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CONTEMPORARY POSSIBILITIES OF MODELING OF THE PROBLEMS OF VEHICLE TRACK INTERACTION

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1. Introduction

Works of Civil Engineer R. Willis and mathematician G. G. Stoks trying to clear up the breakdown of Chester Rail Bridge in England in 1847 are thinking not only the first in the solution of the problems of vehicle track interaction but the first in the field of structural dynamics at all. Actual admission to the solution of these problems comes out from the mutual combination of numerical and experimental approaches. Numerical methods in the present days offer effective tool for the solution of this problem. If the entering values are put into calculation in regular magnitudes, verifying on the basis of experimental measurements, the results of numerical calculations corresponds to the results obtained by experimental way. Contemporary state of computing technique enables to solve all the problems in real time. For the creation of computing programs it is suitable to use the high-level program languages. The results obtained form the numerical and experimental analyses are used in the process of construction of transport means and in the relation to the passengers they are focus in the ride comfort of passengers and in the design of optimal parameters of runway with respect on its lifetime and reliability.

2. Specification of the problem

Numerical solution of the problem of vehicle runway interaction demands to pay attention minimally to the following matters:

- creation of computing models of vehicle and its mathematical description,
- creation of computing models of runway and its mathematical description,
- modelling and mathematical description of road surface unevenness,
- creation of computer program for numerical solution of equations of motion,
- creation of computer program for evaluation and displaying of obtained data.

There are many concrete techniques how to create computing models of vehicles and runways. Computing models can be basically divided into two categories on the face of resulting type of equations of motion. Equations of motion can be formed as differential or integral equations. The possibilities of numerical solution of both types motion equations are in the present time very large. It is practically the question of individual author's approach. Computing models of vehicles are created with favour as discrete models composed from the systems of mass points or mass bodies, discrete springs and dampers, or they are created in the sense of Finite Element Methods. Such computing models are described by the system of ordinary differential equations. The sample of usually used 1D, 2D or 3D computing models of vehicles is plot on the Fig. 1. Runway computing models - bridge, railway, roadway - can be continual or discrete. It depends on the kind of structure, Fig. 2, 3, 4.

