THE RESEARCH OF FUNCTIONING OF THREE-UNIT LORRY CONVOYS

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Summary

It is proposed to improve functioning of transport vehicles in a way of dismemberment of its main masses with the help of tractive-joint devices with the further joint of these masses. Prismatic and turning kinematic pairs are combined in the tractive-joint devices. Limited full-scale and extended computer experiments were held. They proved efficiency of the proposed construction decision. The worked out mathematical model allows to investigate the operating modes of operations of three-unit lorry convoys at different travelling terms.

Keywords: transport vehicles, three-unit lorry convoys, tractive-joint device, full-scale and computer experiments.

1. Introduction

Increase of efficiency of transport vehicles usage requests more rational approach to its functioning in the technological cycles. One of the directions of realization of such approach is the dismemberment of main mass of the vehicle on the constituent elements with further its joint in some ways. Similar approach of increase of efficiency of functioning is used in the railway carriages. Before moving rolling stock diesel locomotive moves back and eliminates rail joint gaps in the opposite to the traffic (move) direction. Then, diesel locomotive starts off in the direction of traffic and activates each next coach separately one after another owing to rail joint gaps. By such a way of starting off diesel locomotive needs power for starting off of one coach, but not the whole rolling stock.

It is expedient to use mathematical models of such vehicles functioning by the creation of new models of vehicles. It allows to use resources and time economically, as there is no need to manufacture experimental specimens aiming at checking of functioning of separate elements or aggregates of new vehicles. At the same time mathematical models of vehicles functioning that are being projected of appropriate level and quality are necessary for holding computer experiments.

Software environment CRUISE [1] allows to model different modes of traffic of automobiles with different constructive schemes of transmission. Processor of the Pentium class is appropriate for functioning of such vehicles.

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NEWEU 83 02] (for the carrying out of mathematical modeling with changes of degrees of freedom of the elements of system and characteristics of non-linearity); DYNA 3D [3]; PAM – CRASH [4] and RADIOSS [5] (for the research of fluctuations of automobile, safety and structural optimization); OPTIM [6] (for the research of automobile or road train steadiness and handling); different software products are used for the solution of different questions of dynamics and dynamic analyses of the construction of wheeled system – packages of the complete element analysis (Ansys, Nastran), of packages of analysis of kinematics of mechanisms (Adams), such products as IMITA, COMPACT, Design Studio, Unigraphics, Most-7.2, EULER and others are widely used [6-8].

At the same time, typical modes or processes can be researched in the software environments. In case of new specimen of machinery it is still necessary to put into them new mathematical models, that corresponds to the new product. The choice of the level of accuracy and detailing of described processes still remains the urgent problem.

To investigate functioning of transport vehicle in case of dismemberment of its main masses.

2. The idea of splitting of masses of automobile

Such ways of improvement of characteristics of dynamics can be proposed on the bases of the carried out review of possible variants of the dismemberment of the main masses of transport vehicles [9] (Fig. 1.)

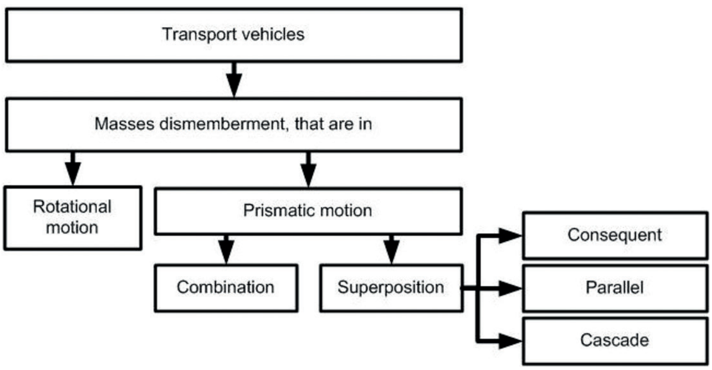


Fig. 1. Possible ways of improvement of characteristics of the dynamics of transport vehicles

Mechanical transmission of the automobile is the example of dismemberment of rotational masses. By the starting off with the help of joint, engine is separating from the gear and only when it starts working in the set mode it joints the transmission.

