TOPICAL SCIENTIFIC RE-SEARCHES INTO RESOURCE-SAVING TECHNOLOGIES OF MIN-ERAL MINING AND PROCESSING

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MAGNETIC FIELD ON ASPHALT, RESIN, PARAFFIN AND SALT DEPOSITS

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Absract. The references of studies about the magnetic field effect on prevention of asphalt, resin, and paraffin and salt deposits formation in the oil are described in the article.

The effect of constant magnetic fields on the well production is currently one of the most interesting, leading to an increase in the overhaul period of the well. At the same time, this method is debatable, sometimes leading to ambiguous and contradictory results. In many cases, the nature of such effect is not properly studied. Often, according to some researchers, effect is discovered, whereas its intensity, on the basis of physical considerations, is clearly inadequate for the production of any useful effect. This refers to the type of magnetic effects, that is based on the principle of protection consisting in a sharp increase in 1000-100000 times the number of paraffins crystals nucleus by the action of static magnetic fields of topology and tension in the natural trace units - rod-shaped mineral oxides / hydroxides of iron are water, oil and gas production in the flow of production wells.

Key words: development of oil fields, asphalt, paraffins, resins, sediments, asphaltene deposits, salt deposits, the magnetic field, the magnetic anti-paraffin device.

Introduction.

Asphalt, resin, and paraffin deposits (ARPD) are one of the most serious complications in downhole oil production. They increase the filtration resistance of oil-bearing layers, clog the pores in the rock, and their deposits reduce the useful section of tubing and pipelines, while not taking countermeasures until their complete blockage. Asphalt, resin, and paraffins (ARP) decrease greatly overhaul period of the well (sometimes to 1-2 days), increase coasts and decrease the oil production [1].

The production of high-paraffin crude oil also creates significant environmental problems because of ARP are serious polluters of the environment. The deposits typically consist of the paraffins, resins and asphaltenes, wherein the total content of these components, the composition of each, and their ratio to various fields varies widely. Mainly, the composition consists of the paraffins (from 5 to 70 %); asphaltene and resin content may reach to 20%, moreover, in larger quantities of oil the latter are present in smaller amounts in comparison with resins [1].

Considerable problems in oil production can be created by the deposits of inorganic salts on the walls of tubing and equipment. Such deposits often form a very dense and mechanically strong layers, which not only reduce the cross-section of pipelines, but may even lead to jamming of moving parts (eg. submersible pumps), and its failure. To prevent, reducing the growth ARP and inorganic salts deposits and their removing, different mechanical, physical and chemical methods are used. Moreover, chemical methods became the most widespread. Thus, according to [1], a variety of chemical compounds are currently being processed about 10% of the wells complicated by ARP [1]. However, the use of chemical methods of protection against ARP deposits and organic salts, substantially increases the cost of oil, and often exacerbates environmental problems. However, the use of chemical methods of protection against deposits of paraffin and organic salts, substantially increases the cost of oil, and often exacerbates environmental problems.

Recent publications analysis. As experience of two decades shows, to improve the productivity and efficiency of high-paraffin crude oil, as well as to deal with the ARP deposits and inorganic salts are used magnetic devices are of high effectiveness.

In recent years there was published a large number of monographs, reports, articles in which lay emphasis primarily on the practical usefulness of magnetic treatment. There were held numerous conferences and meetings on the practical application of magnetic treatment in a wide range of industrial productions. Number of publications and patents on this subject is currently is calculated in the thousands, and even tens of thousands. An important role in maintaining interest in this direction was played by professor V.I. Klassen and academicians B.V. Deriahin and V.I .Lesin.

Emphasizing of recurring parts of the general problems. The simplicity of the procedure, consisting in the fact that the flow of the fluid flows through the gap between the poles of a magnet or the solenoid powered electric current, stimulated experimental work on a wide range of objects. Therefore, in the following years, magnetic treatment was applied not only for aqueous salt solutions but also for oil, motor fuels, solutions of polymers, drilling muds and cement, plant seeds, blood, etc. By using magnetic treatment the salinization was eliminated even when irrigation water with high salt content prevents the deposition of minerals and organic substances in the production and transportation of oil and water, achieved a significant reduction in viscosity slurries, etc. Widespread use of magnetic treatment was found in medicine to improve the condition of blood vessels, cleaning the blood from toxic substances, lowering a blood pressure [2].

