

Mechatronic radial guiding system of railway vehicle wheelsets

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Abstract. In this paper existing active and passive radial guiding systems of railway vehicle wheelsets are presented. The new system described in this paper is based on non-direct measuring lateral forces in bogie elements. As a part of project development there were numerical calculations and experiments on a test stand carried out. As a main issue, there were investigated stress signals from extensometers mounted on guiding elements of wheelsets. In conclusions, there is made a comparison between values obtained from numerical and experimental tests.

1 Introduction

Most of the modern rail vehicles are bogie-based constructions. However, the main problem of this solution are high values of forces which occur between wheels and rail, under certain conditions during the ride through curved track with small radius. Many solutions have been developed to solve this problem and reduce the wear of the bogie elements. There are two main types of such solutions.

The first type consists of passive systems without any electronic elements which are based on mechanical (SAR [1] or FEBA bogie [2]) or hydraulic elements (4ANg bogie [1]).

The popularization of compact, fast and accurate electronic components and high resolution sensors provided the possibility to develop active systems and mount them on the rail vehicles. In this kind of systems the positions of whole bogie or each wheelset can be controlled by the use of strain, acceleration, distance or angle sensors. Nowadays, there are two main commercial active systems developed, the first is called Bombardier FLEXX Tronic [3] and the second is designed for Siemens Vectron locomotive [4].

The system described in this paper is intended to control the position of the entire bogie, and is controlled by the electronic microcontroller. The main purpose of this system is to rotate the entire bogie under the vehicle by the use of hydraulic actuator based on the signals from strain sensors which are processed in the microcontroller. The design of the system allows to implement these solutions in the existing vehicles without serious modifications of the vehicle structure.

The basic source of signal for the control system are the guiding shoes of the wheelsets, additionally equipped with extensometers. This solution allows for obtaining precise signals about the correct position of the bogie in the track, without significant modifications to the vehicle structure.

2 System idea

The position of the bogie in the curved track should be determined by the track radius and the wheel profile. These parameters force the radial position of the bogie, however, the stiffness of the primary and secondary suspension tries to keep the bogie parallel to the vehicle body. As a result, the bogie cannot be set radially, and its position induces high lateral and longitudinal forces. This indirect position is presented on figure 1.

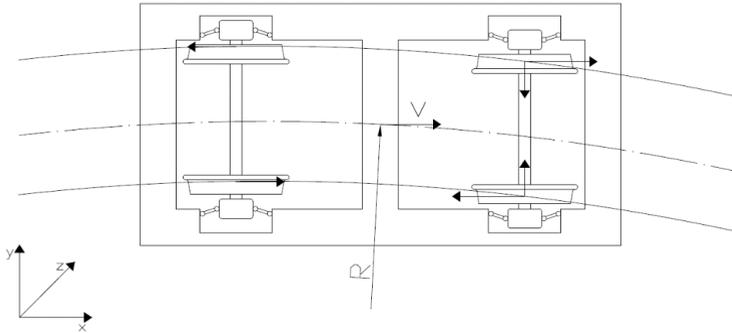


Fig. 1. Indirect position of the bogie on the track curve [5, 6].

To force the turn of the bogie and set it radially, it is required to balance the forces between wheels and rails. This can be achieved by using hydraulic actuators (figure 2).

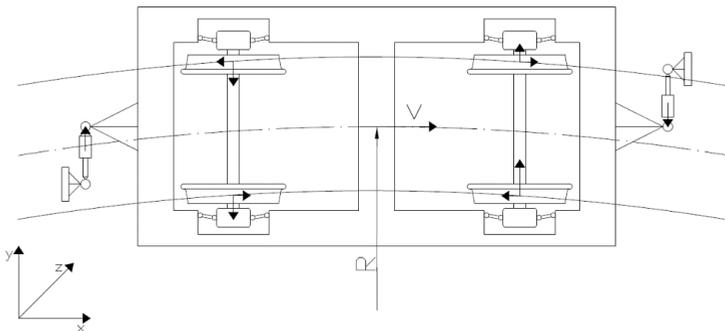


Fig. 2. Radial position of the bogie on the track curve [5, 6].

