Analysis Methodology and Assessment Criteria for Bolted Trunnion Systems of Type B Packages for Radioactive Materials

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Working Group

Mechanical and Thermal Container Assessment / Special Issues

Outline

1 Load Cases for Trunnion Systems

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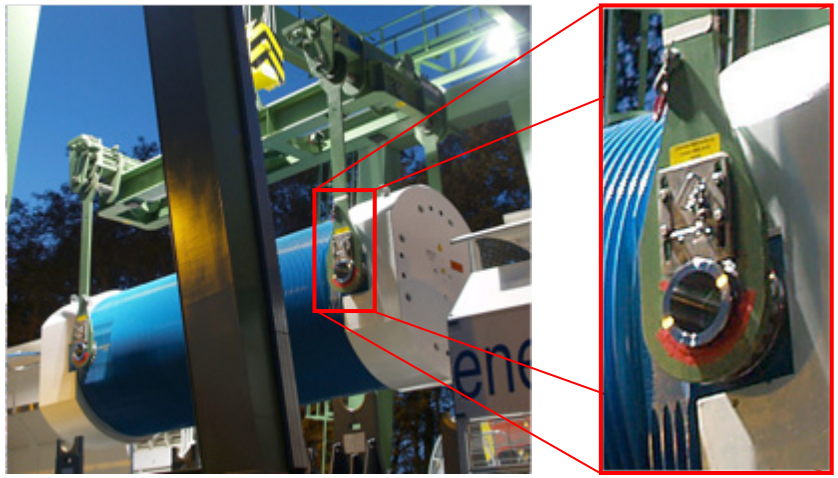
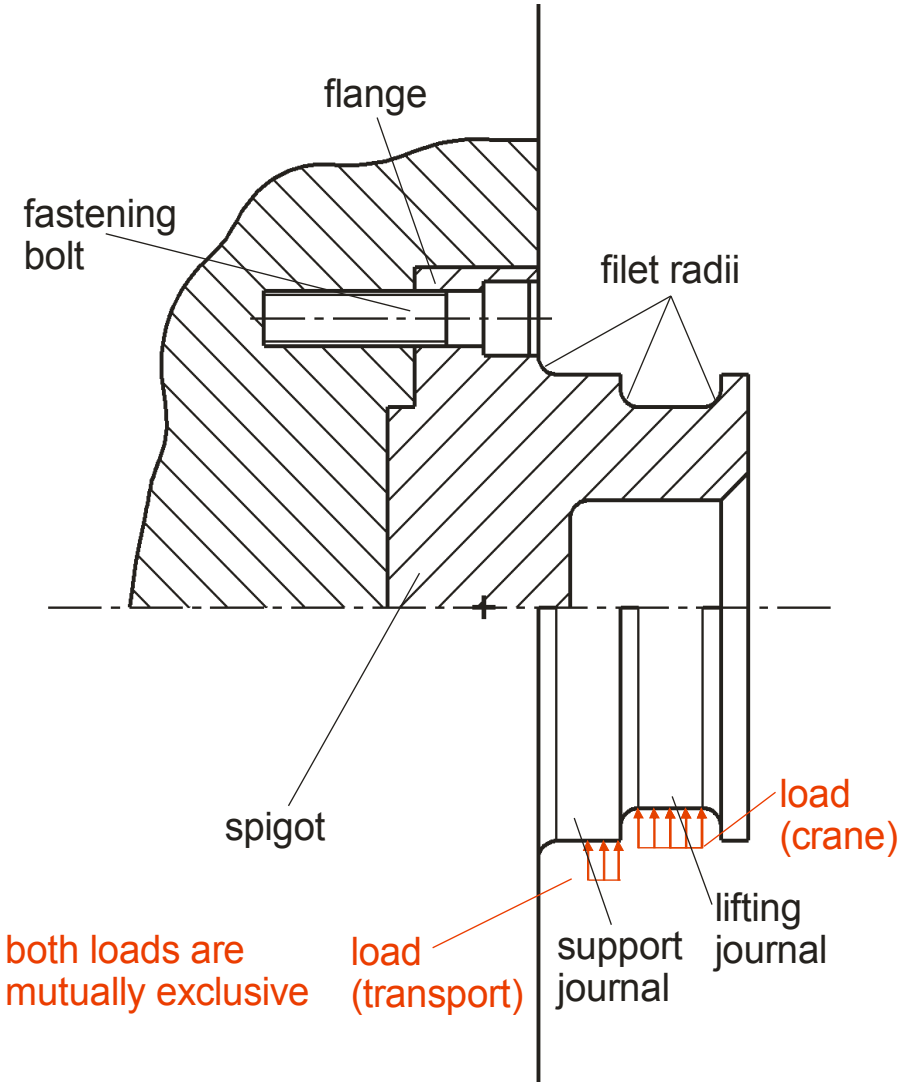