However, in the early years, it was noted that the effects are not always repeated even for externally similar objects and processes. The effect of the magnetic field strength of several hundred oersteds on insensitive to such fields non-ferromagnetic materials - water, oil, blood, animal tissues and plants surprised greatly. All this has led to the fact that with respect to the magnetic effect two opposite opinions were formed: first - quackery and the result of "dirty" experiment, the second - at the heart of magnetic treatment are still unknown in the physics the fundamental properties of the matter. The scientific community is divided into the enthusiasts who continue to investigate the effects of magnetic treatment and the skeptics who did not take seriously the regular reports of the successful use of magnetic treatment [3].

Problem definition. In recent years, interest in the use of magnetic fields for the treatment of drilling fluid in order to prevent the ARPD has increased significantly, due to the appearance on the market of a wide range of high-energy magnets of rare-earth materials.

Basic material and the results. The most widely used were the devices found on the basis of permanent magnets. Structurally, they are comprised of one, two, three pairs of permanent magnets arranged in the case. The liquid flows through the gap between the two poles of the magnets.

However, in practice the application of magnets for specific oil fields, there are numerous cases where the magnetic treatment of oil does not give positive results. Available setbacks to some degree discredited the technology of magnetic treatment in the eyes of oil-industry workers. In fact, the problem complicating a widespread use of magnetic treatment is the absence of theory explaining the nature of the processes, particularly the physical and chemical mechanisms of a magnetic field effect on the flow of oil. Because of this, the conditions under which the magnetic field prevents the formation of solid ARPD, until recently, remained unclear. Considering the experience of these installations operation must meet the following requirements [4]:

- geometrically fit into the design of deep-pumping unit and does not to create a large hydraulic resistance;
- to ensure consistently the treatment of production fluid by a magnetic field with intensity of 20 - 40 kA / m, for at least 2-3 years;
- magnets should be secured and protected from aggressive action of products.

We proposed an original method for multi-reverse fields using a chain of permanent magnets. Using the device of this type, you can get multi-reversal (with a small number of reverse) magnetic field with predominantly perpendicular direction to the of fluid flow lines, with high intensity and gradient [5].

Devices of this kind are easily implemented with magnets installed into pipelines 2 (Fig. 1) and magnetized in a predetermined sequence, alternating directions of magnetization. Thus there is no difficulty in increasing number of reverses field. According to this principle a lot of magnetized devices were made. However, its use creates difficulties in a regions greater length obtaining with high-gradient fields.

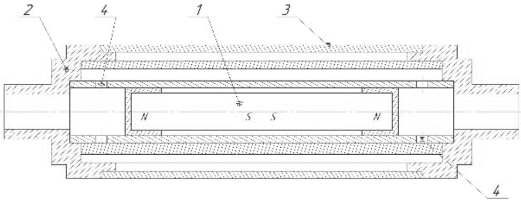

Fig. 1. MAPD construction:
1 – a chain of reverse unmagnetized permanent magnets;
2 – pipeline; *3* – outer casing; *4* – holes fluid input and output

Therefore, the regions of high-gradient fields usually constitute only a small part of the total channel length. Only in this small part of the length a fluids high magnetic treatment is carried out.

In this context, to improve the efficiency of magnetic devices and their mass and size characteristics, a special attention must be paid to the development of devices in which the areas of high-gradient magnetic field are placed inside of the unidirectional field.

Studies have shown that in passing water and in oil, even after their separation, always contain impurities of iron at a concentration of 10 to 500 g/t. These impurities are formed mainly with microcrystals of ferromagnetic oxides and hydroxides of iron in three crystalline forms, which are recorded in natural solutions of water and oil in the sediments. It was experimentally established the existence of ferromagnetic iron microcrystals formed by single microcrystals of a length 10-14 m.

