THE 7TH INTERNATIONAL CONFERENCE RESEARCH AND DEVELOPMENT OF MECHANICAL ELEMENTS AND SYSTEMS

TEST STAND FOR CALIBRATION OF MEASUREMENT RAILWAY WHEELSETS

Milan BIŽIĆ
Miloš TOMIĆ
Zoran ĐINOVIĆ
Dragan PETROVIĆ

Abstract: *The paper describes the development of a special test stand for calibration and testing of measurement railway wheelsets. Measurement railway wheelsets are used for testing dynamic characteristics of railway vehicles from the aspect of quiet running and running safety in accordance with the international regulation UIC 518. During the running of the tested railway vehicle the main task of the measurement wheelset is registration and acquisition of data about Y and Q forces which occur in the wheel-rail contact, as well as their ratio Y/Q, which is one of the most important parameters for assessment of the quality of quiet running and running safety. For calibration of such measurement wheelsets a special test stand that allows working in laboratory conditions was developed. The main function of the test stand is to provide the wheel-rail contact, where the rail is enabled by a specially processed wheelset, while the wheel is enabled by the measurement wheelset. For thus adopted concept the carrying structure that allows easy assembly and disassembly of measurement wheelsets was designed. The test stand allows calibration of measuring wheelsets in quasi-static and dynamic operating modes. It is equipped with a driving electromotor with a gearbox, where the regulation of rotating speed is performed by a frequency regulator. In addition, the test stand is equipped with hydraulic systems for setting loads in vertical and horizontal directions, force converters in vertical and horizontal directions, and alpha numeric displays for reading the values of Y and Q forces.*

Key words*: test stand, calibration, measurement wheelset, wheel-rail contact, railway vehicle*

1. INTRODUCTION

Identification of the behaviour of railway vehicles can be based on theoretical and experimental approach. The theoretical approach involves the forming of appropriate mathematical models, with certain restrictions and assumptions, and the numerical solution of these models. It should be noted that due to the introduction of assumptions and simplifications, as well as various other factors the obtained results to some extent differ from the actual behaviour of the vehicle in operational conditions. Bearing in mind the greater or lesser extents of these differences the results of theoretical methods and simulation cannot be with certainty taken as reliable indicators of the quality of the behaviour of railway vehicles. Given this fact, in addition to theoretical, identification of behaviour of railway vehicles should be based on the experimental approach and the experimental investigation of the vehicle or its components in working condition. In some cases it is possible to performing the experimental tests in laboratory conditions. Experimental tests combined with the use these theoretical methods are an essential prerequisite for the process of quality development and design of new types, or changes to improve the characteristics of the existing types of railway vehicles [1-8]. In addition, in the certification process for all newly-designed types of railway rolling stock performance of some experimental testing is mandatory and required by relevant international standards and norms such as UIC, TSI, EN, ERRI, etc.

One of the major problem in identifying the behaviour of railway vehicles, both theoretical and experimental, is the identification of their dynamic properties related to quiet running and running safety. Experimental tests of quiet running and running safety are prescribed by international standard UIC 518, and these include the following tests [9, 10]: measurement of forces in the wheel-rail contact (Y/Q); measurement of lateral forces (H) at the height of the axle-bearing; measurement of acceleration on some parts of wagon; measurement of deformation of the critical parts of wagons; measurement of the distance covered and speed of wagon.

One of the key indicators of safety movement of railway vehicles on the railway is the ratio of forces in the contact between the wheel and rail Q and Y (ratio Y/Q) which, according to the mentioned standards must be within the certain limits. According to TSI standards [11] in order to limit the risk to avoid climbing the wheel on the rail ratio of forces Y and Q must be within of the following limits:

$(Y/Q) < 1.2$ – for small curvature with radius $R < 250$ m

$(Y/Q) < 0.8$ – for large curvature with radius $R \geq 250$ m

Measurement of forces in contact between the wheel and rail is usually performed by using a specially developed instrumented measurement wheelsets that are mounted on the tested wagon. During the running of the tested wagon these measurement wheelsets registering information about the values of forces Y and Q [12, 13].

