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# INFLUENCE OF DAMPING ON SEALING SURFACE WEAR RATE REDUCTION IN COMPACT-SIZED ELECTROMAGNETIC VALVE

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**Abstract.** The article shows the dependence of operational characteristics of the electromagnetic valve sealing unit with the metal-to-metal sealing on the availability of valve moving assembly kinetic energy damping. The dynamic factor in compact-sized electromagnetic pneumatic valves was obtained. Experimental research of the wear rate dependency on the damping in the sealing unit was conducted. Deformation of the sealing elements was shown using the finite elements method. The deformation of the valve sealing unit elements with and without damping was obtained.

**Keywords:** pneumatic valve, seals, valves, damping.

## Introduction

Pneumatic and hydraulic valves with electromagnetic actuator (EMV) are such a devices, that are used for controlled flow in the aircraft and space systems. Development of the sealing unit rational design in such valves is closely connected to solving the problem of cyclic durability and sealing of the contact zone. Simultaneous solving of these two tasks is the problem of choosing the optimal valve parameters. Minimization of the maximal stress levels and contact pressure is an important task for reducing the operation failure probability.

A distinctive feature of the parts in valve moving assembly is high dynamic loads and high rate of the starting parameters change, which often is resulted in the valve failure. Operation experience and analysis of the failures on the factories allow concluding, that the failures due to the fault of the hydraulic and pneumatic valves are close to 35% from all amount of failures on those factories (Sinou, Jezequel 2007).

One of the ways for increasing reliability of the compact-sized valve is dissipation of the valve moving assembly’s energy, which is gained by using a dedicated damping element in the valve design. The basic of this method is the theory of specific potential energy shape change influence. Thus, the dangerous state of the material in the complex stress condition starts, when specific potential energy of the shape change reaches the yield strength of the simple stretching.

Considering, that manual and automatic electromagnetic valves work with shocks, for its long operation time it is necessary to evaluate the dynamic characteristic of the sealing. As it was shown in the researches of (Dolotov *et al.* 2000), in the valves with the hard sealing a big value of dynamic factor exists. That leads to quick destruction of the valve sealing elements.

As it is shown in (Semin *et al.* 2006), numerical value of the dynamic factor, which depends on stiffness of the valve elements and general damping capability if the valve design, has a direct influence on the valve operation time. If the level of the alternative stress amplitudes is high enough, then in the elements of mechanical systems there is an accumulation of the fatigue, development and evolution of cracks, which ends in valve failure.

All above determines the necessity of the metal-to-metal valve sealing unit degradation research.

## Aims of the research

The research aim is to evaluate the valve slide and saddle degradation speed of the electromagnetic pneumatic valve with stiff sealing. Electromagnetic drive (ED) gives high operational qualities of the electromagnetic valve, as it has the highest performance. ED also provides remote control of the valve, multiple activations, and design simplicity comparing to other drive types. The consequence of the high speed operation of the ED is shock activation, which cause high dynamic loads in the EMV sealing unit. The shock of valve slide on the valve saddle creates significant force, which is proportional to the mass and the valve slide speed, and is inversely proportional to the shock duration. In valves with metal-to-metal sealing, with the consideration of the valve slide and saddle hardness, it leads to significant operational lifetime decrease, because the dynamic factor in such EMV can reach up to 70 (Dolotov *et al.* 2000). For decreasing the dynamic factor damping is used. The damping influence on the decreasing the dynamic factor is researched mostly for the valves with rubber and rubber-polymer sealing units (Kisel' *et al.* 2011). In modern valve design for the aggressive mediums and high operational temperatures the valve slide of sealing unit is made in conical shape, and saddle has rectangular shape of chemically resilient materials, for example, stainless steel 08X18H10T (Dolotov *et al.* 2000). Such sealing unit has a number of advantages over other sealing units design (Shtitel'man *et al.* 1997):

– decreased sealing force because of small contact area;

– contact pressure is evenly distributed by perimeter of the slide and saddle;

– there is no need of lapping and finishing of the sealing unit;

– the requirements for the assembly are decreased.

