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One-membrane drive with autonomous strut rod camera

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Abstract. The paper is devoted to the research of pneumatic membrane probes containing membrane based rod that runs a function of the hard centre. They are widely used in engineering as shut-off and control apparatus machine, chemical, oil gas and other industries. The influence of the rod support parameters on the stiffness characteristic of the rod stroke from the payload is analysed. The operation methods of membrane drives are considered. The possibility of enhancing their efficiency by using the effective membrane area is shown. The authors applied a method in which the effective area of the membrane is used during the drive operation by adjusting the bending stiffness of the support. A device has been developed in which the support is made in the form of a limiter for the flexural deformation of a membrane and an autonomous elastic shell forming a hermetic chamber connected to an overpressure pneumoline. Field studies of a single-membrane pneumatic drive were carried out on a laboratory setup. Studies have confirmed the industrial applicability and effectiveness of the developed technical solutions. In a drive with a membrane made of IPR-1266 rubber, 1 mm thick, 105 mm in diameter, and a camera with a diameter of 62 mm, its stiffness characteristic significantly increases. Compared with the traditional membrane drive, this characteristic is enhanced by more than three times.

1. Introduction

The membrane drive mechanism [1], as well as toroidal ones [2], belong to the chamber, shell type mechanisms. In them, the pressure energy in the chamber creates a force on the flexible element, moving the movable working body attached to it to the desired position.

These devices are widely used in various industries. They mainly meet the requirements for them. However, they have disadvantages that were originally incorporated into the construction of the Saunders diaphragm valve, which has remained virtually unchanged for 90 years [3].

Modern developments to improve membrane drive mechanisms are parametric studies conducted, for example, in the direction of improving the quality of membranes by making them from innovative materials. Increasing the service life of the membranes significantly reduces the cost of equipment maintenance [4]. According to the BioPhorum Operations Group (BPOG), in practice “up to 40% of preventive maintenance tasks are caused by the maintenance of a diaphragm valve” [5].

However, these research directions do not fundamentally change the structure of membrane drives and are not able to qualitatively increase the efficiency of their functioning.

One of the significant drawbacks, especially of the pneumatic membrane converter, compared with the power cylinder, is its non-rigid characteristic of the stroke of the working body of the payload [6]. This disadvantage is due to the fact that in power cylinders, the stroke of the movable working body is obtained by moving the piston by acting on its surface with air pressure. In this case the force is determined by pressure acting on the area of the piston. In membrane converters, the movement of a movable working member is accompanied by bending deformation of the membrane, and the force effect on it is determined by the product of the working medium pressure over the effective area of the membrane in which the supporting member area is of essential importance. The larger the support area is, the greater the force influences on the working medium, but the smaller the stroke is, the deformable part of the membrane decreases. At the maximum possible stroke, when the entire surface of the membrane web is used, only one third of the possible force action on the movable working member is created by air pressure.

Developed in 2014, a new method [7] of the operation of membrane drives, in which it is proposed to change the effective area of the membrane, allows creating fundamentally new structures with significantly expanded functionality and enhanced technical characteristics. The change in the effective area of the membrane during the operation of the drive was achieved by installing a limiter of its flexural deformation on the rod. A minor constructive modernization of the drive expands its functionality and increases the mechanical stiffness characteristic of the course of the load, but it does not allow to control the effective area in the process.

The control of the effective area of the membrane is implemented in a drive with a bending support [8], made with the ability to adjust its flexural rigidity. Structurally, this idea is implemented in the form of a membrane with an elastic shell embedded in it, the cavity of which is connected to a power source. However, this design complicates the design of the membrane, reduces the reliability and durability of its work and limits its deformable part, which does not significantly improve the stiffness characteristic of the drive, depending on the payload.

2. Problem statement and solution methods

The aim of the work is to increase the efficiency of the membrane drive by developing and researching a device with an adjustable effective membrane area.

Control of the effective area of the membrane in the process of operation of the drive to achieve this goal is carried out by adjusting the flexural rigidity of the support. For this purpose, the bending support in the device is made in the form of an autonomous chamber fixed on the rod between the limiter of its flexural deformation and the membrane. Moreover, the support chamber is made with the possibility of adjusting its flexural rigidity.

Membrane drive (figure 1a) consists of a housing (1), a membrane (2), forming the working chamber A of the drive. A limiter (4) is fixed on the rod (3) bending deformation of the membrane. An elastic hermetic shell (5) forming a chamber B, made with the possibility of connection with excess air pressure is installed between the stopper and the membrane.

