# THE RUNNING BEHAVIOUR OF AN ELASTIC WHEELSET

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Summary The dynamic behaviour of a railway passenger coach running on a straight track is investigated with special respect to the structural elasticities of the wheelsets and the rails. The vehicle and the track are coupled by a nonlinear wheel-rail contact.
The simulations are performed with and without taking into account the structural elasticities of the wheelsets and the rails. Comparisons of these results show a strong influence of the structural elasticities.

## FORMULATION OF THE PROBLEM

To simulate the running behaviour of a railway vehicle, the wheelsets are usually considered as rigid bodies; this modelling is regarded to be sufficient for the low frequency-range below about 50 Hz. The wheel-rail contact is however very sensitive to even small relative motions of wheel and rail; so the question arises, whether deformations of the wheelsets can influence the contact and thereby the running behaviour of the entire vehicle.
Beyond a certain travelling speed, the so called critical speed, a limit cycle of the wheelsets occurs; this is called "hunting motion". Since this motion can lead to dangerous operational states, its occurence has to be avoided in regular operation by a proper mechanical design of the vehicle. Because a proper design requires reliable simulations, the influence of structural elasticities of the wheelsets and also of the rails on the simulation results is investigated.

## MODELING OF THE SYSTEM

The entire system representing a railway vehicle running on a straight track is split up into three subsystems, as shown in Fig. 1. The characteristics of the subsystems are described in the following.

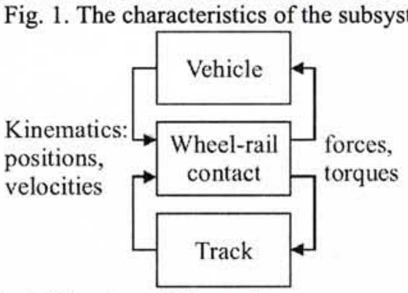


Fig. 1: Structure of the system consisting of subsystems

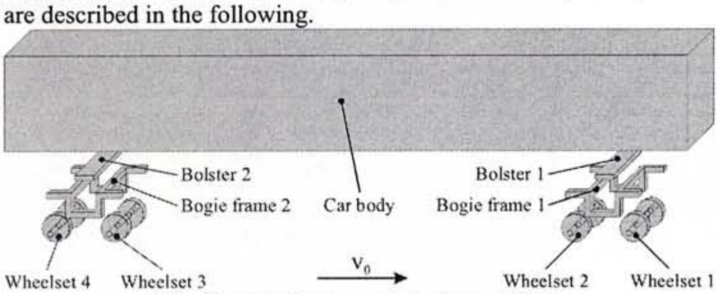


Fig. 2: Multi-body model of the vehicle

### Subsystem "Vehicle"

The subsystem "Vehicle" represents a common european railway passenger coach consisting of a car body and two bogies, each equipped with two wheelsets, cp. Fig. 2.
The bodies are connected by linear visco-elastic elements except the pivot between the car body and the bolsters, where a nonlinear force element using dry friction acts. While the car body, the bolsters and the bogie frames are considered as rigid bodies, the four wheelsets are modelled as elastic bodies by superposing the rigid body motions and the deformations, which are described by a modal synthesis. The shape functions required by the modal synthesis are the eigenmodes of the free wheelset obtained by a Finite Element analysis. Fig. 3 shows two flexural eigenmodes.

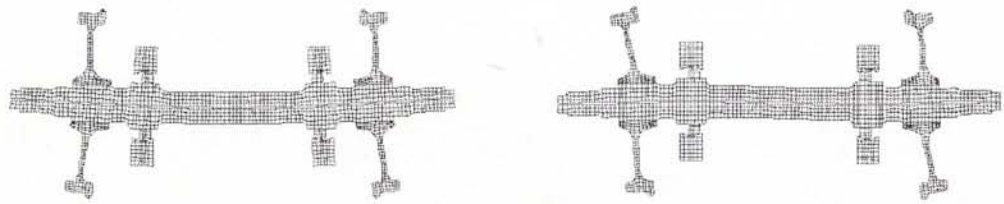

Fig. 3: Eigenmodes of the wheelset.
Left: Symmetric flexural eigenmode (84,2 Hz), right: Antimetric flexural eigenmode (147,2 Hz).