The idea of splitting of masses of automobile and its body with goods on the separate elastically-jointed elements [9, 10] consequently is proposed, in case of masses dismemberment in the prismatic motion in a way of superposition. It is being done when goods on the body are elastically linked among themselves, and then with the frame of automobile or when each good is directly jointed with frame. By the cascade dismemberment the body is elastically jointed with the frame, and goods – with the body.

The idea of the project is to decrease dynamic loading in elements of the construction and transmission of such vehicle, to lessen the energy consumption on its displacement, to provide better comfortableness of the conveying of loads and passengers on the account of dismemberment of the basic masses of the vehicle.

It is proposed to use the idea of splitting the general mass of transport vehicle on the separate elastically-jointed masses, but as the separate parts or sections, in case of dismemberment of masses in the prismatic motion in a way of combination. Elastic joint of truck tractor with trailer or semi-trailer, that consists of prismatic pair and turning pair [9]. On the Fig. 2–4 are provided examples of tractive-jointed devices (TJD), in which prismatic and turning kinematic pairs are combined. Thus, on Fig. 2 is shown TJD of truck tractor with trailer, on Fig. 3 with semi-trailer, on Fig. 4 – on of the variants of TJD for the multi-sectional buses, trolley buses, trams, metro coaches.

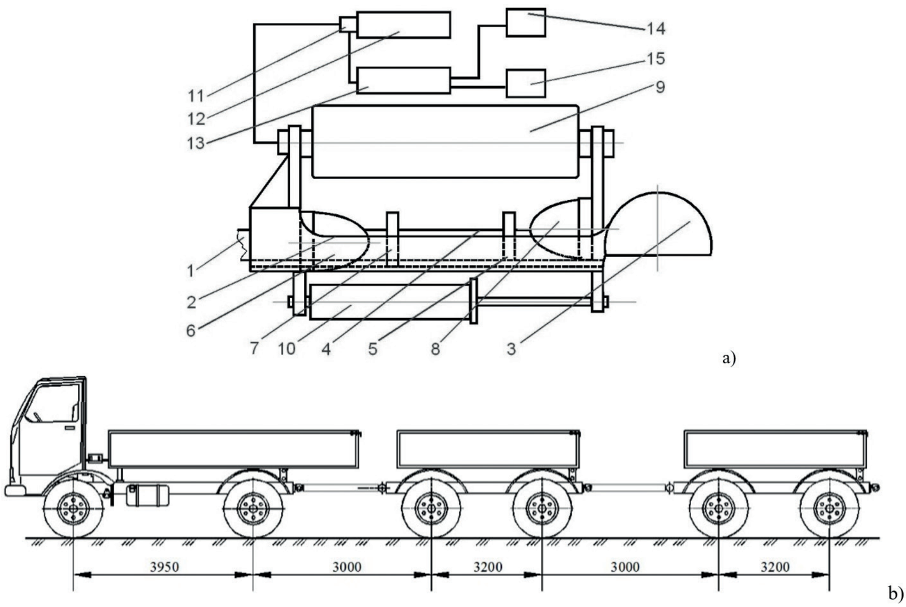
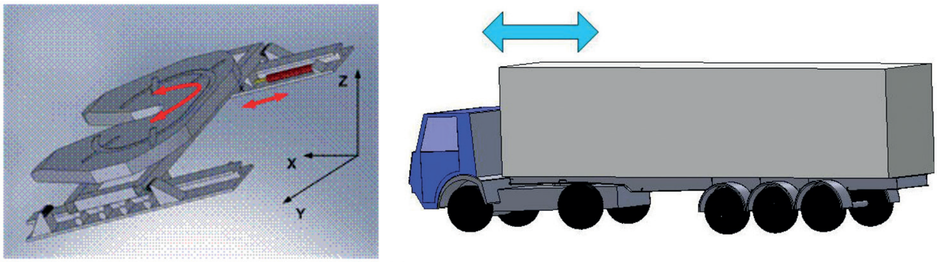
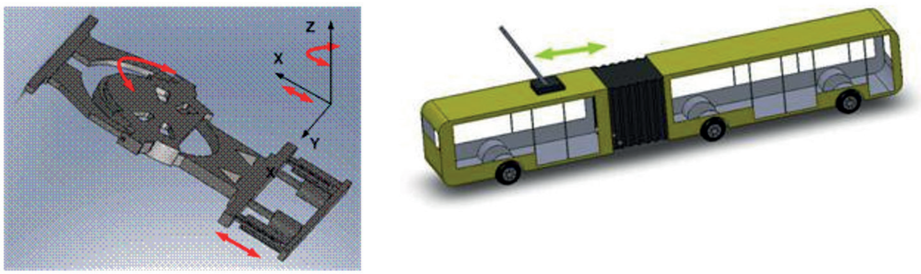


