Vibration induced fatigue for sequential and multiaxial loading

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Declaration

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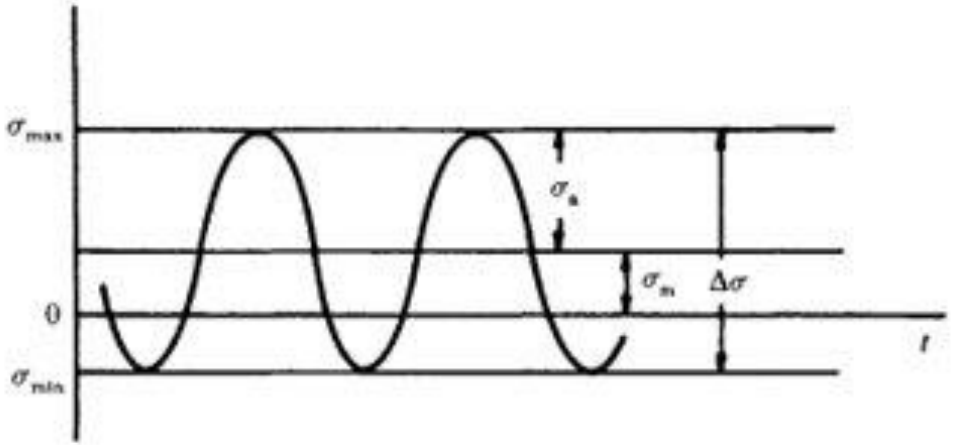
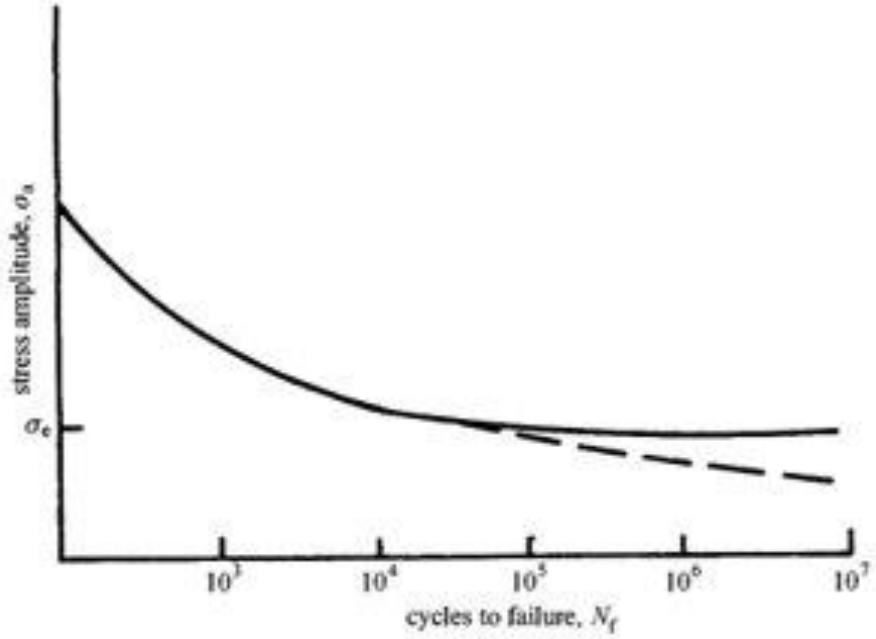
Introduction

- Estimates of fatigue life are of interest in many industries
- Experiments can be expensive and time-consuming to run
- Difficult to apply actual loading conditions during experiments

Fundamental of fatigue failure

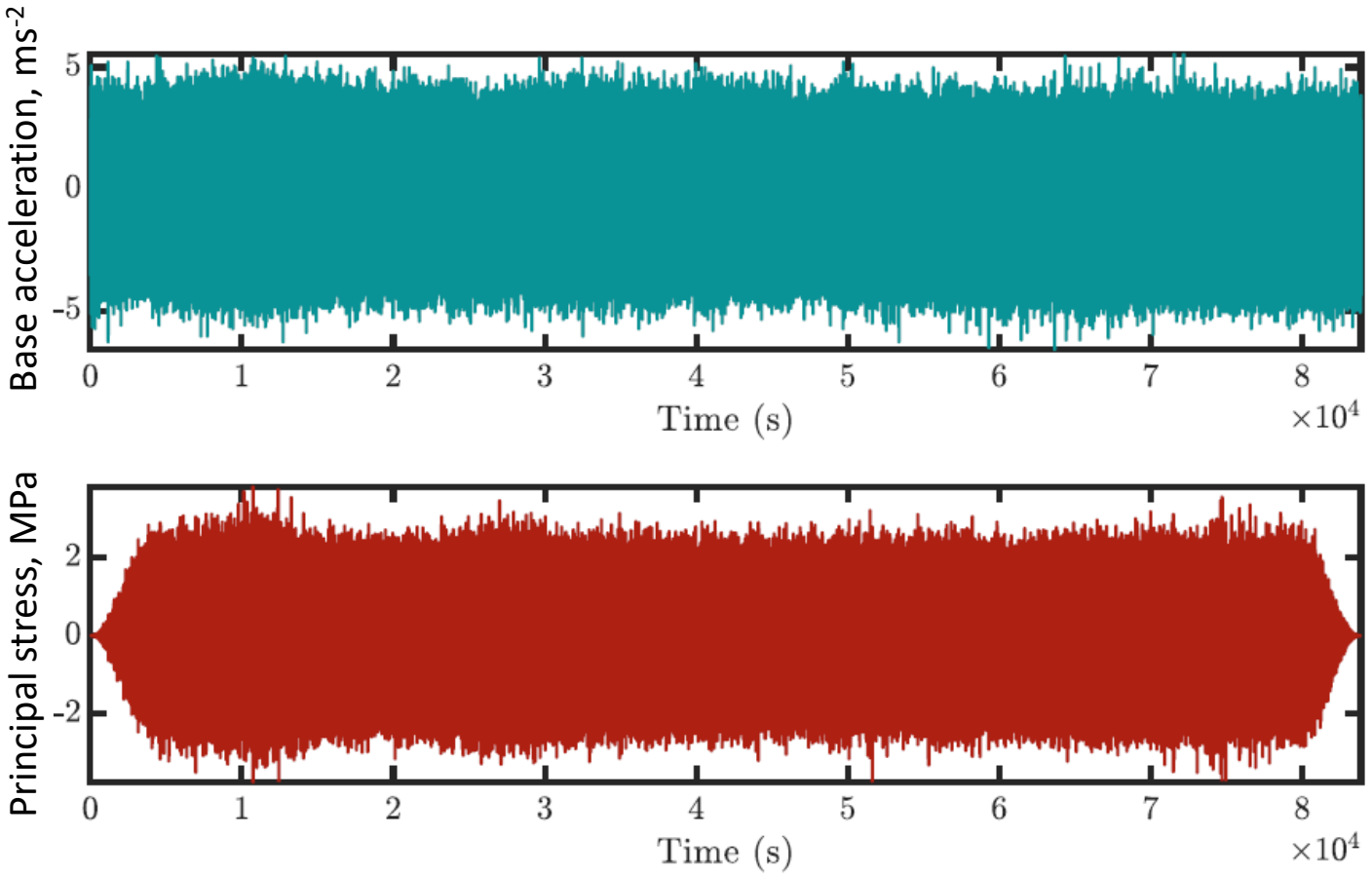




$$\Delta\sigma = \sigma_{max} - \sigma_{min}, \qquad \sigma_a = \frac{\sigma_{max} - \sigma_{min}}{2}, \qquad \sigma_m = \frac{\sigma_{max} + \sigma_{min}}{2}$$

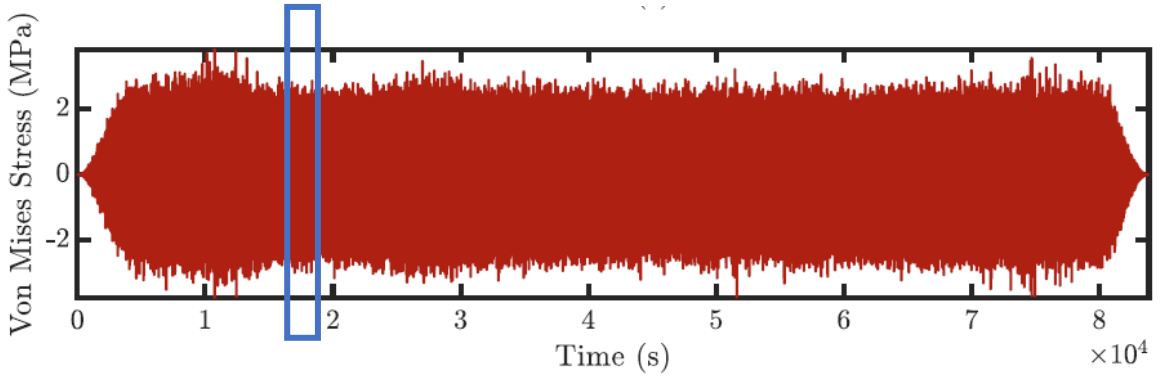
[1] S. Suresh, Fatigue of materials. Cambridge Univ. Pr, 2006.

