Frequency Domain Fatigue Analysis with nCode DesignLife

Jeff Mentley– Senior Application Engineer

nCode

ReliaSoft

Prenscia HBM

empowers engineers to **avoid the cost of unexpected failures**
by using our **software** and **related services**
to deliver **reliable** products and processes.

Software Brands	Training & Education	Services
nCode ReliaSoft	• Design for reliability • Design for durability • Fatigue theory • Hands-on software	• Materials testing • Solutions for design, development and test • Solutions for asset management

HBM Prenscia Software Portfolio

ReliaSoft

Weibull++
Reliability life data analysis

ALTA
Accelerated life testing

BlockSim
RBDs, fault trees, process flows and Markov diagrams

RENO
Probabilistic event and risk analysis

RGA
Reliability growth analysis

λPredict
Standards based reliability prediction

XFMEA
FMEA and related analyses

RCM++
Reliability centered maintenance

RBI
Risk based inspection analysis

MPC
MSG-3 Maintenance program creation

XFRACAS
Web-based failure reporting and problem resolution

SEP
Web portal for ReliaSoft applications

nCode

DesignLife
CAE-based fatigue analysis

GlyphWorks
Test data analysis and durability

VibeSys
Acoustics and vibration analysis

Automation
Data storage and reporting

Aqira
Web-based test and CAE

HBM Prenscia Software Portfolio

ReliaSoft

Weibull++
Reliability life data analysis

ALTA
Accelerated life testing

BlockSim
RBDs, fault trees, process flows and Markov diagrams

RENO
Probabilistic event and risk analysis

RGA
Reliability growth analysis

λPredict
Standards based reliability prediction

XFMEA
FMEA and related analyses

RCM++
Reliability centered maintenance

RBI
Risk based inspection analysis

MPC
MSG-3 Maintenance program creation

XFRACAS
Web-based failure reporting and problem resolution

SEP
Web portal for ReliaSoft applications

nCode

DesignLife
CAE-based fatigue analysis

GlyphWorks
Test data analysis and durability

VibeSys
Acoustics and vibration analysis

Automation
Data storage and reporting

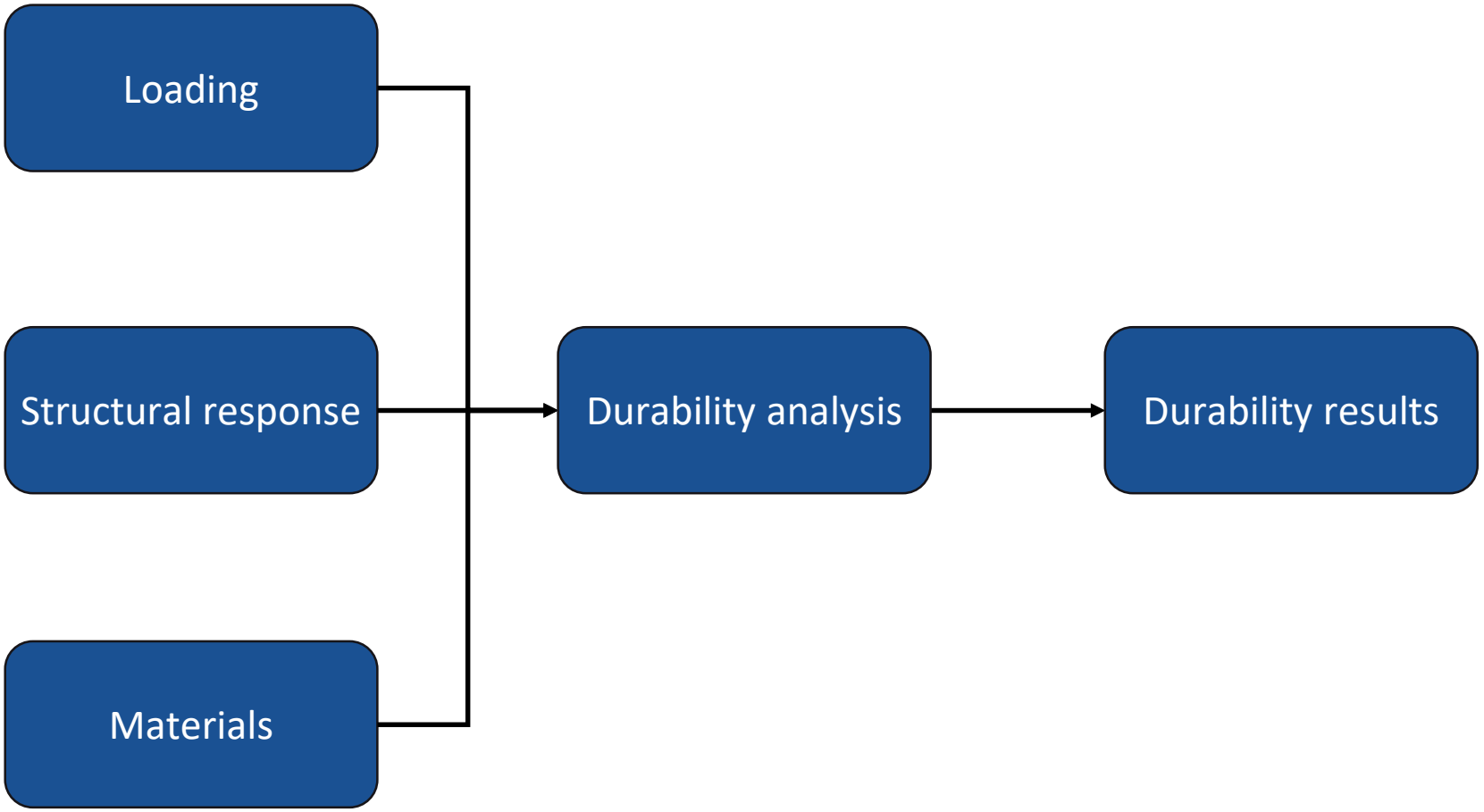
Aqira
Web-based test and CAE

Agenda

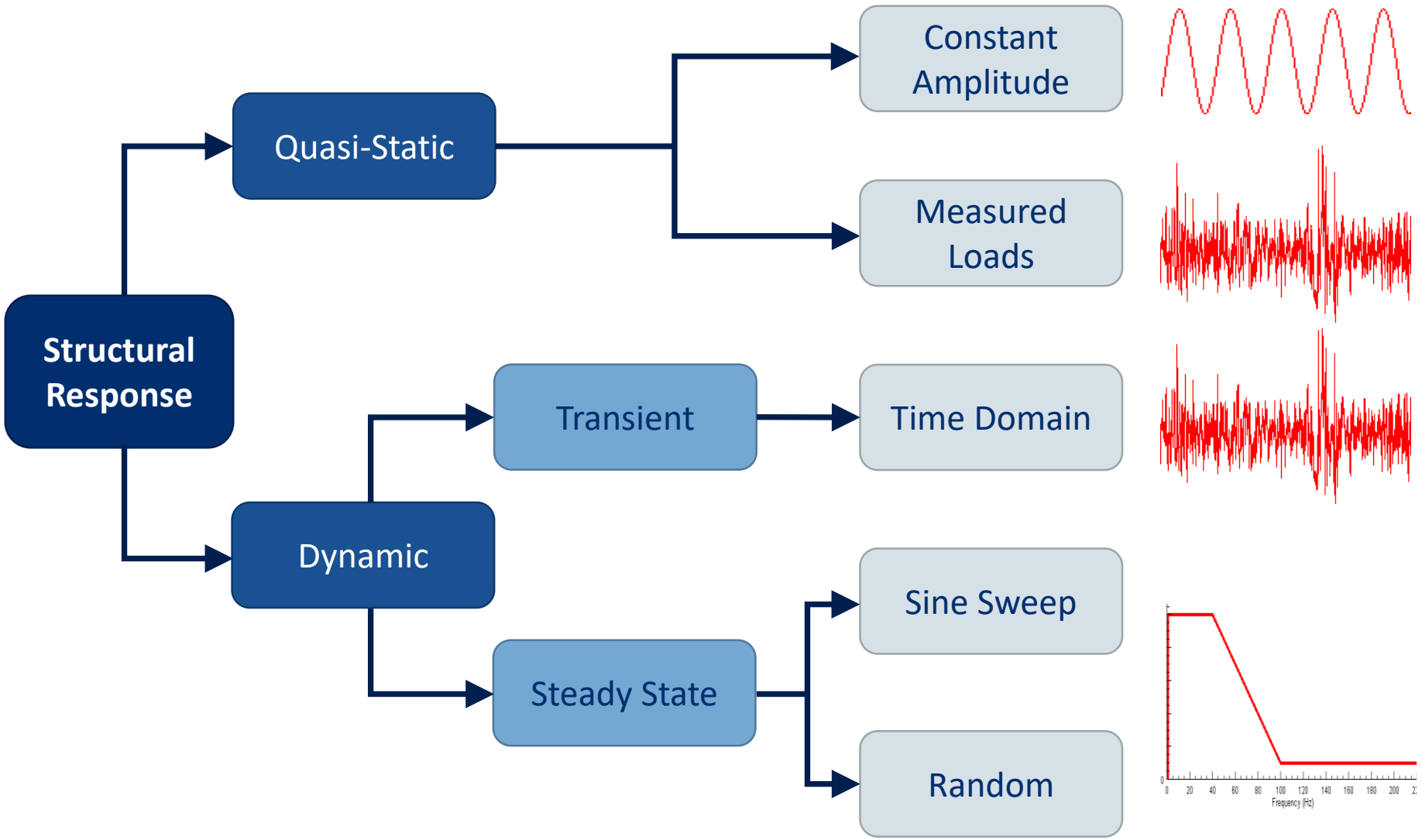
- Introduction to vibration fatigue
- Single-axis, random excitation
- Multi-axis, sequential, random excitation
- Multi-axis, simultaneous, random excitation
- Advanced features of vibration fatigue
- Summary

