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Use of FEM Programs in Solving General Unbalance Simple Mechanical System of Rigid, Flexible Stored Bodies

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Abstract. The contribution solves the effect of the construction, operation and excitation asymmetry of the simple spatial model. The model can be used for simulation of the vibration of the vehicles (road and rail). The solution was performed by experiments and numerical methods. The mathematical model was developed to reliable describe the experimental simple spatial model. The model was verified by experimental results.

Introduction

A vibration of the machines is not requested phenomena, which can leads to failure or breakdown. The main attention is paid to elimination of the problem, but it has not been completely solved yet. The problems are caused mainly by asymmetry vibrations, where the analytical solution is difficult to obtain. The numerical solution has satisfied particular results, but the complex solution still missing. The pilot scale models (half scale or quarter scale) are used for experimental investigation [1-4]. These models are not appropriate for geometry, loading and excitation asymmetry. It is necessary to understand the vibration problems to analyze the state and operation behavior of machines [6-9].

When analyzing the effect of asymmetry on vertical oscillation of mechanical systems we need to distinguish three basic cases of asymmetry in the relation to geometric symmetry axes. These are two mutually perpendicular axes of symmetry intersecting at the geometrical center of the mechanical system

- asymmetry of vehicle mass distribution regarding to the geometric symmetry axes, mass center position, directions of the main central inertial axes,
- asymmetry of distribution geometry of elastic and bond dissipative elements, of the individual bodies of the system and their mechanical properties, spring stiffness, viscous dumping intensity (assuming linear bonds of particular quantities and small displacements and rotations of the system parts),
- asymmetry of kinematic excitation, i.e. for example roughness of the road surface or rail track in road and track vehicles which defines kinematic excitation of the system in the contact point of the wheel – road or wheel track.

These types of asymmetry may exist separately or together. For real objects (such as road or track vehicles) the third case usually (almost always) occurs [5].

Model System

The experimental model (Fig. 1) was manufactured from steel thin plate supported on the four coil springs. The two additional weights distribution on the steel plate allows investigating various cases of geometrical asymmetry. The position of the center of gravity was changed by this way. The five option of the geometrical weight distribution was investigated, one symmetric and four asymmetric. The coil springs was connected with lock pivots. The kinetics excitation was performed by particular spring jump by pivot pulling out.

The experimental and numerical solutions of vertical vibrations of a mechanical system was chosen one symmetrical arrangement of a model system (a variant of storage I - variant is created by placing additional weight on the motherboard) and four different variants unbalanced, labeled with Roman numerals (II, III, IV and V) . This was achieved by shifting the center of gravity model system from the geometric center of e_x and e_y or rotation of the plate φ_x and φ_y.

Kinematic excitation the system model is implemented by unit step (Heaviside function) *h* (in our case, h = 5 mm. Investigation the system was carried out for six jumps variant (variant *A* to *F* - see Table 1).

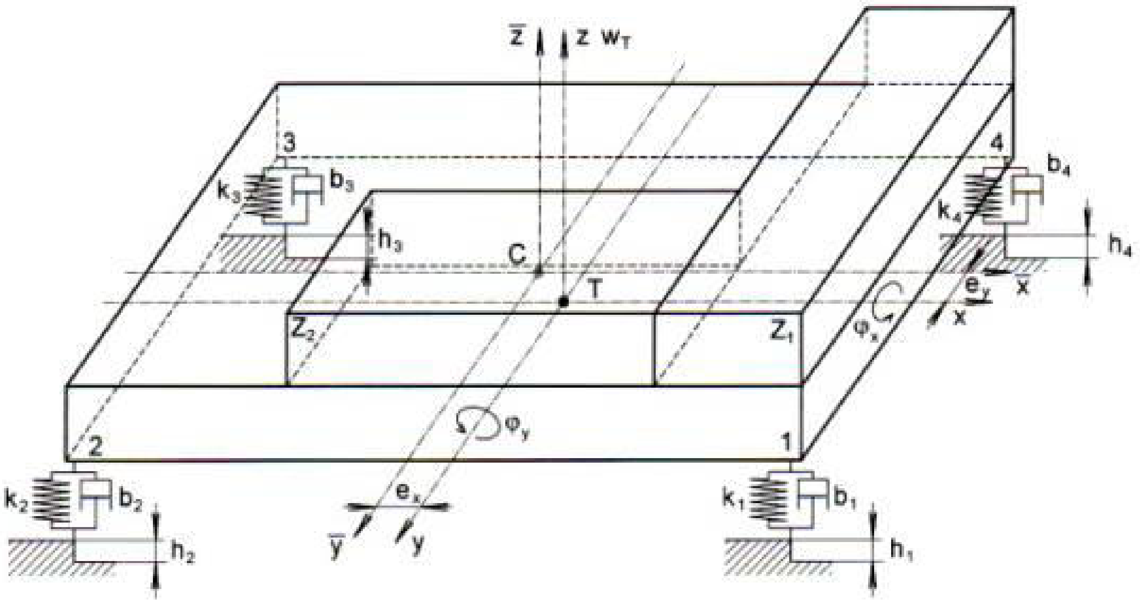
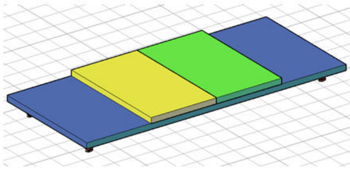
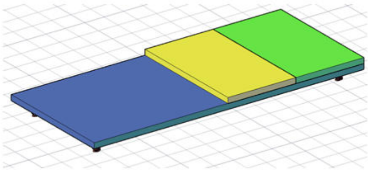
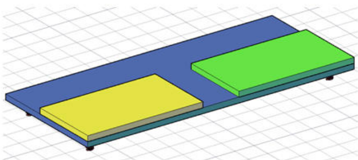
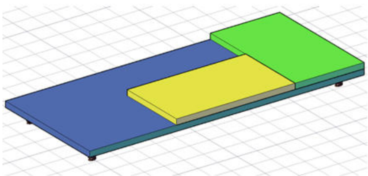
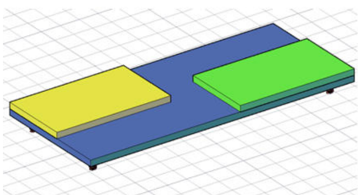


