

GENERALIZED METHOD FOR SELECTING THE PARAMETERS OF PIPELINE VALVES WITH SEALING TYPE «METAL-TO-METAL»

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ОБОБЩЕННЫЙ МЕТОД ВЫБОРА ПАРАМЕТРОВ ТРУБОПРОВОДНОЙ АРМАТУРЫ С УПЛОТНЕНИЕМ ТИПА «МЕТАЛЛ-МЕТАЛЛ»

The design approach to flat-type valve locks with feeding the medium onto the slide has been shown. The dependences for the optimal choice of the parameters the valve sealing elements which depend upon the characteristics of the working environment, as well as surface finish sealing surfaces were given. The features of the flat metal seal of the solenoid valve while feeding work flow on the valve slide were shown. A numerical simulation of deformation of the valve sealing was conducted. A picture of the valve slide and valve seat deformation during the application of the work flow onto the slide was obtained.

Keywords: valve sealing elements, deformation, valve seat, valve slide, design, dependency

Introduction

Scope of the shut-off and control valves use is wide: aviation and space technology, maritime, nuclear, chemical and petrochemical industry, vacuum equipment, pipelines, hydraulic and pneumatic fuel systems in various machines, devices and equipment, utilities, and so on. Reliability of the valves is the most important characteristic of machinery, apparatus and equipment, which determines the normal operation, the risks of accidents, safety, the environment.

For example, pipeline accessories are one of the main technical devices that form the quality of the management processes, as well as security systems and systems of oil refineries. This is due to its large number in different systems (at one manufacturing facility can be used more than 20 000 units of the valves [1]), and the relative complexity of determining its level in ensuring the normal operation and during accident conditions. Valves can itself be a source of danger to the operating personnel. At the same time valve failures may become the initiating events that lead to a breach of the conditions of safe operation. Valve malfunction may increase the flow of the emergency process. Practical exploitation and analysis of accidents that have occurred at facilities in petrochemical industry show that the number of events related to the malfunction of the valves is about 35% of the total amount of failures [1]. This makes it necessary to improve the quality of the design process valves, because it is possible to make major changes to the product only at the design stage.

Aim of research

Before the start of the development process, designer is provided with the following inputs:

- Nominal diameter D_N (or the average diameter of sealing zone D_c)
- appropriate level of tightness Q ;
- the type of working fluid, the pressure p , temperature T ;
- the direction of work environment flow – "onto the disc",
- the life cycles n_c counting "close-open" events.

The task of the designer is to determine such a combination of the parameters for the final product which will ensure that the specified in target specifications properties of the product will be achieved with minimal sealing pressure, provide minimum weight and size characteristics and maximal life length. If choosing between two designs with similar minimal sealing pressure, in that case the design with a large value of n_c . The modern design process dictates that it is necessary to generate a large number of variants of the proposed element to determine the best theoretical solution [2, 3, 4]. However, the results of the processing, even a very large number of alternatives based on traditional approaches, cannot give to the designer an idea of the design possibilities. A complicating factor is the fact that the task of valve developing has conflicting requirements, so it is difficult to choose a justified compromise. In this case it is actual question to create a generalized methodic for choosing the parameters of the pipeline accessories valve with sealing type "metal-to-metal"

