Field-based assessment of rail fixations behaviour under torsional loads

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Introduction

Digital twins and superstructure simulations are increasingly used to understand and optimize the performance of railway components. These tools can predict how operational or structural variations impact the system, such as changes in axle weight or component wear. However, the accuracy of these simulations relies heavily on proper parameterization and validation using field data. While equivalent vertical stiffness is often included in multi-body models, torsional stiffness of rail fixations is frequently neglected. This oversight is significant because torsional fixation stiffness influences rail tilting, which in turn affects wheel-rail contact mechanics [1]. This study addresses this gap by investigating the torsional fixation stiffness using in-field measurements and shows the variation of applied torque during normal operation.

Experimental work

To investigate the torsional behavior of rail fixations, sections of operational railway track were instrumented with strain gauges and displacement sensors. Strain gauges were installed to measure shear strains, allowing calculation of torsional moments over individual sleepers. A custom loading device applied defined lateral forces inducing therefore a torque to the rail, and the resulting tilt was recorded using displacement sensors. These measurements enabled direct calculation of the torsional stiffness of the used fixation.

Additionally, a field campaign was conducted in a curve with a radius of approximately 400 m, capturing torsional moments from numerous train passages with varying wheel loads. This allowed the torque behavior under realistic traffic conditions to be assessed across a broad operational range.

The combination of controlled stiffness measurements and in-service torque data provided a basis for evaluating the performance of simulation models and digital twins of other project partners.

Figure 1: Overview of measurement site in 400m radius curve

Results

Lateral forces were applied to the rail while tilt was recorded using displacement sensors. The resulting torsional moments are shown in Figure 2. The relationship is clearly nonlinear, indicating a reduction in fixation stiffness at higher tilt levels.

In the 400 m radius curve, torsional moments induced by individual wheels during regular train operations were recorded and are presented in Figure 3. While higher axle loads tended to produce greater torque, a substantial amount of scatter was observed. This variability highlights the complex interaction between vehicle and track. Influencing factors include axle load, speed, curving behavior, superelevation, and local variations in track stiffness.

Rather than treating torque as a standalone predictive quantity, the results emphasize the value of detailed field measurements for accurate model parameterization. Incorporating torsional stiffness into simulations improves the representation of rail tilt, which directly affects track gauge and wheel–rail contact conditions. This leads to more realistic and reliable modeling outcomes.

