Technology of identification of natural resource potential in geodynamic ecological and economic assessment of the territory of the developed hydrocarbon deposit

Nikolay Solomatin[1*], *Yuri* Vladov[1], *Maxime* Nesterenko[1], *Yuri* Nesterenko[1], and *Oksana* Kapustina[1]

[1]Orenburg Federal Research Center, UB RAS, 460014 Orenburg, Russia

Abstract. The article investigates the use of aggregated models for geodynamic assessment of the ecological and economic assessment of the territory of the hydrocarbon field under development, including the values of reservoir pressure drops from the initial level. The significant potential of the developed identification technology and the proposed state models suggests the need for further research and enrichment of the created scientific direction. The results of the study allow us to build a more efficient hydrocarbon production program.

1 Introduction

Geodynamic ecological and economic assessment of the territory with the hydrocarbon deposit being developed, as a natural and man-made object, requires taking into account heterogeneous private indicators, including factors that have a negative impact on ecosystems during mining [1-3]. The intensification of the level of hydrocarbon production leads to a drop in reservoir pressure, and this, in turn, is the cause of possible deformations of the earth's surface and transformation of groundwater. Conducting a comprehensive analysis of the ecological and economic state with the identification of the natural resource potential of the territory with the hydrocarbon deposit being developed on the basis of aggregated models can significantly increase geodynamic safety [4-6] and thereby the efficiency of using the natural resource potential.

In [1], the main issues of constructing and modelling intelligent control systems for the state of man-made objects from the standpoint of analytical and nonparametric identification, taking into account information technologies of intelligent decision support, management technologies, design methods and operational efficiency, as well as data mining technologies are outlined. In addition, the methodology for constructing aggregated models of the state of such objects is given. However, there is no information on the ecological and economic assessment of the natural resource potential.

* Corresponding author: nicosvs@mail.ru

In [2], a technology for monitoring the geodynamic state of the subsurface of an exploited hydrocarbon field is proposed. The well-known technical solutions in this area are analysed and it is concluded that they are not relevant, since they characterize only the general state of the art. It is shown in [7] that increasing the geodynamic safety of the developed hydrocarbon deposits of the whole oil and gas basin is an actual scientific and practical problem. The work uses unique data on geodynamic parameters and productive layers in 56 deposits. The methodology is based on the construction of aggregated models for each productive reservoir and each developed hydrocarbon deposit. Tested on the oil and gas basin of the west of Orenburg region, related to the Caspian and Volga-Ural oil and gas provinces. But the assessment of the natural resource potential of the territory with a separate hydrocarbon deposit is not reflected.

In [8], various aspects of geodynamics of the upper part of the Earth's crust in the areas of oil and gas production are considered with an analysis of the geological structure, gas dynamic and hydrological conditions in natural and anthropogenic altered conditions. The factors influencing geodynamics and seismic activity of oil and gas-bearing territories are revealed, the principles of geodynamic and seismic monitoring in oil and gas production areas are formulated. At the same time, the issues of ecological and economic assessment of such territories have not been considered at all.

In [9], the problems associated with the application of the assessment of ecosystem services and their valuation to environmental management are analysed. The article discusses the events and problems associated with the inclusion of ecosystem services in the tools of integrated landscape planning and decision-making. The publication [10] analyzes the spatial distribution and dynamics of the ecosystem of the Lake Ebinur wetland Reserve. The article considers the value of ecosystem services of this landscape and its ecological environment in human health and lifestyle, providing cultural and economic benefits for the maintenance and self-realization of living organisms. In [11], the known impacts on wildlife mortality, habitat loss, fragmentation, noise and light pollution, invasive species and changes in oil, gas and water resources are summarized and compared, taking into account the growth of oil, gas and wind energy production. The works do not take into account the natural resource potential, taking into account the subsurface and geodynamic processes in areas with intensive production of hydrocarbons.

The analysis of published works on the affected problem shows that it is necessary to take into account heterogeneous private indicators characterized by different significance and dimension and developing in different directions. Geodynamic parameters play a decisive role in such territories. We have established that aggregate models of additive type are needed to solve the problem, providing an opportunity to bring incomparable temporal and spatial indicators to a comparable form with minimal losses.

As a result of the analysis of the problem, the purpose of the study is formulated – improving geodynamic safety by constructing aggregated additive-type models with the inclusion of geodynamic parameters and, first of all, reservoir pressure drops in the territory with the hydrocarbon deposit being developed (the first task), as well as developing on this basis an appropriate technology for identifying natural resource potential (the second task) with the possibility of constructing distributions of reservoir pressure drops in the form of corresponding histograms with finding approximation models.

