Shaft

Producer:	Cirstocea Romeo		LOGO
Verify by:			Project:
Program:	MDESIGN 2022 - Secon...	Module version: 19.1.5	Date: 05/16/2024
Customer:	romeo		

This program allows to prove the bearing ability for shafts and axles. The calculation base is provided by DIN 743, edition of December 2012 .

The proof of the bearing ability for shafts an axles is produced by defining a calculated safety. This safety is divided in the safety against fatigue fracture and the residual deformation (and flaw or forced break).

When calculating the avoidance of fatigue fracture, constant stress amplitudes being equivalent to damaging loads are taken as a basis. These ones are resulting from the predetermined loads. When proving against the residual deformation or forced break, designated as a safety against yielding, only the maximum occurring load is determinant. This one is resulting from the predetermined loads, too.

The calculation of factors of safety is related only to the point of a clear notch effect. For it, 9 calculable notches are at your disposal due to the graphical selection, principally.

The scope is limited to steels. Welded members should be calculated separately. But the utilized standard or the present program is ineffective for this purpose!

The calculation base for the module Shaft Calculation is provided by DIN 743, edition of December 2012, part 1-4 " Tragfähigkeitsberechnung von Wellen and Achsen" ("Calculation of bearing capacity of shafts and axles").

Input data:

Shaft calculation in accordance with DIN 743 - extended version

Geometry scheme	General shaft geometry
Calculation process	Dynamic and static strength proof

Geometry

Shaft geometry

Shaft geometry

Nr.	$D_{a\,l}$ mm	$D_{i\,l}$ mm	$D_{a\,r}$ mm	$D_{i\,r}$ mm	L mm	R_z µm	r mm	d: mm	t: mm	$\alpha_{\sigma\,zd}$:	$\alpha_{\sigma\,b}$:	$\alpha_{\tau t}$:	n_{zd}:	n_b:	n_t:	$\beta_{\sigma\,zddBK}$:	$\beta_{\sigma\,bdBK}$:	$\beta_{\tau\,dBK}$:	d_{BK}: mm
1	28	0	28	0	42	3.2	1	0	0	0	0	0	0	0	0	0	0	0	0
2	40	0	40	0	40	1.6	0.8	39.4	0	0	0	0	0	0	0	0	0	0	0
3	50	0	50	0	10	6.3	1	0	0	0	0	0	0	0	0	0	0	0	0
4	39.756	0	39.756	0	39	3.2	1	0	0	0	0	0	0	0	0	0	0	0	0
5	50	0	50	0	10	6.3	0.8	39.4	0	0	0	0	0	0	0	0	0	0	0
6	40	0	40	0	23	1.6	0	0	0	0	0	0	0	0	0	0	0	0	0

Predetermine the diameter determinant for the heat treatment? No

Calculation of the deflection for point x = 111.5 mm
Shaft speed n : 1000 1/min
Considering weight - horizontal or vertical Horizontal shaft
Consider gyroscope effect? No
Consider bearing stiffness? No

Bearing

Nr.	Type =	Position x = mm	Radial bearing stiffness c_r = N/m	Torsional bearing stiffness c_α = N·m	Bending bearing stiffness c_β = N·m
1	Support bearing ->	70.5	1e+15	0	0
2	Support bearing <-	151.5	1e+15	0	0

Loading Data

Type of loading: tension-pressure Dynamically pure cyclic
Type of loading: bending Dynamically pure cyclic

Type of loading: torsion — Dynamically pure cyclic

Factor for maximum loading (tension-pressure)	1
Factor for maximum loading (bending)	1
Factor for maximum loading (torsion)	1

Axial forces F_{ax}

Nr.	Position x = mm	Amount = N	Radius = mm	Angle α = °
1	111.5	-666	25.066	180

Radial forces F_r

Nr.	Position x = mm	Amount = N	Angle α = °
1	21	-1103.8303	270
2	111.5	-1103.8303	0
3	111.5	-3133.395	90

Torsion

Nr.	Position x = mm	Torsion moments M_t: N·mm	Power P: kW	Transition part =
1	21	71620	0	drive
2	111.5	71620	0	takeoff

Specifications about the load/loadings

Loading case	Constant mean stress (loading case 1)
Calculation of finite-life fatigue strength?	No
Minimum safety against fatigue fracture	S_{Dmin} = 1.2
Minimum safety against residual deformation	S_{Fmin} = 1.2

Minimum safety against incipient crack with hard surface $S_{Gmin} = 1.2$

Material Data

Strength values according to	MDESIGN database	
Material designation	18MoCrS4	
Material number	1.7323	
Gage diameter	$d_B = 16$	mm
For the gage diameter		
Tensile strength	$\sigma_{B'}$ (R_m) = 1100	N/mm²
Yield stress	$\sigma_{S'}$ (R_e) = 775	N/mm²
Cyclic fatigue strength under bending stress	$\sigma_{bW'}$ = 550	N/mm²
Cyclic tension and pressure fatigue strength	$\sigma_{zdW'}$ = 440	N/mm²
Cyclic torsional fatigue strength	$\tau_{tW'}$ = 330	N/mm²
Young's modulus	E = 215000	N/mm²
Shear modulus	G = 83000	N/mm²
Density	ρ = 7850	
Apply surface hardening to	Total shaft	
Material group	Cemented steels	
Heat treatment	trial hardened	
Surface hardening	cemented	

Results:

Calculation process: Dynamic and static strength proof

Summary

Minimum safety against yielding:

Position	x	=	42	mm
Amount	S_F	=	21.109	

Minimum safety against fatigue fracture:

Position	x	=	42	mm
Amount	S_D	=	10.459	

Minimum safety against incipient crack with hard surface:

Position	x	=	42	mm
Amount	S_G	=	53.427	
Calculation results for point	**x**	=	111.5	mm
Deflection	y_x	=	0.002011	mm

Geometry

Total shaft length	L	=	164	mm
Total shaft mass	m	=	1.513	kg
Mass moment of inertia of the shaft	J	=	0.00032	kg·m²
Geometrical moment of inertia of the shaft	I	=	101.772	cm⁴
Position of the centre of gravity in the X-axis	x_s	=	92.593	mm
Angle of torsion	φ	=	0.03	°

Additional shaft data:

Shaft fillet number	l mm	I_p cm⁴	W_t cm³	m kg	J kg·m²	I cm⁴	W_b cm³
1	42	6.034	4.31	0.203	0	3.017	2.155
2	40	25.133	12.566	0.395	0.0001	12.566	6.283
3	10	61.359	24.544	0.154	0	30.68	12.272
4	39	24.525	12.338	0.38	0.0001	12.263	6.169
5	10	61.359	24.544	0.154	0	30.68	12.272
6	23	25.133	12.566	0.227	0	12.566	6.283

Loading Data

Calculation results for point	**x**	=	111.5	mm
Trend of curve of the transverse force	Q_x	=	2385.982	N
Deflection	y_x	=	0.002011	mm
Angle of deflection	Θ	=	0.00045	°

Supporting forces:

No.	Type	Position x mm	Radial force in the Y-axis R_y N	Radial force in the Z-axis R_z N	Result. radial force R N	Axial force in the X-axis R_{ax} N	Tilting moment in the Y-axis N·m	Tilting moment in the Z-axis N·m	Result. tilting moment N·m
1	Support bearing ->	70.5	349.792	-231.038	419.205	666	0	0	0
2	Support bearing <-	151.5	768.874	2260.602	2387.779	0	0	0	0

Resulting maximum bending moment:				
Position	x	=	111.5	mm
Amount	M_{bmax}	=	95.464	N·m
Resulting maximum torsional moment:				
Position	x	=	21	mm
Amount	M_{tmax}	=	71.62	N·m
Resulting maximum tension-pressure-force:				
Position	x	=	70.5	mm
Amount	F_{zdmax}	=	-666	N
Resulting maximum tension-pressure-stress:				
Position	x	=	92.074	mm
Amount	σ_{zdmax}	=	-0.537	N/mm²
Resulting maximum bending stress:				
Position	x	=	111.5	mm
Amount	σ_{bmax}	=	15.475	N/mm²
Resulting maximum torsional stress:				
Position	x	=	21	mm
Amount	τ_{tmax}	=	16.616	N/mm²
Resulting maximum equivalent stress:				
Position	x	=	41.937	mm
Amount	σ_{vmax}	=	30.724	N/mm²
Resulting maximum deflection:				
Position	x	=	0	mm
Amount	y_{max}	=	0.010075	mm
Angle of the maximum deflection:				
Position	x	=	1.406	mm
Amount	Θ	=	0.009676	°

Minimum safety against yielding:

Position	x	=	42	mm
Amount	S_F	=	21.109	

Minimum safety against fatigue fracture:

Position	x	=	42	mm
Amount	S_D	=	10.459	

Minimum safety against incipient crack with hard surface:

Position	x	=	42	mm
Amount	S_G	=	53.427	

Parameter of cross-sections:

Tension-pressure force F_{zd} and tension/pressure stress σ_{zd}

No.	Type	Position x mm	Result. F_{zdx} N	Amplitude F_{zda} N	Mean F_{zdm} N	Maximum F_{zdmax} N	Amplitude σ_{zda} N/mm²	Mean σ_{zdm} N/mm²	Maximum σ_{zdmax} N/mm²
1	Shaft fillet	42	0	0	0	0	0	0	0
2	Fillet with recess	82	-666	-666	0	-666	-0.546	0	-0.546
3	Shaft fillet	92	-666	-666	0	-666	-0.537	0	-0.537
4	Shaft fillet	131	0	0	0	0	0	0	0
5	Fillet with recess	141	0	0	0	0	0	0	0
6	Calculation results for point x	111.5	0	0	0	0	0	0	0

