20th International Conference
ENGINEERING MECHANICS 2014
Svratka, Czech Republic, 12 – 15 May 2014

ANALYSIS OF SUBWAY WAGON ROLLER BEARING AXLE BOX STRESSES WITH MEDIUM OPERATION LOAD

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Abstract: *The paper presents the stress-strain analysis of a bearing axle box of a subway wagon. Simulations were performed on a digital model using FEM for medium loads. Calculations were performed for the geometry of the roller with the standard outline.*

Keywords: Cylindrical roller bearings, FEA simulation, Contact stresses.

1. Introduction

The analysis concerns the subway wagon axle box roller bearings (Fig. 1). Bearing parameters: load Cr = 84500 daN, static load Cor = 130200 daN, axial clearance 0.6 to 1.1 mm, radial clearance 0.125 ÷ 0.165 mm, the type of grease: Liten LT-4S3, bearing life L_{10} = 600000 km. Load to the axle box:[passengers], maximum 67.5 kN, speed: maximum 90 km/h, average 45 km/h.

Raceway of main rings is straightforward. A profile of roller (convex) is described with function:

$$P(x_k) = 0.00035 \cdot D_{we} \cdot \ln\left[\frac{1}{1-(2\cdot x_k/L_{we})^2}\right] \qquad (1)$$

where: D_{we}- roller diameter, L_{we} – length of the roller

Permissible stresses contact: dynamic: 2800 ÷ 3000 MPa, static: 4000 MPa.

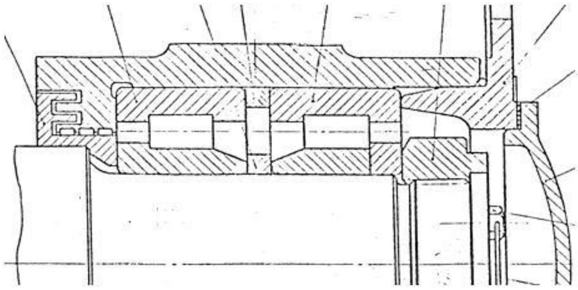

Fig. 1: Longitudinal section of the axle box.

2. Term of Substitute Loads

Tab. 1: The term of transverse substitute load.

Te - operation time of train %	Train weight P [kN]
9.5	540
23.8	340
66.7	440

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Transverse substitute load [for average weight of wagon], is: Psr = 432.4 kN.

Radial substitute load of bearings set is: Ppz = 54 kN. There are eight sets of bearings for four axles per wagon. Longitudinal substitute load for centrifugal force on the curve Psw = 8.918 kN. Longitudinal substitute load of bearings set Pwz = 2.23 kN.

Simulations of stresses and strains in the developed FEM model of the axle box (Rakowski et al., 1993) were performed for these loads. Simulations considered neither overloading nor overheating.

3. Digital Model of Bearing Node

The digital model of axle box is shown on Fig. 2. Fig. 4 shows a global model with FEM mesh. The mesh contains 455827 nodes, and 454359 elements. The mesh is of hexagonal type. The boundary conditions and substitute loads are highlighted on Figure 4. Schematic transfer longitudinal forces of reaction or body shaft reactions [change the direction of the force] are shown on the Fig. 3.

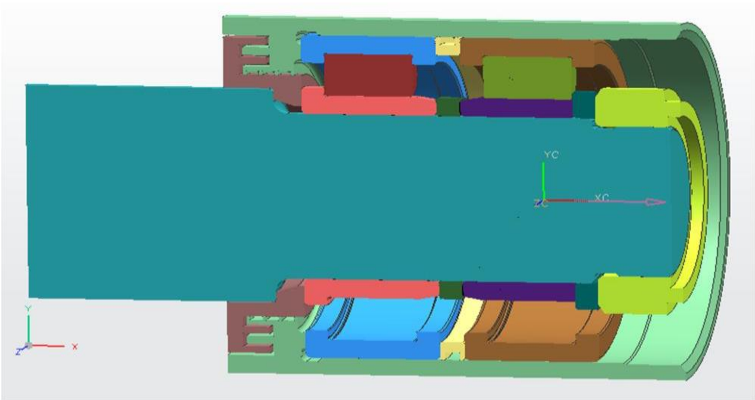


Fig. 2: 3D digital model of axle box.

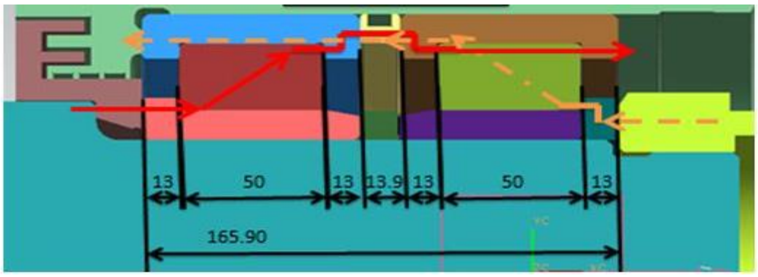


Fig. 3: Transfer of longitudinal force in axle box.

