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INVESTIGATION OF TWO-SIDED SOFT IMPACTS

In various engineering devices used in robotics, transport and agricultural engineering two-sided impacts take place. In this paper two-sided soft impacts are investigated.

Model of the investigated vibrating system with two-sided soft impacts is described in detail. Dynamics of the investigated system with two-sided soft impacts takes place according to the three typical regimes of motion: vibrating system is not connected with the supports, vibrating system is connected with the first support, vibrating system is connected with the second support.

Results of numerical investigations are presented in the form of graphical relationships.

Variation of displacement of the vibrating system, variation of velocity of the vibrating system, variation of displacement of the left support, variation of displacement of the right support, variation of the value of the force and variation of the quantity characterizing the regime of motion of the vibrating system as functions of time are investigated.

Investigation of steady state regimes of motion for various stiffnesses of the supports is performed. Results for several typical values of stiffnesses of the supports are presented in the paper. The obtained graphical representations enable to understand the behavior of the investigated vibrating system with two-sided soft impacts in steady state regimes of motion for various stiffnesses of the supports.

The obtained results of the performed investigation are applied in the process of design of pipe robots and other engineering devices.

Keywords: two-sided impacts, soft impacts, harmonic excitation, nonlinear dynamics, left support, right support.

INTRODUCTION

In various engineering devices two-sided impacts take place.

In this paper two-sided soft impacts are investigated. Model of the system is described in detail. Results of numerical investigations are presented in the form of graphical relationships.

Variation of displacement of the vibrating system, variation of velocity of the vibrating system, variation of displacement of the left support, variation of displacement of the right support, variation of the value of the force and variation of the quantity characterizing the regime of motion of the vibrating system as functions of time are investigated.

The obtained results of the performed investigation are applied in the process of design of pipe robots and other engineering devices.

Ideal impacts are investigated in [1]. Special type of nonlinearity is analyzed in [2]. Impact dynamics is investigated in [3]. Theory of systems with impacts is presented in [4]. Impacts in transmissions are investigated in [5]. Vibrations with impacts are analyzed in [6]. Manipulators and robots are investigated in [7]. Dynamics of robots is analyzed in [8]. Dynamics of mechanisms is investigated in [9]. Nonlinear dynamics is presented in [10]. Impact interactions are investigated in [11].

First model of the system with two-sided soft impacts is presented. Then results of numerical investigations are presented in the form of graphical relationships.

MODEL OF THE SYSTEM WITH TWO-SIDED SOFT IMPACTS

Schematic representation of the investigated system with two-sided soft impacts is presented in Fig. 1.

Dynamics of the investigated system with two-sided soft impacts takes place according to the three typical regimes of motion: vibrating system is not connected with the supports, vibrating system is connected with the first support, vibrating system is connected with the second support.

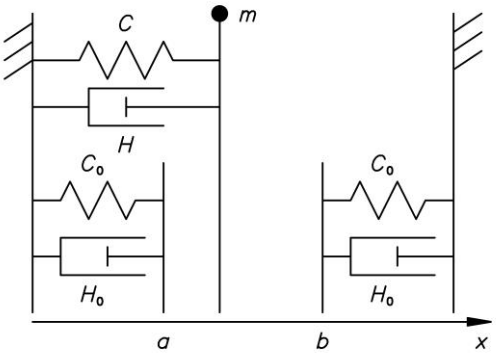


Figure 1. Vibrating system with two-sided soft impacts: the vibrating mass *m* is attached to the immovable support by the spring with the coefficient of stiffness *C* and the damper with the coefficient of viscous damping *H*, the impacting surfaces are attached to the immovable supports by the springs with the coefficients of stiffness C_0 and the dampers with the coefficients of viscous damping H_0

DYNAMICS OF THE SYSTEM WITH TWO-SIDED SOFT IMPACTS WHEN VIBRATING SYSTEM IS NOT CONNECTED WITH THE SUPPORTS

Dynamics of the vibrating system is described by the equation:

$$\ddot{x} + h\dot{x} + cx = f\sin\omega t, \tag{1}$$

where x is the displacement, h is the coefficient of viscous damping, c is the coefficient of stiffness, f is the amplitude of excitation, ω is the frequency of excitation, t is the time variable, and the upper dot denotes differentiation with respect to it.