Bending moment M_b and bending stress σ_b

No.	Type	Position x mm	Result. M_{bx} N·m	Amplitude M_{ba} N·m	Mean M_{bm} N·m	Maximum M_{bmax} N·m	Amplitude σ_{ba} N/mm²	Mean σ_{bm} N/mm²	Maximum σ_{bmax} N/mm²
1	Shaft fillet	42	23.18	23.18	0	23.18	10.756	0	10.756
2	Fillet with recess	82	64.79	64.79	0	64.79	10.79	0	10.79
3	Shaft fillet	92	73.762	73.762	0	73.762	11.957	0	11.957
4	Shaft fillet	131	48.932	48.932	0	48.932	7.932	0	7.932
5	Fillet with recess	141	25.063	25.063	0	25.063	4.174	0	4.174
6	Calculation results for point x	111.5	95.464	95.464	0	95.464	15.475	0	15.475

Torsional moment M_t und Torsional stress τ_t

No.	Type	Position x mm	Result. M_{tx} N·m	Amplitude M_{ta} N·m	Mean M_{tm} N·m	Maximum M_{tmax} N·m	Amplitude τ_{ta} N/mm²	Mean τ_{tm} N/mm²	Maximum τ_{tmax} N/mm²
1	Shaft fillet	42	71.62	71.62	0	71.62	16.616	0	16.616
2	Fillet with recess	82	71.62	71.62	0	71.62	5.964	0	5.964
3	Shaft fillet	92	71.62	71.62	0	71.62	5.805	0	5.805
4	Shaft fillet	131	0	0	0	0	0	0	0
5	Fillet with recess	141	0	0	0	0	0	0	0
6	Calculation results for point x	111.5	71.62	71.62	0	71.62	5.805	0	5.805

Critical shaft speed values:

Critical bending shaft speed values

No.	Critical shaft speed values n_b 1/min	Eigenfrequencies ω rad/s
1	264419.11	27689.9
2	669626.57	70123.13
3	1081236.57	113226.83
4	1723250.47	180458.37
5	2268583.55	237565.51

Critical torsional shaft speed values

No.	Critical shaft speed values n_b 1/min	Eigenfrequencies ω rad/s
1	705008.67	73828.34
2	1126827.44	118001.09
3	1713924.04	179481.71
4	2323507.03	243317.09
5	3008243.86	315022.56

Material Data

Material parameter for	d_{max}	=	50	mm
Material designation		18MoCrS4		
Material number		1.7323		
Tensile strength	σ_B	=	876.823	N/mm²
Yield stress	σ_S	=	617.761	N/mm²
Cyclic tension and pressure fatigue strength	σ_{zdW}	=	350.729	N/mm²
Cyclic fatigue strength under bending stress	σ_{bW}	=	438.411	N/mm²
Cyclic torsional fatigue strength	τ_{tW}	=	263.047	N/mm²
Technological dimension factor (tensile strength)	$K_{1B}(d_{max})$	=	0.797	
Technological dimension factor (yield stress)	$K_{1S}(d_{max})$	=	0.797	

Proof of Strength

$K_1(d)$ - Technological dimension factor
$K_2(d)$ - Geometrical dimension factor
K_F - Influence factor of surface roughness
$\alpha_{\sigma,\tau}$ - Form factors

No.	Type	Position x mm	$K_{1B}(d)$	$K_{1S}(d)$	Tension - pressure $K_2(d)$	Bending and torsion $K_2(d)$	Tension-pressure, bending $K_{F\sigma}$	Torsion $K_{F\tau}$	Tension - pressure $\alpha_{\sigma zd}$	Bending $\alpha_{\sigma b}$	Torsion α_τ
1	Shaft fillet	42	0.84	0.84	1	0.91	0.93	0.96	2.6	2.31	1.68
2	Fillet with recess	82	0.8	0.8	1	0.89	0.97	0.98	3.01	2.69	1.86
3	Shaft fillet	92	0.8	0.8	1	0.89	0.93	0.96	2.78	2.5	1.76
4	Shaft fillet	131	0.8	0.8	1	0.89	0.93	0.96	2.78	2.5	1.76
5	Fillet with recess	141	0.8	0.8	1	0.89	0.97	0.98	3.01	2.69	1.86
6	Calculation results for point x	111.5	0.84	0.84	1	0.89	0.93	0.96	-	-	-

G′ - Relative stress drop
$n_{\sigma,\tau}$ - Bearing factor

No.	Type	Position x mm	Tension-pressure G'_{zd} 1/mm	Bending G'_b 1/mm	Torsion G'_t 1/mm	Tension-pressure $n\sigma_{zd}$	Bending $n_{\sigma b}$	Torsion n_τ
1	Shaft fillet	42	2.49	2.49	1.15	1.32	1.32	1.21
2	Fillet with recess	82	3.11	3.11	1.44	1.35	1.35	1.24
3	Shaft fillet	92	2.51	2.51	1.15	1.32	1.32	1.21
4	Shaft fillet	131	2.51	2.51	1.15	1.32	1.32	1.21
5	Fillet with recess	141	3.11	3.11	1.44	1.35	1.35	1.24
6	Calculation results for point x	111.5	-	-	-	-	-	-

$\beta_{\sigma zddBK}$, $\beta_{\sigma bdBK}$, $\beta_{\tau dBK}$ - Stress concentration factor at d_{BK}
$\beta_{\sigma zd}$, $\beta_{\sigma b}$, β_{τ} - Stress concentration factors
K_V - Influence factor of surface hardening

No.	Type	Position x mm	Tension - pressure $\beta_{\sigma zddBK}$	Bending $\beta_{\sigma bdBK}$	Torsion $\beta_{\tau dBK}$	Tension - pressure $\beta_{\sigma zd}$	Bending $\beta_{\sigma b}$	Torsion β_{τ}	Tension - pressure K_{vzd}	Bending K_{vb}	Torsion $K_{v\tau}$
1	Shaft fillet	42	-	-	-	1.98	1.76	1.39	1.1	1.1	1.1
2	Fillet with recess	82	-	-	-	2.23	1.99	1.5	1.1	1.1	1.1
3	Shaft fillet	92	-	-	-	2.11	1.9	1.45	1.1	1.1	1.1
4	Shaft fillet	131	-	-	-	2.11	1.9	1.45	1.1	1.1	1.1
5	Fillet with recess	141	-	-	-	2.23	1.99	1.5	1.1	1.1	1.1
6	Calculation results for point x	111.5	-	-	-	1	1	1	1	1.1	1.1

K_σ, K_τ - Total influence factor

σ_{zdWK}, σ_{bWK}, τ_{tWK} - Cyclic fatigue strength of the notched part

K_{2F} - Static bearing effect

No.	Type	Position x mm	Tension - pressure K_σ	Bending K_σ	Torsion K_τ	Tension - pressure σ_{zdWK} N/mm²	Bending σ_{bWK} N/mm²	Torsions τ_{tWK} N/mm²	Tension - pressure K_{2Fzd}	Bending K_{2Fb}	Torsion K_{2Ft}
1	Shaft fillet	42	1.87	1.83	1.42	196.91	252.1	194.2	1	1	1
2	Fillet with recess	82	2.05	2.06	1.55	170.98	212.51	170.15	1	1	1
3	Shaft fillet	92	1.99	2.01	1.52	176.16	217.72	173.19	1	1	1
4	Shaft fillet	131	1.99	2.01	1.52	176.16	217.72	173.19	1	1	1
5	Fillet with recess	141	2.05	2.06	1.55	170.98	212.51	170.15	1	1	1
6	Calculation results for point x	111.5	1.08	1.1	1.06	341.5	420.73	260.07	1	1	1

γ_F - Yield point rise

σ_{zdFK}, σ_{bFK}, τ_{tFK} - Yield point of the part

No.	Type	Position x mm	Tension-pressure γ_{Fzd}	Bending γ_{Fb}	Torsion γ_{Ft}	Tension-pressure σ_{zdFK} N/mm²	Bending σ_{bFK} N/mm²	Torsion τ_{tFK} N/mm²
1	Shaft fillet	42	1	1	1	648.55	648.55	374.44
2	Fillet with recess	82	1	1	1	617.76	617.76	356.66
3	Shaft fillet	92	1	1	1	617.76	617.76	356.66
4	Shaft fillet	131	1	1	1	617.76	617.76	356.66
5	Fillet with recess	141	1	1	1	617.76	617.76	356.66
6	Calculation results for point x	111.5	1	1	1	649.4	649.4	374.93

Static safety

No.	Type	Position x mm	S_F	In Point1 S_{F1}	in Point2 S_{F2}
1	Shaft fillet	42	21.11	-	-
2	Fillet with recess	82	40.28	-	-
3	Shaft fillet	92	38.52	-	-
4	Shaft fillet	131	77.88	-	-
5	Fillet with recess	141	148	-	-
6	Calculation results for point x	111.5	35.19	-	-