In the initial position (figure 1a), when atmospheric air pressure is in chambers A and B, the rod support has a minimum area. In the absence of a payload on the rod (figure 1b), an increase in air pressure in the working chamber A to p_1 leads to bending deformation of the entire membrane surface under the action of force F_1 and a displacement of the rod by the value X_1.

The impact of the N payload (figure 1d) exceeding F_1 results in a decrease in the rod stroke to X_2.

The creation of excess air pressure $p_к$ (figure 1e) in chamber B leads to an increase in the effective area of the membrane by increasing the area of the rod support, which increases the force applied to the rod at constant pressure in chamber A and the rod stroke increases to X_3.

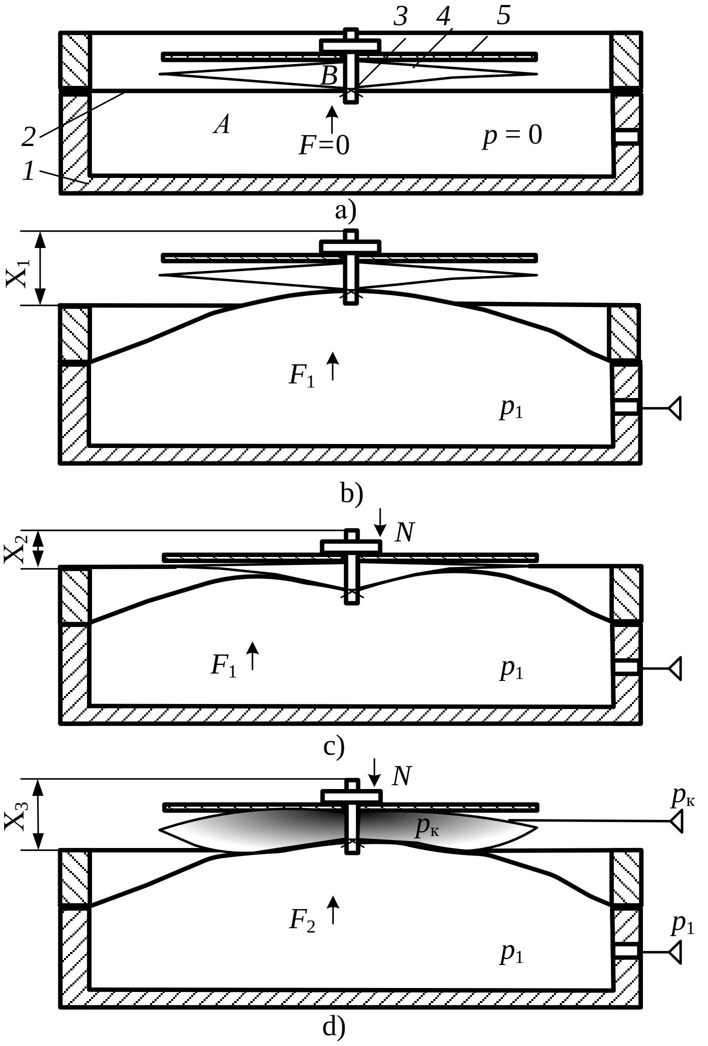


Figure 1. Schemes of the stages of the drive: a), b) and c), d) - respectively, the drive without the payload on the rod and with it.

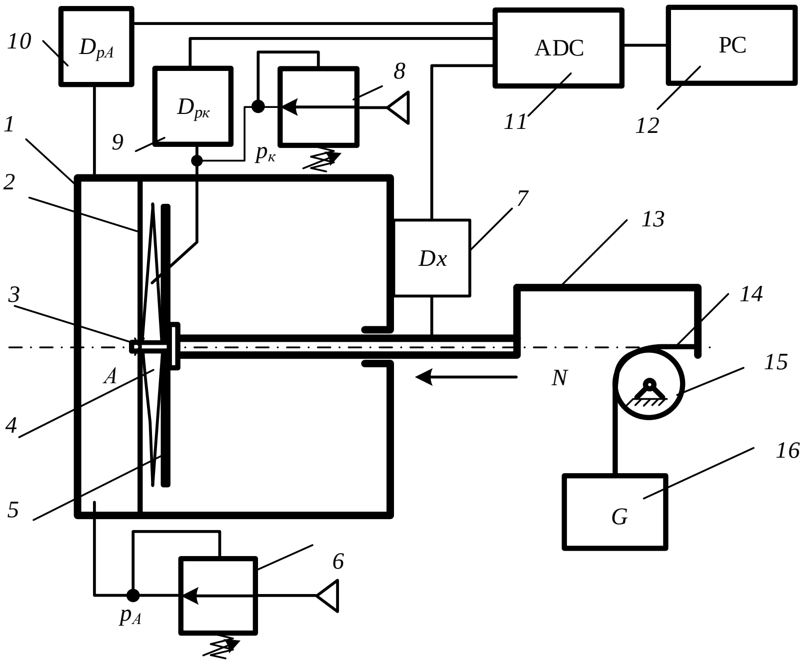
Studies of the influence of the effective membrane area on the characteristics of the drive were carried out on a laboratory setup (figure 2).