The wide dissemination of such sealing units is prevented by the difficulty in determining the rational dimensions of the valve saddle and slide, especially such, that can operate under the shock loads. Considering aforesaid, the task of determining the influence of damping on the sealing unit of EMV is an actual task.

**Formulation of the problem**

For this purpose, an experimental stand was created for a for dynamic loading of samples valve slide and saddle with metal-to-metal sealing. Its core is a small electromagnetic valve used in aerospace technology (Fig. 1).

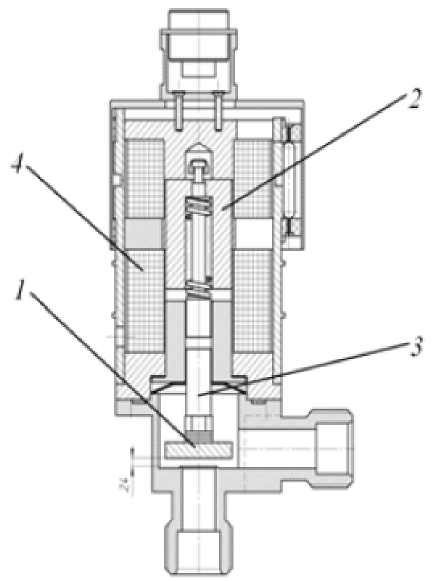



**Fig. 1.** General drawing of the experimental stand:
1 – valve slide; 2 – armature; 3 – rod; 4 – coil

During the experiment, samples of stainless steel 08X18H10T (Fig. 2) operated a number of cycles. At regular intervals, the air leak through the valve was measured.

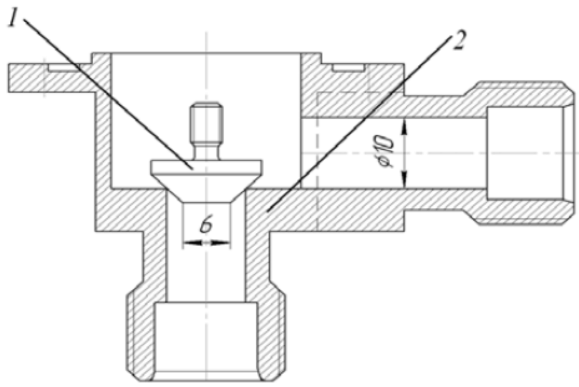



**Fig. 2.** Drawing of the valve slide and saddle:
1 – valve slide; 2 – saddle

The deformation of the sealing unit elements can be decreased through the kinetic energy dissipation using an elastic deformation of a special element. This dampener was a 1-mm thick rubber ring (Fig. 3), located at the non-sealing part of the valve rod (see Fig. 1).

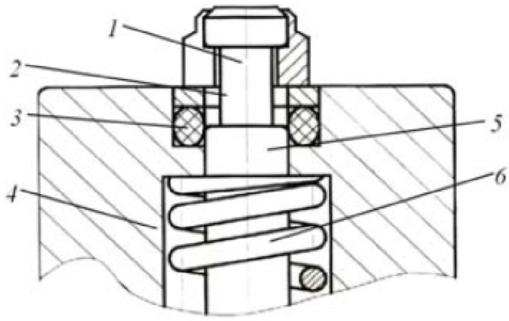


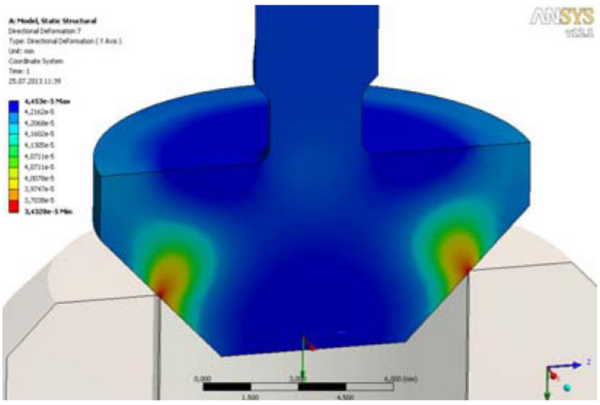

**Fig. 3.** Damping element installation in the valve:
1 – lock washer; 2 – pressing plate; 3 – damping element;
4 – armature; 5 – rod, buffer spring

After installing the damper ring in the valve under the locking washer, a new pair of samples passed the number of operation cycles. The gas leakage through the closed valve was measured.

