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***G. P. METAKSA*[1], *Head of Laboratory, Doctor of Engineering Sciences, gmetaksa@mail.ru*
***Zh. N. ALISHEVA*[2], *Associate Professor*
***A. S. METAKSA*[1], *Senior Researcher*
***N. A. FEDOTENKO*[3], *Candidate of Engineering Sciences*

[1]*D.A. Kunayev Mining Institute, Almaty, Kazakhstan*
[2]*Al-Farabi Kazakh National University, Almaty, Kazakhstan*
[3]*IPKON RAS, Moscow, Russia*

SCIENTIFIC AND TECHNICAL FUNDAMENTALS OF CHANGING THE PROPERTIES OF HYDROCARBONS IN CONDITIONS OF OPTIMAL SUBSOIL USE

The article provides a rationale for the development of a new geotechnology of subsoil use. It is shown that in order to change the viscosity of formation waters it is necessary to study the phenomena occurring at the interface between the phases "water-oil-quartz" fluid system in order to solve the problem of managing the properties of hydrocarbons in the conditions of natural occurrence.
The results of the experimental work on physical and chemical modeling of the processes of synthesis and decomposition of hydrocarbons (HC) at the interface under conditions as close as possible to the reservoir state are presented. The obtained data indicate that under natural conditions the oil field is in a dynamic state, which responds to any external influence by changing the chemical composition of the components of the system "quartz-oil-water" [1].
The aggregate of the obtained data allows us to make the following predictions:
–the main geological feature in physical modeling of HC synthesis and decomposition processes in the "quartz-oil-water" system is the resonance correspondence of sound velocities of quartz and associated components of the interface. This is evidenced by the fact of the harmonic series of responses to an external pulse action at the frequency of water decomposition;
–the change of chemical composition in the three-component system manifests itself by the appearance of low-amplitude responses located between the frequencies of the harmonic series from the quartz particles of the three-component surface.

Keywords: *Subsoil, hydrocarbons, spectrum, response, impact, hydrogenation*
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Introduction

For the first time in Kazakhstan an industrial experiment on hydrogenation of heavy oil by means of energy-accumulating substances decomposing water was carried out at enterprises of Embamunaigas. In order to exclude the effect of well ringing it is necessary to study the processes of controlling the chemical composition of the hydrogenated oil under reservoir pressure and temperature conditions [2].

The knowledge accumulated during the development of the subsoil was used to identify problems and priority research areas in mining science in the near future, among which the development of physical and chemical justification for the creation of fundamentally new geotechnologies of production and processing of hydrocarbons in conditions of natural occurrence is very important. The degree of completion of research in solving various problems is different: some solutions have found or may find application in the near future in the practice of development of fields of different types [3].

The modern period of the existence of mining science is characterized by the development of works in the following directions:

—Research of rock mechanics and rock pressure, creation of efficient development systems with mechanization and automation of technological processes for coal and ore deposits;

— Research of rock fracturing and drilling;

— Increasing the resources, complexity and efficiency of the use of minerals, especially ores, based on the theory and new methods of enrichment;

— Creation of new geotechnologies;

— Modern geodynamic fields and processes caused by man-made activities;

Theory of mineral deposit development and integrated processing of mineral raw materials on the basis of resource- and energy-saving technologies [4, 5].

The above list of accumulated achievements indicates that the time has come for conscious application of this knowledge in solving fundamentally new problems of conservation of ecological equilibrium in an increasing volume of subsoil use. This approach to the problems is possible only if the mechanisms of formation of structural features of interaction between elements of the rock mass in response to changes in its stress state are studied. Experimental data in the geomechanics section give an idea of the uneven distribution of the main stresses in the sublatitudinal and meridional directions. Experimental modeling of anisotropy of properties in response to external periodic influence shows a jump-like response depending on periodicity, composition, form and aggregate state of rock massif components [6].

An objective prerequisite for the development of the dynamic approach to solving the problems of mineral processing in conditions of natural occurrence is the integrated use of traditional technological techniques, proven in practice, to create the latest geotechnologies.

