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Problematics of Twin-disc Wear Resistance Tests for Selected Wheel Rim Materials

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Abstract. Presented paper deals with problematics of methodology of twin-disc wear resistance tests for various types of commercially available materials, which are used for production process of rail wheel rims. Currently, there doesn´t exist an integrated document, which will deal with problematics of loading force correction according to the actual width of the contact path. The aim of this paper is to present findings related to the effect of correction of loading force according to the actual width of the contact path in the transversal direction on the weight loss, resulting contact path width and sample diameter. Proposed paper presents two techniques of measurement the contact path width, which is further used for computation of the real maximum contact pressure.

Introduction

Thanks to progressively higher traveling speeds with increasing axle loads takes the railway industry ever greater demands on the materials, used for production of wheel rims as well as rails. Currently, the more attention is paid on various tests [1,2,3], which will as best as possible simulate real conditions. Twin-disc test is nowadays widely used as a standard experiment for qualitative analysis in terms of obtaining the information related to wear resistance as well as resistance to contact fatigue [4,5,6]. In most cases, the authors do not include the effect of change of contact path width on the number of realized cycles [7,8]. This phenomenon can, however, significantly influence the final results in terms of the wear rate or the profile of accumulated plastic shear deformation below contact surface. Proposed paper deals with the problematics of the variation of contact pressure as a consequence of the overall sample deformation in case of twin-disc test experiments. The authors also focused on the effect of the change of the contact path width with increasing number of cycles. The results point to the fact, that to each couple of samples (wheel rim/rail material) needs to be proposed a specific test procedure, which will take into account the specimen’s geometry, testing conditions and as well as mechanical properties of tested materials in itself.

Experimental procedure

The experiments have been realized on twin-disc experimental rig (Fig. 1), manufactured by INOVA company. Authors focused on two wheel rim/rail material sets of specimen. Set 1 consists from Class C (AAR M107 Standard) wheel rim sample and Class C rail sample hardened up to 350 HB. Set 2 consists from ER7 (EN 13262) wheel rim sample and the same rail sample as used in Set 1. The initial diameter of wheel rim specimen was for both sets equal to 70 millimeters with initial contact path width of 10 millimeters. The initial diameter of the rail samples was equal to 220 millimeters. The width of the rail samples was equal to 30 millimeters (See Figs. 2 and 3). Both sets carried out 100000 cycles. The slip and maximum Hertz contact pressure were equal to 2% and 1200 MPa respectively.

