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Development of technologies for increasing the efficiency of well equipment and oil-pipe pipelines

Oil and gas

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One of the topical problems in increasing the working capacity of downhole equipment and oil collecting pipelines is considered. In this connection, the facing corrosion-resistant, impact-resistant, anti-wear and anti-scratch composite plastic material based on polyester resins reinforced with basalt fiber was developed. The essence of technology is the lining of steel pipes with basalt plastic shells. The technology provides for pipe cladding directly at the factory and in the conditions of the pipe repair facilities. Also investigated and recommended for the application of casing strings, oil collector pipes and pump rods of pure basalt plastic for use in the highly corrosive oilfields. The efficiency of oilfield equipment in the environment of the extracted products depends on the durability of the material from which it is made, as well as the operating conditions of the deposit, the period of its development.

Key words: downhole equipment, oil collecting pipelines, corrosion-resistant, anti-wear and anti-scratch composite plastic material, basalt plastic pipes, corrosion - erosion wear.

Introduction

The increase in technical and economic indicators of oil and gas production is largely due to the increase in well operability and providing the high reliability of equipment and pipelines. Experience in field development shows that a decrease in the level of protection of oilfield equipment and pipelines in conditions of corrosion aggressiveness leads to a sharp increase in damage from corrosion. Oilfield pipelines, a system of inside gathering and transport of oil, are subject to intensive corrosion because of the content of aggressive, mineral water in the mined production. The efficiency of oilfield equipment in the environment of the extracted products depends on the durability of the material from which it is made, as well as the operating conditions of the deposit, the period of its development.

Statement of the problem

Corrosion - erosion wear, which is a complex process of destruction of the surface of metal equipment under the influence of physical and chemical and mechanical impact of the environment is the main factor that determines the efficiency of well equipment. It is a consequence of two simultaneous processes: electrochemical (rarely chemical) corrosion and mechanical destruction of products of corrosion and metal. Corrosion processes in oil wells are mainly electrochemical. According to the nature of the destruction of metal, general (entire) or local corrosion is distinguished. Entire corrosion covers the all surface of the metal and is uniform and uneven. Local corrosion is usually concentrated in separate areas. The most common in practice are ulcerative, pitting, intercrystallite and corrosive cracking. Ulcerative and pitting corrosion are the greatest danger for pipelines, tanks, gangways, etc., since in this case, a breach of the sealing of the transportation and storage system of oil and oil products is possible. Intercrystallite corrosion and stress corrosion cracking are most dangerous for structures carrying load. They can lead to catastrophic destruction of the metal. An example of such structures are casing strings, pump-compressor pipes, depth pump rods, etc. The intensity of the corrosion process depends on the aggressive properties of the oil and gas system, including oil, the associated reservoir water containing mineral salts and dissolved in them natural (hydrocarbon) and aggressive gases (hydrogen sulphide, oxygen and carbon dioxide).

Solution of the problem

In recent years, the use of corrosion inhibitors has got widespread as the main anticorrosive measure. They are used to protect mainly underground equipment of production wells and partly for prefabricated collectors at those sites where this technology is implemented. There is experience in the use of steel pipes lined with polyethylene cover and the construction of pipelines from polyethylene pipes. Based on the conditions of operation of oilfield pipelines, the requirements for new materials as protective coatings should be increased in terms of chemical resistance to aggressive media, mechanical strength, especially impact resistance, heat resistance, and wear resistance under the influence of mechanical impurities contained in transported products. On the other hand, a prerequisite for selecting new materials should be their availability, i.e. availability of industrial production. Experience shows that paint coatings, bitumen, polymer coatings and even on the basis of good insulating materials do not provide reliable anticorrosion protection of steel pipelines when operating in aggressive environments of oil fields, because of the rapid disruption by transported products containing mechanical impurities, salts, sand, asphalt-tar-paraffin deposits, etc.