ψ - Influence factor of the mean stress sensitivitz

σ_{mv}, τ_{mv} - Comparative mean stress

No.	Type	Position x mm	Tension - pressure $\psi_{zd\sigma K}$	Bending $\psi_{b\sigma K}$	Torsion $\psi_{\tau K}$	σ_{mv} N/mm^2	τ_{mv} N/mm^2	σ_{mv1} N/mm^2	τ_{mv1} N/mm^2	σ_{mv2} N/mm^2	τ_{mv2} N/mm^2
1	Shaft fillet	42	-	0.16	0.12	0	0	-	-	-	-
2	Fillet with recess	82	0.11	0.14	0.11	0	0	-	-	-	-
3	Shaft fillet	92	0.11	0.14	0.11	0	0	-	-	-	-
4	Shaft fillet	131	-	0.14	-	0	0	-	-	-	-
5	Fillet with recess	141	-	0.14	-	0	0	-	-	-	-
6	Calculation results for point x	111.5	-	0.3	0.16	0	0	-	-	-	-

Alternating fatigue strength of the part (rated fatigue limit)

No.	Type	Position x mm	Tension - pressure σ_{zdADK} N/mm²	Bending σ_{bADK} N/mm²	Torsion τ_{tADK} N/mm²	Tension - pressure in Point1 σ_{zdADK1} N/mm²	Bending in Point1 σ_{bADK1} N/mm²	Torsion in Point1 τ_{tADK1} N/mm²	Tension - pressure in Point2 σ_{zdADK2} N/mm²	Bending in Point2 σ_{bADK2} N/mm²	Torsion in Point2 τ_{tADK2} N/mm²
1	Shaft fillet	42	-	252.1	194.2	-	-	-	-	-	-
2	Fillet with recess	82	170.98	212.51	170.15	-	-	-	-	-	-
3	Shaft fillet	92	176.16	217.72	173.19	-	-	-	-	-	-
4	Shaft fillet	131	-	217.72	-	-	-	-	-	-	-
5	Fillet with recess	141	-	212.51	-	-	-	-	-	-	-
6	Calculation results for point x	111.5	-	420.73	260.07	-	-	-	-	-	-

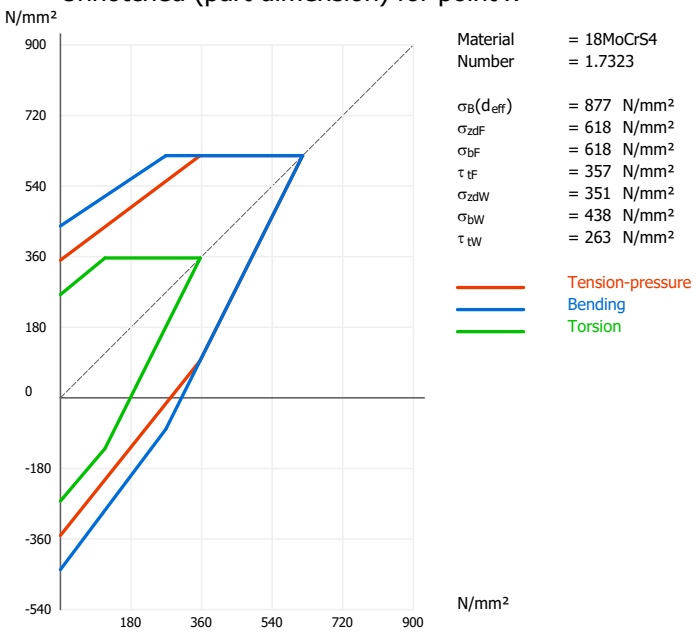
Dynamic safety

No.	Type	Position x mm	S_D	in Point1 S_{D1}	in Point2 S_{D2}
1	Shaft fillet	42	10.46	-	-
2	Fillet with recess	82	15.54	-	-
3	Shaft fillet	92	14.93	-	-
4	Shaft fillet	131	27.45	-	-
5	Fillet with recess	141	50.91	-	-
6	Calculation results for point x	111.5	23.24	-	-

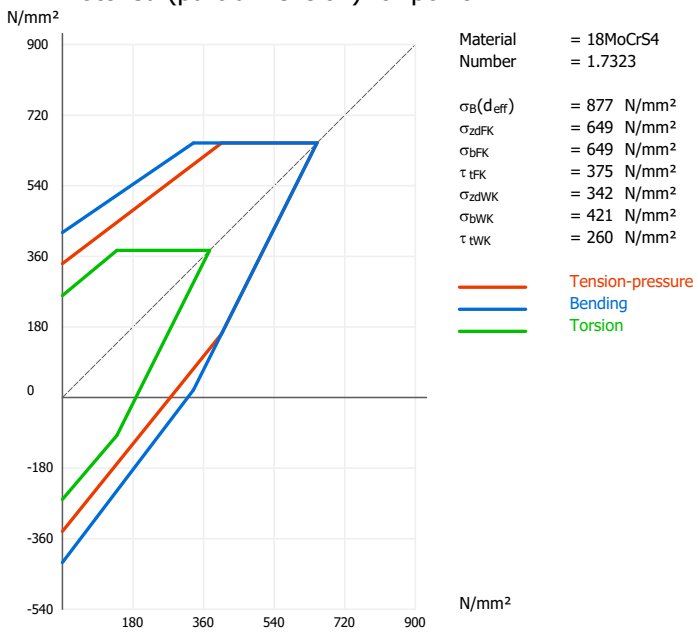
Safety against incipient crack
with hard surface

No.	Type	Position x mm	S_G	In Point1 S_{G1}	in Point2 S_{G2}
1	Shaft fillet	42	53.43	-	-
2	Fillet with recess	82	73.45	-	-
3	Shaft fillet	92	72.58	-	-
4	Shaft fillet	131	115.96	-	-
5	Fillet with recess	141	204.67	-	-
6	Calculation results for point x	111.5	132.1	-	-

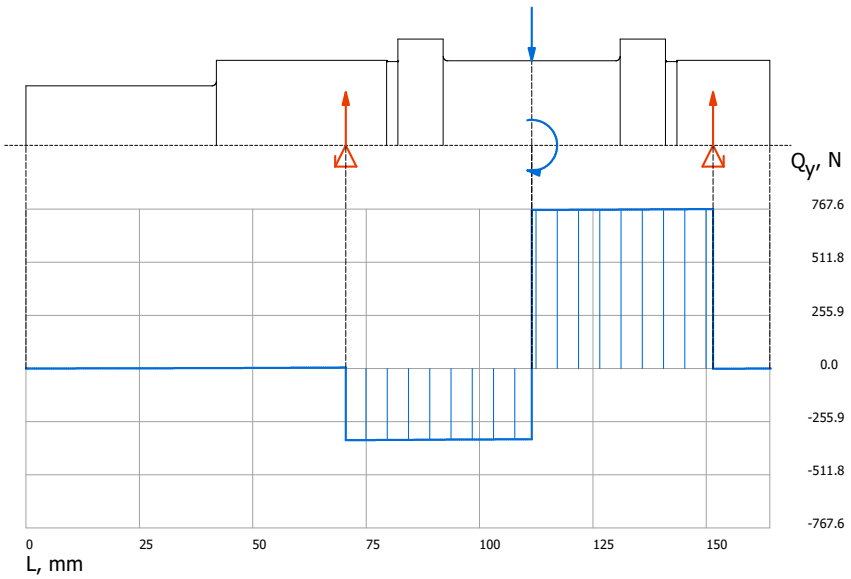
Unnotched (part dimension) for point x



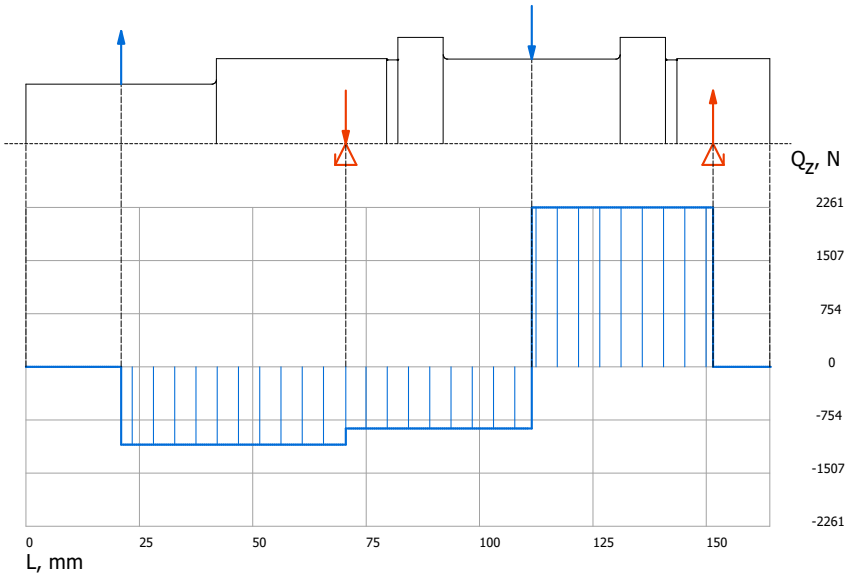
Notched (part dimension) for point x



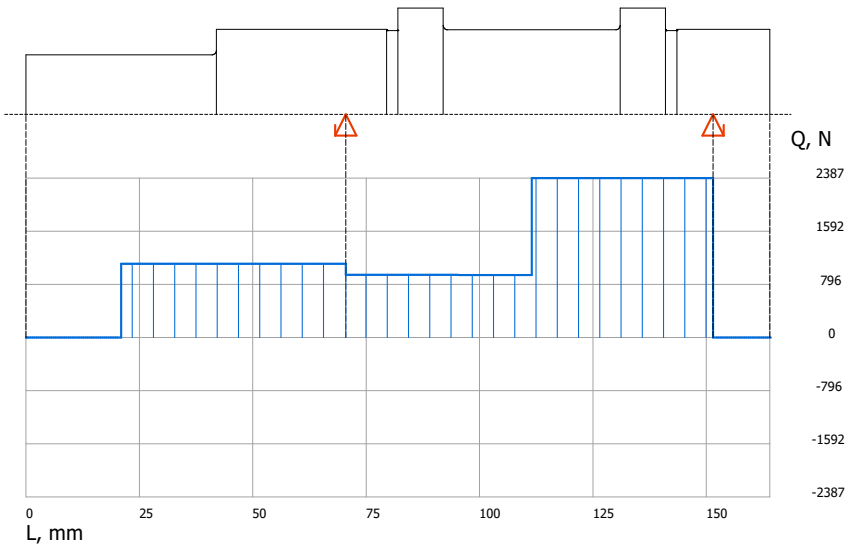
Trend of curve of the transverse force in the Y-X-plane



