File

Name: Unnamed

Changed by: Zemlicka on: 14.05.2023 at: 09:46:25

Varianta_IV

Power inputs:

_O.Varianta_IV.Input

Speed	[1/min]	1000
Torque	[Nm]	200.535
Power	[kW]	21

Power outputs:

_O.Varianta_IV.Output1

Speed	[1/min]	-28.034
Torque	[Nm]	3576.678
Power	[kW]	10.5

_O.Varianta_IV.Output2

Speed	[1/min]	-28.034
Torque	[Nm]	3576.678
Power	[kW]	10.5

Inhalt

_O.Varianta_IV.G12.G12_calc

1 Overview

Calculation method		Bevel gear ISO 10300:2014, Method B1	
Drive side			
Geometry calculation according to method		3, ISO 23509:2016	
Uniform tooth depth, Figure 3, Klingelnberg			
Drawing or article number:			
Gear 1:	0.000.0		
Gear 2:	0.000.0		

		------- Gear 1 ----------	Gear 2 -------
Power (kW)	[P]	21.000	
Speed (1/min)	[n]	1000.0	422.2
Number of load cycles (in mio.)	[NL]	6000.000	2533.333
Rotation direction, Gear 1, viewed on cone tip:		right	
Torque (Nm)	[T]	200.5	475.0
Application factor	[KA]	1.25	
Distribution factor	[Kγ]	1.00	
Required service life	[H]	100000.00	
Gear driving (+) / driven (-)		+	-
Working flank Gear 1: Right flank			

2 Tooth geometry

		------- Gear 1 ----------	Gear 2 -------
Hypoid offset (mm)	[a]	0.000	
Shaft angle (°)	[Σ]	90.0000	
Mean normal module (mm)	[mmn]	3.2500	
Cutter blade module (mm)	[m0]	3.20	
Normal pressure angle (°)	[αn]	20.0000	
Mean spiral angle (°)	[βm]	30.0000	
Hand of gear		right	left
Number of teeth	[z]	19	45
Facewidth (mm)	[b]	24.00	24.00
Assumed and measured contact pattern width (mm)	[be]	20.40	20.40
b_e/b =0.850, b_{veff} =20.400 mm, b_v =24.000 mm			
Accuracy grade according ISO 17485	[Q]	6	6
Internal diameter gearbody (mm)	[di]	0.000	50.000
Pitch apex to front of gear blank (mm)	[yi]	76.042	39.285
Pitch apex to back of gear blank (mm)	[yo]	98.152	48.620
Mounting distance (mm)	[MD]	98.152	53.000
V misalignment (or E misalignment) (µm)	[ΔV]	0.000	
H misalignment (or P misalignment) (µm)	[ΔH]	0.000	

J misalignment (or G misalignment) (µm)	[ΔJ]	0.000

3 Materials

Gear 1
16 MnCr 5 (1), Case hardening steel, case-hardened, ISO 6336-5 Figure 9/10 (MQ), Core hardness >=25HRC Jominy J=12mm<HRC28

Gear 2
16 MnCr 5 (1), Case hardening steel, case-hardened, ISO 6336-5 Figure 9/10 (MQ), Core hardness >=25HRC Jominy J=12mm<HRC28

		------- Gear 1 ----------	Gear 2 -------
Surface hardness		HRC 59	HRC 59
Material treatment according to ISO 6336:2006:	Normal, life factors Z_{NT} and $Y_{NT} \geq 0.85$		
Infinite life strength for tooth root stress (N/mm²)	[σFlim]	430.00	430.00
Fatigue strength for Hertzian pressure (N/mm²)	[σHlim]	1500.00	1500.00
Young's modulus (N/mm²)	[E]	206000	206000
Poisson's ratio	[v]	0.300	0.300
Tensile strength (N/mm²)	[σB]	1000.00	1000.00
Yield point (N/mm²)	[σS]	695.00	695.00

3.1 Roughnesses

		------- Gear 1 ----------	Gear 2 -------
Roughness average value DS, flank (µm)	[RAH]	0.60	0.60
Roughness average value DS, root (µm)	[RAF]	3.00	3.00
Mean roughness height, Rz, flank (µm)	[RZH]	4.80	4.80
Mean roughness height, Rz, root (µm)	[RZF]	20.00	20.00

3.2 Lubrication

Lubrication type	Oil bath lubrication	
Type of oil	ISO-VG 220	
Lubricant base	Mineral-oil base	
Oil nominal kinematic viscosity at 40°C (mm²/s)	[v40]	220.00
Oil nominal kinematic viscosity at 100°C (mm²/s)	[v100]	17.50
Specific density at 15°C (kg/dm³)	[ρ]	0.895
Oil temperature (°C)	[TS]	70.000

4 Tooth geometry

4.1 Reference profiles

4.1.1 Information on pre-machining

Gear reference profile 1

Reference profile	1.40 / 0.39 / 1.0 ISO 53:1998 Profil D	
Final machining stock (mm)	[q]	0.120
Dedendum coefficient	[hfP*]	1.400
Root radius factor	[ρfP*]	0.390
	[ρfPmax*]	0.394
Addendum coefficient	[haP*]	1.000
Tip radius factor	[ρaP*]	0.000
Protuberance height coefficient	[hprP*]	0.000
Protuberance angle	[αprP]	0.000
Tip form height coefficient	[hFaP*]	0.000
Ramp angle	[αKP]	0.000
	not topping	

Smallest radius of curvature, root rounding (mm)	[ρmin.e/i]	1.362 / 1.367	

Gear reference profile 2

Reference profile	1.40 / 0.39 / 1.0 ISO 53:1998 Profil D		
Final machining stock (mm)	[q]	0.120	
Dedendum coefficient	[hfP*]	1.400	
Root radius factor	[ρfP*]	0.390	
	[ρfPmax*]	0.394	
Addendum coefficient	[haP*]	1.000	
Tip radius factor	[ρaP*]	0.000	
Protuberance height coefficient	[hprP*]	0.000	
Protuberance angle	[αprP]	0.000	
Tip form height coefficient	[hFaP*]	0.000	
Ramp angle	[αKP]	0.000	
	not topping		
Smallest radius of curvature, root rounding (mm)	[ρmin.e/i]	1.347 / 1.349	

4.1.2 Reference profile of the final tooth form

		------- Gear 1	---------- Gear 2 -------
Dedendum reference profile	[hfP*]	1.292	1.292
Tooth root radius Refer. profile	[ρfP*]	0.390	0.390
Addendum Reference profile	[haP*]	1.000	1.000
Protuberance height coefficient	[hprP*]	0.000	0.000
Protuberance angle (°)	[αprP]	0.000	0.000
Tip form height coefficient	[hFaP*]	0.000	0.000
Ramp angle (°)	[αKP]	0.000	0.000
Data for final machining:			
Depth of immersion	[hgrind*]	1.101	1.101
Radius at cutter head	[rgrind*]	0.100	0.100
Grinding only flank (0), flank & root (1)		0	0
Generation grinding (0), form grinding (1)		0	0
Type of profile modification:	none (only running-in)		
Tip relief by running in (µm)	[Ca L/R]	2.0 / 2.0	2.0 / 2.0

4.2 Basic data

		------- Gear 1	---------- Gear 2 -------
No modification at tip circle			
Overall transmission ratio	[itot]	-2.368	
Gear ratio	[u]	2.368	
Outer spiral angle (°)	[βe]	34.4576	34.4576
Mean spiral angle (°)	[βm]	30.0000	30.0000
Inner spiral angle (°)	[βi]	25.5296	25.5296
Pinion offset angle in axial plane (°)	[ζm]	0.0000	
Pinion offset angle in pitch plane (°)	[ζmp]	0.0000	
Offset in pitch plane (mm)	[ap]	0.000	
Outer normal module (mm)	[men]	3.4995	
Transverse module, outside (mm)	[met]	4.2441	4.2441
Mean normal module (mm)	[mmn]	3.2500	
Mean transverse module (mm)	[mmt]	3.7528	3.7528
Inner normal module (mm)	[min]	2.9430	
Transverse module, inside (mm)	[mit]	3.2614	3.2614
Sum of profile shift coefficients	[xhm1+xhm2]	0.0000	
Profile shift coefficient	[xhm]	0.3345	-0.3345

Undercut boundary	[xhmmin]	-0.5028		-6.7596
Tooth thickness modification coefficient	[xsmn]	0.0000		-0.0000
Outer pitch diameter (mm)	[de]	80.638		190.985
Outer tip diameter (mm)	[dae]	88.630		192.667
Outer root diameter (mm)	[dfe]	74.904		186.872
Mean pitch diameter (mm)	[dm]	71.303		168.875
Mean tip diameter (mm)	[dam]	79.294		170.557
Mean root diameter (mm)	[dfm]	65.569		164.762
Inner pitch diameter (mm)	[di]	61.967		146.765
Inner tip diameter (mm)	[dai]	69.959		148.447
Inner root diameter (mm)	[dfi]	56.234		142.652
Outer addendum (mm)	[hae]	4.337		2.163
Mean addendum (mm)	[ham]	4.337		2.163
Inner addendum (mm)	[hai]	4.337		2.163
Outer dedendum (mm)	[hfe]	3.112		5.286
Mean dedendum (mm)	[hfm]	3.112		5.286
Inner dedendum (mm)	[hfi]	3.112		5.286
Outer whole depth (mm)	[he]	7.449		7.449
Mean whole depth (mm)	[hm]	7.449		7.449
Inner whole depth (mm)	[hi]	7.449		7.449
Outer working depth (mm)	[hew]		6.500	
Mean working depth (mm)	[hmw]		6.500	
Inner working depth (mm)	[hiw]		6.500	
Outer tip clearance (mm)	[ce]	0.949		0.949
Mean tip clearance (mm)	[cm]	0.949		0.949
Inner tip clearance (mm)	[ci]	0.949		0.949
Theoretical tip clearance (mm)	[c]	0.949		0.949
Effective tip clearance (mm)	[c.e/i]	0.949 / 0.949		0.949 / 0.949

4.3 Angles and distances

		------- Gear 1	----------	Gear 2 -------
Pitch angle (°)	[δ]	22.8906		67.1094
Pitch angle	[δ]	22°53'26"		67°6'34"
Face angle (°)	[δa]	22.8906		67.1094
Face angle	[δa]	22°53'26"		67°6'34"
Addendum angle (°)	[θa=δa-δ]	0.0000		0.0000
Addendum angle	[θa=δa-δ]	0°0'0"		0°0'0"
Root angle (°)	[δf]	22.8906		67.1094
Root angle	[δf]	22°53'26"		67°6'34"
Dedendum angle (°)	[θf=δ-δf]	0.0000		0.0000
Dedendum angle	[θf=δ-δf]	0°0'0"		0°0'0"
Outer cone distance (mm)	[Re]	103.655		103.655
Mean cone distance (mm)	[Rm]	91.655		91.655
Inner cone distance (mm)	[Ri]	79.655		79.655
Characteristic values for sizing	[Re2/b2]		4.319	
	[b2/mmn]		7.385	
Crown to crossing point (mm)	[txo]	93.805		38.327
Front crown to crossing point (mm)	[txi]	71.695		28.991
Pitch apex beyond crossing point (mm)	[tz]	0.000		0.000
Face apex beyond crossing point (mm)	[tzF]	11.151		2.348
Root apex beyond crossing point (mm)	[tzR]	-8.000		-5.738

Pitch cone outside to pitch apex (mm)	[ye]	95.492	40.319
Face cone outside to pitch apex (mm)	[yae]	93.805	38.327
Face cone inside to pitch apex (mm)	[yai]	71.695	28.991

4.4 Manufacturing

Manufacture process:	ground/hard-cut	
Spiral toothing		
Face hobbing (continuing indexing method)		
Number of cutter blade groups	[z0]	5.00
Cutter radius (mm)	[rc0]	100.00
Ratio involute/outer cone	[inv/Re]	1.32
Ratio involute/mean cone	[inv/Rm]	1.49

5 Equivalent spur gear

5.1 Equivalent spur gear in tooth center

		------- Gear 1 ----------	---------- Gear 2 -------
Normal module (mm)	[mn]	3.2500	
Transverse module (mm)	[mtv]	3.7528	
Normal pressure angle (°)	[αe,αvn]	20.0000	
Transverse pressure angle (°)	[αvt]	22.7959	
Helix angle at reference circle (°)	[βv]	30.0000	
Base helix angle (°)	[βvb]	28.0243	
Virtual center distance (mm)	[av]	255.777	
Working pressure angle (°)	[αvwt]	22.7959	
Number of teeth	[zv]	20.624	115.690
Gear ratio	[uv]	5.609	
Profile shift coefficient	[xv]	0.3345	-0.3345
Profile shift (mm)	[xv*mn]	1.0873	-1.0873
Generating profile shift coefficient			
Information on pre-machining	[xvE.e/i]	0.4129/0.3960	-0.2667/-0.2879
Information on final machining	[xvE.e/i]	0.3050/0.2880	-0.3747/-0.3958
Theoretical tip clearance (mm)	[c]	0.949	0.949
Effective tip clearance (mm)	[c.e/i]	0.949 / 0.949	0.949 / 0.949
Reference diameter (mm)	[dv]	77.398	434.157
Base diameter (mm)	[dvb]	71.352	400.245
Tip diameter (mm)	[dva]	86.072	438.483
Tip form diameter (mm)	[dvFa]	86.072	438.483
Active tip diameter (mm)	[dvNa]	86.072	438.483
Operating pitch diameter (mm)	[dvw]	77.398	434.157
Root diameter (mm)	[dvf]	71.174	423.584
Root form diameter (mm)	[dvFf]	73.644	425.780
Active root diameter (mm)	[dvNf]	73.870	427.452
Reserve (dNf-dFf)/2 (mm)	[cF]	0.113	0.836
Normal tooth thickness at tip circle (mm)	[svan]	2.118	2.716
Normal tooth thickness at tip form circle (mm)	[svFan]	2.118	2.716
Virtual gear no. of teeth	[zvn]	30.561	171.431
Pitch on reference circle (mm)	[pvt]	11.790	
Base pitch (mm)	[pvbt]	10.869	
Transverse pitch on contact-path (mm)	[pvet]	10.869	

5.1.1 Contact ratios

Length of path of contact (mm)	[gva]	14.509

Virtual cylindrical gear toothing (ISO 10300:2014, Annex A):

Referenced to facewidth	[bveff]	20.400
Transverse contact ratio	[εvα]	1.335
Contact ratio in normal section	[εvαn]	1.713
Overlap ratio	[εvβ]	0.999
Total contact ratio	[εvγ]	2.334

5.2 Contact lines

Auxiliary values for the tooth flank:				
Distance from center (mm)	[ft,fm,fr]	9.591	-0.003	-9.598
Length of contact line (mm)	[lbt,lbm,lbr]	3.715	21.306	3.700
Related tooth contact area (mm)	[A*t,A*m,A*r]	0.604	16.734	0.600
Profile crowning (barreling): big	[e]		1.500	
Fractions of line load (%)	[flct,flcm,flcr]	3.369	93.287	3.343
Auxiliary values for the tooth root:				
Distance from center (mm)	[ft,fm,fr]	9.598	0.003	-9.591
Length of contact line (mm)	[lbt,lbm,lbr]	3.700	21.306	3.715
Angle of contact lines (°)	[βB]		0.0000	

6 General influence factors

6.1 Forces and circumferential speed

		------- Gear 1	---------- Gear 2 -------
Nominal circum. force at pitch circle (N)	[Fmt]	5624.9	5624.9
Nominal circumferential force of virtual cylindrical gear (N)	[Fvmt]	5624.9	
Drive side			
Axial force (N)	[Fa]	3911.3	914.6
Radial force (N)	[Fr]	914.6	3911.3
Normal force (N)	[Fnorm]	6911.9	6911.9
Axial force (%)	[Fa/Ft]	69.536	16.261
Radial force (%)	[Fr/Ft]	16.261	69.536
Remarks:			
Forces if rotation goes in opposite direction (coast-sided):			
Axial force (N)	[Fa]	-2072.3	3441.0
Radial force (N)	[Fr]	3441.0	-2072.3
Normal force (N)	[Fnorm]	6911.9	6911.9
Axial force (%)	[Fa/Ft]	-36.841	61.175
Radial force (%)	[Fr/Ft]	61.175	-36.841
Normal circumferential force on reference circle per mm (N/mm)			
	[w]	234.37	
$w = F_{vmt}/b_v$			
Circumferential speed reference circle (m/s)	[v]	3.73	3.73
Compound velocity in direction of tooth height (m/s)	[vΣvert]	2.21	
Sliding velocity in direction of contact lines (m/s)	[vgpar]	0.00	
Compound velocity (m/s)	[vΣ]	4.34	
Sliding velocity (m/s)	[vg]	0.00	

6.2 General

		------- Gear 1	---------- Gear 2 -------
Drive side			
Singular tooth stiffness (N/mm/µm)	[c']	14.00	
Meshing stiffness (N/mm/µm)	[cg]	20.00	
Single pitch deviation (µm)	[fp]	12.00	13.00
Running-in value y_α (µm)	[yα]	0.97	

Reduced mass (kg/mm)	[mRed]	0.011
Resonance speed (min-1)	[nE1]	21209
Resonance ratio (-)	[N]	0.047
Subcritical range		

6.3 K factors

Dynamic factor	[Kv]	1.02
Cutter radius (mm)	[rc0]	100.00
Coefficient	[KF0]	1.00
Mounting factor	[KHβbe]	1.25
Width factors		
- Flank	[KHβ]	1.88
- Tooth root	[KFβ]	1.88
- Scuffing	[KBβ]	1.88
Transverse load factors		
- Flank	[KHα]	1.08
- Tooth root	[KFα]	1.08
- Scuffing	[KBα]	1.08
Helical load factor for scuffing	[KBγ]	1.19
Application factor	[KA]	1.250

7 Calculation of tooth root strength (fracture)

		------- Gear 1	---------- Gear 2 -------
Calculation of tooth form coefficients according to method: B1 (ISO 10300-3:2014)			
Manufacture process: generated			
Calculation with drive side			
Calculated with profile shift coefficient	[x]	0.33	-0.33
Tooth form factor	[YF]	2.24	2.21
Stress correction factor	[YS]	1.75	1.76
Bending moment arm (mm)	[hF]	6.40	6.26
Bending moment arm (-)	[hF/mn]	1.97	1.93
Load application angle (°)	[αh]	29.10	20.90
Tooth thickness at root (mm)	[sFn]	7.20	7.42
Tooth thickness at root (-)	[sFn/mn]	2.22	2.28
Tooth root radius (mm)	[ρF]	1.53	1.63
Tooth root radius (-)	[ρF/mn]	0.47	0.50
Contact ratio factor	[Yε]	0.63	
Load distribution coefficient	[YLS]	0.93	
Effective facewidth (mm)	[bv]	24.00	24.00
Bevel gear factor, root	[YBS (YK)]	1.023	
Nominal stress at tooth root (N/mm²)	[σF0]	168.71	166.82
Tooth root stress (N/mm²)	[σF]	437.78	432.88
Permissible bending stress at root of Test-gear			
Notch sensitivity factor	[YdrelT]	0.999	0.998
Surface factor	[YRrelT]	0.957	0.957
Size factor, tooth root	[YX]	1.000	1.000
Life factor	[YNT]	0.859	0.874
$Y_{drelT}*Y_{RrelT}*Y_X*Y_{NT}$		0.820	0.834
Alternating bending factor, mean stress influence coefficient			
	[YM]	1.000	1.000

Stress correction factor	[YST]	2.00	
YST*σFlim (N/mm²)	[σFE]	860.00	860.00
Permissible tooth root stress (N/mm²)	[σFP]	705.60	717.35
Required safety	[SFmin]	1.40	1.40
Safety for tooth root stress	[SF=σFP/σF]	1.61	1.66

8 Calculation of flank strength (pitting)

		------- Gear 1 ----------	Gear 2 -------
Normal force (N)	[Fn]	6911.91	
Normal force calculated without coefficient of friction			
Relative radius of curvature (mm)	[ρ.rel]	14.978	
Elasticity factor (√N/mm²)	[ZE]	189.81	
Load distribution coefficient	[ZLS]	0.966	
Bevel gear factor, flank	[ZK]	0.850	
Medium length of contact lines (mm)	[lbm]	21.31	
Projected m. length of contact lines (mm)	[lbm']	18.81	
Effective facewidth (mm)	[b=lbm]	21.31	
Mid-zone factor	[ZM-B]	0.955	
Nominal contact stress (N/mm²)	[σH0]	692.44	
Effective contact stress (N/mm²)	[σH]	1115.43	
Hypoid factor	[Zhyp]	1.000	1.000
Lubricant coefficient for N_L	[ZL]	1.020	1.020
Speed factor at N_L	[ZV]	0.976	0.976
Roughness factor for N_L	[ZR]	0.974	0.974
Material hardening factor for N_L	[ZW]	1.000	1.000
Life factor	[ZNT]	0.863	0.887
	[ZL*ZV*ZR*ZNT]	0.837	0.859
Limited pitting is permissible: No			
Size factor (flank)	[ZX]	1.000	1.000
Permissible contact stress (N/mm²)	[σHP]	1254.85	1288.48
Required safety	[SHmin]	1.00	1.00
Safety factor for contact stress	[SH=σHP/σH]	1.12	1.16

9 Scuffing load capacity according to ISO/TS 10300-20:2021

9.1 Flash temperature-criteria

		------- Gear 1 ----------	Gear 2 -------
Tooth mass temperature (°C)	[θMB]	80.29	
Lubrication coefficient for lubrication type	[XS]	0.985	
Depth of immersion from middle line, Gear 2 (mm)	[h]	0.00	
Depth of immersion as defined in ISO 10300, Gear 2 (mm)	[ed]	95.49	
Surface roughness structure factor	[C_{RS}]	1.000 *	

*ISO 10300-20: C_{RS}=1+(0.3*Sin(β_b))^ε, ε = 2.0 for ground surfaces

Calculation at critical point g_Y=7.62 mm			
Local coefficient of friction	[μ_Y]	0.079	
Maximum flash temperature (°C)	[θflamax]	50.64	
Scuffing temperature (°C)	[θS]	419.56	
Required safety	[SBmin]	2.000	
Margin of safety for scuffing, flash temperature	[SB]	5.737	

(Intermediate results are listed under “Special reports”)

10 Allowances for tooth thickness

		------- Gear 1	---------- Gear 2 -------
Tooth thickness tolerance		DIN 3967 cd25	DIN 3967 cd25
Tooth thickness allowance (normal section) (mm)	[As.e/i]	-0.070 /-0.110	-0.095 /-0.145
The following data apply on the middle of the facewidth (ISO 23509)			
Tooth thickness, arc, middle (mm)	[smn]	5.897	4.314
(mm)	[smn.e/i]	5.827 / 5.787	4.219 / 4.169
Tooth thickness, arc, middle (mm)	[smt]	6.809	4.981
(mm)	[smt.e/i]	6.728 / 6.682	4.871 / 4.814
Tooth thickness in reference circle, chord (mm)	[smnc]	5.893	4.314
(mm)	[smnc.e/i]	5.823 / 5.783	4.219 / 4.169
Chordal height from d_{am} (mm)	[hamc]	4.425	2.171
Theoretical tooth thickness at tip, middle, AGMA 929 (mm)	[tLNP/G]	2.106	2.716

10.1 Backlash

		------- Gear 1	---------- Gear 2 -------
Circumferential backlash, middle (mm)	[jmt]	0.294 / 0.191	
Circumferential backlash, outside (mm)	[jet]	0.333 / 0.215	
Normal backlash, middle (mm)	[jmn]	0.240 / 0.155	
Normal backlash, outside (mm)	[jen]	0.258 / 0.167	
Axial displacement for the predefined backlash:			
Required backlash due to axial displacement (mm)	[Δj]	0.065	
Additional backlash per gear (mm)	[Δj1,2]	0.010	0.055
Required axial displacement per gear (mm)	[α1,2]	0.035	0.082
Backlash for the predefined axial displacement:			
Change of mounting distance (mm)	[α1,2]	0.100	0.100
Additional backlash per gear (mm)	[Δj1,2]	0.028	0.067

11 Toothing tolerances

		------- Gear 1	---------- Gear 2 -------
According to	ISO 17485:2006		
Accuracy grade	[Q-ISO17485]	6	6
Diameter (mm)	[dT]	74.21	167.65
Single pitch deviation (µm)	[fpT]	12.00	13.00
Total cumulative pitch deviation (µm)	[FpT]	44.00	48.00
Runout (µm)	[FrT]	35.00	39.00
Single flank composite, tooth-to-tooth (µm)	[fisT.e/i]	20.00 /0.00	20.00 /0.00
f_{isTmax}, f_{isTmin}: ISO 17485:2006, Table B1, q=2			
Single flank composite, total (µm)	[FisT]	64.00	69.00

12 Modifications and determination of the tooth form

12.1 Data for the tooth form calculation

Data not available.
Please run the calculation in the "Tooth form" tab and open the main report again.

13 Supplementary data

13.1 Input data for calculating the gear dimensions according to ISO 23509:2019

Type 1 data, according to table 3, ISO 23509:
x_{hm1}=0.3345, k_{hap}=1.0000, k_{hfp}=1.2920, x_{smn}=0.0000

Type 2 data, according to table 3, ISO 23509:
c_{ham}=0.3327, k_d=2.0000, k_c=0.1460, k_t=0.0000

13.2 Gear power loss and coefficient of friction

Calculation according to	Niemann	
Coefficient of friction, own input	[μ_m]	0.070
Compound velocity (m/s)	[vΣ]	4.339
Loss factor	[HV]	0.110
Gear power loss (kW)	[PVZ]	0.162
Meshing efficiency (%)	[ηz]	99.231

13.3 Masses and moment of inertia

		------- Gear 1	---------- Gear 2 -------
Weight - approximate calculation with pitch cone (kg)	[m]	0.735	2.250
Moment of inertia			
Approximate calculation with pitch cone (kg*m²)	[J]	4.9759e-04	1.1094e-02

14 Service life, damage

Required safety for tooth root	[S_{Fmin}]	1.40
Required safety for tooth flank	[S_{Hmin}]	1.00
Required service life	[H]	100000.00
Service life (calculated with required safeties):		
System service life (h)	[H_{att}]	> 1000000

		------- Gear 1	---------- Gear 2 -------
Tooth root service life (h)	[H_{Fatt}]	1e+06	1e+06
Tooth flank service life (h)	[H_{Hatt}]	1e+06	1e+06

Note: The entry 1e+006 h means that the Service life > 1,000,000 h.

14.1 Damage

Damage relative to the required service life (H, 100000.0 h)

F_1 (%)	F_2 (%)	H_1 (%)	H_2 (%)
0.0000	0.0000	0.0000	0.0000

15 Remarks

15.1 Conventions

- Specifications with **.e/i** mean: Maximum value **.e** and Minimum value **.i**, taking all tolerances into account.
- Specifications with **.m** mean: Mean value within tolerance.

- The positive sign set for the apexes (t_{zF}, t_{zR}) means: apex before the center line, according to ISO 23509.

15.2 Calculations and factors

K_v, $K_{H\alpha}$, $K_{F\alpha}$ according to Method B
$K_{H\beta}$, $K_{F\beta}$ according to Method C
Y_{drel}, Y_R according to Method B1
Z_L, Z_V, Z_R according to Method B
The logarithmically interpolated value must be entered for factors Z_L, Z_V, Z_R, Z_W, Z_X, Y_{drelT}, Y_{RrelT} and Y_X. This value is calculated from the infinite life strength and static strength values, based on the number of load cycles.