To visually show deformation of the sealing surfaces, a simulation using the finite elements method was carried out for three-dimensional models of valve sealing units in software package Ansys 12.1 (Fig. 4). For visual convenience the valve slide and valve saddle are shown separately.

It has been determined, that damping allows to decrease the wear rate of the valve slide and saddle. This statement is proven by the leakage change speed with the increase of the operational cycles (Fig. 5).

The average depth of sealing surface wear after 300 thousand cycles is close to 19 micrometers. At the same time the experimental sealing unit, which operated with the installed damping element has the average of sealing surface wear close to 13 micrometers. Thus, accordingly to the literature sources, the design with the installed damping element has lower dynamic factor.

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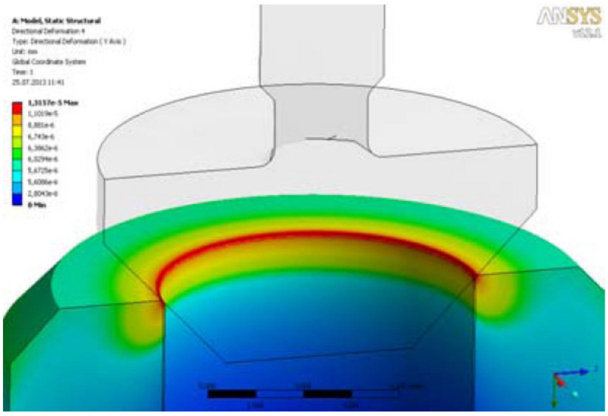
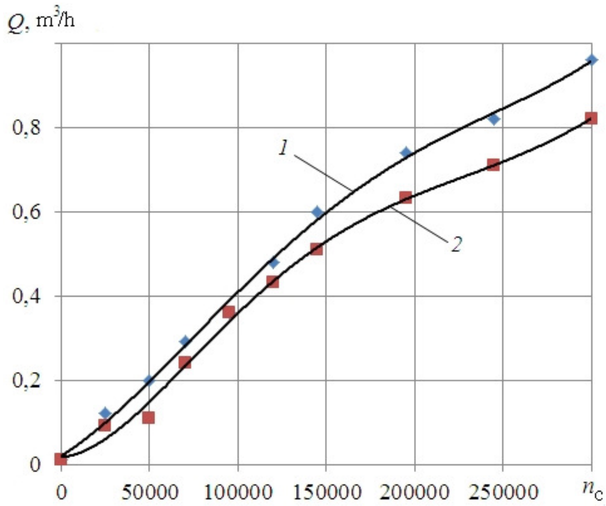



b)

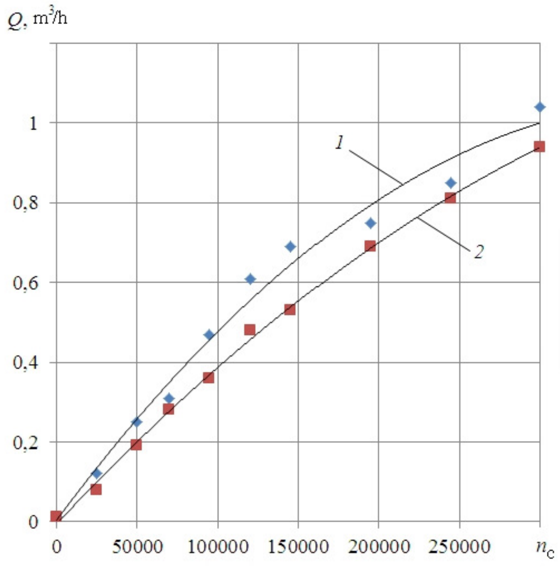
**Fig. 4.** Valve sealing elements deformation after 300 thousand operational cycles: a – valve slide; b – valve saddle




b)

**Fig. 5.** The dependency of the rate of leakage change on operational cycles: a – valve and saddle made of 08X18H10T; b – valve and saddle made of BT1-0

The form of the obtained dependencies on the Fig. 5 allows to state, that damping element has a positive influence of the valve sealing unit lifetime. This damping element dissipates the kinetic energy of the valve moving assembly through the elastic deformation of the rubber ring. That allows the sealing surfaces of the valve sealing unit to exhibit decreased stress level and deformation. The latter statement is proven by the conducted research of the sealing unit contact surfaces roughness (Fig. 6).

