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MODIFIED APPROACH TO COMPUTER SIMULATIONS OF THE COAL WAGON LABORATORY KINEMATIC EXCITATION

MODIFIKOVANÝ PŘÍSTUP K POČÍTAČOVÝM SIMULACÍM LABORATORNÍHO KINEMATICKÉHO BUZENÍ NÁKLADNÍHO ŽELEZNIČNÍHO VAGONU

Abstract

Multibody models of the MGR Coal Hopper HAA goods wagon were created using the SIMPACK simulation tool. They are intended for the laboratory tests simulations performed on the test stand in the Dynamic Testing Laboratory ŠKODA VÝZKUM s.r.o. With multibody models it is possible to simulate the laboratory kinematic excitation of wagon wheels. The aim of the laboratory tests and computer simulations is especially to evaluate the impact of using two-leaf composite springs of the wagon suspension instead of five-leaf parabolic steel ones on the monitored dynamic quantities. This paper deals with the improvement of the leaf springs model in the coal wagon multibody models.

Abstrakt

V prostředí software SIMPACK byly vytvořeny multibody modely nákladního železničního vagonu MGR Coal Hopper HAA určené pro simulace laboratorních zkoušek provedených v Dynamické zkušebně ŠKODA VÝZKUM s.r.o. S multibody modely je možné simulovat laboratorní kinematické buzení kol vagonu. Cílem laboratorních zkoušek a počítačových simulací je především posouzení vlivu použití dvoulistových kompozitních pružin vypružení vagonu místo pětilistových parabolických ocelových na sledované dynamické veličiny. Tento příspěvek se zabývá zpřesněním modelu listových pružin v multibody modelech vagonu.

1 INTRODUCTION

Computer simulations of mechanical systems should be performed hand in hand with experimental measurements on real subjects. This paper is intended to connect the numerical and experimental investigations in the field of rail vehicle dynamics. It is focused on the kinematic excitation of a coal wagon on a test stand. In comparison with [3] another simulation tool and in comparison with [3], [4] another approach to the wagon modelling were used. The rail vehicle will be considered a multibody system consisted of rigid bodies coupled by kinematic joints.

The aim of the laboratory tests and computer simulations is the investigation of the dynamic properties of the two types of leaf springs mounted on the MGR Coal Hopper HAA two-axle open goods wagon (Fig. 1). The standard type of utilized leaf springs is a parabolic steel one (see Fig. 2). These springs have some undesirable properties such as corrosion of leaves and silting of an inter-leaf space. Therefore it can be efficient to substitute them by composite leaf springs (see Fig. 2) of better properties.

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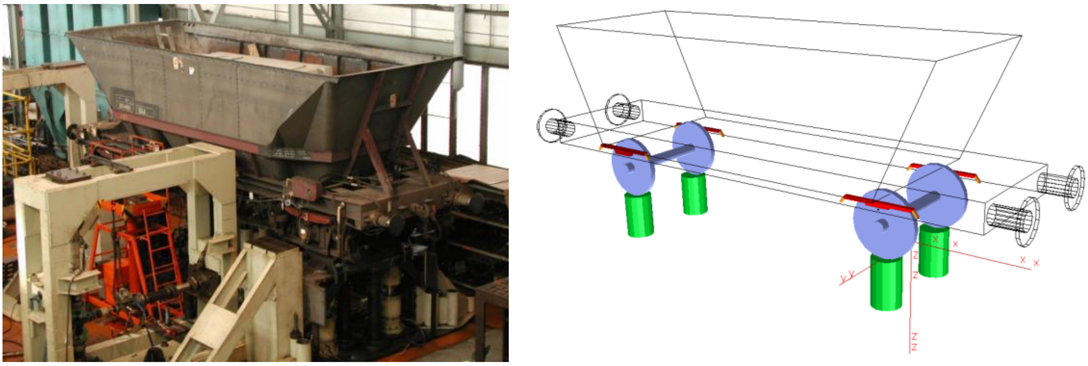

Fig. 1 The MGR Coal Hopper HAA wagon on the test stand in the Dynamic Testing Laboratory ŠKODA VÝZKUM s.r.o. – the real wagon and the multibody model visualization

This paper deals with the improvement of the leaf springs model in the coal wagon multibody models (created in the SIMPACK simulation tool [6]) from the point of view of the agreement of the calculation results with the laboratory measurements results.

