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File

Name : PETG_dynamic
Changed by: jsebe on: 26.05.2023 at: 12:39:22

Important hint: At least one warning has occurred during the calculation:

1-> Note:
For calculations in accordance with VDI, the face load factor KHb with 1.0 is assumed,
as plastics run in.
However a width/module ratio that is too large (b/mn > 10) should be avoided.
Or the face load factor needs to be checked.

CALCULATION OF A HELICAL GEAR PAIR

Drawing or article number:
Gear 1: 0.000.0
Gear 2: 0.000.0

Calculation method Plastic according to VDI 2736:2013 (YF Method C)
Steel wheels: calculated roughly according to DIN 3990!

		------- GEAR 1	-------- GEAR 2 --
Power (W)	[P]	261.799	
Speed (1/min)	[n]	1000.0	250.0
Torque (Nm)	[T]	2.500	10.000
Application factor	[KA]	1.00	
Required service life (h)	[H]	48.00	
Gear driving (+) / driven (-)		+	-

Working flank gear 1: Right flank
Sense of rotation gear 1 clockwise
Gearbox type: Gear with partly closed housing

1. TOOTH GEOMETRY AND MATERIAL

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

		------- GEAR 1	-------- GEAR 2 --
Center distance (mm)	[a]	80.000	
Center distance tolerance	ISO 286:2010 Measure js7		
Normal module (mm)	[mn]	1.2500	
Pressure angle at normal section (°)	[alfn]	20.0000	
Helix angle at reference circle (°)	[beta]	12.0000	
Number of teeth	[z]	25	100
Facewidth (mm)	[b]	30.00	30.00
Hand of gear		right	left
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 >=25HRC Jominy J=12mm<HRC28

Gear 2: PETG, Thermoplastic (POM, PPA, etc.), untreated

3D printed material

Woehler line tooth root stress from file Z014-PETG_VDI2736_BP.DAT

S-N curve (Woehler line) Hertzian pressure from file Z014-PETG_VDI2736_BP.DAT

			------- GEAR 1 --------	GEAR 2 --
Surface hardness			HRC 61	HBW 45
Tooth root temperature (°C)	[TR]		70.0	70.0
Flank temperature (°C)	[TF]		70.0	70.0
Tooth root strength at NL (N/mm²)	[σFadm]		432.01	8.70
Strength against Hertzian pressure at NL (N/mm²)	[σHadm]		1861.40	26.00
Tensile strength (N/mm²)	[σB]		1200.00	34.20
Yield point (N/mm²)	[σS]		850.00	33.80
Young's modulus (N/mm²)	[E]		206000	2317
Poisson's ratio	[v]		0.300	0.400
Roughness average value DS, flank (µm)	[RAH]		0.60	0.00
Roughness average value DS, root (µm)	[RAF]		3.00	0.00
Mean roughness height, Rz, flank (µm)	[RZH]		4.80	0.00
Mean roughness height, Rz, root (µm)	[RZF]		20.00	0.00

Gear reference profile	1 :		
Reference profile	1.25 / 0.38 / 1.0 ISO 53:1998 Profil A		
Dedendum coefficient		[hfP*]	1.250
Root radius factor		[rhofP*]	0.380 (rhofPmax*=0.472)
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	1.25 / 0.38 / 1.0 ISO 53:1998 Profil A		
Dedendum coefficient		[hfP*]	1.250
Root radius factor		[rhofP*]	0.380 (rhofPmax*=0.472)
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

Summary of reference profile gears:

Dedendum reference profile	[hfP*]	1.250	1.250
Tooth root radius Refer. profile	[rofP*]	0.380	0.380
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

Type of profile modification:	none (only running-in)		
Tip relief (µm)	[Ca]	2.0	20.0

Lubrication type Dry-running

Ambient temperature (°C)	[TU]	20.000	
		------- GEAR 1 --------	GEAR 2 --
Overall transmission ratio	[itot]	-4.000	
Gear ratio	[u]	4.000	
Transverse module (mm)	[mt]	1.278	
Pressure angle at pitch circle (°)	[alft]	20.410	
Working transverse pressure angle (°)	[alfwt]	20.658	
	[alfwt.e/i]	20.687 / 20.630	
Working pressure angle at normal section (°)	[alfwn]	20.243	
Helix angle at operating pitch circle (°)	[betaw]	12.019	
Base helix angle (°)	[betab]	11.267	
Reference center distance (mm)	[ad]	79.870	
Sum of profile shift coefficients	[Summexi]	0.1043	
Profile shift coefficient	[x]	0.3003	-0.1960
Tooth thickness (Arc) (module) (module)	[sn*]	1.7894	1.4281
Tip alteration (mm)	[k*mn]	-0.001	-0.001
Reference diameter (mm)	[d]	31.948	127.793
Base diameter (mm)	[db]	29.942	119.770
Tip diameter (mm)	[da]	35.197	129.801
(mm)	[da.e/i]	35.197 / 35.172	129.801 / 129.761
Tip diameter allowances (mm)	[Ada.e/i]	0.000 / -0.025	0.000 / -0.040
Tip form diameter (mm)	[dFa]	35.197	129.801
(mm)	[dFa.e/i]	35.197 / 35.172	129.801 / 129.761
Active tip diameter (mm)	[dNa]	35.197	129.801
Active tip diameter (mm)	[dNa.e/i]	35.197 / 35.172	129.801 / 129.761
Operating pitch diameter (mm)	[dw]	32.000	128.000
(mm)	[dw.e/i]	32.006 / 31.994	128.024 / 127.976
Root diameter (mm)	[df]	29.574	124.178
Generating Profile shift coefficient	[xE.e/i]	0.2409/ 0.2080	-0.3004/ -0.3553
Manufactured root diameter with xE (mm)	[df.e/i]	29.425 / 29.343	123.917 / 123.779
Theoretical tip clearance (mm)	[c]	0.313	0.313
Effective tip clearance (mm)	[c.e/i]	0.539 / 0.428	0.463 / 0.372
Active root diameter (mm)	[dNf]	30.621	125.637
(mm)	[dNf.e/i]	30.662 / 30.604	125.677 / 125.612
Root form diameter (mm)	[dFf]	30.563	125.061
(mm)	[dFf.e/i]	30.480 / 30.437	124.848 / 124.737
Reserve (dNf-dFf)/2 (mm)	[cF.e/i]	0.112 / 0.062	0.470 / 0.382
Addendum (mm)	[ha=mn*(haP*+x+k)]	1.624	1.004
(mm)	[ha.e/i]	1.624 / 1.612	1.004 / 0.984
Dedendum (mm)	[hf=mn*(hfP*-x)]	1.187	1.807
(mm)	[hf.e/i]	1.261 / 1.303	1.938 / 2.007
Roll angle at dFa (°)	[xsi_dFa.e/i]	35.401 / 35.310	23.936 / 23.886
Roll angle to dNa (°)	[xsi_dNa.e/i]	35.401 / 35.310	23.936 / 23.886
Roll angle to dNf (°)	[xsi_dNf.e/i]	12.633 / 12.109	18.217 / 18.112
Roll angle at dFf (°)	[xsi_dFf.e/i]	10.908 / 10.456	16.861 / 16.672
Tooth height (mm)	[h]	2.811	2.812
Virtual gear no. of teeth	[zn]	26.573	106.291
Normal tooth thickness at tip circle (mm)	[san]	0.789	1.030
(mm)	[san.e/i]	0.745 / 0.697	0.950 / 0.883
Normal tooth thickness on tip form circle (mm)	[sFan]	0.789	1.030
(mm)	[sFan.e/i]	0.745 / 0.697	0.950 / 0.883
Normal space width at root circle (mm)	[efn]	0.000	0.950
(mm)	[efn.e/i]	0.000 / 0.000	0.971 / 0.983
Max. sliding velocity at tip (m/s)	[vga]	0.472	0.319
Specific sliding at the tip	[zetaa]	0.487	0.487

Specific sliding at the root	[zetaf]		-0.951			-0.950		
Mean specific sliding	[zetam]			0.487				
Sliding factor on tip	[Kga]		0.282			0.190		
Sliding factor on root	[Kgf]		-0.190			-0.282		
Pitch on reference circle (mm)	[pt]			4.015				
Base pitch (mm)	[pbt]			3.763				
Transverse pitch on contact-path (mm)	[pet]			3.763				
Lead height (mm)	[pz]		472.195			1888.778		
Axial pitch (mm)	[px]			18.888				
Length of path of contact (mm)	[ga, e/i]		6.044 (	6.086 /	5.926)			
Length T1-A, T2-A (mm)	[T1A, T2A]	3.206(	3.164/	3.301)	25.017(	25.017/	24.965)	
Length T1-B (mm)	[T1B, T2B]	5.488(	5.488/	5.464)	22.736(	22.693/	22.802)	
Length T1-C (mm)	[T1C, T2C]	5.645(	5.636/	5.653)	22.579(	22.545/	22.613)	
Length T1-D (mm)	[T1D, T2D]	6.969(	6.927/	7.064)	21.255(	21.255/	21.203)	
Length T1-E (mm)	[T1E, T2E]	9.250(	9.250/	9.226)	18.973(	18.931/	19.040)	
Length T1-T2 (mm)	[T1T2]		28.224 (	28.181 /	28.266)			
Diameter of single contact point B (mm)	[d-B]	31.890(	31.890/	31.874)	128.111(	128.081/	128.158)	
Diameter of single contact point D (mm)	[d-D]	33.028(	32.992/	33.108)	127.090(	127.090/	127.055)	
Addendum contact ratio	[eps]	0.958(	0.961/	0.950)	0.648(	0.657/	0.625)	
Minimal length of contact line (mm)	[Lmin]			46.013				
Transverse contact ratio	[eps_a]			1.606				
Transverse contact ratio with allowances	[eps_a.e/m/i]		1.618 /	1.596 /	1.575			
Overlap ratio	[eps_b]			1.588				
Total contact ratio	[eps_g]			3.195				
Total contact ratio with allowances	[eps_g.e/m/i]		3.206 /	3.185 /	3.163			

2. FACTORS OF GENERAL INFLUENCE

		------- GEAR 1	-------- GEAR 2 --
Nominal circum. force at pitch circle (N)	[Ft]	156.5	
Axial force (N)	[Fa]	33.3	
Radial force (N)	[Fr]	58.2	
Normal force (N)	[Fnorm]	170.3	
Nominal circumferential force per mm (N/mm)	[w]	5.22	
Only as information: Forces at operating pitch circle:			
Nominal circumferential force (N)	[Ftw]	156.2	
Axial force (N)	[Faw]	33.3	
Radial force (N)	[Frw]	58.9	
Circumferential speed reference circle (m/s)	[v]	1.67	
Circumferential speed operating pitch circle (m/s)	[v(dw)]	1.68	
Correction factor	[CM]	0.800	
Gear blank factor	[CR]	1.000	
Basic rack factor	[CBS]	0.975	
Material coefficient	[E/Est]	0.022	
Singular tooth stiffness (N/mm/µm)	[c']	0.316	
Meshing stiffness (N/mm/µm)	[cg]	0.460	
Dynamic factor	[KV]	1.000	
Face load factor - flank	[KHb]	1.000	
- Tooth root	[KFb]	1.000	
- Scuffing	[KBb]	1.000	
Transverse load factor - flank	[KHa]	1.000	

- Tooth root	[KFa]	1.000	
- Scuffing	[KBa]	1.000	

Number of load cycles (in mio.)	[NL]	2.880	0.720

3. TOOTH ROOT STRENGTH

Calculation of Tooth form coefficients according method: C

		------- GEAR 1	-------- GEAR 2 --
Calculated with manufacturing profile shift	[xE.m]	0.2245	-0.3278
Tooth form factor	[YF]	2.46	2.47
Stress correction factor	[YS]	1.69	1.67
Load application angle (°)	[alfFen]	30.03	21.84
Bending moment arm (mm)	[hF]	2.53	2.54
Tooth thickness at root (mm)	[sFn]	2.67	2.76
Tooth root radius (mm)	[roF]	0.61	0.66

(hF* = 2.024/ 2.034 sFn* = 2.135/ 2.208 roF* = 0.487/ 0.529)
(den (mm) =
36.465/ 134.872 dsFn(mm) = 29.845/ 124.383 alfsFn(°) = 30.00/ 30.00 qs = 2.193/ 2.088)

Contact ratio factor	[Yeps]		0.717	
Helix angle factor	[Ybet]		0.900	
Effective facewidth (mm)	[beff]	30.00		30.00
Nominal stress at tooth root (N/mm²)	[sigF0]	10.78		11.14
Tooth root stress (N/mm²)	[sigF]	10.78		11.14
Permissible bending stress at root from data tables				
Notch sensitivity factor	[YdrelT]	0.998		1.000
Surface factor	[YRrelT]	0.957		1.000
size factor (Tooth root)	[YX]	1.000		1.000
Notice: When using Wohler lines from data files, the factors YdrelT, YRrelT, YX will be interpolated according to the breakpoints NLstatic and NLendurance following ISO.				
Finite life factor	[YNT]	1.005		1.000
	[YdrelT*YRrelT*YX*YNT]	0.959		1.000
Alternating bending factor (mean stress influence coefficient)	[YM]	1.000		1.000
Stress correction factor	[Yst]		2.00	
Yst*sigFlim (N/mm²)	[sigFE]	860.00		17.40
Permissible tooth root stress (N/mm²)	[sigFP=sigFG/SFmin]	659.96		13.92
Limit strength tooth root (N/mm²)	[sigFG]	824.95		17.40
Required safety	[SFmin]	1.25		1.25
Safety for tooth root stress	[SF=sigFG/sigF]	76.56		1.56
Transmittable power (W)	[WRating]	16034.00		327.15

4. SAFETY AGAINST PITTING (TOOTH FLANK)

		------- GEAR 1	-------- GEAR 2 --
Zone factor	[ZH]		2.434
Elasticity factor (√N/mm²)	[ZE]		29.452
Young's modulus for tooth flank (N/mm²)	[E]	206000	2317
Contact ratio factor	[Zeps]		0.789
Helix angle factor	[Zbet]		1.000
Effective facewidth (mm)	[beff]		30.00
Nominal contact stress (N/mm²)	[sigH0]		25.55

Contact stress at operating pitch circle (N/mm²)	[sigHw]	25.55	
Lubrication coefficient at NL	[ZL]	1.020	1.000
Speed coefficient at NL	[ZV]	0.954	1.000
Roughness coefficient at NL	[ZR]	1.000	1.000
Material pairing coefficient at NL	[ZW]	1.000	1.000
Notice: When using Wohler lines from data files, the factors ZL, ZV, ZR, ZW will be interpolated according to the breakpoints NLstatic and NLendurance following ISO.			
Finite life factor	[ZNT]	1.241	1.000
	[ZL*ZV*ZR*ZNT]	1.208	1.000
Limited pitting is permitted:	No		
Size factor (flank)	[ZX]	1.000	1.000
Permissible contact stress (N/mm²)	[sigHP=sigHG/SHmin]	1959.32	28.11
Pitting stress limit (N/mm²)	[sigHG]	1812.38	26.00
Required safety	[SHmin]	0.93	0.93
Safety factor for contact stress at operating pitch circle			
	[SHw]	71.72	1.02
Transmittable power (W)	[WRating]	1573968.19	288.01

4a. WEAR

Line load at reference diameter (N/mm)	[w]	5.22
Line load at reference diameter (N/mm)	[K_A*K_γ*K_V*$K_{H\beta}$*$K_{H\alpha}$*w]	5.22
Loss factor	[H_V]	0.117
Calculation only for Gear 2		
Length of active flank (mm)	[l_{Fl}]	2.20
Wear factor (mm^3/Nm/10^6)	[k_W]	3.40000
Data from file k_W: Z014-PETG_VDI2736_BP.DAT		
Normal tooth thickness in pitch circle (mm)	[s_n]	1.79
Maximum permissible wear (%)	[W_{limit}]	15.00
Permissible wear on flank (mm)	[δ_{Wlimn}]	0.27
Wear removal (mm)	[δ_{Wn}]	0.00273
Wear removal (mg)	[=lFL*b*z*ro*δWn]	24.7
Required safety	[S_{Wmin}]	1.10
Safety against wear	[S_W]	97.97

Calculation for safety against shearing for plastics			
Normal tooth thickness in the active root diameter (mm)	[s_{dNf}-δWn]		2.37
Shearing stress (N/mm²)	[τ_{nom}]	2.20	
Notch effect coefficient	[K_T]	1.25	
Permitted shearing strength (N/mm²)	[τ_B]	4.85	
Required safety	[S_{Tmin}]	2.50	
Safety shearing	[S_T]	1.76	

$\tau_B = 0.557 * \sigma_{Fadm}$; $S_T = \tau_B / (\tau_{nom} * K_T)$

Calculation of local wear with speeds and load distribution according to method A:
Calculation was not carried out. (Contact analysis under load is required.)

Important note:
the kw wear coefficients are usually determined using a plastic/steel pairing..
The coefficients may be very different if pairings of other materials are used..
This calculation is designed to give an indication of possible service life,
however it has not yet been checked exhaustively in real life..

5. BENDING

For plastics:

Tooth deformation (µm)	[fa]	17.459
Permissible tooth deformation (µm)	[fazul]	87.500
Required safety	[Sdel]	1.000
Safety against deformation	[Sdelmin]	5.012

Experimental method using tooth stiffness according ISO6336:2006:

Tooth deformation (µm)	[faExp]	0.350	20.012
Permissible tooth deformation (µm)	[fazulExp]	151.874	151.874
Required safety	[Sdel]	1.000	
Safety against jamming	[SdelExp]	433.739	7.589

6. MEASUREMENTS FOR TOOTH THICKNESS

		------- Gear 1 ------	Gear 2 --
Tooth thickness deviation		DIN 3967 cd25	DIN 3967 cd25
Tooth thickness allowance (normal section) (mm)	[As.e/i]	-0.054 / -0.084	-0.095 / -0.145
Number of teeth spanned	[k]	4.000	12.000
Base tangent length (no backlash) (mm)	[Wk]	13.638	44.134
Actual base tangent length ('span') (mm)	[Wk.e/i]	13.588 / 13.560	44.045 / 43.998
(mm)	[ΔWk.e/i]	-0.051 / -0.079	-0.089 / -0.136
Diameter of measuring circle (mm)	[dMWk.m]	32.768	127.313
Theoretical diameter of ball/pin (mm)	[DM]	2.268	2.088
Effective diameter of ball/pin (mm)	[DMeff]	2.500	2.500
Radial single-ball measurement backlash free (mm)	[MrK]	18.329	65.833
Radial single-ball measurement (mm)	[MrK.e/i]	18.275 / 18.245	65.711 / 65.646
Diameter of measuring circle (mm)	[dMMr.m]	32.926	127.972
Diametral measurement over two balls without clearance (mm)	[MdK]	36.590	131.666
Diametral two ball measure (mm)	[MdK.e/i]	36.482 / 36.422	131.422 / 131.292
Diametral measurement over pins without clearance (mm)	[MdR]	36.658	131.666
Measurement over pins according to DIN 3960 (mm)	[MdR.e/i]	36.550 / 36.489	131.422 / 131.292
Measurement over 2 pins (free) according to AGMA 2002 (mm)	[dk2f.e/i]	36.479 / 36.418	0.000 / 0.000
Measurement over 2 pins (axial) according to AGMA 2002 (mm)	[dk2t.e/i]	36.615 / 36.554	0.000 / 0.000
Measurement over 3 pins (axial) according to AGMA 2002 (mm)	[dk3A.e/i]	36.550 / 36.489	131.422 / 131.292
Chordal tooth thickness (no backlash) (mm)	[sc]	2.235	1.785
Actual chordal tooth thickness (mm)	[sc.e/i]	2.181 / 2.151	1.690 / 1.640
Reference chordal height from da.m (mm)	[ha]	1.656	1.000
Tooth thickness (Arc) (mm)	[sn]	2.237	1.785
(mm)	[sn.e/i]	2.183 / 2.153	1.690 / 1.640
Backlash free center distance (mm)	[aControl.e/i]	79.796 / 79.685	
Backlash free center distance, allowances (mm)	[jta]	-0.204 / -0.315	
dNf.i with aControl (mm)	[dNf0.i]	30.294	125.101
Reserve (dNf0.i-dFf.e)/2 (mm)	[cF0.i]	-0.093	0.127
Tip clearance (mm)	[c0.i(aControl)]	0.128	0.072
Center distance allowances (mm)	[Aa.e/i]	0.015 / -0.015	
Circumferential backlash from Aa (mm)	[jtw_Aa.e/i]	0.011 / -0.011	

Radial backlash (mm)	[jrw.e/i]	0.330 /	0.189
Circumferential backlash (transverse section) (mm)	[jtw.e/i]	0.246 /	0.141
Normal backlash (mm)	[jnw.e/i]	0.226 /	0.130
Angle of rotation on input with fixed output.:			
Entire torsional angle (°)	[j.tSys]		0.8802/ 0.5059

7. GEAR ACCURACY

		------- GEAR 1	-------- GEAR 2 --
According to DIN 3961:1978			
Accuracy grade	[Q-DIN3961]	6	6
Profile form deviation (µm)	[ff]	6.00	6.00
Profile slope deviation (µm)	[fHa]	5.00	5.00
Total profile deviation (µm)	[Ff]	8.00	8.00
Helix form deviation (µm)	[fbf]	5.50	5.50
Helix slope deviation (µm)	[fHb]	9.00	9.00
Total helix deviation (µm)	[Fb]	10.00	10.00
Normal base pitch deviation (µm)	[fpe]	7.00	8.00
Single pitch deviation (µm)	[fp]	7.00	8.00
Adjacent pitch difference (µm)	[fu]	8.00	10.00
Total cumulative pitch deviation (µm)	[Fp]	19.00	29.00
Sector pitch deviation over z/8 pitches (µm)	[Fpz/8]	12.00	18.00
Runout (µm)	[Fr]	14.00	19.00
Tooth Thickness Variation (µm)	[Rs]	8.00	11.00
Single flank composite, total (µm)	[Fi']	22.00	30.00
Single flank composite, tooth-to-tooth (µm)	[fi']	10.00	11.00
Radial composite, total (µm)	[Fi"]	17.00	24.00
Radial composite, tooth-to-tooth (µm)	[fi"]	6.00	10.00
According to DIN 58405:1972 (Feinwerktechnik):			
Tooth-to-tooth composite error (µm)	[fi"]	7.00	9.00
Composite error (µm)	[Fi"]	20.00	25.00
Axis alignment error (µm)	[fp]	13.60	13.60
Flank direction error (µm)	[fbeta]	6.30	6.30
Runout (µm)	[Trk, Fr]	21.00	28.00

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

Maximum value for deviation error of axis (µm)	[fSigbet]	13.00 (Fb=13.00)
Maximum value for inclination error of axes (µm)	[fSigdel]	26.00

8. ADDITIONAL DATA

Maximal possible center distance (eps_a=1.0)	[aMAX]	80.833	
Mass (kg)	[m]	0.193	0.521
Total mass (kg)	[m]	0.714	
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]	2.537e-005	0.001049
System ((da+df)/2...di) (kg*m²)	[TraeghMom]	9.095e-005	
Coefficient of friction	[mum]	0.200	
Loss factor	[HV]	0.117	
Coefficient for frequency of running	[KstEDf]	1.000	
Casing surface (m²)	[Oberflache]	0.16961	
Gear power loss (W)	[PVZ]	6.138	

(Meshing efficiency (%)	[etaz]		97.656)	
Tooth root temperature (°C)	[TR]		70.0	70.0
Flank temperature (°C)	[TF]		70.0	70.0
Heat transfer coefficient, root	[KF]		0.0	0.0
Heat transfer coefficient, flank	[KH]		0.0	0.0
Indications for the manufacturing by wire cutting:				
Deviation from theoretical tooth trace (µm)		[WireErr]	317.1	79.5
Permissible deviation (µm)	[Fb/2]		5.0	5.0

9. MODIFICATIONS AND TOOTH FORM DEFINITION

Data for the tooth form calculation :

Calculation of Gear 1
Tooth form, Gear 1, Step 1: Automatic (final machining)
haP*= 1.070, hfP*= 1.250, rofP*= 0.380

Calculation of Gear 2
Tooth form, Gear 2, Step 1: Automatic (final machining)
haP*= 1.123, hfP*= 1.250, rofP*= 0.380

10. SERVICE LIFE, DAMAGE

Required safety for tooth root	[SFmin]	1.25	
Required safety for tooth flank	[SHmin]	0.93	
Required safety for wear	[SWmin]	1.10	
Service life (calculated with required safeties):			
System service life (h)	[Hatt]	71.886	
Tooth root service life (h)	[HFatt]	1e+006	131.7
Tooth flank service life (h)	[HHatt]	1e+006	71.89
Wear service life (h)	[HWatt]	1e+006	4275

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] (48.0 h)

F1%	F2%	H1%	H2%	W1%	W2%
0.00	36.4471	0.0000	66.7724	0.0000	1.1228

Damage calculated on basis of system service life [Hatt] (71.9 h)

F1%	F2%	H1%	H2%	W1%	W2%
0.00	54.5842	0.0000	100.0000	0.0000	1.6816

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

Gear		fac	b	t0	T	R(H)%
1	Tooth root	60000	1.7	9.654e+029	1.484e+030	100.00
1	Tooth flank	60000	1.3	9.014e+029	4.295e+030	100.00
2	Tooth root	15000	1.7	1.907e+006	2.931e+006	100.00
2	Tooth flank	15000	1.3	9.72e+005	4.631e+006	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.
- Calculation of steel/plastic pair:
  the steel gear's strength is calculated approximately, according to DIN 3990, to obtain an indication of the service life..

End of Report lines: 511

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File

Name : 2m_dynamic
Changed by: jsebe on: 03.05.2023 at: 14:03:15

Important hint: At least one warning has occurred during the calculation:

1-> Note:
For calculations in accordance with VDI, the face load factor KHb with 1.0 is assumed,
as plastics run in.
However a width/module ratio that is too large (b/mn > 10) should be avoided.
Or the face load factor needs to be checked.

2-> Notice:
According to findings of the Technical University Berlin
the combination of gears made of the same plastic shows
substantially more wear!

CALCULATION OF A HELICAL GEAR PAIR

Drawing or article number:
Gear 1: 0.000.0
Gear 2: 0.000.0

Calculation method Plastic according to VDI 2736:2013 (YF Method C)

		------- GEAR 1	-------- GEAR 2 --
Power (W)	[P]	314.159	
Speed (1/min)	[n]	1000.0	250.0
Torque (Nm)	[T]	3.000	12.000
Application factor	[KA]	1.00	
Required service life (h)	[H]	26.00	
Gear driving (+) / driven (-)		+	-

Working flank gear 1: Right flank
Sense of rotation gear 1 clockwise
Gearbox type: Gear with partly closed housing

1. TOOTH GEOMETRY AND MATERIAL

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

		------- GEAR 1	-------- GEAR 2 --
Center distance (mm)	[a]	80.000	
Center distance tolerance	ISO 286:2010 Measure js7		
Normal module (mm)	[mn]	2.0000	
Pressure angle at normal section (°)	[alfn]	20.0000	
Helix angle at reference circle (°)	[beta]	12.0000	
Number of teeth	[z]	15	60
Facewidth (mm)	[b]	30.00	30.00
Hand of gear		right	left
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:	PETG, Thermoplastic (POM, PPA, etc.), untreated	
	3D printed material	
	Woehler line tooth root stress from file	Z014-PETG_VDI2736_BP.DAT
	S-N curve (Woehler line) Hertzian pressure from file	Z014-PETG_VDI2736_BP.DAT
Gear 2:	PETG, Thermoplastic (POM, PPA, etc.), untreated	
	3D printed material	
	Woehler line tooth root stress from file	Z014-PETG_VDI2736_BP.DAT
	S-N curve (Woehler line) Hertzian pressure from file	Z014-PETG_VDI2736_BP.DAT

		------- GEAR 1	-------- GEAR 2 --
Surface hardness		HBW 45	HBW 45
Tooth root temperature (°C)	[TR]	70.0	70.0
Flank temperature (°C)	[TF]	70.0	70.0
Tooth root strength at NL (N/mm²)	[σFadm]	7.30	10.10
Strength against Hertzian pressure at NL (N/mm²)	[σHadm]	21.90	30.20
Tensile strength (N/mm²)	[σB]	34.20	34.20
Yield point (N/mm²)	[σS]	33.80	33.80
Young's modulus (N/mm²)	[E]	2317	2317
Poisson's ratio	[v]	0.400	0.400
Roughness average value DS, flank (µm)	[RAH]	0.00	0.00
Roughness average value DS, root (µm)	[RAF]	0.00	0.00
Mean roughness height, Rz, flank (µm)	[RZH]	0.00	0.00
Mean roughness height, Rz, root (µm)	[RZF]	0.00	0.00

Gear reference profile 1 :

Reference profile	1.25 / 0.38 / 1.0 ISO 53:1998 Profil A	
Dedendum coefficient	[hfP*]	1.250
Root radius factor	[rhofP*]	0.380 (rhofPmax*=0.472)
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	1.25 / 0.38 / 1.0 ISO 53:1998 Profil A	
Dedendum coefficient	[hfP*]	1.250
Root radius factor	[rhofP*]	0.380 (rhofPmax*=0.472)
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	

Summary of reference profile gears:

