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Multibody dynamics simulations of the railway vehicle for heavy loads transport

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Numerical simulations are efficiently used for the evaluation of the design of various mechanical systems in pre-production states. Since the railway industry is very strictly controlled by various standards and codes, the usage of computational models to verify proposed vehicle design according to standards is quite convenient. This paper is aimed at the description of the evaluation process for a special purposed 32-axle wagon (see Figs. 1 and 2) intended for carrying large size and heavy loads.

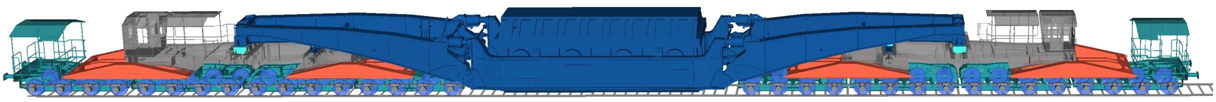

Fig. 1. Visualization of the whole wagon multibody model in the SIMPACK software

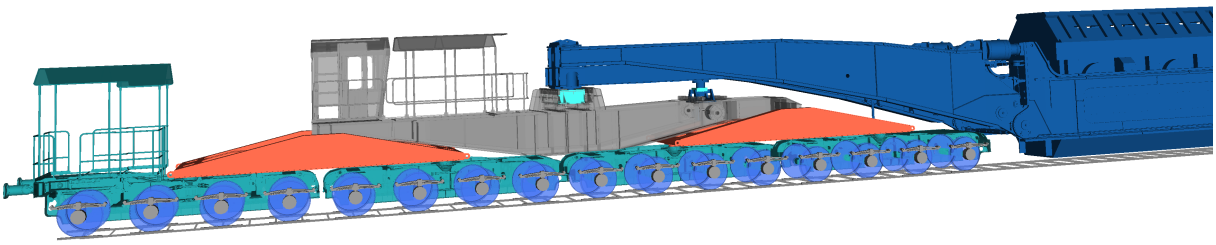

Fig. 2. Visualization of the rear wagon section with two small bridges (red bodies) and one large bridge (gray body) and half of the main bridge with payload

Railway vehicles are typical representatives of multibody systems that are composed of kinematically constrained bodies [2]. The SIMPACK software was used as the main software tool in this modelling task. The modelling methodology is based on the vehicle decomposition into particular design elements characterized as rigid bodies. Except for particular bogies (each with four wheelsets), the modelled wagon is designed with several functional components called bridges carrying payload. The wagon multibody model contains these main rigid bodies: 32 wheelsets, 8 bogie frames, 4 small bridges, 2 large bridges, and 1 main bridge (+payload and/or platforms), see Fig. 3 for the kinematical scheme of the whole model.

The SIMPACK multibody formalism is formulated for relative coordinates between bodies, and therefore each rigid body has exactly one kinematical joint. Other kinematical relations are represented by so-called constraints. Several bodies, which form a functional group and are

