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Experimental Measurement of Twin-Disc Wear Resistance Test by Laser Profilometer

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Abstract. In this work, two laser profilometers are used for measuring the specimen dimensions in real time during twin-disc test. The proposed technique allows to characterize the changes in the specimen dimensions during the test in itself and doesn´t require to interrupt the test at the same time. Using the real-time values of the specimen dimensional contours, it is possible to calculate instantaneous value of slip ratio or the contact path width.

Introduction

Thanks to progressive development of rails and raising travel speed of trains, the requirements for material quality are constantly growing. Nowadays, materials are tested using different dedicated experimental testing rigs, like SUROS, etc [1]. In our case, twin-disc test has been used as a substitute of the real in-service material loading process [2, 3]. In the past, several authors have to interrupt the test for measurement of the specimen dimensions, especially their diameter and the contact path width [4, 5]. This interrupting, however, is not favourable for automated testing. Also, if there is a requirement on the surface ratcheting measurement, a dedicated destructive method has to be used, which will not allow further use of the tested specimen in following tests [6]. One of modern contactless methods of research is chromatic confocal microscopy which is non-contact probe [7]. Or technology based on floating giant-magnetoresistance for search microcrack under surface [8]. Proposed paper deals with measurement procedure of specimen dimensional contour in real time, which is especially convenient for the calculation of the slip ratio or estimation of the contact area width.

Experimental procedure

The experimental rig was constructed by the INOVA company. The measurement of the specimen contours has been performed using Keyence LV-7200 laser profilers, which were mounted on self-developed holders, manufactured using 3D printing technology (Fig. 1). Controller for these profilers was used Keyence LJ-V7001P. Each laser profilers divided the signal into 800 points parallel to the axis of rotation and the sample frequency was set to 500 Hz. The material of specimens was Class C (AAR M107 Standart) [9], which were used for subsequent twin-disc tests, with additional hardening of the rail samples. Initial diameter of the wheel rim sample was 70 mm, while the diameter of rail was 220 mm. The twin-disc test was scheduled for 50 000 cycles. The initial Hertzian contact pressure was set to 1200 MPa with the initial slip ratio equal to 2 %. The appearance of the measured contour is shown on Figure 2.

