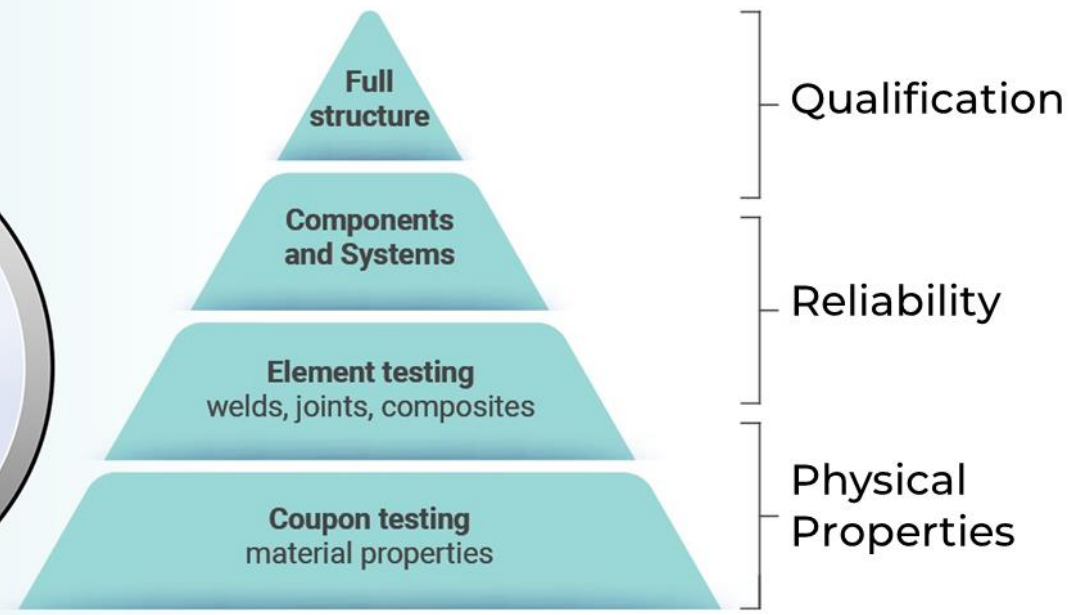
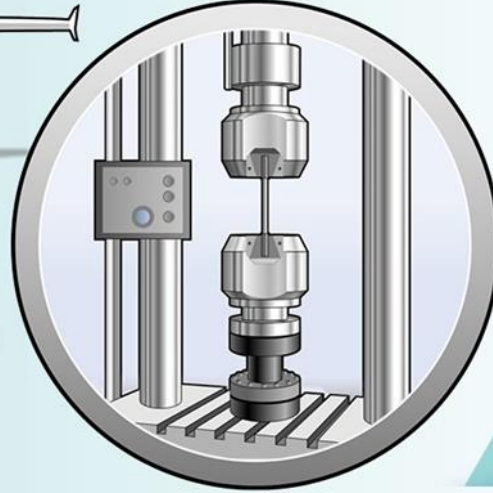
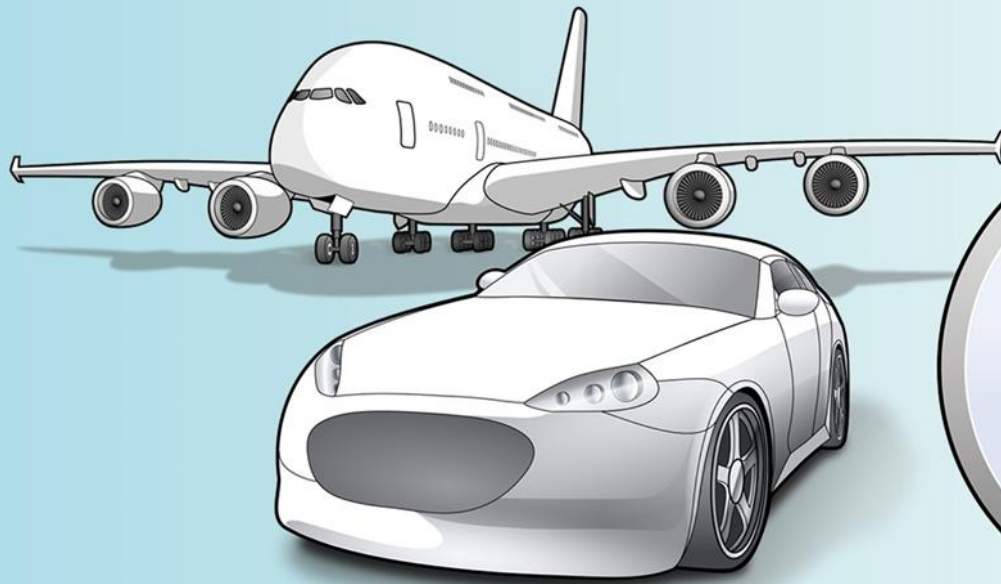
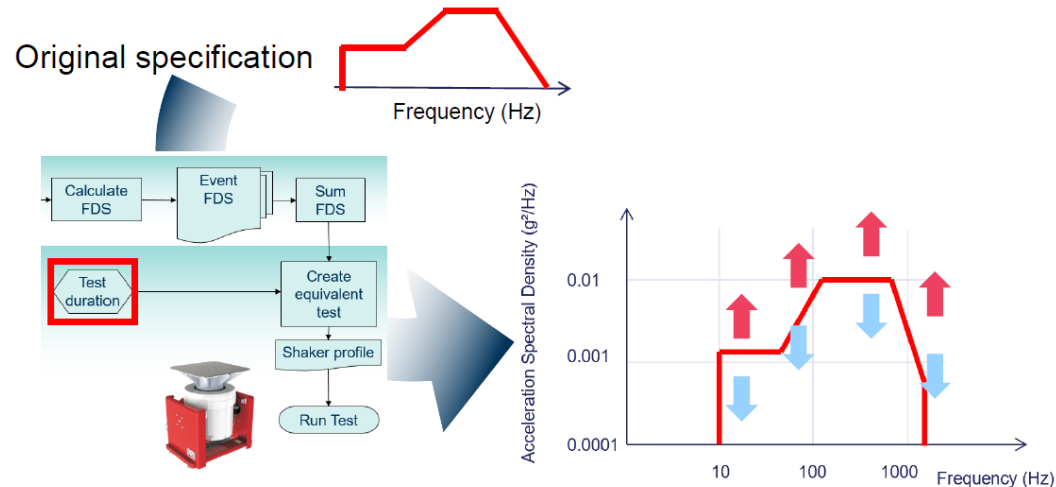




2023 HBK Technology Days

7 November 2023



- Vibration test profile design and test simulation,

Dr. Frédéric Kihm,
Product Manager – Analytics and Signal Processing, HBK

Vibration test profile design and test simulation

Abstract

- This presentation will cover various topics around endurance vibration testing. In the first part of the presentation, we will look specifically at the vibration profile : how to create one from measurements, how to compare several profiles in terms of severity – especially if they are of different natures. We will understand how to scale up the profile to reduce the test duration or to scale it down to increase the test duration.
- In the second part, we will discuss the complementarity of numerical simulation and physical testing, especially in cases where a component is responding dynamically to random excitations. We will insist on how CAE can enrich testing and vice versa. This will include the use of virtual sensors for test- CAE correlation and modal analysis for damping values and mode shapes.

