PROBABILITY-BASED DURABILITY PREDICTION FOR CORRODED SHELL OF STEEL CYLINDRICAL TANK FOR LIQUID FUEL STORAGE

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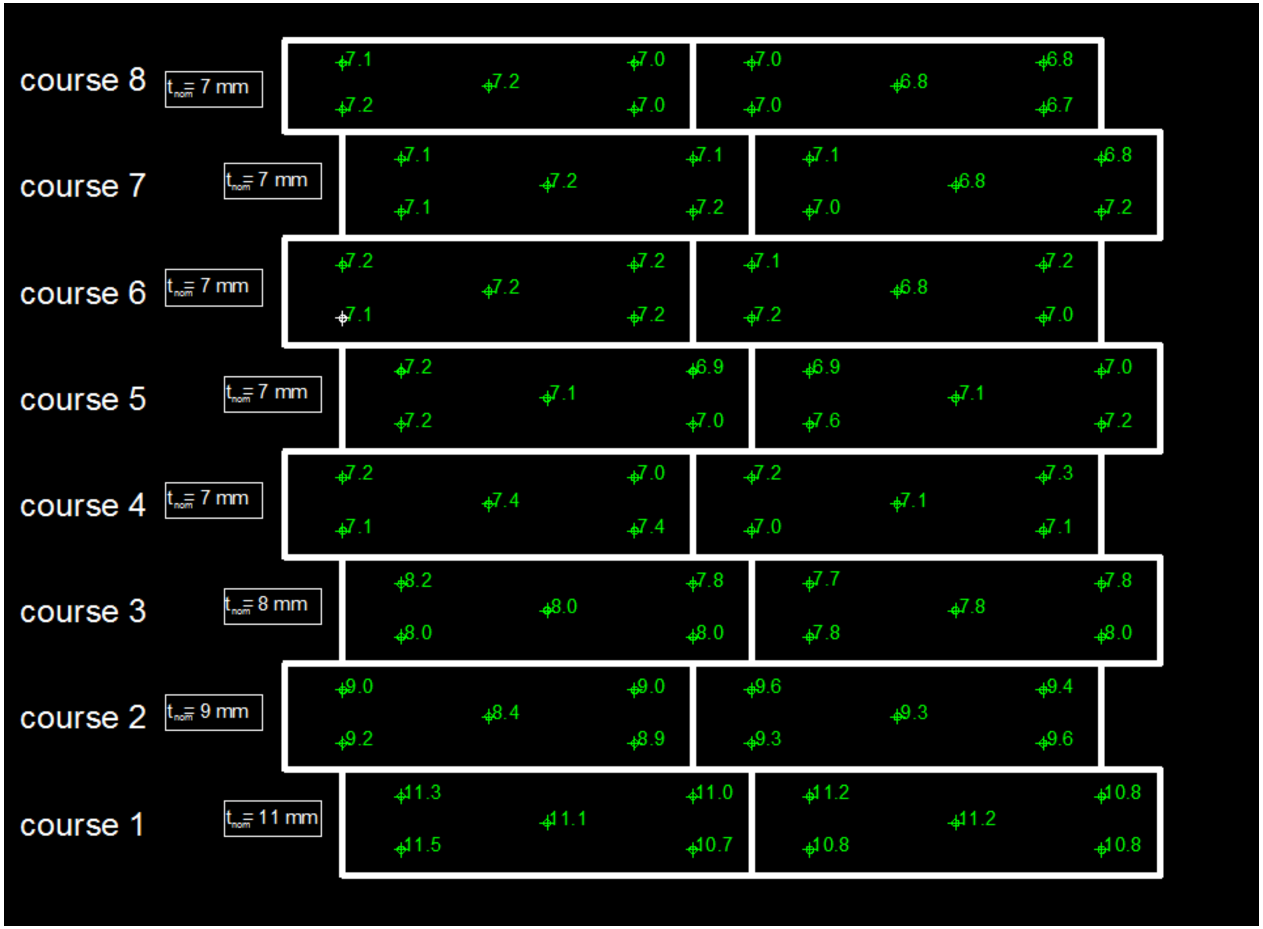
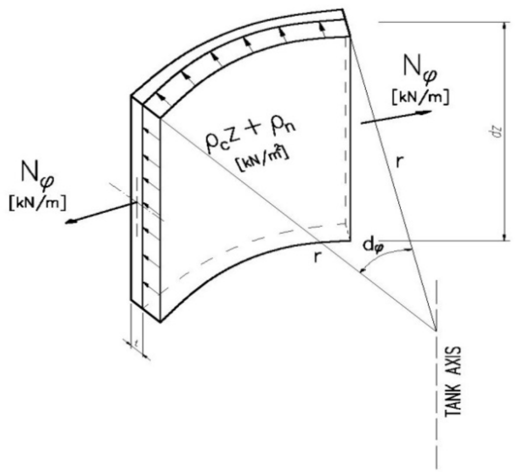
Durability of the tank shell

