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INCREASING BALL VALVE WORKABILITY BY CHANGING THE DESIGN OF ITS HERMETIC ELEMENT

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Abstract- To investigate the effect of weariness over the ball valve construction under different conditions, the current paper considered the main element of the construction as a point of study. The study altered a new 3D model of the construction in which the simulation works run in order to analyze the pressure distribution over the seal and valve body. Various parameters are considered in the work to define the relevant pressure distribution over the elements of the construction. The theoretical approach, SOLIDWORKS simulation and pragmatic approaches were carried out due to study the connection between ball and sea of the valve as well as its sealing elements tightness. Pressure distribution over the oval crossed section hermetic seal was checked at first time in given condition. Thus, the research work proved the reliability and effectiveness of the improved valve's construction. Based on the results, it has been observed that various hermetic parts of the ball valve could be under different pressure application despite the inlet pressure is the same and it is concluded with the evaluation that this condition can be eliminated by usage of the oval crossed section sealing element. Results illustrate that initial force is affected by type of flow condition and in its turn, it affects the displacement of the hermetic element.

Keywords: Ball Valve, Friction, Hermetic Elements, Corrosion, Erosion, Oval, Workability.

1. INTRODUCTION

Current oil and gas industry requires a lot of reliability over the equipment those are in demand for proper operations. One of the mostly used units in industry are the valves which are generally being utilized to control the flow, direct it from well to other equipment for processing further steps, as well as shut the flow etc. [1].

Nowadays, the development of oil and gas industry is basing on the improvement of closing units' reliability which are applied over or under the water. As a long-established closing device, the ball valve plays a vital role in continuous operations in production. This is not only limited with the oil and gas industry, but also widely used in industry of chemistry, energy conversions, metallurgy etc. [2, 3].

These types of valves are the most suitable choice for on/off purpose in aggressive environment in the oil and gas industry. They are most robust compared to the butterfly or gate valves for such kind of conditions [4]. Wide varieties of materials are readily achievable to manufacture the distinctive components of ball valve. The manufacturing materials for ball valve constructions are selected based on pressure, diameter of the valve, type of the ball and temperature. Several kinds of weariness or process streams might seek a compromise in material selection that is suitable for the aggressive environment to extend the life of valve or its components [5].

The main failure factor of the ball valve constructions is typically related to the weariness level of its hermetic elements which prevent the flow flooding and direct the product from one to another location. Corrosion, erosion, are mostly observed type of weariness for such kind of valves. These main reasons are leading to failure of the valve construction while it is in production, and this key element accomplishes the increase of mechanical breakdown for the overall operations [6].

Considering high-pressure rated ball valves are typically applied in environment where necessarily on/off operations are required, thus they are mainly remaining in closed position, that leads to form incrustation around the ring of the ball. One more point that would need to be emphasized is the fretting weariness which is usual for such kind of the constructions considering they are obliged to resist the high pressure over the lifetime of operations [7].

2. LITERATURE REVIEW

In the current research, the pressure distribution on the improved valve construction has been analyzed. The difference between the existing and improved construction is basing on the one of its closing elements which has got an oval type of cross section. This leads the pressure distribution to be relevantly maintained over the valve's main closing elements and to increase the workability of the unit [8, 9]. To increase the reliability as well as the workability of the valve constructions, a lot of research have been conducted over the years and they have been thoroughly examined.

Chern Ming Jyh, [10] experimented the performance of the flow in the ball valve construction by referencing to the pattern as well as the cavitation scenes using the method of particle tracking flow visualization. The main factor of the experiment was basing on the visualization of inlet velocities and several opening diameters of the valve (based on the rotation of ball inside of the construction) in and underneath (seating) conditions. Xue Guan, Seung Gyu, [11] in his research work, the authors have studied various properties of materials which are being used in order to manufacture body of the units. These are mainly the ones which maintain the sealing function of the valve construction. The proposed model of author is referenced to decrease the corrosion by resisting to its creation. And in this purpose, the researcher used Stainless steel model CF8M. Finite element method has been used to analyses structural strengthening. The RSM run to figure out the maximum optimal dimension of the construction and the result of the research concludes that using of the process could save lots of mass.