It is experimentally established is the fact of aggregates disintegration of particles on individual particles under the influence of a magnetic field. These particles are additional centers of crystallization. In one tonne of oil total number of ferromagnetic microparticlesis in the range from 200 to 10 000 m^2, and the total surface area of one gram of particles is 20-40 m^2.

Microcrystalline ferromagnetic particles effect by electric charges, so that at their surfaces are adsorbed paraffins molecules, resins and asphaltenes which contained in the oil and which contain polar interclasts. In addition, due to the presence of water and heteroatomic impurities in the oil, water, gas mixtures such particles may exhibit hydrophobic - hydrophilic properties, in conjunction with high surface curvature of such particles reduces the energy consumption for the formation of these bubbles of gas phase and thus contributes to the absorption as cores of micelles in paraffin molecules. The experience proved complete absence or minor effect by using distilled water, which also confirms the validity of the proposed mechanism of magnetic influence [1, 2].

In addition, there are also data on the efficiency of magnetic treatment of water and oil, which is extracted to improve and reduce ARPD. According to the research and industrial use, in most cases it was possible to completely prevent ARPD for the period of about one year, and in some cases it was possible to achieve prolongation of the well cleaning interval from 1-2 days to 10-20 months. Growth of the injection capacity of layers ranged from 30 to 100%.

There is a number of other useful effects (growth completeness oil displacement, increasing the waterless displacement, and etc.) that increase the productivity of oil. It can be assumed that the role of magnetic device for treatment of oil, water or oil system is to create more centers of crystallization. When oil refining by the magnetic field due to the formation of additional centers of crystallization, paraffin crystals do not grow on the walls of the equipment and the amount of oil that leads to the decrease of ARPD growth.

The magnetic anti-paraffin device has been developed (MAPD) with internal placement of magnets inside the pipe and with a consistently placed permanently magnetized magnets chain, alternating the directions of magnetization. In the proposed design, each of these magnets pairs placed around the axis of the pipe at 180° along the length of the channel's relatively to previous so that each side of the pipe polarity facing her pole magnets, taking turns produce a multireverse magnetic field with any necessary length of the interaction and any areas with a total length high-gradient field.

It is necessary to mention that, despite the high visibility and credibility of the proposed explanation of mechanism for preventing and reducing ARPD, and it is difficult to obtain the necessary practical conclusions on the magnetic parameters of corresponding magnetic devices [3-6].

It should be noted that the use of magnetic treatment of liquids in oil extraction, even in spite of the multiplicity of its objectives, and achieved technical effects, does not use up the areas of its application.

MAD utilization increases between refining (overhaul) period of wells by direct magnetic field action. MAD mechanism is pointed at the subject of liquid viscosity change, that flows through the device (Fig. 2).

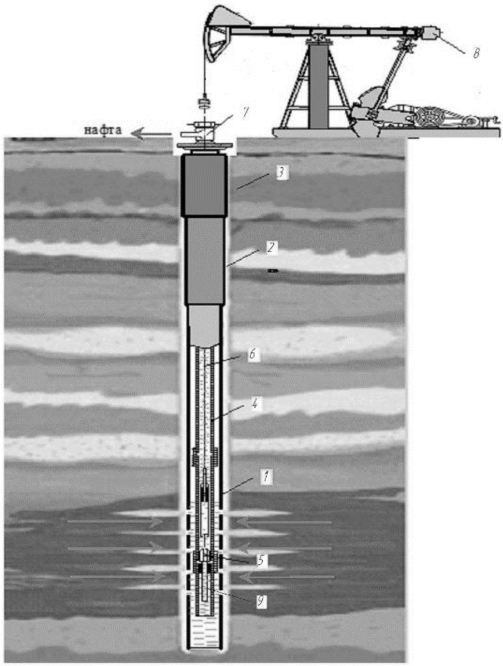

Fig. 2. MAD operational procedure in the well: *1* - capital string; *2* - intermediate string; *3* - surface casing; *4* - tubing; *5* - well pump; *6* - pump rod; *7* - tee; *8* - pumpjack; *9* - MAD

In MAD each of these pairs (blocks) magnets is rotated around the axis of the tube by 180° along of the channel's length in relation to previous so that each side of the pipe, polarity facing her pole magnets, alternating, create multi reverse magnetic field of any desired length of interaction region and with any total length of the sites with high gradient field.