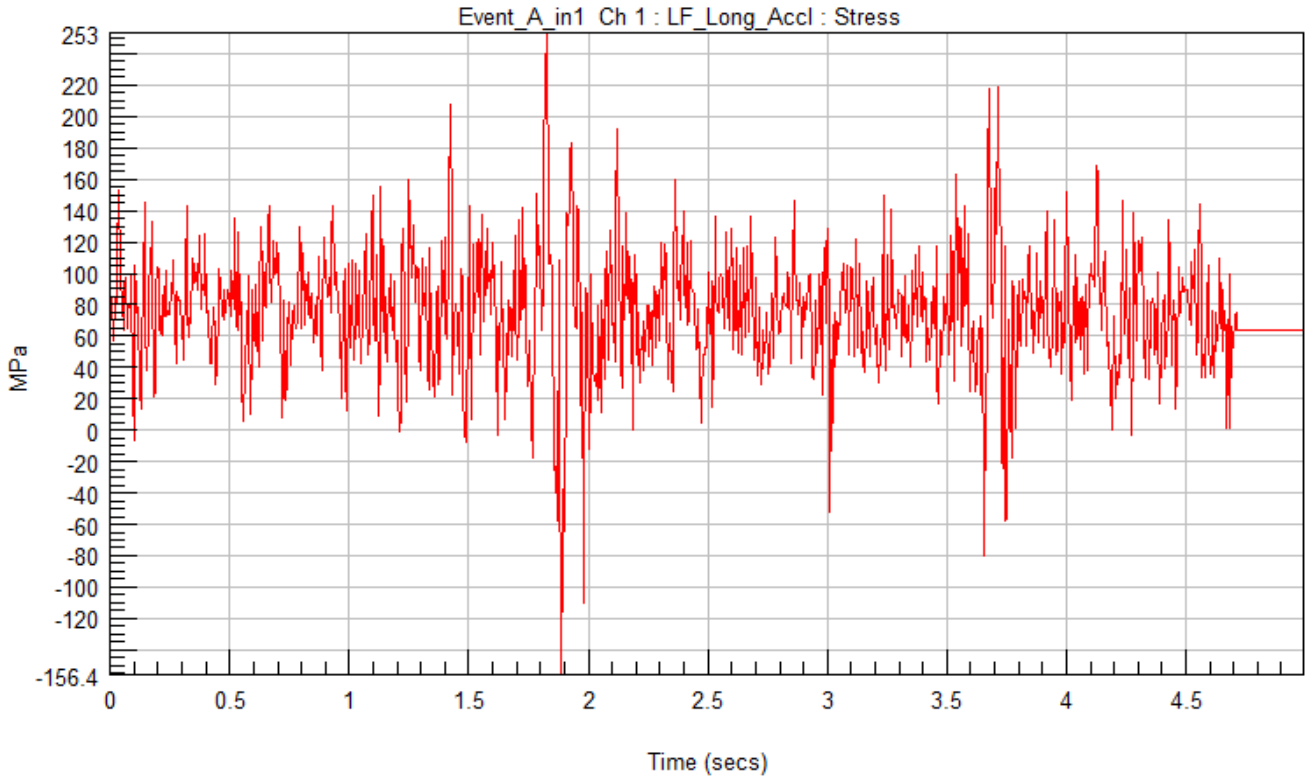
Handover data



Variable Amplitude stress loading history

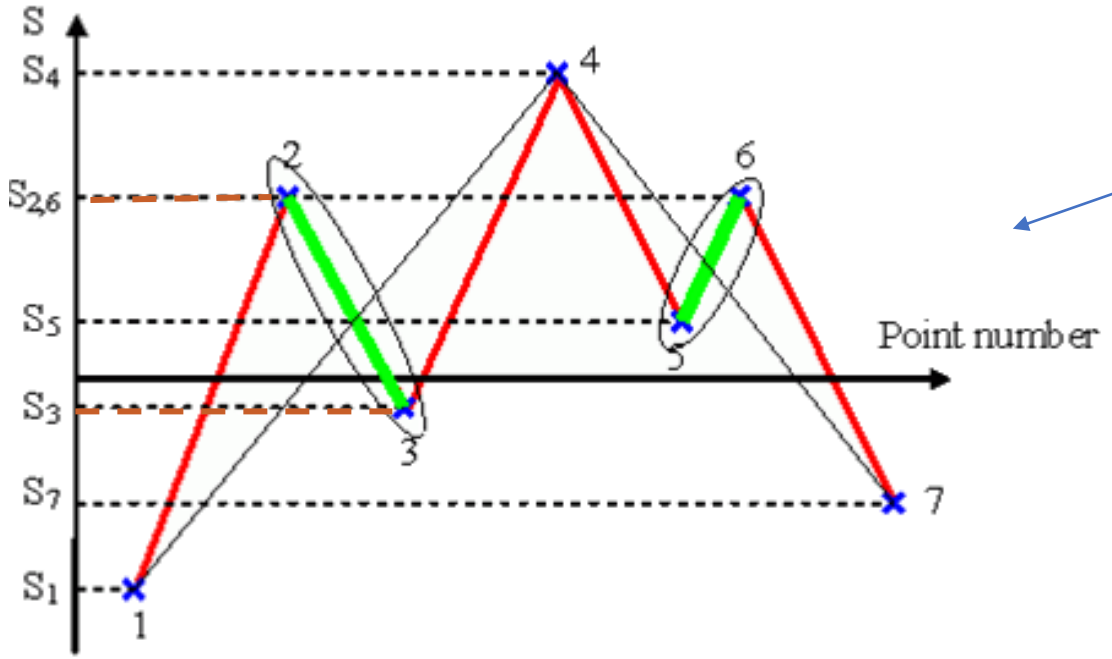
1. Data processing
2. Cycle counting
3. Damage calculation
4. Total life