2 Specific Features and General Assessment



Conceptual sketch of a bolted trunnion

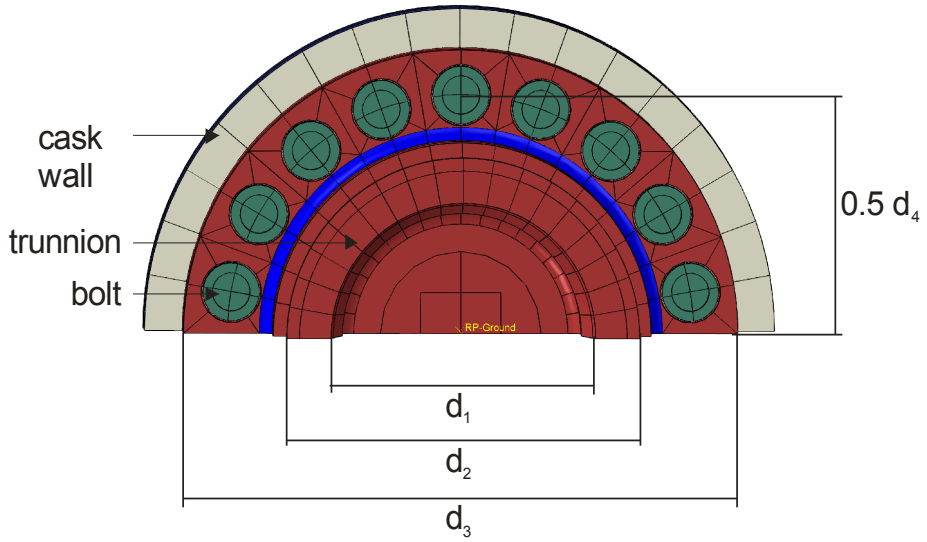
Trunnion: solid structure with specific features
→ modern methods (e.g. Finite-Element-Analyses)

Concepts different from nominal stresses
→ special assessment is necessary in this particular case [KTA 3905]