The use of polyethylene pipes, although provides long-term resistance of pipelines in the transport of aggression, however, it has inadequate strength, heat resistance in hot climate conditions, because of which the polyethylene pipes are deformed under the influence of heat. For the reliable protection of oilfield pipelines against corrosion and erosion wear, the properties of one of the polymer composite materials – basalt-plastic – were investigated. In this material, a polyester resin (depending on the aggressiveness of the medium) is used as the matrix, and basalt fiber is used as the reinforcing filler [1]. To define the chemical stability in the aggressive environments of oil fields, performed long-term experiments (up to 1 year) with samples of basalt plastic in 12 different oil environments, which consist of oil of different quality, the chlor-alkalic and hydro-carbonate sodium type formation waters of the of various mineralization, containing carbon dioxide and hydrogen sulphide, oil-gas and water systems of these components in a wide range of combinations of the oil and water. In some media, hydrogen sulphide content reached 1000 mg / l. The corrosion rate of steel 45 in these media ranged from 0.15 to 2.16 $g/m^2.h$ (except for clean oil environments). Samples of basalt plastic were also tested, in a concentrated acid environment - hydrochloric and sulfuric. Evaluation of the durability of basalt plastic in aggressive media in time was carried out by changing the weight of the samples, the presence of swelling of the material, and the change in the geometric dimensions of the samples. As a result of the conducted experiments it was established that basalt plastics are very resistant in all aggressive environments of oil fields in Azerbaijan, including in light and heavy oils, in mineralized reservoir waters and in oil and water mixtures. The change in the weight of the samples was tenth and hundredths of a percent, with no change in their geometric dimensions. Weakly resistant were the basalt-plastics in concentrated sulfuric and hydrochloric acids. For 320 days, samples of basalt-plastic samples in concentrated hydrochloric acid lost in weight of 14% and swelling and stratification of the material took place in concentrated sulfuric acid with a weight gain of 20%. However, in practice, when the 22% concentration is affected by the bottom hole zone of hydrochloric acid, contact with the structure can only be short-term, i.e. for no more than 1 hour (during the acid treatment), so this process does not represent a particular hazard for lined basalt-plastic steel pipes. Sulfuric acid treatments in our oilfields are not carried out. Basalt plastics have a significant advantage over other plastics in terms of strength characteristics. Thus, the compressive strength in basalt-plastic is 250 MPa, and for high-density polyethylene it is 20-32 MPa, for low-density polyethylene 10-12 MPa, for polypropylene 25-26 MPa. The tensile strength at basalt-plastic is 85-95 MPa, and for high density polyethylene 23 MPa, low density polyethylene 11 MPa, for polypropylene 30 MPa. The coefficient of linear expansion of basalt plasticity compared with carbon steel is 1.3-1.8 times, the tensile strength is 1.7 times, the specific strength is 7 times greater, and the modulus of elasticity and the coefficient of thermal conductivity are 7 and 118 times lower, respectively. In this material, a polyester or epoxy resin is used as the matrix, and basalt fiber is used as reinforcing material. Basalts are highly stable igneous rocks, whose reserves in the world are practically unlimited and make up from 25 to 38% of the area occupied by all magmatic rocks on Earth. From basalt rock it is possible to obtain harmless to the human body basalt fiber in a one-stage process, this causes their lower cost (15-20%) in comparison with other fibers. At the same time, 1 kg of basalt raw material produces almost 1 kg of finished high-quality fiber. Basalt fiber is a perspective material for the production of new composite materials - basalt plastics and products from them that do not burn, and the alloys of the rock itself are not hygroscopic and do not emit moisture.