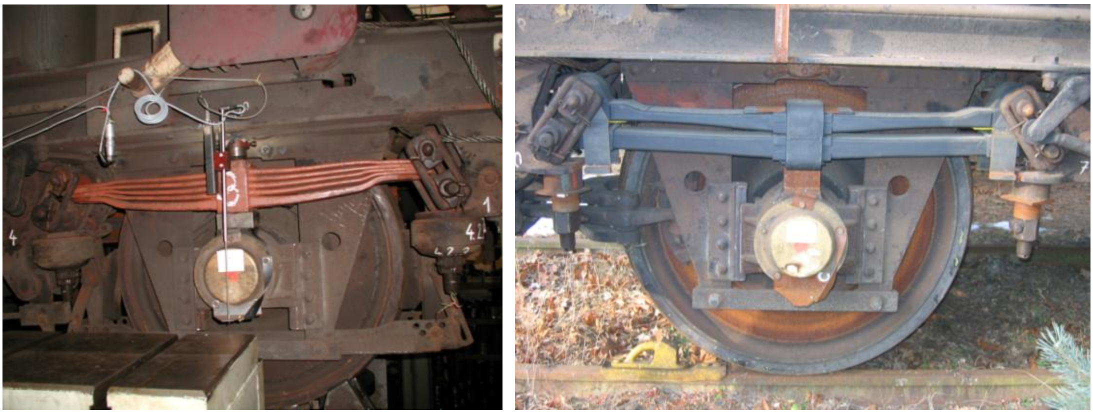

Fig. 2 The five-leaf parabolic steel spring and the two-leaf composite spring

Dynamic properties of the MGR Coal Hopper HAA goods wagon were investigated on the computer controlled Instron Schenck electrohydraulic loading system in the Dynamic Testing Laboratory ŠKODA VÝZKUM s.r.o. [5]. The wagon wheels were excited kinematically by the loading servo valves. The wagon was subjected to several loading modes on the test stand. The wagon natural frequencies and natural mode shapes were identified during the kinematic excitation of the wheels by a wideband sweep signal in vertical direction ("sweep test"). The wheels were excited by loading servo valves in phase ("bump test") or out of phase ("roll test").

2 MULTIBODY MODEL DESCRIPTION

The multibody models of the MGR Coal Hopper HAA wagon (see Fig. 1) were created mainly on the basis of [1], [5].

The multibody model consists of 20 bodies (including frame = laboratory stand, without dummy bodies) connected by 19 kinematic joints. Considering the aim of the modelling, the wagon body can be represented by one rigid body, which has six degrees of freedom with respect to the frame. The laboratory stand is considered to be the rigid reference frame. The front and rear wheelsets are connected with the frame using special user defined joint that allows the rotation around the *x*-axis and translation along the *z*-axis (see Fig. 1). The wagon body and the wheelsets are mutually connected by four leaf springs (two leaf springs between the wagon body and the front wheelset and two leaf springs between the wagon body and the rear wheelset).

The leaf springs are complex spatial suspension elements and they can transmit forces and torques in all three directions. Their properties are influenced by the flexibility of the leaves, by contact and friction forces between the leaves and between chain links (shackles) and by other operational conditions. Various types of the leaf spring models in the framework of multibody models are described in [2]. The methodology based on the artificial division of the leaf spring into several rigid bodies connected by joints with imposed artificial stiffnesses is used in the wagon multibody models. The stiffness and damping characteristics of the leaf spring model are determined by the force elements introduced between the chosen bodies of the substructure. In order to catch the flexible bending behaviour the bending torques are defined in spherical joints using stiffness and damping coefficients. Additionally friction force elements (torques) are defined in the chosen joints because the friction has an important influence in the leaf springs modelling.

The contact between the wheels and the loading servo valves was modelled by a contact force with defined stiffness and damping. With multibody models it is possible to simulate the laboratory kinematic excitation of the wagon wheels, which corresponds to the chosen real loading states performed on the test stand.