Dong Soo Kim [12] carried out the numerical analyses and thermal shock due to explore the accomplishment of ball vale high-pressure rated parts such as the hermetic elements. In the conclusion the author managed to optimize the overall material usage for different parts of the ball valve such as the ball, spring, seat etc., and the research proposed a new type of the zero-leakage model. This is mainly could be explained by distribution of the relevant pressure close to equal over the hermetic elements of the unit.

Thus, in 2022 a different type of solution in order to manage the relevant distribution pressure over the hermetic elements was proposed by C.N. Aslanov and Kh. S. Mammadov [13]. Various calculations run in order to gain the results of the proposed model and proposed new model of the valve simulated over the solid works by referencing to several positions of the unit such as the close, semi-open and open. The pressure distribution for each case has been separately identified and all the data collected in a graph which was presented in the article. It proves that the distribution of pressure could be solved by changing the construction of valves main parts such as hermetic elements.

In 2019 Aslanov, et al. used the fuzzy logic for the various type of materials to anticipate the effectiveness of changes over the developed valve construction. Using the fuzzy equations, an enormous range of data were collected and analyzed. The result was based on the loss of valve workability and this assisted to identify the worst-case scenarios for each case in the flow [14, 15].

It is determined from the literature review that a lot of researchers run an experiment or the re-design of the products to increase the workability of the unit. Several methodologies applied to increment the durability of construction. It is overall concluded that the structured examination for re-designing and engineering of ball valve hermetic elements might lead to change the conventional methodology and replace it with valued engineering which is much precise and supported by simulations [16].

3. ASSESSMENT OF BALL VALVE AND ITS HERMETIC ELEMENTS

Current work concerns modelling of an improved ball valve and reviewing of the load distribution onto its sealing elements. The reference taken from existing ball valve construction and its effectiveness was evaluated. SOLIDWORKS program used to establish the modelling and run the simulation in order to grant the load distribution over the body and ball of valve. The study covers evaluation of the existing valve hermetic element models, and a novel approach suggested for improvement of the sealing which drawn via the SOLIDWORKS and simulated with a pressure application.

3.1. Review of Ball Valve Construction and its Evaluation

Ball valves current usage in industry are as wide and differed as industry itself. The constructions are in range of arranging delivery of several type of chemicals, liquids, solvent, as well as natural gas etc. The usage limitation is applicable with the design factors of the valves based on their working pressure, diameter, and temperature that they work based on the chosen material for manufacturing of it. One of the main factors is to have easy maintenance on the designed valve in order to reduce the interruptions during the operations. Many types of the ball valves got an operating temperature ranged between -300 C and 2 300 C, basing on the size [18].

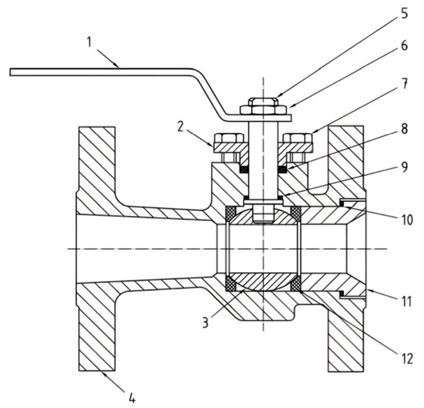

Figure 1. Floating Ball Valve Rendering [19], 1: Handle (lever), 2: Gland, 3: Ball, 4: Body, 5: Stem, 6: Stem nut, 7: Gland bolt, 8: Stem seal, 9: Washer, 10: Body seal, 11: Body inserts, 12: Seat

In Figure 1 the ball valve simple construction could be reviewed. It is equipped with a cylindrical port of the ball which let the product pass through the ball when the valve is in open position. Sides of the ball valve's hermetic element i.e., ball itself is accompanied with seats/ seals.