Introduction to vibration fatigue

Fatigue analysis roadmap

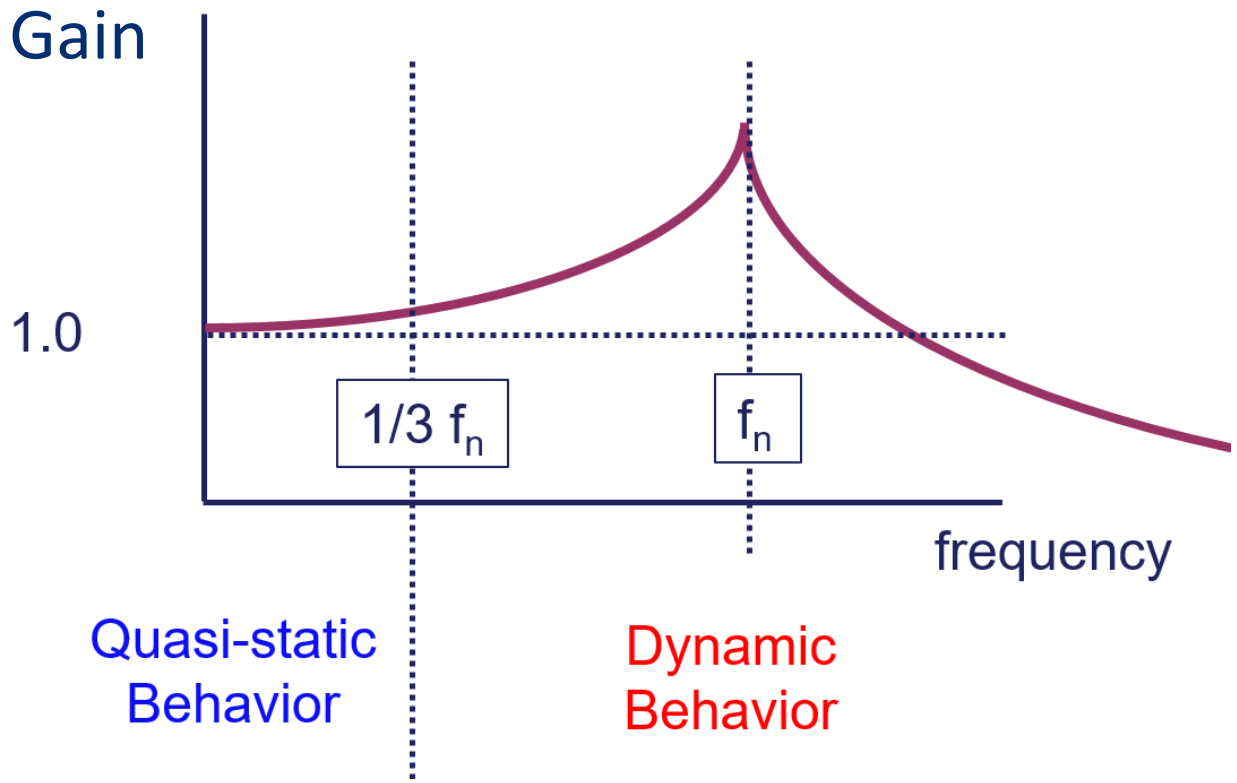


Loading



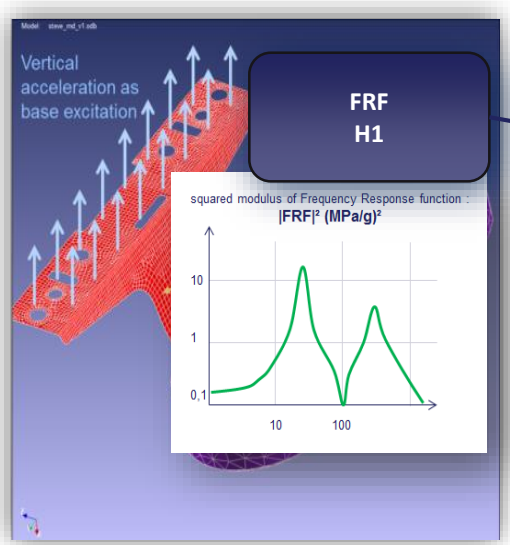
Dynamic finite element analysis

- Dynamic behavior needs to be accounted for if excitation frequencies are greater than 1/3 of the structure's lowest resonant frequency



