Beam

With the following program the static stress analysis of beams can be run.

The calculation results can be displayed graphically (resulting transverse forces, bending moments, bending stresses, shear stresses, deflection, tendency angle, static safety).

Groundwork Calculations

The groundwork of calculations for the calculation module 'Beam Calculation' is the Finite-Element Method.

Scope of the Program

- Loadings:

- Axial forces (centric, eccentric)	*Fa*	max. 20
- Radial forces	*Fr*	max. 20
- Distributed loads	*q*	max. 20
- Bending moments	*Mb*	max. 10
- Torsion moments	*T*	max. 10

  For the calculation of the beam for the constrained torsion the following limitations are in force:
  1. The beam must have a constant longitudinal cross-section.
  2. The beam can not have more than one span.
  3. Supports of a single beam can be two hinges or two restraints.
  4. The calculation is made with aaccording to "TM - Prof. Dr. Wandinger", the results are to be assessed as the first classification of the load. Due to local effects, curvature and the dependence of the load application, the results deviate considerably from a local view using the FEM calculation.
- Bearings
  - Number of max. bearings: 10
  - Rigid resp. elastic bearings (given bearing stiffness coefficients for degree of freedom)
  - Rigid bearing, free bearing, support, rigid clamping
- Analysis of the maximum deflection
- Analysis of the tendency angle of the bearing points
- Optional consideration of own weight
- Determination of different results for any beam position (Moments, Bending, Deflection, Angle of Deflection)
- Static stress analysis *Sf*
- max. 50 beam sections
- Available beam profiles:
  - Strip steel, hot DIN EN 10058
  - Equal leg angles DIN EN 10056-1
  - I-beams, I-series DIN 1025-1
  - I-beams, IPB-series DIN 1025-2
  - I-beams, IPBI-series DIN 1025-3
  - I-beams, IPBv-series DIN 1025-4
  - I-beams, IPE-series DIN 1025-5
  - Square, cold hollow sections DIN EN 10219-2
  - Square, hot hollow sections DIN EN 10210-2*
  - Rectangular, cold hollow sections DIN EN 10219-2
  - Rectangular, hot hollow sections DIN EN 10210-2*
  - Rounds, cold hollow sections DIN EN 10219-2
  - Rounds, hot hollow sections DIN EN 10210-2*
  - Rod, hot DIN EN 10060
  - T-steel, circular DIN EN 10055
  - Unequal leg angles DIN EN 10056-1

- U-profile, incline shelf DIN 1026-1
- U-profile, direct shelf DIN 1026-2
- Square profile, hot DIN EN 10059
- Z-steel, hot DIN 1027

* Profiles, whose symbolic notations include the suffix „(1997)", are no longer part of the present edition of the Norm DIN EN 10210-2.

Input data:

Beam Calculation

Geometry

Geometry scheme: General beam

Detailed calculation for position: x = 275 mm

Bearings

Nr.	Position x mm	Stiffness c_x N/mm	Stiffness c_y N/mm	Stiffness c_z N/mm	Tilt stiffness T_y N·m/°	Tilt stiffness T_z N·m/°
1	0	-1	-1	-1	-1	-1
2	1100	-1	-1	-1	-1	-1

Loading Data

Axial forces F_{ax}

Nr.	Position x mm	Amount F_{ax} N	Radius r mm	Angle α °
1	552.926	300	0	0

Bending moments M_b

Nr.	Position x mm	Amount M_b N·mm	Angle α °
1	550	75000	0
2	550	90000	90

Torsion moments T

Nr.	Position x mm	Amount T N·mm	Length l mm
1	550	585000	0

Material Data

Material (strength values) according to	MDESIGN database	
Material designation	S235JR	
Material number	1.0038	
Material group	Unalloyed structural steel	
Heat treatment / State	none	
Standard dimension	d_{Nm} = 40	mm
Standard dimension	d_{Np} = 40	mm
Ultimate strength for d_{Nm}	R_{mN} = 360	N/mm²
Yield point for d_{Np}	R_{pN} = 235	N/mm²
Modulus of elasticity	E = 210000	N/mm²
Poisson's ratio	ν = 0.3	
Density	ρ = 7850	kg/m³
Temperature	T = 20	°C
Material, surface hardened	no	
Loads mainly crosswise to the preferred direction of machining (rolling)	no	

Results:

Geometry

Total length of the beam	l_g	=	1100	mm
Total mass of the beam	m	=	8.39	kg
Position of center of gravity (x-axis)	x_s	=	550	mm

Beam profiles

Cross section nr.	Beam profile	Symbolic notation	Width b mm	Height h mm	Diameter (Distance to axis) d mm	Beam flange t mm	Wall thickness s mm
1	Square, hot hollow sections	50x5	50	50	0	5	0
2	Square, hot hollow sections	60x5	60	60	0	5	0
3	Square, hot hollow sections	50x5	50	50	0	5	0

Beam geometry

Nr	l_i mm	A cm²	I_y cm⁴	I_z cm⁴	W_y cm³	W_z cm³	S_y cm³	S_z cm³
1	275	8.73	28.9	28.9	11.6	11.6	7.625	7.625
2	550	10.7	53.3	53.3	17.8	17.8	11.375	11.375
3	275	8.73	28.9	28.9	11.6	11.6	7.625	7.625

Loading Data

Bearing react. force

Nr	Type	Position x mm	R_y N	R_z N	R N	R_{ax} N	α °
1	Rigid clamping	0	865.28	212.8	891.06	-149.28	0
2	Rigid clamping	1100	634.72	404.93	752.89	-150.72	0

Calculation results of maximum stresses and loadings

Max. bending moment

Max. bending moment around y-axis:

Position	x	=	550	mm
Amount	M_{ymax}	=	143.082	N·m

Max. bending moment around z-axis:

Position	x	=	550	mm
Amount	M_{zmax}	=	281.861	N·m

Resulting maximum bending moment:

Position	x	=	550	mm
Amount	M_{bmax}	=	289.967	N·m

Resulting maximum tension-pressure-stress:

Position	x	=	825	mm
Amount	σ_{zdmax}	=	-0.173	N/mm²

Maximum value of the normal stress

Salient point	Tension-pressure-stress σ_{zd} N/mm²	Bending stress in consequence of M_{ymax} ($M_{\eta max}$) $\sigma_{\eta max}$ N/mm²	Bending stress in consequence of M_{zmax} ($M_{\zeta max}$) $\sigma_{\zeta max}$ N/mm²	Combined characteristic of normal stress σ_{res} N/mm²
P1	0.14	15.86	8.05	24.06
P2	0.14	15.86	0	16
P3	0.14	15.86	-8.05	7.95
P3*	0.14	15.86	-8.05	7.95
P4	0.14	0	-8.05	-7.91
P5*	0.14	-15.86	-8.05	-23.78
P5	0.14	-15.86	-8.05	-23.78
P6	0.14	-15.86	0	-15.73
P7	0.14	-15.86	8.05	-7.67
P7*	0.14	-15.86	8.05	-7.67
P8	0.14	0	8.05	8.19
P1*	0.14	15.86	8.05	24.06

