The Fifth International Conference on Railway Technology
RAILWAYS 2022
22–25 August 2022
Montpellier, France

Proceedings of the Fifth International Conference on
Railway Technology:
Research, Development and Maintenance
Edited by J. Pombo
Civil-Comp Conferences, Volume 1, Paper 25.5
Civil-Comp Press, Edinburgh, United Kingdom, 2022, doi: 10.4203/ccc.1.25.5

Development of trackside test rig for testing of railway sensing systems

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Abstract

This paper briefly deals with development process of trackside test rig for testing of advanced railway sensing systems. The main aim of this development is the design of down-scaled device which could be used for testing of rail sensors and this device provide approximately similar strain and deflection of the rail model in comparison with real track. The model-based design and FEM analysis were used for tuning up of individual parameters and the pneumatic actuation system is used for simulation of passing load of train axle. The used load is in ratio 1:1000 and it provide similar rail strain as a real application. The developed test rig is used for testing of piezoelectric sensors and smart systems for future railways.

Keywords: rail, model, test, piezoelectric sensor, load, experiment.

1 Introduction

Our mechatronic team is developing sensing systems and smart rail solution for maintenance systems under several projects. The developed sensing systems are based on piezoelectric elements for sensing of strain and vibration [1]. Such piezoelectric sensing system provide several benefits in case of an effective signal processing and low power operation [2]. Tests of sensing system in real environment is difficult, mainly in case of railways. For this reason, our team developed a testing device which could be efficiently used for testing of rail sensors and sensing system before employment in a trackside application [3].

The sensors outputs measurement has a key role in the verification process of rail sensors and sensing systems. However, the real work condition measurement could be in early development stages incontinent due to uncontrollable trackside environment. Also, the inability of fault condition modelling could cause problems in the future data processing.

Therefor were decided to design a test rig which represents a railway track deformation but also enables to test rail sensors in controlled condition. To satisfy the controlled condition, limit the volume also reduce loading forces the rig was designed in force scale 1:1000. The length and deformation in the direction of the main loading force were retained. The developed process and responses of tested sensors are presented in this contribution.

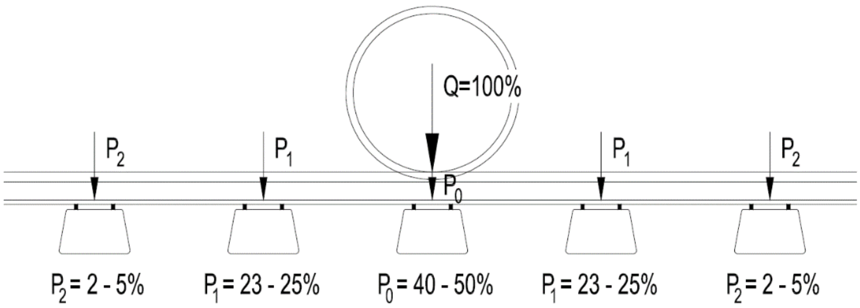

Figure 1: Load distribution on rail sleepers

The developed test rig represents a model of the S49 rail and 600 mm sleepers spacing. Accordingly, the rig parameters can be tuned according to measured conditions, also a wear of track could be realized and wear sensing tested. The main goal of the lab test rig design is to get a similar strain in the model rail base, where is the highest potential to attach the sensors.

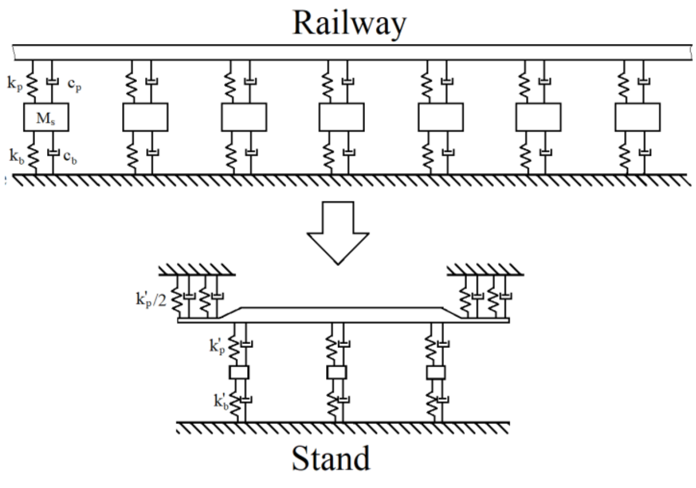

Figure 2: Schematic diagram of test rig representation dynamics

The test rig aim is to represent the behaviour of railway [4], due to this fact it is necessary to build the computation model of both rig and the original railway. For the rail model is possible to use the assumption that three nearest sleepers care most of the load, see Fig.1. However, this assumption does not apply in general. The simplified model in Fig. 2 is used for development of our test rig and it could simulate the rail behaviour.

