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IMPROVED VALVES STUDY OF THE EFFECT OF SEALING

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Abstract: The most widespread type of closing structures, valves, are used in various fields of industry. Ensuring maximum tightness in these equipment remains an urgent issue. In scientific research, the parameters on which the sealing effect is based have been revealed and the principles of ensuring tightness have been developed. It has been determined that ensuring the principle of equal pressure distribution inside the closing structures is the main condition. Ensuring equal pressure distribution inside the improved valve structures will eliminate the non-parallel wear occurring in the shield-saddle pair and ensure maximum tightness between the pairs.
Keywords: *valve, sealing, equal pressure distribution, wear resistance, operability*

Introduction.

Valve structures included in the wellhead equipment complex used in the wellhead operation by the fountain method operate in complex operating conditions with variable temperatures in contact with highly saline formation waters, as well as high operating pressure under the influence of aggressive media and abrasive and mechanical parts contained in the working material (Fig. 1**)** [1,2].

It was noted that wear is predominant among the factors affecting the performance of valves, the most common type of sealing structure, which is related to the interpretation of operating conditions and the investigation of the causes of their failure.

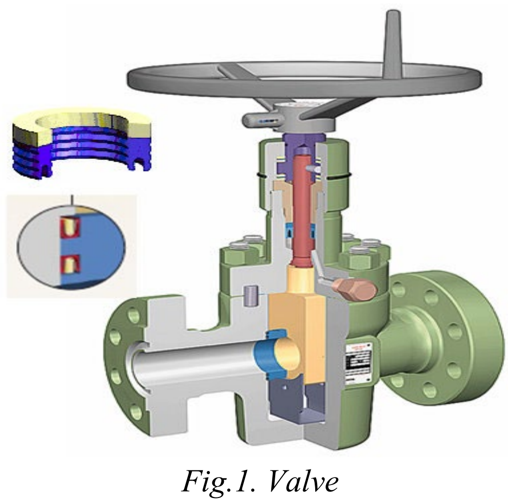

Fig.1. Valve

According to STANDARD 23.002-74, corrosion is classified into mechanical, corrosion-mechanical and electric current-dependent. Oil-gas-mining equipment is exposed to the effects of the first and second of these types in operating conditions [3]. Mechanical wear includes abrasive, hydro-

(gas) abrasive, erosion, cavitation, fatigue, fretting and seizing .

Corrosion-mechanical wear includes wear caused by oxidation and fretting corrosion. These wears affect the performance and longevity of the valve assembly in an exclusive or complex manner[4, 5].

In the valve assembly of currently operated valves, the tightness of the contact surfaces is achieved on the basis of three principles . These are the following:

-metal-metal;

-supply of sealing lubricant between the metal-metal;

-metal-rubber (elastic element).

Regardless of the choice of these principles, one or another wear process occurs in the parts included in the valve assembly. Among them, abrasive wear is important. The vast majority of oil-gas-mining equipment, including fountain fittings, are exposed to abrasive wear during operation due to the influence of the working product. The reason for this is the presence of sand grains and other solids in the working product. Abrasive particles falling between the contact surfaces of the valve plug assembly participate in the friction process and transmit force from one part to another, forming scratches on the surfaces. Later, these scratches turn into grooves in the sliding direction, disrupting the tightness of the valve plug assembly and causing failure [6,7]. Since abrasive wear occurs with the participation of the working product (gas, oil, condensate, formed water, etc.), the intensity of wear is determined by the physicochemical properties of the liquid or gas. The results of the studies conducted in this direction show that the intensity and mechanism of abrasive wear are different in different oil environments. During the study, oil emulsions with different viscosities and a wide range of formation waters were used for testing. The results of the studies showed that as the viscosity of the oil increases, the depth of scratches formed on the contact surfaces and the value of the chip formation coefficient decrease. As the amount of formation waters in oil emulsions increases, the depth of scratches increases. A similar situation is observed when studying the friction force and friction coefficient.

As a result of the study of the reliability and durability of valves in sandy wells, it was determined that their performance is very low. Most of them failed due to wear of the sealing working surfaces.