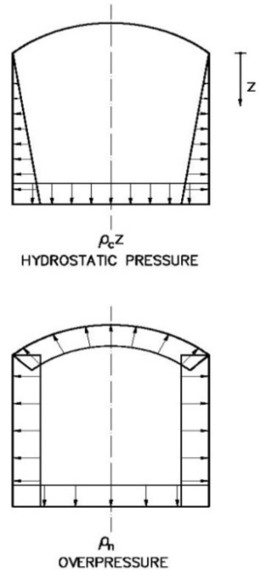
Statistical trend of a corrosion progress should be identified first and next extrapolated for coming service years

Structural health monitoring

- the inspections of the tank technical condition with detailed measurement of the thickness-loss of corroded sheets must be performed at least every 6 years if the tank service life exceeds 30 years,
- the development of such corrosion is recorded for each sheet of the shell in five characteristic points, i.e. in its geometrical center and in four corners,
- due to the cyclic repetition of such inspections the statistical trend describing the previous corrosion progress can be identified and documented.







$$N_{\varphi} = (\rho_c z + \rho_n) r \qquad N_R = \alpha_{\perp} f_y t$$

$$LN\left(\breve{f}_y, \upsilon_f\right), \; LN\left(\breve{t}, \upsilon_t\right) \rightarrow LN\left(\breve{N}_R, \upsilon_{NR}\right)$$

$$\breve{f}_y = f_{y,k} \exp\left(2{,}05\sqrt{\upsilon_f^2 + \upsilon_A^2}\right)$$

$$\upsilon_R = \sqrt{\upsilon_f^2 + \upsilon_A^2} = \sqrt{0{,}08^2 + 0{,}06^2} = 0{,}10$$

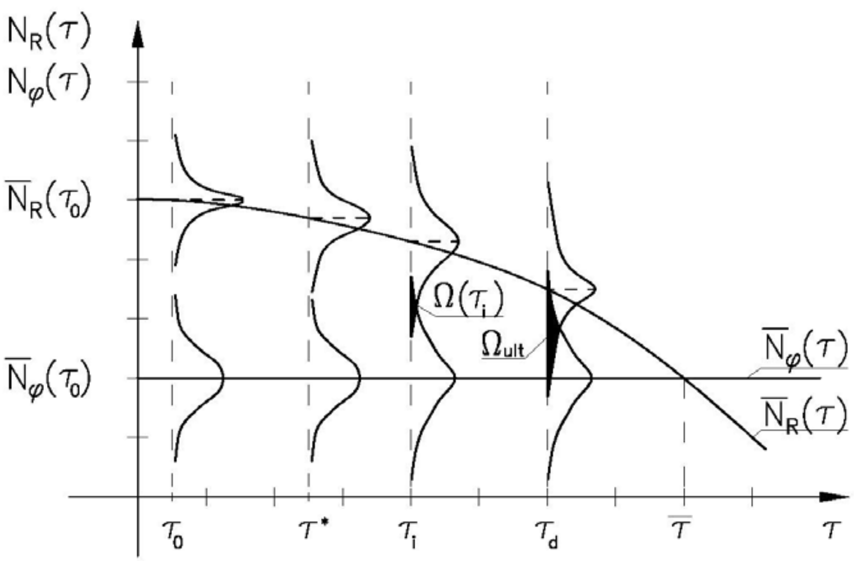
Empirical parameters:

$$\ln \breve{t}^* = \frac{1}{N}\sum_{i=1}^{N} \ln t_i^* \rightarrow \breve{t}^*$$

$$\upsilon_t^* = \sqrt{\frac{1}{N-1}\sum_{i=1}^{N} \ln^2\left(\frac{t_i^*}{\breve{t}^*}\right)}$$

$$\breve{N}_R^* = \alpha_{\perp} \breve{f}_y \breve{t}^* \qquad \upsilon_{NR}^* = \sqrt{\upsilon_f^2 + \left(\upsilon_t^*\right)^2}$$