Dedendum reference profile	[hfP*]	1.250	1.250
Tooth root radius Refer. profile	[rofP*]	0.380	0.380
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
Type of profile modification:	none (only running-in)		
Tip relief (µm)	[Ca]	20.0	20.0
Lubrication type		Dry-running	
Ambient temperature (°C)	[TU]	20.000	
		------- GEAR 1 --------	GEAR 2 --
Overall transmission ratio	[itot]	-4.000	
Gear ratio	[u]	4.000	
Transverse module (mm)	[mt]	2.045	
Pressure angle at pitch circle (°)	[alft]	20.410	
Working transverse pressure angle (°)	[alfwt]	26.068	
	[alfwt.e/i]	26.090 / 26.046	
Working pressure angle at normal section (°)	[alfwn]	25.529	
Helix angle at operating pitch circle (°)	[betaw]	12.504	
Base helix angle (°)	[betab]	11.267	
Reference center distance (mm)	[ad]	76.676	
Sum of profile shift coefficients	[Summexi]	1.8912	
Profile shift coefficient	[x]	0.6724	1.2188
Tooth thickness (Arc) (module) (module)	[sn*]	2.0603	2.4580
Tip alteration (mm)	[k*mn]	-0.458	-0.458
Reference diameter (mm)	[d]	30.670	122.681
Base diameter (mm)	[db]	28.745	114.979
Tip diameter (mm)	[da]	36.444	130.640
(mm)	[da.e/i]	36.444 / 36.419	130.640 / 130.600
Tip diameter allowances (mm)	[Ada.e/i]	0.000 / -0.025	0.000 / -0.040
Tip form diameter (mm)	[dFa]	36.444	130.640
(mm)	[dFa.e/i]	36.444 / 36.419	130.640 / 130.600
Active tip diameter (mm)	[dNa]	36.444	130.640
Active tip diameter (mm)	[dNa.e/i]	36.444 / 36.419	130.640 / 130.600
Operating pitch diameter (mm)	[dw]	32.000	128.000
(mm)	[dw.e/i]	32.006 / 31.994	128.024 / 127.976
Root diameter (mm)	[df]	28.360	122.556
Generating Profile shift coefficient	[xE.e/i]	0.6353/ 0.6147	1.1707/ 1.1433
Manufactured root diameter with xE (mm)	[df.e/i]	28.212 / 28.129	122.364 / 122.254
Theoretical tip clearance (mm)	[c]	0.500	0.500
Effective tip clearance (mm)	[c.e/i]	0.679 / 0.581	0.650 / 0.559
Active root diameter (mm)	[dNf]	29.916	124.560
(mm)	[dNf.e/i]	29.958 / 29.897	124.602 / 124.534
Root form diameter (mm)	[dFf]	29.570	123.579
(mm)	[dFf.e/i]	29.473 / 29.422	123.378 / 123.264
Reserve (dNf-dFf)/2 (mm)	[cF.e/i]	0.268 / 0.212	0.669 / 0.578
Addendum (mm)	[ha=mn*(haP*+x+k)]	2.887	3.980
(mm)	[ha.e/i]	2.887 / 2.874	3.980 / 3.960
Dedendum (mm)	[hf=mn*(hfP*-x)]	1.155	0.062
(mm)	[hf.e/i]	1.229 / 1.271	0.159 / 0.213
Roll angle at dFa (°)	[xsi_dFa.e/i]	44.655 / 44.574	30.906 / 30.864
Roll angle to dNa (°)	[xsi_dNa.e/i]	44.655 / 44.574	30.906 / 30.864
Roll angle to dNf (°)	[xsi_dNf.e/i]	16.825 / 16.385	23.927 / 23.839
Roll angle at dFf (°)	[xsi_dFf.e/i]	12.984 / 12.512	22.296 / 22.139
Tooth height (mm)	[h]	4.042	4.042
Virtual gear no. of teeth	[zn]	15.944	63.775
Normal tooth thickness at tip circle (mm)	[san]	1.268	1.542
(mm)	[san.e/i]	1.223 / 1.169	1.489 / 1.426

Normal tooth thickness on tip form circle (mm)	[sFan]		1.268			1.542		
(mm)	[sFan.e/i]	1.223 /	1.169		1.489 /	1.426		
Normal space width at root circle (mm)	[efn]		0.000			1.321		
(mm)	[efn.e/i]	0.000 /	0.000		1.320 /	1.319		
Max. sliding velocity at tip (m/s)	[vga]		0.546			0.378		
Specific sliding at the tip	[zetaa]		0.465			0.465		
Specific sliding at the root	[zetaf]		-0.871			-0.871		
Mean specific sliding	[zetam]			0.465				
Sliding factor on tip	[Kga]		0.326			0.226		
Sliding factor on root	[Kgf]		-0.226			-0.326		
Pitch on reference circle (mm)	[pt]			6.424				
Base pitch (mm)	[pbt]			6.020				
Transverse pitch on contact-path (mm)	[pet]			6.020				
Lead height (mm)	[pz]		453.307			1813.227		
Axial pitch (mm)	[px]			30.220				
Length of path of contact (mm)	[ga, e/i]		7.057 (	7.091 /	6.961)			
Length T1-A, T2-A (mm)	[T1A, T2A]	4.144(	4.110/	4.220)	31.011(	31.011/	30.969)	
Length T1-B (mm)	[T1B, T2B]	5.181(	5.181/	5.161)	29.974(	29.940/	30.028)	
Length T1-C (mm)	[T1C, T2C]	7.031(	7.024/	7.038)	28.124(	28.097/	28.151)	
Length T1-D (mm)	[T1D, T2D]	10.164(	10.130/	10.241)	24.991(	24.991/	24.948)	
Length T1-E (mm)	[T1E, T2E]	11.202(	11.202/	11.181)	23.954(	23.919/	24.008)	
Length T1-T2 (mm)	[T1T2]		35.155 (	35.121 /	35.189)			
Diameter of single contact point B (mm)	[d-B]	30.556(	30.556/	30.542)	129.668(	129.637/	129.719)	
Diameter of single contact point D (mm)	[d-D]	35.207(	35.168/	35.295)	125.373(	125.373/	125.339)	
Addendum contact ratio	[eps]	0.693(	0.694/	0.688)	0.480(	0.484/	0.468)	
Minimal length of contact line (mm)	[Lmin]			35.673				
Transverse contact ratio	[eps_a]			1.172				
Transverse contact ratio with allowances	[eps_a.e/m/i]		1.178 /	1.167 /	1.156			
Overlap ratio	[eps_b]			0.993				
Total contact ratio	[eps_g]			2.165				
Total contact ratio with allowances	[eps_g.e/m/i]		2.171 /	2.160 /	2.149			

2. FACTORS OF GENERAL INFLUENCE

		------- GEAR 1	-------- GEAR 2 --
Nominal circum. force at pitch circle (N)	[Ft]	195.6	
Axial force (N)	[Fa]	41.6	
Radial force (N)	[Fr]	72.8	
Normal force (N)	[Fnorm]	212.8	
Nominal circumferential force per mm (N/mm)	[w]	6.52	
Only as information: Forces at operating pitch circle:			
Nominal circumferential force (N)	[Ftw]	187.5	
Axial force (N)	[Faw]	41.6	
Radial force (N)	[Frw]	91.7	
Circumferential speed reference circle (m/s)	[v]	1.61	
Circumferential speed operating pitch circle (m/s)	[v(dw)]	1.68	
Correction factor	[CM]	0.800	
Gear blank factor	[CR]	1.000	
Basic rack factor	[CBS]	0.975	
Material coefficient	[E/Est]	0.011	
Singular tooth stiffness (N/mm/µm)	[c']	0.172	
Meshing stiffness (N/mm/µm)	[cg]	0.194	
Dynamic factor	[KV]	1.000	

Face load factor - flank	[KHb]		1.000
- Tooth root	[KFb]		1.000
- Scuffing	[KBb]		1.000
Transverse load factor - flank	[KHa]		1.000
- Tooth root	[KFa]		1.000
- Scuffing	[KBa]		1.000
Number of load cycles (in mio.)	[NL]	1.560	0.390

3. TOOTH ROOT STRENGTH

Calculation of Tooth form coefficients according method: C

		------- GEAR 1	-------- GEAR 2 --
Calculated with manufacturing profile shift	[xE.m]	0.6250	1.1570
Tooth form factor	[YF]	1.88	1.76
Stress correction factor	[YS]	1.90	2.01
Load application angle (°)	[alfFen]	35.53	27.21
Bending moment arm (mm)	[hF]	3.60	3.48
Tooth thickness at root (mm)	[sFn]	4.46	4.75
Tooth root radius (mm)	[roF]	0.81	0.80

(hF* = 1.799/ 1.741 sFn* = 2.231/ 2.373 roF* = 0.403/ 0.398)
(den (mm) =
37.661/ 135.509 dsFn(mm) = 28.752/ 123.031 alfsFn(°) = 30.00/ 30.00 qs = 2.770/ 2.980)

Contact ratio factor	[Yeps]	0.890	
Helix angle factor	[Ybet]	0.901	
Effective facewidth (mm)	[beff]	30.00	30.00
Nominal stress at tooth root (N/mm²)	[sigF0]	9.32	9.21
Tooth root stress (N/mm²)	[sigF]	9.32	9.21
Permissible bending stress at root from data tables			
Notch sensitivity factor	[YdrelT]	1.000	1.000
Surface factor	[YRrelT]	1.000	1.000
size factor (Tooth root)	[YX]	1.000	1.000

Notice: When using Wohler lines from data files, the factors YdrelT, YRrelT, YX
will be interpolated according to the breakpoints NLstatic and NLendurance following ISO.

Finite life factor	[YNT]	1.000	1.000
[YdrelT*YRrelT*YX*YNT]		1.000	1.000
Alternating bending factor (mean stress influence coefficient)	[YM]	1.000	1.000
Stress correction factor	[Yst]	2.00	
Yst*sigFlim (N/mm²)	[sigFE]	14.60	20.20
Permissible tooth root stress (N/mm²)	[sigFP=sigFG/SFmin]	10.43	14.43
Limit strength tooth root (N/mm²)	[sigFG]	14.60	20.20
Required safety	[SFmin]	1.40	1.40
Safety for tooth root stress	[SF=sigFG/sigF]	1.57	2.19
Transmittable power (W)	[WRating]	351.53	492.02

4. SAFETY AGAINST PITTING (TOOTH FLANK)

		------- GEAR 1	-------- GEAR 2 --
Zone factor	[ZH]		2.137

Elasticity factor (√N/mm²)	[ZE]	20.952	
Young's modulus for tooth flank (N/mm²)	[E]	2317	2317
Contact ratio factor	[Zeps]	0.924	
Helix angle factor	[Zbet]	1.000	
Effective facewidth (mm)	[beff]	30.00	
Nominal contact stress (N/mm²)	[sigH0]	21.32	
Contact stress at operating pitch circle (N/mm²)	[sigHw]	21.32	
Lubrication coefficient at NL	[ZL]	1.000	1.000
Speed coefficient at NL	[ZV]	1.000	1.000
Roughness coefficient at NL	[ZR]	1.000	1.000
Material pairing coefficient at NL	[ZW]	1.000	1.000
Notice: When using Wohler lines from data files, the factors ZL, ZV, ZR, ZW will be interpolated according to the breakpoints NLstatic and NLendurance following ISO.			
Finite life factor	[ZNT]	1.000	1.000
	[ZL*ZV*ZR*ZNT]	1.000	1.000
Limited pitting is permitted:	No		
Size factor (flank)	[ZX]	1.000	1.000
Permissible contact stress (N/mm²)	[sigHP=sigHG/SHmin]	21.90	30.20
Pitting stress limit (N/mm²)	[sigHG]	21.90	30.20
Required safety	[SHmin]	1.00	1.00
Safety factor for contact stress at operating pitch circle			
	[SHw]	1.03	1.42
Transmittable power (W)	[WRating]	322.67	444.96

4a. WEAR

Line load at reference diameter (N/mm)	[w]	6.52	
Line load at reference diameter (N/mm)	[K_A*K_γ*K_V*$K_{H\beta}$*$K_{H\alpha}$*w]	6.52	
Loss factor	[H_V]	0.144	
Length of active flank (mm)	[l_{Fl}]	3.75	3.35
Wear factor (mm^3/Nm/10^6)	[k_W]	3.40000	3.40000
Data from file k_{W1}: Z014-PETG_VDI2736_BP.DAT			
Data from file k_{W2}: Z014-PETG_VDI2736_BP.DAT			
Normal tooth thickness in pitch circle (mm)	[s_n]	4.12	4.92
Maximum permissible wear (%)	[W_{limit}]	15.00	
Permissible wear on flank (mm)	[δ_{Wlimn}]	0.62	0.74
Wear removal (mm)	[δ_{Wn}]	0.00851	0.00238
Wear removal (mg)	[=lFL*b*z*ro*δWn]	19.7	19.7
Required safety	[S_{Wmin}]	1.10	
Safety against wear	[S_W]	72.61	310.02
Calculation for safety against shearing for plastics			
Normal tooth thickness in the active root diameter (mm)	[s_{dNf}-δWn]	4.20	4.17
Shearing stress (N/mm²)	[τ_{nom}]	1.55	1.56
Notch effect coefficient	[K_T]	1.25	1.25
Permitted shearing strength (N/mm²)	[τ_B]	4.07	5.63
Required safety	[S_{Tmin}]	2.50	
Safety shearing	[S_T]	2.09	2.88

$\tau_B = 0.557 * \sigma_{Fadm}$; $S_T = \tau_B / (\tau_{nom} * K_T)$

Calculation of local wear with speeds and load distribution according to method A:
Calculation was not carried out. (Contact analysis under load is required.)

Important note:
the kw wear coefficients are usually determined using a plastic/steel pairing..
The coefficients may be very different if pairings of other materials are used..

This calculation is designed to give an indication of possible service life, however it has not yet been checked exhaustively in real life..

5. BENDING

For plastics:			
Tooth deformation (µm)	[fa]	43.161	
Permissible tooth deformation (µm)	[fazul]	140.000	
Required safety	[Sdel]	1.000	
Safety against deformation	[Sdelmin]	3.244	
Experimental method using tooth stiffness according	ISO6336:2006:		
Tooth deformation (µm)	[faExp]	33.722	22.788
Permissible tooth deformation (µm)	[fazulExp]	147.795	147.795
Required safety	[Sdel]	1.000	
Safety against jamming	[SdelExp]	4.383	6.486

6. MEASUREMENTS FOR TOOTH THICKNESS

		------- Gear 1	------ Gear 2 --
Tooth thickness deviation		DIN 3967 cd25	DIN 3967 cd25
Tooth thickness allowance (normal section) (mm)	[As.e/i]	-0.054 / -0.084	-0.070 / -0.110
Number of teeth spanned	[k]	3.000	9.000
Base tangent length (no backlash) (mm)	[Wk]	16.128	53.644
Actual base tangent length ('span') (mm)	[Wk.e/i]	16.077 / 16.049	53.578 / 53.540
(mm)	[ΔWk.e/i]	-0.051 / -0.079	-0.066 / -0.103
Diameter of measuring circle (mm)	[dMWk.m]	32.779	126.409
Theoretical diameter of ball/pin (mm)	[DM]	4.519	3.907
Effective diameter of ball/pin (mm)	[DMeff]	4.500	4.000
Radial single-ball measurement backlash free (mm)	[MrK]	20.141	66.732
Radial single-ball measurement (mm)	[MrK.e/i]	20.098 / 20.073	66.659 / 66.617
Diameter of measuring circle (mm)	[dMMr.m]	33.249	127.530
Diametral measurement over two balls without clearance (mm)	[MdK]	40.087	133.464
Diametral two ball measure (mm)	[MdK.e/i]	40.000 / 39.952	133.317 / 133.233
Diametral measurement over pins without clearance (mm)	[MdR]	40.283	133.464
Measurement over pins according to DIN 3960 (mm)	[MdR.e/i]	40.195 / 40.147	133.317 / 133.233
Measurement over 2 pins (free) according to AGMA 2002 (mm)	[dk2f.e/i]	39.987 / 39.939	0.000 / 0.000
Measurement over 2 pins (axial) according to AGMA 2002 (mm)	[dk2t.e/i]	40.378 / 40.329	0.000 / 0.000
Measurement over 3 pins (axial) according to AGMA 2002 (mm)	[dk3A.e/i]	40.195 / 40.147	133.317 / 133.233
Chordal tooth thickness (no backlash) (mm)	[sc]	4.109	0.000
Actual chordal tooth thickness (mm)	[sc.e/i]	4.055 / 4.025	0.000 / 0.000
Reference chordal height from da.m (mm)	[ha]	3.013	0.000
Tooth thickness (Arc) (mm)	[sn]	4.121	0.000
(mm)	[sn.e/i]	4.067 / 4.037	0.000 / 0.000

The tooth thickness at reference circle [sn], [sc] is set to the value 0 if the reference circle is outside the tooth flank's involute area.
Note: Select "Calculation" -> "Tooth thickness" to calculate the tooth thickness in any diameters..

Backlash free center distance (mm)	[aControl.e/i]	79.864 / 79.787

Backlash free center distance, allowances (mm)	[jta]	-0.136 /	-0.213
dNf.i with aControl (mm)	[dNf0.i]	29.661	124.189
Reserve (dNf0.i-dFf.e)/2 (mm)	[cF0.i]	0.094	0.406
Tip clearance (mm)	[c0.i(aControl)]	0.383	0.361
Center distance allowances (mm)	[Aa.e/i]	0.015 /	-0.015
Circumferential backlash from Aa (mm)	[jtw_Aa.e/i]	0.015 /	-0.015
Radial backlash (mm)	[jrw.e/i]	0.228 /	0.121
Circumferential backlash (transverse section) (mm)	[jtw.e/i]	0.222 /	0.118
Normal backlash (mm)	[jnw.e/i]	0.204 /	0.108
Angle of rotation on input with fixed output.:			
Entire torsional angle (°)	[j.tSys]	0.7936/	0.4211

7. GEAR ACCURACY

		------- GEAR 1	-------- GEAR 2 --
According to DIN 3961:1978			
Accuracy grade	[Q-DIN3961]	6	6
Profile form deviation (µm)	[ff]	6.00	6.00
Profile slope deviation (µm)	[fHa]	5.00	5.00
Total profile deviation (µm)	[Ff]	8.00	8.00
Helix form deviation (µm)	[fbf]	5.50	5.50
Helix slope deviation (µm)	[fHb]	9.00	9.00
Total helix deviation (µm)	[Fb]	10.00	10.00
Normal base pitch deviation (µm)	[fpe]	7.00	7.00
Single pitch deviation (µm)	[fp]	7.00	7.00
Adjacent pitch difference (µm)	[fu]	8.00	9.00
Total cumulative pitch deviation (µm)	[Fp]	19.00	25.00
Sector pitch deviation over z/8 pitches (µm)	[Fpz/8]	12.00	15.00
Runout (µm)	[Fr]	14.00	16.00
Tooth Thickness Variation (µm)	[Rs]	8.00	10.00
Single flank composite, total (µm)	[Fi']	22.00	26.00
Single flank composite, tooth-to-tooth (µm)	[fi']	10.00	11.00
Radial composite, total (µm)	[Fi"]	17.00	20.00
Radial composite, tooth-to-tooth (µm)	[fi"]	6.00	8.00
According to DIN 58405:1972 (Feinwerktechnik):			
Tooth-to-tooth composite error (µm)	[fi"]	8.00	10.00
Composite error (µm)	[Fi"]	22.00	28.00
Axis alignment error (µm)	[fp]	13.60	13.60
Flank direction error (µm)	[fbeta]	6.30	6.30
Runout (µm)	[Trk, Fr]	21.00	28.00

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

Maximum value for deviation error of axis (µm)	[fSigbet]	12.00 (Fb= 12.00)
Maximum value for inclination error of axes (µm)	[fSigdel]	24.00

8. ADDITIONAL DATA

Maximal possible center distance (eps_a=1.0)	[aMAX]	80.461	
Mass (g)	[m]	33.89	517.35
Total mass (g)	[m]	551.24	
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]	4.448e-006	0.001036
System ((da+df)/2...di) (kg*m²)	[TraeghMom]	6.923e-005	
Coefficient of friction	[mum]	0.280	
Loss factor	[HV]	0.144	
Coefficient for frequency of running	[KstEDf]	1.000	
Casing surface (m²)	[Oberflache]	0.16192	
Gear power loss (W)	[PVZ]	12.623	
(Meshing efficiency (%)	[etaz]	95.982)	
Tooth root temperature (°C)	[TR]	70.0	70.0
Flank temperature (°C)	[TF]	70.0	70.0
Heat transfer coefficient, root	[KF]	0.0	0.0
Heat transfer coefficient, flank	[KH]	0.0	0.0

Indications for the manufacturing by wire cutting:

Deviation from theoretical tooth trace (µm)	[WireErr]	330.3	82.8
Permissible deviation (µm)	[Fb/2]	5.0	5.0

9. MODIFICATIONS AND TOOTH FORM DEFINITION

Data for the tooth form calculation :

Calculation of Gear 1
Tooth form, Gear 1, Step 1: Automatic (final machining)
haP*= 0.815, hfP*= 1.250, rofP*= 0.380

Calculation of Gear 2
Tooth form, Gear 2, Step 1: Automatic (final machining)
haP*= 0.828, hfP*= 1.250, rofP*= 0.380

10. SERVICE LIFE, DAMAGE

Required safety for tooth root	[SFmin]	1.40	
Required safety for tooth flank	[SHmin]	1.00	
Required safety for wear	[SWmin]	1.10	

Service life (calculated with required safeties):

System service life (h)	[Hatt]	29.754	
Tooth root service life (h)	[HFatt]	45.27	191.6
Tooth flank service life (h)	[HHatt]	29.75	119
Wear service life (h)	[HWatt]	1716	7328

Damage calculated on the basis of the required service life [H] (26.0 h)

F1%	F2%	H1%	H2%	W1%	W2%
57.43	13.5680	87.3820	21.8455	1.5149	0.3548

Damage calculated on basis of system service life [Hatt] (29.8 h)

F1%	F2%	H1%	H2%	W1%	W2%
65.73	15.5272	100.0000	25.0000	1.7337	0.4061

Calculation of the factors required to define reliability R(t) according to B. Bertsche with Weibull distribution; t in (h):

R(t) = 100 * Exp(-((t*fac - t0)/(T - t0))^b) %

Gear		fac	b	t0	T	R(H)%
1	Tooth root	60000	1.7	2.622e+006	4.03e+006	100.00
1	Tooth flank	60000	1.3	1.609e+006	7.667e+006	100.00
2	Tooth root	15000	1.7	2.775e+006	4.264e+006	100.00
2	Tooth flank	15000	1.3	1.609e+006	7.667e+006	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.

End of Report lines: 511

KISSsoft Release 03/2018 C

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File

Name : 0.8m_dynamic
Changed by: jsebe on: 03.05.2023 at: 14:01:05

Important hint: At least one warning has occurred during the calculation:

1-> Note:
For calculations in accordance with VDI, the face load factor KHb with 1.0 is assumed,
as plastics run in.
However a width/module ratio that is too large (b/mn > 10) should be avoided.
Or the face load factor needs to be checked.

CALCULATION OF A HELICAL GEAR PAIR

Drawing or article number:
Gear 1: 0.000.0
Gear 2: 0.000.0

Calculation method Plastic according to VDI 2736:2013 (YF Method C)

		------- GEAR 1	-------- GEAR 2 --
Power (W)	[P]	314.159	
Speed (1/min)	[n]	1000.0	250.0
Torque (Nm)	[T]	3.000	12.000
Application factor	[KA]	1.00	
Required service life (h)	[H]	20.00	
Gear driving (+) / driven (-)		+	-

Working flank gear 1: Right flank
Sense of rotation gear 1 clockwise
Gearbox type: Gear with partly closed housing

1. TOOTH GEOMETRY AND MATERIAL

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

		------- GEAR 1	-------- GEAR 2 --
Center distance (mm)	[a]	80.000	
Center distance tolerance	ISO 286:2010 Measure js7		
Normal module (mm)	[mn]	0.8000	
Pressure angle at normal section (°)	[alfn]	20.0000	
Helix angle at reference circle (°)	[beta]	12.0000	
Number of teeth	[z]	39	156
Facewidth (mm)	[b]	30.00	30.00
Hand of gear		right	left
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: PETG, Thermoplastic (POM, PPA, etc.), untreated
3D printed material
Woehler line tooth root stress from file Z014-PETG_VDI2736_BP.DAT

S-N curve (Woehler line) Hertzian pressure from file Z014-PETG_VDI2736_BP.DAT

Gear 2: PETG, Thermoplastic (POM, PPA, etc.), untreated

3D printed material

Woehler line tooth root stress from file Z014-PETG_VDI2736_BP.DAT

S-N curve (Woehler line) Hertzian pressure from file Z014-PETG_VDI2736_BP.DAT

			------- GEAR 1 --------	GEAR 2 --
Surface hardness			HBW 45	HBW 45
Tooth root temperature (°C)		[TR]	70.0	70.0
Flank temperature (°C)		[TF]	70.0	70.0
Tooth root strength at NL (N/mm²)		[σFadm]	7.70	10.70
Strength against Hertzian pressure	at NL (N/mm²)	[σHadm]	23.10	32.20
Tensile strength (N/mm²)		[σB]	34.20	34.20
Yield point (N/mm²)		[σS]	33.80	33.80
Young's modulus (N/mm²)		[E]	2317	2317
Poisson's ratio		[v]	0.400	0.400
Roughness average value DS, flank (µm)		[RAH]	0.00	0.00
Roughness average value DS, root (µm)		[RAF]	0.00	0.00
Mean roughness height, Rz, flank (µm)		[RZH]	0.00	0.00
Mean roughness height, Rz, root (µm)		[RZF]	0.00	0.00

Gear reference profile 1 :

Reference profile	1.25 / 0.38 / 1.0 ISO 53:1998 Profil A		
Dedendum coefficient	[hfP*]	1.250	
Root radius factor	[rhofP*]	0.380 (rhofPmax*=0.472)	
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	1.25 / 0.38 / 1.0 ISO 53:1998 Profil A		
Dedendum coefficient	[hfP*]	1.250	
Root radius factor	[rhofP*]	0.380 (rhofPmax*=0.472)	
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	

Summary of reference profile gears:

Dedendum reference profile	[hfP*]	1.250	1.250
Tooth root radius Refer. profile	[rofP*]	0.380	0.380
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

Type of profile modification: none (only running-in)

Tip relief (µm)	[Ca]	20.0	20.0

Lubrication type		Dry-running	
Ambient temperature (°C)	[TU]	20.000	
		------- GEAR 1 --------	GEAR 2 --
Overall transmission ratio	[itot]	-4.000	
Gear ratio	[u]	4.000	
Transverse module (mm)	[mt]	0.818	
Pressure angle at pitch circle (°)	[alft]	20.410	
Working transverse pressure angle (°)	[alfwt]	20.900	
	[alfwt.e/i]	20.928 / 20.872	
Working pressure angle at normal section (°)	[alfwn]	20.479	
Helix angle at operating pitch circle (°)	[betaw]	12.038	
Base helix angle (°)	[betab]	11.267	
Reference center distance (mm)	[ad]	79.743	
Sum of profile shift coefficients	[Summexi]	0.3255	
Profile shift coefficient	[x]	0.2550	0.0705
Tooth thickness (Arc) (module) (module)	[sn*]	1.7564	1.6221
Tip alteration (mm)	[k*mn]	-0.003	-0.003
Reference diameter (mm)	[d]	31.897	127.588
Base diameter (mm)	[db]	29.895	119.578
Tip diameter (mm)	[da]	33.899	129.295
(mm)	[da.e/i]	33.899 / 33.874	129.295 / 129.255
Tip diameter allowances (mm)	[Ada.e/i]	0.000 / -0.025	0.000 / -0.040
Tip form diameter (mm)	[dFa]	33.899	129.295
(mm)	[dFa.e/i]	33.899 / 33.874	129.295 / 129.255
Active tip diameter (mm)	[dNa]	33.899	129.295
Active tip diameter (mm)	[dNa.e/i]	33.899 / 33.874	129.295 / 129.255
Operating pitch diameter (mm)	[dw]	32.000	128.000
(mm)	[dw.e/i]	32.006 / 31.994	128.024 / 127.976
Root diameter (mm)	[df]	30.305	125.701
Generating Profile shift coefficient	[xE.e/i]	0.1622/ 0.1107	-0.0926/ -0.1785
Manufactured root diameter with xE (mm)	[df.e/i]	30.157 / 30.074	125.440 / 125.303
Theoretical tip clearance (mm)	[c]	0.200	0.200
Effective tip clearance (mm)	[c.e/i]	0.427 / 0.316	0.350 / 0.259
Active root diameter (mm)	[dNf]	30.921	126.443
(mm)	[dNf.e/i]	30.970 / 30.900	126.487 / 126.415
Root form diameter (mm)	[dFf]	30.872	126.164
(mm)	[dFf.e/i]	30.768 / 30.713	125.928 / 125.805
Reserve (dNf-dFf)/2 (mm)	[cF.e/i]	0.129 / 0.066	0.341 / 0.244
Addendum (mm)	[ha=mn*(haP*+x+k)]	1.001	0.853
(mm)	[ha.e/i]	1.001 / 0.988	0.853 / 0.833
Dedendum (mm)	[hf=mn*(hfP*-x)]	0.796	0.944
(mm)	[hf.e/i]	0.870 / 0.911	1.074 / 1.143
Roll angle at dFa (°)	[xsi_dFa.e/i]	30.633 / 30.531	23.563 / 23.512
Roll angle to dNa (°)	[xsi_dNa.e/i]	30.633 / 30.531	23.563 / 23.512
Roll angle to dNf (°)	[xsi_dNf.e/i]	15.509 / 14.985	19.757 / 19.651
Roll angle at dFf (°)	[xsi_dFf.e/i]	13.954 / 13.501	18.918 / 18.729
Tooth height (mm)	[h]	1.797	1.797
Virtual gear no. of teeth	[zn]	41.454	165.814
Normal tooth thickness at tip circle (mm)	[san]	0.570	0.656
(mm)	[san.e/i]	0.526 / 0.481	0.576 / 0.509
Normal tooth thickness on tip form circle (mm)	[sFan]	0.570	0.656
(mm)	[sFan.e/i]	0.526 / 0.481	0.576 / 0.509
Normal space width at root circle (mm)	[efn]	0.628	0.559
(mm)	[efn.e/i]	0.655 / 0.672	0.570 / 0.576
Max. sliding velocity at tip (m/s)	[vga]	0.299	0.230

Specific sliding at the tip	[zetaa]		0.357			0.357		
Specific sliding at the root	[zetaf]		-0.556			-0.556		
Mean specific sliding	[zetam]			0.357				
Sliding factor on tip	[Kga]		0.178			0.137		
Sliding factor on root	[Kgf]		-0.137			-0.178		
Pitch on reference circle (mm)	[pt]			2.569				
Base pitch (mm)	[pbt]			2.408				
Transverse pitch on contact-path (mm)	[pet]			2.408				
Lead height (mm)	[pz]		471.439			1885.756		
Axial pitch (mm)	[px]			12.088				
Length of path of contact (mm)	[ga, e/i]		4.040 (	4.082 /	3.919)			
Length T1-A, T2-A (mm)	[T1A, T2A]	3.951(	3.909/	4.046)	24.588(	24.588/	24.535)	
Length T1-B (mm)	[T1B, T2B]	5.583(	5.583/	5.557)	22.956(	22.914/	23.024)	
Length T1-C (mm)	[T1C, T2C]	5.708(	5.699/	5.716)	22.831(	22.798/	22.865)	
Length T1-D (mm)	[T1D, T2D]	6.359(	6.317/	6.454)	22.180(	22.180/	22.127)	
Length T1-E (mm)	[T1E, T2E]	7.992(	7.992/	7.965)	20.548(	20.506/	20.616)	
Length T1-T2 (mm)	[T1T2]		28.539 (	28.497 /	28.581)			
Diameter of single contact point B (mm)	[d-B]	31.912(	31.912/	31.894)	128.089(	128.059/	128.138)	
Diameter of single contact point D (mm)	[d-D]	32.488(	32.455/	32.562)	127.541(	127.541/	127.504)	
Addendum contact ratio	[eps]	0.948(	0.952/	0.934)	0.729(	0.743/	0.694)	
Minimal length of contact line (mm)	[Lmin]			49.264				
Transverse contact ratio	[eps_a]			1.678				
Transverse contact ratio with allowances	[eps_a.e/m/i]		1.695 /	1.661 /	1.627			
Overlap ratio	[eps_b]			2.482				
Total contact ratio	[eps_g]			4.160				
Total contact ratio with allowances	[eps_g.e/m/i]		4.177 /	4.143 /	4.109			