Fig. 1. Scheme of a mechanical system - a symmetrical arrangement of extra weights.

Legend: C – geometric center, T – gravity system, Z_1, Z_2 – extra weights, k – stiffness of the springs, b – damping coefficients, e_x, e_y – displacements of gravity system, h – unit step, w_T – shift the center of gravity (vertical), φ_x, φ_y – angle of rotation according to the individual axes (y, x)

Table 1. Variants of storage and excitation of mechanical system.

variant of storage		variant of excitation	
marking	scheme	marking	falling springs
I		A	3
		B	2, 4
		C	3, 4
		D	2, 3
		E	2, 3, 4
		F	1, 2, 3, 4
II		A	3
		B	2, 4
		C	3, 4
		D	2, 3
		E	2, 3, 4
		F	1, 2, 3, 4
III		A	3
		B	2, 4
		C	3, 4
		D	2, 3
		E	2, 3, 4
		F	1, 2, 3, 4
IV		A	3
		B	2, 4
		C	3, 4
		D	2, 3
		E	2, 3, 4
		F	1, 2, 3, 4
V		A	3
		B	2, 4
		C	3, 4
		D	2, 3
		E	2, 3, 4
		F	1, 2, 3, 4

Experimental Solutions

Were monitored vertical displacement at the mounting point of springs (points 1, 2 and 3 in Fig. 1). For experimental solutions were used inductive sensors, processing was done in the LabVIEW and MS Excel programs. In Figs. from 3 to 5 are shown some results of experimental investigation. In Figs. 4 and 5 are on the bottom to see a detailed shapes of oscillations in one second of time.

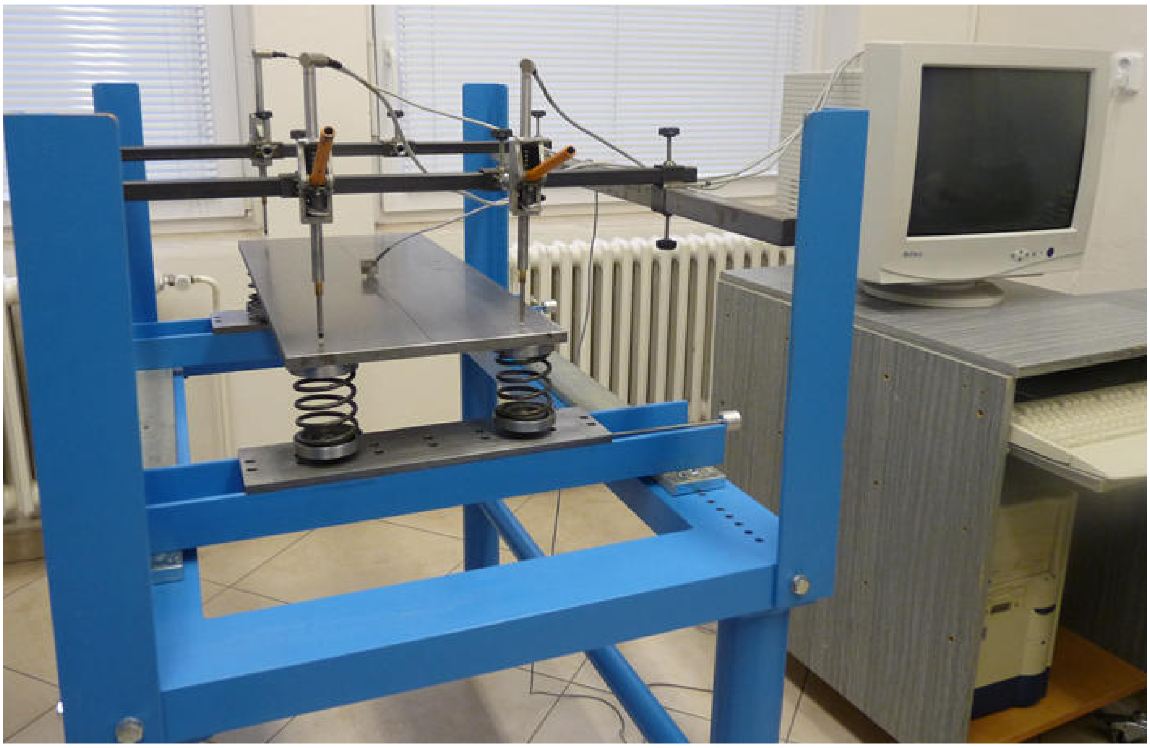


Fig. 2. Laboratory model of a mechanical system (without weights).