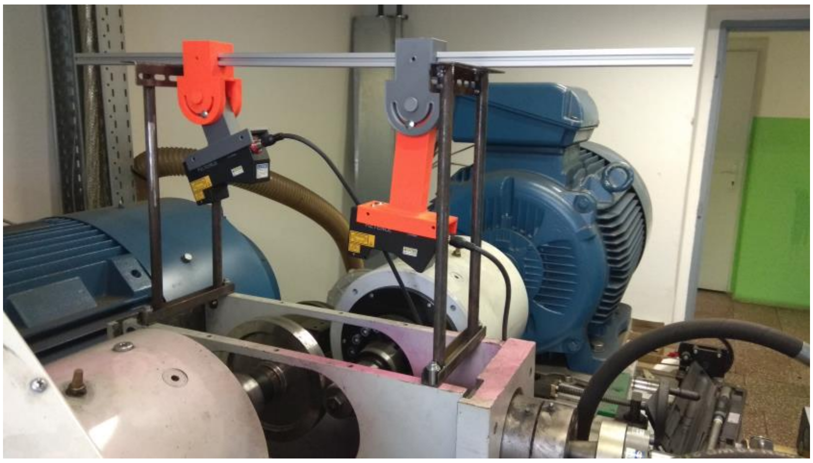

Fig. 1: INOVA twin-disc experimental rig with Keyence LV-7200 laser profiler

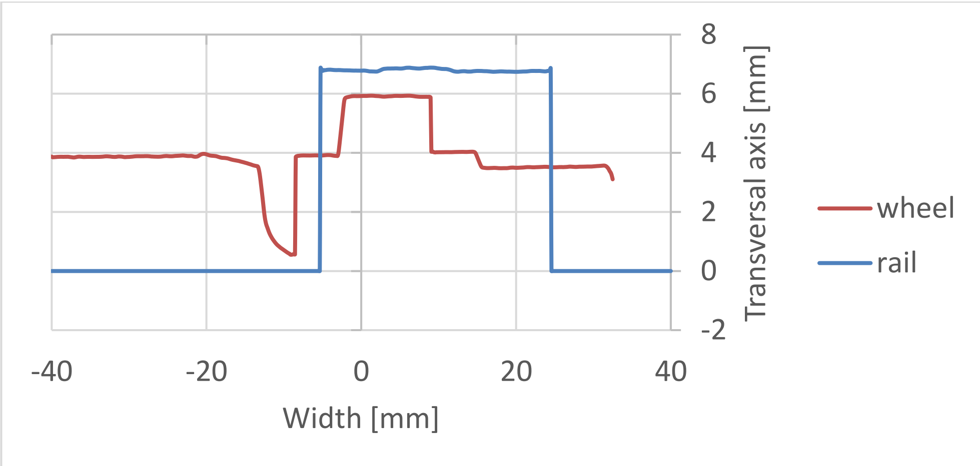

Fig. 2: Measured contour line by Keyence LV-7200 laser profiler

Result

Figure 3 respectively Figure 4 show change of contact radius of wheel and rail respectively as a function of number of cycles. Figure 5 shows the variation of slip ratio over the number of cycles. First 10,000 cycles approximately carried out a stabilization of test in itself, the results during this period are only tentative. From the next part of the evaluation it is possible to determine the trend of the course.

At the end of the test, the diameter of wheel sample was smaller about 0.5mm, while the wheel specimen diameter decreases at about 0.2mm. The final change of diameter was verified using callipers. The actual slip ratio was calculated on the proportion of peripheral speeds based on the measured diameter and the stable specimen´s revolutions per minute refer to formula (1).

$$s = \frac{v_1 - v_2}{\frac{v_1 + v_2}{2}} = \frac{\frac{d_1}{2} \cdot \omega_1 - \frac{d_2}{2} \cdot \omega_2}{\frac{\frac{d_1}{2} \cdot \omega_1 + \frac{d_2}{2} \cdot \omega_2}{2}} = \frac{2(d_1 \cdot \omega_1 - d_2 \cdot \omega_2)}{d_1 \cdot \omega_1 + d_2 \cdot \omega_2} \tag{1}$$

In this particular experiment, the slip ratio decreased from 2 % to approximately 1.2 % after only 50000 cycles. Presented approach is relatively simple for measuring specimen’s diameter in real time with additional calculation of the slip ratio.

