SEES conference 14-15 May 2024 in Borås, Sweden.
Conference theme: “**Environmental durability in vehicles”**

Synthesis of shaker test profile from virtual models

Content

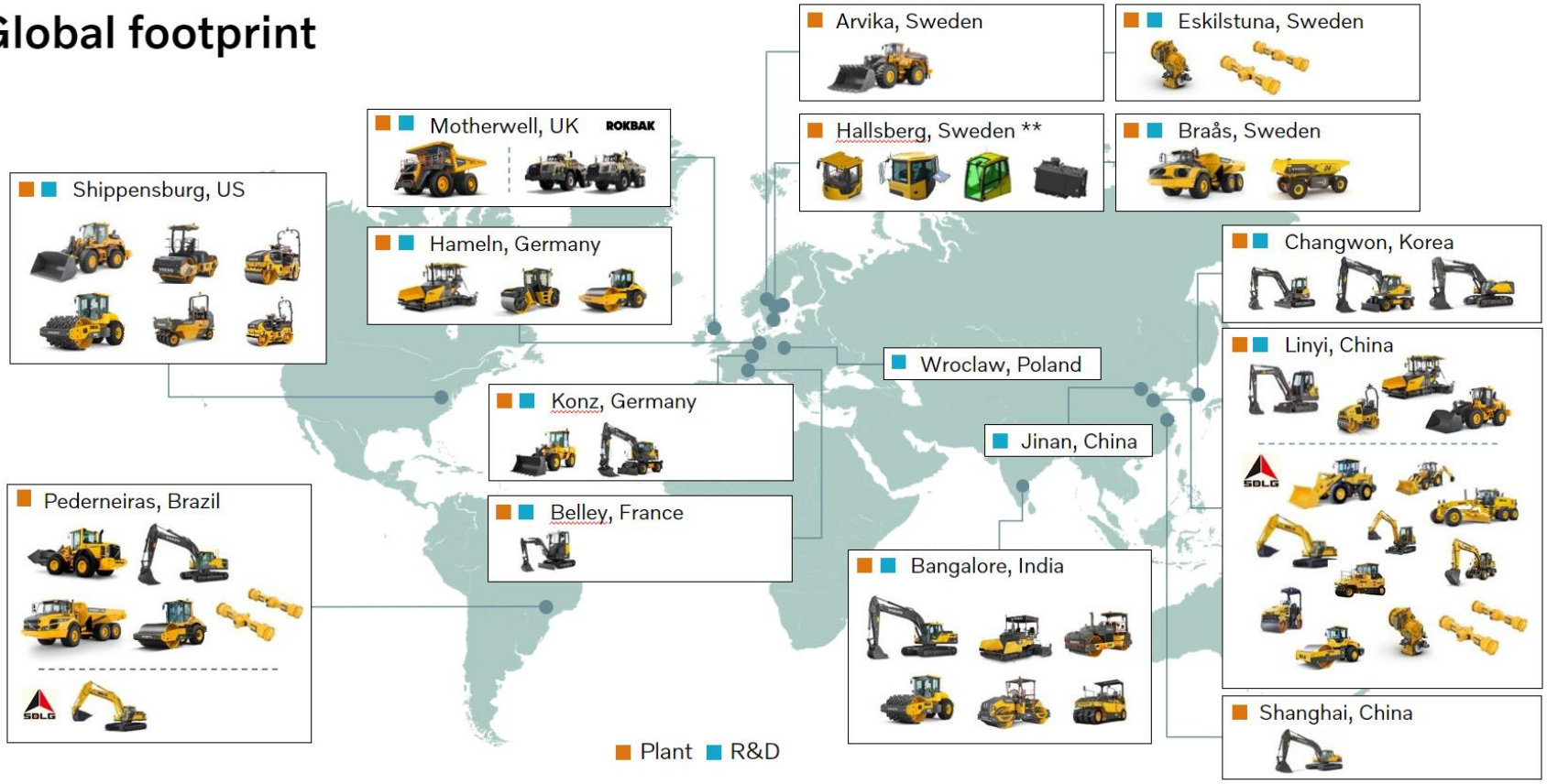
- About Volvo CE and me
- Background/Epilogue from previous session 17th Oct 2023
  - *“Vibration prediction on mobile Power Electronics”*
- Continued work➔ Synthesis of shaker test profile without access to final hardware, nor all load-cases.
- The results and relation to new ISO 19014-3

