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Roller Rig for Wheel-Rail Wear Investigations Using Thermal Imaging

T. Staśkiewicz[1], P. Pawłowski[2], B. Firlik[1] and M. Słowiński[1]

[1]Institute of Transport, Poznan University of Technology, Poland
[2]Institute of Automatic Control and Robotics, Poznan University of Technology, Poland

Abstract

This paper presents design and measurement results of an experimental roller rig dedicated to wheel-rail wear investigation using thermal imaging. The laboratory test stand is capable of reproducing (in an automatic way) actual wheel-rail movement range and also takes into account the operating conditions such as temperature, humidity and air flow. The rig may also be used for investigations of new wheel and rail materials, friction modifiers and rolling noise emission.

Keywords: wheel-rail interface, railway roller rig, wheel-rail wear, contact, thermal imaging, railway dynamics.

1 Introduction

Wear of wheel-rail interface is without any doubt one of the critical operational parameters for rolling stock. However, wheel-rail interface is a particularly difficult object to be recorded directly due to very limited access. According to [1,2] it is currently not possible to measure the real-time wear. Laboratory experiments may at most be stopped to measure intermittent wear basing on wear products mass or volume. A solution to this problem may be to identify frictional heat dissipation in the interface [3–5]. Because, the wear index cannot be read directly in real operation of a rail vehicle, the obtained temperature distribution needs to be processed by a neural network that has been trained how to assign an appropriate wear index values to a temperature reading in the wheel-rail interface resulting from the dissipation of frictional heat. An appropriate test rig is then required to supply the network with a sufficiently large and diversified data set to achieve satisfactory recognition accuracy.

2 Design

The main construction concept of the rig was inspired by the machine built at University of Huddersfield and described in [6]. The idea was further developed by adding automatic control of the rig (reproduction of driving scenarios) and data gathering. Lower roller (the one with wheel profile) has 3 degrees of freedom: rolling, lateral displacement and angle of attack. Upper roller (with rail profile) has 2 degrees of freedom: rolling and vertical displacement (for exerting vertical force). Both rollers have diameter of approx. 300 mm and are made of C45 and 42CrMo4-T steel. The architecture of the machine was depicted in Figure 1 and Figure *2*.

