HORN FATIGUE LIFE ESTIMATION UNDER MAGNETIC FORCES (SPECTRAL METHOD)

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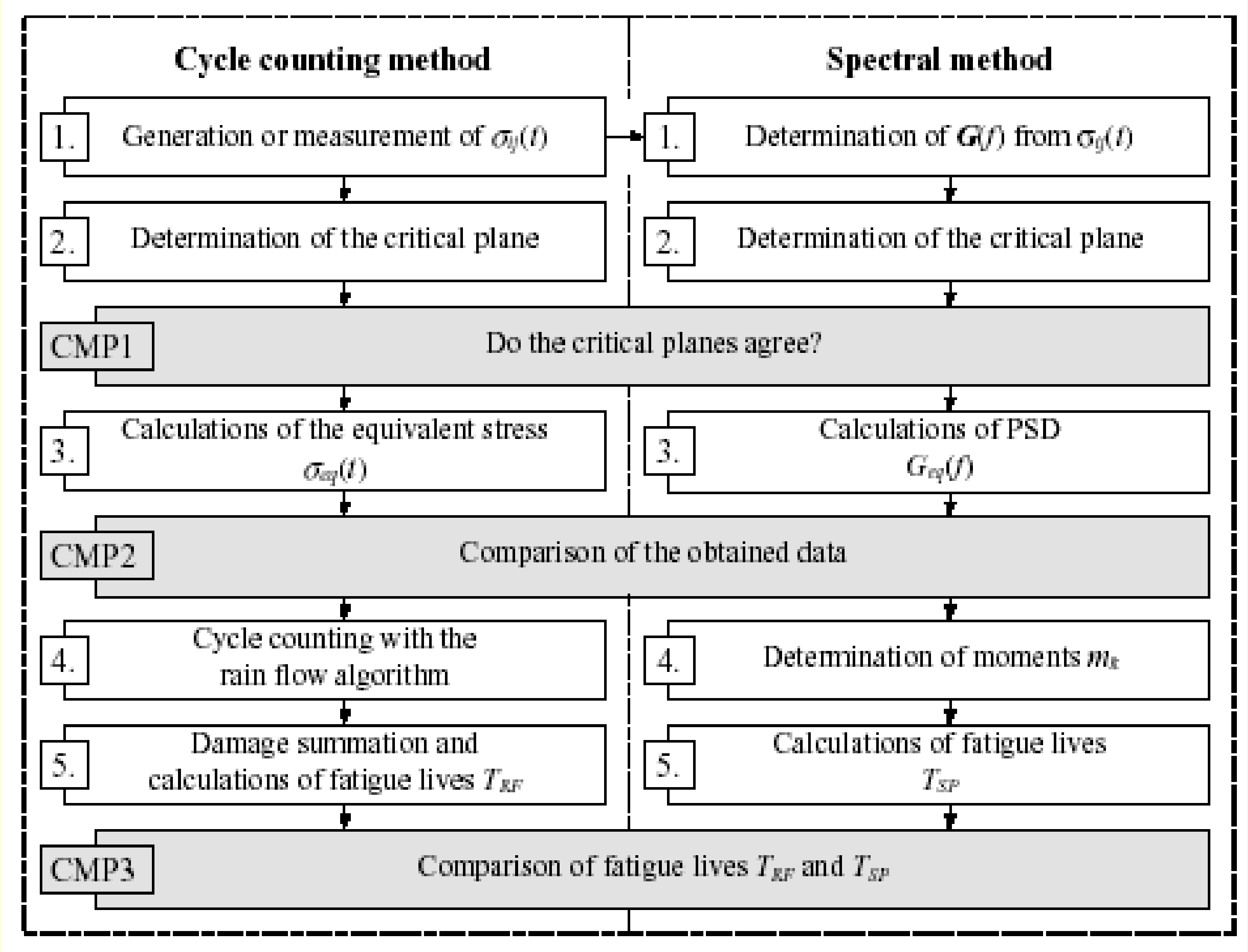
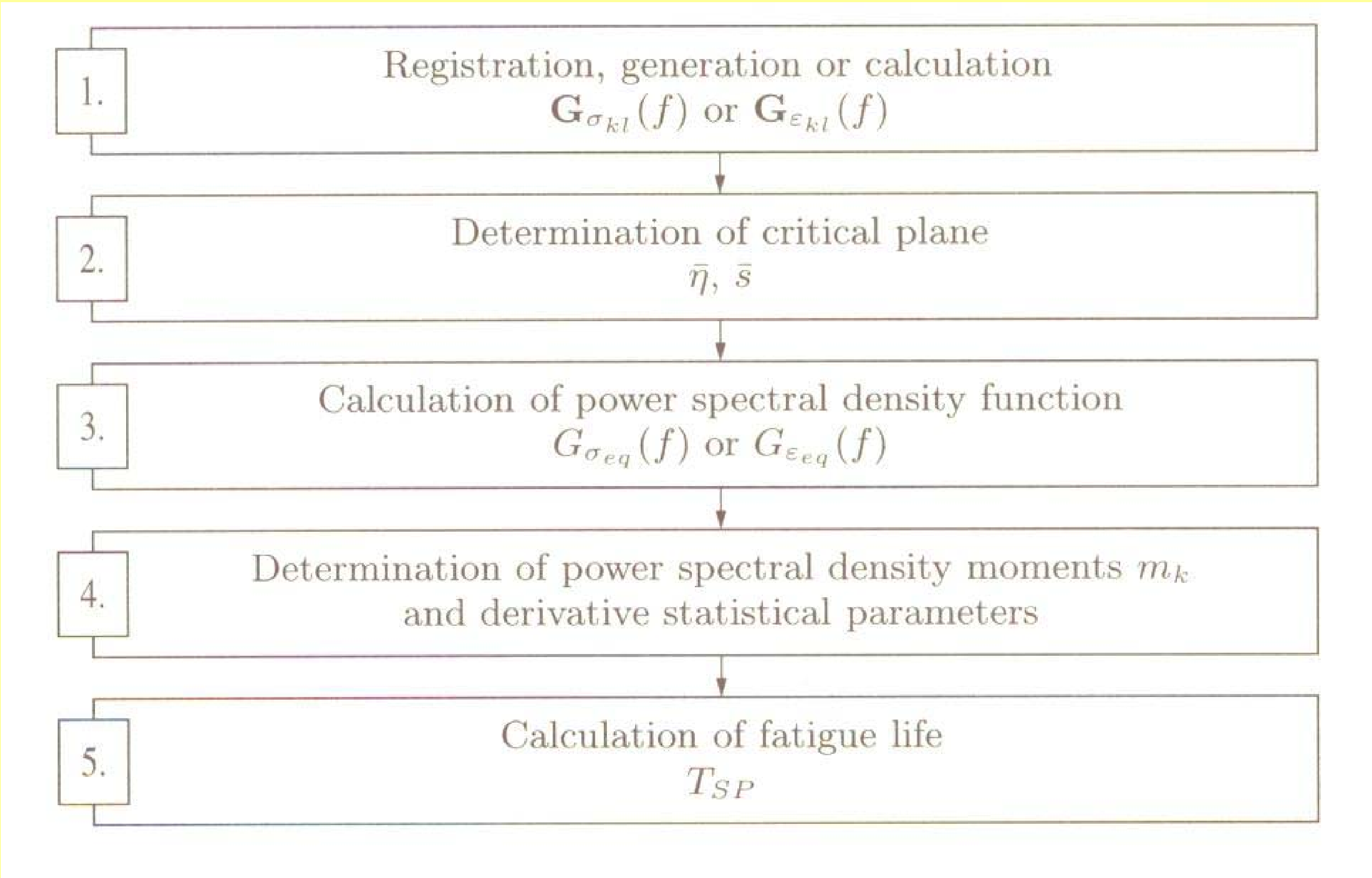
Outline of the talk

