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MOVEMENT OF A VEHICLE ALONG PERIODICALLY REPEATED ROAD UNEVENNESS

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1. Introduction

Solution of the problems of vehicle road interaction represents an actual task of structural dynamic. One of the recent collected work, dedicated to this subject, was published by D. Cebon in 1999, [1]. The current approach to these problems results from mutual combination of numerical and experimental approaches. Numerical methods at present offer an effective tool for the solution of this problem. If the input values are put into calculation in accurate magnitudes, verified by experimental measurements, the results of numerical calculations correspond to the results obtained in an experimental way. Contemporary state of computing technique enables to solve above mentioned problems in real time using various software packages for example MATLAB. The results obtained from numerical and experimental analyses are used in the process of construction of transport means and in relation to passengers they are focused on the ride comfort of passengers and on the design of optimal parameters of runway with respect to its lifetime and reliability.

2. Computing model of a vehicle

The computing models of vehicle suitable for numerical solution of the vehicle road interaction problem can be created on various level of complexity – full space model, half plane model or quarter model. The quarter model on the Fig. 1 is used for the purpose of this contribution. Quarter model is the simplest but mostly used in praxis. This model concisely modeled the dynamic effect of one half of one axle on the road. The model has got 3 degrees of freedom, 2 mass degrees of freedom and 1 mass-less degree of freedom. Mass-less degree of freedom corresponds to the vertical movements the contact point of the model with road surface. Vertical vibration of mass points m_1 and m_2 is described by two functions $r_1(t)$ and $r_2(t)$. The differential equations for the calculation of the unknown functions $r_1(t)$ and $r_2(t)$ can be written as

$$\ddot{r}_1(t) = \{-k_1 \cdot [r_1(t) - r_2(t)] - b_1 \cdot [\dot{r}_1(t) - \dot{r}_2(t)]\} / m_1 , \qquad (1)$$

$$\ddot{r}_2(t) = \{+k_1 \cdot [r_1(t) - r_2(t)] - k_2 \cdot [r_2(t) - h(t)] + b_1 \cdot [\dot{r}_1(t) - \dot{r}_2(t)] - b_2 \cdot [\dot{r}_2(t) - \dot{h}(t)]\} / m_2 . \qquad (2)$$

The contact force F belongs to the mass-less degree of freedom. It can be expressed as

$$F(t) = G - k_2 \cdot [r_2(t) - h(t)] - b_2 \cdot [\dot{r}_2(t) - \dot{h}(t)] . \quad (3)$$

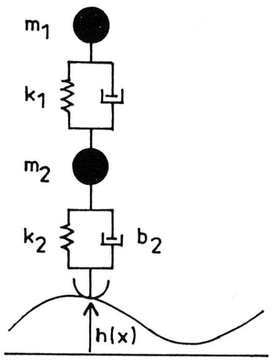

Fig. 1 Quarter model of a vehicle

3. Periodically repeated road unevenness

Periodically repeated road unevenness is advisable to model by sine or cosine functions [2], Fig. 2 and Fig. 3.

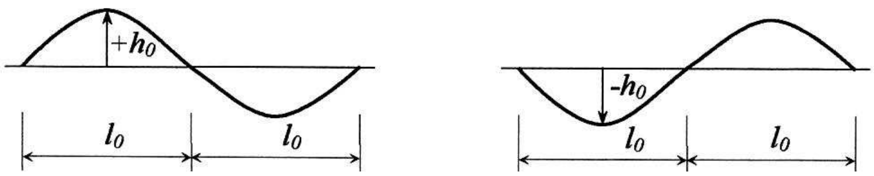

Fig. 2 Periodically repeated road unevenness in the shape of sine function

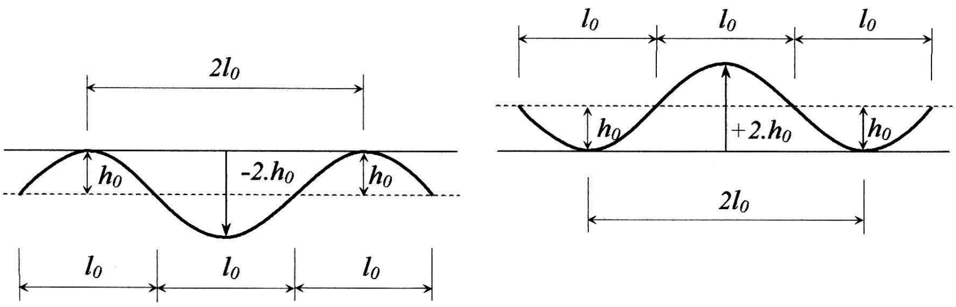

Fig. 3 Periodically repeated road unevenness in the shape of cosine function

Such waves can be mathematically described by following expressions

$$h(x) = \pm h_0 \cdot \sin(\frac{\pi \cdot x}{l_0}) \text{ eventually } h(t) = \pm h_0 \cdot \sin(\omega \cdot t) . \quad (4)$$