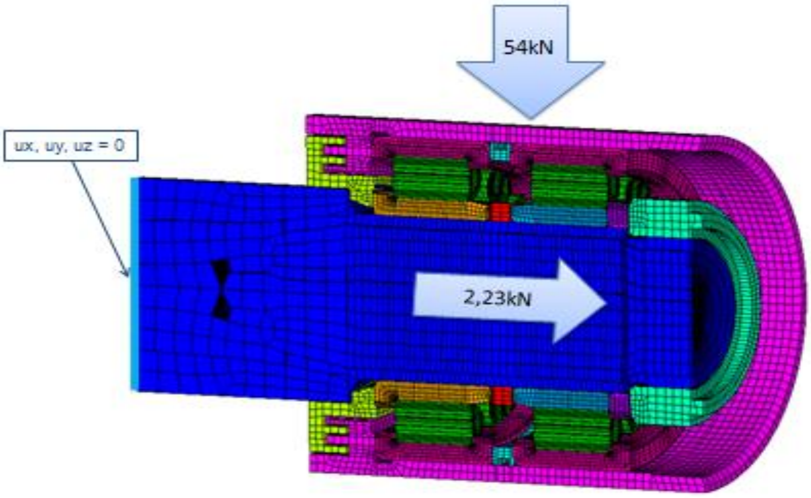
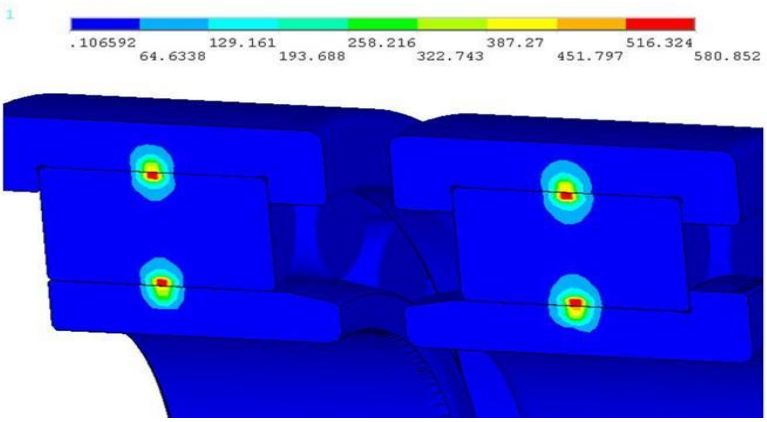


Fig. 4: 3D model with FEM mesh, loads and boundary conditions.

4. Simulation of Stresses and Strains on the Global Model

The simulation of stress and deformation of bearing was conducted for average substitute loads of the roller bearing set described in Chapter 2 and shown in Fig. 4.



1.

Fig. 5: Huber Mises equivalent stresses.

The maximum equivalent stresses, which occurred in the central zone of the roller contact with the track, were 580 MPa (Fig. 5).

The global 3D mesh model is too thin to provide more accurate results. It is, however, useful for preliminary estimation of stress distribution. It allows the area of the largest loads to be specified.

Thus it was necessary to build a submodel with enhanced mesh for better micro-geometry mapping in contact zone.

5. Submodel

The 3D Submodel (Fig. 7) was developed for micro-geometry mapping of maximum load zone of a standard roller outline (Rakowski et al., 1993), (Fig. 6).

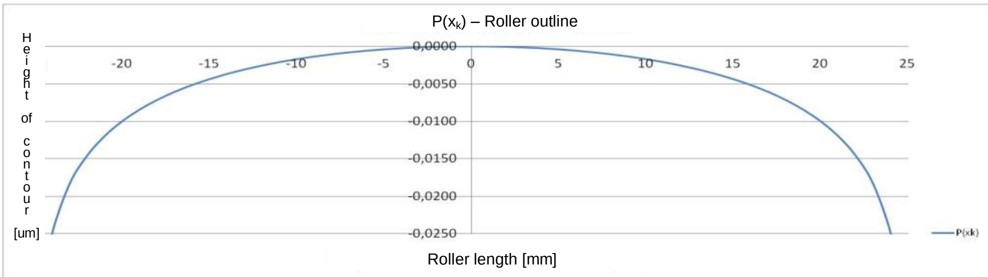


Fig. 6: Roller outline.

The number of nodes in submodel: 218954; the number of elements: 215363; hexagonal mesh (Hexahedra).

Submodel load conditions were determined based on results of simulation basis for the global model of maximum stress zone (Fig. 7).