For fluid-bearing deposits, such as oils — the creation of reactor technology is proposed for the first time. The main prerequisites for the development of such technology are [7]:

— Elevated temperatures in the setting (30–90 °C);

— Presence of water as a supplier of hydrogen and oxygen;

— Presence of carbon-containing components;

— Presence of surface-active substances (aluminosilicates) at the interface.

Resource saving is achieved by using natural creators of the main stress states of the natural massif with no capital investments in above-ground facilities designed for hydrocarbon processing.

Energy saving is carried out by using our developed methods of obtaining a given chemical composition inside the treated reactor, as well as by applying methods of unconventional energy (for example, wind-helio-piezoelectric converters).

For liquid and gaseous minerals in order to increase the recoverability of oil and gas in places of their development in the Institute of Mining, Siberian Branch, Russian Academy of Sciences (Novosibirsk) successfully conducted experimental research and methodological developments in the field of vibroseismic effects on oil deposits from the day surface [8].

Large industrial experiments carried out at the enterprises of Territorial Production Enterprise, Lukoil Oil Company, "Yugraneft", "Orenburgneft" of "Tyumen Oil Company" and British British Petroleum showed the prospects of using the wave impact on the oil reservoir to solve the problems of increasing the oil recovery factor. At the same time the accompanying changes in physical-chemical and filtration properties of the oil reservoir in the course of vibroseism treatment were revealed, as well as the intensification of development of highly watered oil reservoirs [9].

Research methods

The method of vibroseismic influence on oil reservoirs belongs to the group of wave impacts. The first full-scale experiments to assess the applicability of this method for intensification of oil recovery from watered productive formations, which are at the final stage of development, were started at four fields Abuzy, Ubezhinskoye, Zybza (Krasnodar region) and Radchenkovskoye (Poltava region). The depth of productive noted reservoirs was 500–1400 m, and the water cut of produced oil varied from 10 to 90%. Pilot vibroseismic operations were carried out on Terskoye field of Urayneftegaz and on B-10 and B-11 formations of Druzhnoye field of Kogalymneftegaz [10].

The results of the experimental work are that in general the success rate of vibroseismic influence was 20–25%, well rates increased by 5–35%, the water content of production either did not change or slightly decreased.

Wells, located at a distance of 1 km from the seismic vibrator, reacted to the effect, but no regularity in the nature of their reactions was noted. In general we can note that this method of wave influence on productive strata is still at the stage of scientific study, which should pay special attention to the nature and extent of the impact of seismic waves created on the structures of the wells closest to seismic vibrators, as well as not only on reservoir rocks and fluids contained in them, but also on the rocks-fluids, which compose the screens of the deposits.

The method of electrohydraulic influence belongs to the group of pulse impacts on the near-wellbore formation zones. It is based on creation of hydraulic pressure pulses with energy of 1–5 kJ using electric discharge, spreading through the rocks of the treated formation, dispersing and removing colmatants from it.

Methods of physical and chemical influence are widely used in practice not only on oil transported in oil pipelines, but also on environment of oil reservoirs. It is proved by the results of activity of specialists of "Scientific And Production Enterprise Oil-Engineering", at the fields with hard-to-recover reserves [11].

The reason for application of vibro-wave methods to influence oil reservoirs was caused by numerous field observations showing that seismic waves generated by earthquakes and noise considerably increase oil and water production [12].

Each of the methods has its positive and negative sides. The influence of vibration equipment from the ground surface is the processing of the entire reservoir or group of reservoirs but the big obstacle is the presence of reflecting horizons (layers of solid rocks) on the path of the wave from the ground surface to the oil-saturated reservoir. Since oil reservoirs currently being exploited are usually deep, it seriously limits the application of this group of methods. Another big disadvantage is the lack of selectivity.

The disadvantage of high-frequency downhole technologies is the limitation in energy transmitted from the ground surface through the cable. The main object of treatment here is the near-wellbore zone of deteriorated permeability - the so-called area of hydrodynamic flow, which is critical for effective well operation. The flow area is characterized by maximum velocities of fluid filtration, so it is here where collimation occurs and, accordingly, deterioration of rock permeability. The depth of this zone from the borehole wall is from tens of centimeters to one meter, and therefore it does not require significant energies for its treatment [13].

