ИНЖЕНЕРИЯ ЖӘНЕ ИНЖЕНЕРЛІК ІС
ИНЖЕНЕРИЯ И ИНЖЕНЕРНОЕ ДЕЛО
ENGINEERING AND ENGINEERING

МАШИНАЖАСАУ
МАШИНОСТРОЕНИЕ
MECHANICAL ENGINEERING

DOI 10.51885/1561-4212_2024_3_13
IRSTI 55.39.45

R. Gabdyssalyk[1], M.N. Argynbayev[2], К.T. Sherov[3], S.R. Baigereyev[1],
[1]D. Serikbayev East Kazakhstan Technical University, Ust-Kamenogorsk, Kazakhstan
*E-mail: riza.gabdyssalyk@mail.ru**
E-mail: sbaigereyev@edu.ektu.kz
[2]«Ust-Kamenogorsk Industrial Valves Plant» JSC, Ust-Kamenogorsk, Kazakhstan
E-mail: meddetello@gmail.com
[3]Kazakh Agro-Technical Research University, Astana, Kazakhstan
E-mail: shkt1965@mail.ru

IMPROVEMENT OF PIPE FITTINGS – DN50 BALL VALVE TO ENSURE TIGHTNESS AT PN 40 MPA

ҚҰБЫР АРМАТУРАСЫН ЖЕТІЛДІРУ – DN50 ШАРЛЫ КРАНЫНДА PN 40 МПА КЕЗІНДЕ ГЕРМЕТИКАЛЫҚТЫ ҚАМТАМАСЫЗ ЕТУ

СОВЕРШЕНСТВОВАНИЕ ТРУБОПРОВОДНОЙ АРМАТУРЫ – КРАНА ШАРОВОГО DN50 ДЛЯ ОБЕСПЕЧЕНИЯ ГЕРМЕТИЧНОСТИ ПРИ PN 40 МПА

Abstract. *The article discusses pipeline fittings for flow control at high pressure. The authors proposed replacing the seat manufacturing material with heat treatment and making changes to improve the design of the body. The proposed option for upgrading the ball valve body makes it possible to ensure PN 40 MPa and improves tightness, increases durability and wear resistance. The proposed changes are confirmed by calculations using the ANSYS program, special attention is paid to calculations for checking the strength of the structure due to complete deformation of the body under different conditions and separate calculations for the saddle.*
Keywords: *pipeline fittings, ball valve improvement, tightness, high pressure.*

Аңдатпа. *Мақалада жоғары қысымды ағынды реттеуге арналған құбыр арматурасы қарастырылады. Авторлар ер-тоқымның материалын термиялық өңдеуге ауыстыруды және тұрқының құрылымын жақсарту бойынша өзгерістер енгізуді ұсынады. Шарлы кранның тұрқысын жетілдіру PN 40МПа-ды қамтамасыз етуге мүмкіндік береді және тығыздықты жақсартады, беріктік пен тозуға төзімділікті арттырады. Ұсынылған өзгерістер ANSYS бағдарламасындағы есептеулермен расталады, әртүрлі жағдайларда тұрқының толық деформациясы арқылы құрылымның беріктігін тексеруге және ер-тоқымға жеке есептеулер жүргізуге ерекше назар аударылады.*
Түйін сөздер: *құбыр арматурасы, шарлы кранды жетілдіру, тығыздау, жоғары қысым.*

Аннотация. *В статье рассматривается трубопроводная арматура для регулирования потока при высоком давлении. Авторами предложено замена материала изготовления седла с термообработкой и внесение изменения по совершенствованию конструкции корпуса. Предложен вариант по модернизации корпуса крана шарового дает возможность для обеспечения PN 40 МПа и улучшает герметичность, увеличивает долговечность и износостойкость. Предложенные изменения подтверждаются расчетами с*

помощью программы ANSYS, особое внимание уделяется расчетам проверки прочности конструкции за счет полной деформации корпуса при разных условиях и отдельным расчётам на седло.
Ключевые слова: *трубопроводная арматура, совершенствование шарового кран, герметичность.*

Introduction.

In the Republic of Kazakhstan, the main technical task is to develop a highly organized pipeline transport system for the transportation of various liquid neutral and aggressive environments such as oil, petroleum products, steam, cold and hot water. The purpose of this system is to guarantee a high degree of reliability and maximum compliance with environmental standards and environmental safety requirements (Gabdyssalyk, 2019).

According to its functional purpose, valves are classified into several main groups: shut-off, regulating, distribution, safety, protective, phase separation. To perform the same functions, there are various types of valves, among which the main ones are gate valves, ball valves, taps and dampers. Among the main operational characteristics of the valve, the pressure with which it must work is highlighted. To meet various technical requirements, several types of pressure are distinguished which are conditional, working, and trial. Each of these pressures has its own specific role in ensuring the safety and efficiency of the valve (Gurevich, 1981).

Ball valve are devices that include armature components with movable elements capable of performing rotational movement around an axis perpendicular to the direction of flow of the medium. The shape of the movable part determines the following type of crane which are conical, spherical or cylindrical. They are often used in applications with high pressure and high temperature, as well as in applications where precise flow control is required.

Figure 1 shows the design of a standard ball valve manufactured at JSC «Ust-Kamenogorsk Industrial Fittings Plant» (UIFP).

The ball valve we are considering is a ball (spherical) valve, which is widely used in various branches of mechanical engineering, the oil and gas industry and water supply.