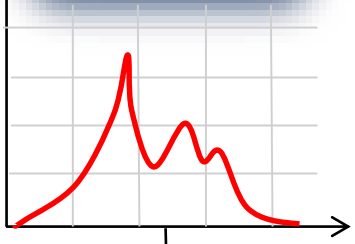
Vibration Fatigue Process

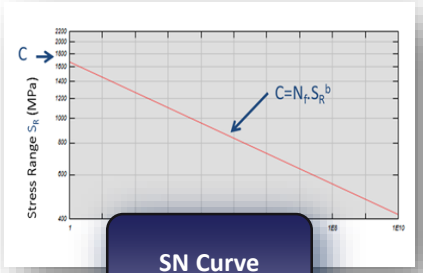
$$[\sigma_A] = [H1]^2.L1$$



FRF
H1

Stress PSD

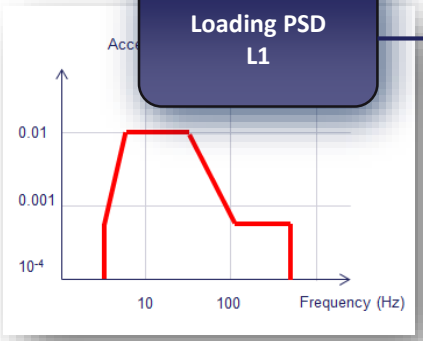




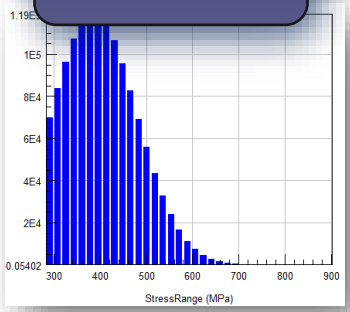
SN Curve

PSD
Cycle Counting

Loading PSD
L1



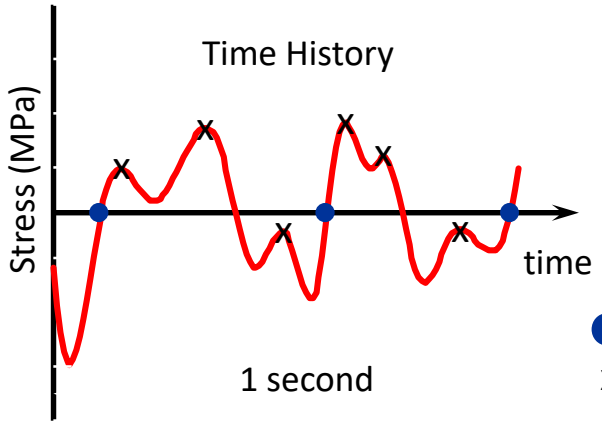
Statistical Cycle
Distribution



SN
Analysis

Fatigue Results

PSD Rainflow Counter



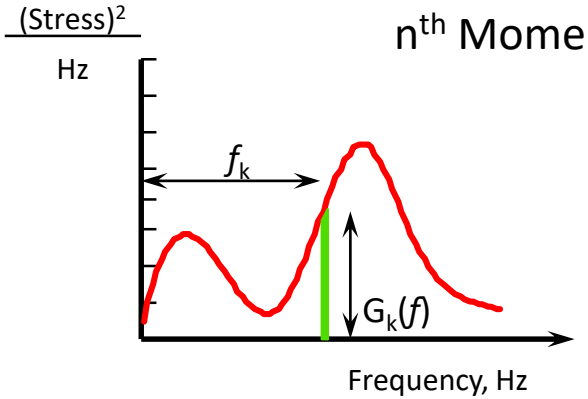
= upward zero crossing

x = peak

Number of upward zero crossings, E[0] = 3

Number of peaks, E[*P*] = 6

$\gamma = E[0]/E[P]$



(Theory of SO Rice, 1954)

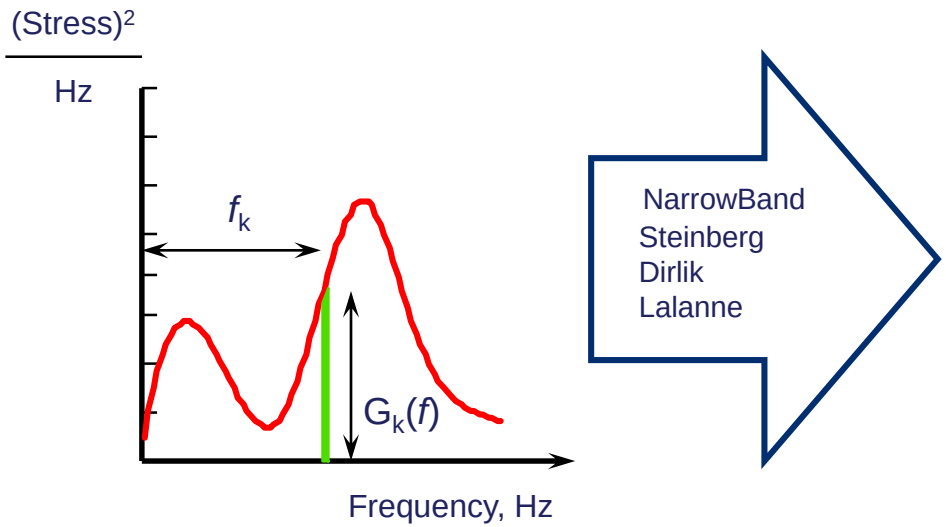
nth Moment of area under PSD $m_n = \sum f^n \cdot G(f) \cdot \delta f$

Number of upward zero crossings, $E[0] = \sqrt{\frac{m_2}{m_0}}$

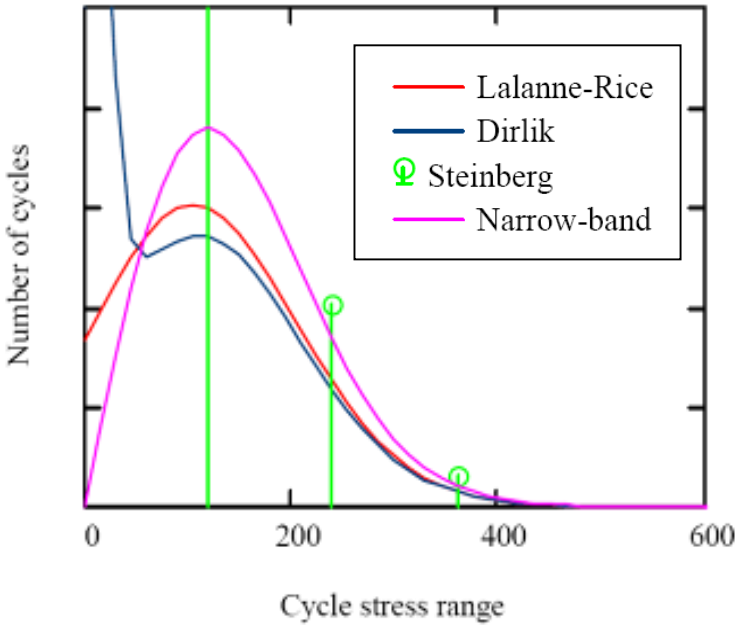
Number of peaks, $E[P] = \sqrt{\frac{m_4}{m_2}}$

PSD Rainflow Counters

From the area moments of the stress PSD, the number of cycles per second and the range distribution of the cycles are estimated.