The chain of cylindrical permanent magnets that is fixed in the conduit has reversible axial magnetization, created so that outer poles have the same polarity and opposite polarity is formed in the middle of its length that makes it possible to receive multi reverse magnetic field mostly perpendicular to the direction of fluid flow lines with high intensity and gradient.

Results of MAD COMSOL Multiphysics software modeling

a - The distribution of the magnetic induction in the MAD:

Magnetic induction is a vector physical value, the main characteristics of the magnetic field strength and direction. Magnetic induction vector is usually denoted by Latin letter B. In the CGS system the magnetic induction field is measured in gauss (Gs) in the SI-system - in Tesla (T).

The distribution of magnetic induction can be observed in Fig. 3 and 4.

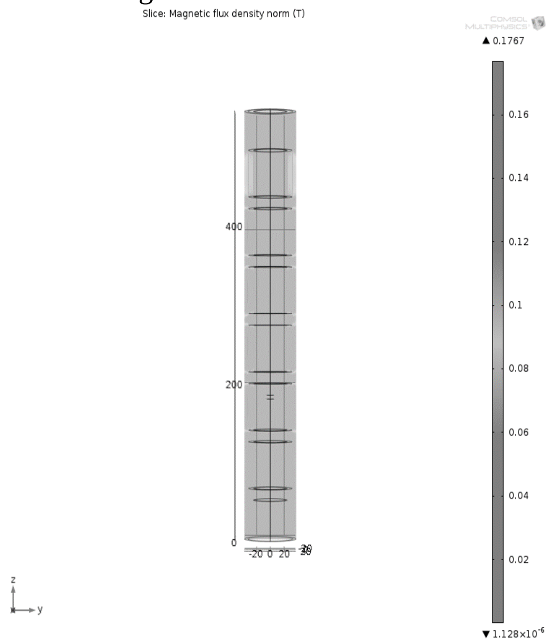

Fig. 3. The distribution of magnetic induction in the MAD

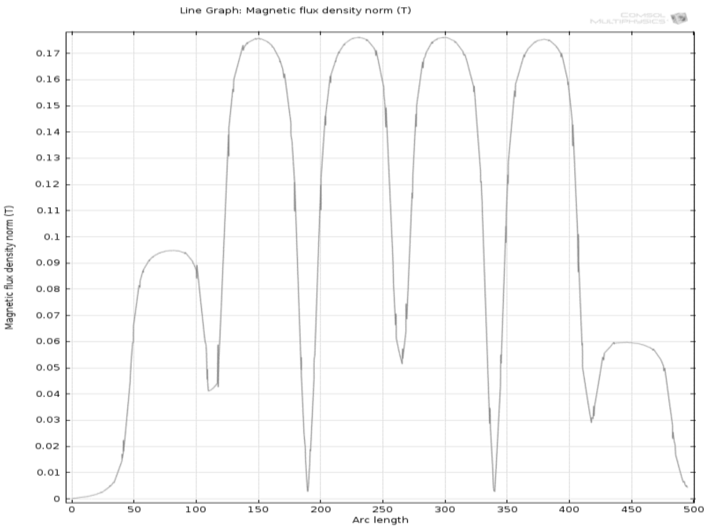

Fig. 4. The graph of magnetic induction distribution on the length of MAD

As a result of obtained values, we can see that while the maximum residual magnetic induction of 150 mT, which we pre-assigned in the initial terms in Figs 2 and 3, the maximum value after calculation is 187,5 mT. This change can be easily explained by the fact that the pipe is made of steel, which is ferromagnetic, i.e. the magnetic field strength increases, so we observe the pipe magnetization process.

When building a computer model of MAD, six blocks of axially magnetized permanent magnets were formed. The distance between them was 15 mm. The first pair of blocks has a magnetic induction of 50 mT and 150, respectively. The next pair was magnetized to the same values of 150 mT and was returned at 180° in relation to the previous block so that the second block of the first pair and the first block of the second pair were rotated to each pole of the same pole. The latter, the third pair of blocks was also returned at 180° relative to the previous and the first block of third couple had a magnetic induction of 150 mT, the second - 80 mT.

b - The distribution of the magnetic field in the MAD

The magnetic field strength is a vector characteristic that determines the magnitude and direction of the magnetic field at present point and present sample time.