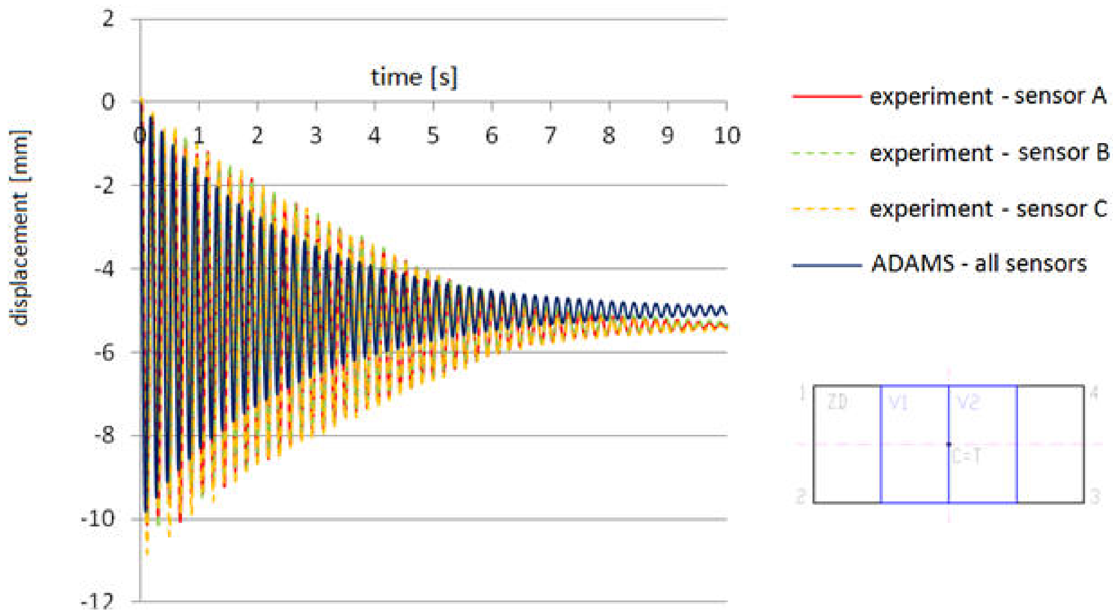


Fig. 3. Variant of loadings I – falling spring 1, 2, 3, 4.

