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DESIGN AND PERFORMANCE ANALYSIS OF IMPROVED VALVE CONSTRUCTION BEING USED IN OIL AND GAS INDUSTRY

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Abstract- To explore the effect of the weariness to the valve constructions under various angles of opening & closing conditions, this paper considered the main seal of the valve construction as the point of study which is a part of valve's hermetic elements. The research adapted a new rotating 3D model, which was made to analyze pressure impact on seal edges. To identify the pressure distribution over the valve inner elements, various parameters were considered for analysis. Thus, theoretical phenomena, Solid works simulation, and confrontation were done in order to research the connection between pressure distribution and its dynamic characteristics in three different positions of the valve. It is the first time to research the pressure distribution over the trapezoidal cross section in the given conditions. This paper proved reliability and efficiency of the improved valve's model. Results show that the weariness of different parts tend to be much more strained under the rigorous discordant condition in different positions of the valve, however it could be eliminated by applying the trapezoidal cross section for the hermetic element's seals. Results demonstrate that initial force is affected by type of flow condition and fault degrees.

Keywords: Liner Motion Gate Valve, Friction, Efficiency, Reliability, Ball Valve, Packing Element, Gate, Saddle, Hermetic Elements.

1. INTRODUCTION

Currently, one of the most important areas of the oil and gas industry is the development of closing units' reliability to cover demand during operations by decreasing the maintenance break downs [1, 2]. As a widely used opening-closing equipment, liner motion valve plays a completive role in oil and gas industry which affects the economy in its turn accordingly. The usage percentage of valve constructions with various type of seals has significantly increased in industry. Calculated ratio is even much higher in oil & gas industry. The sealing fault can cause an operational downtime which to be considered a rigorous situation. This will lead to casualties and asset damage as well as asset loss at the end [3].

It can be emphasized that the valve constructions are subject to several type of effects which lead the unit to damage. For instance, corrosion, erosion, hydro abrasive wear could be exampled at current case. Due to the affects listed, the valve loses its workability earlier than it should and more premature than specified in its technical passport [4].

Hydro abrasive wear is mostly noted for all type of the valves. The main reason of having the hydro abrasive wear is due to the product passing through the valve closing element while it is in an open position. The product from the ground or other means of source, come with the small particles inside. These particles remain between the closing element of the unit and its body. In each opening-closing movement, the small particles scratch the material of the hermetic elements [5, 6].

The valve loses its capability of the tightening due to such a long range of weariness in the valve elements. The particles which scratch the materials grow over the time and start to create the narrow gaps between the surfaces meet each other in valve's close condition. Considering the high flow rate and the turbulence in the valve, the scratches on contacted surfaces rapidly become large washes, which can be repaired in case if it is observed at early stage.

2. LITERATURE REVIEW

In this, current research is dedicated to research the pressure distribution over the improved valve construction. The main difference of current proposed construction is to have the sealing element cross section changed to a trapezoid which in terms will lead to get the pressure distributed over the faces, relatively equal [4-6].

Over the past several decades, the usage of different type valves has grown significantly. This is associated with a significant increase of the industry's demand in all areas to deliver the product from one to another station [7, 8]. A lot of research conducted for different types of valves. For instance, Qian, et al., [4, 5] employed the Tesla constructed valves to a hydrogen decompression operation and explored pressure distributions drops and Mach number in multi-stage Tesla valves.

Migout, et al., [9] carried out research for the relationship for the temperature variation in the sealing surfaces atmosphere pressures and seal vaporization rings face deterioration condition. A conclusion made that fluid film stability could be significantly changed in the case that temperature change gradient of the atmosphere is overwhelming.

Yuan, et al., [10] did various numerical simulations to run research for the cavitation globe valve inner elements and its characteristics as well as the structural definitions which affected the cavitation process at the end. Zhang, et al., [11] run a sealing investigation for leakage between metal-to-metal surface by proposing a new fractal model for the surface smoothing and leakage process.

