

Assessment of wear of tram wheels

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Abstract. The article presents the results of the two-year observed operation of the flexible tram wheel tyres of the SAB type for new types of trams operated in Poland. The chemical composition of the rim material, their microstructure and hardness were initially checked. During the operation, covering the mileage of 70,000 km, every 10,000 km the diameter of the rolling circle of the wheels D and the parameters of the rim profile, e.g. flange height (Sh), flange width (Sw) were measured. Every 30,000 km, the wheel rims were reprofiled by machining on a track bed lathe, in accordance with the requirements of the tram maintenance system.

Keywords: wheel set; tram wheel tyre; diameter of wheel; observed operation; caliper; abrasive wear

1. INTRODUCTION

The serviceability of a tram depends on the condition of its main units. The wheel set is a unit whose technical condition has a direct impact on traffic safety. The wear of wheels/rims and axles is the basic parameter that allows to determine the durability of the tram and the proper selection of maintenance processes that ensure the proper course of the operation process. The intensity of tram wheel rim (tyre) wear determines the length of the service and repair period, including the reprofiling of the wheel rims. To ensure an optimal service and repair cycle, periodic wear measurements of wheels and wheelsets are carried out.

The correct contact of the wheel with the rail depends on the construction of the wheel, and in particular on its transverse profile. Properly defining the values of its profile parameters affect:

- reduction of a rail side wear,
- driving safety on turnouts and track by preventing derailment,
- extending the cycle between successive reprofilings and, as a result, extending the service life of the wheelset,
- limiting the vehicle's narrowing due to the conical shape of the wheel profile.

Bearing in mind the impact of monobloc wheel rim or wheel rim profiles on safety, the priority of the rolling stock maintenance system is to monitor the values of geometric parameters of the wheel/rim profile, understood as their precise measurement, control and keeping them within acceptable ranges.

In the wheel-rail system, the observed loss of contact surface material indicates the ongoing process of abrasive wear. As a result of this process, the values of the profile parameters: flange height (Sh), flange width (Sw) and flange slope (qR), as well as the diameter of the rolling circle (D) change. The complexity of the process of accelerated wear of the railway wheel profile is influenced by many factors, which can be divided into:

- primary, i.e. arising at the stage of improper wheel/rim design and manufacturing (e.g. wrong material or lack of proper heat treatment),

- operational origin, which result from improper use of the vehicle by the driver, and the process of vehicle maintenance, and the condition of the track infrastructure.

2. METHODOLOGY OF MEASUREMENT OF RAIL VEHICLE WHEEL PARAMETERS

Measurements of wheels of wheelsets can be made using:

- special attachment on the underfloor lathe,
- electronic wheel diameter measuring instrument (three-point wheel diameter gauge).

Measurements of the wheel outline profile, including measurements of the thickness, height and steepness of the rim, are made using:

- mechanical caliper for wheel profile parameters measurement - Fig. 1,
- laser wheel profile measuring instrument (1 laser line so rigid positioning is necessary)
- multifunctional non-contact laser profile measurement device, usually Calipri C41/42 – Fig. 2 (3 central laser lines so freehand movement of the laser scanner is possible), which can be used for measurement of: wheel profile, brake disc, wheel/tyre thickness, back to back, wheel diameter, radial/axial runout, defects, rail profile, switch, track geometry, equivalent conicity.



Fig. 1. Electronic wheel diameter measuring instrument
(<https://www.ascorail.pl/en/electronic-wheel-diameter-measuring-instrument.html>)

It should be noted that the measurement of the wheel rolling diameter is one of the most difficult to implement in operating conditions. It forces the necessity to measure the diameter in a theoretically selected cone section away from the conventionally adopted measurement base, i.e. 70 mm from the inner surface of the rim (or wheel rim) of the wheel. The surface of the measuring base and the cone on which the rolling diameter of the wheel is identified is made in the quality resulting from rolling and additionally there are dynamic effects and uneven wear and tear.