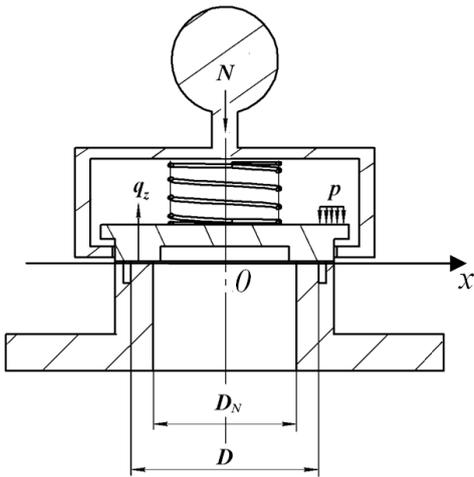


Fig. 1. Design of metal valve with flat sealing surfaces

According to [5], when the valve is closed without pressure influence of the environment, under the centrally applied force it deforms as it is shown in Fig. 2, it is the expansion of the lock ring joint that happens on the outer side. With the increase of specific pressure on the O-rings, the size of the diameter D (see Fig. 1) must be close to D_c . To visualize the processes which take place in the sealing unit we used numerical simulation software package ANSYS v11. A three-dimensional model of the valve slide and valve seat with flat sealing surfaces was subjected to single static loading with a force of 100 N. This value is selected by the conditions of equivalence to a single shock load on the valve elements during its single work cycle. Numerical simulation of the flat sealing unit shows that the deformation occurs, as shown in Fig. 3. Contact edge seal is fully preserved by appropriate deformation of the sealing surfaces and the cylindrical part of the saddle.

Thus the linear load needed for sealing can to be calculated by simplified formula

$$q_n = \frac{Sp}{b},$$

where $b = D - D_N$ — width of the contact zone (see Fig. 1).

In addition, the deformation of the valve assembly as shown on Fig. 3, will result in a surfaces that slide against each other. This sliding force will be calculated as:

$$q_\tau = \mu_{fr} q_z,$$

where μ_{fr} — is the friction factor.

Research results

Let's consider the design of metal valve with flat sealing surfaces, because the valve of this type has the largest contact area, thus resulting in the sealing edge to have the minimum contact stress. When sealing the work fluid or gas, the following force (Fig. 1) act on the valve and the seat, which is created by the executive electromagnetic drive. It is force N — force on the valve slide.

For the simplification of the calculations we will assume that each of the contacting bodies (exposed elements of the saddle and the valve) near the contact area is an elastic half-space. Thus the necessary force to seal the valve will be defined as:

$$q_z = \frac{N + Sp}{\pi D_c},$$

where $D_c = (D + D_N) / 2$ — width of the effective contact zone, q_z — linear load, which is required for creating the necessary landed force, p — distributed force of work fluid influence on the valve slide (while supplying on top of the valve slide), S — effective valve slide surface.

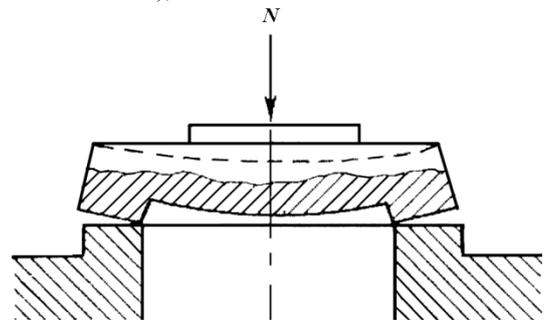


Fig. 2. Deformation pattern of the metal-to-metal valve sealing unit under the load



Fig. 3. Numerical modeling of the valve with flat sealing surfaces deformation under the load

Therefore we have:

$$q_n = c \int_{-1}^1 q_z(X) dX = \frac{q_z}{\sin \alpha + \mu_{fr} \cos \alpha},$$

where c – is a real contact zone which is determined from equation $\frac{c}{r} \left(\arccos \frac{b}{c} - \frac{b}{c} \sqrt{1 - \frac{b^2}{c^2}} \right) = \frac{\theta q_z}{c}$; α – is the real angle of the valve conicity; x – point coordinate on the $0x$ axis; $X = x/c$; $r = \frac{(D + D_N)}{2}$; θ — elasticity factor.

Considering equation (4), the needed distributed contact force can be calculated as:

$$\theta q_n(X) = \frac{c}{2\pi r} \sqrt{1 - X^2} \cdot 2 \arccos B + (X + B) \cdot \ln \left| \frac{B + X}{1 + BX + \sqrt{(1 - X^2)(1 - B^2)}} \right| -$$

$$- (X - B) \ln \left| \frac{B - X}{1 - BX + \sqrt{(1 - X^2)(1 - B^2)}} \right|,$$

where $B = b/c$.

Let's determine the flow of working fluid through the valve within a uniform distribution of the contact pressure. Since the penetrability of the valve seal unit is defined as:

$$U = \frac{Q}{p},$$

where Q – leakage of the working fluid through the capillary seal.