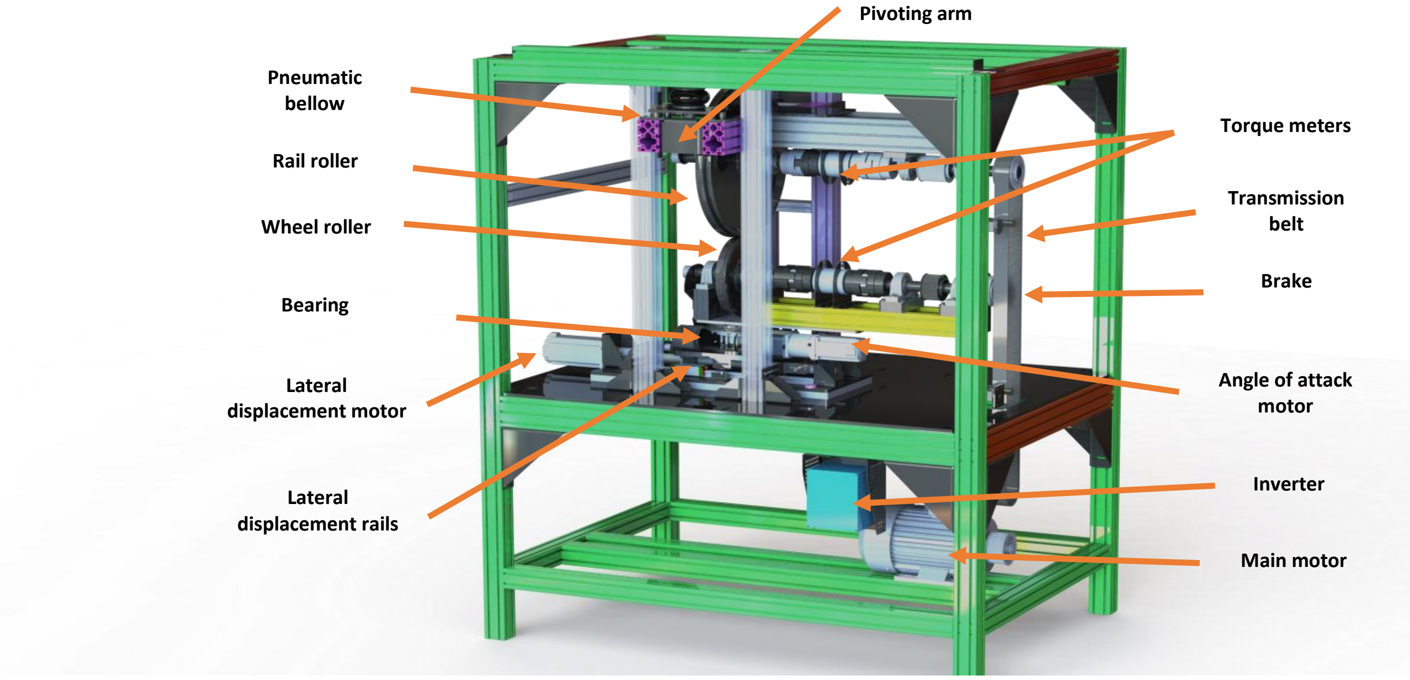

Figure 1: Roller rig architecture

The novelty about this rig is that it enables investigations of real-time wheel-rail wear, which may be measured in two ways:

- using torque meters to record frictional work,
- utilizing thermal camera and a neural network combining temperature distribution in the interface with desired wear index.

The second way is intended mainly for real operation conditions where it is impossible to use torque meters to record frictional work. Two torque meters are necessary to record wheel-rail frictional work by subtracting braking work from the work supplied by the main motor. The rolling speed of the rollers is programmable and also independent of any loads present in the interface (feedback loop in the inverter). The relative motion of the rollers (lateral displacement and angle of attack) is enabled by two stepper motors combined with appropriate transmissions. This also helps to overcome the problem of having wheel-rail contact in the same position during the whole experiment and inevitable crowning of the rollers. The rig is also equipped with an electromagnetic brake introducing longitudinal creepage adjustment and a fan to simulate air flow. The vertical load is exerted by a pneumatic bellow and the force value is set reproduce similar magnitude of contact pressure as in real operation of a tram with maximum axle load equal to 10 kN. The vertical load is set manually hence is constant for the whole experiment.