In the laboratory of the Center for Railway Vehicles in Faculty of Mechanical Engineering Kraljevo there is a special test stand for calibration of the measurement railway wheelsets. This test stand was developed as a part of the implementation of international FP-7 project "Strengthening Railway Vehicles Centre of Faculty of Mechanical Engineering Kraljevo – acronym Service" [14]. The technical description and characteristics of the test stand are in the focus of this paper.

2. CHARACTERISTICS AND FUNCTION OF THE MEASUREMENT WHESLSETS

The main task of the measurement wheslsets is a continuous measurement of lateral force Y and the vertical force Q that appear in the contact between the wheel and rail (Figure 1). The measurement wheelsets allow measurements of forces Y and Q in quasi static and dynamic operating modes, which means that the values of the forces can be registered when the vehicle is stationary or moving on the railway track.

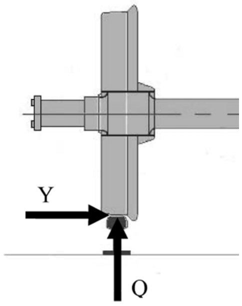

Fig.1. Y and Q forces in the wheel-rail contact

In most cases the technical design of the measurement wheelsets is based on the measurement of deformation of the wheels in a specially selected points that have bonded strain gauges connected to the corresponding measuring Wheatstone bridges (Figure 2) [12, 13].

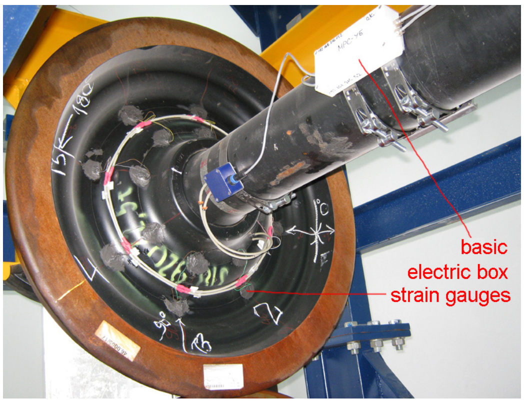

Fig.2. Measurement wheelset

The choice of the strain gauges positions on the wheel are determined according to the so called principle ''zero impact''. It means that mutual interaction between the Y and Q forces at these points is minimal. These points are calculated by the stress-strain analysis of the wheel using the finite element method (FEM) (Figure 3). The measurement wheelset is mounted on the tested wagon, where the regime and test conditions must comply with the conditions prescribed in standards.

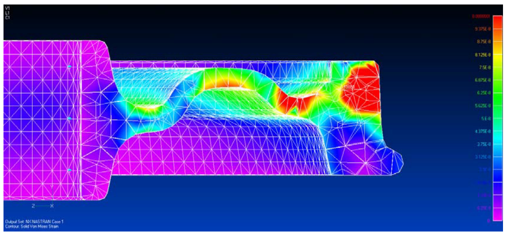

Fig.3. Stress-strain calculations of the wheel using FEM

During the running of the tested wagon on the railway track the wheel-rail interaction leads to the deformations of the wheel that are registered by the strain gauges. The information is further transferred to the corresponding electronic modules that on line acquire and storage the signals in real time. Using a specially developed software package these signals are processed and real values of Y and Q forces and their ratio Y/Q is calculated.

In the process of development, production and using of the measurement wheelsets one of the most important activities is to solve the problem of their calibration. This problem is under researching (which is presented in this paper) resolved by a special test stand which allows working in the laboratory conditions.