The purpose of the seats is to maintain the sealing of all in order to avoid the fluid leakage from the valve while it is in closed condition. Despite the design of seats (12) are not well observed, it can be found that the ball (3) is supported by 2 seats (12) around it which is the main purpose of sealing during the operation. It should be emphasized that the valve is described in open condition. During the movement of the valve from open to close position, it could be freely moved to upstream and downstream directions [20].

Ball is being operated by stem which gets the applied load from lever and deliver it to the ball which let the valve to keep opening or closing based on the operational requirements. The components namely stem, seats, ball are the ones which considered as a pressure contained boundaries. This is because of having the constant pressure application over these elements. Sealing of the ball valve is mainly managed by the seats, however the prevention of leakage is being maintained by the gaskets. Steam bearing is a component that located between the steam and body. The purpose of this bearing usage is to avoid weariness and galling while the 2 components are moving against or onto each other. Sealing of the stem is being managed by usage of the gland packing, its follower. The gland packing is compressed during the operation and a seal surface is created between the body and components of the steam. In this particular, the lever changes the mechanical force to the torque that valve steam is getting onto itself and maintain the valve position between open and close [21].

3.2. Review of Ball Valve's Hermetic Elements

The summary of the assessment could be concluded that the main working nodes of the ball valves is its ball and hermetic elements which maintain the sealing between the seat and ball. The number of failures is classified basing on the nature of the defects. Major portion of the break downs are related to unexpected leakages of the seals that occur during the operation. The different pressure circulation in valve construction leads to have the unequal distribution of the load over the hermetic elements and consequently, they are failing to maintain the sealed position during closure of the valve element [22, 23].

Figure 2 describes the types of valves trim dependence. However, we essentially use 3 off them as per the manual of construction. Those are quick opening, linear and equal percentage.

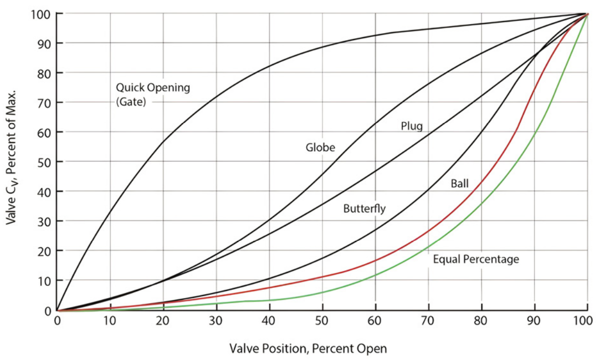

Figure 2. Inherent flow characteristic types [24]

The construction and working principles of ball valves are close to the ball-shaped plug valves. It has got a lever that is connected to the ball via the stem and maintaining the valve open/close position by turning. The ball has got 2 sliding rings around the construction, and it is the main element considered for sealing of the unit. Depending on the type and construction of the ball, different characteristics could be visible in different pressure applications. However, the seat of the ball is circular which is relevantly distributing the stress onto the seat circumferentially uniform [25, 26]. Judging by the assessment run for the ball valve constructions, it could be observed that the ball itself are always working under the pressure, however its rejection during the operations is lesser than the seals failure compared to each other.

As it could also be analyzed form above that the seal tightness is a vital point at designing and manufacturing of the valve used in oil and gas industry. Leakage of the seals in the seats are primarily due to angular loading and misalignment of the ball against the body and seat. Tightening of the seal is made with the pressure control over the hermetic elements which is to avoid the seat leakage. However, unequal distribution of the load is the main factor to get the sufficient torque which is overcome seal pressure and ending up the construction life span earlier than it is expected.