- Spectral method
- Horn pulse magnetic force response (Ansys)
- Life time for magnetic stress (dynamic)
- Life time for magnetic stress (dynamic) and thermal stress (static)
- Conclusions

Cycle counting vs. Spectral method



Spectral method



Dirlik formulas

Probability density function of stress ranges

$$p(\Delta\sigma) = \frac{1}{2\sqrt{\xi_0}}\left[\frac{G_1}{Q}e^{\frac{-Z}{Q}} + \frac{G_2 Z}{R^2}e^{\frac{-Z^2}{2R^2}} + G_3 Z e^{\frac{-Z^2}{2}}\right], \qquad (3.47)$$

$$Z = \frac{\Delta\sigma}{2\sqrt{\xi_0}}, \qquad G_1 = \frac{2(x_\xi - I^2)}{1+I^2},$$

$$G_2 = \frac{1 - I - G_1 + G_1^2}{1-R}, \qquad G_3 = 1 - G_1 - G_2,$$

$$R = \frac{I - x_\xi - G_1^2}{1 - I - G_1 + G_1^2}, \qquad Q = \frac{1{,}25(I - G_3 + G_2 R)}{G_1},$$

$$x_\xi = \frac{\xi_1}{\xi_0}\left(\frac{\xi_2}{\xi_4}\right)^{\frac{1}{2}}, \qquad I = \frac{\xi_2}{\sqrt{\xi_0 \xi_4}}.$$