_O.Varianta_IV.G34.G34_calc

1 Overview

Calculation method		ISO 6336:2019	
Drawing or article number:			
Gear 1:		G3(G34)	
Gear 2:		G4(G34)	
		------- Gear 1	---------- Gear 2 -------
Power (kW)	[P]	21.000	
Speed (1/min)	[n]	422.2	109.5
Number of load cycles (in mio.)	[NL]	506.667	131.358
Torque (Nm)	[T]	475.0	1832.0
Application factor	[KA]	1.25	
Required service life (h)	[H]	20000.00	
Gear driving (+) / driven (-)		+	-
Working flank Gear 1:		Left flank	
Gear 1 direction of rotation:		Counterclockwise	

2 Tooth geometry

Geometry calculation according to		ISO 21771:2007	
		------- Gear 1	---------- Gear 2 -------
Center distance (mm)	[a]	157.000	
Center distance tolerance		ISO 286:2010 Measure js7	
Normal module (mm)	[mn]	3.0000	
Normal pressure angle (°)	[αn]	20.0000	
Helix angle at reference circle (°)	[β]	12.0000	
Number of teeth	[z]	21	81
Facewidth (mm)	[b]	50.00	41.00
Hand of gear		left	right
Accuracy grade	[Q-ISO 1328:2013]	A6	A6
Inner diameter (mm)	[di]	0.00	75.00
Inner diameter of gear rim (mm)	[dbi]	0.00	0.00

3 Materials

Gear 1

16 MnCr 5 (1), Case hardening steel, case-hardened, ISO 6336-5 Figure 9/10 (MQ), Core hardness >=25HRC Jominy J=12mm<HRC28

Gear 2

16 MnCr 5 (1), Case hardening steel, case-hardened, ISO 6336-5 Figure 9/10 (MQ), Core hardness >=25HRC Jominy J=12mm<HRC28

		------- Gear 1	---------- Gear 2 -------
Surface hardness		HRC 59	HRC 59

Material treatment according to ISO 6336:2006 Normal, Life factors Z_{NT} and $Y_{NT} \geq 0.85$			
Infinite life strength for tooth root stress (N/mm²)	[σFlim]	430.00	430.00
Fatigue strength for Hertzian pressure (N/mm²)	[σHlim]	1500.00	1500.00
Young's modulus (N/mm²)	[E]	206000	206000
Poisson's ratio	[v]	0.300	0.300
Tensile strength (N/mm²)	[σB]	1000.00	1000.00
Yield point (N/mm²)	[σS]	695.00	695.00

3.1 Roughnesses

		------- Gear 1	---------- Gear 2 -------
Roughness average value DS, flank (µm)	[RAH]	0.60	0.60
Roughness average value DS, root (µm)	[RAF]	3.00	3.00
Mean roughness height, Rz, flank (µm)	[RZH]	4.80	4.80
Mean roughness height, Rz, root (µm)	[RZF]	20.00	20.00

3.2 Lubrication

Lubrication type	Oil bath lubrication	
Type of oil	ISO-VG 220	
Lubricant base	Mineral-oil base	
Oil nominal kinematic viscosity at 40°C (mm²/s)	[v40]	220.00
Oil nominal kinematic viscosity at 100°C (mm²/s)	[v100]	17.50
Specific density at 15°C (kg/dm³)	[ρ]	0.895
Oil temperature (°C)	[TS]	70.000

4 Geometry

4.1 Reference profiles

4.1.1 Information on pre-machining

Tool reference profile from gear 1

Cutter denomination	DIN 3972 Profil III x 3	
Final machining stock (mm)	[q]	0.120
Addendum coefficient	[haP0*]	1.370
Dedendum coefficient	[hfP0*]	1.200
Tip radius factor	[ρaP0*]	0.200
	[ρaP0max*]	0.409
Root radius factor	[ρfP0*]	0.001
Protuberance height coefficient	[hprP0*]	0.000
Protuberance angle (°)	[αprP0]	0.000
Root form height coefficient	[hFfP0*]	0.000
Ramp angle (°)	[αKP0]	0.000
Tooth thickness factor reference line	[sP0*]	1.571
	not topping	
Addendum coefficient Reference profile Gear	[haP*]	1.003
Smallest radius of curvature, root rounding (mm)	[ρmin.e/i]	0.742 / 0.749

Tool reference profile from gear 2

Cutter denomination	DIN 3972 Profil III x 3	
Final machining stock (mm)	[q]	0.120
Addendum coefficient	[haP0*]	1.370
Dedendum coefficient	[hfP0*]	1.200
Tip radius factor	[ρaP0*]	0.200
	[ρaP0max*]	0.409
Root radius factor	[ρfP0*]	0.001
Protuberance height coefficient	[hprP0*]	0.000

Protuberance angle (°)	[αprP0]	0.000
Root form height coefficient	[hFfP0*]	0.000
Ramp angle (°)	[αKP0]	0.000
Tooth thickness factor reference line	[sP0*]	1.571
	not topping	
Addendum coefficient Reference profile Gear	[haP*]	1.000
Smallest radius of curvature, root rounding (mm)	[ρmin.e/i]	0.710 / 0.714

4.1.2 Reference profile of the final tooth form

		------- Gear 1	---------- Gear 2 -------
Dedendum reference profile	[hfP*]	1.253	1.253
Tooth root radius Refer. profile	[ρfP*]	0.200	0.200
Addendum Reference profile	[haP*]	1.003	1.000
Protuberance height coefficient	[hprP*]	0.000	0.000
Protuberance angle (°)	[αprP]	0.000	0.000
Tip form height coefficient	[hFaP*]	0.000	0.000
Ramp angle (°)	[αKP]	0.000	0.000
Data for final machining:			
Depth of immersion	[hgrind*]	1.212	1.147
Radius at cutter head	[rgrind*]	0.400	0.500
Grinding only flank (0), flank & root (1)		0	0
Generation grinding (0), form grinding (1)		1	1
Type of profile modification:	none (only running-in)		
Tip relief by running in (µm)	[Ca L/R]	2.0 / 2.0	2.0 / 2.0

4.2 Basic data

Overall transmission ratio	[itot]	-3.857
Gear ratio	[u]	3.857
Transverse module (mm)	[mt]	3.067
Transverse pressure angle (°)	[αt]	20.410
Working pressure angle (°)	[αwt]	20.974
(°)	[αwt.e/i]	20.993 /20.955
Working pressure angle at normal section (°)	[αwn]	20.551
Base helix angle (°)	[βb]	11.267
Helix angle at operating pitch circle (°)	[βw]	12.043
Reference center distance (mm)	[ad]	156.418
Sum of profile shift coefficients	[Σxi]	0.1965

		------- Gear 1	---------- Gear 2 -------
Profile shift coefficient			
Information on pre-machining	[x]	0.4657	-0.0352
Information on final machining	[x]	0.3487	-0.1522
Generating profile shift coefficient			
Information on pre-machining	[xE.e/i]	0.4336/0.4153	-0.0787/-0.1016
Information on final machining	[xE.e/i]	0.3167/0.2983	-0.1957/-0.2186
Virtual gear no. of teeth	[zn]	22.321	86.096
Involute length (mm)	[l_dFa-l_dFf]	6.128	5.668

4.3 Diameters and their allowances

		------- Gear 1	---------- Gear 2 -------
Reference diameter (mm)	[d]	64.407	248.429
Base diameter (mm)	[db]	60.364	232.832
Tip alteration (mm)	[k*mn]	-0.008	-0.008

Tip diameter (mm)	[da]	72.500	253.500
(mm)	[da.e/i]	72.500 /72.470	253.500 /253.448
Tip diameter allowances (mm)	[Ada.e/i]	0.000 /-0.030	0.000 /-0.052
Tip form diameter (mm)	[dFa]	72.500	253.500
(mm)	[dFa.e/i]	72.500 /72.470	253.500 /253.448
Active tip diameter (mm)	[dNa]	72.500	253.500
(mm)	[dNa.e/i]	72.500 /72.470	253.500 /253.448
Operating pitch diameter (mm)	[dw]	64.647	249.353
(mm)	[dw.e/i]	64.655 /64.639	249.385 /249.321
Root diameter (mm)	[df]	58.980	239.996
Generated root diameter with xE (mm) (calculated with pre-machining tool)	[df.e/i]	58.788 /58.678	239.735 /239.598
Active root diameter (mm)	[dNf]	61.572	243.781
(mm)	[dNf.e/i]	61.620 /61.550	243.830 /243.748
Root form diameter (mm)	[dFf]	61.455	242.865
(mm) (calculated with final machining tool)	[dFf.e/i]	61.262 /61.153	242.604 /242.467

4.4 Tip clearances and tooth heights

		------- Gear 1 ----------	Gear 2 -------
Theoretical tip clearance (mm)	[c]	0.752	0.760
Effective tip clearance (mm)	[c.e/i]	0.986 / 0.862	0.957 / 0.836
Reserve (dNf-dFf)/2 (mm)	[cF.e/i]	0.234 / 0.144	0.681 / 0.572
Addendum, $m_n(h_{aP}^*+x+k)$ (mm)	[ha]	4.046	2.536
(mm)	[ha.e/i]	4.046 / 4.031	2.536 / 2.510
Dedendum, $m_n(h_{fP}^*-x)$ (mm)	[hf]	2.714	4.216
(mm)	[hf.e/i]	2.810 / 2.865	4.347 / 4.415
Tooth height (mm)	[h]	6.760	6.752

4.5 Roll angle

		------- Gear 1 ----------	Gear 2 -------
Roll angle at dFa (°)	[ξFa.e/i]	38.114 /38.063	24.671 /24.639
Roll angle to dNf (°)	[ξNf.e/i]	11.750 /11.413	17.817 /17.749
Roll angle at dFf (°)	[ξFf.e/i]	9.922 / 9.292	16.773 /16.653

4.6 Tooth thickness and pitch

		------- Gear 1 ----------	Gear 2 -------
Tooth thickness, arc, in module	[sn*]	1.8246	1.4600
Normal tooth thickness at tip circle (mm)	[san]	1.730	2.454
(mm)	[san.e/i]	1.671 / 1.607	2.378 / 2.306
Normal tooth thickness at tip form circle (mm)	[sFan]	1.730	2.454
(mm)	[sFan.e/i]	1.671 / 1.607	2.378 / 2.306
Normal space width at root circle (mm)	[efn]	0.000	2.329
(mm)	[efn.e/i]	0.000 / 0.000	2.355 / 2.369

Pitch on reference circle (mm)	[pt]	9.635	9.635
Base pitch (mm)	[pbt]	9.030	9.030
Transverse pitch on contact-path (mm)	[pet]	9.030	9.030
Lead height (mm)	[pz]	951.944	3671.785
Axial pitch (mm)	[px]	45.331	45.331

4.7 Sliding

		------- Gear 1	---------- Gear 2 -------
Max. sliding velocity at tip (m/s)	[vga]	0.474	0.306
Specific sliding at the tip	[ζa]	0.534	0.533
Specific sliding at the root	[ζf]	-1.142	-1.144
Mean specific sliding	[ζm]	0.533	
Sliding factor on tip	[Kga]	0.331	0.214
Sliding factor on root	[Kgf]	-0.214	-0.331

4.8 Contact ratios

		---------- Pair ----------
Minimal length of contact line (mm)	[Lmin]	62.877
Transverse contact ratio	[εα]	1.551
	[εα.e/m/i]	1.558 / 1.546/ 1.535
Overlap ratio	[εβ]	0.904
Total contact ratio	[εγ]	2.456
	[εγ.e/m/i]	2.462 / 2.451/ 2.439
Length of path of contact (mm)	[ga]	14.010
(mm)	[ga.e/i]	14.066 /13.861

		------- Gear 1	---------- Gear 2 -------
Addendum contact ratio	[ε]	0.942	0.609
	[ε.e/i]	0.943 / 0.938	0.614 / 0.597
Length T1-A and T2-A (mm)	[T1A,T2A]	6.068	50.128
(mm)	[.e/i]	6.012 / 6.189	50.128 / 50.063
Length T1-B and T2-B (mm)	[T1B,T2B]	11.047	45.149
(mm)	[.e/i]	11.047 / 11.020	45.093 / 45.232
Length T1-C and T2-C (mm)	[T1C,T2C]	11.570	44.626
(mm)	[.e/i]	11.558 / 11.581	44.582 / 44.671
Length T1-D and T2-D (mm)	[T1D,T2D]	15.098	41.098
(mm)	[.e/i]	15.042 / 15.220	41.098 / 41.032
Length T1-E and T2-E (mm)	[T1E,T2E]	20.078	36.119
(mm)	[.e/i]	20.078 / 20.051	36.063 / 36.201
Length T1-T2 (mm)	[T1T2]	56.196	
(mm)	[.e/i]	56.140 / 56.252	
Diameter of single contact point B (mm)	[d-B]	64.280	249.729
(mm)	[d-B.e/i]	64.280 / 64.262	249.689 /249.789
Diameter of single contact point D (mm)	[d-D]	67.495	246.915
(mm)	[d-D.e/i]	67.445 / 67.605	246.915 /246.871

5 General influence factors

5.1 Forces and circumferential speed

		------- Gear 1	---------- Gear 2 -------
Nominal circum. force at pitch circle (N)	[Ft]	14748.3	
Axial force (N)	[Fa]	3134.9	3134.9
Radial force (N)	[Fr]	5487.9	5487.9
Normal force (N)	[Fnorm]	16045.5	16045.5
Nominal circumferential force per mm (N/mm)	[w]	359.72	
Only as information: Forces at operating pitch circle:			
Nominal circumferential force (N)	[Ftw]	14693.7	
Axial force (N)	[Faw]	3134.9	3134.9
Radial force (N)	[Frw]	5632.6	
Circumferential speed reference circle (m/s)	[v]	1.42	
Circumferential speed operating pitch circle (m/s)	[v(dw)]	1.43	

5.2 Contact stiffness

Running-in value (µm)	[yp]	0.6
Running-in value (µm)	[yf]	0.7
Correction factor	[CM]	0.800
Gear blank factor	[CR]	1.000
Basic rack factor	[CBS]	0.973
Material coefficient	[E/Est]	1.000
Singular tooth stiffness (N/mm/µm)	[c']	13.960
Meshing stiffness (N/mm/µm)	[cγα]	19.733
Meshing stiffness (N/mm/µm)	[cγβ]	16.773
Reduced mass (kg/mm)	[mRed]	0.01465
Resonance speed (min-1)	[nE1]	16687
Resonance ratio (-)	[N]	0.025
Subcritical range		

5.3 Calculation of K factors

Running-in value (µm)	[yα]	0.7
Bearing distance l of pinion shaft (mm)	[l]	100.000
Distance s of pinion shaft (mm)	[s]	10.000
Outside diameter of pinion shaft (mm)	[dsh]	50.000
Load in accordance with Figure 13, ISO 6336-1:2006	[-]	4
0:a), 1:b), 2:c), 3:d), 4:e)		
Coefficient K' according to Figure 13, ISO 6336-1:2006	[K']	-1.00
Without stiffening		
Tooth trace deviation (active) (µm)	[Fβy]	4.35
from deformation of shaft (µm)	[fsh*B1]	1.42
fsh (µm)	[fsh]	1.42
B1	[B1]	1.00
fHβ5 (µm)	[fHβ5]	7.00
Tooth without flank line modification		
Position of contact pattern:	favorable	
from production tolerances (µm)	[fmα*B2]	13.79
B_2=1.00		
Tooth trace deviation, theoretical (µm)	[Fβx]	5.11
Running-in value (µm)	[yβ]	0.77

5.4 K factors

Dynamic factor	[Kv]	1.006
Width factors		
- Flank	[KHβ]	1.081
- Tooth root	[KFβ]	1.067
- Scuffing	[KBβ]	1.081
Transverse load factors		
- Flank	[KHα]	1.054
- Tooth root	[KFα]	1.054
- Scuffing	[KBα]	1.054
Application factor	[KA]	1.250
Distribution factor	[Kγ]	1.000

6 Calculation of tooth root strength (fracture)

Calculation of Tooth form coefficients according method: B

		------- Gear 1	---------- Gear 2 -------
Calculated with generating profile shift coefficient	[xE.i]	0.4153	-0.1016
Tooth form factor	[YF]	1.03	1.17
Stress correction factor	[YS]	2.42	2.21
Load application angle (°)	[αFen]	21.92	19.77
Load distribution influence factor	[fε]	0.810	
Load application diameter, virtual spur gear (mm)	[d_{en}]	69.734	259.338
Load application diameter (mm)	[d_{en}]	67.178	249.479
Bending moment arm (mm)	[hF]	3.13	3.87
Tooth thickness at root (mm)	[sFn]	6.60	6.94
Tooth root radius (mm)	[ρF]	1.05	1.17
Bending moment arm (-)	[hF/mn]	1.043	1.290
Tooth thickness at root (-)	[sFn/mn]	2.200	2.313
Tooth root radius (-)	[ρF/mn]	0.351	0.391
Calculation cross section diameter (mm)	[d_{sFn}]	59.386	240.419
Tangents on calculation cross section (°)	[$α_{sFn}$]	30.000	30.000
Notch parameter	[q_s]	3.137	2.956
Helix angle factor	[Yβ]	0.972	
Deep tooth factor	[YDT]	1.000	
Gear rim factor	[YB]	1.00	1.00
Effective facewidth (mm)	[beff]	47.00	41.00
Nominal stress at tooth root (N/mm²)	[σF0]	254.64	302.93
Tooth root stress (N/mm²)	[σF]	360.39	428.75
Permissible bending stress at root of Test-gear			
Notch sensitivity factor	[YdrelT]	1.006	1.004
Surface factor	[YRrelT]	0.957	0.957
Size factor, tooth root	[YX]	1.000	1.000
Life factor	[YNT]	0.902	0.927
$Y_{drelT}*Y_{RrelT}*Y_X*Y_{NT}$		0.868	0.891
Alternating bending factor, mean stress influence coefficient			
	[YM]	1.000	1.000
Stress correction factor	[YST]	2.00	
YST*σFlim (N/mm²)	[σFE]	860.00	860.00
Permissible tooth root stress σFG/SFmin (N/mm²)	[σFP]	533.35	547.12
Limit strength tooth root (N/mm²)	[σFG]	746.69	765.96

6.1 Safety factors

		------- Gear 1	---------- Gear 2 -------
Required safety	[SFmin]	1.40	1.40
Safety for tooth root stress	[SF=σFG/σF]	2.07	1.79
Transmittable power (kW)	[kWRating]	31.08	26.80

7 Calculation of flank strength (pitting)

		------- Gear 1	---------- Gear 2 -------
Zone factor	[ZH]	2.414	
Elasticity factor (√N/mm²)	[ZE]	189.812	
Contact ratio factor	[Zε]	0.813	
Helix angle factor	[Zβ]	1.011	
Effective facewidth (mm)	[beff]	41.00	
Nominal contact stress (N/mm²)	[σH0]	998.71	
Contact stress at operating pitch circle (N/mm²)	[σHw]	1195.73	
Coefficient [fZCa] 1.20 (Helical gear sets without flank modifications)			
Single tooth contact factor	[ZB,ZD]	1.09	1.09
Contact stress (N/mm²)	[σHB, σHD]	1300.95	1298.96
Lubricant coefficient for N_L	[ZL]	1.020	1.020
Speed factor at N_L	[ZV]	0.959	0.959
Roughness factor for N_L	[ZR]	0.961	0.961
Material hardening factor for N_L	[ZW]	1.000	1.000
Life factor	[ZNT]	0.931	0.971
	[ZL*ZV*ZR*ZNT]	0.876	0.913
Limited pitting is permissible: No			
Size factor (flank)	[ZX]	1.000	1.000
Permissible contact stress, σHG/SHmin (N/mm²)	[σHP]	1313.27	1368.79
Pitting stress limit (N/mm²)	[σHG]	1313.27	1368.79

7.1 Safety factors

		------- Gear 1	---------- Gear 2 -------
Required safety	[SHmin]	1.00	1.00
Safety factor for contact stress on operating pitch circle	[SHw]	1.10	1.14
Safety against pressure, σHG/σHBD Single contact	[SHBD]	1.01	1.05
Safety regarding transmittable torque	[SHBD²]	1.02	1.11
Transmittable power (kW)	[kWRating]	21.40	23.32

8 Micropitting

Calculation method according to ISO/TS 6336-22:2018

Calculation has not been carried out, lubricant: Load stage micropitting test not known

9 Scuffing load capacity

Calculation method according to ISO/TS 6336-20/21:2017

		------- Gear 1	---------- Gear 2 -------
Thermal contact coefficient (N/mm/s^.5/K)	[BM]	13.780	13.780
Relevant tip relief (µm)	[Ca]	2.00	2.00
Optimal tip relief (µm)	[Ceff]	22.79	

C_a taken as optimal in the calculation. 0=no, 1=yes		0	0

		Pair	
Helical load factor for scuffing	[KBγ]	1.215	
Lubrication coefficient for lubrication type	[XS]	1.000	
Scuffing test and load stage	[FZGtest]	FZG - Test A / 8.3 / 90 (ISO 14635 - 1)	12
Multiple meshing factor	[Xmp]	1.000	
Relative structural factor, scuffing	[XWrelT]	1.000	
Effective facewidth (mm)	[beff]	41.000	
Applicable circumferential force/facewidth (N/mm)	[wBt]	515.639	
$K_{B\gamma}$ = 1.215, $w_{Bt}*K_{B\gamma}$ = 626.702			
Angle factor	[Xαβ]	0.988	
ε_1 =0.942, ε_2 =0.609			

9.1 Flash temperature-criteria

		Pair	
Lubricant factor	[XL]	0.830	
Tooth mass temperature (°C)	[θMi]	77.31	
$\theta_{Mi} = \theta_{oil} + X_S*0.47*X_{mp}*\theta_{flm}$			
Average flash temperature (°C)	[θflm]	15.55	
Scuffing temperature (°C)	[θS]	348.81	
Γ coordinates (point of highest temperature)	[Γ]	0.735	
[Γ.A]= -0.476, [Γ.E]= 0.735			
Maximum contact temperature (°C)	[θB]	108.74	
Flash factor (°K*N^-.75*s^.5*m^-.5*mm)	[XM]	50.058	
Approach factor	[XJ]	1.000	
Load sharing factor	[XΓ]	0.527	
Dynamic viscosity (mPa*s)	[ηM]	41.87	(70.0 °C)
Coefficient of friction	[μ_m]	0.086	
Required safety	[SBmin]	2.000	
Margin of safety for scuffing, flash temperature	[SB]	7.198	

9.2 Integral temperature-criteria

		Pair	
Lubricant factor	[XL]	1.000	
Tooth mass temperature (°C)	[θMC]	79.18	
$\theta_{MC} = \theta_{oil} + X_S*0.70*\theta_{flaint}$			
Integral scuffing temperature (°C)	[θSint]	360.78	
Flash factor (°K*N^-.75*s^.5*m^-.5*mm)	[XM]	50.058	
Running-in factor, well run in	[XE]	1.000	
Contact ratio factor	[Xε]	0.245	
Dynamic viscosity (mPa*s)	[ηOil]	41.87	(70.0 °C)
Mean coefficient of friction	[μ_m]	0.095	
Geometry factor	[XBE]	0.308	
Meshing factor	[XQ]	1.000	
Tip relief factor	[XCa]	1.143	
Mean flash temperature (°C)	[θflaint]	13.12	
Integral tooth flank temperature (°C)	[θint]	98.85	
Required safety	[SSmin]	1.800	
Safety factor for scuffing (intg.-temp.)	[SSint]	3.650	
Safety factor for transmitted moment (int.-T.)	[SSL]	10.078	

10 Measurements for tooth thickness

10.1 Tooth thickness tolerances and inputs

		------- Gear 1	---------- Gear 2 -------
10.1.1 Information on pre-machining			
Tooth thickness allowance, final machining (mm)	[As.e/i]	-0.070 /-0.110	-0.095 /-0.145
Input for final machining stock, per flank (mm)	[q]	0.120	0.120
Additional measure for pre-machining (mm)	[ΔAs_p.e/i]	0.255 / 0.255	0.255 / 0.255
Tooth thickness allowance (normal section) (mm)	[As_p.e/i]	0.185 / 0.145	0.160 / 0.110
10.1.2 Information on final machining			
Tooth thickness tolerance		DIN 3967 cd25	DIN 3967 cd25
Tooth thickness allowance (normal section) (mm)	[As.e/i]	-0.070 /-0.110	-0.095 /-0.145

10.2 Base tangent lengths

		------- Gear 1	---------- Gear 2 -------
10.2.1 Information on pre-machining			
Number of teeth spanned	[k]	4.000	10.000
Base tangent length with allowance (mm)	[Wk.e/i]	32.827 /32.789	87.599 /87.552
(mm)	[ΔWk.e/i]	0.174 / 0.137	0.151 / 0.104
10.2.2 Information on final machining			
Number of teeth spanned	[k]	4.000	10.000
Base tangent length (no backlash) (mm)	[Wk]	32.653	87.448
Base tangent length with allowance (mm)	[Wk.e/i]	32.587 /32.549	87.359 /87.312
(mm)	[ΔWk.e/i]	-0.066 /-0.103	-0.089 /-0.136
Diameter of measuring circle (mm)	[dMWk.m]	68.293	248.087

10.3 Measurement over balls and pins

		------- Gear 1	---------- Gear 2 -------
10.3.1 Information on pre-machining			
Effective diameter of ball/pin (mm)	[DMeff]	6.000	5.250
Diametral measurement over two balls (mm)	[MdK.e/i]	75.949 /75.874	255.512 /255.381
10.3.2 Information on final machining			
Theoretical diameter of ball/pin (mm)	[DM]	5.609	5.017
Effective diameter of ball/pin (mm)	[DMeff]	6.000	5.250
Radial single-ball measurement backlash free (mm)	[MrK]	37.897	127.569
Radial single-ball measurement (mm)	[MrK.e/i]	37.830 /37.791	127.443 /127.377
Diameter of measuring circle (mm)	[dMMr.m]	66.884	247.763
Diametral measurement over two balls without clearance (mm)	[MdK]	75.599	255.091
Diametral measurement over two balls (mm)	[MdK.e/i]	75.465 /75.388	254.840 /254.707
Diametral measurement over pins without clearance (mm)	[MdR]	75.794	255.138
Measurement over pins according to DIN 3960 (mm)	[MdR.e/i]	75.660 /75.583	254.887 /254.754
Measurement over 2 pins, free, AGMA 2002 (mm)	[dk2f.e/i]	75.454 /75.378	254.837 /254.704
Measurement over 2 pins, transverse, AGMA 2002 (mm)	[dk2t.e/i]	75.847 /75.770	254.933 /254.800
Measurement over 3 pins, axial, AGMA 2002 (mm)	[dk3A.e/i]	75.660 /75.583	254.887 /254.754

10.4 Tooth thickness

		------- Gear 1	---------- Gear 2 -------
10.4.1 Information on pre-machining			
Reference chordal height from da.m (mm)	[ha]	4.157	2.542
Chordal tooth thickness in reference circle (mm)	[sc.e/i]	5.652 / 5.613	4.540 / 4.490
Tooth thickness, arc (mm)	[sn.e/i]	5.659 / 5.619	4.540 / 4.490
10.4.2 Information on final machining			
Reference chordal height from da.m (mm)	[ha]	4.150	2.541
Chordal tooth thickness (mm)	[sc]	5.468	4.380
(mm)	[sc.e/i]	5.400 / 5.361	4.285 / 4.236
Tooth thickness, arc (mm)	[sn]	5.474	4.380
(mm)	[sn.e/i]	5.404 / 5.364	4.285 / 4.235

10.5 Backlash

		---------- Pair ----------
Circumferential backlash from Aa (mm)	[jtw_Aa.e/i]	0.015 /-0.015
Radial backlash (mm)	[jrw.e/i]	0.364 / 0.202
Circumferential backlash (transverse section) (mm)	[jtw.e/i]	0.277 / 0.154
Normal backlash (mm)	[jn.e/i]	0.253 / 0.141
Center distance allowances (mm)	[Aa.e/i]	0.020 /-0.020
Backlash free center distance (mm)	[aControl.e/i]	156.778 /156.656
Backlash free center distance, allowances (mm)	[jta]	-0.222 /-0.344

		------- Gear 1	---------- Gear 2 -------
dNf.i with aControl (mm)	[dNf0.i]	61.220	243.214
Reserve (dNf0.i-dFf.e)/2 (mm)	[cF0.i]	-0.021	0.305
Tip clearance (mm)	[c0.i(aControl)]	0.538	0.512

Torsional angle on input with output fixed:

Total torsional angle (°)	[j.tSys]	0.4910/0.2729

11 Toothing tolerances

		------- Gear 1	---------- Gear 2 -------
According to ISO 1328-1:2013, ISO 1328-2:1997			
Accuracy grade	[Q]	A6	A6
Single pitch deviation (µm)	[fptT]	9.00	9.00
Base circle pitch deviation (µm)	[fpbT]	8.43	8.43
Sector pitch deviation over k/8 pitches (µm)	[Fpk/8T]	19.00	21.00
Profile form deviation (µm)	[ffαT]	9.50	9.50
Profile slope deviation (µm)	[fHαT]	7.50	7.50
Total profile deviation (µm)	[FαT]	12.00	12.00
Helix form deviation (µm)	[ffβT]	11.00	11.00
Helix slope deviation (µm)	[fHβT]	9.50	10.00
Total helix deviation (µm)	[FβT]	15.00	15.00
Total cumulative pitch deviation (µm)	[FpT]	26.00	33.00
Adjacent pitch difference (µm)	[fuT]	13.00	13.00
Runout (µm)	[FrT]	24.00	30.00
Single flank composite, total (µm)	[FisT]	35.00	42.00
Single flank composite, tooth-to-tooth (µm)	[fisT]	8.50	8.50

Radial composite, total (µm)	[FidT]	36.00	43.00
Radial composite, tooth-to-tooth (µm)	[fidT]	14.00	15.00

FidT (Fi") and fidT (fi") according to ISO 1328:1997 calculated with the geometric mean values for m_n and d.