2. FACTORS OF GENERAL INFLUENCE

		------- GEAR 1	-------- GEAR 2 --
Nominal circum. force at pitch circle (N)	[Ft]	188.1	
Axial force (N)	[Fa]	40.0	
Radial force (N)	[Fr]	70.0	
Normal force (N)	[Fnorm]	204.6	
Nominal circumferential force per mm (N/mm)	[w]	6.27	
Only as information: Forces at operating pitch circle:			
Nominal circumferential force (N)	[Ftw]	187.5	
Axial force (N)	[Faw]	40.0	
Radial force (N)	[Frw]	71.6	
Circumferential speed reference circle (m/s)	[v]	1.67	
Circumferential speed operating pitch circle (m/s)	[v(dw)]	1.68	
Correction factor	[CM]	0.800	
Gear blank factor	[CR]	1.000	
Basic rack factor	[CBS]	0.975	
Material coefficient	[E/Est]	0.011	
Singular tooth stiffness (N/mm/µm)	[c']	0.171	
Meshing stiffness (N/mm/µm)	[cg]	0.257	
Dynamic factor	[KV]	1.000	
Face load factor - flank	[KHb]	1.000	
- Tooth root	[KFb]	1.000	
- Scuffing	[KBb]	1.000	

Transverse load factor - flank	[KHa]	1.000	
- Tooth root	[KFa]	1.000	
- Scuffing	[KBa]	1.000	
Number of load cycles (in mio.)	[NL]	1.200	0.300

3. TOOTH ROOT STRENGTH

Calculation of Tooth form coefficients according method: C

		------- GEAR 1	-------- GEAR 2 --
Calculated with manufacturing profile shift	[xE.m]	0.1365	-0.1355
Tooth form factor	[YF]	2.45	2.43
Stress correction factor	[YS]	1.70	1.76
Load application angle (°)	[alfFen]	26.80	21.69
Bending moment arm (mm)	[hF]	1.64	1.70
Tooth thickness at root (mm)	[sFn]	1.75	1.82
Tooth root radius (mm)	[roF]	0.39	0.37

(hF* = 2.045/ 2.128 sFn* = 2.181/ 2.280 roF* = 0.489/ 0.458)
(den (mm) =
35.165/ 134.358 dsFn(mm) = 30.427/ 125.692 alfsFn(°) = 30.00/ 30.00 qs = 2.229/ 2.491)

Contact ratio factor	[Yeps]		0.697	
Helix angle factor	[Ybet]		0.900	
Effective facewidth (mm)	[beff]	30.00		30.00
Nominal stress at tooth root (N/mm²)	[sigF0]	20.45		20.99
Tooth root stress (N/mm²)	[sigF]	20.45		20.99
Permissible bending stress at root from data tables				
Notch sensitivity factor	[YdrelT]	1.000		1.000
Surface factor	[YRrelT]	1.000		1.000
size factor (Tooth root)	[YX]	1.000		1.000
Notice: When using Wohler lines from data files, the factors YdrelT, YRrelT, YX will be interpolated according to the breakpoints NLstatic and NLendurance following ISO.				
Finite life factor	[YNT]	1.000		1.000
	[YdrelT*YRrelT*YX*YNT]	1.000		1.000
Alternating bending factor (mean stress influence coefficient)	[YM]		1.000	1.000
Stress correction factor	[Yst]		2.00	
Yst*sigFlim (N/mm²)	[sigFE]	15.40		21.40
Permissible tooth root stress (N/mm²)	[sigFP=sigFG/SFmin]	16.04		22.29
Limit strength tooth root (N/mm²)	[sigFG]	15.40		21.40
Required safety	[SFmin]	0.96		0.96
Safety for tooth root stress	[SF=sigFG/sigF]	0.75		1.02
Transmittable power (W)	[WRating]	246.43		333.67

4. SAFETY AGAINST PITTING (TOOTH FLANK)

		------- GEAR 1	-------- GEAR 2 --
Zone factor	[ZH]		2.418
Elasticity factor (√N/mm²)	[ZE]		20.952
Young's modulus for tooth flank (N/mm²)	[E]	2317	2317
Contact ratio factor	[Zeps]		0.772
Helix angle factor	[Zbet]		1.000
Effective facewidth (mm)	[beff]		30.00

Nominal contact stress (N/mm²)	[sigH0]	19.39	
Contact stress at operating pitch circle (N/mm²)	[sigHw]	19.39	
Lubrication coefficient at NL	[ZL]	1.000	1.000
Speed coefficient at NL	[ZV]	1.000	1.000
Roughness coefficient at NL	[ZR]	1.000	1.000
Material pairing coefficient at NL	[ZW]	1.000	1.000
Notice: When using Wohler lines from data files, the factors ZL, ZV, ZR, ZW will be interpolated according to the breakpoints NLstatic and NLendurance following ISO.			
Finite life factor	[ZNT]	1.000	1.000
	[ZL*ZV*ZR*ZNT]	1.000	1.000
Limited pitting is permitted:	No		
Size factor (flank)	[ZX]	1.000	1.000
Permissible contact stress (N/mm²)	[sigHP=sigHG/SHmin]	29.62	41.28
Pitting stress limit (N/mm²)	[sigHG]	23.10	32.20
Required safety	[SHmin]	0.78	0.78
Safety factor for contact stress at operating pitch circle			
	[SHw]	1.19	1.66
Transmittable power (W)	[WRating]	479.84	668.87

4a. WEAR

Line load at reference diameter (N/mm)	[w]	6.27	
Line load at reference diameter (N/mm)	[K_A*K_γ*K_V*$K_{H\beta}$*$K_{H\alpha}$*w]	6.27	
Loss factor	[H_V]	0.077	
Length of active flank (mm)	[l_{Fl}]	1.59	1.50
Wear factor (mm³/Nm/10⁶)	[k_w]	3.40000	3.40000
Data from file k_{w1}: Z014-PETG_VDI2736_BP.DAT			
Data from file k_{w2}: Z014-PETG_VDI2736_BP.DAT			
Normal tooth thickness in pitch circle (mm)	[s_n]	1.41	1.30
Maximum permissible wear (%)	[W_{limit}]	15.00	
Permissible wear on flank (mm)	[δ_{Wlimn}]	0.21	0.19
Wear removal (mm)	[δ_{Wn}]	0.00320	0.00085
Wear removal (mg)	[=lFL*b*z*ro*δWn]	8.2	8.2
Required safety	[S_{Wmin}]	1.10	
Safety against wear	[S_W]	65.84	229.85

Calculation for safety against shearing for plastics			
Normal tooth thickness in the active root diameter (mm)	[s_{dNf}-δWn]	1.60	1.58
Shearing stress (N/mm²)	[τ_{nom}]	3.92	3.98
Notch effect coefficient	[K_T]	1.25	1.25
Permitted shearing strength (N/mm²)	[τ_B]	4.29	5.96
Required safety	[S_{Tmin}]	2.50	
Safety shearing	[S_T]	0.88	1.20

$\tau_B = 0.557 * \sigma_{Fadm}$; $S_T = \tau_B / (\tau_{nom} * K_T)$

Calculation of local wear with speeds and load distribution according to method A:
Calculation was not carried out. (Contact analysis under load is required.)

Important note:
the kw wear coefficients are usually determined using a plastic/steel pairing..
The coefficients may be very different if pairings of other materials are used..
This calculation is designed to give an indication of possible service life,
however it has not yet been checked exhaustively in real life..

5. BENDING

For plastics:

Tooth deformation (µm)	[fa]	41.501
Permissible tooth deformation (µm)	[fazul]	56.000
Required safety	[Sdel]	1.000
Safety against deformation	[Sdelmin]	1.349

Experimental method using tooth stiffness according	ISO6336:2006:		
Tooth deformation (µm)	[faExp]	31.726	23.532
Permissible tooth deformation (µm)	[fazulExp]	164.135	164.135
Required safety	[Sdel]	1.000	
Safety against jamming	[SdelExp]	5.173	6.975

6. MEASUREMENTS FOR TOOTH THICKNESS

		------- Gear 1	------ Gear 2 --		
Tooth thickness deviation		DIN 3967 cd25	DIN 3967 cd25		
Tooth thickness allowance (normal section) (mm)	[As.e/i]	-0.054 /	-0.084	-0.095 /	-0.145
Number of teeth spanned	[k]	6.000		19.000	
Base tangent length (no backlash) (mm)	[Wk]	13.594		45.592	
Actual base tangent length ('span') (mm)	[Wk.e/i]	13.544 /	13.515	45.503 /	45.456
(mm)	[ΔWk.e/i]	-0.051 /	-0.079	-0.089 /	-0.136
Diameter of measuring circle (mm)	[dMWk.m]	32.707		127.626	
Theoretical diameter of ball/pin (mm)	[DM]	1.399		1.344	
Effective diameter of ball/pin (mm)	[DMeff]	1.400		1.400	
Radial single-ball measurement backlash free (mm)	[MrK]	17.126		64.863	
Radial single-ball measurement (mm)	[MrK.e/i]	17.063 /	17.027	64.737 /	64.670
Diameter of measuring circle (mm)	[dMMr.m]	32.159		127.523	
Diametral measurement over two balls without clearance (mm)	[MdK]	34.225		129.727	
Diametral two ball measure (mm)	[MdK.e/i]	34.099 /	34.028	129.474 /	129.340
Diametral measurement over pins without clearance (mm)	[MdR]	34.252		129.727	
Measurement over pins according to DIN 3960 (mm)	[MdR.e/i]	34.126 /	34.055	129.474 /	129.340
Measurement over 2 pins (free) according to AGMA 2002 (mm)	[dk2f.e/i]	34.098 /	34.027	0.000 /	0.000
Measurement over 2 pins (axial) according to AGMA 2002 (mm)	[dk2t.e/i]	34.152 /	34.081	0.000 /	0.000
Measurement over 3 pins (axial) according to AGMA 2002 (mm)	[dk3A.e/i]	34.126 /	34.055	129.474 /	129.340
Chordal tooth thickness (no backlash) (mm)	[sc]	1.405		1.298	
Actual chordal tooth thickness (mm)	[sc.e/i]	1.351 /	1.321	1.203 /	1.153
Reference chordal height from da.m (mm)	[ha]	1.010		0.847	
Tooth thickness (Arc) (mm)	[sn]	1.405		1.298	
(mm)	[sn.e/i]	1.351 /	1.321	1.203 /	1.153
Backlash free center distance (mm)	[aControl.e/i]	79.798	/ 79.688		
Backlash free center distance, allowances (mm)	[jta]	-0.202 /	-0.312		
dNf.i with aControl (mm)	[dNf0.i]	30.517		125.878	
Reserve (dNf0.i-dFf.e)/2 (mm)	[cF0.i]	-0.126		-0.025	
Tip clearance (mm)	[c0.i(aControl)]	0.019		-0.038	
Center distance allowances (mm)	[Aa.e/i]	0.015 /	-0.015		

Circumferential backlash from Aa (mm)	[jtw_Aa.e/i]	0.011 /	-0.011
Radial backlash (mm)	[jrw.e/i]	0.327 /	0.187
Circumferential backlash (transverse section) (mm)	[jtw.e/i]	0.246 /	0.141
Normal backlash (mm)	[jnw.e/i]	0.226 /	0.130
Angle of rotation on input with fixed output.:			
Entire torsional angle (°)	[j.tSys]		0.8821/0.5062

7. GEAR ACCURACY

		------- GEAR 1	-------- GEAR 2 --
According to DIN 3961:1978			
One or several gear data (mn, b or d) lay beyond the limits covered by the standard.			
The tolerances are calculated on the basis of the formulae in the standard.			
However, their values are outside the official range of validity!			
Accuracy grade	[Q-DIN3961]	6	6
Profile form deviation (µm)	[ff]	5.50	5.50
Profile slope deviation (µm)	[fHa]	5.00	5.00
Total profile deviation (µm)	[Ff]	7.00	7.00
Helix form deviation (µm)	[fbf]	5.50	5.50
Helix slope deviation (µm)	[fHb]	9.00	9.00
Total helix deviation (µm)	[Fb]	10.00	10.00
Normal base pitch deviation (µm)	[fpe]	7.00	8.00
Single pitch deviation (µm)	[fp]	7.00	8.00
Adjacent pitch difference (µm)	[fu]	8.00	9.00
Total cumulative pitch deviation (µm)	[Fp]	18.00	28.00
Sector pitch deviation over z/8 pitches (µm)	[Fpz/8]	12.00	17.00
Runout (µm)	[Fr]	12.00	17.00
Tooth Thickness Variation (µm)	[Rs]	7.00	10.00
Single flank composite, total (µm)	[Fi']	21.00	28.00
Single flank composite, tooth-to-tooth (µm)	[fi']	10.00	10.00
Radial composite, total (µm)	[Fi"]	16.00	23.00
Radial composite, tooth-to-tooth (µm)	[fi"]	6.00	9.00
According to DIN 58405:1972 (Feinwerktechnik):			
Tooth-to-tooth composite error (µm)	[fi"]	7.00	9.00
Composite error (µm)	[Fi"]	20.00	25.00
Axis alignment error (µm)	[fp]	13.60	13.60
Flank direction error (µm)	[fbeta]	6.30	6.30
Runout (µm)	[Trk, Fr]	21.00	28.00

8. ADDITIONAL DATA

Maximal possible center distance (eps_a=1.0)	[aMAX]	80.597	
Mass (g)	[m]	33.27	524.73
Total mass (g)	[m]	558.00	
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]	4.285e-006	0.001066
System ((da+df)/2...di) (kg*m²)	[TraeghMom]	7.093e-005	
Coefficient of friction	[mum]	0.280	
Loss factor	[HV]	0.077	
Coefficient for frequency of running	[KstEDf]	1.000	
Casing surface (m²)	[Oberflache]	0.16929	
Gear power loss (W)	[PVZ]	6.806	
(Meshing efficiency (%)	[etaz]	97.833)	
Tooth root temperature (°C)	[TR]	70.0	70.0

Flank temperature (°C)	[TF]		70.0	70.0
Heat transfer coefficient, root	[KF]		0.0	0.0
Heat transfer coefficient, flank	[KH]		0.0	0.0
Indications for the manufacturing by wire cutting:				
Deviation from theoretical tooth trace (µm)		[WireErr]	317.6	79.7
Permissible deviation (µm)	[Fb/2]		5.0	5.0

9. MODIFICATIONS AND TOOTH FORM DEFINITION

Data for the tooth form calculation :

Calculation of Gear 1
Tooth form, Gear 1, Step 1: Automatic (final machining)
haP*= 1.107, hfP*= 1.250, rofP*= 0.380

Calculation of Gear 2
Tooth form, Gear 2, Step 1: Automatic (final machining)
haP*= 1.190, hfP*= 1.250, rofP*= 0.380

10. SERVICE LIFE, DAMAGE

Required safety for tooth root	[SFmin]	0.96	
Required safety for tooth flank	[SHmin]	0.78	
Required safety for wear	[SWmin]	1.10	
Service life (calculated with required safeties):			
System service life (h)	[Hatt]	7.182	
Tooth root service life (h)	[HFatt]	7.182	25.82
Tooth flank service life (h)	[HHatt]	160.1	640.3
Wear service life (h)	[HWatt]	1197	4179

Damage calculated on the basis of the required service life [H] (20.0 h)

F1%	F2%	H1%	H2%	W1%	W2%
278.48	77.4647	12.4933	3.1233	1.6708	0.4786

Damage calculated on basis of system service life [Hatt] (7.2 h)

F1%	F2%	H1%	H2%	W1%	W2%
100.00	27.8167	4.4862	1.1215	0.6000	0.1719

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

Gear		fac	b	t0	T	R(H)%
1	Tooth root	60000	1.7	4.16e+005	6.393e+005	0.02
1	Tooth flank	60000	1.3	8.658e+006	4.125e+007	100.00
2	Tooth root	15000	1.7	3.739e+005	5.746e+005	100.00
2	Tooth flank	15000	1.3	8.658e+006	4.125e+007	100.00

Reliability of the configuration for required service life (%) 0.02 (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.

End of Report lines: 506

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File

Name : 30d_dynamic
Changed by: jsebe on: 03.05.2023 at: 14:05:59

Important hint: At least one warning has occurred during the calculation:

1-> Note:
For calculations in accordance with VDI, the face load factor KHb with 1.0 is assumed,
as plastics run in.
However a width/module ratio that is too large (b/mn > 10) should be avoided.
Or the face load factor needs to be checked.

CALCULATION OF A HELICAL GEAR PAIR

Drawing or article number:
Gear 1: 0.000.0
Gear 2: 0.000.0

Calculation method Plastic according to VDI 2736:2013 (YF Method C)

		------- GEAR 1	-------- GEAR 2 --
Power (W)	[P]	314.159	
Speed (1/min)	[n]	1000.0	250.0
Torque (Nm)	[T]	3.000	12.000
Application factor	[KA]	1.00	
Required service life (h)	[H]	40.00	
Gear driving (+) / driven (-)		+	-

Working flank gear 1: Right flank
Sense of rotation gear 1 clockwise
Gearbox type: Gear with partly closed housing

1. TOOTH GEOMETRY AND MATERIAL

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

		------- GEAR 1	-------- GEAR 2 --
Center distance (mm)	[a]	80.000	
Center distance tolerance	ISO 286:2010 Measure js7		
Normal module (mm)	[mn]	1.2500	
Pressure angle at normal section (°)	[alfn]	30.0000	
Helix angle at reference circle (°)	[beta]	12.0000	
Number of teeth	[z]	25	100
Facewidth (mm)	[b]	30.00	30.00
Hand of gear		right	left
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: PETG, Thermoplastic (POM, PPA, etc.), untreated
3D printed material
Woehler line tooth root stress from file Z014-PETG_VDI2736_BP.DAT

S-N curve (Woehler line) Hertzian pressure from file Z014-PETG_VDI2736_BP.DAT

Gear 2: PETG, Thermoplastic (POM, PPA, etc.), untreated

3D printed material

Woehler line tooth root stress from file Z014-PETG_VDI2736_BP.DAT

S-N curve (Woehler line) Hertzian pressure from file Z014-PETG_VDI2736_BP.DAT

			------- GEAR 1 --------	GEAR 2 --
Surface hardness			HBW 45	HBW 45
Tooth root temperature (°C)		[TR]	70.0	70.0
Flank temperature (°C)		[TF]	70.0	70.0
Tooth root strength at NL (N/mm²)		[σFadm]	6.70	9.10
Strength against Hertzian pressure	at NL (N/mm²)	[σHadm]	20.10	27.20
Tensile strength (N/mm²)		[σB]	34.20	34.20
Yield point (N/mm²)		[σS]	33.80	33.80
Young's modulus (N/mm²)		[E]	2317	2317
Poisson's ratio		[v]	0.400	0.400
Roughness average value DS, flank (µm)		[RAH]	0.00	0.00
Roughness average value DS, root (µm)		[RAF]	0.00	0.00
Mean roughness height, Rz, flank (µm)		[RZH]	0.00	0.00
Mean roughness height, Rz, root (µm)		[RZF]	0.00	0.00

Gear reference profile 1 :

Reference profile	1.25 / 0.38 / 1.0 ISO 53:1998 Profil A		
Dedendum coefficient	[hfP*]	1.250	
Root radius factor	[rhofP*]	0.380 (rhofPmax*=0.110)	
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	1.25 / 0.38 / 1.0 ISO 53:1998 Profil A		
Dedendum coefficient	[hfP*]	1.250	
Root radius factor	[rhofP*]	0.380 (rhofPmax*=0.110)	
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	

Summary of reference profile gears:

Dedendum reference profile	[hfP*]	1.250	1.250
Tooth root radius Refer. profile	[rofP*]	0.380	0.380
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

Type of profile modification: none (only running-in)

Tip relief (µm)	[Ca]	20.0	20.0

Lubrication type		Dry-running	
Ambient temperature (°C)	[TU]	20.000	
		------- GEAR 1 --------	GEAR 2 --
Overall transmission ratio	[itot]	-4.000	
Gear ratio	[u]	4.000	
Transverse module (mm)	[mt]	1.278	
Pressure angle at pitch circle (°)	[alft]	30.551	
Working transverse pressure angle (°)	[alfwt]	30.708	
	[alfwt.e/i]	30.726 / 30.690	
Working pressure angle at normal section (°)	[alfwn]	30.154	
Helix angle at operating pitch circle (°)	[betaw]	12.019	
Base helix angle (°)	[betab]	10.373	
Reference center distance (mm)	[ad]	79.870	
Sum of profile shift coefficients	[Summexi]	0.1040	
Profile shift coefficient	[x]	0.1632	-0.0592
Tooth thickness (Arc) (module) (module)	[sn*]	1.7592	1.5024
Tip alteration (mm)	[k*mn]	0.000	0.000
Reference diameter (mm)	[d]	31.948	127.793
Base diameter (mm)	[db]	27.513	110.052
Tip diameter (mm)	[da]	34.856	130.144
(mm)	[da.e/i]	34.856 / 34.831	130.144 / 130.104
Tip diameter allowances (mm)	[Ada.e/i]	0.000 / -0.025	0.000 / -0.040
Tip form diameter (mm)	[dFa]	34.856	130.144
(mm)	[dFa.e/i]	34.856 / 34.831	130.144 / 130.104
Active tip diameter (mm)	[dNa]	34.856	130.144
Active tip diameter (mm)	[dNa.e/i]	34.856 / 34.831	130.144 / 130.104
Operating pitch diameter (mm)	[dw]	32.000	128.000
(mm)	[dw.e/i]	32.006 / 31.994	128.024 / 127.976
Root diameter (mm)	[df]	29.231	124.519
Generating Profile shift coefficient	[xE.e/i]	0.1258/ 0.1050	-0.1250/ -0.1597
Manufactured root diameter with xE (mm)	[df.e/i]	29.138 / 29.086	124.355 / 124.268
Theoretical tip clearance (mm)	[c]	0.312	0.312
Effective tip clearance (mm)	[c.e/i]	0.465 / 0.379	0.420 / 0.344
Active root diameter (mm)	[dNf]	30.111	125.492
(mm)	[dNf.e/i]	30.166 / 30.087	125.540 / 125.464
Root form diameter (mm)	[dFf]	29.948	125.084
(mm)	[dFf.e/i]	29.876 / 29.836	124.931 / 124.850
Reserve (dNf-dFf)/2 (mm)	[cF.e/i]	0.165 / 0.106	0.345 / 0.266
Addendum (mm)	[ha=mn*(haP*+x+k)]	1.454	1.176
(mm)	[ha.e/i]	1.454 / 1.441	1.176 / 1.156
Dedendum (mm)	[hf=mn*(hfP*-x)]	1.359	1.637
(mm)	[hf.e/i]	1.405 / 1.431	1.719 / 1.762
Roll angle at dFa (°)	[xsi_dFa.e/i]	44.567 / 44.482	36.168 / 36.129
Roll angle to dNa (°)	[xsi_dNa.e/i]	44.567 / 44.482	36.168 / 36.129
Roll angle to dNf (°)	[xsi_dNf.e/i]	25.759 / 25.358	31.449 / 31.366
Roll angle at dFf (°)	[xsi_dFf.e/i]	24.250 / 24.037	30.784 / 30.696
Tooth height (mm)	[h]	2.813	2.813
Virtual gear no. of teeth	[zn]	26.415	105.660
Normal tooth thickness at tip circle (mm)	[san]	0.361	0.494
(mm)	[san.e/i]	0.321 / 0.270	0.422 / 0.346
Normal tooth thickness on tip form circle (mm)	[sFan]	0.361	0.494
(mm)	[sFan.e/i]	0.321 / 0.270	0.422 / 0.346
Normal space width at root circle (mm)	[efn]	0.361	0.227
(mm)	[efn.e/i]	0.377 / 0.386	0.234 / 0.238
Max. sliding velocity at tip (m/s)	[vga]	0.331	0.269

Specific sliding at the tip	[zetaa]		0.296			0.295		
Specific sliding at the root	[zetaf]		-0.419			-0.419		
Mean specific sliding	[zetam]			0.296				
Sliding factor on tip	[Kga]		0.198			0.160		
Sliding factor on root	[Kgf]		-0.160			-0.198		
Pitch on reference circle (mm)	[pt]			4.015				
Base pitch (mm)	[pbt]			3.457				
Transverse pitch on contact-path (mm)	[pet]			3.457				
Lead height (mm)	[pz]		472.195			1888.778		
Axial pitch (mm)	[px]			18.888				
Length of path of contact (mm)	[ga, e/i]		4.582 (	4.612 /	4.495)			
Length T1-A, T2-A (mm)	[T1A, T2A]	6.118(	6.088/	6.185)	34.735(	34.735/	34.698)	
Length T1-B (mm)	[T1B, T2B]	7.243(	7.243/	7.223)	33.610(	33.581/	33.660)	
Length T1-C (mm)	[T1C, T2C]	8.171(	8.165/	8.177)	32.683(	32.659/	32.706)	
Length T1-D (mm)	[T1D, T2D]	9.575(	9.546/	9.642)	31.278(	31.278/	31.241)	
Length T1-E (mm)	[T1E, T2E]	10.700(	10.700/	10.680)	30.153(	30.123/	30.203)	
Length T1-T2 (mm)	[T1T2]		40.853 (	40.824 /	40.883)			
Diameter of single contact point B (mm)	[d-B]	31.093(	31.093/	31.074)	128.957(	128.927/	129.009)	
Diameter of single contact point D (mm)	[d-D]	33.522(	33.488/	33.598)	126.589(	126.589/	126.552)	
Addendum contact ratio	[eps]	0.732(	0.733/	0.724)	0.594(	0.601/	0.576)	
Minimal length of contact line (mm)	[Lmin]			36.747				
Transverse contact ratio	[eps_a]			1.325				
Transverse contact ratio with allowances	[eps_a.e/m/i]		1.334 /	1.317 /	1.300			
Overlap ratio	[eps_b]			1.588				
Total contact ratio	[eps_g]			2.914				
Total contact ratio with allowances	[eps_g.e/m/i]		2.922 /	2.905 /	2.889			

2. FACTORS OF GENERAL INFLUENCE

		------- GEAR 1	-------- GEAR 2 --
Nominal circum. force at pitch circle (N)	[Ft]	187.8	
Axial force (N)	[Fa]	39.9	
Radial force (N)	[Fr]	110.9	
Normal force (N)	[Fnorm]	221.7	
Nominal circumferential force per mm (N/mm)	[w]	6.26	
Only as information: Forces at operating pitch circle:			
Nominal circumferential force (N)	[Ftw]	187.5	
Axial force (N)	[Faw]	39.9	
Radial force (N)	[Frw]	111.4	
Circumferential speed reference circle (m/s)	[v]	1.67	
Circumferential speed operating pitch circle (m/s)	[v(dw)]	1.68	
Correction factor	[CM]	0.800	
Gear blank factor	[CR]	1.000	
Basic rack factor	[CBS]	1.170	
Material coefficient	[E/Est]	0.011	
Singular tooth stiffness (N/mm/µm)	[c']	0.190	
Meshing stiffness (N/mm/µm)	[cg]	0.236	
Dynamic factor	[KV]	1.000	
Face load factor - flank	[KHb]	1.000	
- Tooth root	[KFb]	1.000	
- Scuffing	[KBb]	1.000	

Transverse load factor - flank	[KHa]	1.000	
- Tooth root	[KFa]	1.000	
- Scuffing	[KBa]	1.000	
Number of load cycles (in mio.)	[NL]	2.400	0.600

3. TOOTH ROOT STRENGTH

Calculation of Tooth form coefficients according method: C

		------- GEAR 1	-------- GEAR 2 --
Calculated with manufacturing profile shift	[xE.m]	0.1154	-0.1424
Tooth form factor	[YF]	1.86	1.70
Stress correction factor	[YS]	1.80	1.92
Load application angle (°)	[alfFen]	36.85	31.54
Bending moment arm (mm)	[hF]	2.63	2.58
Tooth thickness at root (mm)	[sFn]	3.13	3.34
Tooth root radius (mm)	[roF]	0.64	0.61

(hF* = 2.101/ 2.061 sFn* = 2.501/ 2.672 roF* = 0.513/ 0.488)
(den (mm) =
35.927/ 134.426 dsFn(mm) = 29.576/ 124.821 alfsFn(°) = 30.00/ 30.00 qs = 2.437/ 2.736)

Contact ratio factor	[Yeps]		0.816	
Helix angle factor	[Ybet]		0.900	
Effective facewidth (mm)	[beff]	30.00		30.00
Nominal stress at tooth root (N/mm²)	[sigF0]	12.32		12.02
Tooth root stress (N/mm²)	[sigF]	12.32		12.02
Permissible bending stress at root from data tables				
Notch sensitivity factor	[YdrelT]	1.000		1.000
Surface factor	[YRrelT]	1.000		1.000
size factor (Tooth root)	[YX]	1.000		1.000

Notice: When using Wohler lines from data files, the factors YdrelT, YRrelT, YX
will be interpolated according to the breakpoints NLstatic and NLendurance following ISO.