Fig. 1: INOVA twin-disc experimental rig

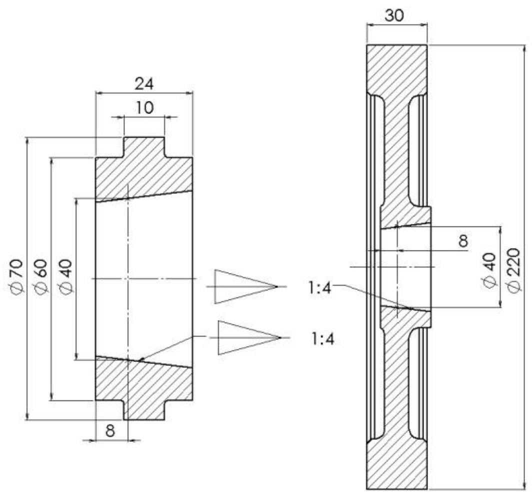


Fig. 2: Geometry of wheel and rail specimen

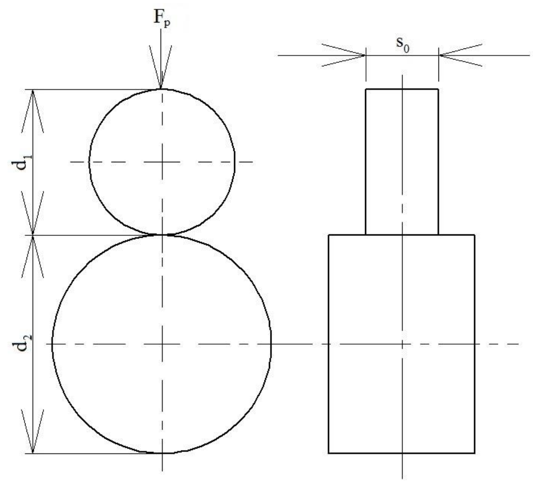


Fig. 3: Dimensions for calculation of maximum Hertz contact pressure

According to the known value of contact pressure, material properties of the specimen, which are in contact and their geometries, it is then possible to calculate the initial loading force from following expression [9]:

$$F_p = 0{,}5 \cdot \left(\frac{p_0}{0{,}59}\right)^2 \cdot \frac{d_1 \cdot d_2}{d_1 + d_2} \cdot \left(\frac{1}{E_1} + \frac{1}{E_2}\right) \cdot s_0, \quad (1)$$

where F_p [N] is loading force, p_0 [MPa] is maximum Hertz contact pressure in terms of line contact, $d_{1,2}$ [mm] are diameters of the specimens, $E_{1,2}$ [MPa] represents Young modulus and s_0 [mm] is initial contact path width. For further evaluation of contact pressure, it is necessary from eq. 1 to derive the maximum contact pressure as the function of loading force, material and geometric properties:

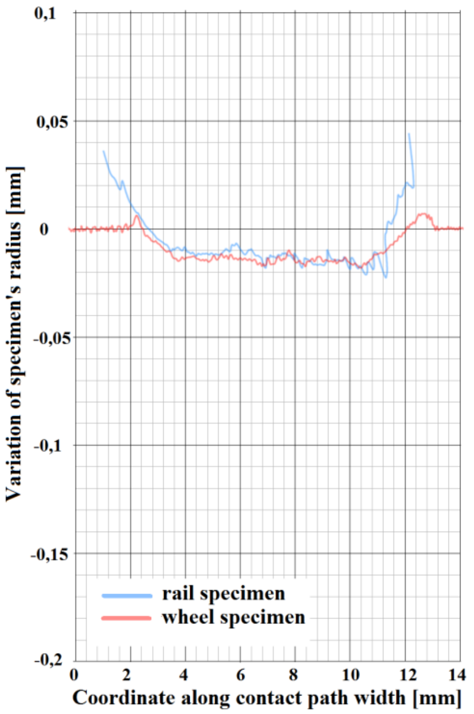
$$p_0 = 0{,}59\sqrt{\frac{2\cdot F_p}{s_0\cdot\left(\frac{1}{E_1}+\frac{1}{E_2}\right)\cdot\frac{d_1\cdot d_2}{d_1+d_2}}} \tag{2}$$

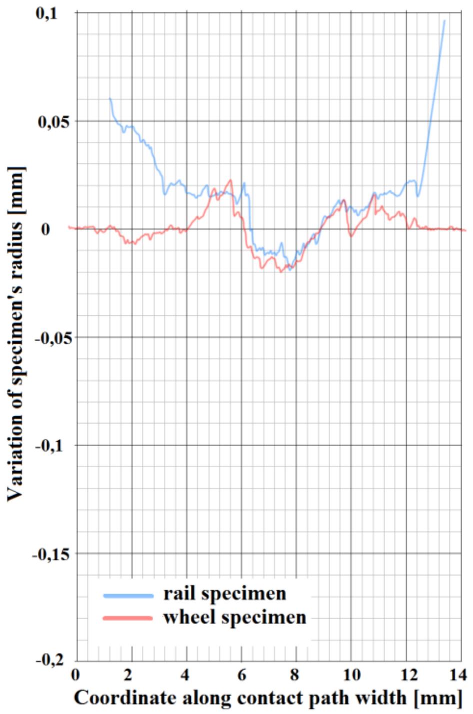
Every 25000 cycles, both specimens were subjected to measurement of the transversal profile in order to obtain more detailed information related to contact path width. The measurements were realized with use of Wenzel LH65 CNC X3M premium 3D coordinate measuring machine. Additionally, authors have also used a red contrast penetrant in order to estimate the contact path width during the test itself, when the specimen were subjected to predefined loading force. The method is based on the application of the contrast penetrant, used for NDT penetration testing, on the contact path of loaded specimen under low speed rotation.
Resulting measured transversal profiles of wheel and rail specimen were then used for estimation of contact path width after 25000, 50000, 75000 and 100000 cycles and as well as for further calculation of real value of maximum contact pressure based on preset loading force.