3. TEST STAND FOR CALIBRATION OF THE MEASUREMENT WHEELSETS

The main task of the test stand is calibration and testing of measurement wheelsets of railway vehicles in quasi static and dynamic operating modes. The test stand provides an important opportunity to work with a measurement wheelsets in the laboratory conditions at minimal costs of testing. The basic function of the test stand is to provide the contact between wheel and rail, as well as to give an opportunity for on line measurement of Y/Q ratio in dependence on the position of the contact point between wheel and rail.

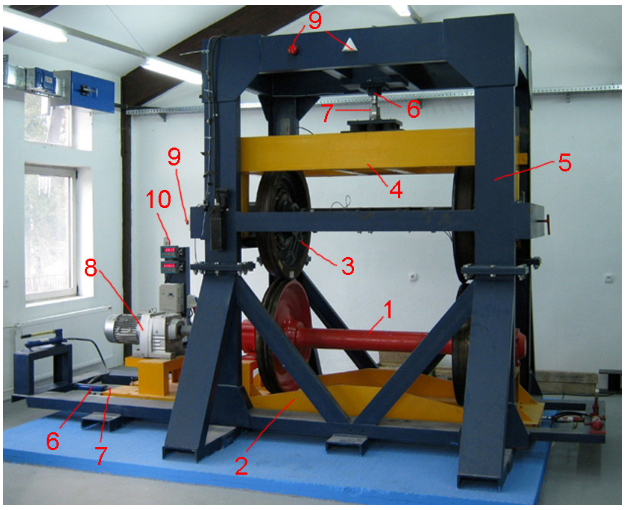

Fig.4. Test stand for calibration of the measurement railway wheelsets

The basic parts of the test stand are (Figure 4):

1. Down wheelset
2. Horizontally motional carrier of down wheelset
3. Top wheelset (wheelset that is calibrated – tested)
4. Vertically motional carrier of top wheelset
5. Supporting construction
6. Hydraulic systems for setting forces Y and Q
7. Systems for registering the values of given forces Y and Q
8. Drive movement
9. Safety and security systems
10. Control console

3.1. Providing of the wheel-rail contact

The role of the rail is accomplished using by the down wheelset, while the function of the wheel is performed by the top wheelset which is calibrated. The down wheelset is specially processed so that its radius of the wheel profile corresponds to the radius of the head of the rail profile (Figure 5).

Fig.5. Wheel-rail contact on the test stand

The down wheelset is fixed on a horizontally motional carrier that over specially designed system of rollers (Figure 6) moves ahead and back in a straight line across the framework of supporting structure of the test stand.

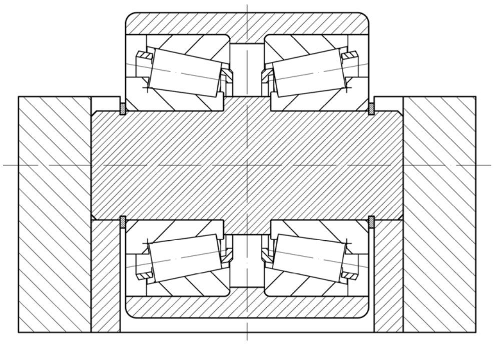

Fig.6. Cross-section of the roller for moving the horizontally motional carrier of the down wheelset

The top wheelset is mounted on the vertically motional carrier that moves up and down in a straight line in guides - vertical pillars of the supporting structure (Figure 7).

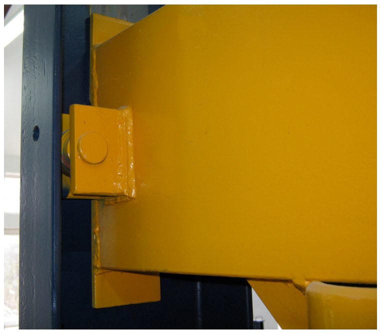

Fig.7. Detail of guides for moving of the vertically motional carrier of the tested wheelset

In this way, the two independent movements are realized, horizontal movement of the down wheelset that is represents the rail, and vertical movement of the top wheelset which is tested (calibrated). By action of the hydraulic cylinder on a horizontally motional carrier, the entire system together with the down wheelset is actuated and creates a horizontal force Y in contact between the wheel of the calibrated wheelset and wheel of the down wheelset. By action of the hydraulic cylinder on a vertically motional carrier, the entire system together with the top calibrated wheelset is actuated and creates a vertical force Q in contact between the wheel of calibrated wheelset and wheel of the down wheelset.