If elastic elements of the bogie primary and secondary suspension have significant stiffness, the wheelsets guiding elements are highly loaded. It allows to register high values of the strain with the use of extensometers mounted on the guiding elements. Thus the guiding elements act as dynamometers which measure lateral and longitudinal forces.

The goal is to minimize these forces in order to decrease the wear of wheels and rails and to set the bogie radially in the track. In some cases the higher values of lateral forces can lead to derailment. The symbolic diagram of bogie which is set radially and equipped with guiding elements with extensometers is presented on figure 3 [5,6].

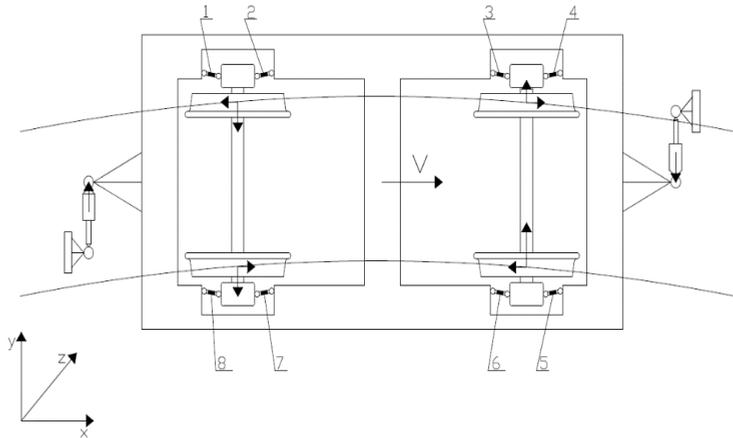


Fig. 3. Radial position of the bogie equipped with guiding elements with extensometers (1-8) [5, 6].

The lateral force causes bending of the guiding element, whereas the longitudinal causes compression or tension of this element. These various strain conditions can be identified when the extensometers are mounted on both sides of each guiding element.

3 Numerical simulation of the modified Alstom guiding element

There were numerical simulations conducted to identify areas where extensometers mounted on the Alstom guiding element could register significant strain values.

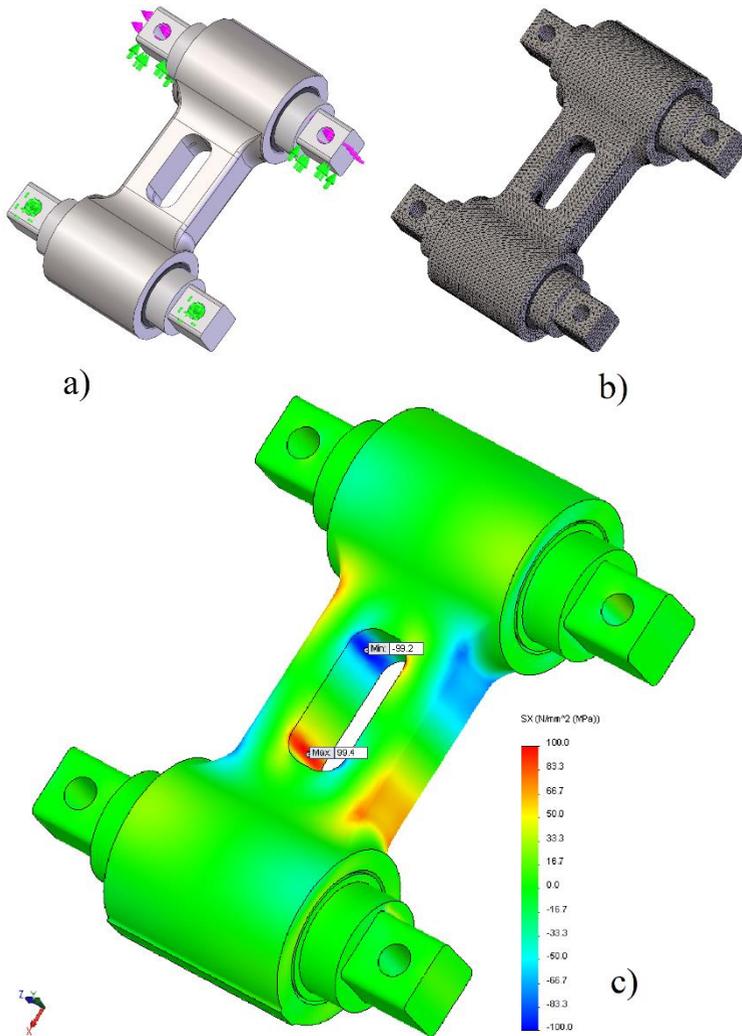


Fig. 4. The numerical model of Alstom guiding shoe in the particular steps of the analysis. (a) – numerical model with loads and boundary conditions, (b) – mesh, (c) – view of the normal stress [6].