Maximum combined characteristic of the normal stress

Position	x	=	550	mm
Amount	σ_{resmax}	=	24.058	N/mm²

Maximum value of the shear stress

Salient point	Shear stress in consequence of F_z τ_{zmax} N/mm²	Shear stress in consequence of F_y τ_{ymax} N/mm²	Stress of torsion moment τ N/mm²	Combined characteristic of shear stress τ_{res} N/mm²
P1	0.45	1.68	0	2.13
P2	0.7	0	0	0.7
P3	0.45	1.68	0	2.13
P3*	0.45	1.68	0	2.13
P4	0	2.62	0	2.62
P5*	0.45	1.68	0	2.13
P5	0.45	1.68	0	2.13
P6	0.7	0	0	0.7
P7	0.45	1.68	0	2.13
P7*	0.45	1.68	0	2.13
P8	0	2.62	0	2.62
P1*	0.45	1.68	0	2.13

Maximum combined characteristic of the shear stress

Position	x	=	275	mm
Amount	τ_{resmax}	=	2.62	N/mm²

Maximum equivalent stress:

Position	x	=	550	mm
Amount	σ_{vxmax}	=	24.084	N/mm²

Min. safety against yield point:

Position	x	=	550	mm
Amount	S_{Fmin}	=	9.758	

Max. deflection

Resultant max. deflection

Position	x	=	538.043	mm
Amount	v_{max}	=	0.135	mm

Angle of the maximum deflection

Position	x	=	538.043	mm

Amount		=	0.003712	°
Calculation results for point	x	=	275	mm
Bending moments around y-axis	M_y	=	43.91	N·m
Bending moments around z-axis	M_z	=	1.364	N·m
Result. max. bending moment	M_b	=	43.931	N·m
Tension-pressure-stress	σ_{zdx}	=	0.171	N/mm²

Normal stress

Salient point	Tension-pressure-stress σ_{zd} N/mm²	Bending stress in consequence of M_y (M_η) σ_η N/mm²	Bending stress in consequence of M_z (M_ζ) σ_ζ N/mm²	Combined characteristic of normal stress σ_{res} N/mm²
P1	0.17	3.8	0.12	4.09
P2	0.17	3.8	0	3.97
P3	0.17	3.8	-0.12	3.85
P3*	0.17	3.8	-0.12	3.85
P4	0.17	0	-0.12	0.05
P5*	0.17	-3.8	-0.12	-3.75
P5	0.17	-3.8	-0.12	-3.75
P6	0.17	-3.8	0	-3.63
P7	0.17	-3.8	0.12	-3.51
P7*	0.17	-3.8	0.12	-3.51
P8	0.17	0	0.12	0.29
P1*	0.17	3.8	0.12	4.09

Maximum combined characteristic of the normal stress	σ_{res}	=	4.087	N/mm²

Shear stresses

Salient point	Shear stress in consequence of F_z τ_z N/mm²	Shear stress in consequence of F_y τ_y N/mm²	Stress of torsion moment τ N/mm²	Combined characteristic of shear stress τ_{res} N/mm²
P1	0.45	1.68	0	2.13
P2	0.7	0	0	0.7
P3	0.45	1.68	0	2.13
P3*	0.45	1.68	0	2.13
P4	0	2.62	0	2.62
P5*	0.45	1.68	0	2.13
P5	0.45	1.68	0	2.13
P6	0.7	0	0	0.7
P7	0.45	1.68	0	2.13
P7*	0.45	1.68	0	2.13
P8	0	2.62	0	2.62
P1*	0.45	1.68	0	2.13

Maximum combined characteristic of the shear stress	τ_{res}	=	2.62	N/mm²
Equivalent stress	σ_{vx}	=	6.107	N/mm²
Safety against yield point	S_F	=	38.48	
Resulting maximum deflection	v	=	0.076	mm
Angle of the deflection		=	0.020948	°

Material Data

Material data for	x	=	275	mm
Effective blank diameter	d_{eff}	=	17.46	mm
Ultimate strength	R_m	=	360	N/mm²
Yielding point	R_e	=	235	N/mm²

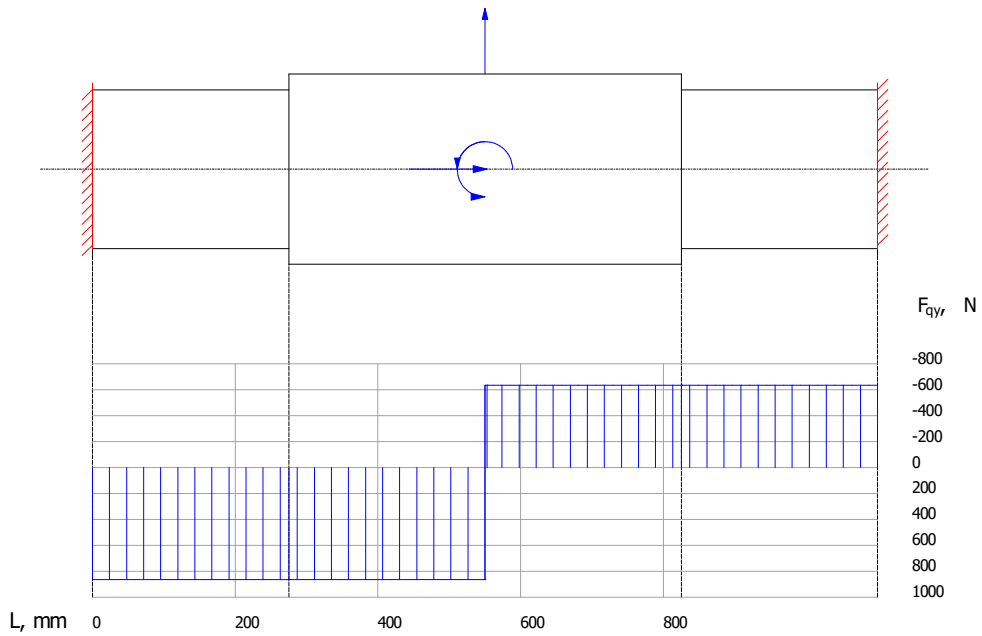
Notice:

For the calculation of the beam for the constrained torsion the following limitations are in force:

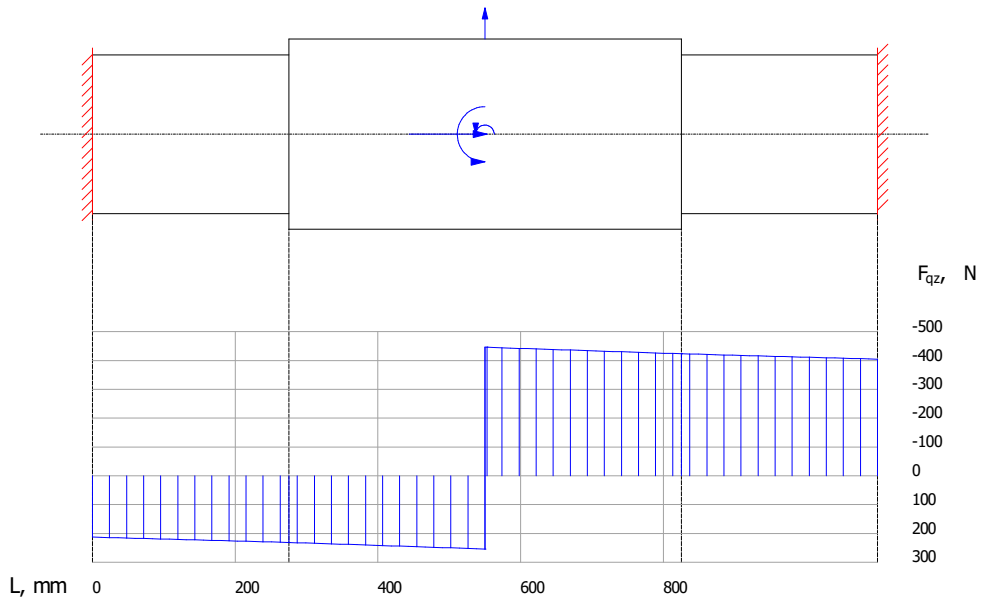
- the beam must have a constant longitudinal cross-section;
- the beam can not have more than one span;
- supports of a single beam can be two hinges or two restraint;

- as beam profiles only standard profiles should be considered.