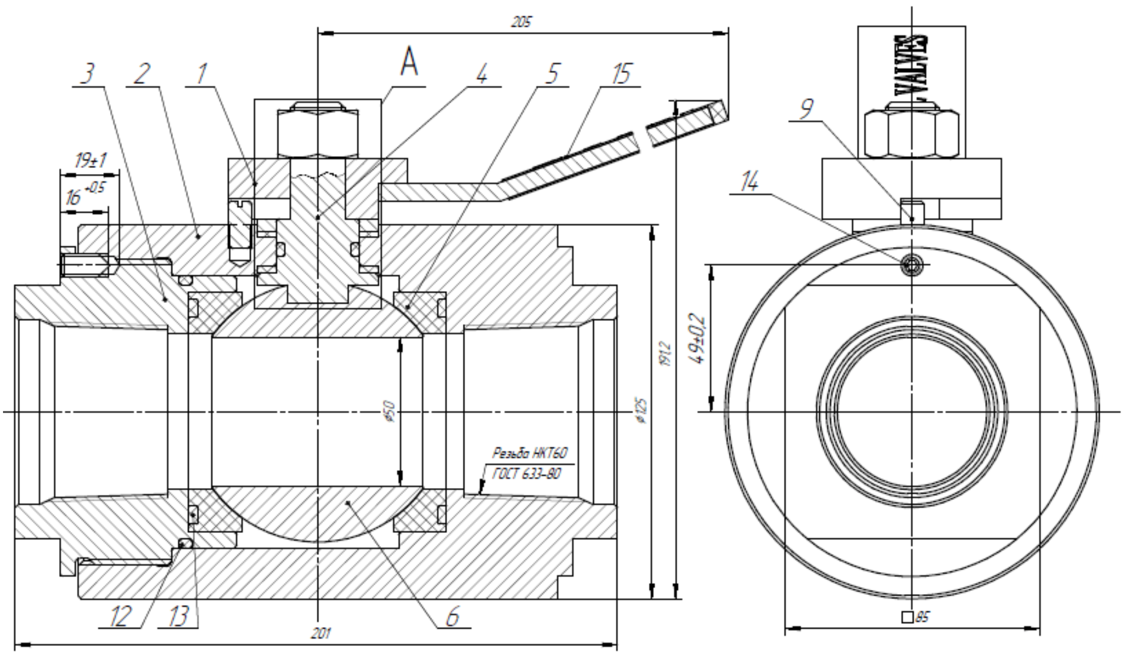

Figure 1. Design of a ball valve manufactured by JSC «Ust-Kamenogorsk Industrial Fittings Plant»
Note – compiled by the authors on the basis of a UIFP drawing (Argymbayev, Gabdysalyk, 2023)

Literature review.

A literary analysis was carried out and the designs of existing enterprises for the manufacture of ball valves were considered. In the course of the research, three patents were studied (Panchekha, Andreev & Burmistrov, 2006; Aghababyan, 2019; Galaganov 2006), each of which has its advantages and disadvantages. One of the patents developed by Panchekha Y.S., Andreev A. P., Burmistrov B.V. improves the design of the saddle, making it composite, which helps to ensure tightness. However, such an improvement increases the complexity of manufacturing the saddle and leads to an increase in cost, which is undesirable.

Another patent, proposed by R.E. Aghababyan, is distinguished by the presence of a groove in each hole of the body, which allows you to securely fix the saddle. However, the disadvantage of this design is the difficulty of replacing the deformed saddle, after which there may be a problem with tightness.

The invention proposed by Galaganov V.N. is based on the use of a metal saddle and a bushing with uneven end surfaces. However, this leads to wear of the ball sphere and leads to an increase in the cost of the ball valve when using a non-metallic saddle.

In this regard, none of these patents and the solutions used in them are completely suitable for improving the ball valve without changing the cost.

Materials and methods of research.

Ball valves manufactured by JSC UIFP are divided into threaded, flanged and welded according to the connection principle. Their ball valves are designed to operate at a nominal pressure of up to 12.5 MPa and a nominal diameter of 50 mm.

The faucet we are considering is threaded. The connecting threads of this ball valve are НКТ 60, НКТ 73, NPT 2 и LP 2.

Ball valves are supplied both separately and as part of fountain fittings. Or rather, as part of the rod-pump fittings (Figure 2) or the equipment of the wedge columns.