Finite life factor	[YNT]	1.000		1.000
[YdrelT*YRrelT*YX*YNT]		1.000		1.000
Alternating bending factor (mean stress influence coefficient)	[YM]		1.000	1.000
Stress correction factor	[Yst]		2.00	
Yst*sigFlim (N/mm²)	[sigFE]	13.40		18.20
Permissible tooth root stress (N/mm²)	[sigFP=sigFG/SFmin]	10.72		14.56
Limit strength tooth root (N/mm²)	[sigFG]	13.40		18.20
Required safety	[SFmin]	1.25		1.25
Safety for tooth root stress	[SF=sigFG/sigF]	1.09		1.51
Transmittable power (W)	[WRating]	273.41		380.56

4. SAFETY AGAINST PITTING (TOOTH FLANK)

		------- GEAR 1	-------- GEAR 2 --
Zone factor	[ZH]		2.113
Elasticity factor (√N/mm²)	[ZE]		20.952
Young's modulus for tooth flank (N/mm²)	[E]	2317	2317
Contact ratio factor	[Zeps]		0.869
Helix angle factor	[Zbet]		1.000
Effective facewidth (mm)	[beff]		30.00

Nominal contact stress (N/mm²)	[sigH0]	19.03	
Contact stress at operating pitch circle (N/mm²)	[sigHw]	19.03	
Lubrication coefficient at NL	[ZL]	1.000	1.000
Speed coefficient at NL	[ZV]	1.000	1.000
Roughness coefficient at NL	[ZR]	1.000	1.000
Material pairing coefficient at NL	[ZW]	1.000	1.000
Notice: When using Wohler lines from data files, the factors ZL, ZV, ZR, ZW will be interpolated according to the breakpoints NLstatic and NLendurance following ISO.			
Finite life factor	[ZNT]	1.000	1.000
	[ZL*ZV*ZR*ZNT]	1.000	1.000
Limited pitting is permitted:	No		
Size factor (flank)	[ZX]	1.000	1.000
Permissible contact stress (N/mm²)	[sigHP=sigHG/SHmin]	21.73	29.41
Pitting stress limit (N/mm²)	[sigHG]	20.10	27.20
Required safety	[SHmin]	0.93	0.93
Safety factor for contact stress at operating pitch circle			
	[SHw]	1.06	1.43
Transmittable power (W)	[WRating]	358.64	485.33

4a. WEAR

Line load at reference diameter (N/mm)	[w]		6.26	
Line load at reference diameter (N/mm)	[K_A*K_γ*K_V*$K_{H\beta}$*$K_{H\alpha}$*w]		6.26	
Loss factor	[H_V]		0.090	
Length of active flank (mm)	[l_{Fl}]	2.77		2.67
Wear factor (mm³/Nm/10⁶)	[k_W]	3.40000		3.40000
Data from file k_{W1}: Z014-PETG_VDI2736_BP.DAT				
Data from file k_{W2}: Z014-PETG_VDI2736_BP.DAT				
Normal tooth thickness in pitch circle (mm)	[s_n]	2.20		1.88
Maximum permissible wear (%)	[W_{limit}]		15.00	
Permissible wear on flank (mm)	[δ_{Wlimn}]	0.33		0.28
Wear removal (mm)	[δ_{Wn}]	0.00665		0.00172
Wear removal (mg)	[=lFL*b*z*ro*δWn]	18.9		18.9
Required safety	[S_{Wmin}]		1.10	
Safety against wear	[S_W]	49.63		163.61

Calculation for safety against shearing for plastics				
Normal tooth thickness in the active root diameter (mm)	[s_{dNf}-δWn]		2.91	3.00
Shearing stress (N/mm²)	[τ_{nom}]	2.15		2.09
Notch effect coefficient	[K_T]	1.25		1.25
Permitted shearing strength (N/mm²)	[τ_B]	3.73		5.07
Required safety	[S_{Tmin}]		2.50	
Safety shearing	[S_T]	1.39		1.94

$\tau_B = 0.557 * \sigma_{Fadm}$; $S_T = \tau_B / (\tau_{nom} * K_T)$

Calculation of local wear with speeds and load distribution according to method A:
Calculation was not carried out. (Contact analysis under load is required.)

Important note:
the kw wear coefficients are usually determined using a plastic/steel pairing..
The coefficients may be very different if pairings of other materials are used..
This calculation is designed to give an indication of possible service life,
however it has not yet been checked exhaustively in real life..

5. BENDING

For plastics:			
Tooth deformation (µm)	[fa]	41.435	
Permissible tooth deformation (µm)	[fazul]	87.500	
Required safety	[Sdel]	1.000	
Safety against deformation	[Sdelmin]	2.112	
Experimental method using tooth stiffness according	ISO6336:2006:		
Tooth deformation (µm)	[faExp]	25.752	20.474
Permissible tooth deformation (µm)	[fazulExp]	157.530	157.530
Required safety	[Sdel]	1.000	
Safety against jamming	[SdelExp]	6.117	7.694

6. MEASUREMENTS FOR TOOTH THICKNESS

		------- Gear 1	------ Gear 2 --
Tooth thickness deviation		DIN 3967 cd25	DIN 3967 cd25
Tooth thickness allowance (normal section) (mm)	[As.e/i]	-0.054 / -0.084	-0.095 / -0.145
Number of teeth spanned	[k]	5.000	18.000
Base tangent length (no backlash) (mm)	[Wk]	17.051	65.615
Actual base tangent length ('span') (mm)	[Wk.e/i]	17.005 / 16.979	65.533 / 65.489
(mm)	[ΔWk.e/i]	-0.047 / -0.073	-0.082 / -0.126
Diameter of measuring circle (mm)	[dMWk.m]	32.192	127.530
Theoretical diameter of ball/pin (mm)	[DM]	2.416	2.282
Effective diameter of ball/pin (mm)	[DMeff]	2.500	2.500
Radial single-ball measurement backlash free (mm)	[MrK]	18.157	65.861
Radial single-ball measurement (mm)	[MrK.e/i]	18.116 / 18.093	65.781 / 65.738
Diameter of measuring circle (mm)	[dMMr.m]	32.351	127.753
Diametral measurement over two balls without clearance (mm)	[MdK]	36.248	131.721
Diametral two ball measure (mm)	[MdK.e/i]	36.166 / 36.120	131.561 / 131.477
Diametral measurement over pins without clearance (mm)	[MdR]	36.314	131.721
Measurement over pins according to DIN 3960 (mm)	[MdR.e/i]	36.232 / 36.187	131.561 / 131.477
Measurement over 2 pins (free) according to AGMA 2002 (mm)	[dk2f.e/i]	36.162 / 36.117	0.000 / 0.000
Measurement over 2 pins (axial) according to AGMA 2002 (mm)	[dk2t.e/i]	36.296 / 36.251	0.000 / 0.000
Measurement over 3 pins (axial) according to AGMA 2002 (mm)	[dk3A.e/i]	36.232 / 36.187	131.561 / 131.477
Chordal tooth thickness (no backlash) (mm)	[sc]	2.197	1.878
Actual chordal tooth thickness (mm)	[sc.e/i]	2.143 / 2.113	1.783 / 1.733
Reference chordal height from da.m (mm)	[ha]	1.484	1.173
Tooth thickness (Arc) (mm)	[sn]	2.199	1.878
(mm)	[sn.e/i]	2.145 / 2.115	1.783 / 1.733
Backlash free center distance (mm)	[aControl.e/i]	79.871 / 79.802	
Backlash free center distance, allowances (mm)	[jta]	-0.129 / -0.198	
dNf.i with aControl (mm)	[dNf0.i]	29.803	125.119
Reserve (dNf0.i-dFf.e)/2 (mm)	[cF0.i]	-0.036	0.094
Tip clearance (mm)	[c0.i(aControl)]	0.196	0.161
Center distance allowances (mm)	[Aa.e/i]	0.015 / -0.015	

Circumferential backlash from Aa (mm)	[jtw_Aa.e/i]	0.018 /	-0.018
Radial backlash (mm)	[jrw.e/i]	0.213 /	0.114
Circumferential backlash (transverse section) (mm)	[jtw.e/i]	0.252 /	0.135
Normal backlash (mm)	[jnw.e/i]	0.214 /	0.114
Angle of rotation on input with fixed output.:			
Entire torsional angle (°)	[j.tSys]		0.9035/ 0.4826

7. GEAR ACCURACY

		------- GEAR 1	-------- GEAR 2 --
According to DIN 3961:1978			
Accuracy grade	[Q-DIN3961]	6	6
Profile form deviation (µm)	[ff]	6.00	6.00
Profile slope deviation (µm)	[fHa]	5.00	5.00
Total profile deviation (µm)	[Ff]	8.00	8.00
Helix form deviation (µm)	[fbf]	5.50	5.50
Helix slope deviation (µm)	[fHb]	9.00	9.00
Total helix deviation (µm)	[Fb]	10.00	10.00
Normal base pitch deviation (µm)	[fpe]	7.00	8.00
Single pitch deviation (µm)	[fp]	7.00	8.00
Adjacent pitch difference (µm)	[fu]	8.00	10.00
Total cumulative pitch deviation (µm)	[Fp]	19.00	29.00
Sector pitch deviation over z/8 pitches (µm)	[Fpz/8]	12.00	18.00
Runout (µm)	[Fr]	14.00	19.00
Tooth Thickness Variation (µm)	[Rs]	8.00	11.00
Single flank composite, total (µm)	[Fi']	22.00	30.00
Single flank composite, tooth-to-tooth (µm)	[fi']	10.00	11.00
Radial composite, total (µm)	[Fi"]	17.00	24.00
Radial composite, tooth-to-tooth (µm)	[fi"]	6.00	10.00
According to DIN 58405:1972 (Feinwerktechnik):			
Tooth-to-tooth composite error (µm)	[fi"]	4.41	5.67
Composite error (µm)	[Fi"]	12.61	15.76
Axis alignment error (µm)	[fp]	13.60	13.60
Flank direction error (µm)	[fbeta]	6.30	6.30
Runout (µm)	[Trk, Fr]	21.00	28.00

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

Maximum value for deviation error of axis (µm)	[fSigbet]	13.00 (Fb= 13.00)
Maximum value for inclination error of axes (µm)	[fSigdel]	26.00

8. ADDITIONAL DATA

Maximal possible center distance (eps_a=1.0)	[aMAX]	80.580	
Mass (g)	[m]	33.14	523.37
Total mass (g)	[m]	556.51	
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]	4.254e-006	0.001061
System ((da+df)/2...di) (kg*m²)	[TraeghMom]	7.055e-005	
Coefficient of friction	[mum]	0.280	
Loss factor	[HV]	0.090	
Coefficient for frequency of running	[KstEDf]	1.000	
Casing surface (m²)	[Oberflache]	0.16961	

Gear power loss (W)	[PVZ]		7.901	
(Meshing efficiency (%)	[etaz]		97.485)	
Tooth root temperature (°C)	[TR]	70.0		70.0
Flank temperature (°C)	[TF]	70.0		70.0
Heat transfer coefficient, root	[KF]	0.0		0.0
Heat transfer coefficient, flank	[KH]	0.0		0.0

Indications for the manufacturing by wire cutting:

Deviation from theoretical tooth trace (µm)	[WireErr]	317.1		79.5
Permissible deviation (µm)	[Fb/2]	5.0		5.0

9. MODIFICATIONS AND TOOTH FORM DEFINITION

Data for the tooth form calculation :

Calculation of Gear 1
Tooth form, Gear 1, Step 1: Automatic (final machining)
haP*= 1.043, hfP*= 1.250, rofP*= 0.380

Calculation of Gear 2
Tooth form, Gear 2, Step 1: Automatic (final machining)
haP*= 1.075, hfP*= 1.250, rofP*= 0.380

10. SERVICE LIFE, DAMAGE

Required safety for tooth root	[SFmin]	1.25	
Required safety for tooth flank	[SHmin]	0.93	
Required safety for wear	[SWmin]	1.10	

Service life (calculated with required safeties):

System service life (h)	[Hatt]	20.115	
Tooth root service life (h)	[HFatt]	20.12	90.73
Tooth flank service life (h)	[HHatt]	76.02	304.1
Wear service life (h)	[HWatt]	1805	5949

Damage calculated on the basis of the required service life [H] (40.0 h)

F1%	F2%	H1%	H2%	W1%	W2%
198.85	44.0849	52.6199	13.1550	2.2166	0.6723

Damage calculated on basis of system service life [Hatt] (20.1 h)

F1%	F2%	H1%	H2%	W1%	W2%
100.00	22.1697	26.4619	6.6155	1.1147	0.3381

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

Gear		fac	b	t0	T	R(H)%
1	Tooth root	60000	1.7	1.165e+006	1.791e+006	4.16
1	Tooth flank	60000	1.3	4.111e+006	1.959e+007	100.00
2	Tooth root	15000	1.7	1.314e+006	2.019e+006	100.00
2	Tooth flank	15000	1.3	4.111e+006	1.959e+007	100.00

Reliability of the configuration for required service life (%) 4.16 (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.

End of Report lines: 510

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File

Name : Unnamed
Changed by: jsebe on: 22.05.2023 at: 08:38:49

Important hint: At least one warning has occurred during the calculation:

1-> Note:
For calculations in accordance with VDI, the face load factor KHb with 1.0 is assumed,
as plastics run in.
However a width/module ratio that is too large (b/mn > 10) should be avoided.
Or the face load factor needs to be checked.

CALCULATION OF A CYLINDRICAL SPUR GEAR PAIR

Drawing or article number:
Gear 1: 0.000.0
Gear 2: 0.000.0

Calculation method Plastic according to VDI 2736:2013 (YF Method C)

		------- GEAR 1	-------- GEAR 2 --
Power (W)	[P]	293.215	
Speed (1/min)	[n]	1000.0	250.0
Torque (Nm)	[T]	2.800	11.200
Application factor	[KA]	1.00	
Required service life (h)	[H]	0.01	
Gear driving (+) / driven (-)		+	-

Working flank gear 1: Right flank
Sense of rotation gear 1 clockwise
Gearbox type: Gear with partly closed housing

1. TOOTH GEOMETRY AND MATERIAL

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

		------- GEAR 1	-------- GEAR 2 --
Center distance (mm)	[a]	80.000	
Center distance tolerance	ISO 286:2010 Measure js7		
Normal module (mm)	[mn]	1.2500	
Pressure angle at normal section (°)	[alfn]	20.0000	
Helix angle at reference circle (°)	[beta]	0.0000	
Number of teeth	[z]	25	100
Facewidth (mm)	[b]	30.00	30.00
Hand of gear		Spur gear	
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: ABS, Thermoplastic (POM, PPA, etc.), untreated
3D printed ABS
Woehler line tooth root stress from file Z014-ABS_VDI2736_BP.DAT

S-N curve (Woehler line) Hertzian pressure from file Z014-ABS_VDI2736_BP.DAT

Gear 2: ABS, Thermoplastic (POM, PPA, etc.), untreated

3D printed ABS

Woehler line tooth root stress from file Z014-ABS_VDI2736_BP.DAT

S-N curve (Woehler line) Hertzian pressure from file Z014-ABS_VDI2736_BP.DAT

			------- GEAR 1 --------	GEAR 2 --
Surface hardness			HBW 20	HBW 20
Tooth root temperature (°C)		[TR]	70.0	70.0
Flank temperature (°C)		[TF]	70.0	70.0
Tooth root strength at NL (N/mm²)		[σFadm]	6.80	7.40
Strength against Hertzian pressure	at NL (N/mm²)	[σHadm]	20.40	22.20
Tensile strength (N/mm²)		[σB]	16.20	16.20
Yield point (N/mm²)		[σS]	15.80	15.80
Young's modulus (N/mm²)		[E]	1695	1695
Poisson's ratio		[v]	0.400	0.400
Roughness average value DS, flank (µm)		[RAH]	0.00	0.00
Roughness average value DS, root (µm)		[RAF]	0.00	0.00
Mean roughness height, Rz, flank (µm)		[RZH]	0.00	0.00
Mean roughness height, Rz, root (µm)		[RZF]	0.00	0.00

Gear reference profile 1 :

Reference profile	1.25 / 0.38 / 1.0 ISO 53:1998 Profil A	
Dedendum coefficient	[hfP*]	1.250
Root radius factor	[rhofP*]	0.380 (rhofPmax*=0.472)
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	1.25 / 0.38 / 1.0 ISO 53:1998 Profil A	
Dedendum coefficient	[hfP*]	1.250
Root radius factor	[rhofP*]	0.380 (rhofPmax*=0.472)
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	

Summary of reference profile gears:

Dedendum reference profile	[hfP*]	1.250	1.250
Tooth root radius Refer. profile	[rofP*]	0.380	0.380
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

Type of profile modification: none (only running-in)

Tip relief (µm)	[Ca]	20.2	20.2

Lubrication type		Dry-running	
Ambient temperature (°C)	[TU]	20.000	
		------- GEAR 1 --------	GEAR 2 --
Overall transmission ratio	[itot]	-4.000	
Gear ratio	[u]	4.000	
Transverse module (mm)	[mt]	1.250	
Pressure angle at pitch circle (°)	[alft]	20.000	
Working transverse pressure angle (°)	[alfwt]	23.412	
	[alfwt.e/i]	23.437 / 23.388	
Working pressure angle at normal section (°)	[alfwn]	23.412	
Helix angle at operating pitch circle (°)	[betaw]	0.000	
Base helix angle (°)	[betab]	0.000	
Reference center distance (mm)	[ad]	78.125	
Sum of profile shift coefficients	[Summexi]	1.6258	
Profile shift coefficient	[x]	0.5656	1.0602
Tooth thickness (Arc) (module) (module)	[sn*]	1.9825	2.3426
Tip alteration (mm)	[k*mn]	-0.157	-0.157
Reference diameter (mm)	[d]	31.250	125.000
Base diameter (mm)	[db]	29.365	117.462
Tip diameter (mm)	[da]	34.850	129.837
(mm)	[da.e/i]	34.850 / 34.825	129.837 / 129.797
Tip diameter allowances (mm)	[Ada.e/i]	0.000 / -0.025	0.000 / -0.040
Tip form diameter (mm)	[dFa]	34.850	129.837
(mm)	[dFa.e/i]	34.850 / 34.825	129.837 / 129.797
Active tip diameter (mm)	[dNa]	34.850	129.837
Active tip diameter (mm)	[dNa.e/i]	34.850 / 34.825	129.837 / 129.797
Operating pitch diameter (mm)	[dw]	32.000	128.000
(mm)	[dw.e/i]	32.006 / 31.994	128.024 / 127.976
Root diameter (mm)	[df]	29.539	124.526
Generating Profile shift coefficient	[xE.e/i]	0.5062/ 0.4732	0.9833/ 0.9393
Manufactured root diameter with xE (mm)	[df.e/i]	29.391 / 29.308	124.333 / 124.223
Theoretical tip clearance (mm)	[c]	0.312	0.312
Effective tip clearance (mm)	[c.e/i]	0.491 / 0.393	0.463 / 0.371
Active root diameter (mm)	[dNf]	30.504	125.718
(mm)	[dNf.e/i]	30.550 / 30.483	125.762 / 125.691
Root form diameter (mm)	[dFf]	30.311	125.151
(mm)	[dFf.e/i]	30.207 / 30.151	124.958 / 124.849
Reserve (dNf-dFf)/2 (mm)	[cF.e/i]	0.199 / 0.138	0.456 / 0.366
Addendum (mm)	[ha=mn*(haP*+x+k)]	1.800	2.418
(mm)	[ha.e/i]	1.800 / 1.787	2.418 / 2.398
Dedendum (mm)	[hf=mn*(hfP*-x)]	0.856	0.237
(mm)	[hf.e/i]	0.930 / 0.971	0.333 / 0.388
Roll angle at dFa (°)	[xsi_dFa.e/i]	36.616 / 36.526	26.984 / 26.938
Roll angle to dNa (°)	[xsi_dNa.e/i]	36.616 / 36.526	26.984 / 26.938
Roll angle to dNf (°)	[xsi_dNf.e/i]	16.438 / 15.960	21.916 / 21.820
Roll angle at dFf (°)	[xsi_dFf.e/i]	13.812 / 13.342	20.795 / 20.638
Tooth height (mm)	[h]	2.656	2.656
Virtual gear no. of teeth	[zn]	25.000	100.000
Normal tooth thickness at tip circle (mm)	[san]	0.829	0.976
(mm)	[san.e/i]	0.784 / 0.735	0.922 / 0.862
Normal tooth thickness on tip form circle (mm)	[sFan]	0.829	0.976
(mm)	[sFan.e/i]	0.784 / 0.735	0.922 / 0.862
Normal space width at root circle (mm)	[efn]	0.942	0.825
(mm)	[efn.e/i]	0.976 / 0.000	0.827 / 0.828
Max. sliding velocity at tip (m/s)	[vga]	0.396	0.292

Specific sliding at the tip	[zetaa]		0.403			0.403		
Specific sliding at the root	[zetaf]		-0.675			-0.675		
Mean specific sliding	[zetam]			0.403				
Sliding factor on tip	[Kga]		0.236			0.174		
Sliding factor on root	[Kgf]		-0.174			-0.236		
Pitch on reference circle (mm)	[pt]			3.927				
Base pitch (mm)	[pbt]			3.690				
Transverse pitch on contact-path (mm)	[pet]			3.690				
Length of path of contact (mm)	[ga, e/i]		5.256 (	5.293 /	5.148)			
Length T1-A, T2-A (mm)	[T1A, T2A]	4.128(	4.090/	4.212)	27.660(	27.660/	27.613)	
Length T1-B (mm)	[T1B, T2B]	5.693(	5.693/	5.670)	26.095(	26.057/	26.156)	
Length T1-C (mm)	[T1C, T2C]	6.358(	6.350/	6.365)	25.430(	25.400/	25.460)	
Length T1-D (mm)	[T1D, T2D]	7.818(	7.780/	7.903)	23.970(	23.970/	23.923)	
Length T1-E (mm)	[T1E, T2E]	9.383(	9.383/	9.360)	22.404(	22.367/	22.465)	
Length T1-T2 (mm)	[T1T2]		31.788 (	31.750 /	31.825)			
Diameter of single contact point B (mm)	[d-B]	31.496(	31.496/	31.479)	128.534(	128.503/	128.583)	
Diameter of single contact point D (mm)	[d-D]	33.269(	33.233/	33.349)	126.868(	126.868/	126.832)	
Addendum contact ratio	[eps]	0.820(	0.822/	0.812)	0.604(	0.612/	0.583)	
Minimal length of contact line (mm)	[Lmin]			30.000				
Transverse contact ratio	[eps_a]			1.424				
Transverse contact ratio with allowances	[eps_a.e/m/i]		1.434 /	1.415 /	1.395			
Overlap ratio	[eps_b]			0.000				
Total contact ratio	[eps_g]			1.424				
Total contact ratio with allowances	[eps_g.e/m/i]		1.434 /	1.415 /	1.395			

2. FACTORS OF GENERAL INFLUENCE

		------- GEAR 1	-------- GEAR 2 --
Nominal circum. force at pitch circle (N)	[Ft]	179.2	
Axial force (N)	[Fa]	0.0	
Radial force (N)	[Fr]	65.2	
Normal force (N)	[Fnorm]	190.7	
Nominal circumferential force per mm (N/mm)	[w]	5.97	
Only as information: Forces at operating pitch circle:			
Nominal circumferential force (N)	[Ftw]	175.0	
Axial force (N)	[Faw]	0.0	
Radial force (N)	[Frw]	75.8	
Circumferential speed reference circle (m/s)	[v]	1.64	
Circumferential speed operating pitch circle (m/s)	[v(dw)]	1.68	
Correction factor	[CM]	0.800	
Gear blank factor	[CR]	1.000	
Basic rack factor	[CBS]	0.975	
Material coefficient	[E/Est]	0.008	
Singular tooth stiffness (N/mm/µm)	[c']	0.131	
Meshing stiffness (N/mm/µm)	[cg]	0.173	
Dynamic factor	[KV]	1.000	
Face load factor - flank	[KHb]	1.000	
- Tooth root	[KFb]	1.000	
- Scuffing	[KBb]	1.000	
Transverse load factor - flank	[KHa]	1.000	
- Tooth root	[KFa]	1.000	

- Scuffing	[KBa]	1.000	
Number of load cycles (in mio.)	[NL]	0.001	0.000

3. TOOTH ROOT STRENGTH

Calculation of Tooth form coefficients according method: C

		------- GEAR 1	-------- GEAR 2 --
Calculated with manufacturing profile shift	[xE.m]	0.4897	0.9613
Tooth form factor	[YF]	2.08	1.97
Stress correction factor	[YS]	1.84	1.97
Load application angle (°)	[alfFen]	31.35	24.83
Bending moment arm (mm)	[hF]	2.38	2.36
Tooth thickness at root (mm)	[sFn]	2.79	2.95
Tooth root radius (mm)	[roF]	0.53	0.48

(hF* = 1.901/ 1.891 sFn* = 2.230/ 2.359 roF* = 0.423/ 0.381)
(den (mm) =
34.850/ 129.837 dsFn(mm) = 29.762/ 124.732 alfsFn(°) = 30.00/ 30.00 qs = 2.636/ 3.095)

Contact ratio factor	[Yeps]		0.777	
Helix angle factor	[Ybet]		1.000	
Effective facewidth (mm)	[beff]	30.00		30.00
Nominal stress at tooth root (N/mm²)	[sigF0]	14.20		14.41
Tooth root stress (N/mm²)	[sigF]	14.20		14.41
Permissible bending stress at root from data tables				
Notch sensitivity factor	[YdrelT]	1.000		1.000
Surface factor	[YRrelT]	1.000		1.000
size factor (Tooth root)	[YX]	1.000		1.000

Notice: When using Wohler lines from data files, the factors YdrelT, YRrelT, YX
will be interpolated according to the breakpoints NLstatic and NLendurance following ISO.

Finite life factor	[YNT]	1.000		1.000
	[YdrelT*YRrelT*YX*YNT]	1.000		1.000
Alternating bending factor (mean stress influence coefficient)	[YM]	1.000		1.000
Stress correction factor	[Yst]		2.00	
Yst*sigFlim (N/mm²)	[sigFE]	13.60		14.80
Permissible tooth root stress (N/mm²)	[sigFP=sigFG/SFmin]	10.88		11.84
Limit strength tooth root (N/mm²)	[sigFG]	13.60		14.80
Required safety	[SFmin]	1.25		1.25
Safety for tooth root stress	[SF=sigFG/sigF]	0.96		1.03
Transmittable power (W)	[WRating]	224.62		240.93

4. SAFETY AGAINST PITTING (TOOTH FLANK)

		------- GEAR 1	-------- GEAR 2 --
Zone factor	[ZH]		2.287
Elasticity factor (√N/mm²)	[ZE]		17.920
Young's modulus for tooth flank (N/mm²)	[E]	1695	1695
Contact ratio factor	[Zeps]		0.927
Helix angle factor	[Zbet]		1.000
Effective facewidth (mm)	[beff]		30.00
Nominal contact stress (N/mm²)	[sigH0]		18.56
Contact stress at operating pitch circle (N/mm²)	[sigHw]		18.56

Lubrication coefficient at NL	[ZL]	1.000	1.000
Speed coefficient at NL	[ZV]	1.000	1.000
Roughness coefficient at NL	[ZR]	1.000	1.000
Material pairing coefficient at NL	[ZW]	1.000	1.000
Notice: When using Wohler lines from data files, the factors ZL, ZV, ZR, ZW will be interpolated according to the breakpoints NLstatic and NLendurance following ISO.			
Finite life factor	[ZNT]	1.000	1.000
	[ZL*ZV*ZR*ZNT]	1.000	1.000
Limited pitting is permitted:	No		
Size factor (flank)	[ZX]	1.000	1.000
Permissible contact stress (N/mm²)	[sigHP=sigHG/SHmin]	22.05	24.00
Pitting stress limit (N/mm²)	[sigHG]	20.40	22.20
Required safety	[SHmin]	0.93	0.93
Safety factor for contact stress at operating pitch circle			
	[SHw]	1.10	1.20
Transmittable power (W)	[WRating]	348.36	379.10

4a. WEAR

Line load at reference diameter (N/mm)	[w]	5.97	
Line load at reference diameter (N/mm)	[K_A*K_γ*K_V*$K_{H\beta}$*$K_{H\alpha}$*w]	5.97	
Loss factor	[H_V]	0.096	
Length of active flank (mm)	[l_{Fl}]	2.39	2.22
Wear factor (mm^3/Nm/10^6)	[k_W]	3.40000	3.40000
Data from file k_{W1}: Z014-ABS_VDI2736_BP.DAT			
Data from file k_{W2}: Z014-ABS_VDI2736_BP.DAT			
Normal tooth thickness in pitch circle (mm)	[s_n]	2.48	2.93
Maximum permissible wear (%)	[W_{limit}]	15.00	
Permissible wear on flank (mm)	[δ_{Wlimn}]	0.37	0.44
Wear removal (mm)	[δ_{Wn}]	0.00000	0.00000
Wear removal (mg)	[=lFL*b*z*ro*δWn]	0.0	0.0
Required safety	[S_{Wmin}]	1.10	
Safety against wear	[S_W]	999.99	999.99

Calculation for safety against shearing for plastics

Normal tooth thickness in the active root diameter (mm)	[s_{dNf}-δWn]	2.60	2.59
Shearing stress (N/mm²)	[τ_{nom}]	2.30	2.31
Notch effect coefficient	[K_T]	1.25	1.25
Permitted shearing strength (N/mm²)	[τ_B]	3.79	4.12
Required safety	[S_{Tmin}]	2.50	
Safety shearing	[S_T]	1.32	1.43

$\tau_B = 0.557 * \sigma_{Fadm}$; $S_T = \tau_B / (\tau_{nom} * K_T)$

Calculation of local wear with speeds and load distribution according to method A:
Calculation was not carried out. (Contact analysis under load is required.)

Important note:
the kw wear coefficients are usually determined using a plastic/steel pairing..
The coefficients may be very different if pairings of other materials are used..
This calculation is designed to give an indication of possible service life,
however it has not yet been checked exhaustively in real life..