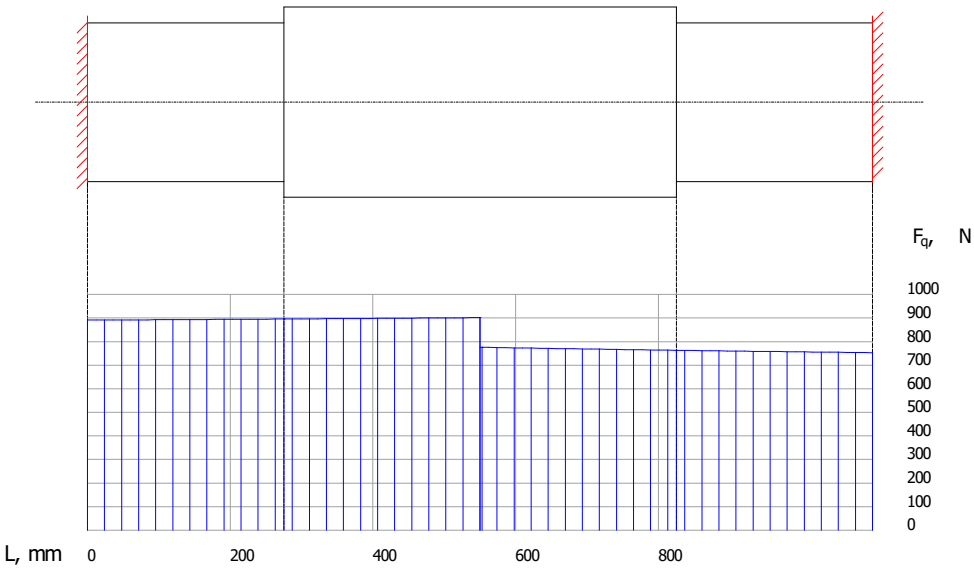
Transverse force development (X - Y - plane)



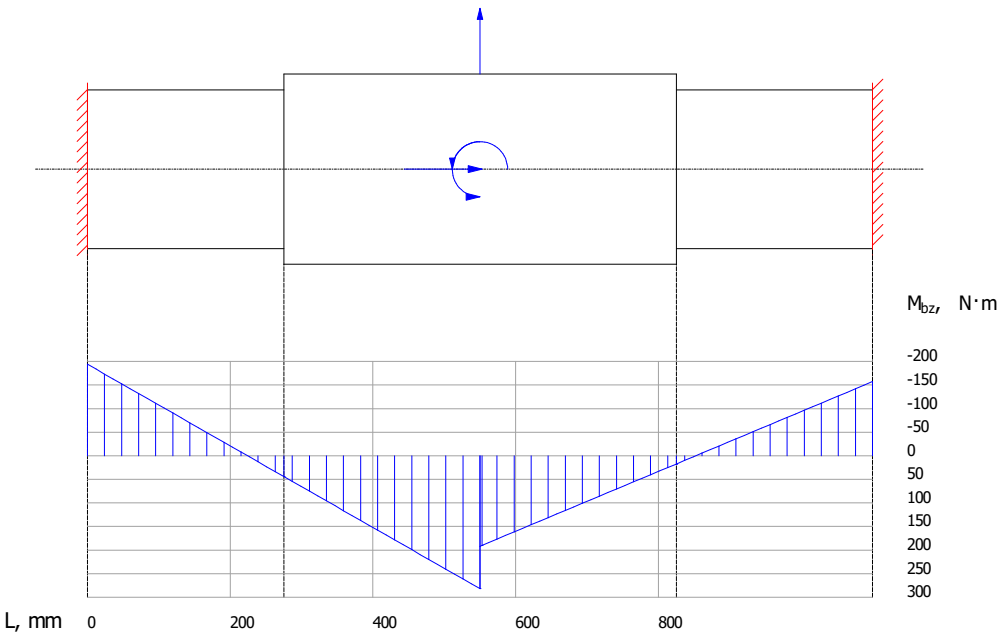
Transverse force development (X - Z - plane)



Transverse force development (resultant)

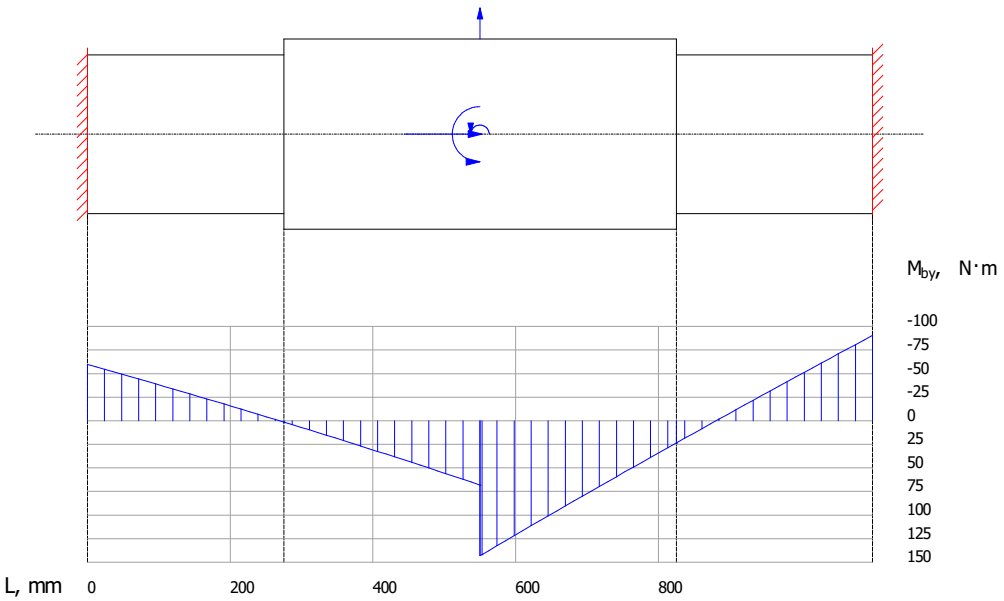


Bending moment development (X - Y - plane)

