The Creation of Clean Robots on The Basis of a Flexible Elastic Thin-Walled Elements

O. Baryshnikova
Department of the Theory of Mechanisms and Machines, Bauman Moscow State Technical University, Moscow, Russia
Email: barysh-oo@bmstu.ru

***Abstract*—Modern vacuum technology requires the creation of robots that do not fill the working area with micro-particles of wear and friction between the elements. The mechanisms in which a flexible elastic thin-walled element with any shape of the axis is used as a working element are considered. The moving of an element is carried out at submission of pressure in a cavity of an element. The given task is nonlinear and are reduced to the second regional task Koshee. For the decision the method of discrete continuation on parameter in a combination to a method multisegment shooting is used. The technique allows to pick up under the given law of moving geometrical parameters of a flexible element.**

***Index Terms*— a flexible elastic thin-walled element, working characteristic, discrete moving, working body**

I. Introduction

In modern technology vacuum technologies are widely used. Vacuum technology has its own characteristics [1, 2, 3]. In manipulators operating in a vacuum, it is necessary to reduce the external friction that adversely affects the working environment. Fig. 1 shows an example of wear parts - a gear wheel, unable to perform operational functions.

Figure 1. The example abrasion the details of the mechanism.

The purpose of this article is not to determine the causes of wear of working surfaces of parts. In robots wear does not take critical values. However, it should be recognized that even a slight friction leads to filling the working environment of vacuum robots with microparticles of wear. This has a negative impact on the quality of the process and manufactured details.

It is possible to apply to elimination of external friction mechanisms, in which the moving of the executive body is carried out thanking deformation of a flexible elastic thin-walled element at submission of pressure in a cavity of an element. Traditionally, flexible, tubular, elastic elements used for pressure measurement. This type of elements is called a manometric spring. In recent years, the scope of tubular springs has expanded significantly. One of the variants of application of flexible elastic elements in modern technology is shown in Fig. 2. The shown robot can perform two main movements due to deformation of two flexible elastic tubes. One tubular spring has a vertical axis. To increase the efficiency of the tube has several turns (in this example, 5 full turns). When the pressure is applied inside the tubular spring, the upper platform of the robot rotates relative to the vertical axis.

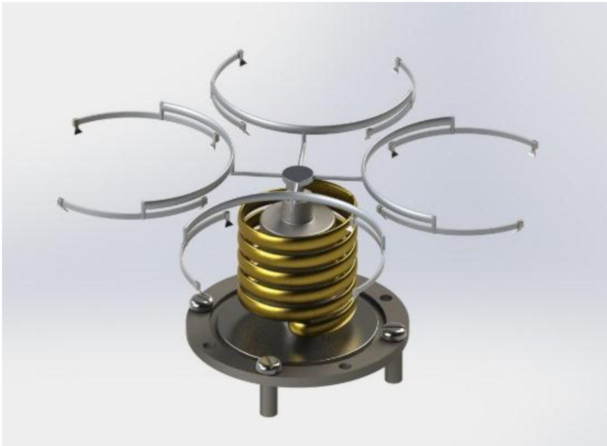

Figure 2. The mechanism of the gripping and turning.

Four gripping blocks are used to grip the detail. Each of these blocks has a tubular spring (second) with a vertical axis. When pressure is applied inside these tubular springs, the gripper block is closed. The control system can be different. The pressure can be applied in the cavity of the single-turn and multi-turn tubular springs simultaneously or alternately. As a result of the pressure supply to the internal cavities of the flexible elements, they are deformed and move the working body of the robot.

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The connection of elements among themselves allows to create mechanisms carrying out various functions: moving of the executive bodies or force influence them on object of processing [4]. The use of a flexible tubular elastic element in the design of robots eliminates friction between the working parts. These robots are called clean robots because they do not pollute the working environment.

The practical interest represents reception of the working characteristic of a flexible element – to dependence of moving of a characteristic point on loading (internal pressure). Depending on the type of elastic element, any point can be selected as a characteristic point. Typically, the point with the most expected displacements in the deformation process is chosen as a characteristic point. In General, the load can be called pressure, force, torque, temperature, and so on. In this article, the load is the internal pressure.

