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DEVELOPMENT AND REALIZATION ON THE ECM OF A MATHEMATICAL MODEL OF A FRICTION MECHANISM WITH A CONTROLLED CONNECTION IN THE CONTACT ZONE

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DEVELOPMENT AND REALIZATION ON THE ECM OF A MATHEMATICAL MODEL OF A FRICTION MECHANISM WITH A CONTROLLED CONNECTION IN THE CONTACT ZONE

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Annotation. In article results of realization on the COMPUTER of mathematical model of the developed design of the frictional mechanism of the converter of the movement with the operated communication in a zone of contact with use of external physical fields (in particular, electrorheological effect) which is one of the effective principles of precision vibromechanics are considered. For engineering applications, with use of the Maple 13 software product regularities of change of key parameters of mechanical system are defined, studied and analyzed.
Key words: friction mechanisms, mechanisms with controlled parameters and connections, precision vibromechanics at contact zone, external physical fields, electrorheological effect, magnetorheological effect, effective resistance coefficient.

At working up a concept for the development and creation of a new generation of mechanisms and mechanical systems with extend functionality in relation to specific industries interest to use promising scientific sense, innovative ideas and technologies. Scientific studies have shown that in the development of theoretical foundations and construction of controlling mechanisms and mechanical systems, the most effective method is the widespread use of the principles of precision vibromechanics and vibration technologies. Among them, the most widespread methods based on a change in the coefficient of friction. In this case, the normal and tangential components are changed by exciting high-frequency elastic vibrations of the “running wave” and “standing wave” types. Using high-frequency microvibrations, it is possible to achieve synchronization of rotation of friction connection wheels and control the phase corner between them [1, 2-4].

Another of the effective principles of precision vibromechanics is the use of external physical fields [1-4]. In particular, electrorheological and magnetorheological effects [5-9].

It should be noted that the electrorheological effect consists in changing the viscosity of electrorheological suspensions (non-Newtonian fluids) in an electric field created by an AC or DC voltage source. For control parameters and bonds in the contact zone of friction-conjugated bodies, one can also use the magnetorheological effect, which is characterized by a sharp change in the mechanical properties (viscosity, plasticity, elasticity) of some suspensions under the influence on magnetic fields. It opens up wide possibilities by direct action of electrical signals for direct control of the hydrodynamic, heat and mass transfer, electro and magnetic characteristics of fluid media [5].

At scientific work [4] view the friction mechanism of a motion transducer with controlled coupling in the contact zone based on the electrorheological effect. In fig. 1 shows a translational drive construction based on the use of an electrorheological effect. The considered translational drive comprises a shaft 1 rotating around a fixed shaft 2, a movable element 3 immersed in an electrorheological fluid 4 mounted in the guides 5, parts of the movable element are isolated by a layer.

The shaft and the movable element are immersed in an electrorheological fluid connecting to two controlled voltage sources. Due to this, the viscosity of the liquid instantly changes and will be the greatest in the zone of the smallest gap between the shaft and the movable element, and on both sides of the contact, the viscosity decreases. This leads to the fact that in the contact zone an intermediate element forms, transmitting rotation from the shaft to the movable element. In this case, it obtain non-contact movement between the shaft and the movable element to eliminate unwanted wear on the surfaces.

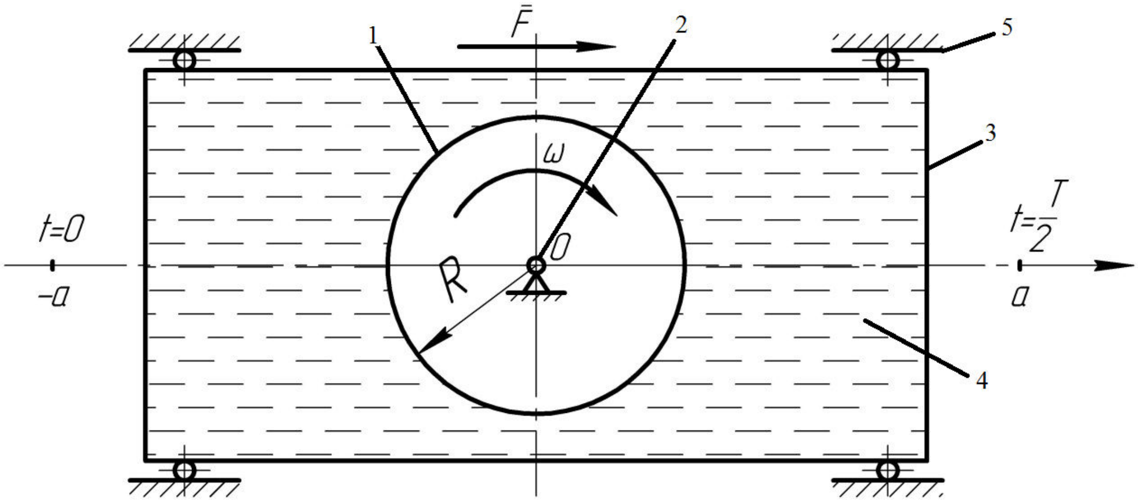

Fig. 1. The accounting scheme of the friction mechanism of the Converter controlled communication movements based on the electrorheological effect