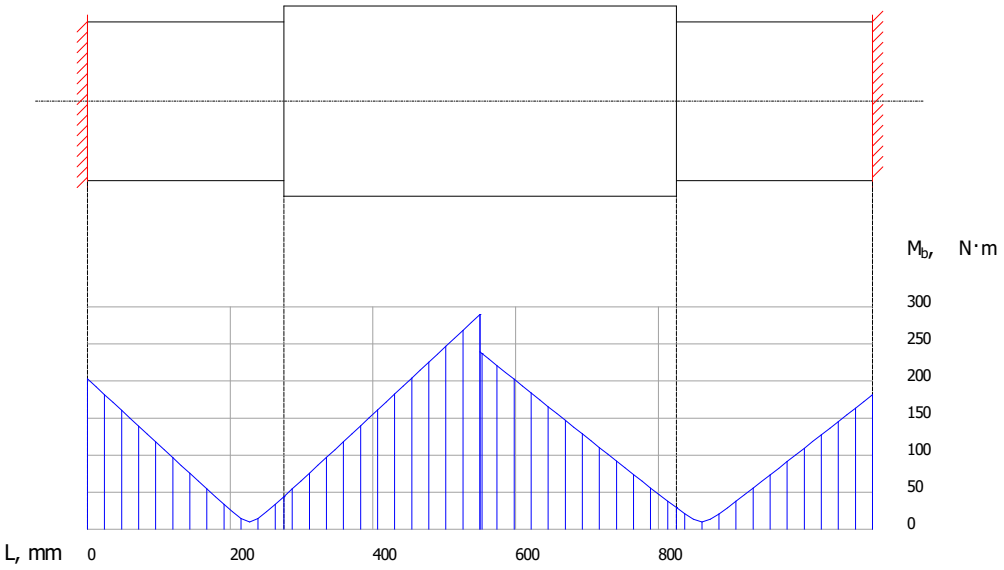


Beam

Bending moment development (X - Z - plane)

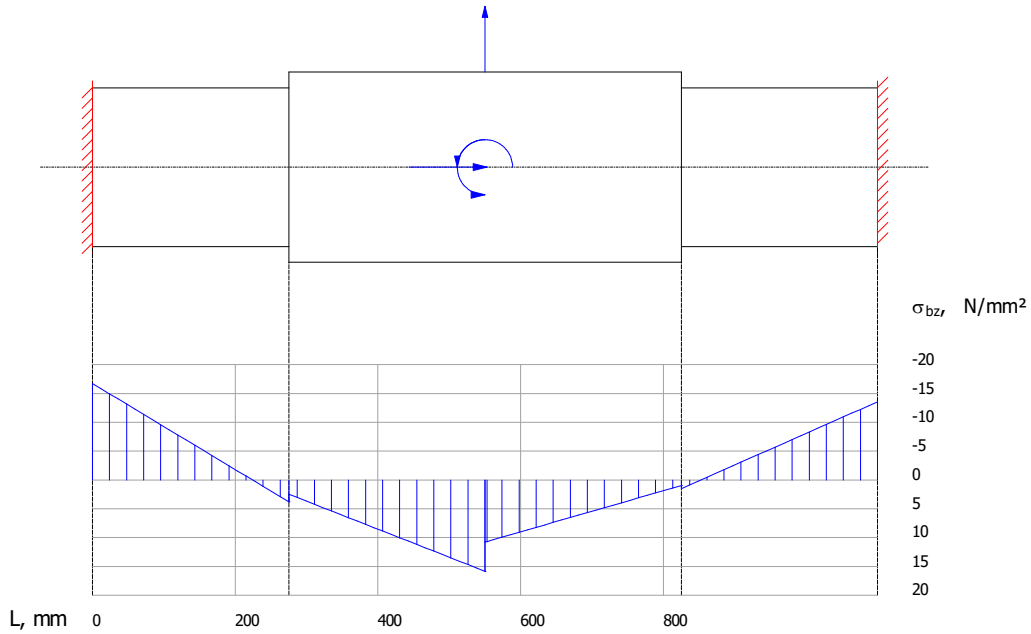


Bending moment development (resultant)

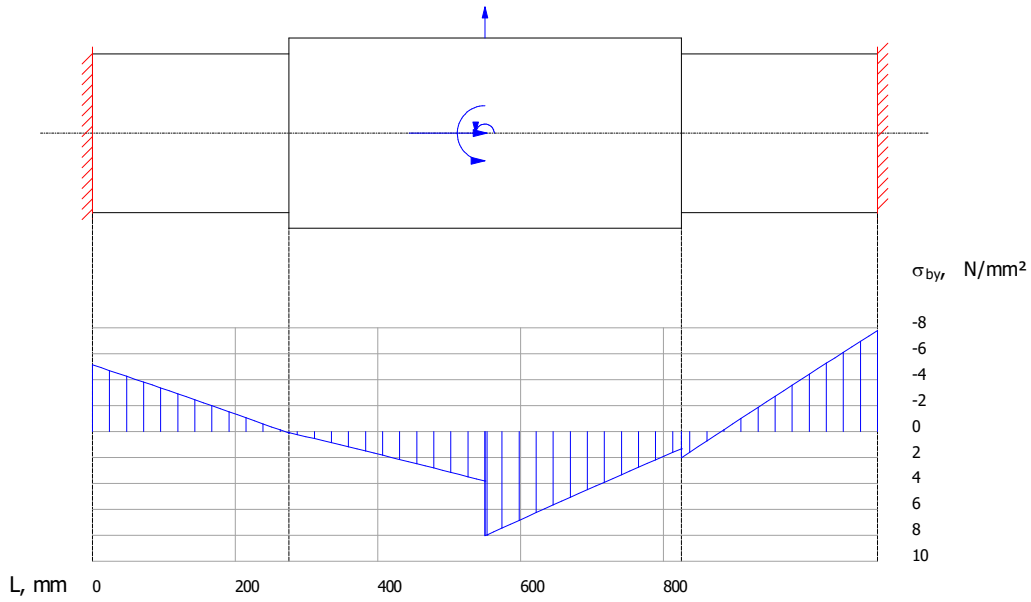


Beam

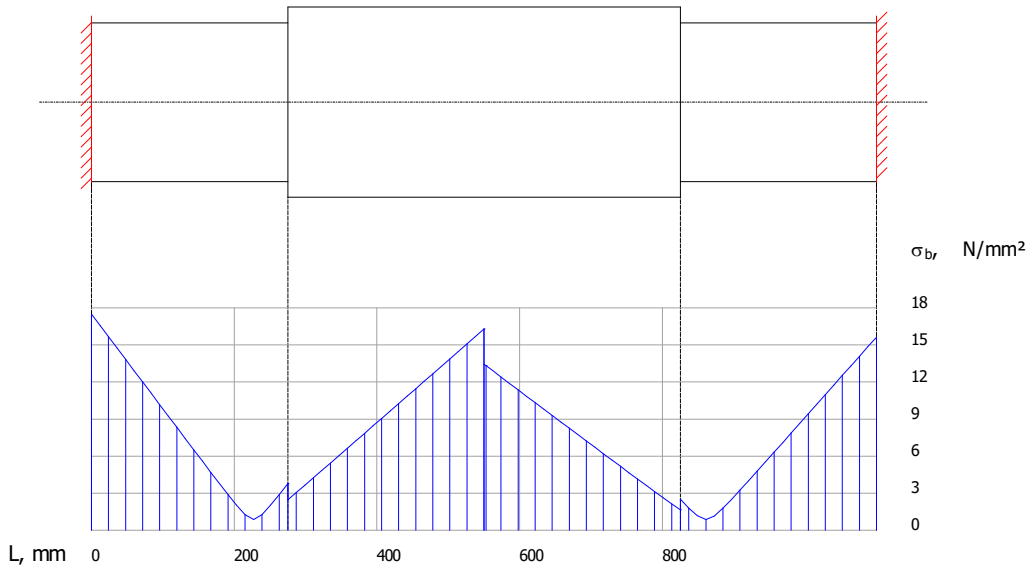
Bending stress development (X - Y - plane)



