Recent development of the multibody dynamics on the efficient modelling of train-track interaction

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Introduction

The real-time simulation of a dynamic train-track system is challenging, due to the complex nature of the vehicle, flexible track, and their interaction. Extending the idea of the floating frame of reference formulation (FFRF), the Moving Mode Method (MMM) is introduced to model track flexibility utilizing multiple mode shapes that move along the track with the vehicle (Recuero and Escalona (2013)). See Fig. 1. MMM is computationally efficient since the localized deformation at a wheel-rail contact pair can be described using a limited number of deformation modes. Still, there is currently a gap in the existing literature regarding whether MMM can effectively simulate the high-frequency wheel-rail contact problem.

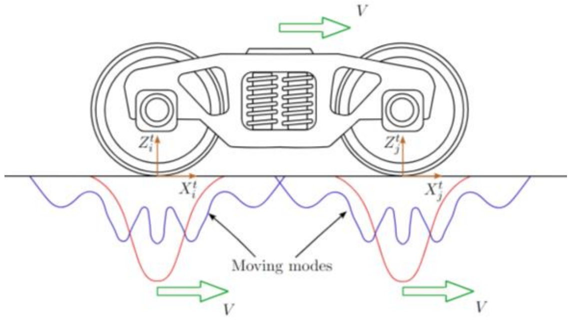

Figure 1. Moving modes at each wheel-rail contact pair.

In this study, the MMM approach is validated by assessing its performance for the short-track defect problem in comparison to the conventional beam model utilized by Shen et al (2021). The wheel-to-rail contact vibration within a high-frequency range (500-2000 Hz) is considered.

Conclusions

The differences between the impact forces predicted by the two models due to a typical rail squat are compared. Finally, MMM shows good agreement compared to the conventional beam model only when the squat is centrally located at the sleeper span.

References

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The effect of freight wagon bogie on track loads – verification process of freight wagon models

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Different wagons cause various track loads depending on for example axle loads and the construction of the bogie. Because of their higher axle loads and great quantity, freight wagons have significant effect on track deterioration in Finland. In this research, the effect of different freight wagon bogies on track loads (figure 1) will be estimated with the help of both field measurements and simulations. The long-term goal is to evaluate the track maintenance costs categorized by different wagon types based on the results of this research.

Three different freight wagon models will be built with bogies K17 (Axle motion III bogie), Y25 and 18-100. The models are then verified with several methods: track load measurements in different curved track sections, eigenmode analysis to unloaded and loaded wagons and video photography of wheel-rail contact in curves. Some curve tests, video photography and eigenmode analysis have already been made and once the vehicle models are built, the measurement results will be used to verify the models. After the model verification process, simulations will be made to identify the typical behaviour of different freight wagons in curves and straight track. Also, the effect of curve radius and cant, train velocity, track irregularities, axle loads and wheel and rail profiles on track loads will be examined.

The presentation shows the process of freight wagon model verification and the measurement results obtained so far.

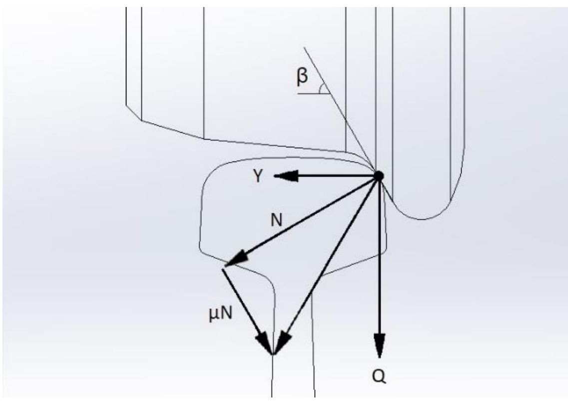

Figure 1. Lateral (Y) and vertical (Q) forces transmitted to rail in wheel-rail contact. These forces can also be defined with normal force (N) and friction force (μN). The contact angle is β.

Rail side wear of switch tip area and its effect on derailment risk

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Introduction

The railway maintenance register in Finland shows quite clearly that in many turnouts there are problems with the increased track gauge in the switch tip area which are results of a side wear in both switch blade and stock rail. Maintenance limits and sometimes even critical limits are achieved and methods to control and repair that track gauge are limited because welding of the switch blade is prohibited. At the same time, also the knowledge of the consequences of these increased track gauges is deficient.

Analysis

The main goal of this study is to deeply understand the consequences of the side wear on switch area. Which kind of different situations create side wear in switch area and how that side wear can also affect on the possibility of derailment? That understanding will give chance to provide aid for maintenance crew to recognize the side wear early enough and give them better tools to repair it more effectively.