According to ISO 1328-2:2020

Accuracy grade	[Q]	R39	R40
Radial composite, total (µm)	[FidT]	29.00	42.00
Radial composite, tooth-to-tooth (µm)	[fidT]	14.00	18.00

Axis alignment tolerances recommendation acc. to ISO TR 10064-3:1996, Quality 6

Maximum value for deviation error of axis (µm)	[fΣβ]	18.29	(F_β=15.00)
Maximum value for inclination error of axes (µm)	[fΣδ]	36.59	

12 Modifications and determination of the tooth form

12.1 Data for the tooth form calculation

Data not available.
Please run the calculation in the "Tooth form" tab and open the main report again.

13 Supplementary data

Maximal possible center distance (eps_a=1.0)	[aMAX]	158.850

13.1 Masses, stiffnesses and moments of inertia

		------- Gear 1	---------- Gear 2 -------
Mass (kg)	[m]	1.329	13.933
Total mass (kg)	[mGes]	15.262	
Moment of inertia for system, relative to the input:			
calculation without consideration of the exact tooth shape			
Gears individually ((da+df)/2...di) (kg*m²)	[J]	0.0007179	0.1158
System (da+df)/2...di (kg*m²)	[J]	0.008504	

13.2 Wear, power loss, sound pressure level

Torsional stiffness at driving gear with fixed driven gear:		
Torsional stiffness (MNm/rad)	[cr]	0.624
Torsion when subjected to nominal torque (°)	[δcr]	0.044
Average coefficient of friction according to Niemann	[μ_m]	0.090
Wear sliding coef. by Niemann	[ζw]	0.828
Loss factor	[HV]	0.136
Gear power loss (kW)	[PVZ]	0.258
Meshing efficiency (%)	[ηz]	98.771
Sound pressure level based on Masuda, without PPTE/δs	[dB(A)]	65.552

14 Service life, damage

Required safety for tooth root	[S_{Fmin}]	1.40
Required safety for tooth flank	[S_{Hmin}]	1.00
Required service life	[H]	20000.00

Service life (calculated with required safeties):

System service life (h)	[H_{att}]	27205

	------- Gear 1	---------- Gear 2 -------

Tooth root service life (h)	[H_{Fatt}]	1e+06	1e+06
Tooth flank service life (h)	[H_{Hatt}]	2.72e+04	1.103e+05

Note: The entry 1e+006 h means that the Service life > 1,000,000 h.

14.1 Damage

Damage relative to the required service life (H, 20000.0 h)

F_1 (%)	F_2 (%)	H_1 (%)	H_2 (%)
0.0000	0.0000	73.5164	18.1312

Damage relative to the system service life (H_{att}, 27204.8 h)

F_1 (%)	F_2 (%)	H_1 (%)	H_2 (%)
0.0000	0.0000	100.0000	24.6628

15 Remarks

15.1 Conventions

- Specifications with **.e/i** mean: Maximum value **.e** and Minimum value **.i**, taking all tolerances into account.
- Specifications with **.m** mean: Mean value within tolerance.

- The center distance tolerances and the tooth thickness allowance are taken into account for the backlash tolerance. The maximum and minimum clearance corresponding to the largest and smallest allowances are shown. The calculation is performed for the operating pitch circle.

15.2 Calculations and factors

- Calculation of Z_β acc. to Corrigendum 1 ISO 6336-2:2008 with Z_β = 1/(COS(β)^0.5)
- Details of calculation method:
  c_γ according to Method B
  K_v according to Method B
  $K_{H\beta}$ and $K_{F\beta}$ according to Method C
  $f_{m\alpha}$ according to equation 66, f_{sh} according to 59/60, $F_{\beta x}$ according to 54/55/57
  $K_{H\alpha}$, $K_{F\alpha}$ according to Method B
- The logarithmically interpolated value must be entered for factors Z_L, Z_V, Z_R, Z_W, Z_X, Y_{drelT}, Y_{RrelT} and Y_X. This value is calculated from the infinite life strength and static strength values, based on the number of load cycles.

_O.Varianta_IV.G56.G56_calc

1 Overview

Calculation method		DIN 3990:1987 Method B	
Drawing or article number:			
Gear 1:		G5(G56)	
Gear 2:		G6(G56)	
		------- Gear 1	---------- Gear 2 -------
Power (kW)	[P]	21.000	
Speed (1/min)	[n]	109.5	28.0
Number of load cycles (in mio.)	[NL]	131.358	33.640
Torque (Nm)	[T]	1832.0	7153.4
Application factor	[KA]	1.25	
Required service life (h)	[H]	20000.00	
Gear driving (+) / driven (-)		+	-
Working flank Gear 1:		Right flank	
Gear 1 direction of rotation:		Clockwise	

2 Tooth geometry

Geometry calculation according to		ISO 21771:2007	
		------- Gear 1	---------- Gear 2 -------
Center distance (mm)	[a]	244.000	
Center distance tolerance		ISO 286:2010 Measure js7	
Normal module (mm)	[mn]	4.5000	
Normal pressure angle (°)	[αn]	20.0000	
Helix angle at reference circle (°)	[β]	17.0000	
Number of teeth	[z]	21	82
Facewidth (mm)	[b]	55.00	51.00
Hand of gear		right	left
Accuracy grade	[Q-ISO 1328:2013]	A6	A6
Inner diameter (mm)	[di]	0.00	110.00
Inner diameter of gear rim (mm)	[dbi]	0.00	110.00

3 Materials

Gear 1

16 MnCr 5 (1), Case hardening steel, case-hardened, ISO 6336-5 Figure 9/10 (MQ), Core hardness >=25HRC Jominy J=12mm<HRC28

Gear 2

16 MnCr 5 (1), Case hardening steel, case-hardened, ISO 6336-5 Figure 9/10 (MQ), Core hardness >=25HRC Jominy J=12mm<HRC28

		------- Gear 1	---------- Gear 2 -------
Surface hardness		HRC 59	HRC 59

Infinite life strength for tooth root stress (N/mm²)	[σFlim]	430.00	430.00
Fatigue strength for Hertzian pressure (N/mm²)	[σHlim]	1500.00	1500.00
Young's modulus (N/mm²)	[E]	206000	206000
Poisson's ratio	[v]	0.300	0.300
Tensile strength (N/mm²)	[σB]	1000.00	1000.00
Yield point (N/mm²)	[σS]	695.00	695.00

3.1 Roughnesses

		------- Gear 1	---------- Gear 2 -------
Roughness average value DS, flank (µm)	[RAH]	0.60	0.60
Roughness average value DS, root (µm)	[RAF]	3.00	3.00
Mean roughness height, Rz, flank (µm)	[RZH]	4.80	4.80
Mean roughness height, Rz, root (µm)	[RZF]	20.00	20.00

3.2 Lubrication

Lubrication type	Oil bath lubrication	
Type of oil	ISO-VG 220	
Lubricant base	Mineral-oil base	
Oil nominal kinematic viscosity at 40°C (mm²/s)	[v40]	220.00
Oil nominal kinematic viscosity at 100°C (mm²/s)	[v100]	17.50
Specific density at 15°C (kg/dm³)	[ρ]	0.895
Oil temperature (°C)	[TS]	70.000

4 Geometry

4.1 Reference profiles

4.1.1 Information on pre-machining

Tool reference profile from gear 1

Cutter denomination	DIN 3972 Profil III x 4.5	
Final machining stock (mm)	[q]	0.140
Addendum coefficient	[haP0*]	1.342
Dedendum coefficient	[hfP0*]	1.200
Tip radius factor	[ρaP0*]	0.200
	[ρaP0max*]	0.424
Root radius factor	[ρfP0*]	0.001
Protuberance height coefficient	[hprP0*]	0.000
Protuberance angle (°)	[αprP0]	0.000
Root form height coefficient	[hFfP0*]	0.000
Ramp angle (°)	[αKP0]	0.000
Tooth thickness factor reference line	[sP0*]	1.571
	not topping	
Addendum coefficient Reference profile Gear	[haP*]	0.999
Smallest radius of curvature, root rounding (mm)	[ρmin.e/i]	1.095 / 1.101

Tool reference profile from gear 2

Cutter denomination	DIN 3972 Profil III x 4.5	
Final machining stock (mm)	[q]	0.140
Addendum coefficient	[haP0*]	1.342
Dedendum coefficient	[hfP0*]	1.200
Tip radius factor	[ρaP0*]	0.200
	[ρaP0max*]	0.424
Root radius factor	[ρfP0*]	0.001
Protuberance height coefficient	[hprP0*]	0.000
Protuberance angle (°)	[αprP0]	0.000

Root form height coefficient	[hFfP0*]	0.000	
Ramp angle (°)	[αKP0]	0.000	
Tooth thickness factor reference line	[sP0*]	1.571	
	not topping		
Addendum coefficient Reference profile Gear	[haP*]	1.009	
Smallest radius of curvature, root rounding (mm)	[ρmin.e/i]	1.019 / 1.023	

4.1.2 Reference profile of the final tooth form

		------- Gear 1	---------- Gear 2 -------
Dedendum reference profile	[hfP*]	1.251	1.251
Tooth root radius Refer. profile	[ρfP*]	0.200	0.200
Addendum Reference profile	[haP*]	0.999	1.009
Protuberance height coefficient	[hprP*]	0.000	0.000
Protuberance angle (°)	[αprP]	0.000	0.000
Tip form height coefficient	[hFaP*]	0.000	0.000
Ramp angle (°)	[αKP]	0.000	0.000
Data for final machining:			
Depth of immersion	[hgrind*]	1.197	1.143
Radius at cutter head	[rgrind*]	0.300	0.450
Grinding only flank (0), flank & root (1)		0	0
Generation grinding (0), form grinding (1)		1	1
Type of profile modification:	none (only running-in)		
Tip relief by running in (µm)	[Ca L/R]	2.0 / 2.0	2.0 / 2.0

4.2 Basic data

Overall transmission ratio	[itot]	-3.905
Gear ratio	[u]	3.905
Transverse module (mm)	[mt]	4.706
Transverse pressure angle (°)	[αt]	20.837
Working pressure angle (°)	[αwt]	21.839
(°)	[αwt.e/i]	21.852 /21.825
Working pressure angle at normal section (°)	[αwn]	20.958
Base helix angle (°)	[βb]	15.946
Helix angle at operating pitch circle (°)	[βw]	17.110
Reference center distance (mm)	[ad]	242.339
Sum of profile shift coefficients	[Σxi]	0.3776

		------- Gear 1	---------- Gear 2 -------
Profile shift coefficient			
Information on pre-machining	[x]	0.4535	0.1060
Information on final machining	[x]	0.3626	0.0151
Generating profile shift coefficient			
Information on pre-machining	[xE.e/i]	0.4322/0.4200	0.0663/0.0480
Information on final machining	[xE.e/i]	0.3412/0.3290	-0.0246/-0.0429
Virtual gear no. of teeth	[zn]	23.752	92.747
Involute length (mm)	[l_dFa-l_dFf]	9.518	8.778

4.3 Diameters and their allowances

		------- Gear 1	---------- Gear 2 -------
Reference diameter (mm)	[d]	98.818	385.860
Base diameter (mm)	[db]	92.355	360.624
Tip alteration (mm)	[k*mn]	-0.038	-0.038
Tip diameter (mm)	[da]	111.000	395.000

(mm)	[da.e/i]	111.000 /110.965	395.000 /394.943
Tip diameter allowances (mm)	[Ada.e/i]	0.000 /-0.035	0.000 /-0.057
Tip form diameter (mm)	[dFa]	111.000	395.000
(mm)	[dFa.e/i]	111.000 /110.965	395.000 /394.943
Active tip diameter (mm)	[dNa]	111.000	395.000
(mm)	[dNa.e/i]	111.000 /110.965	395.000 /394.943
Operating pitch diameter (mm)	[dw]	99.495	388.505
(mm)	[dw.e/i]	99.505 /99.486	388.541 /388.468
Root diameter (mm)	[df]	90.824	374.739
Generated root diameter with xE (mm) (calculated with pre-machining tool)	[df.e/i]	90.632 /90.522	374.382 /374.217
Active root diameter (mm)	[dNf]	94.573	380.052
(mm)	[dNf.e/i]	94.630 /94.547	380.111 /380.013
Root form diameter (mm)	[dFf]	93.833	378.633
(mm) (calculated with final machining tool)	[dFf.e/i]	93.641 /93.531	378.276 /378.111

4.4 Tip clearances and tooth heights

		------- Gear 1 ----------	Gear 2 -------
Theoretical tip clearance (mm)	[c]	1.130	1.088
Effective tip clearance (mm)	[c.e/i]	1.432 / 1.286	1.291 / 1.161
Reserve (dNf-dFf)/2 (mm)	[cF.e/i]	0.550 / 0.453	1.000 / 0.868
Addendum, $m_n(h_{aP}^*+x+k)$ (mm)	[ha]	6.091	4.570
(mm)	[ha.e/i]	6.091 / 6.074	4.570 / 4.541
Dedendum, $m_n(h_{fP}^*-x)$ (mm)	[hf]	3.997	5.561
(mm)	[hf.e/i]	4.093 / 4.148	5.739 / 5.822
Tooth height (mm)	[h]	10.088	10.130

4.5 Roll angle

		------- Gear 1 ----------	Gear 2 -------
Roll angle at dFa (°)	[ξFa.e/i]	38.201 /38.162	25.606 /25.584
Roll angle to dNf (°)	[ξNf.e/i]	12.797 /12.557	19.088 /19.039
Roll angle at dFf (°)	[ξFf.e/i]	9.595 / 9.174	18.145 /18.058

4.6 Tooth thickness and pitch

		------- Gear 1 ----------	Gear 2 -------
Tooth thickness, arc, in module	[sn*]	1.8347	1.5818
Normal tooth thickness at tip circle (mm)	[san]	2.689	3.615
(mm)	[san.e/i]	2.632 / 2.567	3.506 / 3.421
Normal tooth thickness at tip form circle (mm)	[sFan]	2.689	3.615
(mm)	[sFan.e/i]	2.632 / 2.567	3.506 / 3.421
Normal space width at root circle (mm)	[efn]	0.000	3.330
(mm)	[efn.e/i]	0.000 / 0.000	3.357 / 3.370

Pitch on reference circle (mm)	[pt]	14.783	14.783
Base pitch (mm)	[pbt]	13.816	13.816
Transverse pitch on contact-path (mm)	[pet]	13.816	13.816
Lead height (mm)	[pz]	1015.421	3964.979
Axial pitch (mm)	[px]	48.353	48.353

4.7 Sliding

		------- Gear 1	---------- Gear 2 -------
Max. sliding velocity at tip (m/s)	[vga]	0.177	0.120
Specific sliding at the tip	[ζa]	0.501	0.507
Specific sliding at the root	[ζf]	-1.027	-1.004
Mean specific sliding	[ζm]	0.503	
Sliding factor on tip	[Kga]	0.310	0.210
Sliding factor on root	[Kgf]	-0.210	-0.310

4.8 Contact ratios

		---------- Pair ----------
Minimal length of contact line (mm)	[Lmin]	77.754
Transverse contact ratio	[εα]	1.491
	[εα.e/m/i]	1.496 / 1.488/ 1.480
Overlap ratio	[εβ]	1.055
Total contact ratio	[εγ]	2.546
	[εγ.e/m/i]	2.551 / 2.542/ 2.534
Length of path of contact (mm)	[ga]	20.606
(mm)	[ga.e/i]	20.668 /20.443

		------- Gear 1	---------- Gear 2 -------
Addendum contact ratio	[ε]	0.889	0.602
	[ε.e/i]	0.890 / 0.886	0.606 / 0.594
Length T1-A and T2-A (mm)	[T1A,T2A]	10.182	80.584
(mm)	[.e/i]	10.120 / 10.314	80.584 / 80.515
Length T1-B and T2-B (mm)	[T1B,T2B]	16.972	73.795
(mm)	[.e/i]	16.972 / 16.940	73.733 / 73.888
Length T1-C and T2-C (mm)	[T1C,T2C]	18.506	72.261
(mm)	[.e/i]	18.493 / 18.518	72.211 / 72.310
Length T1-D and T2-D (mm)	[T1D,T2D]	23.998	66.768
(mm)	[.e/i]	23.936 / 24.130	66.768 / 66.698
Length T1-E and T2-E (mm)	[T1E,T2E]	30.788	59.979
(mm)	[.e/i]	30.788 / 30.756	59.917 / 60.072
Length T1-T2 (mm)	[T1T2]	90.767	
(mm)	[.e/i]	90.705 / 90.828	
Diameter of single contact point B (mm)	[d-B]	98.395	389.657
(mm)	[d-B.e/i]	98.395 / 98.373	389.610 /389.727
Diameter of single contact point D (mm)	[d-D]	104.082	384.554
(mm)	[d-D.e/i]	104.025 /104.204	384.554 /384.505

5 General influence factors

5.1 Forces and circumferential speed

		Gear 1	Gear 2
Nominal circum. force at pitch circle (N)	[Ft]	37077.4	
Axial force (N)	[Fa]	11335.7	11335.7
Radial force (N)	[Fr]	14111.7	14111.7
Normal force (N)	[Fnorm]	41259.9	41259.9
Nominal circumferential force per mm (N/mm)	[w]	727.01	
Only as information: Forces at operating pitch circle:			
Nominal circumferential force (N)	[Ftw]	36825.1	
Axial force (N)	[Faw]	11335.7	11335.7
Radial force (N)	[Frw]	14757.8	
Circumferential speed reference circle (m/s)	[v]	0.57	
Circumferential speed operating pitch circle (m/s)	[v(dw)]	0.57	

5.2 Contact stiffness

Running-in value (µm)	[yp]	0.7
Running-in value (µm)	[yf]	0.8
Correction factor	[CM]	0.800
Gear blank factor	[CR]	1.000
Basic rack factor	[CBS]	0.975
Material coefficient	[E/Est]	1.000
Singular tooth stiffness (N/mm/µm)	[c']	14.041
Meshing stiffness (N/mm/µm)	[cγ]	19.216
Reduced mass (kg/mm)	[mRed]	0.03485
Resonance speed (min-1)	[nE1]	10677
Resonance ratio (-)	[N]	0.010
Subcritical range		

5.3 Calculation of K factors

Running-in value (µm)	[yα]	0.8
Bearing distance l of pinion shaft (mm)	[l]	110.000
Distance s of pinion shaft (mm)	[s]	11.000
Outside diameter of pinion shaft (mm)	[dsh]	55.000
Load according to Figure 6.8, DIN 3990-1:1987	[-]	4
0:6.8a, 1:6.8b, 2:6.8c, 3:6.8d, 4:6.8e		
Coefficient K' according to Figure 6.8, DIN 3990-1:1987	[K']	-1.00
Without stiffening		
Tooth trace deviation (active) (µm)	[Fβy]	4.67
from deformation of shaft (µm)	[fsh*B1]	4.97
fsh (µm)	[fsh]	4.97
B1	[B1]	1.00
fHβ5 (µm)	[fHβ5]	7.00
Tooth without flank line modification		
Position of contact pattern:	favorable	
from production tolerances (µm)	[fmα*B2]	11.00
B_2=1.00		
Tooth trace deviation, theoretical (µm)	[Fβx]	5.50
Running-in value (µm)	[yβ]	0.82

5.4 K factors

Dynamic factor	[Kv]	1.002
Width factors		
- Flank	[KHβ]	1.049
- Tooth root	[KFβ]	1.039
- Scuffing	[KBβ]	1.049
Transverse load factors		
- Flank	[KHα]	1.000
- Tooth root	[KFα]	1.000
- Scuffing	[KBα]	1.000
Application factor	[KA]	1.250
Distribution factor	[Kγ]	1.000

6 Calculation of tooth root strength (fracture)

Calculation of Tooth form coefficients according method: B

		------- Gear 1	---------- Gear 2 -------
Calculated with profile shift coefficient	[x]	0.4535	0.1060
Tooth form factor	[YF]	1.18	1.31
Stress correction factor	[YS]	2.59	2.48
Load application angle (°)	[αFen]	21.90	20.27
Load application diameter, virtual spur gear (mm)	[d_{en}]	111.171	420.368
Load application diameter (mm)	[d_{en}]	103.103	388.865
Bending moment arm (mm)	[hF]	4.44	5.45
Tooth thickness at root (mm)	[sFn]	10.03	10.58
Tooth root radius (mm)	[ρF]	1.47	1.47
Bending moment arm (-)	[hF/mn]	0.986	1.210
Tooth thickness at root (-)	[sFn/mn]	2.228	2.351
Tooth root radius (-)	[ρF/mn]	0.327	0.327
Calculation cross section diameter (mm)	[d_{sFn}]	91.863	375.847
Tangents on calculation cross section (°)	[$α_{sFn}$]	30.000	30.000
Notch parameter	[q_s]	3.410	3.599
Contact ratio factor	[Yε]	1.000	
Helix angle factor	[Yβ]	0.858	
Effective facewidth (mm)	[beff]	55.00	51.00
Nominal stress at tooth root (N/mm²)	[σF0]	391.92	451.08
Tooth root stress (N/mm²)	[σF]	510.16	587.18
Permissible bending stress at root of Test-gear			
Notch sensitivity factor	[YdrelT]	1.008	1.010
Surface factor	[YRrelT]	0.957	0.957
Size factor, tooth root	[YX]	1.000	1.000
Life factor	[YNT]	1.000	1.000
$Y_{drelT}*Y_{RrelT}*Y_X*Y_{NT}$		0.964	0.966
Alternating bending factor, mean stress influence coefficient			
	[YM]	1.000	1.000
Stress correction factor	[YST]	2.00	
YST*σFlim (N/mm²)	[σFE]	860.00	860.00
Permissible tooth root stress σFG/SFmin (N/mm²)	[σFP]	592.42	593.33
Limit strength tooth root (N/mm²)	[σFG]	829.39	830.66

6.1 Safety factors

		------- Gear 1	---------- Gear 2 -------
Required safety	[SFmin]	1.40	1.40
Safety for tooth root stress	[SF=σFG/σF]	1.63	1.41
Transmittable power (kW)	[kWRating]	24.39	21.22

7 Calculation of flank strength (pitting)

		------- Gear 1	---------- Gear 2 -------
Zone factor	[ZH]	2.344	
Elasticity factor (√N/mm²)	[ZE]	189.812	
Contact ratio factor	[Zε]	0.819	
Helix angle factor	[Zβ]	0.978	
Effective facewidth (mm)	[beff]	51.00	
Nominal contact stress (N/mm²)	[σH0]	1082.97	
Contact stress at operating pitch circle (N/mm²)	[σHw]	1241.43	
Single tooth contact factor	[ZB,ZD]	1.00	1.00
Contact stress (N/mm²)	[σHB, σHD]	1241.43	1241.43
Lubricant coefficient for N_L	[ZL]	1.020	1.019
Speed factor at N_L	[ZV]	0.948	0.952
Roughness factor for N_L	[ZR]	0.986	0.987
Material hardening factor for N_L	[ZW]	1.000	1.000
Life factor	[ZNT]	1.000	1.030
	[ZL*ZV*ZR*ZNT]	0.954	0.986
Limited pitting is permissible: No			
Size factor (flank)	[ZX]	1.000	1.000
Permissible contact stress, σHG/SHmin (N/mm²)	[σHP]	1431.27	1479.23
Pitting stress limit (N/mm²)	[σHG]	1431.27	1479.23

7.1 Safety factors

		------- Gear 1	---------- Gear 2 -------
Required safety	[SHmin]	1.00	1.00
Safety factor for contact stress on operating pitch circle	[SHw]	1.15	1.19
Safety against pressure, σHG/σHBD Single contact	[SHBD]	1.15	1.19
Safety regarding transmittable torque	[SHBD²]	1.33	1.42
Transmittable power (kW)	[kWRating]	27.91	29.82

8 Micropitting

Calculation method according to ISO/TS 6336-22:2018

Calculation has not been carried out, lubricant: Load stage micropitting test not known

9 Scuffing load capacity

Calculation method according to DIN 3990:1987

		------- Gear 1	---------- Gear 2 -------
Thermal contact coefficient (N/mm/s^.5/K)	[BM]	13.780	13.780
Relevant tip relief (µm)	[Ca]	2.00	2.00
Optimal tip relief (µm)	[Ceff]	47.29	
C_a taken as optimal in the calculation. 0=no, 1=yes		0	0

		Pair	
Helical load factor for scuffing	[KBγ]	1.232	
Lubrication coefficient for lubrication type	[XS]	1.000	
Scuffing test and load stage	[FZGtest]	FZG - Test A / 8.3 / 90 (ISO 14635 - 1)	12
Relative structural factor, scuffing	[XWrelT]	1.000	
Effective facewidth (mm)	[beff]	51.000	
Applicable circumferential force/facewidth (N/mm)	[wBt]	1176.516	
Angle factor	[Xαβ]	0.996	
ε_1 =0.889, ε_2 =0.602			

9.1 Flash temperature-criteria

		Pair	
Tooth mass temperature (°C)	[θMB]	90.95	
$\theta_{MB} = \theta_{oil} + X_S*0.47*\theta_{flamax}$			
Maximum flash temperature (°C)	[θflamax]	44.57	
Scuffing temperature (°C)	[θS]	408.58	
Γ coordinates (point of highest temperature)	[Γ]	0.297	
[Γ.A]= -0.450, [Γ.E]= 0.664			
Maximum contact temperature (°C)	[θB]	135.51	
Flash factor (°K*N^-.75*s^.5*m^-.5*mm)	[XM]	50.058	
Geometry factor	[XB]	0.136	
Load sharing factor	[XΓ]	1.000	
Dynamic viscosity (mPa*s)	[ηM]	19.74	(90.9 °C)
Coefficient of friction	[μ_m]	0.171	
Required safety	[SBmin]	2.000	
Margin of safety for scuffing, flash temperature	[SB]	5.168	

9.2 Integral temperature-criteria

		Pair	
Tooth mass temperature (°C)	[θMC]	84.34	
$\theta_{MC} = \theta_{oil} + X_S*0.70*\theta_{flaint}$			
Integral scuffing temperature (°C)	[θSint]	408.58	
Flash factor (°K*N^-.75*s^.5*m^-.5*mm)	[XM]	50.058	
Contact ratio factor	[Xε]	0.256	
Dynamic viscosity (mPa*s)	[ηOil]	41.87	(70.0 °C)
Mean coefficient of friction	[μ_m]	0.153	
Geometry factor	[XBE]	0.281	
Meshing factor	[XQ]	1.000	
Tip relief factor	[XCa]	1.019	
Mean flash temperature (°C)	[θflaint]	20.48	
Integral tooth flank temperature (°C)	[θint]	115.06	
Required safety	[SSmin]	1.800	
Safety factor for scuffing (intg.-temp.)	[SSint]	3.551	
Safety factor for transmitted moment (int.-T.)	[SSL]	7.514	

10 Measurements for tooth thickness

10.1 Tooth thickness tolerances and inputs

		Gear 1	Gear 2
10.1.1 Information on pre-machining			
Tooth thickness allowance, final machining (mm)	[As.e/i]	-0.070 /-0.110	-0.130 /-0.190
Input for final machining stock, per flank (mm)	[q]	0.140	0.140
Additional measure for pre-machining (mm)	[ΔAs_p.e/i]	0.298 / 0.298	0.298 / 0.298