2 Materials and methods

As part of the 1st task of the study, the value of the aggregate model of the additive type is first found for each share of the area of the territory with the field being developed according to the following ratio [12]:

$$x_j = \sum_{i=1}^{n} a_i \tau_i \quad (1)$$

Where x_j is the value of the aggregated additive model for the j[th] share of the area of the territory with the hydrocarbon deposit under development by the drop in reservoir pressure; n is the number of parameters in the corresponding aggregated models; a_i is the i[th] weighting factor; τ_i is the i[th] normalized private indicator.

Next, the value of the aggregated additive model is found for the entire territory with the developed hydrocarbon deposit according to the following ratio [12]:

$$x_k = \sum_{i=1}^{m} b_i x_i \quad (2)$$

Where x_k is the value of the aggregated additive model of the territory with the hydrocarbon deposit being developed; m is the number of fractions with different levels of reservoir pressure drop; b_i is the weighting factor; x_i is the normalized value of the state of the i[th] fraction.

As part of the second task of the study, three stages are provided: 1 – prepare geodynamic data; 2 – determine the shares of the territory of the field under development by the drop in reservoir pressure; 3 – build the distribution of the geodynamic state of these shares.

Stage 1. Select the object of study according to specific criteria: specific area of the territory (operation 1.1); density of drilled wells (1.2) and duration of operation (1.3).

Stage 2. The data of the isobar map on the drop in reservoir pressure of the territory, taking into account productive layers, are processed: the areas of fractions with different levels of drop in reservoir pressure are found (operation 2.1); the weighting coefficients are found by two methods: the method of expert assessments by interviewing specialists in modern geodynamics (2.2), as well as the method using information taken from the map isobar. Then the value of the aggregated additive model is obtained for each fraction of the area of the territory with the field being developed (operation 2.3) by the ratio (1). To do this, the territory with the hydrocarbon deposit under development is ranked by the drop in reservoir pressure (operation 2.4); the corresponding weighting coefficients (2.5) are determined for them; the value of the aggregated additive model for the territory with the hydrocarbon deposit under development (2.6) is found by the ratio (2).

Stage 3. To construct the desired distribution of the shares of the territory of the hydrocarbon deposit under development by a corresponding histogram is constructed for the drop in reservoir pressure (operation 3.1). Then approximation models with a sufficiently high level of confidence are found (3.2).

3 Results

The proposed technology of identification of natural resource potential with geodynamic ecological and economic assessment of the territory of the developed hydrocarbon deposit and the construction of appropriate aggregated models is used for one of the hydrocarbon deposits of the Orenburg region.

On the low-seismic territory of the studied oil and gas field, only a few seismic events per year with a magnitude of ML up to 1.5-2 are recorded. The maximum deformations at

the deposit were minus 1.233 m, and the relative deformations reach values of 352 mm per 1 km of horizontal surface.

The condition and safe operation of oilfield infrastructure facilities, industrial and civil structures are significantly influenced by the results of deformation determination. In regions with intensive hydrocarbon production, the magnitude of the reservoir pressure drop allows for a more complete assessment of the environmental situation and takes into account the anthropogenic load from hydrocarbon production on the geological environment. The change in the natural hydrodynamic state, as well as the stress-strain state of rocks, occurs due to the redistribution of pressure changes in the geological environment, according to the relevant laws of hydro- and gas dynamics inside and outside the field. Some local seismic events occur due to the discharge of local stresses in the geological environment caused by local changes in reservoir pressure associated with uneven extraction of hydrocarbons over time and over area.

Stage 1. Data were obtained on the specific area of the field, the density of wells and the duration of operation by year and presented in the form of oil production volume.

Stage 2. The value of the aggregated additive-type model with weighting coefficients determined by the method of expert assessments, the state of the shares of the field territory by the drop in reservoir pressure and the integrated assessment of the state for the oil and gas field was 0.412, and with weighting coefficients determined by geodynamic information taken from the isobar map, 11.8% less.

Stage 3. The desired distribution of the shares of the area of the developed oil and gas field by the drop in reservoir pressure is shown on the histogram (figure 1), where: row 1 – with weighting coefficients determined by the method of expert assessments; row 2 – with weighting coefficients determined by geodynamic information taken from the isobar map.

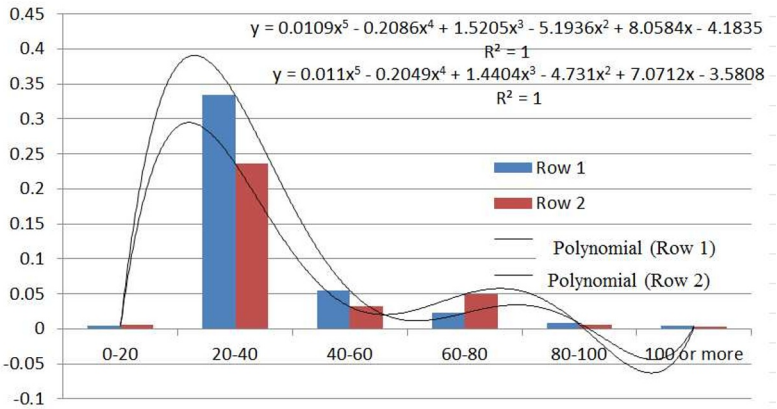

Figure 1. Histograms based on the isobar map for one of the productive layers of a hydrocarbon deposit, in the form of aggregated models of the shares of the territory with certain drops in reservoir pressure.