2 Methods

Simulation and modelling provide useful tool in design proves of this test rig. The key factor for the test rig design is to reduce stiffness parameters a thousand times to reach similar deformation and deflection like in the real rail under train load. According to the load distribution the main rig part is designed as the full length of rail through three sleepers. Other two boundary sleepers are placed on a reduced length of rail to represent boundary behaviour. The test rig represents the behaviour of trackside with 7 sleepers.

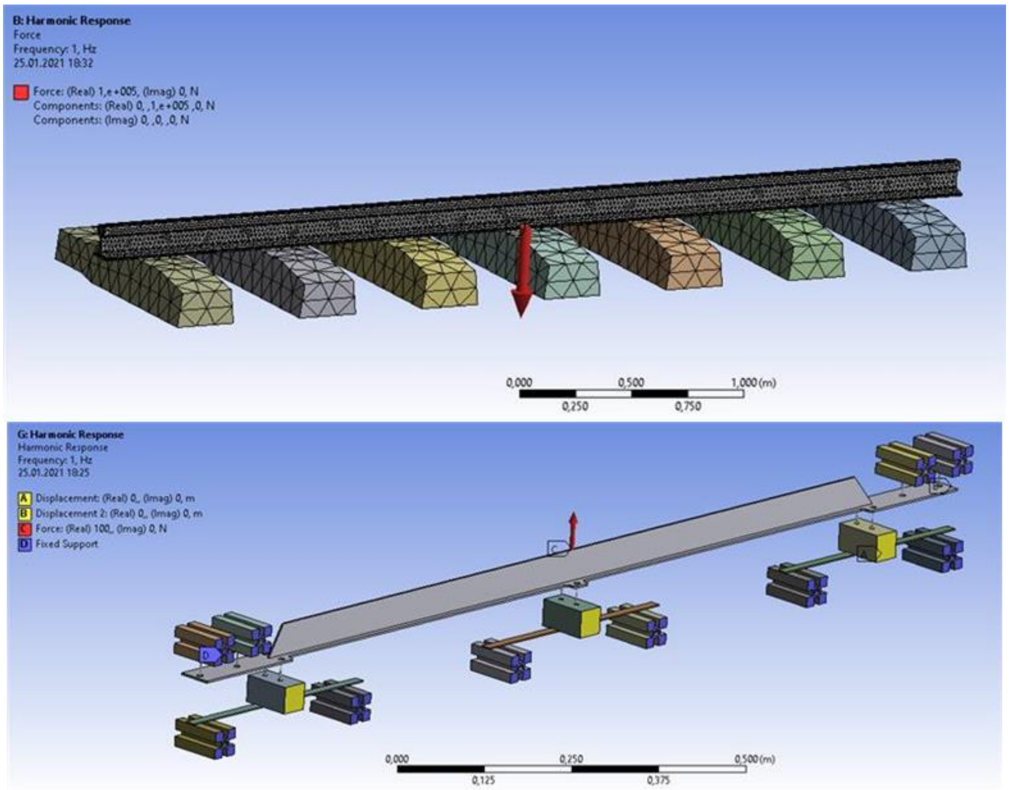

Figure 3: FEM model of the railway with 7 sleepers and FEM model of down-scaled test rig

After considering all requirements for the rig rail the aluminium T profile where chosen. The profile was milled into required quadratic moment whit considering a material change (steal to aluminium). The rail stiffness was replaced by steel pull springs; for the spring mandrel were used bold which also provides required preload in springs. The track bed stiffness parameters are determined by a wear. So, the requirement is to enable change this stiffness parameter during testing. This is enabled by the changeable length of beam suspensions which could be easily tuned. These model assumptions were included in a design of dynamic model of this test rig. The test rig model was created in ANSYS environment and its operation was analysed by finite element method (FEM). The downscaled test rig model was compared with model of real railway model and both models are shown in Fig. 3. Before the test rig manufacturing a behaviour of FEM models were analysed. Static, modal, and harmonic analyses were done for verification of model.

