

CONCEPTUAL SOLUTION OF A TEST STAND FOR CALIBRATION OF MEASURING RAILWAY WHEELSETS FOR DIFFERENT TRACK GAUGES

Milan BIŽIĆ¹ [0000-0002-3815-9784]
Dragan PETROVIĆ² [0000-0002-1140-0662]

Abstract – The paper presents a conceptual solution of a test stand for calibration of measuring railway wheelsets. Unlike existing test stands that are designed for a single, fixed track gauge (1435 mm), the proposed conceptual solution enables testing and calibration of measuring wheelsets for different track gauges – 1435 mm and 1676 mm. The test stand is equipped with a linear platform for moving the contact point and a rotary platform for simulating the wheel angle of attack (angle up to 2.5°). The paper provides the basic concept, a description of the main functional units and technical specifications. The proposed solution is modular and adaptable, and can serve as a basis for further development and fabrication of the test stand.

Keywords – Test stand; Calibration of measuring wheelsets; Track gauge; Wheel-rail contact.

1. INTRODUCTION

The assessment of dynamic behavior of railway vehicles in terms of running safety is based on the measurement of lateral force Y and vertical force Q in wheel-rail contact, as well as their ratio Y/Q . These parameters are key indicators of running stability and the risk of derailment, especially when passing through curves. These measurements are defined by international standards that prescribe procedures for the acceptance of dynamic behavior of railway vehicles [1, 2].

For reliable measurement of forces Y and Q under operating conditions, measuring wheelsets are used, which are installed on the tested vehicle. These assemblies are equipped with sensors (most commonly strain gauges) that measure wheel deformations, based on which the required forces are determined indirectly by applying an appropriate algorithm. An important aspect of the application of measuring wheelsets is their adequate calibration in order to ensure appropriate measurement accuracy [3]. For this purpose, special test stands have been developed that enable calibration of measuring wheelsets under laboratory conditions. One solution of such a test stand is described in [4], where a test stand for calibration of measuring wheelsets is presented, which enables operation in static and dynamic modes, with independent application of

vertical and lateral forces in wheel-rail contact (Fig. 1). A detailed theoretical and experimental basis for the development of similar test stands is given in [5], where the influential parameters in wheel-rail interaction on the running stability of railway vehicles are analyzed, as well as methods for experimental determination of forces using measuring wheelsets.



Fig.1. Test stand for testing and calibration of measuring wheelsets [4, 5]

However, most existing test stand solutions are designed for a single, fixed track gauge. In modern railway practice, there is a need for calibration of measuring wheelsets used on vehicles intended for different track gauges. In addition to the standard gauge (1435 mm), other significant gauges include 1676 mm (broad gauge, present in India, Pakistan,

¹ Milan BIŽIĆ, Faculty of Mechanical and Civil Engineering in Kraljevo, University of Kragujevac, Dositejeva 19, 36000 Kraljevo, Serbia, bizic.m@mfkv.kg.ac.rs

² Dragan PETROVIĆ, Faculty of Mechanical and Civil Engineering in Kraljevo, University of Kragujevac, Dositejeva 19, 36000 Kraljevo, Serbia, petrovic.d@mfkv.kg.ac.rs

Spain), 1520 mm (Russia, Finland, former USSR countries), as well as 1668 mm (Portugal). Different track gauges require an appropriate geometry of the test stand, i.e., the possibility of adjusting the distance between the left and right wheel-rail contact pair. Some contemporary test stand solutions are based on the use of dynamic rollers and rotary platforms, which enable simulation of more realistic loading conditions, including the simulation of the wheel angle of attack [6–9]. However, these solutions are often designed for specific conditions and rarely offer the possibility of track gauge adjustment.

The aim of this paper is to propose a conceptual solution of a new test stand for calibration of measuring wheelsets, which enables testing and calibration for different track gauges (1435 mm and 1676 mm), linear movement of the contact point along the wheel profile, as well as simulation of the wheel angle of attack using a rotary platform (rotation angle up to 2.5°). The paper provides the basic concept, a description of the main functional units and technical specifications of the proposed test stand, which is modular and adaptable, and can serve as a basis for further detailed design and fabrication.

2. PROBLEM FORMULATION

The basic purpose of a test stand for calibration of measuring wheelsets is to enable simulation of loading conditions to which the measuring wheelset is exposed during actual movement of a railway vehicle. The simulation should be as realistic as possible, in order to establish, through calibration, a reliable relationship between the deformations recorded on the wheel and the forces causing these deformations.

In wheel-rail interaction, the key parameters to be determined are the vertical force Q and the lateral force Y (Fig. 2). The force Q represents the load transmitted by the wheel to the rail, originating from the weight of the vehicle and cargo. It is dominant under normal running conditions and directly affects the stresses in wheel-rail contact. The force Y arises as a consequence of centrifugal force when negotiating curves and vehicle guidance. Its value depends on running speed, curve radius, bogie design, etc.