Gropper, et al., [12] furnishes a confront study for various modelling techniques of fluid flow and cavitation. Dasgupta, et al., [13] and Zhang, et al., [14] focused their research on the proportional and pressure relief valves opening and closing conditions, respectively. Moreover, Jin, et al., [15] and Qian, et al., [15, 16] run an investigation for Tesla pilot-control valve under various angles for structural parameters definition where they concluded their opinion with the effect of pressure to meeting seals.

Chen et al., [17] focused on pressure-reducing valve thermal stress and looked at the valve construction under different modelling for gaining a new approach to the relevant pressure distribution which would lead for an increase to the reliability of valve's lifespan.

Thus, in 2015 a different solution was provided by C.N. Aslanov and K.S. Mammadov [18] in the conference held in Canada. It was dedicated to increase the improved plug valve's efficiency by modifying its construction. There were several calculations done to provide the applied mechanical engineering methods. At the result, construction of the proposed valve can be improved by resolution of the force on working pressure which happens on tightened contact area of hermetic elements. A new formula suggested to define the relevant surface pressures onto the contact surfaces.

In 2019, Aslanov, et al., applied the fuzzy logic for the different materials to predict the efficiency changes of improved valves constructions during the statical data-based exploitation. A variety range of the application at current industry to determine the reliability of valves is currently being used. It assists to determine what the worst-case failure scenario of possible failures could be caused in the flowlines by loss of valves [18, 19].

3. ASSESSMENT OF LINER MOTION GATE VALVE, BALL VALVE AND THEIR HERMETIC ELEMENTS

This work covers modeling research for the hermetic elements of the valve by using SOLIDWORKS. The prototype is considered a gate valve which is mainly applied at the industry for various purposes and hermetic element and the ball valve which is known with its high efficiency. Different approach for complex valve constructions reviewed, and a modification to closing element of unit was established.

3.1. Assessment of a Liner Motion Gate Valve Construction

The most common gate valve is the ones which are being installed in a straight pipe at perpendicular direction to the line and have a T-shape installation basis. The operation of a gate valve is managed by the handle installed on top and which delivers the torque to the hermetic elements for opening or closure. In basic concepts, the handle turns at 90° to flow over the way of seat, followed by another turn of 90° to let flow through the outlet. The direction of flow is usually given by the manufacturer. It is vital to have the valve installed as per its instruction manual. The essential parts of the gate valve are seat, stem, valve body, hermetic elements such as saddle, seal, and shield [20].

1. Body
2. Bonnet
3. Wedge
4. Stem
5. Gland
6. Seat ring
7. Yoke
8. Packing
9. Gland Flange
10. Valve port
11. Yoke Bush
12. Lantern
13. Back Seat Bushing;
14. Gland eyebolt, nuts
15. Bonnet bolts, nuts
16. Hand Wheel
17. Hand Wheel nut
18. Bonnet Gasket

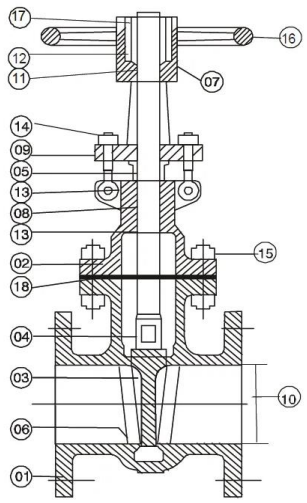

Figure 1. Full port gate valve construction [21]

In Figure 1, the full port gate valve main parts are shown. The hermetic elements of the valve active surfaces must be prepared specifically due to avoid the level of weariness. The hermetic elements of the gate to be focused on while the materials are chosen for construction.

While the valves are being selected for installation in a system, it is a must to consider the one of most important factors which is the Flow coefficient. It is determined by gallons of water per minute at 60 °F. The pressure drop is 1 PSI. The gained result helps us to select an appropriate valve for operations. Pressure drop can be defined from the relations available. It is another main factor while choosing the type of valves for an application. Flow characteristics of a valve is shown by a graphic which is based on the connection between opening of valve and product passing.

Figure 2 describes control valves trim dependence. However, we mainly use the 3 off them as per the handbook of the valve. Those are quick opening, linear and equal percentage [22].