An example is the operability of basalt fibers in a wide temperature range from - 260 to +1000°C. As raw material for the production of basalt fibers, basalt rocks are used whose average chemical composition is the following (% by mass): SiO2 (47.5 - 55, 0); TiO2 (1.36 - 2.0); AI2O3 (14.0 - 20.0); Fe2O3 + FeO (5.38 - 13.5); MnO (0.25-0.5); MgO (3.0-8.5); CaO (7.0-11.0); Na2O (2.7-7.5); K2O (2.5-7.5); P2O5 (no more than 0.5); SO3 (no more than 0.5); other breeds (no more than 5). Strength of insulating shells from basalt plastic determined in the manufacturing process: pressing, winding, molding, pultrusion (obtaining for profiles of different cross-section) and other methods. Basalt plastics in many respects (resistance to aggressive environments, strength, rigidity, heat resistance), surpass fiberglass - fibers from simple alkaline glass. The cost of basalt fibers is much cheaper than others, for example, glass, organic, coal, etc. The fact is that for basalt fibers one component is required - basalt, which in nature has an unlimited amount. The purpose of this technology is increasing the effectiveness of protection against corrosion and wear, to create impact-resistant protective coatings (casings) in steel pipes - casing, pump-compressor pipe and cylindrical equipment operating under high operating pressures, temperatures and flow rates of corrosive media containing mechanical impurities, as well as subjected to impact-abrasion and hydro-abrasive effects. Isolation work is carried out on the radial-intercross winding device. To this end, supporting bushings are fixed to the pre-prepared surface of a cylindrical-shaped pipe or cylindrical steel parts (shot blasting, cleaning, degreasing, drying) and they are installed in the machine holders. Further, a layer of the shell from the thermosetting binder impregnated with basalt fiber is spirally-cross-wound onto the pipe or part. As a binder, thermochemical polymer compositions based on polyester, epoxy, polyurethane, furan resins or their compositions are used (Fig.1 and 2). Casing strings of oil wells are the most responsible type, underground equipment, ensuring the reliability and durability of this mining equipment for oil production. In addition to high strength indicators, the material of the tubular steels from which the casing is made must have a high corrosion resistance. In this direction, certain measures are being taken, nevertheless, the cases of corrosion damage to casing strings are quite frequent, this leads to a violation of the tightness of the well and, as a result, the inflow of water into it and other complications. One of the main causes of leakage of casing pipes is their corrosion damage due to the influence of aggressive external environments. The corrosion protection of casing strings in production and injection wells is usually carried out with corrosion inhibitors. However, only the inner surface of the casing is protected, and the outer surface cannot be treated with inhibitors. The plugging of production columns as well as intermediate technical columns is not always done up to wellhead, as a result of which part of the outer surface of the casing pipes is in direct contact with rocks that can carry aggressive mineralized waters, besides saturated gases - hydrogen sulphide and carbon dioxide. For the insulation of the outer part of the casing strings, composite basalt-plastic casings with the spiral-crossover winding are offered.

Fig.1. Steel pipes (collector) covered basalt plastic materials

Fig.2. Tubular steel pipes (flow lines) covered basalt plastic materials

The use of such pipes should solve a number of serious problems: increasing the corrosion resistance of columns casing due to their high mechanical and physic-chemical resistance, providing control of the production of reserves of productive deposits by geophysical methods. In recent years, the researchers of the leading countries have been paying close attention to the production of casing strings, tubing, pumping rods and within the pipeline oil collection and transportation systems from pure plastic - fiberglass, basalt plastic, etc. Studies on the use of plastics in the construction of wells are multifaceted, as they consider the rationale for the most suitable type of plastics from the many available, taking into account their subsequent operation, the development of equipment and pipes. Casing pipes during the construction of wells and subsequent operation are susceptible to axial extension (up to 200kN) and compression (up to 400kN), internal and external pressure (up to 20 MPa), bend with maximum wellbore curvature 45^o, with temperature on bottom hole up to 90^oC, containing corrosive hydrogen sulphide, carbo and dioxide and oxygen. The analysis of the magnitudes of the influencing factors makes it possible to make a choice for the purpose of fastening casing wells from reinforced plastics with higher strength and chemical resistance to product of the well. The qualitative construction of the wells provides a reliable grip of a plugging stone used for cementing casing strings. Studies have shown that the adhesion value of a grouting stone with the surface of basalt-plastic pipes is higher than for a metal and are respectively equal to: a shift of 3.8 MPa and 0.7 MPa, a 9-MPa hydrobreakthrough in basalt plasticity. At the same time, it is established that the amount of adhesion of a grouting stone to a certain extent can be controlled by the introduction of various modifiers into a grouting stone. To assess the quality of casing cementing acoustic cement meters are used. Studies have shown that the existing equipment basically controls the quality of the contact of the grooved stone with the rock, since the propagation velocity of the longitudinal wave along the plastic column is mostly lower than that of the main types of rocks. A clear dissection of waves along the column and rock in the presence of a cement ring is possible with a probe length of more than 70 mm. To ensure the hydrodynamic connection of the reservoir with the well, the possibility of using existing perforators for perforating the basalt-plastic column was evaluated. When perforating holes in the boreholes at a depth of 800-1000 m, holes of 6-7 mm are formed in the basalt-plastic pipes. Violations of their integrity, cracking and delamination are not observed. Thus, the obtained results of the research made it possible to recommend basalt-plastic pipes for the application of casing strings instead of metal casing in depth up to 2000 m. However, for today, despite the positive experience of their application, the solution of this problem is at the initial stage [2, 3].