Inspection of the valves after operation shows that abrasive wear has occurred on the working surfaces. During the opening and closing of the valves, sand grains falling between the shield and the saddle scratch the working surface of the shield or saddle. Over time, these scratches turn into channels. The channels formed when these surfaces are completely aligned will create gaps between the surfaces, causing product to leak into the outlet throat. High-pressure fluid will turn these gaps into scratches, causing the valve to fail. This is abrasive and hydroabrasive wear, which quickly destroys the sealing structures in sandy wells. If such cases are detected in time, the work is stopped, the sealing structure is dismantled and repaired. After the blocking unit is restored, the work is continued[8].

The overall performance of valves and their valve assembly components largely depends on the optimal solution of material supply for them and the correct determination of operating parameters depending on operating conditions. The optimal solution of material supply implies the correct selection of the strength, hardness and other physical and mechanical properties of the materials of the contacting parts (shield-saddle, plate-cheek, etc.).

When determining operating parameters depending on the conditions, the influence of corrosion conditions, vibrations and shocks, as well as temperature and pressure changes, is taken into account.

The reasons for the rapid destruction of valve parts in multi-sand compressor wells of Binagadineft and Absheronneft OGPD-s were investigated and it was determined that they are hydroabrasive erosion and erosion processes. Depending on the amount of water in the product extracted from the well, its corrosive activity will increase the rate of erosion many times. In a number of studies, the corrosion process in the valve plug assemblies of fountain fittings has been studied and a list of materials that ensure reliable operation of the valves has been proposed [9].

According to TS 26-16-45-77, the choice of material for the valve plug assemblies is determined depending on the corrosion environment. Thus, the valve plug assemblies used for transporting working products containing up to 25 mg/l of mechanical impurities and up to 6% H2S and CO2 should be made of steel 38XMЮA, steel 20X13 and steel 30X13. Parts (saddle and shield) can also be made of carbon and low-alloy steels. In this case, their working surfaces should be coated with corrosion-resistant materials [10].

In order to improve the operational performance of valves, the scientific research work proposes coating the surfaces of the shield and seat with wear-resistant metal powder, as well as polishing these surfaces using a technologically new method. As a result, the tribotechnical properties of the valve plug and its service life have been improved by 1.4÷1.5 times [11].

In the manufacture of the plug, along with the precise preparation of its parts in terms of size and shape, their corrosion resistance must also be ensured.

The results of studies of the materials recommended for the parts of the plug in various environmental conditions have shown that the Al_2O_3 layer impregnated on the surface of the shield by hot impact is second only to stellite in terms of corrosion resistance. In an environment containing H_2, the Al_2O_3 coating is more resistant than stellite. The carbonitrided surface, which is unstable in produced water, is more corrosion resistant than steel 20X13 in acidic mixtures and environments containing H_2.

The resistance of aluminum oxide and stellite materials to contact corrosion is higher than that of other materials. Carbonitrided samples are not resistant to contact corrosion. However, the corrosion rate in this case is 280–290 times lower than the general corrosion rate.

One of the causes of wear in valves is related to pressure changes occurring in the well. Analysis of valves operating under such conditions shows that fretting wear occurs in the shield-saddle assembly . Pressure changes cause relatively small amplitude vibrations in the parts of the plug assembly, and the frequency of these vibrations varies between 3÷273 hs .

As a result of the conducted bench experiments, it was determined that, depending on the cycle of pressure changes, the tightness of the valves is violated. After the cycle value exceeds 2.2×105, the working product begins to fill the inner surface of the valve body as a result of the collapse of the geometric shapes of the contact surfaces.

During visual observation of the parts of the valve assembly, it was determined that traces of the saddle are visible on the working surface of the shield. This is explained by the occurrence of fretting corrosion erosion. As a result of the research, it was determined that in tests on the durability of the parts of the valve assembly in aggressive oil and oil products conditions, samples made of 40X, 38X2MЮA and 20X13 steel from 20X13 materials showed high resistance to fretting erosion. As a result of the research work carried out on the selection of optimal values of the structural parameters and strength limits of the parts of the valve assembly, as well as on achieving full tightness, it was determined that the effect of pressure changes must be taken into account at the design stage The pressure inside existing valves is distributed non-parallel(Fig. 2).