3.2. Assessment of a Ball Vale Construction

Ball valves are mainly applied to the simply processing units, however they are also majorly being used in the aggressive industries which contain the hydrocarbon oil and gas as well as they are mostly. It is only designed to be used for on/off purposes [23].

The piping in oil and gas industry usually carries the flow of seawater or some other type of products which consisted of various liquid mixture. Ball valves could be considered as the best on/off valve for such type of applications. The alternative units i.e., gate valve, butterfly valve, plug valve are not as robust as ball valve due to their construction and hermetic elements design.

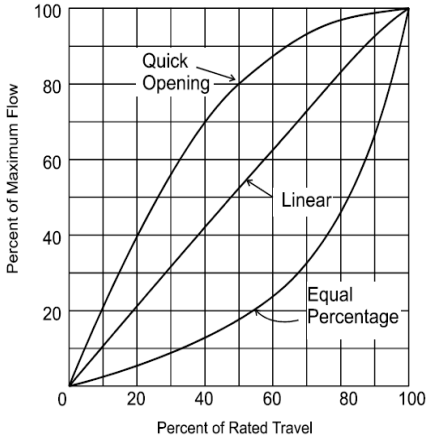

Figure 2. Commonly observed inherent flow characteristic types [22]

Despite the butterfly valves and gate valves are cheaper, they are not highly suggested to be used for the seawater transfer compared to ball valve since the flow is aggressive and has got the mixture of hydrocarbons. It also requires a high-pressure transfer as well as a quick closing for emergency situations [24].

Due to above specified reasons, wedge-type gate valves are not recommended for such kind of applications. The main closing element of the ball valve is ball itself and its hermetic parts seal, gasket, and saddle. The construction of ball is in a sphere shape in the housing. Basically, ball is divided 2 main types which are floating and trunnion. At the first case, the ball arrangement is not fixed from the bottom stem. Here the fluid pressure facilitates sealing by pushing the ball itself against valve seat.

The second option for limitation of floating size is to apply the metal seated ball valves which also called trunnion-mounted ball valves. Here, the ball is in a fixed position through plate or flange or integrated part. Such a design is more applicable for the processes where high pressure is the main factor. To avoid leakage between valve seat and ball when the valve is closed, an annular seal system could be utilized [25]. Leakage of seal can also be caused by imperfection manufacturing of the seal itself or due to imprecation construction of valve seat. Deflection of used seals might vary due to thickness of seal for different units. The studies conducted for such seals prove that seal dynamic inconstancy is much lesser apt ascertaining lower operational difference in kinetic energy to main line inertia ratio. It also differs from decreased velocity, considering velocity in the inlet is much higher than the velocity in outlet. Increase of external surface area improves dynamic stability of the unit, considering outlet velocity fluctuates and decreases at the end [26].

4. TYPICAL HERMETIC ELEMENTS FOR A VALVE CONSTRUCTION

It can be concluded from the assessments of valve constructions that the main working part of a closing unit is its hermetic element. Majority of failures determined in this part taking into account that it is subject to work under differential pressure conditions. Valve construction as a closing device to be also sufficient for a proper sealing during production throughout its life span.

The main sealing element for a gate valve is its gate and seat/saddle pairs. Unequal distribution of relative pressure onto the gate and other hermetic parts is one of the utmost reasons for rejections in sealing [27]. From the assessment of ball valve constructions, it could be realized that the main element for the ball valve remains as ball and sealing hermetic elements. Those are subject to several failures and rejections due to various factors.

In this simulation work, it is considered to mesh the gate valve characteristics over the ball valve and proceed with further evaluation of its parts. Flow simulation describes the movement of product in the valve and its affect to the parts. The new proposed model for the hermetic element is aimed to decrease the friction between the sealing elements of the valve and its body. By this method application, increase of reliability and longevity of the valve construction could be granted [27, 28].