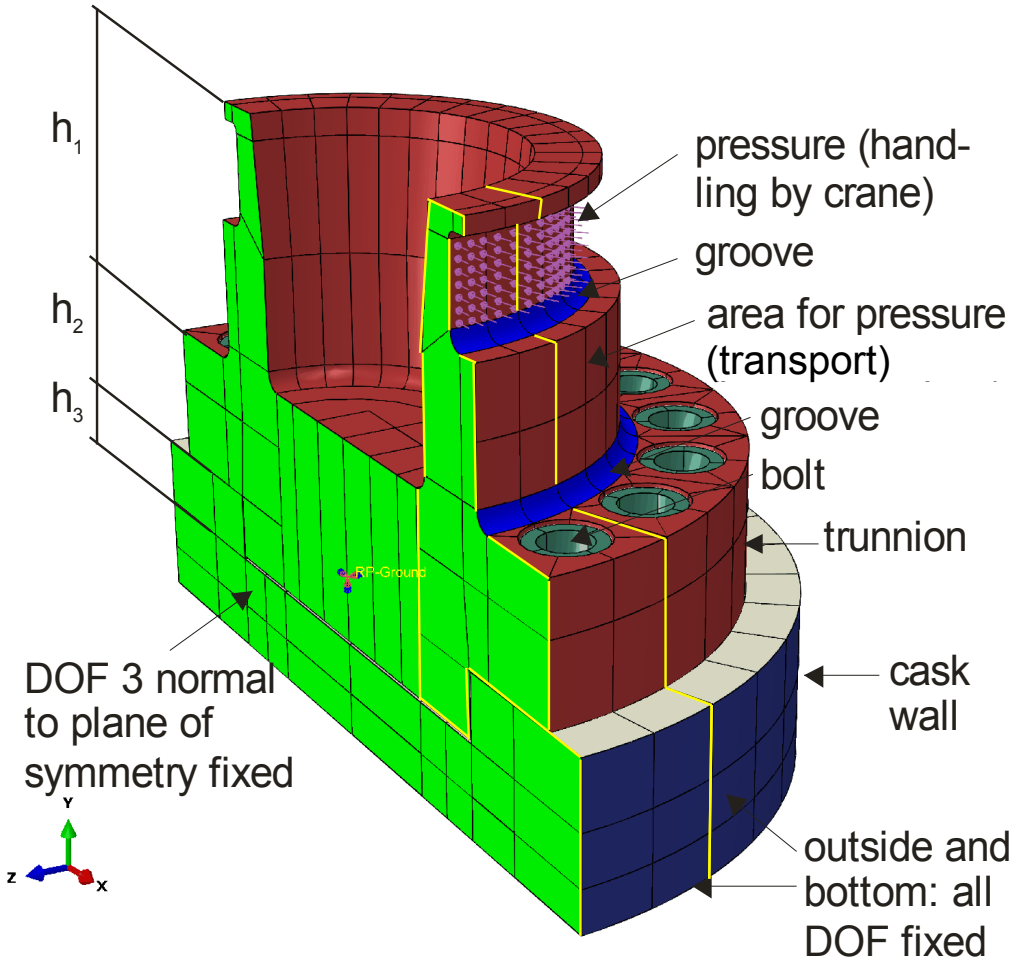
BAM guideline
- Load attachment points [LAP] such as trunnions
  - Handling by crane (inside/outside nuclear facility)
  - Transportation (routine conditions)
- Lid systems
- Guideline's objectives:
  - Assumptions for loading
  - Methods for calculation (preferential FEA)
  - Criteria for assessment

Abstraction

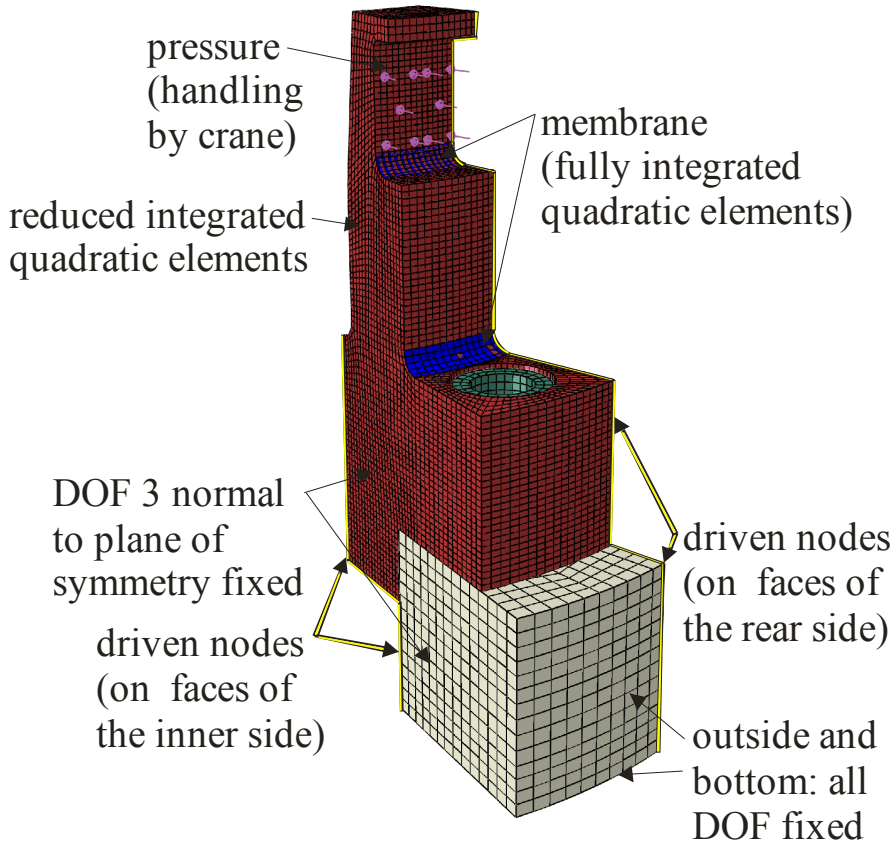
Real trunnion on a CASTOR HAW 28M (with a cap in the center)



