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MECHANISM OF MAGNETIC FIELD EFFECT ON HYDROCARBON SYSTEMS

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МЕХАНІЗМ ВПЛИВУ МАГНІТНОГО ПОЛЯ НА ВУГЛЕВОДНЕВІ СИСТЕМИ

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ABSTRACT

Purpose. The aim is to analyze the problem of preventing the asphalt-resin-paraffin deposits (ARPD) in the oil industry equipment and to justify application of paraffin control methods; to review modern approaches to ARPD problem and possible methods of its solution; to analyze existing methods of hydrocarbons 'treatment by magnetic field.

Methods. Investigations showed that application of magnetic anti-paraffin device (MAPD) makes it possible (during 24-hour operation of the oil well) to double the time between overhauls of oil wells equipped with sucker rod pump installations.

Findings. The results obtained due to MAPD application in oil wells equipped with sucker rod pumps give an opportunity to use it in oilfield practice employing free-flow production method or in wells serviced by centrifugal pumps and in oil pipe lines.

Originality. Application of up-to-date magnets with poles from 60 to160 kA/m enables to decrease ARPD in oil equipment.

Practical implications. The results of MAPD implementation at Boryslav field, in particular in wells No 1343, 797, 948 proved the efficiency of the device application and doubled the overhaul period. Magnetic field effect on hydrocarbons is analyzed in the article.

Keywords: *magnet, hydrocarbon systems, well, magnetic treatment; oil, asphalt, resin and paraffin deposits*

1. INTRODUCTION

Insufficiency of world oil resources brings about the necessity to actively develop and use the fields with a comparatively low well output and also fields located far away from densely populated regions, with difficult oil production conditions, high viscosity of oil and with considerable content of impurities. One of the most harmful impurities is ARPD.

Depending on the composition, physical and chemical properties of ARPD contained in oil, and the properties of oil produced in certain fields, ARPD could vary significantly in terms of production and transportation of produced oil. Besides productivity reduction and significant decrease in economic performance of oil production and transportation, the presence of ARPD leads to environmental deterioration as a result of all these processes, as during oil refining, deposits are becoming detrimental environmental pollutants (Klassen, 1982).

Currently, despite a large number of works devoted to the study of the mechanism responsible for magnetic field effect on oil, water-oil and water systems, there is no single, universally accepted and established view on the essence of processes involved. However, oil extraction is often related to water and water-oil systems.

Given uncertainty of the magnetic field effect on water and water systems, different hypotheses and ideas about this mechanism are subdivided into three main groups. One of these groups relates the magnetic effect to the influence of the field on salt ions which are always present in water. The effect of the field results in polarization and deformation of ions, which increases the probability of their convergence and promotes the formation of crystal nuclei (Klassen, 1982; Nalivaiko, Mangura, Mangura, & Nalivaiko, 2015).

The second group includes hypotheses about the alleged effect of the field on water impurities that are in the colloidal state. Finally, the third group suggests a possible effect of the magnetic field on the structure of water. Consequently, the field could cause changes in the aggregation of molecules and disorientation of hydrogen nuclear spins in molecules. It is also assumed that changes in physical properties (structure, density, viscosity, surface tension, etc.) depend on magnetic susceptibility of water and ions contained in it.

During the magnetic treatment of water-dispersed systems, the precession of the outer electron clouds in molecules is taking place. Molecules acquire induced magnetic moment directed oppositely to external field. It leads to changes in hydrogen bonds energy, their partial rupture, changes of molecules relative position, and, for this reason, changes in the structure and physical properties of water.

Effect of magnetic field on the corrosion activity of water systems was experimentally established long ago (in 1960s) and mass production of various magnetic anti-corrosion and anti-scaling devices began more than five decades ago. Effective anti-corrosion impact of magnetic treatment and its benefits for destruction (dissolution) of accumulated layers of scale have been known for quite a while (Klassen, 1982).

However, the corrosion-resisting mechanism of magnetic treatment effect has not be accurately described so far. It is assumed that reduction of water corrosion effect can be explained by changes in the activity of dissolved oxygen which can be activated under the influence of the magnetic field and form ferromagnetic oxides that protect the metal surface from corrosion.

One important drawback of the proposed general explanation of the mechanism is impossibility to establish links between corrosion resistant efficiency of magnetic treatment and parameters of the magnetic field. Contradictory experimental data significantly contribute to this confusion. There are also quite compelling and elegant hypotheses about the mechanism of the magnetic effect on ARPD (Tung et al., 2001). One of the arguments of such hypotheses is the idea that given the absense of the magnetic field, ARPD appear on equipment cold metal surfaces mainly because of ARPD inclusions movement in the radial direction. These diffusion processes play only a minor role in the growth of deposits, radial movement being inherent to any suspended particles in a flow, when the particles' density differs from the density of the liquid (Zhang, Wang, Li, & Zhang, 2013).

