Damage under variable loading

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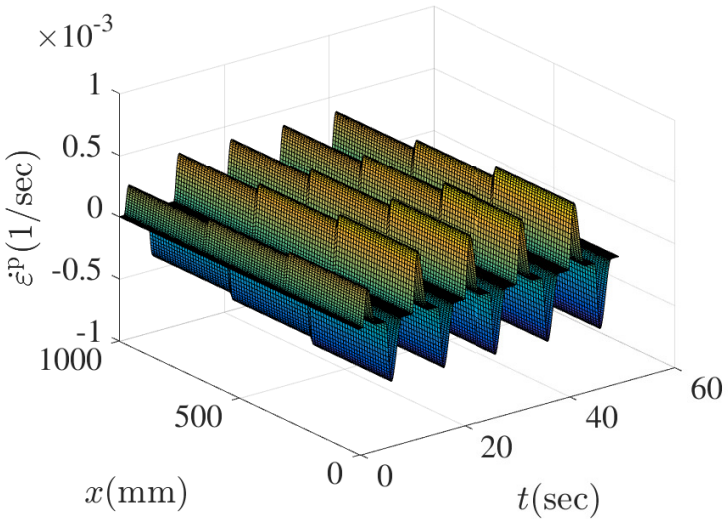
20. September 2017



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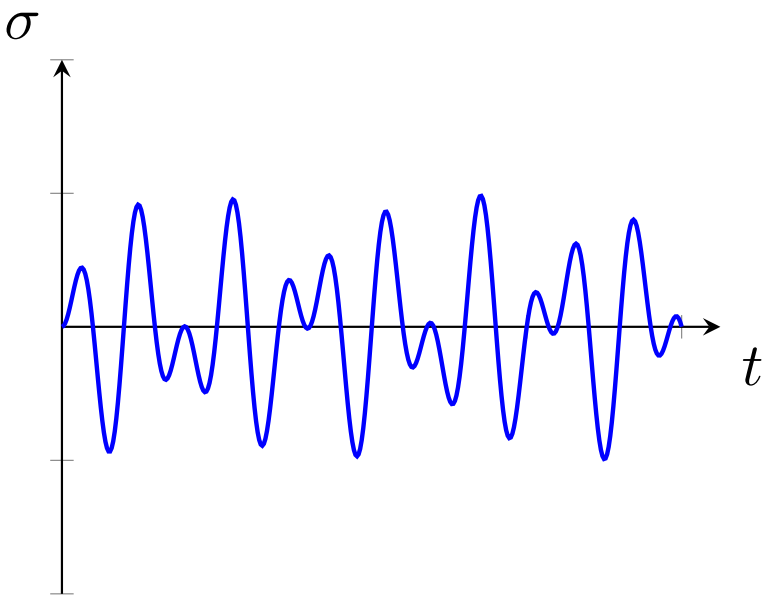
Fatigue damage

- Cyclic loading



Fatigue damage

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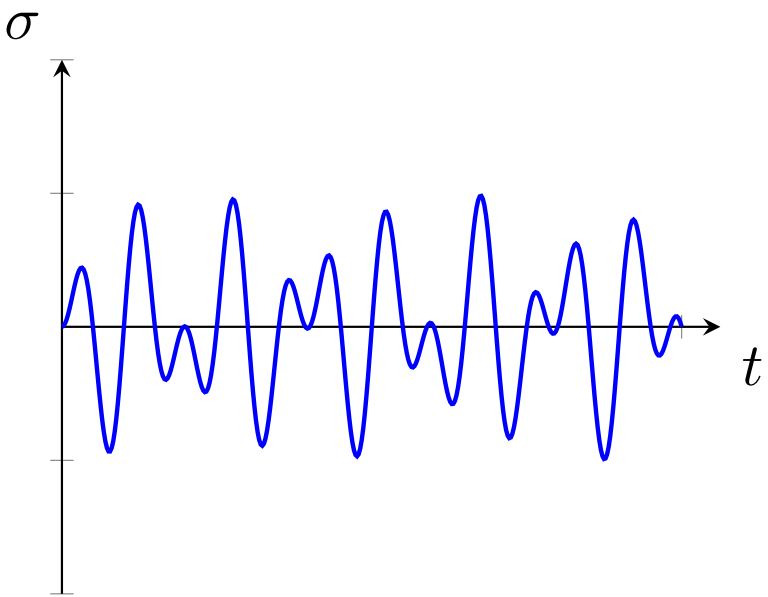