Coefficient matrix for Von Mises hyphothesis

$$\mathbf{Q}_M = \begin{bmatrix} 1 & -0{,}5 & -0{,}5 & 0 & 0 & 0 \\ -0{,}5 & 1 & -0{,}5 & 0 & 0 & 0 \\ -0{,}5 & -0{,}5 & 1 & 0 & 0 & 0 \\ 0 & 0 & 0 & 3 & 0 & 0 \\ 0 & 0 & 0 & 0 & 3 & 0 \\ 0 & 0 & 0 & 0 & 0 & 3 \end{bmatrix}.$$

Life time (S-N curve)

$$T = \frac{1}{M + \int_0^\infty \frac{p(\Delta\sigma)}{N_f(\Delta\sigma)} d\Delta\sigma}$$

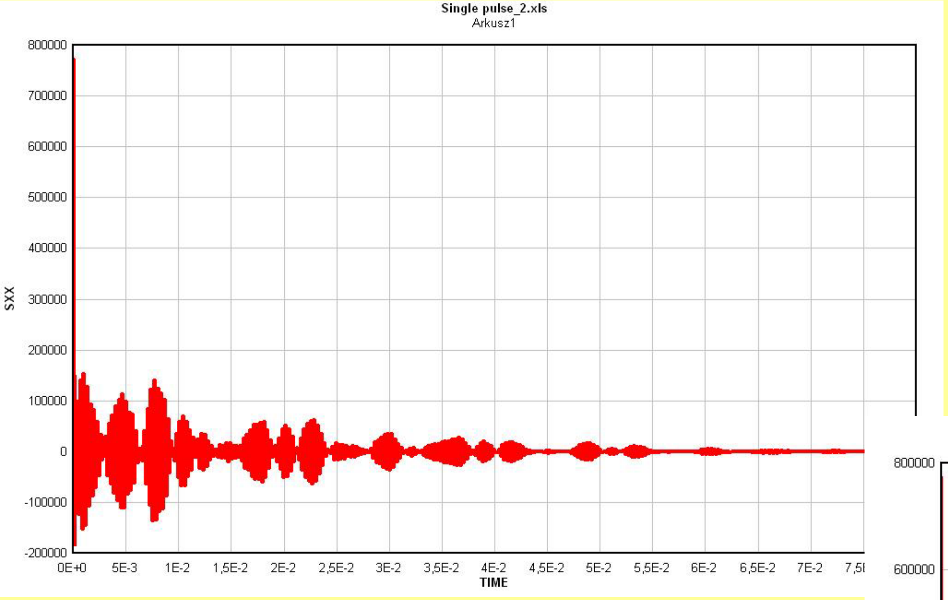
Equivalent PSD function for multiaxial stress

$$G_{eq}(f) = \mathrm{Trace}\{\mathbf{Q}\mathbf{G}_{\sigma\sigma}(f)\} = \sum_{i,j} Q_{ij} G_{\sigma_i\sigma_j}(f), \qquad (2.73)$$

where: Q_{ij} – ij indexed coefficient of $\mathbf{Q}$ matrix,
$G_{\sigma_i\sigma_j}(f)$ – power autospectral density ($i = j$) or cross-spectral density ($i \neq j$) functions of vector $\boldsymbol{\sigma}$ components.

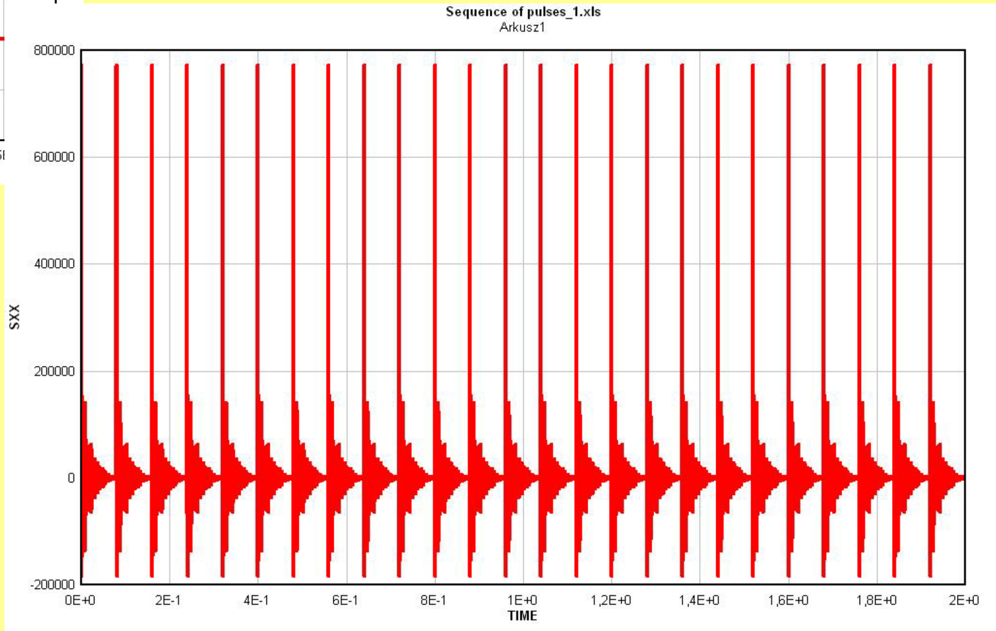
Horn response under pulse magnetic forces