In the above monograph [4] received the following mathematical model of the equation of motion of a moving element

$$m\ddot{x} = \beta(r\omega - \dot{x}), \tag{1}$$

where: r - the radius of the shaft; β - viscous friction coefficient, determined experimentally and depending on the physical properties of the electrorheological fluid, as well as the magnitude of the input control voltage. The value of this voltage is assumed to be constant and therefore the value of the coefficient is time-independent, therefore, apply the following dimensionless form of equation (1)

$$\xi'' + n\xi' = n. \tag{2}$$

When taking into account the initial conditions, the following functional dependences were obtained to determine the law of the motion of the moving element, the period of vibration

$$\xi = \tau - 1 - \frac{1+v}{n}(1 - e^{-n\tau}), \tag{3}$$

$$\eta = \frac{2}{n}\ln\frac{1+v}{1-v}, \tag{4}$$

as well as the transcendental equation for determining v

$$n = \frac{1}{2}\ln\frac{1+v}{1-v} - v, \quad v \cong \sqrt{\frac{n}{2}}. \tag{5}$$

The expression for determining the dimensionless amplitude A is:

$$A = 1 + \frac{v}{n} - \frac{1}{n}\ln(1+v). \qquad (6)$$

For engineering applications, it is of interest to determine and study the laws of change in the main parameters of the studied mechanical system. Based on the above analytical dependencies, using the software product *Maple 13*, dependency graphs of the main parameters of the studied mechanical system, in particular, dimensionless amplitude and oscillation period in a function v, can be constructed, i.e. $A = A(v)$ и $\eta = \eta(v)$.

Numerical values of changes in the kinematic parameters of the moving link of the friction mechanism (tab. 1-3).

Table 1

Patterns of changes ща velocity body based on the formula $v \cong \sqrt{n/2}$ by varying the effective coefficient of resistance of an electrorheological fluid n

n	0,1	0,2	0,3	0,4	0,5	0,6	0,7	0,8	1
v	0,223	0,316	0,387	0,447	0,50	0,548	0,592	0,632	0,707
n	1,5	2	2,5	3	3,5	4	4,5	5	5,5
v	0,866	1	1,118	1,225	1,323	1,4142	1,5	1,581	1,658
n	6	8	10	12	15	20	30	50	100
v	1,732	2	2,236	2,449	2,739	3,162	3,873	5	7,071

Table 2

Patterns of change in the effective coefficient of resistance of an electrorheological fluid based on a formula $n = 0{,}5\ln\left(\frac{1+v}{1-v}\right) - v$ when varying the dimensionless velocity body v

v	0,10	0,15	0,20	0,25	0,30	0,35	0,40	0,45	0,50
n	0,0003	0,0011	0,0027	0,0054	0,0095	0,0154	0,0236	0,0347	0,0493
v	0,55	0,60	0,65	0,70	0,75	0,80	0,85	0,90	0,99
n	0,0684	0,0931	0,125	0,167	0,223	0,299	0,406	0,572	1,657

Table 3

Patterns of change in process of movement of a moving element on the basis of the formula $\xi = \tau - 1 - \frac{1+v}{n}(1 - e^{-n\tau})$ for different values of the effective resistance coefficient of the electrorheological fluid n and the dimensionless velocity body v

n=0,0011	τ	0	0,5	1	1,5	2	2,5	3	3,14
v=0,15	ξ	-1	-1,059	-1,089	-1,09	-1,064	-1,014	-0,939	-0,913
n=0,125	τ	0	0,5	1	1,5	2	2,5	3	3,14
v=0,65	ξ	-1	-1,3	-1,55	-1,76	-1,92	-2,04	-2,13	-2,15
n=0,299	τ	0	0,5	1	1,5	2	2,5	3	3,14
v=0,8	ξ	-1	-1,34	-1,56	-1,68	-1,71	-1,67	-1,57	-1,53
n=0,572	τ	0	0,5	1	1,5	2	2,5	3	3,14
v=0,9	ξ	-1	-1,33	-1,45	-1,41	-1,26	-1,03	-0,72	-0,63

According to the obtained numerical values in table. 1-3, construct graphs of changes in the kinematic parameters of the moving element of the mechanism.