It is usually denoted by Latin letter H, measured in Oersted in the CGS electromagnetic system and ampere-turns per meter (*A·V/m*) in the SI system [7].

The distribution of the magnetic field depicted in Fig. 4 and 5.

After obtained results we can see that the concentration of magnetic field strength is observed at the end points of the magnets. On the graph is clearly observed a significant potential drop in the range of 190 and 340 mm due to the fact that the given points a pair of magnets rotated to each other with the same poles, i.e. there is some «compensation» of the magnetic field.

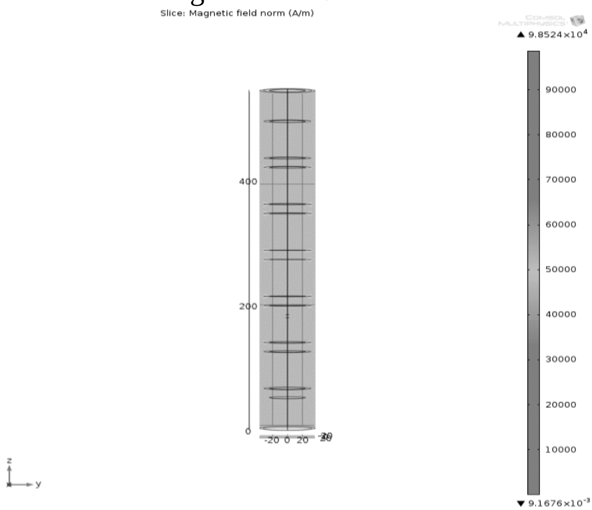

Fig. 5. The distribution of the magnetic field in the MAD

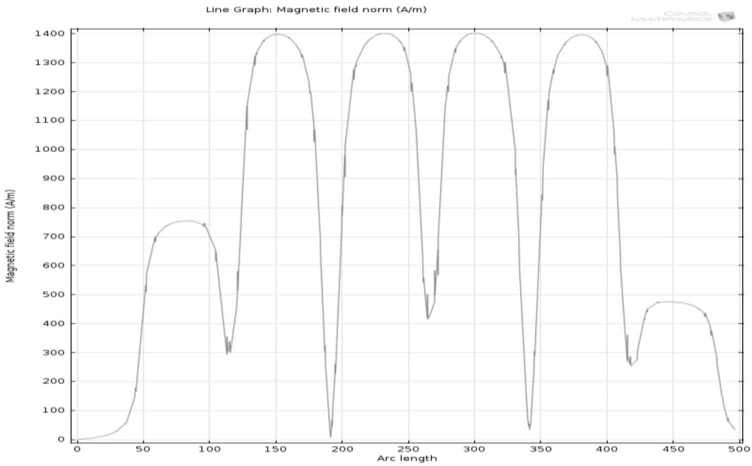

Fig. 6. Graph of the magnetic field distribution along the length of installation

c - Distribution of the scalar potential in the MAD

Vector field scalar potential A (often a potential vector field) **-** is a scalar function such that at all points of the domain of the field $A = \text{grad}\phi$ where $\text{grad}\phi$ denotes the gradient. In physics, potential is a magnitude, converse (force potential, power potential of the electric field).

Distribution of the scalar potential in the MAD is depicted in Fig. 7.

The maximum and minimum values of the scalar potential are observed in places where the magnetic blocks converge rotated to each other with the same poles [7].

d - Influence of MAD on mechanical impurities

Magnetic treatment of fluids long and widely used also to improve corrosion resistance of pipes and boiler equipment in water and heat to improve crop yield in agriculture irrigation systems for desalination of soil in irrigation systems to improve the effectiveness of drugs and medical procedures, and for many other purposes.

