UC 13

13th Users Conference on BiAxial Fatigue Testing
November 08th, 2017

Fraunhofer LBF

Dipl. Ing. Ivo Krause
Fraunhofer-Institut für Betriebsfestigkeit und Systemzuverlässigkeit LBF
www.lbf.fraunhofer.de
AGENDA

BRK Updates

- BRK Group members
- Review on “new” topics of 2015
- Interesting projects
  - EU-LIVE
  - CARIM
  - Cooperation with KATECH
- Update on BiAx Technology:
  - I: Design spectrum
  - II: Kind of test facility
  - III: Wheel influences to hub
- Differences in EUWA and LBF standard load program for commercial vehicles
- LBF approval strategy
- Update crack detection on ZWARP machine shaft
- Vibration control avoiding loss of specimen
- New LBF flat base roll rig
- New pre-loading facility
- www.zwarp.de news
- Update by Ömer Cetin
Group: Evaluation wheel related components (BRK)
Team 2017

Project manager
- S. Allouch
- M. Breitenberger (deputy group manager)
- Ö. Cetin
- N. Elmoussaoui
- M. Keilbach

Assistance
- D. Lotz
- B. Tryjanowski

Lab team
- T. Glenz (team manager)
- U. Grupp
- B. Peter
- M. Petri
- H. Ramge (retired)
- P. Tempel

Design, purchasing
- P. Sälzer

Group manager
- Ivo Krause
Review on “new” topics UC 12

Update

- Thin film sensor systems
- Cooperation with Fraunhofer Institute for Surface Engineering and Thin Films, IST (Braunschweig)
- Washer system for pre-clamping force measurement of wheel bolts/nuts
- Contact pattern measurement of wheel-hub contact area
- R&D projects with industry partners
- Tire pressure monitoring system for a non-stop online detection of air pressure loss during test rig operation
  - Cooperation with Fraunhofer Institute for Microelectronic Circuits and Systems, IMS (Duisburg)
  - Light weight sensor (passive/active)
  - Test rig controller integration by can open bus system
- EU research projects
  - EU-LIVE: Efficient Urban Light Vehicles, 2-3-4 wheelers (http://eu-live.eu)
  - CARIM: Commercialization of a full carbon wheel manufactured with an automated high-volume process for the automotive market

After initial cooperation it has to be recognized that the expected information of local stresses at the contact pattern can’t be given by these sensors.

Topic on hold

Update on next slides
Interesting projects
Current update

- EU-LIVE
  - Efficient Urban Light Vehicles (EU-LIVE)
  - European R&D project funded by HORIZON 2020
  - Project duration: 06/2015 – 05/2018
  - Main goal: EU-LIVE will provide a solution covering a wide range of L-category vehicles i.e. a comprehensive platform for the next generation of electrified, cost- and energy-efficient light urban vehicles. It will enable economies of scale by providing modular powertrains as well as bodies and an integrated co-simulation platform.
  - Project partners: Virtual Vehicle (Austria), PSA Group (France), Peugeot Scooters (France), Continental Automotive GmbH (Germany), Samsung SDI (Austria), Fraunhofer LBF (Germany), Mondragon University (Spain), fka (Germany), spirit design (Austria), IFP Energy Nouvelles (France), Brembo (Italy), Elaphe (Slovenia)
  - LBF contribution: Development of light and reliable wheels regarding additional cooling effects at low velocity for usage with an electric in-wheel motor; light weight technologies for chassis components
  - Project web site: www.eu-live.eu

Interim design steps
Interesting projects

Current update

- CARIM
  - Carbon Rim Project (CARIM)
  - European R&D project funded by HORIZON 2020 (Fast Trac to Innovation)
  - Project duration: 01/2016 – 12/2017
  - Main goal: To develop a carbon composite wheel that is lighter than an aluminium-forged wheel and that can be produced with automated preforming and infusion technology (High Pressure Resin Transfer Molding HP-RTM) according to OEM specifications.
  - Project partners: Fraunhofer ITC (Germany), Alpex (Austria), Riba (Italy), University of Bologna (Italy), TÜV Süd (Germany), Fraunhofer LBF (Germany)
  - LBF contribution: Performing biaxial wheel fatigue tests according current standard
  - Project web site: www.carimproject.eu
Interesting projects
Current update