Research and practical observation showed that more than 80% of failures in field pipelines are due to their damage by internal or external corrosion. In many fields onshore every two years, it is necessary to change individual sections of pipelines due to their destruction under the influence of hydrogen sulfide and carbon dioxide. The presence of bio flora, reducing the content of sulfates, intensifies the reduction in the service life of pipelines made of carbon steel. Basalt plastic pipes are more expensive than steel ones but considering that they non-crash serve at the oilfields 10 to 20 times longer and do not require any care, in just 4-5 years their cost already pays off (Fig.3 and 4). The most effective application of basalt plastic pipes for those oil (gas) industries where on high-pressure transported the well product highly aggressive and contaminated active bio flora [4, 5]. When oil wells are operated with sucker-rod deep-well pumps, the main link of the deep-pumping unit is subjected to intense mechanical alternating stresses, as a result of which their lifetime is determined by fatigue phenomena in the metal. These fatigue overloads are most often manifested in production wells, whose products are highly corrosive. Experience shows that, due to the influence of the corrosive environment, the fatigue phenomena in the rods increase by 2-3 times. The presence of hydrogen sulphide in an environment that leads to embrittlement of steel is most dangerous for operation and booms, which leads to loss of elastic properties and premature failure of the rods due to a break in both the body and in the couplings.

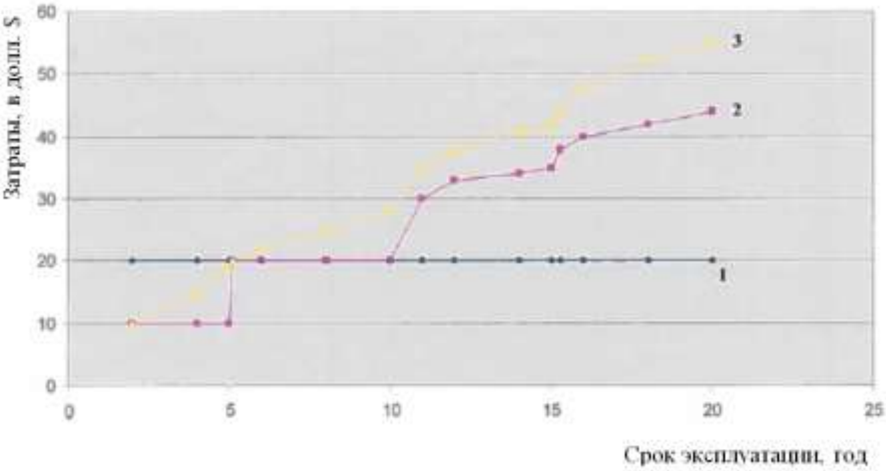

Fig.3. Comparative indicators of the dependence between the cost and service life of basalt plastic and steel pipelines
1 – 75x8 mm basalt plastic pipes; 2 – 89x4 mm steel pipes covered basalt plastic materials; 3 – 89x4 mm steel pipelines, protected by internal corrosion inhibitors