Tooth thickness allowance (normal section) (mm)	[As_p.e/i]	0.228 / 0.188	0.168 / 0.108

10.1.2 Information on final machining

Tooth thickness tolerance		DIN 3967 cd25	DIN 3967 cd25
Tooth thickness allowance (normal section) (mm)	[As.e/i]	-0.070 /-0.110	-0.130 /-0.190

10.2 Base tangent lengths

		------- Gear 1 ----------	Gear 2 -------

10.2.1 Information on pre-machining

Number of teeth spanned	[k]	4.000	11.000
Base tangent length with allowance (mm)	[Wk.e/i]	49.330 /49.292	145.562 /145.506
(mm)	[ΔWk.e/i]	0.214 / 0.177	0.158 / 0.101

10.2.2 Information on final machining

Number of teeth spanned	[k]	4.000	11.000
Base tangent length (no backlash) (mm)	[Wk]	49.115	145.405
Base tangent length with allowance (mm)	[Wk.e/i]	49.050 /49.012	145.282 /145.226
(mm)	[ΔWk.e/i]	-0.066 /-0.103	-0.122 /-0.179
Diameter of measuring circle (mm)	[dMWk.m]	103.692	386.724

10.3 Measurement over balls and pins

		------- Gear 1 ----------	Gear 2 -------

10.3.1 Information on pre-machining

Effective diameter of ball/pin (mm)	[DMeff]	9.000	8.000
Diametral measurement over two balls (mm)	[MdK.e/i]	116.201 /116.125	398.260 /398.106

10.3.2 Information on final machining

Theoretical diameter of ball/pin (mm)	[DM]	8.373	7.573
Effective diameter of ball/pin (mm)	[DMeff]	9.000	8.000
Radial single-ball measurement backlash free (mm)	[MrK]	58.032	198.915
Radial single-ball measurement (mm)	[MrK.e/i]	57.964 /57.925	198.747 /198.669
Diameter of measuring circle (mm)	[dMMr.m]	102.805	386.579
Diametral measurement over two balls without clearance (mm)	[MdK]	115.764	397.829
Diametral measurement over two balls (mm)	[MdK.e/i]	115.629 /115.552	397.494 /397.338
Diametral measurement over pins without clearance (mm)	[MdR]	116.064	397.829
Measurement over pins according to DIN 3960 (mm)	[MdR.e/i]	115.928 /115.851	397.494 /397.338
Measurement over 2 pins, free, AGMA 2002 (mm)	[dk2f.e/i]	115.593 /115.515	0.000 / 0.000
Measurement over 2 pins, transverse, AGMA 2002 (mm)	[dk2t.e/i]	116.216 /116.139	0.000 / 0.000
Measurement over 3 pins, axial, AGMA 2002 (mm)	[dk3A.e/i]	115.928 /115.851	397.494 /397.338

10.4 Tooth thickness

		------- Gear 1 ----------	Gear 2 -------

10.4.1 Information on pre-machining

Reference chordal height from da.m (mm)	[ha]	6.248	4.587
Chordal tooth thickness in reference circle (mm)	[sc.e/i]	8.475 / 8.436	7.285 / 7.226
Tooth thickness, arc (mm)	[sn.e/i]	8.484 / 8.444	7.286 / 7.226

10.4.2 Information on final machining

Reference chordal height from da.m (mm)	[ha]	6.240	4.586
Chordal tooth thickness (mm)	[sc]	8.248	7.118
(mm)	[sc.e/i]	8.180 / 8.141	6.988 / 6.929
Tooth thickness, arc (mm)	[sn]	8.256	7.118
(mm)	[sn.e/i]	8.186 / 8.146	6.988 / 6.928

10.5 Backlash

		Pair
Circumferential backlash from Aa (mm)	[jtw_Aa.e/i]	0.018 /-0.018
Radial backlash (mm)	[jrw.e/i]	0.419 / 0.241
Circumferential backlash (transverse section) (mm)	[jtw.e/i]	0.334 / 0.192
Normal backlash (mm)	[jn.e/i]	0.298 / 0.172
Center distance allowances (mm)	[Aa.e/i]	0.023 /-0.023
Backlash free center distance (mm)	[aControl.e/i]	243.736 /243.604
Backlash free center distance, allowances (mm)	[jta]	-0.264 /-0.396

		Gear 1	Gear 2
dNf.i with aControl (mm)	[dNf0.i]	94.136	379.382
Reserve (dNf0.i-dFf.e)/2 (mm)	[cF0.i]	0.247	0.553
Tip clearance (mm)	[c0.i(aControl)]	0.913	0.788

Torsional angle on input with output fixed:

Total torsional angle (°)	[j.tSys]	0.3850/0.2213

11 Toothing tolerances

		Gear 1	Gear 2
According to ISO 1328-1:2013, ISO 1328-2:1997			
Accuracy grade	[Q]	A6	A6
Single pitch deviation (µm)	[fptT]	10.00	10.00
Base circle pitch deviation (µm)	[fpbT]	9.35	9.35
Sector pitch deviation over k/8 pitches (µm)	[Fpk/8T]	21.00	24.00
Profile form deviation (µm)	[ffαT]	11.00	11.00
Profile slope deviation (µm)	[fHαT]	8.50	8.50
Total profile deviation (µm)	[FαT]	13.00	14.00
Helix form deviation (µm)	[ffβT]	11.00	12.00
Helix slope deviation (µm)	[fHβT]	10.00	11.00
Total helix deviation (µm)	[FβT]	15.00	16.00
Total cumulative pitch deviation (µm)	[FpT]	29.00	38.00
Adjacent pitch difference (µm)	[fuT]	14.00	14.00
Runout (µm)	[FrT]	26.00	34.00
Single flank composite, total (µm)	[FisT]	39.00	47.00
Single flank composite, tooth-to-tooth (µm)	[fisT]	9.50	9.50
Radial composite, total (µm)	[FidT]	44.00	60.00
Radial composite, tooth-to-tooth (µm)	[fidT]	22.00	22.00

FidT (Fi") and fidT (fi") according to ISO 1328:1997 calculated with the geometric mean values for m_n and d.

According to ISO 1328-2:2020			
Accuracy grade	[Q]	R41	R41
Radial composite, total (µm)	[FidT]	43.00	56.00
Radial composite, tooth-to-tooth (µm)	[fidT]	20.00	24.00

Axis alignment tolerances recommendation acc. to ISO TR 10064-3:1996, Quality 6

Maximum value for deviation error of axis (µm)	[fΣβ]	17.25	(F_β=16.00)
Maximum value for inclination error of axes (µm)	[fΣδ]	34.51	

12 Modifications and determination of the tooth form

12.1 Data for the tooth form calculation

Data not available.
Please run the calculation in the "Tooth form" tab and open the main report again.

13 Supplementary data

13.1 Masses, stiffnesses and moments of inertia

		------- Gear 1	---------- Gear 2 -------
Mass (kg)	[m]	3.444	42.662
Total mass (kg)	[mGes]	46.106	
Moment of inertia for system, relative to the input:			
calculation without consideration of the exact tooth shape			
Gears individually ((da+df)/2...di) (kg*m²)	[J]	0.00438	0.85443
System (da+df)/2...di (kg*m²)	[J]	0.06042	

13.2 Wear, power loss, sound pressure level

Torsional stiffness at driving gear with fixed driven gear:		
Torsional stiffness (MNm/rad)	[cr]	2.076
Torsion when subjected to nominal torque (°)	[δcr]	0.051
Average coefficient of friction according to Niemann	[μ_m]	0.089
Wear sliding coef. by Niemann	[ζw]	0.751
Loss factor	[HV]	0.129
Gear power loss (kW)	[PVZ]	0.241
Meshing efficiency (%)	[ηz]	98.850
Sound pressure level based on Masuda, without PPTE/δs	[dB(A)]	64.728

14 Service life, damage

Required safety for tooth root	[S_{Fmin}]	1.40
Required safety for tooth flank	[S_{Hmin}]	1.00
Required service life	[H]	20000.00

Service life (calculated with required safeties):

System service life (h)	[H_{att}]	> 1000000

		------- Gear 1	---------- Gear 2 -------
Tooth root service life (h)	[H_{Fatt}]	1e+06	1e+06
Tooth flank service life (h)	[H_{Hatt}]	1e+06	1e+06

Note: The entry 1e+006 h means that the Service life > 1,000,000 h.

14.1 Damage

Damage relative to the required service life (H, 20000.0 h)

F_1 (%)	F_2 (%)	H_1 (%)	H_2 (%)
0.0000	0.0000	0.0000	0.0000

15 Remarks

15.1 Conventions

- Specifications with **.e/i** mean: Maximum value **.e** and Minimum value **.i**, taking all tolerances into account.
- Specifications with **.m** mean: Mean value within tolerance.

- The center distance tolerances and the tooth thickness allowance are taken into account for the backlash tolerance. The maximum and minimum clearance corresponding to the largest and smallest allowances are shown. The calculation is performed for the operating pitch circle.

15.2 Calculations and factors

- Details of calculation method:
  c_γ according to Method B
  K_v according to Method B
  $K_{H\beta}$ and $K_{F\beta}$ according to Method C
  $K_{H\alpha}$, $K_{F\alpha}$ according to Method B

_O.Varianta_IV.Shaft1.Shaft1_calc

1 Input data

Coordinate system shaft: see picture W-002

1.1 Shafts

1.1.1 Shaft 'Shaft1'

Drawing		
Initial position (mm)		0.000
Length (mm)		235.551
Speed (1/min)		1000.000
Direction of rotation:	clockwise	
Material	16 MnCr 5 (1)	
Young's modulus (N/mm²)		206000.000
Poisson's ratio nu		0.300
Density (kg/m³)		7830.000
Coefficient of thermal expansion (10^-6/K)		11.500
Temperature (°C)		40.000
Weight of shaft (kg)		2.520
Note: the weight is only for the shaft. The gears are not considered		
Weight of shaft, including additional masses (kg)		2.520
Mass moment of inertia (kg*mm²)		845.351
Momentum of mass GD2 (Nm²)		0.033

1.2 Weight force

The direction of the weight is not considered

1.3 Shaft modeling

Gears mounted with stiffness according to ISO

1.4 Shear deformations

Consider deformations due to shearing

Shear correction factor	1.100

1.5 Rolling bearings

Rolling bearing stiffness is calculated from inner bearing geometry

Tolerance field: Mean value

1.6 Housing

Housing material		EN-GJL-200 (GG 20)	
Coefficient of thermal expansion	(10^-6/K)		11.700
Temperature of housing (°C)			40.000
Thermal housing reference point (mm)			2.265
Reference temperature (°C)			20.000

1.7 Load applications

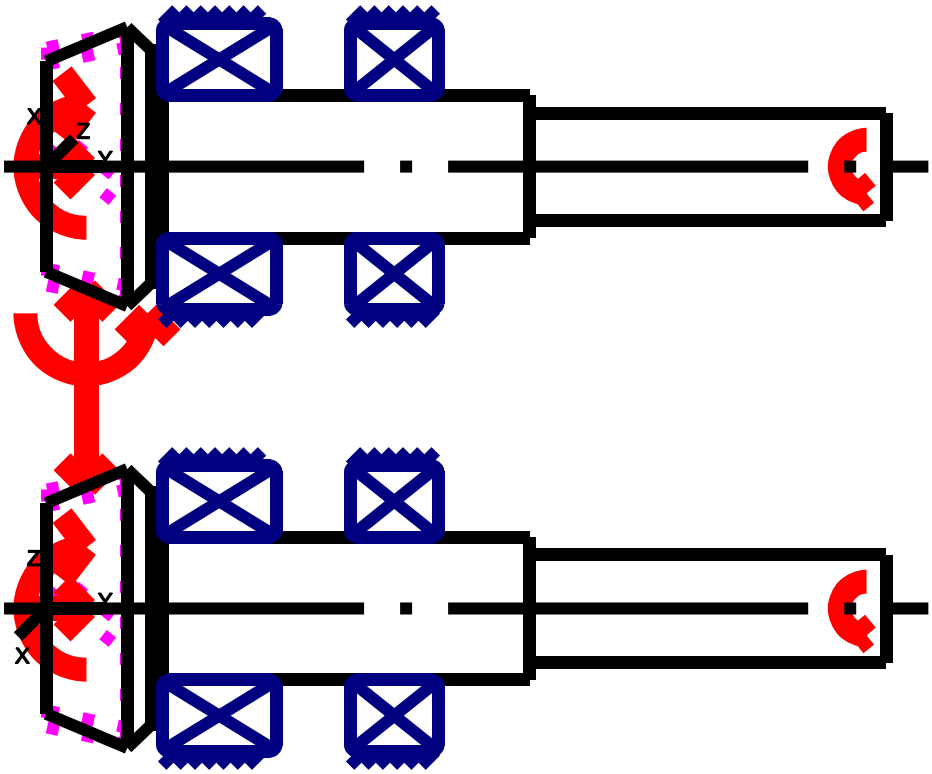


Figure: Load applications

2 Shaft definition (Shaft1)

2.1 Outer contour

2.1.1 Cone(Cone), 0.000mm ...22.765mm

Diameter left (mm)	[d_l]	58.9231
Diameter right (mm)	[d_r]	78.0940
Length (mm)	[l]	22.7652
Surface roughness (µm)	[Rz]	8.0000

2.1.2 Cone(Cone), 22.765mm ...29.551mm

Diameter left (mm)	[d_l]	78.0070
Diameter right (mm)	[d_r]	65.0000
Length (mm)	[l]	6.7859
Surface roughness (µm)	[Rz]	8.0000

2.1.3 Cylinder (Cylinder), 29.551mm ...32.551mm

Diameter (mm)	[d]	65.0000	
Length (mm)	[l]	3.0000	
Surface roughness (µm)	[Rz]	8.0000	

2.1.4 Cylinder (Cylinder), 32.551mm ...135.551mm

Diameter (mm)	[d]	40.0000	
Length (mm)	[l]	103.0000	
Surface roughness (µm)	[Rz]	8.0000	

Chamfer right (Chamfer right)
l=1.50 (mm), alpha=30.00 (°)

Relief groove left (Relief groove left)
r=1.20 (mm), t=0.20 (mm), l=2.50 (mm), Rz=8.0, Machined (Ra=3.2µm/125µin)
Form F (DIN 509), Series 1, with raised fatigue limit

Thread (Thread) 102.551 mm ... 135.551 mm
t=1.50 (mm), l=33.00 (mm), Rz=8.0, Machined (Ra=3.2µm/125µin)

2.1.5 Cylinder (Cylinder), 135.551mm ...235.551mm

Diameter (mm)	[d]	30.0000	
Length (mm)	[l]	100.0000	
Surface roughness (µm)	[Rz]	8.0000	

Relief groove left (Relief groove left)
r=1.20 (mm), t=0.20 (mm), l=2.50 (mm), Rz=8.0, Machined (Ra=3.2µm/125µin)
Form F (DIN 509), Series 1, with raised fatigue limit

Key way (Key way) 185.551 mm ... 230.551 mm
l=45.00 (mm), i=2, Rz=16.0, Machined (Ra=3.2µm/125µin)

Chamfer right (Chamfer right)
l=1.00 (mm), alpha=30.00 (°)

2.2 Forces

2.2.1 Bevel gear (G1(G12))

Position on shaft (mm)	[y_{local}]	11.3326	
Position in global system (mm)	[y_{global}]	11.3326	
Operating pitch diameter (mm)		71.3028	
Helix angle (°)		30.0000	helix right hand (spiral teeth)
Pitch angle (°)		22.8906	Tip to the left
Working pressure angle at normal section (°)		20.0000	
Position of contact (°)		180.0000	
Facewidth (mm)		24.0000	
Power (kW)		21.0000	driving (output)
Torque (Nm)		-200.5352	
Axial force (N)		3911.3237	
Shearing force X (N)		914.6446	
Shearing force Z (N)		-5624.8940	

Bending moment X (Nm)		-0.0000	
Bending moment Z (Nm)		-139.4441	

2.2.2 Coupling (Input(Input))

Position on shaft (mm)	[y_{local}]	230.0000	
Position in global system (mm)	[y_{global}]	230.0000	
Effective diameter (mm)		30.0000	
Radial force factor (-)		0.0000	
Direction of the radial force (°)		0.0000	
Axial force factor (-)		0.0000	
Length of load application (mm)		10.0000	
Power (kW)		21.0000	driven (input)
Torque (Nm)		200.5350	
Axial force (N)		0.0000	
Shearing force X (N)		0.0000	
Shearing force Z (N)		0.0000	
Bending moment X (Nm)		0.0000	
Bending moment Z (Nm)		0.0000	
Mass (kg)		0.0000	
Mass moment of inertia Jp (kg*m²)		0.0000e+00	
Mass moment of inertia Jxx (kg*m²)		0.0000e+00	
Mass moment of inertia Jzz (kg*m²)		0.0000e+00	
Eccentricity (mm)		0.0000	

2.3 Bearing

2.3.1 A (SKF 32208)

Bearing type		Taper roller bearing (single row) SKF Explorer
Bearing position (mm)	[y_{lokal}]	97.612
Bearing position (mm)	[y_{global}]	97.612
Attachment of external ring		Set fixed bearing left
Inner diameter (mm)	[d]	40.000
External diameter (mm)	[D]	80.000
Width (mm)	[b]	24.750
Corner radius (mm)	[r]	1.500

Calculation was performed using real bearing internal geometry provided by bearing manufacturer. These values are however not available for reports.

The bearing pressure angle will be considered in the calculation

Contact angle (°)	[α]	14.036
Position (center of pressure) (mm)	[$y_{D,lokal}$]	103.876
Position (center of pressure) (mm)	[$y_{D,global}$]	103.876
Basic static load rating (kN)	[C_0]	86.500
Basic dynamic load rating (kN)	[C]	91.600
Fatigue load limit (kN)	[C_u]	9.800
Values for approximated geometry:		
Basic dynamic load rating (kN)	[C_{theo}]	74.737
Basic static load rating (kN)	[C_{0theo}]	86.500
Correction factor Basic dynamic load rating		
	[f_C]	1.000
Correction factor Basic static load rating		
	[f_{C0}]	1.000

2.3.2 B **(SKF 33208)**

Bearing type		Taper roller bearing (single row) SKF Explorer
Bearing position (mm)	[y_{lokal}]	48.551
Bearing position (mm)	[y_{global}]	48.551
Attachment of external ring		Set fixed bearing right
Inner diameter (mm)	[d]	40.000
External diameter (mm)	[D]	80.000
Width (mm)	[b]	32.000
Corner radius (mm)	[r]	1.500

Calculation was performed using real bearing internal geometry provided by bearing manufacturer. These values are however not available for reports.

The bearing pressure angle will be considered in the calculation

Contact angle (°)	[α]	13.241
Position (center of pressure) (mm)	[$y_{D,lokal}$]	43.995
Position (center of pressure) (mm)	[$y_{D,global}$]	43.995
Basic static load rating (kN)	[C_0]	132.000
Basic dynamic load rating (kN)	[C]	128.000
Fatigue load limit (kN)	[C_u]	15.000
Values for approximated geometry:		
Basic dynamic load rating (kN)	[C_{theo}]	103.653
Basic static load rating (kN)	[C_{0theo}]	132.000
Correction factor Basic dynamic load rating		
	[f_C]	1.000
Correction factor Basic static load rating		
	[f_{C0}]	1.000

3 Gears

Gears are considered as mass and as stiffness according to ISO 6336-1 (interference fit).

4 Results

4.1 Shafts

Maximum deflection (µm)	50.122
Position of the maximum (mm)	235.551
Mass center of gravity (mm)	80.977
Total axial load (N)	3911.324
Torsion of the shaft under torque (°) (Difference between left and right shaft end)	0.233

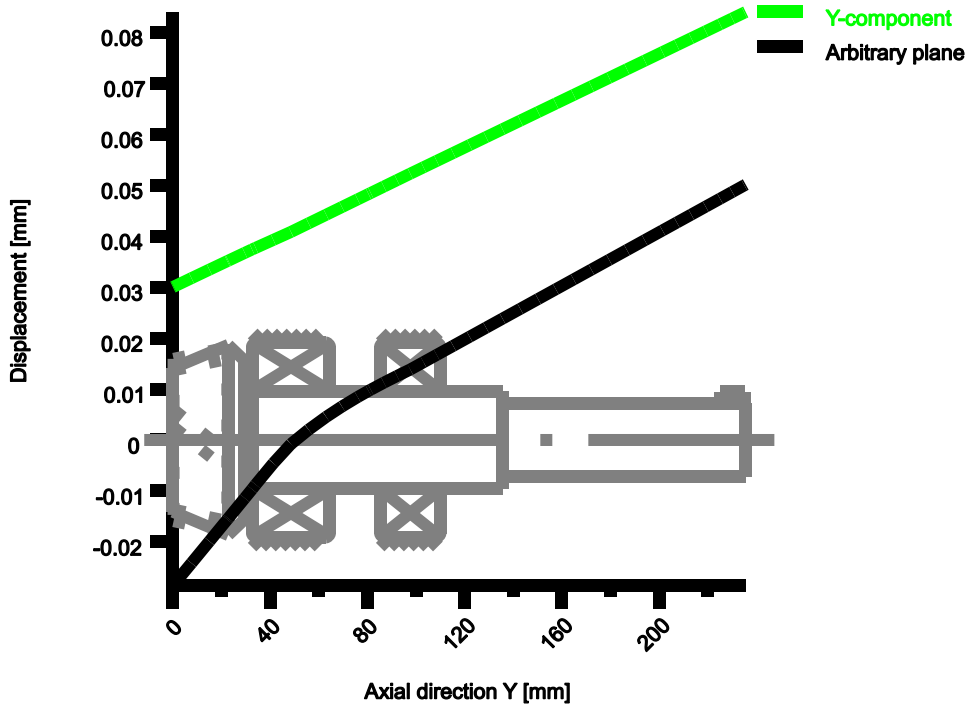
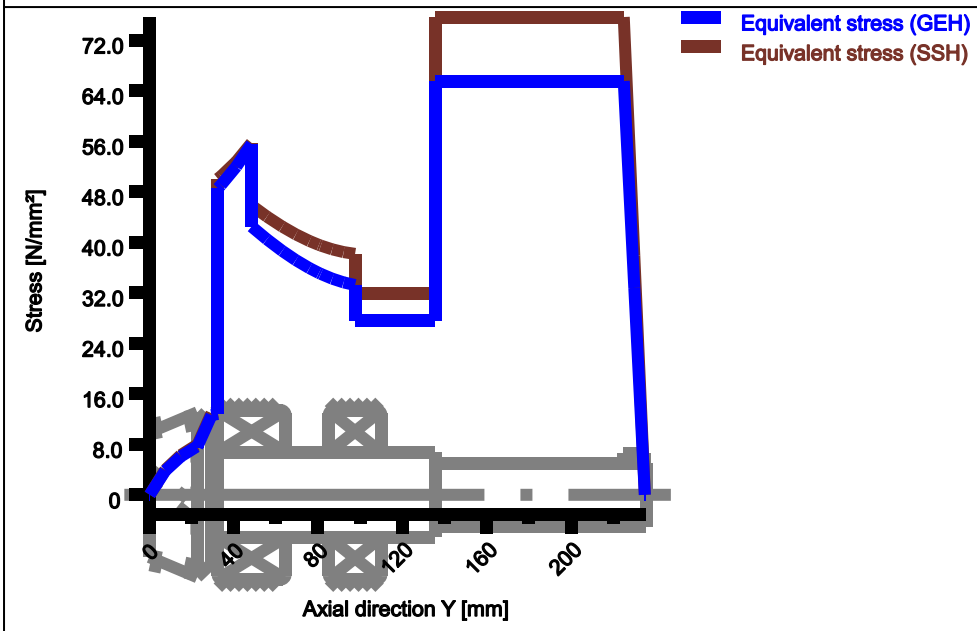


Figure: Deformation (bending etc.) (Arbitrary plane 60.64905497 127)



Nominal stresses, without taking into account stress concentrations
GEH(von Mises): sigV = ((sigB+sigZ,D)^2 + 3*(tauT+tauS)^2)^1/2
SSH(Tresca): sigV = ((sigB-sigZ,D)^2 + 4*(tauT+tauS)^2)^1/2

Figure: Equivalent stress

4.2 Bearing

Probability of failure	[n]	10.00	%
Axial clearance (ISO 281)	[u_A]	10.00	µm
Lubricant	ISO-VG 220		
Lubricant - service temperature	[T_B]	70.00	°C
Rolling bearing rating life according to ISO/TS 16281:2008			

4.3 'Shaft1' Rolling bearing 'A'

Position (Y-coordinate)	[y]	97.61	mm
Dynamic equivalent load	[P]	2.88	kN
Static equivalent load	[P_0]	2.88	kN
Minimum EHL lubricant film thickness	[h_{min}]	0.161	µm
Life modification factor for reliability	[a_1]	1.000	

4.3.1 Operating bearing clearance

Total diametral clearance change	[ΔPd]	0.000	µm
Operating diametral clearance	[Pd]	0.000	µm
Operating axial clearance	[Pa]	0.000	µm

4.3.2 Results according to ISO 281

Lubricant	ISO-VG 220		
Load ratio	[C/P]	31.844	
Operating viscosity	[v]	48.884	mm²/s

Reference viscosity	[v_1]	0.000	mm²/s
Viscosity ratio	[κ]	0.000	
Basic bearing rating life	[L_{nh}]	> 1000000	h
Static safety factor	[S_0]	30.07	

4.3.3 Calculation with proprietary bearing internal geometry data (ISO/TS 16281)

Contamination factor	[e_C]	0.161	
Fatigue load limit	[C_u]	9.800	kN
Reference rating life	[L_{nrh}]	> 1000000	h
Maximum pressure inner ring	[p_{max_i}]	1049.499	N/mm²
Effective static safety factor	[S_{0w}]	14.53	
Static safety factor	[S_{0ref}]	20.81	
Static equivalent load	[P_{0ref}]	4.16	kN

4.3.4 Bearing reactions

Bearing reaction force	[F_x]	-1.602	kN
Bearing reaction force	[F_y]	0.791	kN
Bearing reaction force	[F_z]	-2.389	kN
Bearing reaction force	[F_r]	2.877	kN
Inclination angle	[α_{Fr}]	-123.837	°
Bearing reaction moment	[M_x]	-19.513	Nm
Bearing reaction moment	[M_y]	0.000	Nm
Bearing reaction moment	[M_z]	13.042	Nm
Bearing reaction moment	[M_r]	23.470	Nm
Inclination angle	[α_{Mr}]	146.243	°
Displacement of bearing	[u_x]	7.989	µm
Displacement of bearing	[u_y]	52.259	µm
Displacement of bearing	[u_z]	11.380	µm
Displacement of bearing	[u_r]	13.904	µm
Inclination angle	[α_{ur}]	54.929	°
Misalignment of bearing	[r_x]	0.234	mrad
Misalignment of bearing	[r_y]	0.677	mrad
Misalignment of bearing	[r_z]	-0.120	mrad
Misalignment of bearing	[r_r]	0.263	mrad

4.3.5 Friction and power loss

Oil level	[H]	0.000	mm
Rolling moment of friction	[M_{rr}]	0.475	Nm
Sliding moment of friction	[M_{sl}]	0.007	Nm
Moment of friction, seals	[M_{seal}]	0.000	Nm

Moment of friction for seals determined according to SKF main catalog 17000/1 EN:2018

Moment of friction flow losses	[M_{drag}]	0.000	Nm
Torque of friction	[M_{loss}]	0.482	Nm
Power loss	[P_{loss}]	50.472	W

The moment of friction is calculated according to the details in SKF Catalog 2018.
The calculation is always performed with a coefficient for additives in the lubricant µbl=0.15.