5. BENDING

For plastics:			
Tooth deformation (µm)	[fa]	52.868	
Permissible tooth deformation (µm)	[fazul]	87.500	
Required safety	[Sdel]	1.000	
Safety against deformation	[Sdelmin]	1.655	
Experimental method using tooth stiffness according	ISO6336:2006:		
Tooth deformation (µm)	[faExp]	39.785	28.542
Permissible tooth deformation (µm)	[fazulExp]	145.693	145.693
Required safety	[Sdel]	1.000	
Safety against jamming	[SdelExp]	3.662	5.105

6. MEASUREMENTS FOR TOOTH THICKNESS

		------- Gear 1	------ Gear 2 --
Tooth thickness deviation		DIN 3967 cd25	DIN 3967 cd25
Tooth thickness allowance (normal section) (mm)	[As.e/i]	-0.054 / -0.084	-0.070 / -0.110
Number of teeth spanned	[k]	4.000	13.000
Base tangent length (no backlash) (mm)	[Wk]	13.837	48.784
Actual base tangent length ('span') (mm)	[Wk.e/i]	13.786 / 13.758	48.719 / 48.681
(mm)	[ΔWk.e/i]	-0.051 / -0.079	-0.066 / -0.103
Diameter of measuring circle (mm)	[dMWk.m]	32.434	127.157
Theoretical diameter of ball/pin (mm)	[DM]	2.454	2.275
Effective diameter of ball/pin (mm)	[DMeff]	2.500	2.500
Radial single-ball measurement backlash free (mm)	[MrK]	18.202	65.803
Radial single-ball measurement (mm)	[MrK.e/i]	18.151 / 18.122	65.724 / 65.678
Diameter of measuring circle (mm)	[dMMr.m]	32.611	127.892
Diametral measurement over two balls without clearance (mm)	[MdK]	36.337	131.606
Diametral two ball measure (mm)	[MdK.e/i]	36.235 / 36.178	131.447 / 131.356
Diametral measurement over pins without clearance (mm)	[MdR]	36.337	131.606
Measurement over pins according to DIN 3960 (mm)	[MdR.e/i]	36.235 / 36.178	131.447 / 131.356
Measurement over 3 pins (axial) according to AGMA 2002 (mm)			
	[dk3A.e/i]	36.235 / 36.178	131.447 / 131.356
Dimensions over 3 pins without clearance (mm)	[Md3R]	36.270	0.000
Effective dimensions over 3 pins (mm)	[Md3R.e/i]	36.168 / 36.112	0.000 / 0.000
Chordal tooth thickness (no backlash) (mm)	[sc]	2.476	2.928
Actual chordal tooth thickness (mm)	[sc.e/i]	2.422 / 2.392	2.858 / 2.818
Reference chordal height from da.m (mm)	[ha]	1.843	2.425
Tooth thickness (Arc) (mm)	[sn]	2.478	2.928
(mm)	[sn.e/i]	2.424 / 2.394	2.858 / 2.818
Backlash free center distance (mm)	[aControl.e/i]	79.853 / 79.769	
Backlash free center distance, allowances (mm)	[jta]	-0.147 / -0.231	
dNf.i with aControl (mm)	[dNf0.i]	30.207	125.305
Reserve (dNf0.i-dFf.e)/2 (mm)	[cF0.i]	0.000	0.173
Tip clearance (mm)	[c0.i(aControl)]	0.177	0.155
Center distance allowances (mm)	[Aa.e/i]	0.015 / -0.015	
Circumferential backlash from Aa (mm)	[jtw_Aa.e/i]	0.013 / -0.013	
Radial backlash (mm)	[jrw.e/i]	0.246 / 0.132	
Circumferential backlash (transverse section) (mm)	[jtw.e/i]	0.212 / 0.114	
Normal backlash (mm)	[jnw.e/i]	0.199 / 0.107	

Angle of rotation on input with fixed output.:

Entire torsional angle (°)	[j.tSys]	0.7579/ 0.4082

7. GEAR ACCURACY

		GEAR 1	GEAR 2
According to DIN 3961:1978			
Accuracy grade	[Q-DIN3961]	6	6
Profile form deviation (µm)	[ff]	6.00	6.00
Profile slope deviation (µm)	[fHa]	5.00	5.00
Total profile deviation (µm)	[Ff]	8.00	8.00
Helix form deviation (µm)	[fbf]	5.50	5.50
Helix slope deviation (µm)	[fHb]	9.00	9.00
Total helix deviation (µm)	[Fb]	10.00	10.00
Normal base pitch deviation (µm)	[fpe]	7.00	7.00
Single pitch deviation (µm)	[fp]	7.00	7.00
Adjacent pitch difference (µm)	[fu]	8.00	9.00
Total cumulative pitch deviation (µm)	[Fp]	19.00	25.00
Sector pitch deviation over z/8 pitches (µm)	[Fpz/8]	12.00	15.00
Runout (µm)	[Fr]	14.00	16.00
Tooth Thickness Variation (µm)	[Rs]	8.00	10.00
Single flank composite, total (µm)	[Fi']	22.00	26.00
Single flank composite, tooth-to-tooth (µm)	[fi']	10.00	11.00
Radial composite, total (µm)	[Fi"]	17.00	20.00
Radial composite, tooth-to-tooth (µm)	[fi"]	6.00	8.00
According to DIN 58405:1972 (Feinwerktechnik):			
Tooth-to-tooth composite error (µm)	[fi"]	7.00	9.00
Composite error (µm)	[Fi"]	20.00	25.00
Axis alignment error (µm)	[fp]	13.60	13.60
Flank direction error (µm)	[fbeta]	6.30	6.30
Runout (µm)	[Trk, Fr]	21.00	28.00

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

Maximum value for deviation error of axis (µm)	[fSigbet]	12.00 (Fb=12.00)
Maximum value for inclination error of axes (µm)	[fSigdel]	24.00

8. ADDITIONAL DATA

Maximal possible center distance (eps_a=1.0)	[aMAX]	80.635	
Mass (g)	[m]	33.46	522.13
Total mass (g)	[m]	555.59	
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]	4.335e-006	0.001056
System ((da+df)/2...di) (kg*m²)	[TraeghMom]	7.031e-005	
Coefficient of friction	[mum]	0.280	
Loss factor	[HV]	0.096	
Coefficient for frequency of running	[KstEDf]	1.000	
Casing surface (m²)	[Oberflache]	0.16539	
Gear power loss (W)	[PVZ]	7.909	
(Meshing efficiency (%)	[etaz]	97.303)	
Tooth root temperature (°C)	[TR]	70.0	70.0
Flank temperature (°C)	[TF]	70.0	70.0

Heat transfer coefficient, root	[KF]	0.0	0.0
Heat transfer coefficient, flank	[KH]	0.0	0.0

9. MODIFICATIONS AND TOOTH FORM DEFINITION

Data for the tooth form calculation :

Calculation of Gear 1
Tooth form, Gear 1, Step 1: Automatic (final machining)
haP*= 0.945, hfP*= 1.250, rofP*= 0.380

Calculation of Gear 2
Tooth form, Gear 2, Step 1: Automatic (final machining)
haP*= 0.965, hfP*= 1.250, rofP*= 0.380

10. SERVICE LIFE, DAMAGE

Required safety for tooth root	[SFmin]	1.25
Required safety for tooth flank	[SHmin]	0.93
Required safety for wear	[SWmin]	1.10

Service life (calculated with required safeties):

System service life (h)	[Hatt]	0.000

Tooth root service life (h)	[HFatt]	0.0001207	0.0003794
Tooth flank service life (h)	[HHatt]	0.1765	0.7062
Wear service life (h)	[HWatt]	1755	7681

Damage calculated on the basis of the required service life [H] (0.0 h)

F1%	F2%	H1%	H2%	W1%	W2%
8288.38	2636.0052	5.6642	1.4160	0.0006	0.0001

Damage calculated on basis of system service life [Hatt] (0.0 h)

F1%	F2%	H1%	H2%	W1%	W2%
100.00	31.8036	0.0683	0.0171	0.0000	0.0000

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

Gear		fac	b	t0	T	R(H)%
1	Tooth root	60000	1.7	6.988	10.74	0.00
1	Tooth flank	60000	1.3	9549	4.549e+004	100.00
2	Tooth root	15000	1.7	5.493	8.442	0.00
2	Tooth flank	15000	1.3	9549	4.549e+004	100.00

Reliability of the configuration for required service life (%) 0.00 (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.

End of Report lines: 502

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File

Name : ABS_dynamic
Changed by: jsebe on: 26.05.2023 at: 12:40:40

Important hint: At least one warning has occurred during the calculation:

1-> Note:
For calculations in accordance with VDI, the face load factor KHb with 1.0 is assumed,
as plastics run in.
However a width/module ratio that is too large (b/mn > 10) should be avoided.
Or the face load factor needs to be checked.

CALCULATION OF A HELICAL GEAR PAIR

Drawing or article number:
Gear 1: 0.000.0
Gear 2: 0.000.0

Calculation method Plastic according to VDI 2736:2013 (YF Method C)
Steel wheels: calculated roughly according to DIN 3990!

		------- GEAR 1	-------- GEAR 2 --
Power (W)	[P]	47.124	
Speed (1/min)	[n]	1000.0	250.0
Torque (Nm)	[T]	0.450	1.800
Application factor	[KA]	1.00	
Required service life (h)	[H]	48.00	
Gear driving (+) / driven (-)		+	-

Working flank gear 1: Right flank
Sense of rotation gear 1 clockwise
Gearbox type: Gear with partly closed housing

1. TOOTH GEOMETRY AND MATERIAL

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

		------- GEAR 1	-------- GEAR 2 --
Center distance (mm)	[a]	80.000	
Center distance tolerance	ISO 286:2010 Measure js7		
Normal module (mm)	[mn]	1.2500	
Pressure angle at normal section (°)	[alfn]	20.0000	
Helix angle at reference circle (°)	[beta]	12.0000	
Number of teeth	[z]	25	100
Facewidth (mm)	[b]	30.00	30.00
Hand of gear		right	left
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 >=25HRC Jominy J=12mm<HRC28

Gear 2: ABS, Thermoplastic (POM, PPA, etc.), untreated
3D printed ABS
Woehler line tooth root stress from file Z014-ABS_VDI2736_BP.DAT
S-N curve (Woehler line) Hertzian pressure from file Z014-ABS_VDI2736_BP.DAT

			------- GEAR 1 --------	GEAR 2 --
Surface hardness			HRC 61	HBW 20
Tooth root temperature (°C)	[TR]		70.0	70.0
Flank temperature (°C)	[TF]		70.0	70.0
Tooth root strength at NL (N/mm²)	[σFadm]		432.01	3.20
Strength against Hertzian pressure at NL (N/mm²)	[σHadm]		1861.40	9.70
Tensile strength (N/mm²)	[σB]		1200.00	16.20
Yield point (N/mm²)	[σS]		850.00	15.80
Young's modulus (N/mm²)	[E]		206000	1695
Poisson's ratio	[v]		0.300	0.400
Roughness average value DS, flank (µm)	[RAH]		0.60	0.00
Roughness average value DS, root (µm)	[RAF]		3.00	0.00
Mean roughness height, Rz, flank (µm)	[RZH]		4.80	0.00
Mean roughness height, Rz, root (µm)	[RZF]		20.00	0.00

Gear reference profile 1 :
Reference profile 1.25 / 0.38 / 1.0 ISO 53:1998 Profil A

Dedendum coefficient	[hfP*]	1.250
Root radius factor	[rhofP*]	0.380 (rhofPmax*=0.472)
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 1.25 / 0.38 / 1.0 ISO 53:1998 Profil A

Dedendum coefficient	[hfP*]	1.250
Root radius factor	[rhofP*]	0.380 (rhofPmax*=0.472)
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

Summary of reference profile gears:

Dedendum reference profile	[hfP*]	1.250	1.250
Tooth root radius Refer. profile	[rofP*]	0.380	0.380
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

Type of profile modification: none (only running-in)

Tip relief (µm)	[Ca]	2.0	20.2

Lubrication type Dry-running

Ambient temperature (°C)	[TU]	20.000	
		------- GEAR 1 --------	GEAR 2 --
Overall transmission ratio	[itot]	-4.000	
Gear ratio	[u]	4.000	
Transverse module (mm)	[mt]	1.278	
Pressure angle at pitch circle (°)	[alft]	20.410	
Working transverse pressure angle (°)	[alfwt]	20.658	
	[alfwt.e/i]	20.687 / 20.630	
Working pressure angle at normal section (°)	[alfwn]	20.243	
Helix angle at operating pitch circle (°)	[betaw]	12.019	
Base helix angle (°)	[betab]	11.267	
Reference center distance (mm)	[ad]	79.870	
Sum of profile shift coefficients	[Summexi]	0.1043	
Profile shift coefficient	[x]	0.3003	-0.1960
Tooth thickness (Arc) (module) (module)	[sn*]	1.7894	1.4281
Tip alteration (mm)	[k*mn]	-0.001	-0.001
Reference diameter (mm)	[d]	31.948	127.793
Base diameter (mm)	[db]	29.942	119.770
Tip diameter (mm)	[da]	35.197	129.801
(mm)	[da.e/i]	35.197 / 35.172	129.801 / 129.761
Tip diameter allowances (mm)	[Ada.e/i]	0.000 / -0.025	0.000 / -0.040
Tip form diameter (mm)	[dFa]	35.197	129.801
(mm)	[dFa.e/i]	35.197 / 35.172	129.801 / 129.761
Active tip diameter (mm)	[dNa]	35.197	129.801
Active tip diameter (mm)	[dNa.e/i]	35.197 / 35.172	129.801 / 129.761
Operating pitch diameter (mm)	[dw]	32.000	128.000
(mm)	[dw.e/i]	32.006 / 31.994	128.024 / 127.976
Root diameter (mm)	[df]	29.574	124.178
Generating Profile shift coefficient	[xE.e/i]	0.2409/ 0.2080	-0.3004/ -0.3553
Manufactured root diameter with xE (mm)	[df.e/i]	29.425 / 29.343	123.917 / 123.779
Theoretical tip clearance (mm)	[c]	0.313	0.313
Effective tip clearance (mm)	[c.e/i]	0.539 / 0.428	0.463 / 0.372
Active root diameter (mm)	[dNf]	30.621	125.637
(mm)	[dNf.e/i]	30.662 / 30.604	125.677 / 125.612
Root form diameter (mm)	[dFf]	30.563	125.061
(mm)	[dFf.e/i]	30.480 / 30.437	124.848 / 124.737
Reserve (dNf-dFf)/2 (mm)	[cF.e/i]	0.112 / 0.062	0.470 / 0.382
Addendum (mm)	[ha=mn*(haP*+x+k)]	1.624	1.004
(mm)	[ha.e/i]	1.624 / 1.612	1.004 / 0.984
Dedendum (mm)	[hf=mn*(hfP*-x)]	1.187	1.807
(mm)	[hf.e/i]	1.261 / 1.303	1.938 / 2.007
Roll angle at dFa (°)	[xsi_dFa.e/i]	35.401 / 35.310	23.936 / 23.886
Roll angle to dNa (°)	[xsi_dNa.e/i]	35.401 / 35.310	23.936 / 23.886
Roll angle to dNf (°)	[xsi_dNf.e/i]	12.633 / 12.109	18.217 / 18.112
Roll angle at dFf (°)	[xsi_dFf.e/i]	10.908 / 10.456	16.861 / 16.672
Tooth height (mm)	[h]	2.811	2.812
Virtual gear no. of teeth	[zn]	26.573	106.291
Normal tooth thickness at tip circle (mm)	[san]	0.789	1.030
(mm)	[san.e/i]	0.745 / 0.697	0.950 / 0.883
Normal tooth thickness on tip form circle (mm)	[sFan]	0.789	1.030
(mm)	[sFan.e/i]	0.745 / 0.697	0.950 / 0.883
Normal space width at root circle (mm)	[efn]	0.000	0.950
(mm)	[efn.e/i]	0.000 / 0.000	0.971 / 0.983
Max. sliding velocity at tip (m/s)	[vga]	0.472	0.319
Specific sliding at the tip	[zetaa]	0.487	0.487

Specific sliding at the root	[zetaf]		-0.951			-0.950		
Mean specific sliding	[zetam]			0.487				
Sliding factor on tip	[Kga]		0.282			0.190		
Sliding factor on root	[Kgf]		-0.190			-0.282		
Pitch on reference circle (mm)	[pt]			4.015				
Base pitch (mm)	[pbt]			3.763				
Transverse pitch on contact-path (mm)	[pet]			3.763				
Lead height (mm)	[pz]		472.195			1888.778		
Axial pitch (mm)	[px]			18.888				
Length of path of contact (mm)	[ga, e/i]		6.044 (	6.086 /	5.926)			
Length T1-A, T2-A (mm)	[T1A, T2A]	3.206(	3.164/	3.301)	25.017(	25.017/	24.965)	
Length T1-B (mm)	[T1B, T2B]	5.488(	5.488/	5.464)	22.736(	22.693/	22.802)	
Length T1-C (mm)	[T1C, T2C]	5.645(	5.636/	5.653)	22.579(	22.545/	22.613)	
Length T1-D (mm)	[T1D, T2D]	6.969(	6.927/	7.064)	21.255(	21.255/	21.203)	
Length T1-E (mm)	[T1E, T2E]	9.250(	9.250/	9.226)	18.973(	18.931/	19.040)	
Length T1-T2 (mm)	[T1T2]		28.224 (	28.181 /	28.266)			
Diameter of single contact point B (mm)	[d-B]	31.890(	31.890/	31.874)	128.111(	128.081/	128.158)	
Diameter of single contact point D (mm)	[d-D]	33.028(	32.992/	33.108)	127.090(	127.090/	127.055)	
Addendum contact ratio	[eps]	0.958(	0.961/	0.950)	0.648(	0.657/	0.625)	
Minimal length of contact line (mm)	[Lmin]			46.013				

Transverse contact ratio	[eps_a]		1.606	
Transverse contact ratio with allowances	[eps_a.e/m/i]	1.618 /	1.596 /	1.575
Overlap ratio	[eps_b]		1.588	
Total contact ratio	[eps_g]		3.195	
Total contact ratio with allowances	[eps_g.e/m/i]	3.206 /	3.185 /	3.163

2. FACTORS OF GENERAL INFLUENCE

		------- GEAR 1	-------- GEAR 2 --
Nominal circum. force at pitch circle (N)	[Ft]	28.2	
Axial force (N)	[Fa]	6.0	
Radial force (N)	[Fr]	10.5	
Normal force (N)	[Fnorm]	30.6	
Nominal circumferential force per mm (N/mm)	[w]	0.94	
Only as information: Forces at operating pitch circle:			
Nominal circumferential force (N)	[Ftw]	28.1	
Axial force (N)	[Faw]	6.0	
Radial force (N)	[Frw]	10.6	
Circumferential speed reference circle (m/s)	[v]	1.67	
Circumferential speed operating pitch circle (m/s)	[v(dw)]	1.68	

Correction factor	[CM]	0.800
Gear blank factor	[CR]	1.000
Basic rack factor	[CBS]	0.975
Material coefficient	[E/Est]	0.016
Singular tooth stiffness (N/mm/µm)	[c']	0.232
Meshing stiffness (N/mm/µm)	[cg]	0.338
Dynamic factor	[KV]	1.000
Face load factor - flank	[KHb]	1.000
- Tooth root	[KFb]	1.000
- Scuffing	[KBb]	1.000
Transverse load factor - flank	[KHa]	1.000

- Tooth root	[KFa]	1.000	
- Scuffing	[KBa]	1.000	

Number of load cycles (in mio.)	[NL]	2.880	0.720

3. TOOTH ROOT STRENGTH

Calculation of Tooth form coefficients according method: C

		------- GEAR 1	-------- GEAR 2 --
Calculated with manufacturing profile shift	[xE.m]	0.2245	-0.3278
Tooth form factor	[YF]	2.46	2.47
Stress correction factor	[YS]	1.69	1.67
Load application angle (°)	[alfFen]	30.03	21.84
Bending moment arm (mm)	[hF]	2.53	2.54
Tooth thickness at root (mm)	[sFn]	2.67	2.76
Tooth root radius (mm)	[roF]	0.61	0.66

(hF* = 2.024/ 2.034 sFn* = 2.135/ 2.208 roF* = 0.487/ 0.529)
(den (mm) =
36.465/ 134.872 dsFn(mm) = 29.845/ 124.383 alfsFn(°) = 30.00/ 30.00 qs = 2.193/ 2.088)

Contact ratio factor	[Yeps]	0.717	
Helix angle factor	[Ybet]	0.900	
Effective facewidth (mm)	[beff]	30.00	30.00
Nominal stress at tooth root (N/mm²)	[sigF0]	1.94	2.01
Tooth root stress (N/mm²)	[sigF]	1.94	2.01

Permissible bending stress at root from data tables

Notch sensitivity factor	[YdrelT]	0.998	1.000
Surface factor	[YRrelT]	0.957	1.000
size factor (Tooth root)	[YX]	1.000	1.000

Notice: When using Wohler lines from data files, the factors YdrelT, YRrelT, YX
will be interpolated according to the breakpoints NLstatic and NLendurance following ISO.

Finite life factor	[YNT]	1.005	1.000	
	[YdrelT*YRrelT*YX*YNT]	0.959	1.000	
Alternating bending factor (mean stress influence coefficient)	[YM]	1.000		1.000
Stress correction factor	[Yst]	2.00		
Yst*sigFlim (N/mm²)	[sigFE]	860.00	6.40	
Permissible tooth root stress (N/mm²)	[sigFP=sigFG/SFmin]	659.96	5.12	
Limit strength tooth root (N/mm²)	[sigFG]	824.95	6.40	
Required safety	[SFmin]	1.25	1.25	
Safety for tooth root stress	[SF=sigFG/sigF]	425.32	3.19	
Transmittable power (W)	[WRating]	16034.00	120.33	

4. SAFETY AGAINST PITTING (TOOTH FLANK)

		------- GEAR 1	-------- GEAR 2 --
Zone factor	[ZH]	2.434	
Elasticity factor (√N/mm²)	[ZE]	25.230	
Young's modulus for tooth flank (N/mm²)	[E]	206000	1695
Contact ratio factor	[Zeps]	0.789	
Helix angle factor	[Zbet]	1.000	
Effective facewidth (mm)	[beff]	30.00	
Nominal contact stress (N/mm²)	[sigH0]	9.29	

Contact stress at operating pitch circle (N/mm²)	[sigHw]	9.29	
Lubrication coefficient at NL	[ZL]	1.020	1.000
Speed coefficient at NL	[ZV]	0.954	1.000
Roughness coefficient at NL	[ZR]	1.000	1.000
Material pairing coefficient at NL	[ZW]	1.000	1.000
Notice: When using Wohler lines from data files, the factors ZL, ZV, ZR, ZW will be interpolated according to the breakpoints NLstatic and NLendurance following ISO.			
Finite life factor	[ZNT]	1.241	1.000
	[ZL*ZV*ZR*ZNT]	1.208	1.000
Limited pitting is permitted:	No		
Size factor (flank)	[ZX]	1.000	1.000
Permissible contact stress (N/mm²)	[sigHP=sigHG/SHmin]	1959.32	10.49
Pitting stress limit (N/mm²)	[sigHG]	1812.38	9.70
Required safety	[SHmin]	0.93	0.93
Safety factor for contact stress at operating pitch circle			
	[SHw]	197.34	1.04
Transmittable power (W)	[WRating]	2144760.46	53.22

4a. WEAR

Line load at reference diameter (N/mm)	[w]	0.94
Line load at reference diameter (N/mm)	[K_A*K_γ*K_V*$K_{H\beta}$*$K_{H\alpha}$*w]	0.94
Loss factor	[H_V]	0.117
Calculation only for Gear 2		
Length of active flank (mm)	[l_{Fl}]	2.20
Wear factor (mm^3/Nm/10^6)	[k_W]	3.40000
Data from file k_W: Z014-ABS_VDI2736_BP.DAT		
Normal tooth thickness in pitch circle (mm)	[s_n]	1.79
Maximum permissible wear (%)	[W_{limit}]	15.00
Permissible wear on flank (mm)	[δ_{Wlimn}]	0.27
Wear removal (mm)	[δ_{Wn}]	0.00049
Wear removal (mg)	[=lFL*b*z*ro*δWn]	4.4
Required safety	[S_{Wmin}]	1.10
Safety against wear	[S_W]	544.25

Calculation for safety against shearing for plastics		
Normal tooth thickness in the active root diameter (mm)	[s_{dNf}-δWn]	2.37
Shearing stress (N/mm²)	[τ_{nom}]	0.40
Notch effect coefficient	[K_T]	1.25
Permitted shearing strength (N/mm²)	[τ_B]	1.78
Required safety	[S_{Tmin}]	2.50
Safety shearing	[S_T]	3.60

$\tau_B = 0.557 * \sigma_{Fadm}$; $S_T = \tau_B / (\tau_{nom} * K_T)$

Calculation of local wear with speeds and load distribution according to method A:
Calculation was not carried out. (Contact analysis under load is required.)

Important note:
the kw wear coefficients are usually determined using a plastic/steel pairing..
The coefficients may be very different if pairings of other materials are used..
This calculation is designed to give an indication of possible service life,
however it has not yet been checked exhaustively in real life..

5. BENDING

For plastics:

Tooth deformation (µm)	[fa]	4.283
Permissible tooth deformation (µm)	[fazul]	87.500
Required safety	[Sdel]	1.000
Safety against deformation	[Sdelmin]	20.428

Experimental method using tooth stiffness according ISO6336:2006:

Tooth deformation (µm)	[faExp]	0.063	4.924
Permissible tooth deformation (µm)	[fazulExp]	143.868	143.868
Required safety	[Sdel]	1.000	
Safety against jamming	[SdelExp]	2282.631	29.216

6. MEASUREMENTS FOR TOOTH THICKNESS

		------- Gear 1 ------	Gear 2 --
Tooth thickness deviation		DIN 3967 cd25	DIN 3967 cd25
Tooth thickness allowance (normal section) (mm)	[As.e/i]	-0.054 / -0.084	-0.095 / -0.145
Number of teeth spanned	[k]	4.000	12.000
Base tangent length (no backlash) (mm)	[Wk]	13.638	44.134
Actual base tangent length ('span') (mm)	[Wk.e/i]	13.588 / 13.560	44.045 / 43.998
(mm)	[ΔWk.e/i]	-0.051 / -0.079	-0.089 / -0.136
Diameter of measuring circle (mm)	[dMWk.m]	32.768	127.313
Theoretical diameter of ball/pin (mm)	[DM]	2.268	2.088
Effective diameter of ball/pin (mm)	[DMeff]	2.500	2.500
Radial single-ball measurement backlash free (mm)	[MrK]	18.329	65.833
Radial single-ball measurement (mm)	[MrK.e/i]	18.275 / 18.245	65.711 / 65.646
Diameter of measuring circle (mm)	[dMMr.m]	32.926	127.972
Diametral measurement over two balls without clearance (mm)	[MdK]	36.590	131.666
Diametral two ball measure (mm)	[MdK.e/i]	36.482 / 36.422	131.422 / 131.292
Diametral measurement over pins without clearance (mm)	[MdR]	36.658	131.666
Measurement over pins according to DIN 3960 (mm)	[MdR.e/i]	36.550 / 36.489	131.422 / 131.292
Measurement over 2 pins (free) according to AGMA 2002 (mm)	[dk2f.e/i]	36.479 / 36.418	0.000 / 0.000
Measurement over 2 pins (axial) according to AGMA 2002 (mm)	[dk2t.e/i]	36.615 / 36.554	0.000 / 0.000
Measurement over 3 pins (axial) according to AGMA 2002 (mm)	[dk3A.e/i]	36.550 / 36.489	131.422 / 131.292
Chordal tooth thickness (no backlash) (mm)	[sc]	2.235	1.785
Actual chordal tooth thickness (mm)	[sc.e/i]	2.181 / 2.151	1.690 / 1.640
Reference chordal height from da.m (mm)	[ha]	1.656	1.000
Tooth thickness (Arc) (mm)	[sn]	2.237	1.785
(mm)	[sn.e/i]	2.183 / 2.153	1.690 / 1.640
Backlash free center distance (mm)	[aControl.e/i]	79.796 / 79.685	
Backlash free center distance, allowances (mm)	[jta]	-0.204 / -0.315	
dNf.i with aControl (mm)	[dNf0.i]	30.294	125.101
Reserve (dNf0.i-dFf.e)/2 (mm)	[cF0.i]	-0.093	0.127
Tip clearance (mm)	[c0.i(aControl)]	0.128	0.072
Center distance allowances (mm)	[Aa.e/i]	0.015 / -0.015	
Circumferential backlash from Aa (mm)	[jtw_Aa.e/i]	0.011 / -0.011	

Radial backlash (mm)	[jrw.e/i]	0.330 /	0.189
Circumferential backlash (transverse section) (mm)	[jtw.e/i]	0.246 /	0.141
Normal backlash (mm)	[jnw.e/i]	0.226 /	0.130
Angle of rotation on input with fixed output.:			
Entire torsional angle (°)	[j.tSys]	0.8802/ 0.5059	

7. GEAR ACCURACY

		------- GEAR 1	-------- GEAR 2 --
According to DIN 3961:1978			
Accuracy grade	[Q-DIN3961]	6	6
Profile form deviation (µm)	[ff]	6.00	6.00
Profile slope deviation (µm)	[fHa]	5.00	5.00
Total profile deviation (µm)	[Ff]	8.00	8.00
Helix form deviation (µm)	[fbf]	5.50	5.50
Helix slope deviation (µm)	[fHb]	9.00	9.00
Total helix deviation (µm)	[Fb]	10.00	10.00
Normal base pitch deviation (µm)	[fpe]	7.00	8.00
Single pitch deviation (µm)	[fp]	7.00	8.00
Adjacent pitch difference (µm)	[fu]	8.00	10.00
Total cumulative pitch deviation (µm)	[Fp]	19.00	29.00
Sector pitch deviation over z/8 pitches (µm)	[Fpz/8]	12.00	18.00
Runout (µm)	[Fr]	14.00	19.00
Tooth Thickness Variation (µm)	[Rs]	8.00	11.00
Single flank composite, total (µm)	[Fi']	22.00	30.00
Single flank composite, tooth-to-tooth (µm)	[fi']	10.00	11.00
Radial composite, total (µm)	[Fi"]	17.00	24.00
Radial composite, tooth-to-tooth (µm)	[fi"]	6.00	10.00
According to DIN 58405:1972 (Feinwerktechnik):			
Tooth-to-tooth composite error (µm)	[fi"]	7.00	9.00
Composite error (µm)	[Fi"]	20.00	25.00
Axis alignment error (µm)	[fp]	13.60	13.60
Flank direction error (µm)	[fbeta]	6.30	6.30
Runout (µm)	[Trk, Fr]	21.00	28.00

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

Maximum value for deviation error of axis (µm)	[fSigbet]	13.00 (Fb=13.00)
Maximum value for inclination error of axes (µm)	[fSigdel]	26.00

8. ADDITIONAL DATA

Maximal possible center distance (eps_a=1.0)	[aMAX]	80.833	
Mass (kg)	[m]	0.193	0.521
Total mass (kg)	[m]	0.714	
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]	2.537e-005	0.001049
System ((da+df)/2...di) (kg*m²)	[TraeghMom]	9.095e-005	
Coefficient of friction	[mum]	0.200	
Loss factor	[HV]	0.117	
Coefficient for frequency of running	[KstEDf]	1.000	
Casing surface (m²)	[Oberflache]	0.16961	
Gear power loss (W)	[PVZ]	1.105	

(Meshing efficiency (%)	[etaz]		97.656)	
Tooth root temperature (°C)	[TR]		70.0	70.0
Flank temperature (°C)	[TF]		70.0	70.0
Heat transfer coefficient, root	[KF]		0.0	0.0
Heat transfer coefficient, flank	[KH]		0.0	0.0
Indications for the manufacturing by wire cutting:				
Deviation from theoretical tooth trace (µm)		[WireErr]	317.1	79.5
Permissible deviation (µm)	[Fb/2]		5.0	5.0

9. MODIFICATIONS AND TOOTH FORM DEFINITION

Data for the tooth form calculation :

Calculation of Gear 1
Tooth form, Gear 1, Step 1: Automatic (final machining)
haP*= 1.070, hfP*= 1.250, rofP*= 0.380

Calculation of Gear 2
Tooth form, Gear 2, Step 1: Automatic (final machining)
haP*= 1.123, hfP*= 1.250, rofP*= 0.380

10. SERVICE LIFE, DAMAGE

Required safety for tooth root	[SFmin]	1.25
Required safety for tooth flank	[SHmin]	0.93
Required safety for wear	[SWmin]	1.10
Service life (calculated with required safeties):		
System service life (h)	[Hatt]	23749

Tooth root service life (h)	[HFatt]	1e+006	1e+006
Tooth flank service life (h)	[HHatt]	1e+006	8.689e+004
Wear service life (h)	[HWatt]	1e+006	2.375e+004

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] (48.0 h)

F1%	F2%	H1%	H2%	W1%	W2%
0.00	0.0000	0.0000	0.0552	0.0000	0.2021

Damage calculated on basis of system service life [Hatt] (23749.2 h)

F1%	F2%	H1%	H2%	W1%	W2%
0.00	0.0000	0.0000	27.3309	0.0000	100.0000

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

Gear		fac	b	t0	T	R(H)%
1	Tooth root	60000	1.7	9.654e+029	1.484e+030	100.00
1	Tooth flank	60000	1.3	9.014e+029	4.295e+030	100.00
2	Tooth root	15000	1.7	9.654e+029	1.484e+030	100.00
2	Tooth flank	15000	1.3	1.175e+009	5.598e+009	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.
- Calculation of steel/plastic pair:
  the steel gear's strength is calculated approximately, according to DIN 3990, to obtain an indication of the service life..