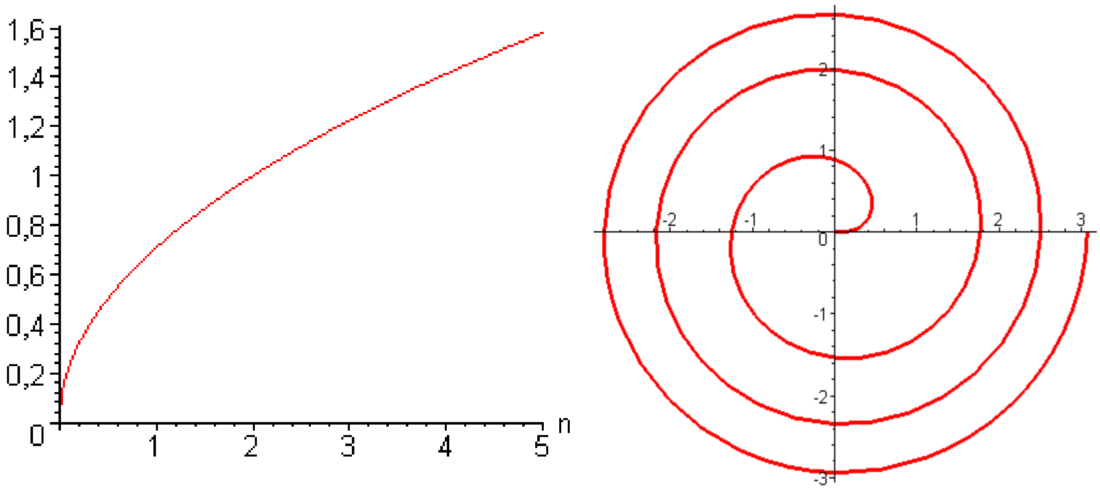

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Fig. 2. Graphs of the speed of the movable element v depending on the moment of effective resistance of the electrorheological fluid in Cartesian (a) and polar (b) coordinates

According to fig. 2, it can be noted that the speed of the movable element varies depending on the moment of effective resistance of the electrorheological fluid. According to fig. 2, it can be noted that the absolute speed of the moving element has the form of a semi-parabola and varies in magnitude ½ from the moment of effective resistance of the electrorheological fluid. Analysis Fig. 2 shows that the graph of speed depending $v = \sqrt{n}$ on the moment of effective resistance of the electrorheological fluid in polar coordinates has the form of continuous cyclic circles. In fig. 4 it can be seen that the speed of the movable element changes even at low resistance values. In general, it is possible to obtain various patterns of change in absolute speed for any given resistance values.

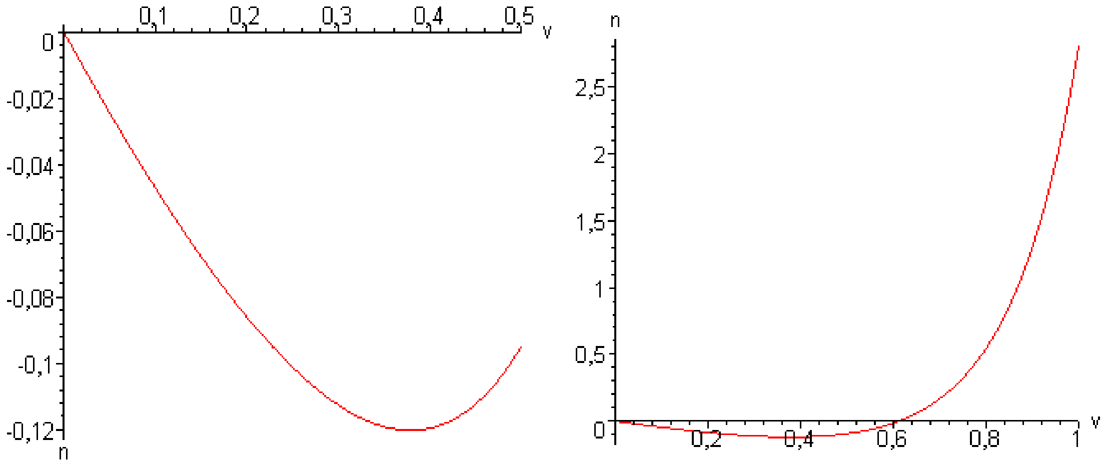

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Fig. 3. Graphs of the change in the moment of effective resistance of the electrorheological fluid $n = 0{,}5\ln(1+v)(1+v+v^2+v^3+\ldots) - v$ **depending on the speed** v**:**

a - when changing the speed v of the intervals from about to 0.5;
b - when changing the speed v of the intervals from about to 1.