In this way it is performed a laboratory investigation of forces in the contact between the wheel and rail that occur during the movement of railway vehicle on the track. Forces can set independently of each other, and the system allows changing the location of the contact point on the tread surface of the wheel. The test stand allows the setting of forces in vertical direction up to 225 kN, and in the horizontal direction up to 100 kN. The whole system is designed to calibrate the measurement wheelsets of a normal track with a width 1435 mm, and to work with wheelsets whose carrying capacity is up to 22.5 t.

In this way it is possible to measure the deformations (or stresses) of the measurement wheelset in dependence of the predefined Y/Q ratio.

3.2. Supporting construction

The supporting structure of the test stand is composed of steel UNP profiles that are connected with bolted and welded connections (Figure 8). Basis of supporting structure makes the framework that serves for the suspension of the test stand on a hard concrete base. In addition, the framework acts as a support for a hydraulic cylinder through which the force Y is set, and across the framework is moving the horizontally motional carrier of down wheelset. On the framework there are welded four vertical pillars, which are mutually connected in the upper part and a make space frame. This space frame serves as a support for the hydraulic cylinder through which specifies the force Q, and pillars also serve as guides for movement of the vertically motional carrier.

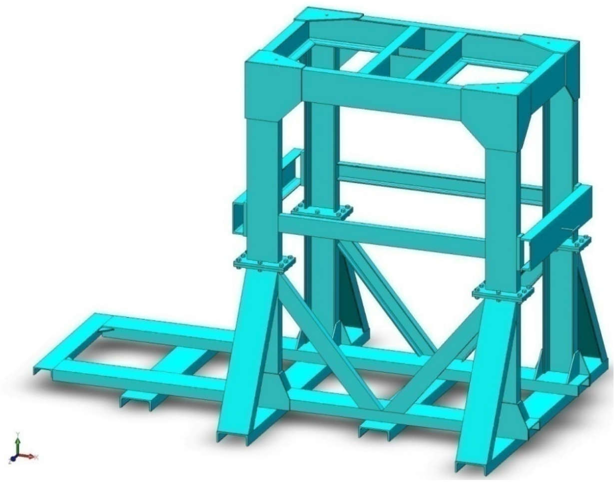

Fig.8. Supporting construction of test stand

The whole system has been further stiffened using ribs and rods to achieve the required stiffness during the work regime and ensure the preservation of the projected geometry. Supporting structure in its middle part can be disassembled which ensures easy assembly and disassembly of measurement wheelsets with minimal risk of their damage.

Thus, the supporting structure is designed to provide quality testing and maximum stability of the entire system during the maximal loads and rotating speeds of wheelsets.

3.3. Systems for setting and registering the values of forces Y and Q

For setting the force Y in the horizontal direction is used the hydraulic cylinder which is driven over the hand pump (Figure 9). This system allows the assignment of force up to 100 kN.

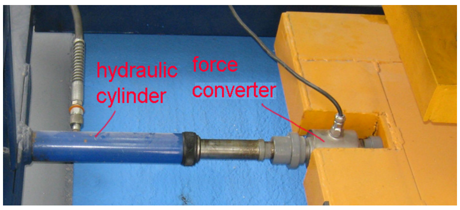

Fig.9. System for setting and registering force Y

Detection of values of given force Y is done using the converter produced by FLINTEC that is set between the piston of hydraulic cylinder and construction of horizontally motional carrier of down wheelset (Figure 9). For setting the force Q in the vertical direction it is also used the hydraulic cylinder which is driven over its hand pump (Figure 10). This system allows the assignment of force up to 225 kN. Detection of values of given force Q is also done using the converter produced by FLINTEC that is set between the piston of hydraulic cylinder and construction of vertically motional carrier of top wheelset (Figure 10).

