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Team-SolidSQUAD

File

Name : Bakalarska prace

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CALCULATION OF A HELICAL GEAR PAIR

Drawing or article number:

Gear 1: 2018-03-01

Gear 2: 2018-03-02

Calculation method DIN 3990:1987 Method B

		------- GEAR 1	-------- GEAR 2 --
Power (kW)	[P]	13.492	
Speed (1/min)	[n]	15.0	2.2
Torque (Nm)	[T]	8589.0	57737.2
Application factor	[KA]	1.75	
Required service life (h)	[H]	120000.00	
Gear driving (+) / driven (-)		+	-

Working flank gear 1: Right flank

Sense of rotation gear 1 clockwise

1. TOOTH GEOMETRY AND MATERIAL

(geometry calculation according to ISO 21771:2007, DIN ISO 21771)

		------- GEAR 1	-------- GEAR 2 --
Center distance (mm)	[a]	560.045	
Centre distance tolerance	ISO 286:2010 Measure js7		
Normal module (mm)	[mn]	8.0000	
Pressure angle at normal section (°)	[alfn]	20.0000	
Helix angle at reference circle (°)	[beta]	8.0000	
Number of teeth	[z]	18	121
Facewidth (mm)	[b]	169.00	162.00
Hand of gear		left	right
Chamfer facewidth (mm)	[bK]	0.50	0.50
Accuracy grade	[Q-DIN 3961:1978]	6	6
Inner diameter (mm)	[di]	0.00	0.00
Inner diameter of gear rim (mm)	[dbi]	0.00	0.00

Material

Gear 1: 18CrNiMo7-6, Case-carburized steel, case-hardened
ISO 6336-5 Figure 9/10 (MQ), Core hardness >=30HRC

Gear 2: 18CrNiMo7-6, Case-carburized steel, case-hardened
ISO 6336-5 Figure 9/10 (MQ), Core hardness >=30HRC

		------- GEAR 1	-------- GEAR 2 --
Surface hardness		HRC 61	HRC 61
Fatigue strength. tooth root stress (N/mm²)	[σFlim]	500.00	500.00
Fatigue strength for Hertzian pressure (N/mm²)	[σHlim]	1500.00	1500.00
Tensile strength (N/mm²)	[σB]	1200.00	1200.00
Yield point (N/mm²)	[σS]	850.00	850.00
Young's modulus (N/mm²)	[E]	206000	206000
Poisson's ratio	[v]	0.300	0.300
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

Information on pre-machining

Gear reference profile 1 :		
Reference profile (Own input)		
Final machining stock (mm)	[q]	0.250
Dedendum coefficient	[hfP*]	1.313
Root radius factor	[rhofP*]	0.200 (rhofPmax*= 0.439)
Addendum coefficient	[haP*]	1.000
Tip radius factor	[rhoaP*]	0.000
Protuberance height coefficient	[hprP*]	0.000
Protuberance angle	[alfprP]	0.000
Tip form height coefficient	[hFaP*]	0.000
Ramp angle	[alfKP]	0.000
	not topping	

Gear reference profile 2 :		
Reference profile (Own input)		
Final machining stock (mm)	[q]	0.250
Dedendum coefficient	[hfP*]	1.313
Root radius factor	[rhofP*]	0.200 (rhofPmax*= 0.439)
Addendum coefficient	[haP*]	1.000
Tip radius factor	[rhoaP*]	0.000
Protuberance height coefficient	[hprP*]	0.000
Protuberance angle	[alfprP]	0.000
Tip form height coefficient	[hFaP*]	0.000
Ramp angle	[alfKP]	0.000
	not topping	

Information on final machining

Dedendum reference profile	[hfP*]	1.222	1.222
Tooth root radius Refer. profile	[rofP*]	0.200	0.200
Addendum Reference profile	[haP*]	1.000	1.000
Protuberance height coefficient	[hprP*]	0.000	0.000
Protuberance angle (°)	[alfprP]	0.000	0.000
Tip form height coefficient	[hFaP*]	0.000	0.000
Ramp angle (°)	[alfKP]	0.000	0.000
Data for Grinding / Honing:			
Depth of immersion	[hgrind*]	1.156	1.156
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 (µm)	[Ca]	23.0	10.0

