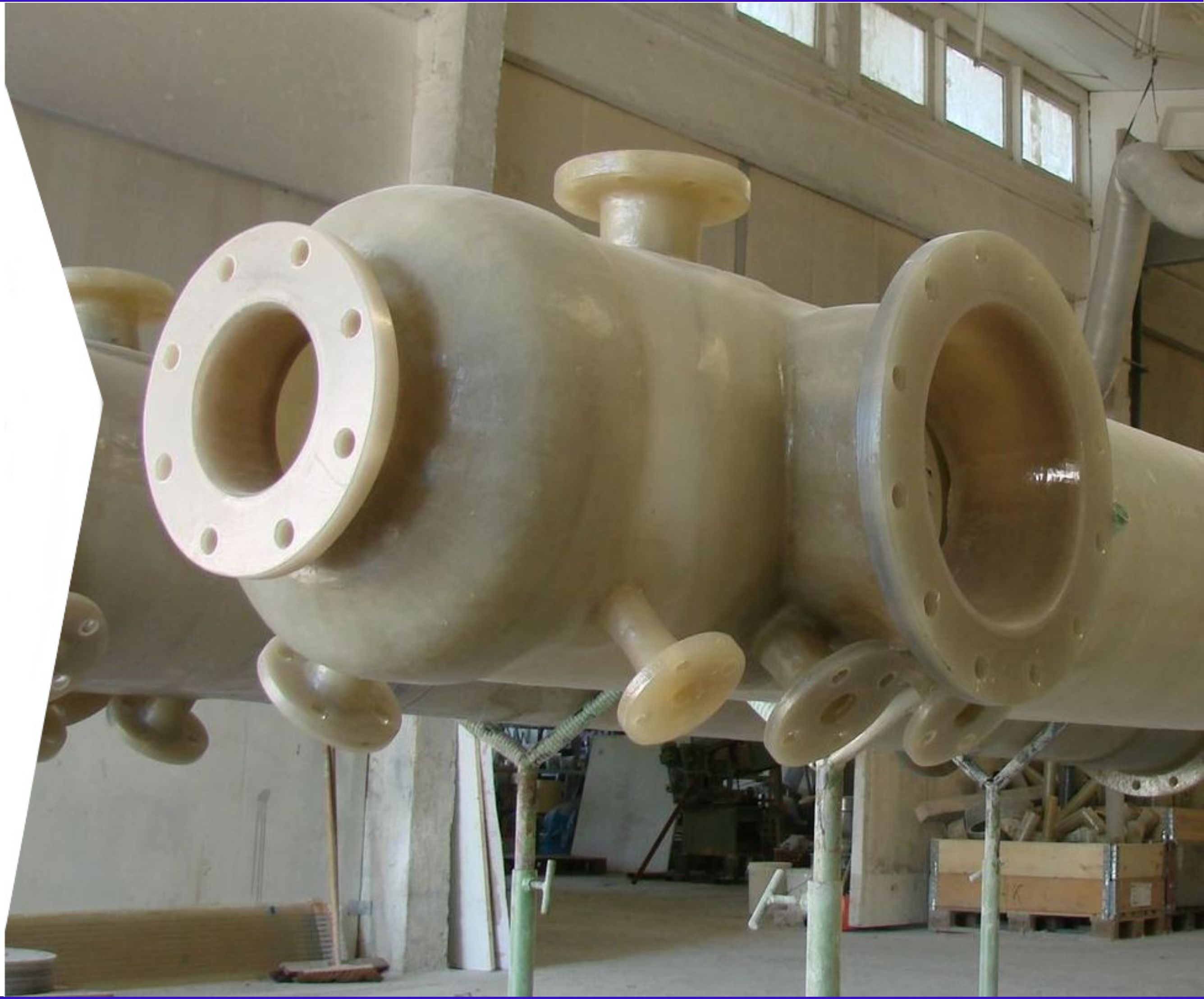
Nozzle-loads in tank construction



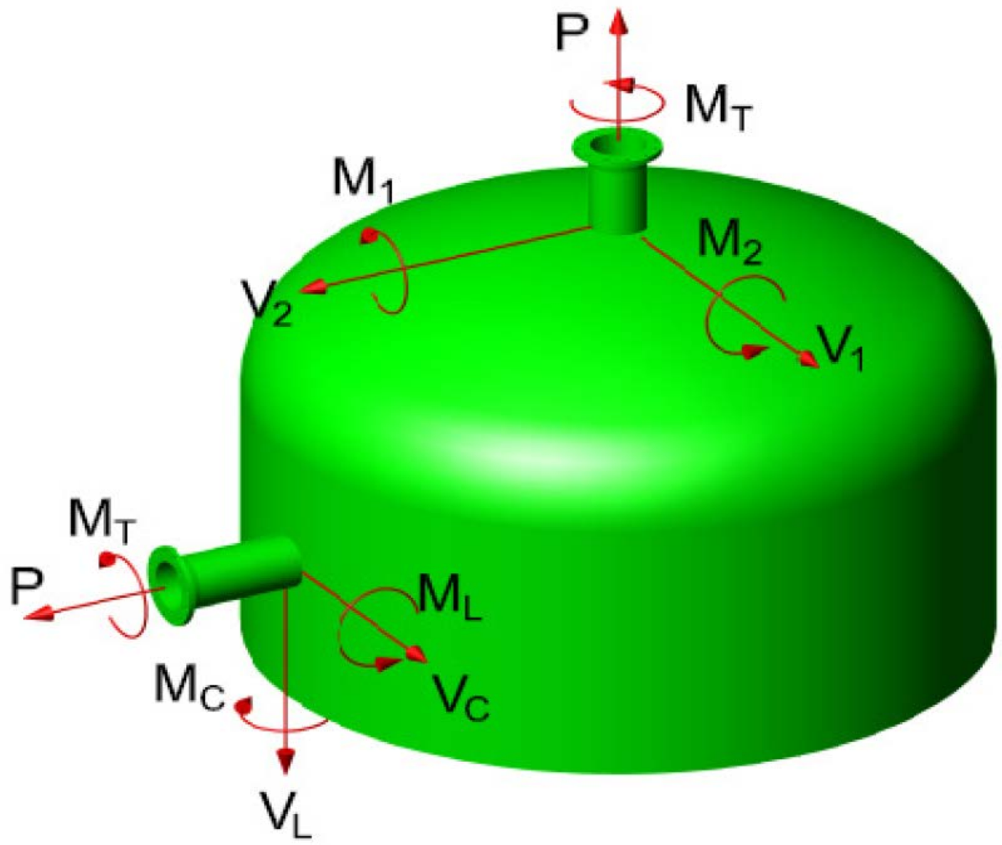
Dr.-Ing. Ingo Lukas, IFKI

Basics

„All nozzles of the tank must be connected free of force “

Pressure, temperature, filling, wind, dead load and earthquakes induce ***always***

Normal - and shear forces as well as bending moments and a torsional moment within the nozzle