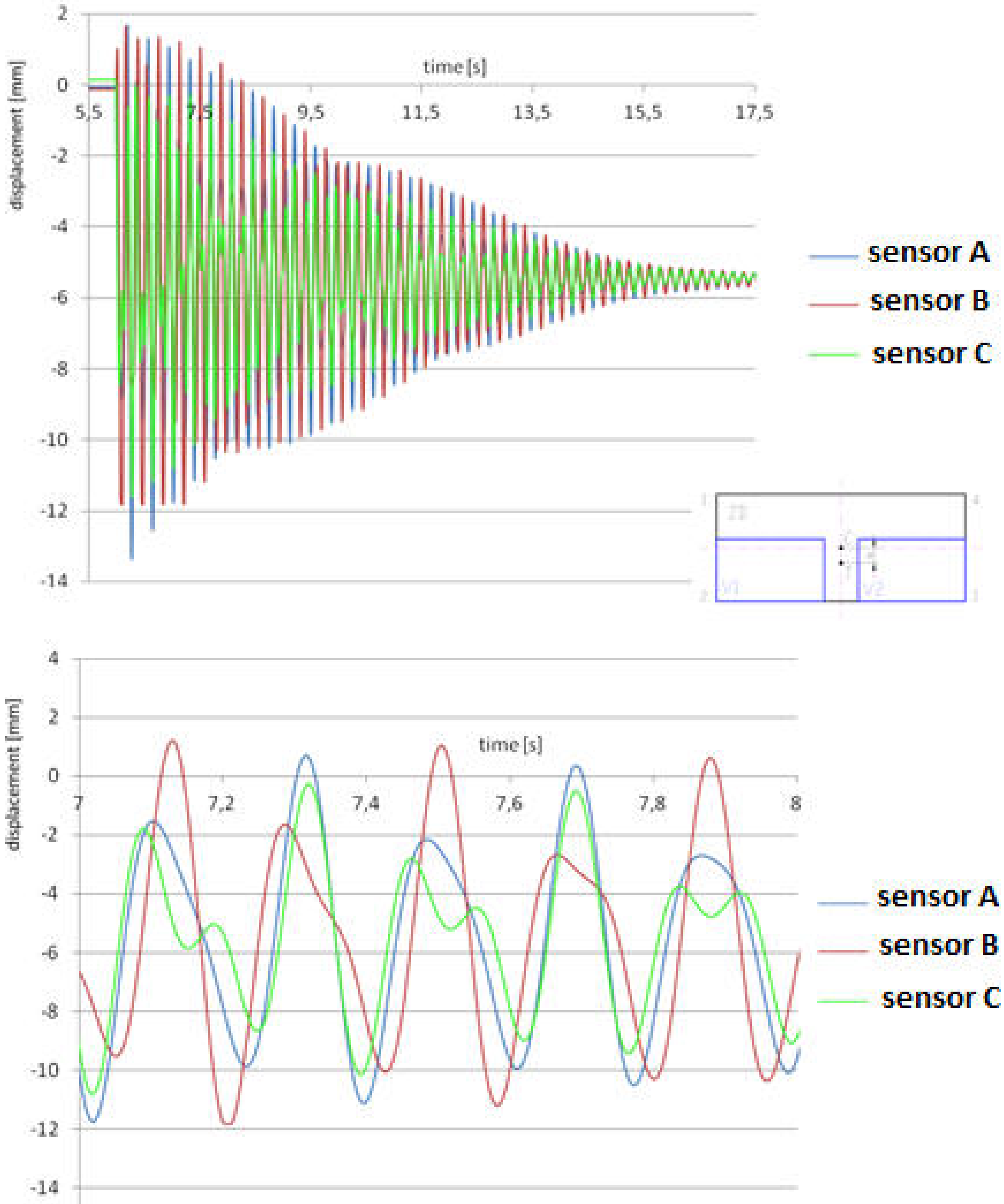


Fig. 4. Variant of loadings III – falling spring 1, 2, 3, 4.

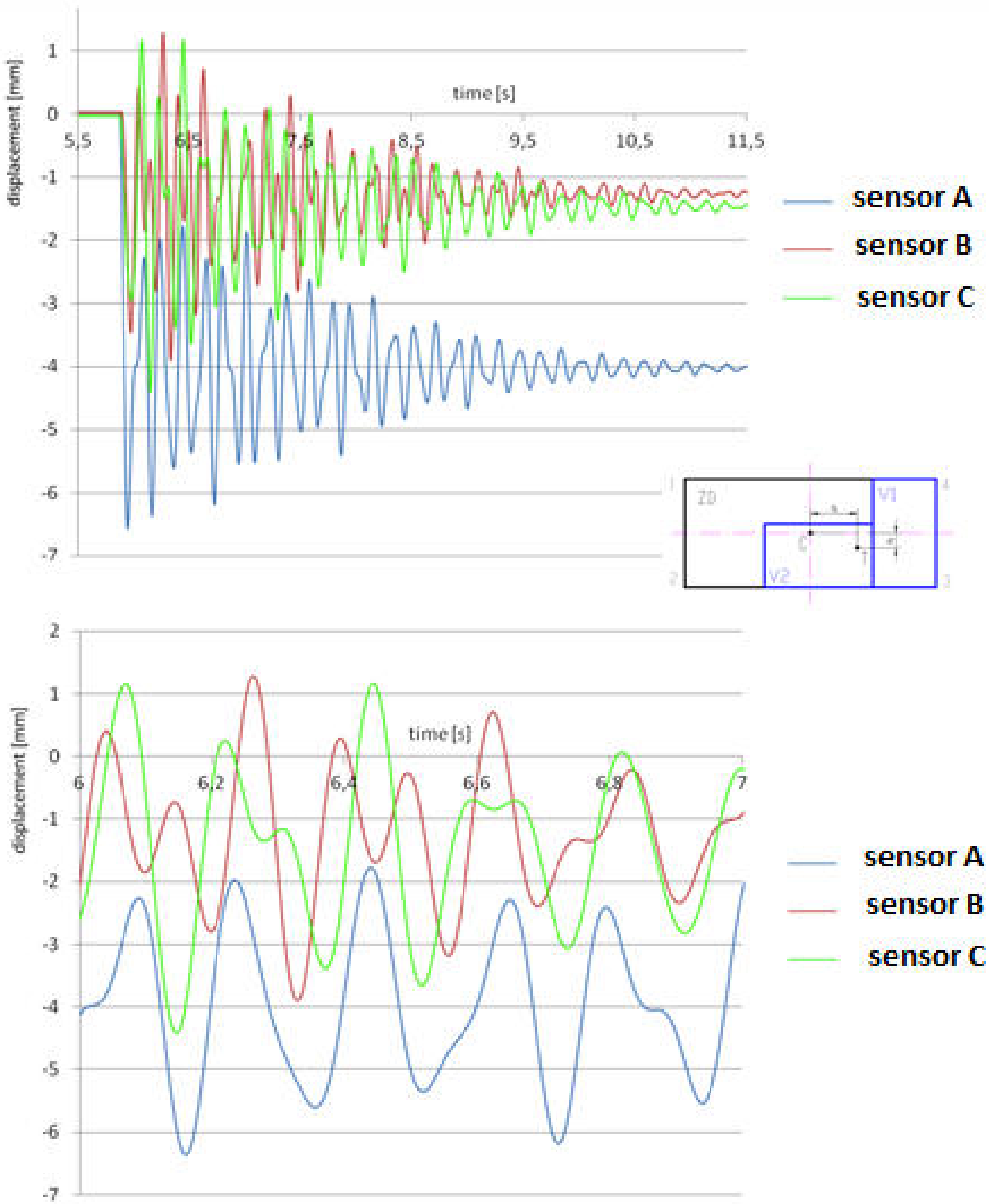


Fig. 5. Variant of loadings IV – falling spring 3.

