RESEARCH DYNAMICS OF MATHEMATICAL MODEL CARRIAGE IN DEPENDENCE ON HIS SPEED

E. Suharcova, S. Rudenko

***Summary*. Influence of speed is in-process investigational on the parameters of the mathematical model of carriage, made on the basis of differential equalizations for the single-axle system of bodies with two degrees of freedom with bringing in of method of phase portraits in the environment of package of Maple.**

***Keywords:* a phase trajectory, critical values of speed, single-axle model, two degree of freedom.**

Formulation of the problem. Development of railway transport generates the questions constrained and by safety of transportations of loads and passengers on condition of increase of speeds. The new appear and develop existent methods of calculations of dynamics of rolling stock depending on the state of claotype economy [1,2]. Therefore actual is an improvement of calculations of dynamics of carriages with the use of mathematical methods able to investigate the parameters of vibrations of knots of carriage depending on the rate of his movement. The method of phase portraits, by means of that it is possible to carry out the analysis of vibrations of elements of rolling stock including at quality level, behaves to such methods [3].

Analysis of recent research. By the question of dynamics of carriage the devoted works [4-7], where the expounded bases of theory of free and force vibrations of carriage taking into account a friction in a spring hanging, phenomenon of resonance at the vibrations of carriage under the action of periodic inequalities, and also oscillation of carriages in the system of train, that moves on a resilient claotype way. Differential equalizations of mainly 4th or 5th orders, that get untied by numeral methods, are used in existent models, that is why them it is difficult to use for the analysis of influence of entry parameters on the got decision. For example, to influence of speed on the vertical moving of knots of carriage for the select parameters of inflexibility of axle and central springs of a spring hanging and coefficients of dissipation of corresponding dampers. It is Therefore expedient to use the method of phase portraits in the environment of mathematical package of high level (for example, Maple).

Formulation of article purposes. To investigate influence of speed on the vertical moving of loads of the mathematical model of carriage, made on the basis of differential equalizations for the single-axle system of bodies with two degrees of freedom with bringing in of method of phase portraits in the environment of package of Maple.

Main part. There is a far of mathematical models, corresponding to the types carriages, light carts and systems of hanger, where dynamic cooperations of carriage and claotype way are taken into account. In certain cases description of model will have distinguishing features in relation to a certain task. But all of them within the framework of creation of engineering model are based on the typical base model represented on rice.1. If necessary this model is complemented by elements that allow to investigate influence of parameters.

Let's accept as datains the models of carriage such parameters: z_1 and z_2 are coordinates of the vertical moving of cents of the masses of basket and light cart; mass to the light cart of m_1=18,7 т; mass of basket of m_2=53,2 т; inflexibility of axle spring of a spring hanging of c_1= 16120 kH/m; inflexibility of central spring of a spring hanging of c_2= 10640 kH/m; coefficients of the relative fading of dampers of $n_1=n_2=0{,}3$; coefficient of dissipation of damper of the буксового hanging [5,7] $b_1 = 2n_1\sqrt{m_1(c_1+c_2)}$; coefficient of dissipation of damper of the central hanging $b_2 = 2n_2\sqrt{m_2 c_2}$.

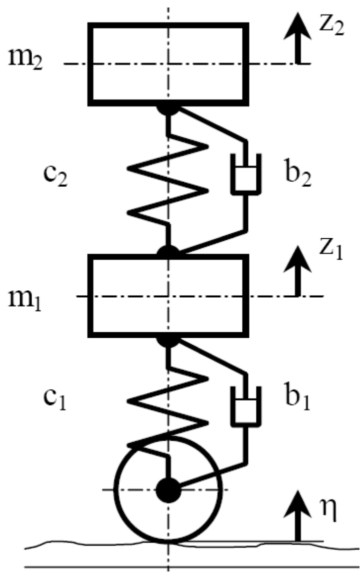


Fig. 1. A scheme of the system of bodies with two degrees of freedom.

The parameter of inequality of way is calculated on a formula:

$$\eta(t) = A\left(1-\cos 2\pi\frac{V}{L}t\right), \qquad (1)$$

where: wave-length of inequality of L=5m; height of inequality A = 0,005 m; rate of movement of model for inequalities to V= 30 m/c (that is to 108 km/h).