Lubrication type		Oil bath lubrication
Type of oil		Oil: Klübersynth GE 4 75 W 90
Lubricant base		Synthetic oil based on Polyglycol
Kinem. viscosity oil at 40 °C (mm²/s)	[nu40]	130.00
Kinem. viscosity oil at 100 °C (mm²/s)	[nu100]	18.00
Specific density at 15 °C (kg/dm³)	[roOil]	0.860
Oil temperature (°C)	[TS]	70.000

		------- GEAR 1 --------	GEAR 2 --
Overall transmission ratio	[itot]	-6.722	
Gear ratio	[u]	6.722	
Transverse module (mm)	[mt]	8.079	
Pressure angle at pitch circle (°)	[alft]	20.181	
Working transverse pressure angle (°)	[alfwt]	19.782	
	[alfwt.e/i]	19.792 / 19.772	
Working pressure angle at normal section (°)	[alfwn]	19.605	
Helix angle at operating pitch circle (°)	[betaw]	7.980	
Base helix angle (°)	[betab]	7.515	
Reference centre distance (mm)	[ad]	561.464	
Sum of profile shift coefficients	[Summexi]	-0.1758	
Profile shift coefficient			
Information on pre-machining	[x]	0.4914	-0.4844
Information on final machining	[x]	0.4000	-0.5758
Tooth thickness (Arc) (module) (module)	[sn*]	1.8620	1.1517
Tip alteration (mm)	[k*mn]	-0.013	-0.013
Reference diameter (mm)	[d]	145.415	977.513
Base diameter (mm)	[db]	136.488	917.502
Tip diameter (mm)	[da]	167.789	984.275
(mm)	[da.e/i]	167.789 / 167.779	984.275 / 984.265
Tip diameter allowances (mm)	[Ada.e/i]	0.000 / -0.010	0.000 / -0.010
Tip form diameter (mm)	[dFa]	167.789	984.275
(mm)	[dFa.e/i]	167.789 / 167.779	984.275 / 984.265
Active tip diameter (mm)	[dNa]	167.789	984.275
Active tip diameter (mm)	[dNa.e/i]	167.789 / 167.779	984.275 / 984.265
Operating pitch diameter (mm)	[dw]	145.048	975.042
(mm)	[dw.e/i]	145.057 / 145.038	975.103 / 974.981
Root diameter (mm)	[df]	132.269	948.754
Generating Profile shift coefficient			
Information on pre-machining	[xE.e/i]	0.4751 / 0.4665	-0.5145 / -0.5282
Information on final machining	[xE.e/i]	0.3837 / 0.3751	-0.6058 / -0.6196
Manufactured root diameter with xE (mm)	[df.e/i]	132.008 / 131.871	948.274 / 948.054
(calculated with pre-machining tool)			
Theoretical tip clearance (mm)	[c]	1.773	1.773
Effective tip clearance (mm)	[c.e/i]	2.163 / 1.978	2.012 / 1.868
Active root diameter (mm)	[dNf]	138.368	959.712
(mm)	[dNf.e/i]	138.407 / 138.334	959.778 / 959.652
Root form diameter (mm)	[dFf]	137.691	953.621
(mm)	[dFf.e/i]	137.593 / 137.544	953.242 / 953.069
(calculated with final machining tool)			
Reserve (dNf-dFf)/2 (mm)	[cF.e/i]	0.432 / 0.370	3.354 / 3.205
Addendum (mm)	[ha=mn*(haP*+x+k)]	11.187	3.381
(mm)	[ha.e/i]	11.187 / 11.182	3.381 / 3.376
Dedendum (mm)	[hf=mn*(hfP*-x)]	6.573	14.379
(mm)	[hf.e/i]	6.703 / 6.772	14.620 / 14.730
Roll angle at dFa (°)	[xsi_dFa.e/i]	40.968 / 40.961	22.253 / 22.251
Roll angle to dNa (°)	[xsi_dNa.e/i]	40.968 / 40.961	22.253 / 22.251
Roll angle to dNf (°)	[xsi_dNf.e/i]	9.641 / 9.456	17.592 / 17.565
Roll angle at dFf (°)	[xsi_dFf.e/i]	7.307 / 7.140	16.147 / 16.107
Tooth height (mm)	[h]	17.760	17.760
Virtual gear no. of teeth	[zn]	18.493	124.315
Normal tooth thickness at tip circle (mm)	[san]	4.055	6.736
(mm)	[san.e/i]	3.953 / 3.888	6.564 / 6.479
Normal-tooth thickness on tip form circle (mm)	[sFan]	4.055	6.736
(mm)	[sFan.e/i]	3.953 / 3.888	6.564 / 6.479
Normal space width at root circle (mm)	[efn]	0.000	6.540