- Damage

Image by alegri / 4freephotos.com

Fatigue damage

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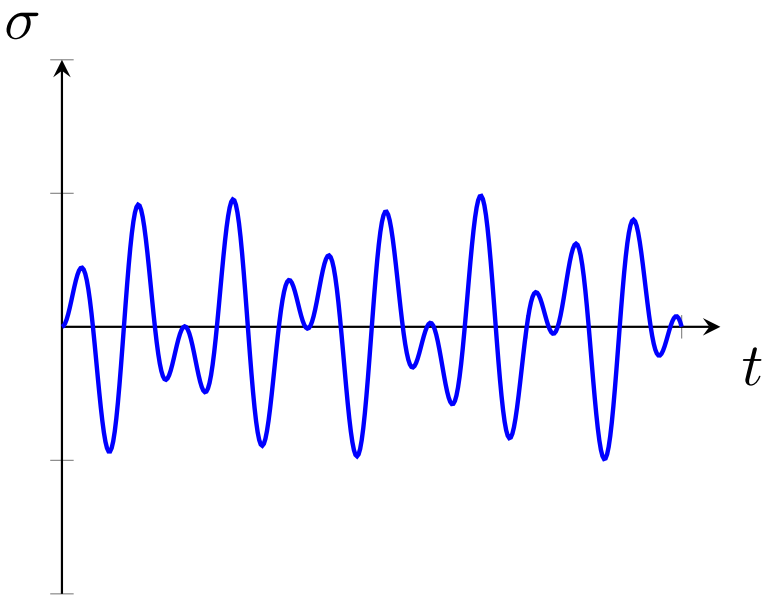

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Fatigue damage

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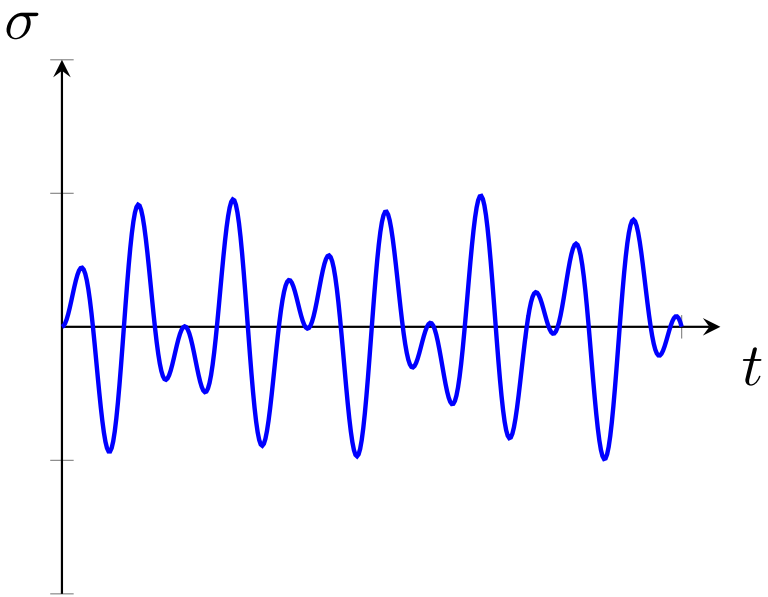