About Volvo CE

VOLVO

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

Global footprint



David Bellgran, Volvo CE, 2024-05-15

Volvo Construction Equipment

About me

- Location: Eskilstuna
- M.Sc LTU 1989
- Saab Linköping 1990-1996 [JAS 39 A/B]
- BAE Hägglunds 1996-2005 [CV90 Mk 1/2/3, CB90, BVS 10, Munitions]
- Volvo CE 2005- [Senior Sp NVH. All NVH]

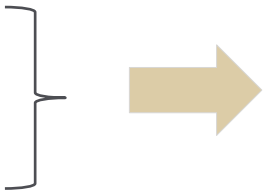
Introduction

Epilogue from previous presentation at SEES Oct 2023:

- The interior built of battery control box on mobile machinery was virtually *predicted* regarding shock & vibrations from real field load-cases.
  - Vibration responses at critical electronic components was predicted vs their Technical Regulation (TR) used in purchasing.
- The main purpose was to find certain hot-spots where problems are expected and/or TR are likely to be exceeded.
- The predictions comprised all major load-cases and was done as time domain simulations to capture typical transient load events in real field applications.
- The outcome of the predictions was used to improve the design before pre-series built and subsequent long term field trials + hardware verification in shaker test.

Continued work after Oct 2023

- The Battery Control Box was improved as for sheet metal design and cable harness routing. Design changes iterated virtually before new hardware built.
- The original plan was to run a classic component shaker verification before pre-serial built and field verification on complete machine.
  - Measurements of critical load-cases in real field application
  - Syntehsis of shaker test profile from measurements
  - Shaker test in-house ESK
  - 24/7 monitoring of electrical status during test
  - Pre –and post test hardware inspections
  - ...
- The real plan:
  - Design delays, still project time plan fixed.
  - Limitation in shaker performance
  - Winter came 3 month earlier in 2023



