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*Piotr Wodziński**

ELASTIC RUBBER SUSPENSIONS

1. Introduction

Figure 1 shows three types of rubber sleeves which are most frequently used in industrial practice. These are the currently used design solutions. Each elastic element can transfer three types of loads shown in Figure 2. These are: a) vibrations, b) impacts, and c) shocks. The loads occur most often in parallel during the operation of a vibrating machine.

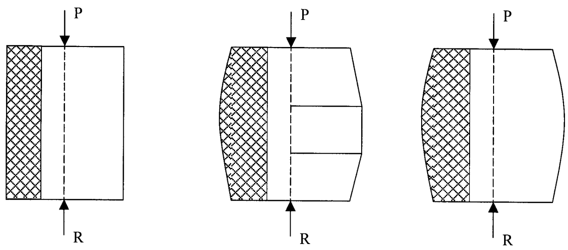

Fig. 1. Rubber sleeves

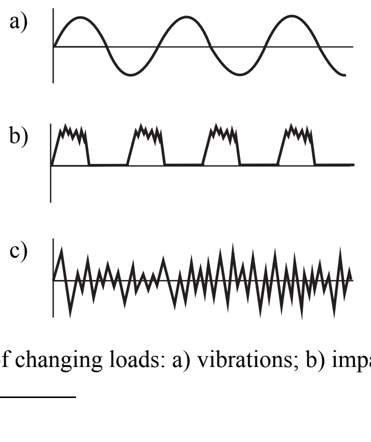

Fig. 2. Types of changing loads: a) vibrations; b) impacts; c) shocks

* Technical University of Łódź

It is well known that an elastic steel element, e.g. helical spring, has a linear characteristic, i.e. relation of the spring deflection and exciting force is represented by a straight line. In the case of an elastic rubber element, the characteristic is non-linear (Fig. 3), where 1 denotes load curve, 2 is the unload curve, and field 3 denotes the quantity of energy lost during the element movement which is transformed into heat.

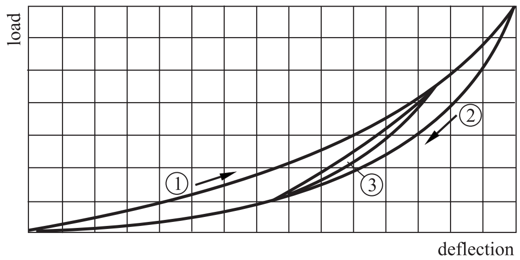

Fig. 3. Hysteresis loop of a rubber element

Explanations in text

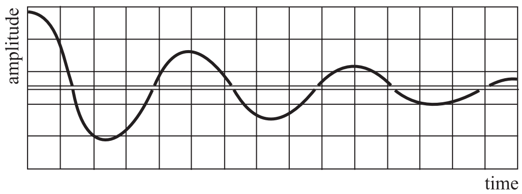

Fig. 4. Damping of mechanical vibrations

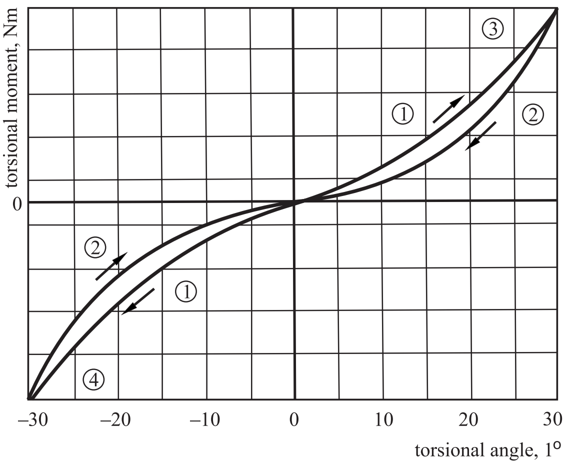

Fig. 5. Characteristics of a rubber torsional element:
1 — loading, 2 — unloading, 3 — range of positive twists, 4 — range of negative twists

Mechanical vibrations occurring in the vibratory machines are damped, as shown in Figure 4. Damping is not a constant value but is variable and depends on temperature, acceleration in vibrating motion and initial deflection of a rubber element.

