Simulation as a Tool for Assessing the Match between Track and Vehicle Standards

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SUMMARY
Computer simulation techniques can be used to quantify the effects of changes to railway vehicle and track parameters and the likelihood of derailment. Using this knowledge the precise effects of possible changes to vehicle and track standards can be evaluated. In this paper these tools have been used to analyse the nature of the interaction of vehicles running over twisted track.

INTRODUCTION

Using modern computer packages it is possible to carry out realistic simulation of the dynamic behaviour of railway vehicles. The theoretical basis of the mathematical modelling used is now mature and reliable and programs originally written by research institutes have been developed into powerful, validated and user-friendly packages. Examples are: ADAMS/Rail, Medyna, Nucars, Simpack and Vampire.

MODELLING THE VEHICLE

The first stage in setting up a computer model is to prepare a set of mathematical equations that represent the vehicle. These are called the equations of motion and are usually formed as a set of matrices. The equations of motion can be prepared automatically by the computer package, a user interface requiring the vehicle parameters to be described in graphical form or by entering a set of co-ordinates describing all the important aspects of the suspension. The

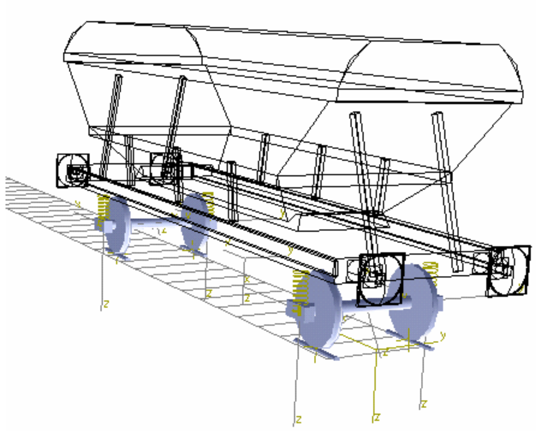

Figure 1. A typical freight vehicle model

amount of detail used to prepare the model will vary according to the type of suspension and the required outcome of the modelling exercise. Freight vehicles have suspensions which are particularly difficult to analyse because of the presence of friction and clearance which cause the equations describing the vehicle dynamics to be highly non-linear.

The vehicle is represented by a network of bodies connected to each other by flexible elements. This is called a multibody system and the complexity of the system can be varied to suit the vehicle and the results required. The bodies are usually rigid but can be flexible with a given value of stiffness. Masses and moments of inertia need to be specified. Points on the bodies, or nodes, are defined as connection locations and dimensions are specified for these. Springs, dampers, links, joints, friction surfaces or wheel-rail contact elements can be selected from a library and connected between any of the nodes. A example of a vehicle model is shown in Figure 1.

INPUTS
Inputs to the model are usually made at each wheelset. Typical inputs are cross level, gauge and lateral alignment for the track. These can be idealised discrete events such as dipped joints or switches or can be measured values from a real section of track. Additional forces may be specified such as wind loading or powered actuators (eg in tilting mechanisms).

OUTPUTS
Depending on the purpose of the simulation a wide range of outputs for example displacements, accelerations, forces at any point can be extracted.

SIMULATING A VEHICLE RUNNING ON TWISTED TRACK
Three computer simulations have been carried out using the simulation package SIMPACK to quantify the effects of various vehicle and track parameters on the level of wheel unloading for a typical freight vehicle running on twisted track. This information was used to assess the match between existing track and vehicle standards.

The vehicle simulated was a two-axle wagon with a wheelbase varying from 3m to 10 m. The mass and stiffness properties are chosen from the typical value for a 45t GLW hopper mineral wagon. Two vertical stiffnesses are defined to represent two different torsional characteristics of the vehicle.