Results

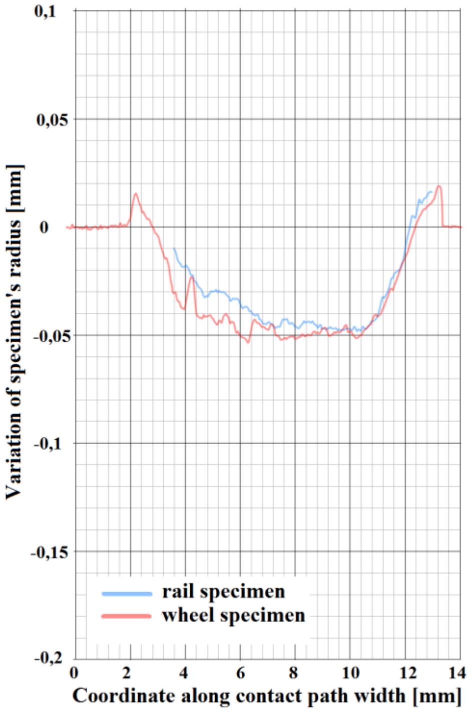
Figure 4 shows transverse profiles of wheel and rail specimen for both sets after 25000, 50000, 75000 and 100000 cycles, which have been measured with use of Wenzel LH65 3D coordinate measuring machine. According to the similarity of both profiles can be estimated the width of the contact path, which is listed, together with the results determined by use of contrast penetrant, in table 1. As can be seen, the conformity between the wheel and rail profile is higher in case of Set 1, where the wheel as well as rail specimen is manufactured from Class C material with additional hardening of the rail specimen up to 350 HB. The higher hardness of the Class C wheel specimen as well as its different mechanical properties causes the higher rates of plastization of the contact path´s surroundings compared to ER7 wheel specimen (Set 2).

