Simulation of running a vehicle with a Y25 bogie on a theoretical track

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Abstract. This paper is focused on the simulation of a railway vehicle with a Y25 bogie running on a theoretical track and it will simulate its dynamic properties. The model was created in multi-body simulation software SIMULIA - SIMPACK. The first part mentions the basics theoretical information about the forces which acts in the bogie for example vertical load, slip or lateral forces of the wheelset. The definition of the theoretical track is listed as well. The second part deals with the basics information about technical specifications of the Y25 bogie and its usage. In the next part, the 3D model of the Y25 bogie is described. This section also describes the simulation, which is performed at different speeds. In the last part, results are evaluated and compared for each speed. Results will be suitable for further academic research and development.

1. Introduction
Indeed, about 1.5 billion tons per kilometre are transported by lorries at distances farther than 150 kilometres and only 0.4 billion tons per kilometre are transported by train. Over the past decade, the importance of railway transportation increases massively again either in passenger transport or transportation of goods. By higher and higher environmental requirements, many goods are transported by freight wagons over long distances [1, 2, 12].

Due to the greater efficiency of railway transportation in the term of lower fuel consumption per tone of cargo transported per kilometre, the continuation in this trend is necessary if we want to achieve carbon neutrality.

One approach to achieve this is for freight wagons’ speeds and acceleration capabilities to allow them to be fully integrated with passenger traffic. It will be critical to ensure that the dynamics of freight wagons allow for safe and dependable track operation [3].

Dynamic properties are especially important in terms of the driving characteristics of a vehicle when running through a curve but also when running on a straight track. These properties affect a lot of characteristics that act during running such as lateral forces, the angle of attack etc. They are also very important because of running stability on a straight track [15].

The Y-25 type chassis is among Europe’s most used rail freight chassis [4]. Because of that, the paper is focused on a simulation of Y-25 bogie on a theoretical track.

2. Forces that act during vehicle running
During a vehicle running a large amount of forces act on that vehicle. These forces can be divided according to the direction of action and their character.

By direction of action, forces can be divided into vertical, longitudinal and lateral. By character, forces can be divided into static and quasi-static.

2.1. Longitudinal, lateral and vertical forces
Longitudinal forces act in a direction of railway track [5]. In a rail vehicle dynamic, this axis is usually labelled as “x”. The longitudinal train dynamic concept includes wagon and locomotive motions, as well as the motions of each moving compartment and the forces between those individual sections. The train's forward velocity, the dynamic properties of each coupler, the delay time due to applied braking of the cars, and how loads are distributed in each wagon are all elements that affect longitudinal train dynamics [6].

Lateral forces act in a direction perpendicular to a railway track. This axis is commonly labelled as “y” in a rail vehicle dynamic. In lateral direction mostly act lateral inertial forces, lateral forces in couplings, lateral friction forces in bumper plates etc. [7]. Lateral forces are also very important from an anti-derailment safety point of view and wheel and rail wear, too [14].

Vertical forces are forces that act in a direction of gravitational acceleration. The main component of vertical force is the weight of the vehicle and cargo. Track and wheel unevenness play a significant role in the change of vertical forces. These forces are also dependent on primary and secondary suspension stiffness, stiffness of frame etc. [8]. The vertical axis is usually labelled “z”. All axes are shown in figure 1. Vertical force Q also affect the size and shape of the wheel-rail contact area [13].

\[ w = R\omega - v. \]  
\[ s = \frac{w}{v}. \]  
\[ T = \mu Q. \]

Where \( R \) is wheel radius, \( \omega \) is the angular velocity, \( v \) is velocity, \( \mu \) is coefficient of adhesion and \( Q \) is normal load as shown in figure 2.
The theoretical or ideal railway track is a track that has no inequalities.

3. Running on a straight track
During running a railway vehicle on a straight track, the vehicle performs wavy motion, which is related to the stability of the railway vehicle. These motions can be stable or unstable (figure 3).

The wheel axle returns to its central position through damped parasitic oscillations when the wheelset moves a little to the side from its central location. This demonstrates the wheel axle’s motion stability. Stimulated vibrations occur when there is a minor deviation in the rail track, and the maximum amplitude boost and parasitic oscillations can only be prevented by flange contact. The wheel axle motion is described as unstable in this condition [9].

This unstable motion happened at a certain speed or faster and this certain speed is called critical speed [10].

4. Y-25
Y-25 type chassis is one of the most common used freight bogies in Europe, in central and western Europe, especially. There is a lot of types of Y-25 and in this part will be shown main specifications (Table 1).