To verify results obtained in the simulations, there was test stand made and guiding element modified.

The extensometers were mounted in the inner surface of the guiding element which was machined especially for this test. The test stand is presented on figure 5a and the modified pair of guiding elements are presented on figure 5b.



Fig. 5. The guide shoes test stand. (a) – test stand, (b) – connected guide shoes [6].

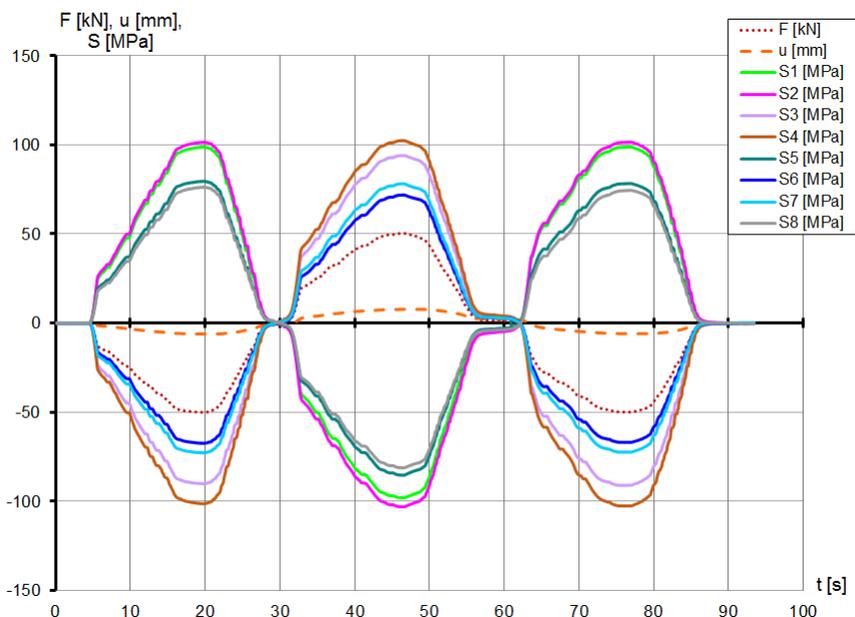


Fig. 6. Stresses, force and displacement measured on the guide shoes [6].

The results obtained in the test stand are presented on figure 6. The lines marked by symbols S1-S4 refer to the extensometers mounted on the first guiding element. The second group of lines, that are marked by symbols S5-S8, refer to the extensometers that are mounted on the second guiding element. The stress values measured by the first group of extensometers are lower than the stress values measured by the second group of extensometers. The different results are caused by the different condition of the elastic elements. Despite this, the results obtained in the numerical simulation and experiments are similar [6].

4 Numerical simulation of the 111E locomotive guiding element

There was conducted also a numerical simulation and experiment of the second type of guiding element which was designed for the 111E locomotive. In this design, there is only

one guiding element per an axlebox. But this element did not need modifications of the extensometers to register high strain values.