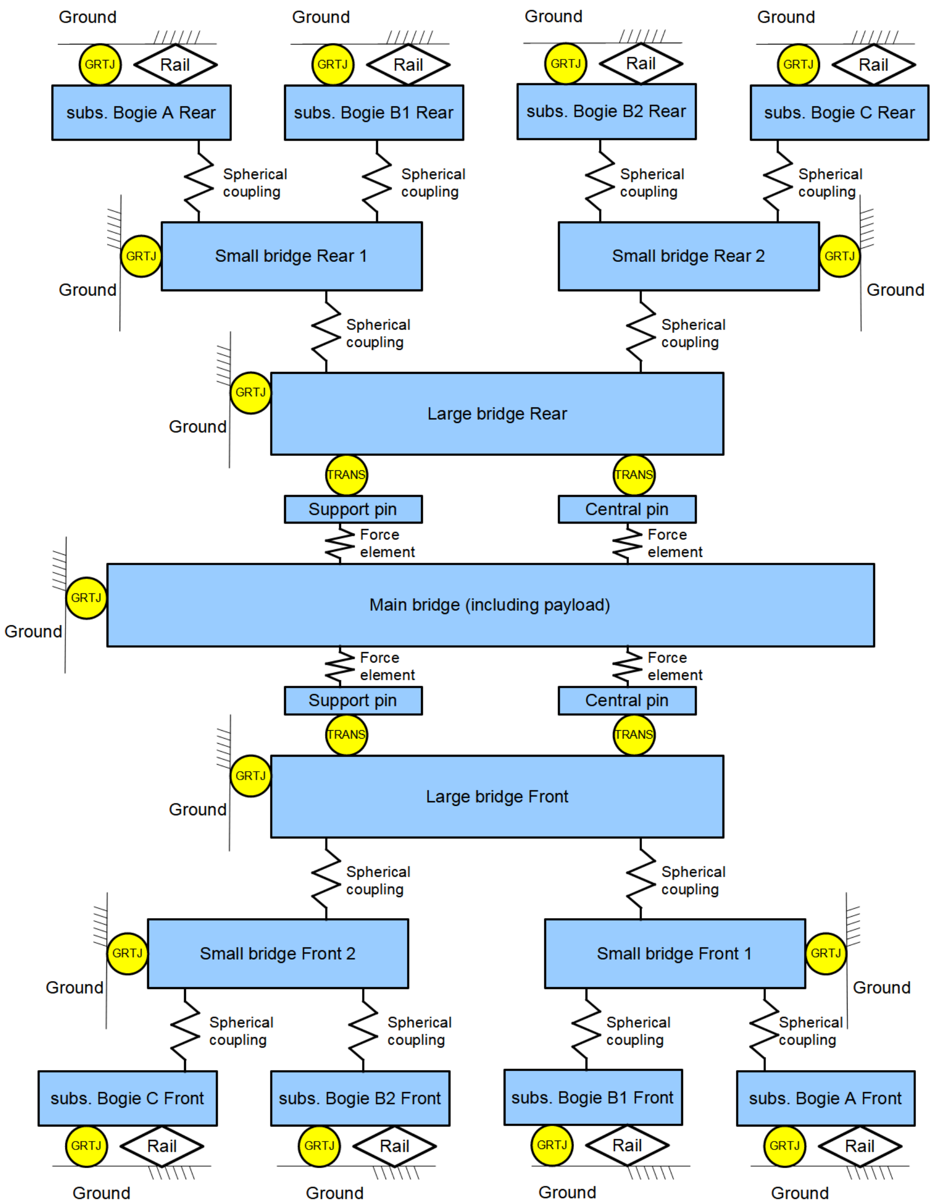

Fig. 3. Kinematical scheme of the wagon multibody model

repeated in the model, could be set as substructures. There are bogie substructures, composed of a rigid body representing a bogie frame and four wheelset substructures. The bogie frame and wheelset bearings are connected by force elements representing leaf springs [3]. Each wheelset substructure contains the wheelset represented by one rigid body with six degrees of freedom and coupled with the ground (basic frame) by so-called General Rail Track joint (GRTJ) related to a defined track. The interaction of wheels and rails is ensured by a complex rail-wheel force element, which represents spatial forces and torques between the wheel and the rail depending on the wheel-rail design parameters and model kinematical variables.

Each two bogies are mutually joined with one small bridge (as it was already mentioned, 4 small bridges in total). The bogies and the bridge are connected using bushing force elements, that substitute real spherical joints. Analogously, each two small bridges are mutually joined with one large bridge (as it was already mentioned, 2 large bridges in total). The last mentioned design element of the wagon is the main bridge carrying possible a payload. The connection of the main bridge and the large bridges is realized using movable support and central pins.