Geometry of a half-symmetric FE-model



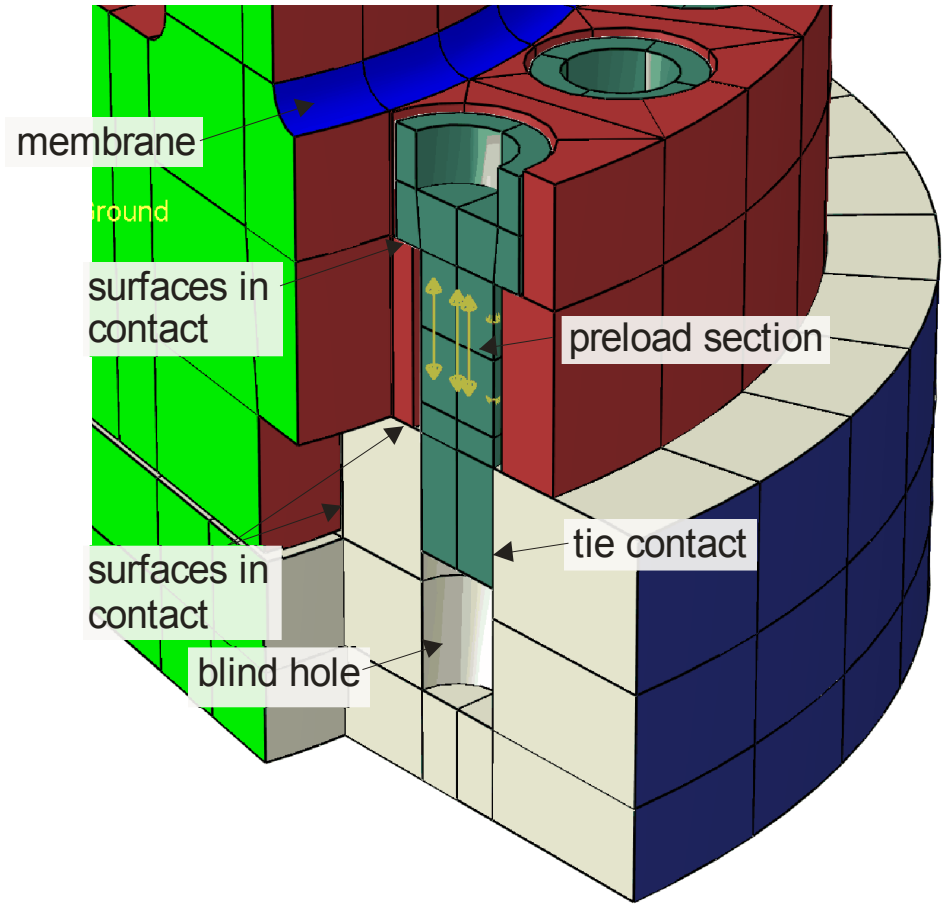
Boundary conditions and loading



Meshed submodel of most highly stressed sector with marked driven nodes

Bolts: Solid FE-model and concept of nominal stress

- Preload for bolts taken from VDI2230
- Calculation of minimum/maximum preload considers
  - uncertainty of tightening and friction resp. lubrication conditions
  - embedding of the contact surfaces and
  - relaxation of the materials



Details of preloaded bolt and the surfaces for contact

Particular Approach for Trunnion

- *Outdated:* Separation of local stresses in classes and the estimation of fatigue notch factor → ambiguous assessment
- *Contemporary:* Assessment of solid structures with local stresses (e.g. FKM-guideline) instead of nominal values

} **Assessment of local stresses**

(stresses taken directly from FEA)