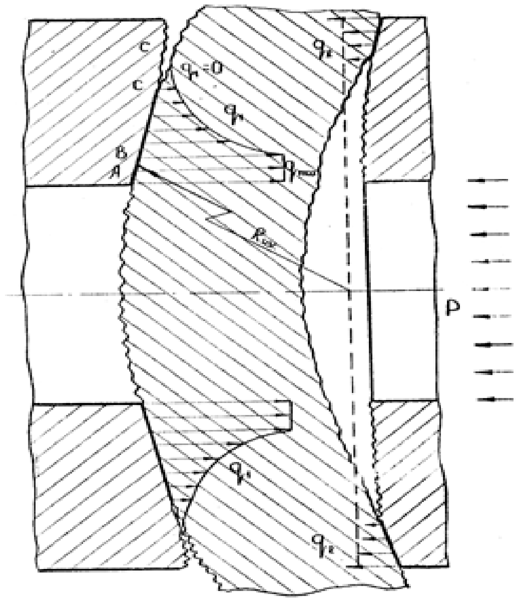

Fig. 2. Change in relative pressure inside the valves [2]

The geometric dimensions of the details of a given valve depend on the value of the mechanical and hydrostatic forces to which they are exposed. The structural shape and dimensions of the parts should be chosen so that they fully fulfill their intended functions in the design and are resistant to the pressures and stresses to which they are exposed.

It should be noted that since the uneven distribution of relative pressure increases the scale of mechanical wear during operation many times, ensuring the even distribution of relative pressure by ensuring the fit between surfaces is one of the main issues we set in the research work.

-even distribution of relative pressure in the sealing unit;

-resistance to mechanical wear;

-ensuring the strength of the contact surfaces, taking into account the influence of the environment;

-resistance of the materials of the body and parts to mechanical stresses;

-having low metal consumption;

-ease of manufacturing technology;

-resistance of the material of the parts to low or high temperatures.

Studies have shown that erosion areas exist in the inlet throat of the valve and in the connecting pipe, depending on the operating pressure and the solid particles contained in the product. These erosion areas reduce the operating resources and increase the risk of rejection. In the study of the pressure-dependent change in the depth of erosion areas, it was found that, regardless of the material properties, the characteristic result is that the depth and length of erosion increase as the pressure increases.

One of the reasons for the loss of the operability of the valves is the stress state and change in the shape of the knot details. Due to the working pressure of the product, the shield is pressed against the annular working surface of the saddle and bends along the radii (diameters) of the saddle. As a result, the principle of equal distribution of relative pressure on the sealing contact surface of the shield-saddle pair is violated, and non-parallel wear occurs during the opening and closing of the valve.

In addition, cases of crushing on the surfaces as a result of improper provision of the shear resistance of the parts of the blocking node at high pressures have been observed. The uneven distribution of the relative contact pressure of the shield on the working surface and the back-and-forth movement of the shield gradually destroy the working surface. After a while, the tightness is broken and the valve fails.

The purpose of the work: For this reason, the task is to develop designs of valves that ensure uniform distribution of stress on the contact surface of the shield-saddle pair and that are resistant to wear of the sealing knot.

Methodology: Considering that the main driving parts of the valve sealing knot are its shield and saddles, and the spindle and cuffs in the spindle-nut knot, the design initially requires the calculation of their shape and dimensions depending on the working pressure. Other elements, which are structurally related to them, should be based on the known strength theory depending on the values of the pressure and deformations they perceive. The width of the contact surface of the saddle with the shield is determined depending on the value of the pressure that the shield can tolerate for the material and varies between 12÷32 mm. As can be seen, although the reliability of the sealing increases as the width of the contact surface of the saddle increases, the fact that this value exceeds 32 mm increases the overall dimensions of the knot. A large force is required to open and close the valve. The width of the saddle increases the reliability of the contact.

The geometric dimensions of the shield are among the parameters that ensure the reliable operation of the valve. Its thickness is determined according to the plate theory, depending on the ability of the product to overcome the deformations caused by the working pressure when the valve is closed. It is known that creating a completely perfect design is a difficult problem. Each design, including valves, has certain advantages and disadvantages. Most of the shortcomings fall on the shield-saddle pair. Ensuring the tightness of this pair, reducing the friction force arising from the reciprocating movement of the shield, and eliminating the static friction that occurs when the working pressure bends the shield are among the most important issues. In this sense, the difficulty of the reciprocating movement of the shield in known designs and the possibility of bending the shield under the influence of the working pressure load to increased wear on the contact surfaces. In order to solve the above-mentioned reasons, the following conditions should be taken into account when developing new designs of the valve assembly.

- the design of the saddle should be selected so that the working surface of the saddle is bent to the same extent during the maximum deflection of the shield;
- the sealing joints should be redesigned based on this deflection;
- the material selection of the valve assembly parts should be updated and the update should be carried out in accordance with the working principle of the design;
- in the design of the valve assembly in wedge valve designs, in order to ensure a straight flow of fluid, the forward and backward movement of the saddle should be ensured during the forward and backward movement of the shield.