(mm)	[efn.e/i]	0.000 /	0.000		6.582 /	6.601		
Max. sliding velocity at tip (m/s)	[vga]		0.044			0.024		
Specific sliding at the tip	[zetaa]		0.571			0.571		
Specific sliding at the root	[zetaf]		-1.332			-1.331		
Mean specific sliding	[zetam]			0.571				
Sliding factor on tip	[Kga]		0.384			0.209		
Sliding factor on root	[Kgf]		-0.209			-0.384		
Pitch on reference circle (mm)	[pt]			25.380				
Base pitch (mm)	[pbt]			23.822				
Transverse pitch on contact-path (mm)	[pet]			23.822				
Lead height (mm)	[pz]		3250.552			21850.930		
Axial pitch (mm)	[px]			180.586				
Length of path of contact (mm)	[ga, e/i]		37.430 (	37.533 /	37.304)			
Length T1-A, T2-A (mm)	[T1A, T2A]	11.366(	11.263/	11.484)	178.175(	178.175/	178.161)	
Length T1-B (mm)	[T1B, T2B]	24.975(	24.975/	24.966)	164.567(	164.463/	164.679)	
Length T1-C (mm)	[T1C, T2C]	24.545(	24.532/	24.558)	164.997(	164.906/	165.087)	
Length T1-D (mm)	[T1D, T2D]	35.188(	35.085/	35.305)	154.353(	154.353/	154.340)	
Length T1-E (mm)	[T1E, T2E]	48.796(	48.796/	48.788)	140.745(	140.642/	140.857)	
Length T1-T2 (mm)	[T1T2]		189.541 (	189.438 /	189.645)			
Diameter of single contact point B (mm)	[d-B]	145.341(	145.341/	145.335)	974.751(	974.681/	974.827)	
Diameter of single contact point D (mm)	[d-D]	153.564(	153.469/	153.671)	968.045(	968.045/	968.036)	
Addendum contact ratio	[eps]	1.018(	1.019/	1.017)	0.553(	0.557/	0.549)	
Minimal length of contact line (mm)	[Lmin]			246.694				
Transverse contact ratio	[eps_a]			1.571				
Transverse contact ratio with allowances	[eps_a.e/m/i]		1.576 /	1.571 /	1.566			
Overlap ratio	[eps_b]			0.892				
Total contact ratio	[eps_g]			2.463				
Total contact ratio with allowances	[eps_g.e/m/i]		2.467 /	2.462 /	2.458			

2. FACTORS OF GENERAL INFLUENCE

		------- GEAR 1 --------	GEAR 2 --
Nominal circum. force at pitch circle (N)	[Ft]	118130.7	
Axial force (N)	[Fa]	16602.2	
Radial force (N)	[Fr]	43418.6	
Normal force (N)	[Fnorm]	126947.5	
Nominal circumferential force per mm (N/mm)	[w]	733.73	
Only as information: Forces at operating pitch circle:			
Nominal circumferential force (N)	[Ftw]	118430.2	
Axial force (N)	[Faw]	16602.2	
Radial force (N)	[Frw]	42595.1	
Circumferential speed reference circle (m/s)	[v]	0.11	
Circumferential speed operating pitch circle (m/s)	[v(dw)]	0.11	
Running-in value (µm)	[yp]	0.9	
Running-in value (µm)	[yf]	1.1	
Correction coefficient	[CM]	0.800	
Gear body coefficient	[CR]	1.000	
Basic rack factor	[CBS]	0.989	
Material coefficient	[E/Est]	1.000	
Singular tooth stiffness (N/mm/µm)	[c']	13.911	
Meshing stiffness (N/mm/µm)	[cg]	19.871	
Reduced mass (kg/mm)	[mRed]	0.08149	
Resonance speed (min-1)	[nE1]	8284	
Resonance ratio (-)	[N]	0.002	
Subcritical range			