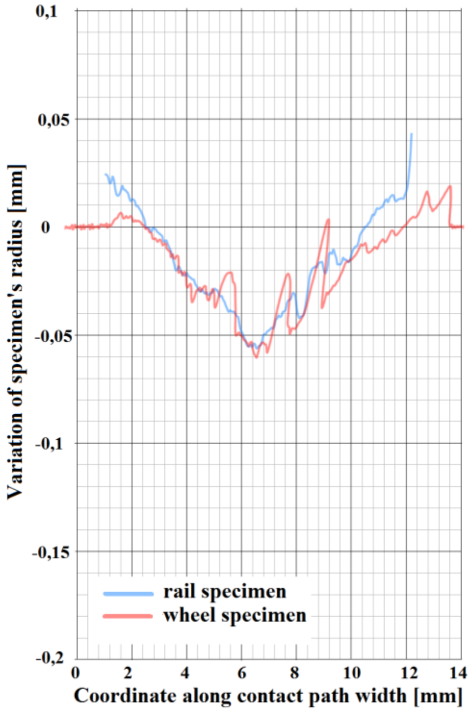
Set 1	Set 2
25000 cycles	



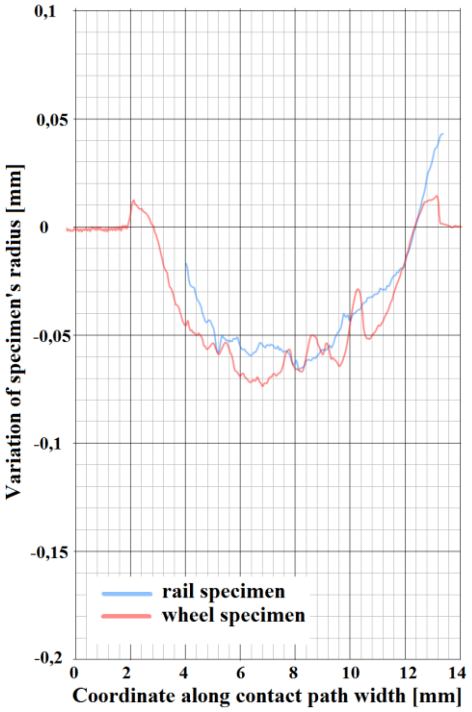


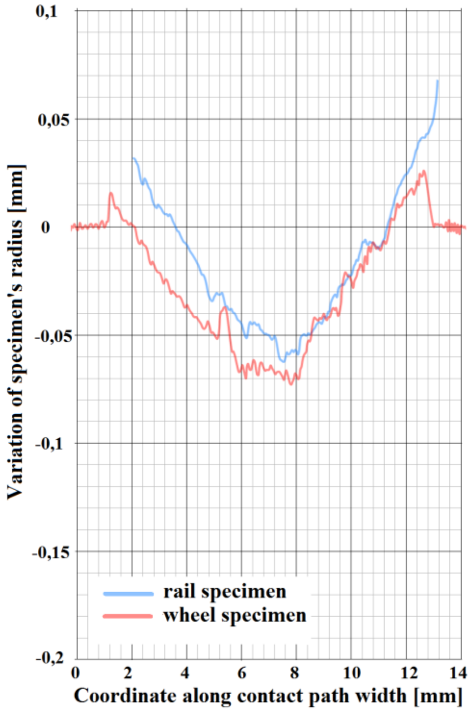
50000 cycles





75000 cycles





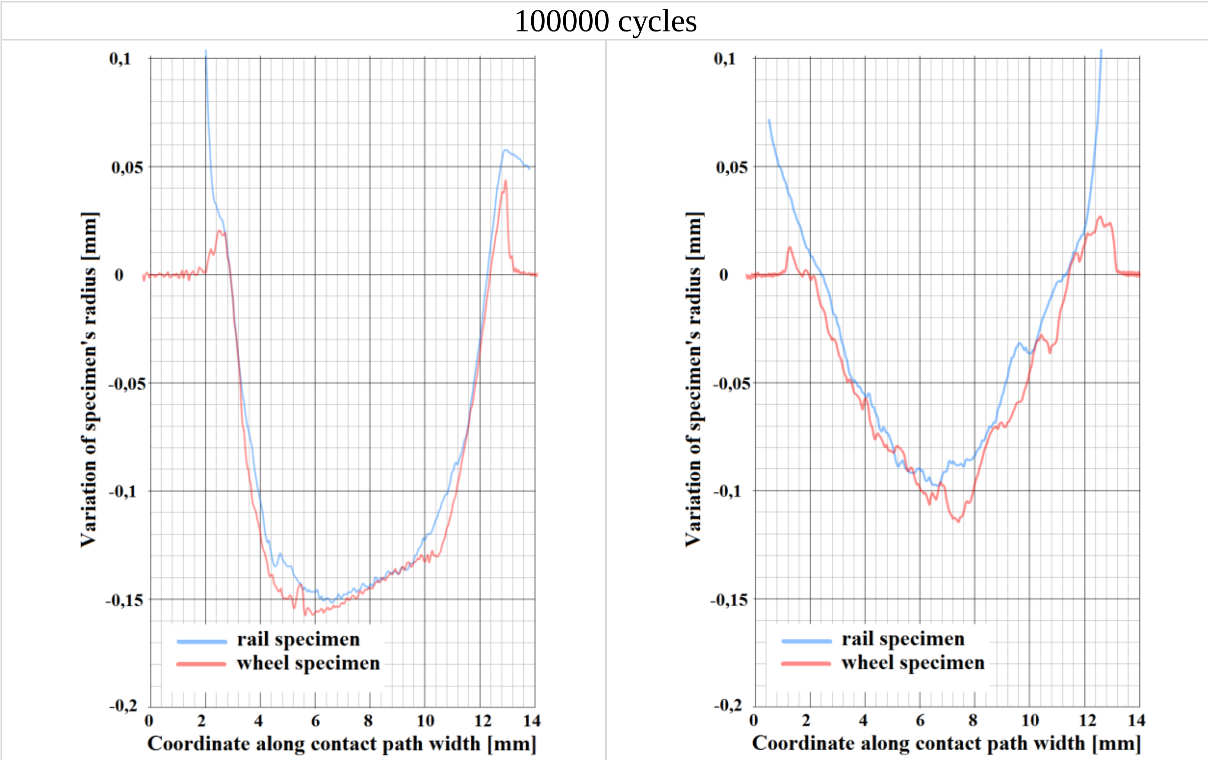


Fig. 4: Transverse profiles for Set 1 and Set 2 after 25000, 50000, 75000 and 100000 cycles obtained by use of Wenzel LH65 3D coordinate measuring machine

On the other hand, the lower hardness of the ER7 wheel specimen together with the hardened Class C rail specimen results in the lower plastization rates in both, horizontal as well as vertical, directions across the transverse profile (see Fig. 4 – Set 2).

Table 1 contains data of contact path width, which have been measured with use of 3D coordinate measuring machine (CMM) and contrast penetrant method (CP). In most cases, the CP method exhibit higher value of contact path width compared to CMM method. This finding is mainly caused by the measurement method in itself. In case of CP method, the specimen are loaded and are in contact, while in case of CMM method, the specimen are during their measurement unloaded. Overally, the ER7 wheel specimen exhibit during its test slightly higher values of contact path width compared to Class C wheel specimen. This fact is mainly caused by the lower values of specimen´s surface hardness.