Analysis of the graphs in the Fig. 3 shows that these patterns are logically opposite to the patterns reduction to Fig. 2. In other words, these figures show that the moment of effective resistance of the electrorheological fluid changes as the absolute speed of the moving link changes. The given graphs differ by a change in absolute speed at different time intervals. According to these graphs, it is clear that the values of the effective resistance of the electrorheological fluid at small values of speed take positive values when the negative values of speed are more than 0.6. This fact means that when time changes (or as a function of time), the absolute velocity vector of the moving element changes its direction. The timeline of the effective resistance of the electrorheological fluid as a function of time will be presented as a continuous semi-parabola. In this regard, it seems necessary to take these dependencies into account when further studying the motion of the electromechanical system. This makes it possible according to these graphs to uniquely determine the moment of effective resistance of the electrorheological fluid, corresponding to a certain value of the absolute speed of the moving element and vice versa. In addition, it will be possible to determine the nature of the influence of their interconnected changes on the general (or aggregate) movement of the electromechanical system. Using this method, it seems possible to construct graphs when the speed and the moment of effective resistance of the electrorheological fluid change for an arbitrary time interval.

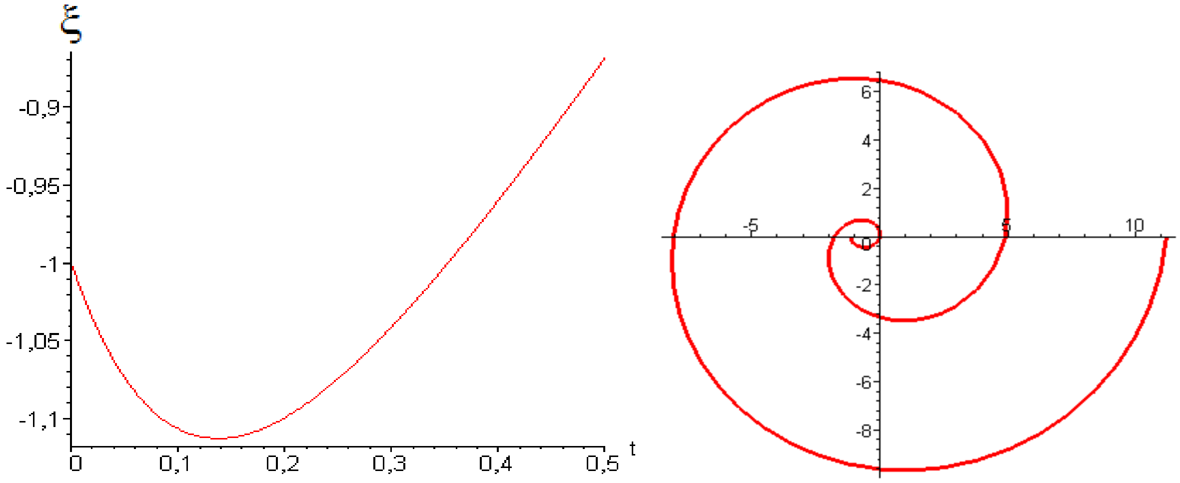

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Fig. 4. Graphs of changes in the law of motion of a moving element $\xi = t - 1 - \frac{1+v}{n}(1 - e^{-nt})$ in Cartesian (a) and polar (b) coordinates

In fig. 4 shows graphs of changes in the law of motion of a moving element. Based on these graphs, it will be possible to determine the position of the moving element (link) of an arbitrary length of time. In fig. 4 shows the trajectory of the moving element at the exact values v (values) of the absolute speed and the moment of effective resistance of the electrorheological fluid. It can be seen that the motion will occur according to a parabolic law with positive components of the Cartesian coordinate system axes and graphs of changes in the law of motion of the moving element in the polar coordinate system are given, where the trajectories have the form of cyclic circles. It should be noted that the graphs are built for a fixed period of time. Along with this, graphs can be obtained for an arbitrary or infinite period of time. From these graphs it will be possible to determine what position the moving element will take in the plane in an arbitrary time interval. In this case, it can be clearly noted that the movable element will have a certain curvilinear movement. This fact is confirmed by graphs in the polar coordinate system.

In purpose, the friction mechanism theoretically studied above based on the electrorheological effect can be considered as a new class of vibration motor with controlled coupling in the contact zone. The class of such constructions can be used in positioning drives of magnetic heads of disk storage devices or in computer information sampling devices and minicomputers. It can also be used in the design of high-speed electromechanical devices, precision high-speed components and mechanisms for obtaining reverse motion and converting rotational motion into translational movement.

In this way, using the principles of precision mechanics, the created new controlled structures and devices can be used as a drive for the executive organs of manipulators, in robotics when constructing the bases of mobile minimizers, in the construction of positioning and orientation devices, motion converters, in computer information sampling devices and minicomputers, in scan and micro feed nodes of precision devices, in vibration machines, stepper motors, self-braking mechanisms and etc. [3 - 4, 6].

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