
VOLVO
VOLVO CONSTRUCTION EQUIPMENT
BUILDING TOMORROW
Corporate presentation 2023

Vibration prediction of Power Electronics

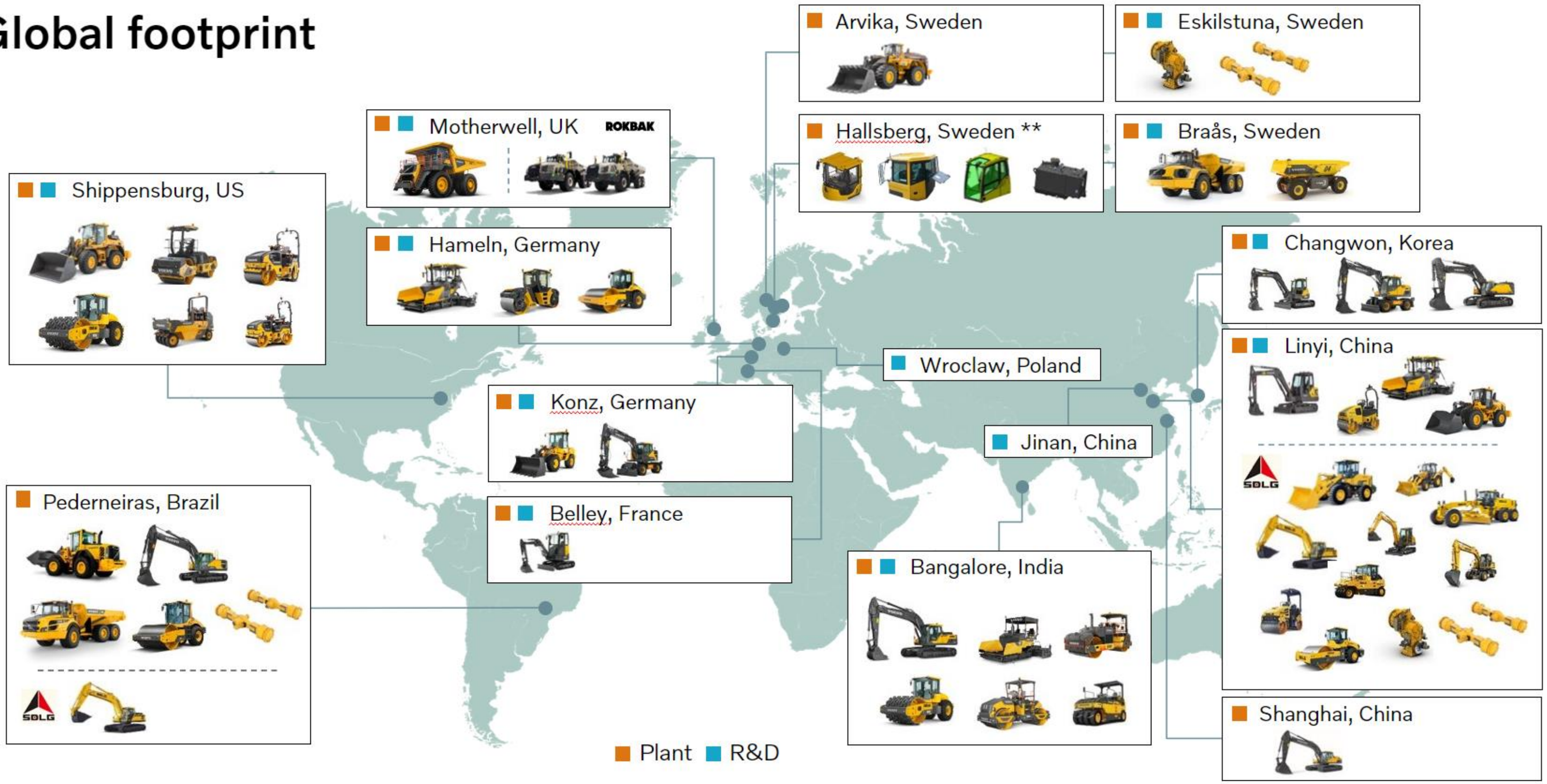
[Battery Box interior]

- Content
  - About Volvo CE
  - Background today's tech topic
  - Why doing vibration predictions
  - Example: Next Gen WLO Battery/Magic box
  - Extras …

VOLVO

Year 2023
Sales 105 BSEK
Profit 16 %
15 000+ employees

Global footprint



Introduction

Vibration prediction on mobile Power Electronics

WLO Battery Box

Scope

- >10 WLO machine sizes
- Classic WLO with very different layout vs eMob WLO
- And autonomous machines …

[… and other heavy power electronic boxes]

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Vibration prediction of mobile Power Electronics

Why do it?