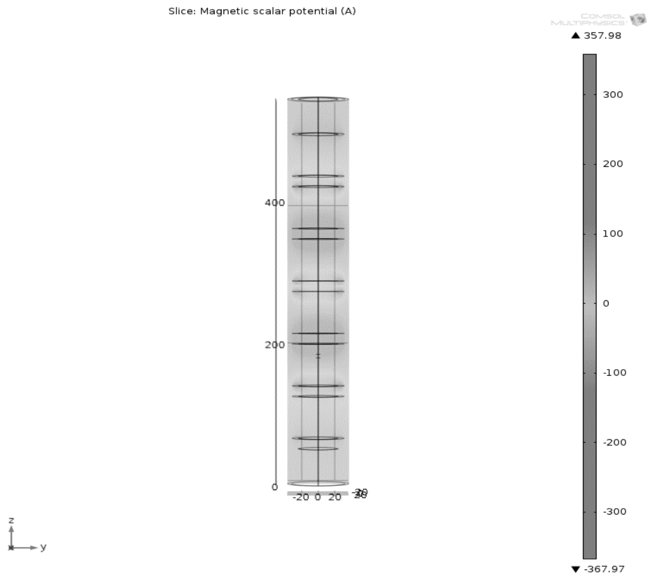

Fig. 7. Distribution of the scalar potential in the MAP

The presence of impurities in the flow of oil fosters formation of ARPD crystallization centers, so if you remove these elements from the stream, the rate of sediments formation will significantly reduce. In Figure 8 is depicted how the MAD effects on mechanical impurities. In the process of modeling into the liquid flow was put a piece of cylindrical metal in radius and height of 5 mm. Usually, these particle sizes in the oil are extremely rare, but for the visualization of magnetic field influence such simplification will to be appropriate.

As can be seen, the magnetic field affects the mechanical impurity that is evidenced by the line flow. Thus there is a definite change in the magnetic field around the metal impurities. This is the process of agglomeration and removal of fluid flow particles can serve to the formation of ARPD.

In Fig. 9, one can observe the patterns of magnetic field lines distribution. It should be noted that the magnetic field passes through the oil and has impact on the entire internal environment.

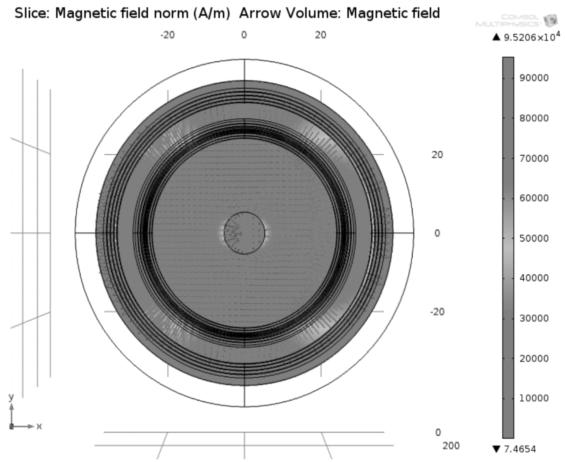

Fig. 8. Influence of magnetic field on mechanical impurities

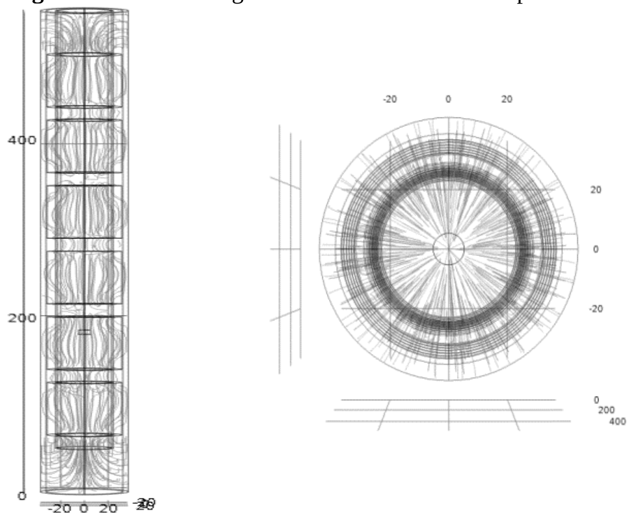

Fig. 9. Lines of the magnetic field

e - Graphs, showing the patterns of magnetic fields distribution

For better clarity, in Fig. 9 and 10 the magnetic field lines and the 3D model of the distribution of magnetic induction are exemplified.

