# Multidisciplinary Coupling Approach for Dynamic Response Analysis of Maglev Trains using Panel Aerodynamics

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## Introduction

With the development of high-speed maglev trains, design is faced with the challenge of reducing lightweight construction and structural strength. In addition, the dynamic interaction between the train and the aerodynamic forces caused by the crosswind, passing or entering the tunnel at high speeds is a challenge for load calculation, stability, and passenger comfort, Ding et al. 2023.

This research investigates the dynamic response characteristics of high-speed trains when exposed to transient crosswind gusts. The study employs advanced multi body simulation (MBS) and panel based aerodynamic analysis to assess the impact of varying crosswind conditions on the train's dynamic behaviour, considering key factors such as train speed and car body weight in the analysis.

## Analysis

In order to analyse the coupling effects, various disciplines such as aerodynamics, vehicle dynamics model and control system must be taken into account. For this purpose, a dynamic model with the necessary interfaces for the external force excitation was created and analysed in SIMPACK. The unsteady aerodynamic forces are determined with USAERO and applied to the MBS model at each time step via the Matlab interface given in Figure 1. This approach allows the multidisciplinary extension of different boundary conditions, forcing functions or control rules to the simulations.

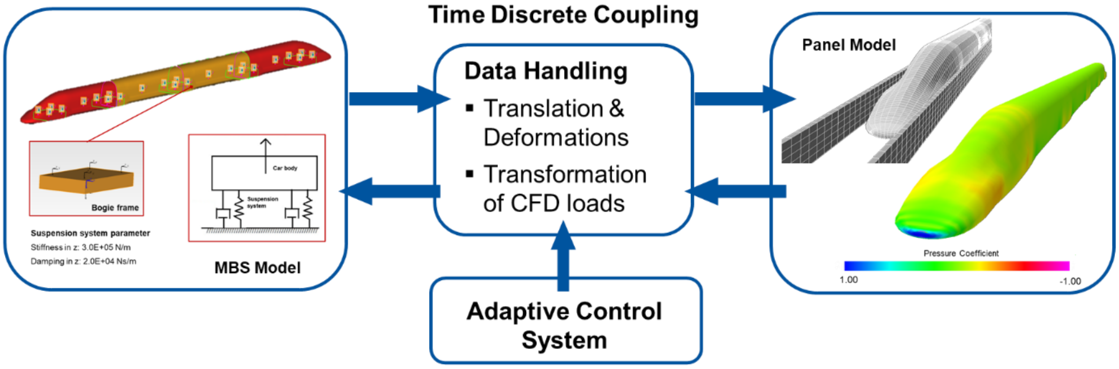

Figure 1. Multidisciplinary Coupling Approach

## Conclusions

The study provides crucial insights into the dynamic response behaviour of high-speed maglev trains, by using advanced simulations technique and considering different gust profiles. The results emphasis the complex interplay between aerodynamics and structural dynamics and help to improve the safety and stability of maglev trains, to provide valuable design principles and operational considerations under transient crosswind conditions.

## References

Ding X., Chang C., Ling L. et al., Mechanism analysis of low-frequency swaying motion of high-speed trains induced by aerodynamic loads, Journal of Vibration and Control, 2023.

# Multi-Body Dynamic Fault Simulation in Primary Suspension Systems and Convolutional Neural Network based Diagnosis

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## Introduction

It has been realised over previous five years, that 75–85% rail accidents are due to manual inspection errors. It emphasizes the need for real-time detection of bogie component failures. This study aims to create a dynamic model of a railway coach with 57 degrees of freedom, incorporating the car-body, bolster, bogie frames, and suspension elements and do simulations for fault diagnosis. A finite element model is developed and sub-structured to retain vibration shapes with fewer super-elements. Track irregularities data is obtained from track inspection reports. Rail-wheel contacts are modeled through Hertzian contact theory and FASTSIM is used to estimate rail-wheel interaction forces. Acceleration responses at 120 km/h are obtained from selected nodes. Faulty suspension is treated as the deterioration of equivalent parameters outside of acceptable values, with diagnosis focused on spring and damping parameters, categorized into three levels (normal, moderately deteriorated, highly deteriorated) with five consolidated fault conditions.