Simplified approach - durability analysis of a single tank shell plate, ideal geometry and bending moment free stress state in the shell



$$\Delta(\tau) = N_R(\tau) - N_\varphi(\tau) \qquad u(\tau) = \frac{\Delta(\tau) - \overline{\Delta(\tau)}}{\sigma_\Delta(\tau)}$$

$$\Omega(\tau) = P\left(N_R(\tau) \le N_\varphi(\tau)\right) = P(\Delta(\tau) \le 0) = F(\Delta(\tau)) = \Phi(u(\tau))$$

Failure: $u(\tau) = u_0(\tau)$

$$\Omega(-u_0(\tau)) = \Phi(-u_0(\tau)) = \Phi(-\beta_\Delta(\tau))$$

$$-u_0(\tau) = \frac{0 - \overline{\Delta(\tau)}}{\sigma_\Delta(\tau)} = -\frac{\overline{N_R(\tau)} - \overline{N_\varphi}}{\sqrt{(\sigma_{NR}(\tau))^2 + \sigma_{N\varphi}^2}}$$

Safety conditions:

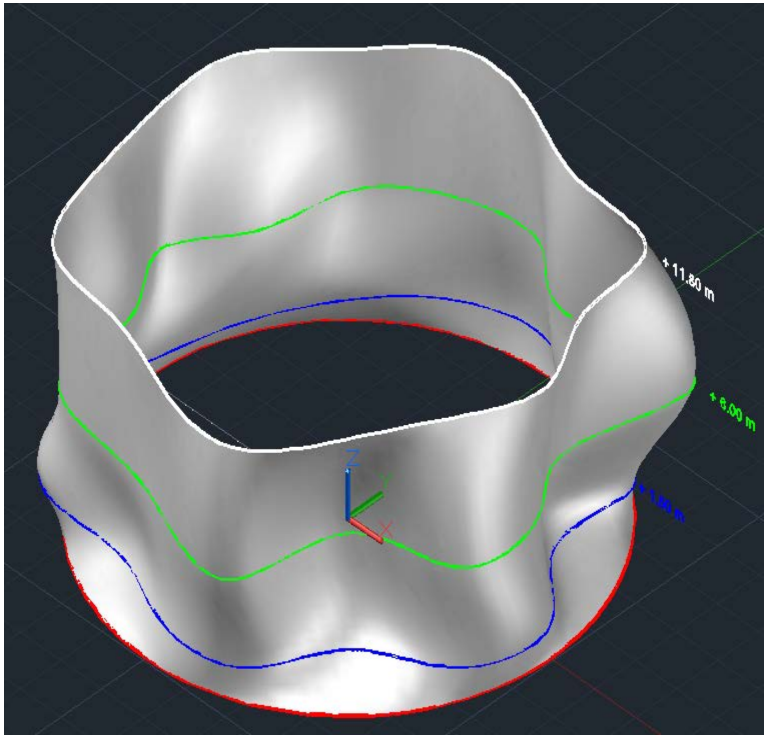
$$\Omega(-u_0(\tau)) \le \Omega_{ult} \;\Rightarrow\; u_0(\tau) = \beta_\Delta(\tau) > u_{ult} = \beta_{\Delta,req}$$

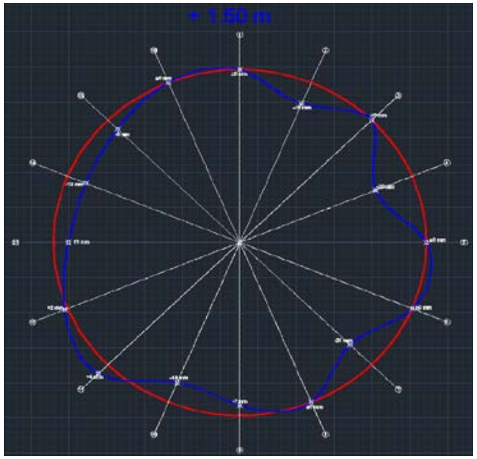
$$\Delta(\tau) > \Delta_{ult}(\tau)$$

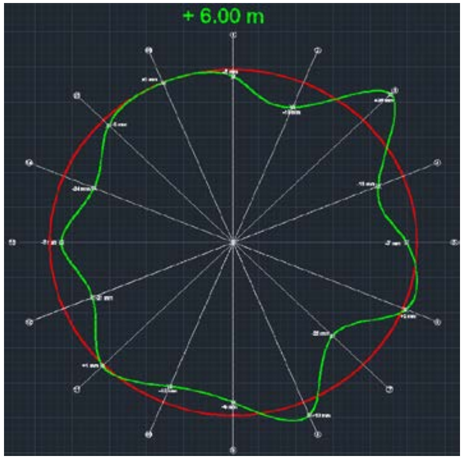
$$\overline{\gamma(\tau)} > \overline{\gamma_{ult}(\tau)}$$