Dynamics of the left support is described by the equation:

$$h_0\dot{x}_1 + c_0x_1 = c_0a, \tag{2}$$

where x_1 is the displacement of the left support, h_0 is the coefficient of viscous damping of the supports, c_0 is the coefficient of stiffness of the supports, a is the position of the left support in the status of equilibrium.

Dynamics of the right support is described by the equation:

$$h_0\dot{x}_2 + c_0x_2 = c_0b, \tag{3}$$

where x_2 is the displacement of the right support, b is the position of the right support in the status of equilibrium.

This regime of motion takes place until the following condition is satisfied:

$$x = x_1, \tag{4}$$

or until the following condition is satisfied:

$$x = x_2. \tag{5}$$

DYNAMICS OF THE SYSTEM WITH TWO-SIDED SOFT IMPACTS WHEN VIBRATING SYSTEM IS CONNECTED WITH THE LEFT SUPPORT

Dynamics of the vibrating system is described by the equation:

$$\ddot{x} + (h + h_0)\dot{x} + (c + c_0)x = f\sin\omega t + c_0a. \tag{6}$$

Dynamics of the right support is described by the equation:

$$h_0\dot{x}_2 + c_0x_2 = c_0b. \tag{7}$$

Also, the following force is calculated:

$$P = h_0 \dot{x}_1 + c_0 x_1 - c_0 a. \quad (8)$$

This regime of motion takes place until the following condition is satisfied:

$$P = 0. \quad (9)$$

DYNAMICS OF THE SYSTEM WITH TWO-SIDED SOFT IMPACTS WHEN VIBRATING SYSTEM IS CONNECTED WITH THE RIGHT SUPPORT

Dynamics of the vibrating system is described by the equation:

$$\ddot{x} + (h + h_0)\dot{x} + (c + c_0)x = f \sin \omega t + c_0 b. \quad (10)$$

Dynamics of the left support is described by the equation:

$$h_0 \dot{x}_1 + c_0 x_1 = c_0 a. \quad (11)$$

Also, the following force is calculated:

$$P = h_0 \dot{x}_2 + c_0 x_2 - c_0 b. \quad (12)$$

This regime of motion takes place until the following condition is satisfied:

$$P = 0. \quad (13)$$

INVESTIGATION OF DYNAMICS OF THE SYSTEM WITH TWO-SIDED SOFT IMPACTS

The following initial conditions are assumed in the performed investigation:

$$x(0) = 0,\ \dot{x}(0) = 0,\ x_1(0) = a,\ x_2(0) = b. \quad (14)$$

The following parameters of the investigated system were assumed:

$$\omega = 0.2,\ f = 1,\ h = 0.1,\ c = 1,\ h_0 = 0.4,\ c_0 = 16,\ a = -0.4,\ b = 0.4. \quad (15)$$

Variation of displacement of the vibrating system is presented in Fig. 2. Variation of velocity of the vibrating system is presented in Fig. 3. Variation of displacement of the left support is presented in Fig. 4. Variation of displacement of the right support is presented in Fig. 5. Variation of the value of the force is presented in Fig. 6. Also, the following quantity characterizing the regime of motion of the vibrating system is introduced:

$$I = \begin{cases} 1, & \text{when the mass is not connected with the supports,} \\ 2, & \text{when the mass is connected with the left support,} \\ 3, & \text{when the mass is connected with the right support.} \end{cases} \quad (16)$$

Variation of this quantity is presented in Fig. 7.

The obtained graphical representations enable to understand the behavior of the investigated vibrating system with two-sided soft impacts.