Trend for future products

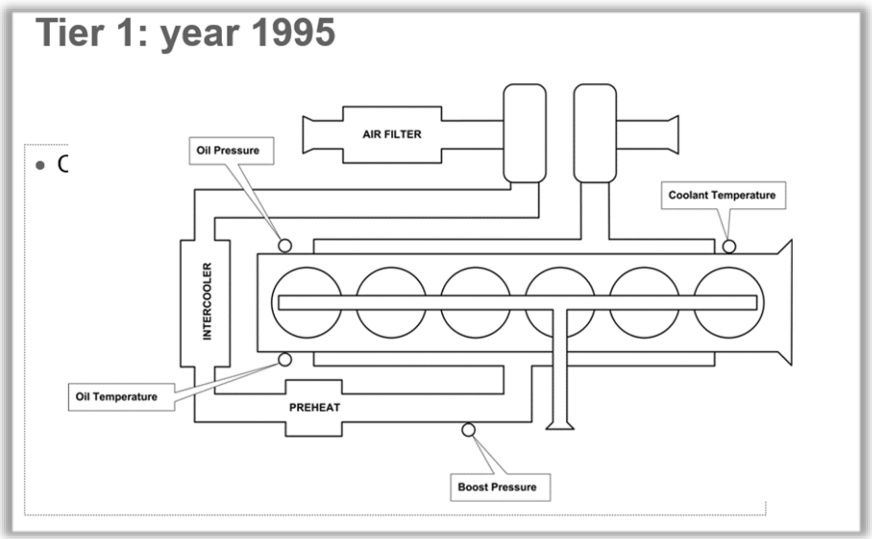
- Lack of hardware [for Test/Meas]
- Lack of previous “carry-over” experience
- Development process with reduced time constraint ie less project phases
- PE too heavy for in-house physical iteration tests on shaker
- PE have new content that must fulfil durability requirements
- PE have new content that must fulfil electrical **safety** requirements
- PE contains both in-house designed structures and purchased electronics ie “grey boxes”
- PE design concept need to be decided up-front pre-series design freeze and purchasing contracts

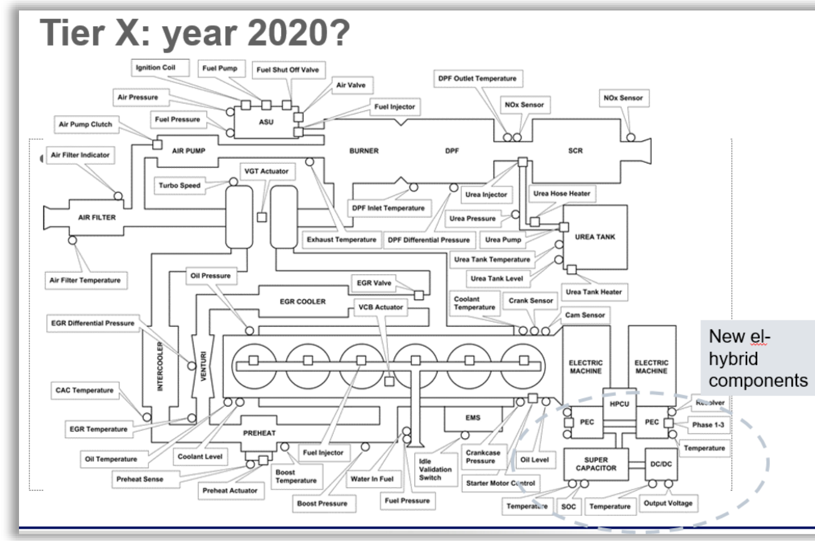
Reformation of virtual approach

- Go virtual to predict vibration response vs Technical Requirements
  - Check TR Pass/Fail **|** Re-Design **|** Tailorize new TR
- Go virtual to predict hot-spots for later investigations
  - Later measurements to get absolute levels and to correlate simulation model

Increase of sensor and electronic controls

An outlook in 2008 got our attention ➔Need for enhanced development test -and simulation methods as for shock & vibration on electronics





The **2020?** was vaguely foreseen in 2008.

