методика, геодинамічна зона, геодинамічний ризик, геологічний блок, пошкодження, аварійність.*

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