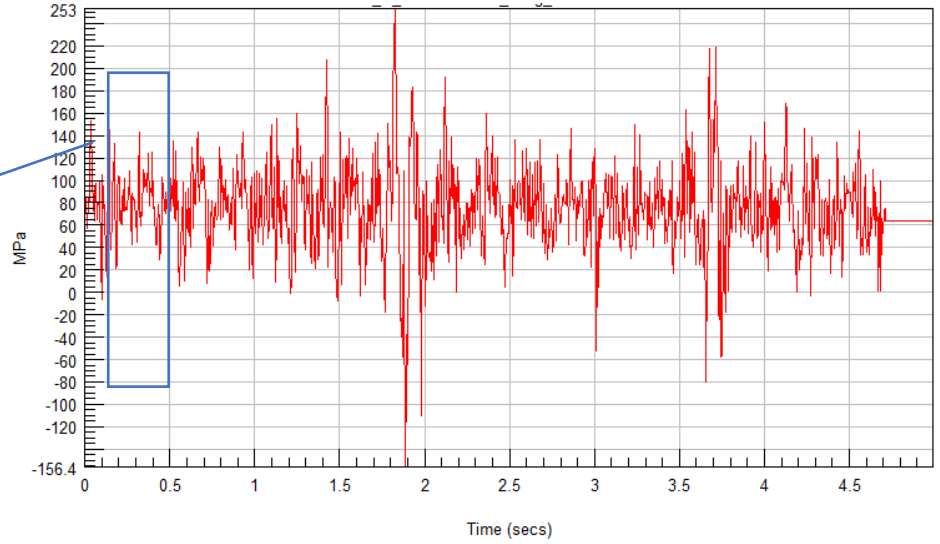




[2] “GlyphWorks Fatigue Theory Guide,” 2012. NCode manual

Cycle counting



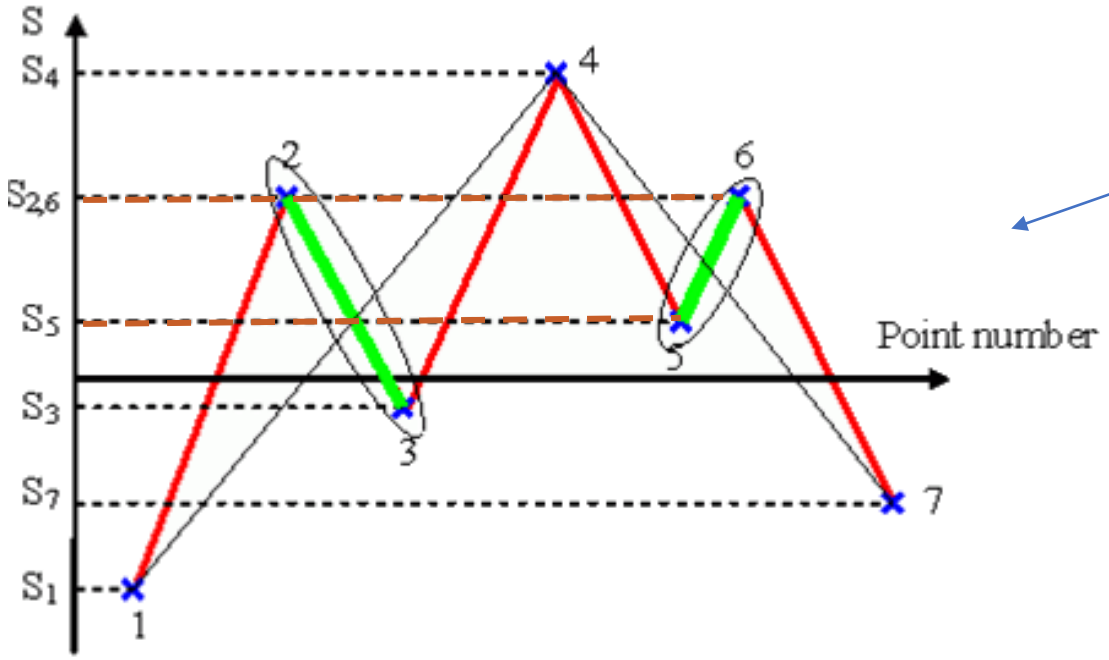


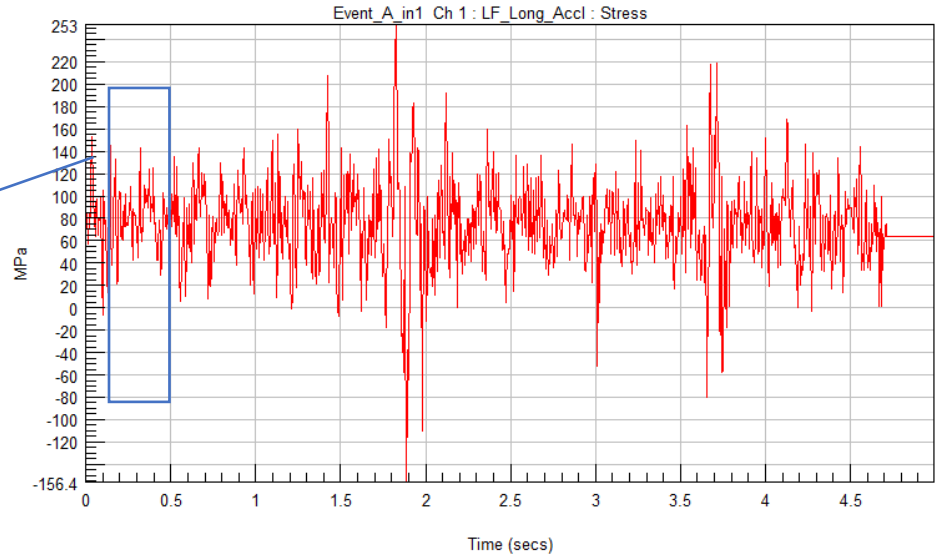
Cycles are identified by considering four points at a time. The logic is as follows:

1. If point 4 is a maximum, then IF point 4 ≥ point 2 AND point 3 ≥ point 1 then point 2 and point 3 make a cycle that can be extracted from the sequence.

[2] "GlyphWorks Fatigue Theory Guide," 2012. NCode manual

Cycle counting

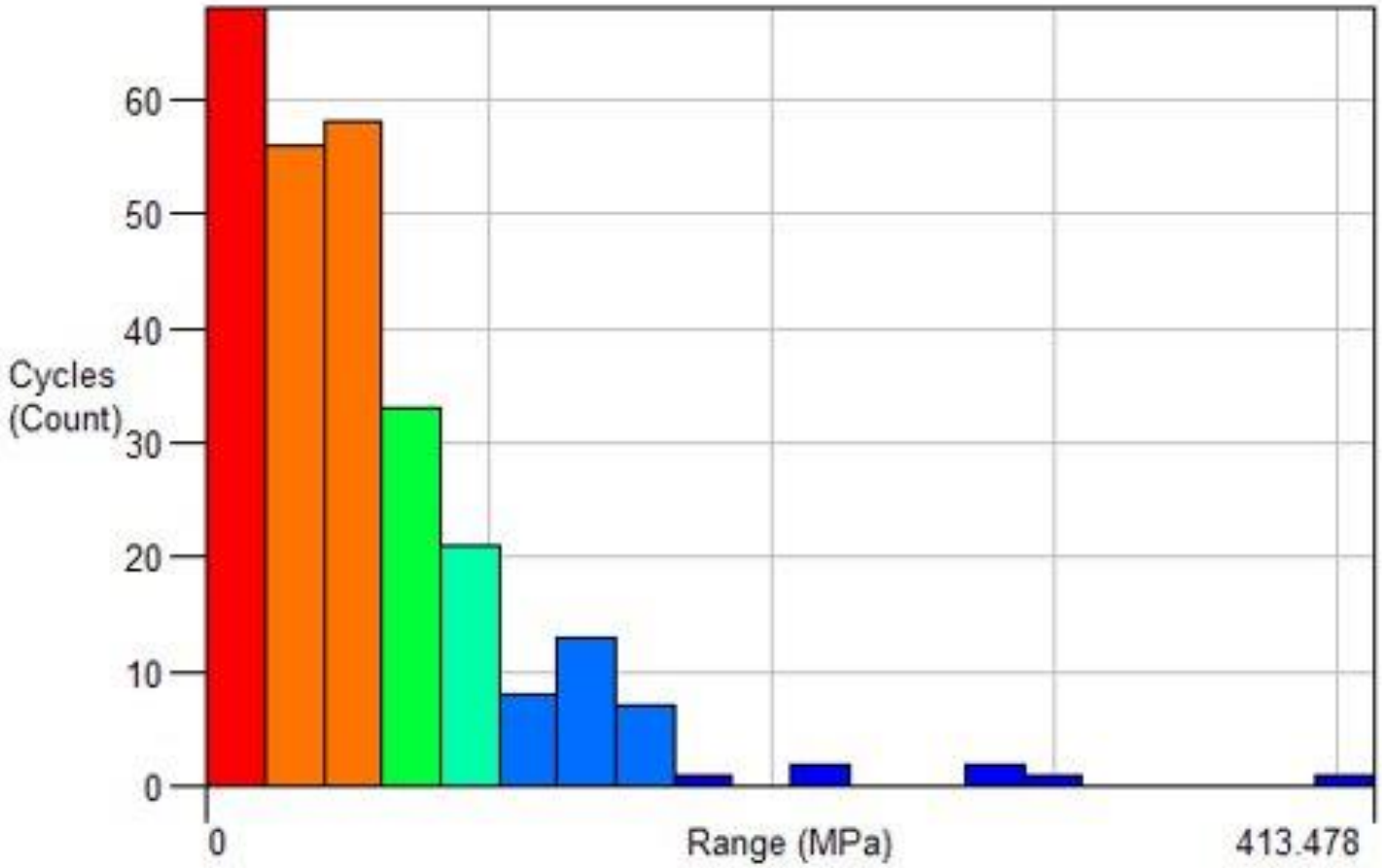




2. If point 7 is a minimum, IF point 7 ≤ point 5 AND point 6 ≤ point 4 then point 5 and Point 6 make a cycle that can be extracted from the sequence.