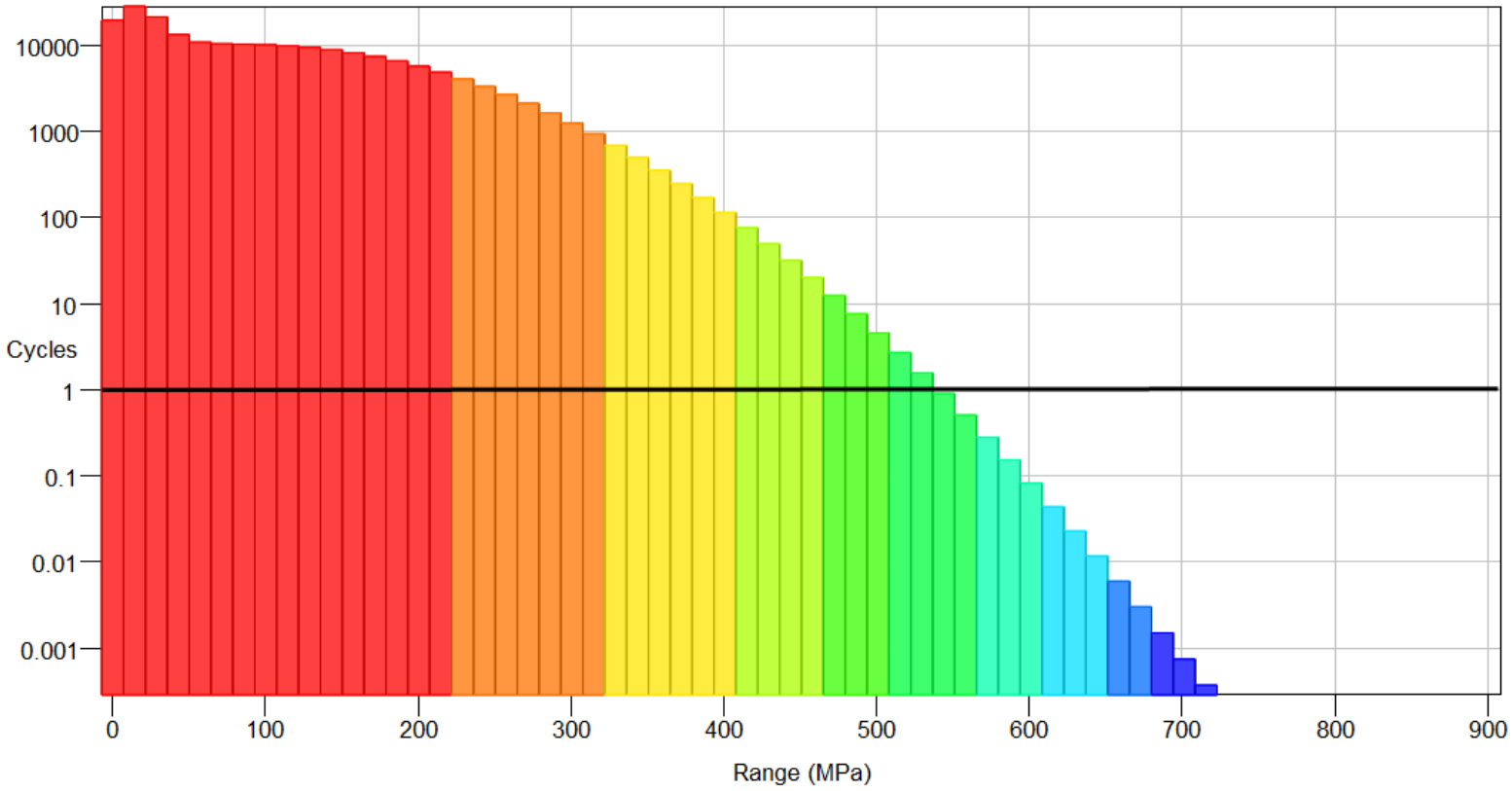


Stress Range Probability Density Function

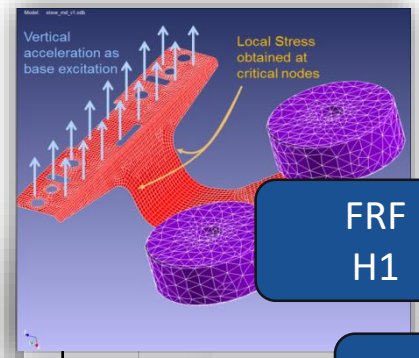


Probability Density of Cycles

- The cycles histogram is actually a probability density
- Damages are calculated for fractions of cycles



Vibration fatigue from multiple inputs



FRF H1

FRF H2

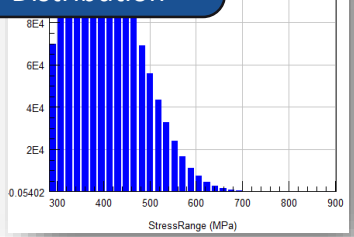
PSD L2

PSD L1

CSD L12

$$[\sigma_A] = [H1]^2.L1 + [H2]^2.L2 + [H1]^*.[H2].L12 + [H1].[H2]^*.L21$$

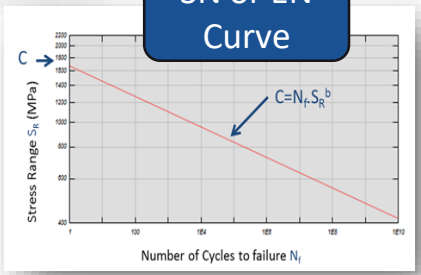
Response PSD and Statistical Cycle Distribution

