

## Analysis of a Railway Vehicle with Unevenness on Wheel

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**One of the basic principles of railway vehicles is their carrying and guiding. In the contact pair of a wheel and a rail, one body is rolled on the surface of the other part and all main forces are transmitted in this contact. Contact between wheel and rail is also important from an economic aspect as it is related to the wear of the track rails and the wheel thread itself, including the wheel flange, and has caused the necessary maintenance of the track and the vehicles themselves. Therefore, our article focuses on simulating the influence of a flat wheel on changes in wheel forces. The model was created in the CATIA program and was consequently imported into the SIMPACK program, which was followed by analysis of the passage of the vehicle along the track. In the simulation, we considered an ideal track and a wheel flat on the right front wheel. We also plan to work with these results by adding and comparing them with results obtained by applying irregularity to our ideal track.**

**Keywords:** Wheel flat, simulation, rail – wheel contact, safety against derailment.

### 1 Introduction

In the wheel-rail contact pair, one body is being rolled over the surface of the second body [8, 10, 11, 13]. The issue of wheel-rail contact is also addressed in other professional publications [9, 12, 15, 17, 19, 20, 24]. If the contact surfaces are sufficiently smooth, there is no vibration and consequent negative effects (noise generation, increased forces in wheel-rail contact) [21, 22]. In Fig. 1, there is a picture of a wheel damaged by the formation of wheel flat on the wheel tread.



**Fig. 1** Wheel with a wheel flat

The wheel is the second part of the contact pair and its unevenness can be defined as the deviations of the circularity (differences between an actual radius of the wheel and an ideal nominal radius) [4, 6]. Non-circularity can be evaluated in the plane of the touch circles (70 mm from the inner face of the wheel) or in planes parallel therewith. Numerical processing of measured data is necessary to perform the analysis. The basis for evaluating wheel non-

circularity is to know the instantaneous radius values of the wheel, depending on the angle of rotation of the wheel [14, 16, 23].

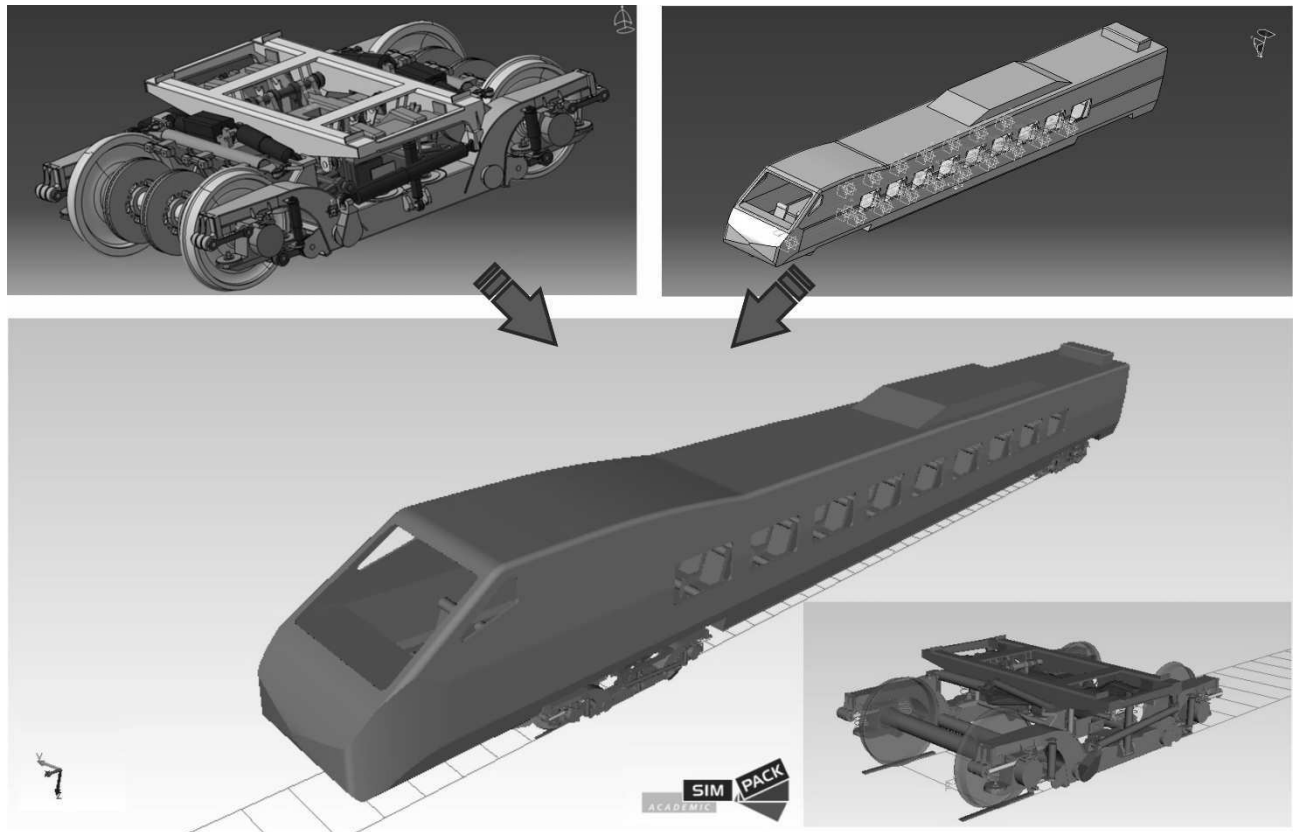
Measurement of circular deviations can be performed by several methods [7, 18]. Circularity is most often controlled by special touch devices where a measuring contact rotates around a fixed component or inversely, the component rotates around the rotary axis and the deviations are continuously scanned by the deviation meter.