[2] “GlyphWorks Fatigue Theory Guide,” 2012. NCode manual

Histogram data



Histogram representation of stress range and cycles in small bins.

[2] “GlyphWorks Fatigue Theory Guide,” 2012. NCode manual

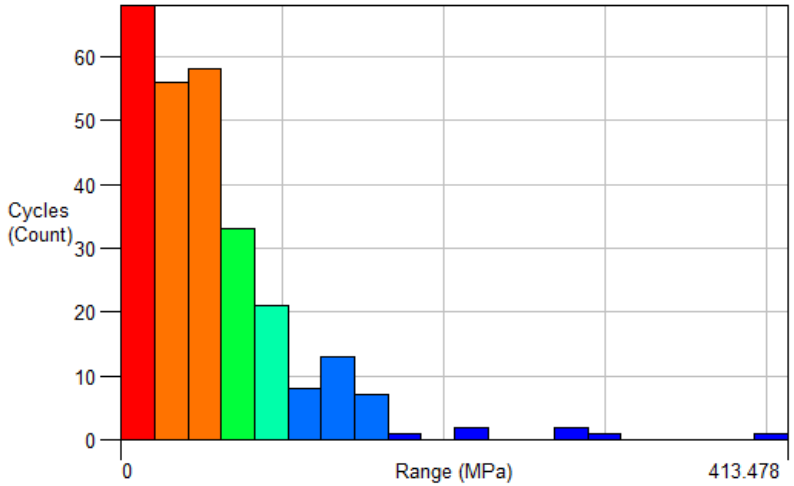
Example:

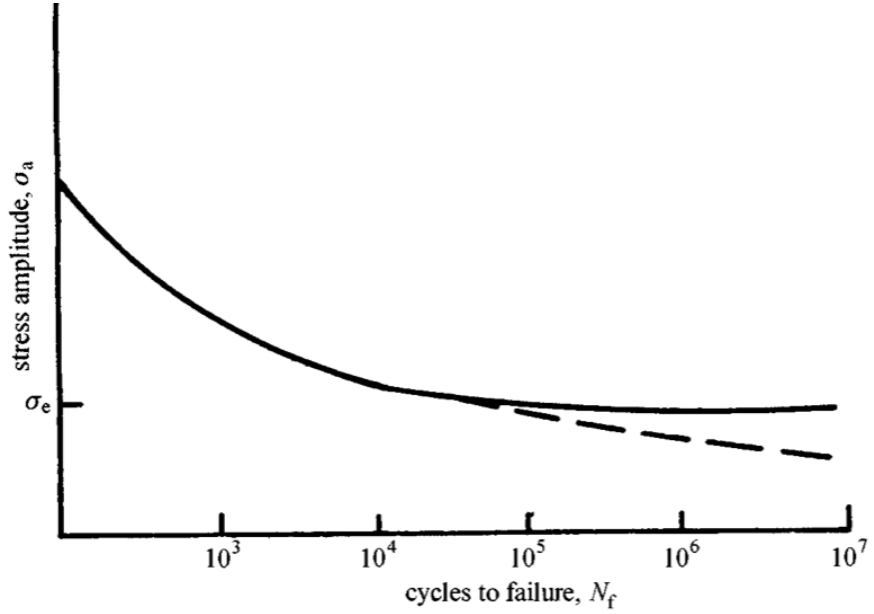
At stress range 400 MPa total cycle to failure, Nf is 100000.

From the histogram if we have 1000 cycle at 400 MPa, the damage is D1=n/Nf = 1000/100000= 0.01

Total Damage D= D1+ D2+ D3+…… = 1

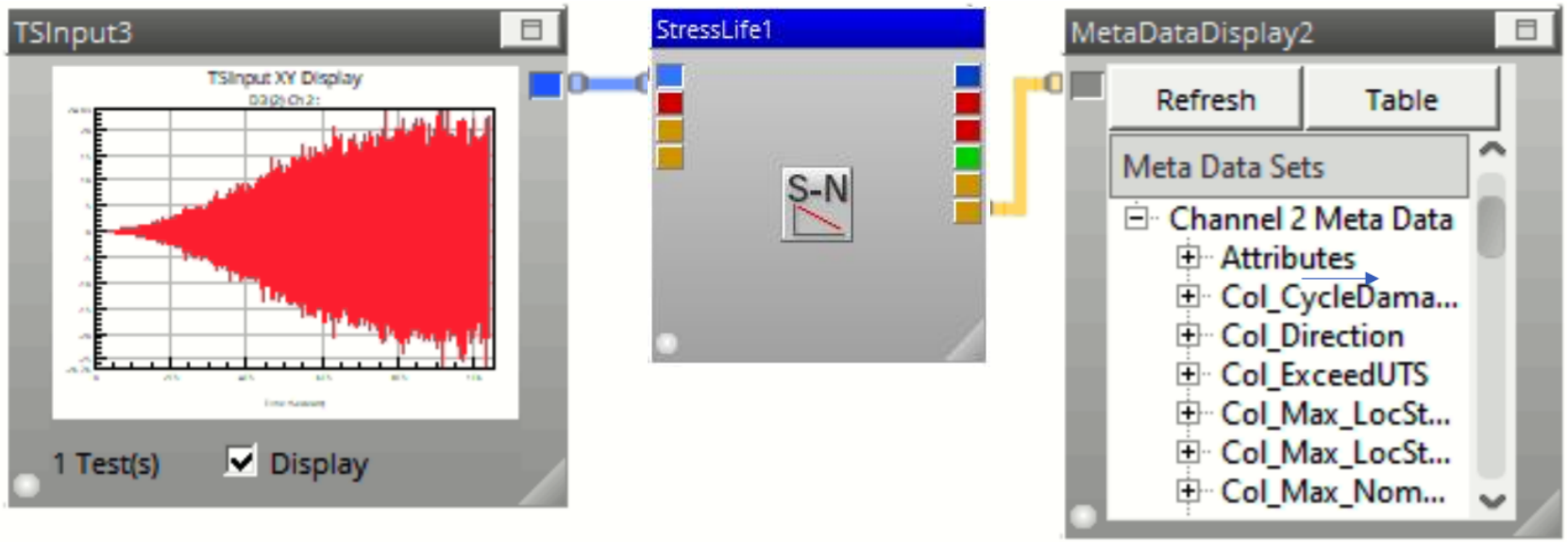
When total damage is 1, the structure would fail





[2] "GlyphWorks Fatigue Theory Guide," 2012. NCode manual
[1] S. Suresh, Fatigue of materials. Cambridge Univ. Pr, 2006.

