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Method of detecting leaks in oil pipelines and elimination of accidents

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Abstract

This article is devoted to the detection of leaks in oil pipelines and the elimination of accidents. During the transportation of hydrocarbons through the main pipeline, losses classified as operational losses such as evaporation of oil products in tanks, leakage from connecting fittings and pumps were reported. At the same time, during the transportation by the main oil pipeline, the occurrence of accidental losses as a result of the loss of hermeticity of the technological and main pipelines was also noted. Accidental spills have been shown to result in loss of injected product, subsequent additional costs for restoration and repair work, serious environmental damage, and pollution of the atmosphere, soil, and water bodies.

Currently, the existence of many different methods for the detection of leaks, each of which has both advantages and disadvantages, is noted, and their internal and external classification is given. It was emphasized that the detection of leaks and the elimination of accidents in oil pipelines, especially in the sea water area, is a technical, economic and ecological problem that has not yet been fully resolved.

To detect possible liquid leaks from the oil pipeline, a method based on the determination of waves reflected from the possible leak site in the oil pipeline was proposed. The generation of pressure waves allows not only the detection of the leak itself, but also the identification of the damaged section of the oil pipeline. To determine the location of the leak, it is necessary to install a timer on the pressure sensors. By setting the time from the origin of the recorded pressure wave to the arrival of the reflected wave, the distance to the likely leak can be found by knowing the exact time of travel and speed of sound.

Since the calculations are complex and large-scale, commonly, they are carried out using computer programs. To determine the optimal calculation volume, it is necessary to correctly define the calculation step. It is indicated that the calculation for the Oil Rocks-Dubandy subsea oil pipeline should be carried out for 222 points.

A classification of methods for detecting leaks in oil pipelines is given and a more effective method based on the wave theory of hydrodynamics is explained.

Considering that the repair process in offshore conditions can take days, to reduce oil losses and pollution of the sea, it was proposed to transfer the oil up to the point of leakage to the non-accident part of the pipeline by connecting the receiving lines of the pumps to the sea water source in advance and injecting water instead of oil into the pipeline in case of an accident.

Keywords: oil pipeline, technological losses, accidental leaks, pressure wave, reverse wave, leak location, sound of speed, reduction of oil losses.

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1. Introduction

The large distance between the place of production of hydrocarbons and the place of their direct consumption makes pipeline transportation the most common mode of transportation in the oil and gas sector.

Of course, losses occur during the transportation of hydrocarbons through the main pipeline. Losses such as evaporation of oil products in tanks, leakage from connecting fittings and pumps. Listed losses are usually classified as operating losses. In addition, accidental losses occur as a result of the loss of hermeticity of technological and main pipelines during transportation by the main oil pipeline. Accidental spills are accompanied by loss of injected product and subsequent costs for recovery and repair work. These leaks cause serious damage to the environment, polluting the atmosphere, soil and water bodies. Spills and accidents in offshore oil pipelines result in larger-scale damage. The frequency of emergency leaks in main oil pipelines can be grouped by taking into account the following influencing factors: - corrosion of pipes; - mechanical damage to the pipeline; - operational factors; - quality of pipe production; - natural phenomena (floods, earthquakes, landslides, etc.); - quality of construction and installation works [1,4].

Currently, there are many different methods for detecting leaks. Moreover, each of them has advantages and disadvantages. The internal and external classification of leak detection systems and methods in various sources has already been defined. External methods include systems based on external manifestations accompanying its occurrence, as well as detection of leakage based on their presence: acoustic noise, leakage of the injected product onto the surface of the transported oil, level of gas pollution, etc. This group of methods also includes sensitive cables, patrolling the route, using thermal imagers, etc. Internal methods include systems using gauges and sensors used to measure parameters inside the pipeline (measurement of temperature, flow rate, pressure, etc. of the transported product). There are several other classifications of pipeline leak detection methods and systems: interaction with the environment, monitoring frequency, according to the leak detection criteria.