INVESTIGATION OF STEADY STATE REGIMES OF MOTION FOR VARIOUS STIFFNESSES OF THE SUPPORTS

The following parameters of the investigated system were assumed:

$$\omega = 0.2,\ f = 1,\ h = 0.1,\ c = 1,\ h_0 = 0.4,\ a = -0.4,\ b = 0.4. \quad (17)$$

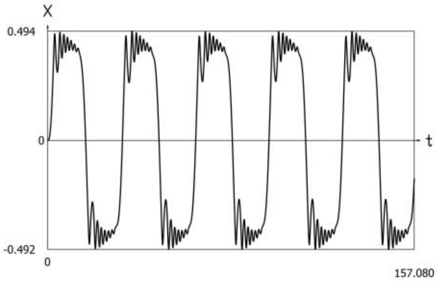


Figure 2. Displacement of the vibrating system as function of time

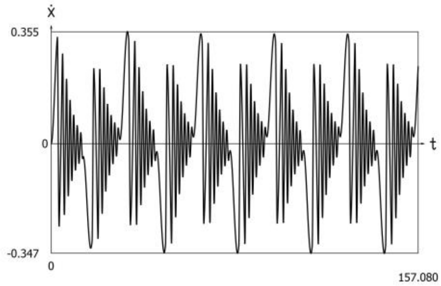


Figure 3. Velocity of the vibrating system as function of time

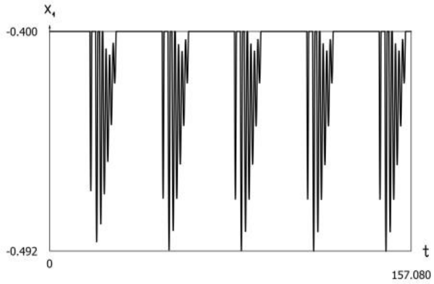


Figure 4. Displacement of the left support as function of time

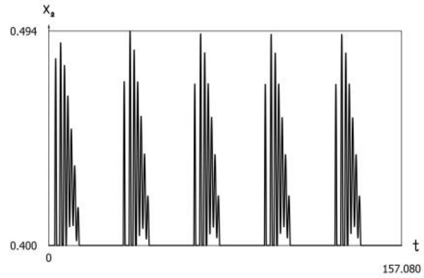


Figure 5. Displacement of the right support as function of time

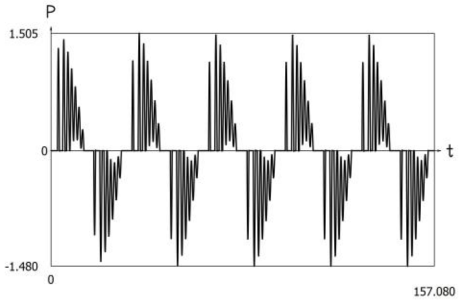


Figure 6. Force as function of time

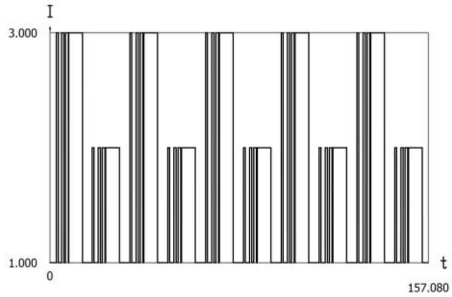


Figure 7. Regime of motion of the vibrating system as function of time

For the following values of the stiffness of the supports:

$$c_0 = 16, \qquad (18)$$

$$c_0 = 8, \qquad (19)$$

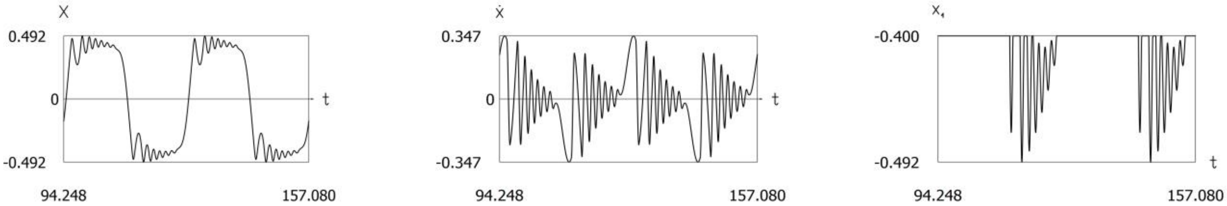
$$c_0 = 4, \qquad (20)$$

$$c_0 = 2, \qquad (21)$$

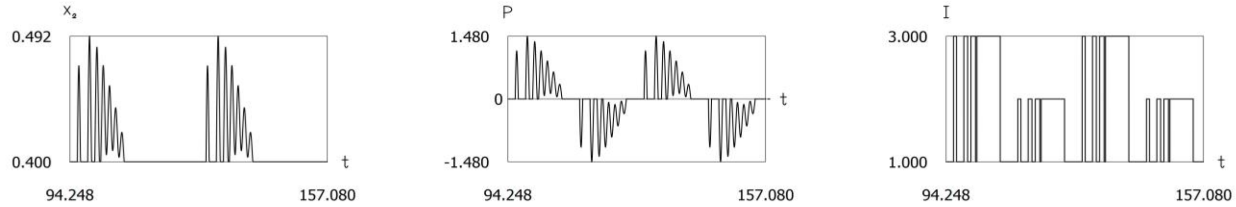
$$c_0 = 1, \qquad (22)$$

results of investigation of steady state regime of motion are presented in Fig. 8, Fig. 9, Fig. 10, Fig. 11, Fig. 12.

The obtained graphical representations enable to understand the behavior of the investigated vibrating system with two-sided soft impacts in steady state regimes of motion for various stiffnesses of the supports.