Criteria for Assessment

Criterion is fulfilled

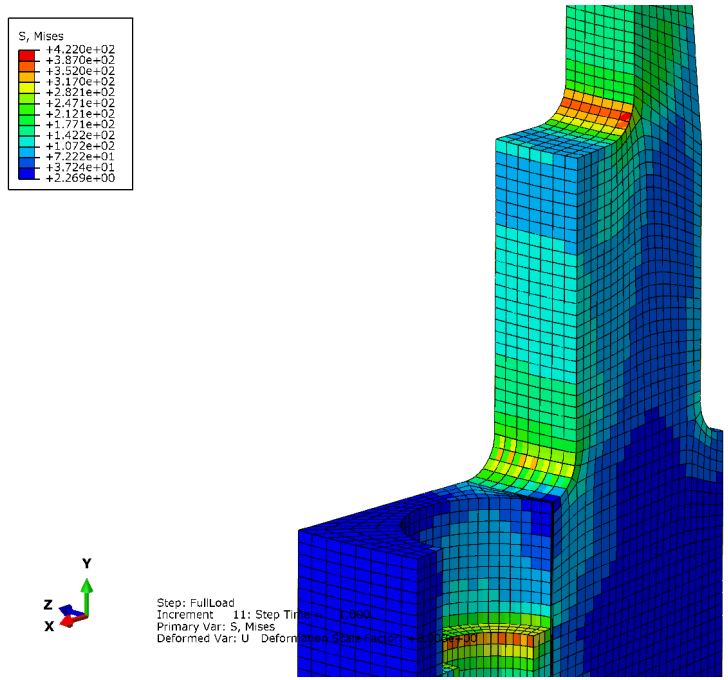
- if $\sigma_v \leq \frac{R_{p0,2}(T)}{1{,}5}$ is true everywhere with local stresses taken from FEA [derived from KTA 3905]

} **elastic**

- or if $\frac{R_{p0,2}(T)}{1{,}5} \leq \sigma_v \leq R_{p0,2}(T)$

→ additional limit analyses with 2.25-fold load. Plastic deformation of whole section has to be avoided.

} **elastic-plastic**



Particular Approach for Bolt

- Nominal stresses → well-defined assessment
- No framework for assessment of local stresses

Assessment of nominal stresses

(derived from nodal values of FEA)

Assessment

- Effective stresses due to assembly (according to KTA 3905)

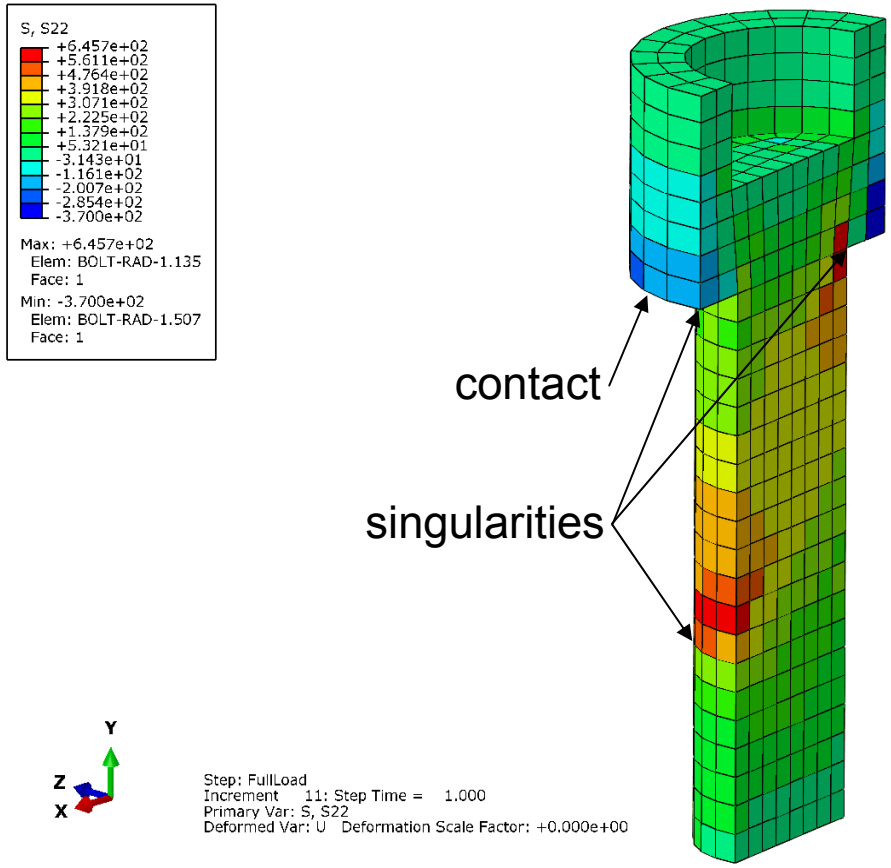
$$\sigma_v \leq 0{,}7 R_{p0,2}(T)$$

- Additional tensile stresses due to operation (according to KTA 3905)