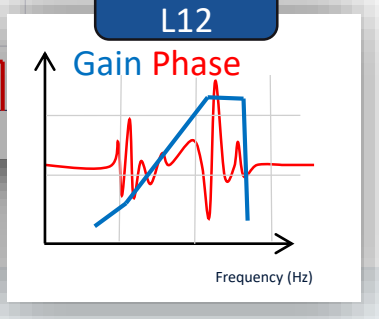


SN or EN Analysis

Fatigue Results

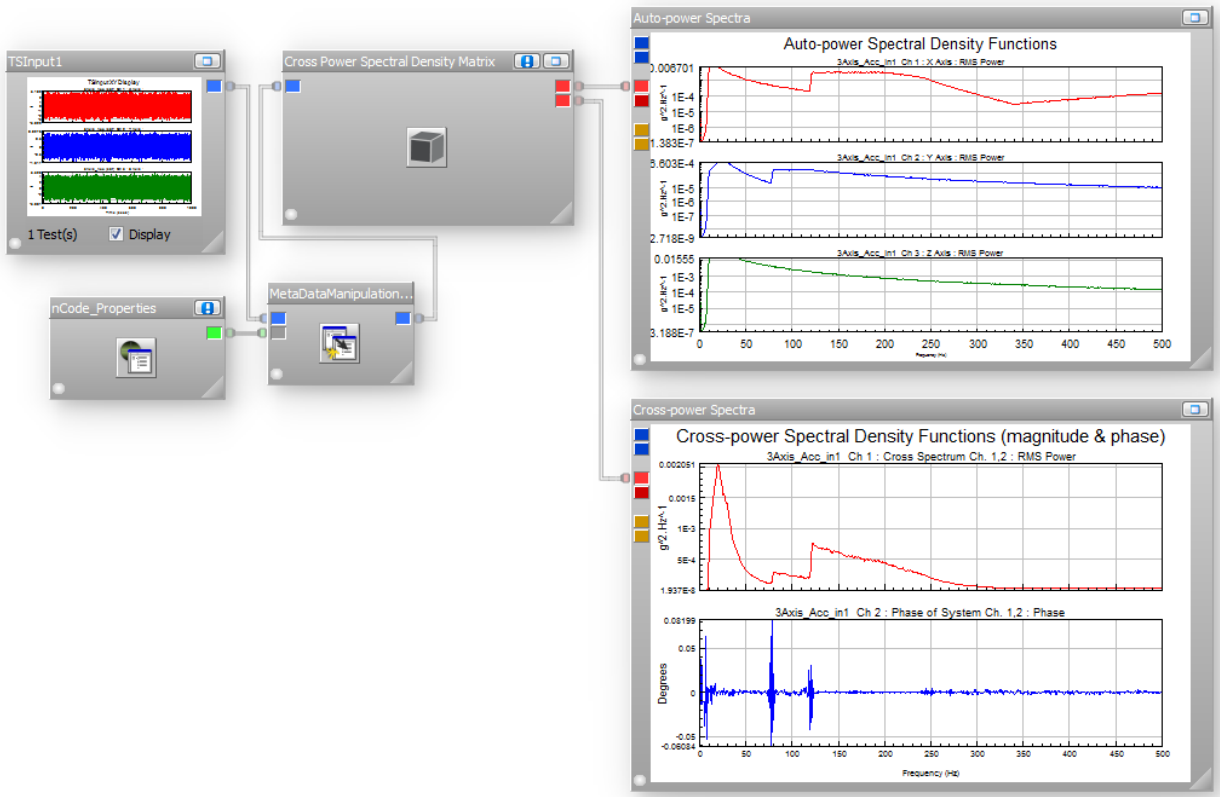
SN or EN Curve



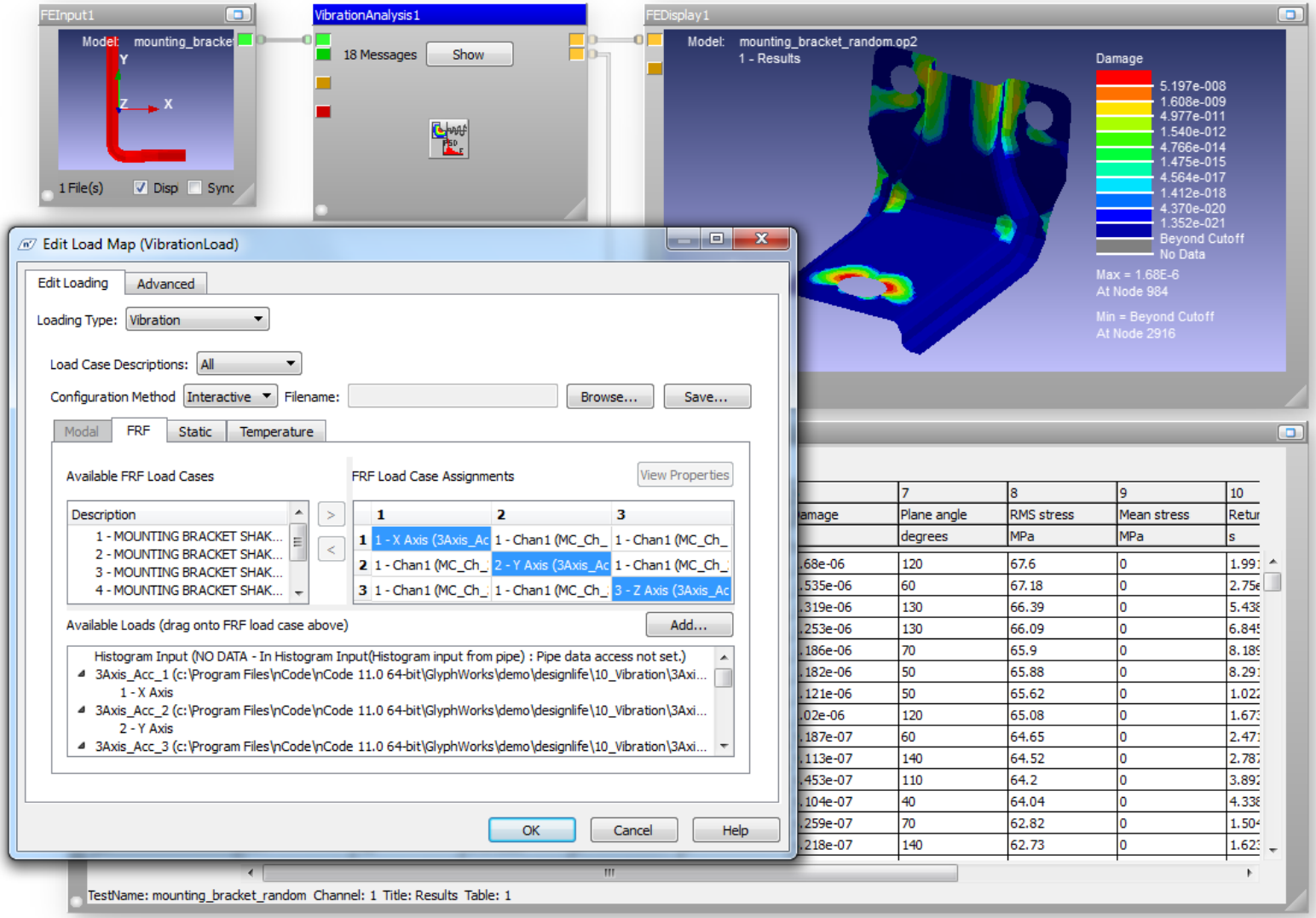


Generating the PSDs and CSDs

- PSDs and Cross Spectral Densities (CSDs) can be created from time series data