Running-in value (µm)	[ya]		0.9	
Bearing distance l of pinion shaft (mm)	[l]		338.000	
Distance s of pinion shaft (mm)	[s]		101.400	
Outside diameter of pinion shaft (mm)	[dsh]		132.200	
Load according to Figure 6.8, DIN 3990-1:1987 (0:6.8a, 1:6.8b, 2:6.8c, 3:6.8d, 4:6.8e)	[-]	2		
Coefficient K' according to Figure 6.8, DIN 3990-1:1987	[K']	1.33		
Without support effect				
Tooth trace deviation (active) (µm)	[Fby]		10.21	
from deformation of shaft (µm)	[fsh*B1]		15.05	
(fsh (µm) = 150.49, B1= 0.10, fHb5 (µm) = 8.00)				
Tooth trace: width-crowned with helix angle modification				
(Factors from ISO 9085:2002)				
Position of Contact pattern: favorable				
from production tolerances (µm)	[fma*B2]		5.50	
(B2= 0.50)				
Tooth trace deviation, theoretical (µm)	[Fbx]		12.02	
Running-in value (µm)	[yb]		1.80	
Dynamic factor	[KV]		1.000	
Face load factor - flank	[KHb]		1.079	
- Tooth root	[KFb]		1.070	
- Scuffing	[KBb]		1.079	
Transverse load factor - flank	[KHa]		1.000	
- Tooth root	[KFa]		1.000	
- Scuffing	[KBa]		1.000	
Helical load factor scuffing	[Kbg]		1.217	
Number of load cycles (in mio.)	[NL]	108.000		16.066

3. TOOTH ROOT STRENGTH

Calculation of Tooth form coefficients according method: B

		------- GEAR 1	-------- GEAR 2 --
Calculated with profile shift	[x]	0.4914	-0.4844
Tooth form factor	[YF]	1.16	1.47
Stress correction factor	[YS]	2.65	2.13
Grinding notch tg / rog	[tg/rog]	0.073	0.074
(tg, rog (mm): 0.134/ 1.852 0.200/ 2.683)			
Additional coefficient for grinding notch	[Yg'=YSg/YS]	1.14	1.14
Working angle (°)	[alfFen]	22.29	18.92
Bending moment arm (mm)	[hF]	7.46	10.01
Tooth thickness at root (mm)	[sFn]	17.46	18.15
Tooth root radius (mm)	[roF]	2.53	3.40
(hF* = 0.933/ 1.251 sFn* = 2.183/ 2.269 roF* = 0.316/ 0.425)			
(den (mm) = 155.706/ 991.486 dsFn(mm) = 133.942/ 951.070 alfsFn(°) = 30.00/ 30.00 qs = 3.454/ 2.670)			

Contact ratio factor	[Yeps]	1.000	
Helix angle factor	[Ybet]	0.941	
Effective facewidth (mm)	[beff]	169.00	162.00
Nominal stress at tooth root (N/mm²)	[sigF0]	287.32	307.26
Tooth root stress (N/mm²)	[sigF]	538.17	575.51

Permissible bending stress at root of Test-gear				
Notch sensitivity factor	[YdrelT]	1.008	1.002	
Surface factor	[YRrelT]	0.957	0.957	
size factor (Tooth root)	[YX]	0.970	0.970	
Finite life factor	[YNT]	1.000	1.000	
[YdrelT*YRrelT*YX*YNT]		0.936	0.930	
Alternating bending factor (mean stress influence coefficient)	[YM]	1.000		1.000
Stress correction factor	[Yst]	2.00		
Yst*sigFlim (N/mm²)	[sigFE]	1000.00	1000.00	
Permissible tooth root stress (N/mm²)	[sigFP=sigFG/SFmin]	668.44	663.93	
Limit strength tooth root (N/mm²)	[sigFG]	935.81	929.50	
Required safety	[SFmin]	1.40	1.40	
Safety for tooth root stress	[SF=sigFG/sigF]	1.74	1.62	
Transmittable power (kW)	[kWRating]	16.76	15.56	