Now year 2023 we know. Perhaps even worse …

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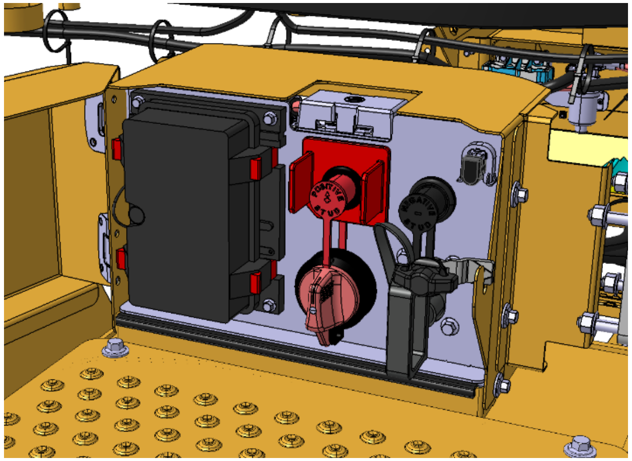
End of Introduction

Example: Vibration prediction of WLO Battery Box interior

Purpose

- Use CAE to predict if purchasing TR's for critical components inside Battery Central Box are okay
- Use CAE to predict hot-spots for further investigations (harness damping)



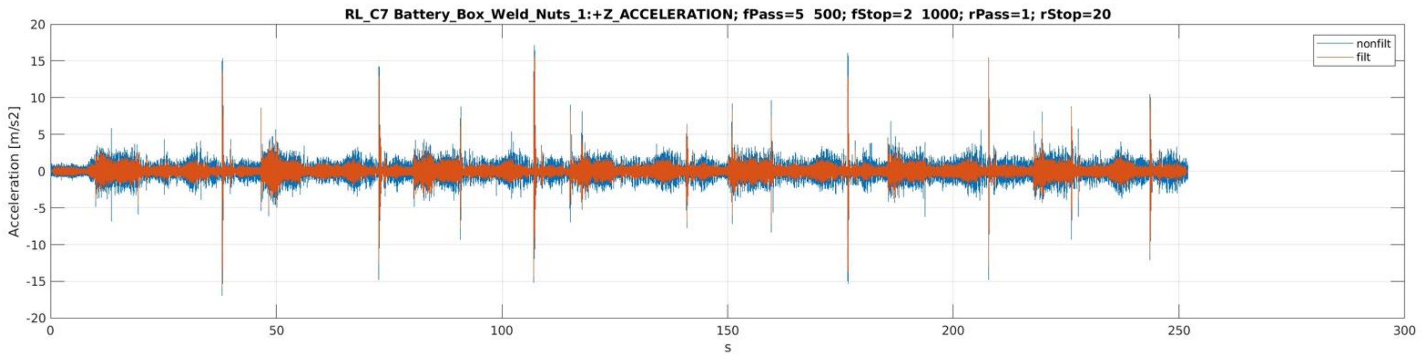
CAD model early 2023

Physical proto model Sept 2023

Technical challenges as for analysis

Typical drive signal at machine main frame (base excitation) in time domain:
- Mixed environment (sine from tire, random offroad, transient from bucket shakeout)
- PSD does not capture transient [Time2PSD2SRS < Time2SRS]
- PSD does not capture multi-point 3D response [1-axial shaker vs 3-axial reality]

Needs prediction in 3D time domain



Typical WLO Rock Loading 252 sec. Measured accelerometer drive signal. Non-filtered vs filtered.