Depending on parameters of an element and character loading the occurrence of effect bifurkation, allowing by jump to change the form of an element and, due to this is possible, to provide discrete moving of a working body. In connection with wide use of elastic thin-walled elements the research of elements with various geometrical parameters is necessary.

II. Definition of a Task

Two types of flexible elements are considered:

- Flexible element having a plane of symmetry;
- Flexible element as a pneumatic spring bent on some radius of curvature.

The element of the first type can be simulated by the bent core, which form coincides with the form of cross section. Different variants of parities for flexible cores are known today. As permitting system the system of the nonlinear differential equations concerning basic unknown is used. Vector basic unknown in current section of a core enters the name as

$$X^T = \{X, Y, \psi, N, Q, M\} \tag{1}$$

where X, Y - coordinates of the current point on an axis of a core; ψ - corner of an inclination toucher in a considered point; N, Q - longitudinal and cross force; M - bending moment.

The initial differential parities represent system of the nonlinear differential equations which have been written down in the standard form Koshee, are complemented by regional conditions [5, 6]. Thus, the problem of research of nonlinear behaviour of cores is reduced to a point-to-point regional task. The task is solved in a dimensionless kind.

The element of the second type represents thin axis-symmetrican cover of rotation open-ended in a district direction. As initial the basic parities of variant of the theory thin axis-symmetrican covers, modernized for the tubular manometrical elements [7]. At research two-dimensional the task is reduced to one-dimensional with the help of the generalized hypothesis of flat sections. A vector basic unknown in the current section of an cover:

$$X^T = \{u, v, \psi, U, V, M_1\} \tag{2}$$

where U and V - horizontal and vertical making internal force; M_1 - bending moment working in meridional direction.

Is entered additional unknown χ - relative change of the central corner determined by the following expression:

$$\chi = \frac{\phi - \phi_0}{\phi_0} \tag{3}$$

where ϕ and ϕ_0 - central corners of cover before and after deformation accordingly.

The additional equation closing system, is received from a condition of balance: the size of the equivalent moment of internal forces in cross section should be equal to the external moment enclosed to cut off part [8]. The system of the nonlinear differential equations enters the name in a dimensionless kind [9, 10]. Supplementing system by regional conditions, we reduce a problem of research of behaviour of an element to a regional task.

With use of a method multisegment shooting [11] the point-to-point regional task is replaced multidot (for rod and for cover models). The procedure of the step-by-step decision by a method of discrete continuation on parameter is used.

As a result of the calculation it is necessary to obtain the performance of a flexible elastic element. The working characteristic allows to estimate quality and efficiency of work of an elastic element, and also to estimate possibilities of use of an elastic element in a design of the machine.

III. Results

The rod model was used for the numerical solution of a practical problem-the analysis of the process of nonlinear deformation of the emergency switch, shown in Fig. 3. The need for research and creation of the presented element is dictated by the needs of modern technology.

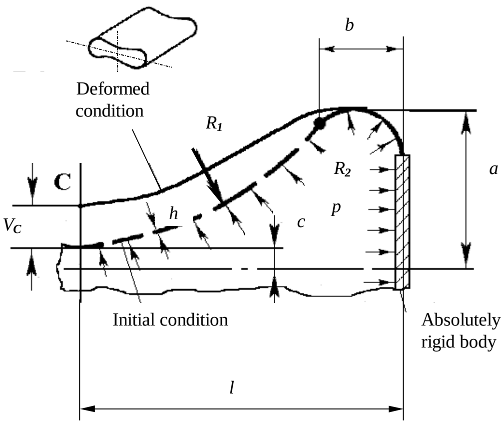

Figure 3. The settlement circuit of the emergency switch.

The task of creating emergency elements that are triggered by an increase in pressure above the permissible limit, with an increase in temperature and other operating parameters is relevant for modern technologies. The operation of the proposed emergency switch on the basis of a flexible elastic element is automatic. When the load decreases, the element returns to its original state, maintaining its operability. The ability to reuse the emergency switch is a significant advantage.