### 2 Simulation conditions

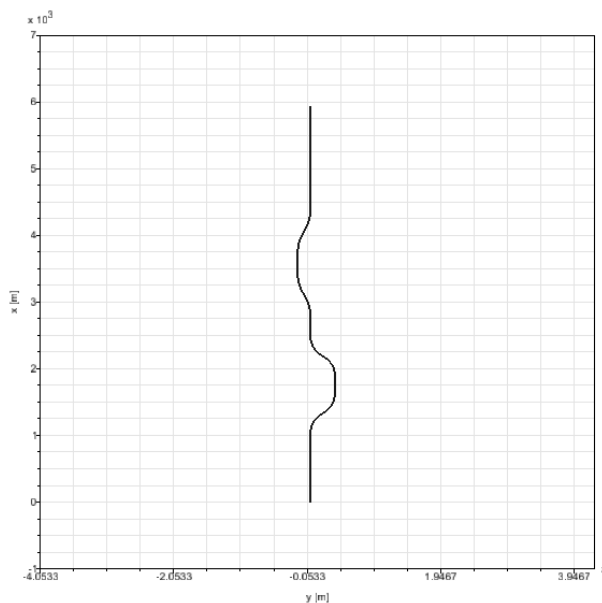
For the needs of the simulation, a model of a tilting bogie and car body of the rail vehicle was created in CATIA V5R20 program and imported into SIMPACK 9.9 program afterwards. It was necessary to define joints between individual parts using force elements in SIMPACK and set the characteristics of springs and dampers using input parameters. Important was also to define two hydraulic cylinders that cause the upper tilting bolster to tilt and therefore also the tilting of the car body in curve. The model uses an active system of tilting comparable to the Pendolino train. In our simulation however, the tilting mechanism was turned off. The created model can be seen in Fig. 2.

The vehicle ran along a track with the length of 6 km, composed of 4 curves with a radius of 600 m (Fig.2). The superelevation of the track was set to 150 mm. Wheel profile S 1002 with a nominal radius of 445 mm and rail profile defined by the S91700\_16 geometry were set for the track model.

In order to simulate the rail vehicle running and evaluate ride properties of motion smoothing of rail vehicles by means of computer simulation, program Simpack 2014 has been used. This software allows to create subsystems of rail vehicles, whole rail vehicles and trains.