Internal methods for detecting leaks in main oil pipelines:

- A method based on the analysis of the oil pipeline's hydraulic operating mode;

- Determination of oil pipeline leakage based on hydraulic slope analysis;

- Differential pressure method;

- Graphic-analytical method;

- Oil pipeline hydraulic testing method.

External methods for detecting leaks in main oil pipelines:

- Fiber optic cable method;

- Radiation method of leak detection;

- Visual inspection method;

- Cable method with gas sensor;

Probe devices for detecting leaks:

- Ultrasonic defectoscopes;
- Vortex defectoscopes;
- Magnetic defectoscopes;

Leakage detection by monitoring transport process parameters:

- Material balance method;
- Flow comparison method for leak detection;
- Method of negative shock waves;
- The method of comparing the flow rate change;

Methods of acoustic detection of leaks:

- Acoustic emission method;
- Acoustic (ultrasound) method;
- Ultrasonic testing of leaks;

Requirements for leak monitoring systems: - accuracy of leak location determination; - high sensitivity; simplicity of operation; - high degree of reliability; - efficiency; - control of long-distance pipelines; - protection from the noise of transport modes; - application in any weather conditions.

2. Methodological part

Detection of leaks and accidents in oil pipelines, especially in the sea area, is a technical, economic and environmental problem, so it has not yet been fully resolved and is considered one of the most urgent issues in the modern era.

3. Results and discussion

Development of a method based on the wave theory of hydrodynamics to detect possible liquid leaks from an oil pipeline, which will be based on the generation of high pressure waves in the oil pipeline, as well as the identification of waves reflected from the location of a possible leak in the oil pipeline. The generation of pressure waves in the oil pipeline will allow not only to detect the leak itself, but also to determine the damaged section of the oil pipeline.

The method of monitoring the integrity of main oil pipelines is based on a physical phenomenon such as the breakdown of a pressure wave at the point of defect (point of possible leakage) in the oil pipeline. The observed integrity monitoring method was first proposed by N.E. Zhukovsky.

So, let's look at the essence of the method.

Consider the nature of pressure wave propagation along a fixed-diameter oil pipeline without loopings, separations, connecting fittings and other possible obstacles. Pressure waves propagate along the entire length of the belt without significant changes. Due to frictional dissipation of pressure wave energy, only gradual attenuation is observed (Figure 1).

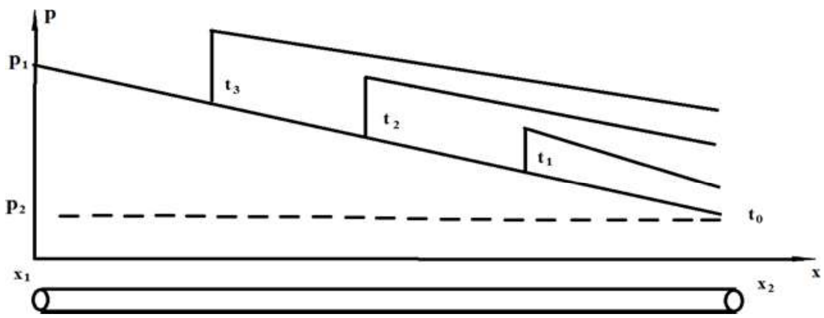

Figure 1. Propagation of a pressure wave in an oil pipeline.

Let's imagine that the pipe has been damaged in any part of the oil pipeline and a certain leakage has occurred. Since the damage is in the pipe wall, the spatial direction of the leakage flow is perpendicular to the spatial direction of the main flow in the pipeline. In addition, due to the pulsating nature of the leakage flow configuration due to the influence of the main flow, a source of resistance is formed at the end of the damage. For this reason, the main pressure wave that encounters the obstacle will be split into two waves.

One pressure wave will continue to propagate in its original direction, while the other wave will be reflected. At this time, an increased pressure is formed before the obstacle, and a reduced one after the obstacle.

The amplitudes of the reflected pressure waves depend on the degree of influence of the leakage flow on the uniformity of the fluid flow in the oil pipeline and the size of the vortices.