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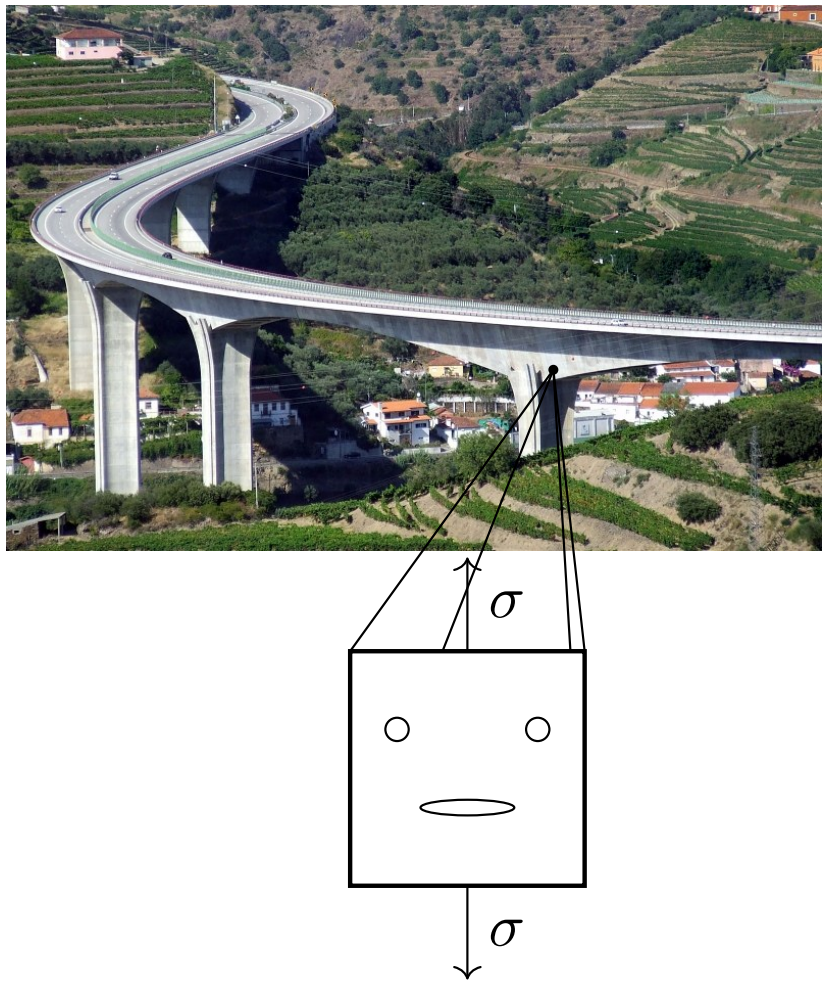


Fatigue damage

- LATIN method

  • An approximation on the **whole time-space domain** is obtained.

  • The balance equation is solved as a **linear** problem.

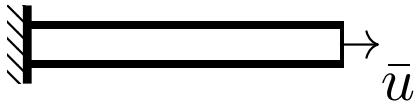
- Model order reduction (MOR)

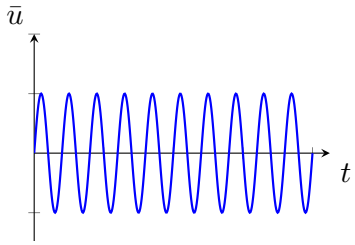
  • Proper generalised decomposition (PGD)

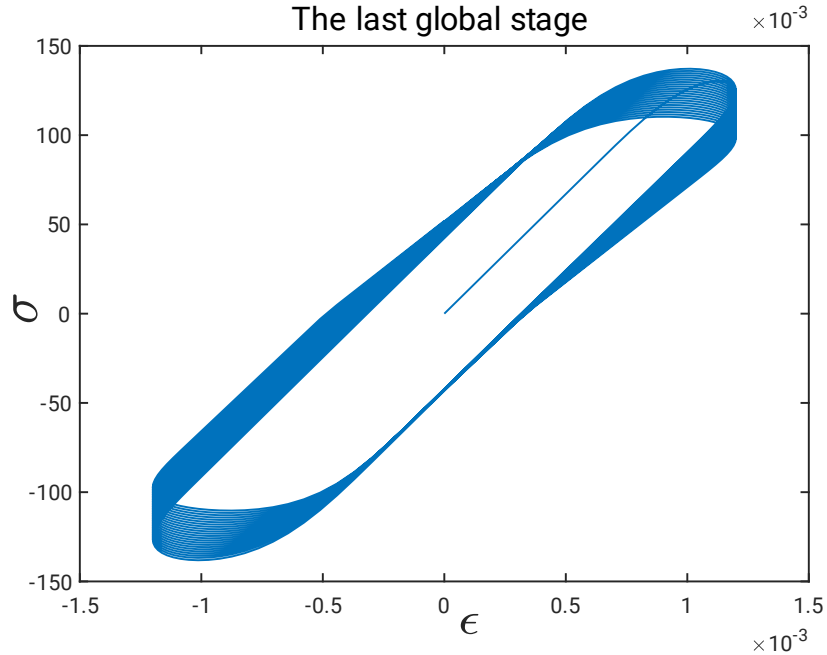
  [Chinesta, Ladevèze 2014]