4. SAFETY AGAINST PITTING (TOOTH FLANK)

		------- GEAR 1	-------- GEAR 2 --
Zone factor	[ZH]	2.502	
Elasticity factor (√N/mm²)	[ZE]	189.812	
Contact ratio factor	[Zeps]	0.809	
Helix angle factor	[Zbet]	0.995	
Effective facewidth (mm)	[beff]	161.00	
Nominal contact stress (N/mm²)	[sigH0]	920.82	
Contact stress at operating pitch circle (N/mm²)	[sigHw]	1265.53	
Single tooth contact factor	[ZB,ZD]	1.00	1.00
Contact stress (N/mm²)	[sigHB, sigHD]	1265.53	1265.53
Lubrication coefficient at NL	[ZL]	0.982	0.986
Speed coefficient at NL	[ZV]	0.938	0.949
Roughness coefficient at NL	[ZR]	1.008	1.007
Material pairing coefficient at NL	[ZW]	1.000	1.000
Finite life factor	[ZNT]	1.000	1.090
	[ZL*ZV*ZR*ZNT]	0.929	1.026
Limited pitting is permitted:	No		
Size factor (flank)	[ZX]	1.000	1.000
Permissible contact stress (N/mm²)	[sigHP=sigHG/SHmin]	1394.23	1539.66
Pitting stress limit (N/mm²)	[sigHG]	1394.23	1539.66
Required safety	[SHmin]	1.00	1.00
Safety factor for contact stress at operating pitch circle			
	[SHw]	1.10	1.22
Safety for stress at single tooth contact	[SHBD=sigHG/sigHBD]	1.10	1.22
(Safety regarding transmittable torque)	[(SHBD)^2]	1.21	1.48
Transmittable power (kW)	[kWRating]	16.38	19.97

4b. MICROPITTING ACCORDING TO ISO/TR 15144-1:2014

Calculation of permissible specific film thickness			
Lubricant load according to FVA Info sheet 54/7	10	(Oil: Klübersynth GE 4 75 W 90)	
Reference data FZG-C Test:			
Torque (Nm)	[T1Ref]	265.1	
Line load at contact point A (N/mm)	[FbbRef,A]	236.3	
Oil temperature (°C)	[theOilRef]	90.0	

Tooth mass temperature (°C)	[theMRef]	119.3	
Contact temperature (°C)	[theBRef,A]	206.7	
Lubrication gap thickness (µm)	[hRef,A]	0.066	
Specific film thickness in test (µm)	[lamGFT]	0.131	
Material coefficient	[WW]	1.00	
Permissible specific film thickness (µm)	[lamGFP]	0.184	

Interim results in accordance with ISO/TR 15144:2014

Coefficient of friction	[mym]	0.096	
Lubricant factor	[XL]	0.700	
Roughness factor	[XR]	0.899	
Tooth mass temperature (°C)	[theM]	70.4	
Tip relief factor	[XCa (A)]	1.404	
Loss factor	[HV]	0.156	
Equivalent Young's modulus (N/mm²)	[Er]	226374	
Pressure-viscosity coefficient (m²/N)	[alf38]	0.01301	
Dynamic viscosity (Ns/m²)	[etatM]	33.5	
Roughness average value (µm)	[Ra]	0.6	

Calculation of speeds, load distribution and flank curvature according to method B following ISO/TR 15144-1:2014

Ca taken as optimal in the calculation (0=no, 1=yes)		0	0
Calculation at point (0:A, 1:AB, 2:B, 3:C, 4:D, 5:DE, 6:E, -1:No Point)			0
Diameter (mm)	[dy]	138.368	984.275
Relative radius of curvature (mm)	[pred]	10.777	
Load sharing factor	[XY]	0.510	

(XY interpolated between XY(eps.b=0.8) and XY(eps.b=1.2) according ISO/TC60/WG6)

Contact stress (N/mm²)	[pH]	1154.917	
Contact stress (N/mm²)	[pdyn]	1587.248	
Minimal specific film thickness (µm)	[lamGFY]	0.018	(hY=0.011 µm)
Safety against micropitting	[Slam(B)]	0.099	