The eigenmodes are calculated for the non-rotating wheelset. Gyroscopic effects resulting from the rolling motion of the wheelsets are taken into account by additional terms. For the description of the rotating wheelsets, an Arbitrary Lagrangian-Eulerian approach is used providing a very simple mathematical structure of the model.

**Subsystem "Wheel-rail contact"**

The wheel-rail contact is a force element, which is nonlinear in two ways: Firstly, the contact geometry is nonlinear, i.e. the location where the contact forces act depends in a nonlinear way on the relative position of wheel and rail. Secondly, the relations between relative motions and the forces are nonlinear. The coupling of the subsystem "wheel-rail contact" to the other subsystems is performed by an interchange of kinematics and forces at invariant nodes, so that the shifting of the contact area is performed within the subsystem "wheel-rail contact", cp. Fig. 4.

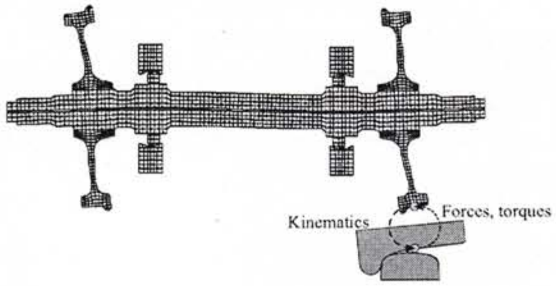


Fig. 4: Coupling of the subsystems

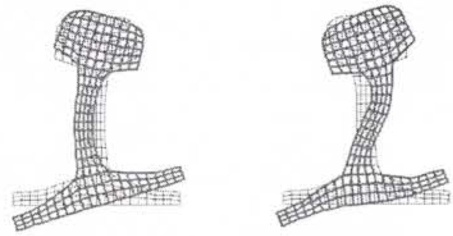

Fig. 5: Deformations of the cross section of the rail

**Subsystem "Track"**

The subsystem "track" consists of two rails with a continuous support representing the fastenings, the sleepers and the underground. Since the foot of the rail is fastened to the sleeper and the web of the rail is thin compared to the head, deformations of the cross section of the rails are taken into account. Therefore, the cross section is discretized by Finite Elements. This provides further deformations as shown in Fig. 5, additionally to the usual flexural or torsional deformations.

## SIMULATION RESULTS

To investigate the influence of the structural flexibility on the running behaviour, different calculations are performed, in which the elasticities of the wheelsets and the track are taken into account or neglected. As an example, the lateral motion of the center of mass of the first wheelset during hunting at $v_0 = 350$ km/h is investigated. Fig. 6 shows the corresponding phase portraits.

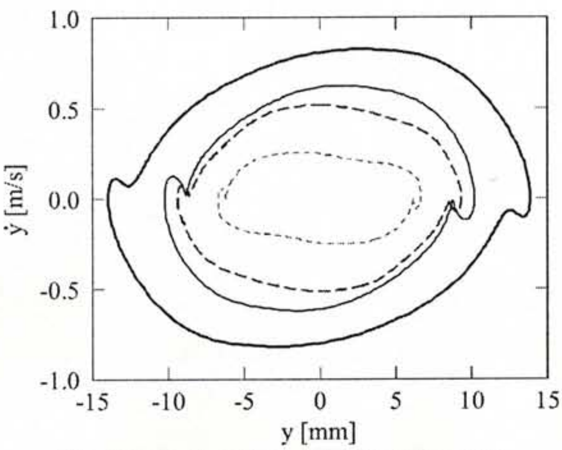


Fig. 6: Lateral motions of the first wheelset.
Thin line: Rigid wheelset, thick line: Elastic wheelset, broken line: Rigid track, full line: Elastic track.

The structural flexibility of the wheelsets and the track leads to distinctly larger amplitudes. Furthermore, the curve for the rigid wheelset on the rigid track is "flattened" at its left and right side; this results from the wheel flange hitting the rail head. Taking into account the structural flexibility leads to smoother curves, because the elastic wheelsets and the elastic track act as springs which are softer than the stiff wheel-rail contact.

Further calculations show, that these elasticities also cause a drop of the critical speed. While the hunting motion of a rigid wheelset on a rigid track starts at $v_0 = 341$ km/h, this motion already occurs at $v_0 = 282$ km/h for an elastic wheelset on an elastic track. This distinct difference may also be of technical interest for the design of a railway vehicle.