4.4 'Shaft1' Rolling bearing 'B'

Position (Y-coordinate)	[y]	48.55	mm
Dynamic equivalent load	[P]	11.21	kN
Static equivalent load	[P_0]	8.25	kN
Minimum EHL lubricant film thickness	[h_{min}]	0.151	µm
Life modification factor for reliability	[a_1]	1.000	

4.4.1 Operating bearing clearance

Total diametral clearance change	[ΔPd]	0.000	µm
Operating diametral clearance	[Pd]	0.000	µm

Operating axial clearance	[Pa]	0.000	µm

4.4.2 Results according to ISO 281

Lubricant	ISO-VG 220		
Load ratio	[C/P]	11.417	
Operating viscosity	[v]	48.884	mm²/s
Reference viscosity	[v_1]	0.000	mm²/s
Viscosity ratio	[κ]	0.000	
Basic bearing rating life	[L_{nh}]	55856.03	h
Static safety factor	[S_0]	15.99	

4.4.3 Calculation with proprietary bearing internal geometry data (ISO/TS 16281)

Contamination factor	[e_C]	0.160	
Fatigue load limit	[C_u]	15.000	kN
Reference rating life	[L_{nrh}]	238403.43	h
Maximum pressure inner ring	[p_{max_i}]	1242.071	N/mm²
Effective static safety factor	[S_{0w}]	10.37	
Static safety factor	[S_{0ref}]	13.11	
Static equivalent load	[P_{0ref}]	10.07	kN

4.4.4 Bearing reactions

Bearing reaction force	[F_x]	0.687	kN
Bearing reaction force	[F_y]	-4.702	kN
Bearing reaction force	[F_z]	8.014	kN
Bearing reaction force	[F_r]	8.044	kN
Inclination angle	[α_{Fr}]	85.099	°
Bearing reaction moment	[M_x]	-72.613	Nm
Bearing reaction moment	[M_y]	0.000	Nm
Bearing reaction moment	[M_z]	13.776	Nm
Bearing reaction moment	[M_r]	73.908	Nm
Inclination angle	[α_{Mr}]	169.258	°
Displacement of bearing	[u_x]	1.137	µm
Displacement of bearing	[u_y]	40.825	µm
Displacement of bearing	[u_z]	-1.540	µm
Displacement of bearing	[u_r]	1.914	µm
Inclination angle	[α_{ur}]	-53.577	°
Misalignment of bearing	[r_x]	0.382	mrad
Misalignment of bearing	[r_y]	0.183	mrad
Misalignment of bearing	[r_z]	-0.219	mrad
Misalignment of bearing	[r_r]	0.441	mrad

4.4.5 Friction and power loss

Oil level	[H]	0.000	mm
Rolling moment of friction	[M_{rr}]	0.974	Nm
Sliding moment of friction	[M_{sl}]	0.030	Nm
Moment of friction, seals	[M_{seal}]	0.000	Nm
Moment of friction for seals determined according to SKF main catalog 17000/1 EN:2018			
Moment of friction flow losses	[M_{drag}]	0.000	Nm
Torque of friction	[M_{loss}]	1.003	Nm
Power loss	[P_{loss}]	105.078	W

The moment of friction is calculated according to the details in SKF Catalog 2018.
The calculation is always performed with a coefficient for additives in the lubricant µbl=0.15.

(*) Note about roller bearings with an approximated bearing geometry:
The internal geometry of these bearings has not been input in the database.
The geometry is back-calculated as specified in ISO 281, from C and C0 (details in the manufacturer's catalog).
For this reason, the geometry may be different from the actual geometry.
This can lead to differences in the service life calculation and, more importantly, the roller bearing stiffness.

4.5 Damage relative to the required service life (L_{req} = 20000 h)

Load case	B1	B2
1	0.63	8.39
Σ	0.63	8.39

B1 : A (SKF 32208)
B2 : B (SKF 33208)

4.6 Utilization relative to the required service life (L_{req} = 20000 h)

Rolling bearings	B1	B2
Utilization (%)	30.92	47.55

Note: Utilization = $(L_{req}/L_h)^{(1/k)}$
Ball bearing: k = 3, roller bearing: k = 10/3

B1 : A (SKF 32208)
B2 : B (SKF 33208)

4.7 Calculation of the factors required to define reliability R(t) using the Weibull distribution. t in (h)

Reliability not calculated

5 Strength calculation according to DIN 743:2012

5.1 Summary

Shaft1

Material	16 MnCr 5 (1)
Material type	Case hardening steel
Material treatment	case-hardened
Surface treatment	No

Calculation of endurance limit and the static strength

Calculation for load case 2 (σav/σmv = const)

Cross section	Position (Y-Coord) (mm)	
A-A	201.31	Key
B-B	75.98	Smooth shaft
D-D	32.55	Shoulder with relief groove
C-C	135.55	Shoulder with relief groove

Results:

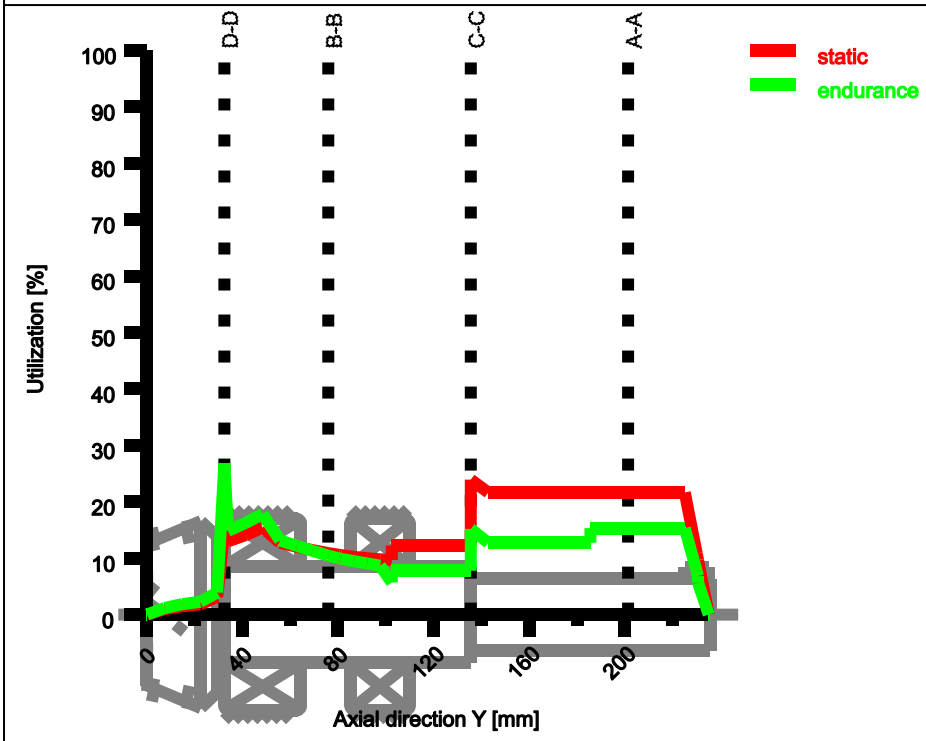
Cross section	βσ	Kfσ	K2d	SD	SS	SA
A-A	3.29	1.00	0.91	7.83	5.54	16.59
B-B	1.00	0.88	0.89	11.49	11.00	52.10
D-D	1.95	0.89	0.89	4.47	8.15	17.82
C-C	1.71	0.88	0.91	7.90	5.02	20.13
Required safeties:				1.20	1.20	1.20

Abbreviations:
βσ: Notch factor, bending
KFσ: Surface factor
K2d: size factor bending
SD: Safety endurance limit
SS: Safety against yield point
SA: Safety against incipient crack

5.1.1 Utilization (%)

Cross section	Static (yield point)	Endurance
A-A	21.655	15.322
B-B	10.911	10.446
D-D	14.720	26.839
C-C	23.925	15.191

Maximum utilization (%)	[A]	26.839



Utilization = Smin/S (%)

Figure: Strength (nominal load)

5.2 Calculation details

General statements

Label	Shaft1		
Drawing			
Length (mm)		[l]	235.55
lcElem =0			
Speed (1/min)		[n]	1000.00

Material	16 MnCr 5 (1)
Material type	Case hardening steel
Material treatment	case-hardened
Surface treatment	No

	Tension/Compression	Bending	Torsion	Shearing
Load factor static calculation	1.700	1.700	1.700	1.700
Load factor endurance limit	1.000	1.000	1.000	1.000

Reference diameter material (mm)	[dB]	16.00
σB according to DIN 743 (at dB) (N/mm²)	[σB]	1000.00
σB according to DIN 743 (at dB) (N/mm²)	[σS]	695.00
[σzdW], bei dB (N/mm²)		400.00
[σbW], bei dB (N/mm²)		500.00

[τtW], bei dB (N/mm²)		300.00
Thickness of raw material (mm)	[dWerkst]	80.00

Material data calculated with K1(d), according to DIN 743/3
Geometric size factor K1d calculated with shaft diameter D
Material strength calculated from shaft diameter
(Requirement: Through hardening of pre-machined shaft)

Notice: The following material values are only valid for
the first cross-section, the next ones are corresponding
to their actual 'Diameter for size factor'.

[σBeff] (N/mm²)	888.07
[σSeff] (N/mm²)	617.21
[σbFK] (N/mm²)	617.21
[τtFK] (N/mm²)	356.35
[σbBRand] (N/mm²)	2180.00
[σzdW] (N/mm²)	355.23
[σbW] (N/mm²)	444.03
[τtW] (N/mm²)	266.42

Endurance limit for single stage use

Calculation for load case 2 (σ.av/σ.mv = const)

5.2.1 Cross section 'A-A' **Key**

Comment		
Position (Y-Coordinate) (mm)	[y]	201.307
External diameter (mm)	[da]	30.000
Inner diameter (mm)	[di]	0.000
Diameter for size factors (mm)	[deff]	30.000
Notch effect	Key	
Number of keys	[n]	2

Groove with manufactured with end milling cutter
Own input of:

[b, t] (mm)	8.000 4.100	
Mean roughness (µm)	[Rz]	16.000

		Tension/Compression	Bending	Torsion	Shearing
Load: (N) (Nm)					
Mean value	[Fzdm, Mbm, Tm, Fqm]	0.0	0.0	100.3	0.0
Amplitude	[Fzda, Mba, Ta, Fqa]	0.0	0.0	100.3	0.0
Maximum value	[Fzdmax, Mbmax, Tmax, Fqmax]	0.0	0.0	340.9	0.0
Cross section, moment of resistance: (mm²)					
[A, Wb, Wt, A]		706.9	2650.7	5301.4	706.9
Stresses: (N/mm²)					
[σzdm, σbm, τm, τqm] (N/mm²)		0.000	0.000	18.913	0.000
[σzda, σba, τa, τqa] (N/mm²)		0.000	0.000	18.913	0.000
[σzdmax,σbmax,τmax,τqmax] (N/mm²)		0.000	0.000	64.305	0.000

Technological size influence	[K1(σB)]	0.888
	[K1(σS)]	0.888

	Tension/Compression	Bending	Torsion

Notch effect coefficient	[ß(dB)]	3.321	3.321	2.056
[dB] (mm) = 40.0				
Geometrical size influence	[K3(d)]	0.952	0.952	0.971
Geometrical size influence	[K3(dB)]	0.942	0.942	0.965
Notch effect coefficient	[ß]	3.286	3.286	2.044
Geometrical size influence	[K2(d)]	1.000	0.907	0.907
Influence coefficient surface roughness	[KF]	1.000	1.000	1.000
Roughness factor is included into the notch effect coefficient				
Surface stabilization factor	[KV]	1.379	1.379	1.379
Total influence coefficient	[K]	2.384	2.627	1.633

Present safety for endurance limit:		
Equivalent mean stress (N/mm²)	[σmV]	32.759
Equivalent mean stress (N/mm²)	[τmV]	18.913

Fatigue limit of part (N/mm²)	[σWK]	149.025	169.040	163.106
Influence coefficient of mean stress sensitivity.				
	[ψσK]	0.092	0.105	0.101
Permissible amplitude (N/mm²)	[σADK]	0.019	0.019	148.128
Safety against fatigue	[S]			7.832
Required safety against fatigue	[Smin]			1.200
Result (%)	[S/Smin]			652.7

Present safety				
for proof against exceed of yield point:				
Static notch sensitivity factor	[K2F]	1.000	1.000	1.000
Increase coefficient	[γF]	1.000	1.000	1.000
Yield stress of part (N/mm²)	[σFK]	617.208	617.208	356.345
Safety yield stress	[S]			5.541
Required safety	[Smin]			1.200
Result (%)	[S/Smin]			461.8

Present safety		
for proof of avoiding incipient crack on hard surface layers:		
Safety against incipient crack	[S]	16.589
Required safety	[Smin]	1.200
Result (%)	[S/Smin]	1382.4

5.2.2 Cross section 'B-B' **Smooth shaft**

Comment		
Position (Y-Coordinate) (mm)	[y]	75.977
External diameter (mm)	[da]	40.000
Inner diameter (mm)	[di]	0.000
Diameter for size factors (mm)	[deff]	40.000
Notch effect		Smooth shaft
Mean roughness (µm)	[Rz]	8.000

		Tension/Compression	Bending	Torsion	Shearing
Load: (N) (Nm)					
Mean value	[Fzdm, Mbm, Tm, Fqm]	395.4	0.0	100.3	0.0
Amplitude	[Fzda, Mba, Ta, Fqa]	395.4	85.7	100.3	2876.6
Maximum value	[Fzdmax, Mbmax, Tmax, Fqmax]	1344.3	145.7	340.9	4890.2
Cross section, moment of resistance: (mm²)					
[A, Wb, Wt, A]		1256.6	6283.2	12566.4	1256.6

Stresses: (N/mm²)					
[σzdm, σbm, τm, τqm] (N/mm²)		0.315	0.000	7.979	0.000
[σzda, σba, τa, τqa] (N/mm²)		0.315	13.640	7.979	3.052
[σzdmax,σbmax,τmax,τqmax] (N/mm²)		1.070	23.188	27.129	5.189
Technological size influence	[K1(σB)]			0.837	
	[K1(σS)]			0.837	
		Tension/Compression	Bending	Torsion	
Notch effect coefficient	[ß]	1.000	1.000	1.000	
Geometrical size influence	[K2(d)]	1.000	0.888	0.888	
Influence coefficient surface roughness	[KF]	0.876	0.876	0.929	
Surface stabilization factor	[KV]	1.000	1.083	1.083	
Total influence coefficient	[K]	1.141	1.169	1.110	
Present safety for endurance limit:					
Equivalent mean stress (N/mm²)	[σmV]			13.824	
Equivalent mean stress (N/mm²)	[τmV]			7.981	
Fatigue limit of part (N/mm²)	[σWK]	293.397	357.881	226.242	
Influence coefficient of mean stress sensitivity.					
	[ψσK]	0.213	0.272	0.156	
Permissible amplitude (N/mm²)	[σADK]	12.944	280.549	167.874	
Safety against fatigue	[S]			11.488	
Required safety against fatigue	[Smin]			1.200	
Result (%)	[S/Smin]			957.3	
Present safety for proof against exceed of yield point:					
Static notch sensitivity factor	[K2F]	1.000	1.000	1.000	
Increase coefficient	[γF]	1.000	1.000	1.000	
Yield stress of part (N/mm²)	[σFK]	581.607	581.607	335.791	
Safety yield stress	[S]			10.999	
Required safety	[Smin]			1.200	
Result (%)	[S/Smin]			916.5	
Present safety for proof of avoiding incipient crack on hard surface layers:					
Safety against incipient crack	[S]			52.096	
Required safety	[Smin]			1.200	
Result (%)	[S/Smin]			4341.4	

5.2.3 Cross section 'D-D' **Shoulder with relief groove**

Comment						
Position (Y-Coordinate) (mm)	[y]					32.551
External diameter (mm)	[da]					40.000
Inner diameter (mm)	[di]					0.000
Diameter for size factors (mm)	[deff]					65.000
Notch effect				Shoulder with relief groove		
[D, d, D1, r, t1] (mm)	65.000	39.600	40.000	1.200	0.200	
Shape B						
Mean roughness (µm)	[Rz]					8.000

		Tension/Compression	Bending	Torsion	Shearing
Load: (N) (Nm)					
Mean value	[Fzdm, Mbm, Tm, Fqm]	-1955.6	0.0	100.3	0.0
Amplitude	[Fzda, Mba, Ta, Fqa]	1955.6	169.3	100.3	5698.8
Maximum value	[Fzdmax, Mbmax, Tmax, Fqmax]	-6649.2	287.8	340.9	9687.9
Cross section, moment of resistance: (mm²)					
[A, Wb, Wt, A]		1231.6	6096.6	12193.1	1231.6
Stresses: (N/mm²)					
[σzdm, σbm, τm, τqm] (N/mm²)		-1.588	0.000	8.223	0.000
[σzda, σba, τa, τqa] (N/mm²)		1.588	27.765	8.223	6.169
[σzdmax,σbmax,τmax,τqmax] (N/mm²)		-5.399	47.201	27.959	10.488
Technological size influence	[K1(σB)]			0.750	
	[K1(σS)]			0.750	

		Tension/Compression	Bending	Torsion
Stress concentration factor	[α]	2.834	2.484	1.785
References stress slope	[G']	1.917	1.917	0.958
Notch sensitivity factor	[n]	1.276	1.276	1.195
Notch effect coefficient	[ß]	2.221	1.946	1.493
Geometrical size influence	[K2(d)]	1.000	0.888	0.888
Influence coefficient surface roughness	[KF]	0.886	0.886	0.934
Surface stabilization factor	[KV]	1.000	1.000	1.000
Total influence coefficient	[K]	2.350	2.320	1.752
Present safety for endurance limit:				
Equivalent mean stress (N/mm²)	[σmV]			14.154
Equivalent mean stress (N/mm²)	[τmV]			8.172
Fatigue limit of part (N/mm²)	[σWK]	127.746	161.723	128.522
Influence coefficient of mean stress sensitivity.				
	[ψσK]	0.093	0.121	0.094
Permissible amplitude (N/mm²)	[σADK]	52.604	152.343	117.579
Safety against fatigue	[S]			4.471
Required safety against fatigue	[Smin]			1.200
Result (%)	[S/Smin]			372.6
Present safety for proof against exceed of yield point:				
Static notch sensitivity factor	[K2F]	1.000	1.000	1.000
Increase coefficient	[γF]	1.000	1.000	1.000
Yield stress of part (N/mm²)	[σFK]	521.524	521.524	301.102
Safety yield stress	[S]			8.152
Required safety	[Smin]			1.200
Result (%)	[S/Smin]			679.4
Present safety for proof of avoiding incipient crack on hard surface layers:				
Safety against incipient crack	[S]			17.823
Required safety	[Smin]			1.200
Result (%)	[S/Smin]			1485.3

5.2.4 Cross section 'C-C' **Shoulder with relief groove**

Comment						
Position (Y-Coordinate) (mm)		[y]				135.551
External diameter (mm)		[da]				30.000
Inner diameter (mm)		[di]				0.000
Diameter for size factors (mm)		[deff]				40.000
Notch effect				Shoulder with relief groove		
[D, d, D1, r, t1] (mm)	40.000	29.600	30.000	1.200	0.200	
Shape B						
Mean roughness (µm)		[Rz]				8.000

		Tension/Compression	Bending	Torsion	Shearing
Load: (N) (Nm)					
Mean value	[Fzdm, Mbm, Tm, Fqm]	0.0	0.0	100.3	0.0
Amplitude	[Fzda, Mba, Ta, Fqa]	0.0	0.0	100.3	0.0
Maximum value	[Fzdmax, Mbmax, Tmax, Fqmax]	0.0	0.0	340.9	0.0
Cross section, moment of resistance: (mm²)					
[A, Wb, Wt, A]		688.1	2546.1	5092.2	688.1

Stresses: (N/mm²)				
[σzdm, σbm, τm, τqm] (N/mm²)	0.000	0.000	19.690	0.000
[σzda, σba, τa, τqa] (N/mm²)	0.000	0.000	19.690	0.000
[σzdmax,σbmax,τmax,τqmax] (N/mm²)	0.000	0.000	66.947	0.000

Technological size influence	[K1(σB)]	0.837
	[K1(σS)]	0.837

		Tension/Compression	Bending	Torsion
Stress concentration factor	[α]	2.451	2.200	1.617
References stress slope	[G']	2.102	2.102	0.958
Notch sensitivity factor	[n]	1.289	1.289	1.195
Notch effect coefficient	[ß]	1.901	1.706	1.353
Geometrical size influence	[K2(d)]	1.000	0.907	0.907
Influence coefficient surface roughness	[KF]	0.876	0.876	0.929
Surface stabilization factor	[KV]	1.000	1.083	1.083
Total influence coefficient	[K]	2.042	1.866	1.447

Present safety for endurance limit:		
Equivalent mean stress (N/mm²)	[σmV]	34.105
Equivalent mean stress (N/mm²)	[τmV]	19.690

Fatigue limit of part (N/mm²)	[σWK]	163.910	224.287	173.533
Influence coefficient of mean stress sensitivity.				
	[ψσK]	0.109	0.155	0.116
Permissible amplitude (N/mm²)	[σADK]	0.017	0.017	155.541
Safety against fatigue	[S]			7.899
Required safety against fatigue	[Smin]			1.200
Result (%)	[S/Smin]			658.3

Present safety				
for proof against exceed of yield point:				
Static notch sensitivity factor	[K2F]	1.000	1.000	1.000
Increase coefficient	[γF]	1.000	1.000	1.000
Yield stress of part (N/mm²)	[σFK]	581.607	581.607	335.791

Safety yield stress	[S]	5.016
Required safety	[Smin]	1.200
Result (%)	[S/Smin]	418.0

Present safety
for proof of avoiding incipient crack on hard surface layers:

Safety against incipient crack	[S]	20.134
Required safety	[Smin]	1.200
Result (%)	[S/Smin]	1677.9

Remarks:
- The shearing force is not considered in the analysis specified in DIN 743.
- Cross section with interference fit: The notch factors for the 'Slight interference fit' case are no longer defined in DIN 743.
  The notch factors are taken from the FKM Guideline, except if those for the 'tight interference fit' according to DIN are smaller, in which case they will be used.

_O.Varianta_IV.Shaft2.Shaft2_calc

1 Input data

Coordinate system shaft: see picture W-002

1.1 Shafts

1.1.1 Shaft 'Shaft2'

Drawing		
Initial position (mm)		0.000
Length (mm)		177.000
Speed (1/min)		422.222
Direction of rotation:	counterclockwise	
Material	16 MnCr 5 (1)	
Young's modulus (N/mm²)		206000.000
Poisson's ratio nu		0.300
Density (kg/m³)		7830.000
Coefficient of thermal expansion (10^-6/K)		11.500
Temperature (°C)		60.000
Weight of shaft (kg)		3.270
Note: the weight is only for the shaft. The gears are not considered		
Weight of shaft, including additional masses (kg)		4.767
Mass moment of inertia (kg*mm²)		7301.260
Momentum of mass GD2 (Nm²)		0.287

1.2 Weight force

The direction of the weight is not considered

1.3 Shaft modeling

Gears mounted with stiffness according to ISO

1.4 Shear deformations

Consider deformations due to shearing

Shear correction factor	1.100

1.5 Rolling bearings

Rolling bearing stiffness is calculated from inner bearing geometry

Tolerance field:	Mean value

1.6 Housing

Housing material		EN-GJL-200 (GG 20)	
Coefficient of thermal expansion	(10^-6/K)		11.700
Temperature of housing (°C)			40.000
Thermal housing reference point (mm)			49.000
Reference temperature (°C)			20.000

1.7 Load applications

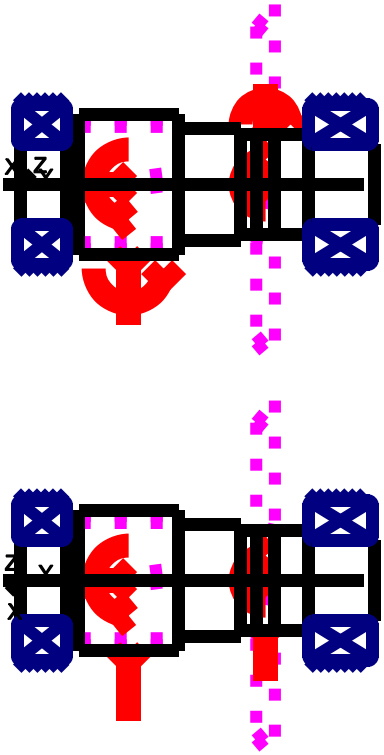


Figure: Load applications

2 Shaft definition (Shaft2)

2.1 Outer contour

2.1.1 Cylinder (Cylinder), 0.000mm ...23.000mm

Diameter (mm)	[d]	40.0000
Length (mm)	[l]	23.0000
Surface roughness (µm)	[Rz]	8.0000

Chamfer left (Chamfer left)
l=2.00 (mm), alpha=30.00 (°)

Relief groove right (Relief groove right)
r=1.20 (mm), t=0.20 (mm), l=2.50 (mm), Rz=8.0, Machined (Ra=3.2µm/125µin)
Form F (DIN 509), Series 1, with raised fatigue limit

2.1.2 Cylinder (Cylinder), 23.000mm ...29.000mm

Diameter (mm)	[d]	50.0000
Length (mm)	[l]	6.0000
Surface roughness (µm)	[Rz]	8.0000

Chamfer left (Chamfer left)
l=0.50 (mm), alpha=45.00 (°)

Radius right (Radius right)
r=3.00 (mm), Rz=8.0, Machined (Ra=3.2µm/125µin)

2.1.3 Cylinder (Cylinder), 29.000mm ...79.000mm

Diameter (mm)	[d]	70.0000
Length (mm)	[l]	50.0000
Surface roughness (µm)	[Rz]	8.0000

2.1.4 Cylinder (Cylinder), 79.000mm ...110.000mm

Diameter (mm)	[d]	56.0000
Length (mm)	[l]	31.0000
Surface roughness (µm)	[Rz]	8.0000

Radius left (Radius left)
r=3.00 (mm), Rz=8.0, Machined (Ra=3.2µm/125µin)

Chamfer right (Chamfer right)
l=0.50 (mm), alpha=45.00 (°)

2.1.5 Cylinder (Cylinder), 110.000mm ...144.000mm

Diameter (mm)	[d]	50.0000
Length (mm)	[l]	34.0000
Surface roughness (µm)	[Rz]	8.0000

Relief groove left (Relief groove left)
r=0.80 (mm), t=0.30 (mm), l=2.50 (mm), Rz=8.0, Machined (Ra=3.2µm/125µin)
Form F (DIN 509), Series 1, with the usual stressing

Chamfer right (Chamfer right)
l=2.00 (mm), alpha=20.00 (°)

2.1.6 Cylinder (Cylinder), 144.000mm ...177.000mm

Diameter (mm)	[d]	40.0000
Length (mm)	[l]	33.0000
Surface roughness (µm)	[Rz]	8.0000

Chamfer right (Chamfer right)
l=2.00 (mm), alpha=30.00 (°)

Relief groove left (Relief groove left)
r=1.20 (mm), t=0.20 (mm), l=2.50 (mm), Rz=8.0, Machined (Ra=3.2µm/125µin)
Form F (DIN 509), Series 1, with raised fatigue limit

2.2 Forces

2.2.1 Bevel gear (G2(G12))

Position on shaft (mm)	[y_{local}]	122.5000	
Position in global system (mm)	[y_{global}]	122.5000	
Operating pitch diameter (mm)		168.8750	
Helix angle (°)		30.0000	helix left hand (spiral teeth)
Pitch angle (°)		67.1094	Tip to the left
Working pressure angle at normal section (°)		20.0000	
Position of contact (°)		0.0000	
Facewidth (mm)		24.0000	
Power (kW)		21.0000	driven (input)
Torque (Nm)		-474.9519	
Axial force (N)		914.6446	
Shearing force X (N)		-3911.3237	
Shearing force Z (N)		5624.8940	
Bending moment X (Nm)		-0.0000	
Bending moment Z (Nm)		77.2303	

2.2.2 Cylindrical gear (G3)

Position on shaft (mm)	[y_{local}]	54.0000	
Position in global system (mm)	[y_{global}]	54.0000	
Operating pitch diameter (mm)		64.6471	
Helix angle (°)		12.0433	Helix left hand
Working pressure angle at normal section (°)		20.5509	
Position of contact (°)		180.0000	
Length of load application (mm)		50.0000	
Power (kW)		21.0000	driving (output)
Torque (Nm)		474.9519	
Axial force (N)		3134.8585	
Shearing force X (N)		5632.6036	
Shearing force Z (N)		14693.6880	
Bending moment X (Nm)		-0.0000	
Bending moment Z (Nm)		-101.3297	

2.3 Bearing

2.3.1 C (SKF 32208)

Bearing type		Taper roller bearing (single row) SKF Explorer	
Bearing position (mm)	[y_{lokal}]	10.625	
Bearing position (mm)	[y_{global}]	10.625	
Attachment of external ring		Set fixed bearing left	
Inner diameter (mm)	[d]	40.000	
External diameter (mm)	[D]	80.000	
Width (mm)	[b]	24.750	
Corner radius (mm)	[r]	1.500	

Calculation was performed using real bearing internal geometry provided by bearing manufacturer. These values are however not available for reports.