About the presenter, Dr. Frédéric Kihm, Product Manager – Analytics and Signal Processing, HBK

- Frédéric Kihm is Product Manager at HBK, responsible for the signal processing related software products, which includes GlyphWorks, VibeSys and nCodeDS. Frédéric previously worked as an Engineering Consultant for nCode and then HBM, involved with signal processing, durability and vibration analyses in the automotive, aerospace, and defence industries. Frédéric holds a MS in Mechanical Engineering from IFMA University in France and a PhD from the Institute of Sound & Vibration Research (ISVR) in Southampton, UK.

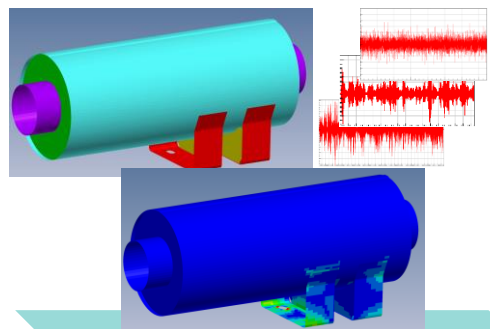
Vibration test profile design and test simulation

Dr. Frederic Kihm
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Today's agenda

1. Introduction
2. Use the Fatigue Damage Spectrum to design, compare and scale shaker vibration profiles
3. How can numerical simulation complement physical testing?
4. How many samples should I test?
5. Conclusions

A journey into design and validation of a reliable product



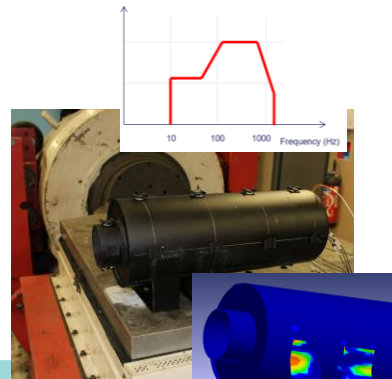
Design

- Geometry, materials, etc.
- For a given life



Prototype

- Validate design
- Increase trust in design and digital twin



Qualification

- Validate for production
- Calculate reliability and design margins

Warranty Analysis

		RETURNS		
SHIPPED		07/19	08/19	09/19
07/19	425	4	6	9
08/19	550	-	4	7
09/19	780	-	-	6

Service

- Predict future warranty returns
- Optimise maintenance strategy
- Provision spare parts