The ratio Y/Q is the main indicator of running safety against derailment. When this ratio exceeds limit values (according to UIC 518 and EN 14363 standards, the limit is 0.8 for large radius curves, i.e. 1.2 for small radius curves), the wheel flange climbs onto the rail head and derailment occurs, which can have catastrophic consequences. Therefore, precise measurement and calibration of forces Y and Q is of crucial importance for railway safety.

In addition to forces Q and Y , the wheel angle of attack is also a significant parameter for analyzing vehicle behavior in curves, as it directly affects the

intensity of lateral forces and profile wear.

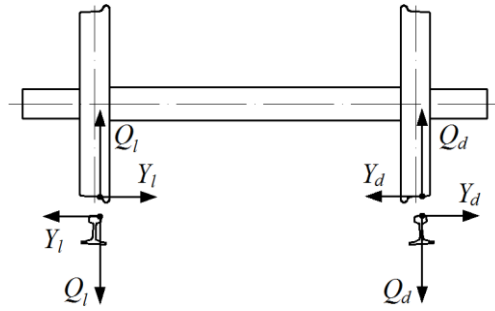


Fig.2. Forces in wheel-rail contact

Considering the above, the task of the test stand is to enable the following functions under laboratory conditions: independent application of force Q and force Y over a wide range; change of the contact point position along the wheel profile (from the rolling surface to the flange); simulation of wheel attack at a certain angle; operation in static mode (loading without rotation) and dynamic mode (loading during wheel rotation). In this way, the test stand should enable calibration of measuring wheelsets for different loading conditions corresponding to actual operation.

Existing test stand solutions are designed for a fixed track gauge – most commonly the standard gauge of 1435 mm. However, in some cases there is also a need for calibration of measuring wheelsets of larger track gauge. Namely, several standard track gauges exist on world railways. In addition to the standard gauge (1435 mm), broad gauges also exist – 1520 mm (Russia, Finland, former USSR countries), 1600 mm (Ireland), 1668 mm (Portugal, Spain) and 1676 mm (India, Pakistan, Bangladesh, Argentina, Chile). Based on the above, a requirement has been formulated for the development of a conceptual solution of a test stand for calibration of measuring wheelsets for different track gauges (1435 mm and 1676 mm). The test stand should enable linear movement of the contact point along the wheel profile, simulation of the wheel angle of attack, and independent application of Q and Y forces on the left and right wheels. Solving such a problem requires the synthesis of several engineering disciplines from the fields of railway engineering, mechanical structures, hydraulic and electrical systems, as well as control engineering.

3. CONCEPTUAL SOLUTION OF THE NEW TEST STAND

Starting with the defined problem, a conceptual solution of the new test stand has been developed, which is shown in Fig. 3. Unlike existing solutions, which are designed for a fixed track gauge, the proposed test stand enables operation with measuring wheelsets for two different track gauges – 1435 mm and 1676 mm. The difference is only in the universal

bracket with housing that is fitted onto the axle journal of the measuring wheelset being calibrated or tested. A telescopic type bracket is envisaged to enable removal of the wheelset from the supporting columns of the test stand. More precisely, two types of brackets are envisaged – one bracket for accommodating measuring wheelsets for 1435 mm gauge, and the other bracket for 1676 mm gauge.

Installation and removal of the measuring wheelset into the test stand is envisaged from the side of the test stand, using special rails and an additional structure with a roller system. In this process, after removing the load cell and with an appropriate attachment, the lifting function of the measuring wheelset is performed by the hydraulic cylinders for applying the vertical force. Guidance of the measuring wheelset bracket within the columns of the test stand

supporting structure is provided by a bearing system. In this way, handling is facilitated and the risk of damage to sensitive sensors (strain gauges) during installation and removal is reduced.

The function of changing the contact point position between the wheel and the rail imitation is envisaged by means of a linear platform that moves on a roller system. This platform is envisaged to be fixed onto the rotary platform, and its movement should enable positioning of the wheel-rail contact point in very fine intervals with an accuracy of ± 0.5 mm. Hydraulic cylinders with electric control are envisaged for moving the linear platform. The operation of the hydraulic cylinders on the left and right sides of the measuring wheelset should be synchronized, and the contact point position should be monitored using appropriate position sensors with electric readout.