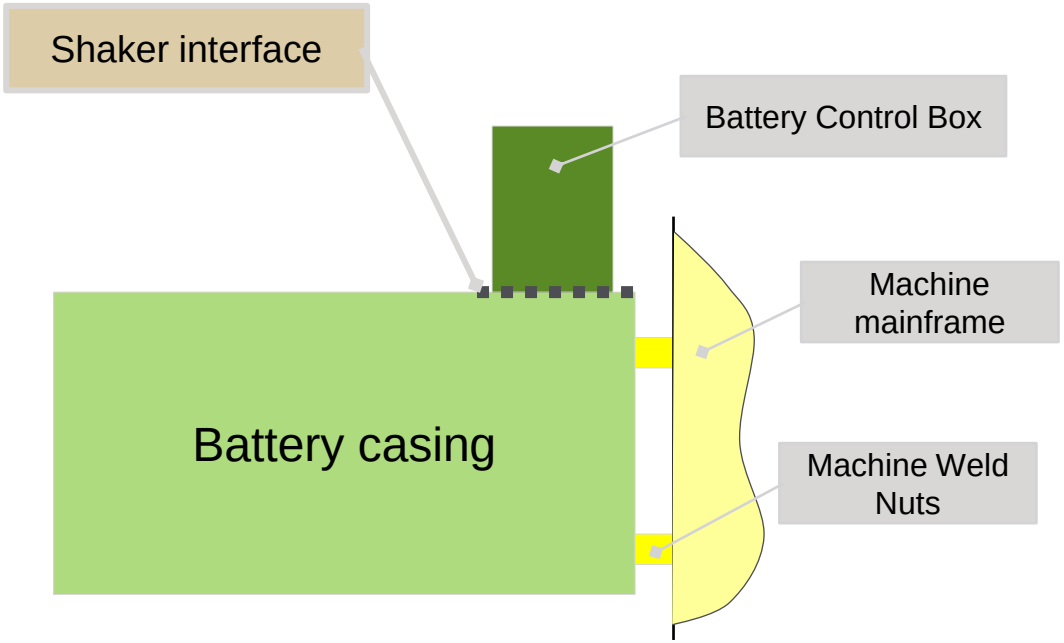
Innovative non-classic approach

The hardware installation

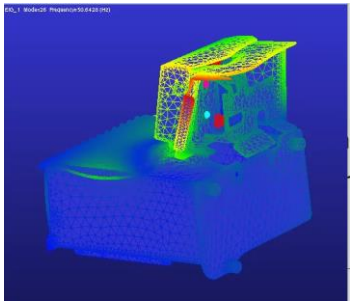
WLO battery installation

A

A



A-A view



Creation of at shaker profile

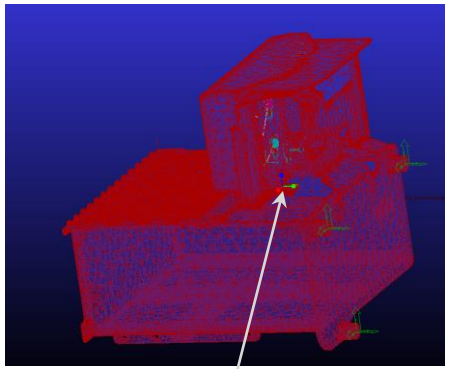
Some complications

1

Due to shaker limitation, verification of the complete battery installation could not be done.

Solution:

Since no changes in battery casing➔ run the shaker test on Battery Control Box only.



Shaker interface

2

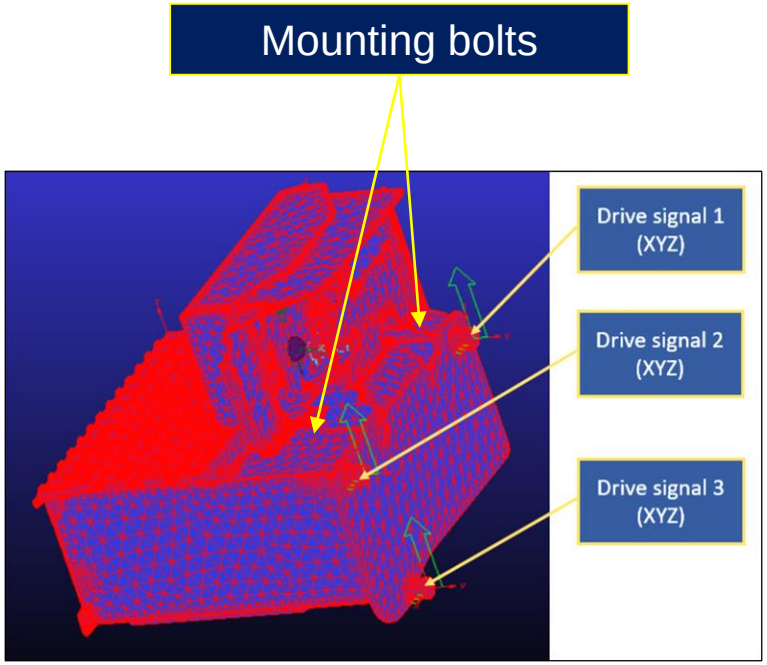
Due to rapid on-set of winter conditions in Dec 2023, one important load case could not be measured for the new design of battery control box.

Design-deadline in Feb 2024.

Solution:

1. Use simulation model and ”summer” DriveSignals at WeldNuts ➔ predict the ”winter” response at shaker interface using simulation model on latest hardware.
2. Correlate simulation model using the other ”winter” load-cases we could measure.