End of Report lines: 511

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File

Name : ABS_static_fin
Changed by: jsebe on: 22.05.2023 at: 08:40:53

Important hint: At least one warning has occurred during the calculation:

1-> Note:
For calculations in accordance with VDI, the face load factor KHb with 1.0 is assumed,
as plastics run in.
However a width/module ratio that is too large (b/mn > 10) should be avoided.
Or the face load factor needs to be checked.

CALCULATION OF A CYLINDRICAL SPUR GEAR PAIR

Drawing or article number:
Gear 1: 0.000.0
Gear 2: 0.000.0

Calculation method Plastic according to VDI 2736:2013 (YF Method C)

		------- GEAR 1	-------- GEAR 2 --
Power (W)	[P]	555.015	
Speed (1/min)	[n]	1000.0	250.0
Torque (Nm)	[T]	5.300	21.200
Application factor	[KA]	1.00	
Required service life (h)	[H]	0.01	
Gear driving (+) / driven (-)		+	-

Working flank gear 1: Right flank
Sense of rotation gear 1 clockwise
Gearbox type: Gear with partly closed housing

1. TOOTH GEOMETRY AND MATERIAL

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

		------- GEAR 1	-------- GEAR 2 --
Center distance (mm)	[a]	80.000	
Center distance tolerance	ISO 286:2010 Measure js7		
Normal module (mm)	[mn]	1.2500	
Pressure angle at normal section (°)	[alfn]	20.0000	
Helix angle at reference circle (°)	[beta]	0.0000	
Number of teeth	[z]	25	100
Facewidth (mm)	[b]	30.00	30.00
Hand of gear		Spur gear	
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: PLA, Thermoplastic (POM, PPA, etc.), untreated
3D printed material
Woehler line tooth root stress from file Z014-PLA_VDI2736_BP.DAT

S-N curve (Woehler line) Hertzian pressure from file Z014-PLA_VDI2736_BP.DAT

Gear 2: PLA, Thermoplastic (POM, PPA, etc.), untreated

3D printed material

Woehler line tooth root stress from file Z014-PLA_VDI2736_BP.DAT

S-N curve (Woehler line) Hertzian pressure from file Z014-PLA_VDI2736_BP.DAT

		------- GEAR 1 --------	GEAR 2 --
Surface hardness		HBW 40	HBW 40
Tooth root temperature (°C)	[TR]	70.0	70.0
Flank temperature (°C)	[TF]	70.0	70.0
Tooth root strength at NL (N/mm²)	[σFadm]	12.50	13.70
Strength against Hertzian pressure at NL (N/mm²)	[σHadm]	37.60	41.10
Tensile strength (N/mm²)	[σB]	30.20	30.20
Yield point (N/mm²)	[σS]	29.40	29.40
Young's modulus (N/mm²)	[E]	2390	2390
Poisson's ratio	[v]	0.400	0.400
Roughness average value DS, flank (µm)	[RAH]	0.00	0.00
Roughness average value DS, root (µm)	[RAF]	0.00	0.00
Mean roughness height, Rz, flank (µm)	[RZH]	0.00	0.00
Mean roughness height, Rz, root (µm)	[RZF]	0.00	0.00

Gear reference profile 1 :

Reference profile	1.25 / 0.38 / 1.0 ISO 53:1998 Profil A	
Dedendum coefficient	[hfP*]	1.250
Root radius factor	[rhofP*]	0.380 (rhofPmax*=0.472)
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	1.25 / 0.38 / 1.0 ISO 53:1998 Profil A	
Dedendum coefficient	[hfP*]	1.250
Root radius factor	[rhofP*]	0.380 (rhofPmax*=0.472)
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	

Summary of reference profile gears:

Dedendum reference profile	[hfP*]	1.250	1.250
Tooth root radius Refer. profile	[rofP*]	0.380	0.380
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

Type of profile modification: none (only running-in)

Tip relief (µm)	[Ca]	20.0	20.0

Lubrication type		Dry-running	
Ambient temperature (°C)	[TU]	20.000	
		------- GEAR 1 --------	GEAR 2 --
Overall transmission ratio	[itot]	-4.000	
Gear ratio	[u]	4.000	
Transverse module (mm)	[mt]	1.250	
Pressure angle at pitch circle (°)	[alft]	20.000	
Working transverse pressure angle (°)	[alfwt]	23.412	
	[alfwt.e/i]	23.437 / 23.388	
Working pressure angle at normal section (°)	[alfwn]	23.412	
Helix angle at operating pitch circle (°)	[betaw]	0.000	
Base helix angle (°)	[betab]	0.000	
Reference center distance (mm)	[ad]	78.125	
Sum of profile shift coefficients	[Summexi]	1.6258	
Profile shift coefficient	[x]	0.5656	1.0602
Tooth thickness (Arc) (module) (module)	[sn*]	1.9825	2.3426
Tip alteration (mm)	[k*mn]	-0.157	-0.157
Reference diameter (mm)	[d]	31.250	125.000
Base diameter (mm)	[db]	29.365	117.462
Tip diameter (mm)	[da]	34.850	129.837
(mm)	[da.e/i]	34.850 / 34.825	129.837 / 129.797
Tip diameter allowances (mm)	[Ada.e/i]	0.000 / -0.025	0.000 / -0.040
Tip form diameter (mm)	[dFa]	34.850	129.837
(mm)	[dFa.e/i]	34.850 / 34.825	129.837 / 129.797
Active tip diameter (mm)	[dNa]	34.850	129.837
Active tip diameter (mm)	[dNa.e/i]	34.850 / 34.825	129.837 / 129.797
Operating pitch diameter (mm)	[dw]	32.000	128.000
(mm)	[dw.e/i]	32.006 / 31.994	128.024 / 127.976
Root diameter (mm)	[df]	29.539	124.526
Generating Profile shift coefficient	[xE.e/i]	0.5062/ 0.4732	0.9833/ 0.9393
Manufactured root diameter with xE (mm)	[df.e/i]	29.391 / 29.308	124.333 / 124.223
Theoretical tip clearance (mm)	[c]	0.312	0.312
Effective tip clearance (mm)	[c.e/i]	0.491 / 0.393	0.463 / 0.371
Active root diameter (mm)	[dNf]	30.504	125.718
(mm)	[dNf.e/i]	30.550 / 30.483	125.762 / 125.691
Root form diameter (mm)	[dFf]	30.311	125.151
(mm)	[dFf.e/i]	30.207 / 30.151	124.958 / 124.849
Reserve (dNf-dFf)/2 (mm)	[cF.e/i]	0.199 / 0.138	0.456 / 0.366
Addendum (mm)	[ha=mn*(haP*+x+k)]	1.800	2.418
(mm)	[ha.e/i]	1.800 / 1.787	2.418 / 2.398
Dedendum (mm)	[hf=mn*(hfP*-x)]	0.856	0.237
(mm)	[hf.e/i]	0.930 / 0.971	0.333 / 0.388
Roll angle at dFa (°)	[xsi_dFa.e/i]	36.616 / 36.526	26.984 / 26.938
Roll angle to dNa (°)	[xsi_dNa.e/i]	36.616 / 36.526	26.984 / 26.938
Roll angle to dNf (°)	[xsi_dNf.e/i]	16.438 / 15.960	21.916 / 21.820
Roll angle at dFf (°)	[xsi_dFf.e/i]	13.812 / 13.342	20.795 / 20.638
Tooth height (mm)	[h]	2.656	2.656
Virtual gear no. of teeth	[zn]	25.000	100.000
Normal tooth thickness at tip circle (mm)	[san]	0.829	0.976
(mm)	[san.e/i]	0.784 / 0.735	0.922 / 0.862
Normal tooth thickness on tip form circle (mm)	[sFan]	0.829	0.976
(mm)	[sFan.e/i]	0.784 / 0.735	0.922 / 0.862
Normal space width at root circle (mm)	[efn]	0.942	0.825
(mm)	[efn.e/i]	0.976 / 0.000	0.827 / 0.828
Max. sliding velocity at tip (m/s)	[vga]	0.396	0.292

Specific sliding at the tip	[zetaa]		0.403			0.403		
Specific sliding at the root	[zetaf]		-0.675			-0.675		
Mean specific sliding	[zetam]			0.403				
Sliding factor on tip	[Kga]		0.236			0.174		
Sliding factor on root	[Kgf]		-0.174			-0.236		
Pitch on reference circle (mm)	[pt]			3.927				
Base pitch (mm)	[pbt]			3.690				
Transverse pitch on contact-path (mm)	[pet]			3.690				
Length of path of contact (mm)	[ga, e/i]		5.256 (	5.293 /	5.148)			
Length T1-A, T2-A (mm)	[T1A, T2A]	4.128(	4.090/	4.212)	27.660(	27.660/	27.613)	
Length T1-B (mm)	[T1B, T2B]	5.693(	5.693/	5.670)	26.095(	26.057/	26.156)	
Length T1-C (mm)	[T1C, T2C]	6.358(	6.350/	6.365)	25.430(	25.400/	25.460)	
Length T1-D (mm)	[T1D, T2D]	7.818(	7.780/	7.903)	23.970(	23.970/	23.923)	
Length T1-E (mm)	[T1E, T2E]	9.383(	9.383/	9.360)	22.404(	22.367/	22.465)	
Length T1-T2 (mm)	[T1T2]		31.788 (	31.750 /	31.825)			
Diameter of single contact point B (mm)	[d-B]	31.496(	31.496/	31.479)	128.534(	128.503/	128.583)	
Diameter of single contact point D (mm)	[d-D]	33.269(	33.233/	33.349)	126.868(	126.868/	126.832)	
Addendum contact ratio	[eps]	0.820(	0.822/	0.812)	0.604(	0.612/	0.583)	
Minimal length of contact line (mm)	[Lmin]			30.000				
Transverse contact ratio	[eps_a]			1.424				
Transverse contact ratio with allowances	[eps_a.e/m/i]		1.434 /	1.415 /	1.395			
Overlap ratio	[eps_b]			0.000				
Total contact ratio	[eps_g]			1.424				
Total contact ratio with allowances	[eps_g.e/m/i]		1.434 /	1.415 /	1.395			

2. FACTORS OF GENERAL INFLUENCE

		------- GEAR 1	-------- GEAR 2 --
Nominal circum. force at pitch circle (N)	[Ft]	339.2	
Axial force (N)	[Fa]	0.0	
Radial force (N)	[Fr]	123.5	
Normal force (N)	[Fnorm]	361.0	
Nominal circumferential force per mm (N/mm)	[w]	11.31	
Only as information: Forces at operating pitch circle:			
Nominal circumferential force (N)	[Ftw]	331.2	
Axial force (N)	[Faw]	0.0	
Radial force (N)	[Frw]	143.4	
Circumferential speed reference circle (m/s)	[v]	1.64	
Circumferential speed operating pitch circle (m/s)	[v(dw)]	1.68	
Correction factor	[CM]	0.800	
Gear blank factor	[CR]	1.000	
Basic rack factor	[CBS]	0.975	
Material coefficient	[E/Est]	0.012	
Singular tooth stiffness (N/mm/µm)	[c']	0.185	
Meshing stiffness (N/mm/µm)	[cg]	0.244	
Dynamic factor	[KV]	1.000	
Face load factor - flank	[KHb]	1.000	
- Tooth root	[KFb]	1.000	
- Scuffing	[KBb]	1.000	
Transverse load factor - flank	[KHa]	1.000	
- Tooth root	[KFa]	1.000	

- Scuffing	[KBa]	1.000	
Number of load cycles (in mio.)	[NL]	0.001	0.000

3. TOOTH ROOT STRENGTH

Calculation of Tooth form coefficients according method: C

		------- GEAR 1	-------- GEAR 2 --
Calculated with manufacturing profile shift	[xE.m]	0.4897	0.9613
Tooth form factor	[YF]	2.08	1.97
Stress correction factor	[YS]	1.84	1.97
Load application angle (°)	[alfFen]	31.35	24.83
Bending moment arm (mm)	[hF]	2.38	2.36
Tooth thickness at root (mm)	[sFn]	2.79	2.95
Tooth root radius (mm)	[roF]	0.53	0.48

(hF* = 1.901/ 1.891 sFn* = 2.230/ 2.359 roF* = 0.423/ 0.381)
(den (mm) =
34.850/ 129.837 dsFn(mm) = 29.762/ 124.732 alfsFn(°) = 30.00/ 30.00 qs = 2.636/ 3.095)

Contact ratio factor	[Yeps]	0.777	
Helix angle factor	[Ybet]	1.000	
Effective facewidth (mm)	[beff]	30.00	30.00
Nominal stress at tooth root (N/mm²)	[sigF0]	26.88	27.28
Tooth root stress (N/mm²)	[sigF]	26.88	27.28
Permissible bending stress at root from data tables			
Notch sensitivity factor	[YdrelT]	1.000	1.000
Surface factor	[YRrelT]	1.000	1.000
size factor (Tooth root)	[YX]	1.000	1.000

Notice: When using Wohler lines from data files, the factors YdrelT, YRrelT, YX
will be interpolated according to the breakpoints NLstatic and NLendurance following ISO.

Finite life factor	[YNT]	1.000	1.000	
	[YdrelT*YRrelT*YX*YNT]	1.000	1.000	
Alternating bending factor (mean stress influence coefficient)	[YM]	1.000		1.000
Stress correction factor	[Yst]	2.00		
Yst*sigFlim (N/mm²)	[sigFE]	25.00	27.40	
Permissible tooth root stress (N/mm²)	[sigFP=sigFG/SFmin]	20.00	21.92	
Limit strength tooth root (N/mm²)	[sigFG]	25.00	27.40	
Required safety	[SFmin]	1.25	1.25	
Safety for tooth root stress	[SF=sigFG/sigF]	0.93	1.00	
Transmittable power (kW)	[kWRating]	0.41	0.45	

4. SAFETY AGAINST PITTING (TOOTH FLANK)

		------- GEAR 1	-------- GEAR 2 --
Zone factor	[ZH]	2.287	
Elasticity factor (√N/mm²)	[ZE]	21.278	
Young's modulus for tooth flank (N/mm²)	[E]	2390	2390
Contact ratio factor	[Zeps]	0.927	
Helix angle factor	[Zbet]	1.000	
Effective facewidth (mm)	[beff]	30.00	
Nominal contact stress (N/mm²)	[sigH0]	30.33	
Contact stress at operating pitch circle (N/mm²)	[sigHw]	30.33	

Lubrication coefficient at NL	[ZL]	1.000	1.000
Speed coefficient at NL	[ZV]	1.000	1.000
Roughness coefficient at NL	[ZR]	1.000	1.000
Material pairing coefficient at NL	[ZW]	1.000	1.000
Notice: When using Wohler lines from data files, the factors ZL, ZV, ZR, ZW will be interpolated according to the breakpoints NLstatic and NLendurance following ISO.			
Finite life factor	[ZNT]	1.000	1.000
	[ZL*ZV*ZR*ZNT]	1.000	1.000
Limited pitting is permitted:	No		
Size factor (flank)	[ZX]	1.000	1.000
Permissible contact stress (N/mm²)	[sigHP=sigHG/SHmin]	40.65	44.43
Pitting stress limit (N/mm²)	[sigHG]	37.60	41.10
Required safety	[SHmin]	0.93	0.93
Safety factor for contact stress at operating pitch circle			
	[SHw]	1.24	1.36
Transmittable power (kW)	[kWRating]	0.74	0.81

4a. WEAR

Line load at reference diameter (N/mm)	[w]	11.31	
Line load at reference diameter (N/mm)	[K_A*K_γ*K_V*$K_{H\beta}$*$K_{H\alpha}$*w]	11.31	
Loss factor	[H_V]	0.096	
Length of active flank (mm)	[l_{Fl}]	2.39	2.22
Wear factor (mm^3/Nm/10^6)	[k_W]	3.40000	3.40000
Data from file k_{W1}: Z014-PLA_VDI2736_BP.DAT			
Data from file k_{W2}: Z014-PLA_VDI2736_BP.DAT			
Normal tooth thickness in pitch circle (mm)	[s_n]	2.48	2.93
Maximum permissible wear (%)	[W_{limit}]	15.00	
Permissible wear on flank (mm)	[δ_{Wlimn}]	0.37	0.44
Wear removal (mm)	[δ_{Wn}]	0.00000	0.00000
Wear removal (mg)	[=lFL*b*z*ro*δWn]	0.0	0.0
Required safety	[S_{Wmin}]	1.10	
Safety against wear	[S_W]	999.99	999.99

Calculation for safety against shearing for plastics			
Normal tooth thickness in the active root diameter (mm)	[s_{dNf}-δWn]	2.60	2.59
Shearing stress (N/mm²)	[τ_{nom}]	4.36	4.36
Notch effect coefficient	[K_T]	1.25	1.25
Permitted shearing strength (N/mm²)	[τ_B]	6.96	7.63
Required safety	[S_{Tmin}]	2.50	
Safety shearing	[S_T]	1.28	1.40

$\tau_B = 0.557 * \sigma_{Fadm}$; $S_T = \tau_B / (\tau_{nom} * K_T)$

Calculation of local wear with speeds and load distribution according to method A:
Calculation was not carried out. (Contact analysis under load is required.)

Important note:
the kw wear coefficients are usually determined using a plastic/steel pairing..
The coefficients may be very different if pairings of other materials are used..
This calculation is designed to give an indication of possible service life,
however it has not yet been checked exhaustively in real life..

5. BENDING

For plastics:			
Tooth deformation (µm)	[fa]	70.974	
Permissible tooth deformation (µm)	[fazul]	87.500	
Required safety	[Sdel]	1.000	
Safety against deformation	[Sdelmin]	1.233	
Experimental method using tooth stiffness according	ISO6336:2006:		
Tooth deformation (µm)	[faExp]	53.411	38.317
Permissible tooth deformation (µm)	[fazulExp]	156.552	156.552
Required safety	[Sdel]	1.000	
Safety against jamming	[SdelExp]	2.931	4.086

6. MEASUREMENTS FOR TOOTH THICKNESS

		------- Gear 1	------ Gear 2 --
Tooth thickness deviation		DIN 3967 cd25	DIN 3967 cd25
Tooth thickness allowance (normal section) (mm)	[As.e/i]	-0.054 / -0.084	-0.070 / -0.110
Number of teeth spanned	[k]	4.000	13.000
Base tangent length (no backlash) (mm)	[Wk]	13.837	48.784
Actual base tangent length ('span') (mm)	[Wk.e/i]	13.786 / 13.758	48.719 / 48.681
(mm)	[ΔWk.e/i]	-0.051 / -0.079	-0.066 / -0.103
Diameter of measuring circle (mm)	[dMWk.m]	32.434	127.157
Theoretical diameter of ball/pin (mm)	[DM]	2.454	2.275
Effective diameter of ball/pin (mm)	[DMeff]	2.500	2.500
Radial single-ball measurement backlash free (mm)	[MrK]	18.202	65.803
Radial single-ball measurement (mm)	[MrK.e/i]	18.151 / 18.122	65.724 / 65.678
Diameter of measuring circle (mm)	[dMMr.m]	32.611	127.892
Diametral measurement over two balls without clearance (mm)	[MdK]	36.337	131.606
Diametral two ball measure (mm)	[MdK.e/i]	36.235 / 36.178	131.447 / 131.356
Diametral measurement over pins without clearance (mm)	[MdR]	36.337	131.606
Measurement over pins according to DIN 3960 (mm)	[MdR.e/i]	36.235 / 36.178	131.447 / 131.356
Measurement over 3 pins (axial) according to AGMA 2002 (mm)			
	[dk3A.e/i]	36.235 / 36.178	131.447 / 131.356
Dimensions over 3 pins without clearance (mm)	[Md3R]	36.270	0.000
Effective dimensions over 3 pins (mm)	[Md3R.e/i]	36.168 / 36.112	0.000 / 0.000
Chordal tooth thickness (no backlash) (mm)	[sc]	2.476	2.928
Actual chordal tooth thickness (mm)	[sc.e/i]	2.422 / 2.392	2.858 / 2.818
Reference chordal height from da.m (mm)	[ha]	1.843	2.425
Tooth thickness (Arc) (mm)	[sn]	2.478	2.928
(mm)	[sn.e/i]	2.424 / 2.394	2.858 / 2.818
Backlash free center distance (mm)	[aControl.e/i]	79.853 / 79.769	
Backlash free center distance, allowances (mm)	[jta]	-0.147 / -0.231	
dNf.i with aControl (mm)	[dNf0.i]	30.207	125.305
Reserve (dNf0.i-dFf.e)/2 (mm)	[cF0.i]	0.000	0.173
Tip clearance (mm)	[c0.i(aControl)]	0.177	0.155
Center distance allowances (mm)	[Aa.e/i]	0.015 / -0.015	
Circumferential backlash from Aa (mm)	[jtw_Aa.e/i]	0.013 / -0.013	
Radial backlash (mm)	[jrw.e/i]	0.246 / 0.132	
Circumferential backlash (transverse section) (mm)	[jtw.e/i]	0.212 / 0.114	
Normal backlash (mm)	[jnw.e/i]	0.199 / 0.107	

Angle of rotation on input with fixed output.:

Entire torsional angle (°)	[j.tSys]	0.7579/ 0.4082

7. GEAR ACCURACY

		GEAR 1	GEAR 2
According to DIN 3961:1978			
Accuracy grade	[Q-DIN3961]	6	6
Profile form deviation (µm)	[ff]	6.00	6.00
Profile slope deviation (µm)	[fHa]	5.00	5.00
Total profile deviation (µm)	[Ff]	8.00	8.00
Helix form deviation (µm)	[fbf]	5.50	5.50
Helix slope deviation (µm)	[fHb]	9.00	9.00
Total helix deviation (µm)	[Fb]	10.00	10.00
Normal base pitch deviation (µm)	[fpe]	7.00	7.00
Single pitch deviation (µm)	[fp]	7.00	7.00
Adjacent pitch difference (µm)	[fu]	8.00	9.00
Total cumulative pitch deviation (µm)	[Fp]	19.00	25.00
Sector pitch deviation over z/8 pitches (µm)	[Fpz/8]	12.00	15.00
Runout (µm)	[Fr]	14.00	16.00
Tooth Thickness Variation (µm)	[Rs]	8.00	10.00
Single flank composite, total (µm)	[Fi']	22.00	26.00
Single flank composite, tooth-to-tooth (µm)	[fi']	10.00	11.00
Radial composite, total (µm)	[Fi"]	17.00	20.00
Radial composite, tooth-to-tooth (µm)	[fi"]	6.00	8.00
According to DIN 58405:1972 (Feinwerktechnik):			
Tooth-to-tooth composite error (µm)	[fi"]	7.00	9.00
Composite error (µm)	[Fi"]	20.00	25.00
Axis alignment error (µm)	[fp]	13.60	13.60
Flank direction error (µm)	[fbeta]	6.30	6.30
Runout (µm)	[Trk, Fr]	21.00	28.00

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

Maximum value for deviation error of axis (µm)	[fSigbet]	12.00 (Fb=12.00)
Maximum value for inclination error of axes (µm)	[fSigdel]	24.00

8. ADDITIONAL DATA

Maximal possible center distance (eps_a=1.0)	[aMAX]	80.635	
Mass (g)	[m]	33.46	522.13
Total mass (g)	[m]	555.59	
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]	4.335e-006	0.001056
System ((da+df)/2...di) (kg*m²)	[TraeghMom]	7.031e-005	
Coefficient of friction	[mum]	0.280	
Loss factor	[HV]	0.096	
Coefficient for frequency of running	[KstEDf]	1.000	
Casing surface (m²)	[Oberflache]	0.16539	
Gear power loss (W)	[PVZ]	14.970	
(Meshing efficiency (%)	[etaz]	97.303)	
Tooth root temperature (°C)	[TR]	70.0	70.0
Flank temperature (°C)	[TF]	70.0	70.0

Heat transfer coefficient, root	[KF]	0.0	0.0
Heat transfer coefficient, flank	[KH]	0.0	0.0

9. MODIFICATIONS AND TOOTH FORM DEFINITION

Data for the tooth form calculation :

Calculation of Gear 1
Tooth form, Gear 1, Step 1: Automatic (final machining)
haP*= 0.945, hfP*= 1.250, rofP*= 0.380

Calculation of Gear 2
Tooth form, Gear 2, Step 1: Automatic (final machining)
haP*= 0.965, hfP*= 1.250, rofP*= 0.380

10. SERVICE LIFE, DAMAGE

Required safety for tooth root	[SFmin]	1.25
Required safety for tooth flank	[SHmin]	0.93
Required safety for wear	[SWmin]	1.10

Service life (calculated with required safeties):

System service life (h)	[Hatt]	0.000

Tooth root service life (h)	[HFatt]	0.0001088	0.0003481
Tooth flank service life (h)	[HHatt]	0.9244	3.697
Wear service life (h)	[HWatt]	927.2	4058

Damage calculated on the basis of the required service life [H] (0.0 h)

F1%	F2%	H1%	H2%	W1%	W2%
9188.39	2872.9789	1.0818	0.2705	0.0011	0.0002

Damage calculated on basis of system service life [Hatt] (0.0 h)

F1%	F2%	H1%	H2%	W1%	W2%
100.00	31.2675	0.0118	0.0029	0.0000	0.0000

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

Gear		fac	b	t0	T	R(H)%
1	Tooth root	60000	1.7	6.304	9.688	0.00
1	Tooth flank	60000	1.3	4.999e+004	2.382e+005	100.00
2	Tooth root	15000	1.7	5.04	7.746	0.00
2	Tooth flank	15000	1.3	4.999e+004	2.382e+005	100.00

Reliability of the configuration for required service life (%) 0.00 (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.

End of Report lines: 502

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File

Name : PLA_dynamic
Changed by: jsebe on: 26.05.2023 at: 12:38:00

Important hint: At least one warning has occurred during the calculation:

1-> Note:
For calculations in accordance with VDI, the face load factor KHb with 1.0 is assumed,
as plastics run in.
However a width/module ratio that is too large (b/mn > 10) should be avoided.
Or the face load factor needs to be checked.

CALCULATION OF A HELICAL GEAR PAIR

Drawing or article number:
Gear 1: 0.000.0
Gear 2: 0.000.0

Calculation method Plastic according to VDI 2736:2013 (YF Method C)
Steel wheels: calculated roughly according to DIN 3990!