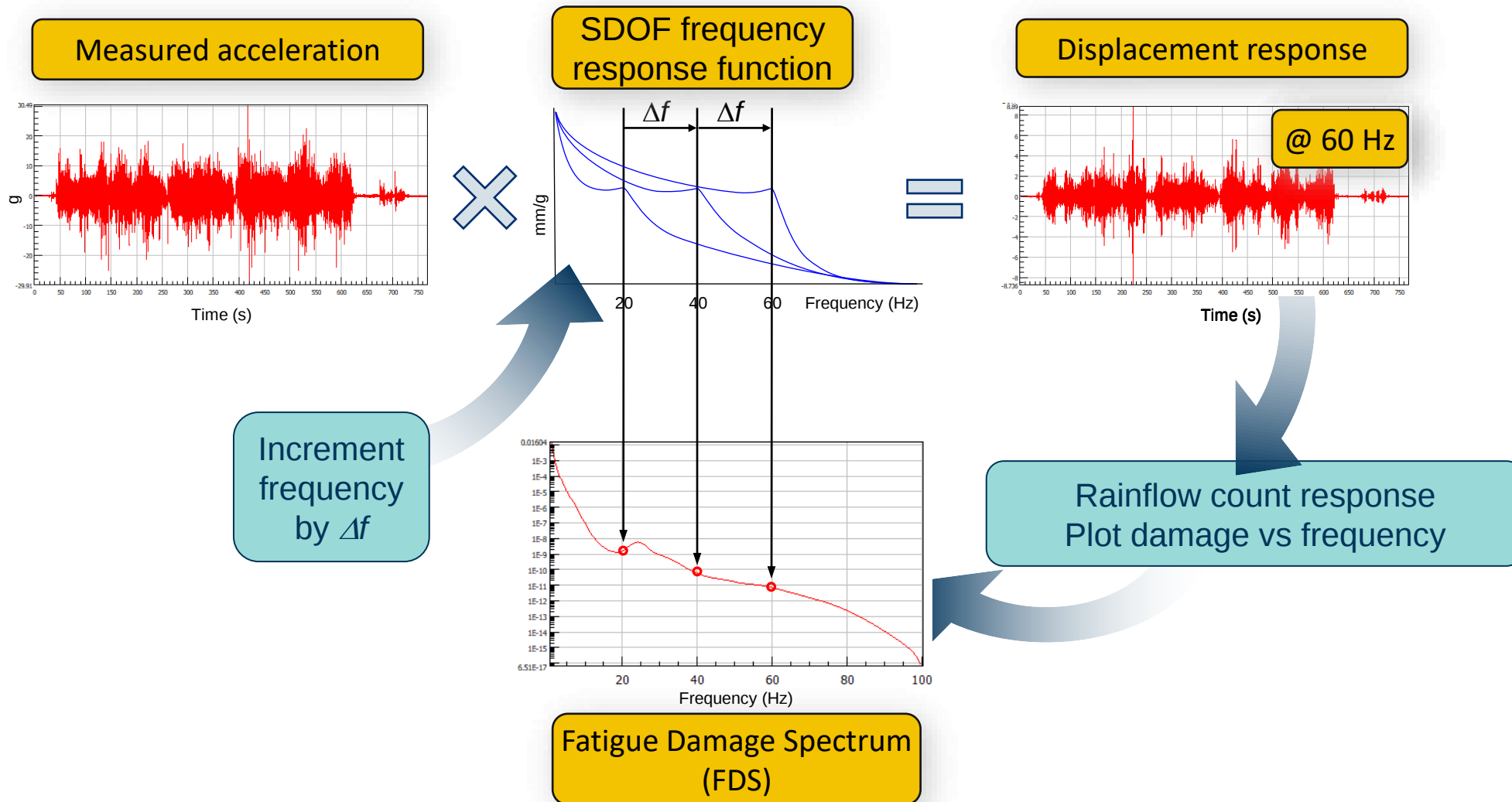
Design and compare shaker profiles

Vibration Profile Design

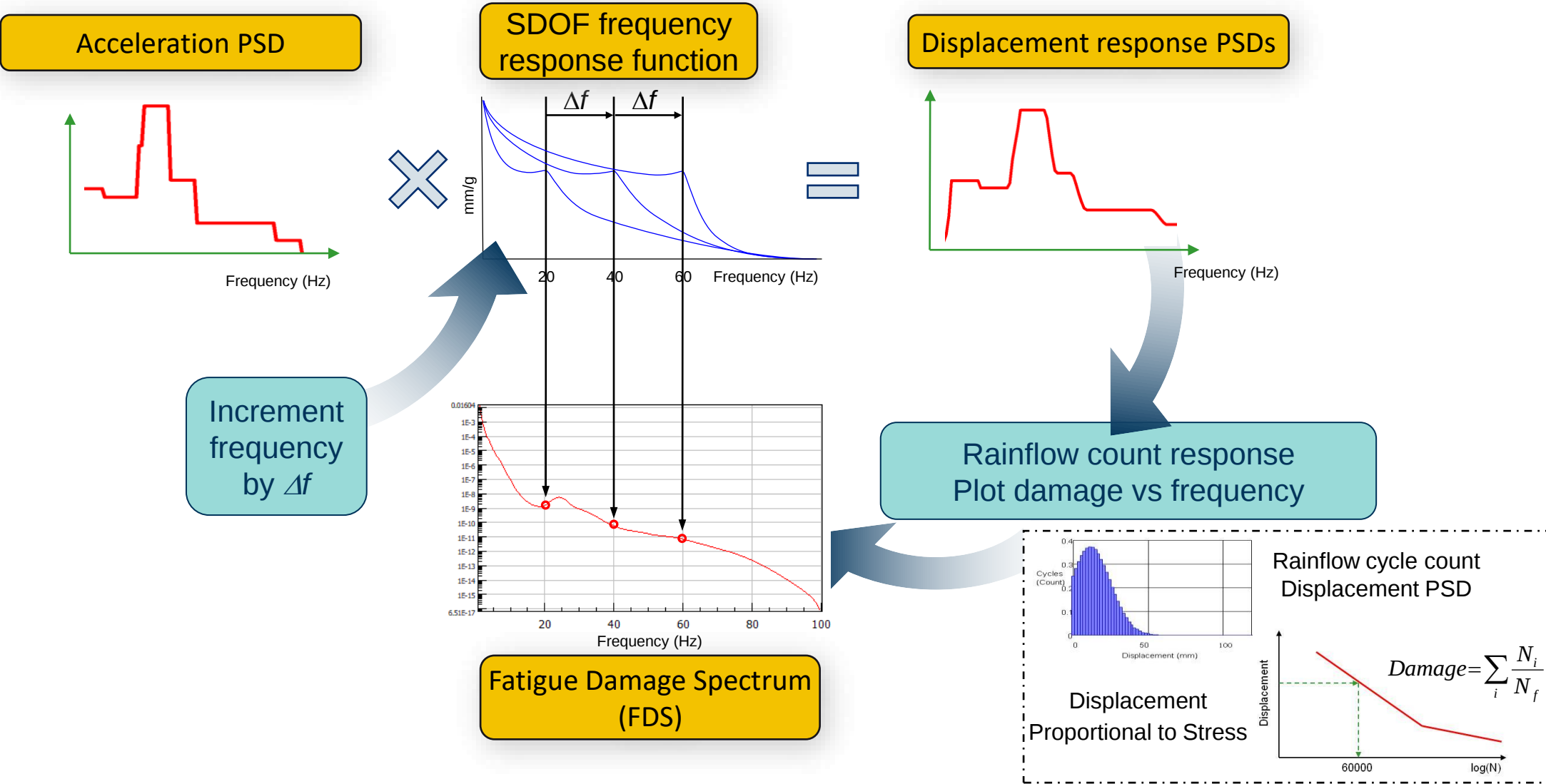
1. Create an equivalent damage shaker profile
2. Compare different shaker test specifications
 - Which is more severe:
 - swept sine
 - PSD random
3. Compare an existing test specification with service vibration data
 - Is the existing shaker test more or less severe than the measured service vibration?



Key tool : the fatigue damage spectrum (FDS)



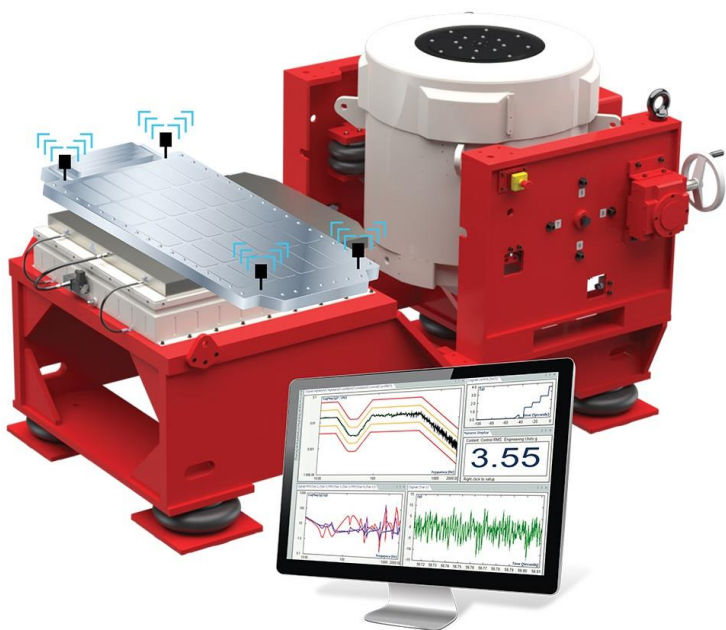
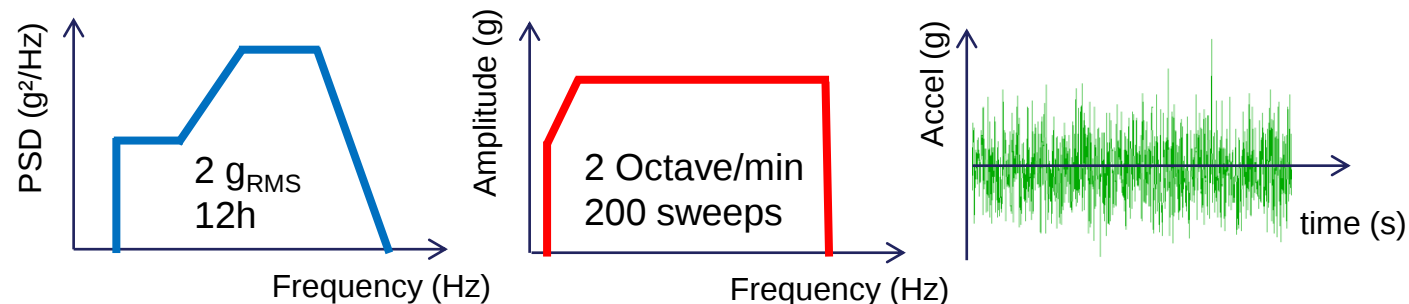
Key tool : the fatigue damage spectrum (FDS)



