Railway Axles Fatigue Strength Assessment – where does the journey go – „Quo Vadis“?

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Content

- Introduction
- General Requirements on Railway Axles
- History
- Fatigue Strength Assessment Yesterday – Today – Tomorrow
- Service Experience
- Open Questions
- Conclusion
Introduction

1. Wheel set axles are high stressed components, **non redundant safety components** in the railway traffic.
2. Even if we have a high safety level a continuous **improvement** of the **safety** is always recommended.
3. The design of axles **is/was?** since decades approved and always adjusted according the newest state of the art.
4. Extensive service data and **experience** at the operators are available.
5. Against the background of the positive experience in Railway traffic over the decades in the past it could be said that the previous technical rules make the attainment of the necessary standard of **safety seems as protected**.
6. But the situation has been changed especially after some recurring events in the recent past – **broken axles => accidents!**, the safety is in public discussion at the moment.
7. In addition the roles between operator car-builder and component deliverer has been changed within the last years, the **chain of experience has been broken**, the responsibilities and competencies have been shifted.
8. All that what was based on experience till now, must be **proved again now by new approaches** from all stakeholders.
General Requirements on Railway Axles

• The design load must be well known.

• All during operation occur loadings must be recorded sufficiently by load-factors.

• Metrological validated loadings must be always ensured in future by the maintenance concept of the Infrastructure.

• The fatigue strength must be proved for the present axle geometries.

• The compliance of the technical nominal condition must be ensured by the maintenance concept of axles.
General Requirements on Railway Axles

Reliability of structural components

- Design (Geometry, Dimensioning)
- Production (Material, Manufacturing, Quality Assessment)
- Maintenance (Inspection, Repair)

Dimensioning of structural components

- Load Evaluation
- Stress calculation
- Fatigue Strength Assessment

ESIS TC 24 Workshop on Fatigue Strength and Fatigue Life of Railway Axles, BAM, Berlin, 11th to 12th October 2010
General Requirements on Railway Axles

Manufacturing of structural components

Material (chemical composition, strength, internal integrity)

Production (Geometry, Surface integrity)

Quality Assessment

Some possible improvements:

Production/Material:
Decrease limit of admissible inner flaws,
Increase the cleanliness factor => lowest non metallic inclusions, e.g. ESU process:
electroslag remelting, change NDT test method higher flaw detectability, 100% UT volume test. (available technology)

Service:
Safe protection against impacts and corrosion, e.g. axle coatings or shields at the gear or bogie, improvement of paint-coatings, other coating processes. (answers from Euraxles)

Maintenance/Inspection:
Improvement NDT – test methods and the POD, (answers from EBFW3, Euraxles)
## History / Evolution of Rules and Standards

### Standards / Rules/ Specifications

#### Germany

<table>
<thead>
<tr>
<th>Design</th>
<th>Manufacturing</th>
</tr>
</thead>
<tbody>
<tr>
<td>(Geometry and Calculation)</td>
<td>(Material, Production and Quality inspection)</td>
</tr>
<tr>
<td>August Wöhler, fatigue strength tests (1858 – 1870)</td>
<td>European operator leaflet UIC 811-1/2</td>
</tr>
<tr>
<td>National operator standards e.g. DB-Formblatt FW 28.02.08 (draft 1960, start approx. 1941)</td>
<td>and Operator standards and approvals DB- Railway - standards HPQ (producer-related product qualification)</td>
</tr>
<tr>
<td>DB-Bahnnorm 421022 (1992)</td>
<td>European Standards EN13261 / 13260 (product requirements axles/ wheel sets) and Operator standards and approvals New DB- Railway standard HPQ (producer-related product qualification)</td>
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<tr>
<td>European standards Design method EN13103 / EN13104 (2009)</td>
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<td>TSI Wag, TSI Loc&amp;Pas</td>
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Fatigue Strength Assessment Yesterday – Today - Tomorrow

1. Based on the standards development axles became bigger diameter since the introduction of the current legal EN standards. Yesterday and today it is the practise to use the endurance fatigue strength assessment acc. EN 13103 / 13104.