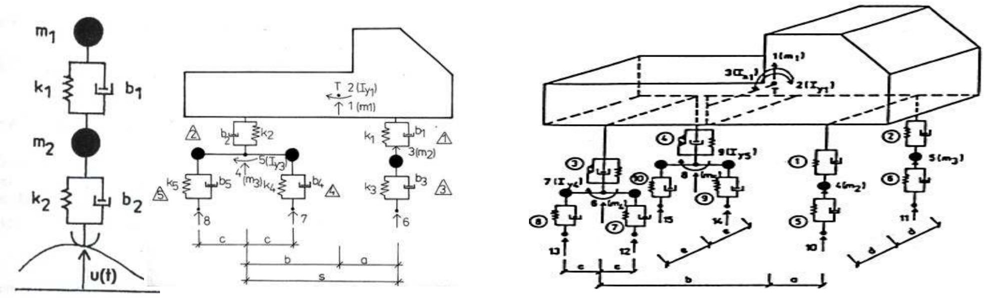

Fig. 1. Usually used 1D, 2D or 3D computing models of vehicles

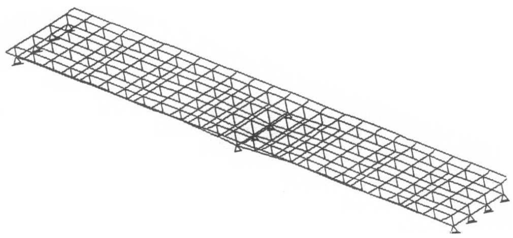

Fig. 2. Computing model of a bridge track

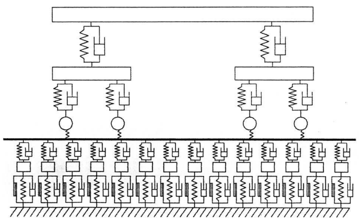

Fig. 3. Computing model of railway

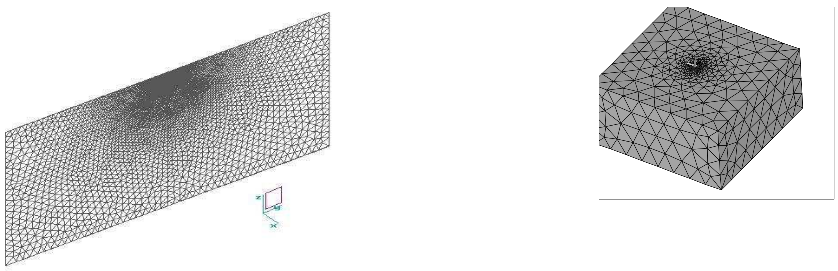

Fig. 4. Computing model of a roadway

On the author’s working place the equations of motion are usually compiled as differential equation and they are solved numerically. Various methods are used for numerical solution of differential equations. For example the central difference method, Newmark’s method, Wilson’s method, predictor-corrector method. Very good experience is with the use of Runge-Kutta 4^{th} or 5^{th} order method. In the present time it is optimal to use for the creation of computing program such higher level programming language, for example MATLAB. This programming language is matrix oriented, interactive and computing procedures are supported by effective graphics. The creation of a program is more easily in comparison with classical program languages. For example the program statement for numerical integration of differential equations by the Runge-Kutta 4th order integration method can be written on one line.

Mathematical description of road surface unevenness is also an integral part of the problem. Road surface unevenness can be defined deterministically or stochastically. Local discrete unevenness and periodically repeated unevenness are modeled deterministically, for example in the shape of sine or cosine waves, Fig. 5.

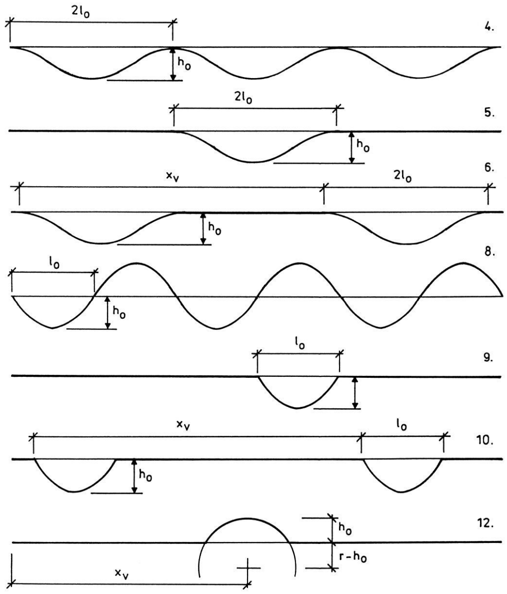

Fig. 5. Deterministically defined unevenness

Specific case of deterministic unevenness represents the terrain step. It is from mathematical point of view a function with point singularity. For the purpose of numerical modeling of such unevenness it is better to substitute the real shape of the terrain step by alternate function identical with the function describing the trajectory of wheel hub of vehicle. Existing dependences are showed on the Fig. 6.

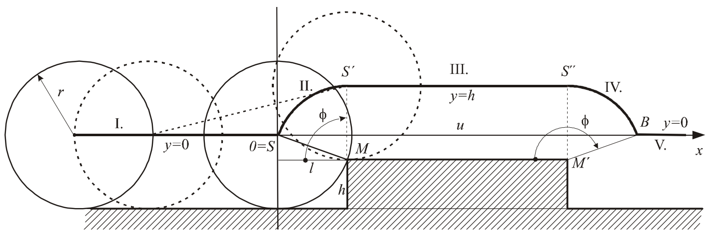

Fig. 6 Passage of wheel over terrain step

Randomly variable unevenness is very frequently modeled by the power spectral density in the present time.

$$S(\Omega) = C \,.\, \Omega^{-2} \tag{1}$$

where C [rad.m] is a parameter describing the measure of unevenness and Ω is so called length angular frequency in [rad.m^{-1}]. When the coordinates on the vertical and horizontal axes are plotted in logarithmical measure, the power spectral densities of unevenness can be very good approximated by straight line, Fig. 7.