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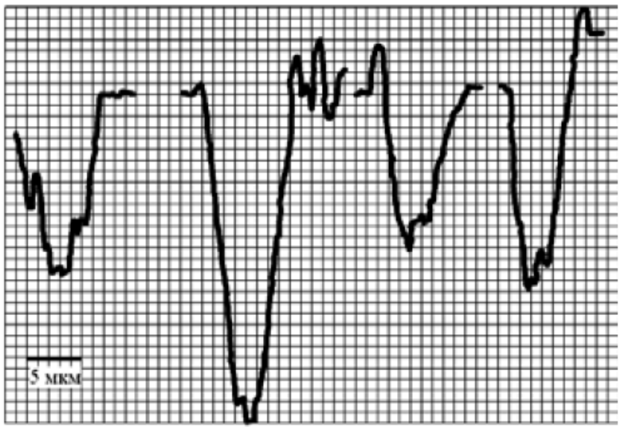


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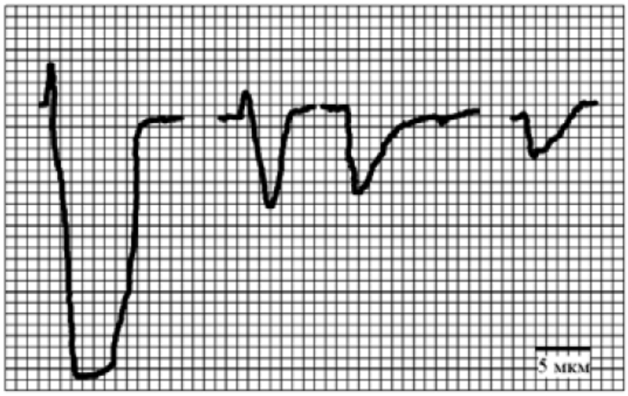


b)

**Fig. 6.** Profilogram of the valve slide sealing unit contact surface after 300 thousand operational cycles: a – without damping element; b – with the installed damping

The dynamic factor, accordingly to the (Dolotov *et al.* 2000) is the integral meter of the dynamic system loads. It allows quick evaluation of loads that occur during the system operation. Using mathematical model for calculating forces, that act on the valve elements requires more time. To calculate the dynamic coefficient of valve actuation the following formula was used (Bulanov 2012):

$$K_{\mathrm{D}} = 1 + \sqrt{1 + \frac{V^2}{2g \cdot \delta_{\mathrm{st}}}}, \qquad (1)$$

where $V$ – valve moving assembly speed; $g$ – free fall acceleration; $\delta_{st}$ – deformation of the valve element.

For used in the experiment valve accordingly to the formula (1) without the damping element in the EMV the dynamic factor is equal $K_D = 35.45$. After installing the damping element the dynamic factor has significantly decreased to the level of $K_D = 29.50$. Thus, installation of the damping element into the EMV allows to decrease the valve sealing degradation speed.

## Conclusions

This article shows the influence level of installed in the electromagnetic valve damping element on the speed of its characteristics change during the operation time. It has been established, that damping element significantly decreases dynamic factor of the valve moving system, and, as a result, maximal loads on the sealing elements.

Installation of the proposed damping element doesn't require significant changes in the valve design. It can be concluded, that installation of the damping element in the valve moving assembly is an optimal way, considering the requirement of possibly lowest mass, decreasing the wear rate of the sealing unit. The value of the dynamic coefficient has a direct influence on the resource of the valve elements, and its operation time. It has been established, that decreasing the dynamic factor by 16.7% allow to decrease the degradation speed of valve sealing unit (Fig. 5). Such effect can be explained by the partly dissipation of the kinetic energy of the valve moving assembly through the elastic deformation of the damping element. If the dynamic factor is high, the energy is converted into the plastic deformation of the sealing surfaces. During the operation cycles it leads to the leakage increase in the valve closed position, and valve failure.

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