- An *.mpl* file can be used to simplify the assignment of the PSDs and CSDs



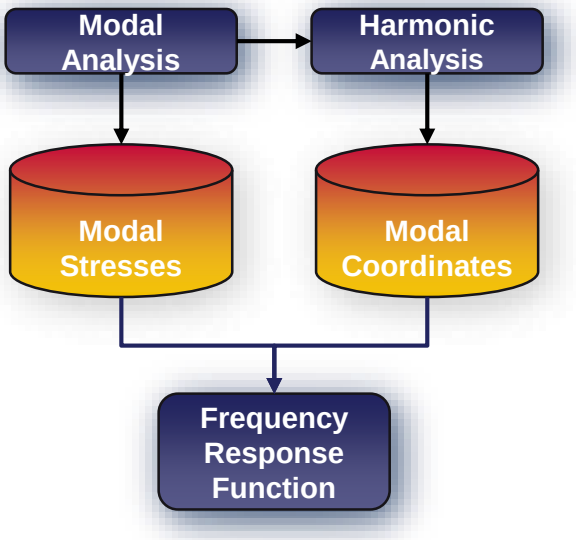
Multi-axis, simultaneous, random excitation

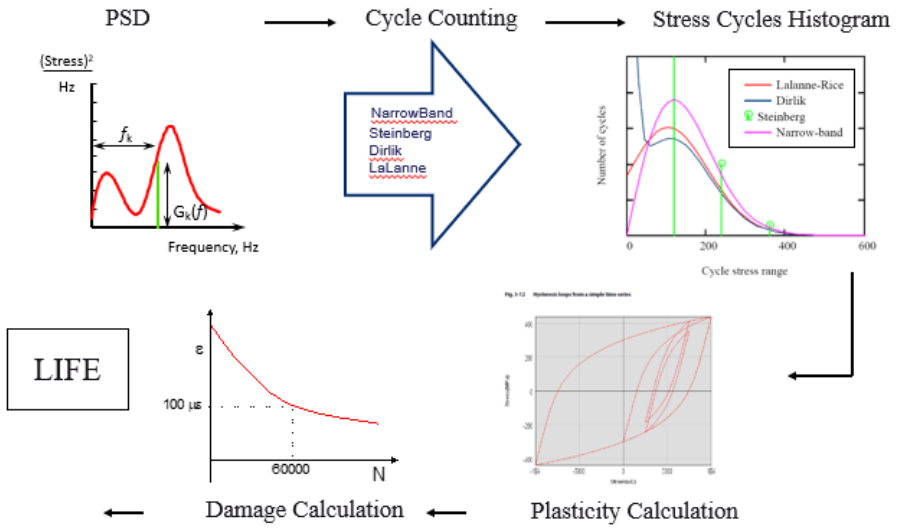


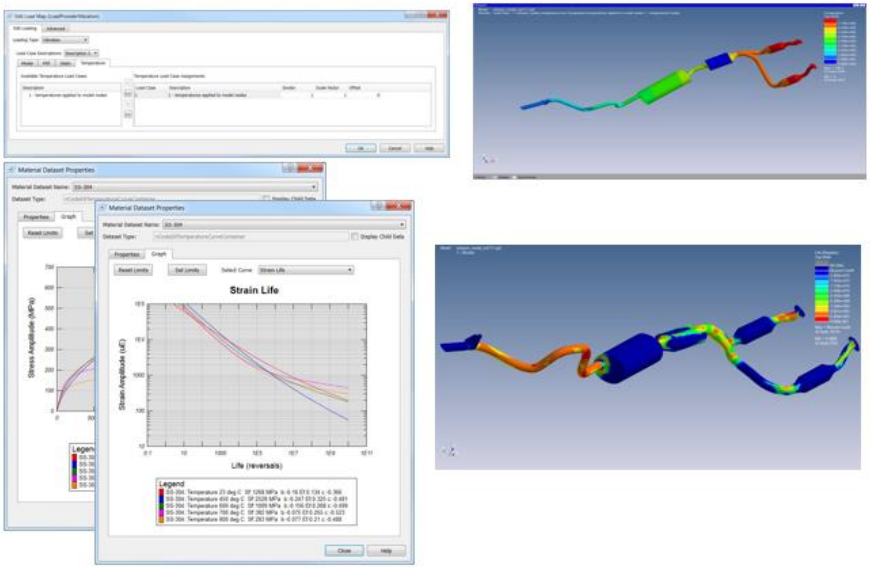
Capabilities Supported in Vibration Fatigue