Fig. 2. TJD (a) of automobile with trailer (b) allows prismatic motion as to the longitudinal axis X and rotational motion as to axis Y [9]: 1 – trailer hitch; 2 – slide-block; 3 – hook; 4 – directing; 6, 8 – restrictive buffer; 5, 7 – supporting plate; 9 – pneumatic balloon; 10 – shock absorber of bilateral action; 11 – control valve; 12 – receiver; 13 – CU; 14 – sensor of weight; 15 – sensor of acceleration



a) b)

Fig. 3. TJD (a) of automobile with semi-trailer (b) allows prismatic motion as to the longitudinal axis X and rotational motion as to axis Z



a) b)

Fig. 4. TJD (a) of the two-sectional trolley bus (b) allows prismatic motion as to the longitudinal axis X and rotational motion as to axis Z

3. Mathematical model of motor transport vehicles motion

Mathematical models of motion of motor transport vehicles, linked with the help of TJD, shown on the Fig.5, were elaborated. Characteristics of the energy aggregates of models, profile of the road, parameters of goods, that are being carried and characteristics of its TJD were taken into account in these models [9].

Mathematical modeling was carried out with the use of flat calculating schemes, transport vehicle and trailers linked with the help of TJD, one of which is presented on the Fig.5. and commonly accepted presumptions for the research of the functioning of transport vehicles [9, 11–13]:

1. Motor transport vehicle with the body, goods – rigid inertial bodies;
2. Geometrical characteristic of the transport vehicle with trailers: location of the centers of the masses of the track, semi-trailer (trailer), goods; attitude of the support of the chassis of the track and frame of the semi-trailer, coordinates of the center of the hinge, that joints semi-trailer (trailer) with track, sizes in the free state of spring supports of tractor and semi-trailer;

3. Inertial characteristics of the transport vehicle: the mass and moment of the sluggishness of tractor, semi-trailer (trailer), goods, leading wheels together with the part of transmission;
4. Sluggishness of the elements of the running part of the automobile in its relative rotational motion is led to the tractive wheels and split between them proportionally to the distribution of turning moment from the gear engine;
5. Wheels have tangential and radial compliance;
6. Limiting researches of the unidentified traffic of transport vehicle by the case of its rectilinear motion, that is the motion in the vertical and longitudinal plane, the calculating scheme is considerate as flat;
7. Mechanical characteristics of the engine gear and brakes of the wheels of transport vehicle;
8. The engine of the gear has perfect external mechanic characteristic (that is the power of engine – stable value in the operational band of the angular speeds of its crankshaft);
9. Geometrical characteristics of the road and quality of its cover.

Lagrange equation of the second kind was used for the writing down of the equation of motion of the inertial elements of the calculating scheme of the transport vehicle:

$$\frac{d}{dt}\left(\frac{\partial T}{\partial \dot{q}_i}\right) - \frac{\partial T}{\partial q_i} = Q_i \qquad i = 1 \ldots n, \tag{1}$$

where

T – total kinetic energy of inertial elements of mechanical system;

q_i, $\dot{q}_i$ – some (i-th) generalized coordinate and speed;

Q_i – some generalized energy;

n – number of degrees of freedom of the mechanical system.