Single pulse



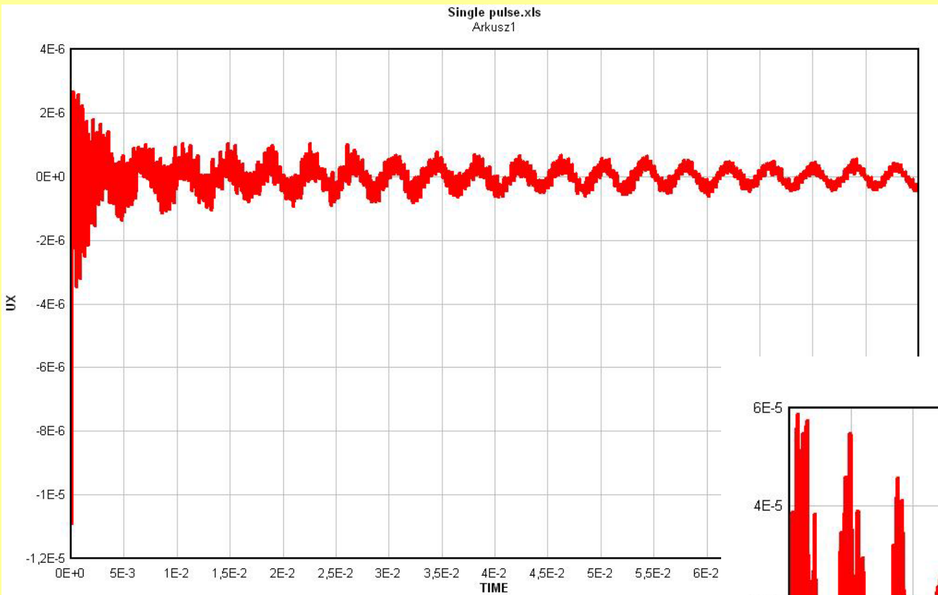
SXX STRESS

Sequence of 25 pulses



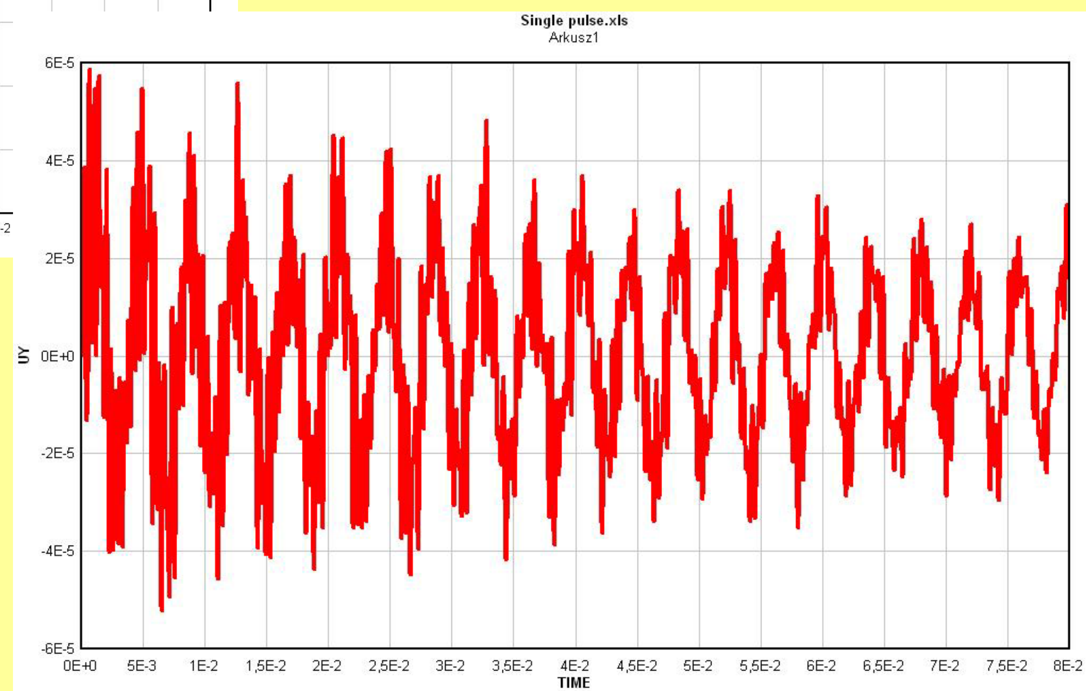
Horn response under pulse magnetic forces