The bearing pressure angle will be considered in the calculation

Contact angle (°)	[α]	14.036

Position (center of pressure) (mm)	[$y_{D,lokal}$]	16.889
Position (center of pressure) (mm)	[$y_{D,global}$]	16.889
Basic static load rating (kN)	[C_0]	86.500
Basic dynamic load rating (kN)	[C]	91.600
Fatigue load limit (kN)	[C_u]	9.800
Values for approximated geometry:		
Basic dynamic load rating (kN)	[C_{theo}]	74.737
Basic static load rating (kN)	[C_{0theo}]	86.500
Correction factor Basic dynamic load rating		
	[f_C]	1.000
Correction factor Basic static load rating		
	[f_{C0}]	1.000

2.3.2 D (SKF 33208)

Bearing type		Taper roller bearing (single row) SKF Explorer
Bearing position (mm)	[y_{lokal}]	160.000
Bearing position (mm)	[y_{global}]	160.000
Attachment of external ring		Set fixed bearing right
Inner diameter (mm)	[d]	40.000
External diameter (mm)	[D]	80.000
Width (mm)	[b]	32.000
Corner radius (mm)	[r]	1.500

Calculation was performed using real bearing internal geometry provided by bearing manufacturer. These values are however not available for reports.

The bearing pressure angle will be considered in the calculation

Contact angle (°)	[α]	13.241
Position (center of pressure) (mm)	[$y_{D,lokal}$]	155.443
Position (center of pressure) (mm)	[$y_{D,global}$]	155.443
Basic static load rating (kN)	[C_0]	132.000
Basic dynamic load rating (kN)	[C]	128.000
Fatigue load limit (kN)	[C_u]	15.000
Values for approximated geometry:		
Basic dynamic load rating (kN)	[C_{theo}]	103.653
Basic static load rating (kN)	[C_{0theo}]	132.000
Correction factor Basic dynamic load rating		
	[f_C]	1.000
Correction factor Basic static load rating		
	[f_{C0}]	1.000

3 Gears

Gears are considered as mass and as stiffness according to ISO 6336-1 (interference fit).

3.1 Shaft 'Shaft2': Bevel gear 'G2(G12)'

Center point	[y]	122.500	mm
Left side of the gear			
Position (Y-coordinate)	[y]	117.832	mm
Second moment of area	[I_{zz}]	5722673.059	mm^4
Product E·I	[$E \cdot I_{zz}$]	1178870.650	Nm^2

Right side of the gear			
Position (Y-coordinate)	[y]	127.168	mm
Second moment of area	[I_{zz}]	8574959.623	mm⁴
Product E·I	[$E \cdot I_{zz}$]	1766441.682	Nm²
Mass	[m]	1.496	kg
Center of mass	[y_S]	122.723	mm
Polar mass moment of inertia	[J_p]	5.8417e-03	kg·m²
Mass moment of inertia	[J_{xx}]	2.9316e-03	kg·m²
Mass moment of inertia	[J_{zz}]	2.9316e-03	kg·m²

4 Results

4.1 Shafts

Maximum deflection (µm)	24.617
Position of the maximum (mm)	37.333
Mass center of gravity (mm)	79.914
Total axial load (N)	4049.503
Torsion of the shaft under torque (°) (Difference between left and right shaft end)	-0.019

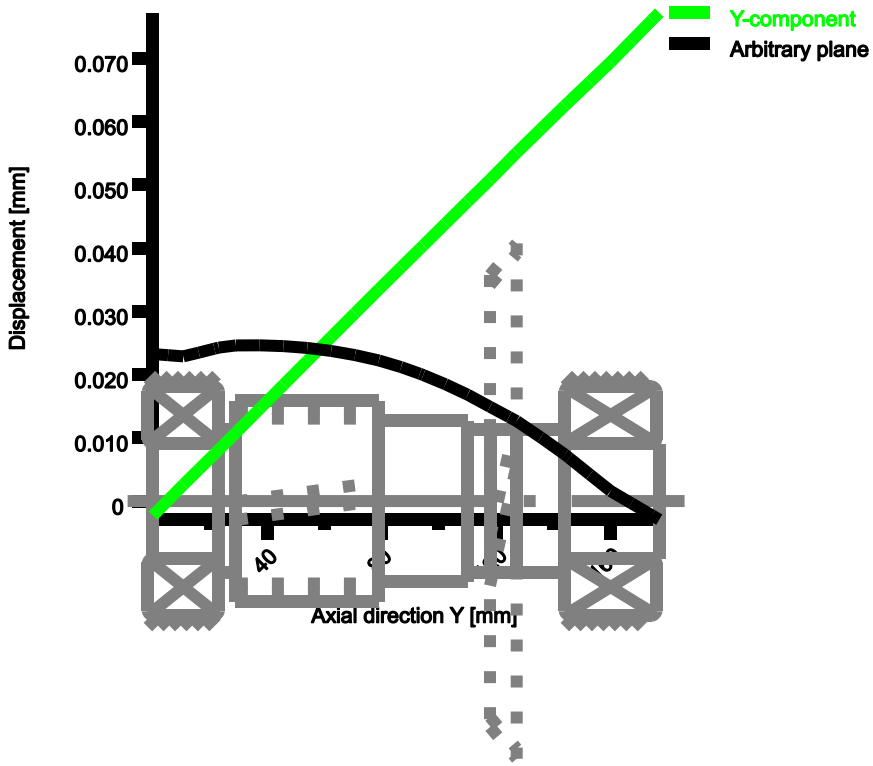
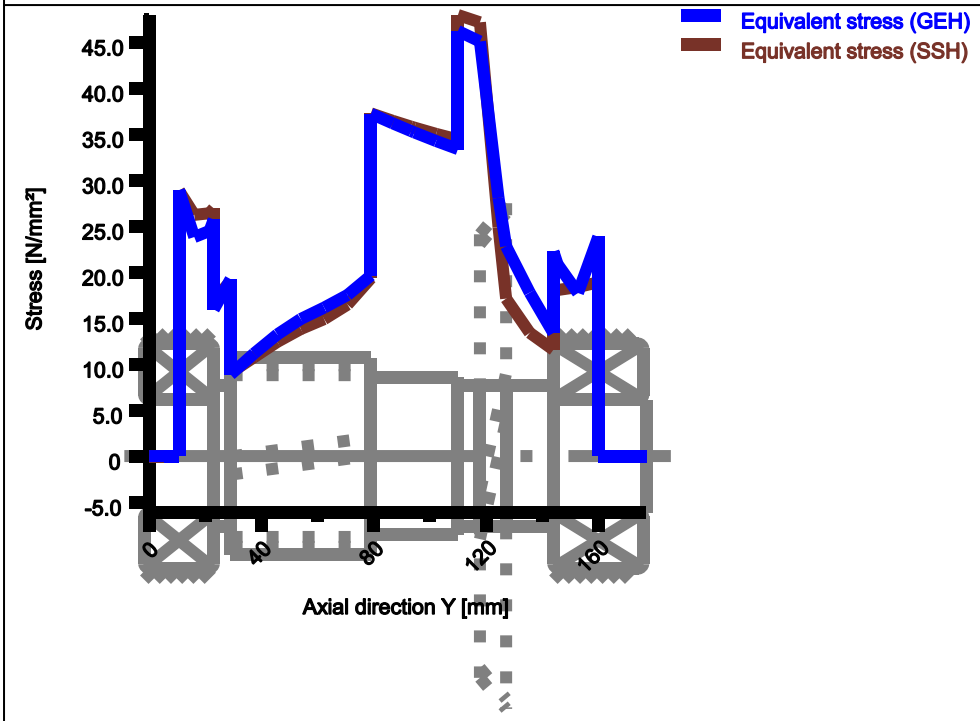


Figure: Deformation (bending etc.) (Arbitrary plane 76.0360651 127)



Nominal stresses, without taking into account stress concentrations
GEH(von Mises): sigV = ((sigB+sigZ,D)^2 + 3*(tauT+tauS)^2)^1/2
SSH(Tresca): sigV = ((sigB-sigZ,D)^2 + 4*(tauT+tauS)^2)^1/2

Figure: Equivalent stress

4.2 Bearing

Probability of failure	[n]	10.00	%
Axial clearance (ISO 281)	[u_A]	10.00	µm
Lubricant	ISO-VG 220		
Lubricant - service temperature	[T_B]	70.00	°C
Rolling bearing rating life according to ISO/TS 16281:2008			

4.3 'Shaft2' Rolling bearing 'C'

Position (Y-coordinate)	[y]	10.62	mm
Dynamic equivalent load	[P]	12.33	kN
Static equivalent load	[P_0]	12.33	kN
Minimum EHL lubricant film thickness	[h_{min}]	0.075	µm
Life modification factor for reliability	[a_1]	1.000	

4.3.1 Operating bearing clearance

Total diametral clearance change	[ΔPd]	0.000	µm
Operating diametral clearance	[Pd]	0.000	µm
Operating axial clearance	[Pa]	0.000	µm

4.3.2 Results according to ISO 281

Lubricant	ISO-VG 220		
Load ratio	[C/P]	7.427	
Operating viscosity	[v]	48.884	mm²/s

Reference viscosity	[v_1]	0.000	mm²/s
Viscosity ratio	[κ]	0.000	
Basic bearing rating life	[L_{nh}]	31549.16	h
Static safety factor	[S_0]	7.01	

4.3.3 Calculation with proprietary bearing internal geometry data (ISO/TS 16281)

Contamination factor	[e_C]	0.097	
Fatigue load limit	[C_u]	9.800	kN
Reference rating life	[L_{nrh}]	93949.56	h
Maximum pressure inner ring	[p_{max_i}]	1691.601	N/mm²
Effective static safety factor	[S_{0w}]	5.59	
Static safety factor	[S_{0ref}]	5.95	
Static equivalent load	[P_{0ref}]	14.54	kN

4.3.4 Bearing reactions

Bearing reaction force	[F_x]	-3.045	kN
Bearing reaction force	[F_y]	3.654	kN
Bearing reaction force	[F_z]	-11.952	kN
Bearing reaction force	[F_r]	12.334	kN
Inclination angle	[α_{Fr}]	-104.293	°
Bearing reaction moment	[M_x]	-91.583	Nm
Bearing reaction moment	[M_y]	0.000	Nm
Bearing reaction moment	[M_z]	23.284	Nm
Bearing reaction moment	[M_r]	94.496	Nm
Inclination angle	[α_{Mr}]	165.735	°
Displacement of bearing	[u_x]	5.738	µm
Displacement of bearing	[u_y]	2.582	µm
Displacement of bearing	[u_z]	22.140	µm
Displacement of bearing	[u_r]	22.871	µm
Inclination angle	[α_{ur}]	75.470	°
Misalignment of bearing	[r_x]	-0.031	mrad
Misalignment of bearing	[r_y]	0.000	mrad
Misalignment of bearing	[r_z]	0.017	mrad
Misalignment of bearing	[r_r]	0.036	mrad

4.3.5 Friction and power loss

Oil level	[H]	0.000	mm
Rolling moment of friction	[M_{rr}]	0.475	Nm
Sliding moment of friction	[M_{sl}]	0.289	Nm
Moment of friction, seals	[M_{seal}]	0.000	Nm

Moment of friction for seals determined according to SKF main catalog 17000/1 EN:2018

Moment of friction flow losses	[M_{drag}]	0.000	Nm
Torque of friction	[M_{loss}]	0.764	Nm
Power loss	[P_{loss}]	33.801	W

The moment of friction is calculated according to the details in SKF Catalog 2018.
The calculation is always performed with a coefficient for additives in the lubricant µbl=0.15.

4.4 'Shaft2' Rolling bearing 'D'

Position (Y-coordinate)	[y]	160.00	mm
Dynamic equivalent load	[P]	16.48	kN
Static equivalent load	[P_0]	11.17	kN
Minimum EHL lubricant film thickness	[h_{min}]	0.080	µm
Life modification factor for reliability	[a_1]	1.000	

4.4.1 Operating bearing clearance

Total diametral clearance change	[ΔPd]	0.000	µm
Operating diametral clearance	[Pd]	0.000	µm

Operating axial clearance	[Pa]	0.000	µm

4.4.2 Results according to ISO 281

Lubricant	ISO-VG 220		
Load ratio	[C/P]	7.765	
Operating viscosity	[v]	48.884	mm²/s
Reference viscosity	[v_1]	0.000	mm²/s
Viscosity ratio	[κ]	0.000	
Basic bearing rating life	[L_{nh}]	36596.44	h
Static safety factor	[S_0]	11.82	

4.4.3 Calculation with proprietary bearing internal geometry data (ISO/TS 16281)

Contamination factor	[e_C]	0.097	
Fatigue load limit	[C_u]	15.000	kN
Reference rating life	[L_{nrh}]	177750.10	h
Maximum pressure inner ring	[p_{max_i}]	1378.951	N/mm²
Effective static safety factor	[S_{0w}]	8.41	
Static safety factor	[S_{0ref}]	9.96	
Static equivalent load	[P_{0ref}]	13.25	kN

4.4.4 Bearing reactions

Bearing reaction force	[F_x]	1.324	kN
Bearing reaction force	[F_y]	-7.704	kN
Bearing reaction force	[F_z]	-8.367	kN
Bearing reaction force	[F_r]	8.471	kN
Inclination angle	[α_{Fr}]	-81.010	°
Bearing reaction moment	[M_x]	74.735	Nm
Bearing reaction moment	[M_y]	0.000	Nm
Bearing reaction moment	[M_z]	5.268	Nm
Bearing reaction moment	[M_r]	74.920	Nm
Inclination angle	[α_{Mr}]	4.032	°
Displacement of bearing	[u_x]	-1.049	µm
Displacement of bearing	[u_y]	69.379	µm
Displacement of bearing	[u_z]	1.893	µm
Displacement of bearing	[u_r]	2.164	µm
Inclination angle	[α_{ur}]	118.979	°
Misalignment of bearing	[r_x]	-0.257	mrad
Misalignment of bearing	[r_y]	-0.333	mrad
Misalignment of bearing	[r_z]	0.069	mrad
Misalignment of bearing	[r_r]	0.266	mrad

4.4.5 Friction and power loss

Oil level	[H]	0.000	mm
Rolling moment of friction	[M_{rr}]	0.702	Nm
Sliding moment of friction	[M_{sl}]	0.417	Nm
Moment of friction, seals	[M_{seal}]	0.000	Nm
Moment of friction for seals determined according to SKF main catalog 17000/1 EN:2018			
Moment of friction flow losses	[M_{drag}]	0.000	Nm
Torque of friction	[M_{loss}]	1.119	Nm
Power loss	[P_{loss}]	49.491	W

The moment of friction is calculated according to the details in SKF Catalog 2018.
The calculation is always performed with a coefficient for additives in the lubricant µbl=0.15.

(*) Note about roller bearings with an approximated bearing geometry:
The internal geometry of these bearings has not been input in the database.
The geometry is back-calculated as specified in ISO 281, from C and C0 (details in the manufacturer's catalog).
For this reason, the geometry may be different from the actual geometry.
This can lead to differences in the service life calculation and, more importantly, the roller bearing stiffness.

4.5 Damage relative to the required service life (L_{req} = 20000 h)

Load case	B1	B2
1	21.29	11.25
Σ	21.29	11.25

B1 : C (SKF 32208)
B2 : D (SKF 33208)

4.6 Utilization relative to the required service life (L_{req} = 20000 h)

Rolling bearings	B1	B2
Utilization (%)	62.87	51.92

Note: Utilization = $(L_{req}/L_h)^{(1/k)}$
Ball bearing: k = 3, roller bearing: k = 10/3

B1 : C (SKF 32208)
B2 : D (SKF 33208)

4.7 Calculation of the factors required to define reliability R(t) using the Weibull distribution. t in (h)

Reliability not calculated

5 Strength calculation according to DIN 743:2012

5.1 Summary

Shaft2

Material	16 MnCr 5 (1)
Material type	Case hardening steel
Material treatment	case-hardened
Surface treatment	No

Calculation of endurance limit and the static strength

Calculation for load case 2 (σav/σmv = const)

Cross section	Position (Y-Coord) (mm)	
B-B	110.00	Shoulder with relief groove
A-A	124.45	Interference fit
C-C	144.00	Shoulder with relief groove
D-D	79.00	Shoulder

Results:

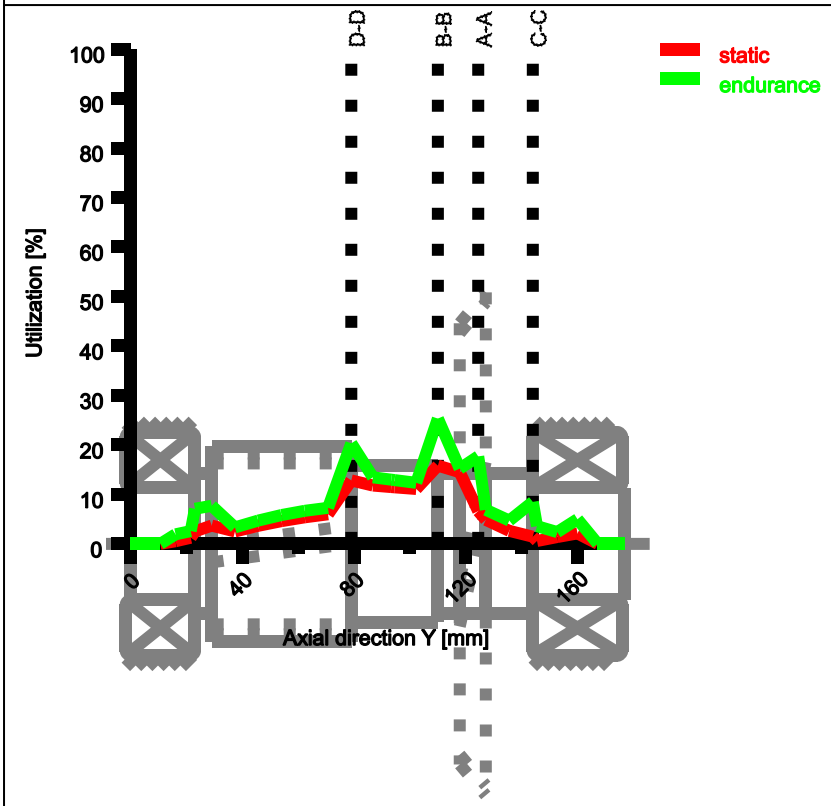
Cross section	βσ	Kfσ	K2d	SD	SS	SA
B-B	1.98	0.88	0.87	4.74	7.90	17.88
A-A	2.51	1.00	0.87	6.79	18.89	33.86
C-C	1.83	0.88	0.89	14.14	86.00	174.99
D-D	1.67	0.89	0.87	5.91	9.75	27.07
Required safeties:				1.20	1.25	1.25

Abbreviations:
βσ: Notch factor, bending
KFσ: Surface factor
K2d: size factor bending
SD: Safety endurance limit
SS: Safety against yield point
SA: Safety against incipient crack

5.1.1 Utilization (%)

Cross section	Static (yield point)	Endurance
B-B	15.819	25.321
A-A	6.619	17.684
C-C	1.454	8.485
D-D	12.825	20.321

Maximum utilization (%)	[A]	25.321



Utilization = Smin/S (%)

Figure: Strength (nominal load)

5.2 Calculation details

General statements

Label	Shaft2		
Drawing			
Length (mm)		[l]	177.00
lcElem =0			
Speed (1/min)		[n]	422.22

Material	16 MnCr 5 (1)
Material type	Case hardening steel
Material treatment	case-hardened
Surface treatment	No

	Tension/Compression	Bending	Torsion	Shearing
Load factor static calculation	1.700	1.700	1.700	1.700
Load factor endurance limit	1.000	1.000	1.000	1.000

Reference diameter material (mm)	[dB]	16.00
σB according to DIN 743 (at dB) (N/mm²)	[σB]	1000.00
σB according to DIN 743 (at dB) (N/mm²)	[σS]	695.00
[σzdW], bei dB (N/mm²)		400.00
[σbW], bei dB (N/mm²)		500.00

[τtW], bei dB (N/mm²)		300.00
Thickness of raw material (mm)	[dWerkst]	75.00

Material data calculated with K1(d), according to DIN 743/3
Geometric size factor K1d calculated with shaft diameter D
Material strength calculated from shaft diameter
(Requirement: Through hardening of pre-machined shaft)

Notice: The following material values are only valid for
the first cross-section, the next ones are corresponding
to their actual 'Diameter for size factor'.

[σBeff] (N/mm²)	776.93
[σSeff] (N/mm²)	539.97
[σbFK] (N/mm²)	539.97
[τtFK] (N/mm²)	311.75
[σbBRand] (N/mm²)	2180.00
[σzdW] (N/mm²)	310.77
[σbW] (N/mm²)	388.47
[τtW] (N/mm²)	233.08

Endurance limit for single stage use

Calculation for load case 2 (σ.av/σ.mv = const)

5.2.1 Cross section 'B-B' **Shoulder with relief groove**

Comment						
Position (Y-Coordinate) (mm)			[y]			110.000
External diameter (mm)			[da]			50.000
Inner diameter (mm)			[di]			0.000
Diameter for size factors (mm)			[deff]			56.000
Notch effect				Shoulder with relief groove		
[D, d, D1, r, t1] (mm)	56.000	49.400	50.000	0.800	0.300	
Shape B						
Mean roughness (µm)			[Rz]			8.000

		Tension/Compression	Bending	Torsion	Shearing
Load: (N) (Nm)					
Mean value	[Fzdm, Mbm, Tm, Fqm]	-3394.4	0.0	237.5	0.0
Amplitude	[Fzda, Mba, Ta, Fqa]	3394.4	281.0	237.5	3770.1
Maximum value	[Fzdmax, Mbmax, Tmax, Fqmax]	-11541.1	477.6	807.4	6409.2
Cross section, moment of resistance: (mm²)					
[A, Wb, Wt, A]		1916.7	11835.3	23670.7	1916.7
Stresses: (N/mm²)					
[σzdm, σbm, τm, τqm] (N/mm²)		-1.771	0.000	10.032	0.000
[σzda, σba, τa, τqa] (N/mm²)		1.771	23.739	10.032	2.623
[σzdmax,σbmax,τmax,τqmax] (N/mm²)		-6.021	40.356	34.110	4.459

Technological size influence	[K1(σB)]	0.777
	[K1(σS)]	0.777

		Tension/Compression	Bending	Torsion
Stress concentration factor	[α]	2.921	2.683	1.808
References stress slope	[G']	3.159	3.159	1.437

Notch sensitivity factor	[n]	1.355	1.355	1.239
Notch effect coefficient	[ß]	2.156	1.981	1.459
Geometrical size influence	[K2(d)]	1.000	0.873	0.873
Influence coefficient surface roughness	[KF]	0.883	0.883	0.933
Surface stabilization factor	[KV]	1.000	1.000	1.000
Total influence coefficient	[K]	2.289	2.400	1.743

Present safety for endurance limit:		
Equivalent mean stress (N/mm²)	[σmV]	17.286
Equivalent mean stress (N/mm²)	[τmV]	9.980

Fatigue limit of part (N/mm²)	[σWK]	135.794	161.828	133.747
Influence coefficient of mean stress sensitivity.				
	[ψσK]	0.096	0.116	0.094
Permissible amplitude (N/mm²)	[σADK]	50.180	149.198	122.290
Safety against fatigue	[S]			4.739
Required safety against fatigue	[Smin]			1.200
Result (%)	[S/Smin]			394.9

Present safety				
for proof against exceed of yield point:				
Static notch sensitivity factor	[K2F]	1.000	1.000	1.000
Increase coefficient	[γF]	1.000	1.000	1.000
Yield stress of part (N/mm²)	[σFK]	539.968	539.968	311.751
Safety yield stress	[S]			7.902
Required safety	[Smin]			1.250
Result (%)	[S/Smin]			632.2

Present safety		
for proof of avoiding incipient crack on hard surface layers:		
Safety against incipient crack	[S]	17.885
Required safety	[Smin]	1.250
Result (%)	[S/Smin]	1430.8

5.2.2 Cross section 'A-A' **Interference fit**

Comment		
Position (Y-Coordinate) (mm)	[y]	124.451
External diameter (mm)	[da]	50.000
Inner diameter (mm)	[di]	0.000
Diameter for size factors (mm)	[deff]	50.000
Notch effect	Interference fit	
Characteristic:	Firm interference fit	
Mean roughness (µm)	[Rz]	8.000

		Tension/Compression	Bending	Torsion	Shearing
Load: (N) (Nm)					
Mean value	[Fzdm, Mbm, Tm, Fqm]	-3718.7	0.0	69.1	0.0
Amplitude	[Fzda, Mba, Ta, Fqa]	3718.7	221.2	69.1	6732.7
Maximum value	[Fzdmax, Mbmax, Tmax, Fqmax]	-12643.6	376.0	234.9	11445.5
Cross section, moment of resistance: (mm²)					
[A, Wb, Wt, A]		1963.5	12271.8	24543.7	1963.5

Stresses: (N/mm²)

[σzdm, σbm, τm, τqm] (N/mm²)		-1.894	0.000	2.815	0.000
[σzda, σba, τa, τqa] (N/mm²)		1.894	18.023	2.815	4.572
[σzdmax,σbmax,τmax,τqmax] (N/mm²)		-6.439	30.640	9.572	7.772
Technological size influence	[K1(σB)]			0.797	
	[K1(σS)]			0.797	
		Tension/Compression	Bending	Torsion	
Notch effect coefficient	[ß(dB)]	2.494	2.494	1.597	
[dB] (mm) = 40.0					
Geometrical size influence	[K3(d)]	0.950	0.950	0.974	
Geometrical size influence	[K3(dB)]	0.956	0.956	0.977	
Notch effect coefficient	[ß]	2.510	2.510	1.602	
Geometrical size influence	[K2(d)]	1.000	0.873	0.873	
Influence coefficient surface roughness	[KF]	1.000	1.000	1.000	
Roughness factor is included into the notch effect coefficient					
Surface stabilization factor	[KV]	1.039	1.039	1.039	
Total influence coefficient	[K]	2.416	2.766	1.766	
Present safety for endurance limit:					
Equivalent mean stress (N/mm²)	[σmV]			4.493	
Equivalent mean stress (N/mm²)	[τmV]			2.594	
Fatigue limit of part (N/mm²)	[σWK]	131.968	144.067	135.414	
Influence coefficient of mean stress sensitivity.					
	[ψσK]	0.090	0.099	0.093	
Permissible amplitude (N/mm²)	[σADK]	108.695	140.585	124.744	
Safety against fatigue	[S]			6.786	
Required safety against fatigue	[Smin]			1.200	
Result (%)	[S/Smin]			565.5	
Present safety for proof against exceed of yield point:					
Static notch sensitivity factor	[K2F]	1.000	1.000	1.000	
Increase coefficient	[γF]	1.000	1.000	1.000	
Yield stress of part (N/mm²)	[σFK]	553.992	553.992	319.848	
Safety yield stress	[S]			18.885	
Required safety	[Smin]			1.250	
Result (%)	[S/Smin]			1510.8	
Present safety for proof of avoiding incipient crack on hard surface layers:					
Safety against incipient crack	[S]			33.857	
Required safety	[Smin]			1.250	
Result (%)	[S/Smin]			2708.5	

5.2.3 Cross section 'C-C' **Shoulder with relief groove**

Comment						
Position (Y-Coordinate) (mm)	[y]					144.000
External diameter (mm)	[da]					40.000
Inner diameter (mm)	[di]					0.000
Diameter for size factors (mm)	[deff]					50.000
Notch effect				Shoulder with relief groove		
[D, d, D1, r, t1] (mm)	50.000	39.600	40.000	1.200	0.200	