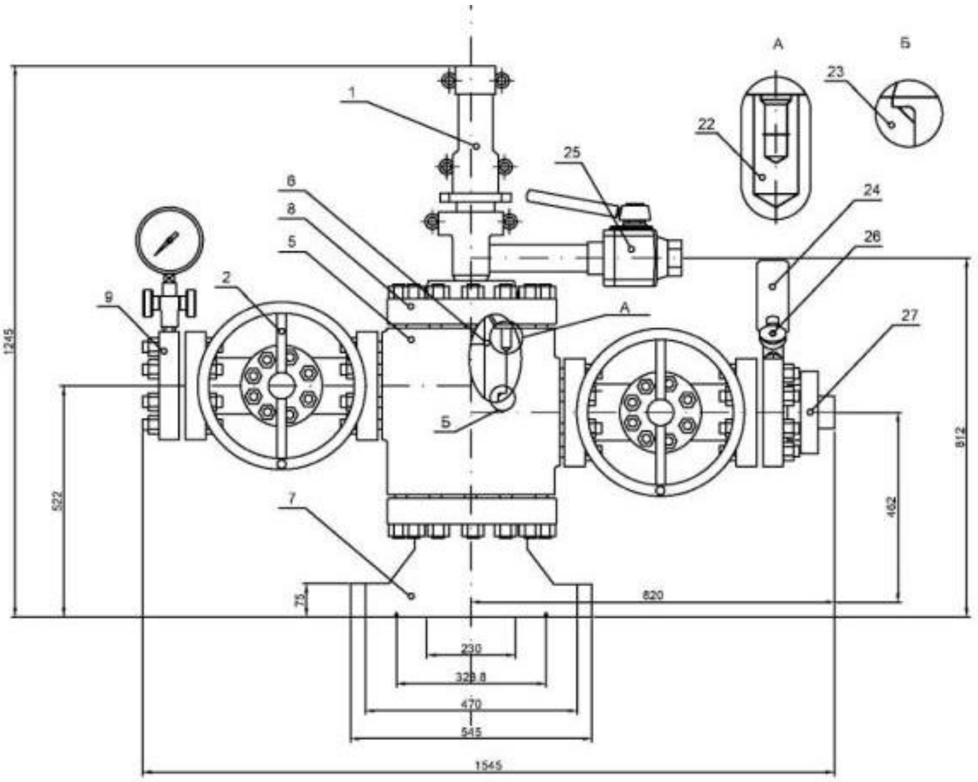

Figure 2. Rod pump fitting

Note – compiled by the authors on the basis of a UIFP drawing (Argymbayev, Gabdyssalyk, 2023)

The rod-pump fittings are designed for sealing the mouth of oil wells, suspension of the downhole pipeline, control of the flow of the working environment, control over the parameters of the downhole environments in the pipe and annulus space.

In position 25 of Figure 2, a ball valve is shown in the drawing of the valve of the rod pump installation.

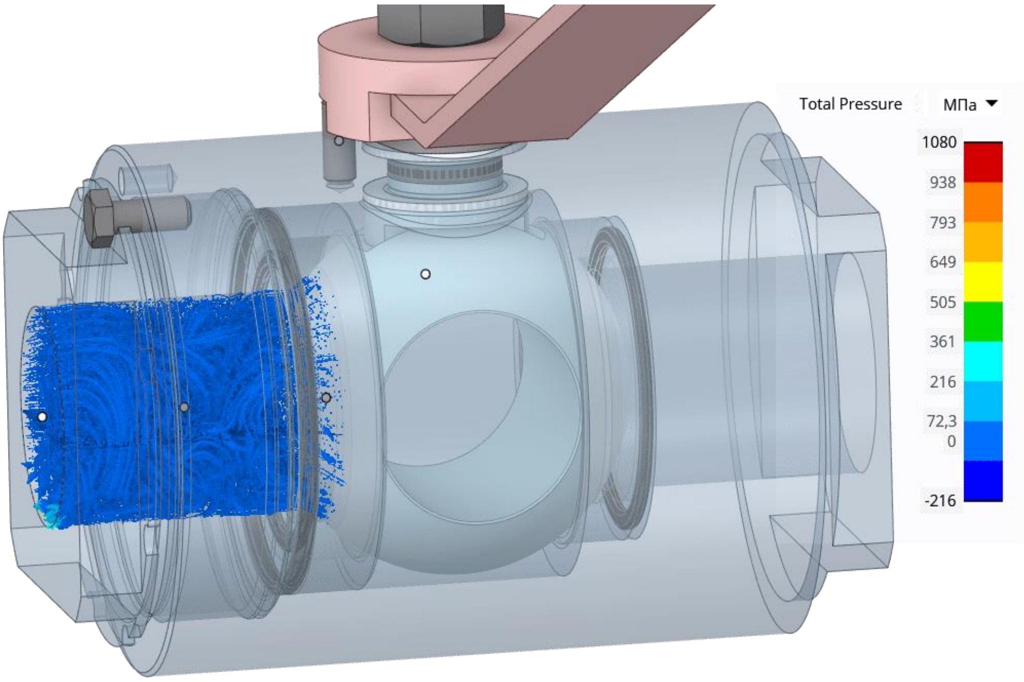

Figure 3. Ball valve in the «closed» position

Note – compiled by the authors on the basis of (Argymbayev, Gabdyssalyk, 2023)

Since the manufacturer came to the conclusion to switch to the market of valves with higher pressure, it was decided to improve the design of the ball valve to ensure tightness at high pressures, or rather up to 40 MPa (Argynbayev & Gabdyssalyk, 2022).

It is proposed to replace the saddle manufacturing material and make changes to refine the design of the ball valve body to improve tightness, increase durability and wear resistance (Argynbayev & Gabdyssalyk, 2023).

Figure 3 shows a 3D model with modifications and a ball valve in the closed working position.

The ball inside the ball valve has a hole that corresponds to the diameter of the pipeline. In the closing position, this hole is aligned perpendicular to the flow of the working environment, blocking it completely. As a result, the ball valve ensures complete cessation of the flow of the working environment when closed.

When the ball valve is in the closed position, it ensures tightness and prevents leakage of the working environment in the system. This is important for the control and safety of the process, as it prevents unwanted leakage or loss of the working environment in an undefined direction.

With the help of the ANSYS 2023 program, we were able to perform calculations of the ball valve body in order to assess its strength and reliability under specified operating conditions. We created a three-dimensional model of the ball valve and determined boundary conditions such as applied loads, movement restrictions and materials used in the structure.

First of all, we performed a calculation to determine whether the ball valve can withstand the high pressures that we plan to apply in its work.

To test the strength of the structure, we used several basic parameters: complete deformation of the body, equivalent stress and safety margin. These parameters help us to assess how well the ball valve design is able to cope with the specified loads without exceeding the permissible limits.

By applying pressure to the ANSYS ball valve model, we obtained information about the complete deformation of the body (Figure 4). This allowed us to determine how much the structure will change its shape under the influence of the load. If the total deformation does not exceed the permissible limits, then the structure is considered suitable for use.