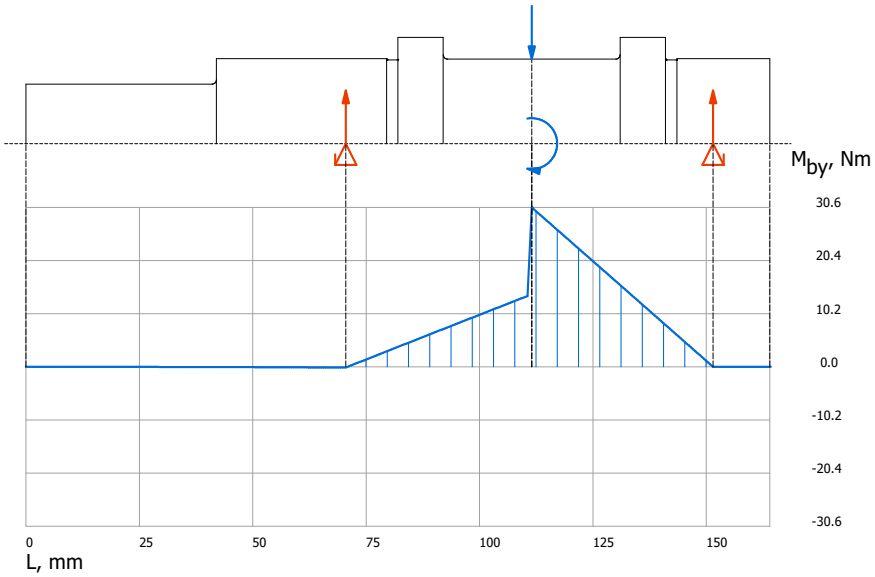
Trend of curve of the transverse force in the Z-X-plane



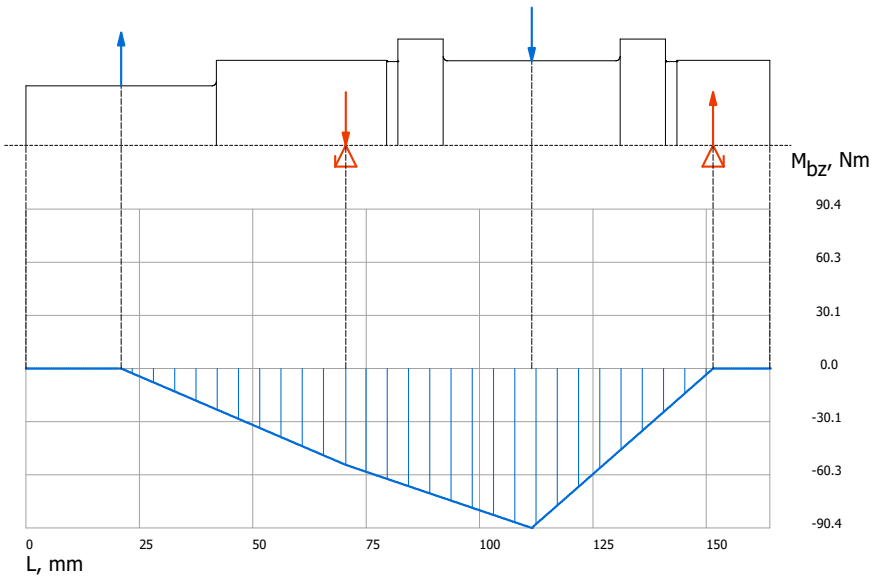
Trend of curve of the transverse force (combined characteristic)



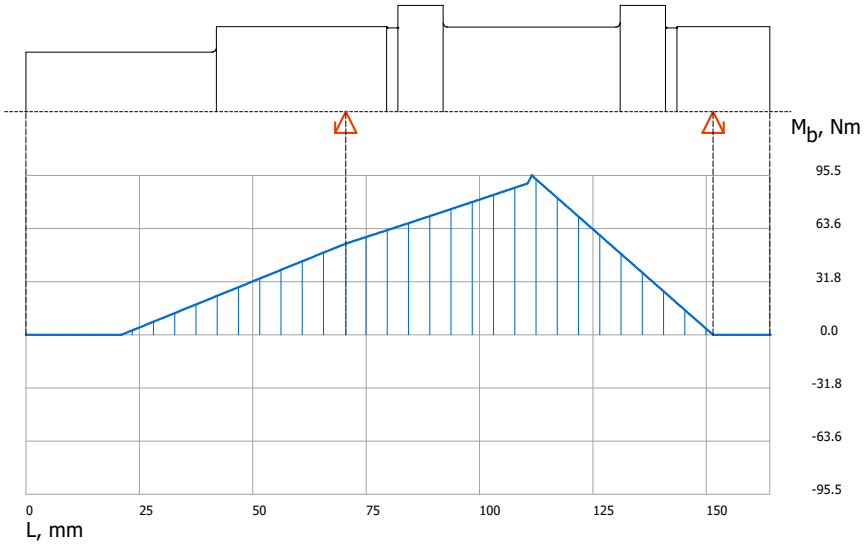
Bending moment in the Y-X-plane



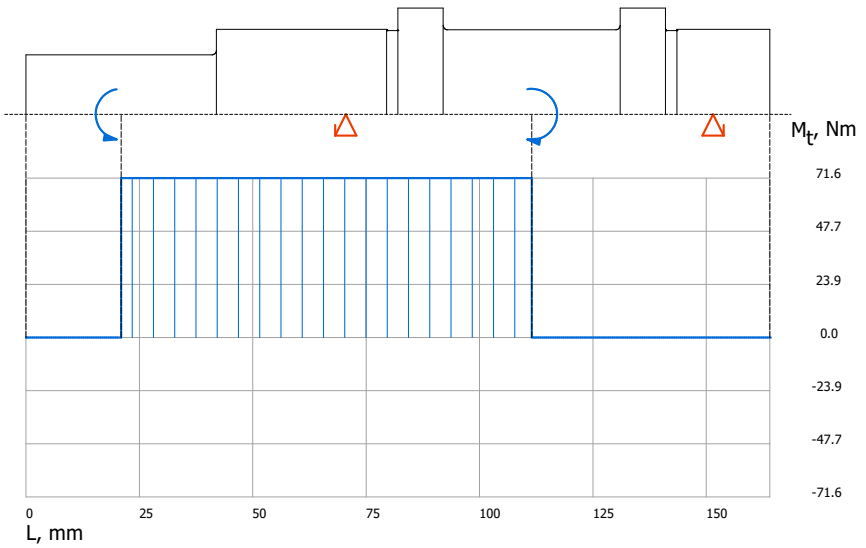
Trend of curve of the bending moment curve in the Z-X plane



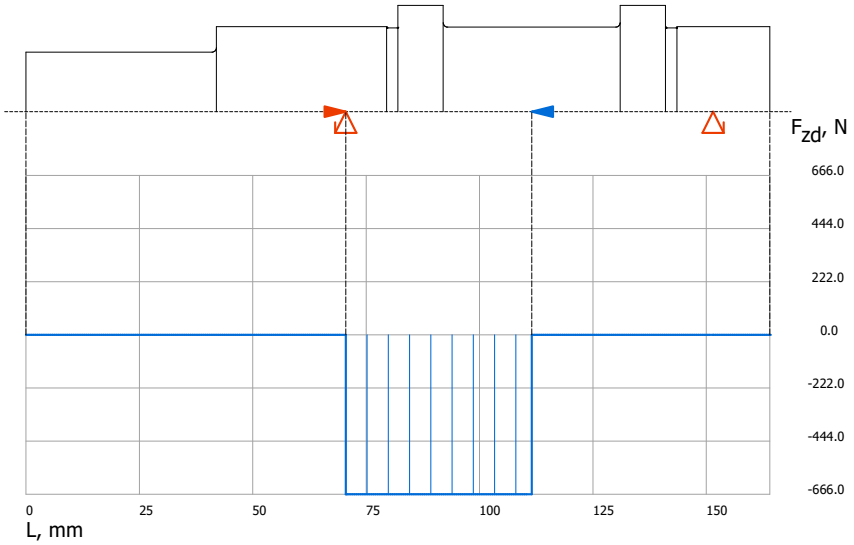
Trend of curve of the bending moment (combined characteristic)