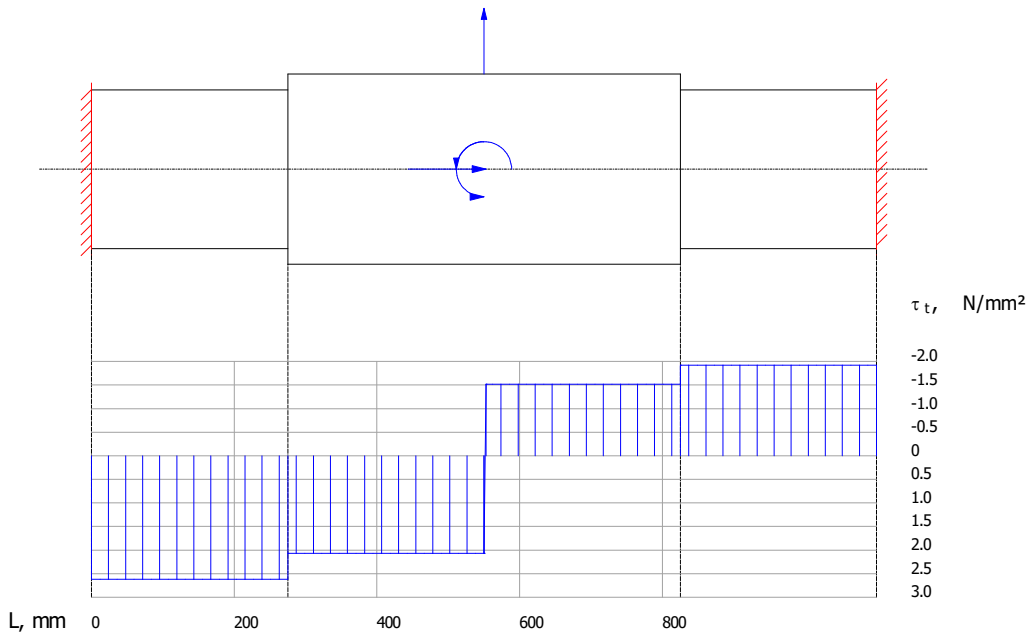
Bending stress development (X - Z - plane)



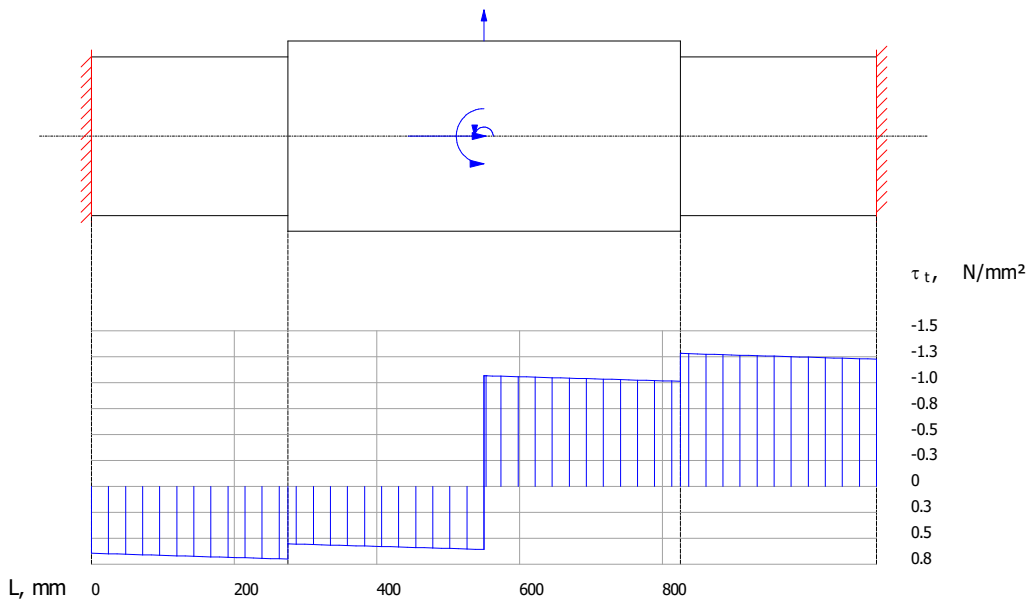
Bending stress development (resultant)



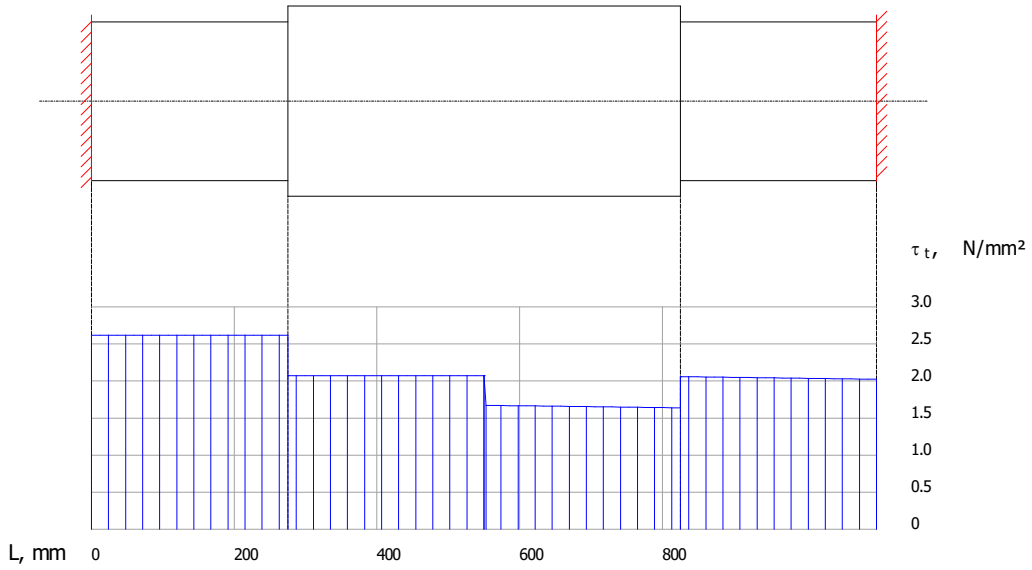
Shear stress development (X - Y - plane)



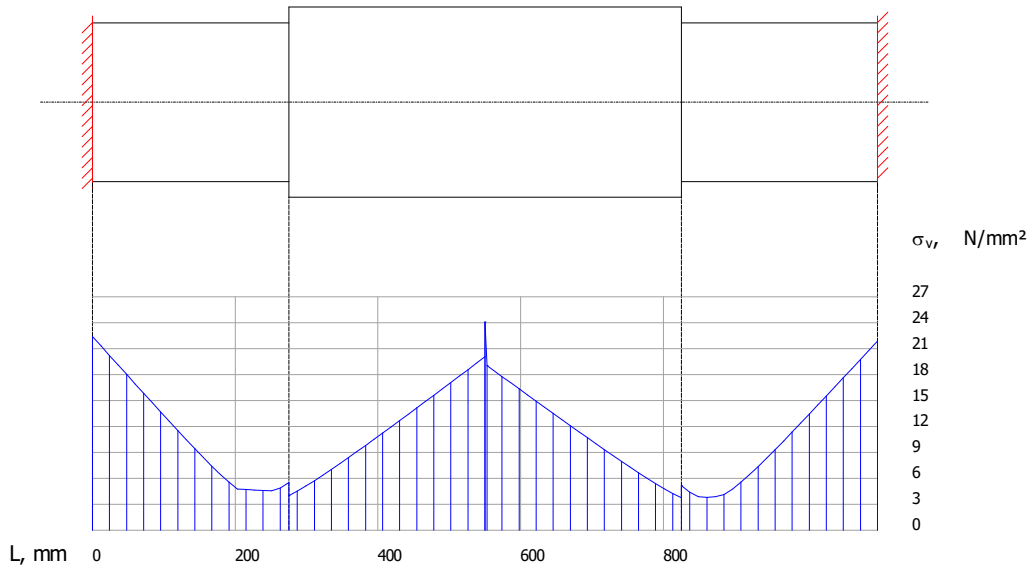
Shear stress development (X - Z - plane)