Displacement UX



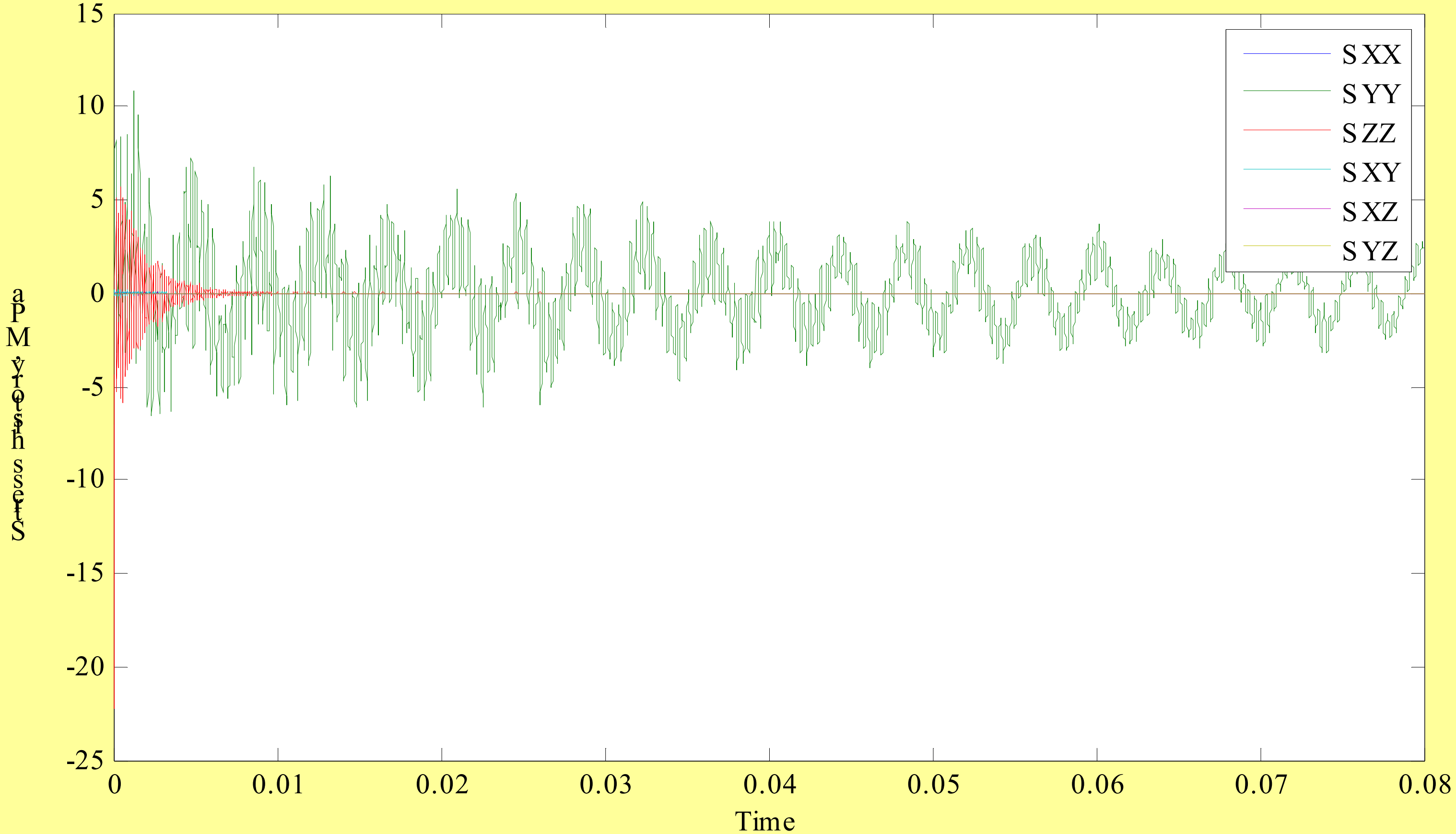
SINGLE PULSE

Displacement UY



Horn response under