Tab. 1: Contact path width measurement with use of 3D coordinate measuring machine (CMM) and contrast penetrant (CP)

Number of cycles	Class C/Class C		ER7/Class C	
	CP	CMM	CP	CMM
0	9,97 mm	-	10,00 mm	-
25.000	8,45 mm	8,13 mm	9,06 mm	8,12 mm
50.000	9,12 mm	8,52 mm	9,49 mm	9,03 mm
75.000	8,74 mm	7,99 mm	10,03 mm	9,80 mm
100.000	10,1 mm	9,76 mm	9,15 mm	9,67 mm

Another subject of discussion is the real value of maximum Hertz contact pressure. In the beginning of each test, the loading force has been set in order to induce maximum Hertz contact pressure of 1200 MPa for 10 millimeters wide specimen. The value of the loading force hasn´t been changed during the entire test in order to evaluate the real value of the maximum Hertz contact pressure and compare it to initially preset value of the contact pressure. Table 2 and Fig. 5 summarize the values and trends of calculated maximum Hertz contact pressure (Eq. 1) according to measured contact path width by CP and CMM method. For 25000 cycles, the value of maximum Hertz contact pressure is in case of both sets increasing up to 1330 MPa. Between 25000 and 100000 cycles, the trend is for both sets almost the same. The value of the maximum contact pressure is progressively decreasing or remains almost stable (Set 1) with the final decrease within the interval of 1200÷1250 MPa.