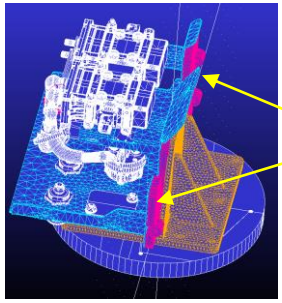
Synthesis of test spectrum



Having some DriveSignals from measurements on latest hardware, and some DiveSignals from older measurements:
How to find the 1-axial excitation profile for the shaker?

Real installation with 3D dynamics

1D shaker



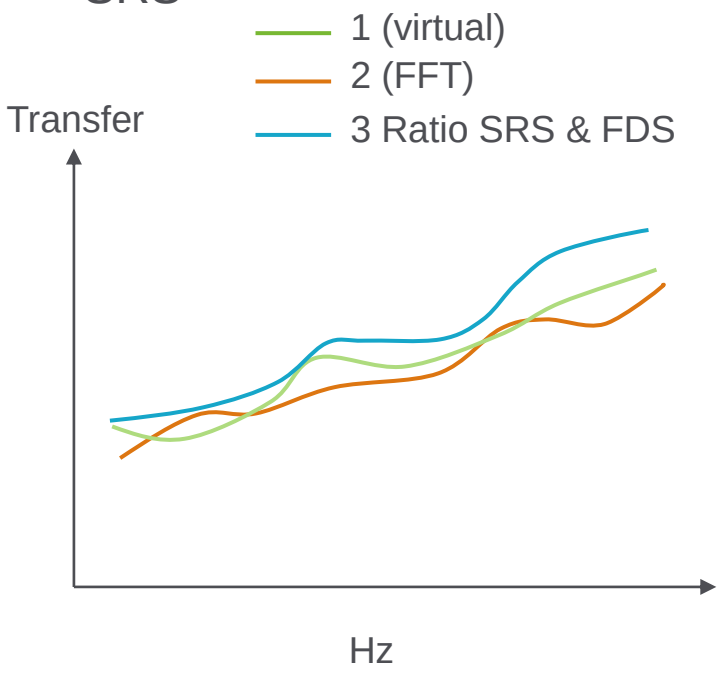
Synthesis of test spectrum.

Possible approaches

Several approaches investigated to get TransferFunction=Response/Input:

1. Virtually prediction using old DriveSignals and new updated simulation model to get **TF**
    1. PROBLEM: Damping Drive2Response
2. Available measurements & FFT: **TF**=ResponseFFT/DriveSignalInputFFT.
    1. PROBLEM: 9ch Input vs 1ch Response + lower TF for transient load-cases.
3. Ratio Response/Input for SRS &FDS: **TF**=ResponseSRS/DriveSignal
    1. Most conservative. Good capturing of transient load-cases.