4 Discussion

As can be seen, polynomial models of the fifth degree of approximation provide a fairly high level of reliability. Consequently, the proposed technology makes it possible not only to identify the natural resource potential when analysing the ecological and economic condition of the territory with the hydrocarbon deposit being developed, but also to predict changes in the components of the natural environment when the anthropogenic load

changes and, as a consequence, to further manage its condition when carrying out economic activities.

5 Conclusion

The scientific novelty of the presented material is as follows. Aggregated models of additive type of shares with a certain drop in reservoir pressure of the territory with the developed hydrocarbon deposit are constructed, which, unlike the known ones, allow, along with the usual parameters used in the ecological and economic assessment of natural resource potential, to introduce basic geodynamic parameters that take into account the inherent significant unevenness of the intensity of hydrocarbon production.

The technology of identification of the natural resource potential of a territory with a hydrocarbon deposit under development is substantiated, which, unlike the well-known ones that give an ecological and economic assessment of the natural resource potential in subjective points, allows identifying its assessment taking into account modern geodynamics and bringing it to a numerical value in the range from 0 to 1, as well as constructing a distribution of shares with certain drops formation pressure of such a territory, for example, in the form of a histogram with subsequent finding of approximating models.

The obtained results are aimed at solving the fundamental problem of increasing the efficiency of functioning and use of natural and man-made objects, the most important of which are the territories with the developed hydrocarbon deposits. The significant practical and scientific potential of the obtained results necessitates the continuation of research to enrich the created scientific direction.

References

1. Kochurov B I 2016 *Ecodiagnostics and Balanced Development* (Moscow: Infra-M Publishing House) 362
2. Vladov Yu R 2013 Construction and modeling of intelligent control systems for the condition of man-made objects (Orenburg: publishing house of IPK "University" LLC) 243
3. Vladova A Yu 2012 Construction of intelligent control systems for the condition of technogenic objects (Orenburg: publishing house of IPK "University" LLC) 176
4. Solomatin N V and Nesterenko M Yu 2019 Nature and ecological and economic condition of the territory of the Baytugan oil field. *Bulletin of the Orenburg Scientific Center of the Ural Branch of the Russian Academy of Sciences* **4** 9
5. Nesterenko M, Tsviak A, Kapustina O, Nesterenko A and Nikiforov S 2020 Dangerous geodynamic processes of the Eastern Orenburg. Actual Problems of Ecology and Environmental Management: Cooperation for Sustainable Development and Environmental Safety (APEEM 2020) E3S Web Conferences **169**
6. Nesterenko M, Tsviak A and Belov V 2020 Natural and technogenic geodynamic processes in the South Ural. First Conference on Sustainable Development: Industrial Future of Territories (IFT 2020) Yekaterinburg, Russia, September 28-29 E3S Web of Conferences **208**
7. Vladov Yu R, Nesterenko M Yu and Vladova A Yu 2019 Technology for monitoring the geodynamic state of the subsurface of an exploited hydrocarbon deposit. *Managing the Development of Large-scale systems (MLSD'2019): Proceedings of the Twelfth International Conference* (Moscow: IPU RAS Publishing House) 1055-1061

8. Vladov Yu R, Nesterenko M Yu, Nesterenko Yu M and Vladova A Yu 2021 Improving the geodynamic safety of the developed hydrocarbon deposits of the oil and gas basin. *Occupational safety in industry* **7** 31-37
9. Groot R S, Alkemade R, Braat L, Hein L and Willemen L 2010 Challenges in integrating the concept of ecosystem services and values in landscape planning, management anddecision making. *Ecological Complexity* **7** 260–272
10. Zhang F, Yushanjiang A and Jing Y 2019 Assessing and predicting changes of the ecosystem service values based on land use/cover change in ebinur lake wetland national nature reserve, xinjiang, China. *Science of the Total Environmen* **656** 1133–1144
11. Jones N F, Pejchar L and Kiesecker J M 2015 The Energy Footprint: How Oil, Natural Gas, and Wind Energy Affect Land for Biodiversity and the Flow of Ecosystem Services. *BioScience* **1(3)** 290-301
12. Solomatin N V, Vladov Yu R, Nesterenko M Yu and Vladova A Yu 2022 Identification of the natural resource potential of the territory with the hydrocarbon deposit under development. *Questions of steppe studies* **4** 33-43