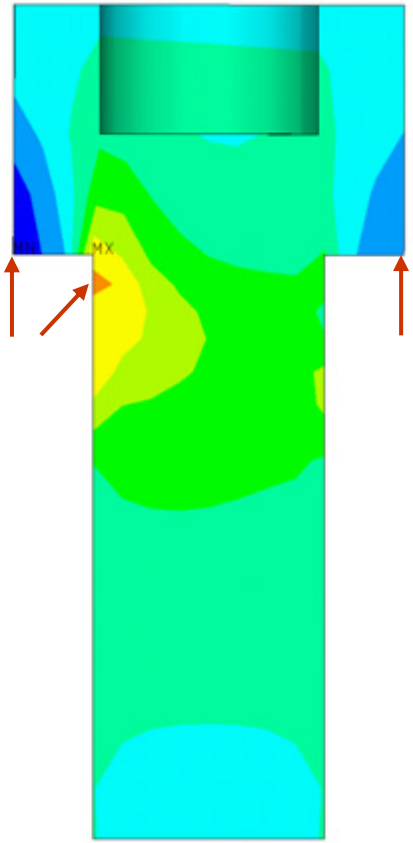
$$\sigma_z - \sigma_{z,asm} \leq 0{,}1 R_{p0,2}(T)$$

- Limitation of effective stress due to operation (total stresses including residual torsional stresses)

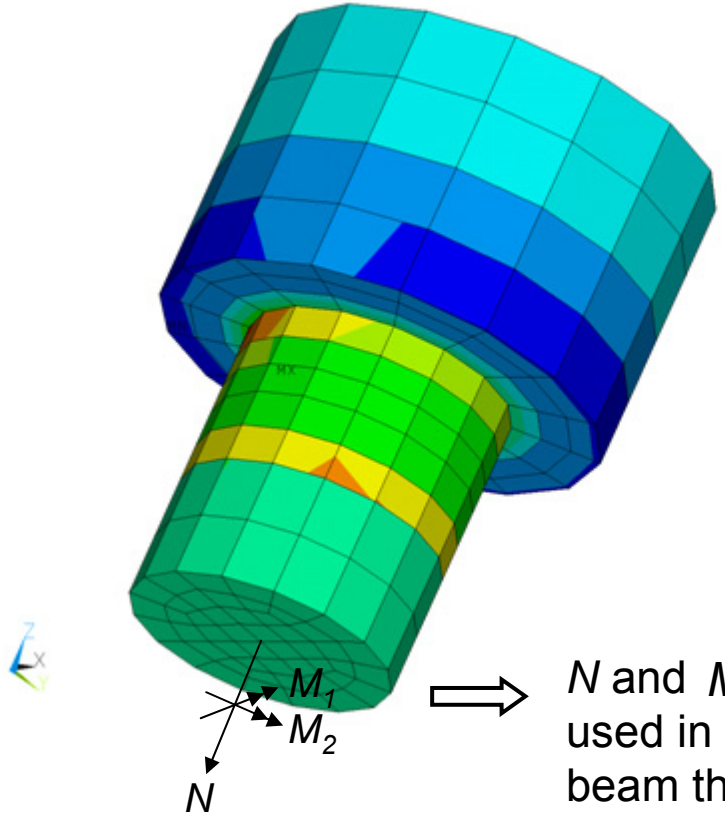
$$\sigma_v \leq R_{p0,2}(T)$$



Calculation of nominal forces



Axial stresses σ_z
Longitudinal section



N and $M = \sqrt{M_1^2 + M_2^2}$ used in beam theory

$$N = \sum_i F_i \qquad M_1 = \sum_i r_{2,i} F_i \qquad M_2 = \sum_i r_{1,i} F_i$$

i : nodes of the cross section

Normal force (N) and bending moment (M) from section's nodal forces (F_i) and distance (r_i)