In the current simulation paper, it is taken into account to mesh the ball valve construction by using the SOLIDWORKS program. The improved valve construction hermetic element is modified with a type of the ball that is oval rather than circular. The unit is transferred to program, simulation of the body run by giving the consideration to the type of ball used. The pressure application is started from zero and increased to 105 MPa at maximum to complete the simulation. Flow simulation illustrates the movement of liquid in the valve and how it affects the hermetic elements. The proposed construction of the ball is purposed to decrease the friction factor between two hermetic units while operating onto each other and maintain the equal distribution of the pressure in the valve construction.

4. SIMULATION OF IMPROVED BALL VALVE MAIN CLOSING ELEMENT OF IMPROVED

In order to proceed with assessment of the improved type of ball valve construction's main elements, an analysis of the pressure distribution onto its hermetic elements run by using the SOLIDWORKS application. The valve construction has been looked in a closed condition only when the flow is passing through the ball and how it affects the nodes in contact with the flow distribution.

New construction for Ball valve 65×105 along with its different internal parts such as seal, seats, ball, body, was modelled in the program. Ball construction has been made from circular to oval which in turn aimed to increase the reliability of the construction and keep its long lifetime during usage of valve in operation.

New type of the valve construction body and sealing element modelled in the AUTOCAD and transferred to the SOLIDWORKS for further evaluation. Each of the sections separately created and meshed. In order to proceed with simplification of construction and avoid the long lead readings, non-essential nodes of the constructions have been eliminated from the construction such as nuts, screws, wheel and etc.

The flow is passing through the valve is water. The wheel of the valve is kept in constant position without any changes based on the pressure application. This is due to verify the strain of valve against the pressure flow.

The flow highest pressure is considered during the simulation taking into account that the process of simulating based on the initial static pressure given to the system. The static pressure is noted to be 105 MPa, and the nominal diameter for improved valve construction is considered 65 mm. Although the inlet pressure is noted to be 70 MPa, outlet pressure from the system is calculated by adding the atmospheric pressure. Maximum velocity is considered for the system in open and closed position. In each constrains, the new crossed sectioned seal's construction reviewed.

Figure 3 expresses the creating of ball valve body section which is fit for utilization of oval type sealing element in it. The valve has been sealed by blind flanges from each side. It is because of allowing the system to keep the pressure inside while it is in operation and examine the pressure distribution over the hermetic elements. Flow pressure during simulation is chosen to be static.

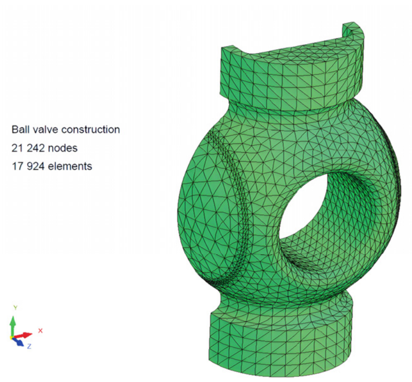

Figure 3. Improved valve's construction meshing for simulation

Figure 4 shows the distribution of the pressure over the seats of as well as the sealing elements of the ball valve in improved type of construction.

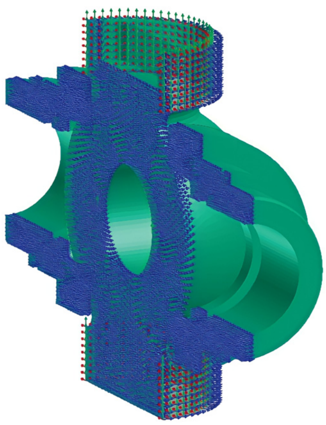

Figure 4. Pressure distribution over the inner elements of the ball valve construction

The products pass through the ball are water and always remain at system's highest pressure. Valve diameter is taken 65mm. Inlet pressure of the valve is considered to be 105 MPa, however the outlet pressure is noted to be summed up with atmospheric pressure. Material of valve is chosen as per GOST 7809. Maximum design temperature is noted as 60 °C.