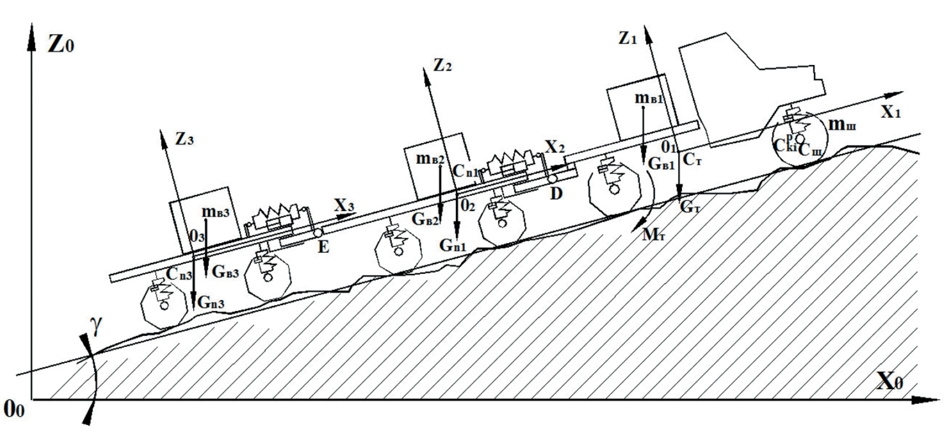


Fig. 5. Calculating scheme of the truck jointed with trailers

4. Experimental testing of mathematical model

Determination of experimental characteristics was carried out experimentally (Fig. 6).

Enumerated known parameters and set functions let us to claim the built mathematical model allows researching wide range of tasks of the dynamic of acceleration, rectilinear unidentified traffic and braking of transport vehicles, shown on the Fig. 2–4, along the roads of various profile and quality of cover. For doing this, initial values of generalized coordinates are chosen in a requested way [10, 14].

Verification of the adequateness of the elaborated mathematical models was carried out for the one of them using full-scale experiment with the help of complex of measuring apparatus for measuring of the distance and speed of traffic of transport vehicles (Fig. 7).

Fig. 6. Experimental researches of the operational characteristics of the truck for the computer simulating of its work with trailers

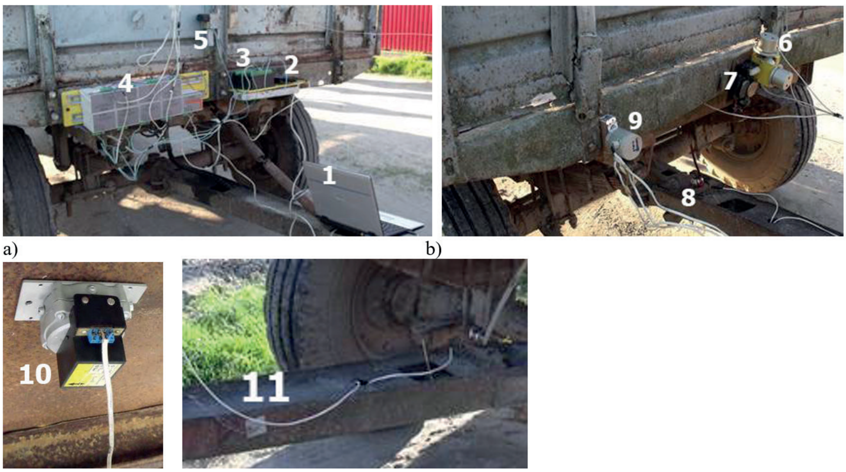


Fig. 7. Three-unit vehicle with the measuring equipment 's complex. (a-d) 1) Integrated into the measuring complex of the stand alone PC with software based on a laptop. 2) Modem for data transmissions 3) module analog digital transformer – digital analog transformer with galvanic decoupling lines of digital input and output 4) power supply units for sensors 5, 7) sensors of linear displacement between truck and first trailer and first trailer and second trailer 6) vibration sensors 8) sensor of angular displacement 9) speed sensors 10) accelerometer, 11) tenzo sensor

5. Analysis of the received results

Mathematical modeling was carried out for the system of truck with trailers with the help of specialized software MathCAD 2001 [15]. Solution of the system of equations was received according to the Runge-Kutta method with adaptive choice of step (in-built function *Rkadapt*).

