Modeling of flow in field pipeline to confirm effectiveness of insertion of splitting couplings in control of rill-washing corrosion.

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Abstract. This paper considers the relevance of the control with rill-washing corrosion. The flow of fluid in the pipe is modeled by the example of a conditional pipeline. This will allow one to determine the moment of formation of the flow of a two-phase fluid flow and to determine the interval for placement of the dissecting couplings. A scheme is proposed for arranging dissecting couplings along the whole route of the field pipeline.

1. Introduction

Safe operation of pipelines is associated with the problem of increasing their reliability and durability and is a complex task, including the solution of technical, technological, economic and organizational aspects. Numerous studies of domestic and foreign authors are devoted to this problem; however, at present it is not completely solved, and many questions remain open [1].

The operational reliability of oil pipelines is largely determined by the intensity of corrosion of the pipeline walls.

Analysis of operating conditions of field pipelines and existing ways to improve their durability in conditions of intensification of internal corrosion shows that the number of failures of field pipelines due to internal corrosion accounts for about 90% of the total number of the industry [2]. Over 70% of accidents are caused by specific destruction in the form of "groove" wear.

Experience in the operation of pipelines and oil collection tanks shows that the groove corrosion-mechanical fracture and corrosion fatigue are the most dangerous types of destruction. The protection of oilfield pipelines from grooving (riveted) corrosion caused by the interaction of the pipe metal and the pumped corrosive medium is actual at present in many regions of Russia, especially in the fields of Western Siberia [3]. With the increase in the life of the deposits, the volume of mined water extracted is increased, pumped into the reservoir to maintain reservoir pressure. This increases the risk of internal corrosion of pipelines, tanks and other equipment. The destruction of a number of pipeline systems takes place less than one year after the commissioning of the pipeline.

It should be noted that most pipelines subject to intense internal wear are operated without external insulation. Frequent gusts of pipelines, caused by "grooving" wear, require the search for new technical solutions aimed at ensuring their safe operation, increasing durability and stability of operation [4, 5].

Therefore, the problem of ensuring safe operation and increasing the longevity of oil pipelines,
undoubtedly, remains relevant and timely.

2. Relevance

Most oil pipelines transport highly watered oil. In the composition of the reservoir water there are components with a high degree of corrosive activity. Corrosion processes are intensified due to the work of macro-galvano-steam "metal-corrosion products" or "metal-scale", formed during corrosion of a metal flowing under the influence of a stratified flow of a gas-water mixture [6].

With the increase in the volumes of mineralized water mined along with oil, the danger of the occurrence and development of corrosion of the internal surface of pipelines, tanks, and other equipment is increasing. The mineralization of water varies from 2 to 30 g/l.

Oil-field waters with dissolved in them aggressive gases (H23, C02), in contact with the surface of metal pipelines and other equipment, cause their intense corrosion. Therefore, the protection of field equipment and pipelines from corrosion occupies an important place at present.

The main ways to increase the resistance of pipes to various types of internal corrosion is the use of special grades of steel and protective coatings [7].

According to [8, 9], the accident rate of pipelines in recent years has been reduced, largely due to the increase in the rates of in-pipe diagnostics and subsequent targeted repairs, as well as through the implementation of a number of targeted programs.

During the operation of the fields of OISC Rosneft-Dagneft, the majority of oil pipeline failures occurred along the lower generatrix in the form of grooves and extended grooves [10, 11]. The results of the measurements showed that the losses in the thickness of the wall of the field pipelines are concentrated mainly along the lower generatrix. As a result of the inspection of the pipeline from Well No. 220, it was found out that the pipeline had undergone a groove corrosion along the lower generatrix. Corrosion centers are located both in groups and singly. Their depth reaches 4-5 mm.

The analysis of production of wells pumped through pipelines showed the content of highly mineralized formation water (the dry residue reaches 12 g/l). The relatively low velocity of the flow of the water-oil mixture contributes to the settling of the water phase in the lower part of the pipe cross-section [12]. Associated gas CO2 in the mixture increases the acidity of the water fraction, intensifying the corrosion process. As a result, the failure rate of the pipeline due to groove corrosion reaches 70% [13].

For the field pipelines of the "Dmitrovskaya" and "Makhachkala-Tarki" deposits [4, 16, 18], the rate of grooving corrosion was determined for various operating pressures in the oil pipeline (Figure 1).

![Figure 1. Dependence between overhaul period on rate of grooving corrosion](image-url)
3. Results and discussion

The known technological methods for corrosion protection of pipelines that convert a stratified flow into an emulsion by changing its hydrodynamic characteristics (pressure, diameter, etc.) are not able to provide a stable emulsion [17].