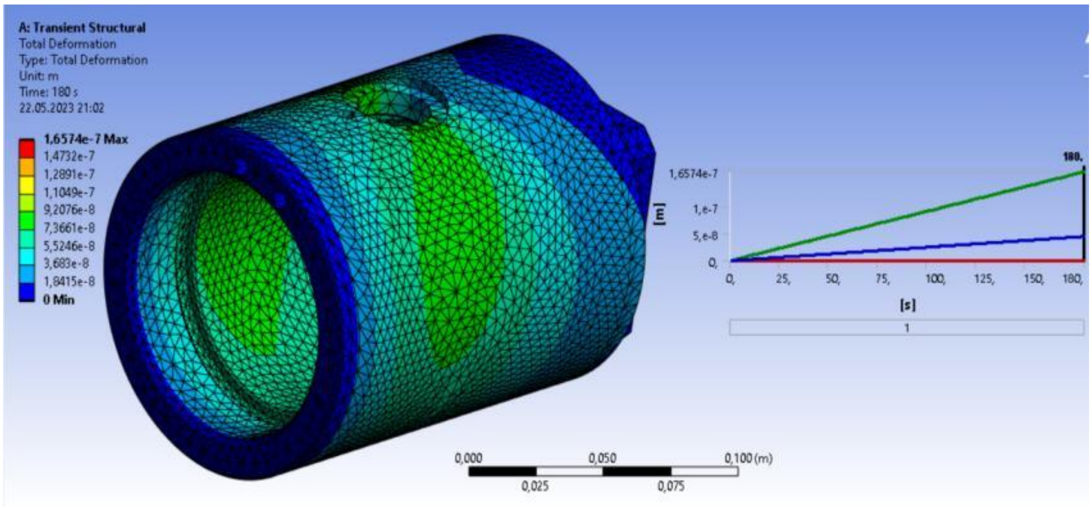

Figure 4. Calculation of the total deformation of the ball valve body structure

Note – compiled by the authors on the basis of (Argymbayev, Gabdyssalyk, 2023)

In the process of calculating the complete deformation of the ball valve body structure around the spindle hole, we found that this area is a weak link in the structure. Possible reasons may be related to geometry features, the chosen material, or other factors.

Applied loads and pressures can cause significant deformations and stresses in the vicinity of the spindle hole. This can lead to overloading and deformation of the material in this area, which can negatively affect the strength and reliability of the structure.

During the calculations, we applied a pressure increasing from 0 to 180 MPa for 3 minutes. This pressure was gradually increased every second during this time. Our goal was to check whether the ball valve body is capable of withstanding such a load.

The calculation results showed that the design of the ball valve body successfully coped with the applied pressure. Deformations and stresses were observed for three minutes, but they remained within the safe values, and the structure did not exceed the limit values.

This indicates that our ball valve design has sufficient strength and is able to withstand the high pressures that we want to apply in the future.

To estimate the stresses in the structure, we used an equivalent stress (Figure 5). This is an indicator that takes into account different types of stresses in the material and brings them to a single value for comparison with acceptable values. If the equivalent stress remains within safe values, then the structure is considered durable.

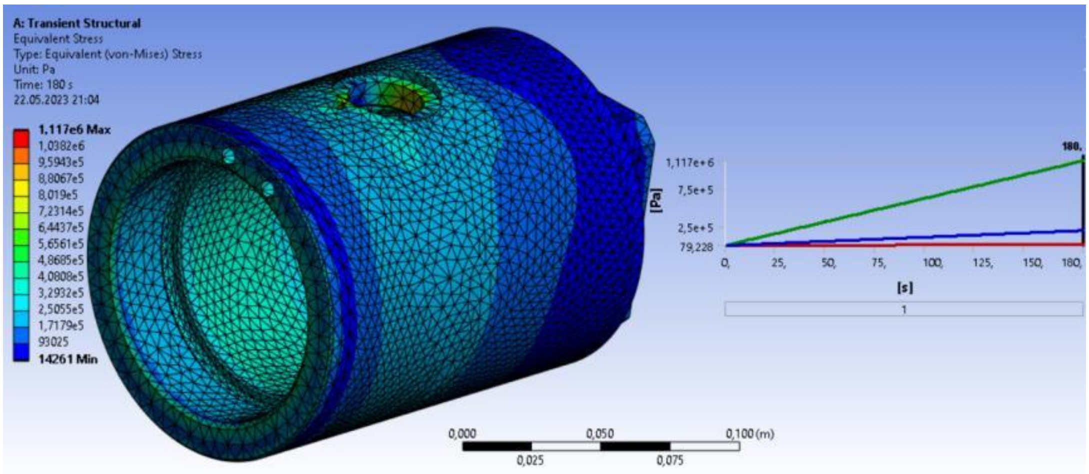

Figure 5. Calculation of the equivalent stress of the ball valve body structure
Note – compiled by the authors on the basis of (Argymbayev, Gabdyssalyk, 2023)

When calculating the equivalent stress inside the ball valve body using the ANSYS program and other engineering tools, we obtained the result that the body can withstand up to 111.7 MPa of pressure.

This means that the applied pressure inside the ball valve body should not exceed 111.7 MPa to ensure the safe operation of the structure. If the pressure exceeds this limit, there is a risk of exceeding the permissible values of the equivalent stress, which can lead to deformation or damage to the valve body.

The calculation results allow us to evaluate the strength characteristics of the valve body and verify its ability to withstand specified pressures within safe values of equivalent stress.

The margin of safety (Figure 6) is the ratio between the maximum load that the structure can withstand and the actual load that we plan to apply. A greater margin of safety means that the design has greater safety and reliability in working.