Calculation method for an alternate external pressure

- Simple usage
- *Very conservative*
- *Uneconomical calculation results*

Example

- Unpressurised tank DN 2000, t = 7,70 mm
- Nozzle DN 100

$$p_c^* = 672,3\ kN/m^2$$

$$t_{üa} = 21,80\ mm$$

$$n_S = \frac{p_c^* \cdot r_S}{2}$$

$$n_S = \frac{V_L}{2 \cdot r_S \cdot \pi} + \frac{M_R}{r_S^2 \cdot \pi}$$

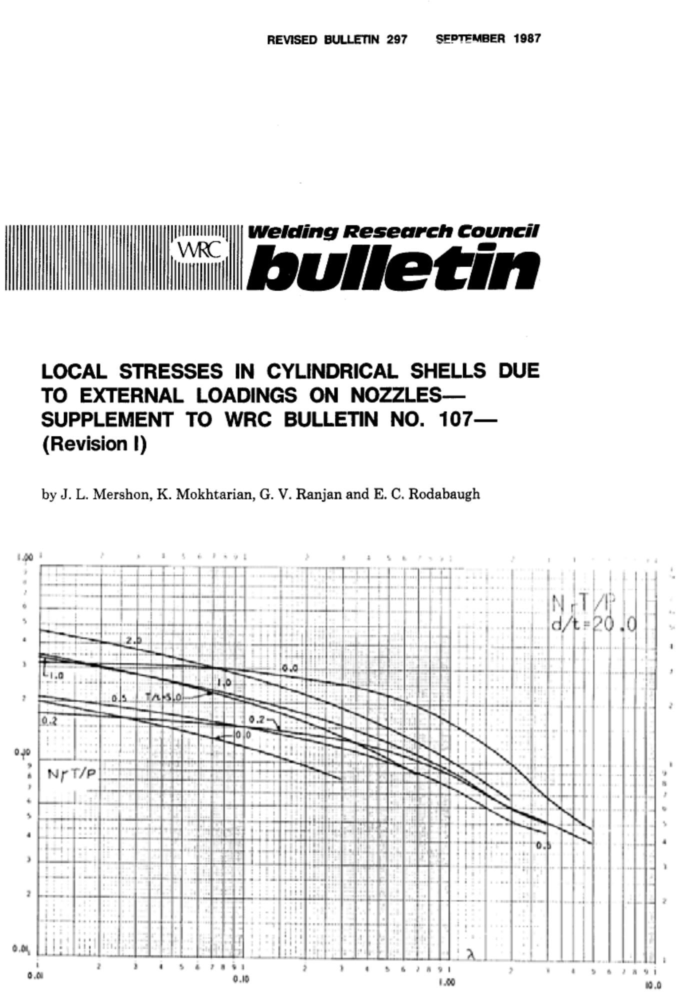
$$\frac{p_c^* \cdot r_S}{2} = \frac{V_L}{2 \cdot r_S \cdot \pi} + \frac{M_R}{r_S^2 \cdot \pi}$$

$$p_c^* = \frac{V_L}{r_s^2 \cdot \pi} + \frac{2 \cdot M_R}{r_s^3 \cdot \pi}$$

N			Nm			
P	V_L V_1	V_C V_2	M_L M_1	M_C M_2	M_T	M_R
215	240	175	105	70	130	126

Calculation method WRC Bulletin 297

- Accepted procedure
- Useful calculation results
- *Very time-consuming and complicated usage*
- *Iterative method, needs to be repeated again and again*
- *Modification for torispherical heads necessary*



D: Diameter cylinder T: Wall thickness cylinder

d: Diameter nozzle t: Wall thickness nozzle

Nozzle-loads: P, M_L , M_Θ

Diagramm parameter

d/t, T/t , $\lambda = (d/D) \cdot (D/T)^{0,5}$

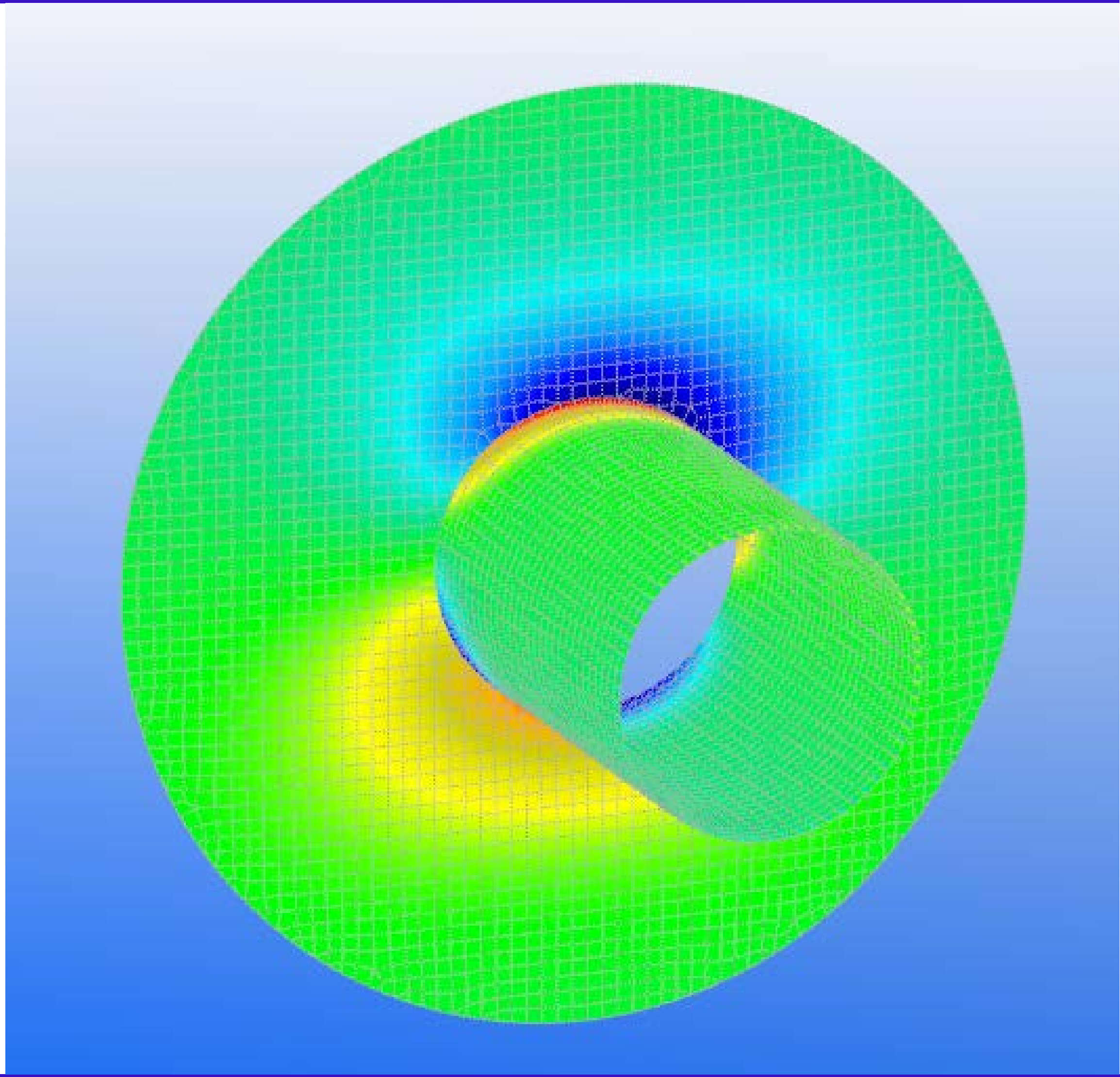
Usually:

Evaluation of 24 diagramms needs to be done with an interpolation for each iteration step

➢ Calculation complicated and time-consuming!