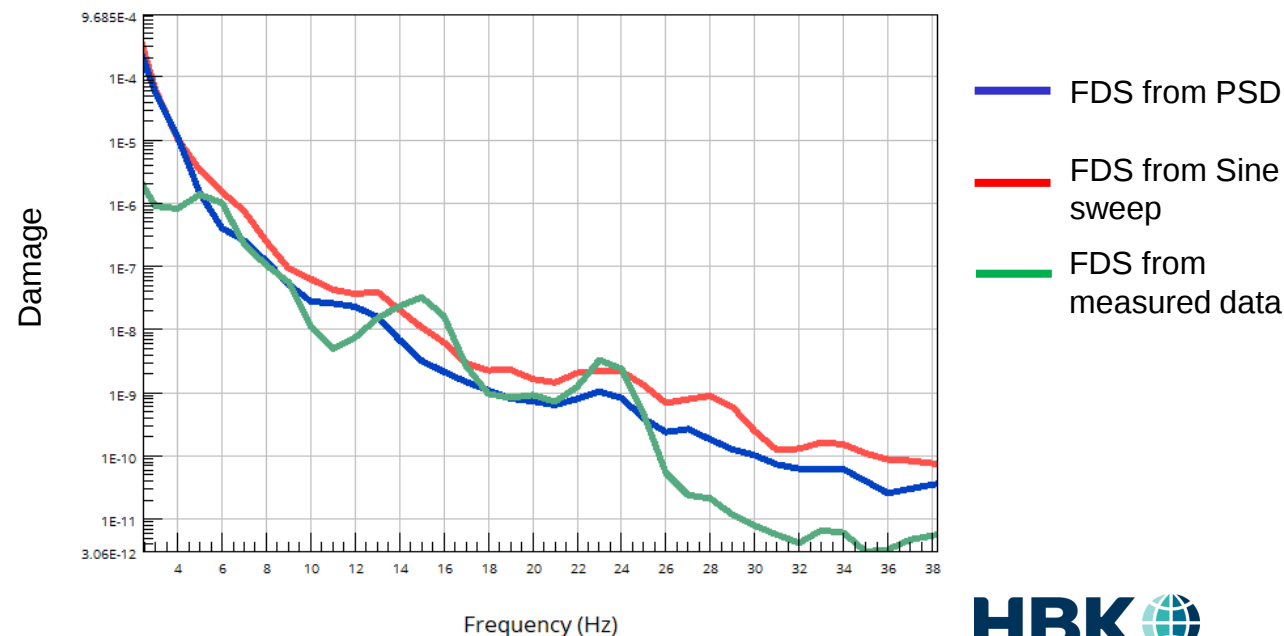
The Fatigue Damage Spectrum to compare shaker profiles

Which is more severe?

- An existing internal test spec?
- New measured vibration?
- The PSD random test from supplier A?
- The sine sweep from supplier B?