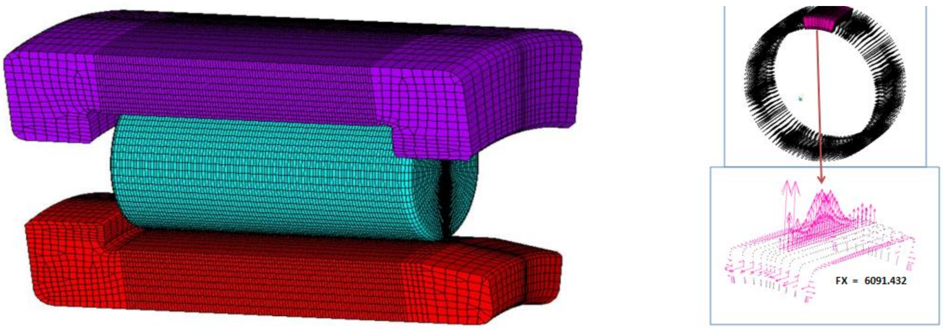


Fig. 7: Submodel with the distribution of forces in the zone of maximum load.

6. Simulation of Stress on the Developed Submodel

The simulation results of stress in submodel for the state of maximum load (Fig. 7) are shown in Figs. 8 and 9. The stresses in the rolling element contact with the inner race (Fig. 9) were calculated for the standard outline of the roller.

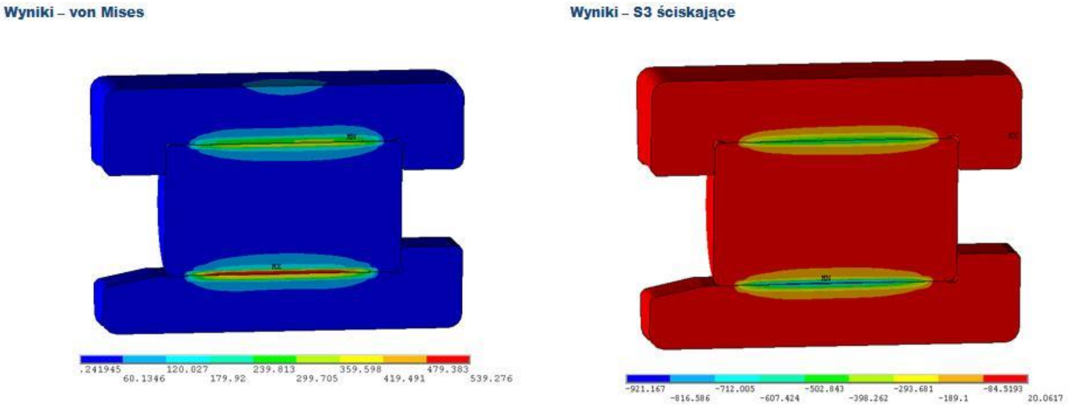


Fig. 8: Substitute loads [MPa] (left); Compressive stresses [MPa] (right).

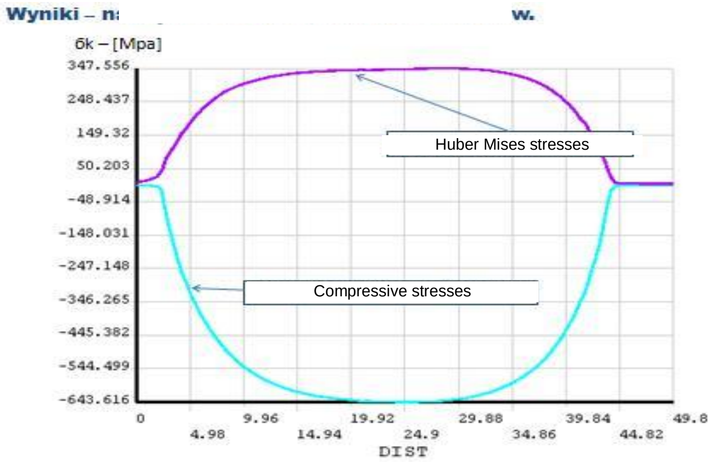


Fig. 9: The contact stresses - the inner ring raceway.

The resulting values of maximum substitute stress in the inner ring raceway do not exceed 400 MPa and compressive stress does not exceed 700 MPa. The amplitude of the maximum shear stress is 180 MPa. This is well below allowable contact stress values. It should be noted that these values are calculated for the average operating load condition. For states with maximum traction, load is expected to be higher. With the required time of operating L_{10}=600000 km, with proper installation and lubrication of bearings, durability of the axle box will be absolutely sufficient.

7. Conclusions

The developed digital model and the simulations on the FEM model of the axle box made possible the state of stress estimation of bearings for medium duty operation. In order to more accurately map the geometry, the submodel of the most loaded contact zone was developed. The area of maximum stress was determined as a result of global FEM model simulations. Stress distribution along a roller is uniform in both raceways which is beneficial to strength.

The result obtained is beneficial operationally in the specified load conditions. In the case of operating a wagon with a maximum number of passengers, the substitute load would increase by about 23%. The maximum stress increases, respectively, however, are still far below the limit values. The basis for the calculations were average loads. This article did not focus on thermal loads. Temperature differences in the axle box retain minimal radial clearance.

References

Rakowski, G., Kacprzyk, Z. (1993) Finite element method in engineering design. OWPW Warszawa (in Polish).