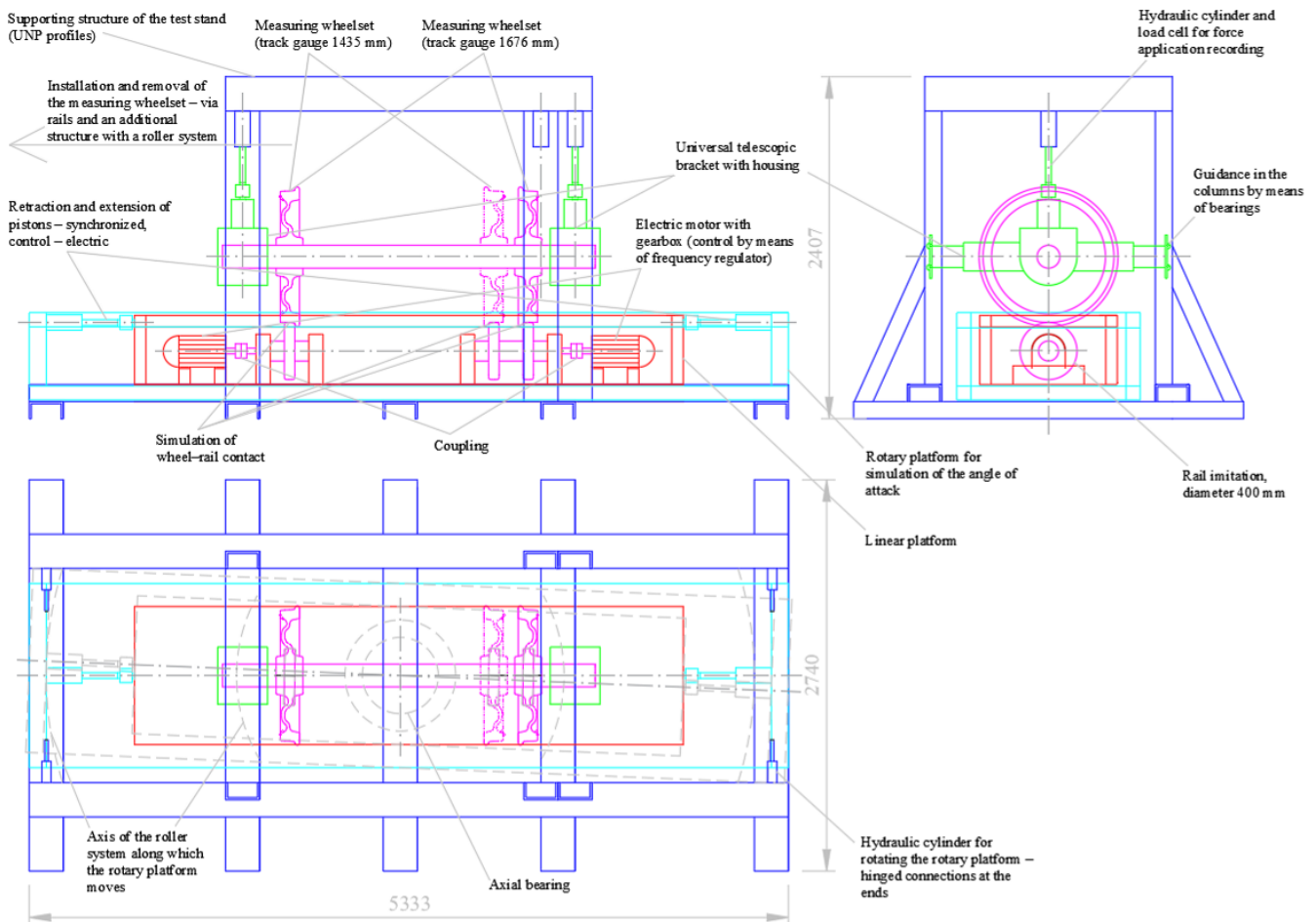


Fig.3. Conceptual solution of the test stand for different track gauges

Simulation of the wheel attack under a certain angle is envisaged by means of a rotary platform. The platform is envisaged to be rotated using four hinged hydraulic cylinders, with a maximum rotation angle of 2.5° . Movement of the platform is envisaged via a special roller system fixed to the test stand supporting structure. Rotation of the platform is envisaged via a large-diameter axial bearing (similar to solutions used on excavators). As already mentioned, the linear platform

would be supported onto this rotary platform via a roller system, thus enabling independent movement along both axes. Control of the hydraulic cylinders for platform rotation is envisaged to be electric, with the possibility of fine adjustment of the wheel-rail angle of attack.

Simulation of wheel-rail contact is envisaged by means of a lower pair of wheels which are specially machined so that their profile imitates the rail head. The diameter of these wheels should be 400 mm. Rotation of

this lower pair of wheels is envisaged via two drive electric motors with gearboxes and cardan shafts, which also enables rotation of the tested measuring wheelset. Control of the electric motors is envisaged using frequency regulators, and the rotation speed can be finely adjusted in accordance with the calibration requirements of the measuring wheelset (the maximum rotation speed should correspond to a linear speed of approximately 70 km/h). For more efficient and simpler calibration of both wheels of the measuring wheelset, it is envisaged that both drive electric motors are connected to the lower pair of wheels via couplings. In this way, during calibration, simple connection and disconnection of the drive is enabled – when one coupling is engaged, the other should be disengaged, and vice versa.