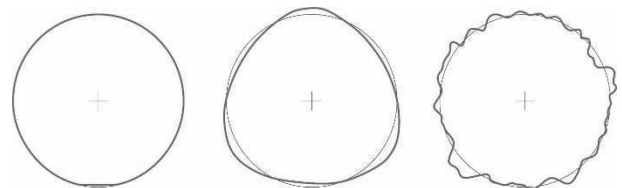


**Fig. 2** Model of bogie and body vehicle in program Simpack imported into program CATIA

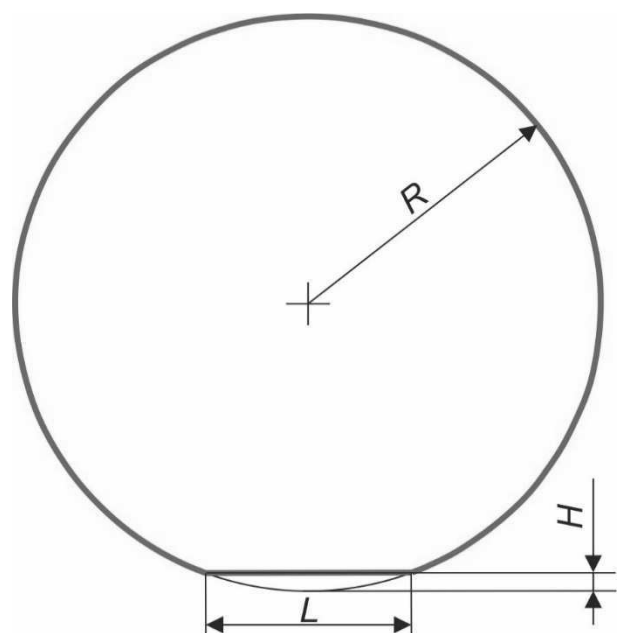


**Fig. 3** Geometry of the track model

Wheel untrueness causes force changes in wheel-rail contact. If untrueness is created on a wheel, the nominal wheel radius is not constant anymore, but varies with the wheel rotation angle. In program Simpack, it is possible to specify the wheel untrueness in three different ways: radius deviations, Fourier coefficients and harmonic function (simple polygonality) (Fig. 4). We used radius deviation (Fig. 5) for our simulation, with parameters defined in Tab.1.