If there is no leakage in the considered part of the oil pipeline, then the phenomenon of wave splitting does not occur and, accordingly, there are no reflected waves.

The criterion for a leak in a part of an oil pipeline will be the presence of a reflected wave. At the moment when the weakened wave reaches the end of the pipeline, a sharp drop in pressure can be observed. A sharp and abrupt pressure drop indicates a leak in the considered part of the oil pipeline.

Registration of the presence of a reflected wave (recording of a pressure jump) allows not only to detect a leak in an oil pipeline, but also to determine its exact coordinate xo. In order to determine the location of the leak, it is necessary to install a timer on the pressure sensors, which will record the time from the moment when the fixed pressure wave occurs to the moment when the reflected wave arrives. Knowing exactly the travel time of the reflected wave and the speed of sound in the considered part of the oil pipeline, the distance to the probable leak can be found using the formula $s = x_2 - x_o$:

$s = (c \cdot t)/2$ (1)

where t is the time from the moment of hydraulic shock generation until the reflected wave reaches the end of the oil pipeline.

c is the speed of propagation of waves in the oil pipeline.

The speed of propagation of waves is determined by the following formula.

$$s = \frac{1}{\sqrt{\frac{\rho_O}{K} + \frac{\rho_O d_O}{E\delta}}} \quad (2)$$

If there are several damages in the considered part of the oil pipeline, the reflected waves (pressure drops) will be the same number, and by recording each of them, it is possible to determine the location of all the leaks on the oil pipeline. The absence of a reflected pressure wave indicates the absence of leaks in the oil pipeline or a small leak that cannot be detected by the method in question. A sensor is installed at the end of the oil pipeline to record the arrival moment of the reflected pressure wave. The sensor must respond to pressure changes and also record its bounce time. Since all oil pipelines have pressure fluctuations, a minimum pressure jump (sensitivity limit) must be applied for the sensor. The threshold of sensitivity can be accepted at the level of 3 kPa.

Since the calculations are complex and large-scale, as a rule, they are carried out using computer programs. Therefore, to determine the optimal calculation volume, it is necessary to correctly define the calculation step.

For example, for the Oil Rocks-Dubandy subsea oil pipeline, it is sufficient to accept the calculation step of 300 meters. Since the total length of this pipeline with a diameter of 500 mm is 66.6 km, the calculation should be made for 66600/300 = 222 points of the belt. At the beginning of the indicated oil pipeline, the pressure is Pb = 1.75 MPa, 16-17 thousand m3 of oil is transported daily.

It should be noted that the determination of the leakage and its location depends on the operating parameters of the oil pipeline (starting and final pressure), structural parameters (length of the pipeline, diameter, thickness of the pipe wall), corrosive environment, environment (wind, underwater currents), compliance with the operating mode depends on availability and other factors. Oil spilled onto the water surface can occupy large areas of water bodies - one unit of oil can contaminate a thousand times more water. The first step is to organize measures to localize the accident, for this purpose, special pontoon traps are used to limit the spread of oil-water emulsion beyond them. The fact that the density of oil is lower than the density of water and the fact that part of the harmful medium is on the surface, forming a layer up to several centimeters thick, makes it much easier to collect products. One method of collection after containing the spill is the use of oil skimmers placed on oil collection vessels.

It is possible to use surface pumps with a small cavitation reserve or to collect the water-oil emulsion in cisterns or tanks for further treatment and disposal. After the accident is cleared, a dispersant is used for the final removal of oil compounds - a surface-active chemical compound that breaks the oil into many individual droplets that are denser than water. Some dispersants can accelerate the processing of oil by microorganisms.

At the same time, we believe that conducting operational technological operations in order to reduce oil losses and sea pollution in sea conditions can also be beneficial. So, once a leak is detected, it is not enough to simply stop the pumps and maintain the supply. Taking into account that the repair process in sea conditions can take days, by connecting the intake lines of the pumps to the seawater source in advance, by injecting water instead of oil into the pipeline in case of an accident, it is possible to transfer the oil up to the point of the leak at least to the uninjured part of the pipeline and reduce the losses.