5. SIMULATION OF PRESSURE EFFECT TO THE HERMETIC ELEMENTS OF IMPROVED VALVE CONSTRUCTION

To assess the technical reliability of an improved liner motion gate valve hermetic elements, an analysis of the flow distribution in the system is carried out for different positions of the valve such as close, open, semi-open. New construction for ZMS 65×70 gate valve along with its various internal parts such as the seal, O-ring, seat, body, gate, saddle was produced in Solid works. Each parts modelled separately which for items specified above. To simplify the flow analysis as well as to visualize its effect to the parts, the non-essential nodes of the valve for current simulation removed, such as bolts, nuts etc.

The product chosen for analysis is water. The wheel of the valve is replaced with a handle to simplify the overall construction and make the movements of the gate much easier which is connected to the handle through stem. The valve is closed with the blind flanges from both sides. This is due to allow the system to show how the internal elements of valve construction being affected by the flow and prevent any leakage might lead the seal failure.

The flow passing through the valve considered at the highest pressure of the chosen gate valve and it remained static during the flow. The static pressure is noted as 70 MPa, and the nominal diameter of the valve considered as 65 mm. Despite the inlet pressure considered 70 MPa, the outlet pressure summed up with the atmospheric pressure. SG maximum velocity considered in the flow for all 3 positions. Maximum total pressure equaled to the sum of maximum dynamic and maximum static pressure.

During analysis, the cross section of saddle considered as trapezoid and various grade of steel materials considered in preparation. Those are chosen as per following, based on GOST 7809: ST 20, ST 20 X, ST 40, ST 40 X. Material differentiation is not considered in this simulation because of the current analysis is to define the pressure distribution onto the surface of new constructed element. The internal forces of material as well as the maximum permissible pressure voided while running the analysis. At first stage, it was considered that the water passes through the valve in a liner mode as laminar flow.

Figure 3 shows the distribution of the pressure in the valve while it is in fully open position. Figure 4 shows the flow movement in the valve while it is open, and pressure is static. The proposed type of the hermetic element makes the valve to improve its velocity at high, however, not to limit the quick sealing whenever required.

Figure 5 is an extraction from Figure 4 simplified view to describe the overall movement of the fluid (in our case water). At both cases, the movement of fluid is based on a range of the flow rate which leads to achieve a speed required to deliver the product from one to another station.

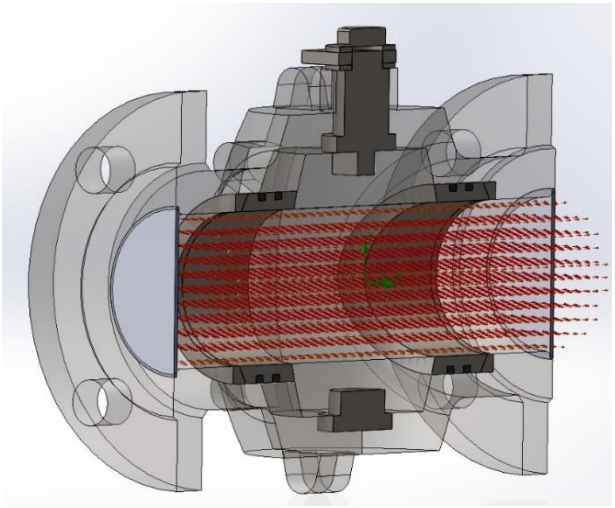

Figure 3. Improved valve's construction in fully open position

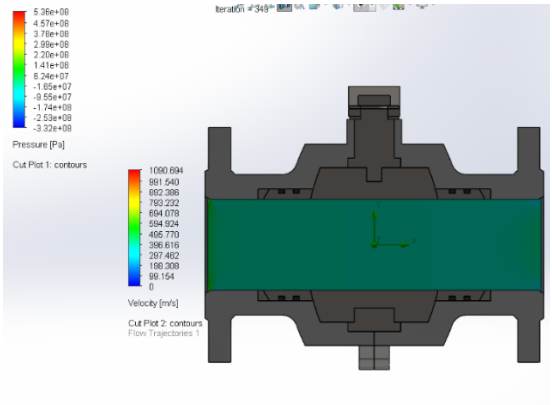

Figure 4. Flow movement in improved valve's construction in fully open position and its effects to hermetic elements

