Eisenbahnfahrwerke 3 – EBFW3
Description and aims of the new project
ESIS TC24
Railway axles: Advances in Durability Analysis and Maintenance
01.-02.10.2014, Dipartimento di Meccanica, Politecnico di Milano

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Overview

- Starting point
- Project history and goals
- Participants & project organization
- Work packages
Definition of NDT intervals for railway axles

a) from experience
b) by computation (→ EBFW3)
c) combined approach

a) define NDT interval from previous operating experience

b) define NDT interval from crack growth computations (→ EBFW3)

c) define NDT interval from a combination of experience and computation → „curve method“ (under development)

Determination of residual life from
- component tests
- computation of crack growth
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Project history

**EBFW1** (2001 – 2004)

Contents:
- Determination of allowable stresses at the free surface and at the press fit of railway axles
- Measurement of load spectra (ICE 3)
- Development of a design and safety concept for railway axles (complementary to the design following standards EN 13103 / EN 13104)

**EBFW2** (2005 – 2009)

Contents:
- Development of a computational method for determining the residual life and inspection intervals of railway axles by means of fracture mechanics
- Determination of fracture mechanics material parameters for axle materials
- Validation of the computational model by means of laboratory specimens and component tests on the scales 1:3 and 1:1
- Measurement of load spectra (locomotive and passenger car)
- Differences between computation and 1:1 test results showed the need for additional research → EBFW3
Validated computational method for determining crack growth rate and inspection intervals

- Model for crack growth rate in railway axles from EA1N and EA4T shall allow residual lifetime prediction for
  - different designs (e.g. hollow axles),
  - different stress concentrations and
  - different load spectra

- Method for materials characterization for other materials long-term goal: 1:1 tests only for validation

- Method for determination of inspection intervals, with special attention to the enormous amount of existing knowledge ("large-scale test: 150 years railway transportation")
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Project participants

**Industry Partners**
- Alstom
- BVV
- GHH
- Siemens
- Stadler
- Voith

**Scientific Partners**
- Virtuelles Fahrzeug
- Materials Center Leoben
- TU Graz
- TU Clausthal
- Fraunhofer IWM
- Erich Schmid Institute
- MU Leoben

**Scientific Board**
- Politecnico di Milano
- TU Graz
- Verband der deutschen Bahnindustrie e.V.
- DB Systemtechnik GmbH
Project and sub-projects – funding and participation

Funding

Project Lead

K2 Comet
Public Funding
1.8 Mio.

Scientific Board

K2 Project
MCL

K2 Project
ViF

TU Graz

1:1 tests
35

TU Clausthal

Scientific partners in sub-projects.

MU
Leoben

IWM
Freiburg

ESI
Leoben

Volume ~ € 5 Mio.

Industry 1)-6)

Industry Funding
3.14 Mio.

Scientific Partners

1) Alstom
2) BVV
3) GHH Radsatz
4) Siemens
5) Stadler
6) Voith Turbo

7) Materials Center Leoben (MCL)
8) Virtuelles Fahrzeug (ViF)
9) TU Graz, Institut für Leichtbau
10) TU Clausthal, IMAB
11) Montan Universität Leoben, AMB
12) Fraunhofer IWM Freiburg (IWM)
13) Erich Schmid Institut (ESI)

Scientific Board

14) Politecnico di Milano, DdM
15) TU Graz
16) Verband der Bahnindustrie in Deutschland e.V.
17) DB Systemtechnik GmbH
Timeline

EBFW1+2 WIDEM, EURAXLES …

10/2013

Project EBFW 3

plausibility and practicability

09/2017

year 1

year 2

year 3

year 4

data base for computation and transferability

load spectra, load blocks for residual life tests

deterministic and probabilistic models

method development

validation tests (1:1)

Validated computational method for determining crack growth rate and inspection intervals
Project organization