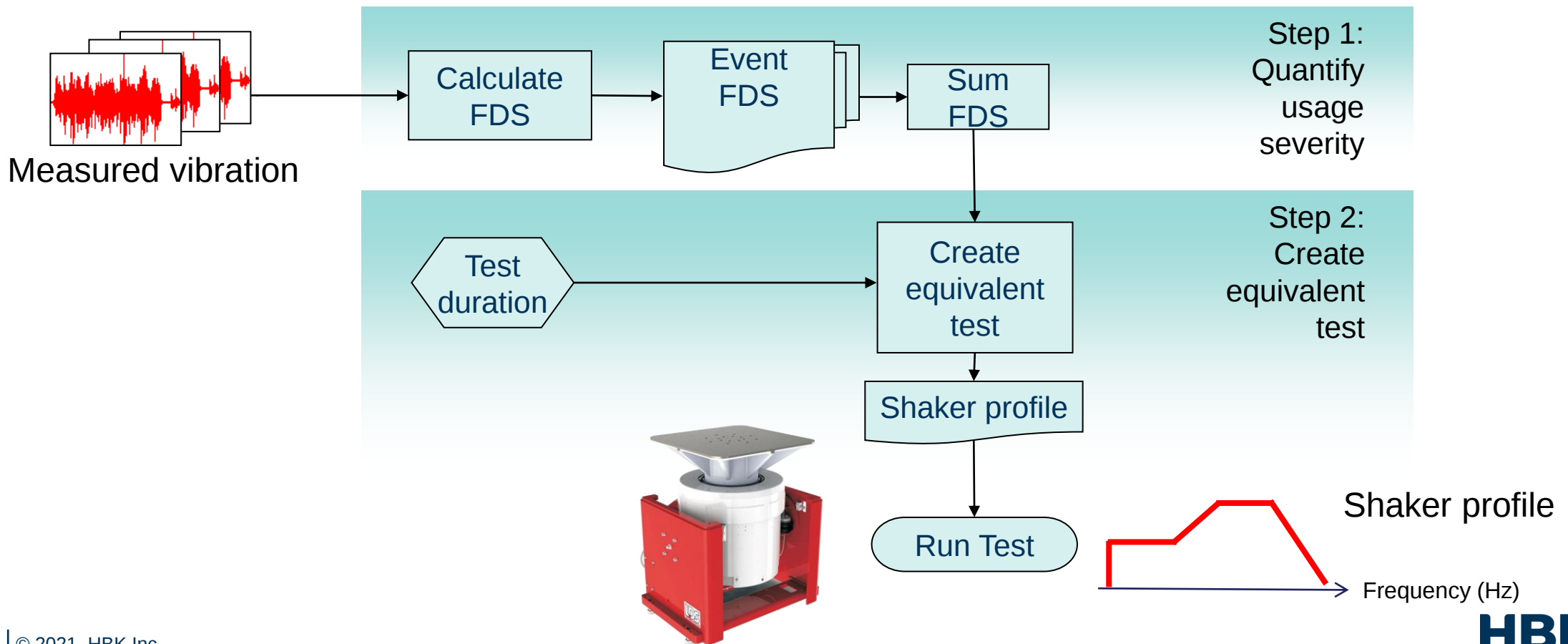


Compare FDS



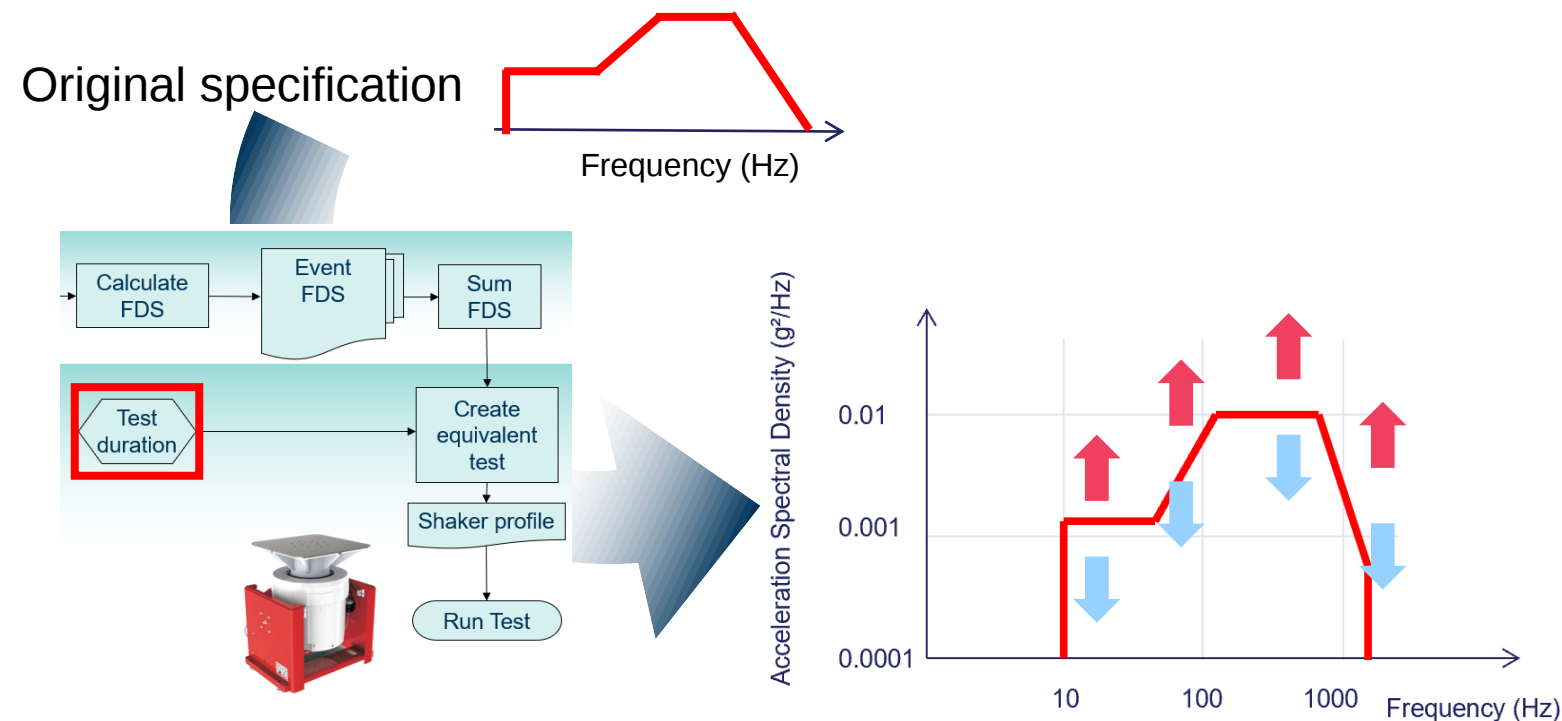
From measured vibration to a shaker profile

- ▲ Step 1: Quantify usage severity in terms of shock and damage
- ▲ Step 2: Create an equivalent test spec



Scaling up or down the shaker profile

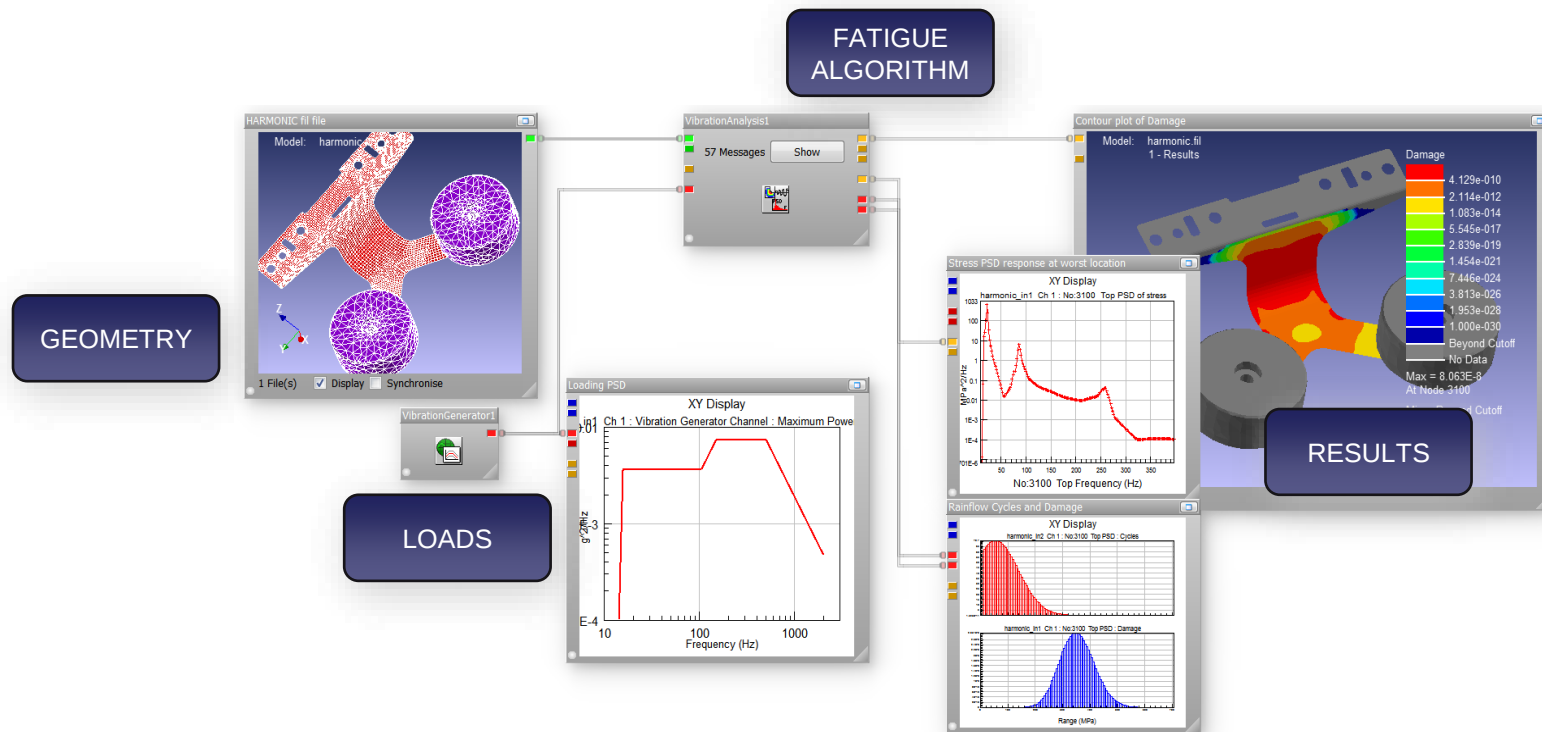
- ▲ Test duration is one important property when synthesizing an equivalent vibration profile.
- ▲ Reduce testing time would **increase excitation levels**.
- ▲ **Adjust the profile** to account for the maximum performance of the shaker, i.e. make a wider use of your current shaker.