Depending on the adopted measurement method, an indirect measurement of the center point distance is made between the base points on the rolling diameter and the distance from the theoretically determined wheel chord, and the result obtained in this way is converted into the value of the rolling diameter (Fig. 1). Available devices using this method have an accuracy of ± 0.1 mm or ± 0.2 mm. Another method is to determine the outline profile of the wheel rim and measure the flange diameter, converting it to the rolling diameter based on the previously measured wheel profile (Fig. 2). The manufacturer of this type of device gives an accuracy of ± 0.2 mm.

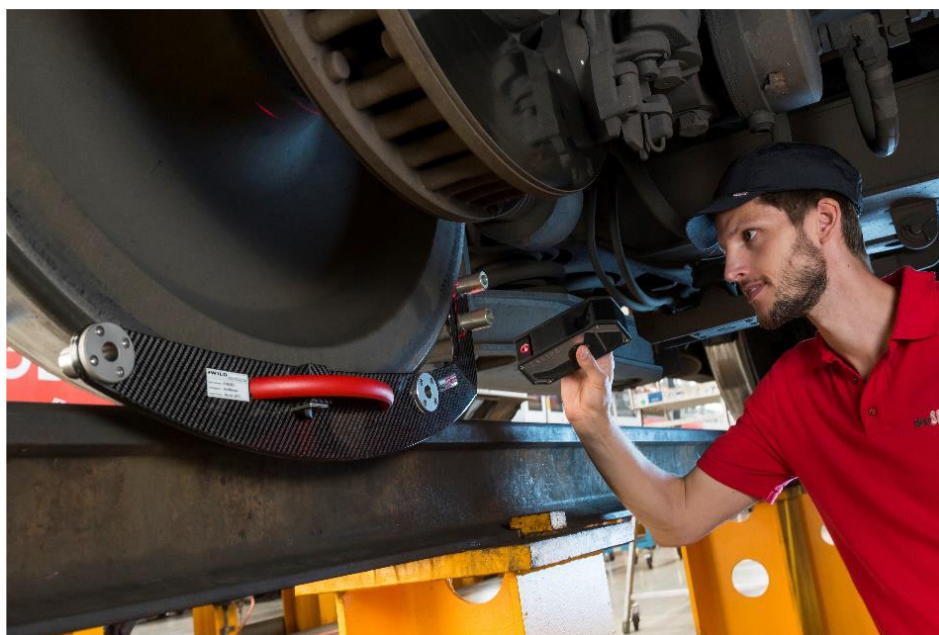


Fig. 2. Wheel diameter measurement with Calipri sensor and D-gauge (www.nextsense-worldwide.com)

These relatively small in relation to the requirements of measurement accuracy result from the method used, short measurement base and indirect measurement.

3. MATERIAL FOR RESEARCH

The observed exploitation was performed on the rims of flexible tram wheels SAB type, which are used in newly built trams operated in Poland. The flexible element in this solution is a V-shaped rubber ring.

The rims of the tram wheels are made of P70 steel according to PN-K-92016:1997 and within the scope of requirements for P70 steel according to PN-H-84027-06:1984 + Az1:1999.

Chemical composition of the steel from rims were made is presented in Tab. 1.

Tab. 1

Chemical composition of the wheel rims

Steel grade	Elements content, weight %									
	C	Si	Mn	P	S	Cr	Cu	Ni	Mo	V
P70 acc. to PN-K-92016:1997	0.65	0.15	0.65	max	max	max	max	max	max	max
	0.75	0.40	0.95	0.040	0.040	0.30	0.30	0.30	0.05	0.05
Tested rim	0.68	0.32	0.83	0.009	0.006	0.40	0.01	0.02	0.004	0.005

Metallographic examinations revealed (Fig. 3) that the microstructure of the rim material consists of pearlite (alternating plates of cementite and ferrite), which is characteristic of P70 grade steel (with approximately 0.70% C).