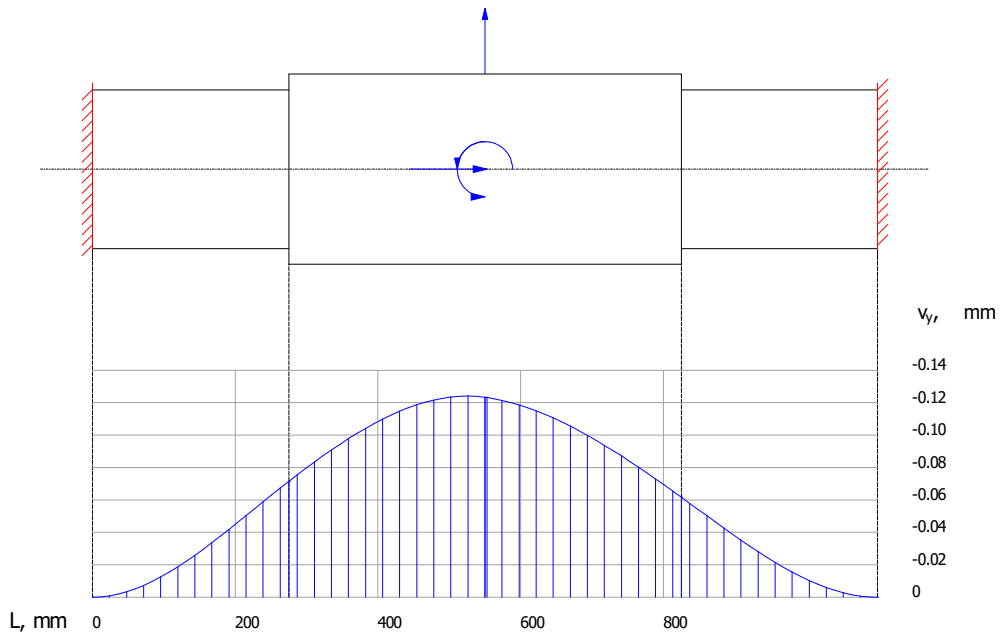
Shear stress development (resultant)



Equivalent stress development (resultant)

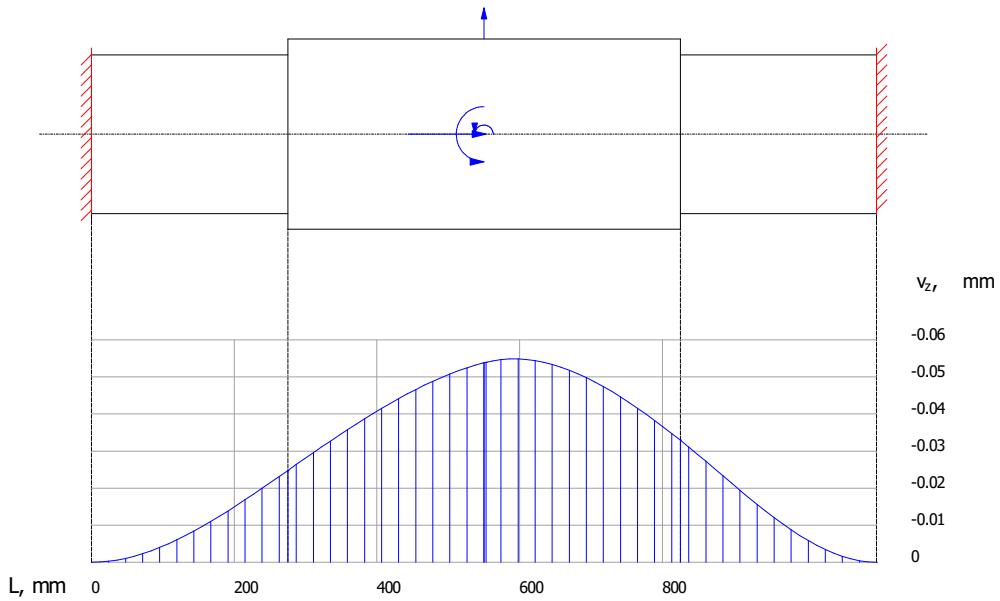


Deflection (X - Y - plane)

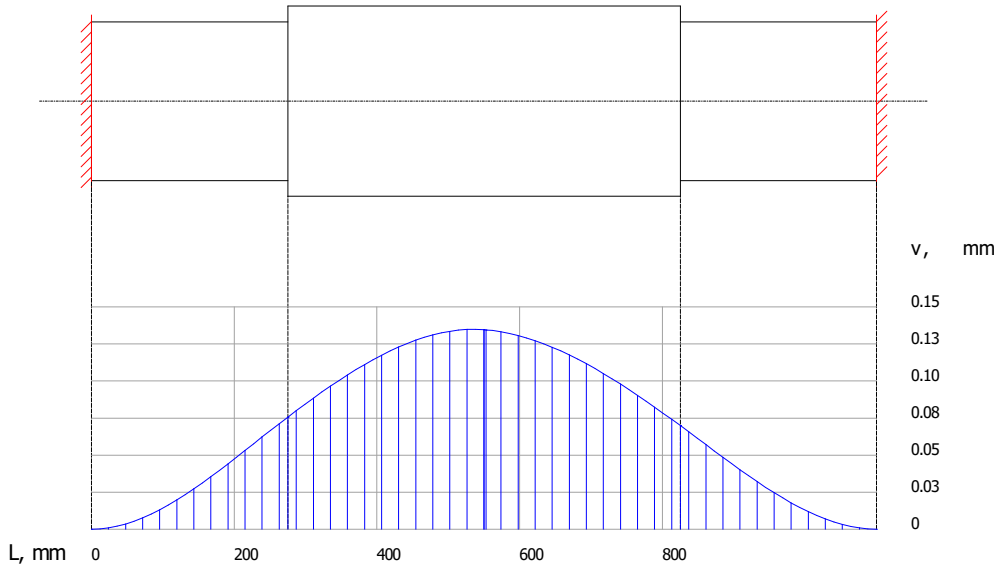


Beam

Deflection (X - Z - plane)