Typical look when comparing 1,2,3 for SRS

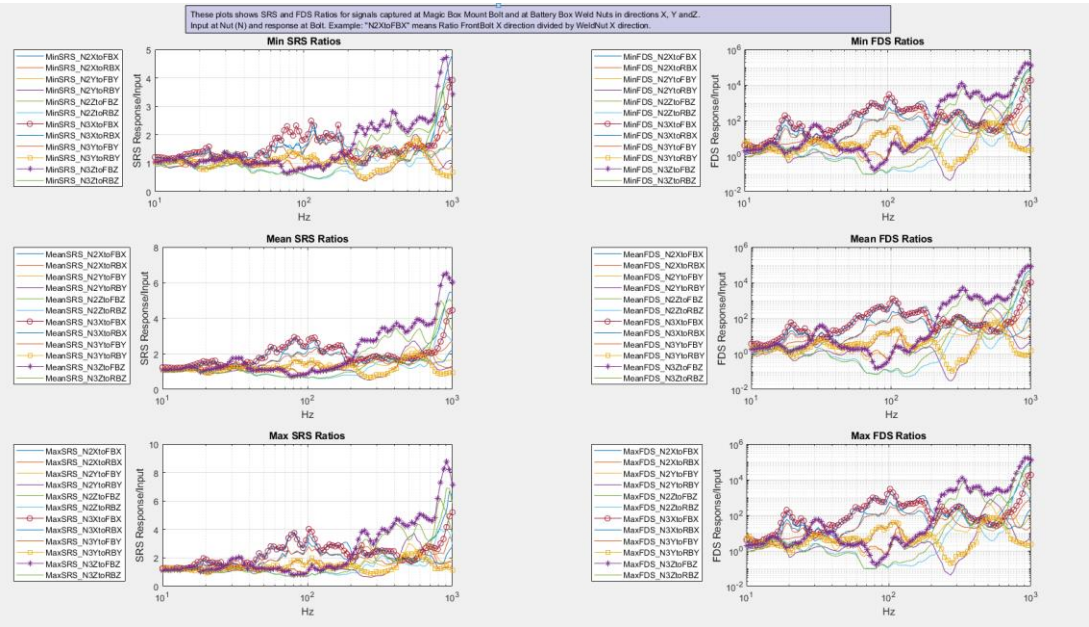


Approach 3 used for test synthesis

Converting SRS&FDS from one location to another

$$Ratio = \frac{ShakerInterface}{WeldNut}$$

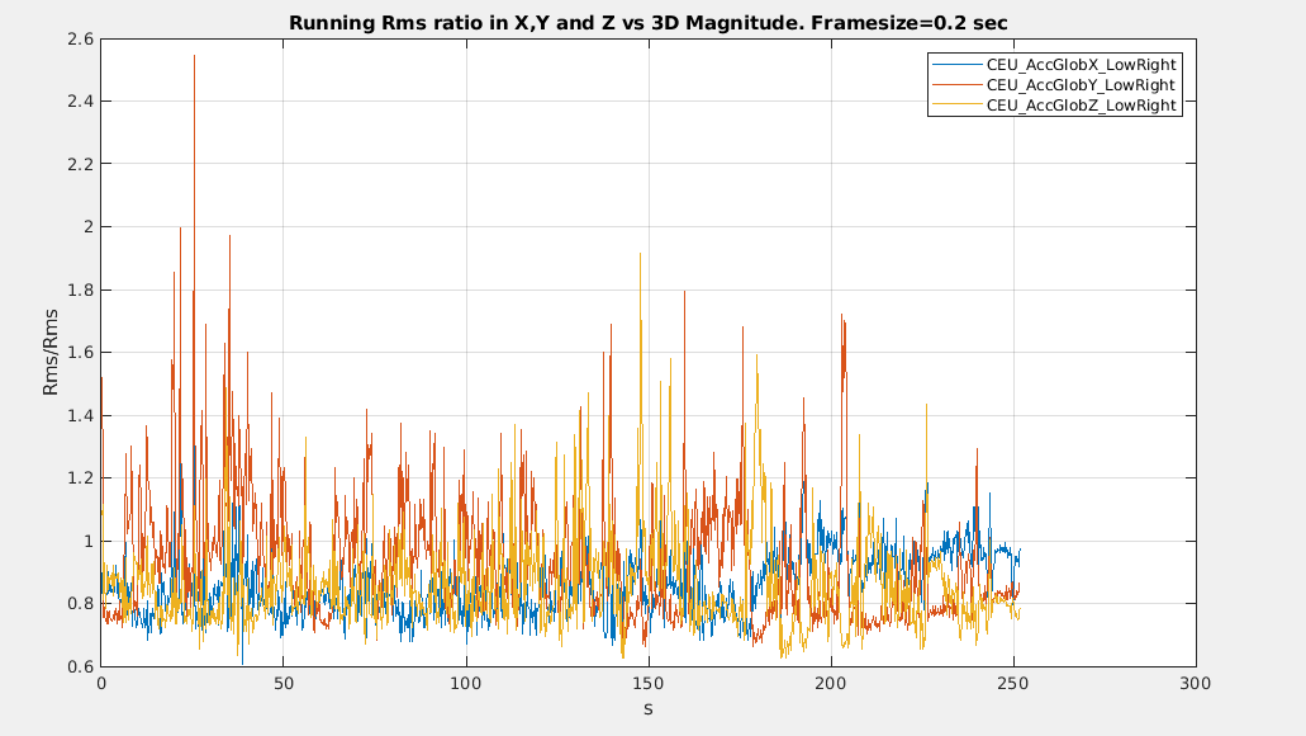
The vector of Ratios for each frequency used to scale SRS and FDS as DriveSignal2ShakerInterface.