3 LEAF SPRING CHARACTERISTICS TUNING

The stiffness and damping characteristics of the leaf spring model in multibody models of the MGR Coal Hopper HAA wagon were tuned in such a way, that computed relative displacements between the wheels and the wagon body at the “sweep bump test” (vertical displacements amplitudes on front wheels of A = 0.5 mm) were equal to the experimentally measured ones (see Fig. 3). The relative displacements of the empty wagon with the five-leaf parabolic steel springs of the front suspension and the two-leaf composite springs of the rear suspension were utilized.

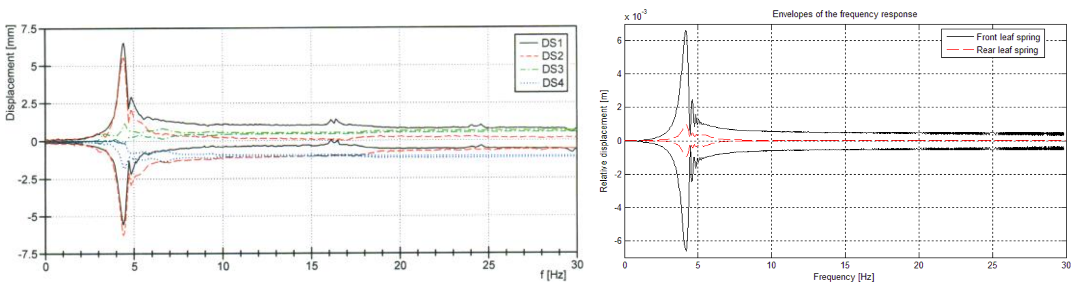

Fig. 3 Envelopes of the experimentally measured and computed relative displacements between the wheels and the wagon body of the empty wagon (with the five-leaf parabolic steel springs of the front suspension and the two-leaf composite springs of the rear suspension) at the “sweep bump test” and the vertical displacements amplitudes on the front wheels of A = 0.5 mm (DS1 – front left wheel, DS2 – front right wheel, DS3 – rear left wheel, DS4 – rear right wheel)

4 RESULTS

Verification of the stiffness and the damping characteristics used in the leaf spring model of the MGR Coal Hopper HAA wagon was performed by means of the simulation of the “sweep roll test” at the vertical displacements amplitudes on the front wheels of A = 0.5 mm. The compared quantities were the computed relative displacements between the wheels and the wagon body of the empty wagon with the five-leaf parabolic steel springs of the front suspension and the two-leaf composite springs of the rear suspension and experimentally measured displacements.

On the basis of the simulation analyses it was verified that selection of the stiffness and the damping characteristics used in the leaf spring model, which leads to the identical results of the experimentally measured and computed relative displacements at the “sweep bump test” (see Fig. 3), is not unique. The significant friction and the damping effect at the “roll test” cannot be found at the “bump test” and therefore it was not possible to tune all the necessary leaf spring characteristics. Due to the lack of time a new tuning of the stiffness and the damping characteristics used in the leaf spring model of the MGR Coal Hopper HAA wagon has not been performed yet. In the characteristics not only results of the “bump test” but also results of the “roll test” would be taken into account. However it is evident that contrary to [3] and [4] the suitable approach to the modelling of the leaf springs, at which vertical dynamic characteristics are not known, was chosen.

5 CONCLUSIONS

The influence of using the composite leaf springs instead of the original parabolic steel leaf springs on the dynamic qualities of the MGR Coal Hopper HAA wagon was examined during the laboratory tests on the test stand in the Dynamic Testing Laboratory ŠKODA VÝZKUM s.r.o. The multibody models of the wagon were created in the SIMPACK simulation tool. With the existing multibody models it is possible to simulate the laboratory kinematic wheels excitation, which corresponds to the loading modes performed on the test stand.

The presented multibody models are the third approximation (the first approximation was presented in [3], the second one in [4]) of the computational wagon models, intended for the dynamic quantities investigation, to the real rail vehicle. Contrary to [3] and [4] new approach to the modelling of leaf springs used in the MGR Coal Hopper HAA wagon was chosen. In the nearest future it is planned to improve the used approach to the leaf spring model more thoroughly.

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