**WP1** Test specification
- TUG / IMAB
  - Prof. C. Moser
  - Prof. A. Esderts
- BVV
  - F. Murawa

**WP2** 1:1 tests
- TUG / IMAB
  - Prof. C. Moser
  - Prof. A. Esderts
- Alstom
  - K. Lütkepohl

**WP3** Materials charact.
- MCL
  - H.-P. Gänsner
- Siemens
  - G. Rüf

**WP4** Crack growth comp.
- MCL
  - R. Tichy
- Alstom
  - K. Lütkepohl

**WP6** Load spectra
- ViF
  - K. Kunter
- Stadler
  - M. v. Borany

**WP7** Safety concept
- MCL
  - H.-P. Gänsner
- Siemens
  - F.-J. Weber

**Project Lead**
- M. Koch
  - (A. Deisl)

**Scientific Board**
- Prof. S. Beretta (POLIMI)
- Prof. C. Sommitsch (TU Graz)
- H.-P. Lang (DB)
- W. Schwab (VDB)

**Industry lead of WP**
- Siemens
  - F. Murawa
- Siemens
  - F.-J. Weber

**Scientific lead of WP**
- TUG / IMAB
  - Prof. C. Moser
  - Prof. A. Esderts
- MCL
  - H.-P. Gänsner
- MCL
  - R. Tichy

**ViF** Virtual Vehicle
**TUG** TU Graz, Institute of Lightweight Structures
**IMAB** TU Clausthal, Institute of Plant Engineering and Fatigue Analysis
**MCL** Materials Center Leoben
**Interaction of work packages**

- **WP6** Load spectra
  - sequence of block loads
- **WP1** Test specification
  - test specification
- **WP2** 1:1 tests
  - crack growth data
    - (1:1 components)
    - material data
      - (lab specimens)
- **WP3** Materials characterization
  - separated influence factors
- **WP4** Crack growth computations
  - models & parameters
- **WP7** Safety concept
  - results for validation

*Source: McInnes et al. (2023)*
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## Work packages

### WP1 Test specification

<table>
<thead>
<tr>
<th>Duration: 10/2013 – 06/2014</th>
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</thead>
<tbody>
<tr>
<td>WP lead: TU Clausthal / TU Graz, BVV</td>
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</tbody>
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**WP contents:**
- development of a test concept
- preliminary tests for pre-cracking and measurement technology
- preliminary component tests
- substantiation of the concept by comparison of local stresses
- definition of test load spectra
- definition of test specification

### WP2 1:1 component tests

<table>
<thead>
<tr>
<th>Duration: 10/2013 – 09/2016</th>
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</thead>
<tbody>
<tr>
<td>WP lead: TU Clausthal / TU Graz, Alstom</td>
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**WP contents:**
- definition and procurement of 1:1 test axles
- 1:1 component tests (35 pcs.) at TU Graz
WP3 Materials characterization

Duration: 10/2013 – 06/2016

WP lead: MCL, Siemens

WP contents:

• data base of current knowledge

• complementary experiments on laboratory specimens for:
  - constraint
  - batch influence
  - crack closure effects
  - load sequence effects

• deterministic modelling

WP contents:

• deterministic modelling

• separation of influence factors for transferability

• ~160 laboratory specimens
  • 35 1:3 specimens
  • 35 1:1 specimens
Work packages

WP4 Crack growth computations

Duration: 10/2013 – 06/2016

WP lead:
MCL, Alstom

WP contents:

- deduction of a generic crack shape and corresponding analytical SIF expression
- software implementation (INARA and ERWIN)
- FE simulation of test specimens
- simulation of 1:1 components (test rig / real operating conditions)
- probabilistic modelling
- determination of main influence parameters on local stresses etc.

Partial safety factors for:
- stress
- initial crack size
- material parameters
Work packages

WP6 Load spectra

Duration: 10/2013 – 10/2016

WP lead: ViF, Stadler

WP contents:

• extrapolation to load maxima
• investigation of load sequences
• derivation of load spectra for crack growth experiments
• investigation of the influence of the load discretization on crack growth predictions
• specification for the determination of load spectra for residual life assessment

load sequence effects

extraction of load blocks
Work packages

WP7 Safety concept

Duration: 07/2016 – 10/2017

WP lead: MCL, Siemens

WP contents:
• finalization and implementation of assessment method
• verification
• analysis and assessment of project results
• preparation of standardization efforts

consolidation of WP results

material loads fracture mech.

validated computational method for determining crack growth rate and inspection intervals
Conclusion

"Industry and science collaborate in the development of a method for determining inspection intervals for railway axles"

Slide 19

Load sequence effects versus crack depth and load spectrum.

1:1 components: impossible, possible, planned.

Standard specimen: straight crack front, M(T), SE(T), SE(B).

Cylindrical specimen: semi-elliptical crack front, plane/rotating bending.

Geometry, loading type.

Residual life: L, interval n, n+1, n+2, a_{crit}, a_0, POD.