Numerical Solution

Numerical solutions of vertical vibrations of a mechanical system was done in ADAMS program. This simulation program allows you to perform static, kinematic and dynamic analysis of the proposed models, it also enables to optimize and verify their mathematical models and is commercially used.

The assembled model in ADAMS program can be seen in Fig. 6. It was designed so that the most reliable conveyed the laboratory model. Setting boundary conditions was carried out using the results of experimental solutions which also serve to verify the data.

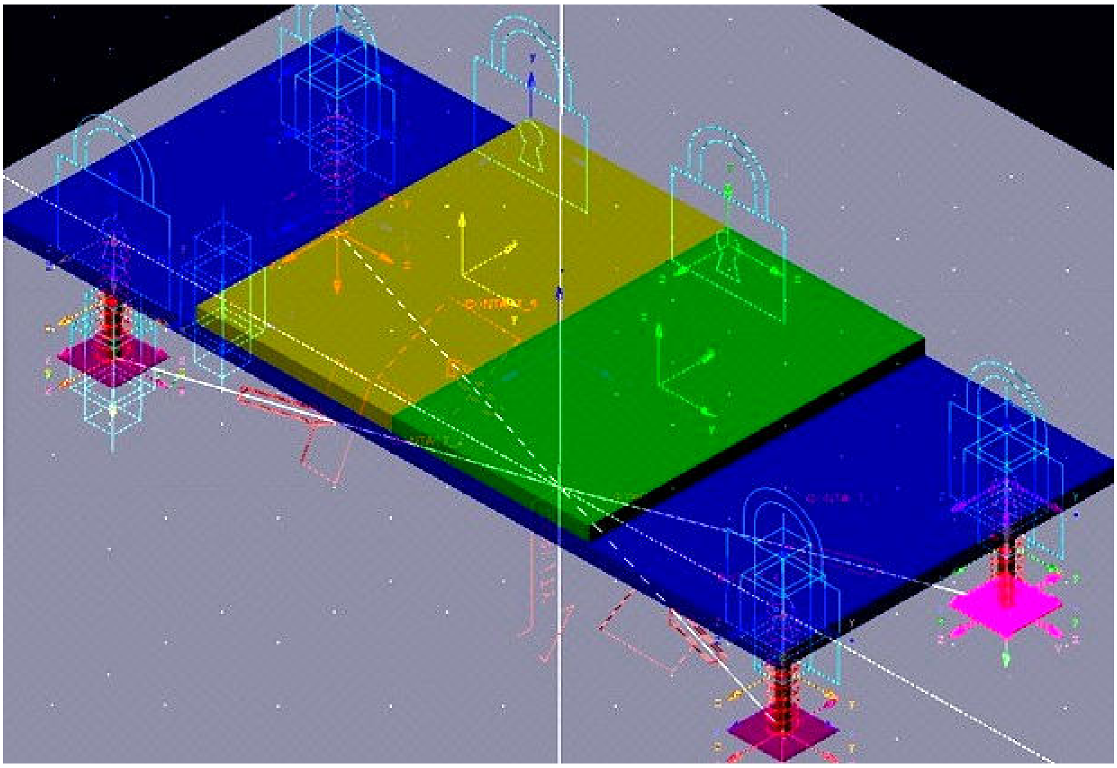


Fig. 6. Model of mechanical system in ADAMS program.

In the pictures below you can see some results of numerical solution (Fig. 7 and 8). Were measured vertical displacements at points of geometrical center of the springs.