Comparison of the results of the full-scale experiment and computer simulating gives error up to 30%. On the whole deviation of the results of the mathematical modeling is up to 23% (Fig.8).

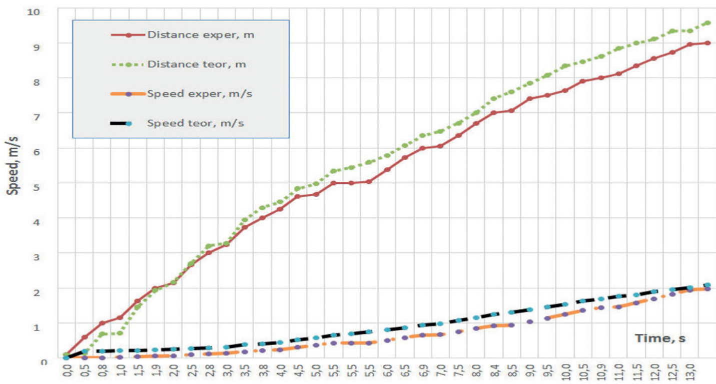


Fig. 8. Comparison of the results of the physical experiment and computer simulating: index *exper* mean results by experiment; index *teor* mean results by calculating with computer simulating

The variant of automobile passing the obstacle of the "footboard" type was calculated as the one of the elements of computer simulating. Depending on time t of power pi(t), that influence links of the automobile and trailer can be written down in the analytical form

$$p_i(t) = m_i g \cdot \left[H(t - \frac{B_0}{v}) H(\frac{B_0}{v} + \tau - t) + H(t - \frac{B_1}{v} - \tau) H(\frac{B_1}{v} + 2\tau - t) \right], \qquad (2)$$

where

m_i – masses of links (elements);

τ — time of passage of single obstacle;

matrix B_i set lengths of the elements of passenger car jointed with trailer;

g – acceleration of the free fall;

$H(x)$ – Heaviside function, calculated in an ordinary way.

Values of the parameters a (value of the preliminary pressing) and b (values of the gap) are varied for the research of the dynamic properties of the system in the dependency on the elastic characteristic of the joint device c(s) .

In case of linear characteristic of elastic element (Fig.9a, 10a, a=0, b=0) natural fluctuations are carried out with the constant frequency, amplitudes of fluctuations do not influence value of natural frequencies; natural frequencies depend only on coefficient of elasticity C and led masses of the automobile and trailer $\frac{m_0 m_1}{m_0 + m_1}$ [9]. Friction in the TJD can rather lessen frequency of longitudinal fluctuations of links "automobile-trailer", but exponentially it lessens its amplitude.

6. Conclusions

The idea of dismemberment of main masses of transport vehicles does not only lessen maximum power, necessary by the starting off or braking in the process of traffic. It also allows lessening the peak dynamic loadings in the transmission, to reduce vibroloading, to increase smoothness of traffic and correspondingly, comfortableness, longevity and reliability of vehicle. Improvement of these indexes is possible by the choice and provision of corresponding laws of motion of dismembered masses. Confidence in positive realization of this idea gives received scientific groundworks on the basis of held researches. Thus, the new approaches to the creation and improvement of wheeled transport vehicles with elastically jointed elements of its construction are proposed. Such approaches lie in the complex modeling of vehicle functioning taking into consideration conditions of its exploitation, characteristics of the vehicle and load.

The worked out mathematical model allows to investigate the operating modes of operations of three-unit lorry convoys at different travelling terms. Model of work of wheeled transport vehicles with elastically jointed elements is generalized. For the first time it takes into account effect of the vehicle dismemberment on the elements, taking into consideration conditions of exploitation, characteristics of the vehicle and load. Improved methodology of the correlation between wheeled transport vehicle with elastically jointed elements, conditions of exploitation, characteristics of the vehicle and load. Methodology of the vehicle dismemberment on the elements taking into account construction of the vehicle and conditions of its exploitation is proposed for the first time.