The primary suspension on the standard Y25 (figure 4) chassis is duplex coil springs, which has a non-smooth characteristic. The axel box includes suspension with a damper. It has a friction damper and an axel guard with no allowance. The Flex-coil effect is used for some lateral suspensions [4].

| Table 1. Technical specification Y-25 Ls(s) [11] |
|------------------------------------------------|
| Weight                                      | 4.6 t       |
| Width                                       | 2356 mm     |
| Length                                      | 3250 mm     |
| Track Gauge                                 | 1435 mm     |
| Wheelbase                                   | 1800 mm     |
| Max. speed at an axel load 20/22.5t         | 120/100 km/h|
| Wheel diameter                              | 920 mm      |
5. Model and simulation

5.1. Model
As it was told Y-25 chassis is one of the most common freight bogies in central Europe. Because of that, it is important to know how it behaves.

Model is based on standard Y-25 bogie with one Lenoir friction damper and wheelset guiding is without cross-coupling. 3D model of Y-25 (figure 5) was created in SIMPACK software and some parts such as the frame were imported from CAD software as well. Wheelsets, rails and joints were added in SIMPACK.

5.2. Simulation
The simulation was made on a track, which was about 1400 metres long and track geometry is shown in figure 6. A standard definition of railway model track was used, which mean that the gauge is 1435 millimetres, with railhead profile UIC60. Railway wheels had a driving profile S1002.

The simulation was made for four different speeds. Firstly, simulation was made for the speed of 30 kilometres per hour. Afterwards, a speed of 60 kilometres per hour was used. Next, the running speed of the Y-25 bogie was 90 kilometres per hour and the final simulation was made for a speed of 120 kilometres per hour.
6. Results
The simulation was made to show lateral force “Y” that act on vehicle mainly during curve running for different speed. That force is important because of anti-derailment safety.

6.1. Speed of 30 kilometres per hour
The development of lateral force Y for a speed of 30 kilometres per hour is shown in figure 7.
Lateral force hits the peak when bogie is running into the curve and from the figure it is clear that the lateral force is in peak only on one wheel at a time. That wheel is called the guiding wheel. Maximal lateral force on the right front wheel is around negative 25 kilonewtons and on the left, it is about 30 kilonewtons.

6.2. Speed of 60 kilometres per hour
For the speed of 60 kilometres per hour, lateral force is shown in figure 8.

![Figure 8. Front wheelset 60 kilometres per hour](image)

If the geometrical characteristics of the curve are the same and the bogie has a higher speed, the lateral force is higher. On the right wheel, the peak is negative 52 kilonewtons and on the left, it is 65 kilonewtons. The figure shows that the lateral force has the opposite character for each wheel, which mean that the wheel flange on the wheel which is not guiding is not hitting the railhead.

6.3. Speed of 90 kilometres per hour
Peak values of lateral force for the speed of 90 kilometres per hour are for the right wheel negative 45 kilonewtons and for the left it is 100 kilonewtons in the first part of the curve with the radius of 200 metres. Also on the straight part of the railway track, the bogie stabilized and lateral shocks are small. The values are shown in figure 9.
6.4. Speed of 120 kilometres per hour
As it is shown in figure 10 the lateral force for a speed of 120 kilometres per hour is quite high. For the right wheel, it is negative 100 kilonewtons. The left wheel has a peak of around 100 kilonewtons in a curve.

After a curve when the bogie is running on a straight the lateral shocks are pretty high with a value of 120 kilonewtons and are not decreasing. The reason for that may be that the bogie hit a critical speed and is now unstable.

To confirm that the simulation on a straight track with the speed of 120 kilometres per hour was made and the results are shown in figure 11. The values show that the bogie is unstable and after the lateral force is over 550 kilonewtons the bogie has derailed.

Figure 9. Front wheelset 90 kilometres per hour
Figure 10. Front wheelset 120 kilometres per hour

Figure 11. Lateral force on a straight track 120 kilometres per hour
7. Conclusion

The main goal of this paper was to simulate bogie running at a different speed and show the affect of speed on the lateral force which acts on a vehicle during running.

In the first part, basic information about forces is provided. Also, a slip is mentioned in this part. In the next part is the definition of stable and unstable running. Some technical specifications of one of the most used freight bogies in Europe are in the third part. The last part is dedicated to model description and simulations and also to the evaluation of results.

The figures show that the magnitude of lateral force increase with the speed and also the importance of critical speed to integrate freight transportation with passenger transportation.

The future direction of research will be to improve the dynamical properties of the bogie when running through a curve.

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