The track was set up as a mathematically idealised twisted track with its cant gradient defined by a sinusoidal function as shown in figure 1. The amplitude of the oscillations are derived from as the worst track twist defined in the Railway Group Standard (GC/RT5021), at which all traffic must immediately stop (1 in 90). The wavelength of the oscillations is 9 metres. This corresponds to the length of a jointed rail at which many of the cyclic track twist faults appear to occur.

A value of the amplitude of the irregularity A=0.0125m was chosen as this corresponds to a twist of 1 in 90.

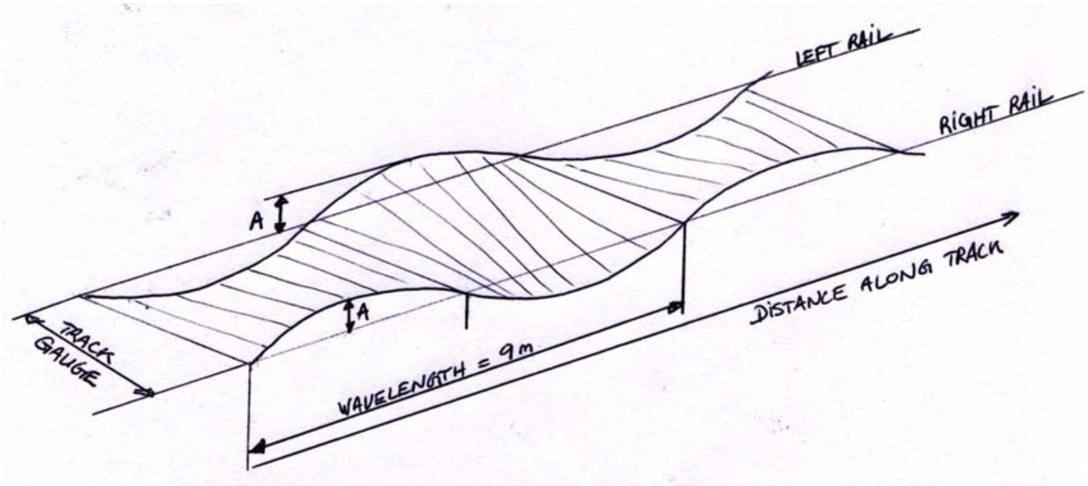

Figure 2. Track case used in the simulations

Simulation case 1: ***Examination of Dynamic Effects of Cyclic Track Twist***
This study aimed to examine wheel unloading against wheelbase for vehicles with different torsional stiffness properties, running over a fixed twisted track at different speeds. Each vehicle is run at four different speeds for each stiffness value. The results are shown in figure 3 and give the maximum unloading of any wheel of the vehicle, as a percentage of the normal static load per wheel.

There are three parameters that have an influence on the results: the wheelbase, the torsional stiffness and the speed. Two different types of behaviour are noticeable for two different wheelbases:

For a wheelbase of 4.5 metres (half the wavelength of the track), the unloading is high even at low speed (50 to 63 %). The stiffness has a significant influence on the unloading but speed has little effect. The unloading seems to be due simply to the inability of the vehicle to follow the track twist through torsional deformation. At this wheelbase the front and rear axle are rolling out of phase but the torsions on the body are balanced (maximum torsional effect and minimal mass and inertia effect).

For a 9 metre wheelbase (the wavelength of the track irregularity), the parameter that has the most influence is the speed as seen in figure 3. At low speed the wheel unloading is fairly low (16-18%) as the vehicle is not twisted but just rolls, whereas when the speed increases the mass and inertia start to play a dynamic role and causes greater wheel unloading (reaching 70-78% at 25mph). The stiffness here has less influence than previously and it is even noticeable that the higher stiffness shows less unloading at higher speed. This is due to the fact that the track excitation frequency is getting closer to the natural roll frequency of the softer vehicle: the speed at which the track excite the lower sway of the softer vehicle is 33.2mph, while for the stiffer it is 36.6mph.