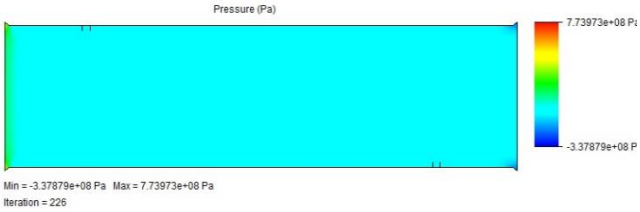

Figure 5. Flow movement in improved valve's construction in fully open position

Second analysis run for the condition where the valve is considered in a semi-open position. Range of the pressure and flow is kept the same as in open position.

Figure 6 shows the movement of fluid in the valve when it is in a semi open position. As it could be noticed, the liner motion has changed from laminar to turbulent flow which increases the number of forces to the hermetic elements of the valve.

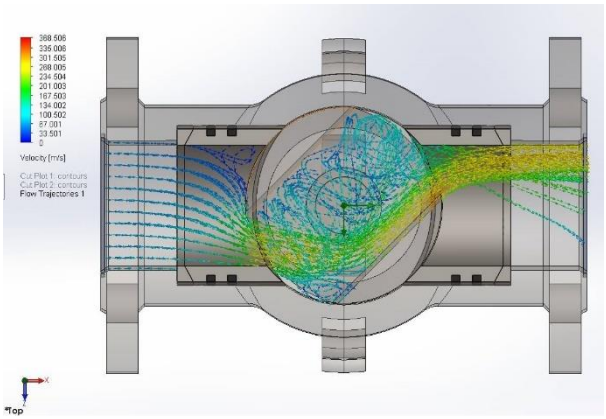

Figure 6. Flow movement in improved valve's construction in semi-open position

Figure 7 is the simplified extraction from Solid works while the valve being evaluated in semi-open position. 45 degree is considered for semi-open position and relevant simulation data produced.

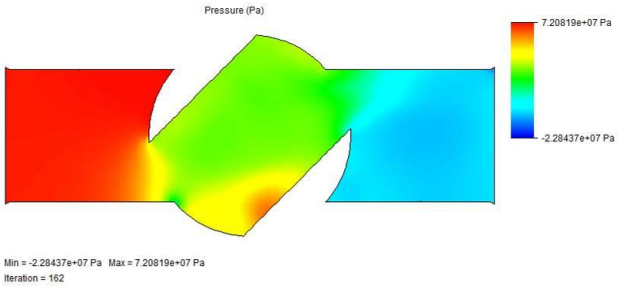

Figure 7. Flow movement in improved valve's construction in semi-open position and its effects to hermetic elements

Figure 8 illustrates the effect of static pressure in inlet as well as the movement of fluid in the valve. Orange color in the photo represents the initial pressure which is at its highest and meet with the surface of the hermetic elements. After a while, the color is changed to yellow which represents that the pressure distribution is not anymore as it was in initial stage. Green part of the chart describes the relevant pressure distribution after the flow normalized in the valve.

Figure 9 represents the improved liner motion valve construction in a closed position. Range of the pressure and flow is kept the same as in open position.

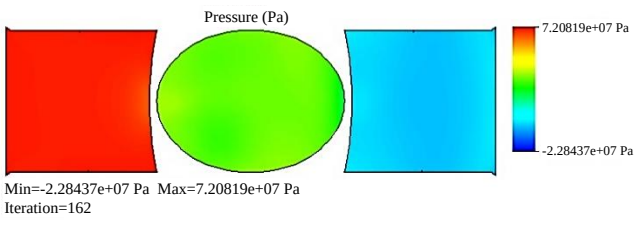

Figure 8. Flow movement in improved valve's construction in semi-open position

The flow was considered as laminar during initial stage, and it could refer to [1] for further calculations. However, the flow changed from laminar to turbulent after a while due to pressure distribution as well as the increase of the flow in passing through the valve.