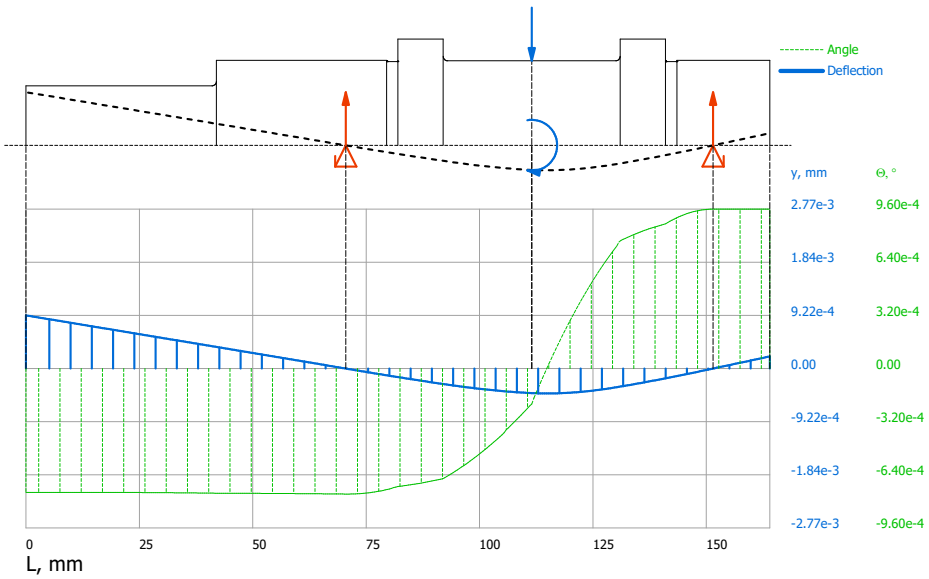
Trend of curve of the torsional moment



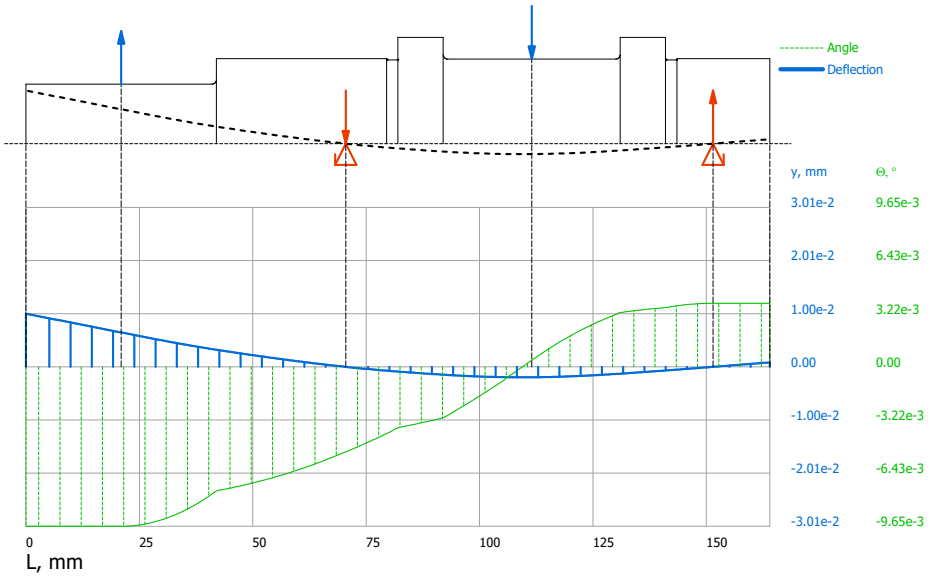
Trend of curve of the tension-pressure forces



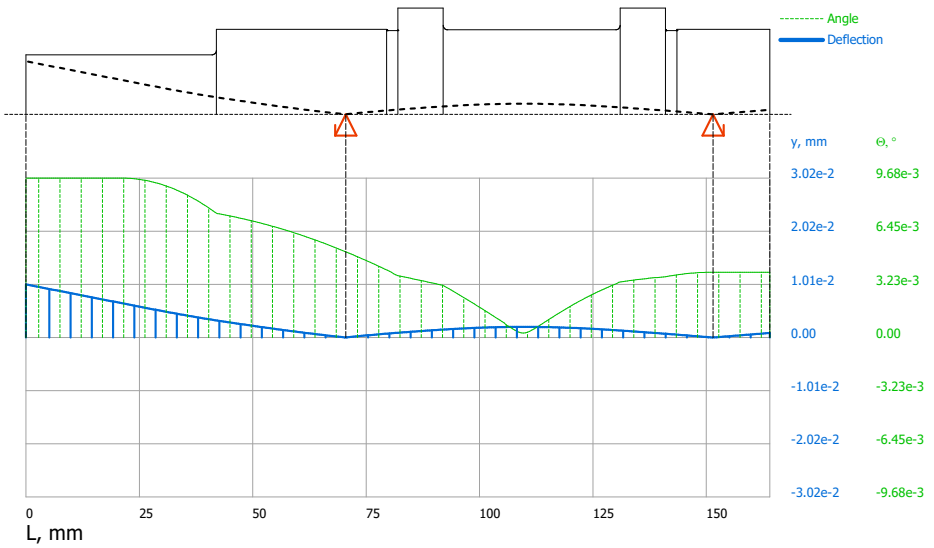
Deflection and angle of deflection in the Y-X-plane



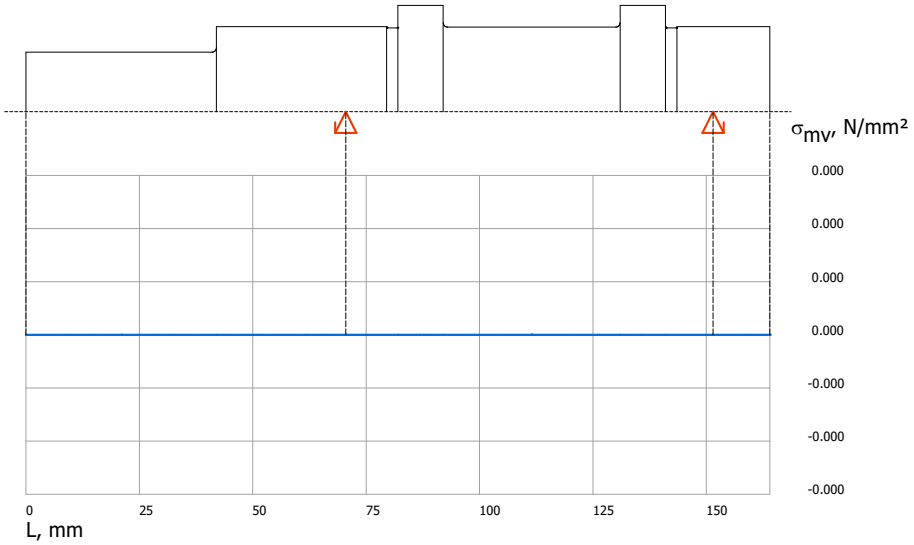
Deflection and angle of deflection in the Z-X-plane



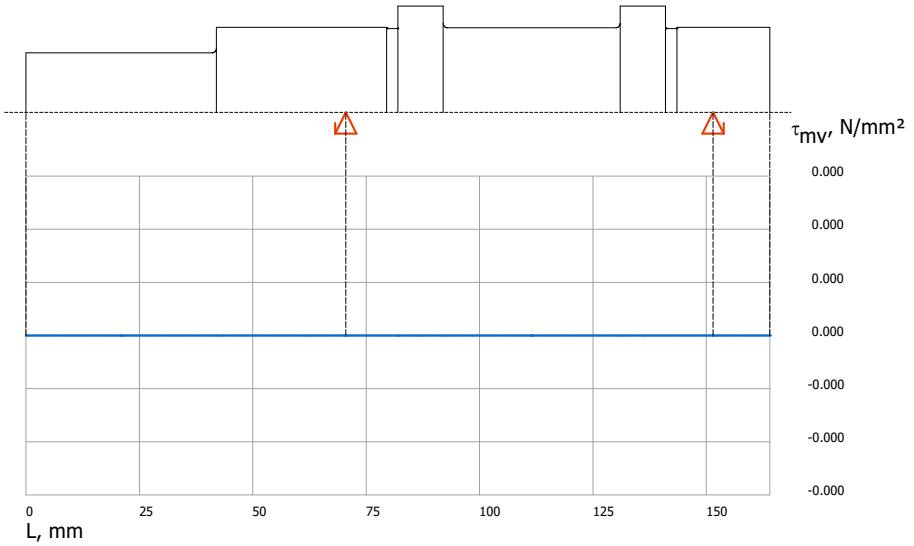
Deflection and angle of deflection (combined characteristic)