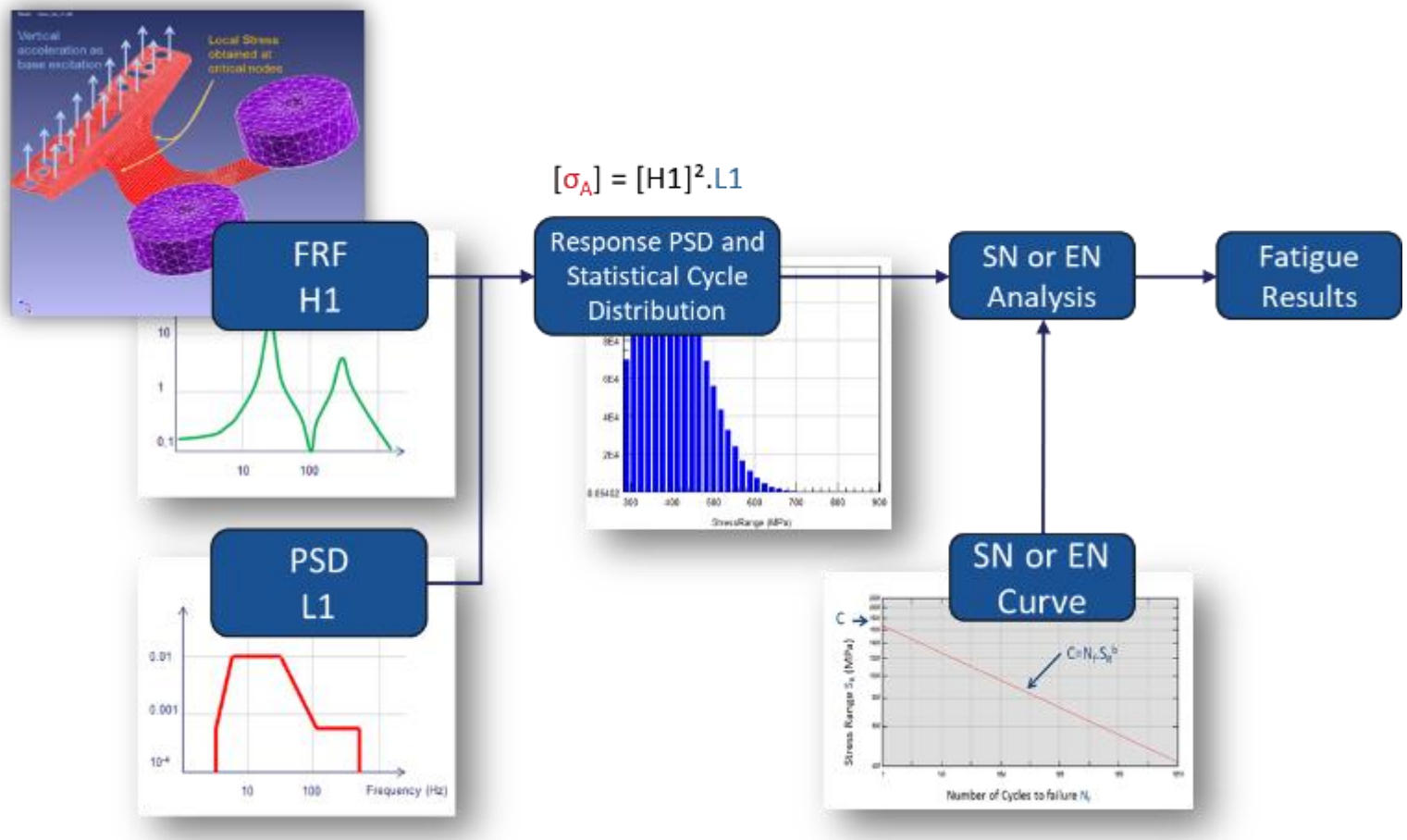
Rainflow counting in nCode Glyphworks



Input time series data → Stress-life approach → Life prediction using damage accumulation technique

Vibration-induced fatigue for sequential loading

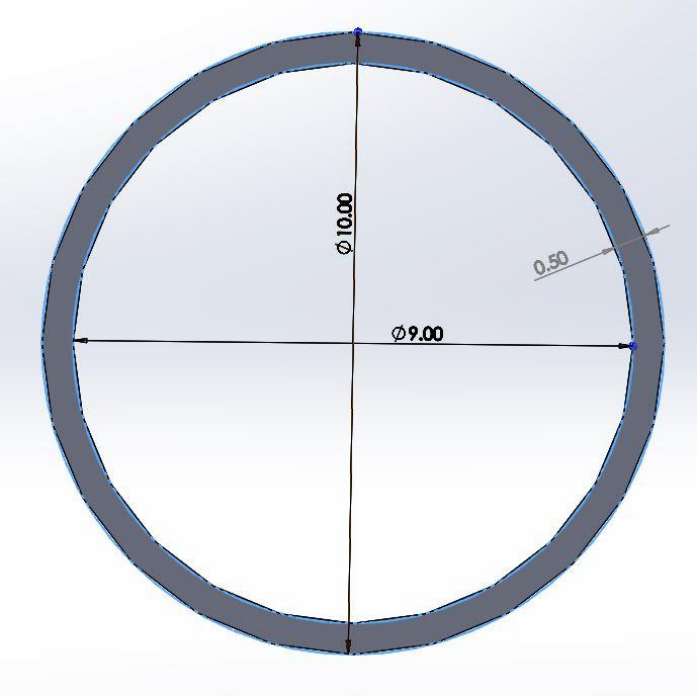
Vibration induced fatigue for sequential loading



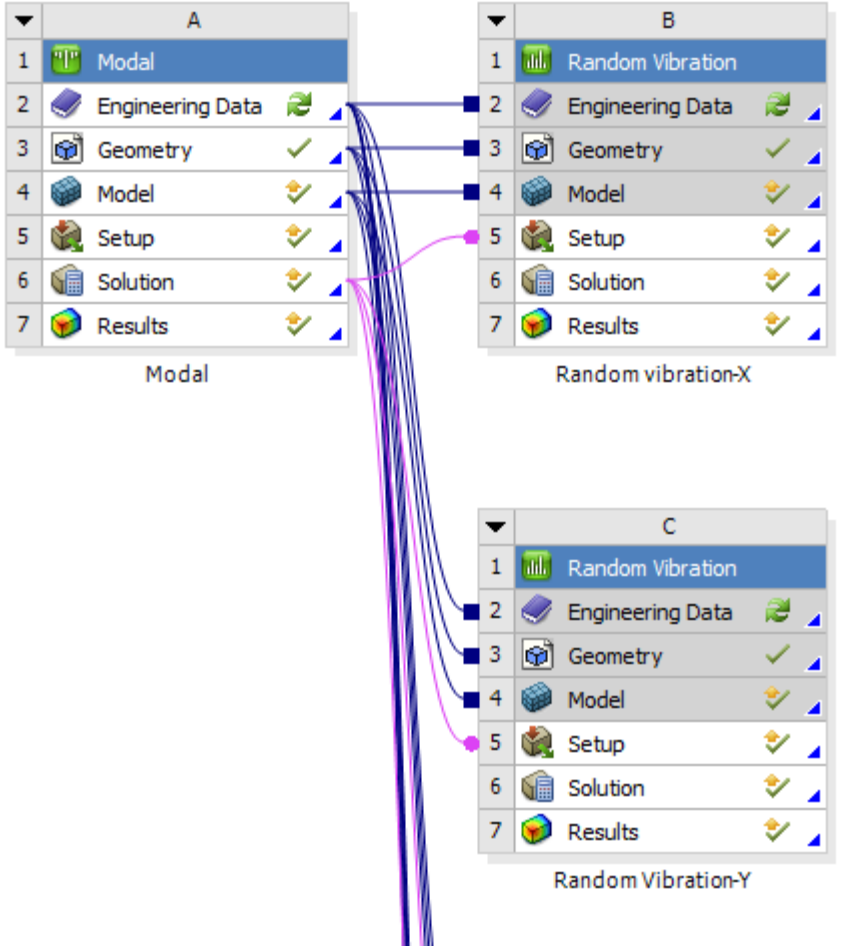
[2] “GlyphWorks Fatigue Theory Guide,” 2012. NCode manual

Vibration-induced fatigue for sequential loading

- 1 tube
- Length = 1 m
- Outer Radius = 10 mm
- Thickness = 0.5 mm
- Both ends clamped
- Structural steel material used
- Modal analysis
- Followed by random vibration analysis