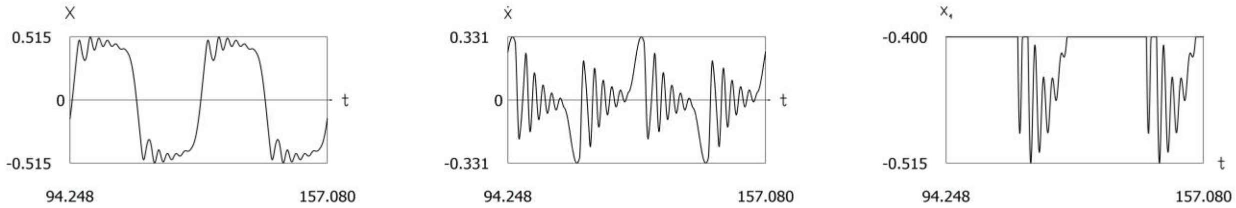


a) $x(t)$ b) $\dot{x}(t)$ c) $x_1(t)$

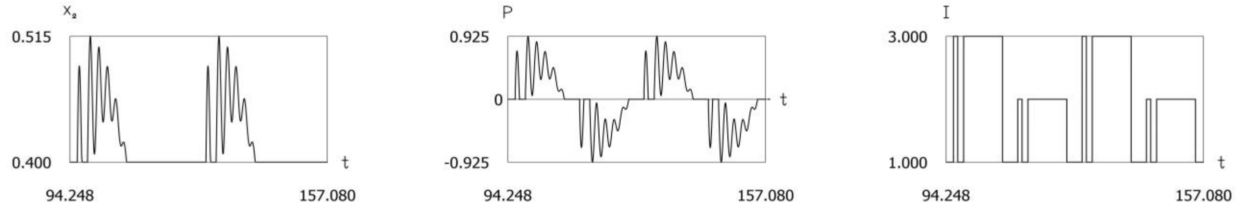


d) $x_2(t)$ e) $P(t)$ f) $I(t)$

Figure 8. Steady state regime of motion for $c_0 = 16$

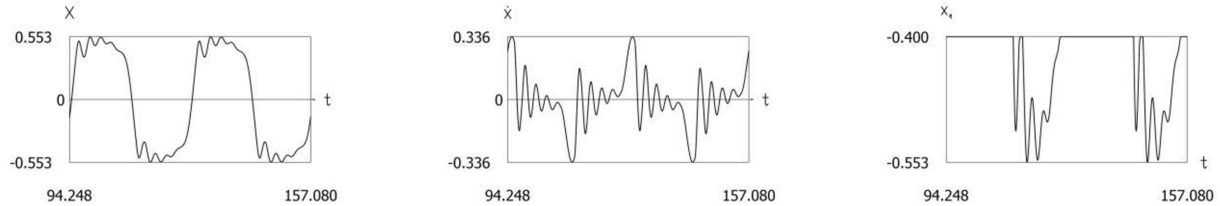


a) $x(t)$ b) $\dot{x}(t)$ c) $x_1(t)$

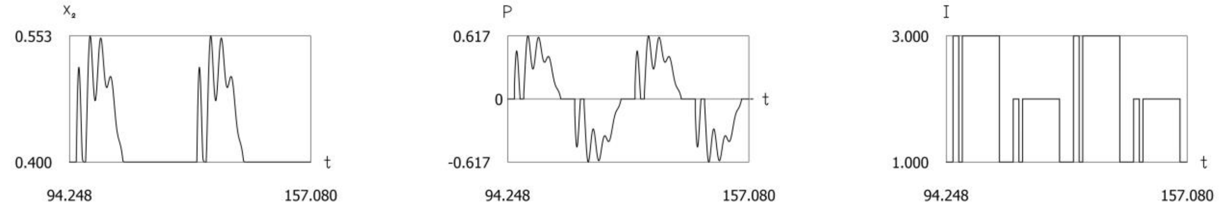


d) $x_2(t)$ e) $P(t)$ f) $I(t)$

Figure 9. Steady state regime of motion for $c_0 = 8$

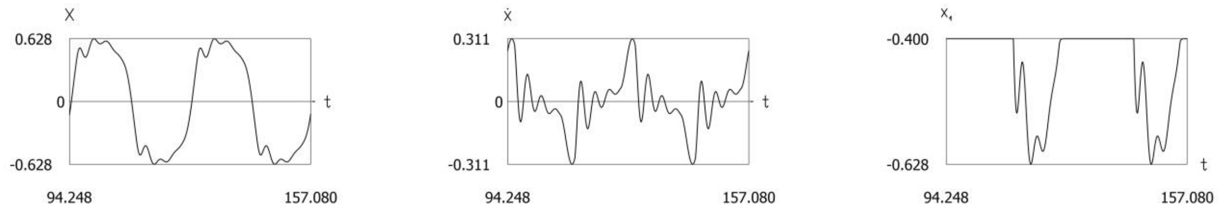


a) $x(t)$ b) $\dot{x}(t)$ c) $x_1(t)$



d) $x_2(t)$ e) $P(t)$ f) $I(t)$

Figure 10. Steady state regime of motion for $c_0 = 4$



a) $x(t)$ b) $\dot{x}(t)$ c) $x_1(t)$

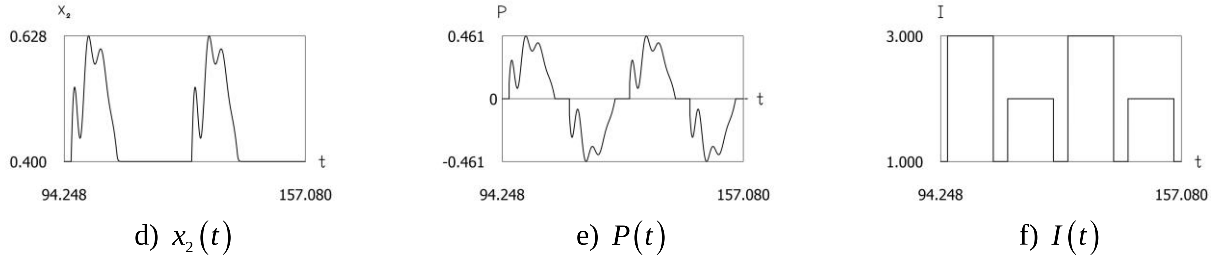


Figure 11. Steady state regime of motion for $c_0 = 2$

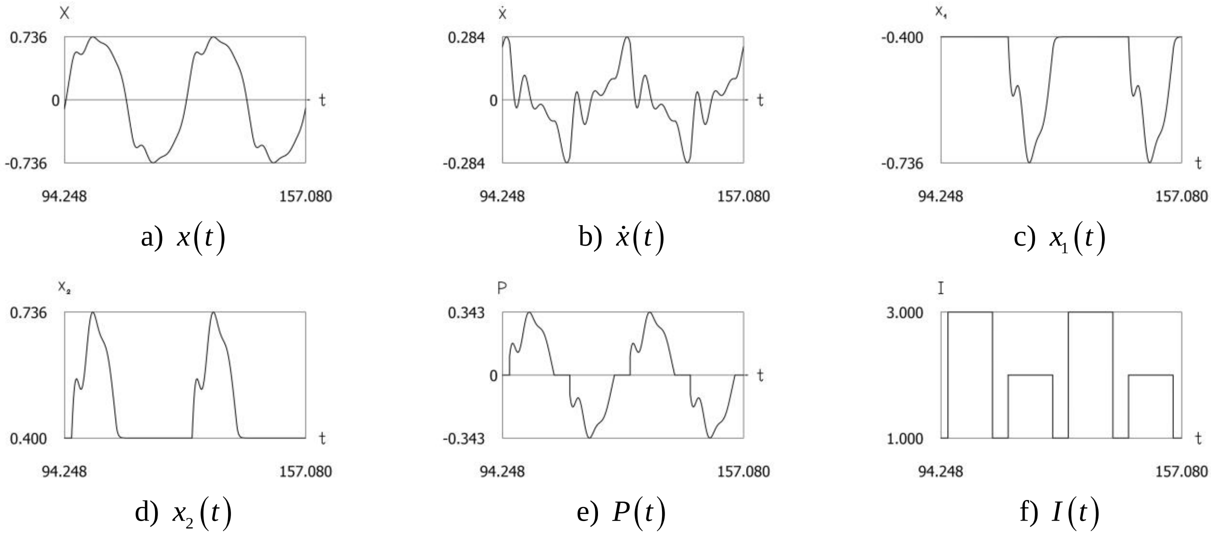


Figure 12. Steady state regime of motion for $c_0 = 1$

CONCLUSIONS

In a number of engineering devices two-sided impacts take place. Investigation of two-sided soft impacts is performed in this paper. Model of the investigated vibrating system with two-sided soft impacts is described in detail. Results of numerical investigations are presented in the form of graphical relationships.

Variation of displacement of the vibrating system, variation of velocity of the vibrating system, variation of displacement of the left support, variation of displacement of the right support, variation of the value of the force and variation of the quantity characterizing the regime of motion of the vibrating system as functions of time are investigated.

The obtained graphical representations for various stiffnesses of the supports show the behavior of the investigated vibrating system with two-sided soft impacts in steady state regimes of motion.

The presented graphical representations enable to understand the behavior of the investigated vibrating system with two-sided soft impacts.