The main idea of these simulations is to compare the model of rail track with the model of the test rig and design correctly individual parameters of the test rig. The simulation results in the Fig. 4 show the comparison of harmonic analysis of rig and railway models, it shows that with a thousand times deference the result seem to match mainly in the low-frequency region in the range below the 20 Hz where the response of conventional train is located.

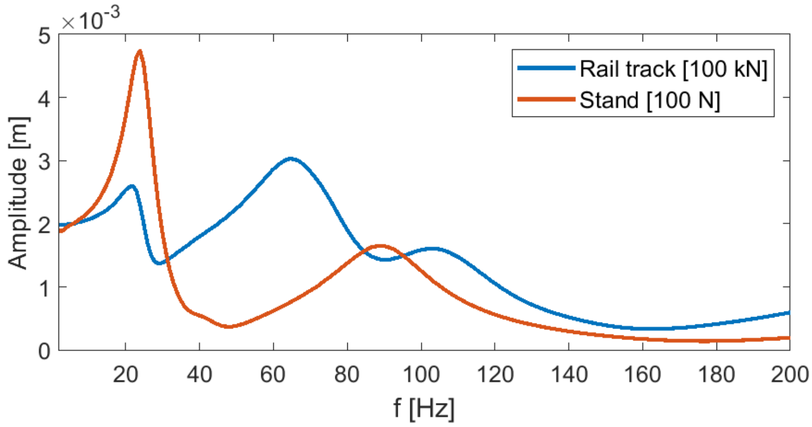

Figure 4 Simulation response of both models for different loads

3 Results

The test rig design has an approximate rail behaviour in comparison and the rig could be manufactured on the base of previous simulation model. The CAD models of this system is shown in Fig. 5. The whole test rig is designed in the aluminium profiles, so it enables easy modification or extension of new requirements, also provides enough rigidity for stand operation.

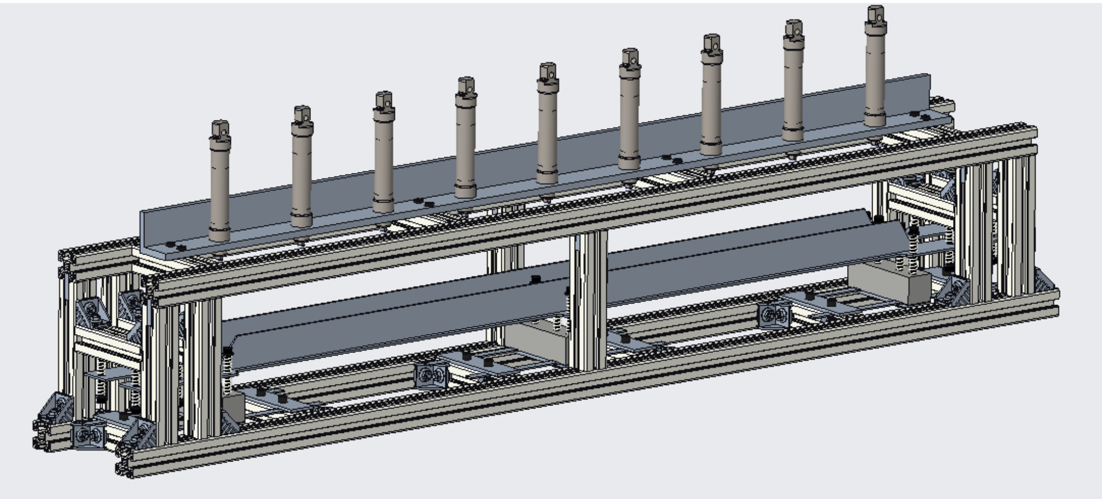
Figure 5 CAD model of rig mechanical assembly

To substitute train load, a system of pneumatic pistons was designed, and this system is controlled to provide a relevant load in case of trackside. System of nine pistons runs gradually and load the stand rail in a different position. The pistons are mounted to stand frame so works as a compact unit, the contact between piston and rail are provided by structural polymer, which reduces reaction shock into the frame.