The membrane material (figure 2b) is RPI-1266 rubber; membrane thickness is 0.5mm; diameter of a membrane is 105 mm; rod diameter is 8 mm; the diameter of the autonomous camera support is 62 mm.

In the housing (1) (figure 2c), a membrane (2) is fixed with a stem (3), as well as with an autonomous chamber (4) installed on it and a bending strain limiter (5). Working chamber A is connected through a pressure regulator (6) to a source of pneumatic supply. The sensor (7) is mounted on the rod of its position. The cavity of the autonomous camera (4) is connected through a pressure regulator (8) with a source of pneumatic power. Information about the pressure in the autonomous chamber and the working chamber A, respectively, from sensors (9) and (10) goes through ADC (11) to PC (12). A bypass element (13) is fixed on the rod, on which an inextensible cable (14) connected through roller (15) with load (16) is fixed along the axis of the rod, performing the function of the payload acting on the drive.

a)

b)



c)

Figure 2. Laboratory setup for studying the parameters of a single-membrane drive: a) view of the general setup; b) view of a common membrane with an autonomous chamber; c) setup layout.

Thus, the authors of the paper have studied:

- In what way the presence in the drive of the limiter bending deformation and autonomous camera support influenced on the magnitude of the stroke in the absence of a payload;
- The dependence of the stoke magnitude on the value of the payload by changing the effective area of the membrane by adjusting the flexural rigidity of the rod support with the value of air pressure in the autonomous chamber;
- A quantitative increase in the stiffness characteristic of the developed drive in comparison with the traditional drive and the drive with the limiter installed in it.

The maximum allowable air pressure for this drive in the working chamber A and the autonomous support chamber is assumed to be 25 kPa.

3. Research results and their discussion

Studies have shown that the installation of the controls with an effective membrane area on the stem does not affect the idling value of the rolling actuator. In the absence of a payload, the stroke value is 30 mm.

Studies have confirmed the possibility of maintaining a constant position of the movable working body in a wide range of changes in the payload by separately adjusting the pressure in the working chamber and the shaft support chamber. In this case, there are many options for the ratio of the pressures in the working chamber and the support chamber.

An example of a variant of the dependence of the stroke x of the rod on the pressure p_a in the working chamber of the drive and the chamber of support of the membrane with a payload of up to 75 N on the rod is shown in figure 3.

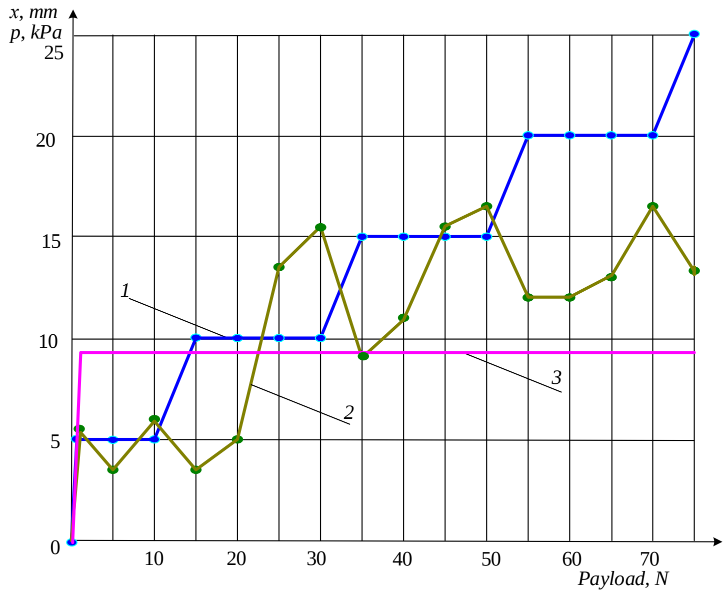


Figure 3. Graphs of the dependence of the rod stroke on the size of the payload with separate control of pressures in the working chamber and the rod chamber support, where: 1 - pressure in the working chamber of the drive; 2 - pressure in the support chamber; 3 - rod position.