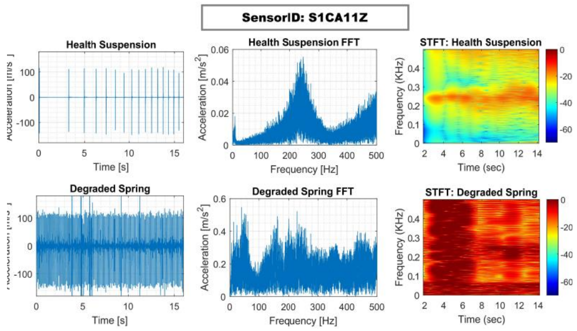

Figure 1. Time domain, Frequency spectrum and STFT of healthy Suspension and Degraded spring case

The STFT spectrogram, shown in Figure 1, is treated as an image and utilized in a deep learning network for diagnosing anomalies in vibration signatures. The network includes an-input layer with 37 neurons representing features and an-output layer with 5 neurons for output features. 'ReLU' activation functions are applied to all hidden layers, and the 'SoftMax' activation function is employed for the output layer.

## Conclusions

Using a Convolutional Neural Network (CNN) architecture, the model is fine-tuned via hyperparameter optimization to enhance prediction accuracy. For the designed CNN model, the incorporated faults have been identified satisfactorily.

## References

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# Improved control system of active wheelset steering in turnouts with preview

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Active wheelset steering is the mechatronic running gear solution to overcome the trade-off between curving performance and stability of passive railway vehicles. This active system has the potential to improve curving performance and thus reduce wheel and rail wear. However, the turnouts, including switches and crossings, might deteriorate the control system performance as their track geometry has tight curvature and lacks a smooth transition curve. Therefore, this study aims to investigate the effect of turnouts on the control system of active wheelset steering and vehicle performance. Subsequently, the improvement of a control system for active wheelset steering is proposed utilizing a preview and supervision system. A conventional railway vehicle with two two-axle bogies is implemented in this study. The Swedish 60E1-R760-1:5 turnout geometry is selected to use as a case study. The simplified turnout geometry in a diverging route is modeled as an s-curve. Figure 1 shows the control system for the active wheelset steering in turnouts supervised by a preview scheme.

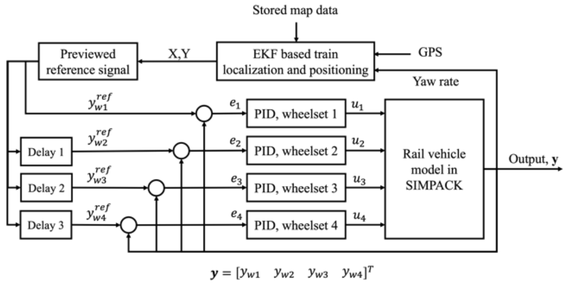

Figure 1 Control system for active wheelset steering with preview

The results reveal that control performance in turnouts is worsened as step responses of the PID controller exhibit delay and overshoot. This affects vehicle performance targets, especially in terms of wear number. The overshoot and delay lead to peaks in wheel-rail wear in the switch rail and crossing nose. The concentrated wear in these sections causes the infrastructure maintenance to remain unimproved and imposes a limitation on active wheelset steering in operations. The control system with a preview scheme is proposed to allow the controller to respond to the track inputs without delay.

**Keywords:** Active wheelset steering; Switches and crossings; Control system with preview

# Running Dynamics of the Self-Steering Single-Axle Running Gear

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## Introduction

The EEF (German for Einzelrad-Einzel-Fahrwerk) is a single-axle running gear with independent wheels invented by Frederich (1985) and produced by DUEWAG for low-floor tramway vehicles. It is characterized by a special wheel mount, which allows the wheels to swivel around individual vertical axes located at the outer side of the wheels, see Figure 1. Thus, the wheels are supposed to align themselves tangentially to the rails by the geometrical lateral wheel/rail forces. However, the running performance of the EEF is not satisfactory, resulting in its disappearance from the market. An oscillation similar to the hunting motion of a wheelset can be observed, cf. Michitsuji (2019). It is characterized by swiveling wheels. Therefore, a sensitivity analysis of various design parameters on the running performance is conducted.