It is necessary for determination of vibrations of dynamic model [5,7] to untie the system of differential equalizations :

$$m_1\ddot{z}_1 + (b_1+b_2)\dot{z}_1 + (c_1+c_2)z_1 - b_2\dot{z}_2 - c_2 z_2 = b_1\dot{\eta} + c_1\eta; \qquad (2)$$

$$m_2\ddot{z}_2 - b_2\dot{z}_1 - c_2 z_1 + b_2\dot{z}_2 + c_2 z_2 = 0. \qquad (3)$$

From the system of equalizations (2) - (3) it is evidently, that the vibrations of both masses are constrained, because to both equalizations enter the generalized coordinates of moving z, of speeds $\dot{z}$ and accelerations $\ddot{z}$ of corresponding loads. Between the coordinates of this system there is elastic-dissipative connection.

Intercommunication of vertical vibrations of the two masses can be shown on the scheme of free vibrations, for this purpose it is necessary to untie equalization (2) and (3) with a zero right part $b_1\dot{\eta} + c_1\eta = 0$, to set the initial moving or speed to one of the masses and build a chart.

But more interesting is the question, related to determination of stalling speeds that "qualitatively" will influence on the vertical moving of loads for the select parameters of inflexibility of axle and central springs of a spring hanging and coefficients of dissipation of dampers of axle and central springs of hanging.

For this purpose it was made Maple- program of construction phase to the portrait for select parameters depending on the change of speed in the mode of computer animation. On fig. 2 some animation shots of phase portraits of vibrations of basket are brought around to a draught 15 s.

Consider such that cause the quality change of image of phase portrait the critical values of speed. For example, phase portraits of vibrations of basket (rice. 2) for the values of parameters of V = 10,17 m/s and V= 16 m/s will be qualitatively different. At discreteness of animation 100 shots are on the interval of speeds from V = 2 m/s to V = 30 m/s was educed such conformities to law of vibrations on the basis of analysis of change of phase portraits.

In relation to the vibrations of light cart results are such.

1. On the interval of speeds from V=2 m/s to V=8 m/s amplitude of vibrations increases from a 0,01 m a to 0,015 m, and rate of climb - from a 0,001 m/ sec a to 0,1 m/of sec.

2. Beginning from speed of V=10 m/s amplitude of vibrations diminishes a to 0,01 m, and a rate of climb is a to 0,07 m/of sec.

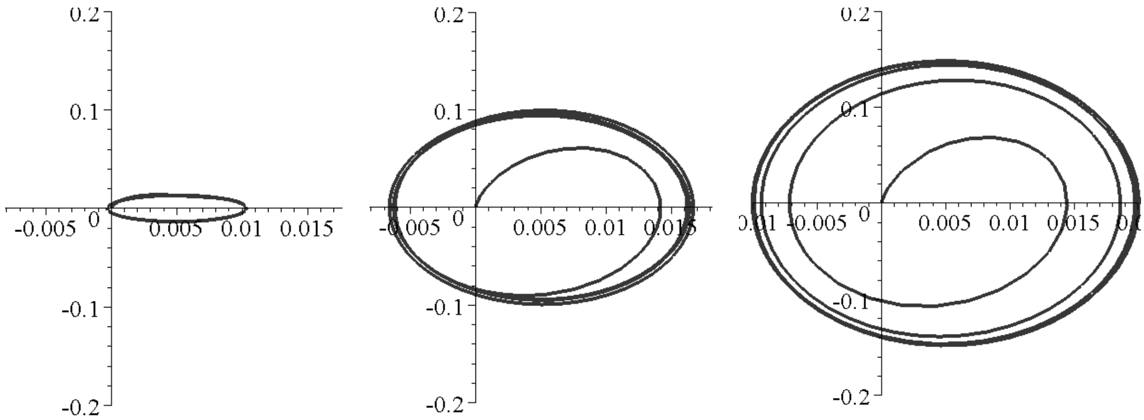
3. Beginning from speed of V= 13 m/s there is alteration of structure of trajectory of phase portrait : "coil from middle" is substituted by "coil from outwardly" at previous (point 2) amplitudes of vibrations and rates of climb.

4. Beginning from speed of V=a 15 m/sec to V=a 30 m/sec amplitude of vibrations increases a to 0,01 m, and a rate of climb is a to 0,15 m/of sec. At what, the central point of "coil" of phase trajectory has coordinate (0,005; 0) that specifies on establishment of the mode of vibrations.