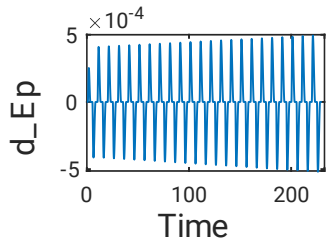
$$\varepsilon^{\mathrm{p}}(x,t) \approx \sum_{i=1}^{n} \bar{\varepsilon}_i^{\mathrm{p}}(x)\ \lambda_i(t)$$

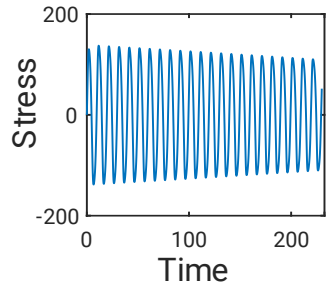
Numerical example

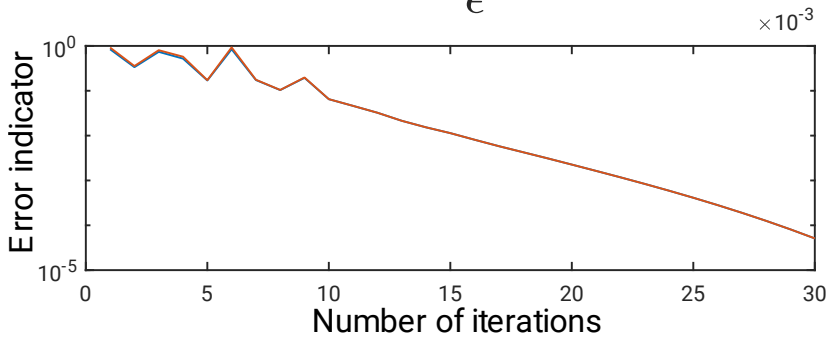


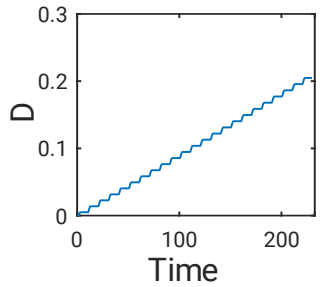




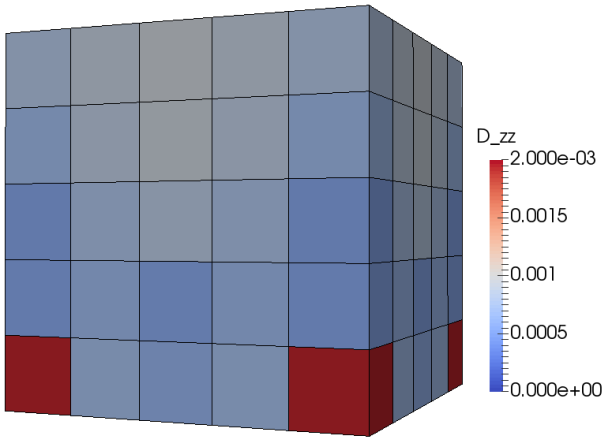


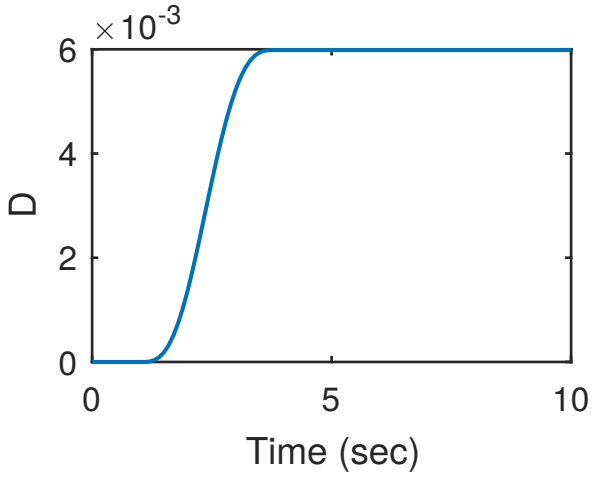


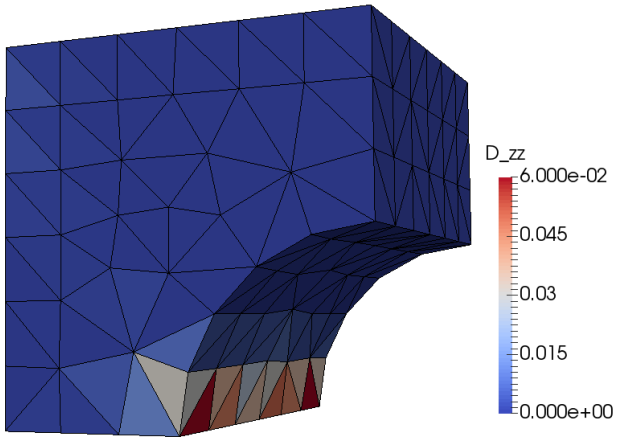


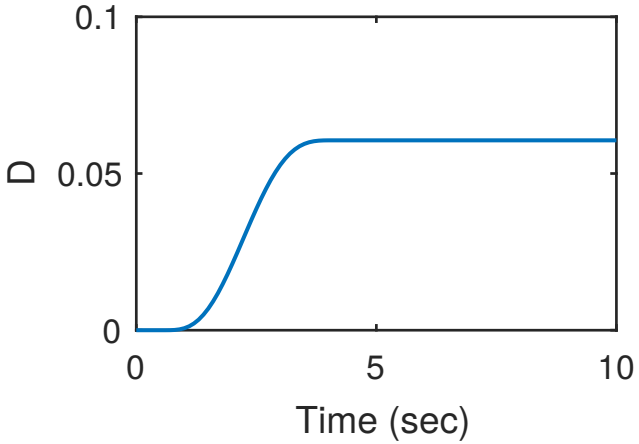