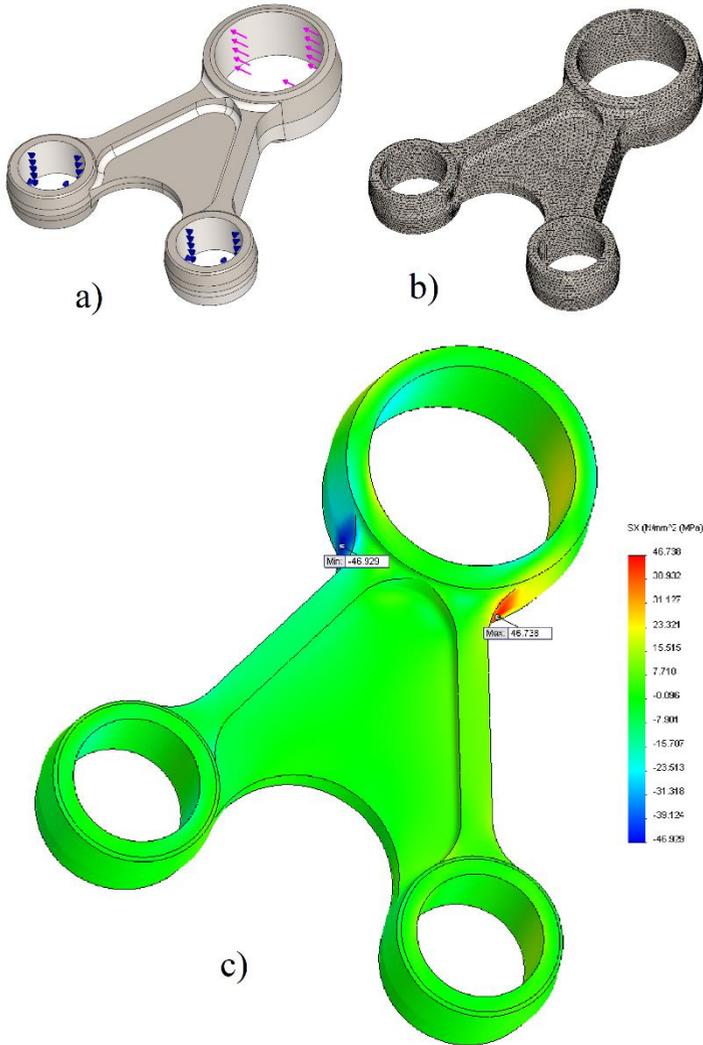


Fig. 7. The numerical model of locomotive 111E guiding shoe in the particular steps of the analysis.
(a) – numerical model with loads and boundary conditions, (b) – mesh, (c) – view of the normal stress.

To identify the optimal surfaces for mounting extensometers, there was made a numerical simulation. The results allowed to choose the surfaces which generated higher values of strain (figure 7).

Moreover, the modifications of the guiding elements were not allowed. The extensometers were mounted of the surfaces near the shape that connects the guiding element with the axlebox.



Fig. 8. The guide shoe of locomotive 111E. (a) – guide shoe view, (b) – view of the wheelset with guide shoe with extensometers.

The guiding element with extensometers mounted is presented on figure 8, whereas the locomotive with test stand equipment is shown on figure 9. During the test, there were strain values registered and are presented on figure 10.



Fig. 9. Locomotive 111E on test stand.

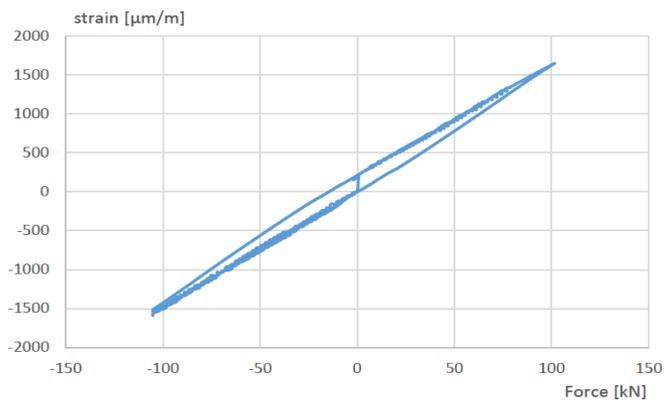


Fig. 10. Results of the strain measurement on test stand.

As it can be seen on the diagram, the force-strain ratio is nearly ideally proportional.

5 Conclusions

There were presented two types of the wheelset guiding elements. In each case, there were conducted numerical simulations and physical experiments. According to the results from all the tests, the registered strain signals appear to be appropriate steering parameters for the active radial steering system.

The Alstom guiding elements are mounted in locomotives with four or six axles, but they are not produced nowadays. In this type of vehicles, the interaction between wheels and rails is characterized by high lateral and longitudinal forces that cause significant wear of wheels and rails. In these vehicles, the radial active system could highly increase the mileage of wheelsets and decrease the noise and vibrations during the ride through a curved track.

The radial steering system is also applicable to modern vehicles without the necessity to modify the bogie elements. In this case, the yaw dampers can be replaced with the hydraulic actuator.

References

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