THE 6th INTERNATIONAL CONFERENCE
MECHANICAL ENGINEERING IN XXI CENTURY

December 14 – 15, 2023, Niš, Serbia
Faculty of Mechanical Engineering University of Niš

CENTER FOR RAILWAY ENGINEERING AND STRUCTURES TESTING AT FACULTY OF MECHANICAL AND CIVIL ENGINEERING IN KRALJEVO – RECENT RESEARCH AND PERSPECTIVES

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Abstract: *The main goal of this paper is an overview of recent activities and research of the Center for Railway Engineering and Structures Testing at the Faculty of Mechanical and Civil Engineering in Kraljevo. A brief overview of the Center's most significant research with basic information is given. Special attention is paid to cooperation with the industry, participation in scientific and innovation projects, as well as the development and procurement of modern measuring equipment. At the end, perspectives and opportunities for further work and development of the Center are analyzed in the context of current trends and the state of the railway industry in Serbia and the region.*

Keywords*: Center, Railway vehicles, Railway engineering, Structures testing, Faculty, Kraljevo.*

1. INTRODUCTION

After the invention of the steam engine and the first locomotives in the 19th century, the development of railway traffic enabled the rapid progress of the economy around the world, and the level of development and the quality of life of most of humanity increased significantly. Since that time, railway vehicles and railway infrastructure have constantly developed and improved. In a historical sense, in a relatively short time of some 200 years, wooden railway vehicles and wooden rails have transformed into today's modern maglev trains. The peak of development of railway was during the thirties of the 20th century at the time of steam traction, when railway were the dominant means of transporting people and goods. After that, the intensive development of road and later air traffic began, as a result of which the share of rail traffic in the total transport of passengers and goods decreased. Despite this, the modern way of life and the functioning of developed economic systems today cannot be imagined without railway traffic, which has many advantages compared to other forms of transport [1].

The first railway in Serbia was opened in 1884 and connected Belgrade and Niš. It was built thanks to the agreement of the Congress of Berlin held in 1878, when Serbia undertook to build this railway, while Austria-Hungary undertook to enable its connection with its railway network. With the construction of this railway, which is part of the railway network that connects the heart of Europe with the Middle East, Serbia became a strategic and extremely important traffic corridor, which it still is today.

The first serious factories of railway vehicles in the former Yugoslavia were established during the middle of the 20th century, at the time of the beginning of the comprehensive expansion of the economy, when there were great needs of domestic and foreign railways for various types of railway vehicles, primarily wagons. This is how renowned Serbian factories were born, such as Wagon Factory Kraljevo, Goša Smederevska Palanka, MIN Lokomotiva Niš, MIN Vagonka Niš, Želvoz Smederevo, Šinvoz Zrenjanin, Bratstvo Subotica, as well as many other smaller factories that produced parts and equipment for railway vehicles [2].

One of the most significant roles in the development and rise of the domestic industry of railway vehicles was played by the Wagon Factory Kraljevo. In its heyday, it was synonymous with quality and exported freight wagons to 5 continents [3]. It had a fully rounded process of production of freight wagons, including its own development center and center for experimental tests, i.e. certification of newly designed wagons. In addition, it had a highly developed production of road vehicles, process equipment, springs, parts for the automotive industry, tools, as well as a modern foundry. In such conditions, highly qualified engineering and professional personnel were needed. This was one of the main motives for establishing the Faculty of Mechanical Engineering in Kraljevo, first as the Center for Extramural Studies of the Faculty of Mechanical Engineering in Belgrade in 1960, then as a regular department of the Faculty of Mechanical Engineering in Belgrade in 1975, and finally as an independent faculty within the University in Kragujevac in 1987 [4]. Within the Wagon Factory Kraljevo, a special organizational unit was established - the Test Center. Its founder and first leader was prof. Ranko Rakanović, later one of the founders and the first dean of the Faculty of Mechanical Engineering in Kraljevo. In this way, a very strong and unbreakable connection was created between the newly founded faculty and the factory. During several decades of successful work, over 200 different types of railway vehicles and other structures were tested in the Test Center of the Wagon Factory Kraljevo [5]. All tests have been performing in accordance with current international and national regulations, and as a result, a