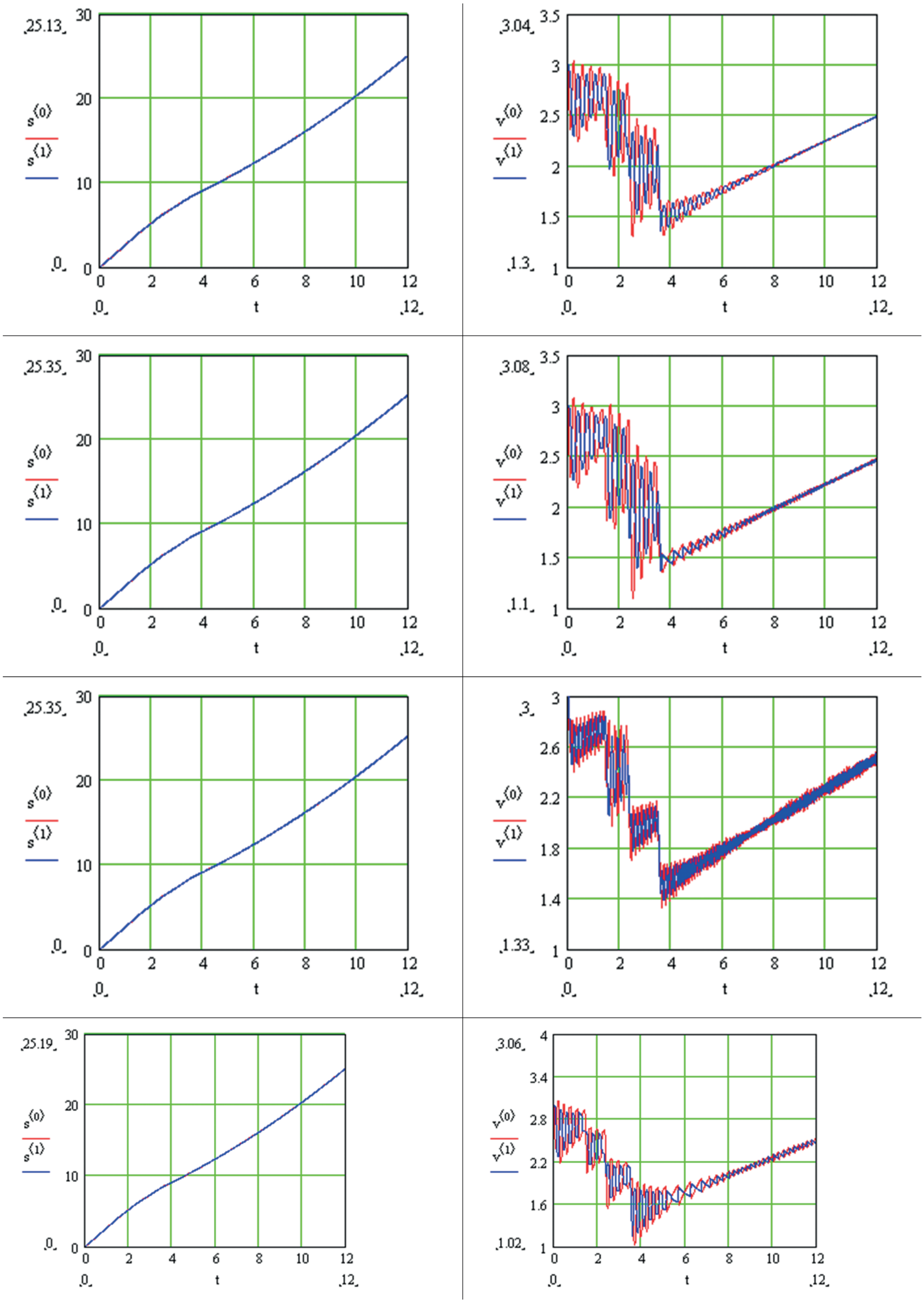


Fig. 9. Graphs of dependencies of the passed way $s^{(i)}$, m (left side) and speeds (right side) $v^{(i)}$, m/s of the both links "automobile-trailer" as the function of time t.