Standard problems preventing filtration in the bottomhole zone are related to mechanical and physicochemical colmatation in injection and production wells. Microscopic particles of clays, paraffins and asphaltene-resin substances with a size much smaller than the pore cross section accumulate in this area and, due to high filtration rates, come together at distances at which electrostatic attraction prevails. Such pore fluid is a structure of colloidal type, characterized by a maximum shear stress. In technological aspect, this means that there is a certain critical pressure gradient below which filtration of the fluid is impossible. As a result, the filtration process in the bottomhole zone slows down and sometimes stops altogether. When this structure is destroyed, the permeability of the bottomhole zone is restored to the original values.

It has been established experimentally that the most effective way of colloidal systems destruction is an acoustic impact. It allows to significantly reduce the ultimate shear stress of the fluid and restore the permeability of the porous medium to its original state. Also the acoustic field reduces the forces of interphase interaction, thus contributing to fluid movement in the porous medium. When applied to production wells, this means that oil-saturated strata that were previously inactive due to collimation may be involved in the filtration process, which will increase the flow rate and reduce the water cut of the production. Due to inertial forces acting on the fluid,acoustic waves also effectively perform cleaning of the porous medium from the collecting material, which is necessary to restore the operation of injection wells.

A cardinal solution to this issue has been proposed and implemented by the management and employees of Sinkrud, Alberta, Canada. The advantage of the company's working process is that it includes a continuous technological chain from field development to obtaining a final product of marketable condition that requires minimum expenses for transportation and, what is important, is in constant demand on the market of oil products [14].

In this process, a viscous, resin-like substance is turned into a product with the brand name Sinkrood Sweet Blend: a high-quality, lightweight, asphalt-free, golden-colored crude oil with the lowest sulfur content in North America. It is a synthetic product with a sulfur content of 0.2 to 0.3% and has an exceptionally low filling temperature. It contains no sludge, although conventional crude oil can contain up to eight percent asphalt sludge.

In order to intensify oil extraction from productive formations different methods are applied, among which the most frequently used are physical ones, including:

– hydro- and gas-dynamic fracturing of formations,

– various types of wave: acoustic, hydroacoustic, vibroseismic,

– pulsed: hydro-pulsed, electro-hydraulic, thermobaric.

The methods of hydraulic fracturing and local hydraulic fracturing of reservoirs are based on generation of stresses in the wells that exceed the strength limits of productive formations, zakolmatichnyh reservoirs, which leads to the formation of the latter "man-made cracks of different orientation, length and openness. Fixing of technogenic cracks in the process of operations is carried out by filling them with proppants (quartz sand grains, artificial grains, etc.). During hydrodynamic fracturing operations a significant amount of special equipment, chemicals and fixing materials are used, most of which are imported, which is a determining factor of high cost of operations [15].

The hydrodynamic fracturing method is based on the use of high-temperature (1200–1600 K) gases generated by combustion of combustible compositions and solid-fuel powder systems with a controlled pressure pulse. The method of hydrodynamic fracturing is complex, and its impact on the treated reservoir is carried out in two stages.

The method of acoustic impact on the reservoirs of near-wellbore zones of productive formations is environmentally friendly and based on the use of a wide range of physical and chemical phenomena, developing in rocks and fluids contained in them under the influence of ultrasonic fields.

The method of hydro-pulse impact is based on pulse drainage of productive formations, which leads to dispersal of material through the volume of the reservoir, to the unblocking of zones of pillars saturated with oil and formation water, to changes in the primary structure of the void space of rocks of productive reservoir zones due to development in them "man-made" microcracks.

Discussion of results

Analysis of the types of external influence on the reservoirs of downhole oil field zones shows the possibility of coverage by these methods of all elements of the structure involved in the processes of oil formation and oil refining. The accumulated information about the advantages and disadvantages of each type of exposure is fundamental for developing the reactor method of processing.

During the experimental work was found out a jump change of rock components properties (strength, plasticity, electrical conductivity, magnetic permeability) depending on the change of external action parameters. Types of external influence varied, and, accordingly, the mechanisms of interaction differed from each other, but some general regularities inherent in each type of influence were revealed.

