LMS Durability Technologies

Virtual prototyping solutions for a more efficient and better quality durability engineering process
Fatigue design process

Component/vehicle design

Building prototypes

Field data collection

Data consolidation

Statistical & rainflow analysis of data

CAE models (FEM, MBS)

‘Virtual test track’
Dynamic simulation

Simulation of rig test

Loads data base

Sign-off

Rig test

• Tired of waiting for physical testing?
• Need better design?

Simulate (virtual )durability tests!

More time for analysis & synthesis!

Shorter development time!

ok

not ok
Virtual prototyping for durability — step 1: external loads to internal forces

from given external loads (spindle forces) compute internal forces acting on components

**problem**
- dynamics
- nonlinear elements (spring, damper, etc)
- nonlinear geometry

**solution**
- multi body simulation
- dynamic FEA
Virtual prototyping for durability —
step 2: internal forces to stress tensor history

from given forces acting on the component,
determine time history of the local pseudo stress tensor based on theory of elasticity

• loading frequency **below** lowest natural frequency: quasi static superposition

• loading frequency **above** lowest natural frequency: modal superposition
Virtual prototyping for durability — step 3: stress tensor to damage model

- fatigue damage is initiation and growth of *short* cracks, but different levels of detail are required for different applications

- analysis approaches/models available for:
  - long life (high cycle fatigue): *stress-life*
  - shorter life (low cycle fatigue): *strain-life*
  - seam welds
  - spot welds
Virtual prototyping for durability —
step 3b: strain-life approach

- initiation and growth of small cracks under elastic-plastic deformation
- estimate elastic-plastic `notch´ response from pseudo stresses based on theory of elasticity
- analyse potentially critical (crack) planes simultaneously to find most severe damage
- maximum damage defines critical plane
Virtual prototyping for durability — step 3b: strain-life critical plane approach

\[ D(\alpha=0^\circ) \]

\[ D(\alpha=170^\circ) \]

\[ D = \max[ D(\alpha) ] \]
Virtual prototyping for durability
- data flow -

multi body model

road profile, driving directions

spindle forces

FALANCS

FEM model

FEM solver

stress from unit load cases

time domain

internal forces

multi body simulation

your favorite FEM post processor

pseudo stress result file

road profile, driving directions

spindle forces

FALANCS
BMW 5 series knuckle —
inner side: predicted vs. real crack initiation

average life in test: 2400 repeats
predicted life: 3055 repeats
FALANCS: node elimination technique

Rainflow projector: detect representative elements

Produce shortened load histories
- eliminate non-damaging sections from load history
- if simultaneously non-damaging at all representative elements
- determine amount of damage eliminated

Eliminate non-critical nodes
- analyze remaining nodes with shortened load history
- eliminate nodes with damage < max(D) - eliminated(D)
Load history: original (lab test) and shortest length (node elimination phase 1)

verified by tests

- longitudinal
- lateral
- vertical

short history
original history

force

time

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LMS virtual prototyping for durability: proven by real life application cases
LMS virtual prototyping for durability: benefits

- find critical locations automatically (without guess work) within reasonable time
- true multiaxial analysis (incl. critical planes)
- seam welds & spot welds
- quasi-static & modal superposition
- shell and 3D elements
- interfaces to most FEA environments
- no need to learn new FEA postprocessor
- same GUI and data bases for FEM and non-FEM
- expert and non-expert mode
- internal force based analysis options for quicker design decisions