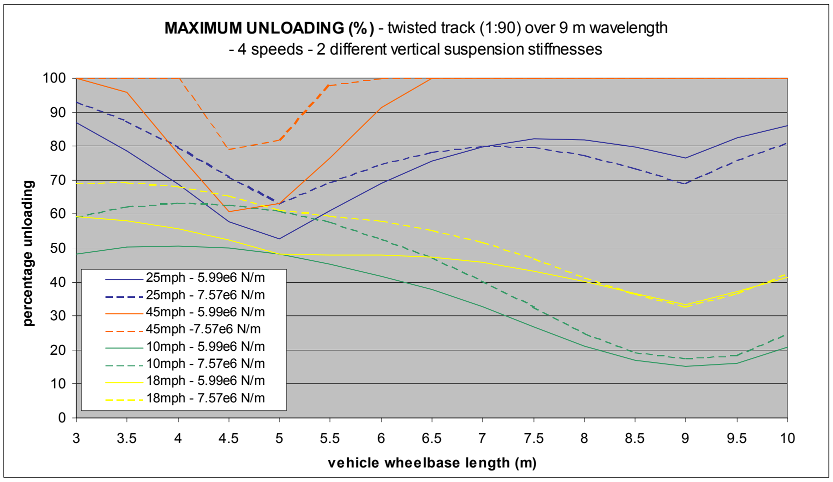

Figure 3. The effect of torsional stiffness and speed on wheel unloading on twisted track

Simulation case 2: *The effect of load imbalance*

The load carried by a freight vehicle may not be evenly distributed and to investigate the effects of this a simulation was carried out. This simulation aimed to look at how significantly this static nominal load imbalance affects the unloading.

In the simulation the wheel load difference was achieved by shifting the body centre of gravity towards the right wheels. Four different vehicles are set up with 0mm, 60mm, 120mm, and 180mm shifts corresponding to 0 N, 2836 N, 6102 N, and 8930 N nominal load differences. Each vehicle is run over the twisted track at 45 mph and the maximum percentage of unloading of the right and left wheels are plotted on the graph together with a reference line of 60 % (the maximum unloading allowed under Group Standard GM/RT/2141).

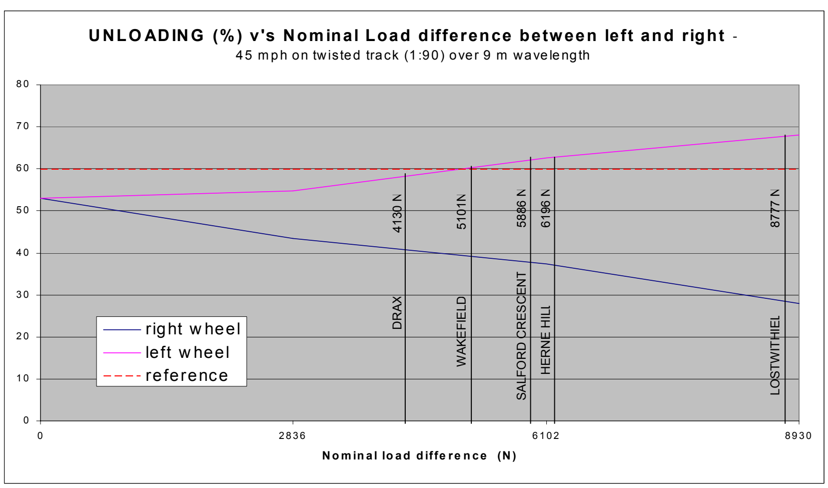

Figure 4. The effect of load imbalance on wheel unloading on twisted track

The maximum unloading of the right and left wheels is shown in Figure 4. It can clearly be seen that the greater the difference in the static nominal load from left to right, the greater the resulting unloading on twisted track. Five actual derailments are also indicated on the graph. Wheel unloading ranging from 15% to 40% is predicted demonstrating the increased risk of derailment.