(For intermediate results refer to file: Micropitting_12.tmp)

5. SCUFFING LOAD CAPACITY

Calculation method according to DIN 3990:1987

Lubrication coefficient (for lubrication type)	[XS]	1.000	
Scuffing test and load stage	[FZGtest]	FZG - Test A / 8.3 / 90 (ISO 14635 - 1)	14
Relative structure coefficient (Scuffing)	[XWrelT]	1.000	
Thermal contact factor (N/mm/s^.5/K)	[BM]	13.780	13.780
Relevant tip relief (µm)	[Ca]	23.00	10.00
Optimal tip relief (µm)	[Ceff]	64.22	
Ca taken as optimal in the calculation (0=no, 1=yes)		0	0
Effective facewidth (mm)	[beff]	161.000	
Applicable circumferential force/facewidth (N/mm)	[wBt]	1686.229	
Angle factor	[Xalfbet]	0.972	

(ε1:1.018, ε2:0.553)

Flash temperature-criteria

Tooth mass temperature (°C)	[theMB]	90.01

(theMB = theoil + XS*0.47*theflamax)

Maximum flash temperature (°C)	[theflamax]	42.57
Scuffing temperature (°C)	[theS]	551.53
Coordinate gamma (point of highest temp.)	[Gamma]	0.434

[Gamma.A]=-0.537 [Gamma.E]=0.988

Highest contact temp. (°C)	[theB]	132.58
Flash factor (°K*N^-.75*s^.5*m^-.5*mm)	[XM]	50.058
Geometry factor	[XB]	0.188

Load sharing factor	[XGam]	1.000
Dynamic viscosity (mPa*s)	[etaM]	18.99 (70.0 °C)
Coefficient of friction	[mym]	0.254
Required safety	[SBmin]	2.000
Safety factor for scuffing (flash temperature)	[SB]	7.694
Integral temperature-criteria		
Tooth mass temperature (°C)	[theMC]	80.16
(theMC = theoil + XS*0.70*theflaint)		
Mean flash temperature (°C)	[theflaint]	14.51
Integral scuffing temperature (°C)	[theSint]	551.53
Flash factor (°K*N^-.75*s^.5*m^-.5*mm)	[XM]	50.058
Contact ratio factor	[Xeps]	0.243
Dynamic viscosity (mPa*s)	[etaOil]	33.89 (70.0 °C)
Mean coefficient of friction	[mym]	0.247
Geometry factor	[XBE]	0.375
Meshing factor	[XQ]	1.000
Tip relief factor	[XCa]	1.383
Integral tooth flank temperature (°C)	[theint]	101.92
Required safety	[SSmin]	1.800
Safety factor for scuffing (intg.-temp.)	[SSint]	5.411
Safety referring to transmittable torque	[SSL]	15.083

6. MEASUREMENTS FOR TOOTH THICKNESS

		------- Gear 1	------ Gear 2 --
Information on pre-machining			
Tooth thickness allowance (final machining) (mm)	[As.e/i]	-0.095 / -0.145	-0.175 / -0.255
Final machining stock (per flank) (mm)	[q]	0.250	0.250
Additional measure for pre-machining (mm)	[ΔAs_pre.e/i]	0.532 / 0.532	0.532 / 0.532
Tooth thickness allowance (normal section) (mm)	[As_pre.e/i]	0.437 / 0.387	0.357 / 0.277
Number of teeth spanned	[k]	3.000	13.000
Actual base tangent length ('span') (mm)	[Wk.e/i]	63.716 / 63.669	306.339 / 306.264
(mm)	[ΔWk.e/i]	0.411 / 0.364	0.336 / 0.260
Effective diameter of ball/pin (mm)	[DMeff]	16.000	14.000
Diametral two ball measure (mm)	[MdK.e/i]	176.725 / 176.635	989.594 / 989.371