- Stress Life
- Strain Life
- Isothermal Fatigue
- Mean Stress Corrections
- FRFs calculated from modal results and modal coordinates

Modal Based FRF

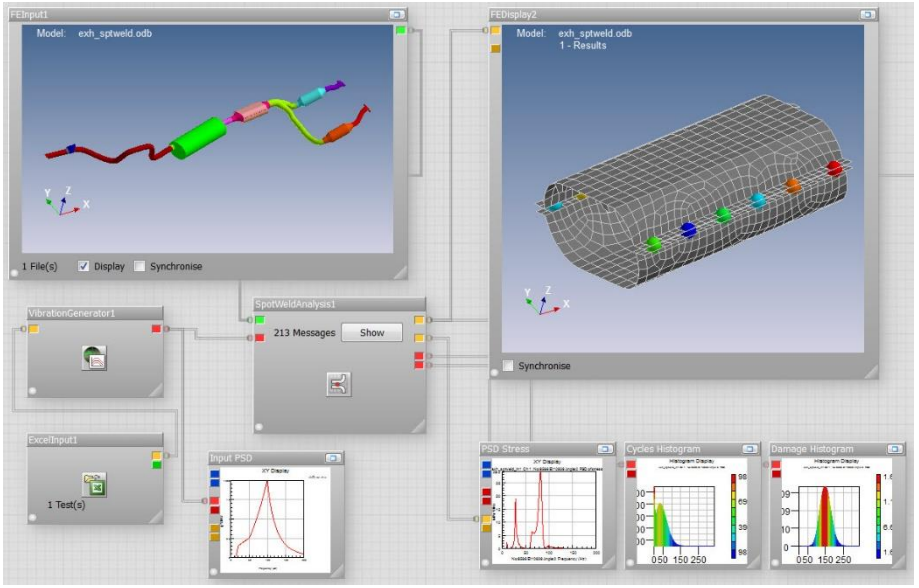


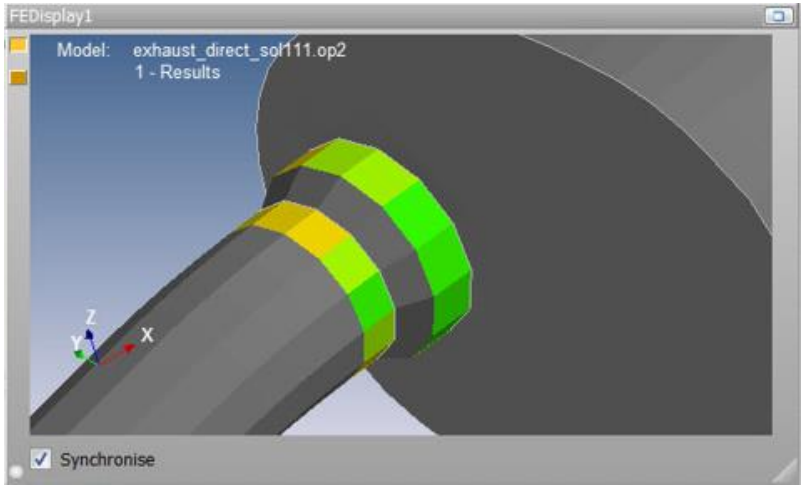


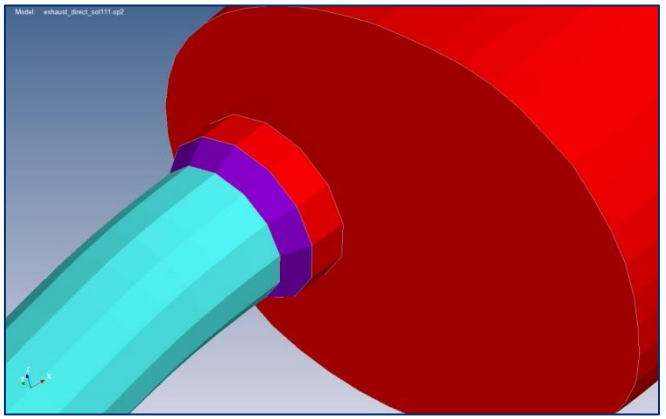


Capabilities Supported in Vibration Fatigue

- P2P and ACM Spotwelds
- Shell and Solid Seamwelds
- Short Fiber Composites







Summary

- nCode DesignLife can be used to perform vibration fatigue analysis on results from many FEA tools
  - The vibration loads can be single or multiple and can be described as:
    - Random PSDs
    - Sine on random
    - Sine sweeps
    - Sine dwells
  - Fatigue methodology includes both Stress-Life and Strain-Life
  - The vibration fatigue method can be extended to seam welds and spot welds

Questions?

www.hbmprenscia.com

Jeff Mentley

Senior Application Engineer

jeff.mentley@hbkworld.com

Prenscia HBM