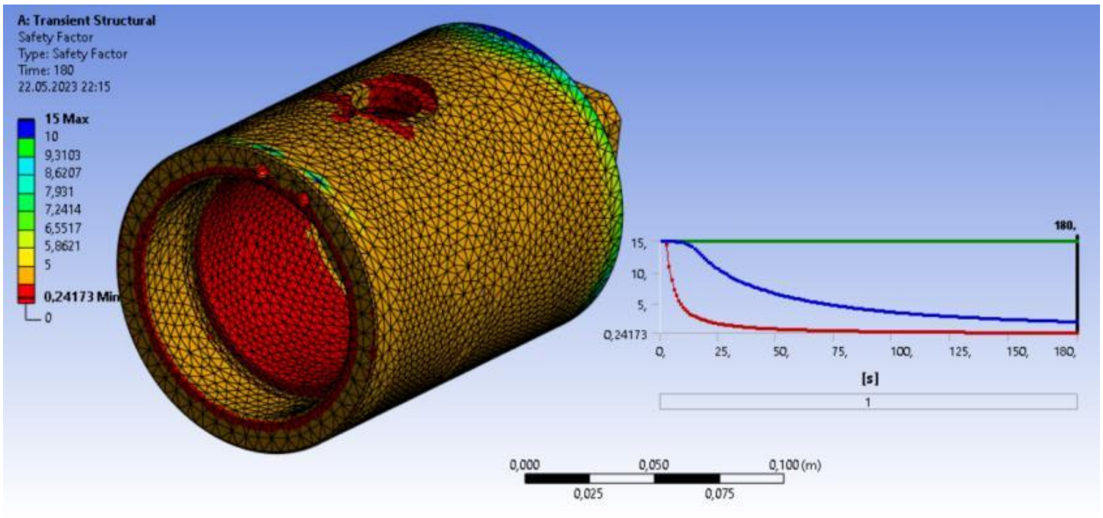

Figure 6. Strength reserve of the structure of the ball crane structure
Note – compiled by the authors on the basis of (Argymbayev, Gabdyssalyk, 2023)

Analyzing the results obtained at ANSYS, we determined that our ball valve design meets the specified parameters. The complete deformation of the body, the equivalent stress and the margin of safety are within acceptable values, which indicates that the crane is able to withstand high pressures and operate reliably and safely.

After completing the calculation of the ball valve body, we moved on to the calculation of the ball valve saddle. The saddle is an important part of the structure, which ensures tightness and coupling with the ball element.

To calculate the saddle of a ball valve, we also used the ANSYS program and other engineering tools. The main parameters that we analyzed were contact pressure and saddle stresses.

We have created a 3D model of the saddle based on drawings and specifications. Then we applied the loads and pressures that usually occur in the operating conditions of the ball valve. Calculations were carried out to check whether the saddle is able to withstand these loads without deformations or damage.

The calculation results allowed us to determine the contact pressure that acts on the saddle and verify that it is within safe limits for the saddle material. We also evaluated the stresses that occur in the saddle under load to ensure that they do not exceed the strength limits of the material.

When calculating the total deformation of the ball valve (Figure 7), we paid attention to the place of contact of the saddle with the ball and its behavior when applying a load. The results showed that this contact point is the most prone to deformation.

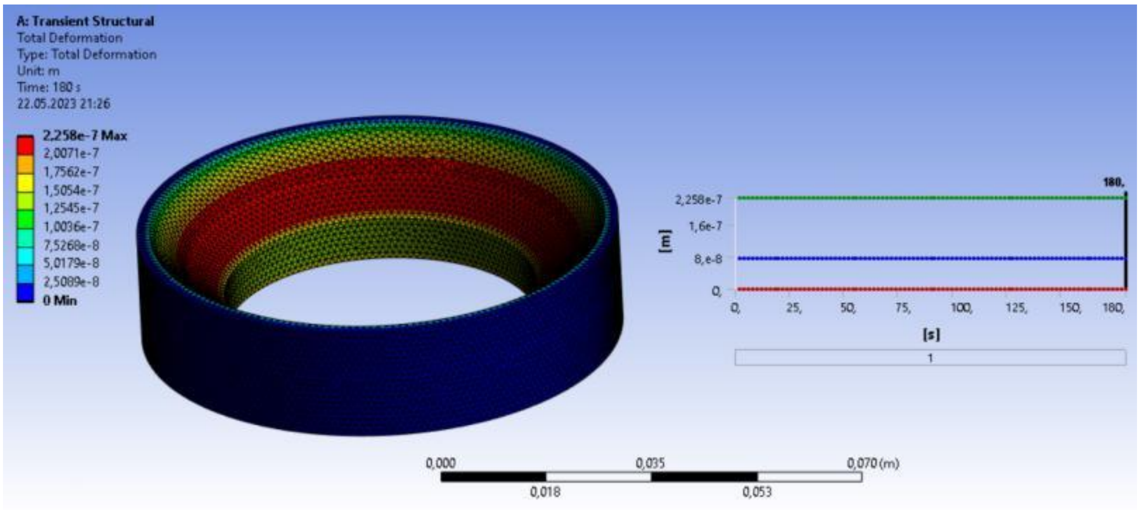

Figure 7. Calculation of the total deformation of the ball valve saddle structure
Note – compiled by the authors on the basis of (Argymbayev, Gabdyssalyk, 2023)

When the ball valve is loaded, the internal pressure causes deformation of the saddle material in the area of contact with the ball. This is due to the high forces transmitted from the ball to the saddle during ball valve operation.

After completing the analysis of deformations and deformability of the ball valve saddle, we moved on to an important stage of calculation which is determining the equivalent stress to which the saddle is subjected during operation.