Using the technique described in the article, the researchers of the process of deformation of flexible elastic elements are carried out. Different cross-sectional shapes with different geometric parameters are researched. The basic geometrical parameters of initial settlement elements are given in the Table I.

TABLE I. GEOMETRICAL PARAMETERS (MM) OF CROSS SECTION OF THE SWITCH

№ of switch	*a*	*b*	R_1	R_2
1	2,0	2,56	4,65	1,5
2	2,5	1,71	6,85	1,0
3	3,0	1,28	8,81	0,75
4	4,0	0,80	3,76	0,4

Note. c =0,2 mm; h =0,1 mm; l =8,0 mm.

The results of account of a flexible element of variable thickness with the various form of cross section are given in a Fig. 4.

The results are the performance working characteristics of the elastic elements researched – dependence of vertical moving V_C of a point C (marked in Fig. 3) from internal pressure. The material is characterized by the module of elasticity of the first sort E=0,2 10^{12} Pa (Pascal) and coefficient of Poisson ν=0,3.

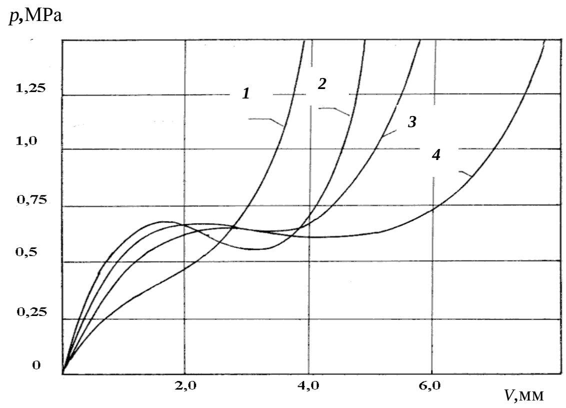

Figure 4. Working characteristics of the switch.

The analysis of the obtained working characteristics allows us to understand the quality of deformation of the elements. For all the studied elements, the working characteristics have linear intervals at the beginning of deformation, which do not differ from each other in principle. Outside the linear interval, all working characteristics has non-linear intervals. For rod element 1, the nonlinear interval has a soft nonlinearity. For other elements (elements 2, 3 and 4) the nonlinearity is significant.

The research of the received working characteristics shows, that at various geometrical parameters of the switch it is possible to receive zones leaps. The area of spasmodic transition from one equilibrium situation in another provides discrete operation of the switch. There is a zone, in which the insignificant increase of internal pressure results in significant movings (curve 1). Depending on the showed requirements the similar elastic elements can be used as sensitive elements of devices.

It is assumed that the deformation of the cross section of the tubular element is similar to the deformation of the flexible rod. The shape of the rod in this case coincides with the shape of the cross section of the tube. The studies carried out for the rods are used as a starting solution. Of practical interest is the determination of the geometrical parameters of the tubular element of discrete action

With the help of the developed algorithm the results of numerical research essentially of nonlinear process deformation of flexible tubular elements are received. The plane-oval manometrical tubular spring with half-axises a=8,55 mm and b =1,35 mm, radius and which thickness according c and h was considered. The material of considered springs is characterized by the module of elasticity of the first sort E=0,1 10^{12} Pa, internal superfluous pressure 0,1 10^6 Pa (MPa).

For reception of a flexible tubular element of discrete action it is offered to use internal membrane partition for creation of area of compression in tubular manometrical elements. The basic geometrical parameters of the considered models are given in the Table II.

The results of numerical research as the working characteristics are given in a Fig. 5.