pulse magnetic forces

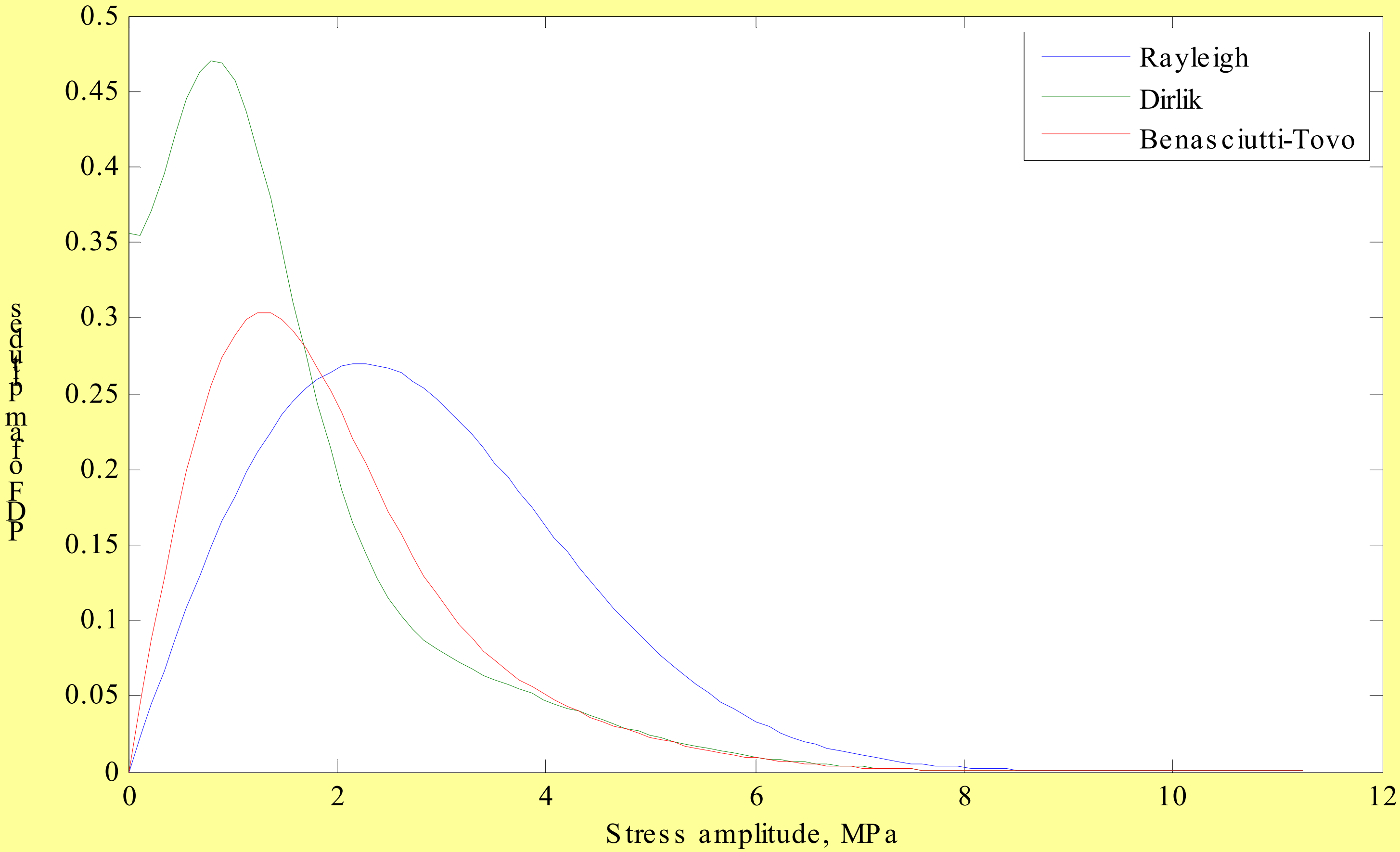
SINGLE PULSE – stress SXX,SYY,SZZ,SXY,SXZ,SYZ