Calculation method FEM

- Universal calculation method
- Direct superposition with tank loads
- Economical calculation results
- Every load can be captured
- ***Very labour-intense***
- ***Just for trained and experienced personnel***
- ***Pressure evaluation necessary***



State of the calculation

Specification of fixed values in a tender or company standard

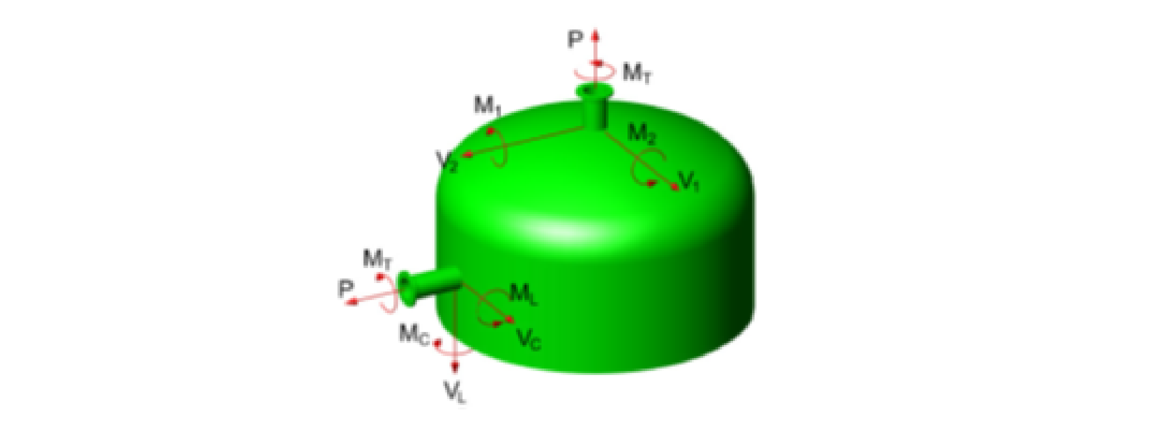
Advantages

- Decoupling of tank- and pipeline calculation
- Simplification of the tender or the development of company standards

Disadvantages

- *Values out of empirical studies or estimations*
- *Thinking in a global safety concept*
- *Origin and allocation of the loading condition is unknown*
- *There are only absolute values known*
- *Relation of bending moment and shear force is decoupled*

Evaluation of the reacting forces out of nozzle loads does not make sense

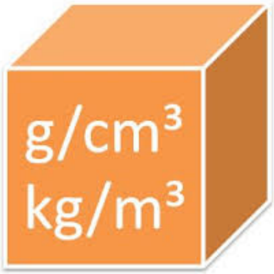


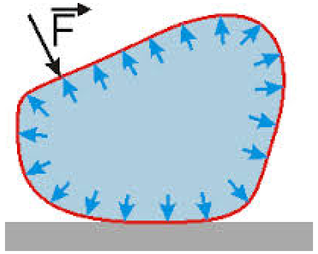
DN	N			Nm		
	P	V_L / V_1	V_C / V_2	M_L M_1	M_C / M_2	M_T
50	230	310	230	50	40	80
80	350	410	300	140	90	180
100	430	480	350	210	140	260
150	670	680	480	400	260	480
200	950	930	630	640	420	730
250	1260	1220	800	910	610	1020
300	1620	1550	980	1220	830	1340
350	2010	1930	1190	1570	1090	1690
400	2430	2340	1400	1960	1380	2090
450	2900	2800	1640	2390	1700	2520
500	3400	3300	1890	2850	2050	2980
600	4520	4430	2450	3900	2860	4010

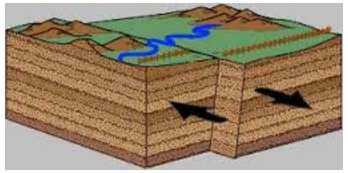
Loads on nozzles

Equalibrium loads

- Dead load
- Filling
- Wind
- Earthquakes

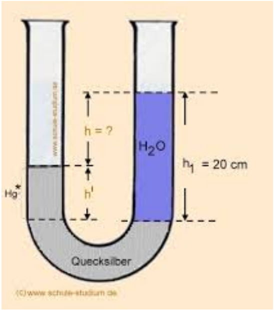


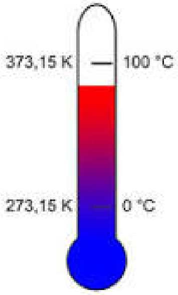




Impressed displacements

- Temperature
- Pressure
    - Internal pressure
    - Test pressure
    - External pressure