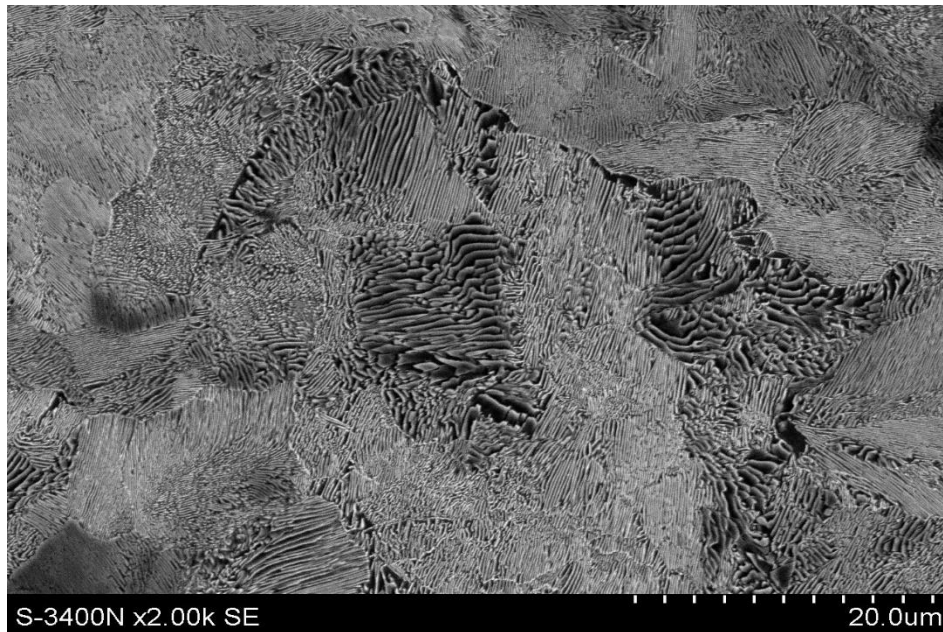


Fig. 3. Microstructure of a tram wheel rim material. Etched longitudinal section. Scanning electron microscope.

The hardness of the rim in the zone of acceptable wear is 309 HB, which meets the requirements of the PN-K-92016:1997 standard regarding the required hardness in the range of 300-362 HB.

4. MEASUREMENTS OF TRAM WHEEL RIMS DURING OPERATION

During the observed operation, cyclic measurements of the rim were made every 10,000 km (about 1.5 months of operation). Measured wheel rim parameters are presented in Fig. 4.

The following measuring instruments were used to measure the wear of tram rims during operation:

- electronic wheel profile wear caliper for flange height (Sh) and flange thickness (Sw)
- electronic three-point wheel diameter gauge for wheel rolling circle diameter (D)

The maximum wear of the rim diameter every 30,000 km should not be greater than 8 mm in diameter. Fig. 5 presents the cumulative results of measurements of the diameter of tram wheels, which indicate a gradual reduction in the diameter of the tram wheels resulting from its operation and abrupt changes in the diameter of the wheels being the effect of rolling for wheel reprofiling.

Fig. 5 presents the cumulative results of measurements of the diameter of tram wheels, which indicate a gradual reduction in the diameter of the tram wheels resulting from its operation and abrupt changes in the diameter of the wheels being the effect of machining for wheel reprofiling.

Fig. 6 and 7 present results of measurements for flange height (Sh) and flange thickness (Sw).