Simulation case 3: ***The effect of roll inertia***

At higher speeds the roll inertia of the wagon can clearly be an issue due to its effect on the resonant behaviour. Simulation was used to examine the influence of the roll inertia of a vehicle, at high and low speed, and for different wheelbase length.

The results are shown in figure 5. For this case the roll inertia of the main body was varied and takes three values: 60% of the initial value, 100% and 140%.

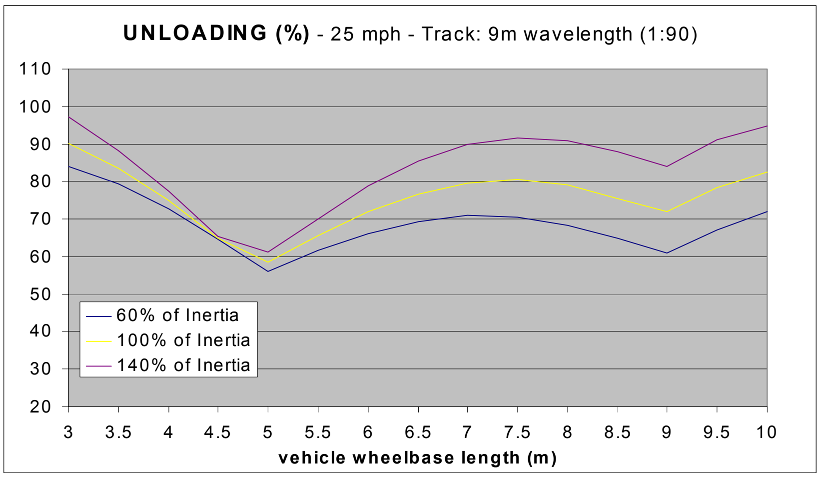

Figure 5. The effect of vehicle body inertia on wheel unloading on twisted track

At low speeds the influence of the inertia is negligible and unloading is dominated by the vehicle torsional stiffness (maximum unloading for a wheelbase length of 4.5 metres). Figure 5 shows that at higher speeds the inertia has little influence for a wheelbase of 4.5m (wheelset roll out of phase), but has a significant influence for longer wheelbases with a maximum at 9m (wheelset roll in phase). The higher the Inertia, the higher the unloading with a maximum difference of about 23%. As the wheelbase is reduced below 4.5m the same effect can be seen with a difference of about 13% for a 3m wheelbase.

Conclusions

- At lower speeds: small wheelbase vehicles are more likely to show wheel unloading on track with high twist and unloading is highly dependant on the vehicle torsional stiffness.
- At higher speeds: longer vehicles (over about 7 m) become vulnerable to wheel unloading as well and their natural roll frequencies can have a significant effect on the level of unloading at speeds corresponding to the track excitation.
- Static suspension imbalance can significantly affect the level of wheel unloading.
- The computer modelling methods described have proved successful in helping to understand and quantify the interaction of a vehicle running on twisted track. A wide range of vehicle and track parameters can be varied and the effects quantified. This could allow more detailed specification of vehicle and track parameters in future standards.

Acknowledgements

The authors would like to thank Railway Safety Ltd for funding the research on which this paper is based. The views presented here are those of the authors and do not necessarily represent the views of Railway Safety Ltd.

The Rail Technology Unit

Rail Technology Unit

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The **Rail Technology Unit** based at **Manchester Metropolitan University** carries out research and consultancy into the dynamic behaviour of railway vehicles and their interaction with the track.

We use state of the art simulation tools to model the interaction of conventional and novel vehicles with the track and to predict track damage, passenger comfort and derailment. Our simulation models are backed up by validation tests on vehicles and supported by tests on individual components in our test laboratory. We are developing methods to investigate the detailed interaction between the wheel and rail.

January, 2004
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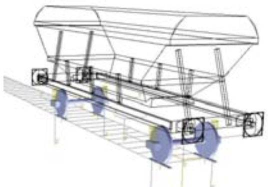

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