2. In addition it will be used today methods based on fracture mechanics for new vehicles based on crack propagation tests original axle size/small specimens and calculations (at the moment conservative)
   a) e. g. required NDT-interval 400.0000 km => thicker diameter than EN
   b) maybe fracture mechanics endurance fatigue analyses, load < threshold => => much thicker diameter?

3. Safe Life fatigue strength assessment (limited life time) thicker diameter than EN, same diameter than calculated acc. 2a) ?

What will be the procedure tomorrow?
Service Experience

• At assessment of occurred damages it is to clarify:
  – Which standards / specifications were applied?
  – Were the loading approach correct?
  – Were the axle in compliance to the technical nominal conditions?
  – Which other negative impacts had have an influence?

• Damages have to be communicated between operator and manufacturer openly.

• The very few damages known from the past, statistically examined, had to be led in the normal case on special influences.

• The most of them were defects growing from the axle surface (stone impacts, corrosion, hot box cracks (freight)…) The knowledge of this were introduced into the processes and specifications.
Service Experience, Statistic

Reported number of precursors to accidents (acc.) in Europe (see also next table)

2006 broken wheels  242  of total 6763 acc., at 4143 million train km
broken axles  78  of total 6763 acc., at 4143 million train km

2007 broken wheels  170  of total 3999 acc., at 4237 million train km
broken axles  103  of total 3999 acc., at 4237 million train km

2008 broken wheels  90   of total 3894 acc., at 4261 million train km
broken axles     104  of total 3894 acc., at 4261 million train km

Source: ERA, Railway safety performance in the European Union 2010
Service Experience, Statistic

Source: ERA, Railway safety performance in the European Union 2010
Open Questions, some

• Which influences appear in the area of very high load cycles approx. $10^8, 10^9$ in fact at original size axles? Are there developments result available e. g. at small specimens tested on high frequency test pulsators and are these result transferable onto original size axles?

• Which effect have inner flaws e. g. non-metallic inclusions on the fatigue behaviour in fact? Are there any development results available? Are there an influence at notched structural components, we have at axles?

• Which influences have changes in operation within the admissible limits at the vehicles potentially on to the loading? Are the safety factors according the EN 13103/13104 sufficient enough to cover this?

• Which experience is available in Europe with the exposure of the addressed problems? Experience with results from the past e. g. from the projects Widem, UK-Axle ....
Conlusion

Following question arises:
Which concept for the dimensioning is the right / best one for all stakeholders?
One approach could be to have different concepts for different traffic applications.

Concept: Fracture Mechanics based on a defined start crack with periodic NDT testing beginning at the first day of service up to 30 years or the end of a defined limited lifetime?

Concept: Safe Life (crack-free lifetime) under defined influences (surface- und inner flaws...) for a defined period x km and than axle-replacement?

Concept: Safe Life period and than Fracture Mechanics with periodic NDT testing up to 30 years or the end of a defined limited lifetime? (Service Phase model?)

The preparation of different concepts require in any case the knowledge of all possible influences out from the service. We need this experience from the service.
Conclusion

• Of course the safety must be the first target and the remaining risk be minimised here.
• At all it may not be forgotten in everything that the railway traffic still must remain economic and competitive in future.
• The future dimensioning concept should also be done with a manageable, maintainable, and economical justifiable effort and also with a common European approach.
• In the past there were introduced many return of experience into the standards by the operators (improvement of standards), but in the future all has to be verified fundamental by the engineers based on scientific approach.
• In the railway traffic opposite other countries and industries it seems there is no remaining risk accepted by the civil society. Therewith is no clear planning and legal certainty for the agents as well.
“The Journey is the Goal”
(Citation: Konfuzius (Chinese Philosopher, 551 – 479 b. c.)

Thank you for your kind attention

And now we are looking forward to hearing the following promising presentations and having also a constructive discussion.