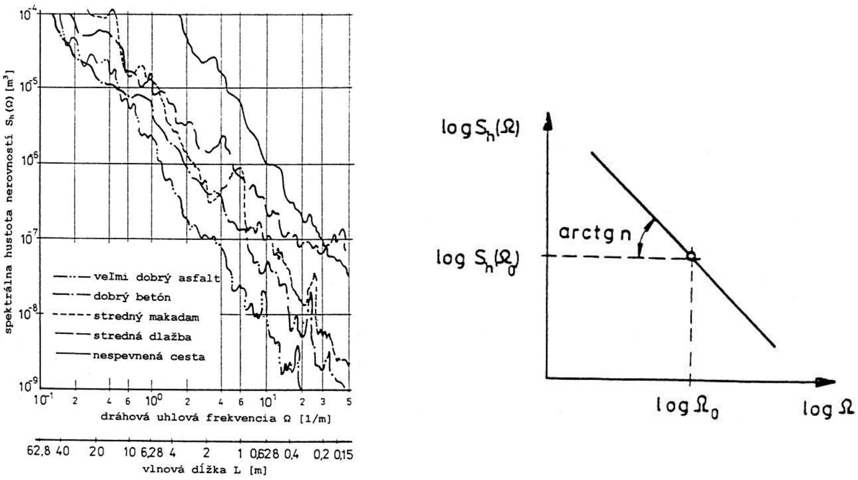

Fig. 7. Power spectral densities of road unevenness

3. Obtained results

For the solution of the problems of vehicle runway interaction a few computing programs and program systems were created enabling of modeling of various phenomena. In the following text there are some samples of obtained results. For example there are time courses of vibration of 2D computing model of vehicle during passing over shutters on the Fig. 9. Interactive forces between individual wheels and runway are showed in the Fig. 8.

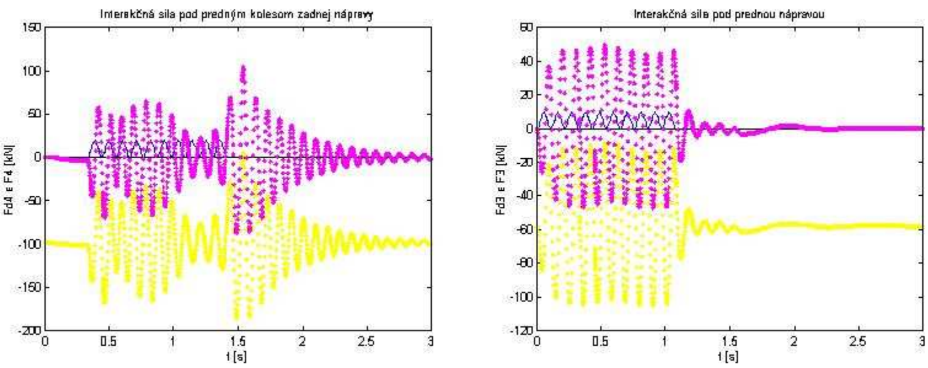

Fig. 8. Interactive forces under rear and front axle of 2D computing model of vehicle

For the solution of the problems of bridge vibration excited by passing vehicles the program system BRIDGEW2 was created, Fig. 10. The system enables by numerical way to model all kinematical stages of vehicle (deflections, speeds, accelerations) and bridge and also interactive forces originating between vehicle and bridge. It enables to follow up the influence of various parameters, to do interval analysis and to obtain in the state of project preparation such data which could be obtained in the past only on the basis of experimental measurements realized on finishing structure. It enables to do the basic statistical processing of modeled phenomena. The computing program is interconnected with program system DAS16 using for analysis of experimentally obtained data. There is the possibility to work measured and modeled data by the same algorithm and to compare obtained results mutually. The sample of possible output is on the Fig. 11.