If we consider a flexible rubber element which performs torsional vibrations from zero position in both directions + and –, the characteristic of such an element is shown in Figure 5. On the X-axis deflection is shown in the form of the angle of element torsion in both directions starting from 0, while on the Y-axis the torsional moment is drawn in both directions as well. Worth noting is the run of relevant curves of loads and unloads of the rubber torsional element.

An extremely important part of the characteristic is the frequency of free vibrations of the elastic element. Figure 6 shows a method for determination of the value of n_e. If we have useful load *G*, suspended on the elastic element of constant elasticity *C*, which performs a motion of shift *S*, the frequency of free vibrations of this element will be determined according to the quoted formulas. If there is an elastic rubber element whose operation is shown in the diagram in Figure 7, the frequency of free vibrations of this element is determined by drawing a tangent to the diagram in point *A*.

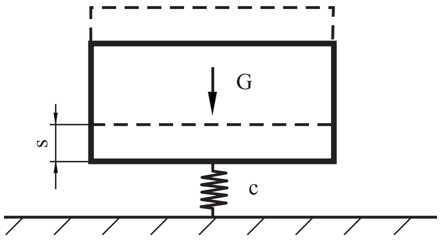

Fig. 6. Frequency of free vibrations of an elastic element

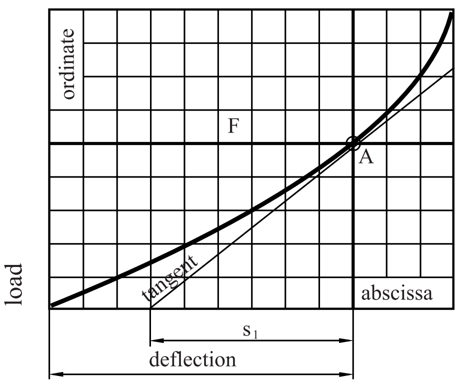

Fig. 7. Rubber sleeve characteristics

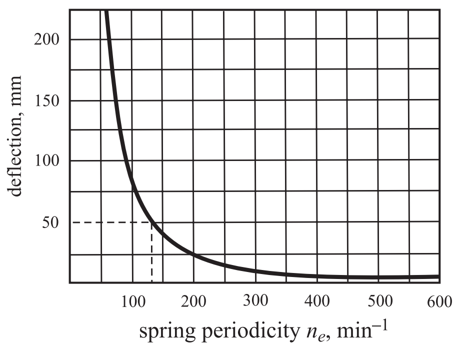

Fig. 8. Dependence of deflection on specific frequency n_e

This point corresponds to the assumed load F of this element. Then, from the diagram we read abscissa s_1 and by means of the known formulas we determine n_e.

Assume that s_1 = 5 cm, then

$$n_e = \frac{300}{\sqrt{5,0}} \cong 134 \quad \text{mm}^{-1} = 2,2\ \text{Hz}$$

$$n_e = \frac{300}{\sqrt{s} \quad \text{cm}} \quad \text{min}^{-1}$$

$$n_e = \frac{5}{\sqrt{s} \quad \text{cm}} \quad \text{Hz}$$

Figure 8 illustrates a relationship between the frequency of free vibrations n_e and deflection of the elastic element calculated according to the formula quoted above.

Difference between the properties of steel and rubber elements is illustrated in Figure 9 (at common time basis).

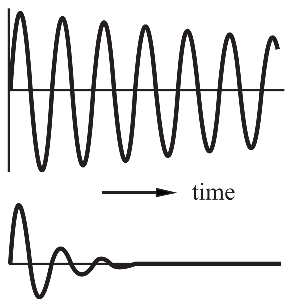

Fig. 9. Comparison of free vibrations of a steel and rubber element

2. Elastic rubber-metal elements

The oldest known rubber suspensions are elastic rubber-metal elements (Fig. 10). They can be produced in different configurations. However, these are always rubber blankets vulcanized in metal frames which are mounted directly on a supporting frame and vibrating casing. Figure 10d shows a pack of rubber blankets used in resonance screens applied in extractive industry, especially in hard coal mining. Since the application of these elastic elements is more and more limited, they will not be discussed in more detail.