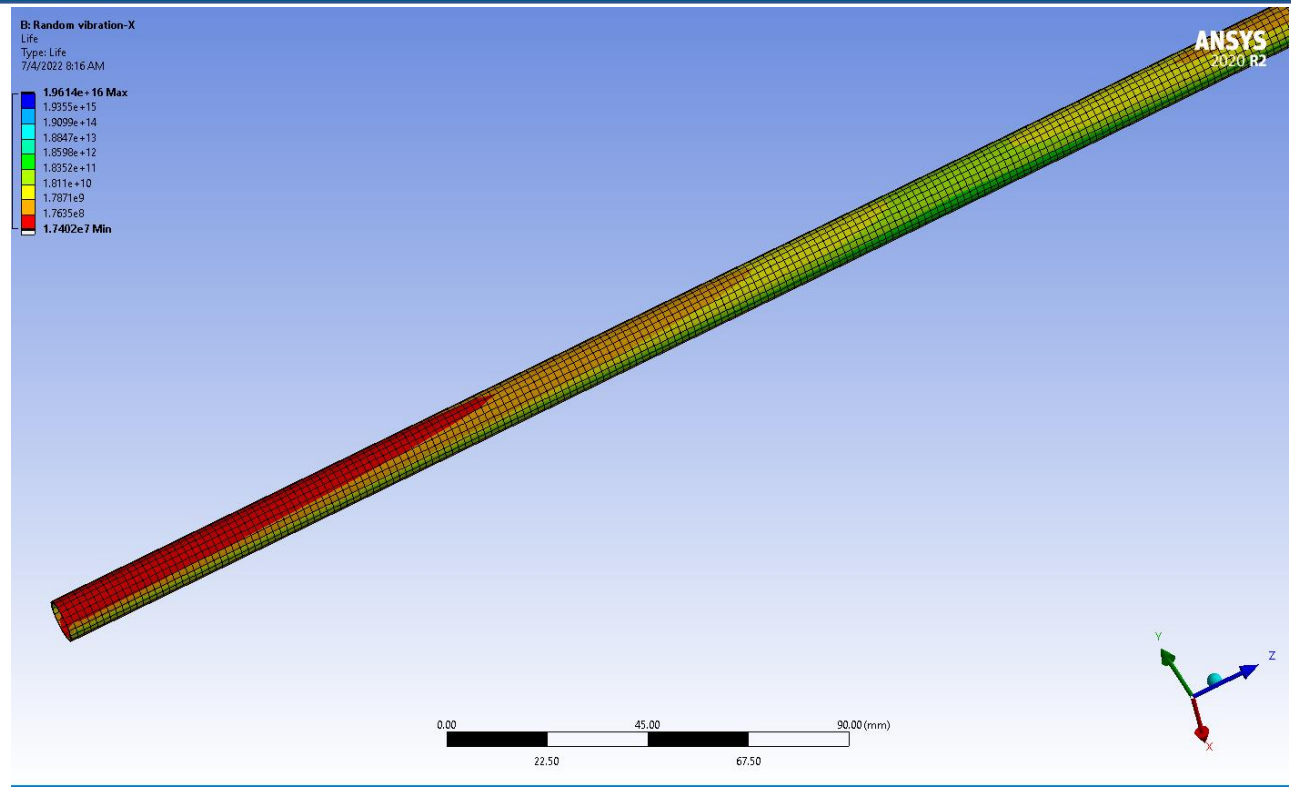


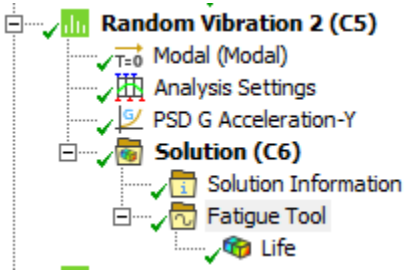
- Modal analysis
  1. 3D solid tube
  2. Hexahedral meshing was used
  3. Modal analysis was done for the first six modes.
  4. Acceleration was sequentially applied in X, Y and Z directions.



Stress Amplitudes from FRF

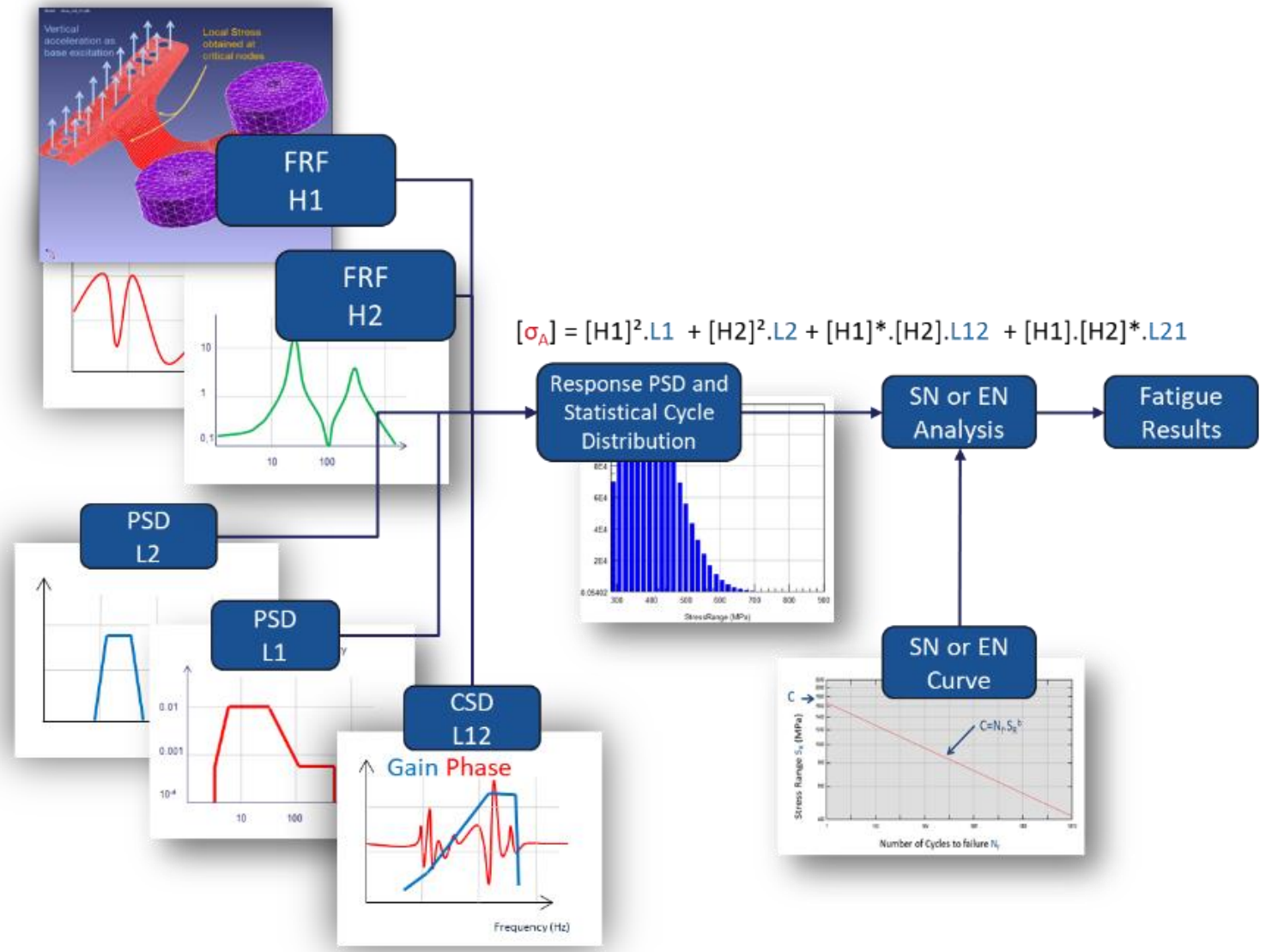
- Random vibration analysis
  1. Acceleration was sequentially applied in X, Y and Z directions.
  2. Three damage counting methods, namely Narrow-band, Steinberg and Wirsching.
  3. Equivalent von-mises stress was used for the calculation.