Then the leakage through the sealing can be calculated as:

$$Q = \frac{\pi D_c R_{\max}^3 p^2 \Lambda^3 v_i}{8 l \mu (1 - \eta)^2 K_l},$$

where μ — dynamical viscosity, Λ — dense of the gaps in the joint, η — relative area of the contact, K_l — curve factor, v_i — share of the effective micro channels, R — height of the microroughnesses in the contact zone.

According to [4], the relationship of specific leaks in the seal is determined by the equation:

$$\int_{-1}^1 \exp(2,3(k_{0i} k_r \theta q_n(X) - b_{0i})) dX = \frac{\pi D_c R_{\max}^3 p^2 \Lambda^3 v_i}{8 l \mu (1 - \eta)^2 K_l}$$

In addition, metallic sealing surfaces are characterized by the fact that in them the value of leakage depends on the purity of the working surfaces shut-off unit. Therefore, the final step is to select the design of the valve seal will be the process of choosing the surface smoothness according to [5]:

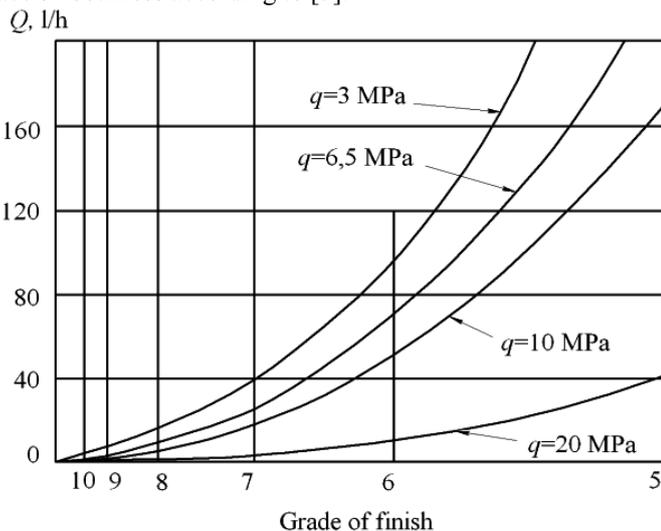


Fig. 4. Dependence the level of leakage on the influence of the microroughnesses in the sealing surfaces

Conclusion

The above given method allows to choose on the initial electromagnetic valve with metal on metal sealing design phase the parameters of the valve, which are depending on the characteristics of the working environment and the

requirements of sealing. With the help of numerical simulation made in software package ANSYS v11 it was visually shown the stresses that occur during the deformation of the valve sealing elements. Thanks to that the necessity of taking into consideration the effect of valve sealing surfaces sliding against each other when calculating the parameters of the valve.

Аннотация. Показан подход к проектированию затворов трубопроводной арматуры плоского типа с подачей среды на золотник. Приведены зависимости для оптимального выбора параметров уплотнительных элементов клапана в зависимости от характеристик рабочей среды, а также чистоты обработки уплотнительных поверхностей. Показаны особенности герметизации плоского металлического золотника электромагнитного клапана при подаче среды на золотник. Проведено численное моделирование деформации элементов перекрывного уплотнения, в результате чего получена картина деформации золотника и седла при подаче среды на золотник.

Abstract. Purpose. At the initial stage of the development process, the designer has to choose compromise options of the valve which are based on the requirements of the technical specifications. To ease his task we gave the necessary calculation methods of the valve parameters for the valves with flat sealing surfaces and sealing type metal-metal

Design/methodology/approach. The modern design process dictates that it is necessary to generate a large number of variants of the proposed element to determine the best theoretical solution. However, the results of the processing, even a very large number of alternatives based on traditional approaches, cannot give to the designer an idea of the design possibilities. A complicating factor is the fact that the task of valve developing has conflicting requirements, so it is difficult to choose a justified compromise. The above given method allows to choose on the initial electromagnetic valve with metal on metal sealing design phase the parameters of the valve, which are depending on the characteristics of the working environment and the requirements of sealing.

Findings. It is found that there is necessity of taking into consideration the effect of sealing surfaces sliding against each other when calculating the parameters of the valve.

Originality/value. The above given method requires to be added with more types of valves with sealing type metal-to-metal. In the state as it is it allows to quickly choose basic parameters of the valve sealing unit and use them for further developments of the valve.

Keywords: valve sealing elements, deformation, valve seat, valve slide, design, dependency

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