**Fig. 4** Typical untrue wheels: wheel flat (left), 'triangle' (center), arbitrary shape (right)



**Fig. 5** Geometry of track model

**Tab. 1** Parameters of a wheel with a wheel flat

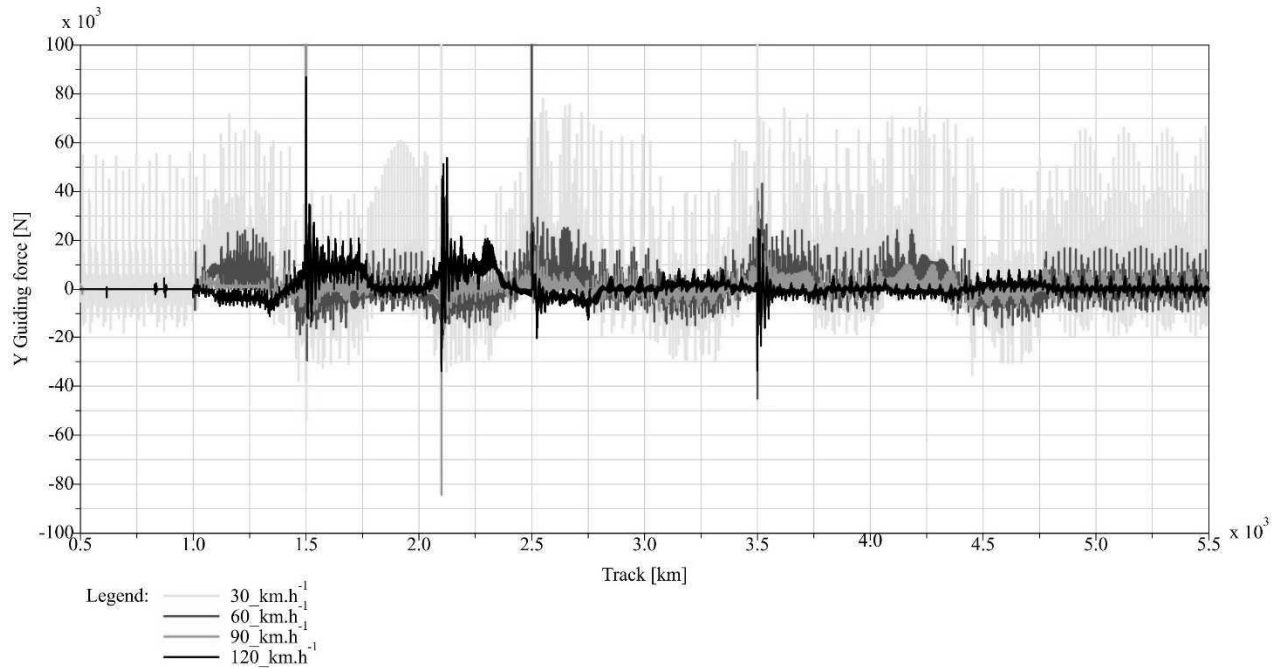
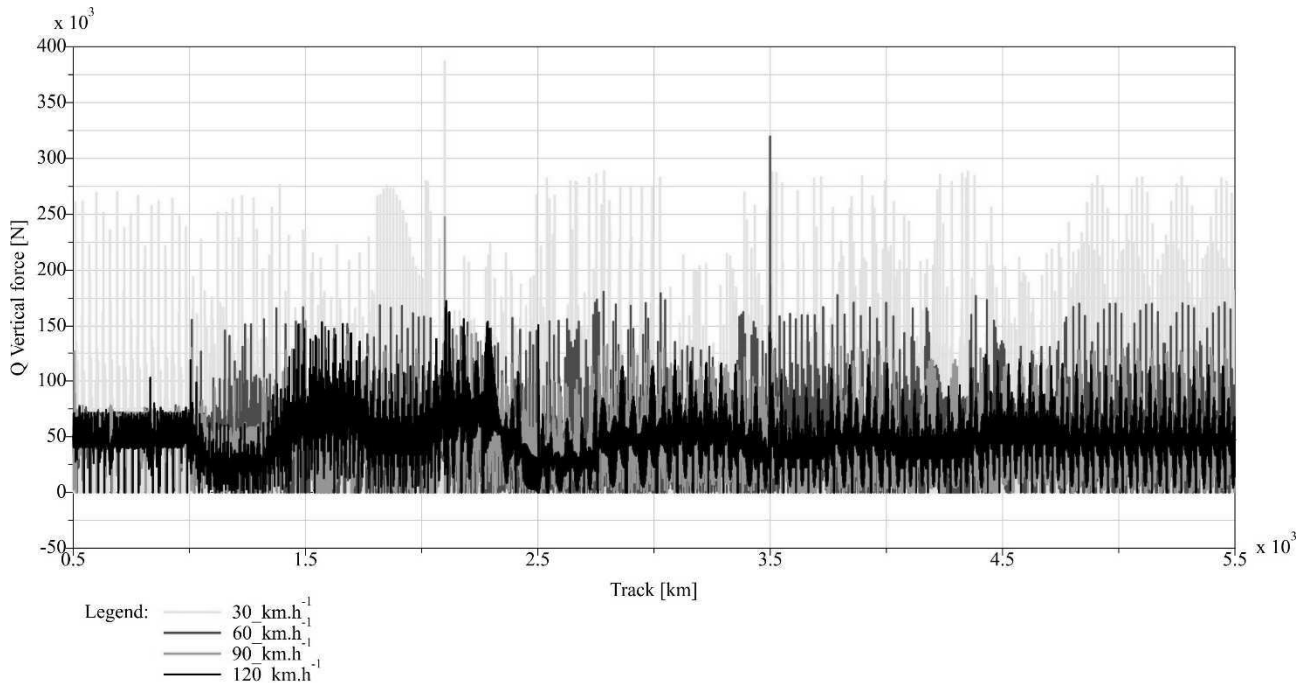
Parameter	[mm]
$R$ - wheel radius	445
$L$ - Length of the wheel flat	20
$H$ - Wheel flat depth	0.1123