- Load file development for KATECH based on LBF strategy
  - Customer funded research project
  - Project duration: 03/2015 – 07/2017
  - Main goal: Development of two load programs based on road and race track input,
  - LBF contribution:
    - Supply and sensor instrumentation of test vehicle
    - Road Load Data Acquisition (RLDA) in Germany on public roads and race track
    - Comparison between RLDA and LBF standard design spectrum and test spectrum
    - Load program developments based on RLDA’s
    - Biaxial wheel tests with all load programs at LBF
    - Several seminars at LBF and customer site
    - Successful project result defense at project committee in Korea
  - Project partners:
    - Korea Automotive Technology Institute KATECH, Dr. Jung Sungpil, Dr. Sim Kyungseok, Dr. Min Yoonsang
    - LBF: S. Allouch, J. Käsgen, M. Jackel, I. Krause
LBF BiAx Technology

Current update I

- Design spectrum verification
  - (Stress) Design spectrum defined by
    - max. loads resp. stresses,
    - number of cycles at max. stress level,
    - shape of distribution,
    - number of total cycles,
    - portion of partial spectra

- A side study at Katech project was done to evaluate portion of partial spectra and shape of partial spectra (straight driving and cornering)
  - As a first result it can be shown that the LBF assumptions of
    - 96% straight driving, linear distributed (n=1)
    - 4% cornering, Gaussian distributed (n=2)
  Can be used as a good assumption when no other information is available
  -> More optimization potential is given by more accurate definition

Further details of these analysis will be presented/published.
LBF BiAx Technology
Current update II

- Kind of test facility for passenger car application
  - Inner drum “ZWARP”
  - Outer drum wheel test facilities (multiaxial)
- What is the right machine, type A, B, C or other?
- Advantages vs. disadvantages
- What is of interest?
  - To generate “good” results by realistic loading
  - Stable and reliable test run
  - Efficient machine performance
- According to LBF BiAx technology the local stress and damage is the most relevant, hence these are the base for an evaluation of what is better
- Comparative measurements on different machines were and will be performed
- As a first clue it can be stated that load files from one kind of test machine must not used w/o correct transformation to another kind of test machine
- Currently a general equation for this transformation is not available
- Further details of these analysis will be presented/published.
Influence of wheels to local hub stresses/RFS

- 8 t - front axle hub,
- Wheel size 9.00x22.5 OS175
- 3 different manufacturers
  - A, ~30 kg, 10.1 mm
  - B, ~40 kg, 13.7 mm
  - C, ~38 kg, 12.7 mm
- RFS differ up to 10%
- A weight optimized wheel may make a optimized hub critical

![Graph showing RFS values for different manufacturers and wheel disc thicknesses.](image)
Commercial vehicle load program
EUWA vs. LBF standard load file – front axle

- LBF
  - 98 steps
  - Velocity 73/122 km/h
  - Sequence duration: time

- EUWA
  - 98 steps
  - Velocity 73/122 km/h
  - Sequence duration: drum cycles

Comparison
- Differences in sequence 90: straight driving
  - LBF duration 108 s (~900 1/n)
  - EUWA duration 600 1/n (71 s)
- Straight driving vs. 5 load file loops to cover test requirement of 16,000 km
- Effect will be insignificant
LBF approval strategy
Wheel fatigue test process

- Road experiments
- Load library
- Virtual RLD

- Design loads
  - LBF design spectra definition

- Experimental stress analysis
  - "flat track"

- Standardized load program
- Specific load program

- BiAx lab testing

- Numerical stress analysis

- Fatigue life assessment
  - Design

- Fatigue life evaluation
  - Design | Material | Manufacturing
LBF approval strategy
Wheel fatigue test process

Road experiments -> Load library -> Virtual RLD

Design loads
LBF design spectra definition

Experimental stress analysis
"flat track"

Standardized load program

Specific load program

BiAx lab testing

Numerical stress analysis

Fatigue life assessment
Design | Material | Manufacturing

Fatigue life evaluation
Design | Material | Manufacturing
LBF approval strategy
Wheel fatigue test process