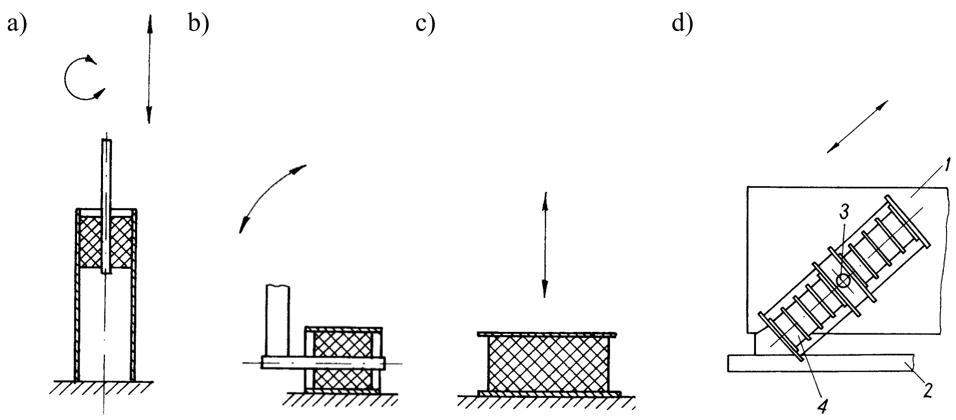

Fig. 10. Rubber-metal suspensions

3. Rubber disks

A few machine building factories use rubber disks as elastic suspensions in screens (Fig. 11). Basic part of these suspensions is a rubber disk which is similar to a puck, the only difference is that it has a central hole in the axis of symmetry which is used to fix a rod of the screen riddle.

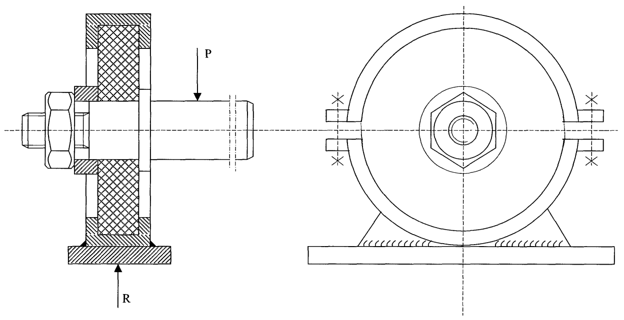

Fig. 11. Rubber disk suspension
Explanations in text

Useful force P (taken as the one generated by the riddle weight), is the force acting upon the rod of the elastic element, and reaction R is the action of the machine frame. Construction of such an element is very simple. A significant characteristic feature of this suspension is a possibility of radial and axial force transmission. Radial forces P can be transmitted in all radial directions at the same elasticity constant. Hence, flexibility of this element is identical in all directions. This means that the screen can be built as horizontal one and then it can be inclined in an arbitrary way, depending on process conditions or its construction.

4. Pneumatic suspensions

Pneumatic suspensions have very interesting operating properties. Two basic types of pneumatic suspensions are known (Fig. 12): circular (Fig. 12a) and balloon-like (Fig. 12b). The oldest known were the balloon-like suspensions which for constructional reasons have been rarely used. The suspension shown in Fig. 12b is designed for suspended screens, however, an elastic pneumatic element for supported screens is similar. A characteristic feature of pneumatic suspensions is a possibility of control (to some extent) their rigidity by air pump-up or bleed.