Information on final machining			
Tooth thickness deviation		DIN 3967 cd25	DIN 3967 cd25
Tooth thickness allowance (normal section) (mm)	[As.e/i]	-0.095 / -0.145	-0.175 / -0.255
Number of teeth spanned	[k]	3.000	13.000
Base tangent length (no backlash) (mm)	[Wk]	63.306	306.004
Actual base tangent length ('span') (mm)	[Wk.e/i]	63.216 / 63.169	305.839 / 305.764
(mm)	[ΔWk.e/i]	-0.089 / -0.136	-0.164 / -0.240
Diameter of measuring circle (mm)	[dMWk.m]	150.180	966.295
Point of contact in profile-modified area (0=no, 1=yes)		1	0
(! measurement imprecise!)			
Theoretical diameter of ball/pin (mm)	[DM]	15.625	13.311
Effective diameter of ball/pin (mm)	[DMeff]	16.000	14.000
Radial single-ball measurement backlash free (mm)	[MrK]	87.967	494.339
Radial single-ball measurement (mm)	[MrK.e/i]	87.881 / 87.835	494.092 / 493.979
Point of contact in profile-modified area (0=no, 1=yes)		1	0
(! measurement imprecise!)			
Diameter of measuring circle (mm)	[dMMr.m]	152.083	969.499
Diametral measurement over two balls without clearance (mm)	[MdK]	175.935	988.595

Diametral two ball measure (mm)	[MdK.e/i]	175.762 / 175.671	988.103 / 987.877
Diametral measurement over pins without clearance (mm)	[MdR]	175.935	988.677
Measurement over pins according to DIN 3960 (mm)	[MdR.e/i]	175.762 / 175.671	988.185 / 987.959
Measurement over 2 pins (free) according to AGMA 2002 (mm)	[dk2f.e/i]	0.000 / 0.000	988.101 / 987.875
Measurement over 2 pins (transverse) according to AGMA 2002 (mm)	[dk2t.e/i]	0.000 / 0.000	988.266 / 988.041
Measurement over 3 pins (axial) according to AGMA 2002 (mm)	[dk3A.e/i]	175.762 / 175.671	988.185 / 987.959
Chordal tooth thickness (no backlash) (mm)	[sc]	14.871	9.213
Actual chordal tooth thickness (mm)	[sc.e/i]	14.776 / 14.726	9.038 / 8.958
Reference chordal height from da.m (mm)	[ha]	11.559	3.399
Tooth thickness (Arc) (mm)	[sn]	14.896	9.213
(mm)	[sn.e/i]	14.801 / 14.751	9.038 / 8.958
Backlash free center distance (mm)	[aControl.e/i]	559.666 /559.482	
Backlash free center distance, allowances (mm)	[jta]	-0.379 / -0.562	
dNf.i with aControl (mm)	[dNf0.i]	137.859	958.739
Reserve (dNf0.i-dFf.e)/2 (mm)	[cF0.i]	0.133	2.748
Tip clearance (mm)	[c0.i(aControl)]	1.451	1.341
Centre distance allowances (mm)	[Aa.e/i]	0.035 / -0.035	
Circumferential backlash from Aa (mm)	[jtw_Aa.e/i]	0.025 / -0.025	
Radial clearance (mm)	[jrw]	0.597 / 0.344	
Circumferential backlash (transverse section) (mm)	[jtw]	0.428 / 0.247	
Normal backlash (mm)	[jnw]	0.398 / 0.230	
Torsional angle at entry with fixed output:			
Entire torsional angle (°)	[j.tSys]	0.3382/ 0.1950	

7. GEAR ACCURACY

		------- GEAR 1	-------- GEAR 2 --
According to DIN 3961:1978			
Accuracy grade	[Q-DIN3961]	6	6
Profile form deviation (µm)	[ff]	14.00	14.00
Profile slope deviation (µm)	[fHa]	9.00	9.00
Total profile deviation (µm)	[Ff]	16.00	16.00
Helix form deviation (µm)	[fbf]	14.00	14.00
Helix slope deviation (µm)	[fHb]	11.00	11.00
Total helix deviation (µm)	[Fb]	18.00	18.00
Normal base pitch deviation (µm)	[fpe]	11.00	12.00
Single pitch deviation (µm)	[fp]	11.00	12.00
Adjacent pitch difference (µm)	[fu]	13.00	15.00
Total cumulative pitch deviation (µm)	[Fp]	37.00	48.00
Sector pitch deviation over z/8 pitches (µm)	[Fpz/8]	23.00	30.00
Runout (µm)	[Fr]	28.00	35.00
Tooth Thickness Variation (µm)	[Rs]	16.00	21.00
Single flank composite, total (µm)	[Fi']	43.00	52.00
Single flank composite, tooth-to-tooth (µm)	[fi']	19.00	20.00
Radial composite, total (µm)	[Fi'']	31.00	38.00
Radial composite, tooth-to-tooth (µm)	[fi'']	14.00	17.00