Differences in the effect of pipe loads

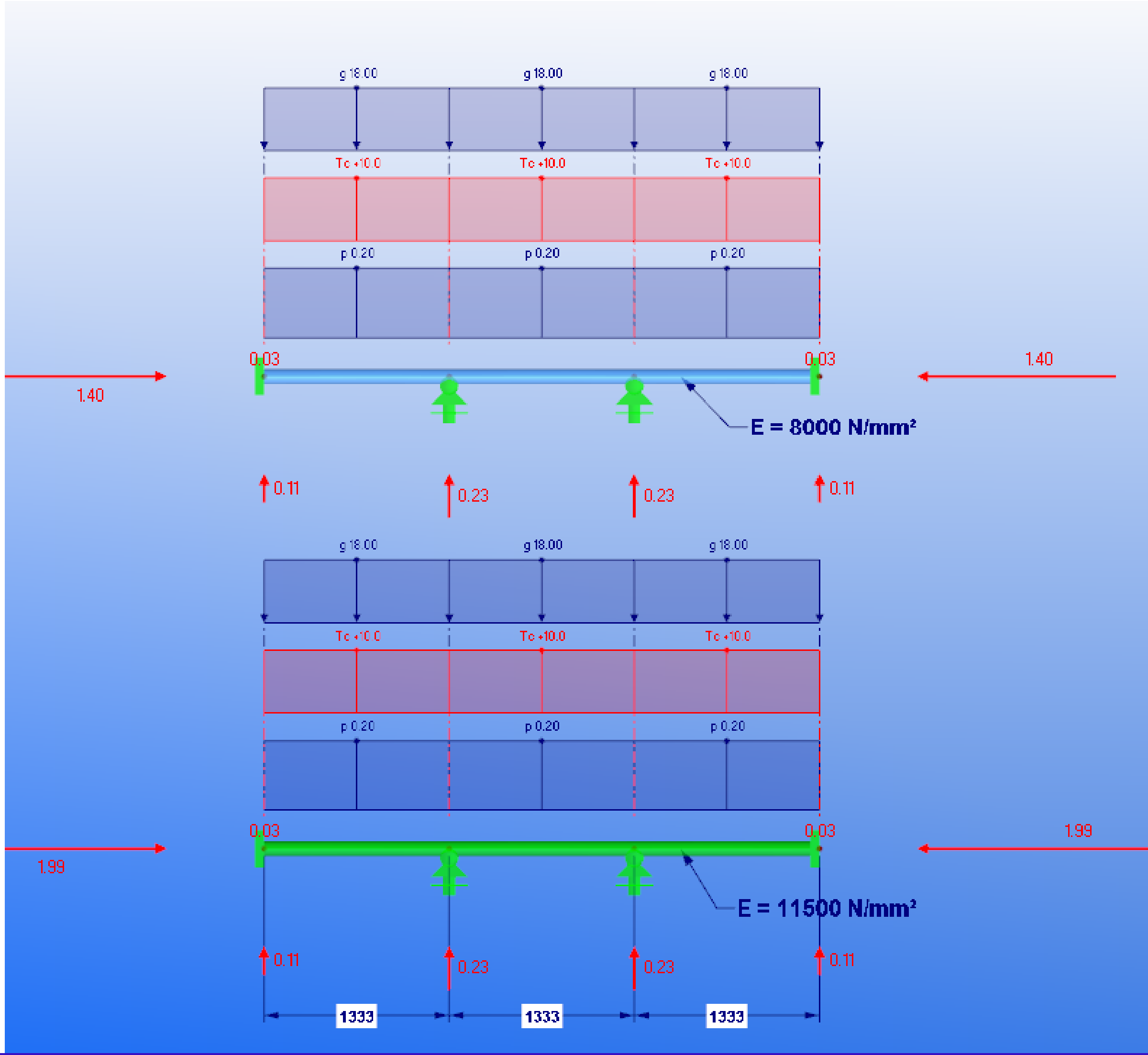
Equalibrium loads

Reaction forces and pipe loads depend on the equalibrium and *the allocation of the rigidities*

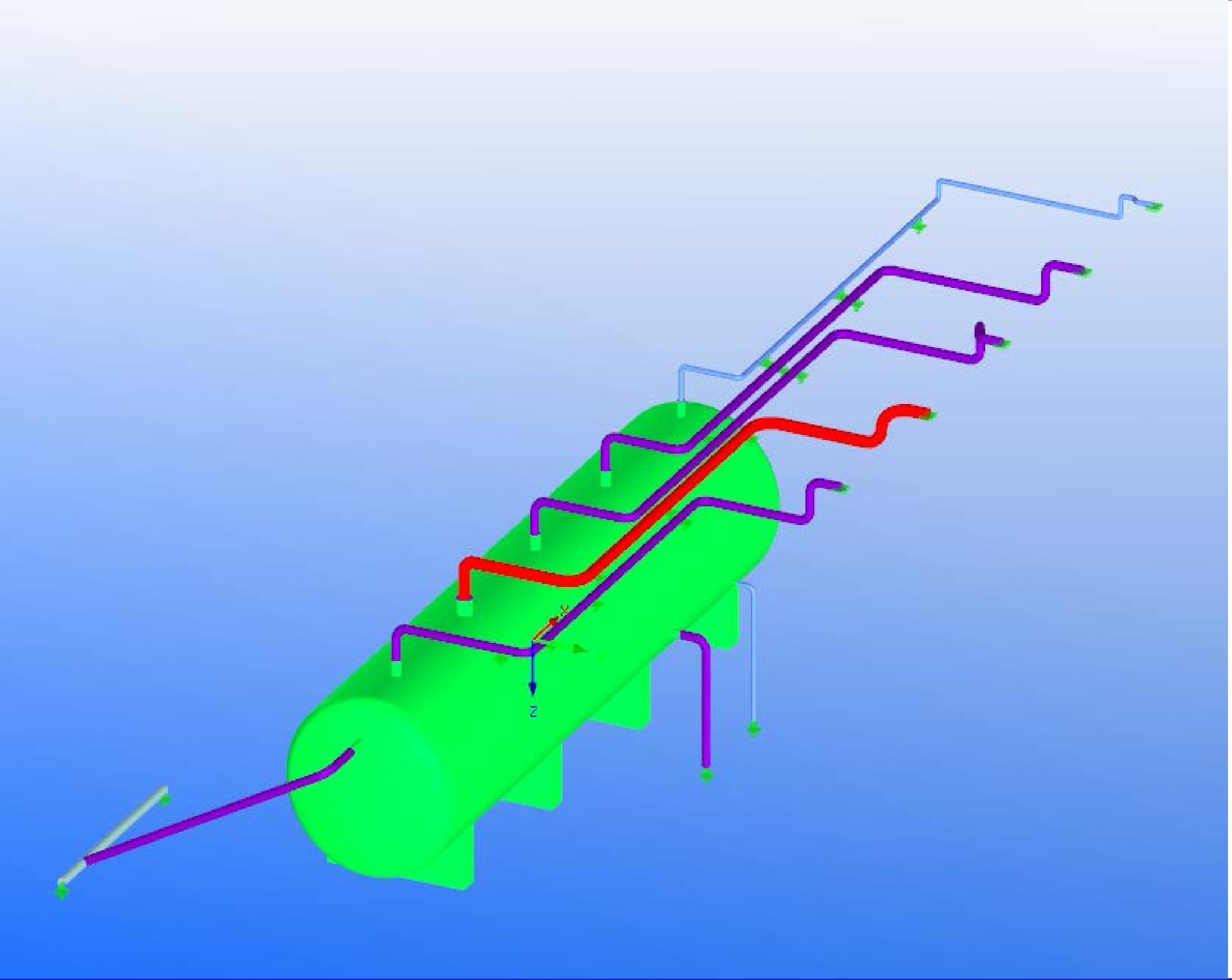
Impressed displacements

Reaction forces and pipe loads depend on the equalibrium and *the absolute value of the rigidities*

A constant reduction of the elastic modulus reduces the load out of impressed displacements, but does not affect the results out of equalibrium loads.



