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USING FINITE ELEMENTS MODEL FOR CALCULATION OF THE DYNAMIC LOADS IN PNEUMATIC ELECTROMAGNETIC VALVES OF TRANSPORT SYSTEMS

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Abstract. The article shows tension changes in the material of sealing elements of the electromagnetic valve when adding damping unit to its kinematic scheme. Using finite elements method the numeric modeling of elements deformation was conducted. The picture of valve and saddle deformation and value of dynamic loads were obtained.

Keywords: electromagnetic valve, sealing, damping, finite elements model.

Introduction

The usage scope of pipeline valves and control valves is wide enough: aviation and space technicsm sea transport, nuclear energy sector, chemical industry and oil refinement, vacuum technics, pipeline transport, hydraulic and pneumatic systems of different machines and gadgets, utilities, etc. At one production facility can be used over 20 000 units of pipeline and control valves (Belokobyl’skij *et al.* 2008).

The reliability of pipeline accessories is one of the most important characteristic of machines, devices and equipment, which defines their normal operation, the risks of emergency situations, the safety of people and the environment. Valves are one of the main technical devices that form the quality management of technological processes, and the safety of apparatus and transport systems. (Astahov A. Ju 2002).

The exploitation practice and analysis of accidents causes that took place at the facilities of the petrochemical industry, indicate that the number of events associated with the valve malfunction, is about 35 % of the total number of failures. This requires improving the quality of the valve design process, as at the design stage drastic changes in the product design can be made.

Aim of the research

The aim of this work is evaluation of the tension level in the material of the valve seat and slide in a compact-sized electromagnetic pneumatic valve (EMV) with metal to metal sealing surfaces.

Electromagnetic actuator provides high performance of the electromagnetic system, because it has the best performance, allows remote control and multiple triggering. It also provides a simple design in comparison with other types of valve actuators (Ogar *et al.* 2007).

A strike of the locking element in the valve seat creates a significant force proportional to the mass and velocity of the slide and the rod, and inversely proportional to the duration of the strike. In valves with metal sealing this leads to a significant reduction of the resource of the valve, since the dynamic factor in such EMV reaches 70 (Sitnikov *et al.* 2004). For reducing the shock impulse damping is used, which is characteristic of the valves with rubber and polymer seals (Barilyuk 2013).

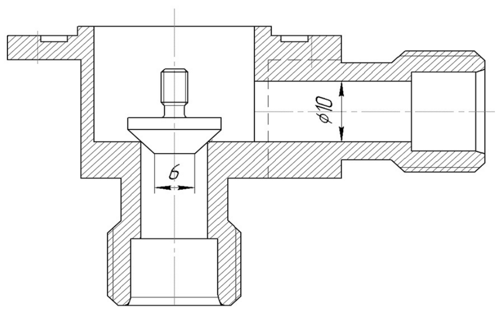

Fig. 1. Scheme of the investigated samples of the seat and valve

In modern industry, especially for the valve that work in harsh environments, the hard metal sealing is used, in which the valve sealing element is conical or hemispherical, and the saddle is in the form of a rectangular element made of chemically resistant material (Fig. 1), for example, stainless steel 08KH18N10T.

The result of influence of such cyclic work impulses can be fatigue processes in areas that are remote from the contact surfaces of the moving parts (in the volume of their construction material). These processes can eventually lead to fatigue cracks, which will cause the destruction of the detail (Bolotin *et al.* 1979).

Moreover, this type of fatigue processes via a number of reasons, which are associated with the dynamics of the load influence, differs from cyclic processes in which there are no impulse loads. Photos of metal sealing valve made of steel 08KH18N10T after $3{\cdot}10^5$ work cycles are shown in figure 2.

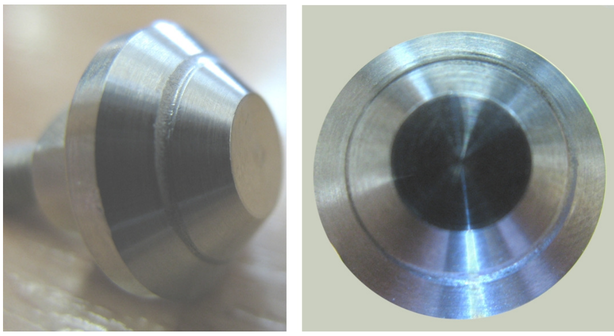

Fig. 2. Photos of metal sealing valve made of steel 08KH18N10T after $3{\cdot}10^5$ work cycles

Investigation of the development of such processes with the usage of experimental methods is quite difficult, although a number of authors (Rykunich *et al*. 2002) have addressed this issue. Therefore, for the visualization of the processes that take place in valve sealing elements were carried out theoretical calculations using the finite element method in an external software package Ansys.

The main objectives of these studies were:

– using the finite element method in 3D-model to calculate the level of stress in the sealing elements of the valve during its opening and closing;

– a comparative analysis of the most loaded areas of sealing parts of the valve in the presence of the damping element and without it. The conclusion for that analysis can be obtained from the results of calculations by the finite element method.

Obtained results

An approximate three-dimensional parametric model of the working elements of the valve during its closing (Fig. 3) consists of a seat, valve with threaded connection and the rod.