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

6)

Maximum value for deviation error of axis (µm)	[fSigbet]	23.09 (Fb= 22.00)
Maximum value for inclination error of axes (µm)	[fSigdel]	46.19

8. ADDITIONAL DATA

Mass (kg)	[m]	23.393	930.644
Total mass (kg)	[m]	954.037	
Moment of inertia (system with reference to the drive):			
calculation without consideration of the exact tooth shape			
single gears ((da+df)/2...di) (kg*m²)	[TraeghMom]	0.06582	108.67011
System ((da+df)/2...di) (kg*m²)	[TraeghMom]	2.47065	
Torsional stiffness at entry with driven force fixed:			
Torsional stiffness (MNm/rad)	[cr]	14.937	
Torsion when subjected to nominal torque (°)	[delcr]	0.033	
Mean coeff. of friction (acc. Niemann)	[mum]	0.063	
Wear sliding coef. by Niemann	[zetw]	0.897	
Gear power loss (kW)	[PVZ]	0.133	
(Meshing efficiency (%)	[etaz]	99.016)	
Sound pressure level (according to Masuda)	[dB(A)]	66.2	

9. MODIFICATIONS AND TOOTH FORM DEFINITION

Profile and tooth trace modifications for gear 1

Symmetric (both flanks)

- Profile crowning (barreling) Ca = 23.000µm
- Crowning Cb = 32.000µm (rcrown=111566mm)
- Helix angle modification, tapered or conical

CHb = -80.000µm

CHb=-80.000µm -> Right Tooth Flank β.eff=7.9717°-left Left Tooth Flank β.eff=8.0283°-left

Comment: Zaporny smer otaceni

Profile and tooth trace modifications for gear 2

Symmetric (both flanks)

- Tip relief, arc-like Caa = 10.000µm LCa = 2.000*mn dCa = 973.146mm

Tip relief verification

Diameter (mm)	[dcheck]	0.000	984.105
Tip relief left/right (µm)	[Ca L/R]	0.0 / 0.0	9.7 / 9.7

Data for the tooth form calculation :

Data not available.

10. SERVICE LIFE, DAMAGE

Required safety for tooth root	[SFmin]	1.40
Required safety for tooth flank	[SHmin]	1.00

Service life (calculated with required safeties):

System service life (h) [Hatt] > 1000000

Tooth root service life (h)	[HFatt]	1e+006	1e+006
Tooth flank service life (h)	[HHatt]	1e+006	1e+006

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

Damage calculated on the basis of the required service life [H] (120000.0 h)

F1% F2% H1% H2%

0.00 0.00 0.00 0.00

Calculation of the factors required to define reliability R(t) according to B. Bertsche with Weibull distribution:
R(t) = 100 * Exp(-((t*fac - t0)/(T - t0))^b) %; t (h)

Gear		fac	b	t0	T	R(H)%
1	Tooth root	900	1.7	9.654e+029	1.484e+030	100.00
1	Tooth flank	900	1.3	9.014e+029	4.295e+030	100.00
2	Tooth root	134	1.7	9.654e+029	1.484e+030	100.00
2	Tooth flank	134	1.3	9.014e+029	4.295e+030	100.00

Reliability of the configuration for required service life (%) 100.00 (Bertsche)

REMARKS:

- Specifications with [.e/i] imply: Maximum [e] and Minimal value [i] with consideration of all tolerances
  Specifications with [.m] imply: Mean value within tolerance
- For the backlash tolerance, the center distance tolerances and the tooth thickness deviation are taken into account. Shown is the maximal and the minimal backlash corresponding the largest resp. the smallest allowances
  The calculation is done for the operating pitch circle.
- Details of calculation method:
  cg according to method B
  KV according to method B
  KHb, KFb according method C
  KHa, KFa according to method B

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