UDC 534.1; 539.3

TO THE DESCRIPTION OF THE MOVEMENT OF A SPRING WITH A SUB-SPRING

Slipchenko M.V., Ph.D., associate professor, Shukaeva O.M., senior lecturer, Gabaidze R.Z., student
(State Biotechnological University)

Designs with piecewise linear power characteristics are common in engineering. These are, first of all, sprung bodies of trucks, mechanical transmissions with safety clutches, vibration shock mechanisms with elastic movement limiters, and others. In them, along with the main one, an additional elastic element is installed, which is included in the work in case of large deformations of the main element. The presence of such an additional element allows you to significantly increase the stiffness of the system during the necessary periods of time, which positively affects the reliability and durability of the suspension [1, 2].

Researchers have paid considerable attention to the study of the dynamics of such mechanical systems. In recent years, many works where the force characteristics were reduced to piecewise-linear when modeling oscillations were included in the bibliography of the monographic edition [3].

In general (under the action of an instantaneously applied force (fig. 1)), such fluctuations can be described by the dependence [4]:

$$m\ddot{x} + c_1 x + c_2 \left(x - x_1\right) \cdot \mathrm{H}\left(x - x_1\right) = P \cdot \mathrm{H}\left(t\right). \qquad (1)$$

Here is a sprung mass m –; c_1 – stiffness coefficient of the main spring; c_2 – spring stiffness coefficient; $x_1 = const$ – displacement value (gap) at which the load of the subspring begins; P – magnitude of instantaneously applied force; $\mathrm{H}\left(x - x_1\right)$, $\mathrm{H}\left(t\right)$ are Heaviside unit functions; the dot above x means the derivative of t.

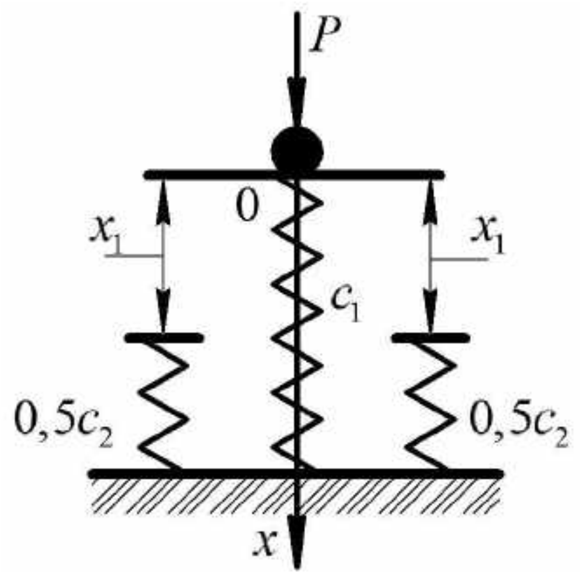

Fig. 1. – Calculation scheme of oscillation under the action of an instantaneously applied force

Equation (1) is supplemented with zero initial conditions (2):

$$x(0) = \dot{x}(0) = 0. \tag{2}$$

Let's consider the first stage of movement $t \in [0, t_1]$ on the gap $x \le x_1$, when only the spring is deformed. With such t and $\mathrm{H}(x - x_1) = 0$ the movement of the oscillator is described by the well-known expression given in the researches of Ya.G. Panovko in [5]:

$$x(t) = \frac{P}{c_1}\left[1 - \cos(\omega_1 t)\right], \tag{3}$$

in which $\omega_1 = \sqrt{c_1 / m}$ – is the frequency of small natural oscillations.

Deformation of the subspring will begin at

$$t = t_1 = \frac{2}{\omega_1}\arcsin\sqrt{\frac{c_1 x_1}{2P}}, \tag{4}$$

with velocity:

$$\upsilon_1 = \dot{x}(t) = \frac{P\omega_1}{c_1}\sin(\omega_1 t_1).$$

The further solution depends on what characteristic the subspring has: soft or hard. Their solution is given in [1].

The solutions of this equation [1, 4] make it possible to obtain the amount of movement of the oscillator, as well as, among other things, to establish the maximum forces acting in both elastic elements. These values are necessary for the selection of the elastic elements and serve as initial data for the selection of their sizes and materials and longer calculations on strength and reliability.

References

1. Ольшанський В.П. Динаміка імпульсно навантажених нелінійних осциляторів / В.П. Ольшанський, М.В. Сліпченко, О.В. Ольшанський, В.В. Бредихін. / Харків: Діса плюс, 2021. – 264 с.

2. Анілович В.Я. Міцність та надійність машин / В.Я. Анілович, О.С. Грінченко, В.В. Карабін та др. – К.: Урожай, 1996. – 288 с.

3. Шатохин В. М. Анализ и параметрический синтез нелинейных силовых передач машин. Харьков: НТУ «ХПИ», 2008. – 456 с.

4. Ольшанський В.П. Про коливання тіла, закріпленого на ресорі з підресорником при імпульсному навантаженні / В.П. Ольшанський, В.В. Бурлака, М.В. Сліпченко // Механіка та машинобудування. – 2018. – № 1. С. 23-29.

5. Пановко Я.Г. Основы прикладной теории колебаний и удара / Я.Г. Пановко. – Ленинград: Машиностроение, 1976. – 320 с.