Tab. 2: Calculated values of maximum Hertz contact pressure according to the values of measured contact path width

Number of cycles	Class C [MPa]		ER7 [MPa]	
	CP	CMM	CP	CMM
0	1200	1200	1200	1200
25.000	1304	1329	1267	1332
50.000	1257	1298	1239	1263
75.000	1286	1341	1198	1212
100.000	1191	1213	1255	1220

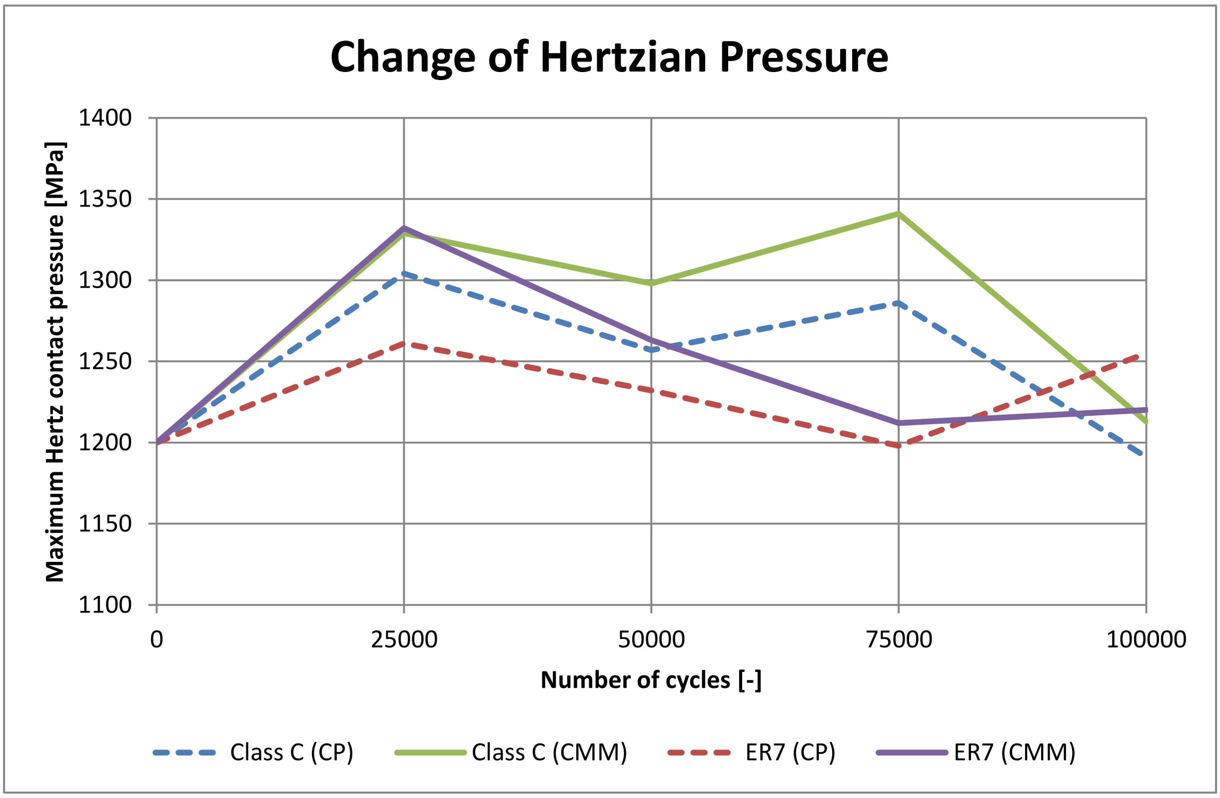


Fig. 5: Computed maximum Hertz contact pressure

Conclusion

Presented results and findings point to the need to deal with precise measurement of contact path width and its evolution during the entire wear resistance test in more detail. The attention must be also paid to the specific combination of wheel/rail material, their material properties and, last but not least, to the desired value of maximum Hertz contact pressure including the number of simulated cycles or the slip ratio value. Proposed paper demonstrates two different methods of measurement the contact path width, the measurement by use of 3D coordinate measuring machine, which is capable to deliver precise results. However, the main drawback of this method is time-consuming measurement with additional complex data processing process. On the other hand, the incorporation of contrast penetrant method for contact path width measurement in case of loaded specimen seems to be a universal and inexpensive way how to relatively quickly obtain reasonable results, which will improve the informative character of the wear resistance test in itself.

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