The obtained results are applied in the process of design of pipe robots and other engineering devices.

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K. Ragulskis, A. Pauliukas, P. Paškevičius, R. Maskeliūnas, L. Ragulskis. Investigation of two-sided soft impacts.

У різних технічних пристроях, що використовуються у робототехніці, транспортній та сільськогосподарській техніці, мають місце двосторонні удари. У цьому роботі досліджуються двосторонні м'які удари.

Детально описана модель досліджуваної коливальної системи з м'якими двосторонніми ударами. Динаміка досліджуваної системи при двосторонніх м'яких ударах відбувається за трьома типовими режимами руху: коливальна система не пов'язана з опорами, коливальна система пов'язана з першою опорою, коливальна система пов'язана з другою опорою.

Результати чисельних досліджень представлені як графічних залежностей.

Зміна переміщення коливальної системи, зміна швидкості коливальної системи, зміна переміщення лівої опори, зміна переміщення правої опори, зміна значення сили та зміна величини, що характеризує режим руху коливальної системи, досліджуються як функції часу.

Проведено дослідження режимів руху, що встановилися, при опорах різної жорсткості. У роботі представлені результати для кількох типових значень жорсткості опор. Отримані графічні зображення дозволяють зрозуміти поведінку досліджуваної коливальної системи при двосторонніх м'яких ударах на режимах руху при опорах різної жорсткості.

Отримані результати проведених досліджень застосовують при проектуванні трубопровідних роботів та інших технічних пристроїв.

Ключові слова: двосторонній удар, м'який удар, гармонійне збудження, нелінійна динаміка, ліва опора, права опора.

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