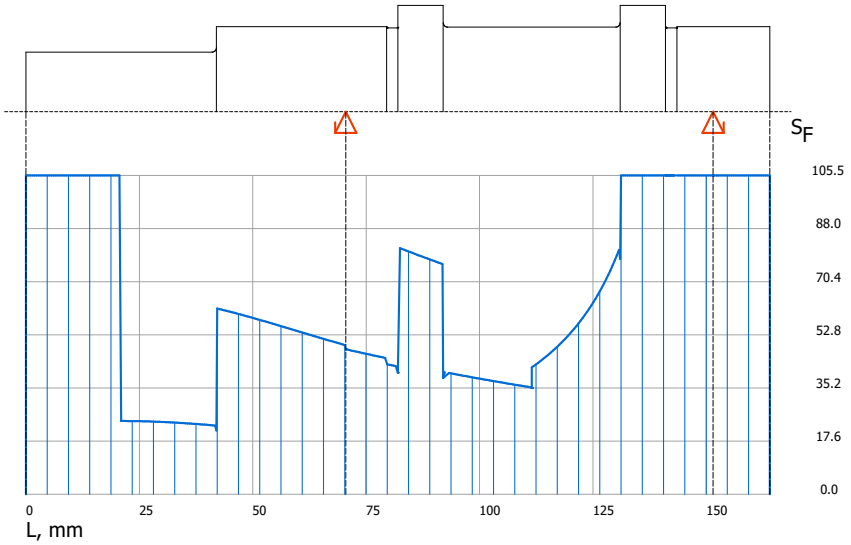
Equivalent mean stress (normal stress)



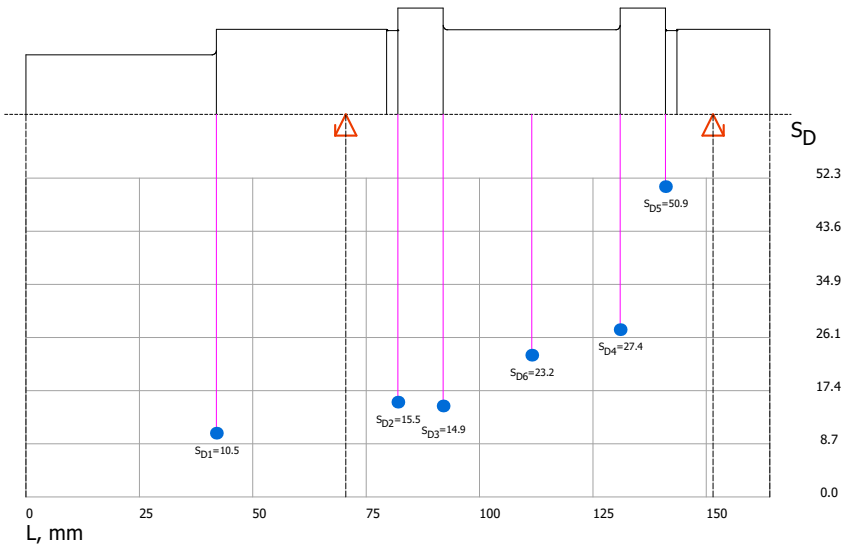
Equivalent mean stress (shear stress)



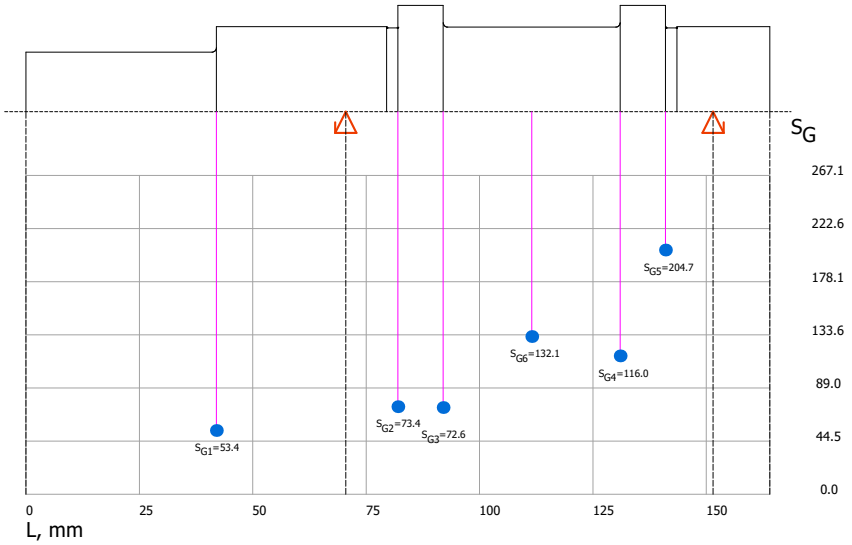
Safety factor against yielding
(diagram section up to 5*minimum safety)



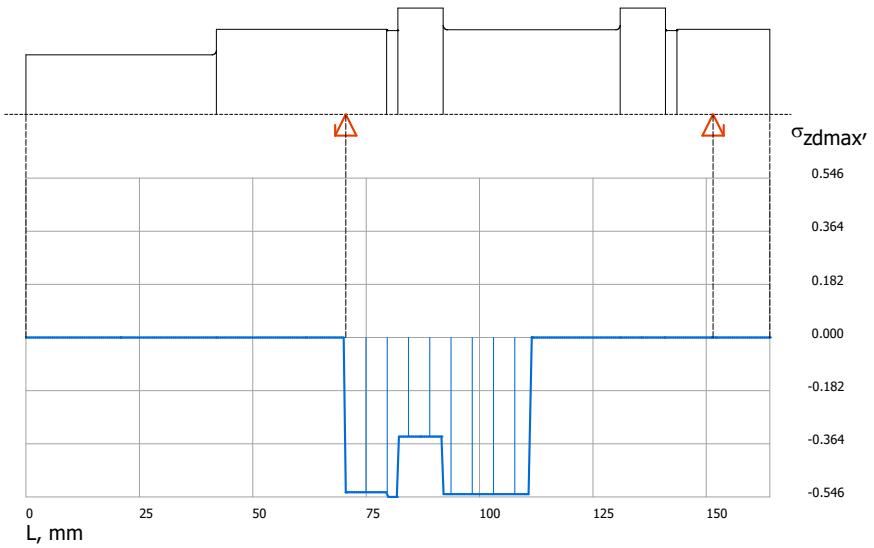
Safety against fatigue fracture
(diagram section up to 5*minimum safety)



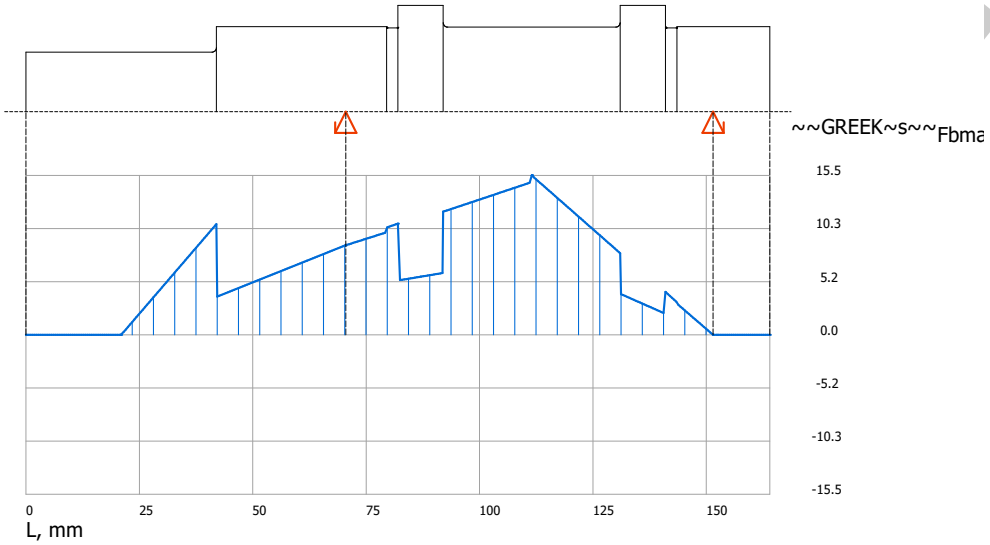
Safety against incipient crack with hard surface
(Cross-section: SG=5*SGmin)



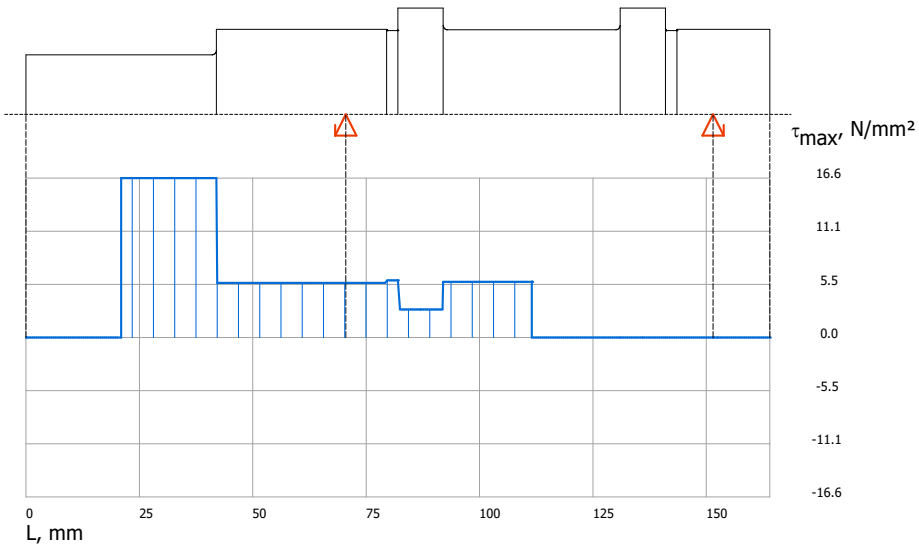
Maximum value of the tension-pressure stress (combined characteristic)