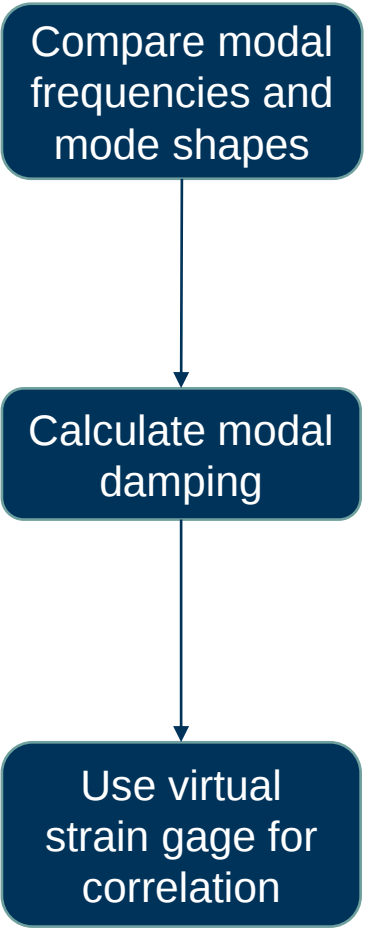
Numerical simulation ~~vs.~~ physical testing with

Benefits of virtual testing for physical testing and prototyping

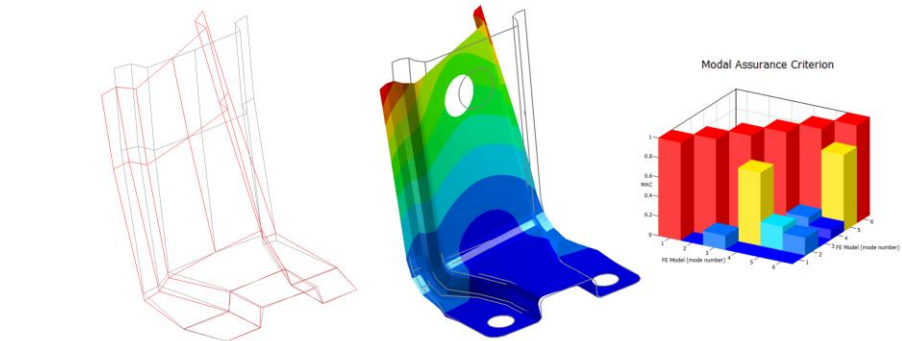
- Use virtual testing to :
 - Ensure test will be successful
 - Assess margins
- Sensitivity analysis on various parameters
- Investigate and re-design after an unsuccessful test
- Reduce number of prototypes



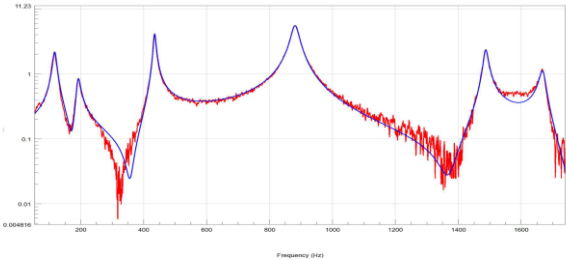
Physical testing to validate and enhance FE Modelling



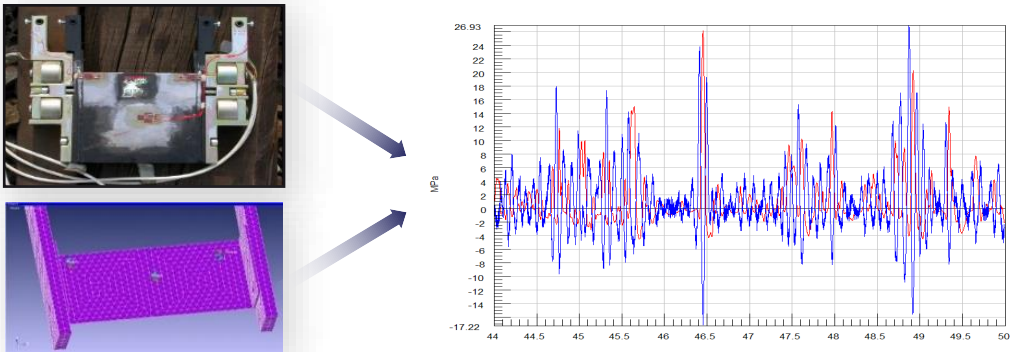
Validate boundary conditions, stiffness and mass distribution