- Measured SRS&FDS for load-cases we could measure on new hardware.
- Simulated SRS&FDS for load-cases we could not measure.

The interior of Battery Control Box is safety related➔
Using conservative approach i.e use worst ratios.

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

Extract the most severe event and add a safety factor at its target SRS&FDS

Final synthesis of shaker PSD

Three steps

1. Use the Ratios and Input(WeldNuts) to get Target SRS and FDS at Response(ShakerInterface)

$$SRS_{Target} = SRS_{Ratio} .* SRS_{Input}$$

$$FDS_{Target} = FDS_{Ratio} .* FDS_{Input}$$

2. Use commercial software to find PSD that covers SRS_target and FDS_target + add safety factors + check if separate shock test is needed.
MATLAB: PSD2SRS, PSD2FDS and SHOCKIND

3. Before running full PSD profile, check the shaker dynamics by short time domain simulation of DUT mounted in shaker fixture.

MATLAB: PSDSYNT ➔ time signal for shaker profile

Next step: verification on shaker

Some aspects not fully predictable (cabling, plastic straps etc)

➔ A hardware verification on shaker was decided

➔ Shaker test only including the Battery Control Box

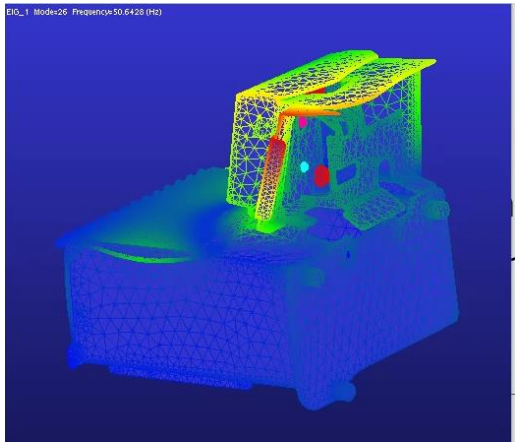
Challenges

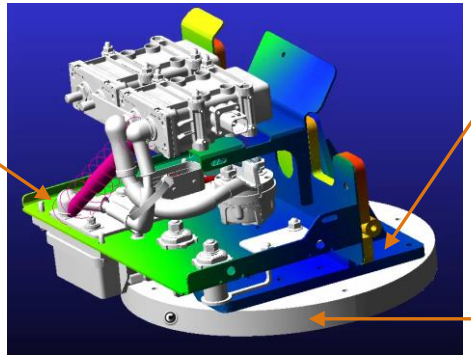
- Conclusions from previous prediction (Oct 2023)
  - Issues with el-box interior sheet metal design was identified and re-worked into test object (DUT)
  - Cabling damping of sheet metal design not fully known
- Shaker payload weight of DUT+fixture close to shaker limits
  - Effect of off-center DUT COG needed investigation
  - Fixture dynamics not to interfere with DUT
- Both ISO 19014-3 and tailorized profile to verified
  - The milder first ...

Reason for physical h/w shaker test ➔ Cable straps

FieldLoad2Lab + Simulation2Lab

1. Local sheet metal modes of control box interior design related to sensitive electronic components were adressed and re-simulated before new h/w built and shaker testing.
2. In the re-simulations, damping from cabling was invoked as non-linear spring dampers, as well as dynamics from shaker fixture. Before running the full shaker profile:
   1. Make sure eigen modes at fixture to be well above critical sheet metal modes.
   2. Check for high displacements at cable harness connections
   3. Check shaker head bearing forces due to DUT off-COG effects
   4. Grab short time signal from shaker profile to demostrate dynamics





Control Box interior response

Amplified PSD for graphic pedagogic effects ...

