Simulation of Railway Vehicles and Bridge Interaction

Gennady Mikheev
Laboratory of Computational Mechanics
Bryansk State Technical University
bulv. 50-let Oktyabrya 7, 241035, Bryansk, Russia
e-mail: gmikheev@mail.ru

EXTENDED ABSTRACT

1 Introduction

The present paper describes the CAE-based approach for analysis of dynamics and stress state of parts of mechanical systems. The approach is being implemented in Universal Mechanism (UM) software. Object of researches is considered as rigid-flexible multibody system. Dynamics of flexible bodies is simulated using data imported from finite element analysis (FEA) software. An application of the approach to the investigation of dynamics of a railway vehicle and a bridge is considered taking into account flexibility of the bridge.

2 Equations of Motion of a Flexible Body

Equations of motion of a flexible body are derived using floating frame of reference method [1]. Linear flexible displacements of the body are described by component mode synthesis method [2, 3]. According to this method, flexible displacements are approximated by a sum of modes:

$$\mathbf{u} = \sum_j \mathbf{h}_j w_j = \mathbf{H}\mathbf{w},$$

where $\mathbf{u}$ is a matrix-column of nodal degrees of freedom of the flexible body, $\mathbf{h}_j$ is a matrix-column of the mode, w_j is a modal coordinate which defines flexible displacements corresponding to the mode with number j.

Modes of flexible body are calculated by external FEA program and imported to UM software. Subsystem technique is used for including a flexible body into a multibody system [4].

The idea that flexible displacements of a body can be represented by the sum of a number of mode shapes, scaled by modal coordinates, can be extended to stresses in the body as well. Modal coordinates can be used as the scaling factors on the stress solution of each mode shape and the superposition of these scaled stresses represents the body’s stress state instantaneous. If the superposition is performed at selected nodes of the finite element model for every time step in the UM solution, the stress time history is defined at their location.

3 Simulation of a Rail-Bridge Interaction

A flexible body interacts with other bodies of a multibody system via joints and force elements. Joint points and points of force elements connections usually locate at nodes of finite element model of the flexible body. Such approach can not be applied to simulation of interaction of a railway vehicle with a flexible bridge. In UM software a rail is modeled as a massless visco-elastic force element (see Fig. 1).

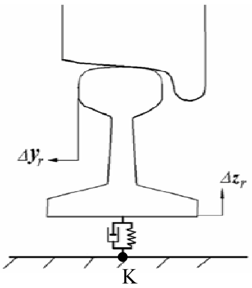

Figure 1. Model of rail.

Transversal Δy_r and vertical Δz_r deflections of the rail as well as their time derivatives depend on location and speed of point K of the force element attachment to ground. Rotation of the rail around a longitudinal axis is not taken into account.

If a rail lies on a flexible bridge, total rail stiffness (displacements) is obtained as a sum of stiffness between the rail and the bridge (sleepers, roadbed and so on) and stiffness (displacements) of a flexible bridge itself (see Fig. 2). During integration of equation of motion, position of point K is defined by position of wheel. Therefore, it is necessary to compute position and speed of any point on surface of a flexible bridge as well as to apply calculated force to any point on a surface.

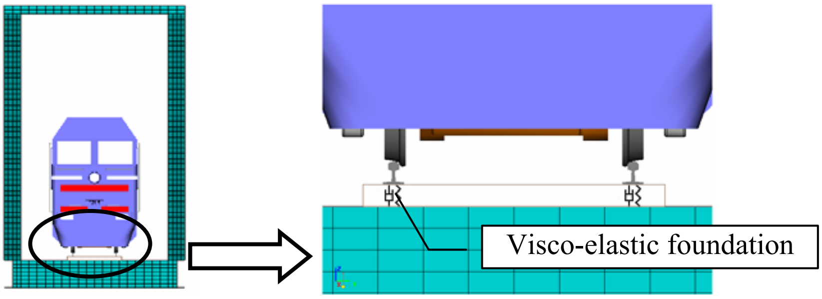

Figure 2. Model of interaction of a railway vehicle with a flexible bridge.

A simple algorithm for simultion of rail-bridge interaction is considered in this paper. A control area consists of surface polygons of finite element model of the bridge is created around rail-wheel contact point. Position and speed of the point K are calculated as linear interpolation of the corresponding values of nearest nodes of the control area. Interaction forces are also distributed between the nearest nodes.

4. Applications

UM software includes tools for simulation of railway vehicles of all types: diesel and electric locomotives, freight and passenger cars, as well as special railway vehicles. It can be simulated as rigid or rigid-flexible multibody systems. The railway bridge is included into a model as a flexible subsystem. An example of a ivestigated object is presented in Fig. 3.

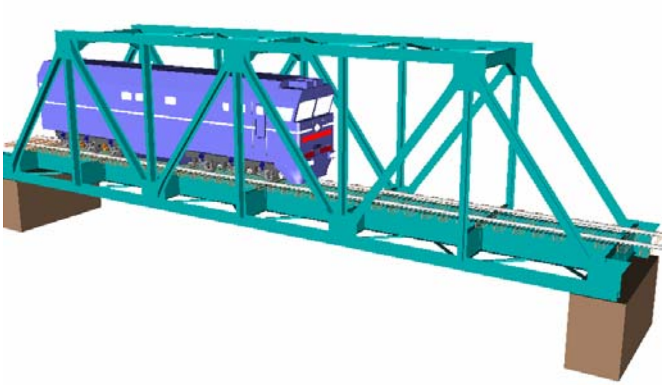

Figure 3. Simulation of locomotive motion on the flexible bridge.

5 Conclusions

The proposed approach allows detailed analysis of a vehicle-bridge interaction taking into account flexibility of a bridge.

Acknowledgements

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