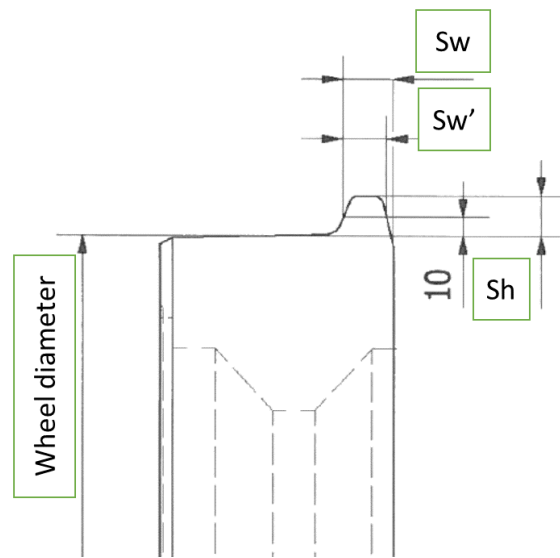


Fig. 4. Profile of a tram wheel rim with parameters to be measured

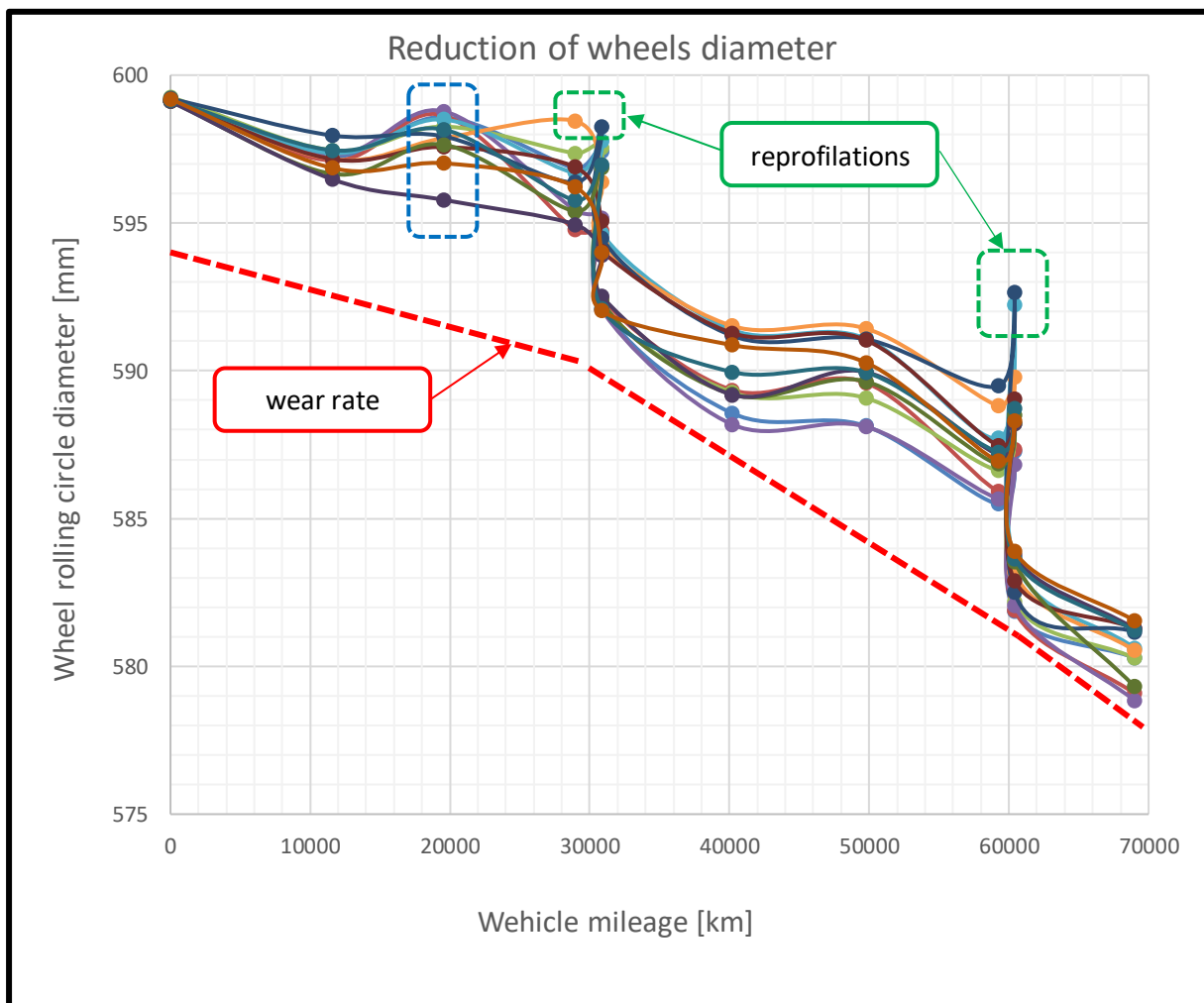


Fig. 5. Tram wheel tyre diameter changes as a function of vehicle mileage (the tram with 3 bogies and 12 wheels)