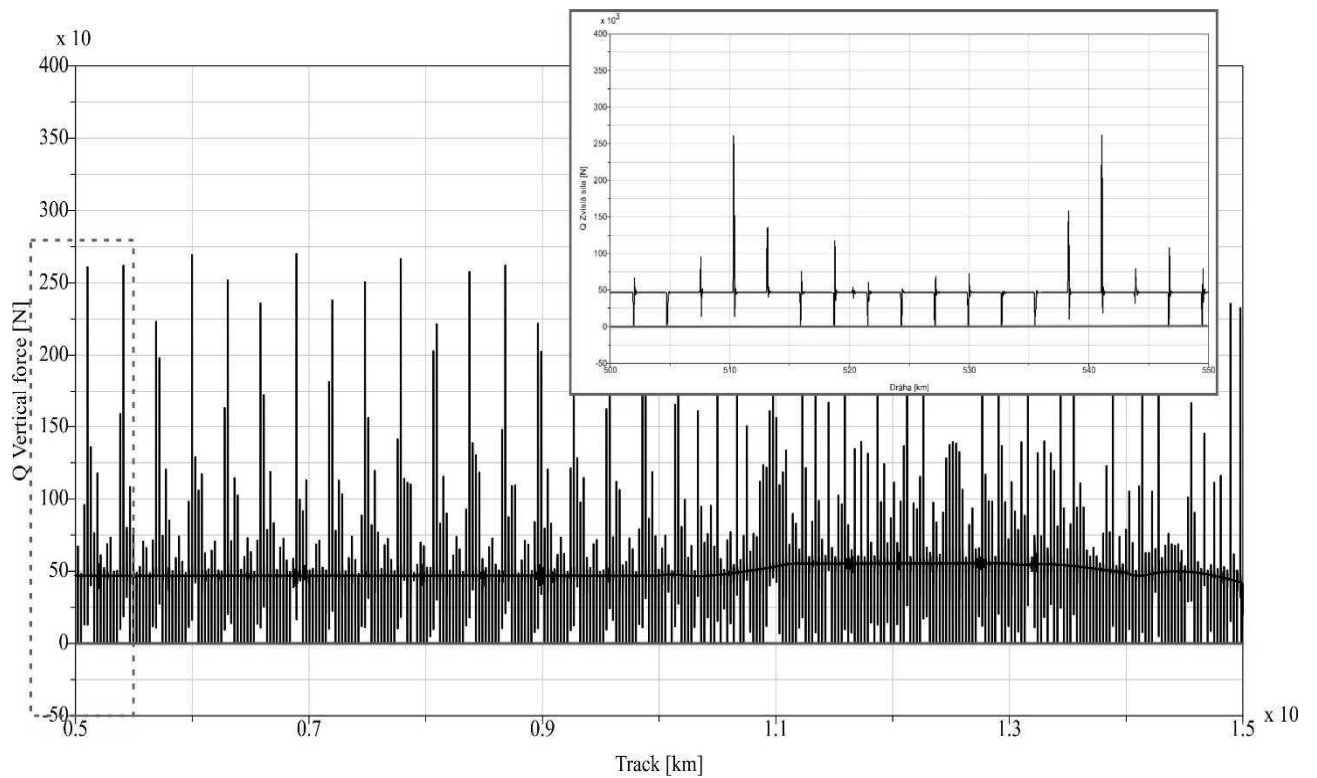
### 3 Simulation results comparison

For a better comparison of the results, we performed

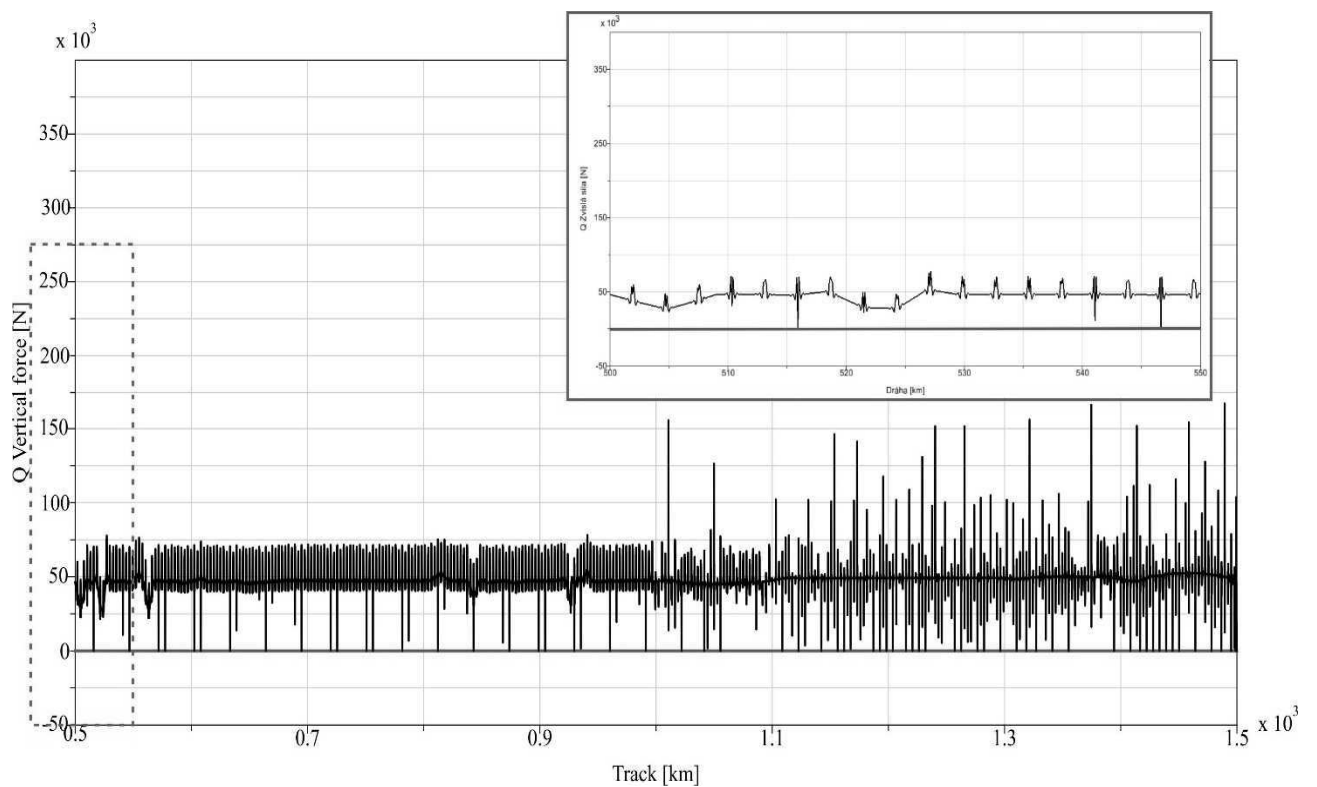
the simulation for the velocities of  $30 \text{ km.h}^{-1}$ ,  $60 \text{ km.h}^{-1}$ ,  $90 \text{ km.h}^{-1}$  and  $120 \text{ km.h}^{-1}$ . Since the wheel flat surface was simulated on the right wheel of the first wheelset of the front bogie, only the forces acting