Damage evolution









Variable loading

Different types of loads are applied on different structures

- Pressure vessels
- Bridges
- Aircraft

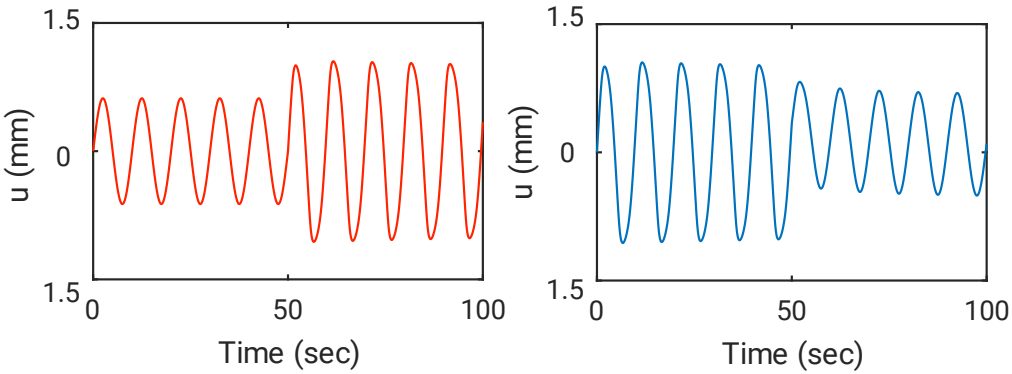
These loads may be characterised in two different groups

- Deterministic loads, e.g. loads on a pressure vessel.
- Stochastic loads, e.g. wind and ocean forces.
  A description of such loads can only be given using a statistical approach.