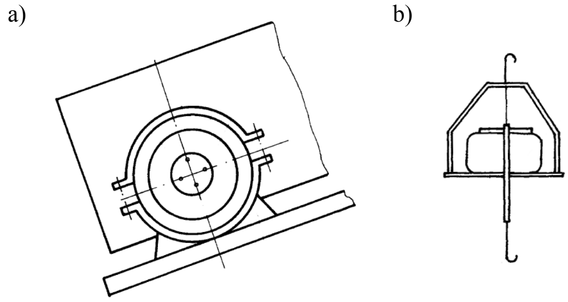

Fig. 12. Pneumatic suspension

An interesting pneumatic suspension is shown in Fig. 12a. The element is composed of a road wheel (e.g. a car wheel) placed in an appropriate casing. The circular pneumatic element is shown in Figure 13. The suspension has also a feature characteristic of a ring suspension – they can transmit forces in all radial directions at the same flexibility constant. Additionally, axial forces can be transmitted. Beside this, it is possible to control constant elasticity of the elastic element like in other pneumatic suspensions. The above mentioned properties cause that a single-plane screen with circular suspensions is constructed as a horizontal one (Fig. 14) and next it is inclined with a supporting frame at an arbitrary angle to the level. In the screen shown in Figure 14 the drive system of the machine is not shown, but any drive applied in single-plane screens can be used here.

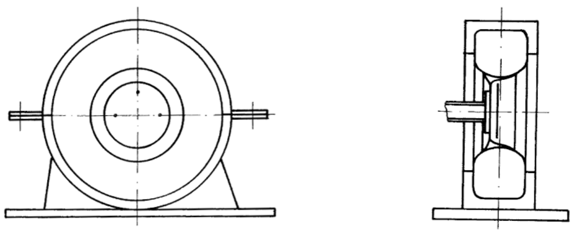

Fig. 13. Pneumatic circular suspension

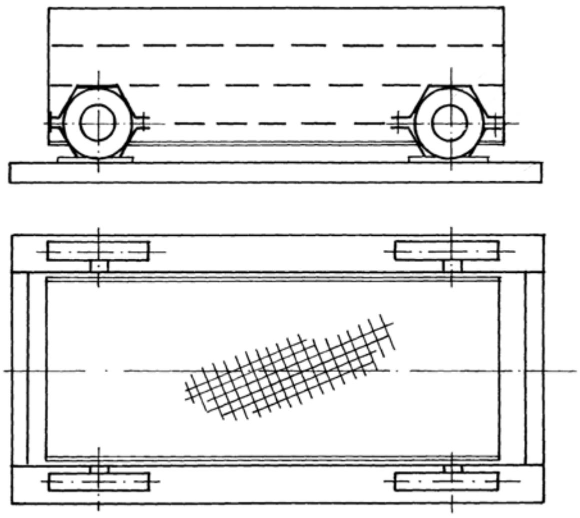

Fig. 14. Single-plane screen with circular pneumatic suspensions

5. X-type suspensions

Rubber X-type suspensions are well known. Figure 15 shows a joint of the X-type element which is illustrated in Figure 16 in the application to a single-plane screen. The rubber joint transmits torsional vibrations (Fig. 15) caused by turning of the inner part by angle α from balance point in both directions. Moreover, torsional vibrations of the joint axis are possible; they are represented by deflections of this axis by angle β. The X-type elastic element is composed of three elastic joints combined by two levers and mounted on the supporting frame and the moving part.

The rubber X-type elements are produced in different dimensions. For a concrete application elements are selected like other elastic parts, depending on the vibrating weight. The elements as mounted wholes are bought to mount them in a vibratory machine.