Correctly predict the magnitude of the stress response



Validate the meshing and the way the loads are applied



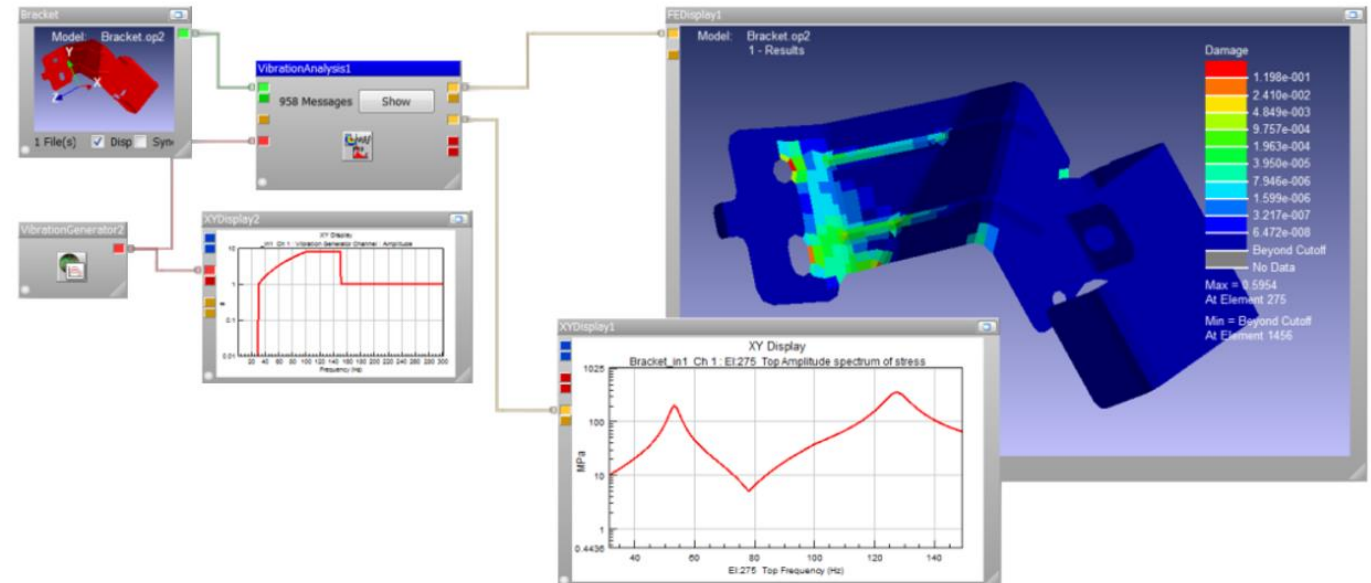
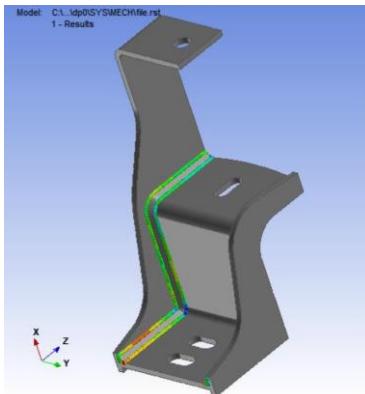
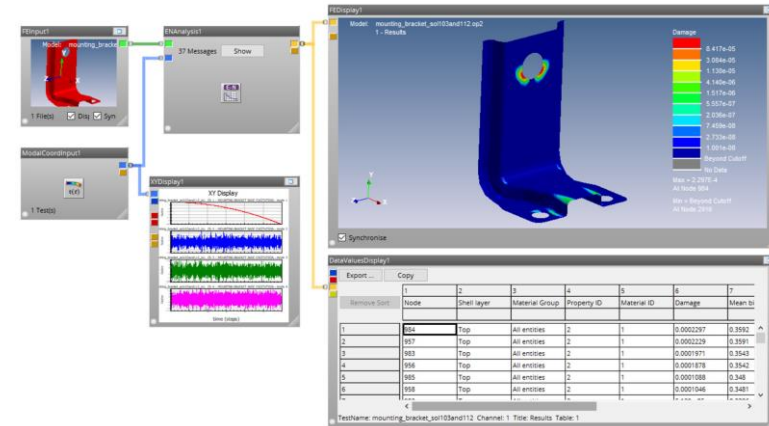
Fatigue simulation in Time and Frequency domains

Predict fatigue life with confidence, using :

Time domain excitation

Frequency domain excitation

- PSD, sine sweep or sine on random
- Multi-correlated PSDs for multiple directions excited simultaneously
- Sheet metal or Weld fatigue



Use your test to demonstrate a given reliability level

Example durability requirement

“The part must pass the test that’s representative of 4000 service hours
... with a **reliability greater than 95% with 90% confidence.**” (R95C90)

- ▲ Reliability can be shown by testing enough samples for a given duration
 - What is the minimum number of samples I need to test?
 - What is the confidence of the result?
 - Can less than one life be tested?
- ▲ Statistical methods are available to answer these questions



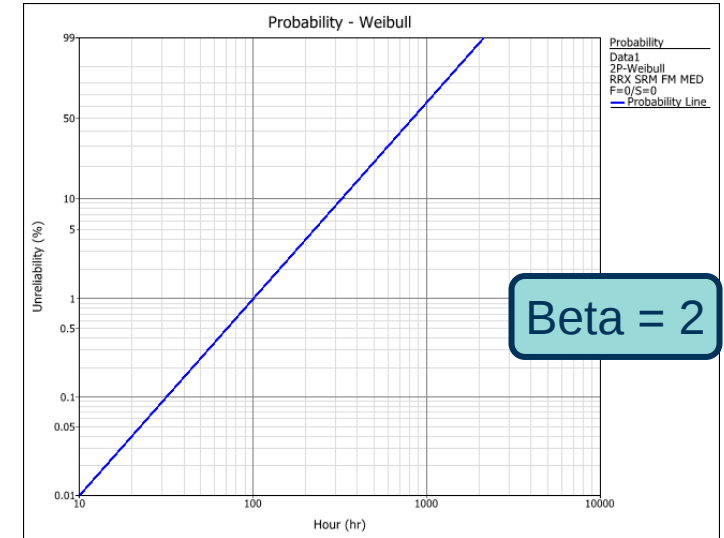
ReliaSoft



Weibull++

Reliability Demonstration Testing

- ▲ The Weibull distribution is frequently utilized to describe different failure behaviors.
- ▲ Confidence, sample size and test time are proportionally related
- ▲ The number of test samples can be reduced by testing longer
- ▲ Weibull slope beta is used to solve for test duration given a fixed sample size



Design a reliability demonstration test

What metric would you like to demonstrate?

Metric	Value
Reliability value at a specific time	90
Demonstrate this reliability (%)	90
With this confidence level (%)	90
At this time (hr)	1000

Assume the failure rate behavior is governed by this distribution

Distribution	Value
2P-Weibull	3.15
With this Beta	3.15

Solve for this value

Value	Value
Required sample size	Required sample size
With this test time (hr)	Required test time
With a maximum of this many failures	Required sample size

Target life

Conclusions

Conclusions

- ▲ Whether you want to:
 - provide your suppliers with realistic shaker profiles for them to validate their components against,
 - sell the same component to several customers, each with a different validation requirement,

- ▲ With the Fatigue Damage Spectrum, you can:
 - Create an endurance vibration test that represents service loading,
 - Compare different shaker profiles,
 - Scale up or down a profile to reduce the test duration or adjust to shaker capacity.

- ▲ And make sure you get the most out of your tests!
 - Use numerical simulation to complement physical testing
 - Decide how many samples and how long to test in order to demonstrate a given reliability level

Related webinars

Look at our recently recorded webinars on the HBK website.

<https://www.hbkworld.com/en/knowledge/resource-center/recorded-webinars>

Search for “shaker” :

[shaker-profile-design-for-optimized-vibration-durability-tests](#)

Search for “vibration fatigue” :

[random-vibration-fatigue-capabilities-in-ncode-designlife](#)

Search for “durability” :

[introduction-to-ncode-glyphworks-for-durability-analysis](#)

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[recorded-webinars/correlating-fe-and-test](#)

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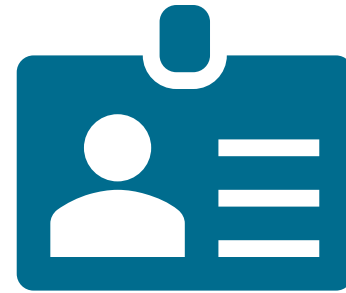
Watch the sessions that interest you

Topics include:

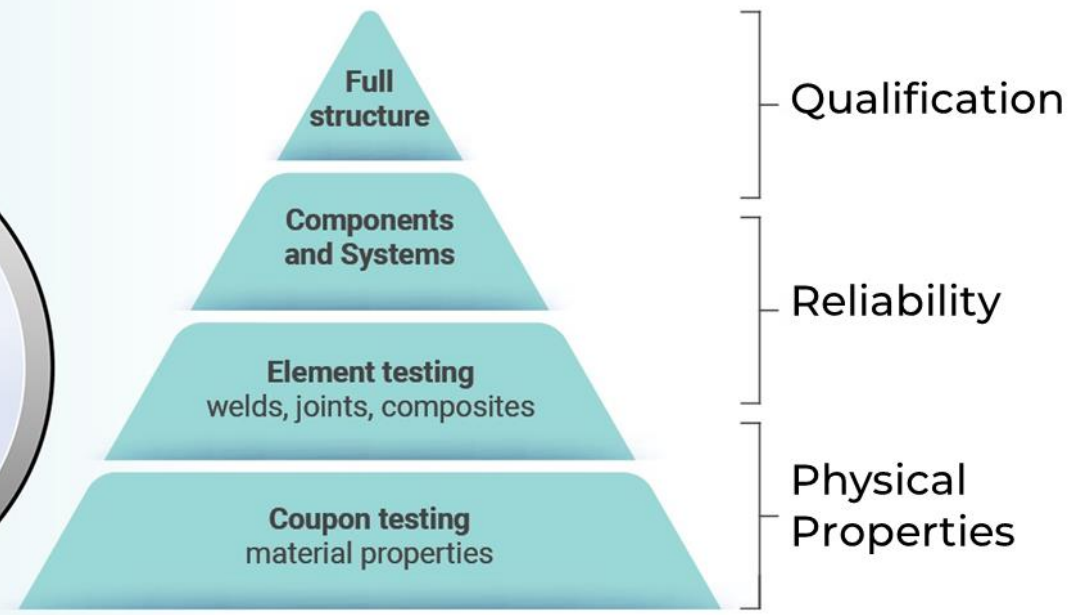
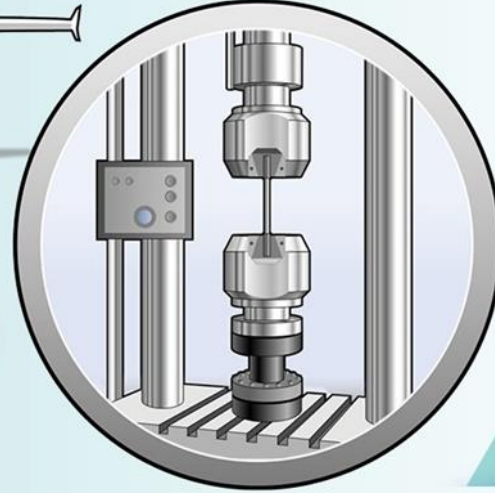
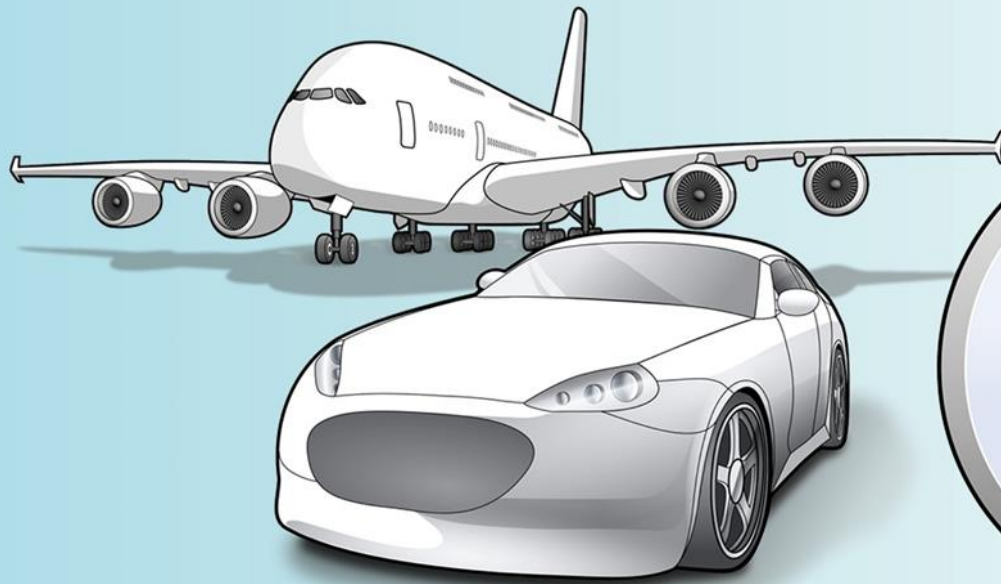
- Understanding and Improving the Performance, Durability and Reliability of Electric Vehicles
- Mechanical and Durability Aspects of Electric Vehicles
- Performance and Efficiency Aspects of Electric Vehicles
- Statistical and Reliability Aspects of Electric Vehicles
- Physical Testing – Battery Structural Durability and Integrity
- Short-circuit Testing of High-performance Batteries
- Physical Single Cell Testing (Pressure Analysis)
- Vibration Testing Live Batteries During Charge/Discharge Cycling
- Physical Testing – Battery Performance and Thermal Integrity

Q & A

Presenter info

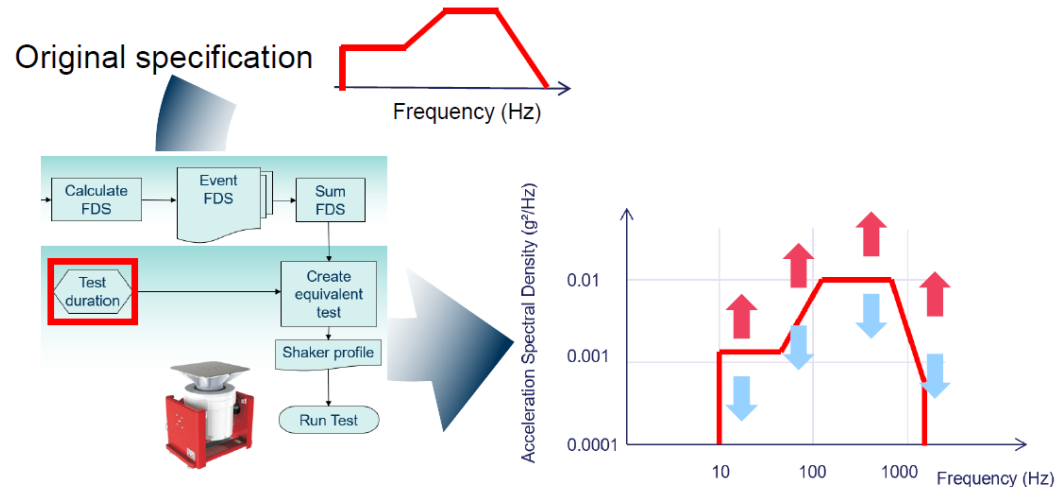


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