– electromagnetic vibrations + deformation processes;

– mechanical vibrations (ultrasonic or sonic);

– Ultrasonic + electric potential difference;

– complex pulse effect.

Conducting experimental works in laboratory conditions has shown that for a jump change in the properties in the treated substance for all of the above types of impact is necessary mutually-perpendicular orientation of the application lines of the forces of the main stress state and the low-energy external impact.

In this case, the mechanism of interaction was reduced to a change in the reactivity of the interface, which is in the stressed state. And to change the state of the interface, consisting of several monolayers of boundary phases, a high intensity (power) impact is not required. Thus, the regime of low-energy control of the main stress state is achieved in order to obtain the specified properties due to a reasonable choice of dynamic parameters of the external transverse action.

As noted above, the methods of impact on oil reservoirs used in the industry have a high energy intensity and do not use the dynamic mode, forming the stress state of the minerals.

In this regard, having a sufficient amount of information obtained in the implementation of various types of physical impact on oil reservoirs, we can begin to develop the reactor technology to change the rheological properties of oil in the conditions of natural occurrence. The basic prerequisites for the solution of this problem, are:

– elevated in-situ temperatures, which vary from 30 to 90° C depending on the depth of occurrence;

– excessive pressures;

– presence of water, the components of which in the process of exposure can provide the processes of hydrogenation of unsaturated hydrocarbons;

– presence of mineral components, mainly aluminosilicates, whose catalytic activity is enhanced by their dispersed state in the basic rock.

To solve the problem of intensification of natural processes it is necessary to obtain information about the mechanisms of transformation of energy coming from the outside at the interfaces of rock components [16, 17]. According to laboratory studies, the structural state of the interface between two or more phases has a significant impact on the course of energy accumulation and discharging of the main type of stress state. To change the state at the interfaces does not require an energy-intensive impact: it is many orders of magnitude less than the basic process, but requires a coordinated external impact in frequency and magnitude of the potential applied perpendicular to the direction of the basic type of stress.

The basic dynamic state of the oil reservoir is characterized by two types of movements:

– The process of diurnal rotation of the Earth, which causes the appearance of the horizontal component of the main stress state;

– The vertical component of the intraplastic stress state is provided here by the tidal effects of our satellite — the Moon.

The geometric sum of vectors of such interaction in the time sweep should look like a balanced system of forward and backward spirals.

At the same time, the transverse low-energy impact should be strictly oriented relative to the main movements of the reservoir. In addition, the choice of external impact orientations should be coordinated with the relief of a particular area, and the presence of faults, i.e., taking into account the energy-saving factors of the external impact.

Under the assumption (according to seismology data), that all processes of stressed state discharging take place at the interface, we can calculate the value of natural productivity of oil reservoir, i.e. time of full cycle of processing of carbon fraction into oil raw material in the presence of water.

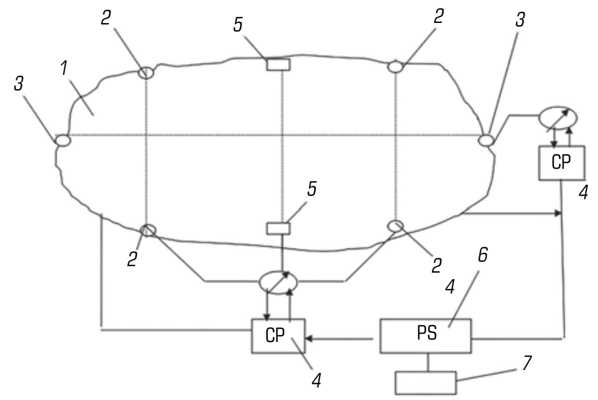

Fig. 1. Functional diagram of the reactor complex for processing and/or refining oil under natural conditions

Legend: *1* – oil reservoir; *2* – electromechanical stimulation unit; *3* – pulse stimulation unit; *4* – external stimulation mode control panel; *5* – reservoir chemical composition measurement unit; *6* – power supply unit for power and control systems; *7* – power supply system (autonomous wind or solar plant)

So for an oil reservoir in diameter of 10 000 m, capacity $H = 20$ m we define a surface of the top and bottom parts of a reservoir (a surface layer of lateral sides we do not consider, as in full-scale conditions cylindrical reservoirs do not exist):

$2S = 2 \cdot (5 \cdot 10^3)^2 \cdot 3.14 = 157 \cdot 10^6 m^2$ $(S = \pi R^2)$.