$$h(x) = \pm\frac{1}{2}\cdot 2\cdot h_0\cdot(1-\cos(\frac{2\cdot\pi\cdot x}{2\cdot l_0})) = \pm h_0\cdot(1-\cos(\frac{\pi\cdot x}{l_0}))\ \text{eventually}$$

$$h(t) = \pm h_0\cdot(1-\cos(\omega\cdot t))\,. \tag{5}$$

In the expressions above

$$x = c\cdot t\,,\quad \omega = \pi\cdot c/l_0\,, \tag{6}$$

where h_0 is the height of the sine half-wave in [m], l_0 is the length of the sine half-wave in [m], x is the length coordinate in [m], t is time coordinate in [s], c is the speed of vehicle motion in [m/s] and ω is the angular frequency in [rad.s^{-1}].

In order to guarantee one-point contact between the wheel and the road as seen on Fig. 4 instead of two-point contact as seen on Fig. 5 certain relation between quantities r, h_0, l_0 should be kept. At the given radius r and the height of the sine half-wave h_0 it must obey the following relation

$$l_0 \geq \pi\cdot\sqrt{h_0\cdot r}\,. \tag{7}$$

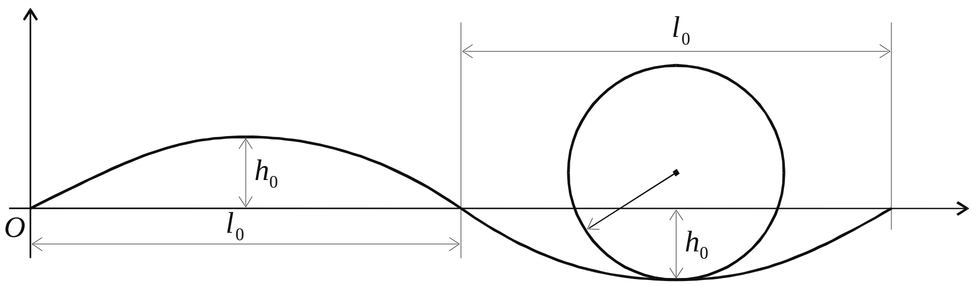

Fig. 4 One-point contact between the wheel and the road

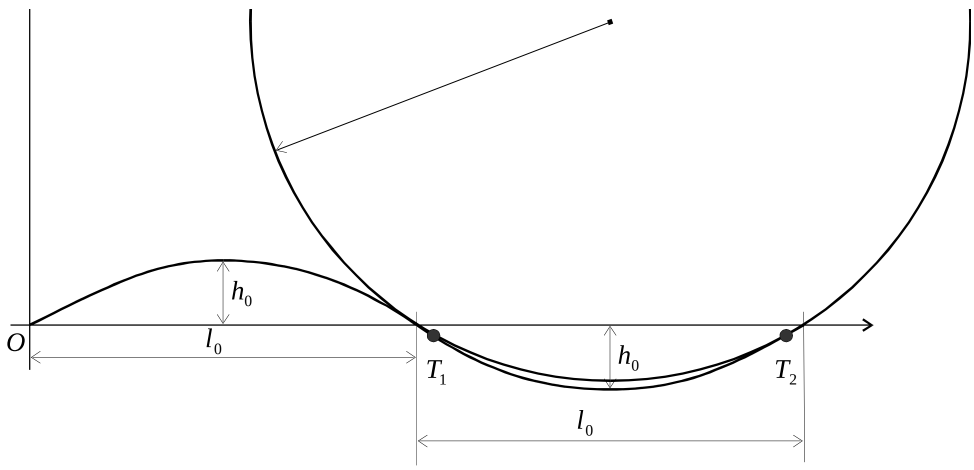

Fig. 5 Two-point contact between the wheel and the road

4. Results of numerical simulations

Results of numerical simulation of quarter model motion along periodically repeated unevenness in the shape of 10 cosine waves with the length of 1 cosine wave $2.l_0$ = 1,2 m and with wave depth $2.h_0$ = 0,04 m are presented. For the wheel radius r = 0,5 m and the wave depth $2.h_0$ = 0,04 m is the limit length of cosine wave $2.l_0$ = 0,6283 m which is smaller value than assumed $2.l_0$ = 1,2 m . At higher speeds of vehicle motion the contact between wheel and road is lost. At the above declared dimensions of unevenness the loss of contact appears at speed approximately 30,5 km/h, Fig. 6, Fig. 7. The results for the 1st and the 2nd critical speeds $V_{(1)}$ = 5,642464 km/h and $V_{(2)}$ = 38,824232 km/h are presented in the Fig. 8 and Fig. 9.