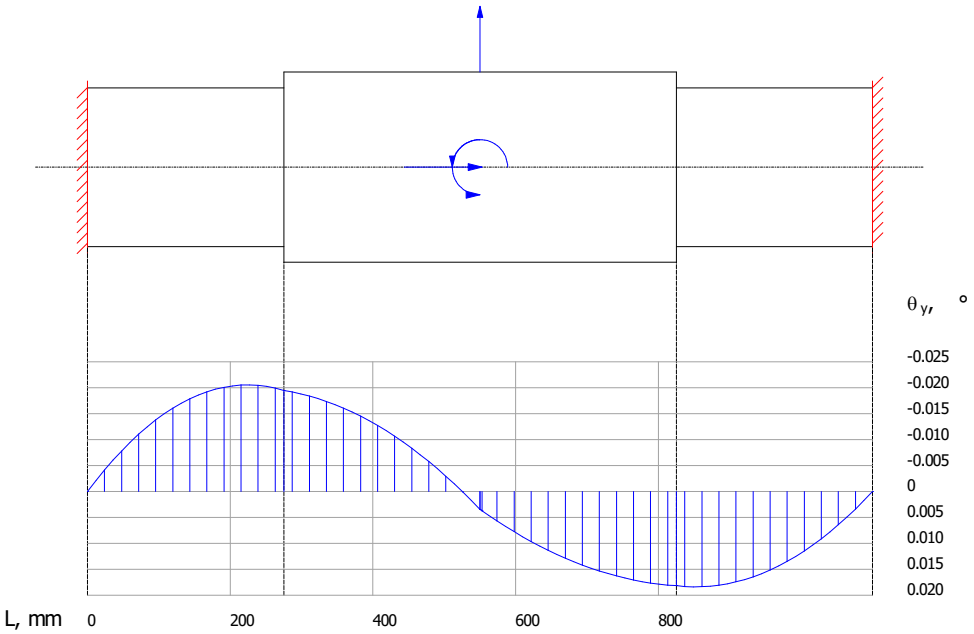


Deflection (resultant)

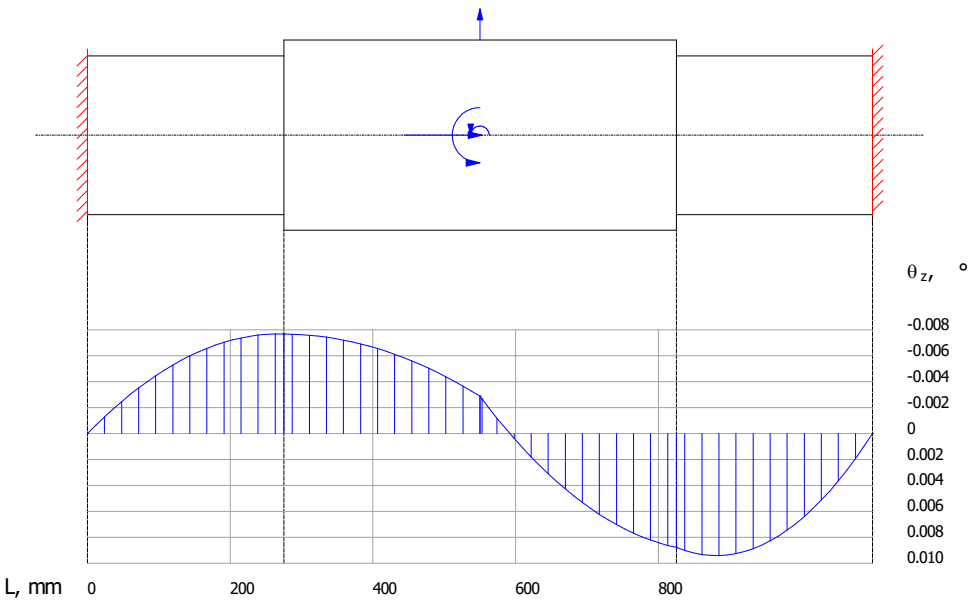


Beam

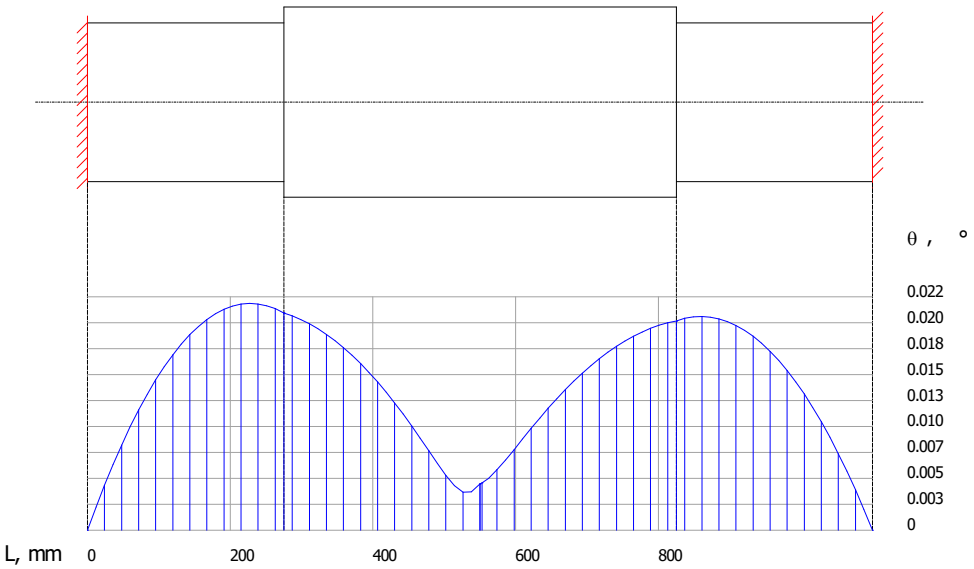
Inclination (X - Y - plane)



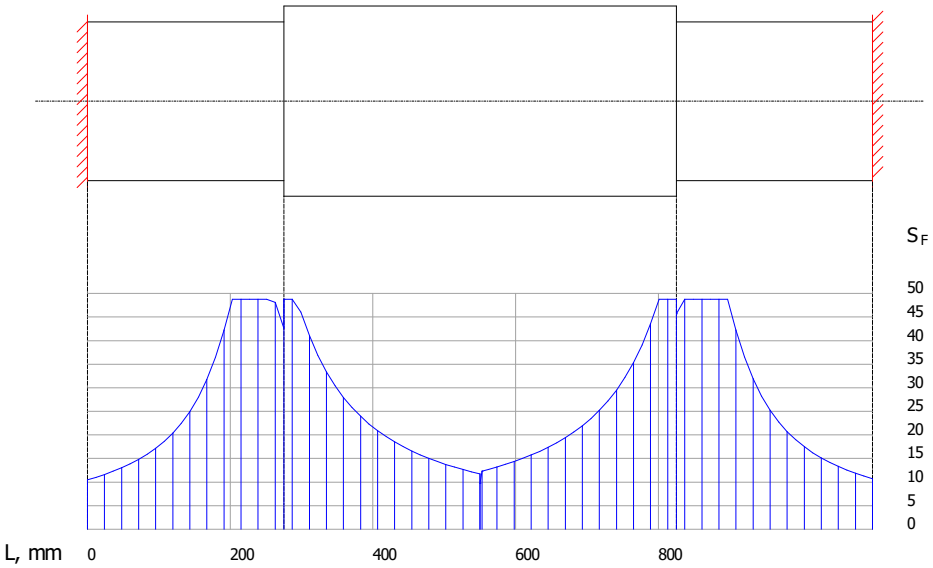
Inclination (X - Z - plane)