in the contact pair of that wheel were processed in the results.

The guiding forces acting in the transverse direction are shown in Fig. 6. From the graph we see that the lower the speed of the vehicle running along the track is, the higher the driving forces affecting the vehicle are.

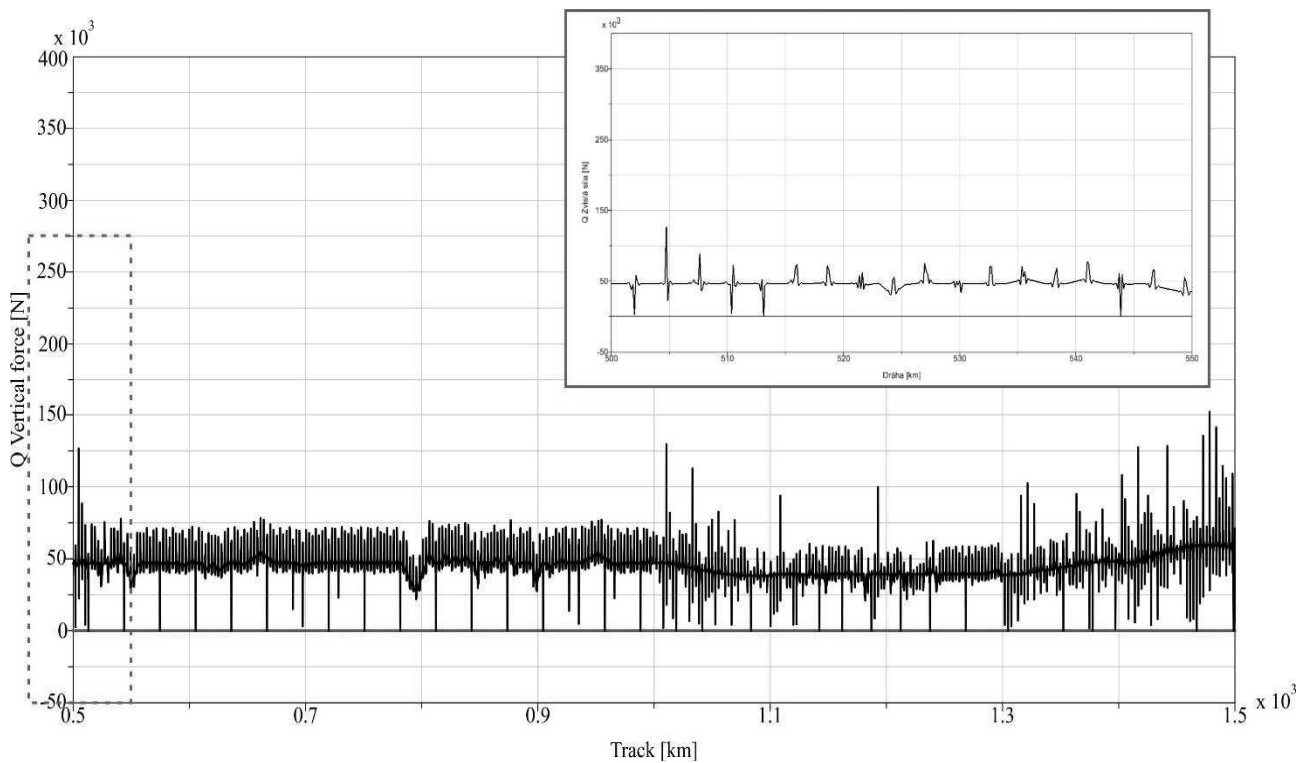
**Fig. 6** Guiding forces acting on a front bogie wheel**Fig. 7** Vertical wheel forces for all velocities