Analysis flowchart

* More in Extras

Signals from previous machine generation

Measured drive signal [3*3 channel signal]

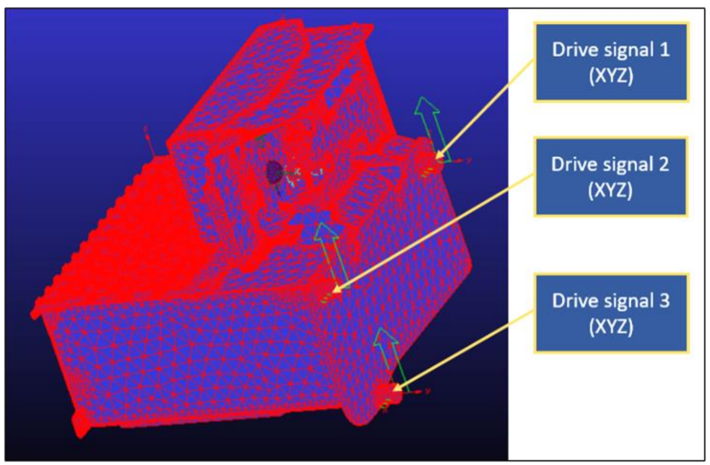
→ MATLAB signal pre-processing* of drive signals to feed Adams model

→ Adams simulation → Results at multiple virtual sensors to find hot-spots

↓ Field SRS and FDS scaled to full life

MRS and FDS from component TR [Lalanne MRS and FDS]

↓ Compare → Pass/Fail



Meshed MNF-file from FE tool

Regime for sampling frequency

- Drive signals, FS>=10*max(f) in SRS and FDS
- Simulation time sampling >= 5*FS drive signal

<u>Verify simulation proper timestep by experiments on short transient event:</u>

- Simulation sampling **<** 5*FS drive signal ➔ lower response than 5*FS
- Simulation sampling **>** 5*FS drive signal ➔ same response as 5*FS

Pass/Fail criteria

Pass

- Field_SRS_envelope <= TR_MRS_envelope
- Field_FDS_sum <= TR_FDS_sum

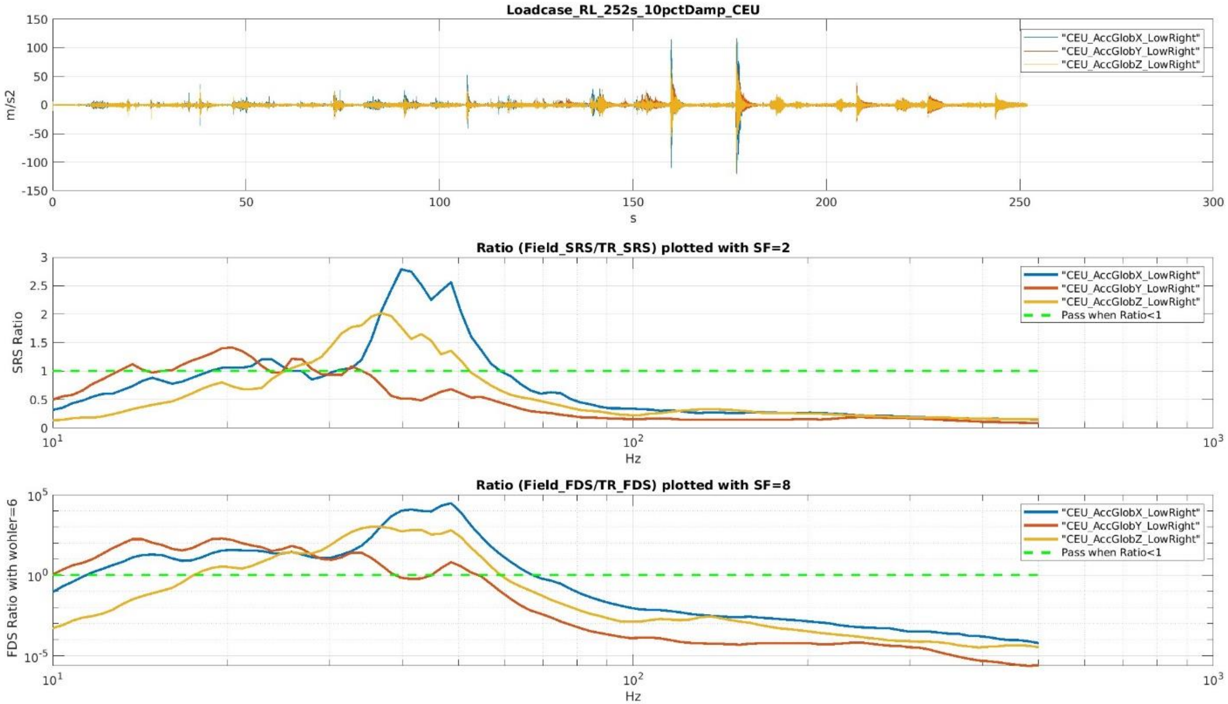
For readability. **Pass** when:

$$\frac{\text{Field\_SRS\_envelope}}{\text{TR\_MRS\_envelope}} <= 1$$

$$\frac{\text{Field\_FDS\_sum}}{\text{TR\_FDS\_sum}} <= 1$$

Example results as Ratio Field/TR

252 seconds 9 channels drive signals gives 252 seconds virtual response in X, Y and Z



Simulated response signal

Simulated response as SRS/SRS_TR

Simulated response as FDS/FDS_TR

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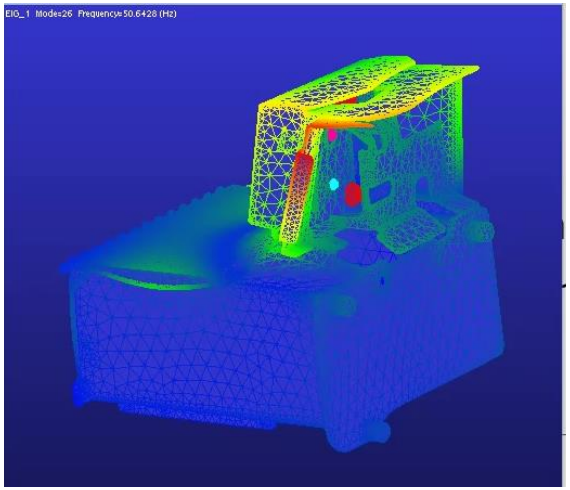
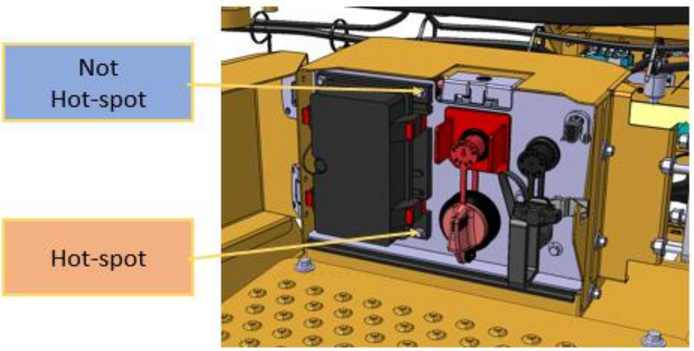
Root cause for TR-overshoot

- Linear mode (not free-free) i.e with boundary conditions etc.
- Virtual re-design based on root cause findings

