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VALUE OF DEFORMATION ENERGY DEPENDING ON DEFORMATION OF FLEXIBLE PNEUMATIC ELEMENT

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Abstract: The article describes a flexible element used in flexible pneumatic couplings. These elements are manufactured by various manufacturers and are mostly made of rubber. Each element, depending on the number of bellows and diameter, has permissible stroke values. It is necessary to expend a certain amount of energy to compress and expand them. The article examines the amount of deformation energy required to compress and expand this elastic element.

1 Introduction

Shaft couplings are among the most important elements in various mechanical systems for torque transmission. Very often used couplings are flexible shaft couplings. They have greater advantages than conventional fixed shaft couplings. At our workplace, we deal with the issue of flexible pneumatic couplings and torque transmission. In our department, we have already developed several types of these flexible couplings with flexible pneumatic elements, as well as various test equipment for determining the static and dynamic properties of flexible pneumatic shaft couplings [1-5].

These flexible pneumatic shaft couplings contain flexible pneumatic elements that carry the entire load. These make it possible to tune the torsionally oscillating system, and to adjust its stiffness, damping or mass parameters according to the operating characteristics so that during the operating mode of the system there is no dangerous resonant state and damage to the whole equipment or injury to the operator. At present, attention is being paid to the development and research of pneumatic flexible members, which are formed from a rubber-cord casing filled with a gaseous medium. These elastic elements are dynamically stressed. However, it should be noted that the load is not transmitted by the rubber but by the gaseous medium with which the pneumatic coupling is filled [3,6-8].

For the correct operation of the coupling, it is important to know the properties of the elastic element such as compressibility, volume and the amount of deformation energy required to compress this element [9,10].

The aim of the article is to find out how large values of deformation energy are needed to compress the elastic element that we use in pneumatic shaft couplings developed at our workplace [11].

2 Flexible elements

The There are various manufacturers of flexible elements in the world. Different sizes and different numbers of bellows are also produced. Most single-wave, double-wave and triple-wave elements are produced Figure 1.

Figure 1 Types of flexible pneumatic elements

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These flexible elements are friction-free and require maintenance and lubrication. They are designed for low strokes and high pressures. The height of the pneumatic element depends on the diameter of the cylinder and the number of bellows. The higher the height of the element, the larger the dimensions of the pneumatic shaft coupling in which this element is mounted. The construction provides insulation against shocks and manufacturers also offer various types of anchoring flanges, which ensures easy assembly of the element. The working pressure is limited by the maximum working pressure which is 800kPa. Normal operating temperature is in the range of -40 °C to 70 °C. For special operations, the manufacturer can provide another material that has a working temperature in the range of -20 °C to 115 °C.

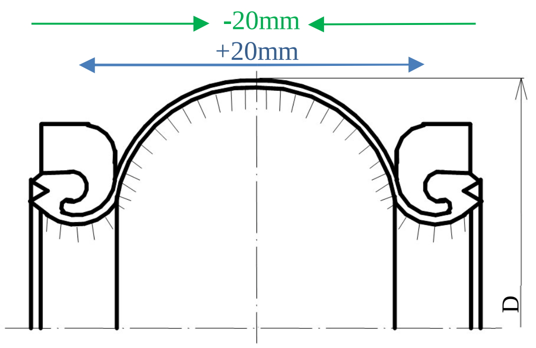

Figure 2 Investigated flexible pneumatic element PE 130/1

For our research, we used a flexible pneumatic element PE 130/1. The marking itself defines the diameter of the cylinder D = 130mm and the number of bellows (Figure 2).

3 Results of experimental measurements

To numerically solve the problem, it was necessary to find out some parameters.

Dependence of the volume of the pneumatic elastic element PE-130/1 on the deformation. This is shown in the following Figure 3. The values obtained were measured in the laboratories of our department. Using experimentally obtained values of the volume of the pneumatic-elastic element at different values of its deformation. Table of values 1. The maximum stroke of our flexible element is in the range of + 20mm and -20mm. (Figure 2) [12-19].

3.1 Volume of the elastic element

We obtained the volume values experimentally. Based on the measured values, we were able to write a numerical formula to describe the volume depending on the stroke. The corresponding dependence is:

$$V(x) = 468{,}6 + 5{,}436 \cdot x - 0{,}0651 \cdot x^2 + 0{,}00162 \cdot x^3. \qquad (1)$$

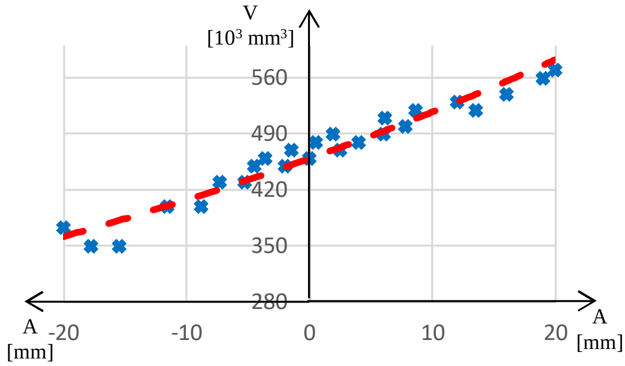

Figure 3 Dependence of volume V on deformation A

Table of experimentally obtained values of volume of pneumatic-elastic element *V* depending on its deformation A (Table 1).