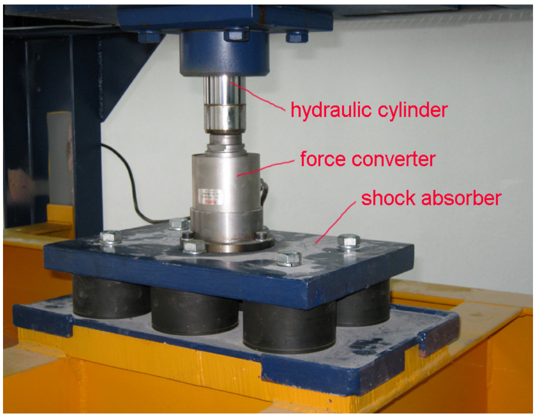

Fig.10. System for setting and registering force Q and rubber-metal shock absorber

To reduce the high-frequency vibrations and prevent overloading of the system it is designed a special rubber-metal shock absorber (Figure 11). The absorber consists of six equal rubber parts of certain rubber hardness and is placed between the converter for Q force and the vertically motional carrier of top calibrated wheelset (Figure 10).

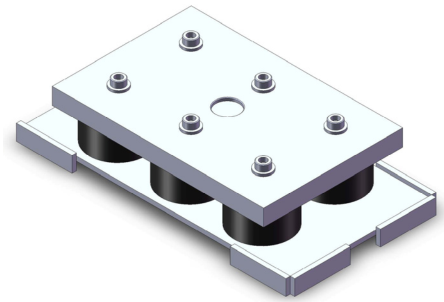

Fig.11. Model of the rubber-metal shock absorber

The values of applied horizontal and vertical forces obtained from the force converters are displayed on two digital alpha numeric displays with a precision ±10 N (Figure 12).

Fig.12. Alpha numeric displays for displaying the values of given forces Y and Q

3.4. Drive movement

For testing and calibration of the measurement wheelsets in dynamic operating mode it is necessary to provide the rotating movement of the tested wheelset. This is provided indirectly through the down wheelset whose task is to represents the rail. The down wheelset receives the rotating movement across the cardan shaft that is powered by the electric motors with gear (Figure 13).

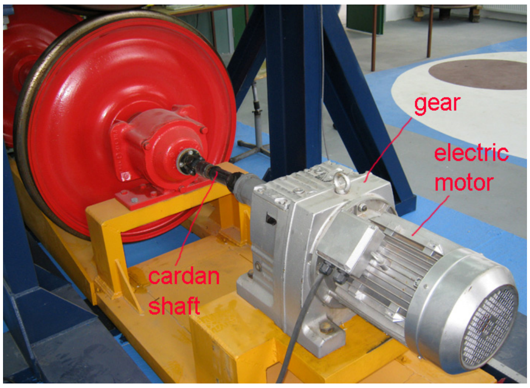

Fig.13. Drive movement

The power of electric motor is 7.5 kW, while speed of rotation is regulated by the frequency regulator (Figure 14).

Fig.14. Frequency regulator

The main electric switch, frequency regulator and the alpha numeric displays for reading the values of forces Y and Q are placed on a special control console that can be moved in the immediate area around the test stand (Figure 15).

Fig.15. Control console

3.5. Safety and security systems

In the interest of safety and prevent accidents and injuries on test stand is set up security electronic curtain (Figure 16). The electronic curtain provides an automatic shutdown of the test stand when it comes to cutting the laser rays, or entry of persons or objects in the forbidden zone around the test stand. In addition, on the test stand is installed a security button "all stop" (Figure 16). In the event of an accident by pressing this button the test stand will be immediately stopped.