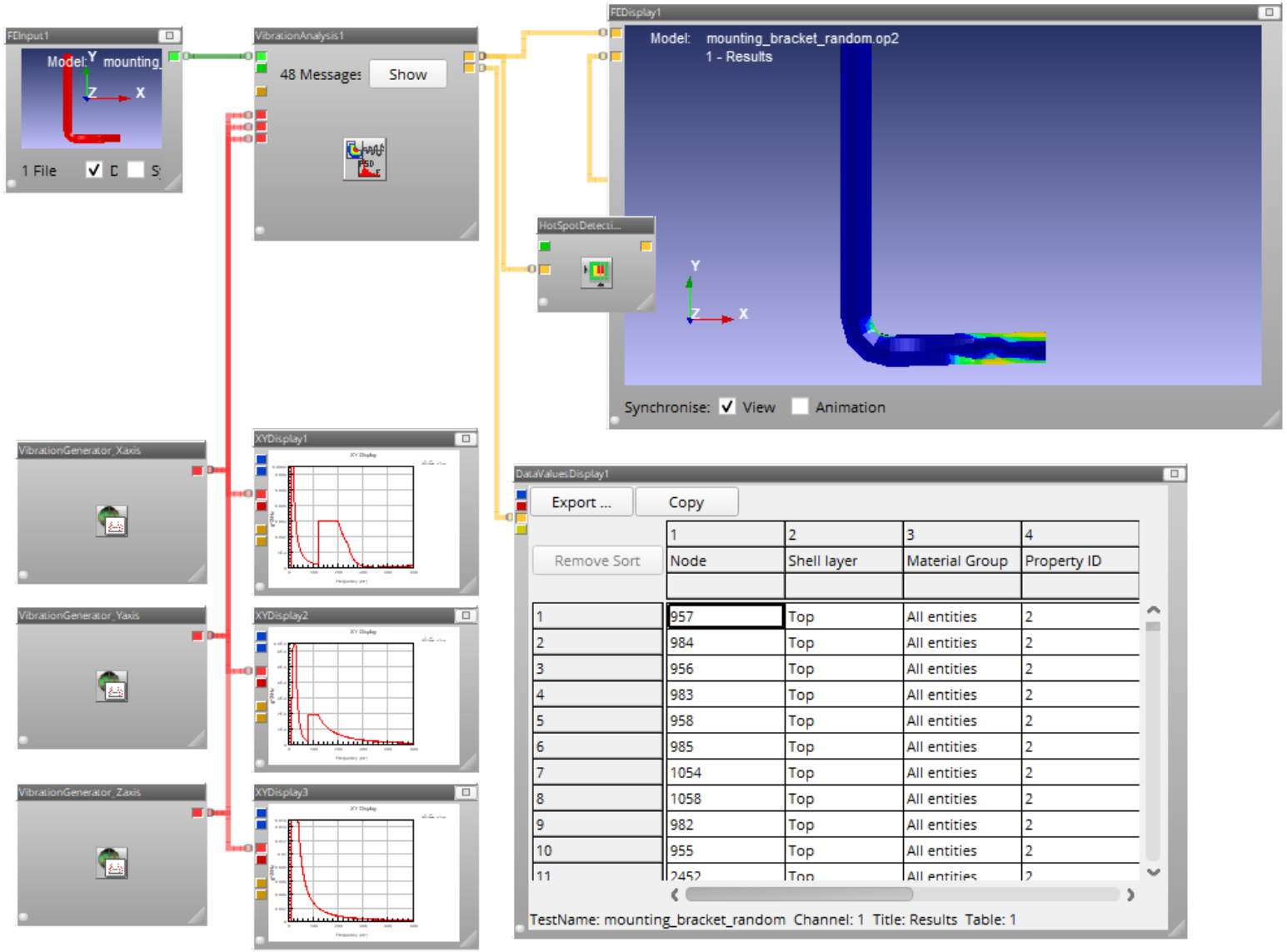
Domain	
Domain Type	Frequency
Options	
Method Selection	Steinberg
Stress Component	Equivalent (von-Mises)
Coordinate System	Solution Coordinate System

Vibration-induced fatigue for multi-axial loading

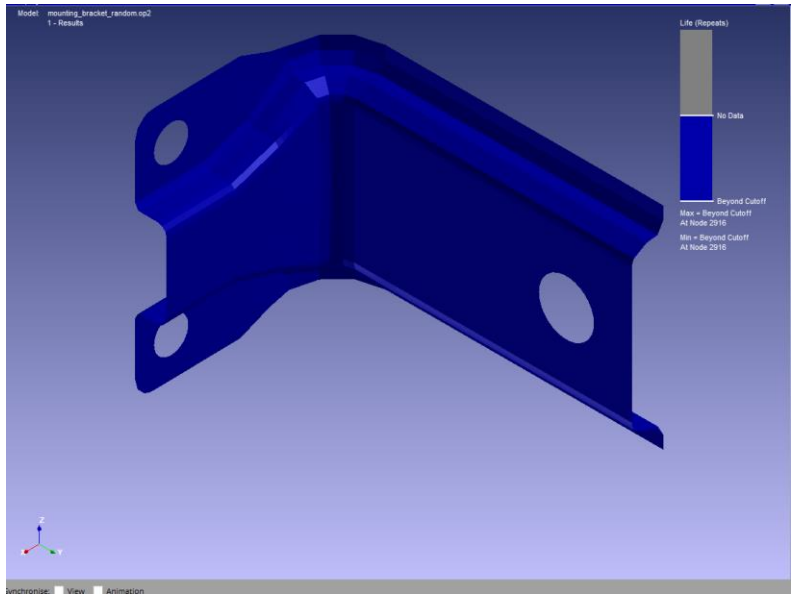


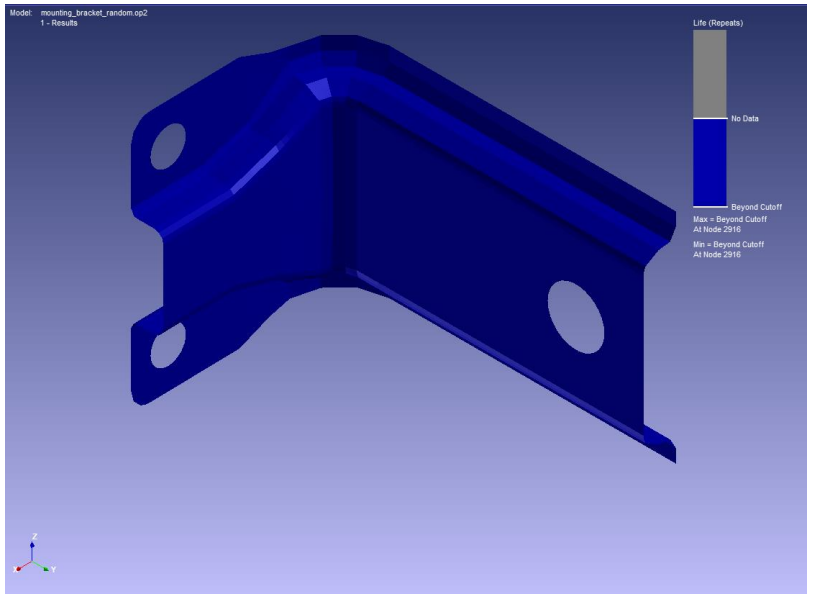
[2] "GlyphWorks Fatigue Theory Guide," 2012. NCode manual

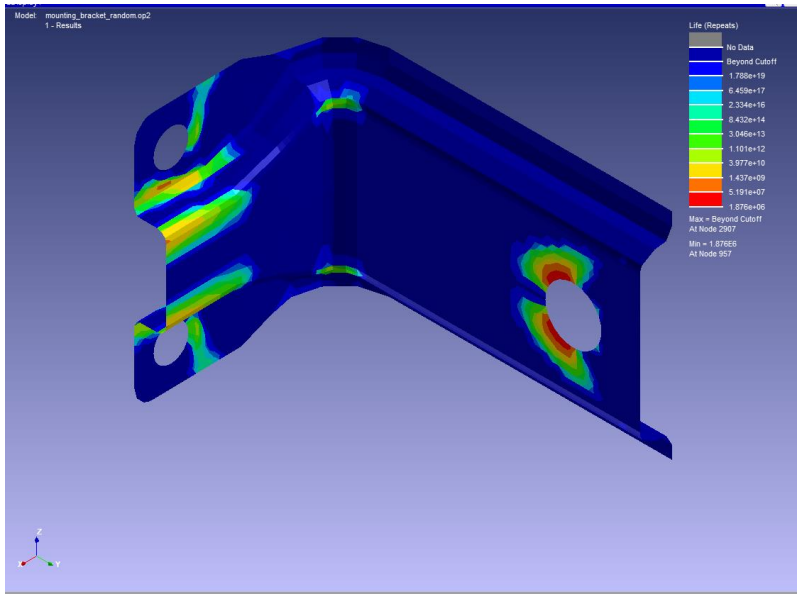
Vibration induced fatigue for sequential loading