Several types of valve designs have been developed within the above-mentioned conditions [12] (Fig.3). The proposed valve allows to reduce or eliminate the causes of pressure changes, dynamic forces arising during opening and closing of the shield, and compressive forces due to plate bending. On the other hand, the most important thing is that careful selection of the details of the design of the plug assembly against dynamic forces will lead to a long service life of the valve.

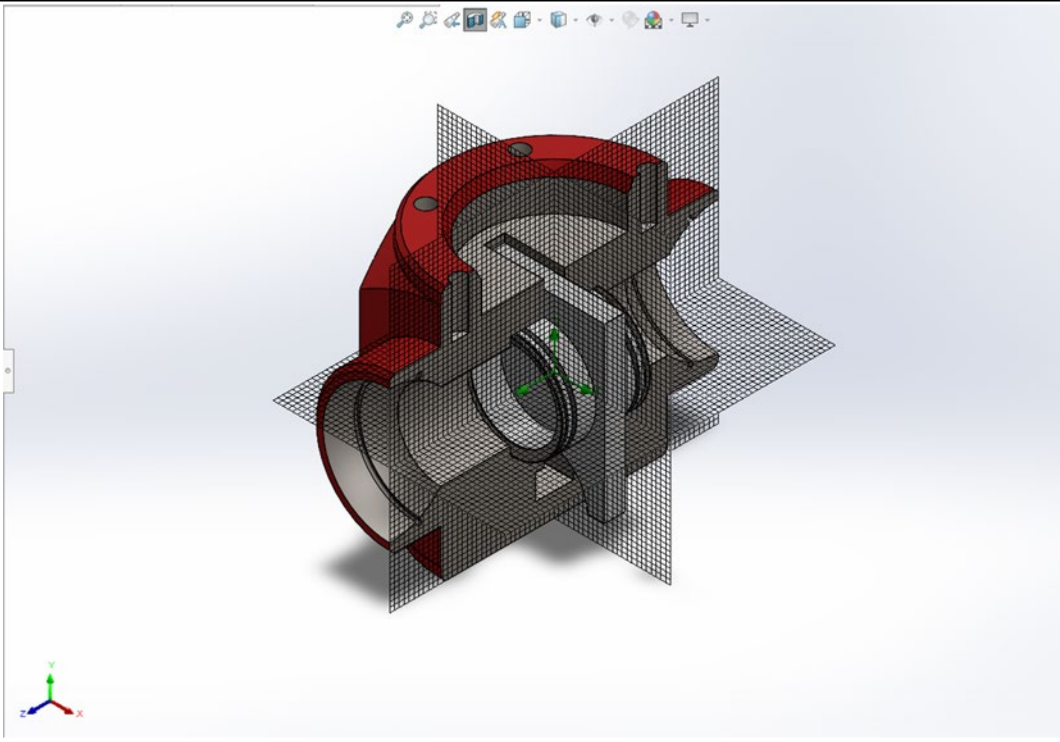

Fig.3. Valve structure.

In innovative valves, the correct determination of the thickness of the shield is a key condition for its long-term operation. We determine this thickness based on the plate theory.

Based on plate theory, the amount of shield deflection is calculated by the following formula.

$$y = \frac{P_i \cdot d^2}{1024 \cdot D} \cdot \frac{5+\gamma}{1+\gamma}. \quad (1)$$

Where, γ - Poisson's ratio for the material of the plate; d-diameter of the circular contour on which the plate rests; D-cylindrical stiffness of the plate

$$D = \frac{Eh^3}{12\left(1-\gamma^2\right)} \quad (2)$$

After mathematical transformations, we determine the thickness of the plate based on the amount of its deflection.

$$h \in \sqrt[3]{\frac{12 \cdot P \cdot D_0{}^4 \cdot (5+\gamma)(1-\gamma)}{1024(1+\gamma) \cdot y_{\min}}} \quad (3)$$

(3)- According to expression (3), considering the minimum and maximum deflection of the shield, we can determine the range of variation of the thickness of the shield. This range will ensure the operability of the valve.