During this study literature review and different site visits showed that some kind of new easy-to-use measuring gauge for validating the side wear would be much needed. Different kind of prototype gauges were created and tested in field and the result showed that a simple measuring gauge shaped as a new S1002-wheel profile will give valuable information about the contact point in the wheel-rail-interface. Because of the critically worn out set of switches, contact point between switch blade and wheel can establish underneath the wheel flange which can lift the wheel and create actual derailment risk. Without the wheel shaped measuring gauge this would be extremely difficult to notice in normal visual inspection.

Conclusions

With the help of this study the understanding regarding side wear in switch area is increased. New measuring gauge for maintenance crew is created which can help them to recognize the critical wear and especially the critical contact between wheel and rail. This way the derailment risk in switch area can be notably decreased.

Comparison of optimisation algorithms for wheel profile design for a high-speed passenger train

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Introduction

The issue of wheel and rail interaction has long been a focal point within railway engineering. Despite progress in railway vehicle design, there's been a lack of attention to developing new wheel and rail profiles that suit modern vehicles and operational loads. Traditionally, engineers have relied on expertise and measured profiles to design for minimal creepages and even contact patch distribution, aiming to reduce wear and RCF.

While these design methods were effective on occasion, they often needed iterations involving field tests, and results were system-specific. Advances in mathematical optimization methods and multi-body simulations (MBS) have paved the way for automated approaches to replace these design processes that relied on human expertise and significant budgets. This study presents two automated design approaches using different optimization algorithms, comparing the specifics of the optimisation process and the resulting wheel profiles in terms of dynamic performance, wear, and resistance to rolling contact fatigue (RCF) during long-distance operation.

Analysis

In this work, two multi-objective optimization algorithms, namely the Non-Dominated Sorting Genetic Algorithm (NSGA-II) [1] and the Particle Swarm Optimization (PSO) [2] are applied to design a variety of wheel profiles for a passenger train.

Following the optimization process and comparison of the performance of optimisation algorithms in terms of computational cost, a comprehensive analysis of wear and RCF evolution in the designed wheel profiles is conducted. This comparative assessment of designed wheel profiles aims to determine which optimization algorithm can generate a profile with the most favourable wear and RCF characteristics while considering vehicle dynamics, safety, and comfort factors.

Conclusions

This work employs a systematic approach that combines advanced optimization techniques with MBS and detailed wear analysis to identify and recommend the most suited optimisation algorithms for designing wheel profiles for passenger trains.

References

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Low Rail RCF Causes for Heavy Haul Operation

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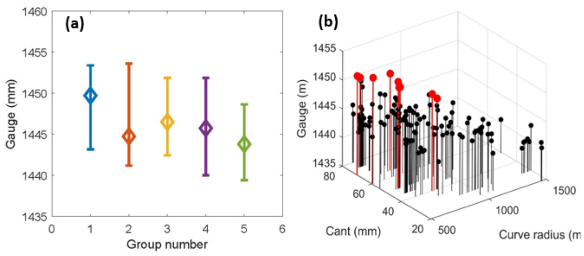
Introduction

Ever since the commencement of heavy haul iron ore trains on the Swedish Malmbanan line, RCF has been the major track problem. Historical advancements in the rail and wheel profile developments and in grinding practices have remarkably controlled the high rail damage, but low rail damage remains a challenge. Low rail damage in the form of spalling, induced by RCF is the major issue and causes rail life reduction and increased maintenance cost. As observed by Asplund et al. [1], this problem is mainly occurring on the small radius curves with large gauge widening. It is also believed that wheel hollowness is another major factor, causing drastic change in the dynamics. Therefore, this study investigates the causes and influencing parameters for the RCF on low rails. The methodology involves MBD modelling and simulation of vehicle-track dynamic interaction using multiple worn rail and wheel profiles.

The initial analysis of track geometry and track irregularities shows a large share of curves below 650 m in the considered section between Kiruna and Riksgränsen. The gauge widening occurs in the small radius curves (Figure 1). The red spikes in the right subfigure correspond to the curves with track gauge over 1450 mm. It is found that the gauge widening occurred mainly in the curves with radius below 850 m. Also, it is found that mostly the gauge widening is occurring on the curves with low track cant in the same group. Therefore, in addition to the gauge and wheel hollowness, other important parameters such as cant, running speed, irregularity level, friction coefficient, etc. are being sought to vary while estimating the so-called fatigue index on different curve groups. The results will be used to define the tonnage v/s allowable wheel hollowness.



Group	1	2	3	4	5	6
Radius (m)	<550	550-650	650-750	750-850	850-1500	>1500
Percent share	4.08%	28.5%	4.26%	5.82%	13.32%	44.02%

Figure 1. Gauge distribution on various curves.

References

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