Table 1 Element volume values

	A [mm]	*V* [10^3mm^3]
1	-20	373
2	-17,8	350
3	-15,5	350
4	-11,6	400
5	-8,8	400
6	-7,3	430
7	-5,3	430
8	-4,5	450
9	-3,6	460
10	-2	450
11	-1,5	470
12	0	460
13	0,5	480
14	1,9	490
15	2,5	470
16	4	480
17	6	490
18	6,1	510
19	7,8	500
20	8,6	520
21	12	530
22	13,5	520
23	16	540
24	19	560
25	20	570

3.2 Bellows deformation

We obtained the volume values experimentally. Based in Table 2 we show the experimentally obtained values of the forces F acting in the axis of the pneumatic-elastic element with the corresponding magnitudes of deformations A. These values are subsequently plotted in the graph in Figure 4.

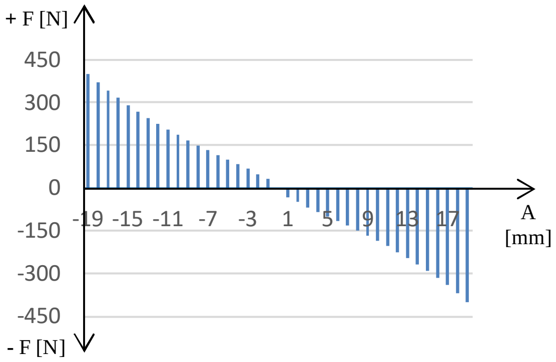

Figure 4 Dependence of force F on deformation A

Table 2 Bellows deformation

A [mm]	*F* [N]	*A* [mm]	*F* [N]
-19	400	1	-32
-18	370	2	-48
-17	341	3	-68
-16	316	4	-84
-15	290	5	-100
-14	268	6	-116
-13	246	7	-132
-12	225	8	-149
-11	204	9	-167
-10	186	10	-186
-9	167	11	-204
-8	149	12	-225
-7	132	13	-246
-6	116	14	-268
-5	100	15	-290
-4	84	16	-316
-3	68	17	-341
-2	48	18	-370
-1	32	19	-400
0	0	20	-430

The translated dependence is described by a function where the value of the stroke *x* is in millimetres

$$F(x) = -18{,}153 \cdot x - 0{,}00686 \cdot x^3. \qquad (2)$$

3.3 Deformation energy

The measured parameters are used to calculate the amount of deformation energy E_D stored in the pneumatic-elastic element at different sizes of its deformation (3).

$$E_D(x) = -\int_0^x F(x')\,\mathrm{d}x'. \qquad (3)$$

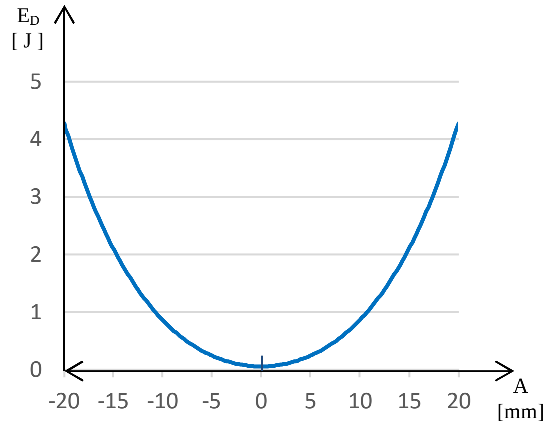

Figure 5 Dependence of deformation energy E_D on deformation A

In Figure 5 we can see that with increasing stroke, the amount of deformation energy also increases up to the value of 4.3J. When the elastic element is compressed up to a maximum value of 20 mm, the amount of deformation energy also acquires the value of 4.3J. The course of deformation energy when compressing or expanding a pneumatic element is not linear but exponential.

When the elastic element is compressed and expanded, the elastic elements heat up and heat is generated. Finding the amount of deformation energy is necessary for the numerical solution of the heat conduction equation.

This heat heats the rubber from which the elastic element is made evenly in volume and thus contributes to increasing its temperature.

It should also be emphasized that the stated values refer to an unpressurized open flexible rubber element. Thus, they really only capture the force and energy needed to deform the rubber.

4 Conclusions

The article describes a flexible element used in flexible pneumatic couplings. These elements are important for the proper operation of the clutch. The article focuses on the flexible element PE130 / 1, which describes in more detail. Experimental measurements were performed on a given elastic element and the course of the volume depending on the compression and expansion of the element was recorded. The volume of this element varied from 373x10^3 mm^3 at maximum compression to 570x10^3 mm^3 at maximum compression. We listed all measured values in the table and also showed the course graphically. By further measurement, we determined the force required to compress or expand the unpressurized elastic element. It changed from 400N at maximum compression to 430 N at maximum expansion of the elastic element. We also displayed the given values graphically and in a table. Based on these measured values, we were able to calculate the value of deformation energy required for compression and expansion of the elastic element. The maximum value of the deformation work was 4.3J and the magnitude changed exponentially with increasing deformation of the elastic element. Finding the magnitude of the deformation energy is necessary for the numerical solution of the heat conduction equation, which we want to address in further research.

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