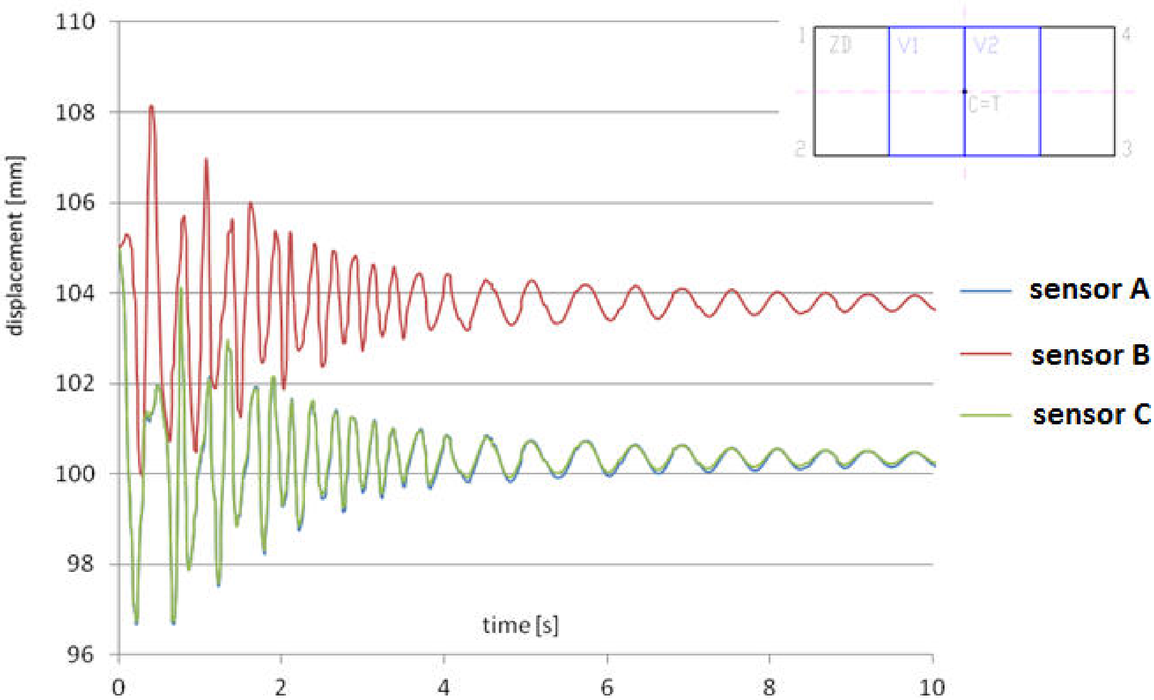


Fig. 7. Variant of loadings II – falling spring 3, 4.

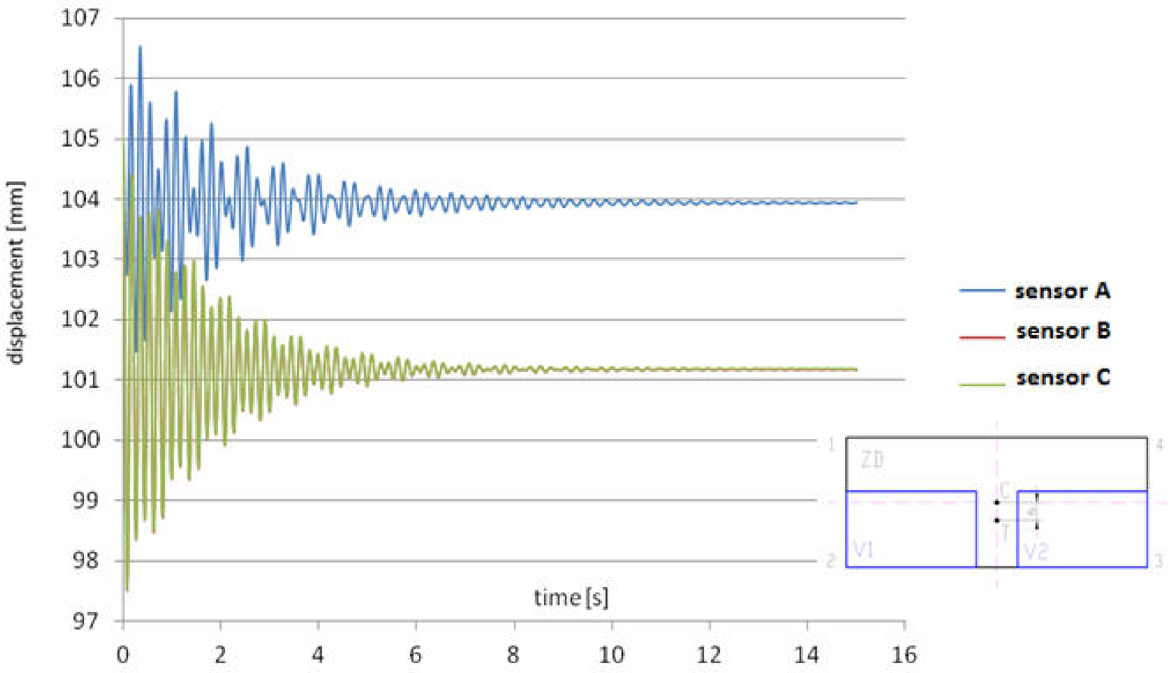


Fig. 7. Variant of loadings III – falling springs 2, 3.