2. THE MAIN PART

Studies have shown that in associated water and in oil, even after their separation, always contain 10 to 500 g/t of iron impurities. They consist mainly of microcrystals of ferromagnetic oxides and iron hydroxides in three crystalline forms that are recorded in natural water solutions and oil sediments. Experiments proved the existence of ferromagnetic iron microcrystals aggregates formed by single microcrystals 10 – 14 m long. It is experimentally established that such aggregates disintegrate into separate particles under the effect of the magnetic field. These particles are additional centers of crystallization which increase the area of internal absorption by orders of magnitude. In one tonne of oil, the total surface of ferromagnetic microparticles is within the range from 200 to 10000 m^2, and the total surface of one gram of particles is 20 – 40 m^2.

Microcrystalline ferromagnetic particles possess electric charges, so their surfaces adsorb paraffin, resin and asphaltene molecules contained in oil. These molecules comprise polar interclasts. In addition, due to the presence of water and heteroatomic impurities in oil, water, and gas mixture such particles may exhibit hydrophobic or hydrophilic properties, which, together with high surface curvature of such particles significantly reduces the amount of energy consumed for the formation of gas phase bubbles on their surface and thus contributes to the absorption of paraffin molecules as on micelles cores. Experience showed that the effect was completely absent or insignificant when distilled water was used, which also confirms validity of the proposed mechanism of magnetic effect (Klassen, 1982; Nalivaiko, Mangura, Mangura, & Nalivaiko, 2015).

In addition, there are also data on the efficiency of magnetic treatment of water and oil, which is extracted to improve injection capacity 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 in the injection capacity of layers ranged from 30 to 100% (Zhang, Wang, Wang, & Zhang, 2015).

There is a number of other useful effects (increase in oil displacement efficiency, longer period of waterless displacement, and etc.) that raise the productivity of oil extraction. It can be assumed that the role of magnetic device in treatment of oil, or water-oil systems consists in creation of more centers of crystallization. When oil is refined by the magnetic field, due to the formation of additional centers of crystallization, paraffin crystals grow not on the equipment walls but in the oil volume which leads to the decrease in intensity of ARPD growth (Chow et al., 2000).

MAPD presupposes internal placement of magnets inside the pipe and consistent placement of permanently magnetized chain of magnets with alternating directions of magnetization. In the proposed design, each of these magnet pairs is placed at 180° relative to the previous one around the axis of the pipe along the length of the channel so that each of the pipe side polarity facing its magnet poles, taking turns, produces a multi-reverse magnetic field with any necessary length of interaction area and with any total length of areas of high-gradient field.

It is necessary to mention that, despite high variability and credibility of the proposed explanation of mechanism for preventing and reducing ARPD, it is difficult to obtain practical conclusions about the necessary magnetic parameters of corresponding magnetic devices (Nalivaiko, Mangura, Mangura, & Nalivaiko, 2015).

MAPD application increases the time between well overhauls due to direct magnetic field action. MAPD mechanism changes viscosity of the liquid flowing through the device (Fig. 1).

It is not clear, however, which parameters of the field intensify separation of ferromagnetic microcrystal aggregates and micelles formation. It can be also assumed that at sufficiently high level of ferromagnetic microcrystal aggregates' content in water-oil system it may be feasible to create the necessary fields only in a part of the magnetic device channel. This helps to explain the practical effectiveness of magnetic fields for devices with high performance only in small parts of their working channel cross section. Therefore, it should be emphasized that the presence of ferromagnetic particles is regarded as experimentally established fact.

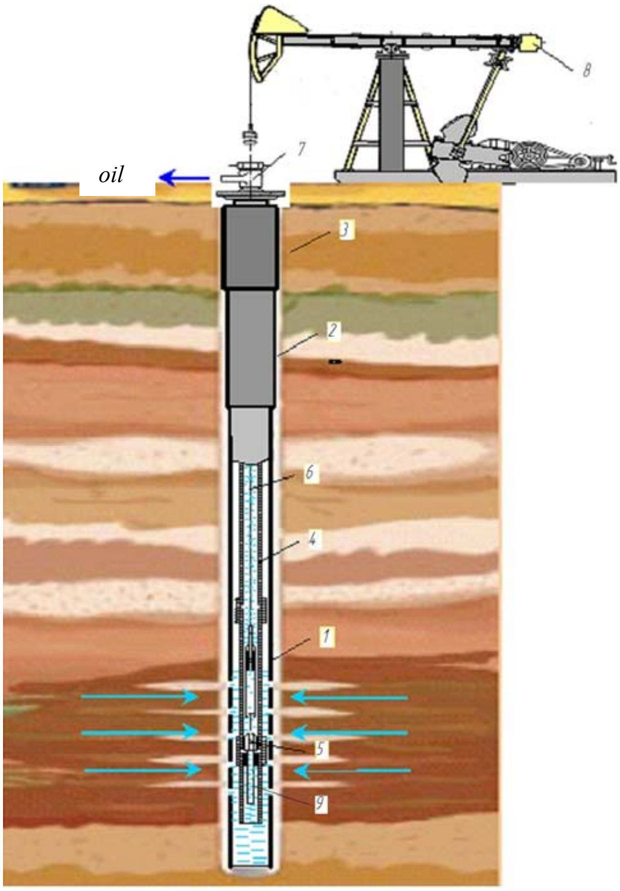

Figure 1. MAPD operation layout in the well: 1 – capital string; 2 – intermediate string; 3 – surface casing; 4 – tubing; 5 – well pump; 6 – pump rod; 7 – tee; 8 – pump jack; 9 – MAPD