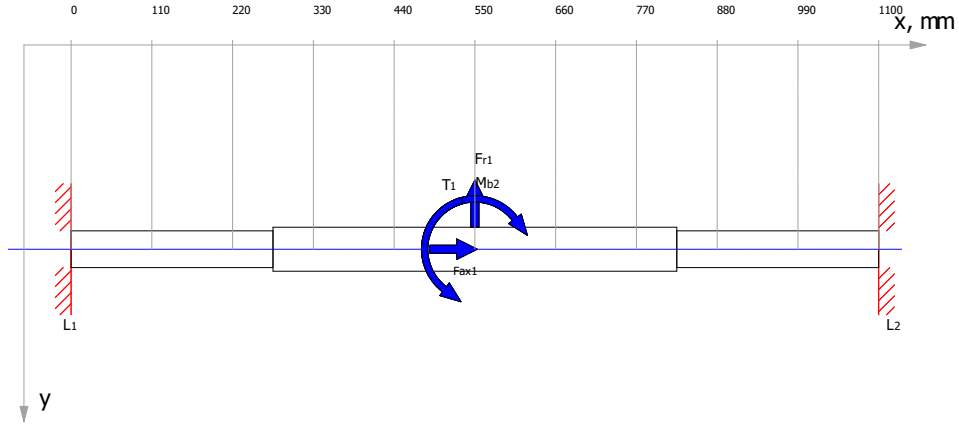
Inclination (resultant)



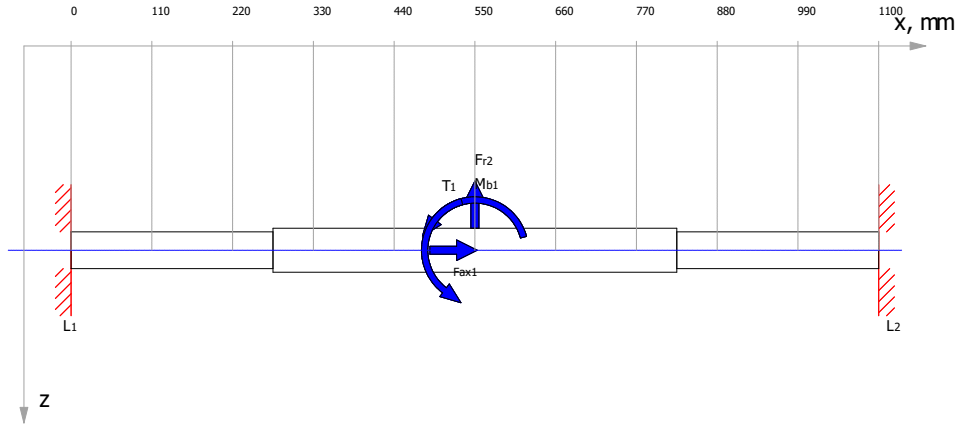
Safety against yield point
(detail: $S_f = 5 * S_{fmin}$)



Resultant graphic (X - Y - plane)

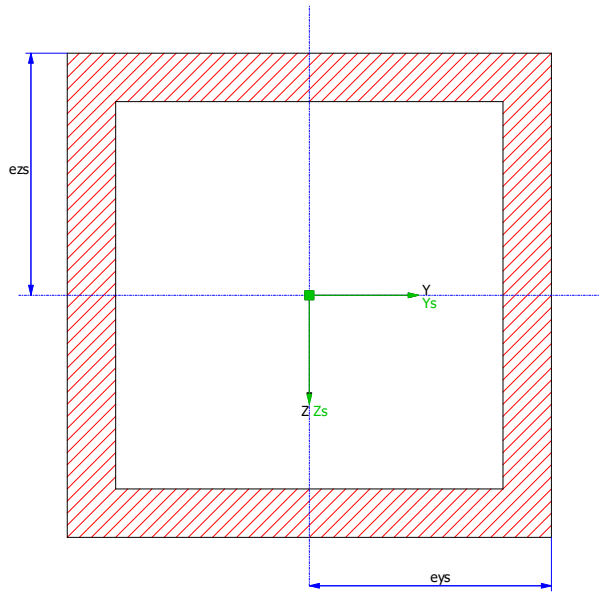


Resultant graphic (X - Z - plane)

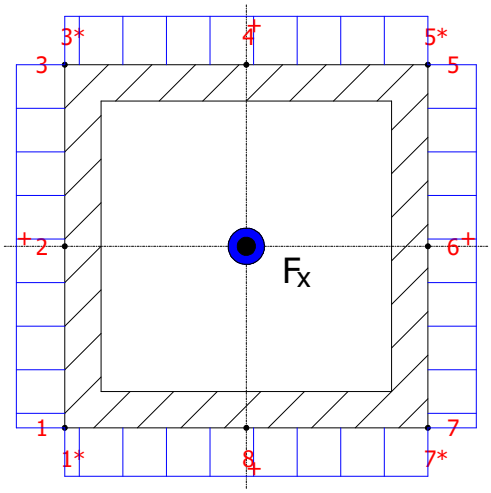


Beam

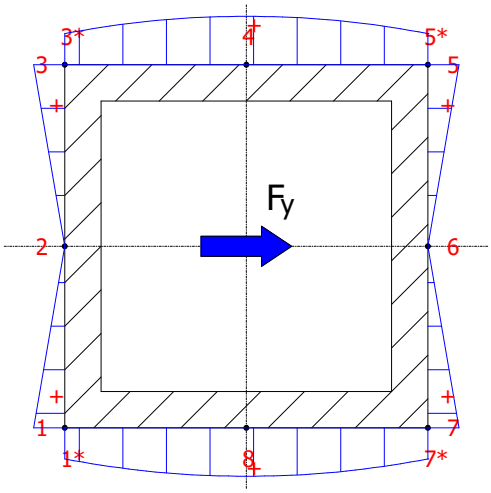
Graphical presentation



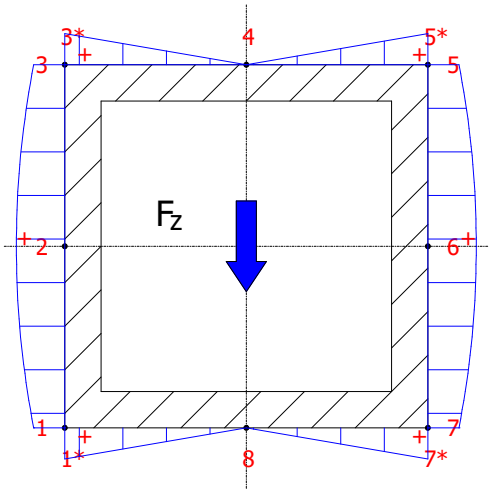
Stress of axial force Fx



Stress of radial force Fy

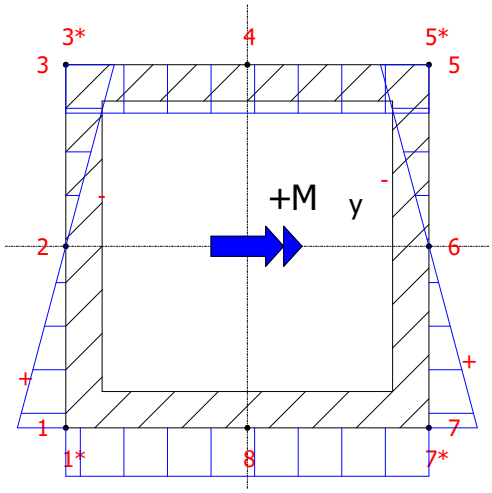


Stress of radial force Fz



Beam

Stress of bending moment My



Stress of bending moment Mz