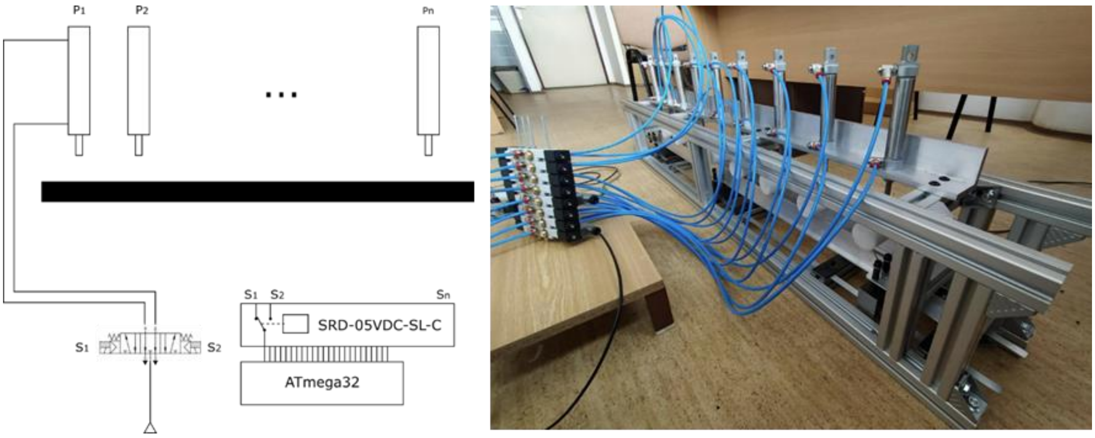

Figure 5 Scheme of pneumatic actuation and realization of test rig loads

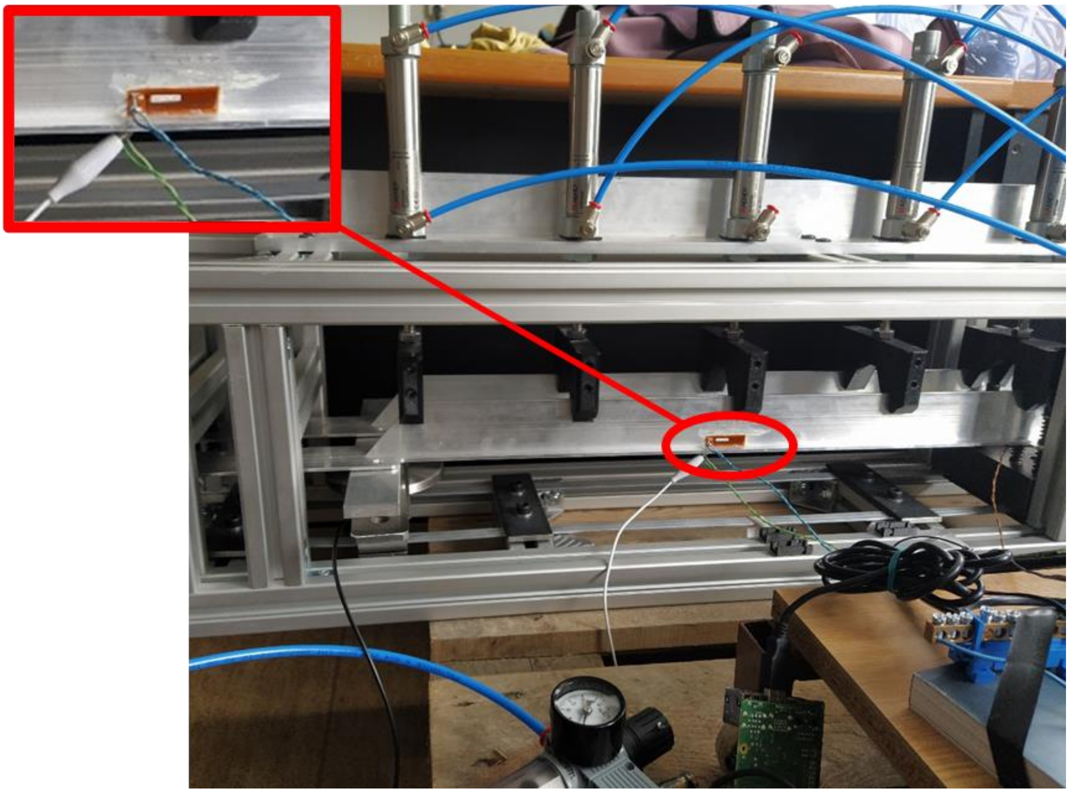
Figure 6 Detail of piezoceramic composite element for rail measurement, test of piezoelectric response on test rig under load

The piezoelectric sensing system is fixed on scaled down model and the electric response is observed, see Fig. 6. The response of this system depends on a rail strain and load velocity, e.g. slower load provide lower electric voltage peaks [5]. The example of this voltage response on the test rig is shown in Fig. 7 (the first picture). This voltage response is compared with response of reals sensing system under passing train, see Fig. 7 (the second picture).