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huge number of reports and studies were created. The Test Center, with the support of the Faculty of Mechanical Engineering in Kraljevo, was one of the main pillars of the development of the Wagon Factory Kraljevo, but also of other factories of railway vehicles and structures for which it has been performing different experimental tests. The Wagon Factory Kraljevo had engineers who were capable for solving the most complex problems in the field of wagon building - it was a time when it had a fully rounded process "From Idea to Realization".

Unfortunately, after the wars in the former Yugoslavia at the end of the 20th century, the NATO bombing and the transition period at the beginning of the 21st century, the Wagon Factory Kraljevo, as well as almost all other factories of railway vehicles in Serbia, have stopped working and producing railway vehicles. In the conditions of cessation of work and bankruptcy of the Wagon Factory Kraljevo, the only way to try to save the decades-long knowledge base was to establish the Center for Railway Engineering and Structures Testing at the Faculty of Mechanical Engineering in Kraljevo - now the Faculty of Mechanical and Civil Engineering in Kraljevo. This was done in 2009, during which Laboratory for Railway Engineering and Structures Testing was established within the Center (Fig. 1).

Fig.1. Detail from Laboratory for Railway Engineering and Structures Testing

2. RESEARCH OF CENTER

From its foundation until today, the Center for Railway Engineering and Structures Testing has been working in the following directions: cooperation with industry; participation in scientific and innovation projects; development and procurement of modern measuring equipment; engaging in scientific research work; implementation of teaching at basic, master's and doctoral academic studies; writing teaching literature, etc. Some of the most significant results of the Center are listed below.

2.1. Measurement of wheel-rail contact forces

Within the international FP-7 project "SeRViCe" which was finished in 2012, modern measuring equipment for continuous measurement of wheel-rail contact forces was developed and acquired. In cooperation with the experts of the Belgrade company "Optical Sensor Systems - OSS", a special measuring system "MEROSA" was developed and produced. It contains two instrumented wheelests of freight wagon, electronic-computer unit for reception and storage of signals and computer module for processing and displaying measurement results (all these components are connected in a wireless ethernet network). The measuring system is based on strain gauges and has a measurement range of vertical force Q up to 120 kN and lateral force Y up to 60 kN. The instrumented wheelset is based on the standard wheelset made of Bonatrans, with a load capacity of 22.5 t, with two BBS type monobloc wheels with a diameter of 920 mm (Fig. 2). In addition, a special test stand for testing and calibrating of instrumented wheelsets was developed and produced (Fig. 1). It is important to emphasize that a unique method was developed for the experimental determination of wheel-rail contact forces and contact point position using instrumented wheelsets.

Fig.2. Instrumented wheelset in development phase

2.2. Measurement of lateral force and acceleration at axle-box

Within mentioned project, 6 special transducers were developed and procured for measuring the lateral force H and acceleration on the axle-box (Fig. 3). The converter is also based on strain gauges and is specially designed to enable efficient conversion of the lateral force H into the strain of the sensor element. Lateral acceleration is measured using a special electronic device equipped with a 2-axis accelerometer.

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Fig.3. Converter for lateral force and acceleration

Fig.4. Converter for measurement of wheel lifting

2.3. Measurement of wheel lifting height

In the given period, a measuring system for measurement of wheel lifting height was also developed. It is primarily intended for testing the wagons in repression through the S curve. The mechanical assembly of converter (Fig. 4) converts the height of wheel lifting into the angular displacement of the legs which keeps the sliders on the rail.