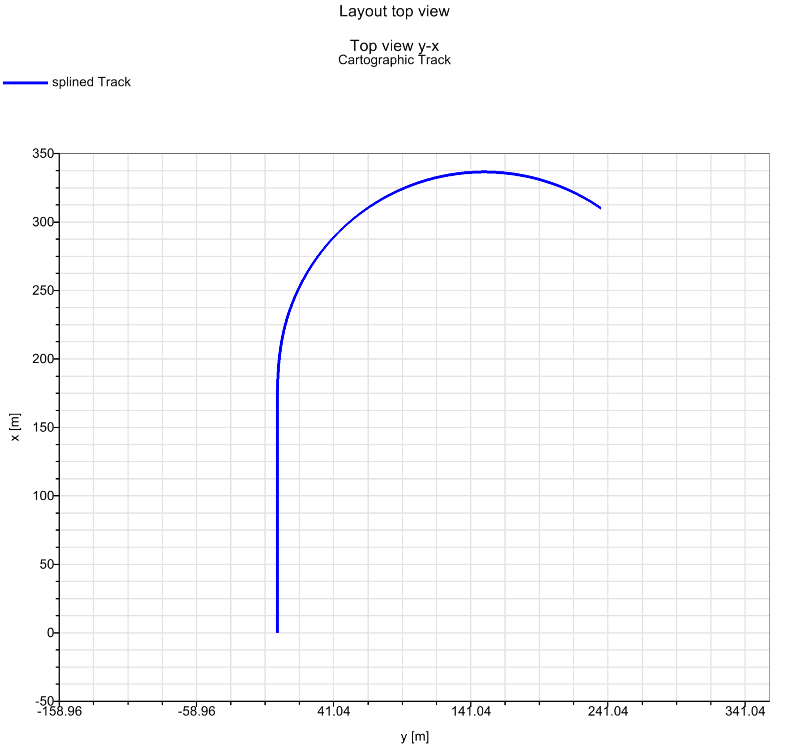

Fig. 4. Twisted track definition — top view

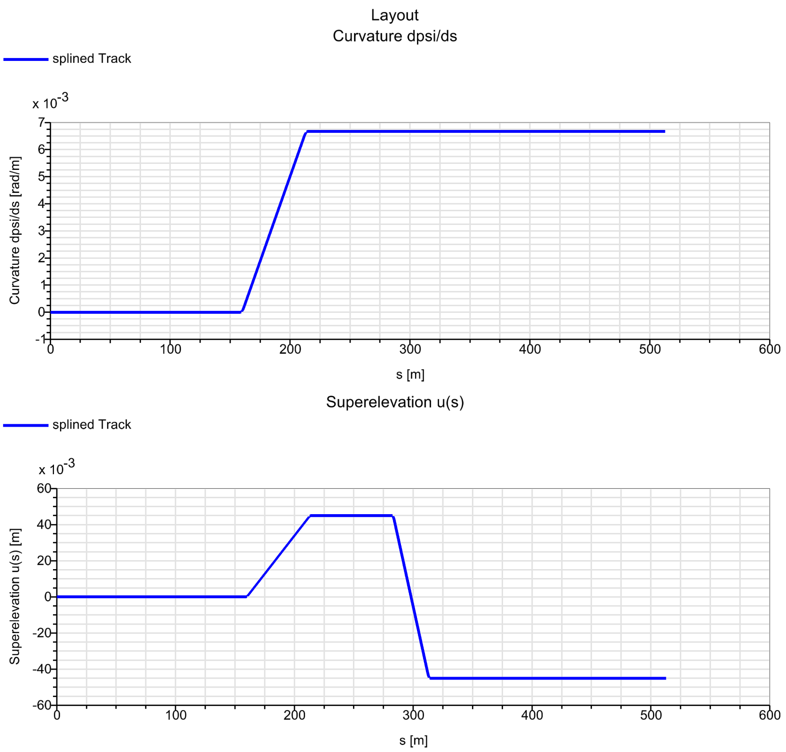

Fig. 5. Twisted track definition — curvature and superelevation

Fig. 6. Time history of the wheel lift on the leading wheelset when running through the twisted track

The computational multibody model of the wagon was implemented to perform various numerical simulations prescribed in railway standards. The main code utilized for railway vehicles is EN 14363 standard "Railway applications – Testing and simulation for the acceptance of running characteristics of railway vehicles – Running behaviour and stationary tests" [1]. At first, the running of the wagon on a straight track by various velocities was numerically simulated. It was followed by linearized modal analysis to investigate stability properties. The extensive set of numerical simulations was dedicated to running on tracks with prescribed curvature and given velocity. All tests were evaluated based on the standard using derailment coefficient and wheel lateral forces. EN 14363 standard prescribes three possible methods [4] how to evaluate the safety against derailment for railway vehicles running on a twisted track. Method 1 from the standard was chosen as the evaluation method. It is based on the vehicle slowly running on a twisted track with a 150 m radius (see Figs. 4 and 5), while the assessment criterion is the outer wheel lift of the leading wheelset which has to be under 5 mm (see Fig. 6 for illustrative results).

Acknowledgement

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