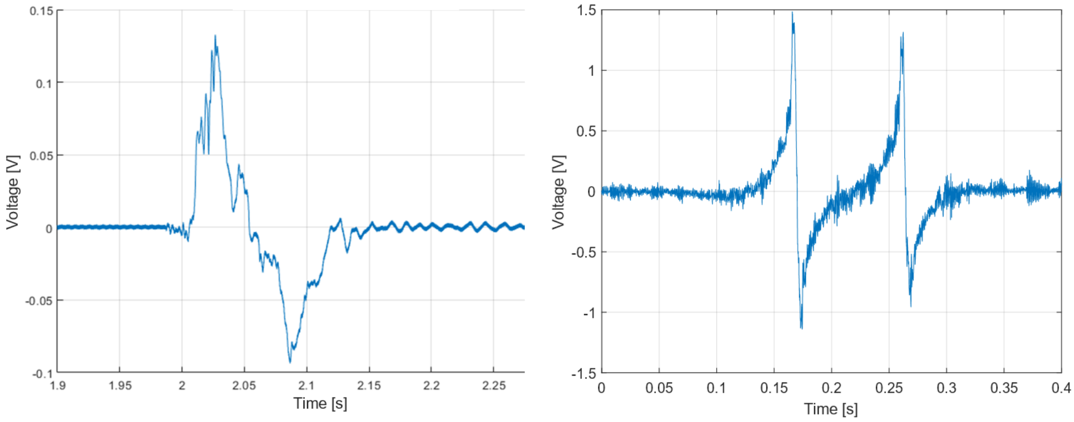

Figure 7 Electric responses of piezoceramic composite elements; response of sensor on test rig and response of sensor on rail under passing train – one bogie

The passing train has significantly higher speed than used velocity of pneumatic load, which was used in this test rig. For this reason the voltage response from real rail is higher, also time of this response is shorter. However, on the base of electric model of this tested sensing system the shape of sensor response is very similar like response of real rail under passing train. For this reason this system could be used for testing of advanced railway sensing systems [6].

4 Conclusions and Contributions

The developed and presented test rig is shortly presented in this contribution. Many simulations and models deal with correct tuning up of all parameters of testing system. The model of pneumatic load is also important for correct operation of this railway rig and it provide similar deflection as is observed on real rail. Due to pneumatic actuation this down scaled device in ratio 1:1000 cannot be used for high-speed operation; however, all system could be tested for low-speed operation with realistic strain of rail.

However, main aim of this device is testing of sensing systems and smart system for railways, e.g. predictive maintenance systems or wear detection systems and for this reason this developed device is prepared for future testing of smart solutions.

The piezoelectric sensors are widely used for structure health monitoring application and this operation could be transferred into railways. The generated voltage signal is proportional with the strain and velocity. In case that this piezoelectric element is placed on rail in correct position the mathematical models could be used for interpretation of the voltage response into mechanical operation of rail under load. The generated electric signal could be in form of vibration response. However, this signal could be effectively transformed to information about stress in rail under passing train. A smart system, like artificial intelligence system, could detect in this signal wear of track or defect on passing trains.

Nowadays this test rig is used for long time testing of smart sensing system based on four piezoelectric sensors. Active voltage signal under mechanical load is generated and is used for waking up of data acquisition unit. This unit is included in IoT (internet of thing) device, which transmit all data to cloud solution. This complex unit (sensing system, DAQ, signal processing and IoT) is developed in our department and currently tested on tract. The presented down scaled railway test rig helps to test and implement all parts of this unit for implementation to real trackside environment. This test rig can be easily modified for the modelling of different rail structure and application under the rail sensor development, and it provide useful tool for our development projects.

Acknowledgements

The authors would like to thank the project Technology Agency of the Czech Republic No. TM01000016 “Affordable Modular Railroad Smart Sensing System 4.0” which provide financial support for the development of presented test rig.

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