Example



Tank DN 3200, t = 15,00 mm

Setup Inside

Mixed Laminate E = 11500 N/mm²

Piping DN 80, DN150, DN 150, PN10

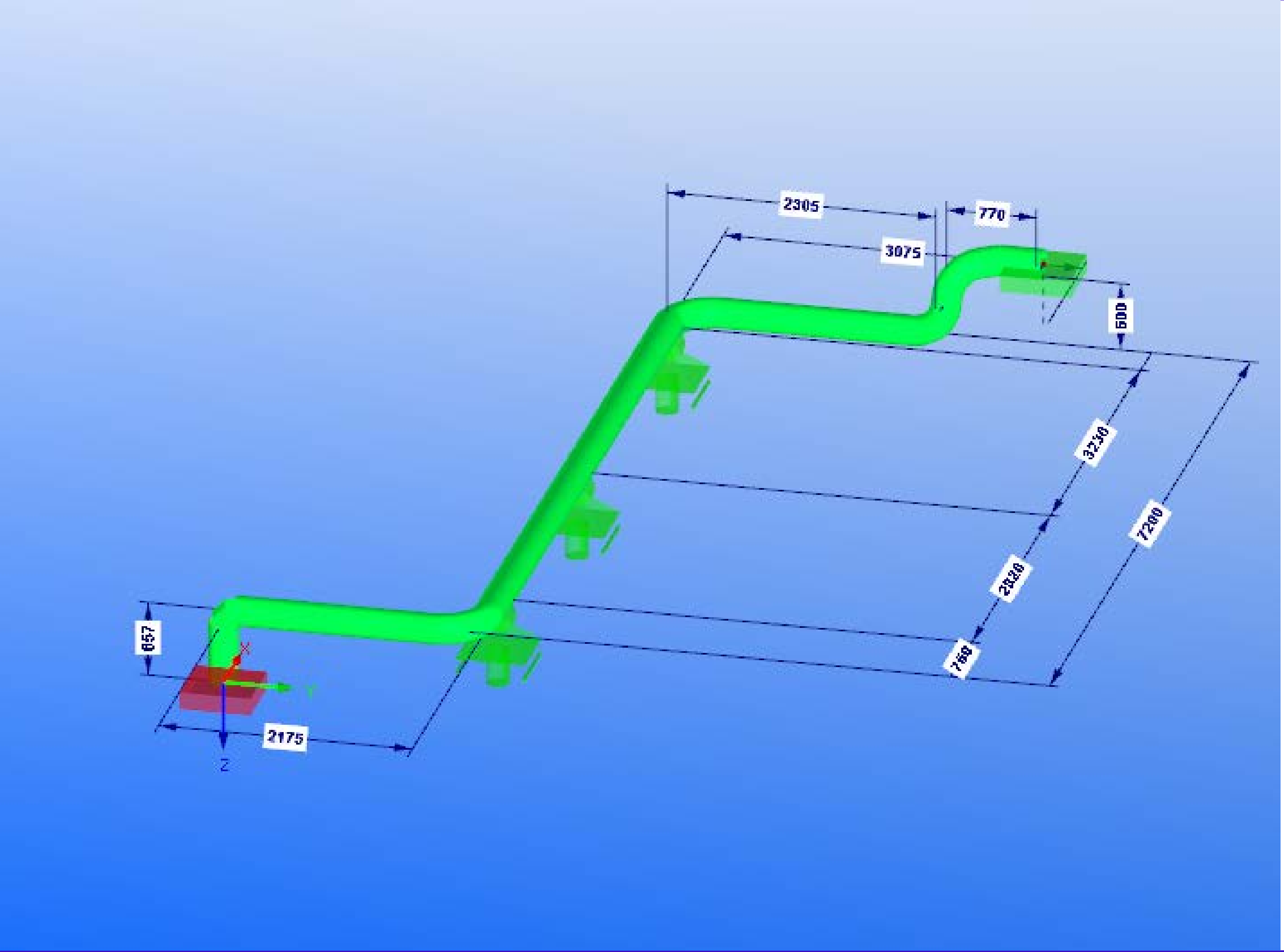
Loadings:

γ_{Fl} = 12,00 kN/m³

P = 1,00 bar

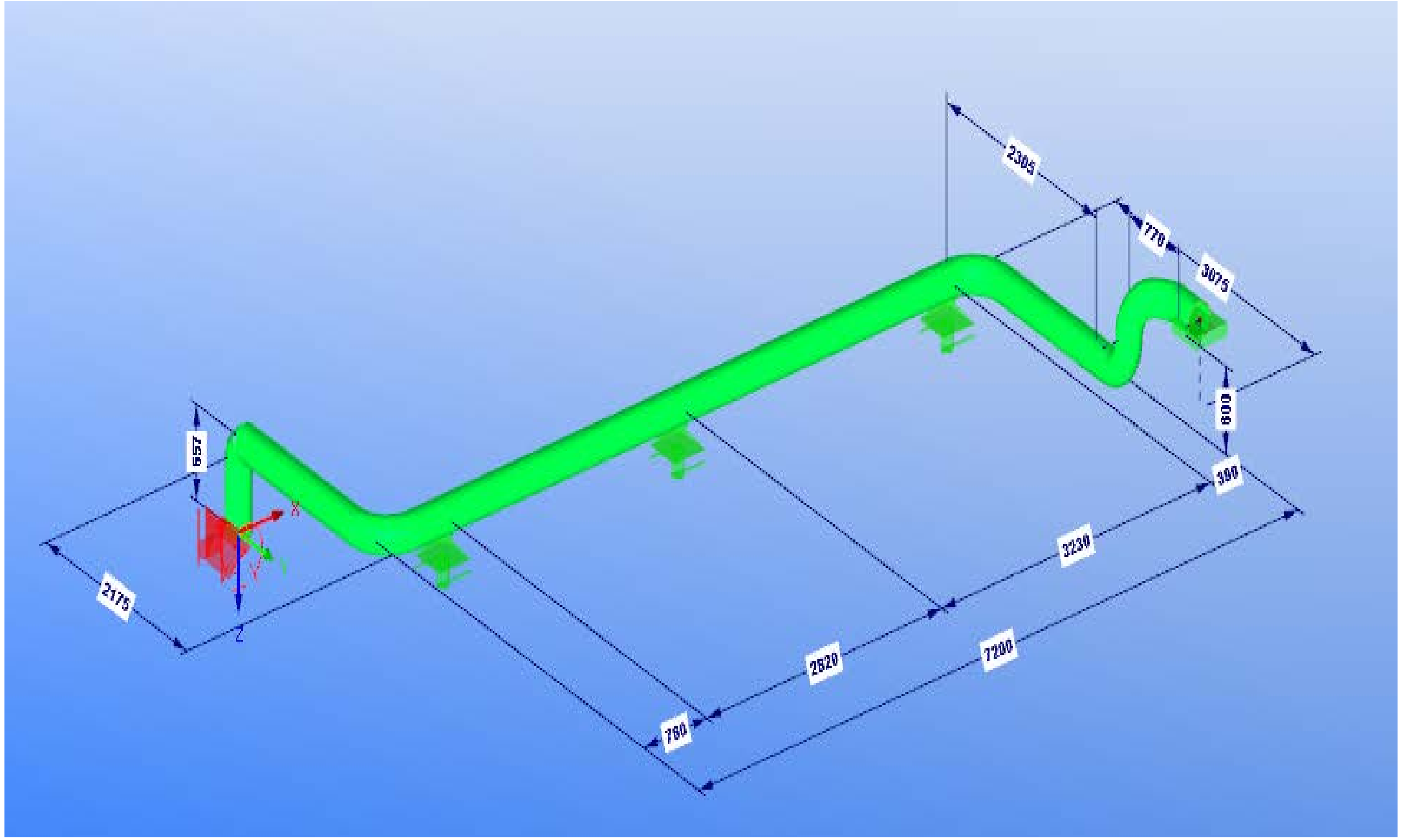
T_{Medium} = 100° C ➔ ΔT = 40° C

Pipeline Modeling – Rigid Modeling



Rigid connection to Tank

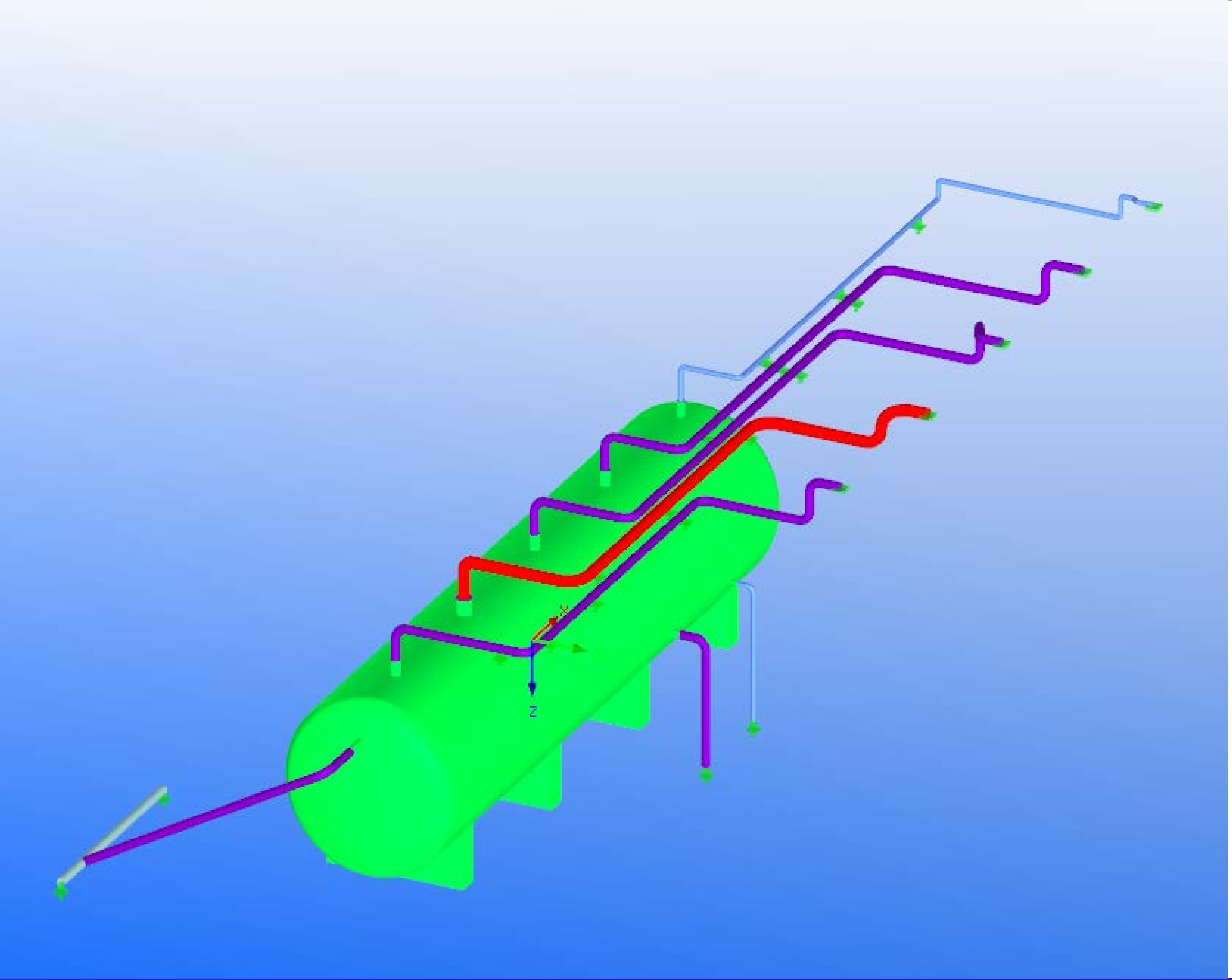
Pipeline Modeling – Semi Rigid Modeling



Rigidity in the direction of the nozzle and the rotations perpendicular to the nozzle axis are represented by springs