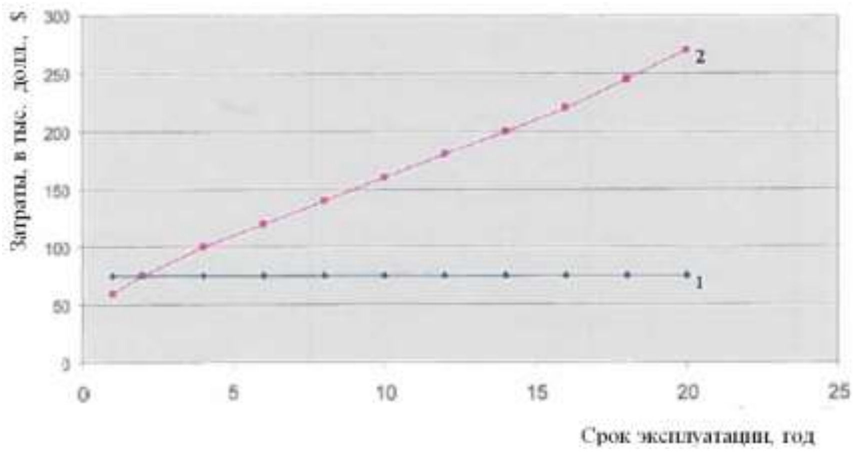

Fig.4. Comparative indicators of the dependence between the cost and service life of basalt plastic and steel pipelines
1 – basalt plastic pipes; 2 – steel pipelines

Advances in the development and application of high-strength bars from alloyed (nickel-molybdenum and other) steels, which at a certain stage of their use provide a significant effect in improving the efficiency of rod columns, to date, when the corrosion situation in the oil fields has become tougher, this effect has sharply decreased [6]. Having a positive experience in using a basalt plastic material to protect against corrosion of steel pipes, a technology was developed to create basalt plastic pumping rods to solve problems: - reducing the weight of the rod (3 times) and increasing corrosion resistance. The bodies of basalt-plastic pumping rods consist of basalt-plastic, heads, connecting of steel. On the metal connector there is a threaded nipple for gripping with sucker keys, thrust and support beads in the transition zone for landing the rod to the elevators during lift up and down operations. When designing a new rod design, they were evaluated for their serviceability in a corrosive environment and the possibility of increasing the depth hang of the pump due to a significantly lower material density, basalt plastic (1900 kg/m3). With regard to corrosion resistance, it is provided in any environment of extracted products containing oil and the maximum amount of mineralized formation water (up to 180-200 g/l) containing hydrogen sulfide (up to 1000 mg/l) and carbon dioxide. The increase in the hanger of the pump due to the low density of basalt plasticity is achieved by an average of 55%. For example, the suspension of a 32 mm downhole pump to a depth of 1,000 m on metal bars 19 mm, the weight of the liquid will be 800 kg, and the bar 2100 kg, i.e. the maximum load on the balancer head is 2900 kg. At that time, the transition to the basalt from basalt plastic with the same suspension of the pump, the weight of the bars will be 1062 kg, i.e. the maximum load on the head of the rocker is 1862 kg. The reduction of the load was 1038 kg compared to the metal ones, due to the operating rocking machine, it is possible to increase the suspension of the pump to 1550 m. The minimum breaking tensile force at tension, the basalt plastic bars with a diameter of 16 mm is 80kN, 20 mm - 100kN, 22 mm - 120kN and 25 mm - 150kN, test axial tensile force from 40 to 75kN, maximum torque when screwing from 300 to 1100kN. The breaking stress at tension (norm 800MPa) is 864MPa, tensile modulus (0.3-105 MPa) 0.37-105 MPa, specific viscosity 250 kJ/m^2, tensile strength 250MPa, an elongation of 0.4%. The carried-out test of basalt plastic materials in the aggressive environments of oil fields and physical and chemical data suggest that basalt plastic materials produced by the "broach" method have a sufficiently high corrosion and chemical resistance as well as strength and can be used to make the body of pumping rods.