Different color intensity of the first and sixth magnets caused by the fact that they have a magnetic induction of 50 mT and 80, respectively, and all the latest 150 mT. Also, on the border between 2-3 and 4-5 there is a significant drop in magnetic induction, due to the fact that these magnets are rotated to each other with the same poles.

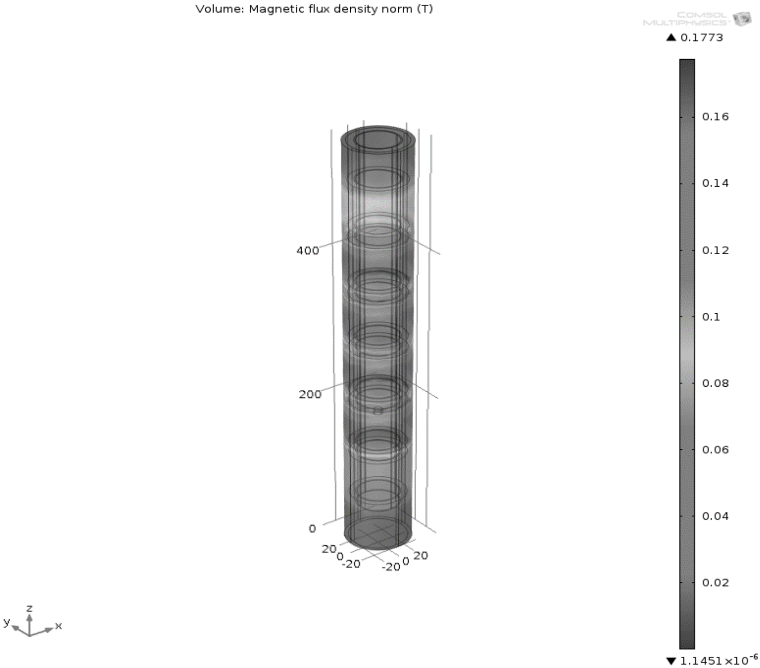

Fig. 10. 3D model of magnetic induction distribution

It is not clear, however, about the optimal parameters of the field that are needed to separate aggregates of microcrystals. It can be also assumed that at sufficiently high content of ferromagnetic microcrystal aggregates of iron in water oil system it may be quite sufficient the creation of necessary fields only in a limited part of the magnetic devices channel or magnetic treatment of oil. This helps to explain the practical effectiveness for devices with high performance magnetic fields only in small parts of the cross section of their working channel. Therefore, it should be emphasized that the presence of ferromagnetic particles is regarded as experimentally established fact.

This lists the application of magnetic treatment now can be considered as a well-established and traditional, with a wealth of accumulated experience in the development and operation of the relevant magnetic devices.

However, in recent years it began to appear a lot of new, innovative applications of magnetic treatment. These include, for example, increasingly spreading practice of using magnetic devices for natural gas and fuel for internal combustion engines. It is considered that the magnetic fuel treatment improves the completeness of its combustion, reduces costs, and simultaneously improves the sustainability of such engines. The new, innovative applications refer the usage of magnetic treatment for disinfection of water and other liquids, as well as for preserving food [7].

It is still difficult to apply some of the above hypotheses about the mechanisms of magnetic effect.

Conclusion. Thus, the application practicability and prospectivity of magnetic treatment is confirmed by the positive experience of its use and spreading in the various regions, not only in Ukraine but also abroad.

The description of magnetic devices modeling, ranging from theoretical concepts to the formulas used in the calculation, are exemplified in the work.

The theoretical and laboratory studies have allowed us to use the results of MAD on wells of highly paraffinic crude oil.

The modeling process of constant magnetic field on the fluid that moves through tubing, especially by the distribution of magnetic fields in the environment, has been held.

In the process of modeling various reservoir fluid properties have been used, as they affect the environment and the permeability and change the intensity distribution of the magnetic field characteristics in the flow of liquid.

The illustrative modeling results allow observing the work of the magnetic anti-paraffin waxes device.

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