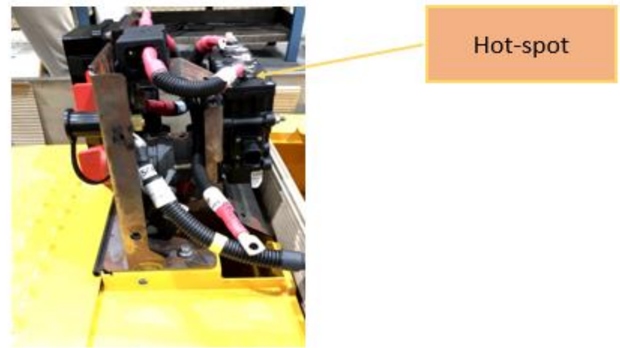


Example mode 51 Hz.mp4

Predicted hot-spots for further investigations and/or re-design



CAD model early 2023



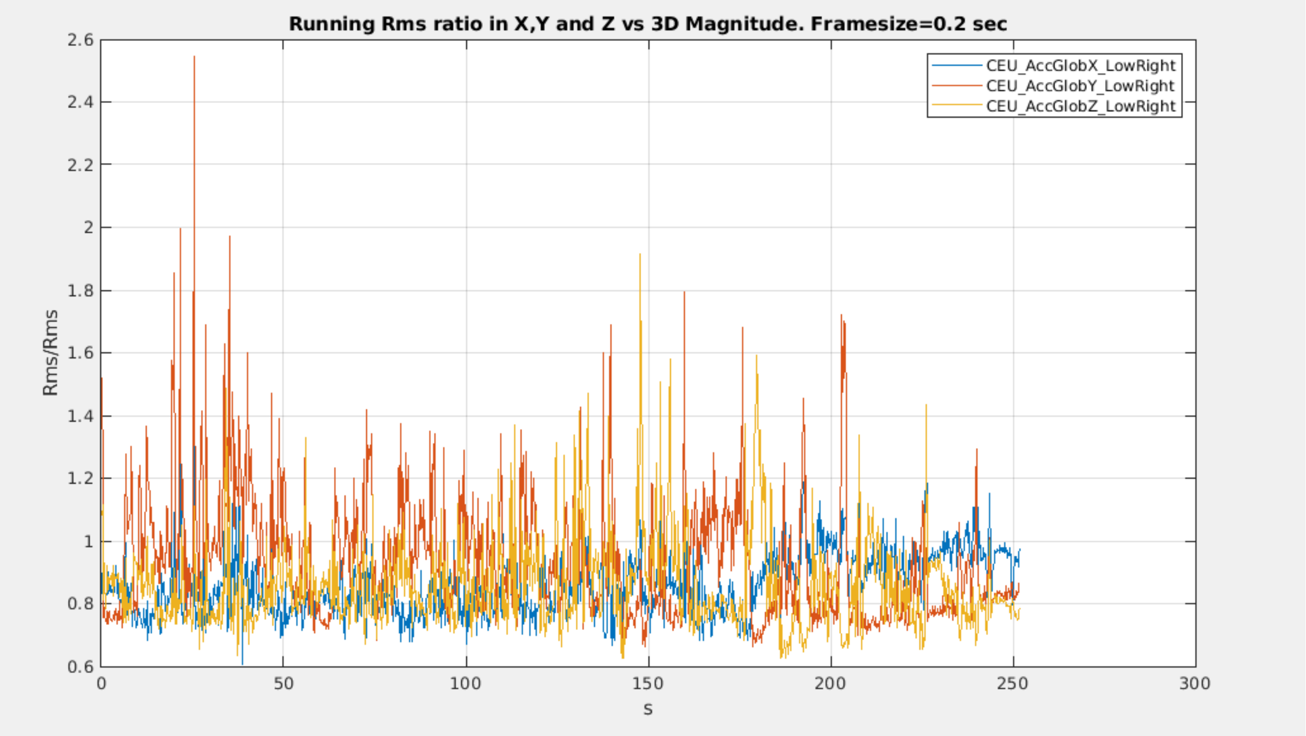
Physical proto model Sept 2023

Further work and re-design:

- Predict effects of changed sheet metal design
- Predict effects of vibration isolators mount for critical black-boxes
- Predict effects from measured dynamics for cable harness
- Consider, propose and predict effects of a tailorized TR

Virtual sensors will detect both hot-spots and Not-hot-spots➔ further focus on hot-spots ➔ smaller measurement scope