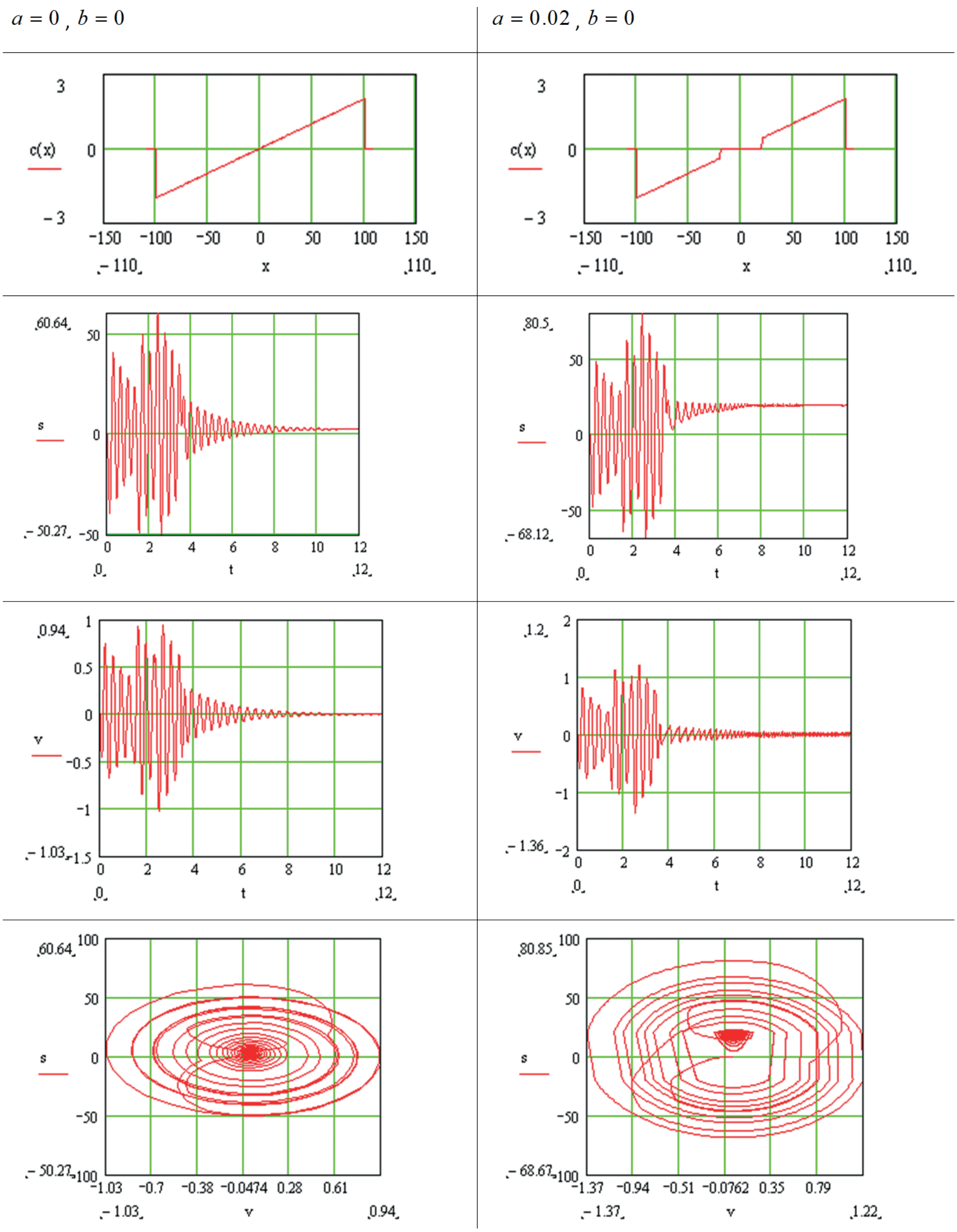


Fig. 10. Top-down:
Dependency of elastic characteristic $c(x)$ from the displacement x, mm;
Dependency of relevant displacement of links "truck-trailer" s, m from time t, s
Dependency of relevant speed of links "truck-trailer" v, m/s from time t, s
Dependency of the relevant speed from the relevant displacement (phase diagram)