It should be noted that the use of magnetic treatment of liquids in oil extraction, in spite of multiplicity of its objectives and achieved technical effects, goes much beyond the mentioned areas.

Magnetic treatment of fluids for a long time has been used to improve corrosion resistance of pipes and boiler equipment in systems of water and heat supply; 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. This list of magnetic treatment applications can now be considered well-established and traditional, with a wealth of accumulated experience in the development and operation of the relevant magnetic devices.

However, recently a lot of innovative applications of magnetic treatment have appeared. These include, for example, increasingly widespread practice of using magnetic devices for natural gas and fuel treatment for internal combustion engines. It is considered that the magnetic fuel treatment improves fuel combustion efficiency, reduces costs, and simultaneously improves environmental friendliness of such engines. Among new applications we should also mention usage of magnetic treatment for disinfection of water and other liquids, as well as for preserving food (Zlobin & Alivanov, 2011).

These unconventional beneficial effects can hardly be explained by any of the above hypotheses about the mechanisms of magnetic effect.

3. CONCLUSIONS

Magnetic effect on various liquids and gaseous materials and a variety of mechanisms of such effect are very broad but still not well studied in practice. 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 the unidirectional field.

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ABSTRACT (IN UKRAINIAN)

Мета. Проаналізувати ефективність застосування магнітного поля на вуглеводневі системи. Викласти сучасні погляди на стан проблеми асфальтосмолистопарафінових відкладень (АСПВ) у нафтопромисловому обладнанні та можливі методи її розв'язання. Подати короткий перелік існуючих методів обробки вуглеводневих систем магнітним полем.

Методика. Дослідами встановлено, що застосування МАП (магнітного антипарафінового пристрою) дає можливість (при цілодобовому режимі роботи свердловини) в середньому збільшити у два рази міжремонтний період роботи нафтових свердловин, які обладнанні штанговими свердловинними насосними установками.

Результати. Отримані результати використання МАП у нафтових свердловинах, які обладнанні штанговими свердловинними насосними установками, дають можливість використовувати його у нафтопромисловій практиці при експлуатації свердловин фонтанним способом або свердловин, що експлуатуються електровідцентровими насосами, а також на нафтопроводах.

Наукова новизна. Використання новітніх магнітів з багатореверсними полями від 60 до 160 кА/м дозволяє зменшити відклади АСПО на нафтовому обладнанні.

Практична значимість. Результати впровадження МАП на Бориславському родовищі, а зокрема на свердловинах №№1343, 797, 948, довели ефективність використання даного пристрою, що призвело до збільшення міжремонтного періоду у два рази.

Ключові слова: *магніт, вуглеводнева система, свердловина, магнітна обробка, нафта, асфальтосмолистопарафінові відклади*

ABSTRACT (IN RUSSIAN)

Цель. Проанализировать эффективность применения магнитного поля на углеводородные системы. Изложить современные взгляды на состояние проблемы асфальтосмолистопарафиновых отложений (АСПО) в нефтепромышленном оборудовании и возможные методы ее решения. Привести краткий перечень существующих методов обработки углеводородных систем магнитным полем.

Методика. Опытами установлено, что применение МАП (магнитного антипарафинового устройства) дает возможность (при круглосуточном режиме работы скважины) в среднем увеличить в два раза межремонтный период работы нефтяных скважин, оборудованных штанговыми скважинными насосными установками.

Результаты. Полученные результаты использования МАП в нефтяных скважинах, оборудованных штанговыми скважинными насосными установками, дают возможность использовать его в нефтепромысловой практике при эксплуатации скважин фонтанным способом или скважин, эксплуатируемых центробежными насосами, а также на нефтепроводах.

Научная новизна. Использование новейших магнитов с многореверсными полями от 60 до 160 кА/м позволяет уменьшить отложения АСПО на нефтяном оборудовании.

Практическая значимость. Результаты внедрения МАП на Бориславском месторождении, а в частности на скважинах №№1343, 797, 948, доказали эффективность данного устройства, что привело к увеличению межремонтного периода в два раза.

Ключевые слова: *магнит, углеводородная система, скважина, магнитная обработка, нефть, асфальтосмолистопарафиновые отложения*

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