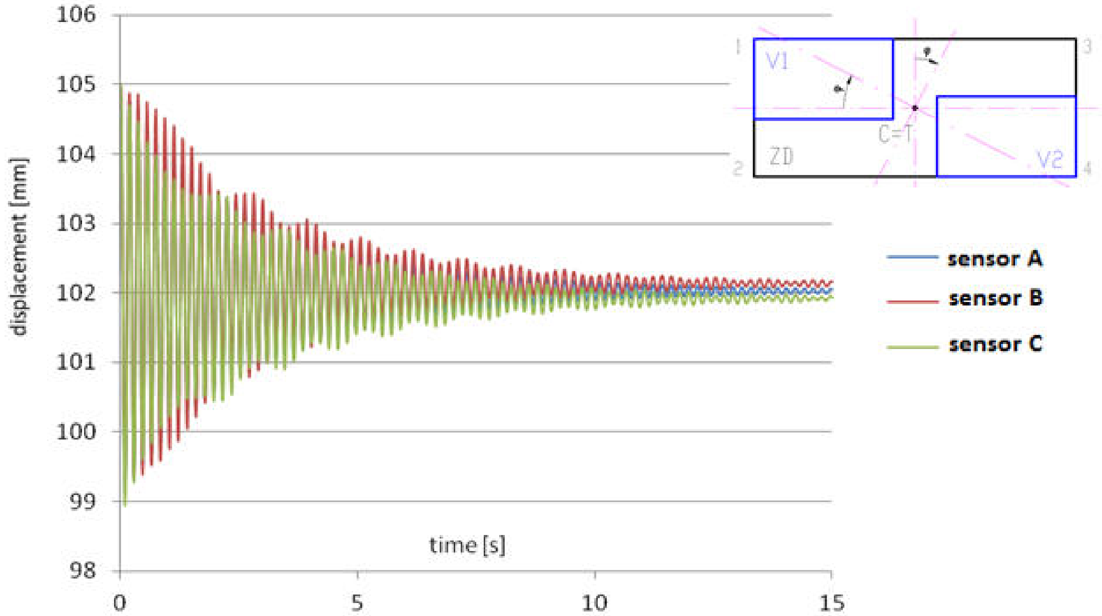


Fig. 7. Variant of loadings IV – falling spring 3.

Conclusions

The comparison of the experimental and numerical results shows the satisfactory agreement (up to 10 %). The small differences were caused by different material constant of the damping and stiffness of the spring. The arrangement of the boundary condition of the model allows increasing the accuracy of the numerical model.

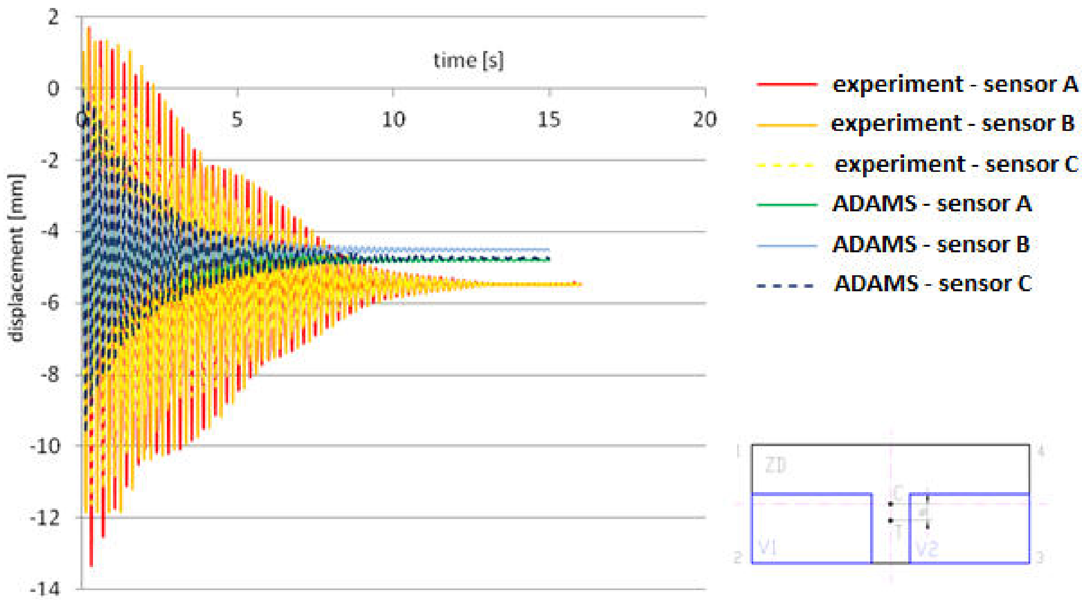


Fig. 8. Variant of loadings III – falling springs 1, 2, 3, 4.