To combat rivulet corrosion, a dissecting sleeve was chosen. The main idea of the technology of the use of dissectors was proposed by I. Yu. Podavalov [18]. It consists in dispersing the entire layer of bottom water moving along with the oil in the lower part of the pipeline in the body of the oil itself, and after precipitating the water in the lower part, again dissipate it.

By solving this problem, it is proposed to install in the lower part of the pipeline splitters that change the direction of motion of the lowest layer of liquid moving in the pipeline (water) during laminar flow. Then, after the elementary flow of water is stressed against a fixed wall fixed at some angle to the axis of the pipeline, it changes the direction of motion and, moving along the wall of the pipeline, is mixed with oil [19]. After separation of water from the water-oil emulsion (sedimentation of associated water) into the lower part of the pipeline, it is necessary to repeat the process.

Before installing the cutting sleeve, it is necessary to know the moment of formation of a two-phase flow in the production pipeline. To achieve this, a model was constructed: a software package for modeling the flow in a pipe, a commercial oil pipeline located between the oil collection unit and the booster pump station (BPS). The horizontal profile of the pipeline route corresponding to the plain is specified.

Parameters of the oil pipeline model are:
- length $L = 15$ km;
- diameter $D = 159$ mm;
- oil density $p = 0.86$ g/cm$^3$;
- water cut of oil $10\%$;
- pressure at the initial point $P = 15.85$ atm;
- pressure at the end point $P = 5$ atm.

After the calculation, a model of fluid flow in the pipe and a graph of the flow indicator are obtained (Figure 2). Based on the graph, it is seen that the flow begins to move in a mixed state, phase separation is not observed, the flow indicator (ID) is 2. Later, when the flow in the pipe is moving, the phases are separated into oil and water. Complete phase separation occurs at 500 meters of the production pipeline, the flow indicator (ID) is 1, further fluid transfer occurs in a two-phase state. Hence, in order to prevent the formation of riveted corrosion, it is necessary to install a cutting sleeve on the 500 m route of the field pipeline.

![Figure 2](image_url)

**Figure 2.** A graph of the flow indicator along the entire profile of the pipeline route.
Introducing into the model, at 500 meters of the route of the field pipeline, a dissecting clutch and performing calculations, we obtain a new graph of the flow indicator along the whole profile of the pipeline route (Figure 3). It can be seen from the graph that when the flow passes through the dissecting sleeve, phases are mixed. The phase of the water goes into a bubble state, the flow indicator (ID) is 4 at the moment of flow through the dissecting sleeve. In the area from 501 meters to 1000 meters of the route of the oil pipeline, precipitation of suspended water drops is observed, formation of rivulet corrosion on this site is impossible. A complete phase separation is observed at 1000 meters of the pipeline section, so a cutting sleeve must be installed at 1000 meters.

Figure 3. Graph of the flow indicator along the entire profile of the oil pipeline route with an installed dissecting clutch.

After the second incision is installed, the phases of oil and water are also mixed (Figure 4). It is also seen from the graph that after the passage of the dissecting coupling, phase separation occurs through an equal distance, which is equal to 500 meters. Hence it can be concluded that every 500 meters on the conventional oil pipeline it is necessary to install a dissecting coupling in order to prevent the formation of a two-phase flow leading to the formation of rivulet corrosion. After the introduction of the oil pipeline into the model along the entire route, we obtain a diagram of the arrangement of the dissecting couplings (Figure 5).

Figure 4. A graph of the flow indicator along the entire profile of the oil pipeline route with two dissecting couplings installed.

This scheme, the arrangement of couplings, allows one to completely prevent the flow of liquid
flow in a two-phase mode, which allows one to eliminate the formation of riveted corrosion. This measure increases the operational life of the oil pipeline, reduces the risk of an emergency.

Figure 5. A diagram of the arrangement of splitting couplings along the route of the conditional oil pipeline, 15 km long.

4. Conclusion
In the course of the conducted studies, the flow motion was modeled in a conditional field pipeline, in a software package for the study of fluid flows in a pipe. The tasks were fulfilled, namely:

• the moment of formation of a two-phase flow of a fluid is determined;
• the effectiveness of the introduction of the dissecting couplings has been confirmed;
• the distance of the distribution of the splitting couplings along the route of the oil pipeline is determined;
• a scheme has been created for the arrangement of the splitting couplings along the pipeline route.

The use of cutting sleeves on field oil pipelines is considered effective in the control of rivulet corrosion. Using this model to simulate the flow of fluid in a pipe, by setting other parameters of the pumped medium and pipeline, by making calculations, it is possible to determine the moment of the formation of a two-phase flow and the distance between the dissecting couplings, and to develop a scheme for placing the couplings along the pipeline route.

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