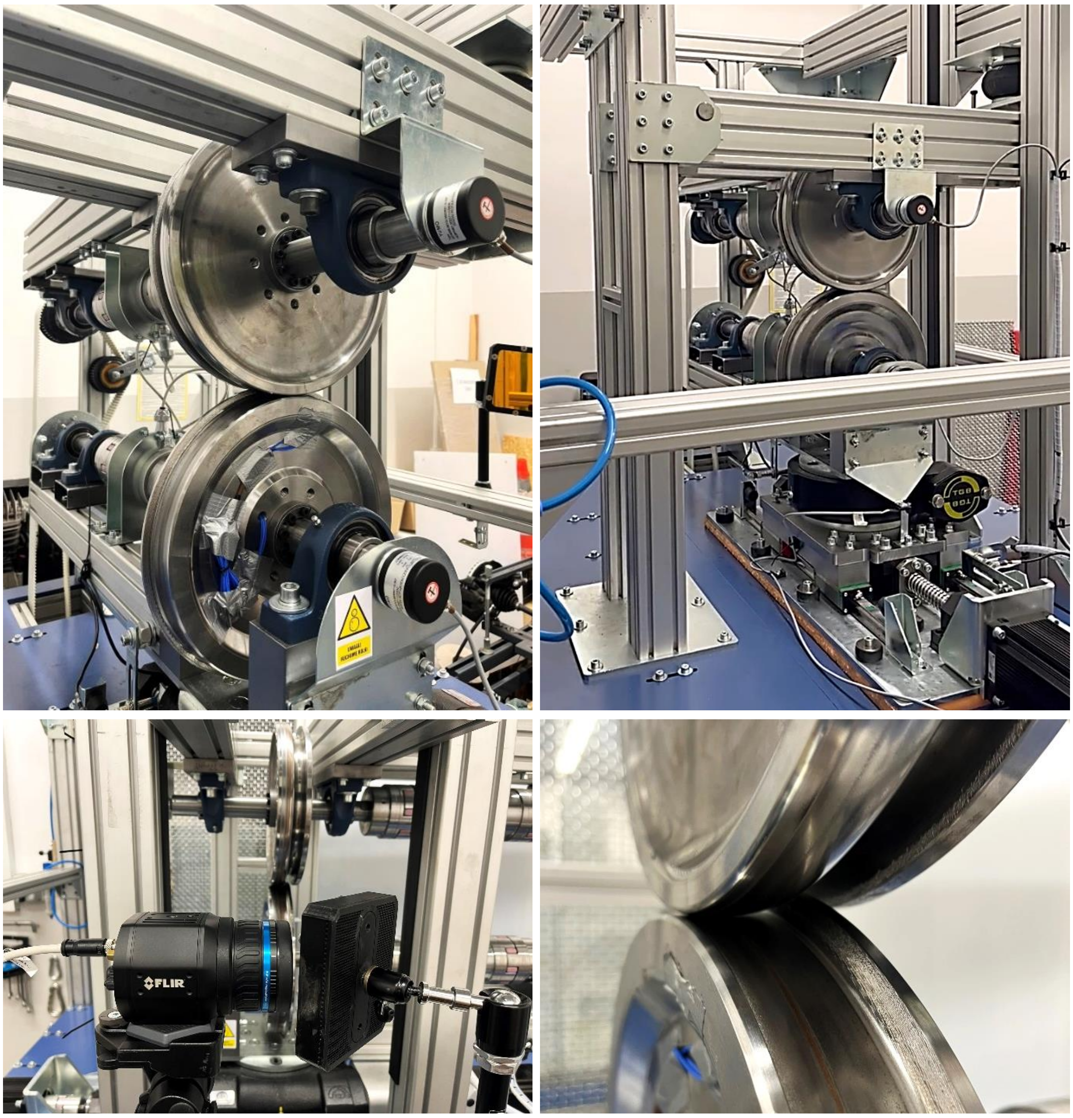

Figure 2: Roller rig setup

The roller rig is operated via a dedicated software either manually or automatically using ride scenarios derived from multibody simulation or measured dynamic response of an actual rail vehicle.

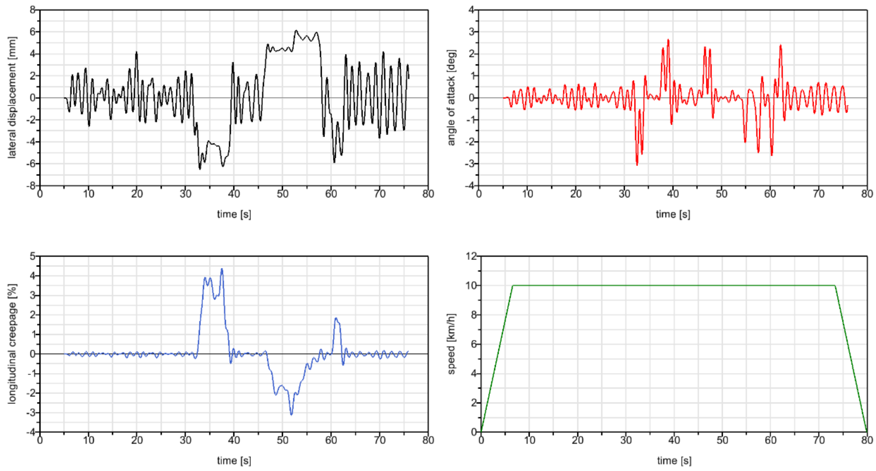

Figure 3: Exemplary scenario signals (route with 3 tight curves)

A ride scenario comprises of time histories of rolling speed, lateral displacement, angle of attack and longitudinal creepage. Exemplary scenario signals are presented in Figure 3.

4 Results

The roller rig reproduces the whole range of wheel-rail lateral displacement and angle of attack, which was depicted in Figure 4. The relative motion enables to simulate complex ride scenarios, moreover it counteracts wear groove formation leading to distorted contact situation. The presented wheel-rail pair consist of PST wheel profile (tram) and 60R2 rail.