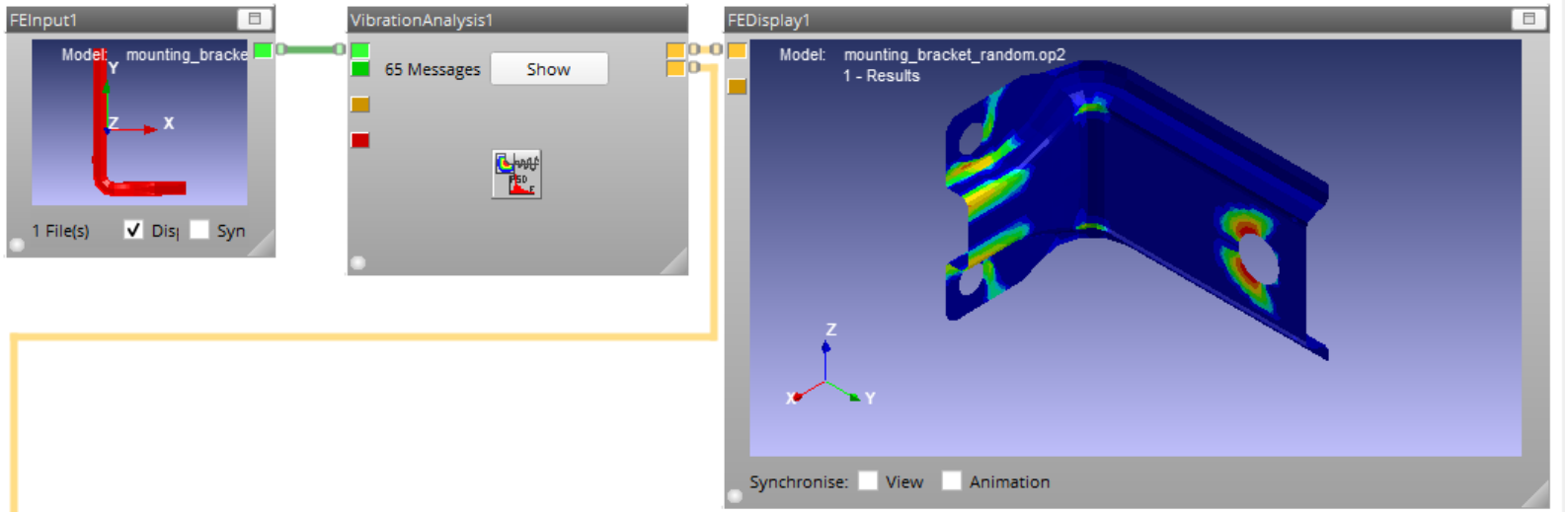
Vibration induced fatigue for sequential loading







Vibration induced fatigue for multi-axial loading



DataValuesDisplay1

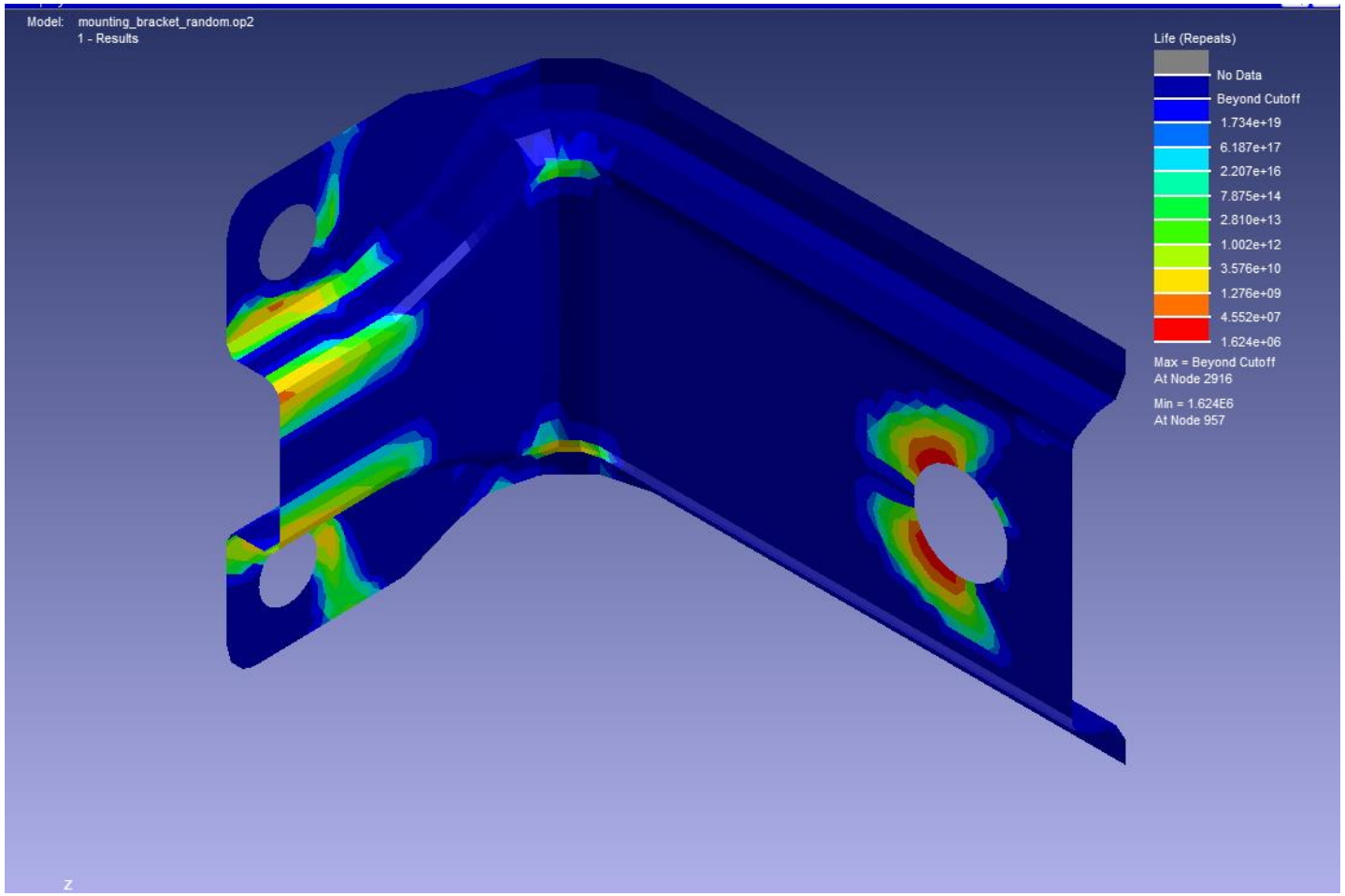
Export ... Copy

Remove Sort

	1	2	3	4	5	6	7	8	9	10
	Node	Shell layer	Material Group	Property ID	Material ID	Damage	RMS stress	Mean stress	Return Period to	Irregularit
							MPa	MPa	s	
1	957	Top	All entities	2	1	5.332e-07	66.21	0	8.251e+08	0.9448
2	984	Top	All entities	2	1	5.202e-07	66.06	0	9.194e+08	0.9447
3	956	Top	All entities	2	1	4.541e-07	64.9	0	2.208e+09	0.9448
4	983	Top	All entities	2	1	4.507e-07	64.83	0	2.317e+09	0.9448
5	958	Top	All entities	2	1	2.709e-07	60.88	0	6.8e+10	0.945
6	985	Top	All entities	2	1	2.632e-07	60.65	0	8.411e+10	0.9447
7	1054	Top	All entities	2	1	1.432e-07	56.48	0	6.878e+12	0.9448
8	1058	Top	All entities	2	1	1.42e-07	56.42	0	7.378e+12	0.9448
9	982	Top	All entities	2	1	1.309e-07	55.85	0	1.463e+13	0.9448
10	955	Top	All entities	2	1	1.305e-07	55.83	0	1.502e+13	0.9447
11	2452	Top	All entities	2	1	8.276e-08	53.04	0	5.877e+14	0.9449
12	1468	Top	All entities	2	1	8.121e-08	52.91	0	6.998e+14	0.9447
13	1060	Top	All entities	2	1	6.525e-08	51.67	0	4.426e+15	0.945

TestName: mounting_bracket_random Channel: 1 Title: Results Table: 1

Vibration induced fatigue for sequential loading



Thank you for your attention

Questions