The calculation of the equivalent stress (Figure 8) is an integral part of the design, as it allows you to assess the loads that the saddle material is experiencing and its ability to cope with these loads without the risk of damage or deformation. It is important to emphasize that the correct assessment of the equivalent stress is the basis for ensuring the reliability and durability of the ball valve design.

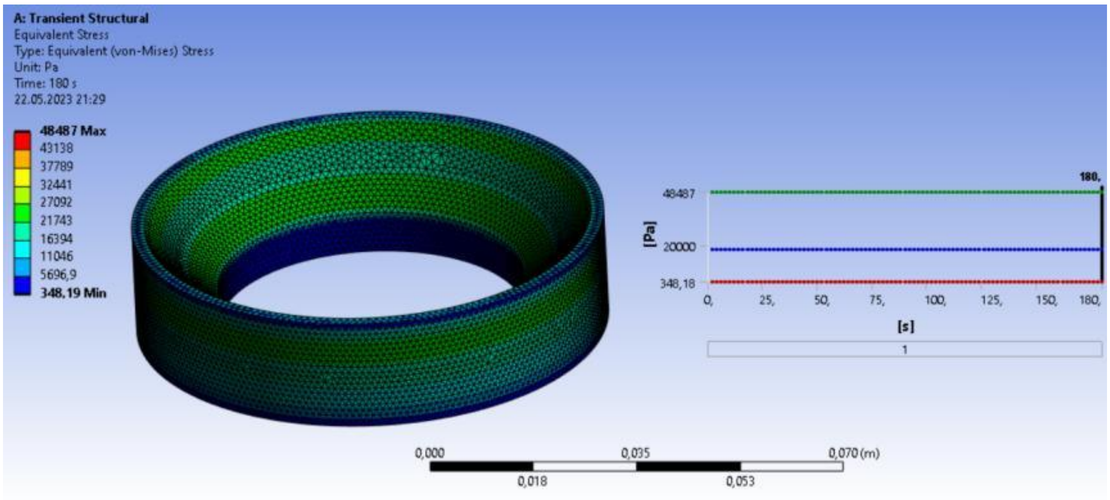

Figure 8. Calculation of the equivalent stress of the ball valve saddle design

Note – compiled by the authors on the basis of (Argymbayev, Gabdyssalyk, 2023)

When calculating the equivalent stress in the saddle of the ball valve, we found that the saddle is able to withstand pressures up to 48.487 MPa.

The equivalent stress is a measure of the stress that acts on the saddle material. It is calculated based on the applied loads and the geometry of the saddle. The results of calculating the equivalent stress allow us to determine how reliably the saddle copes with the applied loads and how close it is to the ultimate strength of the material.

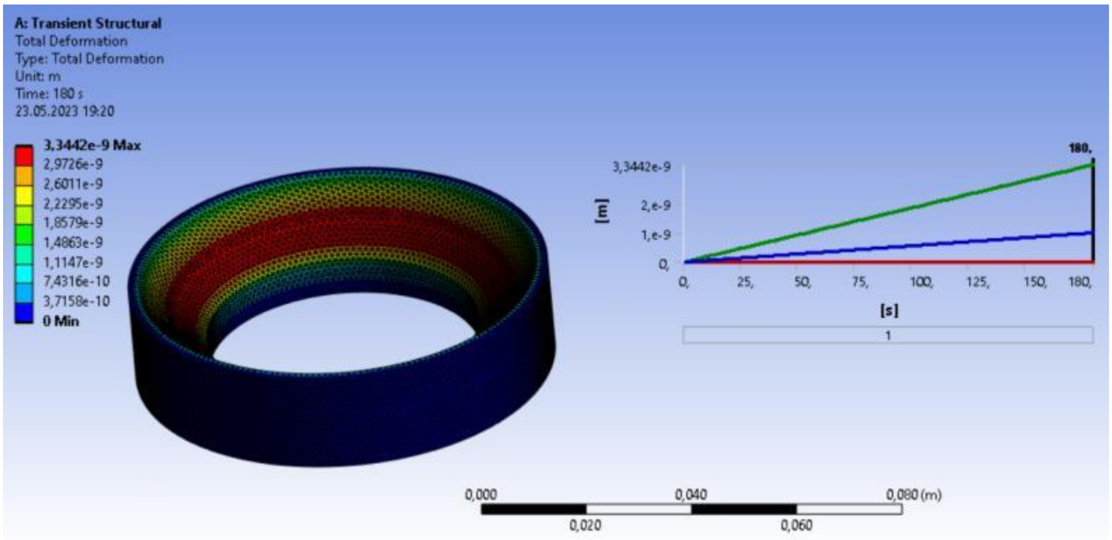

Figure 9. Calculation of the total deformation of the structure of the heat-treated saddle of the ball valve

Note – compiled by the authors on the basis of (Argymbayev, Gabdyssalyk, 2023)

In this case, calculations have shown that the saddle of the ball valve can withstand pressure up to 48.487 MPa. This means that when applying pressure within this value, the saddle remains within the safe strength limits of the material.

However, it is important to note that only the specified loads and geometry are taken into account when calculating the equivalent stress. The actual operating conditions of a ball valve may include additional factors such as dynamic loads, cyclic loads, vibrations, etc. Therefore, it is recommended to conduct additional research and testing to verify the reliability of the saddle in specific operating conditions.

The obtained equivalent stress results are important for the design and selection of saddle materials, as well as for ensuring safe and reliable operation of the ball valve.

For a more detailed analysis and evaluation of the behavior of the heat-treated saddle material, in this case caprolon, the computer program ANSYS 2023 was used. Calculations were performed to determine the reaction of the saddle material at high pressures. Calculations were carried out for the complete deformation of the saddle (Figure 9), which means that the degree of deformation of the material under the action of high pressures was analyzed.