The graphs show that adjusting the pressure values simultaneously in the working chamber and the support chamber ensures that the rod remains 9.5 mm in position while increasing the impact on it of the payload to 75 N.

Comparative studies of the proposed drive based on the stiffness characteristic of the rod stroke from the payload shown on the laboratory setup showed a significant increase in its efficiency. The parameters were compared with the traditional drive and the drive, in which the changes in the effective membrane area are carried out only by a limiter in the absence of an overpressure in the autonomous chamber.

Graphs of the dependence of the rode stroke on the magnitude of the payload for these designs of actuators are shown in figure 4.

The graphs show that the drive with the traditional design has a low stiffness characteristic of the stroke from the payload, ensuring that the position of the rod remains unchanged with an increase in the payload only up to 25N. The use of a bending strain limiter increases its characteristic up to 44 N, and the use of an autonomous rod support chamber up to 85 N.

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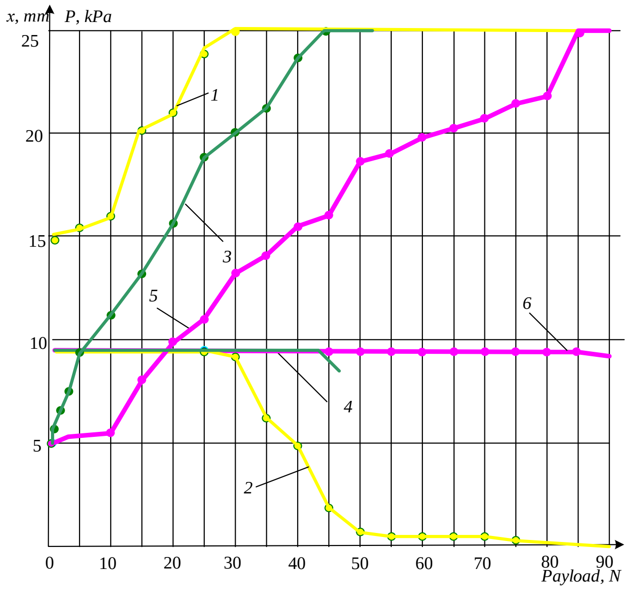

Figure 4. Graphs of the comparative characteristics of membrane drives, where: 1 and 2, 3 and 4, 5 and 6, respectively, are the pressure in the drive chamber and the stroke in the conventional drive, respectively, in the drive with a membrane flexure limiter and in the drive with an independent stem support chamber.

4. Conclusion

The constructive improvement of the drive does not concern the changes of the membrane itself and therefore does not affect the achieved modern characteristics of reliability and durability of its operation. In addition, the use of a limiter and a separately installed camera allows using the maximum possible deformable part while operating, while receiving the stiffness characteristic of the stroke of the working body from the payload, approaching the characteristics of the power cylinder. Compared with the traditional membrane drive, this characteristic is enhanced more than three times.

References

[1] Gurevich D F 2008 *Calculation and design of pipe fittings* (Moscow: LKI) p 686
[2] Shikhrin V 2001 Elastic mechanics. The basis of the machines and mechanisms of the future *Electronics. The science. Technology. Business* **5** 10-15
[3] Jones S 2013 The Future of Valves and Diaphragms Supply *BioPharm International* 32-3
[4] Development of a traditional valve. Challenge to traditional thinking 2014 *Pharmaceutical technologies and packaging* **1** 42-44
[5] Jones S 2012 *BioPhorum Operations Group presentation* (BPOG meeting)
[6] Gurevich D F, Zarinsky O N, Kosykh S I *et al* 1982 Pipeline valves with automatic control (Leningrad: Machinebuilding) pp 301-303
[7] Sysoev S N and Vozdugan A A 2017 Drive control method *Vestnik of Machinebuilding* **5** 35-7
[8] Sysoev S N, Vozdugan A A and Furtikov S A 2018 Single-diaphragm drive with built-in camera stock support *Modern high technology* **7** 120-5