TABLE II. GEOMETRICAL PARAMETERS (MM) OF CROSS SECTION MANOMETRICAL OF ELEMENT

№ of element	*c*	*H*	R_2
1	121	0,6	∞
2	121	0,6	40
3	121	0,6	30
4	121	0,6	2,65
5	121	0,6	5
6	50	0,15	1

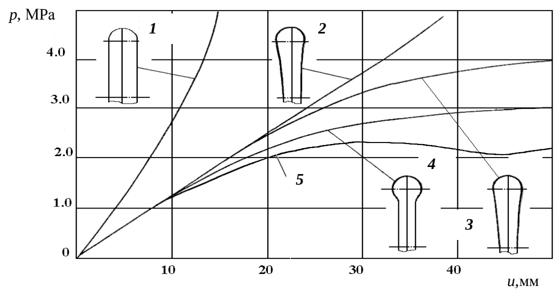

Figure 5. Working characteristics of the manometric elements.

The carried out researches show, what not for all forms of cross section use of such constructive decision as membrane partition is lawful. For some elements the internal partition works on compression.

The developed technique allowed to choose the shape of the cross section of the tubular manometric element. To provide a discrete operation of the element inside the cross section, it is proposed to install a membrane partition. The working characteristic of such element is shown in a Fig. 6. The carried out experimental researches confirm discrete operation of an element.

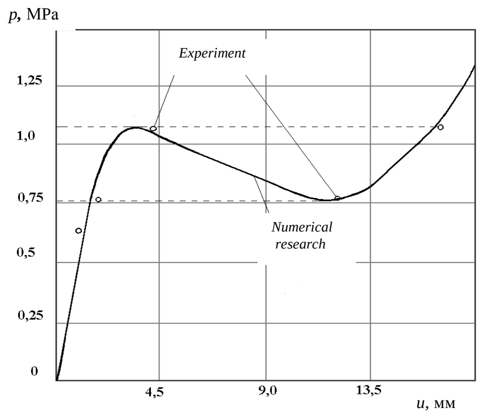

Figure 6. Working characteristics of the tubular element with discrete action.

For some technological processes, the use of flexible elements of discrete action significantly increases the efficiency of the machine. Application of the tubular element in the design of machines may be in different industries.

For example, in medicine and agriculture is use actively selenium as a stimulant of the immune system of humans and animals and means of increasing productivity. For these purposes it is necessary to have selenium nano-solution, the production of which is possible with the use of laser ablation. The process of making the nano-solution has features. The use of a tubular spring allows to solve this problem. The feature of this process is a strict order of the laser position relative to the container with the solution in the process of ablation. To prepare the solution correctly the laser head must be initially opposite to the upper solution layer, the next position must opposite to the lower layer, and the third position must be opposite to the middle layer. To exclude the involvement of foreign elements in the process, it is proposed to use a flexible tubular element as a device that controls movements.

Fig. 7 shows a diagram for selenium laser ablation. A stock solution of selenium is located in container 1. Platform 2, on which the laser head is located, moves along vertical guides 3 under the action of tubular spring 4 or 5 force. In the initial position, the laser head is situated at the lower level

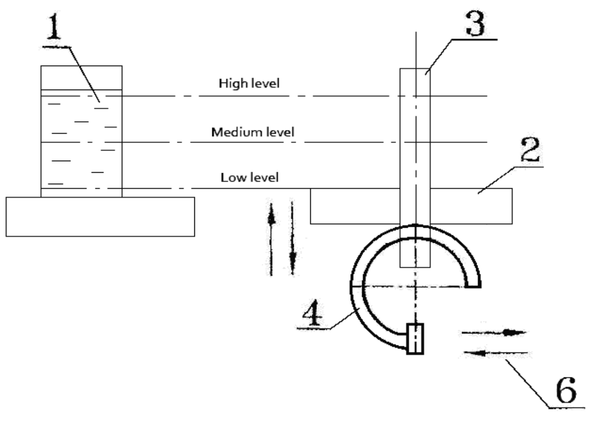

Figure 7. Schematic diagram of a mechanism for laser ablation of selenium.

To move the platform 2 to the middle and upper levels, it is necessary to apply a pressure of 6 different values to the inner cavity of the spring 4. The internal pressure is determined by the working characteristic of the tubular element.

