Analysis of the Service Straining on the Beam-Axle of Lorry

Garan Martin, Ph.D
Slovak University of Technology
Faculty of Mechanical Engineering
Námestieslobody 17, 812 31 Bratislava, Slovakia

ŠulkoMiroslav, Ph.D
Slovak University of Technology
Faculty of Mechanical Engineering
Námestieslobody 17, 812 31 Bratislava, Slovakia

Abstract

This work was devoted to identify the causes of the fracture at the axle on the lorry FGS. It's a beam-axle cushioned by torsion stocks. The results from measurement sensing by strain gages on the beam of axle are presented in various loading condition. The stress-strain analysis in a critical cross-section is also presented in this work as well as the fatigue life-time analysis considering the deviation of the cyclic material properties which is interpreted by distribution function.

Keywords: Axle, Fatigue, Service loading, Fracture, Fatigue Lifetime

1Introduction

The special lorry named FGS is the lorry with height-adjustable chassis for comfortable loading and unloading the articles. This advantageous function is created by two axles coupling by hydro motor using the eccentrically axle flange Fig.1.

Fig. 1 Height-adjustable chassis the special lorry FGS

In operation of this vehicle was occurring the fractures repetitively at the main beam of an axle which was created by the tube including device body for clamping the torque bar. The critical section of the axle becomes evident the places of joint the device body for clamping the torque bar into the main beam of axle. This joint is realized by weld filling of the hole in main tube which provides the torque transition. Task in this casewas

- to identify the failure causes
- suggest a solution to minimize the probability of fracture.

2 Solution

2.1 Fractography

Analysis of the fracture surface disclose the problem in welded point. Technology of welding insufficiently joint the device body for clamping the torque bar with the main beam (tube) of an axle - weld filling the hole in main tube was only „sticked" onto the device body for clamping the torque bar. In addition the filling weld was not joint with tube wall in all thickness

Fig. 2. Outcome this situation was an additional notch factor in forces-flow the bended main beam of an axle. In place the imperfect the weld joint with tube thickness start the process of fatigue crack initiation and propagation.
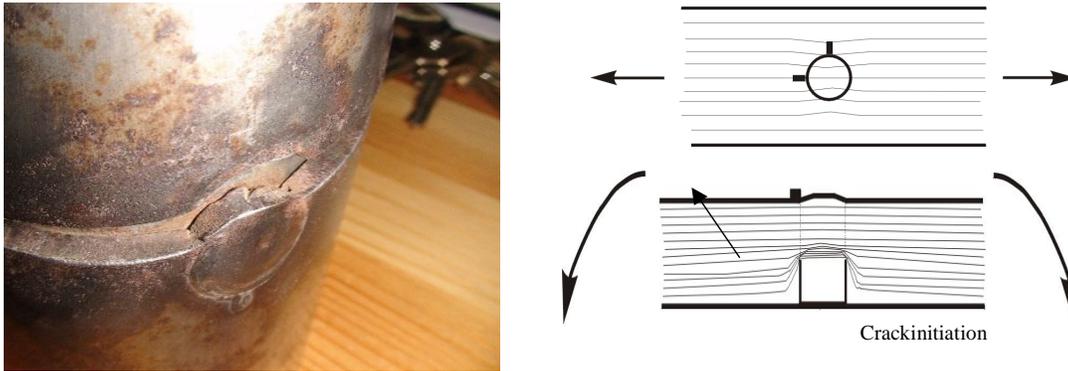

Fig. 2 Fracture surface detail and scheme of force-flow

For repeating this process and evaluation of fatigue life-time in various service condition the axle of lorry FGS was realizedto direct measurement in real operation of full loading lorry. The strain gages were placed in two section of tube of the main beam of the axle between the sections with weld joints Fig. 3. The special arrangement of gauges according the Fig. 3 allowed to calculated the stresses from the torsion, bending and axial loading using the formulas implicit from Mohr's circles [1]. Using the modular and reconfigurable system cRIO was realized measuring during the driving the lorry FGS. Continuously measurement by strain gages was supported by accelerometers synchronically measurement.