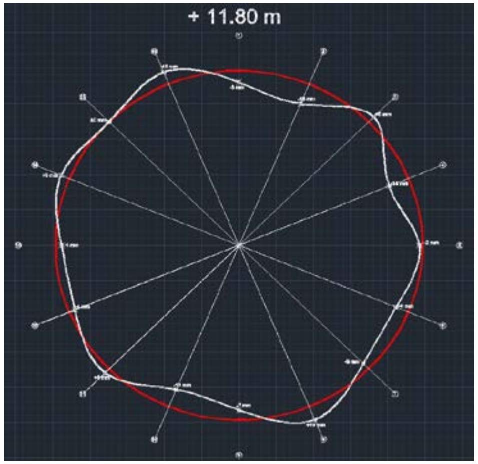
$$\overline{\gamma(\tau)} = \frac{\overline{N_R(\tau)}}{\overline{N_\varphi}}$$

Advanced approach – durability analysis for the whole tank sheathing, replication of real tank shell geometry and geometrically nonlinear stress analysis









Real geometry measured on the fully filled tank with geodetic method

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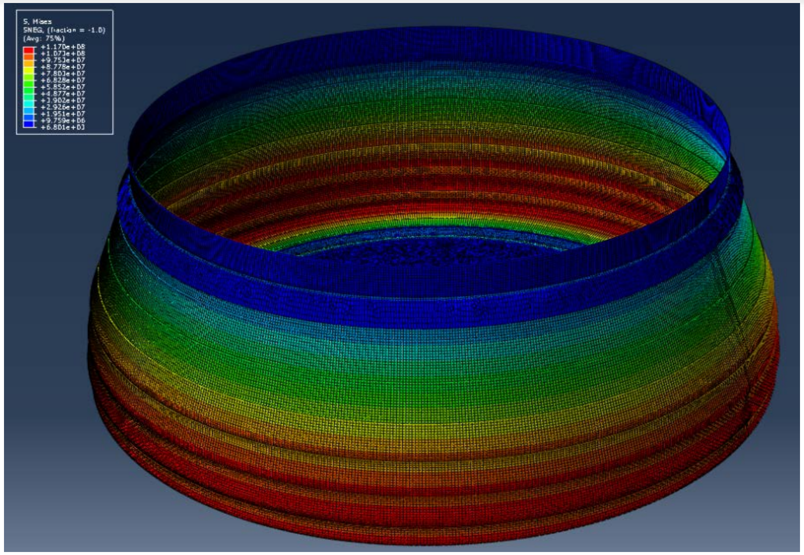
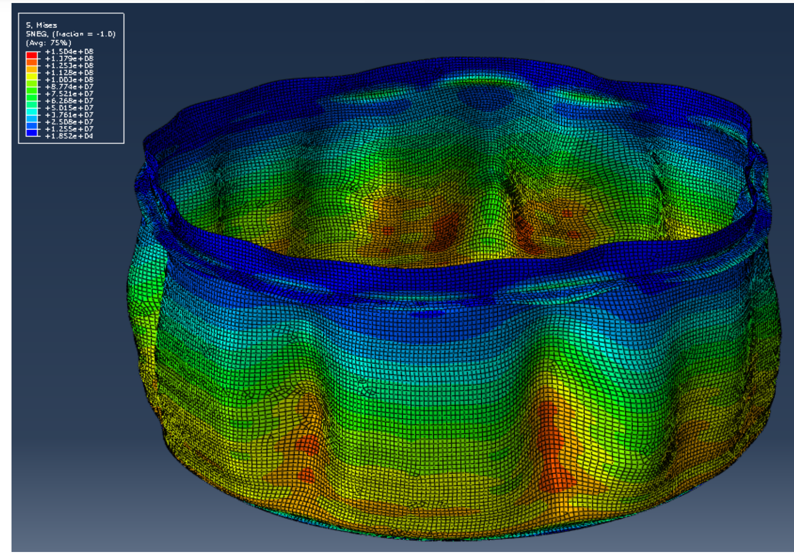
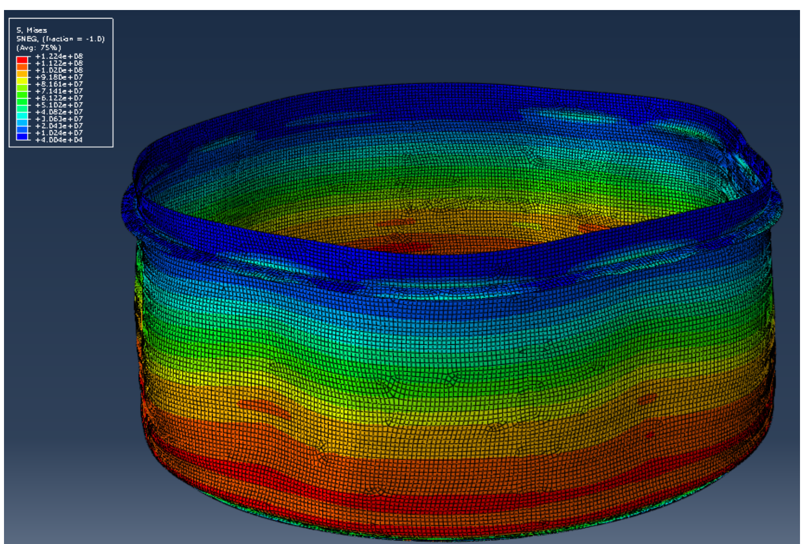