Description of load histories.

Block loading

- Cycle counting methods.
- Randomness may be introduced in the order of the blocks.



- Miner's rule: $D = r = \sum_{i=1}^{k} \frac{n_i}{N_{f\,i}}$

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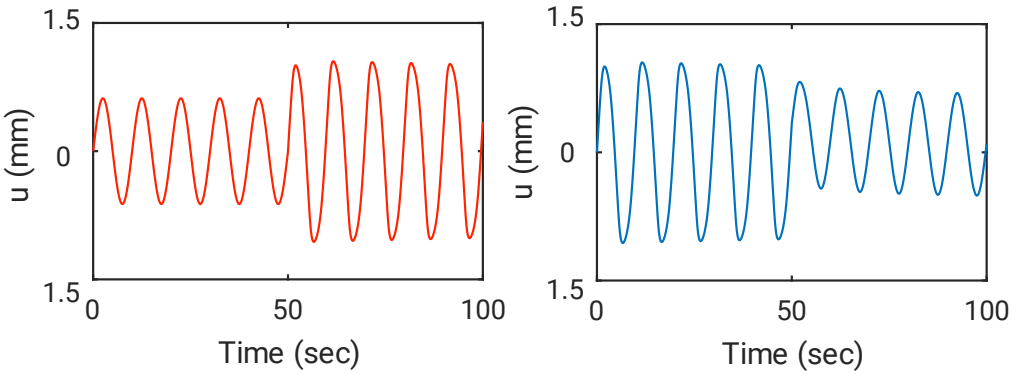

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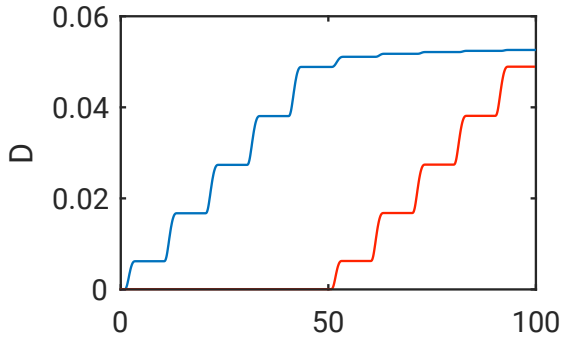
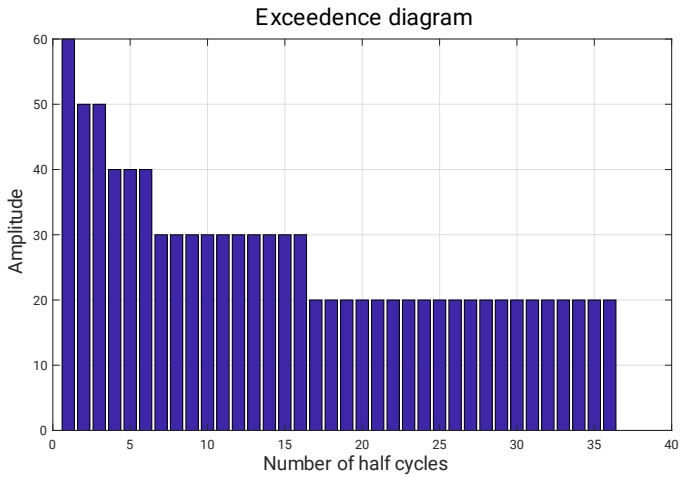
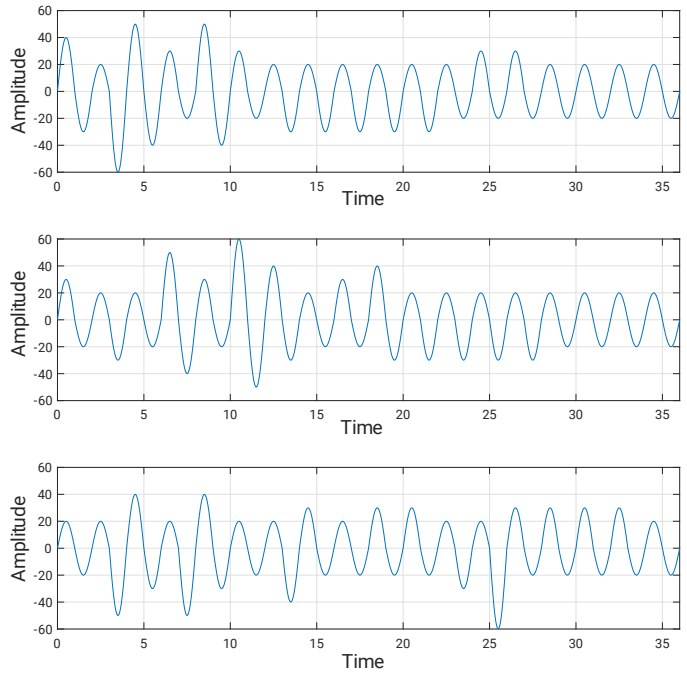