		------- GEAR 1	-------- GEAR 2 --
Power (W)	[P]	178.024	
Speed (1/min)	[n]	1000.0	250.0
Torque (Nm)	[T]	1.700	6.800
Application factor	[KA]	1.00	
Required service life (h)	[H]	48.00	
Gear driving (+) / driven (-)		+	-

Working flank gear 1: Right flank
Sense of rotation gear 1 clockwise
Gearbox type: Gear with partly closed housing

1. TOOTH GEOMETRY AND MATERIAL

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

		------- GEAR 1	-------- GEAR 2 --
Center distance (mm)	[a]	80.000	
Center distance tolerance	ISO 286:2010 Measure js7		
Normal module (mm)	[mn]	1.2500	
Pressure angle at normal section (°)	[alfn]	20.0000	
Helix angle at reference circle (°)	[beta]	12.0000	
Number of teeth	[z]	25	100
Facewidth (mm)	[b]	30.00	30.00
Hand of gear		right	left
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 >=25HRC Jominy J=12mm<HRC28

Gear 2: PLA, Thermoplastic (POM, PPA, etc.), untreated

3D printed material

Woehler line tooth root stress from file Z014-PLA_VDI2736_BP.DAT

S-N curve (Woehler line) Hertzian pressure from file Z014-PLA_VDI2736_BP.DAT

			------- GEAR 1 --------	GEAR 2 --
Surface hardness			HRC 61	HBW 40
Tooth root temperature (°C)	[TR]		70.0	70.0
Flank temperature (°C)	[TF]		70.0	70.0
Tooth root strength at NL (N/mm²)	[σFadm]		432.01	7.30
Strength against Hertzian pressure at NL (N/mm²)		[σHadm]	1861.40	21.80
Tensile strength (N/mm²)	[σB]		1200.00	30.20
Yield point (N/mm²)	[σS]		850.00	29.40
Young's modulus (N/mm²)	[E]		206000	2390
Poisson's ratio	[v]		0.300	0.400
Roughness average value DS, flank (µm)	[RAH]		0.60	0.00
Roughness average value DS, root (µm)	[RAF]		3.00	0.00
Mean roughness height, Rz, flank (µm)	[RZH]		4.80	0.00
Mean roughness height, Rz, root (µm)	[RZF]		20.00	0.00

Gear reference profile	1 :		
Reference profile	1.25 / 0.38 / 1.0 ISO 53:1998 Profil A		
Dedendum coefficient		[hfP*]	1.250
Root radius factor		[rhofP*]	0.380 (rhofPmax*=0.472)
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	1.25 / 0.38 / 1.0 ISO 53:1998 Profil A		
Dedendum coefficient		[hfP*]	1.250
Root radius factor		[rhofP*]	0.380 (rhofPmax*=0.472)
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

Summary of reference profile gears:

Dedendum reference profile	[hfP*]	1.250	1.250
Tooth root radius Refer. profile	[rofP*]	0.380	0.380
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

Type of profile modification:	none (only running-in)		
Tip relief (µm)	[Ca]	2.0	20.0

Lubrication type Dry-running

Ambient temperature (°C)	[TU]	20.000	
		------- GEAR 1 --------	GEAR 2 --
Overall transmission ratio	[itot]	-4.000	
Gear ratio	[u]	4.000	
Transverse module (mm)	[mt]	1.278	
Pressure angle at pitch circle (°)	[alft]	20.410	
Working transverse pressure angle (°)	[alfwt]	20.658	
	[alfwt.e/i]	20.687 / 20.630	
Working pressure angle at normal section (°)	[alfwn]	20.243	
Helix angle at operating pitch circle (°)	[betaw]	12.019	
Base helix angle (°)	[betab]	11.267	
Reference center distance (mm)	[ad]	79.870	
Sum of profile shift coefficients	[Summexi]	0.1043	
Profile shift coefficient	[x]	0.3003	-0.1960
Tooth thickness (Arc) (module) (module)	[sn*]	1.7894	1.4281
Tip alteration (mm)	[k*mn]	-0.001	-0.001
Reference diameter (mm)	[d]	31.948	127.793
Base diameter (mm)	[db]	29.942	119.770
Tip diameter (mm)	[da]	35.197	129.801
(mm)	[da.e/i]	35.197 / 35.172	129.801 / 129.761
Tip diameter allowances (mm)	[Ada.e/i]	0.000 / -0.025	0.000 / -0.040
Tip form diameter (mm)	[dFa]	35.197	129.801
(mm)	[dFa.e/i]	35.197 / 35.172	129.801 / 129.761
Active tip diameter (mm)	[dNa]	35.197	129.801
Active tip diameter (mm)	[dNa.e/i]	35.197 / 35.172	129.801 / 129.761
Operating pitch diameter (mm)	[dw]	32.000	128.000
(mm)	[dw.e/i]	32.006 / 31.994	128.024 / 127.976
Root diameter (mm)	[df]	29.574	124.178
Generating Profile shift coefficient	[xE.e/i]	0.2409/ 0.2080	-0.3004/ -0.3553
Manufactured root diameter with xE (mm)	[df.e/i]	29.425 / 29.343	123.917 / 123.779
Theoretical tip clearance (mm)	[c]	0.313	0.313
Effective tip clearance (mm)	[c.e/i]	0.539 / 0.428	0.463 / 0.372
Active root diameter (mm)	[dNf]	30.621	125.637
(mm)	[dNf.e/i]	30.662 / 30.604	125.677 / 125.612
Root form diameter (mm)	[dFf]	30.563	125.061
(mm)	[dFf.e/i]	30.480 / 30.437	124.848 / 124.737
Reserve (dNf-dFf)/2 (mm)	[cF.e/i]	0.112 / 0.062	0.470 / 0.382
Addendum (mm)	[ha=mn*(haP*+x+k)]	1.624	1.004
(mm)	[ha.e/i]	1.624 / 1.612	1.004 / 0.984
Dedendum (mm)	[hf=mn*(hfP*-x)]	1.187	1.807
(mm)	[hf.e/i]	1.261 / 1.303	1.938 / 2.007
Roll angle at dFa (°)	[xsi_dFa.e/i]	35.401 / 35.310	23.936 / 23.886
Roll angle to dNa (°)	[xsi_dNa.e/i]	35.401 / 35.310	23.936 / 23.886
Roll angle to dNf (°)	[xsi_dNf.e/i]	12.633 / 12.109	18.217 / 18.112
Roll angle at dFf (°)	[xsi_dFf.e/i]	10.908 / 10.456	16.861 / 16.672
Tooth height (mm)	[h]	2.811	2.812
Virtual gear no. of teeth	[zn]	26.573	106.291
Normal tooth thickness at tip circle (mm)	[san]	0.789	1.030
(mm)	[san.e/i]	0.745 / 0.697	0.950 / 0.883
Normal tooth thickness on tip form circle (mm)	[sFan]	0.789	1.030
(mm)	[sFan.e/i]	0.745 / 0.697	0.950 / 0.883
Normal space width at root circle (mm)	[efn]	0.000	0.950
(mm)	[efn.e/i]	0.000 / 0.000	0.971 / 0.983
Max. sliding velocity at tip (m/s)	[vga]	0.472	0.319
Specific sliding at the tip	[zetaa]	0.487	0.487

Specific sliding at the root	[zetaf]		-0.951			-0.950		
Mean specific sliding	[zetam]			0.487				
Sliding factor on tip	[Kga]		0.282			0.190		
Sliding factor on root	[Kgf]		-0.190			-0.282		
Pitch on reference circle (mm)	[pt]			4.015				
Base pitch (mm)	[pbt]			3.763				
Transverse pitch on contact-path (mm)	[pet]			3.763				
Lead height (mm)	[pz]		472.195			1888.778		
Axial pitch (mm)	[px]			18.888				
Length of path of contact (mm)	[ga, e/i]		6.044 (	6.086 /	5.926)			
Length T1-A, T2-A (mm)	[T1A, T2A]	3.206(	3.164/	3.301)	25.017(	25.017/	24.965)	
Length T1-B (mm)	[T1B, T2B]	5.488(	5.488/	5.464)	22.736(	22.693/	22.802)	
Length T1-C (mm)	[T1C, T2C]	5.645(	5.636/	5.653)	22.579(	22.545/	22.613)	
Length T1-D (mm)	[T1D, T2D]	6.969(	6.927/	7.064)	21.255(	21.255/	21.203)	
Length T1-E (mm)	[T1E, T2E]	9.250(	9.250/	9.226)	18.973(	18.931/	19.040)	
Length T1-T2 (mm)	[T1T2]		28.224 (	28.181 /	28.266)			
Diameter of single contact point B (mm)	[d-B]	31.890(	31.890/	31.874)	128.111(	128.081/	128.158)	
Diameter of single contact point D (mm)	[d-D]	33.028(	32.992/	33.108)	127.090(	127.090/	127.055)	
Addendum contact ratio	[eps]	0.958(	0.961/	0.950)	0.648(	0.657/	0.625)	
Minimal length of contact line (mm)	[Lmin]			46.013				
Transverse contact ratio	[eps_a]			1.606				
Transverse contact ratio with allowances	[eps_a.e/m/i]		1.618 /	1.596 /	1.575			
Overlap ratio	[eps_b]			1.588				
Total contact ratio	[eps_g]			3.195				
Total contact ratio with allowances	[eps_g.e/m/i]		3.206 /	3.185 /	3.163			

2. FACTORS OF GENERAL INFLUENCE

		------- GEAR 1	-------- GEAR 2 --
Nominal circum. force at pitch circle (N)	[Ft]	106.4	
Axial force (N)	[Fa]	22.6	
Radial force (N)	[Fr]	39.6	
Normal force (N)	[Fnorm]	115.8	
Nominal circumferential force per mm (N/mm)	[w]	3.55	
Only as information: Forces at operating pitch circle:			
Nominal circumferential force (N)	[Ftw]	106.2	
Axial force (N)	[Faw]	22.6	
Radial force (N)	[Frw]	40.1	
Circumferential speed reference circle (m/s)	[v]	1.67	
Circumferential speed operating pitch circle (m/s)	[v(dw)]	1.68	
Correction factor	[CM]	0.800	
Gear blank factor	[CR]	1.000	
Basic rack factor	[CBS]	0.975	
Material coefficient	[E/Est]	0.023	
Singular tooth stiffness (N/mm/µm)	[c']	0.326	
Meshing stiffness (N/mm/µm)	[cg]	0.474	
Dynamic factor	[KV]	1.000	
Face load factor - flank	[KHb]	1.000	
- Tooth root	[KFb]	1.000	
- Scuffing	[KBb]	1.000	
Transverse load factor - flank	[KHa]	1.000	

- Tooth root	[KFa]	1.000	
- Scuffing	[KBa]	1.000	

Number of load cycles (in mio.)	[NL]	2.880	0.720

3. TOOTH ROOT STRENGTH

Calculation of Tooth form coefficients according method: C

		------- GEAR 1	-------- GEAR 2 --
Calculated with manufacturing profile shift	[xE.m]	0.2245	-0.3278
Tooth form factor	[YF]	2.46	2.47
Stress correction factor	[YS]	1.69	1.67
Load application angle (°)	[alfFen]	30.03	21.84
Bending moment arm (mm)	[hF]	2.53	2.54
Tooth thickness at root (mm)	[sFn]	2.67	2.76
Tooth root radius (mm)	[roF]	0.61	0.66

(hF* = 2.024/ 2.034 sFn* = 2.135/ 2.208 roF* = 0.487/ 0.529)
(den (mm) =
36.465/ 134.872 dsFn(mm) = 29.845/ 124.383 alfsFn(°) = 30.00/ 30.00 qs = 2.193/ 2.088)

Contact ratio factor	[Yeps]	0.717	
Helix angle factor	[Ybet]	0.900	
Effective facewidth (mm)	[beff]	30.00	30.00
Nominal stress at tooth root (N/mm²)	[sigF0]	7.33	7.57
Tooth root stress (N/mm²)	[sigF]	7.33	7.57

Permissible bending stress at root from data tables

Notch sensitivity factor	[YdrelT]	0.998	1.000	
Surface factor	[YRrelT]	0.957	1.000	
size factor (Tooth root)	[YX]	1.000	1.000	

Notice: When using Wohler lines from data files, the factors YdrelT, YRrelT, YX
will be interpolated according to the breakpoints NLstatic and NLendurance following ISO.

Finite life factor	[YNT]	1.005	1.000	
	[YdrelT*YRrelT*YX*YNT]	0.959	1.000	
Alternating bending factor (mean stress influence coefficient)	[YM]	1.000		1.000
Stress correction factor	[Yst]	2.00		
Yst*sigFlim (N/mm²)	[sigFE]	860.00	14.60	
Permissible tooth root stress (N/mm²)	[sigFP=sigFG/SFmin]	659.96	11.68	
Limit strength tooth root (N/mm²)	[sigFG]	824.95	14.60	
Required safety	[SFmin]	1.25	1.25	
Safety for tooth root stress	[SF=sigFG/sigF]	112.58	1.93	
Transmittable power (W)	[WRating]	16034.00	274.51	

4. SAFETY AGAINST PITTING (TOOTH FLANK)

		------- GEAR 1	-------- GEAR 2 --
Zone factor	[ZH]	2.434	
Elasticity factor (√N/mm²)	[ZE]	29.904	
Young's modulus for tooth flank (N/mm²)	[E]	206000	2390
Contact ratio factor	[Zeps]	0.789	
Helix angle factor	[Zbet]	1.000	
Effective facewidth (mm)	[beff]	30.00	
Nominal contact stress (N/mm²)	[sigH0]	21.39	

Contact stress at operating pitch circle (N/mm²)	[sigHw]	21.39	
Lubrication coefficient at NL	[ZL]	1.020	1.000
Speed coefficient at NL	[ZV]	0.954	1.000
Roughness coefficient at NL	[ZR]	1.000	1.000
Material pairing coefficient at NL	[ZW]	1.000	1.000
Notice: When using Wohler lines from data files, the factors ZL, ZV, ZR, ZW will be interpolated according to the breakpoints NLstatic and NLendurance following ISO.			
Finite life factor	[ZNT]	1.241	1.000
	[ZL*ZV*ZR*ZNT]	1.208	1.000
Limited pitting is permitted:	No		
Size factor (flank)	[ZX]	1.000	1.000
Permissible contact stress (N/mm²)	[sigHP=sigHG/SHmin]	1959.32	23.57
Pitting stress limit (N/mm²)	[sigHG]	1812.38	21.80
Required safety	[SHmin]	0.93	0.93
Safety factor for contact stress at operating pitch circle			
	[SHw]	85.66	1.02
Transmittable power (W)	[WRating]	1526659.00	196.12

4a. WEAR

Line load at reference diameter (N/mm)	[w]	3.55
Line load at reference diameter (N/mm)	[K_A*K_γ*K_V*$K_{H\beta}$*$K_{H\alpha}$*w]	3.55
Loss factor	[H_V]	0.117
Calculation only for Gear 2		
Length of active flank (mm)	[l_{Fl}]	2.20
Wear factor ($mm^3/Nm/10^6$)	[k_W]	3.40000
Data from file k_W: Z014-PLA_VDI2736_BP.DAT		
Normal tooth thickness in pitch circle (mm)	[s_n]	1.79
Maximum permissible wear (%)	[W_{limit}]	15.00
Permissible wear on flank (mm)	[δ_{Wlimn}]	0.27
Wear removal (mm)	[δ_{Wn}]	0.00186
Wear removal (mg)	[=lFL*b*z*ro*δWn]	16.8
Required safety	[S_{Wmin}]	1.10
Safety against wear	[S_W]	144.07

Calculation for safety against shearing for plastics			
Normal tooth thickness in the active root diameter (mm)	[s_{dNf}-δWn]		2.37
Shearing stress (N/mm²)	[τ_{nom}]	1.50	
Notch effect coefficient	[K_T]	1.25	
Permitted shearing strength (N/mm²)	[τ_B]	4.07	
Required safety	[S_{Tmin}]	2.50	
Safety shearing	[S_T]	2.17	

$\tau_B = 0.557 * \sigma_{Fadm}$; $S_T = \tau_B / (\tau_{nom} * K_T)$

Calculation of local wear with speeds and load distribution according to method A:
Calculation was not carried out. (Contact analysis under load is required.)

Important note:
the kw wear coefficients are usually determined using a plastic/steel pairing..
The coefficients may be very different if pairings of other materials are used..
This calculation is designed to give an indication of possible service life,
however it has not yet been checked exhaustively in real life..

5. BENDING

For plastics:		
Tooth deformation (µm)	[fa]	11.515
Permissible tooth deformation (µm)	[fazul]	87.500
Required safety	[Sdel]	1.000
Safety against deformation	[Sdelmin]	7.599

Experimental method using tooth stiffness according	ISO6336:2006:		
Tooth deformation (µm)	[faExp]	0.238	13.194
Permissible tooth deformation (µm)	[fazulExp]	148.262	148.262
Required safety	[Sdel]	1.000	
Safety against jamming	[SdelExp]	622.681	11.237

6. MEASUREMENTS FOR TOOTH THICKNESS

		Gear 1	Gear 2
Tooth thickness deviation		DIN 3967 cd25	DIN 3967 cd25
Tooth thickness allowance (normal section) (mm)	[As.e/i]	-0.054 / -0.084	-0.095 / -0.145
Number of teeth spanned	[k]	4.000	12.000
Base tangent length (no backlash) (mm)	[Wk]	13.638	44.134
Actual base tangent length ('span') (mm)	[Wk.e/i]	13.588 / 13.560	44.045 / 43.998
(mm)	[ΔWk.e/i]	-0.051 / -0.079	-0.089 / -0.136
Diameter of measuring circle (mm)	[dMWk.m]	32.768	127.313
Theoretical diameter of ball/pin (mm)	[DM]	2.268	2.088
Effective diameter of ball/pin (mm)	[DMeff]	2.500	2.500
Radial single-ball measurement backlash free (mm)	[MrK]	18.329	65.833
Radial single-ball measurement (mm)	[MrK.e/i]	18.275 / 18.245	65.711 / 65.646
Diameter of measuring circle (mm)	[dMMr.m]	32.926	127.972
Diametral measurement over two balls without clearance (mm)	[MdK]	36.590	131.666
Diametral two ball measure (mm)	[MdK.e/i]	36.482 / 36.422	131.422 / 131.292
Diametral measurement over pins without clearance (mm)	[MdR]	36.658	131.666
Measurement over pins according to DIN 3960 (mm)	[MdR.e/i]	36.550 / 36.489	131.422 / 131.292
Measurement over 2 pins (free) according to AGMA 2002 (mm)	[dk2f.e/i]	36.479 / 36.418	0.000 / 0.000
Measurement over 2 pins (axial) according to AGMA 2002 (mm)	[dk2t.e/i]	36.615 / 36.554	0.000 / 0.000
Measurement over 3 pins (axial) according to AGMA 2002 (mm)	[dk3A.e/i]	36.550 / 36.489	131.422 / 131.292
Chordal tooth thickness (no backlash) (mm)	[sc]	2.235	1.785
Actual chordal tooth thickness (mm)	[sc.e/i]	2.181 / 2.151	1.690 / 1.640
Reference chordal height from da.m (mm)	[ha]	1.656	1.000
Tooth thickness (Arc) (mm)	[sn]	2.237	1.785
(mm)	[sn.e/i]	2.183 / 2.153	1.690 / 1.640
Backlash free center distance (mm)	[aControl.e/i]	79.796 / 79.685	
Backlash free center distance, allowances (mm)	[jta]	-0.204 / -0.315	
dNf.i with aControl (mm)	[dNf0.i]	30.294	125.101
Reserve (dNf0.i-dFf.e)/2 (mm)	[cF0.i]	-0.093	0.127
Tip clearance (mm)	[c0.i(aControl)]	0.128	0.072
Center distance allowances (mm)	[Aa.e/i]	0.015 / -0.015	
Circumferential backlash from Aa (mm)	[jtw_Aa.e/i]	0.011 / -0.011	

Radial backlash (mm)	[jrw.e/i]	0.330 /	0.189
Circumferential backlash (transverse section) (mm)	[jtw.e/i]	0.246 /	0.141
Normal backlash (mm)	[jnw.e/i]	0.226 /	0.130
Angle of rotation on input with fixed output.:			
Entire torsional angle (°)	[j.tSys]		0.8802/ 0.5059

7. GEAR ACCURACY

		------- GEAR 1	-------- GEAR 2 --
According to DIN 3961:1978			
Accuracy grade	[Q-DIN3961]	6	6
Profile form deviation (µm)	[ff]	6.00	6.00
Profile slope deviation (µm)	[fHa]	5.00	5.00
Total profile deviation (µm)	[Ff]	8.00	8.00
Helix form deviation (µm)	[fbf]	5.50	5.50
Helix slope deviation (µm)	[fHb]	9.00	9.00
Total helix deviation (µm)	[Fb]	10.00	10.00
Normal base pitch deviation (µm)	[fpe]	7.00	8.00
Single pitch deviation (µm)	[fp]	7.00	8.00
Adjacent pitch difference (µm)	[fu]	8.00	10.00
Total cumulative pitch deviation (µm)	[Fp]	19.00	29.00
Sector pitch deviation over z/8 pitches (µm)	[Fpz/8]	12.00	18.00
Runout (µm)	[Fr]	14.00	19.00
Tooth Thickness Variation (µm)	[Rs]	8.00	11.00
Single flank composite, total (µm)	[Fi']	22.00	30.00
Single flank composite, tooth-to-tooth (µm)	[fi']	10.00	11.00
Radial composite, total (µm)	[Fi"]	17.00	24.00
Radial composite, tooth-to-tooth (µm)	[fi"]	6.00	10.00
According to DIN 58405:1972 (Feinwerktechnik):			
Tooth-to-tooth composite error (µm)	[fi"]	7.00	9.00
Composite error (µm)	[Fi"]	20.00	25.00
Axis alignment error (µm)	[fp]	13.60	13.60
Flank direction error (µm)	[fbeta]	6.30	6.30
Runout (µm)	[Trk, Fr]	21.00	28.00

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

Maximum value for deviation error of axis (µm)	[fSigbet]	13.00 (Fb=13.00)
Maximum value for inclination error of axes (µm)	[fSigdel]	26.00

8. ADDITIONAL DATA

Maximal possible center distance (eps_a=1.0)	[aMAX]	80.833	
Mass (kg)	[m]	0.193	0.521
Total mass (kg)	[m]	0.714	
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]	2.537e-005	0.001049
System ((da+df)/2...di) (kg*m²)	[TraeghMom]	9.095e-005	
Coefficient of friction	[mum]	0.200	
Loss factor	[HV]	0.117	
Coefficient for frequency of running	[KstEDf]	1.000	
Casing surface (m²)	[Oberflache]	0.16961	
Gear power loss (W)	[PVZ]	4.174	

(Meshing efficiency (%)	[etaz]		97.656)	
Tooth root temperature (°C)	[TR]		70.0	70.0
Flank temperature (°C)	[TF]		70.0	70.0
Heat transfer coefficient, root	[KF]		0.0	0.0
Heat transfer coefficient, flank	[KH]		0.0	0.0
Indications for the manufacturing by wire cutting:				
Deviation from theoretical tooth trace (µm)		[WireErr]	317.1	79.5
Permissible deviation (µm)	[Fb/2]		5.0	5.0

9. MODIFICATIONS AND TOOTH FORM DEFINITION

Data for the tooth form calculation :

Calculation of Gear 1
Tooth form, Gear 1, Step 1: Automatic (final machining)
haP*= 1.070, hfP*= 1.250, rofP*= 0.380

Calculation of Gear 2
Tooth form, Gear 2, Step 1: Automatic (final machining)
haP*= 1.123, hfP*= 1.250, rofP*= 0.380

10. SERVICE LIFE, DAMAGE

Required safety for tooth root	[SFmin]	1.25	
Required safety for tooth flank	[SHmin]	0.93	
Required safety for wear	[SWmin]	1.10	
Service life (calculated with required safeties):			
System service life (h)	[Hatt]	100	
Tooth root service life (h)	[HFatt]	1e+006	852.8
Tooth flank service life (h)	[HHatt]	1e+006	100.1
Wear service life (h)	[HWatt]	1e+006	6287

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] (48.0 h)

F1%	F2%	H1%	H2%	W1%	W2%
0.00	5.6286	0.0000	47.9436	0.0000	0.7635

Damage calculated on basis of system service life [Hatt] (100.1 h)

F1%	F2%	H1%	H2%	W1%	W2%
0.00	11.7401	0.0000	100.0000	0.0000	1.5926

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

Gear		fac	b	t0	T	R(H)%
1	Tooth root	60000	1.7	9.654e+029	1.484e+030	100.00
1	Tooth flank	60000	1.3	9.014e+029	4.295e+030	100.00
2	Tooth root	15000	1.7	1.235e+007	1.898e+007	100.00
2	Tooth flank	15000	1.3	1.354e+006	6.45e+006	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.
- Calculation of steel/plastic pair:
  the steel gear's strength is calculated approximately, according to DIN 3990, to obtain an indication of the service life..

End of Report lines: 511

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File

Name : PLA_static_fin
Changed by: jsebe on: 22.05.2023 at: 08:42:06

Important hint: At least one warning has occurred during the calculation:

1-> Note:
For calculations in accordance with VDI, the face load factor KHb with 1.0 is assumed,
as plastics run in.
However a width/module ratio that is too large (b/mn > 10) should be avoided.
Or the face load factor needs to be checked.

CALCULATION OF A CYLINDRICAL SPUR GEAR PAIR

Drawing or article number:
Gear 1: 0.000.0
Gear 2: 0.000.0

Calculation method Plastic according to VDI 2736:2013 (YF Method C)

		------- GEAR 1	-------- GEAR 2 --
Power (W)	[P]	774.926	
Speed (1/min)	[n]	1000.0	250.0
Torque (Nm)	[T]	7.400	29.600
Application factor	[KA]	1.00	
Required service life (h)	[H]	0.01	
Gear driving (+) / driven (-)		+	-

Working flank gear 1: Right flank
Sense of rotation gear 1 clockwise
Gearbox type: Gear with partly closed housing

1. TOOTH GEOMETRY AND MATERIAL

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

		------- GEAR 1	-------- GEAR 2 --
Center distance (mm)	[a]	80.000	
Center distance tolerance	ISO 286:2010 Measure js7		
Normal module (mm)	[mn]	1.2500	
Pressure angle at normal section (°)	[alfn]	20.0000	
Helix angle at reference circle (°)	[beta]	0.0000	
Number of teeth	[z]	25	100
Facewidth (mm)	[b]	30.00	30.00
Hand of gear		Spur gear	
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: PETG, Thermoplastic (POM, PPA, etc.), untreated
3D printed material
Woehler line tooth root stress from file Z014-PETG_VDI2736_BP.DAT

S-N curve (Woehler line) Hertzian pressure from file Z014-PETG_VDI2736_BP.DAT

Gear 2: PETG, Thermoplastic (POM, PPA, etc.), untreated

3D printed material

Woehler line tooth root stress from file Z014-PETG_VDI2736_BP.DAT

S-N curve (Woehler line) Hertzian pressure from file Z014-PETG_VDI2736_BP.DAT

			------- GEAR 1 --------	GEAR 2 --
Surface hardness			HBW 45	HBW 45
Tooth root temperature (°C)		[TR]	70.0	70.0
Flank temperature (°C)		[TF]	70.0	70.0
Tooth root strength at NL (N/mm²)		[σFadm]	17.90	19.10
Strength against Hertzian pressure	at NL (N/mm²)	[σHadm]	53.60	57.30
Tensile strength (N/mm²)		[σB]	34.20	34.20
Yield point (N/mm²)		[σS]	33.80	33.80
Young's modulus (N/mm²)		[E]	2317	2317
Poisson's ratio		[v]	0.400	0.400
Roughness average value DS, flank (µm)		[RAH]	0.00	0.00
Roughness average value DS, root (µm)		[RAF]	0.00	0.00
Mean roughness height, Rz, flank (µm)		[RZH]	0.00	0.00
Mean roughness height, Rz, root (µm)		[RZF]	0.00	0.00

Gear reference profile 1 :

Reference profile	1.25 / 0.38 / 1.0 ISO 53:1998 Profil A		
Dedendum coefficient	[hfP*]	1.250	
Root radius factor	[rhofP*]	0.380 (rhofPmax*=0.472)	
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	1.25 / 0.38 / 1.0 ISO 53:1998 Profil A		
Dedendum coefficient	[hfP*]	1.250	
Root radius factor	[rhofP*]	0.380 (rhofPmax*=0.472)	
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	

Summary of reference profile gears:

Dedendum reference profile	[hfP*]	1.250	1.250
Tooth root radius Refer. profile	[rofP*]	0.380	0.380
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

Type of profile modification: none (only running-in)

Tip relief (µm)	[Ca]	20.0	20.0

Lubrication type		Dry-running	
Ambient temperature (°C)	[TU]	20.000	
		------- GEAR 1 --------	GEAR 2 --
Overall transmission ratio	[itot]	-4.000	
Gear ratio	[u]	4.000	
Transverse module (mm)	[mt]	1.250	
Pressure angle at pitch circle (°)	[alft]	20.000	
Working transverse pressure angle (°)	[alfwt]	23.412	
	[alfwt.e/i]	23.437 / 23.388	
Working pressure angle at normal section (°)	[alfwn]	23.412	
Helix angle at operating pitch circle (°)	[betaw]	0.000	
Base helix angle (°)	[betab]	0.000	
Reference center distance (mm)	[ad]	78.125	
Sum of profile shift coefficients	[Summexi]	1.6258	
Profile shift coefficient	[x]	0.5656	1.0602
Tooth thickness (Arc) (module) (module)	[sn*]	1.9825	2.3426
Tip alteration (mm)	[k*mn]	-0.157	-0.157
Reference diameter (mm)	[d]	31.250	125.000
Base diameter (mm)	[db]	29.365	117.462
Tip diameter (mm)	[da]	34.850	129.837
(mm)	[da.e/i]	34.850 / 34.825	129.837 / 129.797
Tip diameter allowances (mm)	[Ada.e/i]	0.000 / -0.025	0.000 / -0.040
Tip form diameter (mm)	[dFa]	34.850	129.837
(mm)	[dFa.e/i]	34.850 / 34.825	129.837 / 129.797
Active tip diameter (mm)	[dNa]	34.850	129.837
Active tip diameter (mm)	[dNa.e/i]	34.850 / 34.825	129.837 / 129.797
Operating pitch diameter (mm)	[dw]	32.000	128.000
(mm)	[dw.e/i]	32.006 / 31.994	128.024 / 127.976
Root diameter (mm)	[df]	29.539	124.526
Generating Profile shift coefficient	[xE.e/i]	0.5062/ 0.4732	0.9833/ 0.9393
Manufactured root diameter with xE (mm)	[df.e/i]	29.391 / 29.308	124.333 / 124.223
Theoretical tip clearance (mm)	[c]	0.312	0.312
Effective tip clearance (mm)	[c.e/i]	0.491 / 0.393	0.463 / 0.371
Active root diameter (mm)	[dNf]	30.504	125.718
(mm)	[dNf.e/i]	30.550 / 30.483	125.762 / 125.691
Root form diameter (mm)	[dFf]	30.311	125.151
(mm)	[dFf.e/i]	30.207 / 30.151	124.958 / 124.849
Reserve (dNf-dFf)/2 (mm)	[cF.e/i]	0.199 / 0.138	0.456 / 0.366
Addendum (mm)	[ha=mn*(haP*+x+k)]	1.800	2.418
(mm)	[ha.e/i]	1.800 / 1.787	2.418 / 2.398
Dedendum (mm)	[hf=mn*(hfP*-x)]	0.856	0.237
(mm)	[hf.e/i]	0.930 / 0.971	0.333 / 0.388
Roll angle at dFa (°)	[xsi_dFa.e/i]	36.616 / 36.526	26.984 / 26.938
Roll angle to dNa (°)	[xsi_dNa.e/i]	36.616 / 36.526	26.984 / 26.938
Roll angle to dNf (°)	[xsi_dNf.e/i]	16.438 / 15.960	21.916 / 21.820
Roll angle at dFf (°)	[xsi_dFf.e/i]	13.812 / 13.342	20.795 / 20.638
Tooth height (mm)	[h]	2.656	2.656
Virtual gear no. of teeth	[zn]	25.000	100.000
Normal tooth thickness at tip circle (mm)	[san]	0.829	0.976
(mm)	[san.e/i]	0.784 / 0.735	0.922 / 0.862
Normal tooth thickness on tip form circle (mm)	[sFan]	0.829	0.976
(mm)	[sFan.e/i]	0.784 / 0.735	0.922 / 0.862
Normal space width at root circle (mm)	[efn]	0.942	0.825
(mm)	[efn.e/i]	0.976 / 0.000	0.827 / 0.828
Max. sliding velocity at tip (m/s)	[vga]	0.396	0.292

Specific sliding at the tip	[zetaa]		0.403			0.403		
Specific sliding at the root	[zetaf]		-0.675			-0.675		
Mean specific sliding	[zetam]			0.403				
Sliding factor on tip	[Kga]		0.236			0.174		
Sliding factor on root	[Kgf]		-0.174			-0.236		
Pitch on reference circle (mm)	[pt]			3.927				
Base pitch (mm)	[pbt]			3.690				
Transverse pitch on contact-path (mm)	[pet]			3.690				
Length of path of contact (mm)	[ga, e/i]		5.256 (	5.293 /	5.148)			
Length T1-A, T2-A (mm)	[T1A, T2A]	4.128(	4.090/	4.212)	27.660(	27.660/	27.613)	
Length T1-B (mm)	[T1B, T2B]	5.693(	5.693/	5.670)	26.095(	26.057/	26.156)	
Length T1-C (mm)	[T1C, T2C]	6.358(	6.350/	6.365)	25.430(	25.400/	25.460)	
Length T1-D (mm)	[T1D, T2D]	7.818(	7.780/	7.903)	23.970(	23.970/	23.923)	
Length T1-E (mm)	[T1E, T2E]	9.383(	9.383/	9.360)	22.404(	22.367/	22.465)	
Length T1-T2 (mm)	[T1T2]		31.788 (	31.750 /	31.825)			
Diameter of single contact point B (mm)	[d-B]	31.496(	31.496/	31.479)	128.534(	128.503/	128.583)	
Diameter of single contact point D (mm)	[d-D]	33.269(	33.233/	33.349)	126.868(	126.868/	126.832)	
Addendum contact ratio	[eps]	0.820(	0.822/	0.812)	0.604(	0.612/	0.583)	
Minimal length of contact line (mm)	[Lmin]			30.000				
Transverse contact ratio	[eps_a]			1.424				
Transverse contact ratio with allowances	[eps_a.e/m/i]		1.434 /	1.415 /	1.395			
Overlap ratio	[eps_b]			0.000				
Total contact ratio	[eps_g]			1.424				
Total contact ratio with allowances	[eps_g.e/m/i]		1.434 /	1.415 /	1.395			

2. FACTORS OF GENERAL INFLUENCE

		------- GEAR 1	-------- GEAR 2 --
Nominal circum. force at pitch circle (N)	[Ft]	473.6	
Axial force (N)	[Fa]	0.0	
Radial force (N)	[Fr]	172.4	
Normal force (N)	[Fnorm]	504.0	
Nominal circumferential force per mm (N/mm)	[w]	15.79	
Only as information: Forces at operating pitch circle:			
Nominal circumferential force (N)	[Ftw]	462.5	
Axial force (N)	[Faw]	0.0	
Radial force (N)	[Frw]	200.3	
Circumferential speed reference circle (m/s)	[v]	1.64	
Circumferential speed operating pitch circle (m/s)	[v(dw)]	1.68	
Correction factor	[CM]	0.800	
Gear blank factor	[CR]	1.000	
Basic rack factor	[CBS]	0.975	
Material coefficient	[E/Est]	0.011	
Singular tooth stiffness (N/mm/µm)	[c']	0.179	
Meshing stiffness (N/mm/µm)	[cg]	0.236	
Dynamic factor	[KV]	1.000	
Face load factor - flank	[KHb]	1.000	
- Tooth root	[KFb]	1.000	
- Scuffing	[KBb]	1.000	
Transverse load factor - flank	[KHa]	1.000	
- Tooth root	[KFa]	1.000	

- Scuffing	[KBa]	1.000	
Number of load cycles (in mio.)	[NL]	0.001	0.000

3. TOOTH ROOT STRENGTH

Calculation of Tooth form coefficients according method: C

		------- GEAR 1	-------- GEAR 2 --
Calculated with manufacturing profile shift	[xE.m]	0.4897	0.9613
Tooth form factor	[YF]	2.08	1.97
Stress correction factor	[YS]	1.84	1.97
Load application angle (°)	[alfFen]	31.35	24.83
Bending moment arm (mm)	[hF]	2.38	2.36
Tooth thickness at root (mm)	[sFn]	2.79	2.95
Tooth root radius (mm)	[roF]	0.53	0.48

(hF* = 1.901/ 1.891 sFn* = 2.230/ 2.359 roF* = 0.423/ 0.381)
(den (mm) =
34.850/ 129.837 dsFn(mm) = 29.762/ 124.732 alfsFn(°) = 30.00/ 30.00 qs = 2.636/ 3.095)

Contact ratio factor	[Yeps]	0.777	
Helix angle factor	[Ybet]	1.000	
Effective facewidth (mm)	[beff]	30.00	30.00
Nominal stress at tooth root (N/mm²)	[sigF0]	37.53	38.08
Tooth root stress (N/mm²)	[sigF]	37.53	38.08
Permissible bending stress at root from data tables			
Notch sensitivity factor	[YdrelT]	1.000	1.000
Surface factor	[YRrelT]	1.000	1.000
size factor (Tooth root)	[YX]	1.000	1.000

Notice: When using Wohler lines from data files, the factors YdrelT, YRrelT, YX
will be interpolated according to the breakpoints NLstatic and NLendurance following ISO.