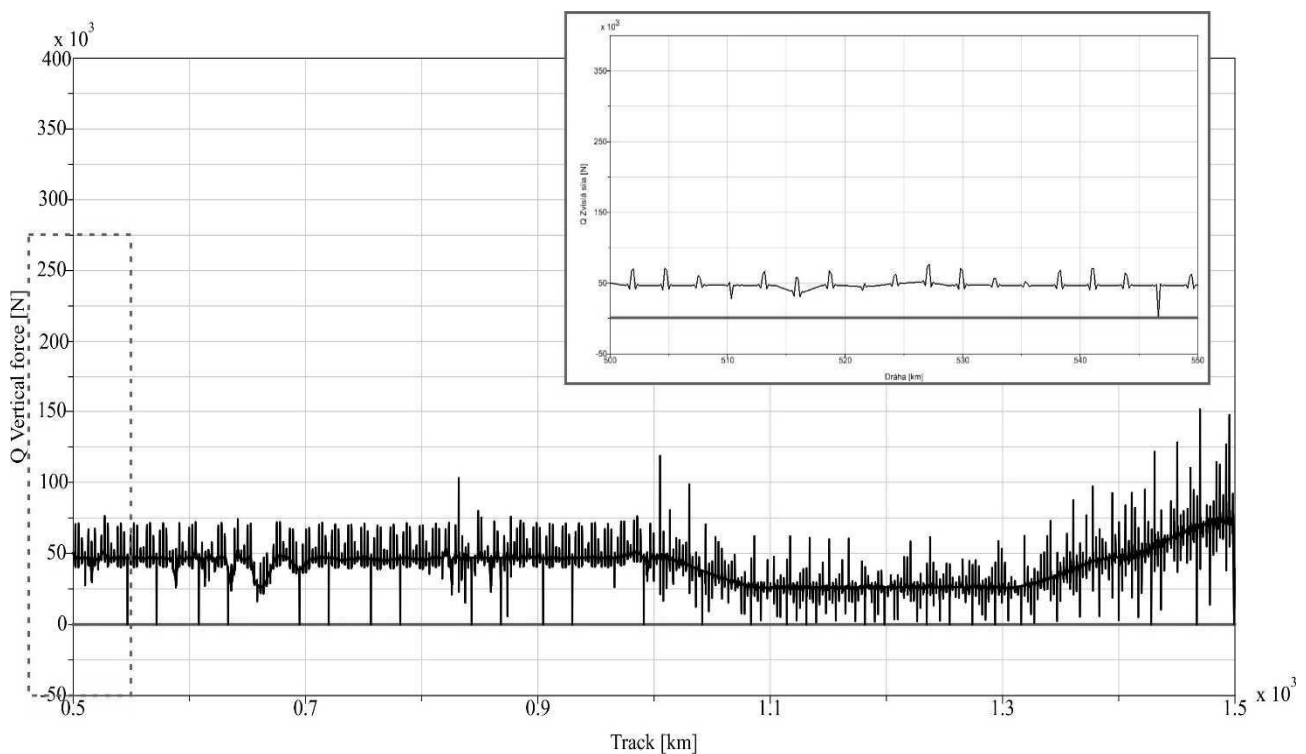
**Fig. 8** Vertical wheel forces for the velocity 30 km.h<sup>-1</sup>