Horn response under pulse magnetic forces

SINGLE PULSE – probability density functions of stress ranges for chosen models

Assumed maximal magnetic stress – SMAX=22.5 MPa



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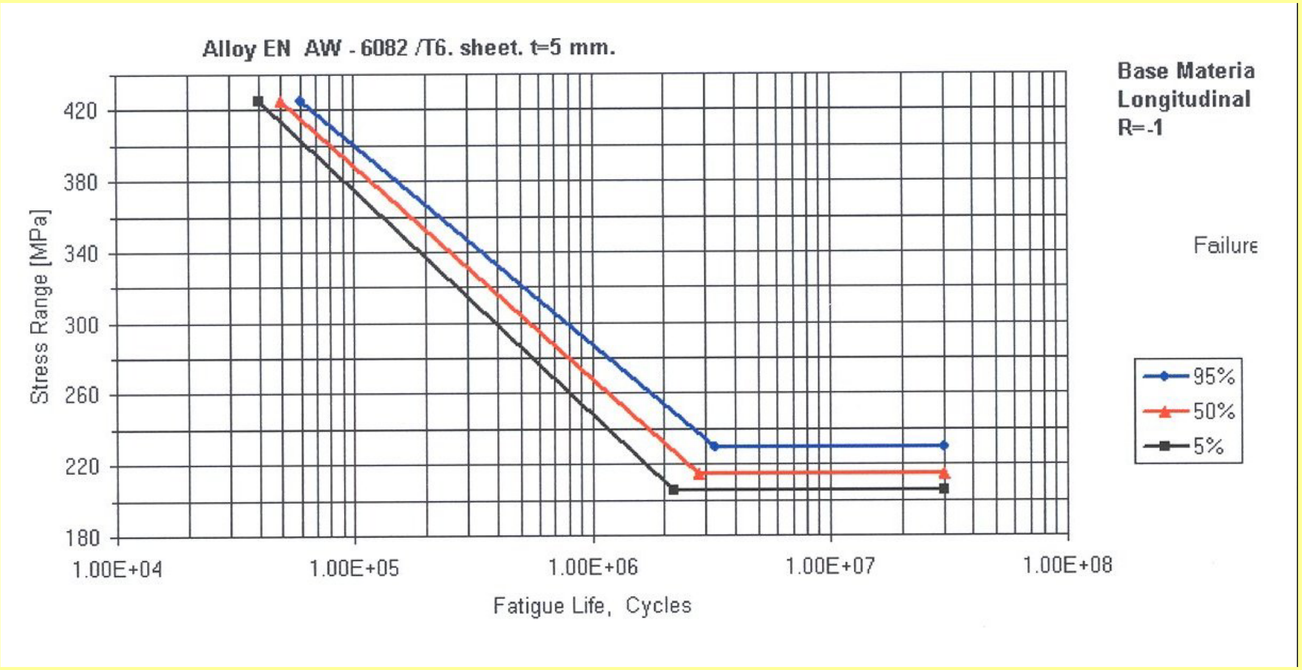
Horn response under pulse magnetic forces

SINGLE PULSE with maximal magnetic stress – SMAX=22.5 MPa
estimated life time

S-N curve – probability	Life time [s]		
	Rayleigh	Dirlik	Benasciutti-Tovo
95%	4.6876e+012	1.6020e+013	1.6579e+013
50%	3.3515e+011	1.1410e+012	1.1682e+012
5%	6.3029e+010	2.1383e+011	2.1720e+011



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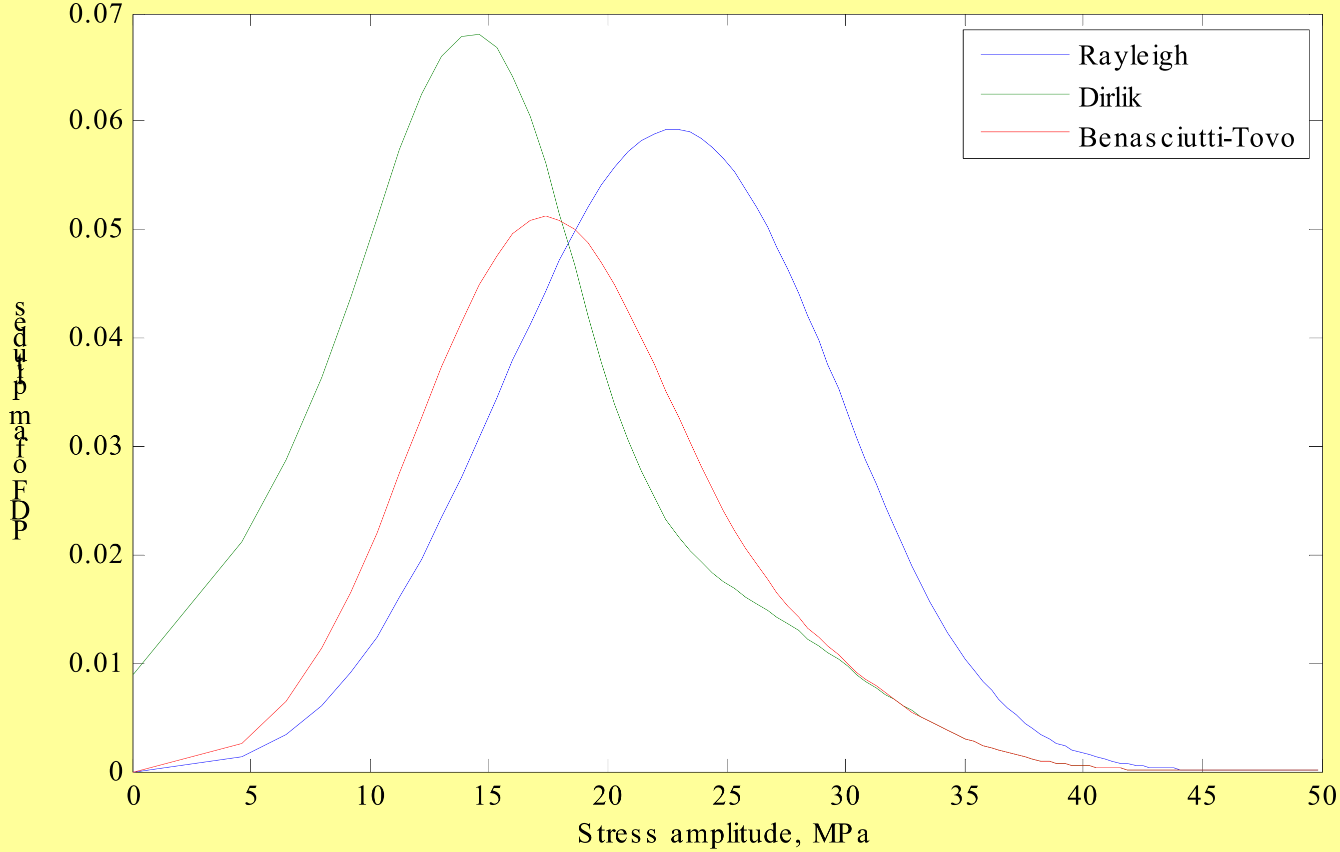
Horn response under pulse magnetic forces