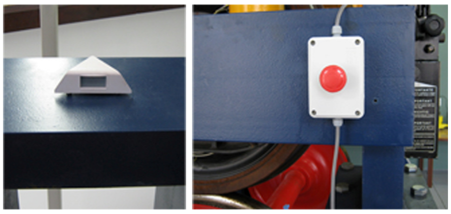

Fig.16. Security electronic curtain (left) and button "all stop" (right)

3.6. Technical specifications of the test stand

The main technical specifications of the test stand are given in the following table.

Table 1. Technical specifications of the test stand

Purpose	Testing and calibration of the measurement railway wheelsets
Modes of testing	Quasistatic; Dynamic
Supporting construction	Steel; profiles UNP
Overall dimensions	Length 4147 mm Height 2935 mm Width 2700 mm
Acceptance of the measurement wheelsets	1435 mm Carrying capacity up to 22.5 t
Driving electric motor	380 V; 50 Hz; 7.5 kW
Frequency regulator	380 V; 10 Hz; 3 PH
The maximum number of revolutions	5 o/sec
Maximum force in vertical direction	225 kN
Maximum force in horizontal direction	100 kN
Force converter in vertical direction	up to 300 kN
Force converter in horizontal direction	up to 300 kN
Safety and security systems	Electronic curtain Button "all stop"

4. CONCLUSION

The paper describes the test stand for testing and calibration of the measurement wheelsets of the railway vehicles. The test stand provides generation of forces that occur in contact between the wheel and rail in laboratory conditions, with minimal costs of testing and with minimal risk of damage of the tested measurement wheelsets.

The wheelset is a part of the railway vehicle which is exposed to extreme loads in working conditions, and therefore represents the most responsible part of the railway vehicle. Security of the entire railway vehicle, and usually the security of the whole train depend on the safety and reliability of the wheelset. Failure of the wheelset in running is in most cases resulted with major incidents that are often accompanied with a huge human casualties and material damage. For these reasons, there are very current scientific researches in the many innovative projects with the topic of increase security and reliability of the wheelsets. Combining the theoretical and numerical calculation methods of the wheel and comparing their results with those obtained by testing on the test stand it is possible to study the influential parameters on the stress-strain state of the wheel. On this basis it is possible to conduct further research in the field of optimization and finding the optimal shapes of the wheel. The test stand also provides laboratory testing of the wheelsets with innovative solutions, shapes and dimensions, and the introduction of new types of materials. In addition the test stand enables laboratory testing of the wheelsets with innovative solutions to increase safety and security such as systems for on-line monitoring, on-line measurement Y/Q ratio, etc.

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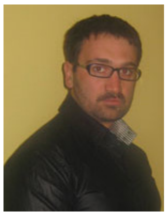
CORRESPONDANCE



Milan BIŽIĆ, Ass. M.Sc. Eng.
University of Kragujevac
Faculty of Mechanical
Engineering Kraljevo
Dositejeva 19,
36000 Kraljevo, Serbia
bizic.m@mfkv.kg.ac.rs

Zoran ĐINOVIĆ, D.Sc. Eng.
Vienna University of Technology
Institute for Sensors and
Actuators Systems
Floragasse 7,
1040 Wien, Austria
Integrated Microsystems Austria GmbH
Viktor Kaplan Straße 2/1,
A-2700 Wiener Neustadt, Austria
djinovic@ima-mst.at

Miloš TOMIĆ, D.Sc. Eng.
University of Beograd
School of Electrical Engineering
Bulevar kralja Aleksandra 73,
11120 Belgrade, Serbia
milos.tomic@gmail.com

Dragan PETROVIĆ, Prof. D.Sc. Eng.
University of Kragujevac
Faculty of Mechanical
Engineering Kraljevo
Dositejeva 19,
36000 Kraljevo, Serbia
petrovic.d@mfkv.kg.ac.rs