If the thickness of the active interface d is equal to 1000 monolayers in water-carbon colloid ($d_{c\text{-}c} = 0.7$Å, $d_{H\text{-}H} = 1.06\ 7$Å, $d_{H\text{-}O} = 0.96$ Å), we obtain the active layer value d_a equal to $d_a = 1A \cdot 1000 = 10^{-7}$m 1 angstrom is taken in the calculation as the average statistical distance between the atoms of the different components of the colloid).

Then the number of daily cycles N at the height H of the collector will be:

$N = H/d_a = 20/10^{-7} = 20 \cdot 10^7$ day $= 0.547 \cdot 10^6$ years

The order of values obtained in the calculation (half a million years) corresponds to the geological time of the Pleistocene.

Under the conditions of activation of chemical processes of hydrogenation of hydrocarbons within the limits of propagation of capillary waves, the wavelength of which (according to V. A. Krasilnikov) is equal to

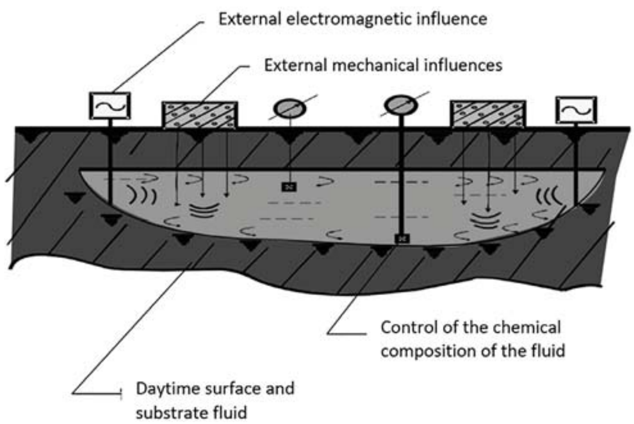

Fig. 2. Functional scheme of oil refining in natural conditions (section)

$\lambda = 17.5$ mm, the same calculation scheme gives the value $N_{cap.}$ *equal to*:

$N_{cap.} = H/\lambda = 20 / 0.0175 = 1142.8$ daily cycles, i.e., 3.13 years.

Taking into account contribution from increase of interphase surface at fracturing and in places of existence of fractures of certain width and extent, calculated values N can be defined by an order of magnitudes in some months.

It follows that at the current level of knowledge about the effects of external influences it is possible to solve the problems of intensification of slowly proceeding processes of oil formation in order to obtain a given finished product by matching modes of external influence on the components of the oil reservoir with their response to this influence [18]. At that, conditions of resonance correspondences in the system "impact-response" have significance. In the case of successful solution of the problems of coordinating the impact with the response, there will be conditions for changing the chemical composition of the oil lens, with gravity features of light fractions will cause their rise into the upper layers of the reservoir at the completion of the synthesis reactions. Lower (heavier in mixture with water) unsaturated hydrocarbons will continue to participate in reactions of destruction and synthesis of hydrocarbons of set composition in conditions of coordinated rhythm of external influences [19, 20].

Upon completion of processing of carbon-containing fraction**s**, the remaining mineral mass contains a large amount of sulfur and other minerals, processing of which can be carried out by complex methods, including bioactive solutions.

Free from hydrocarbons collector can be used to synthesize hydrocarbons of a given composition from the organic waste of the nearest megapolis.

The functional description allows to define the place of the given system and its interrelation with higher level systems, i.e. characterizes its parameters, processes and hierarchy of types of interaction (**Fig. 1, 2**).

For the oil field information objects are [7, 21]:

—automated processing complex of response processes to external impacts;

—control module of the external action parameters matching mode;

—volumetric digital model of the field;

—block of system for evaluation of working massif state;

—module-program of the oil reservoir processing system feedback formation;

—system of executing bodies.