SINGLE PULSE – probability density functions of stress ranges for chosen models

Assumed constant thermal stress (Smith-Watson-Topper model) – SVM=102.5 MPa and maximal magnetic stress – SMAX=41 MPa



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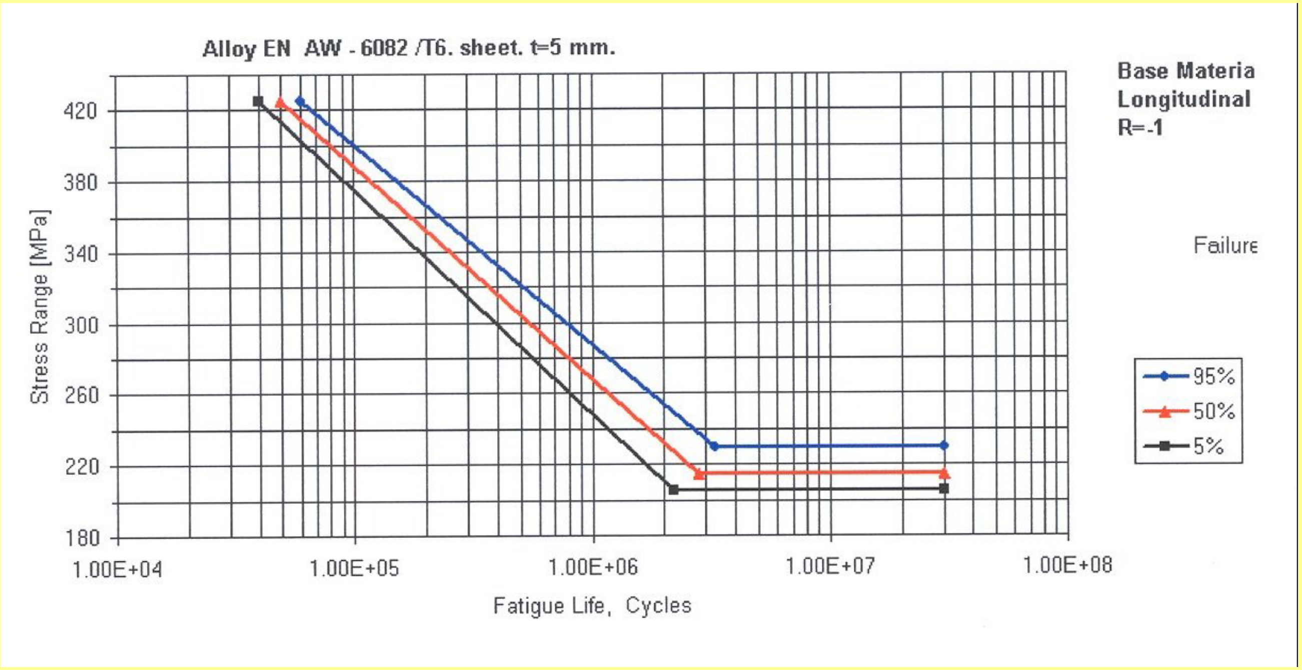
Horn response under pulse magnetic forces

SINGLE PULSE with static THERMAL STRESS
and maximal magnetic stress SMAX=41 MPa – estimated life time

S-N curve - probability	Life time [s]		
	Rayleigh	Dirlik	Benasciutti-Tovo
95%	2.7076e+007	8.6147e+007	7.9627e+007
50%	6.0195e+006	1.8589e+007	1.7026e+007
5%	2.1816e+006	6.5918e+006	6.0132e+006



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Conclusions

- Spectral (in frequency domain) method of life time estimation is an alternative method to the rainflow cycle counting (in time domain).
- Spectral method can be applied to fatigue analysis of the horn.
- The presented life time estimation of horn shows possibility of its application to pulse excited vibrations of horn.
- Detailed fatigue analysis will be carried out for final horn geometry and boundary conditions. Moreower, effects of corrosion fatigue and irradiation damage should be considered.