Road experiments
Load library
Virtual RLD

Design loads
LBF design spectra definition

Experimental stress analysis
„flat track“

Standardized load program
Specific load program

Numerical stress analysis

Fatigue life assessment
Design

Fatigue life assessment
Design | Material | Manufacturing

Fatigue life evaluation
Design | Material | Manufacturing

Test 1: free of cracks at 100%, structural integrity kept at 150%
Test 2: free of cracks at 100%
Test 3: free of cracks at 100%

Fatigue test process heavy duty application

Tier 1:
Wheel/hub design evaluation

Tier 2:
complete wheel/hub evaluation
LBF BiAx Test machine
Crack detection on main shaft

- Cracked main shaft of LBF test machine N4 in 2013
- Failure analysis showed fatigue failure related to fretting fatigue effects on high loaded bearing seat caused by severe load programs for special applications
- Crack check application to detect such cracks needs to be developed
- An ultra sonic equipment was compiled with customized US-sensors so that a disassembly of the shaft is not necessary
- A calibration facility was designed and manufactured with artificial cracks to adjust the sensor
- Main shaft crack checks of LBF test machines showed no issues
- Main shaft crack checks on customer ZWARP machines can be performed on request, e.g. in combination of comparative measurements
LBF BiAx Test machine
Vibration control avoiding loss of specimen

- Testing of heavy duty applications require to use the original wheel end
- Bearings as part of the wheel end may fail early and cause a total loss of one specimen (up to two weeks test time, ~ 10k€)
- To prevent those losses the knuckle/stub axle is equipped with temperature sensors, if possible close/below the bearing seats -> preparation of knuckle/stub axle necessary
- Vibration control of the bearing can identify at an early stage bearing damages and initiate a stop of the test machine
- Frequency analysis between a damaged and a damage free bearing
- Identification of normal and not normal vibration as shut down criteria
- Implementation to machine controller, definition of interfaces for communication
- Definition of shut down criteria by experience

Reference:
Schlecht, B: Maschinenelemente 2, Getriebe - Verzahnungen - Lagerungen, Pearson Studium, Auflage 2, November 2009

LBF flat track roll rig – heavy duty application –
Installation of new facility

- LBF flat base roll rig is an important tool for design spectra definition
- Current flat base roll rig is in service since decades (~40 y.)
- Originally designed for passenger car application but used for heavy duty application as well
- New measurement concept of 4 load cells below bed of rolls is integrated
- The new machine was installed at LBF lab in 2016
- In 2017 we started with installation of new controller (MTS) and a new GUI needs to be developed for actual work flow, comparative measurements needs to be performed
- Technical data of heavy duty flat base roll rig
  - Max. vertical load: 250 kN (can be increased if necessary)
  - Bed of rolls: 1.0 x 1.3 m (LxW)
  - Tire speed: up to 20.0 km/h
  - Tire diameter: standard up to 1.6 m, max. 2.0 m
LBF pre-loading facility – passenger car app. – Design and installation of new facility

- According to LBF and OEM spec. a quasi static preloading of the wheel is required
- LBF had to recognize that our facility performed a good job since years/decades but is not up to date
- We designed a new facility with our experience in biax wheel test preparation
  - Full filling current test specifications (loading by 7 mm/s by an accuracy of +/- 2 mm/s)
  - Max. force 30 kN
  - Easy and economic handling
  - Force - time histories can be recorded
  - Design according national machine guide lines (safety)
  - CE – Certification required as permanent lab device
  - Measurement of inner hump deformation manually
  - Measurement and recording of displacement of inner side of inner hump is scheduled
ZWARP technology website www.zwarp.de

News

- Web site to be understood as contact and know-how platform for LBF BiAx technology
- Basic information of technology and services for interested customers available
- FAQ: Initial videos with explanation of terms uploaded right now, to be continued
- Website transferred to new Fraunhofer CI
- A link from your website to us as technology partner is appreciated
- Feedback is welcome
Thank you very much for your attention.

… we will keep your wheels/hubs running

www.zwerp.de
Contact

Fraunhofer Institute for Structural Durability and System Reliability LBF
Group Validation Wheel Related Components
Bartningstrasse 47, 64289 Darmstadt, Germany
Telefon: +49 6151 705-0, Fax: +49 6151 705-214

Ivo Krause
Group manager
Telefon: +49 6151 705-480, Fax: +49 6151 705-214
ivo.krause@lbf.fraunhofer.de,