Bolts: Solid FE-model and concept of nominal stress

Concept for assessment:

load input

VDI 2230: bolt preload

FE-model for trunnion system

$$N = \iint_{(A)} \sigma dA \qquad \mathbf{M} = \iint_{(A)} \mathbf{r} \times \sigma d\mathbf{A}$$

$$\sigma_z = \frac{N}{A_s} \qquad \sigma_b = \frac{M}{W}$$

VDI 2230:

$$\sigma_v = \sqrt{(\sigma_z + \sigma_b)^2 + (3k_\tau \cdot \tau_{G,asm})^2}$$

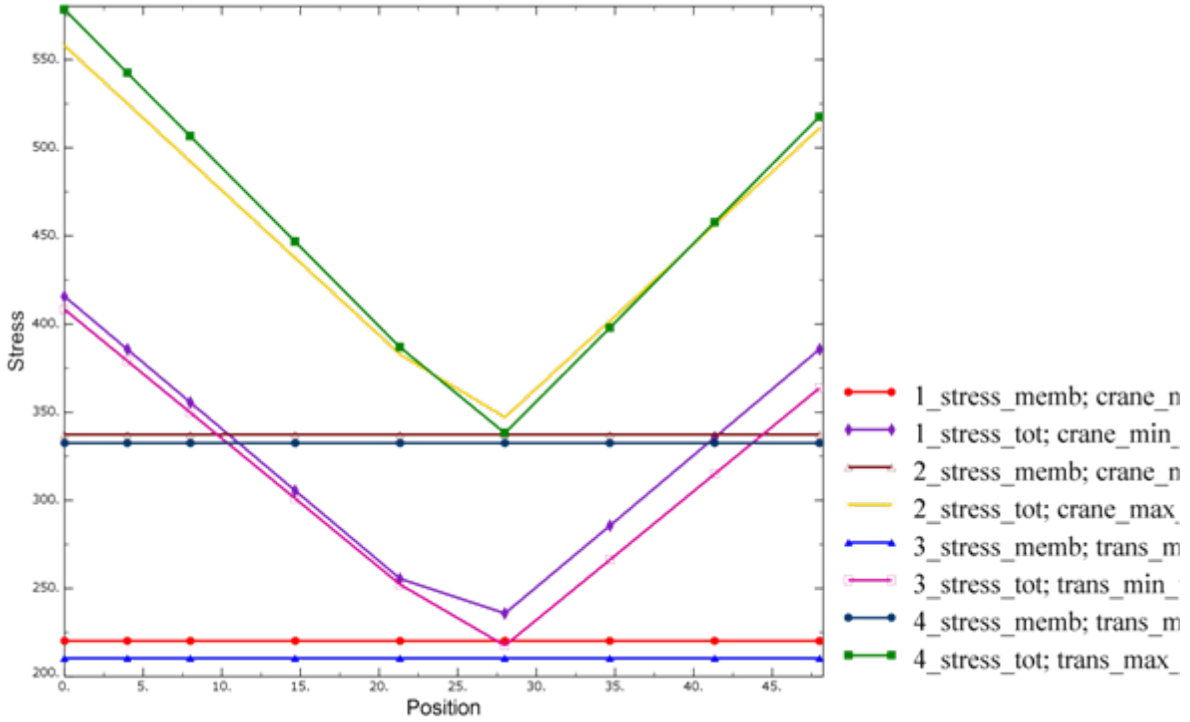
nominal loads

local stresses

nominal forces

nominal stresses

von Mises stress



Solid modelling of the bolt

- avoidance of connecting beam elements to solids
- section's forces/moments computable from nodal forces
  → concept of nominal stress
- assessment stays conform with national standards

Conclusion

- Load attachment point with complex shape
  → FEA recommended

Trunnion

- Local stresses should be assessed
  →use of nominal stresses is not up to date

Bolts

- No standard or guideline available to assess local stresses
- High effort to model resp. calculate local stresses in area of contact

} →nominal stresses should be used

- Necessity to derive input data for calculation of nominal stresses from FEA due to possible slip at bolted flanges