3 Results

The typical operation of lorry FGS is transfer of various alimentary and other articles by the asphalt road. Measurement pass off at the asphalt road with different quality of surfaces, with overcoming small obstacles (retarders) and combined with various placement of a loading. From the measurement results was arranged the typical operation unit, representing the all valid situation and service condition. One part of this considered loading process is at the Fig. 4. Using precise model of critical part of the main beam of the axle, modeling by FEM was obtained transformation formula to transform the nominal stresses into theroot of notch [2]. After this transformation was using the rain flow counting method [3] to obtain the stress amplitudes. The mean stresseswere considered by Morrow´s formula.

$$\sigma_{am} = \sigma_a \left(1 - \frac{\sigma_m}{\sigma_{f'}}\right)^{\frac{c+1}{b+c+1}} \tag{1}$$

where
σ_{am}-centered amplitude of stress, σ_a- amplitude of stress, σ_m- mean stress, $\sigma´_f$- axial fatigue strength coefficient , c – axial fatigue ductility exponent, b- axial fatigue strength exponent.

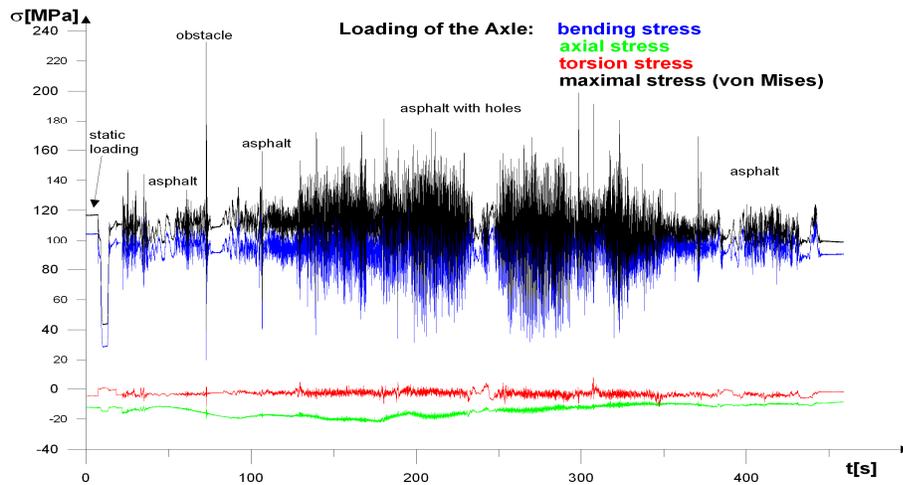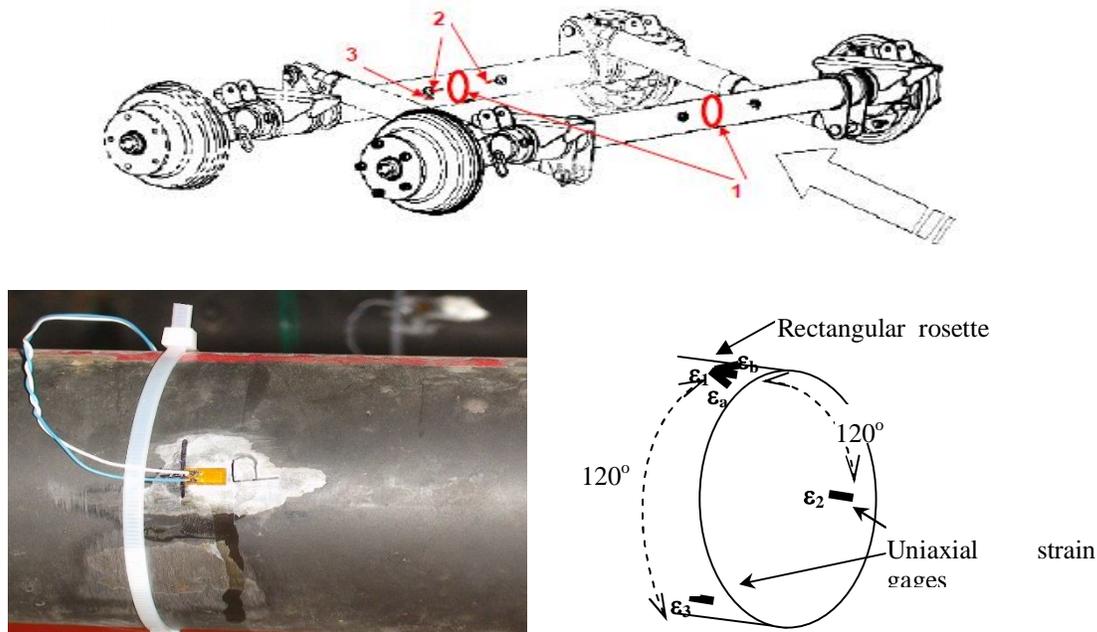**Fig. 3**Strain gages arrangement in section of the main beam of axle