As a result of the studies carried out in the field of constructing the design of deep-pumping rods, the following conclusion can be drawn: a design of deep-pumping rods was developed, the body of which is made of basalt plastic, and the connecting heads are made of steel; a reliable connection of the basalt-plastic body of the rod with metal tips; the basalt plastic rod body is not corroded; weight of fiberglass rods 3 times lower than metal bars (Fig.5).

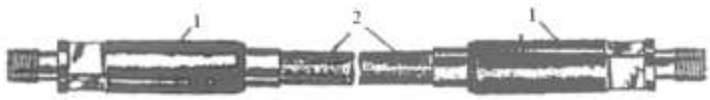

Fig.5. Basalt plastic rod (pump rod):
1 – basalt-plastic body; 2 – metal head

Conclusion

Summarizing the above, it is possible to draw the following conclusions:

– The technology of facing the outer surface of steel pipes (casing, collector, flow lines) with basalt plastic composite materials has been developed.

– The composition, physic-chemical and mechanical properties of basalt-plastic materials are determined.

– Composition of basalt plastic material consists mainly of reinforcing basalt fiber and binder polyester resin.

– Unlike other coatings, such as paintwork, bitumen, polyethylene, etc., besides anticorrosive, also has anti-shock, extreme pressure, anti-wear properties.

– Developed and recommended technology for the use of casing strings and pumping rods made of pure basalt plastic material, in place of metal.

– The use of casing strings and pumping rods from basalt plastic material in wells up to 2000 m deep is recommended.

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Xülasə

Sadıqov R.E.

Quyu avadanlığının və neft kəmərlərinin səmərəliliyinin artırılması üçün texnologiyaların işlənməsi

Quyu avadanlığının və neft boru kəmərlərinin iş qabiliyyətinin yüksəldilməsi üçün aktual problemlərdən birinə baxılmışdır. Bununla əlaqədar olaraq, xarici örtük üçün bazalt lifi ilə gücləndirilmiş poliefir qatranları əsasında korroziyaya qarşı davamlı, zərbəyə, aşınmaya qarşı davamlı və cızılmayan kompozit plastik material işlənmişdir. Texnologiyanın mahiyyəti polad borulara bazalt plastik örtüklərin çəkilməsindən ibarətdir. Həmçinin, çox korroziyalı neft mədənlərində istifadə olunmaq məqsədilə xarici kolonnalarda, neft boru kəmərlərində və nasos ştanqlarında tətbiq edilmək üçün xalis bazalt plastiki tədqiq olunmuş və tövsiyə edilmişdir. Hasil edilən məhsulların mühitində neft mədən avadanlığının effektivliyi avadanlığın hazırlandığı materialın uzun ömürlüyündən, həmçinin, neft yatağının iş şəraitindən və onun işləmə müddətindən asılıdır.

Açar sözlər: quyu avadanlığı, neft boru kəmərləri, korroziyaya qarşı davamlı, aşınmaya qarşı davamlı və cızılmayan kompozit plastik material, bazalt plastik boru, korroziya-eroziya aşınması.

Резюме

Садыгов Р.Э.

Разработка технологий для повышения эффективности скважинного оборудования и нефтепроводов

Рассмотрена одна из актуальных проблем повышения работоспособности скважинного оборудования и нефтесобирающих трубопроводов. В связи с этим, разработан коррозионно-устойчивый, ударопрочный, противоизносный и нецарапливаемый композиционный пластический материал для наружного покрытия, основанный на полиэфирных смолах, усиленных базальтовым волокном. Сущность технологии заключается в покрытии стальных труб базальтовыми пластическими оболочками. Также исследован и рекомендован чистый базальтовый пластик для применения в обсадных колоннах, нефтесобирающих трубопроводах и насосных штангах для использования в очень коррозионных нефтяных месторождениях. Эффективность оборудования нефтяных промыслов в среде добываемых продуктов зависит от долговечности материала, из которого оно сделано, а также рабочих условий месторождения и периода его разработки.

Ключевые слова: скважинное оборудование, нефтесобирающие трубопроводы, коррозионно-устойчивый, противоизносный и нецарапливаемый композиционный пластический материал, базальтовая пластмассовая труба, коррозионно-эрозионное изнашивание.