The results of calculations for full deformation showed that the saddle does experience significant deformations at high pressures. This is an important aspect for evaluating the operability and tightness of the ball valve under extreme loads.

To subsequent assess the safety and reliability of the saddle, calculations (Figure 10) for equivalent stress were carried out. The equivalent stress is the value of the stress that would cause the same degree of deformation as was observed as a result of external loads on the material. In this case, the equivalent saddle stress was 74.3 MPa.

However, it should be noted that the value of the equivalent stress is only an indicator exclusively for this calculation. At such high stress values, the saddle material may undergo plastic deformations, which may affect its durability and reliability in the long term.

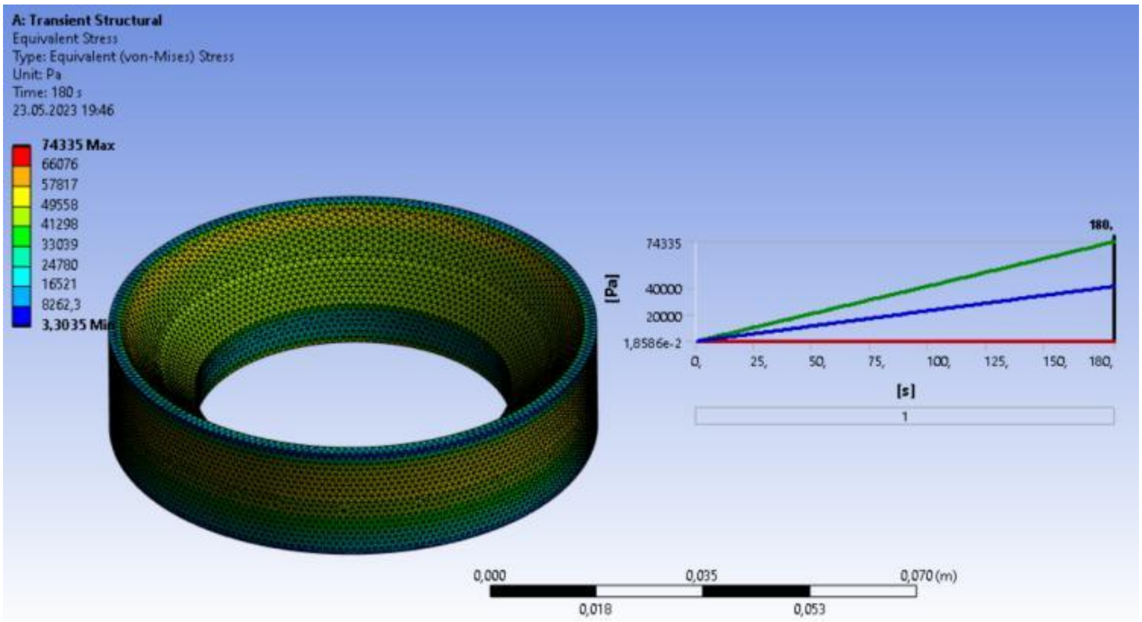

Figure 10. Calculation of the equivalent stress of the structure of the heat-treated saddle of the ball valve

Note – compiled by the authors on the basis of (Argymbayev, Gabdyssalyk, 2023)

It is important to note that the calculation results and stress values are preliminary and require additional verification and analysis. In order to decide on further improvements and optimizations of the saddle design, it is recommended to conduct additional research, such as physical tests or detailed stress analysis using other modeling methods.

In addition, when calculating the complete deformation of the saddle, where pressure was applied to the entire surface of the saddle, the results may differ from real conditions, where stress appears at the point of contact of the saddle with the ball.

In real conditions, when the saddle is in contact with the ball, there is a point or linear contact between them, and it is in these areas that the highest stresses occur. However, in our ANSYS 2023 calculation application, it was not possible to determine the exact pressure contact point between the saddle and the ball. This is due to the limitations of modeling and simplifications that have been applied in the calculation process. Thus, the results obtained as part of the calculation for the complete deformation of the saddle are only approximate and cannot fully reflect the real conditions where stress occurs at the point of true contact between the saddle and the ball.

Results and their discussion

In the course of research and design, among the various options for improving ball valves, the direction of modernization of the ball valve saddle was chosen. To improve the tightness in this link, the following changes were applied which are heat treatment of the saddle material and boring of the groove under the saddle. These measures made it possible to achieve a tight fit of the saddle and the sealing ring, and the sealing ring also performed the function of a spring, providing additional sealing and tightness.

The main result of the modernization is to increase the tightness of ball valves. Before the modernization, the ball valves had a tightness of 12.5 MPa. However, after the introduction of upgraded ball valve, their tightness was significantly improved and reached the level of 40 MPa. This is an important achievement that allows the use of upgraded ball valves in high pressure conditions and ensures reliability and safety in the operation of pipeline systems.

In *conclusion*, the modernization of ball valves manufactured by UIFP JSC was successfully carried out without a slight change in the price indicators of ball valves. It allowed to solve the problem of insufficient tightness, significantly improved the functional characteristics and provided increased tightness of ball valves. This is important for the development and improvement of pipeline fittings, ensuring the safety and reliability of engineering systems.

Thus, consumers can get significant improvements in the tightness and functionality of ball valves at a relatively small additional cost.

Conflict of interest. The authors declare that there is no conflict of interest.

Appreciation. This abstract is funded by the committee of Science of the Ministry of Science and higher education of the Republic of Kazakhstan (Grant No. AP22683698 –"Increasing the wear resistance of sealing surfaces of connecting parts of large gate valves").