5. 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 the influence of periodically repeated unevenness is interested.

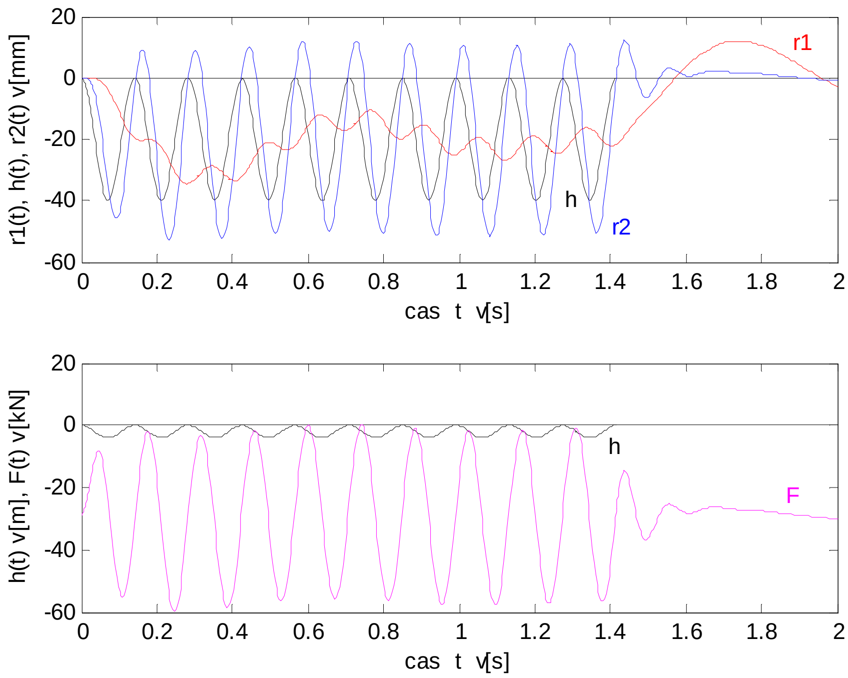

Fig. 6 Quarter model, 10 CW – 1,20 x 0,04 m, V = 30,5 km/h

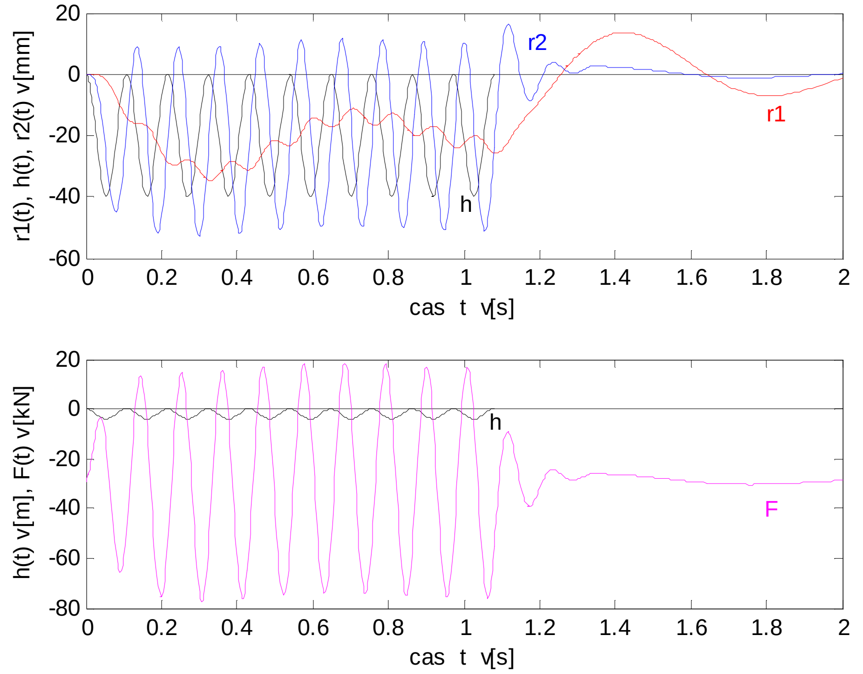

Fig. 7 Quarter model, 10 CW – 1,20 x 0,04 m, V = 40,0 km/h

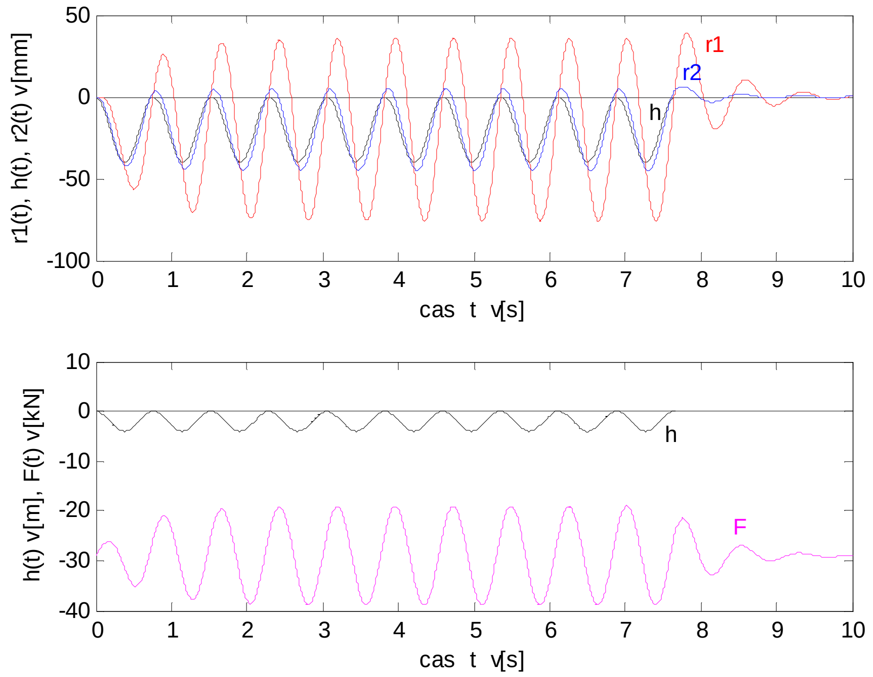

Fig. 8 Quarter model, 10 CW – 1,20 x 0,04 m, $V_{(1)}$ = 5,642464 km/h

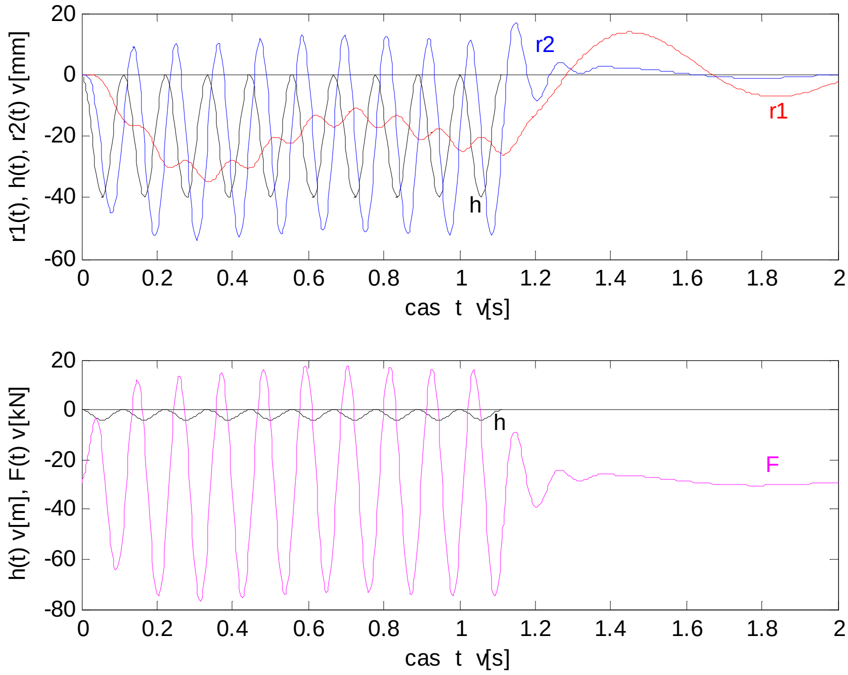

Fig. 9 Quarter model, 10 CW – 1,20 x 0,04 m, $V_{(2)}$ = 38,824232 km/h

References

[1] Cebon, D.: Handbook of Vehicle – Road Interaction. Swets&Zeitlinger Publishers, Lisse, Netherlands, 1999.

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

Acknowledgement

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POHYB VOZIDLA PO PERIODICKY SA OPAKUJÚCICH NEROVNOSTIACH CESTNEJ KOMUNIKÁCIE

Resumé

Predkladaný príspevok je venovaný súčasným možnostiam modelovania problémov interakcie vozidiel s jazdnou dráhou. Sleduje dynamické správanie sa výpočtového modelu vozidla pri pohybe po periodicky sa opakujúcich nerovnostiach cestnej komunikácie. 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.