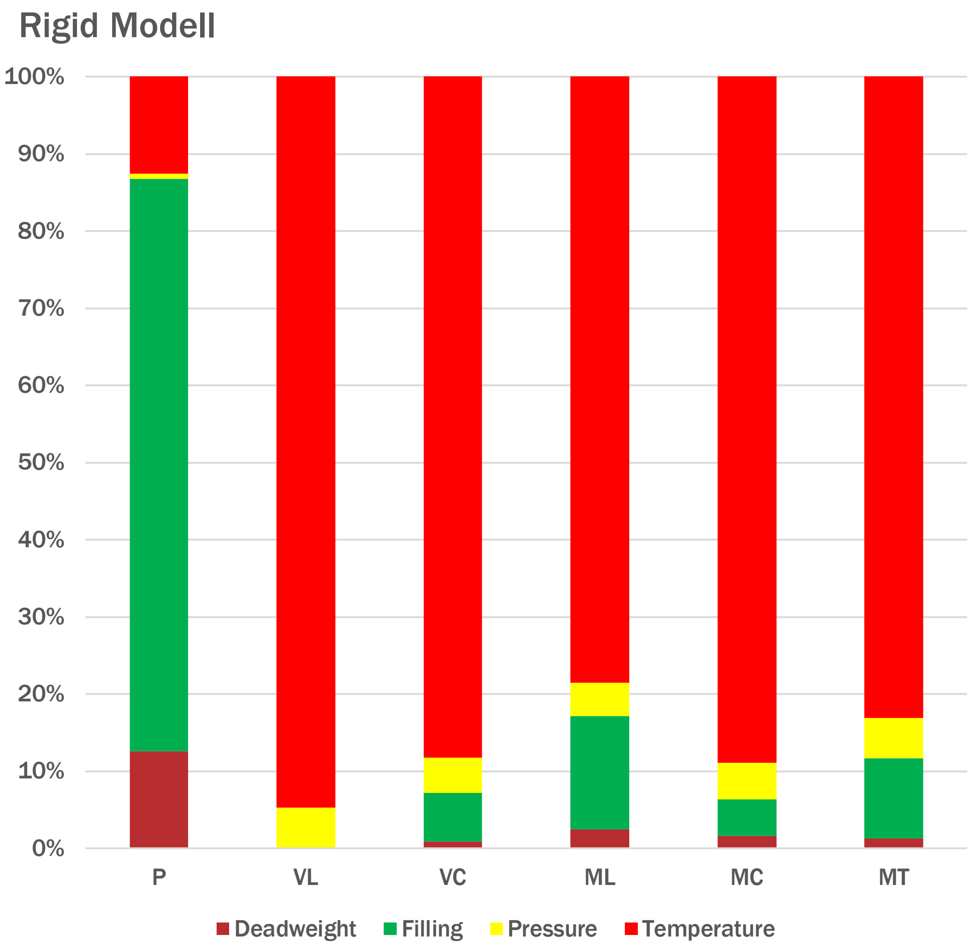
Required:
Replacement FEM
Nozzle -Tank

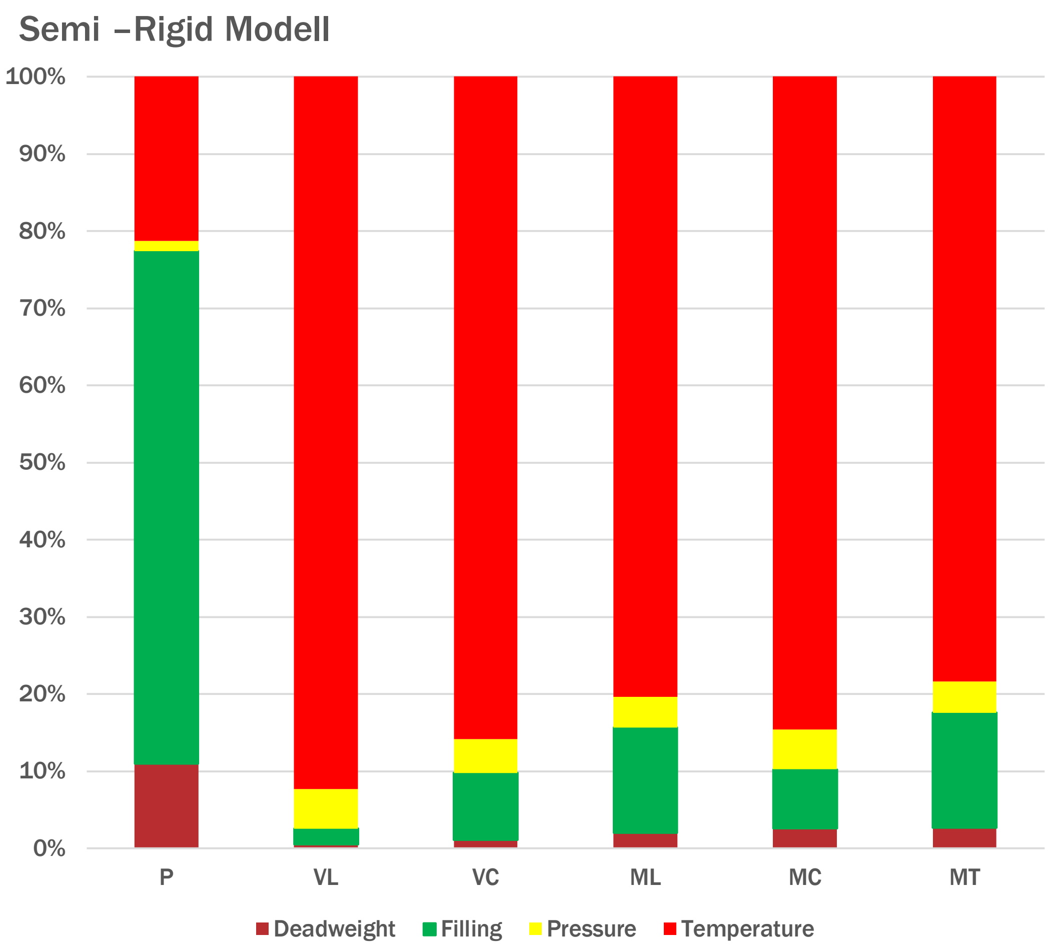
Pipeline Modeling – FEM



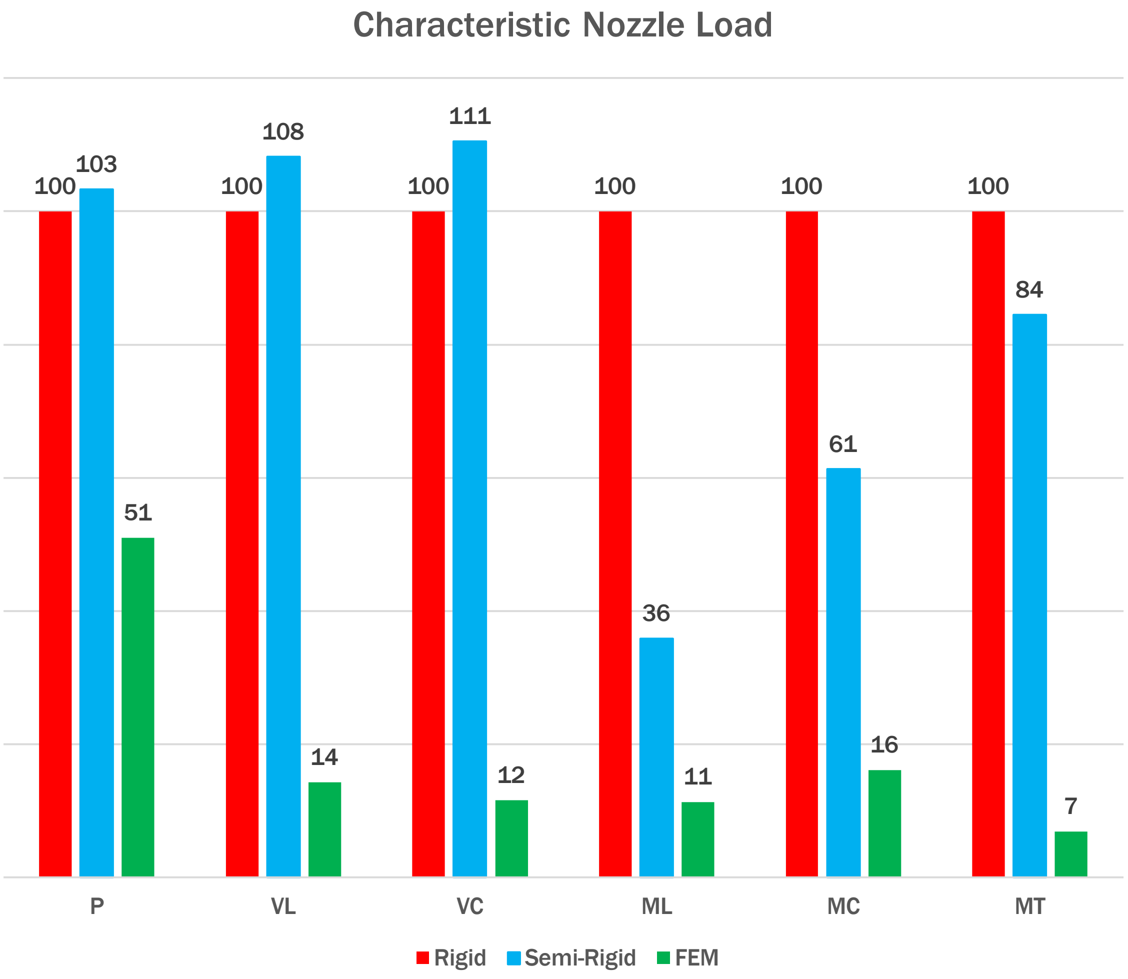
Complete FEM

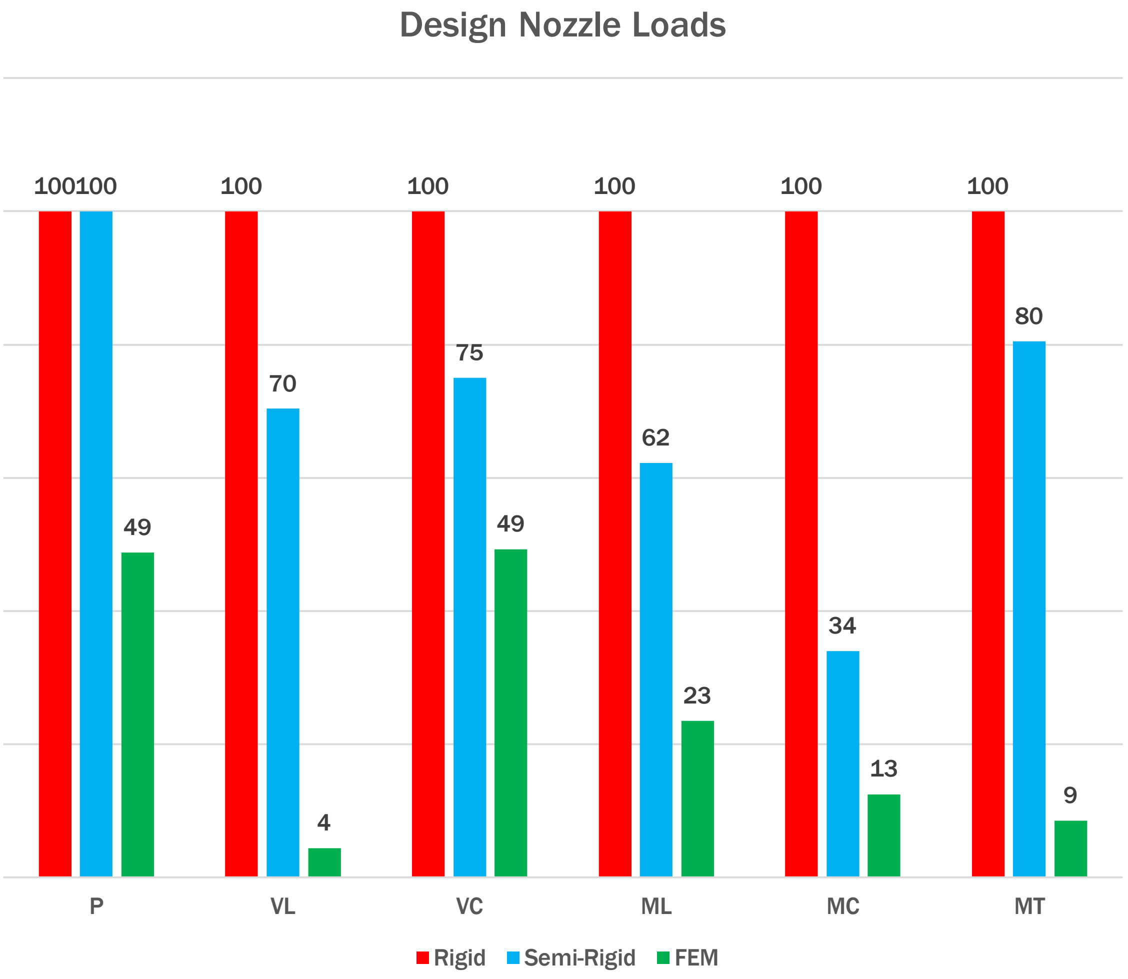
Reason of Nozzle Loads





Resultant Nozzle Loads





Summary of the problem statement

- Proof of nozzle loads is time-consuming and expensive
- Global determination of nozzle loads without taking into account the material properties of GRP and the cause of load is not sensible and uneconomical
- Load tracking to the supports and inclusion of the nozzle loads in the global tank stress resultant makes no sense.
- Intelligent piping modeling can minimize forces from equilibrium loads and greatly reduce the forces from impressed displacements

How can these technical expertise be implemented in the interaction of operating company, pipe - and tank structural engineer?

Approaches to solve the problem

Step 1:

- Fixing of characteristic and design nozzle loads under the definition of $\gamma_{Stutzen}$ und $A_{5,Stutzen}$
- Transformation to any laminate possible
- material-appropriate design

Step 2: Research

- Which nozzle diameters require proof?
- Down from which ratio tank/nozzle diameter a proof has to be done?
- When can a proof be omitted?
- Can a suitable substitute pressure be derived?
