DISTRIBUTION OF THE RADIAL STRAIN COMPONENT OVER THE CROSS SECTION OF A RAILWAY WHEEL

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Introduction

Recent railway disasters in Germany and other countries caused by material failure of wheels are showing that a better understanding of failure mechanism is needed. One limitation of the life-time of railway wheels is the accumulation of plastic strains and formation of micro-cracks due to cyclic loading. Residual stresses are the result of local micro-structural changes especially of local cold-work hardening. The locations of cold work hardening depend on the manufacturing engineering and are re-distributed by interaction between rail and wheels.

Object of the investigation

A 35° section of the hoop of a wheel with rubber suspension (type 064) was used for the investigation. Such wheels are applied in the German ICE high speed trains. The hoop under investigation run about 1.4×10^6 km without any detected damages. The usage level of this hoop is comparable with the usage of the hoop which was broken in the railway disaster of Eschede (Germany) in 1998. It is close to the projected end of live usage.

Strain scanning

Due to the radial load during service the radial strain direction gives sufficient information about local plastic deformations. The measurements were performed using the G5.2 diffractometer at the Orphée reactor (Saclay, France) with a wavelength λ = 0.31 nm. The measurement on a powder of the wheel hoop material confirms the expectation, that the theoretical lattice constant of pure iron (0.2866 nm) can be used as the strain-free reference state. A gauge volume of about 2mm (axial) $\times$ 3 mm (radial) $\times$ 10 mm (hoop) was achieved by slits of 2 mm (horizontal) $\times$ 10 mm (vertical) in the incident and diffracted beams.

Results and Discussion

Fig. 1 shows the distribution of the radial strain for radial cuts at different distances from the inner surface. Close to the tread, small tensile strains were found. These strains increase with increasing depth. At a depth of about 8mm,

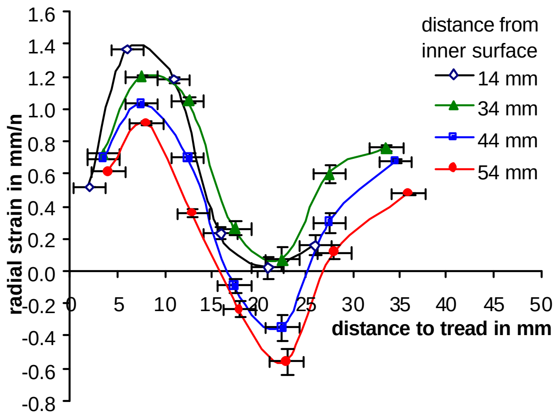

Figure 1. Measured radial strain as a function of depth

maximal tensile strain values exist. At deeper positions the strains decrease and reach minimum tensile strain or maximum compressive strain values in a depth of about 23 mm. At deeper positions, close to the opposite surface the strains increase again and reach values close to those at the tread. This distribution can be understood if local plastic deformation is taken into account. Hertz pressure shall reach maximum values at locations were maximal tensile strains are found [1]. A strain reversal after release of the pressure during contact between railway and wheel occurs. The plastic deformed regions are much more strained than the only elastic deformed ones. After release of the pressure, the elastic strain can not compensate the plastic deformation. In order to fit to the neighbour regions, an elastic strain with opposite sign is formed. The axial distribution of the radial strain is shown in Fig. 2

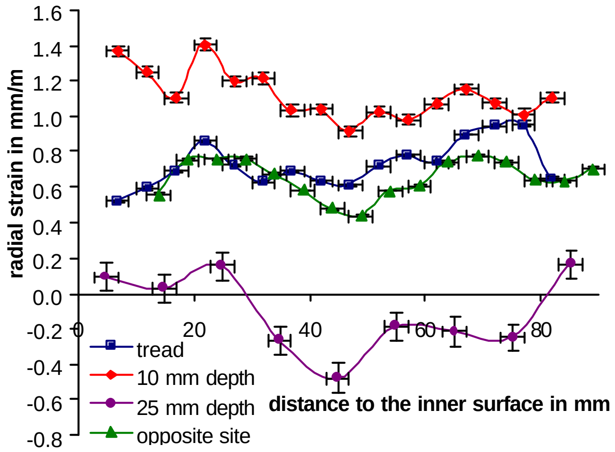

Figure 2. Axial distribution of the radial strain component

for different depths. A gradient in this direction occurs only in a depth where compressive strain was found in Fig. 1. Compressive strain was measured only below the middle of the tread. Fig. 3 shows the distribution of the radial strain over the hoop cross section. Compressive strain was found only in the middle part of the hoop cross section. In a band between a distance of 5 to 12 mm from the tread, relative large tensile strain was quantified. The other regions show only small strains. The fracture surface of a broken wheel hoop with comparable usage is shown in Fig. 4. A comparison with the strain in Fig. 3 shows correlations between strain distribution and fracture appearance. The crack starts at the surface opposite to the tread. At locations with compressive radial strain, the crack growth was stopped. The crack had to bypass this region. At the boundaries of this region, crack branching occurs. Close to the tread, where the highest radial strains were measured, rupture was observed.

Conclusions

Compressive strains were found only in the central part of the hoop cross-section. In a band between a distance of 5 to 12 mm from the tread, relative large tensile strain exist. In other regions, only low strains were obtained.

A comparison of the estimated strain distribution with the fracture surface of a broken hoop shows correlation between the strain distribution and the fracture appearance. The strain and stress distributions strongly influence the fracture process. This shows that the residual stress distribution formed during service has a high relevance for the fracture behaviour.

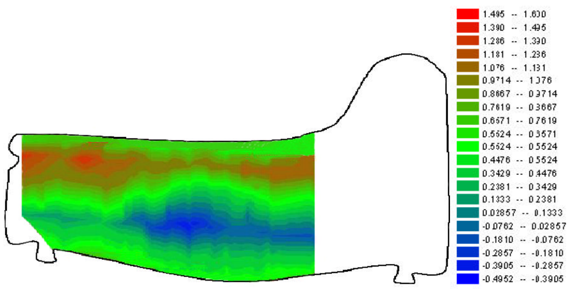

Figure 3. Distribution of radial strain in the hoop cross section.

Figure 4. Fracture surface of a broken railway wheel hoop.

[1] K.L.Johnson: "Contact mechanics", Cambridge University Press, (1985), ISBN 0 521 34796 3