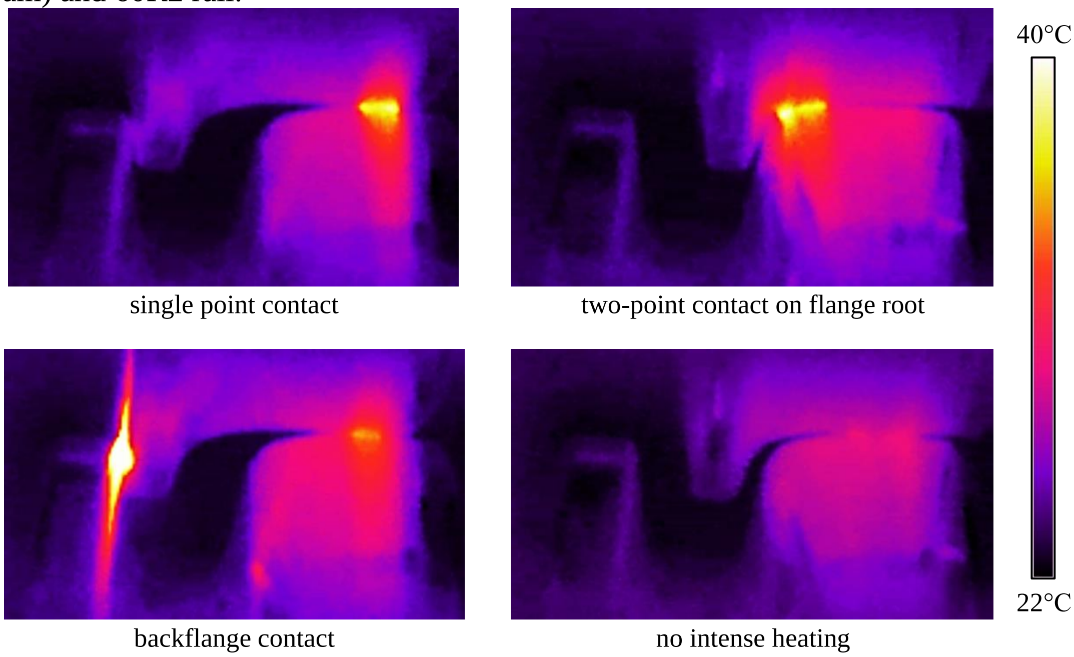

Figure 4: Thermograms recorded on the rig

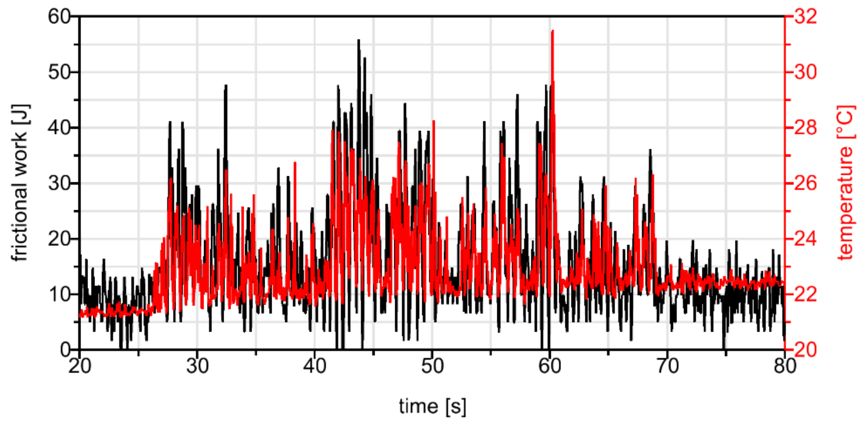

Figure 5: Exemplary compilation of maximum temperature in the wheel-rail interface and frictional work

Exemplary compilation of maximum temperature in the wheel-rail interface and frictional work was presented in Figure 5. It is easy to notice that both time histories have coincident local maxima. This constitutes confirmation of the relationship between frictional work (wear) and dissipated heat (present in the form of temperature changes). One may also notice that wheel and rail rollers accumulate thermal energy, hence short-time experiments separated by a sufficient time of cooling are desired.

5 Conclusions

The roller rig developed at Poznan University of Technology enables the following investigations:

- Measurement of real-time wear index for a wheel-rail pair in conditions close to real operation.
- Reproduction of rolling noise.
- Investigations on new wheel and rail materials.
- Testing of friction modifiers.

It was proven that temperature readings from the wheel-rail interface correspond with the frictional work, hence combining thermal images with wear index is feasible. The main goal of the rig is to generate a sufficient and diversified data set for training the neural network to assign wear index values to recorded thermograms. The algorithm will be the core component of a novel onboard system for real-time wear index measurements.

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