- How should nozzle loads be considered when calculating the support reactions and internal stress resultans of the shell?

Difficulties in developing analytical solutions:

Many solution parameters and their mutual influence

Development of a generally accepted FE Modell

What should the model afford?

- Easy and quick to use through parameterization
- Automatic smoothing of results based on [5]
- Complete documentation of the results

Questions

- **Who develops and who finances?**
- Interface to commercial FE Solution or stand-alone program?

Literature

Literatur

(1) EN 13121-3:2013, Oberirdische GFK-Tanks und -Behälter - Teil 3: Auslegung und Herstellung

(2) Berechnungsempfehlungen für stehende Behälter aus glasfaserverstärkten Kunstoffen 40-B1,DIBt - Berlin, Febr. 2016

(3) Berechnungsempfehlungen für auf Sattelschalen gelagerte Behälter aus glasfaserverstärkten Kunststoffen 40 - B2, DiBt - Berlin, Dez 2012

(4) AD-Merkblatt 2000

(5) Schlussbericht des Forschungsvorhabens Bewertung von strukturellen und mathematischen Störstellen bei der numerischen Simulation von Kunststoffbauteilen, Geschäftszeichen P 52-5-14.2-1411/12, DiBt 2013

Bildquellen

(1) IBB GmbH, IBB - Industriebau & Beratungs GmbH , 37359 Büttstedt, Hinter den Höfen 21, Deutschland

(2) IFKI, 67727 Lohnsfeld, Am Krummen Morgen 1, Deutschland