**Fig. 9** Vertical wheel forces for the velocity 0 km.h<sup>-1</sup>



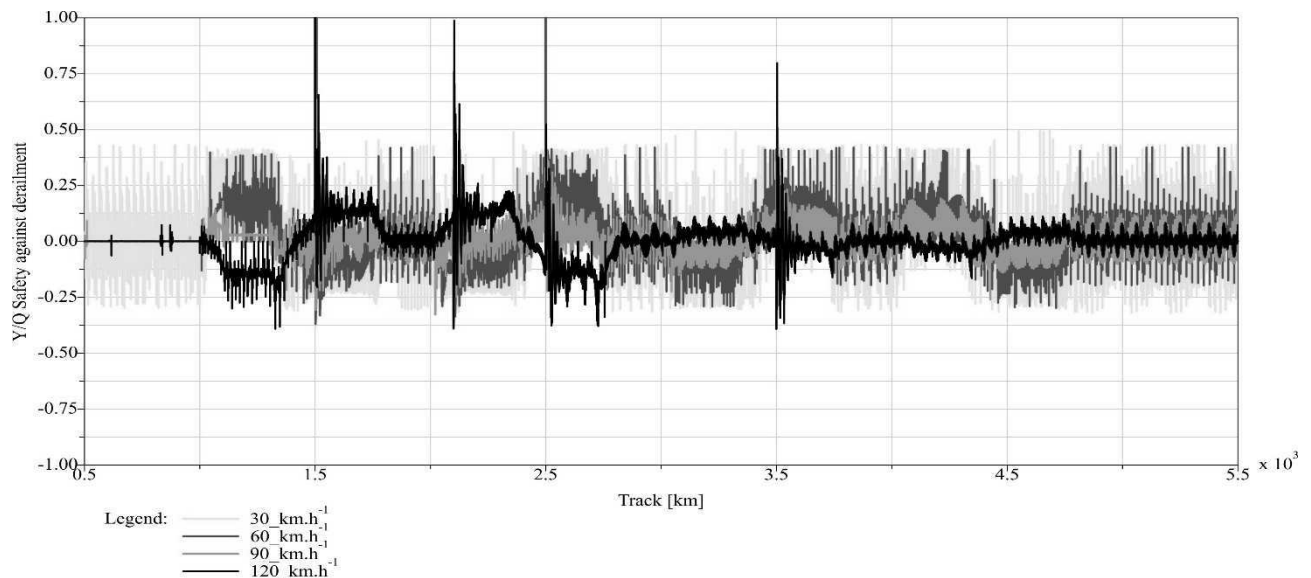
**Fig. 10** Vertical wheel forces for the velocity  $90 \text{ km.h}^{-1}$



**Fig. 11** Vertical wheel forces for the velocity  $120 \text{ km.h}^{-1}$

The expression of safety against derailment (Fig. 12) as a relative value equal to the ratio of the steering and wheel forces on the individual wheels in its course corresponds to the course of the driving forces. Higher values

represent a worse state, lower values represent a safer ratio of horizontal forces to vertical forces. Even at the lowest speed, the vehicle did not exceed the known safety limit 0.8.



**Fig. 12** Safety against derailment of the wheel with a wheel flat

#### 4 Conclusion

In our article, we focused on simulating a ride of a rail vehicle that has a wheel flat on one of the wheels of the attacking wheelset. We compared the results for four driving speeds and compared the sizes of the guiding and vertical wheel forces and the safety against derailment values.

From the resulting graphs we can see that the wheel with a wheel flat reaches the worst results at the slowest speeds, when the highest guiding forces and the greatest difference in vertical wheel forces occur. Despite this fact, the safety against derailment value of the vehicle does not exceed the limit of 0.8.

In the simulation, we considered an ideal track and a wheel flat on the right front wheel. We also plan to work with these results by adding and comparing them with results obtained by applying irregularity to the ideal track.

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