Morphological description (**Fig. 3**) reflects system's structure according to its hierarchical levels, i.e. it defines correlation between energetic and informational properties of controlled object. Physically, information is responsible for the predictability of properties and the behavior of the controlled object in time.

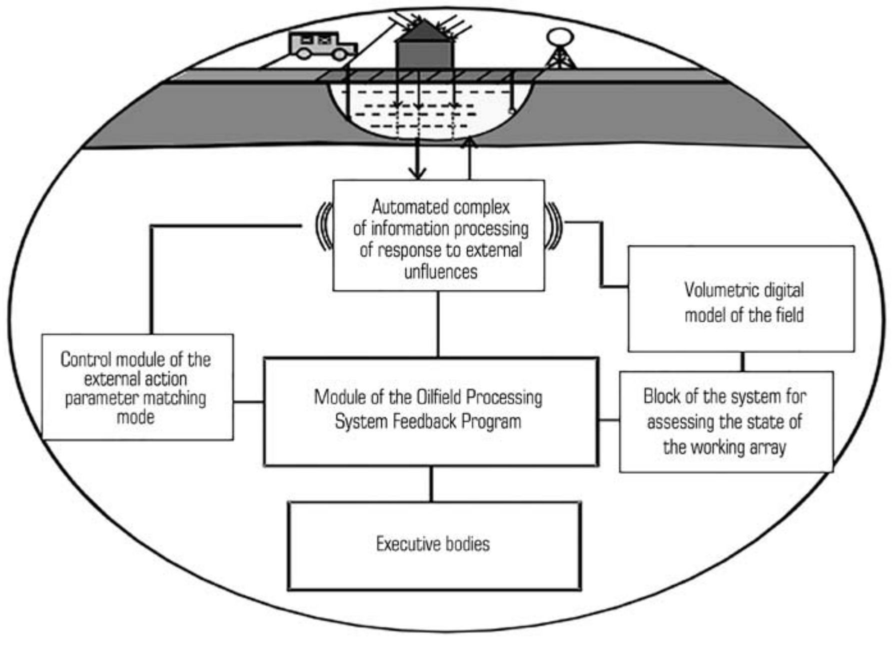

Fig. 3. Morphological scheme of oil refining in natural conditions

—the proposed functional scheme of the reactor complex for processing and/or refining of oil in conditions of natural occurrence allows to solve the following tasks:

—performance of works on creation of a feasibility study of the reactor method of oil raw material processing in the conditions of natural occurrence;

—development of the design documentation for the creation of an experimental polygon;

—manufacture, installation, fine-tuning of non-standard equipment to determine the optimal modes of exposure under the experimental oil reservoir conditions;

—conducting semi-industrial tests;

—preparation of technical specifications for creating a technological cycle of reactor oil processing in natural reservoir conditions;

—industrial tests and commissioning of the developed reactor technology;

—development of the full technological cycle for reactor oil refining in the oil reservoir;

—preparation of a feasibility study for using the working space of the lens for utilization of waste of organic and inorganic origin.

Thus, the solution of the problem of optimal nature management requires the study of systemic relationships of substances in different aggregate states. The construction of the corresponding matrices requires an integrated approach in the "impact-response" system [22, 23]. Then, the existing developments, covering all types of impacts, should be a scientific and practical foundation in this system [24].

Conclusions

1. For the first time is given a physical substantiation for the use of natural oil reservoirs in order to carry out processes of intensification of processing and/or processing of hydrocarbons in conditions of natural occurrence.

2. The spectral composition of variable impacts on the rock massif is experimentally substantiated and the possibilities of transforming the energy of external impacts by elements of the structure of rock components for different levels of consideration are determined.

3. The results of the experiments carried out in laboratory conditions have shown that in order to obtain effectively the given properties of the treated material it is advisable to coordinate the direction of the external influence on the treated fluid with the dynamic parameters of the main stress state of the rock massif.

4. Several ways of matching spatial and temporal parameters of external influence on the structural elements of the processed array, taking into account the natural frequencies of the productive formation and its components, as well as the possibility of converting the incoming energy are developed.

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