4. Conclusion

The classification of methods for detecting leaks in oil pipelines is given and the method is explained based on the wave theory of more effective hydrodynamics.

Taking into account that the repair process in sea conditions can take days, by connecting the intake lines of the pumps to the sea water source in advance and by injecting water instead of oil into the pipeline in case of an accident, at least transfer the oil up to the point of leakage to the non-accident part of the pipeline, thereby reducing oil losses and pollution of the sea can be reduced.

Conflict of interest

The authors declare that they have no conflict of interest in relation to this research

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Ensuring reliability of valves

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Abstract

Ensuring the reliability of the fountain valves is the main criterion for increasing their efficiency. The article examines the criteria for the performance of the valves used in the fountain equipment and determines the reliability indicators. It is established that the serviceability of the gate-and-seat pair of the valve is the main condition for the performance of the connecting unit of the straight-through valve. The main criterion for the performance of straight-through valves is the property of resistance to loads. Uniform pressure distribution on the contact surface of the gate-and-seat pair of the improved valve ensures its performance.

Keywords: valve, gate, seat, reliability, straight-through, performance

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Introduction.

Valves, the most common type of connecting structures, form the basis of fountain fittings in the complex of fountain equipment, along with different methods of use.

1,500-2,000 different types of valves are used in our country only in the oil and gas sector. Increasing the efficiency, durability and reliability of valves, reducing the consumption of materials used in their construction, and meeting the serviceability of all parts and nodes are the most important issues.

Valves are divided into 4 types according to their management.

1. Manual (by hand);

2. Pneumatic (air);

3. Salyonid;

4. Hydraulic (with fluid pressure).

According to the structure of the stopper knot, it is divided into 3 types.

1. Wedge;

2. Disk (one disk - two disks);

3. Gate (one plate - two plates).

Valves have an important role in conditions where they are used under high pressure. When the valve is open, the flow of liquid and gas moves in a straight line along its passage diameter, so the movement of liquid or gas flow inside the valve is called straight-flow. As a result, liquids and gases experience little resistance under steady-state conditions. Precise control over the flow is impossible in the valves, so it is not advisable to use them when adjusting the flow.

One of the most important nodes of the fountain armature used for the operation of oil wells is the connecting structures. The repeatability of this node ensures reliable and reliable operation of the fountain fixture. Therefore, ensuring the functionality of the check valves is the main condition for the quality and reliability of the fountain fixture as a whole.

Closure structures are used to interrupt, close and open the fluid flow. A straight flow valve refers to shut-off structures and is used to allow the flow to be either fully open or fully closed. Most importantly, aggressive environments are also used in different settings.

Valves have also been used primarily in the oil and gas industry in the fountain style, including shut-off isolation service in the oil refining industry, wastewater plants, power plants, and processing facilities.

Valves have their own standards and codes:

1.API 5-Control system

2.API 5-Reverse valve.

3.API 6-Globe drawer.

4.API 6-Butterfly drawer.

5. API RP-Repair of connecting structures.

6.ASME Joint Types

Ensuring the reliability and efficiency of valves remains an actual issue today. Even distribution of stress inside the valves ensures its efficiency. The purpose of the research work is to determine the condition of operability and reliability of the improved valve.

2. Methodological part. For this purpose, a number of experiments were conducted and the reliability indicators of MMS100X70 valves produced at "Neftgazmash"-ASC machine-building plant were determined (fiq.1).

Fİqure. 1. improved valve [6]

The causes of failure of the tested valves (67 out of 125 valves) were studied by careful examination during repair. The inspection showed that 57 of the drawers failed due to the collapse of the locking surfaces (between the wedge and the body), 6 due to perforation of the body due to corrosion and erosion, and 4 due to failure of other parts. From this, it is clear that the breakdown of the fasteners accounts for up to 85% of all failures. This indicates that the node is unreliable and unsustainable.

Experience shows that the repeatability of the fountain fixture depends to a large extent on ensuring the repeatability of the booster assembly in the valve.

