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Assessment of railway wagon suspension characteristics

Josef Soukup^a, Jan Skočilas^{b,*}, Blanka Skočilasová^a^a UJEP in Usti nad Labem, Czech Republic, Faculty of Production Technology and Management, Department of Machines and Mechanics, Na Okraji 1001/7, Usti nad Labem 400 11, Czech Republic^b Czech Technical University in Prague, Faculty of Mechanical Engineering, Department of Process Engineering, Technická 4, 166 07 Prague 6, Czech Republic

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ABSTRACT

The article deals with assessment of railway wagon suspension characteristics. The essential characteristics of a suspension are represented by the stiffness constants of the equivalent springs and the eigen frequencies of the oscillating movements in reference to the main central inertia axes of a vehicle. The premise of the experimental determination of these characteristic is the knowledge of the gravity center position and the knowledge of the main central inertia moments of the vehicle frame. The vehicle frame performs the general spatial movement when the vehicle moves. An analysis of the frame movement generally arises from Euler's equations which are commonly used for the description of the spherical movement. This solution is difficult and it can be simplified by applying the specific assumptions. The eigen frequencies solutions and solutions of the suspension stiffness are presented in the article. The solutions are applied on the railway and road vehicles with the simplifying conditions. A new method which assessed the characteristics is described in the article.

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1. Introduction

The dynamic analysis of the rail vehicle is an assumption not only for the quality drive assessment. It is necessary to measure or to verify the basic characteristics of the suspension for this analysis. The basic characteristics are the stiffness constant of substitutive equivalent springs and the eigen frequencies of oscillation movements referenced to main central inertia axes of the vehicle [1]. These movements are the rotational movement around longitudinal axis x – roll oscillation ω_{xT} , around transversal axis y – swinging ω_{yT} and the translational movement in the direction of vertical axis z – wobbling $\omega_{pzt} = f_{pzt} \cdot 2\pi$. Also the determination of the damping constants which characterize the energy dissipation is important (e.g. determination of logarithmic decrement, damping coefficient, etc.).

The old method called “Assessment of the characteristics of the eigen oscillation of the suspension from system” has been developed more than 40 years ago. This method is usually used for determination of the frequencies and damping of basic kind of eigen oscillation of the rail vehicle suspension. It assumes the rigidity of the frame, bogie and wheel set, and also assumes symmetrical lay out of the primary and secondary suspension. Moreover, it assumes the symmetric vehicles and therefore their oscillations are not bounded with each other or any other kind of frame oscillation, or bogies etc.

The aim of the methodology is to determine frequencies of the translational or rotational movements with respect to

* Corresponding author.

E-mail addresses: soukupj@fvmt.ujep.cz (J. Soukup), jan.skocilas@fs.cvut.cz (J. Skočilas), skocilasova@fvmt.ujep.cz (B. Skočilasová).

Nomenclature		φ	angle or rotation [rad]
		η	coefficient of system tuning [dimensionless]
f	frequency [Hz]	ω	eigen angular frequency [Hz]
h	vertical position of gravity center [m]	ϑ	logarithmic decrement [dimensionless]
J	inertia moment [kg m ²]	γ	normalized amplitude [dimensionless]
k	spring characteristic [N m ⁻¹]	τ	period [s]
l	distance of the frame edge from axis [m]	Ω	resonance frequency [Hz]
L	length of frame [m]		
m	weight [kg]	Index	
o	axis of symmetry [dimensionless]	0	origin
w	displacement [m]	1,2,3,4	number of spring
x	coordinate [m]	12	axis 12
y	coordinate [m]	34	axis 34
z	coordinate [m]	78	axis 78 m – maximum
D	damping coefficient [dimensionless]	T	gravity center
F	force [N]	x, y, z	coordinate system
Q	total gravity force of frame [N]		
Y	amplitude [m]		
Greek symbols			

coordinate system with origin in the frame center of gravity. Frequency and damping are obtained from free oscillation of the system mounted into the special stand or by method so called “running over wedges”.

The spring-loaded part is deflected from its equilibrium position in the measuring stand. The time course of the frame deflection towards to bogies or fixed point of the stand is measured. The harmonic analysis is applied on the measured time courses to determine the oscillation. Then the frequency and damping are assessed.

The wedges are placed on the straight railroad when the method “running over the wedges” is applied [2]. The length of the railroad is twice of wagon length minimally. The high of the wedge is 30–35 mm and it is placed on the surface of rail. The vehicle is running over the wedges. By this method the measuring of the eigen frequencies and damping is performed. The spatial oscillation of the frame and bogie arises from various lay-out of the wedges placed under particular wheels. The separation of the swinging and rolling oscillations from wobbling oscillation is done by connection of the deflectometers into the special schemes of connection.

The dynamic model of the interaction between railway wheel and rail irregularities is given in [3]. The results of the mathematical model predicting dynamics of the wagon system is presented by time curves of dynamic forces excited by wheel contact with rail and they are compared with experiments. The work [4] brings a nice and detailed review of construction development of railway wagon together with wide range of applied simulation and modeling of the wagon dynamics from pioneer's day to present. Also only single wheel model can applied to discover the railway vehicle parameter effects on the features of Hopf bifurcation [5]. Last three references represent the contemporary research in the field of railway wagon vibration.

The number of tests repetition has to be determined with respect to preliminary analysis of the results and in dependence on the value variance. If the difference between tests is less than 10%, the optimal number of measurement is three.

The principle of the method is briefly discussed above. The methodology does not content the theoretical motivation of the procedure. The technique is presented in the following text [6].

Proposed method allows determining the basic characteristics of suspension by assessment of the eigen frequencies of elastically suspended frame. These eigen frequencies are calculated regarding relationship for eigen frequencies particular basic movement of the frame to parallel axes. The proposed method is simple (meeting the prescribed assumptions) and leads to easy and quick determination of suspension characteristic by computational and experimental methods and substitute e.g. the method running over wedges. The application of basic assumptions leads to simple formulation of the mathematical method for solution of the eigen frequencies. Presented method has limitations arise from basic assumption of rigid part of the wagon and linear characteristics of springs.

2. Solution assumptions and frequency determination

Let we assume biaxial vehicle to show the method application, see Fig. 1.

It is important to know the position of the center of gravity and main central moments of inertia of vehicle frame to assess the demanded characteristics [7].

To solve this complicated problem several assumptions, have to be given: vehicle frame, bogies, and wheel sets are rigid

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