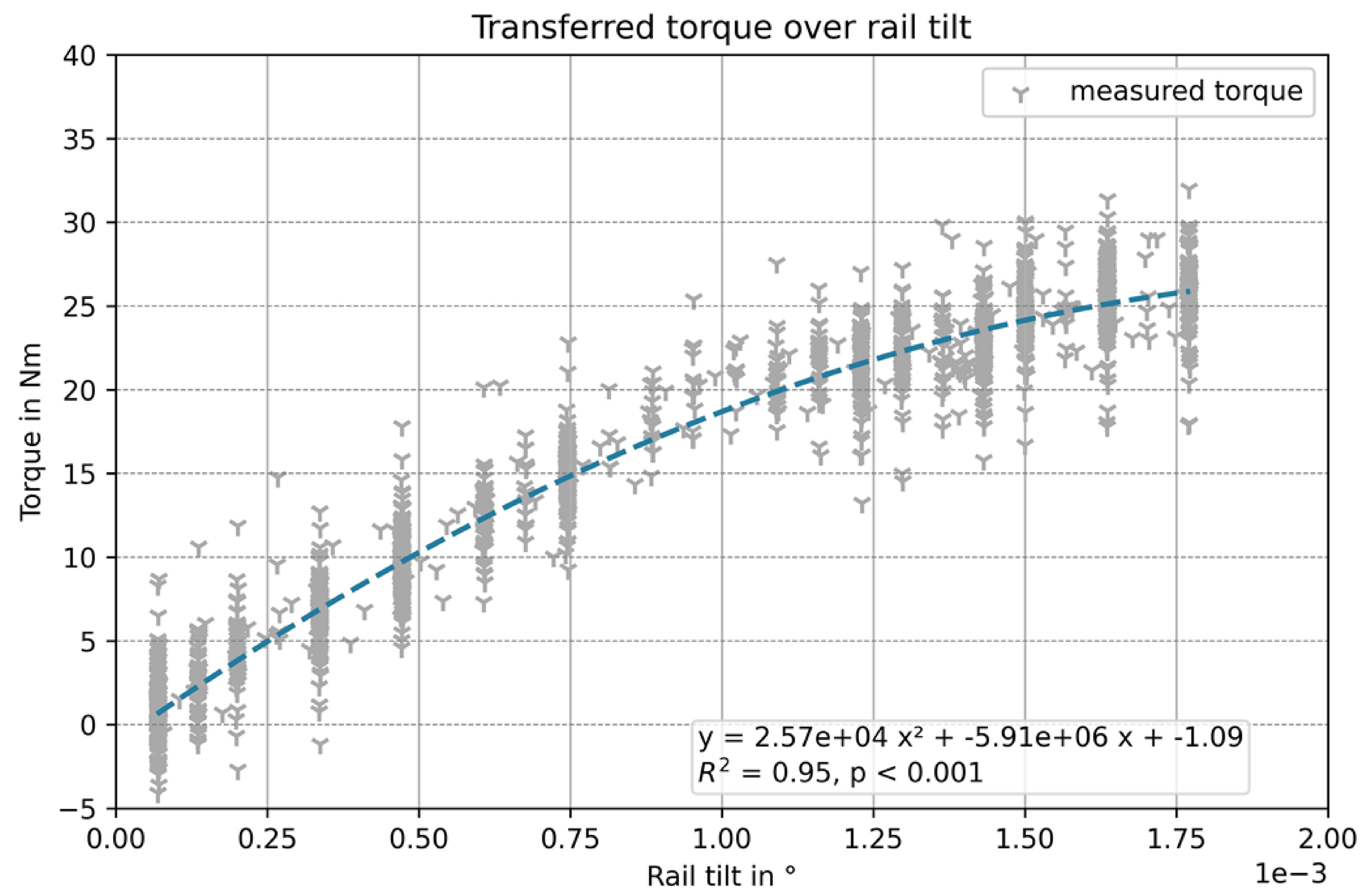

Figure 2: Torque transferred through a single rail seat

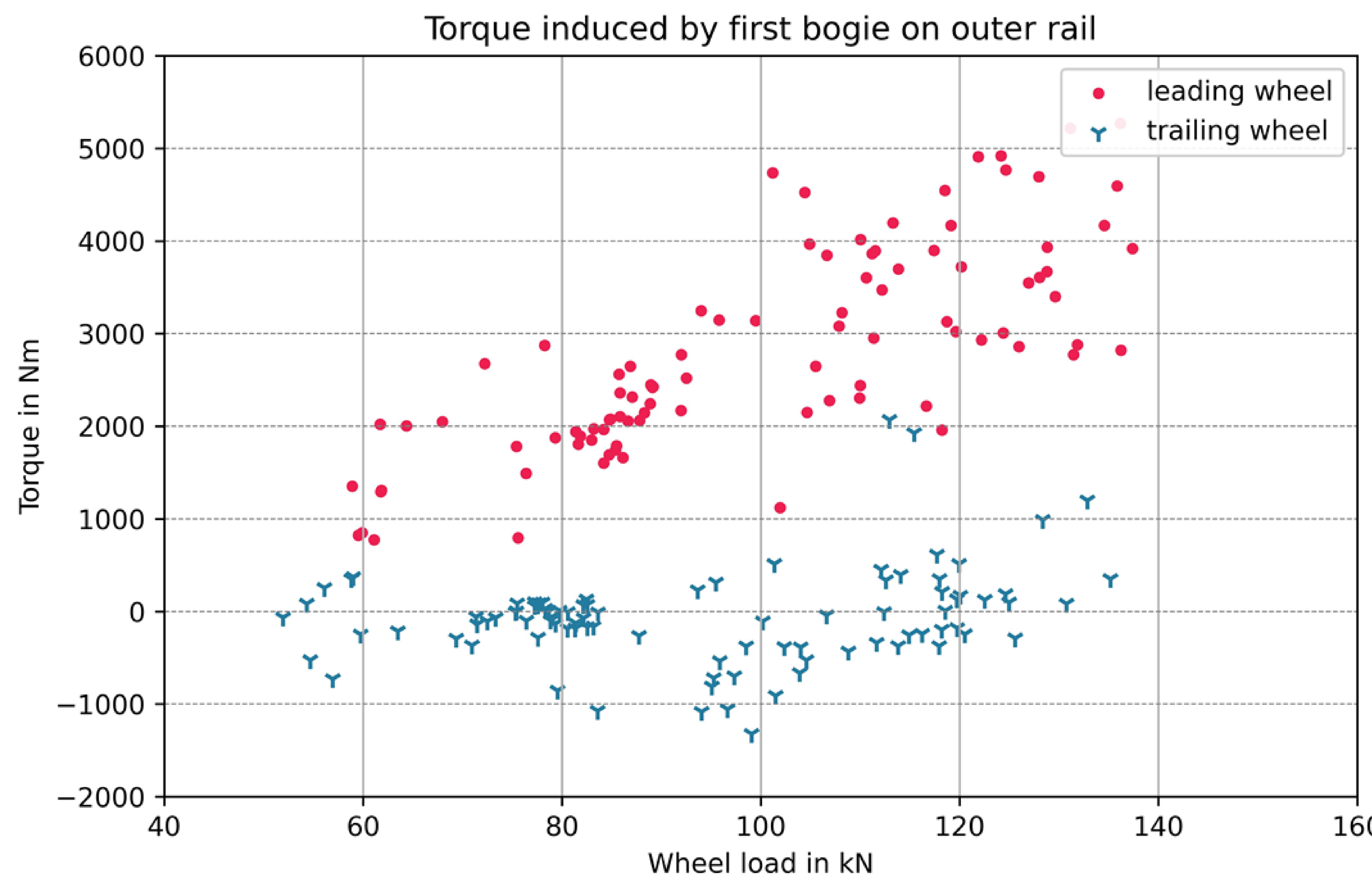

Figure 3: Torque applied to outside rail in 400m radius curve

Conclusions

This study demonstrates that the torsional stiffness of rail fixations can be estimated through a combination of controlled loading and field measurements. The nonlinear relationship between applied torque and rail tilt highlights the importance of considering torsional effects when assessing fixation behavior.

The variation in torque observed during regular operation, influenced by factors such as axle load, speed, curvature, and superelevation, reflects the complexity of real-world interactions. Rather than using torque as a direct input, the results support using field data to realistically parametrize simulation models. Incorporating torsional stiffness improves the representation of rail tilt, track gauge, and contact conditions within digital twins.

This improved parameterization enhances the reliability of simulations used for infrastructure assessment and design. Future work may extend this methodology to additional fixation types and investigate how torsional stiffness evolves under long-term loading or degradation.

References

[1] Weilguny, R., et al. (2023). Investigation of dynamic gauge widening in small radius curves and its impact on lateral wheel-rail contact forces. Vehicle System Dynamics, 62(8), 2112–2137

Acknowledgments

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