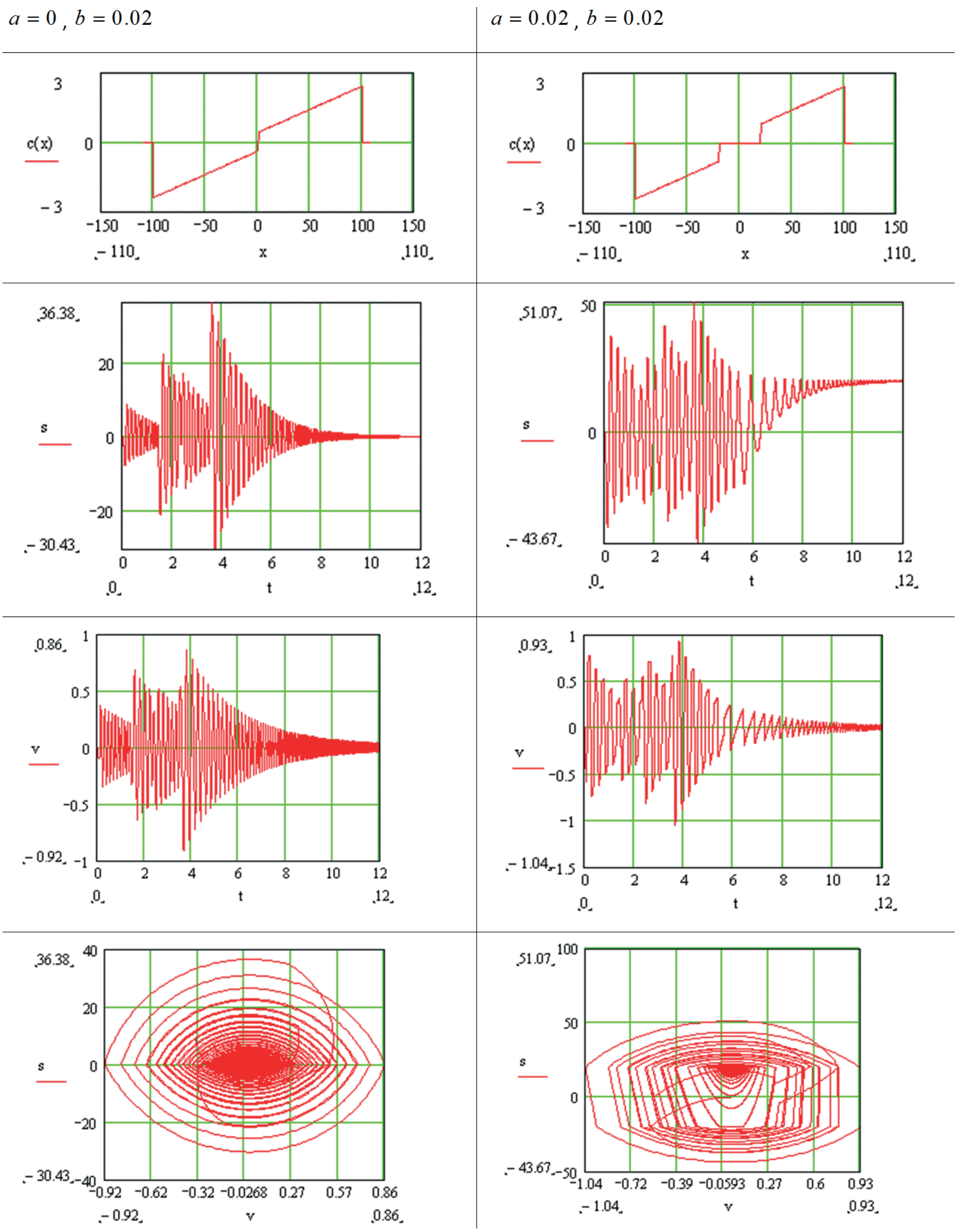


Fig. 10 (continuation) Top-down:
Dependency of elastic characteristic $c(x)$ from the displacement x, mm;
Dependency of relevant displacement of links "truck-trailer" s, m from time t, s
Dependency of relevant speed of links "truck-trailer" v, m/s from time t, s
Dependency of the relevant speed from the relevant displacement (phase diagram)

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