## Analysis

A single-section tram vehicle employing two EEF bogies is modeled as a multi-body system in SIMPACK. Simulations are performed on straight and curved tracks with various parameters of the pivot point distance and the steering damper. The running performance of the running gear is assessed concerning the dynamics on straight track and in curves.

## Conclusions

The vehicle model has poor self-centering behavior. Higher steering damping decreases the amplitudes of the wheel oscillation but deteriorates the passing of curves as the wheels need more time to adjust. The oscillation amplitude is also reduced by a decreased pivot point distance which allows to lower the steering damping, see Figure 2.

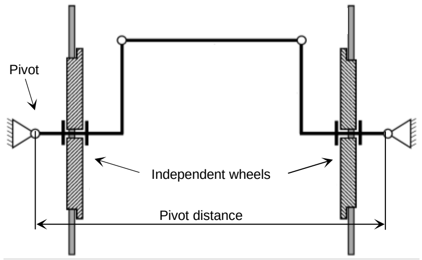

Figure 1. Principle of the EEF.

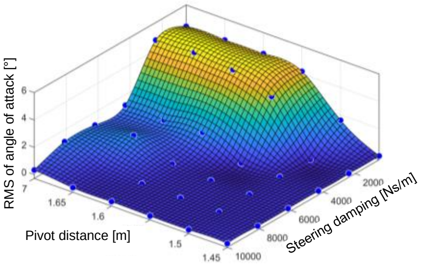

Figure 2. Paramter variation.

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Michitsuji, Y., Mizuno, K., Suda, Y., Lin, S., Makishima, S. “Curving performance evaluation of EEF bogie with inclined wheel axles using scale model vehicle”. Proceedings of the 26th Symposium of the IAVSD*,* pp. 537-540*,* 2019

# Stability of Six-Axle WDG3A Locomotive on Broad Gauge Track

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## Introduction

Three-axle bogie are more suitable for heavy locomotives and heavy haul wagons. Lateral stability for three-axle bogies is more constrained than two-axle bogies. While two-axle bogies have been studied in sufficient detail, stability studies on three-axle bogie are relatively few. In this article a parametric study of a typical six-axle railroad vehicle, WDG3A, is carried out, considering stability as the criteria. Effect of major kinematic, suspension and inertial parameters such as wheelbase, wheel radius, wheel conicity, CG location, lateral distance between suspensions, masses and stiffnesses parameters are investigated.

## Analysis and Simulation

The locomotive is modelled as a twenty-one degree of freedom system running on a broad-gauge tangent track, with gyroscopic effects included. Lateral and yaw motions are incorporated for wheelsets, while roll is additionally included for bogie frames and car body roll motions. The rail-wheel force is estimated using linear creep theory. Nonlinearities due to flange, suspension systems and clearances are not incorporated in the present study. Natural frequencies and their corresponding modes are generated by eigenvalue analysis, with sweeping the running speed up to 360 km/h; hunting modes are identified using root loci method. Critical speeds are obtained. Gyroscopic effects are included. During the hunting motion, wheelsets exhibit a combination of yaw and lateral motions, bogie frames demonstrate yaw and roll motions, while the car body primarily undergoes roll motion.

## Conclusions

It is observed that the wheelbase is the most influential factor in improving stability. The mass of a wheelset can either be increased by increasing the wheel radius or by increasing density. The mass increment due to radius enlargement improves the stability substantially, while the other way worsens it. The increase in bogie frame mass also reduces stability; however, this pattern does not hold true for the car body. Stability is very sensitive to primary lateral stiffness up to a critical value. This sensitiveness is due to the change in hunting mode, the car body yaw oscillation transitioning into roll oscillation.

## References

V. Garg, G. Martin, P. Hartmann, J. Tolomei, Locomotive truck hunting model. Technical documentation, Technical Report, 1976.