Therefore, increasing the efficiency of the plugging junction of the straight-flow valve is one of the current issues.

The operability of the valve is evaluated by the necessary levels of the following criteria [1,8]: strength of the valve parts; ensuring that the friction parts of the drawer continue to be worn; heat resistance of the locking parts of the drawer under operational conditions; continuation of vibration of drawer parts and connections when vibrations and shocks occur as a result of changes in the pressure of the product extracted from the well under operating conditions: continuation of corrosion (rusting) of the metal parts of the valve.

Thus, the use of a large number of fountain fittings of different constructions in different operating conditions shows that the rejections of the blocking junction of the valve (gate-and-seat pair) are quantitatively numerous, and the probability of its failure-free operation is calculated by the following formula:

$$Ps(t)=Psh(t)\cdot Pk(t)\cdot Psis(t)\cdot Pj(t)\cdot Pyay(t) \qquad (1)$$

Here, Pc(t) is the probability that the valve, Psh(t), Pk(t), Psip(t), Pj(t), Pyay(t) will work without fail during time t. From the above formula, it can be seen that the probability of non-failure operation of the valve depends on the probability of non-failure operation of the gate-and-seat pair.

3. Results and discussion. Refusals of the shield-saddle pair occur for various reasons. The main one of these reasons is the change of the stress state and shape of the junction details. Thus, under the pressure of the product extracted from the well, the annular part of the saddle is pressed against the working surface, and the circular part of the shield, which sits freely on the ring, bends along its radii (diameters). As a result, the principle of equal distribution of relative pressure on the locking contact surface of the gate-and-seat pair is violated and does not ensure locking locking.

Uneven distribution of the contact stress on the specified working surface, and in this case, when the drawer is opened and closed, the back and forth movement of the gate breaks the working surface, breaks the mold and destroys the "metal-to-metal" contact surface [2,5]. For this reason, the problem is to ensure equal distribution of stress on the contact surface of the gate-and-seat pair.

It is known that due to the deformation of the shield in bending, normal stresses appear in its cross section. In order to investigate these stresses, it is necessary to consider the bending of the shield along the radii (longitudinal-transverse) of the free-standing circular part on the ring, separately as pure bending deformation. As we know, there is a layer in pure bending which does not undergo bending deformation. Such a layer is called a neutral layer. The normal stress generated at the maximum distance from this layer reaches its maximum value [3-8].

According to the above rule, the shield will bend due to both deformations on the surface of the shield resting on the saddle. The stresses resulting from these deformations will reach their maximum values on the working surface. Then the maximum working normal stress σish max on the working surface of the shield is found as follows:

$$\sigma_{iş\ max} = \sigma_{en\ max} + \sigma_{uc\ max} \qquad (2)$$

where are stresses caused by transverse and longitudinal deformation.

Since the condition of strength due to normal stress is $\sigma_{i\ max} < [\sigma_b]$, we obtain the condition of strength due to normal stress in the bending of the shield under operational conditions:

$$\sigma_{ax} > [\sigma_b] > \sigma_{iş} \qquad (3)$$

σ_{ax} - is the yield strength of the shield material.

It should be noted that since $\sigma_{ax} > \sigma_{is}$ in the most stressed (scariest) place of different cross-sections of the same part, the reserve factor is greater in less stressed parts of this part.

Thus, consideration of the above condition during the selection of the design parameters of the gate-and-seat pair will regulate the satisfaction of the performance criteria of the straight-flow valve.

Research has shown that ensuring equal distribution of stress inside valves is one of the important conditions to ensure its functionality and reliability. The operating state of the valve depends on the voltages generated at the inlet and outlet.

Conclusion

1. The repeatability of the gate-and-seat pair is the main condition for the repeatability of the binding node of the straight-mouth valve.

2. Corrosion resistance is the main criterion for the performance of a straight-flow valve is a property.

3. Even distribution of pressure on the contact surface of the gate-and-seat pair of the valve ensures the serviceability of the node.

Conflict of interest

The authors declare that they have no conflict of interest in relation to this research.

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