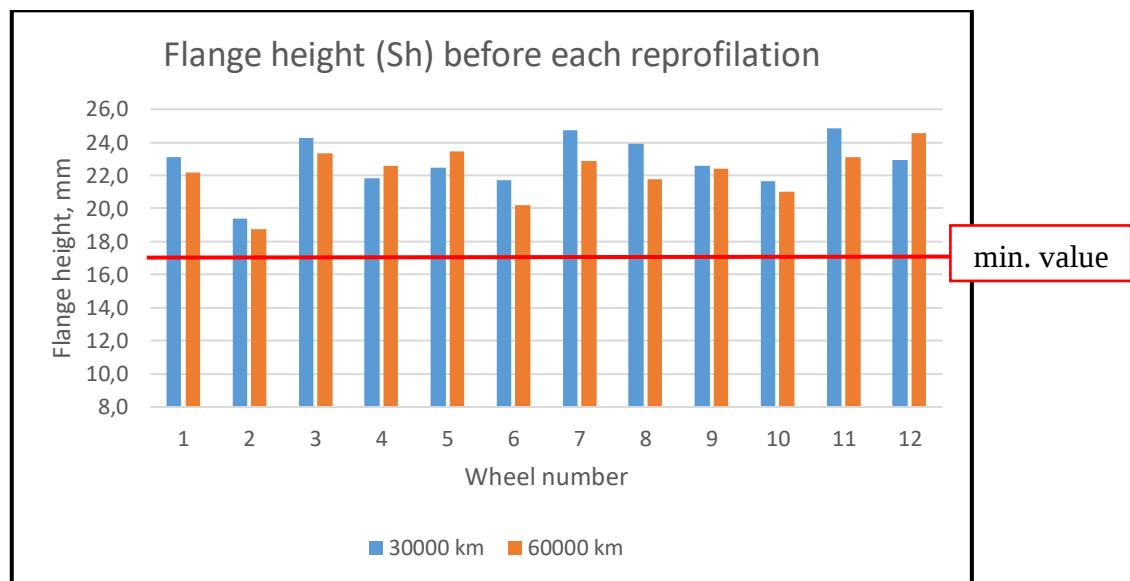


Fig. 6. Tram wheel flange height reduction before each reprofiling

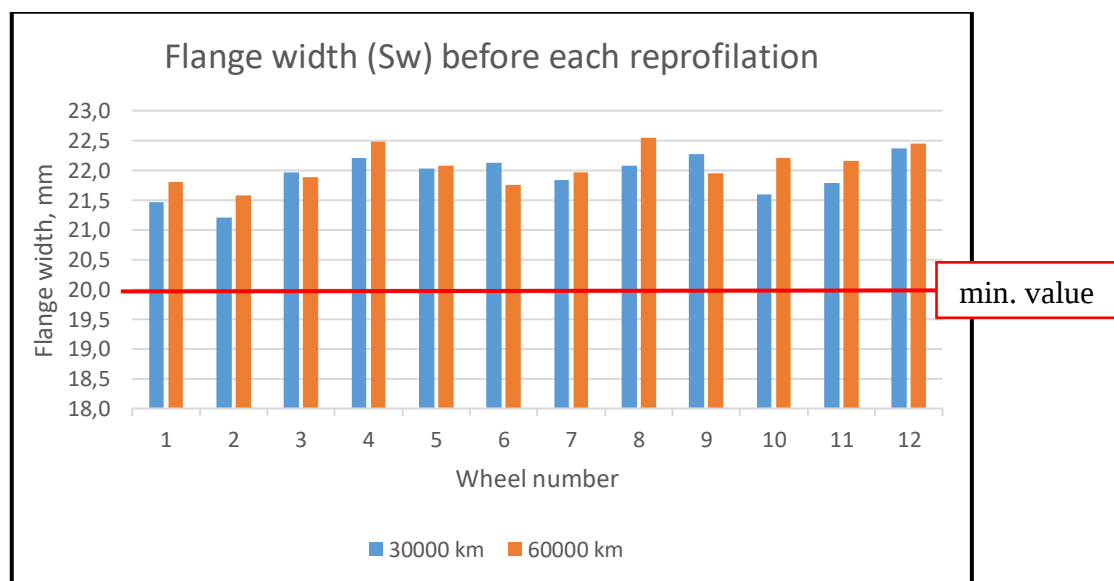


Fig. 7. Tram wheel flange width reduction before each reprofiling

5. DISCUSSION OF THE RESEARCH RESULTS

The analysis of the operational wear of individual wheels indicates that after every 30,000 km, the abrasive wear of the wheels did not exceed the permissible value of 8 mm in diameter, in accordance with the requirements for the observed operation.

The average reduction in wheel diameter for the first reprofiling is 3.20 mm and for the second reprofiling it is as much as 6.00 mm, which in total for the analysis period gives 9.20 mm. The average wear value calculated for a single wheel is 9.50 mm during the observed service period. These values were achieved for a mileage of approximately 70,000 km.

The analysis of wear in relation to individual vehicle axles showed that the smallest wear of the rolling diameter of the wheels was recorded for the middle bogies, which are rolling bogies.

Fig. 5 shows a significant relationship indicating that in the period up to the first reprofiling (the dotted red line), the wear of the material was much slower compared to the rate of wear after the first or

after the second reprofiling. This result corresponds to the general change in the hardness of the wheel material and the reduction of internal stresses, including residual stresses in the outer layers of the material subject to machining, plastic working and heat treatment, resulting from the wheel rim manufacturing process. Along with the reduction of the wheel diameter, the amount of material per unit of the rolling diameter of the wheel D also decreases, which also affects the increase in the intensity of wheel wear in rail transport.