In order to ensure the operability of the proposed design, we can determine the thickness of the plug that ensures the operability of the plug corresponding to the maximum deflection of the shield.

$$h \in \left[\sqrt[3]{\frac{12 \cdot P \cdot D_0{}^4 \cdot (5+\gamma)(1-\gamma)}{1024(1+\gamma) \cdot y_{\min}}} ; \sqrt[3]{\frac{12 \cdot P \cdot D_0{}^4 \cdot (5+\gamma)(1-\gamma)}{1024(1+\gamma) \cdot y_{\max}}} \right]. \quad (4)$$

Where h-plate thickness E-Young's modulus P-working pressure, γ - Poisson's ratio for the material of the plate d-diameter of the circle on which the plate rests D-cylindrical stiffness of the plate.

According to the expression (4), the specified thickness of the shield is 1.5 times smaller than the existing thickness of the shield, which leads to a decrease in material consumption. In order to ensure reliable operation of the valve at the specified thickness of the shield, new designs of the valve opening and closing mechanism should be developed. In this sense, the proposed valve design, which was developed while maintaining the existing thickness of the shield, demonstrated high reliability and durability during the experiment. The forward and backward movement of the shield became 1.2 times easier .

The proposed valve designs, which provide high tightness in high-pressure wells and are easy to control under operating conditions, are made in a wedge-shaped design and the principle of flatness is maintained . These designs allow to reduce or eliminate the causes of changes in pressure force, dynamic forces arising during opening and closing of the shield, and the effect of compressive force as a result of plate bending. On the other hand, the most important thing is that the careful selection of the details of the construction of the plug node against dynamic forces will lead to a long service life of the valve.

The advantage of the improved MMS valve under study is that it ensures uniform pressure distribution in its sealing node, regardless of friction. The loading simulation of the new structure was studied using the SOLIDWORKS program. The obtained result proved that the tightness was ensured (Fig.4).

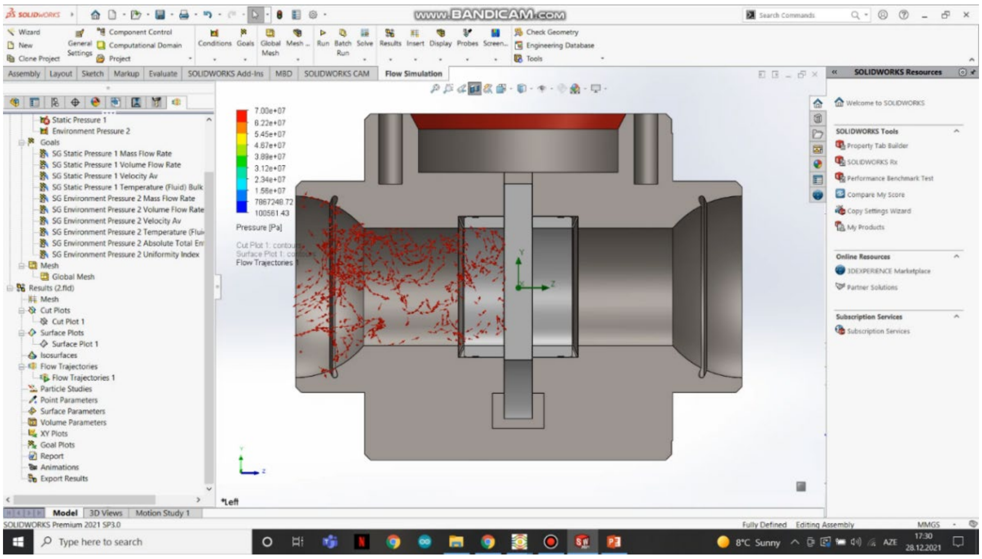

Fig 4. Flow trajectory of a liquid in a closed state.

In the improved design, the preparation of the plug assembly in three parts and the application of an elastic element in their structures ensure an even distribution of stresses along the contact surfaces. Thus, during opening and closing, the shield, which is subjected to a compressive force as a result of the working pressure, is pressed against the metal ring in contact with it. At this time, the metal ring, which is installed with one side in the inner part of the body with the help of an elastic element, receives this force not only at one point, but along its entire surface, and as a result, causes an even distribution of stresses.

Conclusion

1. Ensuring equal pressure distribution inside the improved valve structures will eliminate the non-parallel wear occurring in the shield-seat pair and ensure maximum tightness between the pairs.
2. In order to ensure equal pressure distribution in the plug node of the improved valve structures, a new expression has been proposed for determining the thickness of the shield.

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