2.4. Measurement of compressive force at autocoupler

This measuring system is also used for testing the wagons in repression through the S curve. Measurement of compressive forces at the autocouplers is performed using specially instrumented sets of autocouplers type SA-3 (Fig. 5), which are mounted on the wagons in front and behind the tested wagon in the test train, during the testing through the S curve.

2.5. Measurement of car body acceleration

Measurement of car body acceleration in lateral and vertical directions is performed by 2-axis accelerometer with measurement range ±10g. Since it is an analog accelerometer, a special electronic module is used for signal digitalization, processing and displaying. Block diagram of this measuring system is shown in Fig. 6.

Fig.5. Instrumented autocouplers

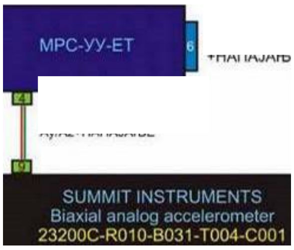

Fig.6. Block diagram of system for car body acceleration measurement

2.6. Measurement of lateral movement between wagons

The measurement of the lateral movement between the wagons during running through the S curve is based on an optoelectronic vision system and image processing. Two CCD cameras are mounted on the test wagon and directed towards the front end the wagons whose buffers mutual position are being measured, as shown in Fig. 7.

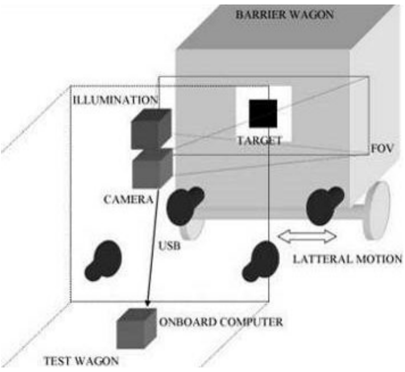

Fig.7. Scheme of measuring system for measurement of lateral movement between wagons

2.7. Conceptual solution of on-line monitoring of axle-boxes temperature

This measuring system is based on wireless signal transmission and is designed as a system for on-line monitoring. On each axle-box of the wagon a special sensor units that collect information about temperature is placed (Fig. 8 - left). The signals from these units are collected into the two transceiver units mounted on each side of wagon (Fig. 8 - right). Data from these units are transmitted by wireless to the receiving unit in the locomotive, which collects data about the temperatures of all axle-boxes and displays an alarm condition.

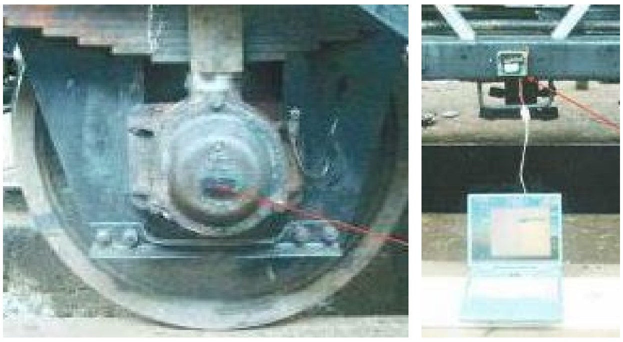

Fig.8. Preliminary tests of system for on-line monitoring of axle-boxes temperature

2.8. Conceptual solution of smart axle

A novel fiber-optic sensing technique for on-line monitoring of fatigue cracks in railway axles has been proposed. The main goal is minimizing the risk of fatigue failure of axles by using reliable on-line monitoring technique. The technique is accurate, reliable and repeatable method that is capable for detection of low scale cracks that occur in early stage of crack generation. It is based on ultrasonic inspection of railway axle in combination with fiber optic sensing. The principle of damage detection is based on the detection of elastic (Lamb) ultrasonic waves, generated by PZT actuators and running through the axle (Fig. 9). The waveform is detected by fiber optic sensing coils, using an "all-in-fiber", low coherence interferometric sensing configuration. The signals obtained from photo-detectors are transmitted from the rotating axles to the wagon or the locomotive, by wireless network, allowing in this way continuous, on-line monitoring the axle damage status.