Shape B

Mean roughness (µm)	[Rz]			8.000	
		Tension/Compression	Bending	Torsion	Shearing
Load: (N) (Nm)					
Mean value	[Fzdm, Mbm, Tm, Fqm]	-3851.8	0.0	0.0	0.0
Amplitude	[Fzda, Mba, Ta, Fqa]	3851.8	61.2	0.0	8470.7
Maximum value	[Fzdmax, Mbmax, Tmax, Fqmax]	-13096.0	104.1	0.0	14400.3
Cross section, moment of resistance: (mm²)					
[A, Wb, Wt, A]		1231.6	6096.6	12193.1	1231.6
Stresses: (N/mm²)					
[σzdm, σbm, τm, τqm] (N/mm²)		-3.127	0.000	0.000	0.000
[σzda, σba, τa, τqa] (N/mm²)		3.127	10.044	0.000	9.170
[σzdmax,σbmax,τmax,τqmax] (N/mm²)		-10.633	17.075	0.000	15.589
Technological size influence	[K1(σB)]			0.797	
	[K1(σS)]			0.797	

		Tension/Compression	Bending	Torsion
Stress concentration factor	[α]	2.619	2.360	1.686
References stress slope	[G']	2.102	2.102	0.958
Notch sensitivity factor	[n]	1.289	1.289	1.195
Notch effect coefficient	[ß]	2.031	1.831	1.411
Geometrical size influence	[K2(d)]	1.000	0.888	0.888
Influence coefficient surface roughness	[KF]	0.881	0.881	0.931
Surface stabilization factor	[KV]	1.000	1.028	1.028
Total influence coefficient	[K]	2.167	2.136	1.617
Present safety for endurance limit:				
Equivalent mean stress (N/mm²)	[σmV]			-3.127
Equivalent mean stress (N/mm²)	[τmV]			0.000
Fatigue limit of part (N/mm²)	[σWK]	147.170	186.553	147.922
Influence coefficient of mean stress sensitivity.				
	[ψσK]	0.102	0.133	0.102
Permissible amplitude (N/mm²)	[σADK]	163.832	194.582	147.922
Safety against fatigue	[S]			14.143
Required safety against fatigue	[Smin]			1.200
Result (%)	[S/Smin]			1178.5
Present safety for proof against exceed of yield point:				
Static notch sensitivity factor	[K2F]	1.000	1.000	1.000
Increase coefficient	[γF]	1.000	1.000	1.000
Yield stress of part (N/mm²)	[σFK]	553.992	553.992	319.848
Safety yield stress	[S]			85.996
Required safety	[Smin]			1.250
Result (%)	[S/Smin]			6879.7
Present safety for proof of avoiding incipient crack on hard surface layers:				
Safety against incipient crack	[S]			174.986
Required safety	[Smin]			1.250
Result (%)	[S/Smin]			13998.9

5.2.4 Cross section 'D-D' **Shoulder**

Comment					
Position (Y-Coordinate) (mm)		[y]			79.000
External diameter (mm)		[da]			56.000
Inner diameter (mm)		[di]			0.000
Diameter for size factors (mm)		[deff]			70.000
Notch effect			Shoulder		
[D, r, t] (mm)	70.000	3.000	7.000		
Mean roughness (µm)		[Rz]			8.000

		Tension/Compression	Bending	Torsion	Shearing
Load: (N) (Nm)					
Mean value	[Fzdm, Mbm, Tm, Fqm]	-3394.4	0.0	237.5	0.0
Amplitude	[Fzda, Mba, Ta, Fqa]	3394.4	386.7	237.5	3770.1
Maximum value	[Fzdmax, Mbmax, Tmax, Fqmax]	-11541.1	657.3	807.4	6409.2
Cross section, moment of resistance: (mm²)					
[A, Wb, Wt, A]		2463.0	17241.1	34482.1	2463.0

Stresses: (N/mm²)					
[σzdm, σbm, τm, τqm] (N/mm²)		-1.378	0.000	6.887	0.000
[σzda, σba, τa, τqa] (N/mm²)		1.378	22.427	6.887	2.041
[σzdmax,σbmax,τmax,τqmax] (N/mm²)		-4.686	38.127	23.416	3.470
Technological size influence	[K1(σB)]			0.737	
	[K1(σS)]			0.737	

		Tension/Compression	Bending	Torsion
Stress concentration factor	[α]	2.174	1.981	1.494
References stress slope	[G']	0.861	0.861	0.383
Notch sensitivity factor	[n]	1.185	1.185	1.124
Notch effect coefficient	[ß]	1.834	1.671	1.330
Geometrical size influence	[K2(d)]	1.000	0.866	0.866
Influence coefficient surface roughness	[KF]	0.887	0.887	0.935
Surface stabilization factor	[KV]	1.000	1.000	1.000
Total influence coefficient	[K]	1.961	2.057	1.605
Present safety for endurance limit:				
Equivalent mean stress (N/mm²)	[σmV]			11.849
Equivalent mean stress (N/mm²)	[τmV]			6.841
Fatigue limit of part (N/mm²)	[σWK]	150.349	179.189	137.796
Influence coefficient of mean stress sensitivity.				
	[ψσK]	0.114	0.138	0.103
Permissible amplitude (N/mm²)	[σADK]	53.385	166.984	124.996
Safety against fatigue	[S]			5.905
Required safety against fatigue	[Smin]			1.200
Result (%)	[S/Smin]			492.1
Present safety for proof against exceed of yield point:				
Static notch sensitivity factor	[K2F]	1.000	1.000	1.000
Increase coefficient	[γF]	1.000	1.000	1.000

Yield stress of part (N/mm²)	[σFK]	512.353	512.353	295.807
Safety yield stress	[S]			9.747
Required safety	[Smin]			1.250
Result (%)	[S/Smin]			779.8

Present safety
for proof of avoiding incipient crack on hard surface layers:

Safety against incipient crack	[S]	27.074
Required safety	[Smin]	1.250
Result (%)	[S/Smin]	2165.9

Remarks:
- The shearing force is not considered in the analysis specified in DIN 743.
- Cross section with interference fit: The notch factors for the 'Slight interference fit' case are no longer defined in DIN 743.
  The notch factors are taken from the FKM Guideline, except if those for the 'tight interference fit' according to DIN are smaller, in which case they will be used.

_O.Varianta_IV.Shaft3.Shaft3_calc

1 Input data

Coordinate system shaft: see picture W-002

1.1 Shafts

1.1.1 Shaft 'Shaft3'

Drawing		
Initial position (mm)		0.000
Length (mm)		185.000
Speed (1/min)		109.465
Direction of rotation:	clockwise	
Material	16 MnCr 5 (1)	
Young's modulus (N/mm²)		206000.000
Poisson's ratio nu		0.300
Density (kg/m³)		7830.000
Coefficient of thermal expansion (10^-6/K)		11.500
Temperature (°C)		40.000
Weight of shaft (kg)		6.422
Note: the weight is only for the shaft. The gears are not considered		
Weight of shaft, including additional masses (kg)		20.680
Mass moment of inertia (kg*m²)		0.127
Momentum of mass GD2 (Nm²)		4.996

1.2 Weight force

Weight towards	0.000		
Weight towards		0.000	
Weight towards			-1.000

1.3 Shaft modeling

Gears mounted with stiffness according to ISO

1.4 Shear deformations

Consider deformations due to shearing	
Shear correction factor	1.100

1.5 Rolling bearings

Rolling bearing stiffness is calculated from inner bearing geometry

Tolerance field:	Mean value

1.6 Housing

Reference temperature (°C)	20.000

1.7 Load applications

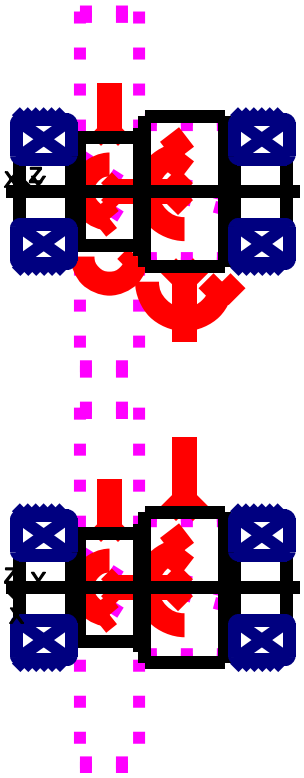


Figure: Load applications

2 Shaft definition (Shaft3)

2.1 Outer contour

2.1.1 Cylinder (Cylinder), 0.000mm ...36.000mm

Diameter (mm)	[d]	45.0000
Length (mm)	[l]	36.0000
Surface roughness (µm)	[Rz]	8.0000

Chamfer left (Chamfer left)
l=2.00 (mm), alpha=30.00 (°)

Relief groove right (Relief groove right)
r=1.20 (mm), t=0.20 (mm), l=2.50 (mm), Rz=8.0, Machined (Ra=3.2µm/125µin)
Form F (DIN 509), Series 1, with raised fatigue limit

2.1.2 Cylinder (Cylinder), 36.000mm ...41.000mm

Diameter (mm)	[d]	55.0000
Length (mm)	[l]	5.0000
Surface roughness (µm)	[Rz]	8.0000

Radius right (Radius right)
r=2.00 (mm), Rz=8.0, Machined (Ra=3.2µm/125µin)

2.1.3 Cylinder (Cylinder), 41.000mm ...83.000mm

Diameter (mm)	[d]	75.0000
Length (mm)	[l]	42.0000
Surface roughness (µm)	[Rz]	8.0000

Chamfer left (Chamfer left)
l=2.00 (mm), alpha=20.00 (°)

Relief groove right (Relief groove right)
r=0.80 (mm), t=0.30 (mm), l=2.50 (mm), Rz=8.0, Machined (Ra=3.2µm/125µin)
Form F (DIN 509), Series 1, with the usual stressing

2.1.4 Cylinder (Cylinder), 83.000mm ...87.000mm

Diameter (mm)	[d]	88.0000
Length (mm)	[l]	4.0000
Surface roughness (µm)	[Rz]	8.0000

Radius right (Radius right)
r=3.00 (mm), Rz=8.0, Machined (Ra=3.2µm/125µin)

Chamfer left (Chamfer left)
l=0.50 (mm), alpha=45.00 (°)

2.1.5 Cylinder (Cylinder), 87.000mm ...142.000mm

Diameter (mm)	[d]	104.0000
Length (mm)	[l]	55.0000
Surface roughness (µm)	[Rz]	8.0000

Chamfer left (Chamfer left)
l=2.00 (mm), alpha=60.00 (°)

Chamfer right (Chamfer right)
l=2.00 (mm), alpha=60.00 (°)

2.1.6 Cylinder (Cylinder), 142.000mm ...149.000mm

Diameter (mm)	[d]	55.0000
Length (mm)	[l]	7.0000
Surface roughness (µm)	[Rz]	8.0000

Radius left (Radius left)
r=4.00 (mm), Rz=8.0, Machined (Ra=3.2µm/125µin)

Chamfer right (Chamfer right)
l=0.50 (mm), alpha=45.00 (°)

2.1.7 Cylinder (Cylinder), 149.000mm ...185.000mm

Diameter (mm)	[d]	45.0000
Length (mm)	[l]	36.0000
Surface roughness (µm)	[Rz]	8.0000

Chamfer right (Chamfer right)
l=2.00 (mm), alpha=30.00 (°)

Relief groove left (Relief groove left)
r=1.20 (mm), t=0.20 (mm), l=2.50 (mm), Rz=8.0, Machined (Ra=3.2µm/125µin)
Form F (DIN 509), Series 1, with raised fatigue limit

2.2 Forces

2.2.1 Cylindrical gear (G4)

Position on shaft (mm)	[y_{local}]	62.5000	
Position in global system (mm)	[y_{global}]	62.5000	
Operating pitch diameter (mm)		249.3529	
Helix angle (°)		12.0433	Helix right hand
Working pressure angle at normal section (°)		20.5509	
Position of contact (°)		-0.0000	
Length of load application (mm)		41.0000	
Power (kW)		21.0000	driven (input)
Torque (Nm)		1831.9572	
Axial force (N)		-3134.8585	
Shearing force X (N)		-5632.6036	
Shearing force Z (N)		-14693.6880	
Bending moment X (Nm)		-0.0000	
Bending moment Z (Nm)		-390.8431	

2.2.2 Cylindrical gear (G5)

Position on shaft (mm)	[y_{local}]	114.5000	
Position in global system (mm)	[y_{global}]	114.5000	
Operating pitch diameter (mm)		99.4951	
Helix angle (°)		17.1097	Helix right hand
Working pressure angle at normal section (°)		20.9577	
Position of contact (°)		180.0000	
Length of load application (mm)		55.0000	
Power (kW)		21.0000	driving (output)
Torque (Nm)		-1831.9572	
Axial force (N)		11335.7130	
Shearing force X (N)		14757.7907	
Shearing force Z (N)		-36825.0561	
Bending moment X (Nm)		-0.0000	
Bending moment Z (Nm)		-563.9242	

2.3 Bearing

2.3.1 E (SKF 32309)

Bearing type		Taper roller bearing (single row) SKF Explorer	
Bearing position (mm)	[y_{lokal}]	16.875	
Bearing position (mm)	[y_{global}]	16.875	
Attachment of external ring		Set fixed bearing left	
Inner diameter (mm)	[d]	45.000	

External diameter (mm)	[D]	100.000
Width (mm)	[b]	38.250
Corner radius (mm)	[r]	2.000

Calculation was performed using real bearing internal geometry provided by bearing manufacturer. These values are however not available for reports.

The bearing pressure angle will be considered in the calculation

Contact angle (°)	[α]	13.241
Position (center of pressure) (mm)	[$y_{D,lokal}$]	22.500
Position (center of pressure) (mm)	[$y_{D,global}$]	22.500
Basic static load rating (kN)	[C_0]	170.000
Basic dynamic load rating (kN)	[C]	173.000
Fatigue load limit (kN)	[C_u]	20.400
Values for approximated geometry:		
Basic dynamic load rating (kN)	[C_{theo}]	140.083
Basic static load rating (kN)	[C_{0theo}]	170.000
Correction factor Basic dynamic load rating		
	[f_C]	1.000
Correction factor Basic static load rating		
	[f_{C0}]	1.000

2.3.2 F (SKF 32309)

Bearing type		Taper roller bearing (single row) SKF Explorer
Bearing position (mm)	[y_{lokal}]	168.125
Bearing position (mm)	[y_{global}]	168.125
Attachment of external ring		Set fixed bearing right
Inner diameter (mm)	[d]	45.000
External diameter (mm)	[D]	100.000
Width (mm)	[b]	38.250
Corner radius (mm)	[r]	2.000

Calculation was performed using real bearing internal geometry provided by bearing manufacturer. These values are however not available for reports.

The bearing pressure angle will be considered in the calculation

Contact angle (°)	[α]	13.241
Position (center of pressure) (mm)	[$y_{D,lokal}$]	162.500
Position (center of pressure) (mm)	[$y_{D,global}$]	162.500
Basic static load rating (kN)	[C_0]	170.000
Basic dynamic load rating (kN)	[C]	173.000
Fatigue load limit (kN)	[C_u]	20.400
Values for approximated geometry:		
Basic dynamic load rating (kN)	[C_{theo}]	140.083
Basic static load rating (kN)	[C_{0theo}]	170.000
Correction factor Basic dynamic load rating		
	[f_C]	1.000
Correction factor Basic static load rating		
	[f_{C0}]	1.000

3 Gears

Gears are considered as mass and as stiffness according to ISO 6336-1 (interference fit).

3.1 Shaft 'Shaft3': Cylindrical gear 'G4'

Center point	[y]	62.500	mm
Left side of the gear			
Position (Y-coordinate)	[y]	42.000	mm
Second moment of area	[I_{zz}]	33956371.610	mm⁴
Product E·I	[$E \cdot I_{zz}$]	6995012.552	Nm²
Right side of the gear			
Position (Y-coordinate)	[y]	83.000	mm
Second moment of area	[I_{zz}]	33956371.610	mm⁴
Product E·I	[$E \cdot I_{zz}$]	6995012.552	Nm²
Mass	[m]	14.259	kg
Center of mass	[y_S]	62.500	mm
Polar mass moment of inertia	[J_p]	1.2085e-01	kg·m²
Mass moment of inertia	[J_{xx}]	6.2421e-02	kg·m²
Mass moment of inertia	[J_{zz}]	6.2421e-02	kg·m²

4 Results

4.1 Shafts

Maximum deflection (µm)	38.841
Position of the maximum (mm)	0.000
Mass center of gravity (mm)	98.203
Total axial load (N)	8200.854
Torsion of the shaft under torque (°) (Difference between left and right shaft end)	-0.004

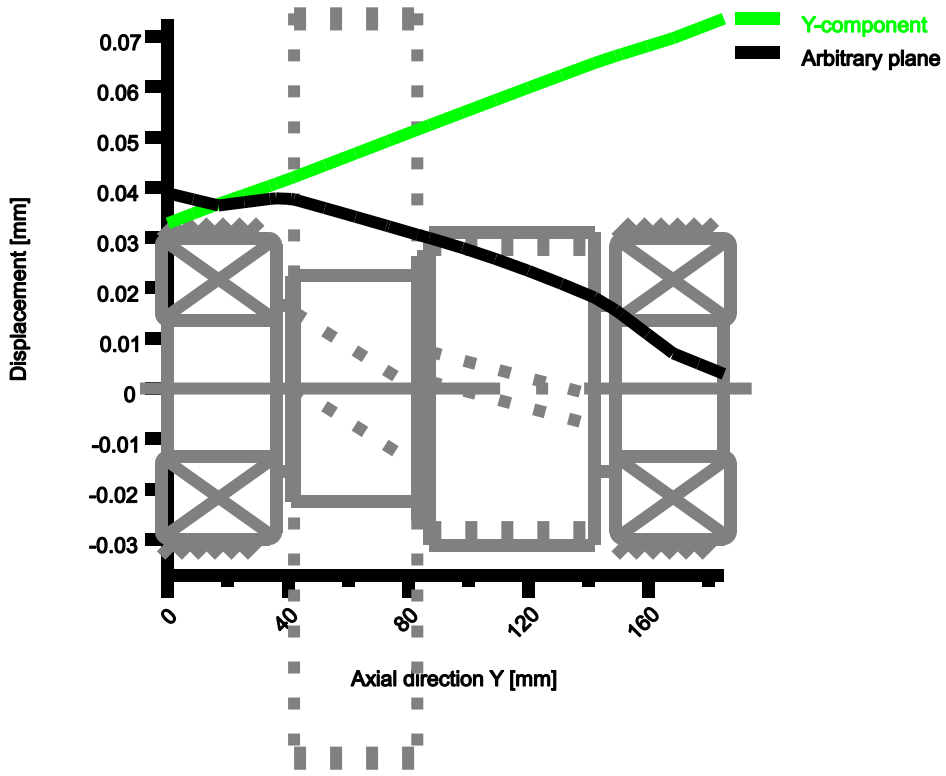
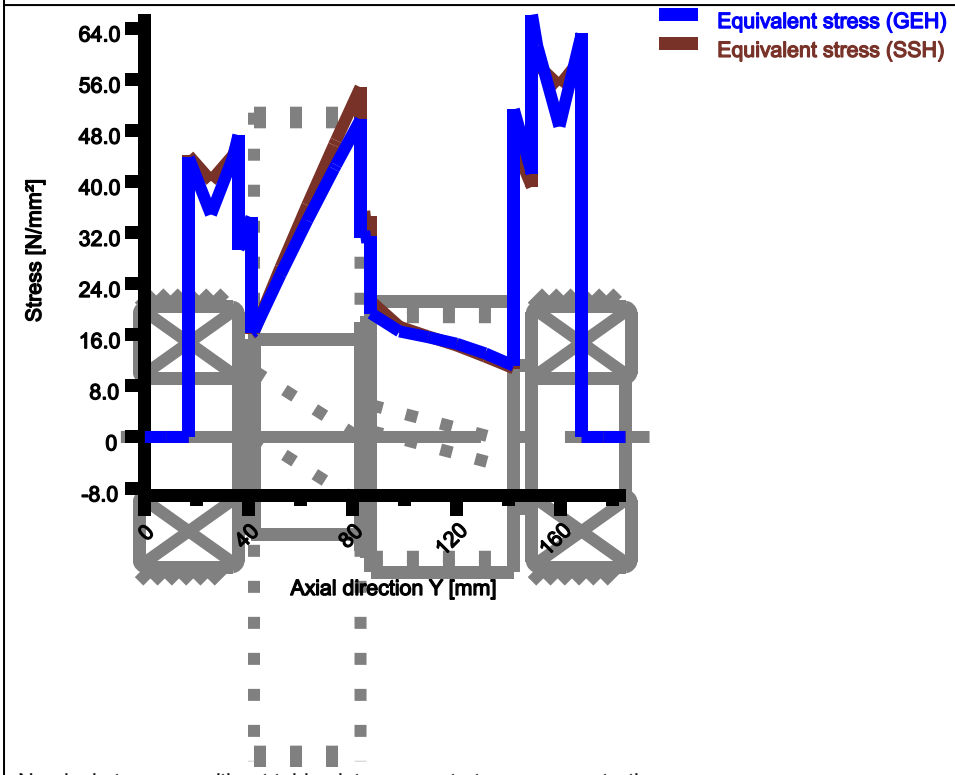


Figure: Deformation (bending etc.) (Arbitrary plane 250.0226115 127)



Nominal stresses, without taking into account stress concentrations
GEH(von Mises): sigV = ((sigB+sigZ,D)^2 + 3*(tauT+tauS)^2)^1/2
SSH(Tresca): sigV = ((sigB-sigZ,D)^2 + 4*(tauT+tauS)^2)^1/2

Figure: Equivalent stress

4.2 Bearing

Probability of failure	[n]	10.00	%
Axial clearance (ISO 281)	[u_A]	10.00	µm
Lubricant	ISO-VG 220		
Lubricant - service temperature	[T_B]	70.00	°C
Rolling bearing rating life according to ISO/TS 16281:2008			

4.3 'Shaft3' Rolling bearing 'E'

Position (Y-coordinate)	[y]	16.88	mm
Dynamic equivalent load	[P]	23.81	kN
Static equivalent load	[P_0]	23.81	kN
Minimum EHL lubricant film thickness	[h_{min}]	0.036	µm
Life modification factor for reliability	[a_1]	1.000	

4.3.1 Operating bearing clearance

Total diametral clearance change	[ΔPd]	0.000	µm
Operating diametral clearance	[Pd]	0.000	µm
Operating axial clearance	[Pa]	0.000	µm

4.3.2 Results according to ISO 281

Lubricant	ISO-VG 220		
Load ratio	[C/P]	7.267	
Operating viscosity	[v]	48.884	mm²/s

Reference viscosity	[ν_1]	0.000	mm²/s
Viscosity ratio	[κ]	0.000	
Basic bearing rating life	[L_{nh}]	113160.53	h
Static safety factor	[S_0]	7.14	

4.3.3 Calculation with proprietary bearing internal geometry data (ISO/TS 16281)

Contamination factor	[e_C]	0.059	
Fatigue load limit	[C_u]	20.400	kN
Reference rating life	[L_{nrh}]	295352.47	h
Maximum pressure inner ring	[p_{max_i}]	1724.613	N/mm²
Effective static safety factor	[S_{0w}]	5.38	
Static safety factor	[S_{0ref}]	5.68	
Static equivalent load	[P_{0ref}]	29.93	kN

4.3.4 Bearing reactions

Bearing reaction force	[F_x]	6.163	kN
Bearing reaction force	[F_y]	6.462	kN
Bearing reaction force	[F_z]	22.996	kN
Bearing reaction force	[F_r]	23.807	kN
Inclination angle	[α_{Fr}]	74.998	°
Bearing reaction moment	[M_x]	196.712	Nm
Bearing reaction moment	[M_y]	0.000	Nm
Bearing reaction moment	[M_z]	-50.519	Nm
Bearing reaction moment	[M_r]	203.095	Nm
Inclination angle	[α_{Mr}]	-14.403	°
Displacement of bearing	[u_x]	-10.648	µm
Displacement of bearing	[u_y]	36.732	µm
Displacement of bearing	[u_z]	-34.867	µm
Displacement of bearing	[u_r]	36.457	µm
Inclination angle	[α_{ur}]	-106.982	°
Misalignment of bearing	[r_x]	0.097	mrad
Misalignment of bearing	[r_y]	-0.000	mrad
Misalignment of bearing	[r_z]	-0.155	mrad
Misalignment of bearing	[r_r]	0.183	mrad

4.3.5 Friction and power loss

Oil level	[H]	0.000	mm
Rolling moment of friction	[M_{rr}]	0.433	Nm
Sliding moment of friction	[M_{sl}]	2.576	Nm
Moment of friction, seals	[M_{seal}]	0.000	Nm
Moment of friction for seals determined according to SKF main catalog 17000/1 EN:2018			
Moment of friction flow losses	[M_{drag}]	0.000	Nm
Torque of friction	[M_{loss}]	3.009	Nm
Power loss	[P_{loss}]	34.491	W

The moment of friction is calculated according to the details in SKF Catalog 2018.
The calculation is always performed with a coefficient for additives in the lubricant µbl=0.15.

4.4 'Shaft3' Rolling bearing 'F'

Position (Y-coordinate)	[y]	168.12	mm
Dynamic equivalent load	[P]	37.94	kN
Static equivalent load	[P_0]	32.54	kN
Minimum EHL lubricant film thickness	[h_{min}]	0.035	µm
Life modification factor for reliability	[a_1]	1.000	

4.4.1 Operating bearing clearance

Total diametral clearance change	[ΔPd]	0.000	µm
Operating diametral clearance	[Pd]	0.000	µm

Operating axial clearance	[Pa]	0.000	µm

4.4.2 Results according to ISO 281

Lubricant	ISO-VG 220		
Load ratio	[C/P]	4.560	
Operating viscosity	[v]	48.884	mm²/s
Reference viscosity	[v_1]	0.000	mm²/s
Viscosity ratio	[κ]	0.000	
Basic bearing rating life	[L_{nh}]	23932.25	h
Static safety factor	[S_0]	5.22	

4.4.3 Calculation with proprietary bearing internal geometry data (ISO/TS 16281)

Contamination factor	[e_C]	0.059	
Fatigue load limit	[C_u]	20.400	kN
Reference rating life	[L_{nrh}]	97111.25	h
Maximum pressure inner ring	[p_{max_i}]	1834.597	N/mm²
Effective static safety factor	[S_{0w}]	4.75	
Static safety factor	[S_{0ref}]	4.87	
Static equivalent load	[P_{0ref}]	34.93	kN

4.4.4 Bearing reactions

Bearing reaction force	[F_x]	-15.288	kN
Bearing reaction force	[F_y]	-14.662	kN
Bearing reaction force	[F_z]	28.726	kN
Bearing reaction force	[F_r]	32.541	kN
Inclination angle	[α_{Fr}]	118.022	°
Bearing reaction moment	[M_x]	-264.530	Nm
Bearing reaction moment	[M_y]	0.000	Nm
Bearing reaction moment	[M_z]	-123.256	Nm
Bearing reaction moment	[M_r]	291.836	Nm
Inclination angle	[α_{Mr}]	-155.017	°
Displacement of bearing	[u_x]	7.323	µm
Displacement of bearing	[u_y]	69.690	µm
Displacement of bearing	[u_z]	-10.110	µm
Displacement of bearing	[u_r]	12.483	µm
Inclination angle	[α_{ur}]	-54.081	°
Misalignment of bearing	[r_x]	0.214	mrad
Misalignment of bearing	[r_y]	-0.072	mrad
Misalignment of bearing	[r_z]	-0.123	mrad
Misalignment of bearing	[r_r]	0.246	mrad

4.4.5 Friction and power loss

Oil level	[H]	0.000	mm
Rolling moment of friction	[M_{rr}]	0.547	Nm
Sliding moment of friction	[M_{sl}]	4.636	Nm
Moment of friction, seals	[M_{seal}]	0.000	Nm
Moment of friction for seals determined according to SKF main catalog 17000/1 EN:2018			
Moment of friction flow losses	[M_{drag}]	0.000	Nm
Torque of friction	[M_{loss}]	5.183	Nm
Power loss	[P_{loss}]	59.410	W

The moment of friction is calculated according to the details in SKF Catalog 2018.
The calculation is always performed with a coefficient for additives in the lubricant µbl=0.15.