References

Ғабдысалық Р. (2019). Совершенствование технологии изготовления крупногабаритных шиберных задвижек для магистральных трубопроводов: диссертация на соискание степени доктора философии.Режим доступа: https://www.kstu.kz/wp-content/uploads/2019/09/Dissertatsiya-abdysaly-R.pdf // Gabdyssalyk R. Sovershenstvovanie tehnologii izgotovleniya krupnogabaritnyh shibernyh zadvijek dlya magistral'nyh truboprovodov: dissertaciya na na soiskanie stepeni doktora filosofii.

Гуревич Д. Ф. (1981). Трубопроводная арматура: Справочное пособие. – 2-е изд., перераб. и доп. – Л.: Машиностроение, Ленингр. отд-ние, – 368 // Gurevich D.F. (1981). Truboprovodnaya armatura: Spravochnoe posobie. – 2-e izd., pererab. i dop. – L.: Mashinostroenie, Leningr. otd-nie. – 368.

Панчеха Ю.С., Андреев А.П., Бурмистров Б.В. "Седло шарового клапана". Патент Российской Федерации № 2273780. Опубликовано 10 марта 2006 г. // Pancheha YU.S., Andreev A.P., Burmistrov B.V. "Sedlo sharovogo klapana". Patent Rossiiskoi Federacii № 2273780. Opublikovano 10 marta 2006 g.

Агабабян Р.Е. "Шаровой кран". Патент Российской Федерации № 2705172. Опубликовано 27 ноября 2019 г. // Agababyan R.E. "Sharovoi kran". Patent Rossiiskoi Federacii № 2705172. Opublikovano 27 noyabrya 2019 g.

Галаганов В. Н. "Шаровой кран". Патент Российской Федерации № RU2277662C1. Опубликовано 10 июня 2006 г. // Galaganov V.N. "SHarovoi kran". Patent Rossiiskoi Federacii № RU2277662C1. Opublikovano 10 iyunya 2006 g.

Argynbayev M., Gabdyssalyk R. (2022). «Suggestion to improve the design of the ball valve to ensure tightness», Proceedings of V International Scientific and Practical Conference, Barcelona, Spain, 5-7 June, 821 p.

Арғынбаев М.Н., Ғабдысалық Р. (2022). «План совершенствования конструкции крана шарового для обеспечения герметичности», VIII Международная научно-техническая конференция студентов, магистрантов и молодых учёных «Творчество молодых – инновационному развитию Казахстана», посвященная 100-летию первого ректора Серикбаева Д.М. и 100-летию второго ректора Сидорова А.К. 7-8 апреля. Часть I, 227 с. // Argynbaev M.N., Gabdyssalyk R. (2022). «Plan sovershenstvovaniya konstrukcii krana sharovogo dlya obespecheniya germetichnosti», VIII Mejdunarodnaya nauchno-tehnicheskaya konferenciya studentov, magistrantov i molodyh uchyonyh «Tvorchestvo molodyh – innovacionnomu razvitiyu Kazahstana», posvyaschennaya 100-letiyu pervogo rektora Serikbaeva D.M. i 100-letiyu vtorogo rektora Sidorova A.K. 7-8 aprelya. Chast' I, 227 s.

Арғынбаев М.Н., Ғабдысалық Р. (2023) «Предложение по усовершенствованию конструкции крана шарового для обеспечения герметичности», IX Международная научно-техническая конференция студентов, магистрантов и молодых учёных «Творчество молодых инновационному развитию Казахстана», посвященная 65-летию университета. 13-14 апреля. Часть I, 243 с. // Argynbaev M.N., Gabdyssalyk R. (2023) «Predlojenie po usovershenstvovaniyu konstrukcii krana sharovogo dlya obespecheniya germetichnosti», IX Mejdunarodnaya nauchno-tehnicheskaya konferenciya studentov, magistrantov i molodyh uchyonyh «Tvorchestvo molodyh innovacionnomu razvitiyu Kazahstana», posvyaschennaya 65-letiyu universiteta. 13-14 aprelya. Chast' I, 243 s.

Арматура Фланцевая, Патрубками Резьбовыми и под Приварку// ASME B16.34 – Valves – Flanged, Threaded, and Welding End.

СТ 1836-1917-01-АО-О6- 2018 – Краны шаровые DN до 1000; PN до 12,5 МПа (125 кг/см2) Технические условия, АО "Усть-Каменогорский завод промышленной арматуры" // ST 1836-1917-01-AO-O6- 2018 - Krany sharovye DN do 1000; PN do 12,5 MPa (125 kg/sm^2) Tehnicheskie usloviya, AO "Ust'-Kamenogorskii zavod promyshlennoi armatury".

Information about authors

Gabdyssalyk Riza – PhD, D. Serikbayev East Kazakhstan technical university, Ust-Kamenogorsk, Kazakhstan, E-mail: riza.gabdyssalyk@mail.ru, ORCID:0000-0001-9184-0897, +7 777 356 87 67

Argynbayev Medet – master of technical sciences,Ust-Kamenogorsk Industrial Fittings Plant JSC, Ust-Kamenogorsk, Kazakhstan, E-mail: meddetello@gmail.com, +7 747 8621250

Sherov Karibek Tagaevich – Doctor of Technical Sciences, Saken Seifullin Kazakh Agrotechnical University, Astana, Kazakhstan, E-mail: shkt1965@mail.ru, ORCID: 0000-0003-0209-180x, +7 775 3501771

Baigereyev Samat – PhD,D. Serikbayev East Kazakhstan technical university, Ust-Kamenogorsk, Kazakhstan, E-mail: sbaigereyev@edu.ektu.kz, ORCID:0000-0002-7773-5457, +7 777 411 96 50