Parametricity of this model is that each characteristic geometrical size corresponds to a single parameter with own name, which has a numeric value. For example, ds_n = 2*2E-003 (here ds_n is the diameter of the lower cylinder rod, 2 mm – its value). This feature of the model allows to easily change the model geometry without rebuilding the whole model (Mossakovs'kij 1999).

The selected type of the finite element supports nonlinear material properties, including ductility (Sitnikov *et al.* 2004). To account for the ductile behavior of the material and to be able to calculate the ductile deformation the yield criterion was applied. For multicomponent stress state the equivalent stress can be represented as a function of the individual components of the stress:

$$\sigma_e = f(\{\sigma\}), \tag{1}$$

where $\{\sigma\}$ – stress vector.

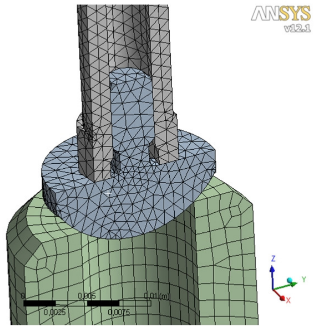

Fig. 3. Three-dimensional parametric model of the valve moving assembly elements

When the equivalent stress reaches the yield limit, the material will begin to experience plastic deformation

$$f(\{\sigma\}) = \sigma_{yield}. \tag{2}$$

To determine the spreading direction and increment of the magnitude of the plastic deformation the flow rule was used:

$$\{d\varepsilon\} = \lambda\left\{\frac{\partial Q}{\partial \sigma}\right\}, \tag{3}$$

where λ – is the coefficient, which determines the magnitude of plastic deformation; Q – function from the stress, which determines the direction of plastic deformation.

The calculated stresses in the structural elements of the valve depending on the availability of the damper in its kinematic scheme are shown on figures 4 and 5.

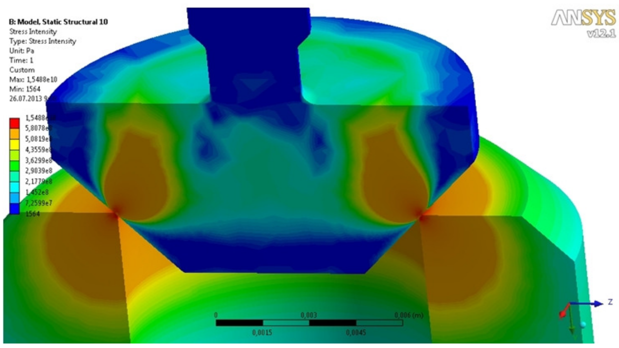

Fig. 4. Detail of stress distribution in the elements of the valve with the absence of the damper in kinematic scheme

The magnitude of the stresses in the elements of the valve depends on the speed of the rod at the moment of impact. The latter during closing process of the valve is not constant, but varies accordingly to the exponential law. Its numeric value at the moment of collision of the valve and seat is 3–5 times greater the average speed of the valve moving assembly.

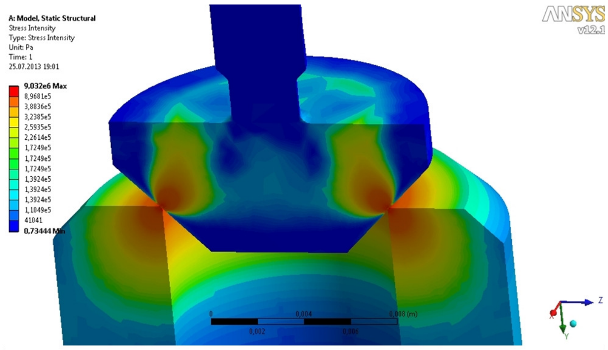

Fig. 5. Detailization of stresses in the material of the valve and saddle with the presence of damping element

Obtained theoretical calculations using the finite elements model show that the damping element has a positive impact on the lifelength of the valve sealing elements. It dissipates the kinetic energy of the valve moving assembly through elastic deformation. Thereby the sealing surface experience the reduced value of stress and deformation.

Conclusions

Since the junction of the seat and valve is a complex system, from the point of view of contact interaction mechanics of rough surfaces and wear dynamics of the of sealing surfaces, as the main method for the study of complex systems was a method of mathematical modeling was selected.

The analysis of the obtained in the Ansys software package data shows that during the closure of the valve the maximum stresses occurs in the area of the indentation of the valve into the saddle, where an area of stress concentrators is located. When triggered, the elements of the valve seal perceive significantly large dynamic loads as compared to the case of static loading. This explains the high rate of the geometry change of the electromagnetic valve elements – sealing surface perceives heavy loads and therefore wears out.

The highest stresses during the closing of the valve with rigid sealing unit occur along the plane of contact of the steel penstock with a saddle that is part of the steel hull. This leads to an indentation ring on the surface of the steel sealing unit. The magnitude of such deepening increases with the valve work cycles, and that reduces the sealing force and increases the probability of fatigue failure for the valve and the saddle.

Implementation of the damping element into the valve moving assembly reduces perceived loads and reduces the valve original geometry deformation speed. The damping element significantly reduces the dynamic factor of the system and, and as a consequence, the maximum loads on the sealing elements. It does not require significant redesign of the electromagnetic valve.

As a consequence, the introduction of the damping element in a compact-sized electromagnetic valve system is the best option from the point of view of reducing the wear and conservation of mass-dimensional characteristics of the final product.

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