Standardised load histories

- Loadings are reported in an exceedance diagram (spectrum shape).
- The root mean square for each block is sometimes defined.

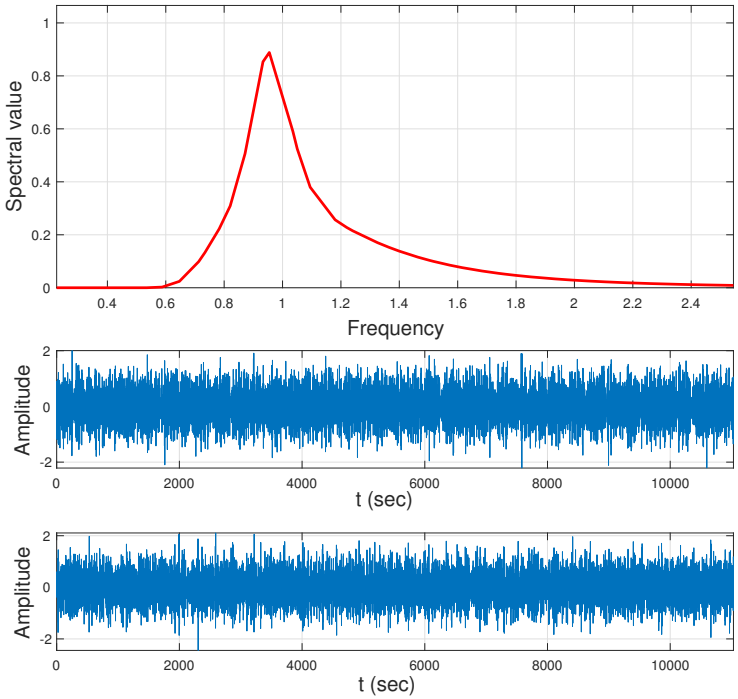


Amplitude	# half cycles
60	1
50	2
40	3
30	10
20	20



Random loading

- defined by a power spectral density function (PSD).
- Variable amplitudes and frequencies.



$$a_i = \sqrt{2 \int_{\omega_1}^{\omega_2} S(\omega)\, \mathrm{d}\omega}$$

$$\approx \sqrt{2\, S_i(\omega_i)\, \Delta\omega_i}$$

$$\eta = \sum_{i=1}^{n} a_i \cos(\omega_i\, t + \varphi_i)$$

Outlook

- 3D continuum damage model.
- LATIN-PGD framework.
- Literature review on variable loading.

Future activities:

- Two-time scale approach
  - Introducing block loading.
  - Accounting for standardised load histories.
- HCF computations.
- Dynamic effects.

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Thank you for your attention.