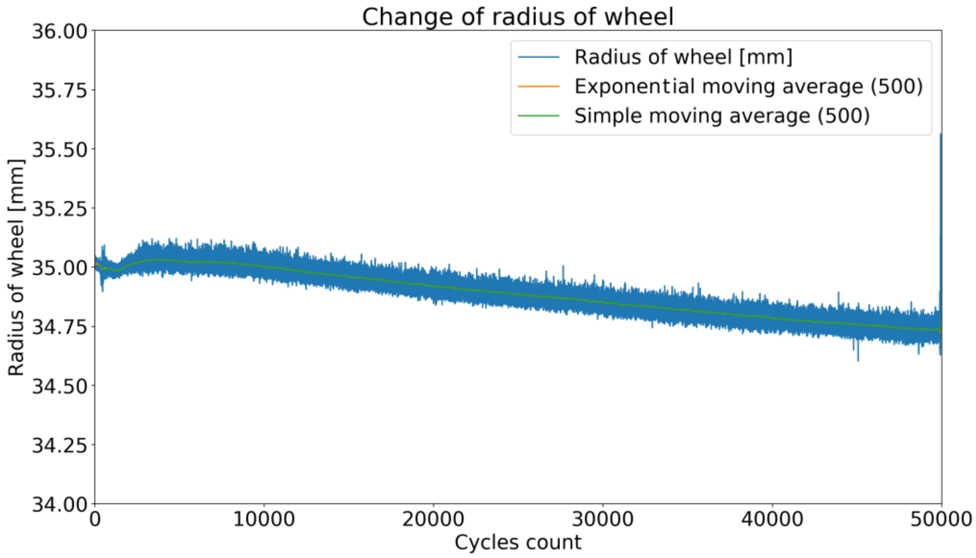

Fig. 3: Change of radius of wheel at number of cycles

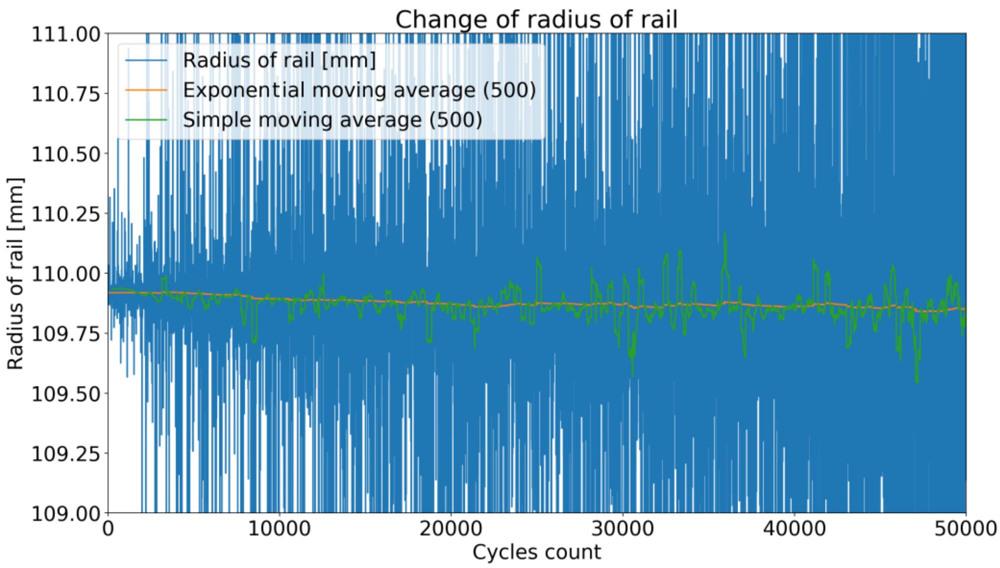

Fig. 4: Change of radius of rail at number of cycles

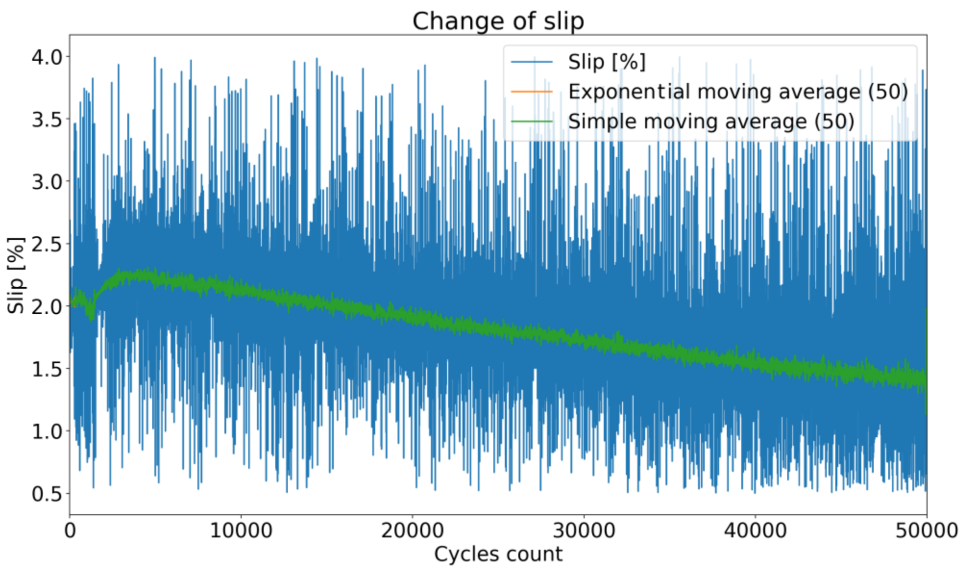

Fig. 5: Change of slip ratio at number of cycles

The oscillation of the raw data was caused by the oscillation of the piston cylinder, which was controlled by PLC. Small changes of pressure in hydraulic circuit in short time caused noticeable vibrations of the lodge, which is a reason why exponential and simple moving average for the results smoothing has been used and refer to formula (2) respectively formula (3).

$$EMA_i = x_i \cdot k + EMA_{i-1} \cdot (1-k) \tag{2}$$

$$SMA_i = \frac{1}{n}\sum_{i=0}^{n-1} x_{n-i} \tag{3}$$

Conclusions

Presented approach has proven to be a suitable method for estimating the specimen´s diameter, which are subjected to twin-disc test. Using the already known value of the diameter and together with the known revolutions per minute, it is possible to estimate the slip ratio in real time and controlling this value at the same time as well. This method can be useful in comparison of the new materials for railways wheelset under the same initial conditions.

The verification of the method requires many additional tests to confirm its suitability, since the estimation of the slip ratio is mainly fraught with a random effect in terms of the measurement error.

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