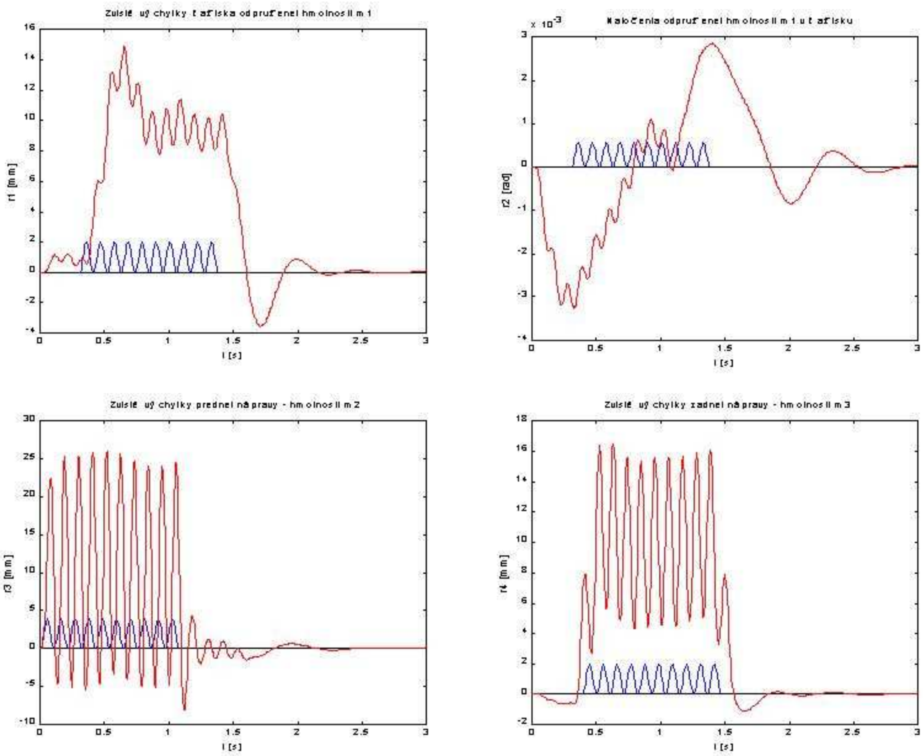

Fig. 9. Vibration of 2D computing model of vehicle running over shutters

4. Conclusions

Numerical modeling of the problems of interaction between vehicle and runway is an effective tool for the solution of real tasks of engineering practice. Quality of obtained results is dependent on the quality of input data. The present state of computing technique enables the numerical processing of solved problems in real time. From the practical point of view of civil engineer the time courses of vehicle and runway responses, stress and stein stages in vehicle and runway and interacting forces accruing between vehicle and runway are interested.

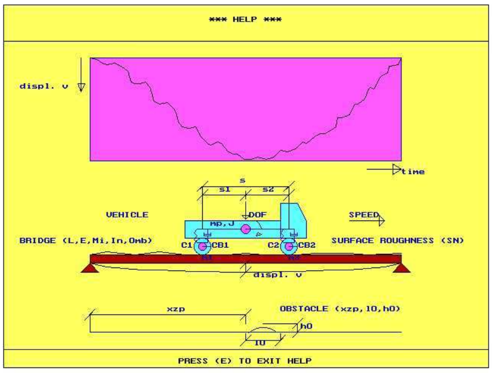

Fig. 10. Entering window of program system BRIDGEW2

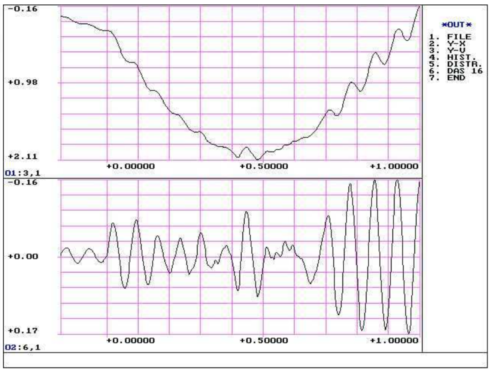

Fig. 11. Mid-span bridge vibration, modeled signal of relative and absolute sensor

References

[1] Levy, S. - Wilkinson, J.P.D.: *The component element methods in dynamics with application to earthquake and vehicle engineering*. McGraw-Hill, New York, 1976.

[2] Melcer, J.: *Dynamic computation of highway bridges* (in Slovak). EDIS, University of Zilina, Zilina, 1997.

Acknowledgement

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SÚČASNÉ MOŽNOSTI MODELOVANIA PROBLÉMU INTERAKCIE VOZIDLA S JAZDNOU DRÁHOU

Summary

Predkladaný príspevok je venovaný súčasným možnostiam modelovania problémov interakcie vozidiel s jazdnou dráhou. Súčasný prístup k riešeniu týchto problémov vychádza zo vzájomnej kombinácie numerických a experimentálnych postupov. Numerické metódy už v súčasnosti poskytujú účinný nástroj na riešenie tohto problému. Pokiaľ vstupné hodnoty vstupujúce do výpočtu sú zadávané v správnych hodnotách, overených na základe experimentálnych meraní, korešpondujú výsledky numerických analýz výsledkom získaným experimentálnou cestou. Súčasný stav výpočtovej techniky umožňuje riešiť všetky problémy v reálnom čase. Pre tvorbu výpočtových programov je možné s výhodou použiť programovacie jazyky vyššej úrovne. Výsledky získavané z numerických a experimentálnych analýz sú využívané jednak pri konštrukcii dopravných prostriedkov a vo vzťahu k cestujúcim sú smerované do oblasti pohodlia jazdy a jednak pri navrhovaní optimálnych parametrov jazdnej dráhy s ohľadom na jej životnosť a spoľahlivosť, bez ohľadu na to či sa jedná o cestnú komunikáciu, železnicu alebo mostnú konštrukciu.