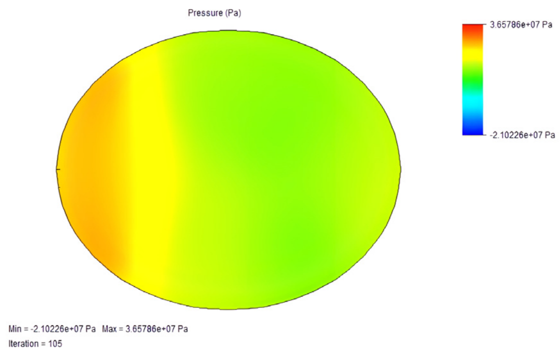

Figure 5. Flow movement in improved valve's construction

Figure 5 illustrates flow movement in the improved valve construction while the operation initiated and simulation run. From the figure it can be identified that the flow distribution over the element has been dramatically reduced compared to the previous type of the construction. This is noticed mainly due to the change of sealing element which is taking much pressure on it, and ball element remains almost under less static pressure during operation.

The sealing element of the ball valve is changed from circular to the oval/ elliptic shape which is done in order to avoid the non-linear distribution of the pressure over the hermetic element. Material difference is not taken into account at the current work, considering the analysis run due to define the distribution of relevant pressure over the modified hermetic element and its affect to the body. Internal force distributions are avoided as well, as the maximum allowable pressure in the system is not being reached while running the evaluation.

Figure 4 is dedicated to the load distribution over the elements; however, Figure 5 is much precise and directed to the inner element positioning in the valve while relevant pressure distribution happens. In Figure 5, it is obviously determined that in lower pressure circles developed closing element of valve construction keeps its shape and is able to have the load distribution maintained over the particles. However, this is going to change as soon as the pressure increases. In each interval of pressure fluctuation, the color of simulation changed much more from green to yellow and ended up with red. The change of pressure in the construction is the main source of valves malfunctioning. Despite the pressure distribution is going higher, the improved type of hermetic element which is in oval shape, can still resist the pressure till the maximum pressure when the valve is operated. Simulation results over the sealing element can be summarized that the hermetic construction can withstand the pressure distribution and rapid changes of the load sharing at different temperatures without damages or failures during the lifetime of ball valve.

Figure 6 describes Von Mises stress for the sealing element of improved ball construction. The simulation based on the product passing through the valve and affecting the hermetic elements of construction. Outer diameter of sealing element is shown in red which the most damageable part during operation. It's been eliminated via changing of the cross section for the sealing element. From outer to inner of the seal, there is a considerable change in amount of stress applied.

Taking into account that the mostly pressurized element of the valve is its seal, and in its turn, seal is being mainly loaded from internal diameter, the simulation assisted to verify that change of cross section shape for seal decreases the pressure distribution over outer elements and it almost distributes pressure equally over inner diameter of the seal.

It is determined that non-proportional division of force over the hermetic element lead to the failures in constructions in several points. Therefore, the current simulation is based on the division of forces over the hermetic element at several points in order to come a conclusion on improved construction's reliability. The points are chosen for pressure distribution check is 11 nodes. Each node consists of the layers over of the element. At each stage, static pressure is summed up with the distributed dynamic pressure over the element in order to simulate the overall distribution. Considering the characteristics of each layer is the same for the element, the hardness check and deflections of the material are not taken into account during the simulation process. 11 nodes are divided proportionally from 0 to 105 MPa of pressure. Process started from inner diameter and increased pressure to outer surface of the construction. Yield strength of the material is summarized in the end of simulation which is in an acceptable range while the valve operating pressure reaches its maximum.