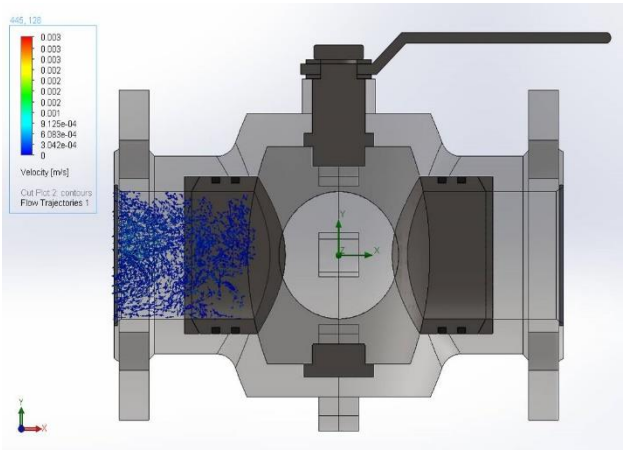

Figure 9. Flow movement in improved valve's construction in closed position

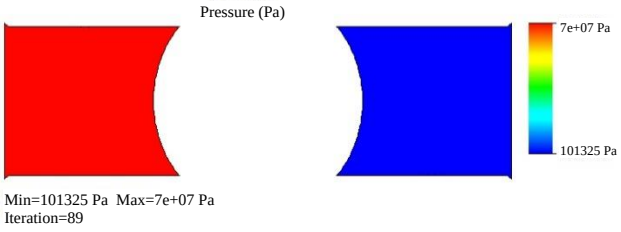

Figure 10. Flow movement in improved valve's construction in closed position and its effects to hermetic elements

Figure 10 shows the simplified extraction from solid works for the condition of new type seal being proposed and its resistance to the given pressure.

5. CONCLUSIONS

This paper considered the main seal of the valve construction as the point of study which is a part of valve's hermetic elements. The research adapted a new rotating 3D model, which was made to analyze pressure impact on seal edges. Various dynamic parameters applied to the valve to identify relevant pressure distribution over inner elements. Theoretical phenomena, Solid works simulation, and confrontation were done in order to research the connection between pressure distribution and its dynamic characteristics in three different positions of the valve. Pressure distribution checked as the first time for such kind of valve in given conditions.

This paper proved reliability and efficiency of the improved valve's model. Results show that the weariness of different parts tend to be much more strained under the rigorous discordant condition in different positions of the valve, however it could be eliminated by applying the trapezoidal cross section for the hermetic element's seals. Results also demonstrate that initial force is affected by type of flow condition and fault degrees.

NOMENCLATURES

1. Acronyms

SOLIDWORKS; Simulation Program
GOST 7809; State Standard of the Soviet Union
ST20: Steel 20
ST20X: Steel 20 X
ST40: Steel 40
ST40X: Steel 40 X
ZMS 65×70: Type of gate valve

2. Symbols / Parameters

Q: Discharge in gpm
SG: Specific gravity of fluid

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BIOGRAPHIES

Jamaladdin Nuraddin Aslanov was born in 1972 in Azerbaijan. He is Doctor of Philosophy in Technology in the field of oil and gas (mechanical engineering) at Azerbaijan State Oil and Industry University. His research interests are related to increase the efficiency of valves being used in industry He has got patents for 6 straight valves, 1 adjustable throttle, 1 plug valve and he is the author of 2 monographs, 2 textbooks, 2 manuals, and 1 methodical instruction. He has several manuscripts, articles, thesis printed in international journals such as the ones including Scopus and WoS indexing.

Khalig Sadig Mammadov was born in Azerbaijan, in 1993. He is graduated as B.Sc. and M.Sc. degrees in Mechanical Engineering from Azerbaijan State Oil and Industry University, Baku, Azerbaijan in 2016 (master's degree with Honours). Currently, he is a Ph.D. candidate in Azerbaijan State Oil and Industry University. His research interests are related to increase the efficiency of valves being used in industry. He has several manuscripts, articles, thesis printed in international and national journals. Currently, he is working as Vessel Maintenance Surveyor within Shah-Deniz-2, CGLP and ACE projects in Azerbaijan under a foreign oil and gas company.