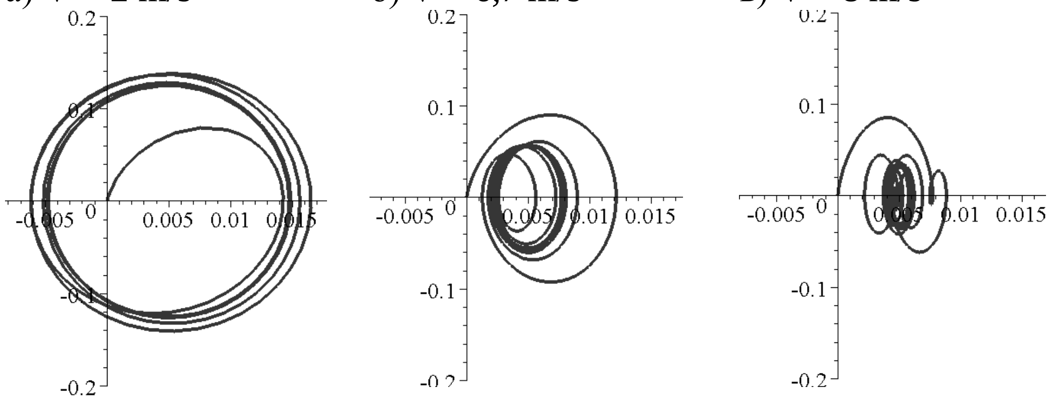
More interesting is an analysis of vibrations of corps of carriage.

1. On the interval of speeds from V= 2 m/s to V=8 m/s amplitude of vibrations increases from a 0,01 m a to 0,02 m, and rate of climb - from a 0,0001 m/s a to 0,15 m/s.

2. Beginning from speed of V=10 m/s amplitude of vibrations diminishes a to 0,015 m, and a rate of climb is a to 0,01 m/s.



а) V = 2 m/s б) V = 6,7 m/s в) V = 8 m/s



г) V = 10,17 m/s д) V= 16 m/s е) V = 30 m/s

Fig. 2. Phase portraits of vibrations of basket are for some values of V.

3. Beginning from speed of V=15 m/s there is alteration of "coil" structure of trajectory of phase portrait. "coil from outwardly" (fig. 2d) there is to speed of V=17 m/s.

4. Beginning from speed of V=17 m/s to V=30 m/s amplitude of vibrations will change within the limits of a 0,01 m, and rate of climb - within the limits of a 0,1 m/s. (fig. 2,e). It specifies on the successful selection of entry parameters, that provided the mode of vibrations of basket of carriage, amplitude of that does not grow.

Conclusions. On the basis of the worked out program it is possible to analyse influence of any parameter on oscillation of dynamic model with two degrees of freedom, including to investigate influence of geometrical parameters of claotype way with taking into account here him dynamic co-operating with a carriage.

Literature

1. Механическая часть тягового подвижного состава : учеб. для вузов ж.-д. трансп. / И.В. Бирюков [и др.]; под ред. И.В. Бирюкова. – М. : Транспорт, 1992. – 440 с.

2. *Вершинский С.В.* Динамика вагона / С.В. Вершинский, В.Н. Данилов, В.Д. Хусидов; под ред. С.В. Вершинского. – М.: Транспорт, 1991. – 360 с.
3. *Голечков Ю.И.* О качественном исследовании движения некоторых технических объектов / Ю.И.Голечков // НТТ – наука и техника транспорта. 2002. №2. С. 21 – 25.
4. *Медель В.Б.* Подвижной состав электрических железных дорог. Конструкция и динамика / В.Б. Медель.–М.: Транспорт, 1974. – 232 с.
5. *Трофимович В.В.* Динамика электроподвижного состава / В.В. Трофимович. – Хабаровск: Изд-во ДВГУПС, 2007, 120 с.
6. *Рубан В.Г.* Решение задач динамики железно-дорожных экипажей в пакете MathCad / В.Г. Рубан, А.М. Матва.– Ростов-на-Дону: Рост. гос. ун-т путей сообщения, 2009. – 99 с.
7. *Ушкалов В.Ф.* Статистическая динамика рельсовых экипажей / В.Ф. Ушкалов, Л.М. Резников, С.Ф. Редько. – К.: Наук. думка, 1982. – 360с.
8. *Камаев В.А*. Оптимизация параметров ходовых частей железнодорожного подвижного состава / В.А. Камаев. – М.: Машиностроение, 1980. – 215 с.