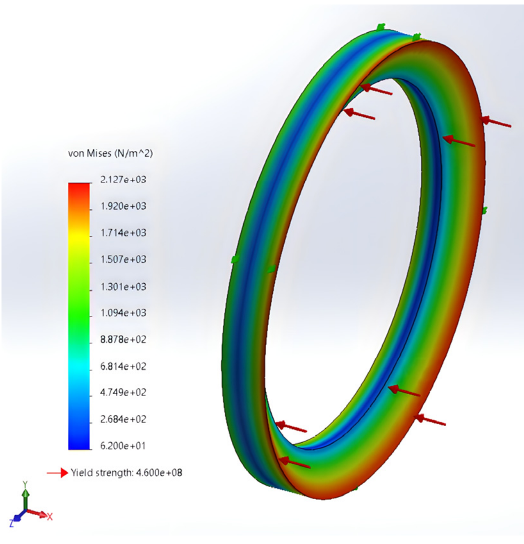

Figure 6. Simulation of Von Misses stress over the oval shaped crossed section sealing element of improved ball valve

Figure 6 is determining the von misses stress over the hermetic element whereas Figure 7 is determining the displacement value while the pressure is being distributed in the inner and outer surfaces of the seal.

Figure 7 depicts the simplified extraction from solid works program for the condition of new oval shaped seal proposed for ball valve construction and its resistance to displacement. Presence of multiple maximum points of displacements can be verified from the figure.

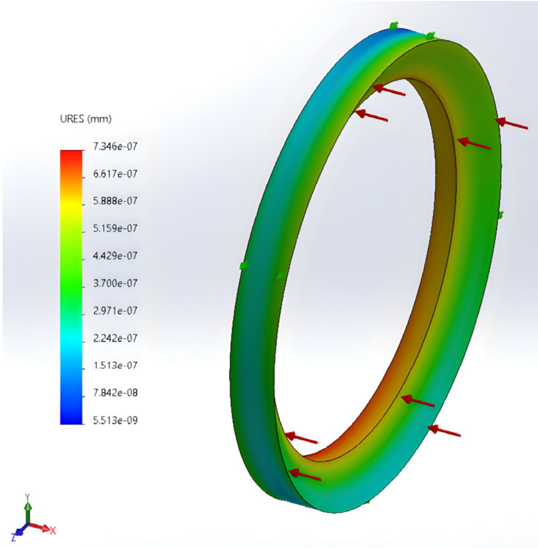

Figure 7. Simulation of URES over the oval shaped crossed section sealing element of improved ball valve

The force applications over the sealing unit are subject to change basing of pressure passing via the nominal diameter of construction. While changing of the pressure range, slight increase in displacement is visible. The simulation scale shows that given linear process consists of eleven points where the pressure changes considered from 0 MPa to 105 MPa. The first few pressure applications involve the small pressure changes which is not affecting the displacement in a considerable volume, and it is proportionally divided over the range of chosen interval. It starts to increase after the pressurizing of sealing around 90 MPa, and changes till 105 MPa. The pressure simulated over the oval shaped element which is described in figure, and it is clear that the despite of displacement construction still withstands the maximum pressure of overall construction without reaching its limit for fatigue of element.

Figure 6 is more robust to be based on in means of the simulation compared to Figure 7 considering displacement value is basing on the chosen material only which in the current research paper remains the same during the operation.

5. CONCLUSIONS

Current simulation work is based on the main seal and ball of the valve construction in order to study its hermetic elements conditions. The research devoted to run the simulation over the hermetic elements of the valve, and in this particular, the 3D model was created. Various parameters are considered in the work in order to define the relevant pressure distribution over the elements of the construction. The theoretical approach, SOLIDWORKS simulation and pragmatic approaches were carried out due to study the connection between ball and seat of the valve as well as its sealing elements tightness. Pressure distribution over the oval crossed section hermetic seal was checked at first time in given condition. Thus, the research work proved the reliability and effectiveness of the improved valve's construction. Based on the results, it has been observed that various hermetic parts of the ball valve could be under different pressure application despite the inlet pressure is the same and it is concluded with the evaluation that this condition can be eliminated by usage of the oval crossed section sealing element.

NOMENCLATURES

1. Acronyms

SOLIDWORKS	Simulation Program
GOST 7809	State Standard of the Soviet Union
FEA	Finite Element Analysis
URES	Resultant Displacement

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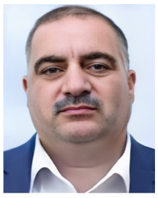
BIOGRAPHIES



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