<u>While having DUT in shaker:</u>

Learn about damping from cables by shaker sine sweep with measurements of response at critical location and frequencies versus input at shaker head.

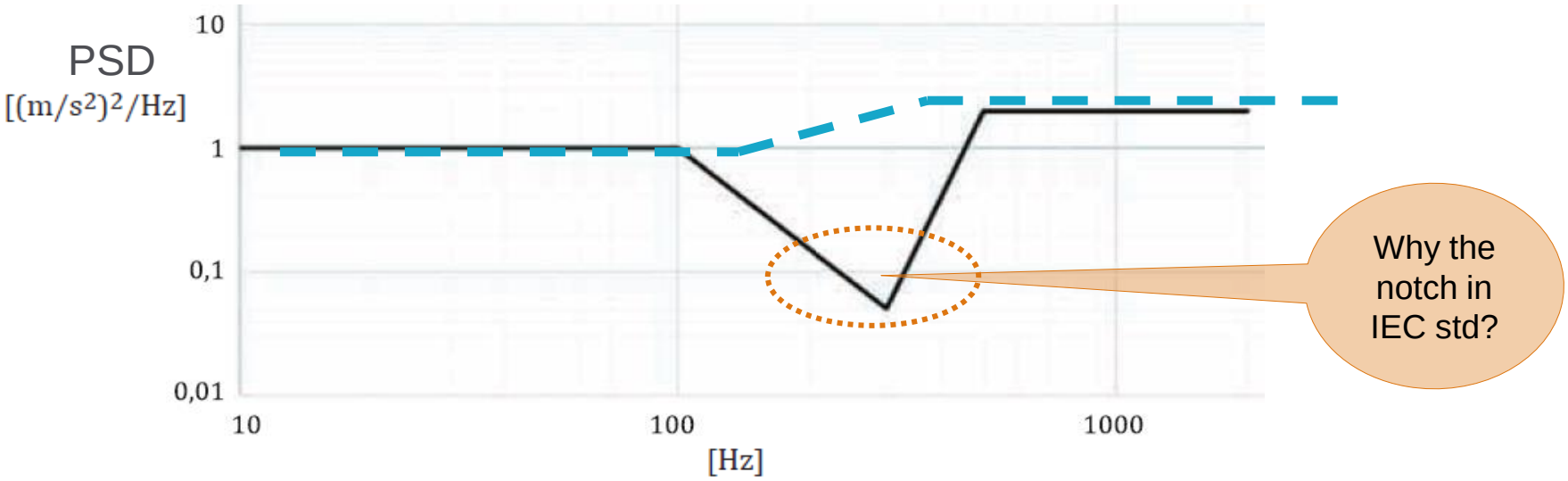
Reason for virtual sim ➔ find weak spots

Final tailorized shaker PSD vs ISO 19014-3

- ISO 19014-3 random vibration test == IEC 60068-2-64:2008. **8 hours.**
- Final tailorized PSD. Duration **>> 8h**.

Both PSD profiles carried out as ”Block-test”

1. 1st test: ISO 19014-3 PSD
2. 2nd test: Tailorized PSD



Final remark

Why going virtual in both design phase and for verification?

- Ideal scenario (the old school):
  - Several hardware iterations before shaker verification
  - Access to complete machine protos/pre-series for field measurements and classic test synthesis from it.
  - Durability/fatigue in focus
  - Favorable project time constraints (... all the time in the world ...)
- Reality scenario
  - Few hardware iterations
  - Few complete machine prototypes and at unclear status
  - Today's future: adding functional safety aspects (eMob, battery's, power-EL)
  - Tight time constraints ... and seasonal weather surprises ☹

Virtual approach finds hot-spot before hardware phase

The future is here now.
Making the Electrification requries more virtual approach!

END

NEXT pages:

Previous SEES presentation Oct 2023

https://www.sees.se/wp-content/uploads/2023/12/SEES_18Oct2023_DavidBellgran.pdf