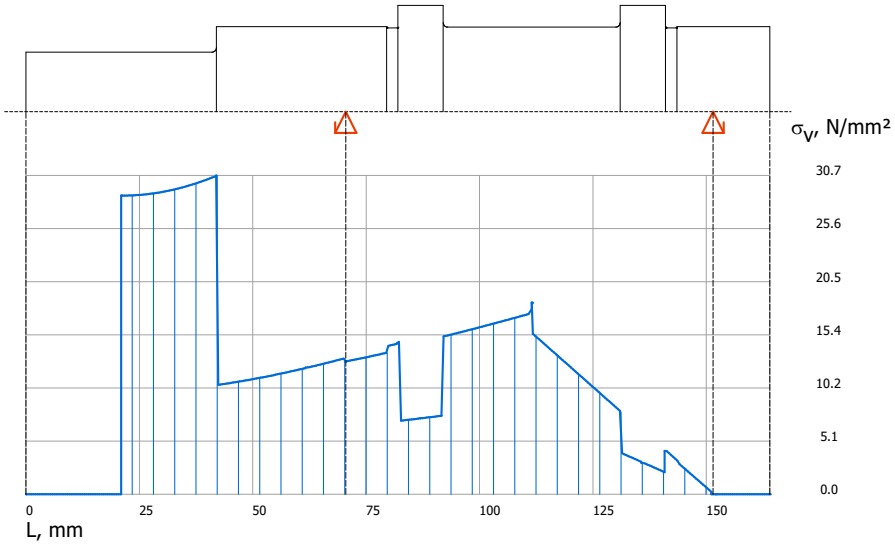
Maximum value of the bending stress (combined characteristic)



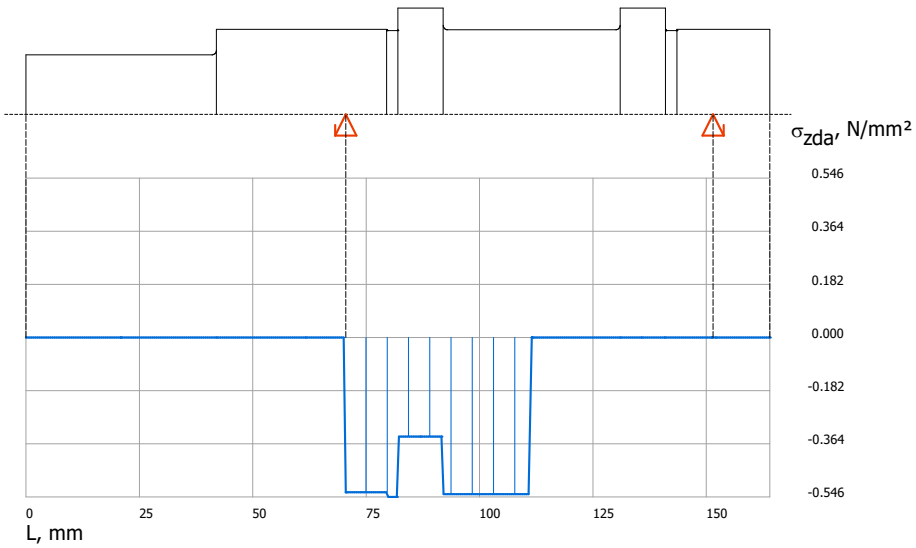
Maximum value of the torsional stress (combined characteristic)



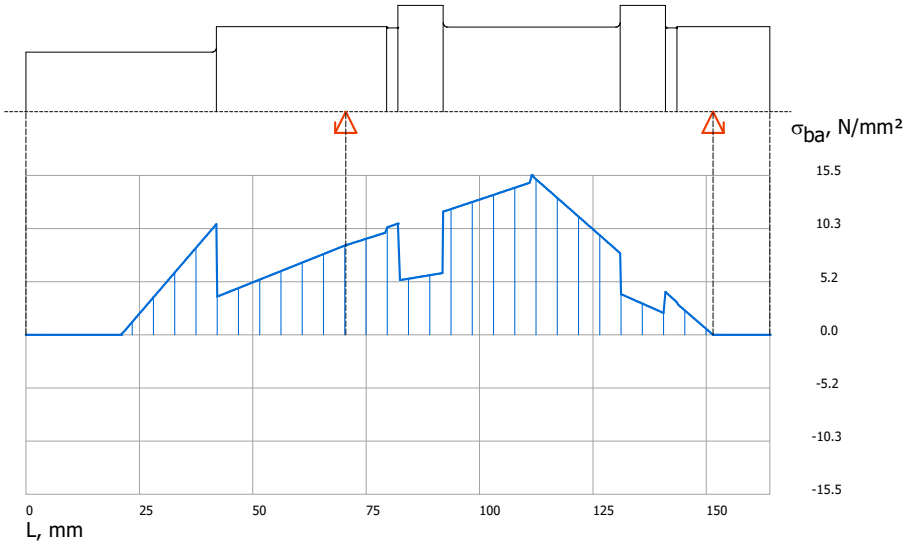
Equivalent stress development (resultant)



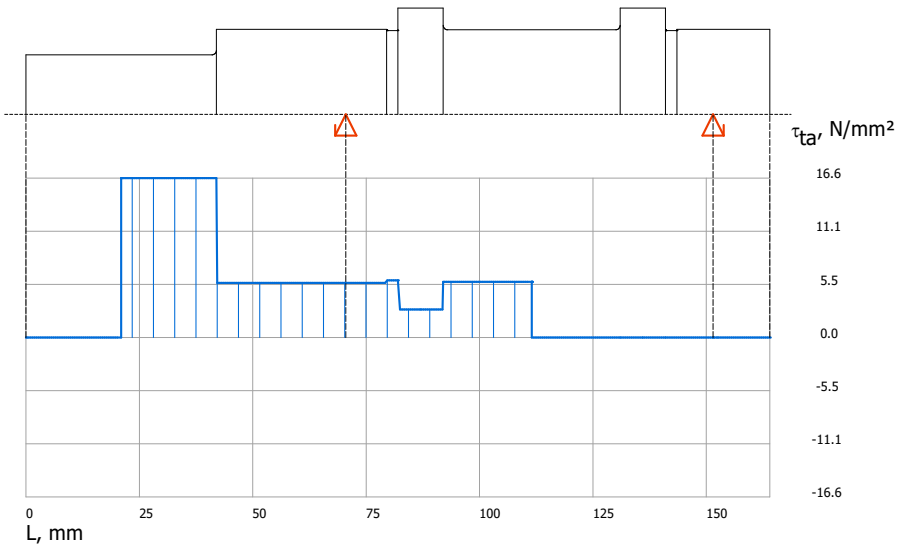
Amplitude value of the tension-pressure stress (combined characteristic)



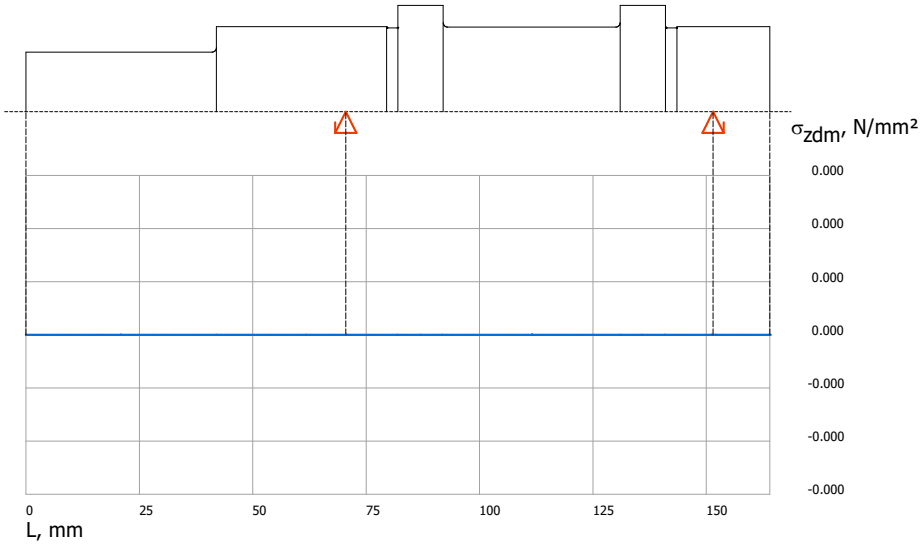
Amplitude value of the bending stress (combined characteristic)