(*) Note about roller bearings with an approximated bearing geometry:
The internal geometry of these bearings has not been input in the database.
The geometry is back-calculated as specified in ISO 281, from C and C0 (details in the manufacturer's catalog).
For this reason, the geometry may be different from the actual geometry.
This can lead to differences in the service life calculation and, more importantly, the roller bearing stiffness.

4.5 Damage relative to the required service life (L_{req} = 20000 h)

Load case	B1	B2
1	6.77	20.59
Σ	6.77	20.59

B1 : E (SKF 32309)
B2 : F (SKF 32309)

4.6 Utilization relative to the required service life (L_{req} = 20000 h)

Rolling bearings	B1	B2
Utilization (%)	44.59	62.25

Note: Utilization = $(L_{req}/L_h)^{(1/k)}$
Ball bearing: k = 3, roller bearing: k = 10/3

B1 : E (SKF 32309)
B2 : F (SKF 32309)

4.7 Calculation of the factors required to define reliability R(t) using the Weibull distribution. t in (h)

Reliability not calculated

4.7.1 Shaft 'Shaft3', Dokumentationspunkt Documentation point

Y position (mm)	[y]	83.00
Equivalent stress (N/mm²)	[σ_V]	49.69
Equivalent stress (Tresca) (N/mm²)	[σ_V]	54.75
Bending Stress (N/mm²)	[σ_b]	24.87
Principal stress (N/mm²)	[σ_{zd}]	-0.75
Shear stress (torsion) (N/mm²)	[τ_T]	22.12
Shear stress (shearing force) (N/mm²)	[τ_Q]	2.46

	X	Y	Z	R
Displacement (mm)	-0.0013	0.0515	-0.0321	0.0321
Rotation (mrad)	0.1294	-0.0012	-0.1640	0.2089
Force (kN)	-0.5300	-3.3267	-8.1427	8.1600
Torque (Nm)	1019.1757	-1831.9572	149.3260	1030.0569

_O.Varianta_IV.Shaft4.Shaft4_calc

1 Input data

Coordinate system shaft: see picture W-002

1.1 Shafts

1.1.1 Shaft 'Shaft4'

Drawing		
Initial position (mm)		0.000
Length (mm)		589.500
Speed (1/min)		28.034
Direction of rotation:	counterclockwise	
Material	C45 (1)	
Young's modulus (N/mm²)		206000.000
Poisson's ratio nu		0.300
Density (kg/m³)		7830.000
Coefficient of thermal expansion (10^-6/K)		11.500
Temperature (°C)		20.000
Weight of shaft (kg)		28.586
Note: the weight is only for the shaft. The gears are not considered		
Weight of shaft, including additional masses (kg)		72.130
Mass moment of inertia (kg*m²)		0.918
Momentum of mass GD2 (Nm²)		36.030

1.2 Weight force

Weight towards	0.000		
Weight towards		0.000	
Weight towards			-1.000

1.3 Shaft modeling

Gears mounted with stiffness according to ISO

1.4 Shear deformations

Consider deformations due to shearing	
Shear correction factor	1.100

1.5 Rolling bearings

Rolling bearing stiffness is calculated from inner bearing geometry

Tolerance field:	Mean value

1.6 Housing

Reference temperature (°C)	20.000

1.7 Load applications

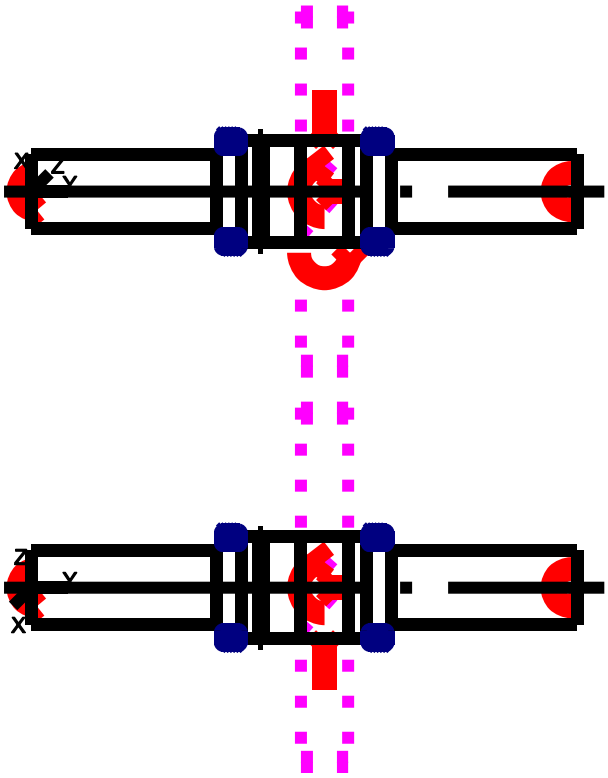


Figure: Load applications

2 Shaft definition (Shaft4)

2.1 Outer contour

2.1.1 Cylinder (Cylinder), 0.000mm ...200.000mm

Diameter (mm)	[d]	80.0000
Length (mm)	[l]	200.0000
Surface roughness (µm)	[Rz]	8.0000

Key way (Key way) 12.000 mm ... 152.000 mm
l=140.00 (mm), i=3, Rz=8.0, Machined (Ra=3.2µm/125µin)

Chamfer left (Chamfer left)
l=1.60 (mm), alpha=30.00 (°)

Radius right (Radius right)
r=4.00 (mm), Rz=8.0, Machined (Ra=3.2µm/125µin)

Circumferential groove (Circumferential groove)
t=0.30 (mm), r=3.00 (mm), Rz=8.0, Machined (Ra=3.2µm/125µin)

2.1.2 Cylinder (Cylinder), 200.000mm ...227.000mm

Diameter (mm)	[d]	90.0000
Length (mm)	[l]	27.0000
Surface roughness (µm)	[Rz]	8.0000

Chamfer left (Chamfer left)
l=1.50 (mm), alpha=30.00 (°)

Relief groove right (Relief groove right)
r=2.50 (mm), t=0.40 (mm), l=5.00 (mm), Rz=8.0, Machined (Ra=3.2µm/125µin)
Form F (DIN 509), Series 1, with raised fatigue limit

2.1.3 Cylinder (Cylinder), 227.000mm ...245.500mm

Diameter (mm)	[d]	110.0000
Length (mm)	[l]	18.5000
Surface roughness (µm)	[Rz]	8.0000

Chamfer left (Chamfer left)
l=0.50 (mm), alpha=45.00 (°)

Radius right (Radius right)
r=5.00 (mm), Rz=8.0, Machined (Ra=3.2µm/125µin)

2.1.4 Cylinder (Cylinder), 245.500mm ...250.500mm

Diameter (mm)	[d]	120.0000
Length (mm)	[l]	5.0000
Surface roughness (µm)	[Rz]	8.0000

Chamfer left (Chamfer left)
l=0.50 (mm), alpha=45.00 (°)

Chamfer right (Chamfer right)
l=0.50 (mm), alpha=45.00 (°)

2.1.5 Cylinder (Cylinder), 250.500mm ...362.500mm

Diameter (mm)	[d]	110.0000
Length (mm)	[l]	112.0000
Surface roughness (µm)	[Rz]	8.0000

Relief groove left (Relief groove left)
r=2.50 (mm), t=0.40 (mm), l=5.00 (mm), Rz=8.0, Machined (Ra=3.2µm/125µin)
Form F (DIN 509), Series 1, with raised fatigue limit

Chamfer right (Chamfer right)
l=2.50 (mm), alpha=20.00 (°)

2.1.6 Cylinder (Cylinder), 362.500mm ...389.500mm

Diameter (mm)	[d]	90.0000
Length (mm)	[l]	27.0000
Surface roughness (µm)	[Rz]	8.0000

Chamfer right (Chamfer right)
l=1.50 (mm), alpha=30.00 (°)

Relief groove left (Relief groove left)
r=2.50 (mm), t=0.40 (mm), l=5.00 (mm), Rz=8.0, Machined (Ra=3.2µm/125µin)
Form F (DIN 509), Series 1, with raised fatigue limit

2.1.7 Cylinder (Cylinder), 389.500mm ...589.500mm

Diameter (mm)	[d]	80.0000
Length (mm)	[l]	200.0000
Surface roughness (µm)	[Rz]	8.0000

Circumferential groove (Circumferential groove)
t=0.30 (mm), r=3.00 (mm), Rz=8.0, Machined (Ra=3.2µm/125µin)

Key way (Key way) 437.500 mm ... 577.500 mm
l=140.00 (mm), i=3, Rz=8.0, Machined (Ra=3.2µm/125µin)

Chamfer right (Chamfer right)
l=1.60 (mm), alpha=30.00 (°)

Radius left (Radius left)
r=4.00 (mm), Rz=8.0, Machined (Ra=3.2µm/125µin)

2.2 Forces

2.2.1 Cylindrical gear (G6)

Position on shaft (mm)	[y_{local}]	316.7500	
Position in global system (mm)	[y_{global}]	316.7500	
Operating pitch diameter (mm)		388.5049	
Helix angle (°)		17.1097	Helix left hand
Working pressure angle at normal section (°)		20.9577	
Position of contact (°)		-0.0000	
Length of load application (mm)		51.0000	
Power (kW)		21.0000	driven (input)
Torque (Nm)		-7153.3565	
Axial force (N)		-11335.7130	
Shearing force X (N)		-14757.7907	
Shearing force Z (N)		36825.0561	
Bending moment X (Nm)		-0.0000	
Bending moment Z (Nm)		-2201.9898	

2.2.2 Coupling (Output_1(Output1))

Position on shaft (mm)	[y_{local}]	583.0000	
Position in global system (mm)	[y_{global}]	583.0000	
Effective diameter (mm)		30.0000	
Radial force factor (-)		0.0000	
Direction of the radial force (°)		0.0000	
Axial force factor (-)		0.0000	
Length of load application (mm)		10.0000	
Power (kW)		10.5000	driving (output)
Torque (Nm)		3576.6780	
Axial force (N)		0.0000	
Shearing force X (N)		0.0000	
Shearing force Z (N)		0.0000	

Bending moment X (Nm)	0.0000
Bending moment Z (Nm)	0.0000
Mass (kg)	0.0000
Mass moment of inertia Jp (kg*m²)	0.0000e+00
Mass moment of inertia Jxx (kg*m²)	0.0000e+00
Mass moment of inertia Jzz (kg*m²)	0.0000e+00
Eccentricity (mm)	0.0000

2.2.3 Coupling (Output_2(Output2))

Position on shaft (mm)	[y_{local}]	6.0000	
Position in global system (mm)	[y_{global}]	6.0000	
Effective diameter (mm)		30.0000	
Radial force factor (-)		0.0000	
Direction of the radial force (°)		0.0000	
Axial force factor (-)		0.0000	
Length of load application (mm)		10.0000	
Power (kW)		10.5000	driving (output)
Torque (Nm)		3576.6780	
Axial force (N)		0.0000	
Shearing force X (N)		0.0000	
Shearing force Z (N)		0.0000	
Bending moment X (Nm)		0.0000	
Bending moment Z (Nm)		0.0000	
Mass (kg)		0.0000	
Mass moment of inertia Jp (kg*m²)		0.0000e+00	
Mass moment of inertia Jxx (kg*m²)		0.0000e+00	
Mass moment of inertia Jzz (kg*m²)		0.0000e+00	
Eccentricity (mm)		0.0000	

2.3 Bearing

2.3.1 G (SKF 32918)

Bearing type		Taper roller bearing (single row) SKF Explorer
Bearing position (mm)	[y_{lokal}]	215.500
Bearing position (mm)	[y_{global}]	215.500
Attachment of external ring		Set fixed bearing left
Inner diameter (mm)	[d]	90.000
External diameter (mm)	[D]	125.000
Width (mm)	[b]	23.000
Corner radius (mm)	[r]	1.500

Calculation was performed using real bearing internal geometry provided by bearing manufacturer. These values are however not available for reports.

The bearing pressure angle will be considered in the calculation

Contact angle (°)	[α]	13.241
Position (center of pressure) (mm)	[$y_{D,lokal}$]	226.055
Position (center of pressure) (mm)	[$y_{D,global}$]	226.055
Basic static load rating (kN)	[C_0]	166.000
Basic dynamic load rating (kN)	[C]	119.000
Fatigue load limit (kN)	[C_u]	18.300
Values for approximated geometry:		
Basic dynamic load rating (kN)	[C_{theo}]	96.600
Basic static load rating (kN)	[C_{0theo}]	166.000

Correction factor Basic dynamic load rating		
	[f_C]	1.000
Correction factor Basic static load rating		
	[f_{C0}]	1.000

2.3.2 H (SKF 32918)

Bearing type		Taper roller bearing (single row) SKF Explorer
Bearing position (mm)	[y_{lokal}]	374.000
Bearing position (mm)	[y_{global}]	374.000
Attachment of external ring		Set fixed bearing right
Inner diameter (mm)	[d]	90.000
External diameter (mm)	[D]	125.000
Width (mm)	[b]	23.000
Corner radius (mm)	[r]	1.500

Calculation was performed using real bearing internal geometry provided by bearing manufacturer. These values are however not available for reports.

The bearing pressure angle will be considered in the calculation

Contact angle (°)	[α]	13.241
Position (center of pressure) (mm)	[$y_{D,lokal}$]	363.445
Position (center of pressure) (mm)	[$y_{D,global}$]	363.445
Basic static load rating (kN)	[C_0]	166.000
Basic dynamic load rating (kN)	[C]	119.000
Fatigue load limit (kN)	[C_u]	18.300
Values for approximated geometry:		
Basic dynamic load rating (kN)	[C_{theo}]	96.600
Basic static load rating (kN)	[C_{0theo}]	166.000
Correction factor Basic dynamic load rating		
	[f_C]	1.000
Correction factor Basic static load rating		
	[f_{C0}]	1.000

3 Gears

Gears are considered as mass and as stiffness according to ISO 6336-1 (interference fit).

3.1 Shaft 'Shaft4': Cylindrical gear 'G6'

Center point	[y]	316.750	mm
Left side of the gear			
Position (Y-coordinate)	[y]	291.250	mm
Second moment of area	[I_{zz}]	189464340.827	mm^4
Product E·I	[$E \cdot I_{zz}$]	39029654.210	Nm^2
Right side of the gear			
Position (Y-coordinate)	[y]	342.250	mm
Second moment of area	[I_{zz}]	189464340.827	mm^4
Product E·I	[$E \cdot I_{zz}$]	39029654.210	Nm^2
Mass	[m]	43.544	kg
Center of mass	[y_S]	316.750	mm
Polar mass moment of inertia	[J_p]	8.8740e-01	$kg \cdot m^2$
Mass moment of inertia	[J_{xx}]	4.5314e-01	$kg \cdot m^2$

Mass moment of inertia	[J_{zz}]	4.5314e-01	kg·m²

4 Results

4.1 Shafts

Maximum deflection (µm)	82.983
Position of the maximum (mm)	589.500
Mass center of gravity (mm)	294.634
Total axial load (N)	-11335.713
Torsion of the shaft under torque (°) (Difference between left and right shaft end)	-0.008

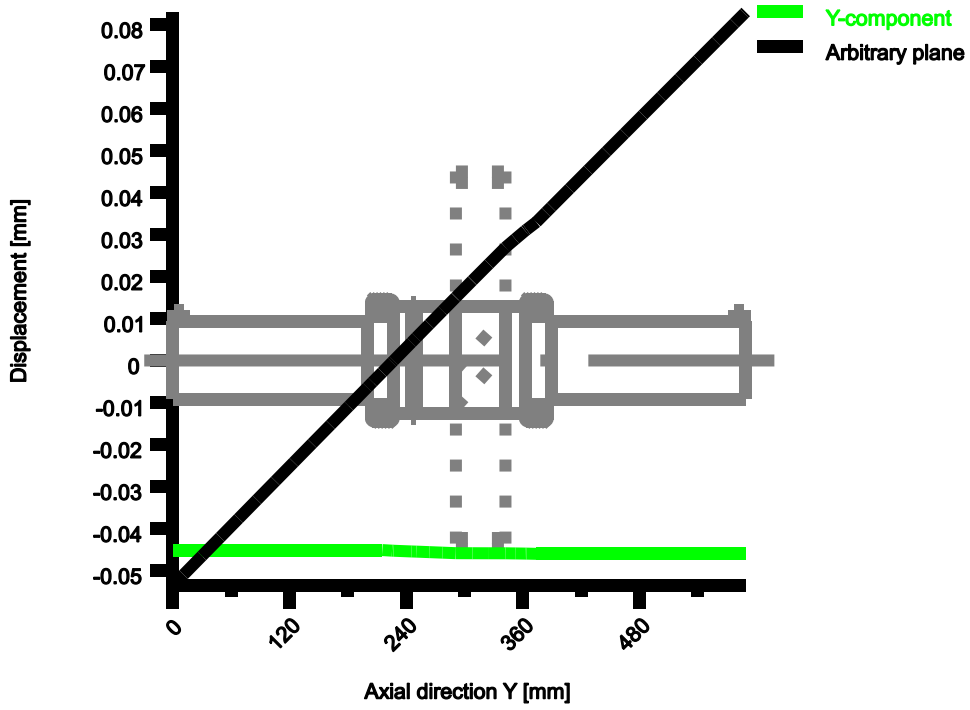
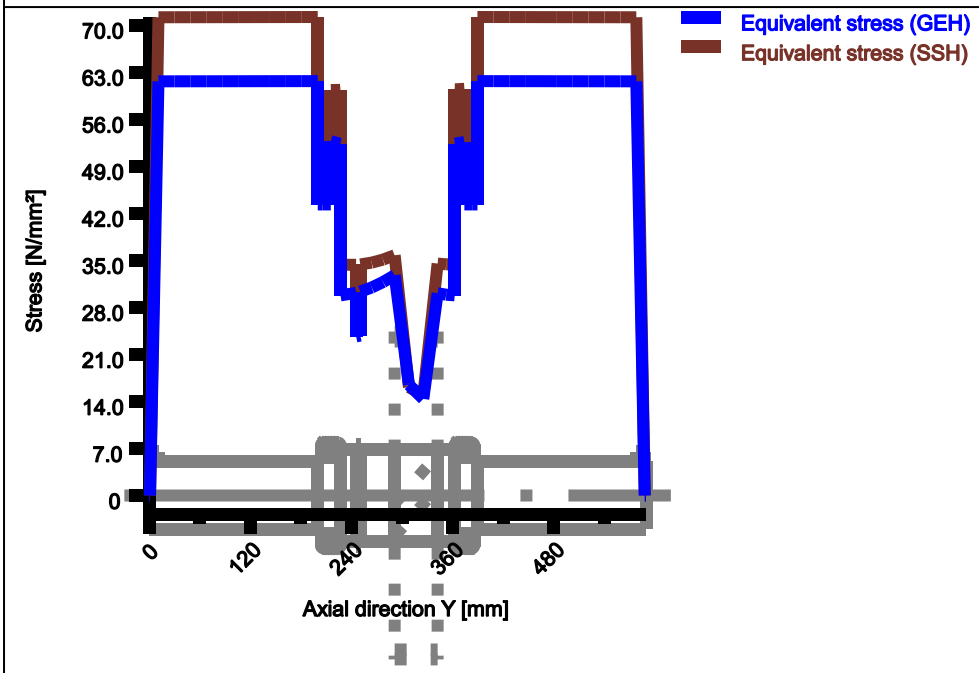


Figure: Deformation (bending etc.) (Arbitrary plane 61.74375887 127)



Nominal stresses, without taking into account stress concentrations
GEH(von Mises): sigV = ((sigB+sigZ,D)^2 + 3*(tauT+tauS)^2)^1/2
SSH(Tresca): sigV = ((sigB-sigZ,D)^2 + 4*(tauT+tauS)^2)^1/2

Figure: Equivalent stress

4.2 Bearing

Probability of failure	[n]	10.00	%
Axial clearance (ISO 281)	[u_A]	10.00	µm
Lubricant	ISO-VG 220		
Lubricant - service temperature	[T_B]	70.00	°C
Rolling bearing rating life according to ISO/TS 16281:2008			

4.3 'Shaft4' Rolling bearing 'G'

Position (Y-coordinate)	[y]	215.50	mm
Dynamic equivalent load	[P]	40.36	kN
Static equivalent load	[P_0]	28.47	kN
Minimum EHL lubricant film thickness	[h_{min}]	0.016	µm
Life modification factor for reliability	[a_1]	1.000	

4.3.1 Operating bearing clearance

Total diametral clearance change	[ΔPd]	-6.167	µm
Operating diametral clearance	[Pd]	-6.167	µm
Operating axial clearance	[Pa]	-13.106	µm

4.3.2 Results according to ISO 281

Lubricant	ISO-VG 220		
Load ratio	[C/P]	2.948	
Operating viscosity	[v]	48.884	mm²/s

Reference viscosity	[v_1]	0.000	mm²/s
Viscosity ratio	[κ]	0.000	
Basic bearing rating life	[L_{nh}]	21849.16	h
Static safety factor	[S_0]	5.83	

4.3.3 Calculation with proprietary bearing internal geometry data (ISO/TS 16281)

Contamination factor	[e_C]	0.045	
Fatigue load limit	[C_u]	18.300	kN
Reference rating life	[L_{nrh}]	86979.69	h
Maximum pressure inner ring	[p_{max_i}]	1802.739	N/mm²
Effective static safety factor	[S_{0w}]	4.92	
Static safety factor	[S_{0ref}]	4.81	
Static equivalent load	[P_{0ref}]	34.49	kN

4.3.4 Bearing reactions

Bearing reaction force	[F_x]	21.413	kN
Bearing reaction force	[F_y]	17.948	kN
Bearing reaction force	[F_z]	-12.161	kN
Bearing reaction force	[F_r]	24.625	kN
Inclination angle	[α_{Fr}]	-29.593	°
Bearing reaction moment	[M_x]	-165.255	Nm
Bearing reaction moment	[M_y]	0.000	Nm
Bearing reaction moment	[M_z]	-264.707	Nm
Bearing reaction moment	[M_r]	312.056	Nm
Inclination angle	[α_{Mr}]	-121.976	°
Displacement of bearing	[u_x]	-7.023	µm
Displacement of bearing	[u_y]	-45.150	µm
Displacement of bearing	[u_z]	0.603	µm
Displacement of bearing	[u_r]	7.048	µm
Inclination angle	[α_{ur}]	175.091	°
Misalignment of bearing	[r_x]	0.208	mrad
Misalignment of bearing	[r_y]	-2.287	mrad
Misalignment of bearing	[r_z]	-0.109	mrad
Misalignment of bearing	[r_r]	0.235	mrad

4.3.5 Friction and power loss

Oil level	[H]	0.000	mm
Rolling moment of friction	[M_{rr}]	0.632	Nm
Sliding moment of friction	[M_{sl}]	4.004	Nm
Moment of friction, seals	[M_{seal}]	0.000	Nm
Moment of friction for seals determined according to SKF main catalog 17000/1 EN:2018			
Moment of friction flow losses	[M_{drag}]	0.000	Nm
Torque of friction	[M_{loss}]	4.636	Nm
Power loss	[P_{loss}]	13.609	W

The moment of friction is calculated according to the details in SKF Catalog 2018.
The calculation is always performed with a coefficient for additives in the lubricant µbl=0.15.

4.4 'Shaft4' Rolling bearing 'H'

Position (Y-coordinate)	[y]	374.00	mm
Dynamic equivalent load	[P]	24.86	kN
Static equivalent load	[P_0]	24.86	kN
Minimum EHL lubricant film thickness	[h_{min}]	0.016	µm
Life modification factor for reliability	[a_1]	1.000	

4.4.1 Operating bearing clearance

Total diametral clearance change	[ΔPd]	0.000	µm
Operating diametral clearance	[Pd]	0.000	µm

Operating axial clearance	[Pa]	0.000	µm

4.4.2 Results according to ISO 281

Lubricant	ISO-VG 220		
Load ratio	[C/P]	4.786	
Operating viscosity	[v]	48.884	mm²/s
Reference viscosity	[v_1]	0.000	mm²/s
Viscosity ratio	[κ]	0.000	
Basic bearing rating life	[L_{nh}]	109837.79	h
Static safety factor	[S_0]	6.68	

4.4.3 Calculation with proprietary bearing internal geometry data (ISO/TS 16281)

Contamination factor	[e_C]	0.045	
Fatigue load limit	[C_u]	18.300	kN
Reference rating life	[L_{nrh}]	210685.14	h
Maximum pressure inner ring	[p_{max_i}]	1798.021	N/mm²
Effective static safety factor	[S_{0w}]	4.95	
Static safety factor	[S_{0ref}]	5.04	
Static equivalent load	[P_{0ref}]	32.93	kN

4.4.4 Bearing reactions

Bearing reaction force	[F_x]	-6.655	kN
Bearing reaction force	[F_y]	-6.612	kN
Bearing reaction force	[F_z]	-23.957	kN
Bearing reaction force	[F_r]	24.864	kN
Inclination angle	[α_{Fr}]	-105.525	°
Bearing reaction moment	[M_x]	299.322	Nm
Bearing reaction moment	[M_y]	0.000	Nm
Bearing reaction moment	[M_z]	-82.365	Nm
Bearing reaction moment	[M_r]	310.448	Nm
Inclination angle	[α_{Mr}]	-15.385	°
Displacement of bearing	[u_x]	9.940	µm
Displacement of bearing	[u_y]	-46.042	µm
Displacement of bearing	[u_z]	32.062	µm
Displacement of bearing	[u_r]	33.567	µm
Inclination angle	[α_{ur}]	72.774	°
Misalignment of bearing	[r_x]	0.192	mrad
Misalignment of bearing	[r_y]	-2.420	mrad
Misalignment of bearing	[r_z]	-0.136	mrad
Misalignment of bearing	[r_r]	0.235	mrad

4.4.5 Friction and power loss

Oil level	[H]	0.000	mm
Rolling moment of friction	[M_{rr}]	0.480	Nm
Sliding moment of friction	[M_{sl}]	2.213	Nm
Moment of friction, seals	[M_{seal}]	0.000	Nm
Moment of friction for seals determined according to SKF main catalog 17000/1 EN:2018			
Moment of friction flow losses	[M_{drag}]	0.000	Nm
Torque of friction	[M_{loss}]	2.694	Nm
Power loss	[P_{loss}]	7.907	W

The moment of friction is calculated according to the details in SKF Catalog 2018.
The calculation is always performed with a coefficient for additives in the lubricant µbl=0.15.

(*) Note about roller bearings with an approximated bearing geometry:
The internal geometry of these bearings has not been input in the database.
The geometry is back-calculated as specified in ISO 281, from C and C0 (details in the manufacturer's catalog).
For this reason, the geometry may be different from the actual geometry.
This can lead to differences in the service life calculation and, more importantly, the roller bearing stiffness.

4.5 Damage relative to the required service life (L_{req} = 20000 h)

Load case	B1	B2
1	22.99	9.49
Σ	22.99	9.49

B1 : G (SKF 32918)
B2 : H (SKF 32918)

4.6 Utilization relative to the required service life (L_{req} = 20000 h)

Rolling bearings	B1	B2
Utilization (%)	64.34	49.34

Note: Utilization = $(L_{req}/L_h)^{(1/k)}$
Ball bearing: k = 3, roller bearing: k = 10/3

B1 : G (SKF 32918)
B2 : H (SKF 32918)

4.7 Calculation of the factors required to define reliability R(t) using the Weibull distribution. t in (h)

Reliability not calculated

4.7.1 Shaft 'Shaft4', Dokumentationspunkt Documentation point

Y position (mm)	[y]	291.00
Equivalent stress (N/mm²)	[σ_V]	32.75
Equivalent stress (Tresca) (N/mm²)	[σ_V]	35.73
Bending Stress (N/mm²)	[σ_b]	11.91
Principal stress (N/mm²)	[σ_{zd}]	-1.89
Shear stress (torsion) (N/mm²)	[τ_T]	13.69
Shear stress (shearing force) (N/mm²)	[τ_Q]	3.46

	X	Y	Z	R
Displacement (mm)	-0.0009	-0.0459	0.0175	0.0175
Rotation (mrad)	0.1932	-2.5635	-0.1351	0.2358
Force (kN)	-21.4129	-17.9480	12.2985	24.6934
Torque (Nm)	-770.1620	-3576.6785	-1351.9707	1555.9480