Automated Crankshaft Durability Analysis at BMW Motorrad.

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Automated Crankshaft Durability Analysis.
Crankshaft design.

Facts
- rpm < 9000 rev/min
- mass > 6 kg
- > 500,000,000 rev. / lifetime possible

The new 2-cylinder boxer crankshaft (R 1200 XX)
Automated Crankshaft Durability Analysis.
Crankshaft design.

R1200GS movie
Automated Crankshaft Durability Analysis.

SIMPACK model.

Rigid Generator on Crankshaft

Flexible Crankshaft
- 40 Eigenmodes + FRMs

Hydrodynamic Bearings
- Impedance method
- 2 rows

Clutch with stiffness characteristic

Primary Drive with Gear Force Element (FE 225)

Rigid Balanceshaft

Rigid Cranktrain (Conrod, Pin, Piston)
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FEA model.

1 – 2 mio. tetraeder elements, depending on mesh degree of fineness.

double-row hydrodynamic bearings

interface nodes are generated by couplings

coarse mesh

fine mesh
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FEA-MBS-FATIGUE Process Chain.

Time Integration

Flexible MBS

ABAQUS

Component mode stresses

FEMFAT Export

*.femfat

Channel mapping

Load data channel #1

Load data channel #2

Load data channel #3...
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FEMFAT.

Internal Woehler-Curve Calculation for each FEA-Node:
S/N-Curve modified by:
- stress gradient
- mean stress influence
- ...

| Channels | Current Channel | 1 | 2 | 3 | 4 | 5 | 6 | 7 | 8 | 9 | 10 | 11 | 12 | 13 | 14 | 15 | 16 | 17 | 18 | 19 | 20 | 21 | 22 | 23 |
| Lbl/Form |                | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 |
|          | Number of OBS | 2 | 2 | 2 | 2 | 2 | 2 | 2 | 2 | 2 | 2 | 2 | 2 | 2 | 2 | 2 | 2 | 2 | 2 | 2 | 2 | 2 | 2 | 2 | 2 |
|          | Form          |   |   |   |   |   |   |   |   |   |   |   |   |   |   |   |   |   |   |   |   |   |   |   |   |
|          | OBS           | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 |
|          |               |   |   |   |   |   |   |   |   |   |   |   |   |   |   |   |   |   |   |   |   |   |   |   |   |
|          |               |   |   |   |   |   |   |   |   |   |   |   |   |   |   |   |   |   |   |   |   |   |   |   |   |
|          |               |   |   |   |   |   |   |   |   |   |   |   |   |   |   |   |   |   |   |   |   |   |   |   |   |
|          |               |   |   |   |   |   |   |   |   |   |   |   |   |   |   |   |   |   |   |   |   |   |   |   |   |

- Equivalent Stresses [N/m²]:
  - 900.0 [N/m²]
  - 60.0 [N/m²]
  - 495.0 [N/m²] (not used for analysis)
  - 7.5 [mm] (not used for analysis)

- Stress Amplitude
- Load Cycles

- Material Data
- Influence Factors
- Internal Woehler-Curve
- Calculation for each FEA-Node:
  - S/N-Curve modified by:
    - stress gradient
    - mean stress influence
    - ...

- Load Pattern (node based)
- Channel Combination
- Load Promotion Factors
- Load Combination
- S/N-Curve modified by:
  - stress gradient
  - mean stress influence
  - ...

- Header Lines
  - Material and Specimen Name
  - Remarks
    - General Data
    - Linear Static Data
    - Multilinear Young's Modulus (no CFD)
    - Cyclic Stabilized Data
    - Stress Data
      - Tension
        - Ultimate Strength
        - Yield Strength
        - Pulsating Endurance Strength
        - Alternating Endurance Strength
        - Thickness of Specimen
      - Compression
        - Ultimate Strength
        - Yield Strength
        - Pulsating Endurance Strength
        - Alternating Endurance Strength
        - Thickness of Specimen
  - Bending
  - Shear

- Samples
  - 1 BSN...

Results:
- min. safety factor
- most critical node
- crank angle of max. stress over rpm range
Automated Crankshaft Durability Analysis.
Script GUI.

General Settings:
- rpm range
- number of revolutions
- output directory

LOADS Settings:
- file references (stress, odb, ff*)
- output directory
- stress export for single nodes
Automated Crankshaft Durability Analysis.

Challenges.

• run SIMPACK and FEMFAT parallel
  → robust process that traps exceptions like missing results for the next rpm step

• do not abort process if license is missing
  → handle exception of temporary missing license (SIMPACK & FEMFAT)

• enable a process start timeout
  → set a timeout for simulation start to run multiple models e.g. whilst a weekend

• no need for manually editing config files or path references
  → avoid manually editing ASCII-Files by using a customized GUI

• no need to place files manually in certain directories
  → automatically handle file transfers (stress, odb, ...) to correct directories by the script
Automated Crankshaft Durability Analysis.
Simulation results.
Automated Crankshaft Durability Analysis.

Simulation results.

Animation

Stress at node xyz - conrod bearing radius

deformation scaling = 50
Automated Crankshaft Durability Analysis. Simulation results.
Automated Crankshaft Durability Analysis.  
Summary / Outlook.

• SIMPACK Scripting was able to make an old PERL Script redundant

• The GUI and the calculations can be carried out from both LINUX or Windows platforms

• Additional data extraction, e.g. the crankshaft angle at maximum load, were added easily to the script

• Expandable system: automated output of bearing loads, interface loads & torques possible

• Huge improvements in LOADS simplify cross-checks, e.g. stress extractions of single nodes

• Additional „features“ in sight: superimposed constant pressure loads, e.g. gear-wheel in press-fit connection, will be available soon?
Thank you very much for your attention.

Final Animation