About 1-axial vs 3D-axial response



Simulation can predict effects from 1-axial TR vs 3-axial real excitation

Most events are close to ratio 1. Others between 2-3

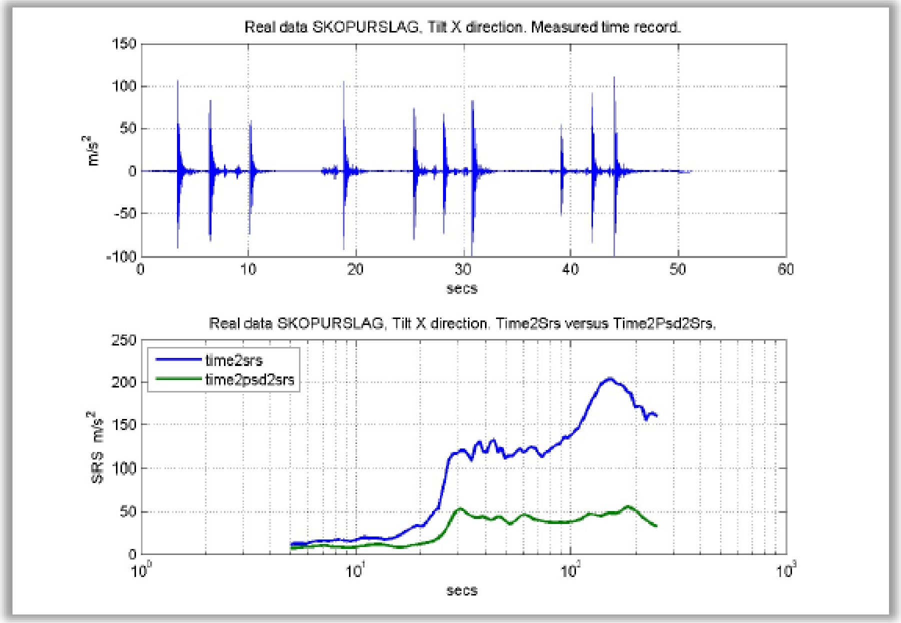
Highlights/Conclusions

- Due to transient events and 3D effects ➔ prediction cannot be done by PSD approach
- Proper prediction of magnitudes requires detailed data on harness-damping and mounting boundary conditions
- Proper prediction of hot-spots (worst XYZ inside box) could be done with simple damping approach
  - Enhanced damping settings to consider cable harness effect
- Finding hot-spots via virtual prediction reduces large scale vibration screening of each Box
- The response at hot-spots reveals issues with TR_1D vs Field_3D

Extras on following pages…

PSD approach requires stationary signal

Time2psd2srs under-estimates
“true” SRS ie Time2SRS



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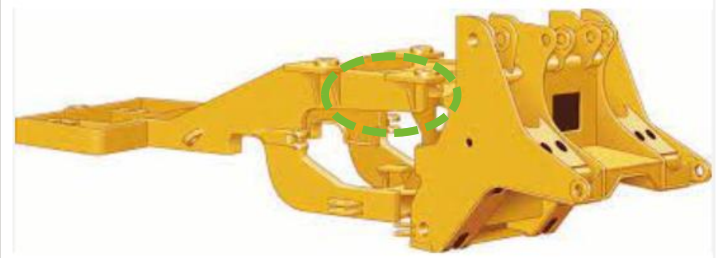
Motivation for frequency domain analysis

Applicability

- Industrial use of frequency domain methods is limited! (or is it?)
  - Engineers prefer deterministic analysis
  - Modern computers are fast (transient FEA more feasible)
  - Loading is not often a true stationary random vibration
- It should be used when you <u>do</u> have true stationary random vibration
- ... but be careful when you have a vibration that is not really stationary random!
  - Do not calculate PSD average!
  - It is possible to derive a PSD (for a stationary random vibration) that is damage equivalent with any type of vibration input, through comparison of <u>Fatigue Damage Spectrum</u> (FDS)

About correlation



Machine frame local stiffness >> Box stiffness

Major simulation uncertainties:

- Boundary conditions BatteryBox2Machine (= ground)
- Damping for BB interior sheet metal structure
- Damping from cable harness
- Quality and preparation of drive-signals
- …

Common questions from project/system owner:

1. "*How about correlation?"*
2. *"Why cant we just measure inside the box*?"

Possible answer from Specialist:

1. *"Better than just trial&error ➔ how much corr. do you need?"*
2. *"We don't have any hardware yet, many variants and need to take concept decisions now"*

Details on computational aspects

- Pre-processing of drive-signal in MATLAB
  - FILTFILT BandPass+DeBiasing ➔ use Acc for TR SRS&FDS and Acc2Displ for Cable Harness displacements
  - FILTFILT is to not distort phase info
- In Adams; SRS up to 500 Hz requires drive-signal at 5000 Hz and internal simulation step at 20 000 Hz
  - Large result sets
  - Simulation time depends on MNF mesh complexity (element type and size)
    - Usually <= 2h on HPC Linux for 250 sec 9 channel drive-signal set
- Post-processing in MATLAB
  - Simulated 250 sec signals from virtual sensors are fed into Lalanne SRS&FDS tool for comparing with TR