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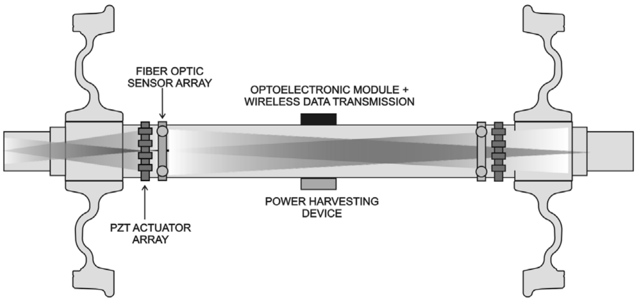

Fig.9. Scheme of measuring system of smart axle

2.9. Development of test stand and measuring system for brake triangles testing

Within project funded by the Innovation Fund of Republic of Serbia, a special test stand and measuring system for brake triangles testing was developed (Fig. 10), in accordance with the international standard UIC 833. This enabled the domestic company Tehnoliv Komerc to produce brake triangles for the international market.

2.10. Development of methodology for fall protection equipment testing

The guided type fall arresters with a rigid anchor line are among the most effective ways to protect against falls from a height. Their role is to ensure easy tracking of the user during climbing and to protect him in the event of a sudden fall. Given that functionality and reliability of this personal fall protection equipment directly affect the safety of users, the requirements for their quality are very rigorous. These requirements are very precisely defined in the European standards. The whole methodology for given equipment testing has been developed for domestic company MBM Pro Inzenjering. Complete tests of the prototype were carried out on specialy designed test stand (Fig. 11), which resulted in obtaining an EC declaration of conformity.

Fig.10. Test stand for brake triangles testing

Fig.11. Test stand for fall protection equipment testing

2.11. Development of test stand and measuring system for bridge models testing

A special test stand and measuring system for bridge models testing was also developed and acquired (Fig. 12). It is equipped with systems for controlled load simulation and detection, as well as a display for the presentation of test results.

Fig.12. Test stand for bridge models testing

3. PERSPECTIVES FOR FURTHER DEVELOPMENT OF CENTER

The main problem that affects the work of the Center is the stagnation of the development of the domestic industry, which is largely reduced to the production of products with a relatively low level of technological complexity. Domestic production of railway vehicles has practically disappeared. There are certain number of companies that deal with the production of railway equipment and spare parts. The development of new products from this field of mechanical engineering in domestic companies has almost completely stopped, while foreign companies operating in Serbia come with ready-made solutions. The situation is further aggravated by actual world events, which bring great uncertainty. In such circumstances, it is unrealistic to expect a high degree of cooperation between the Center and the industry in the development and testing of new products in the coming period. Accordingly, the future activities of the Center are expected in cooperation with domestic companies engaged in the production of railway equipment. In addition, a significant direction of action will be directed to experimental tests of a wide range of engineering structures, according to the possible requirements. The plan is also to actively submit proposals for national and international projects, establish stronger cooperation with domestic and foreign centers and laboratories, deeper develop of international cooperation, etc. Last but not least, activities related to scientific research work, writing of teaching literature, as well as engagement and development of new staff of the Center will continue.

4. CONCLUSION

Within the Center for Railway Engineering and Structures Testing at the Faculty of Mechanical and Civil Engineering in Kraljevo, the core of decades of knowledge and experience in the field of development and testing of railway vehicles in Kraljevo has been preserved. The center is ready for all future challenges and with minimal transformations and adjustments, together with the centers and laboratories of other faculties, it can once again become one of the backbone of the development and domestic production of railway vehicles and other facilities from this field of mechanical engineering.

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ACKNOWLEDGEMENTS

The authors are grateful to the Ministry of Science, Technological Development and Innovation of the Republic of Serbia for support (contract no. 451-03-47/2023-01/200108).

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