An alternative mechanism is also proposed, as shown in Fig. 8. The tubular spring has an internal transverse partition. Moving the free end of the tubular spring is due to pressure in one part of the spring or in both parts of the springs.

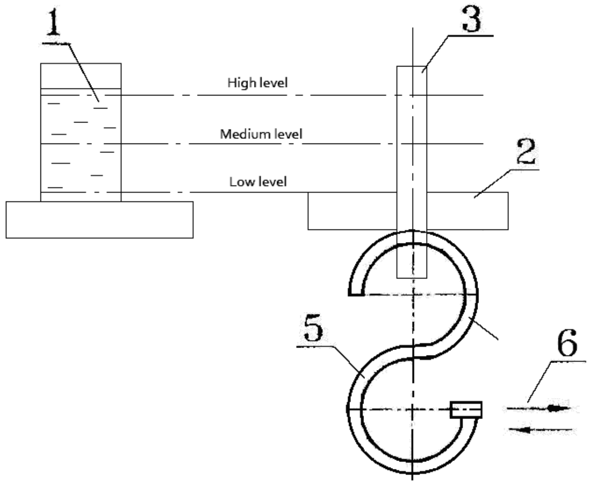

Figure 8. Alternative mechanism for laser ablation of selenium.

An alternative mechanism is also proposed, as shown in Fig. 8. In this case, it is proposed to use a double tubular spring.The tubular spring has an internal transverse partition. Moving the free end of the tubular spring is due to pressure in one part of the spring or in both parts of the springs.

In terms of manufacturing technology and pressure control system, an alternative mechanism is preferable.

Under the atmospheric pressure, in both mechanisms springs have the original geometry, and platform 2 occupies the lowest position. When pressure is applied to the S-shaped spring, platform 2 moves to the upper position, and the laser head is positioned at the upper layer level. The second ablation step occurs at the lower level, while there is no overpressure inside springs of the in both mechanisms. To complete the process of laser ablation, pressure is applied to tubular spring 4, and the laser head is positioned at the level of the middle layer. In an alternative mechanism for positioning the laser head at the middle level, the internal pressure is applied only to one of the two parts of the tubular spring.

The use of a tubular spring in the laser head movement mechanism provides precision and minimal wear. The guides ensure that the linear laser head moves without skewing. The clamps provide required laser positioning. At designing mechanisms, which working bodies realize the given moving, it is recommended to use the considered flexible elastic elements. The advantages are: simple design; high technology; easy operation; small size; high maintainability. A significant advantage of the described flexible element is the preservation of its efficiency when used repeatedly.

The use of flexible elastic elements of discrete action allows to

- Simplify the design of mechanisms;
- Increase the speed of work;
- Increase the efficiency of the robot;
- Reduce energy consumption.

The main advantage of a clean robot is to keep the working environment clean. This requirement is dictated by the properties of the vacuum technology, but also by the attention paid to environmental safety.

Environmental safety has been of great importance in recent years. Safety requirements of modern machines and devices open up new opportunities for the development of clean robots based on flexible elastic thin-walled elements.

IV. CONCLUSION

1. The flexible elastic element of the emergency switch is considered. The influence of geometric parameters of the rod element on the deformation character is investigated.
2. The geometrical parameters of the element of the emergency switch of discrete action are obtained.
3. A flexible elastic manometric element of a pure robot is considered. For several tubular elements obtained performance with different nonlinearity.
4. The geometric parameters of a flexible tubular element implementing a discrete operation in the process of deformation are obtained.

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Olga Baryshnikova was born in Irkutsk, Siberia, Russian Federation, at 28 September 1967. She graduated in aviation engineering from the Irkutsk Polytechnic Institute, Russian Federation, in 1989. She worked as an assistant teacher at the Moscow aviation Institute in 1989-1993 and received PhD degree in field solid mechanics in 1997. Since 1997 she has been working as an associate Professor of robotics and complex automation at Moscow state technical University. Bauman's. Research interests: mechanics of flexible elastic elements, design of advanced machines and mechanisms