Fig. 4 The stresses in the section of the axle during full loading in various service condition

Necessary material properties (σ_f´,b, ε_f´, c, k, n) forSteel St52.1were obtained by the direct cyclic test on specimens created from this material on the electrohydraulic pulsator from INOVA. Results of the specimens tests was utilized in Manson´s formula

$$\varepsilon_a = \frac{\sigma_f^{'}}{E}\left(2N_f\right)^b + \varepsilon_f^{'}\left(2N_f\right)^c \tag{2}$$
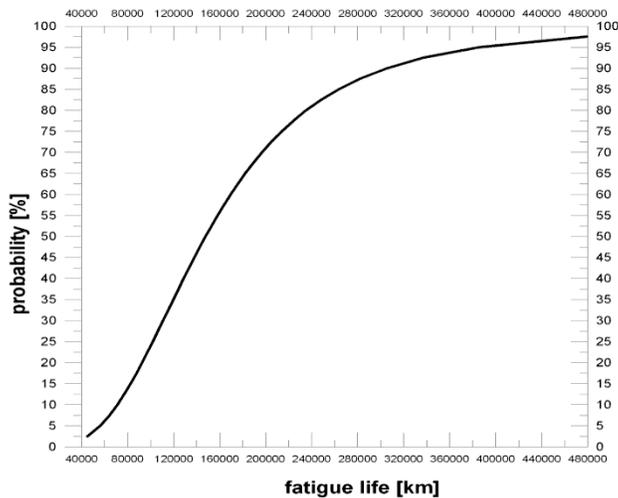
where
ε_a- total strain amplitude, $\sigma_f^{'}$- axial fatigue strength coefficient, c – axial fatigue ductility exponent, b- axial fatigue strength exponent, $\varepsilon_f^{'}$- axial fatigue ductility coefficient, E – Young´s modulus.

Material properties obtained by this way show data dispersion which needs to be considered in the fatigue damage evaluation [4], [5] Fig. 5. As fatigue damage criterion was using the Kliman´s energetic formula [6], [7].

$$D_{E_M} = \frac{1}{N_{f_{MAX}}} \sum_{i=1}^{r} \left(\frac{\sigma_{ami}}{\sigma_{amMAX}} \right)^{\frac{1+n}{n}} \tag{3}$$

where

D_{E_M} - damage of one loading segment, N_{fMAX} – number of cycles from maximal centered stress amplitude in loading segment, σ_{ami} – i-th centered amplitude in loading segment, σ_{amMax}- maximal centered stress amplitude in loading segment, n – exponent of cyclic stress-strain curve, r – number of amplitudes in loading segment.

4 Conclusions

The complex analysis of fracture at the main beam of the axle of the lorry FGS included the fractography, measurement of the stress processes in real service condition, FEM analysis of the critical parts for notch factor wereobtained. The material cyclic tests and fatigue lifetime evaluation using the probability distribution function imply, that

- the reason of the fracture was the imperfect technology of welding
- minimal fatigue lifetime of critical section in axle is 43000km (2,5% probability of fracture)
- weld point was removed from maximal bending stress point to a neutral line of the bending.

References

Poděbradský, J. (1992).Determination of theloadingcomponents by tensometricsensing (published in slovaklanguage), Strojníckyčasopis, Vol. 43, 472-478

Chmelko, V. (2006). Addition to the theory of the fatigue lifetime of the real structures. Dissertation thesis. Faculty of mechanical engineering STU in Bratislava.

Amzallag,C.,Gerey,P.,Robert,J.L.,Bahuaudt,J. (1994). Standardization of the Rainflow Counting Method for Fatigue Analysis. International Journal of Fatigue, 16, 287

Kliman,V. (1998). Probabilistic approach of evaluation of the fatigue lifetime. Metallic materials, 36, 419-435

Chmelko, V. (2010): On-line monitoring the Operation Safety on Pipeline. In: Transport & Logistics. - ISSN 1451-107X. –Special redaction 8, 31-38

Kliman,V. (1984). Fatigue Life Prediction for a Material UnderProgrammable Loading Using Cyclic Stress-Strain Properties. Materials Science & Engineering, 68, 1

Ďurka, R., Margetin, M. (2012). Multiaxial fatigue testing methods. In: Applied Mechanics 2012: 14th Conference. Plzeň, 2012. Plzeň: University of West Bohemia, 29-32