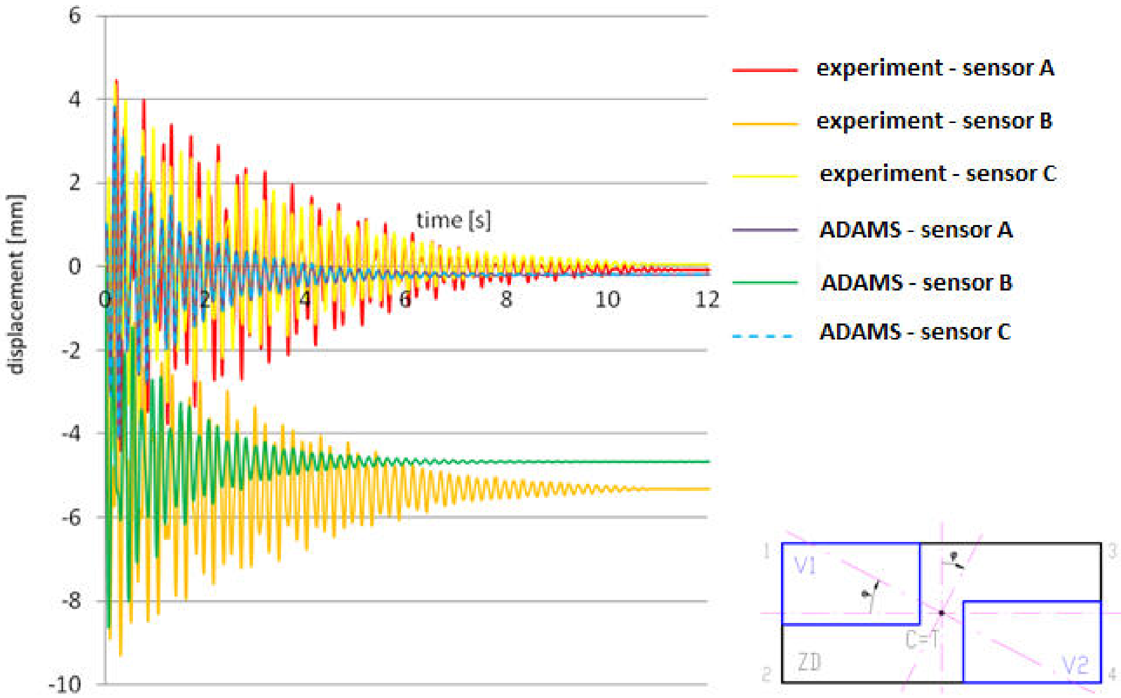


Fig. 9. Variant of loadings V – falling springs 3, 4.

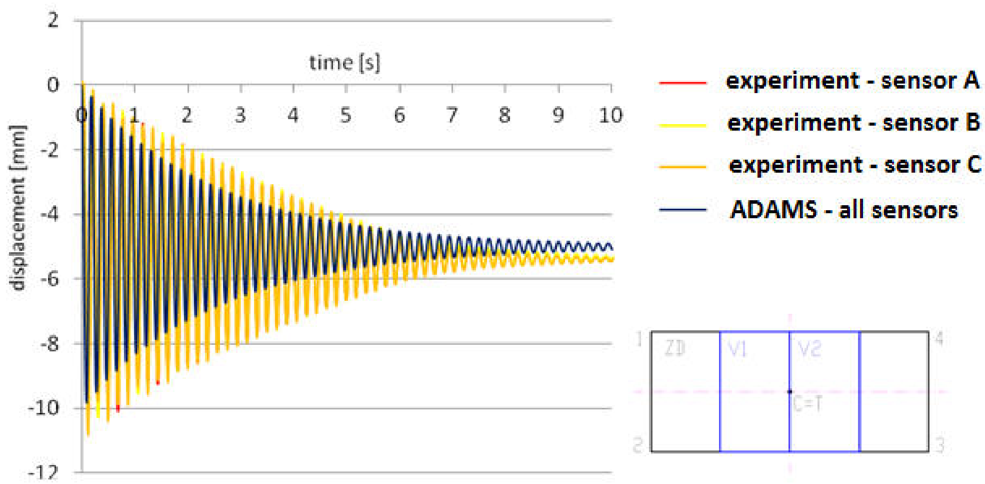


Fig. 10. Variant of loadings I – falling springs 1, 2, 3, 4 (ADAMS and experiment).

The ADAMS software is suitable for simulation of the investigated system and the results of simulation agree with experimental data with higher accuracy. The result of the work is the verification of the numerical model by experiment. This model can be applied to describe the prediction of the behavior of the machines under vibration.

References

[1] J. Awrejcewicz, A. Klimenko, Y.V. Mikhlin, Nonlinear normal vibration modes in pendulum systems, in: J. Awrejcewicz, M. Kaźmierczak, P. Olejnik, J. Mrozowski (Eds.), Proceedings of the 11th Conference on Dynamical Systems – Theory and Applications, Nonlinear Dynamics and Control, Technical University of Łódź, Łódź, 2011, pp. 69-78.

[2] M. Chalupa, L. Severa, R. Vlach, Vehicle Track Loading Simulation, in: Proceedings of the Fourth International Conference on Machine Vision ICMV 2011, SPIE, Singapore, 2012, vol. 8350, pp. 1-5.

[3] M. Chalupa, R. Vlach, Simulation of vehicle track dynamic loading, in: I. Zolotarev (Ed.), Proceedings of 19th International Conference Engineering Mechanics 2013, Institute of Thermomechanics, Academy of Sciences of the Czech Republic, Svratka, 2013, CD-ROM.

[4] D. Karnopp, Vehicle Stability, Marcel Dekker, New York, 2004.

[5] J. Soukup, J. Volek et al., Vibration of mechanical systems – vehicles, Analysis of asymmetry influence, Acta Universitatis UJEP Ústí nad Labem, 2008. (in Czech)

[6] M. Blundell, D. Harty, The Multibody Systems Approach to Vehicle Dynamics, Butterworth-Heinemann, Oxford, 2004.

[7] H.B. Pacejka, The dynamics of vehicles on roads and on railway tracks, in: H.B. Pacejka (Ed.), Proceedings of IUTAM Symposium the Dynamics of Vehicles on Roads and Tracks, Delft, 1975, Swets & Zeitlinger, Amsterdam, 1976.

[8] P. Polach, M. Hajžman, J. Soukup, J. Volek, Analytical and numerical investigation of trolleybus vertical dynamics on an artificial test track, Applied and Computational Mechanics 3 (2009) 351-362.

[9] V. Stejskal, M. Okrouhlík, Vibrations with Matlab, CTU Publishing House, Praha, 2002. (in Czech)