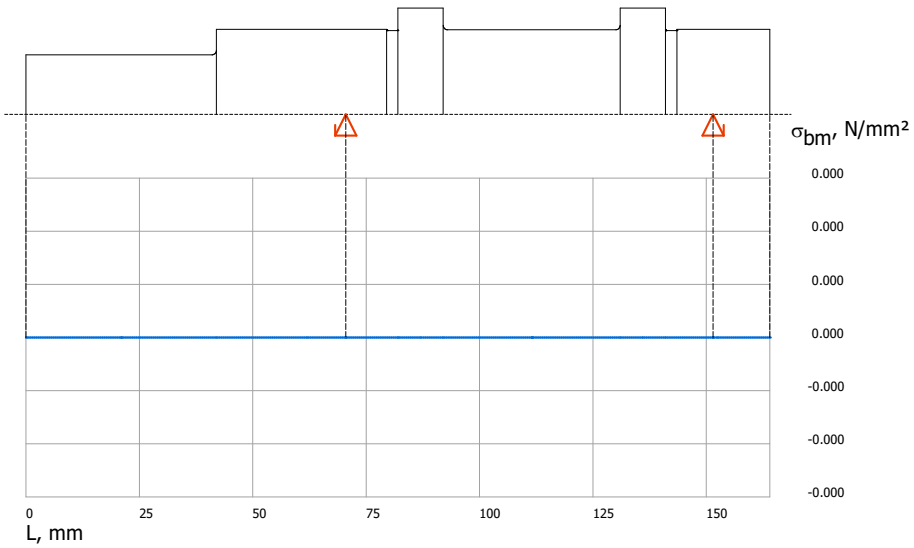
Amplitude value of the torsional stress (combined characteristic)



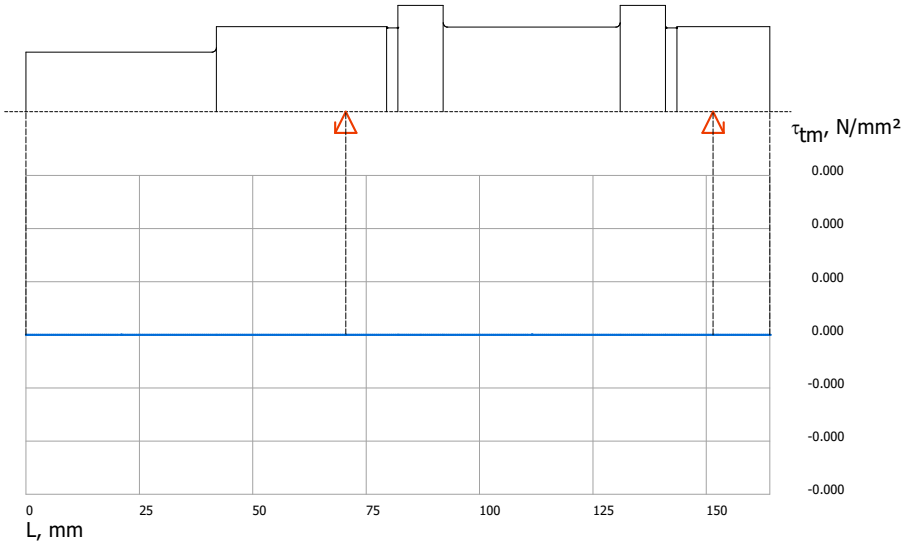
Mean value of the tension-pressure stress (combined characteristic)



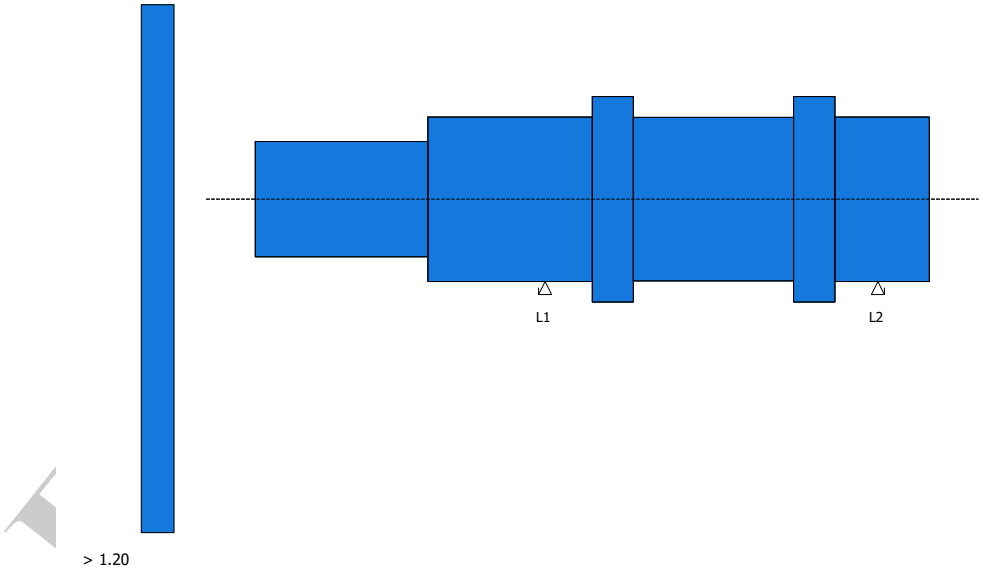
Mean value of the bending stress (combined characteristic)



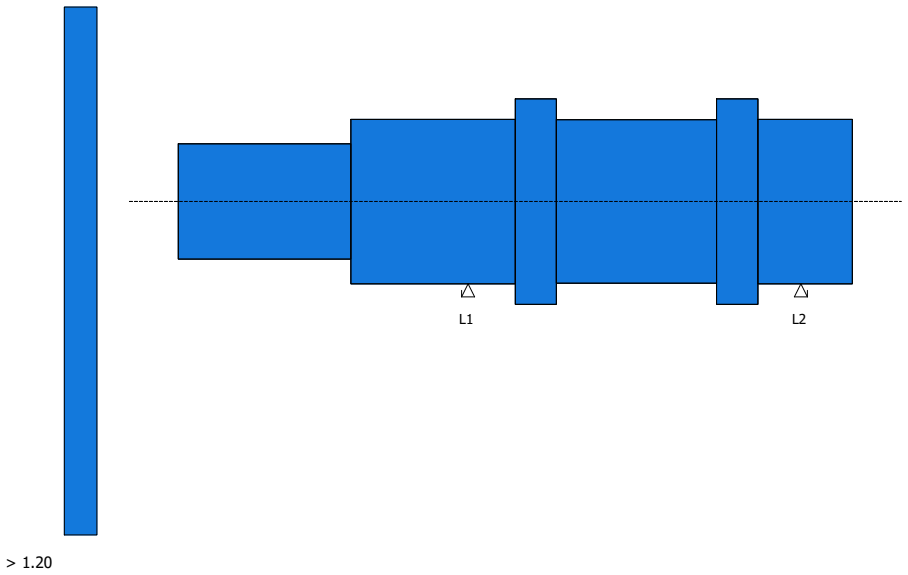
Mean value of the torsional stress (combined characteristic)



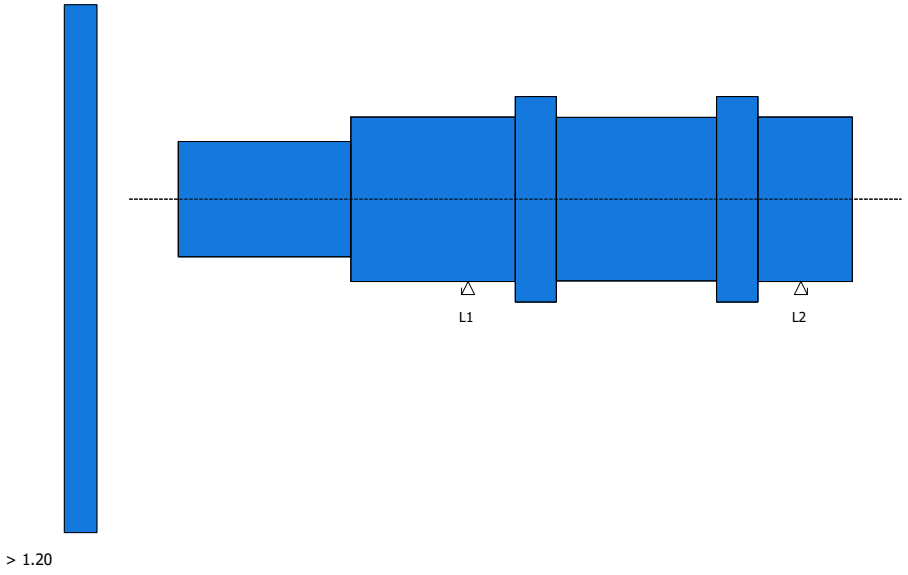
Safety factor against yielding



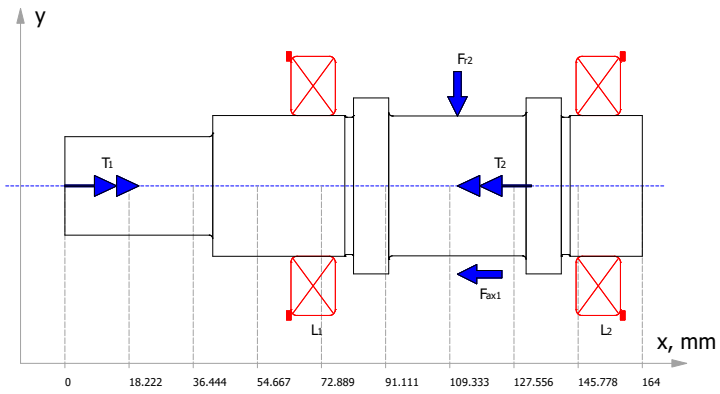
Safety against fatigue fracture



Safety against incipient crack with hard surface



Calculation graphic Y-X-plane



Calculation graphic Z-X-plane