Application of the force Q in the contact between the calibrated wheel and the rail head imitation is envisaged via hydraulic cylinders acting on the vertically movable bracket of the upper wheelset. Application of the force Y is envisaged by moving the linear platform, also via the previously mentioned hydraulic cylinders. It should be possible to apply these forces independently of each other, both in static and dynamic mode (loading during rotation). The test stand should enable application of force Q up to 160 kN and force Y up to 100 kN per wheel being calibrated. Application of forces Q and Y must be possible in steps of 1.0 kN, with an accuracy of approximately 0.1 kN. For recording the values of the applied forces, appropriate load cells connected directly to the test stand control module are envisaged.

The control module of the test stand should enable efficient and integrated control of all the aforementioned functions – positioning of the linear and rotary platforms, application of forces, control of the electric motor rotation speed, as well as monitoring of the safety systems. The supporting structure of the test stand is envisaged from steel UNP profiles, with additional stiffeners providing the required rigidity under maximum loads. The overall dimensions of the test stand are approximately: length 5.3 m, width 2.8 m, height 2.4 m. The test stand should be equipped with all necessary safety systems – an electronic curtain, an emergency stop button, etc. All rotating elements of the test stand should be painted red, linearly movable elements blue, and stationary elements yellow, or other colors as desired.

4. CONCLUSION

The paper presents a conceptual solution of a test stand for calibration of measuring railway wheelsets for different track gauges. Unlike existing test stands, which are designed for a single, fixed track gauge (1435 mm), the proposed solution enables calibration of measuring wheelsets for two different track gauges – 1435 mm and 1676 mm. The test stand is envisaged with a linear

platform for precise positioning of the contact point along the wheel profile (with an accuracy of ± 0.5 mm) and a rotary platform for simulation of the wheel angle of attack (up to 2.5°). Independent application of vertical force Q (up to 160 kN) and lateral force Y (up to 100 kN) is envisaged, with a force step of 1 kN and an accuracy of approximately 0.1 kN. The test stand is envisaged to operate in both static and dynamic modes, with a maximum rotation speed corresponding to a linear speed of 70 km/h. The proposed solution is modular, adaptable and can serve as a basis for further detailed design and fabrication. Future work should focus on detailed structural analysis, selection of specific commercial components, and experimental validation of the proposed test stand.

ACKNOWLEDGEMENT

The authors are grateful to the Ministry of Science, Technological Development and Innovation of the Republic of Serbia for support (contract no. 451–03–34/2026–03/200108).

REFERENCES

- [1] UIC CODE 518 OR, Testing and approval of railway vehicles from the point of view of their dynamic behavior – Safety – Track fatigue – Running behavior, 4th edition, Int. Union of Railways – UIC, 2009.
- [2] EN 14363, Railway applications – Testing for the acceptance of running characteristics of railway vehicles – Testing of running behavior and stationary tests, Eur. Comm. for Standardization – CEN, 2005.
- [3] Petrović, D., Babić, A., Bižić, M., Djelošević, M. (2010). Measuring systems for testing the safety and security of railway vehicles. Proceedings of RAILCON 2010, Niš, pp. 177-181.
- [4] Bižić, M., Tomić, M., Djinić, Z., Petrović, D. (2011). Test stand for calibration of measurement railway wheelsets. Proceedings of IRMES 2011, Zlatibor, pp. 419-424.
- [5] Bižić, M. (2015). Istraživanje uticajnih parametara u interakciji točak-šina na stabilnost kretanja železničkih vozila. Doktorska disertacija, Univerzitet u Kragujevcu., (in Serbian).
- [6] Bracciali, A., Macherelli, M., Boccolini, L. (2016). Design of an Innovative Test Bench to Calibrate Instrumented Wheelsets. Proceedings of the third international conference on railway technology: research, development and maintenance, 4.4.2016-8.4.2016.
- [7] Jin, X. (2020). A measurement and evaluation method for wheel-rail contact forces and axle stresses of high-speed train. Measurement, Volume 149, 106983.
- [8] Jin, X. (2020). Evaluation and analysis approach of wheel-rail contact force measurements through a high-speed instrumented wheelset and related considerations. Vehicle System Dynamics, Volume 58, Issue 8, pp. 1189-1211, 23 pp.
- [9] Kothari, K. (2018). Accurate Wheel-rail Dynamic Measurement using a Scaled Roller Rig. Masters Theses, Virginia Tech.