In Fig. 5, it is also worth noting that out of 12 measurements made for a mileage of about 20,000 km, as many as 11 indicate an increase in wheel diameter during operation. The same is also the case for the measurements before reprofiling performed on the underfloor lathe, here too a sudden increase in the rolling diameter of all wheels is noticeable. These results indicate a high inaccuracy of wheel diameter measurements resulting from the measurement methods used, the measuring instruments used and the typical practice of only one measurement for one wheel. This practice applies to both trams and rail vehicles.

The analysis of the operational wear of individual wheels indicates that the permissible values of the Sh and Sw parameters (Fig. 6-7) were not exceeded during the operation of the observed tram wheel rims.

5. CONCLUSIONS

- the parameters: D , Sh and Sw were not exceeded in relation to the permissible wear values in the observed operation of the tram wheel rims.
- the values of material loss during operation (due to wear) related to wheel reprofiling are significant and close to the value of wheel wear for a mileage of about 70,000 km, which indicates the possibility of their reduction in order to extend the service life of wheelsets.
- The analysis of wear in relation to individual vehicle axles showed that the smallest wear of the rolling diameter of the wheels was recorded for the middle bogies, which are rolling bogies.
- the measurement of the wheel diameter D before reprofiling usually indicates values much higher than the operational measurements, which should be the reason to verify the measurement method on the underfloor lathe.
- individual measurements show an increase in the value of the wheel diameter D during operation, which should be the basis for further analysis of errors and repeatability of measurements of rolling circle diameter D .

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