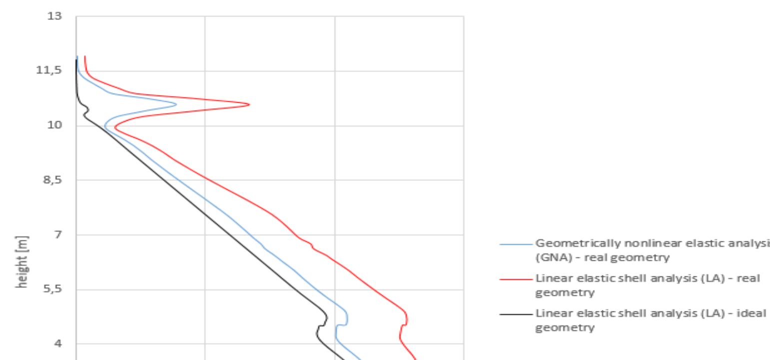
Perfect geometry, linear analysis

Real geometry, linear analysis

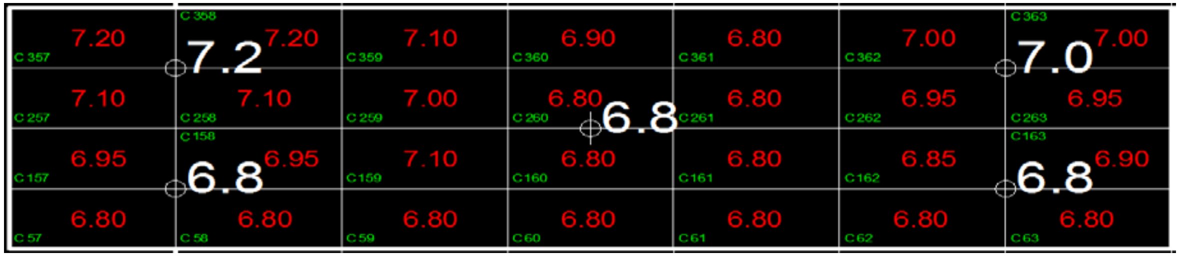




Real geometry, nonlinear analysis



Von Mises equivalent stresses along the selected meridian



Interpolation of the measured values of the thickness of corroded steel sheet selected from the shell of the tank under consideration which allows to adjust the experimental results to the numerical model

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At the current stage of analysis the authors are striving to extend the numerical model of the tank, already including the real geometry and nonlinear reaction of the tank material to applied loads to cover the sheathing corrosion state changing during service life, measured during the technical inspections and projected to the future based on identified statistical trends.

The concept of evaluating the prognosed durability of a tank in service, based on the bayesian approach combining the a'priori information with the a'posteriori measurement data

a'priori structure state

The state of knowledge available to the investigator at the beginning of the consecutive technical state inspection

the information gathered a'posteriori

New empirical data gathered as the result of the technical inspection

the a'posteriori distribution of the parameters which are of interest to the investigator

THANK YOU FOR YOUR ATTENTION