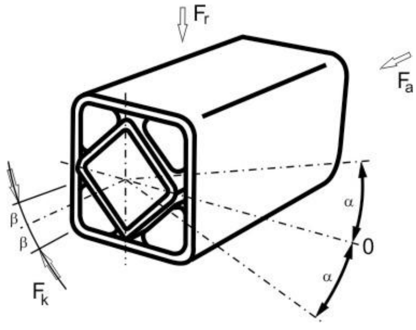

Fig. 15. Rubber joint of X-type elastic element

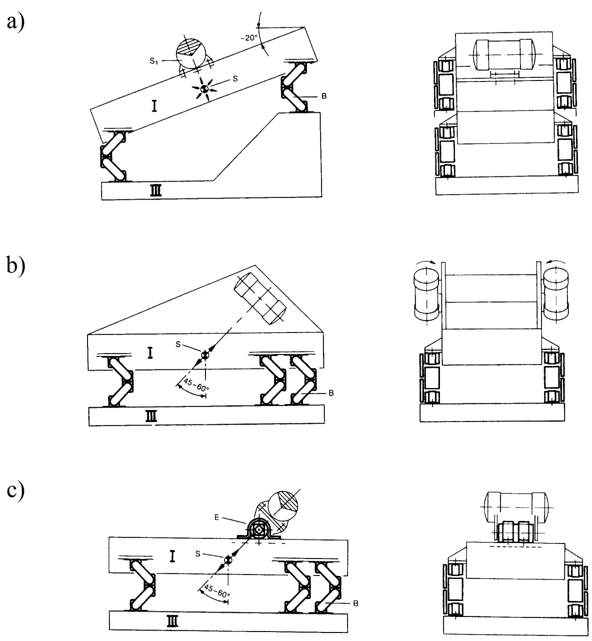

Fig. 16. Single-plane screens suspended on X-type elastic elements: a) Screen driven by an unbalanced shaft placed over the center of gravity of the vibratory system, b) Screen driven by two synchronized rotary vibrators, c) Screen driven by one rotary vibrator placed on a rubber joint

6. Concluding remarks

Elastic rubber elements are very interesting parts characterized by valuable operation properties which distinguish them from elastic steel elements (usually helical springs). Their most important feature is high quality which depends first of all on the quality of rubber mix used in production of an elastic element.

Elastic rubber elements are bought as ready parts, produced by particular manufacturers, which ensures their high quality and durability. It is known that each rubber element has different durability determined by temperature at which it works. The range of temperature at which these elements are used is from –40°C to +60°C. So, this is a quite broad range which covers majority of industrial applications of these parts.

Figure 17 shows some properties of elastic rubber elements in a graphic form. Figure 17a illustrates the relation between plastic strain of the element (Y-axis) and working time (X-axis). Plastic strain of the rubber element was determined after 1 day and after 1 year of its work. Figure 17b shows a diagram of dependence of the torsional moment transmitted by the rubber joint (Y-axis) on temperature (X). The temperature range includes low temperatures (to –40°C) and then M_S [Nm] is the highest, and high ones — then the torsional moment is the smallest. Finally, Figure 17c shows a relation between temperature at which the rubber element works in the range from –40°C to +80°C (X-axis) and the element durability expressed as years of work (Y-axis). The highest durability, taken as the time of work, is reached at room temperature, i.e. at around +20°C.

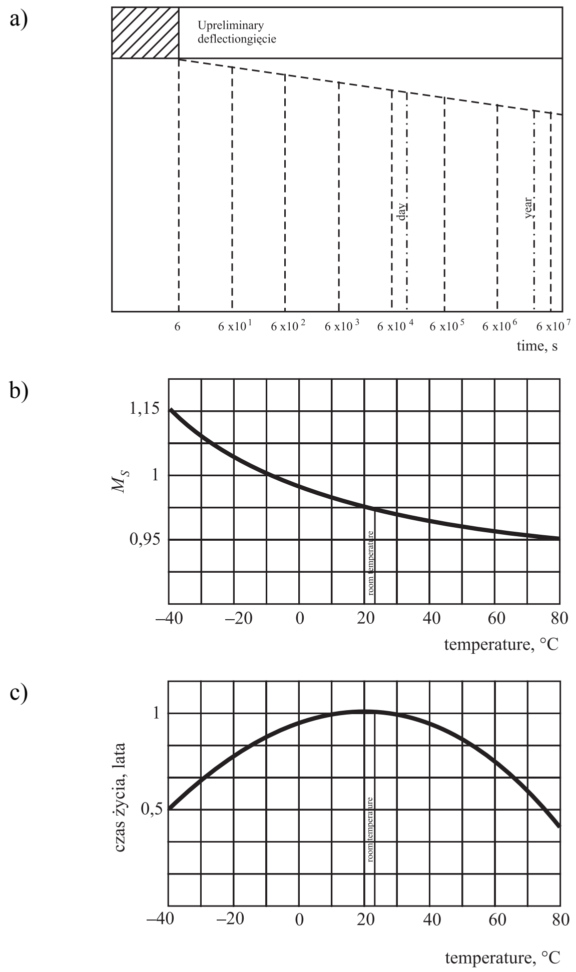

Fig. 17. Properties of elastic rubber elements

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