Finite life factor	[YNT]	1.000	1.000
	[YdrelT*YRrelT*YX*YNT]	1.000	1.000
Alternating bending factor (mean stress influence coefficient)	[YM]	1.000	1.000
Stress correction factor	[Yst]	2.00	
Yst*sigFlim (N/mm²)	[sigFE]	35.80	38.20
Permissible tooth root stress (N/mm²)	[sigFP=sigFG/SFmin]	28.64	30.56
Limit strength tooth root (N/mm²)	[sigFG]	35.80	38.20
Required safety	[SFmin]	1.25	1.25
Safety for tooth root stress	[SF=sigFG/sigF]	0.95	1.00
Transmittable power (kW)	[kWRating]	0.59	0.62

4. SAFETY AGAINST PITTING (TOOTH FLANK)

		------- GEAR 1	-------- GEAR 2 --
Zone factor	[ZH]	2.287	
Elasticity factor (√N/mm²)	[ZE]	20.952	
Young's modulus for tooth flank (N/mm²)	[E]	2317	2317
Contact ratio factor	[Zeps]	0.927	
Helix angle factor	[Zbet]	1.000	
Effective facewidth (mm)	[beff]	30.00	
Nominal contact stress (N/mm²)	[sigH0]	35.28	
Contact stress at operating pitch circle (N/mm²)	[sigHw]	35.28	

Lubrication coefficient at NL	[ZL]	1.000	1.000
Speed coefficient at NL	[ZV]	1.000	1.000
Roughness coefficient at NL	[ZR]	1.000	1.000
Material pairing coefficient at NL	[ZW]	1.000	1.000
Notice: When using Wohler lines from data files, the factors ZL, ZV, ZR, ZW will be interpolated according to the breakpoints NLstatic and NLendurance following ISO.			
Finite life factor	[ZNT]	1.000	1.000
	[ZL*ZV*ZR*ZNT]	1.000	1.000
Limited pitting is permitted:	No		
Size factor (flank)	[ZX]	1.000	1.000
Permissible contact stress (N/mm²)	[sigHP=sigHG/SHmin]	57.95	61.95
Pitting stress limit (N/mm²)	[sigHG]	53.60	57.30
Required safety	[SHmin]	0.93	0.93
Safety factor for contact stress at operating pitch circle			
	[SHw]	1.52	1.62
Transmittable power (kW)	[kWRating]	1.27	1.36

4a. WEAR

Line load at reference diameter (N/mm)	[w]	15.79	
Line load at reference diameter (N/mm)	[K_A*K_γ*K_V*$K_{H\beta}$*$K_{H\alpha}$*w]	15.79	
Loss factor	[H_V]	0.096	
Length of active flank (mm)	[l_{Fl}]	2.39	2.22
Wear factor (mm^3/Nm/10^6)	[k_W]	3.40000	3.40000
Data from file k_{W1}: Z014-PETG_VDI2736_BP.DAT			
Data from file k_{W2}: Z014-PETG_VDI2736_BP.DAT			
Normal tooth thickness in pitch circle (mm)	[s_n]	2.48	2.93
Maximum permissible wear (%)	[W_{limit}]	15.00	
Permissible wear on flank (mm)	[δ_{Wlimn}]	0.37	0.44
Wear removal (mm)	[δ_{Wn}]	0.00001	0.00000
Wear removal (mg)	[=lFL*b*z*ro*δWn]	0.0	0.0
Required safety	[S_{Wmin}]	1.10	
Safety against wear	[S_W]	999.99	999.99

Calculation for safety against shearing for plastics			
Normal tooth thickness in the active root diameter (mm)	[s_{dNf}-δWn]	2.60	2.59
Shearing stress (N/mm²)	[τ_{nom}]	6.08	6.09
Notch effect coefficient	[K_T]	1.25	1.25
Permitted shearing strength (N/mm²)	[τ_B]	9.97	10.64
Required safety	[S_{Tmin}]	2.50	
Safety shearing	[S_T]	1.31	1.40

$\tau_B = 0.557 * \sigma_{Fadm}$; $S_T = \tau_B / (\tau_{nom} * K_T)$

Calculation of local wear with speeds and load distribution according to method A:
Calculation was not carried out. (Contact analysis under load is required.)

Important note:
the kw wear coefficients are usually determined using a plastic/steel pairing..
The coefficients may be very different if pairings of other materials are used..
This calculation is designed to give an indication of possible service life,
however it has not yet been checked exhaustively in real life..

5. BENDING

For plastics:		
Tooth deformation (µm)	[fa]	102.206
Permissible tooth deformation (µm)	[fazul]	87.500
Required safety	[Sdel]	1.000
Safety against deformation	[Sdelmin]	0.856

Experimental method using tooth stiffness according	ISO6336:2006:		
Tooth deformation (µm)	[faExp]	76.914	55.178
Permissible tooth deformation (µm)	[fazulExp]	175.282	175.282
Required safety	[Sdel]	1.000	
Safety against jamming	[SdelExp]	2.279	3.177

6. MEASUREMENTS FOR TOOTH THICKNESS

		------- Gear 1	------ Gear 2 --
Tooth thickness deviation		DIN 3967 cd25	DIN 3967 cd25
Tooth thickness allowance (normal section) (mm)	[As.e/i]	-0.054 / -0.084	-0.070 / -0.110
Number of teeth spanned	[k]	4.000	13.000
Base tangent length (no backlash) (mm)	[Wk]	13.837	48.784
Actual base tangent length ('span') (mm)	[Wk.e/i]	13.786 / 13.758	48.719 / 48.681
(mm)	[ΔWk.e/i]	-0.051 / -0.079	-0.066 / -0.103
Diameter of measuring circle (mm)	[dMWk.m]	32.434	127.157
Theoretical diameter of ball/pin (mm)	[DM]	2.454	2.275
Effective diameter of ball/pin (mm)	[DMeff]	2.500	2.500
Radial single-ball measurement backlash free (mm)	[MrK]	18.202	65.803
Radial single-ball measurement (mm)	[MrK.e/i]	18.151 / 18.122	65.724 / 65.678
Diameter of measuring circle (mm)	[dMMr.m]	32.611	127.892
Diametral measurement over two balls without clearance (mm)	[MdK]	36.337	131.606
Diametral two ball measure (mm)	[MdK.e/i]	36.235 / 36.178	131.447 / 131.356
Diametral measurement over pins without clearance (mm)	[MdR]	36.337	131.606
Measurement over pins according to DIN 3960 (mm)	[MdR.e/i]	36.235 / 36.178	131.447 / 131.356
Measurement over 3 pins (axial) according to AGMA 2002 (mm)	[dk3A.e/i]	36.235 / 36.178	131.447 / 131.356
Dimensions over 3 pins without clearance (mm)	[Md3R]	36.270	0.000
Effective dimensions over 3 pins (mm)	[Md3R.e/i]	36.168 / 36.112	0.000 / 0.000
Chordal tooth thickness (no backlash) (mm)	[sc]	2.476	2.928
Actual chordal tooth thickness (mm)	[sc.e/i]	2.422 / 2.392	2.858 / 2.818
Reference chordal height from da.m (mm)	[ha]	1.843	2.425
Tooth thickness (Arc) (mm)	[sn]	2.478	2.928
(mm)	[sn.e/i]	2.424 / 2.394	2.858 / 2.818
Backlash free center distance (mm)	[aControl.e/i]	79.853 / 79.769	
Backlash free center distance, allowances (mm)	[jta]	-0.147 / -0.231	
dNf.i with aControl (mm)	[dNf0.i]	30.207	125.305
Reserve (dNf0.i-dFf.e)/2 (mm)	[cF0.i]	0.000	0.173
Tip clearance (mm)	[c0.i(aControl)]	0.177	0.155
Center distance allowances (mm)	[Aa.e/i]	0.015 / -0.015	
Circumferential backlash from Aa (mm)	[jtw_Aa.e/i]	0.013 / -0.013	
Radial backlash (mm)	[jrw.e/i]	0.246 / 0.132	
Circumferential backlash (transverse section) (mm)	[jtw.e/i]	0.212 / 0.114	
Normal backlash (mm)	[jnw.e/i]	0.199 / 0.107	

Angle of rotation on input with fixed output.:

Entire torsional angle (°)	[j.tSys]	0.7579/ 0.4082

7. GEAR ACCURACY

		GEAR 1	GEAR 2
According to DIN 3961:1978			
Accuracy grade	[Q-DIN3961]	6	6
Profile form deviation (µm)	[ff]	6.00	6.00
Profile slope deviation (µm)	[fHa]	5.00	5.00
Total profile deviation (µm)	[Ff]	8.00	8.00
Helix form deviation (µm)	[fbf]	5.50	5.50
Helix slope deviation (µm)	[fHb]	9.00	9.00
Total helix deviation (µm)	[Fb]	10.00	10.00
Normal base pitch deviation (µm)	[fpe]	7.00	7.00
Single pitch deviation (µm)	[fp]	7.00	7.00
Adjacent pitch difference (µm)	[fu]	8.00	9.00
Total cumulative pitch deviation (µm)	[Fp]	19.00	25.00
Sector pitch deviation over z/8 pitches (µm)	[Fpz/8]	12.00	15.00
Runout (µm)	[Fr]	14.00	16.00
Tooth Thickness Variation (µm)	[Rs]	8.00	10.00
Single flank composite, total (µm)	[Fi']	22.00	26.00
Single flank composite, tooth-to-tooth (µm)	[fi']	10.00	11.00
Radial composite, total (µm)	[Fi"]	17.00	20.00
Radial composite, tooth-to-tooth (µm)	[fi"]	6.00	8.00
According to DIN 58405:1972 (Feinwerktechnik):			
Tooth-to-tooth composite error (µm)	[fi"]	7.00	9.00
Composite error (µm)	[Fi"]	20.00	25.00
Axis alignment error (µm)	[fp]	13.60	13.60
Flank direction error (µm)	[fbeta]	6.30	6.30
Runout (µm)	[Trk, Fr]	21.00	28.00

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

Maximum value for deviation error of axis (µm)	[fSigbet]	12.00 (Fb=12.00)
Maximum value for inclination error of axes (µm)	[fSigdel]	24.00

8. ADDITIONAL DATA

Maximal possible center distance (eps_a=1.0)	[aMAX]	80.635	
Mass (g)	[m]	33.46	522.13
Total mass (g)	[m]	555.59	
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]	4.335e-006	0.001056
System ((da+df)/2...di) (kg*m²)	[TraeghMom]	7.031e-005	
Coefficient of friction	[mum]	0.280	
Loss factor	[HV]	0.096	
Coefficient for frequency of running	[KstEDf]	1.000	
Casing surface (m²)	[Oberflache]	0.16539	
Gear power loss (W)	[PVZ]	20.901	
(Meshing efficiency (%)	[etaz]	97.303)	
Tooth root temperature (°C)	[TR]	70.0	70.0
Flank temperature (°C)	[TF]	70.0	70.0

Heat transfer coefficient, root	[KF]	0.0	0.0
Heat transfer coefficient, flank	[KH]	0.0	0.0

9. MODIFICATIONS AND TOOTH FORM DEFINITION

Data for the tooth form calculation :

Calculation of Gear 1
Tooth form, Gear 1, Step 1: Automatic (final machining)
haP*= 0.945, hfP*= 1.250, rofP*= 0.380

Calculation of Gear 2
Tooth form, Gear 2, Step 1: Automatic (final machining)
haP*= 0.965, hfP*= 1.250, rofP*= 0.380

10. SERVICE LIFE, DAMAGE

Required safety for tooth root	[SFmin]	1.25
Required safety for tooth flank	[SHmin]	0.93
Required safety for wear	[SWmin]	1.10

Service life (calculated with required safeties):

System service life (h)	[Hatt]	0.000

Tooth root service life (h)	[HFatt]	3.335e-005	9.846e-005
Tooth flank service life (h)	[HHatt]	4.705	18.82
Wear service life (h)	[HWatt]	664.1	2906

Damage calculated on the basis of the required service life [H] (0.0 h)

F1%	F2%	H1%	H2%	W1%	W2%
9999.99	9999.9900	0.2126	0.0531	0.0015	0.0003

Damage calculated on basis of system service life [Hatt] (0.0 h)

F1%	F2%	H1%	H2%	W1%	W2%
100.00	33.8734	0.0007	0.0002	0.0000	0.0000

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

Gear		fac	b	t0	T	R(H)%
1	Tooth root	60000	1.7	1.932	2.969	0.00
1	Tooth flank	60000	1.3	2.544e+005	1.212e+006	100.00
2	Tooth root	15000	1.7	1.426	2.191	0.00
2	Tooth flank	15000	1.3	2.544e+005	1.212e+006	100.00

Reliability of the configuration for required service life (%) 0.00 (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.

End of Report lines: 502

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File

Name : PETG_dynamic
Changed by: jsebe on: 26.05.2023 at: 12:39:22

Important hint: At least one warning has occurred during the calculation:

1-> Note:
For calculations in accordance with VDI, the face load factor KHb with 1.0 is assumed,
as plastics run in.
However a width/module ratio that is too large (b/mn > 10) should be avoided.
Or the face load factor needs to be checked.

CALCULATION OF A HELICAL GEAR PAIR

Drawing or article number:
Gear 1: 0.000.0
Gear 2: 0.000.0

Calculation method Plastic according to VDI 2736:2013 (YF Method C)
Steel wheels: calculated roughly according to DIN 3990!

		------- GEAR 1	-------- GEAR 2 --
Power (W)	[P]	261.799	
Speed (1/min)	[n]	1000.0	250.0
Torque (Nm)	[T]	2.500	10.000
Application factor	[KA]	1.00	
Required service life (h)	[H]	48.00	
Gear driving (+) / driven (-)		+	-

Working flank gear 1: Right flank
Sense of rotation gear 1 clockwise
Gearbox type: Gear with partly closed housing

1. TOOTH GEOMETRY AND MATERIAL

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

		------- GEAR 1	-------- GEAR 2 --
Center distance (mm)	[a]	80.000	
Center distance tolerance	ISO 286:2010 Measure js7		
Normal module (mm)	[mn]	1.2500	
Pressure angle at normal section (°)	[alfn]	20.0000	
Helix angle at reference circle (°)	[beta]	12.0000	
Number of teeth	[z]	25	100
Facewidth (mm)	[b]	30.00	30.00
Hand of gear		right	left
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 >=25HRC Jominy J=12mm<HRC28

Gear 2: PETG, Thermoplastic (POM, PPA, etc.), untreated

3D printed material

Woehler line tooth root stress from file Z014-PETG_VDI2736_BP.DAT

S-N curve (Woehler line) Hertzian pressure from file Z014-PETG_VDI2736_BP.DAT

			------- GEAR 1 --------	GEAR 2 --
Surface hardness			HRC 61	HBW 45
Tooth root temperature (°C)	[TR]		70.0	70.0
Flank temperature (°C)	[TF]		70.0	70.0
Tooth root strength at NL (N/mm²)	[σFadm]		432.01	8.70
Strength against Hertzian pressure at NL (N/mm²)	[σHadm]		1861.40	26.00
Tensile strength (N/mm²)	[σB]		1200.00	34.20
Yield point (N/mm²)	[σS]		850.00	33.80
Young's modulus (N/mm²)	[E]		206000	2317
Poisson's ratio	[v]		0.300	0.400
Roughness average value DS, flank (µm)	[RAH]		0.60	0.00
Roughness average value DS, root (µm)	[RAF]		3.00	0.00
Mean roughness height, Rz, flank (µm)	[RZH]		4.80	0.00
Mean roughness height, Rz, root (µm)	[RZF]		20.00	0.00

Gear reference profile	1 :		
Reference profile	1.25 / 0.38 / 1.0 ISO 53:1998 Profil A		
Dedendum coefficient		[hfP*]	1.250
Root radius factor		[rhofP*]	0.380 (rhofPmax*=0.472)
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	1.25 / 0.38 / 1.0 ISO 53:1998 Profil A		
Dedendum coefficient		[hfP*]	1.250
Root radius factor		[rhofP*]	0.380 (rhofPmax*=0.472)
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

Summary of reference profile gears:

Dedendum reference profile	[hfP*]	1.250	1.250
Tooth root radius Refer. profile	[rofP*]	0.380	0.380
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

Type of profile modification:	none (only running-in)		
Tip relief (µm)	[Ca]	2.0	20.0

Lubrication type Dry-running

Ambient temperature (°C)	[TU]	20.000	
		------- GEAR 1 --------	GEAR 2 --
Overall transmission ratio	[itot]	-4.000	
Gear ratio	[u]	4.000	
Transverse module (mm)	[mt]	1.278	
Pressure angle at pitch circle (°)	[alft]	20.410	
Working transverse pressure angle (°)	[alfwt]	20.658	
	[alfwt.e/i]	20.687 / 20.630	
Working pressure angle at normal section (°)	[alfwn]	20.243	
Helix angle at operating pitch circle (°)	[betaw]	12.019	
Base helix angle (°)	[betab]	11.267	
Reference center distance (mm)	[ad]	79.870	
Sum of profile shift coefficients	[Summexi]	0.1043	
Profile shift coefficient	[x]	0.3003	-0.1960
Tooth thickness (Arc) (module) (module)	[sn*]	1.7894	1.4281
Tip alteration (mm)	[k*mn]	-0.001	-0.001
Reference diameter (mm)	[d]	31.948	127.793
Base diameter (mm)	[db]	29.942	119.770
Tip diameter (mm)	[da]	35.197	129.801
(mm)	[da.e/i]	35.197 / 35.172	129.801 / 129.761
Tip diameter allowances (mm)	[Ada.e/i]	0.000 / -0.025	0.000 / -0.040
Tip form diameter (mm)	[dFa]	35.197	129.801
(mm)	[dFa.e/i]	35.197 / 35.172	129.801 / 129.761
Active tip diameter (mm)	[dNa]	35.197	129.801
Active tip diameter (mm)	[dNa.e/i]	35.197 / 35.172	129.801 / 129.761
Operating pitch diameter (mm)	[dw]	32.000	128.000
(mm)	[dw.e/i]	32.006 / 31.994	128.024 / 127.976
Root diameter (mm)	[df]	29.574	124.178
Generating Profile shift coefficient	[xE.e/i]	0.2409/ 0.2080	-0.3004/ -0.3553
Manufactured root diameter with xE (mm)	[df.e/i]	29.425 / 29.343	123.917 / 123.779
Theoretical tip clearance (mm)	[c]	0.313	0.313
Effective tip clearance (mm)	[c.e/i]	0.539 / 0.428	0.463 / 0.372
Active root diameter (mm)	[dNf]	30.621	125.637
(mm)	[dNf.e/i]	30.662 / 30.604	125.677 / 125.612
Root form diameter (mm)	[dFf]	30.563	125.061
(mm)	[dFf.e/i]	30.480 / 30.437	124.848 / 124.737
Reserve (dNf-dFf)/2 (mm)	[cF.e/i]	0.112 / 0.062	0.470 / 0.382
Addendum (mm)	[ha=mn*(haP*+x+k)]	1.624	1.004
(mm)	[ha.e/i]	1.624 / 1.612	1.004 / 0.984
Dedendum (mm)	[hf=mn*(hfP*-x)]	1.187	1.807
(mm)	[hf.e/i]	1.261 / 1.303	1.938 / 2.007
Roll angle at dFa (°)	[xsi_dFa.e/i]	35.401 / 35.310	23.936 / 23.886
Roll angle to dNa (°)	[xsi_dNa.e/i]	35.401 / 35.310	23.936 / 23.886
Roll angle to dNf (°)	[xsi_dNf.e/i]	12.633 / 12.109	18.217 / 18.112
Roll angle at dFf (°)	[xsi_dFf.e/i]	10.908 / 10.456	16.861 / 16.672
Tooth height (mm)	[h]	2.811	2.812
Virtual gear no. of teeth	[zn]	26.573	106.291
Normal tooth thickness at tip circle (mm)	[san]	0.789	1.030
(mm)	[san.e/i]	0.745 / 0.697	0.950 / 0.883
Normal tooth thickness on tip form circle (mm)	[sFan]	0.789	1.030
(mm)	[sFan.e/i]	0.745 / 0.697	0.950 / 0.883
Normal space width at root circle (mm)	[efn]	0.000	0.950
(mm)	[efn.e/i]	0.000 / 0.000	0.971 / 0.983
Max. sliding velocity at tip (m/s)	[vga]	0.472	0.319
Specific sliding at the tip	[zetaa]	0.487	0.487

Specific sliding at the root	[zetaf]		-0.951			-0.950		
Mean specific sliding	[zetam]			0.487				
Sliding factor on tip	[Kga]		0.282			0.190		
Sliding factor on root	[Kgf]		-0.190			-0.282		
Pitch on reference circle (mm)	[pt]			4.015				
Base pitch (mm)	[pbt]			3.763				
Transverse pitch on contact-path (mm)	[pet]			3.763				
Lead height (mm)	[pz]		472.195			1888.778		
Axial pitch (mm)	[px]			18.888				
Length of path of contact (mm)	[ga, e/i]		6.044 (	6.086 /	5.926)			
Length T1-A, T2-A (mm)	[T1A, T2A]	3.206(	3.164/	3.301)	25.017(	25.017/	24.965)	
Length T1-B (mm)	[T1B, T2B]	5.488(	5.488/	5.464)	22.736(	22.693/	22.802)	
Length T1-C (mm)	[T1C, T2C]	5.645(	5.636/	5.653)	22.579(	22.545/	22.613)	
Length T1-D (mm)	[T1D, T2D]	6.969(	6.927/	7.064)	21.255(	21.255/	21.203)	
Length T1-E (mm)	[T1E, T2E]	9.250(	9.250/	9.226)	18.973(	18.931/	19.040)	
Length T1-T2 (mm)	[T1T2]		28.224 (	28.181 /	28.266)			
Diameter of single contact point B (mm)	[d-B]	31.890(	31.890/	31.874)	128.111(	128.081/	128.158)	
Diameter of single contact point D (mm)	[d-D]	33.028(	32.992/	33.108)	127.090(	127.090/	127.055)	
Addendum contact ratio	[eps]	0.958(	0.961/	0.950)	0.648(	0.657/	0.625)	
Minimal length of contact line (mm)	[Lmin]			46.013				
Transverse contact ratio	[eps_a]			1.606				
Transverse contact ratio with allowances	[eps_a.e/m/i]		1.618 /	1.596 /	1.575			
Overlap ratio	[eps_b]			1.588				
Total contact ratio	[eps_g]			3.195				
Total contact ratio with allowances	[eps_g.e/m/i]		3.206 /	3.185 /	3.163			

2. FACTORS OF GENERAL INFLUENCE

		------- GEAR 1	-------- GEAR 2 --
Nominal circum. force at pitch circle (N)	[Ft]	156.5	
Axial force (N)	[Fa]	33.3	
Radial force (N)	[Fr]	58.2	
Normal force (N)	[Fnorm]	170.3	
Nominal circumferential force per mm (N/mm)	[w]	5.22	
Only as information: Forces at operating pitch circle:			
Nominal circumferential force (N)	[Ftw]	156.2	
Axial force (N)	[Faw]	33.3	
Radial force (N)	[Frw]	58.9	
Circumferential speed reference circle (m/s)	[v]	1.67	
Circumferential speed operating pitch circle (m/s)	[v(dw)]	1.68	
Correction factor	[CM]	0.800	
Gear blank factor	[CR]	1.000	
Basic rack factor	[CBS]	0.975	
Material coefficient	[E/Est]	0.022	
Singular tooth stiffness (N/mm/µm)	[c']	0.316	
Meshing stiffness (N/mm/µm)	[cg]	0.460	
Dynamic factor	[KV]	1.000	
Face load factor - flank	[KHb]	1.000	
- Tooth root	[KFb]	1.000	
- Scuffing	[KBb]	1.000	
Transverse load factor - flank	[KHa]	1.000	

- Tooth root	[KFa]	1.000	
- Scuffing	[KBa]	1.000	

Number of load cycles (in mio.)	[NL]	2.880	0.720

3. TOOTH ROOT STRENGTH

Calculation of Tooth form coefficients according method: C

		------- GEAR 1	-------- GEAR 2 --
Calculated with manufacturing profile shift	[xE.m]	0.2245	-0.3278
Tooth form factor	[YF]	2.46	2.47
Stress correction factor	[YS]	1.69	1.67
Load application angle (°)	[alfFen]	30.03	21.84
Bending moment arm (mm)	[hF]	2.53	2.54
Tooth thickness at root (mm)	[sFn]	2.67	2.76
Tooth root radius (mm)	[roF]	0.61	0.66

(hF* = 2.024/ 2.034 sFn* = 2.135/ 2.208 roF* = 0.487/ 0.529)
(den (mm) =
36.465/ 134.872 dsFn(mm) = 29.845/ 124.383 alfsFn(°) = 30.00/ 30.00 qs = 2.193/ 2.088)

Contact ratio factor	[Yeps]		0.717	
Helix angle factor	[Ybet]		0.900	
Effective facewidth (mm)	[beff]	30.00		30.00
Nominal stress at tooth root (N/mm²)	[sigF0]	10.78		11.14
Tooth root stress (N/mm²)	[sigF]	10.78		11.14
Permissible bending stress at root from data tables				
Notch sensitivity factor	[YdrelT]	0.998		1.000
Surface factor	[YRrelT]	0.957		1.000
size factor (Tooth root)	[YX]	1.000		1.000
Notice: When using Wohler lines from data files, the factors YdrelT, YRrelT, YX will be interpolated according to the breakpoints NLstatic and NLendurance following ISO.				
Finite life factor	[YNT]	1.005		1.000
	[YdrelT*YRrelT*YX*YNT]	0.959		1.000
Alternating bending factor (mean stress influence coefficient)	[YM]	1.000		1.000
Stress correction factor	[Yst]		2.00	
Yst*sigFlim (N/mm²)	[sigFE]	860.00		17.40
Permissible tooth root stress (N/mm²)	[sigFP=sigFG/SFmin]	659.96		13.92
Limit strength tooth root (N/mm²)	[sigFG]	824.95		17.40
Required safety	[SFmin]	1.25		1.25
Safety for tooth root stress	[SF=sigFG/sigF]	76.56		1.56
Transmittable power (W)	[WRating]	16034.00		327.15

4. SAFETY AGAINST PITTING (TOOTH FLANK)

		------- GEAR 1	-------- GEAR 2 --
Zone factor	[ZH]		2.434
Elasticity factor (√N/mm²)	[ZE]		29.452
Young's modulus for tooth flank (N/mm²)	[E]	206000	2317
Contact ratio factor	[Zeps]		0.789
Helix angle factor	[Zbet]		1.000
Effective facewidth (mm)	[beff]		30.00
Nominal contact stress (N/mm²)	[sigH0]		25.55

Contact stress at operating pitch circle (N/mm²)	[sigHw]	25.55	
Lubrication coefficient at NL	[ZL]	1.020	1.000
Speed coefficient at NL	[ZV]	0.954	1.000
Roughness coefficient at NL	[ZR]	1.000	1.000
Material pairing coefficient at NL	[ZW]	1.000	1.000
Notice: When using Wohler lines from data files, the factors ZL, ZV, ZR, ZW will be interpolated according to the breakpoints NLstatic and NLendurance following ISO.			
Finite life factor	[ZNT]	1.241	1.000
	[ZL*ZV*ZR*ZNT]	1.208	1.000
Limited pitting is permitted:	No		
Size factor (flank)	[ZX]	1.000	1.000
Permissible contact stress (N/mm²)	[sigHP=sigHG/SHmin]	1959.32	28.11
Pitting stress limit (N/mm²)	[sigHG]	1812.38	26.00
Required safety	[SHmin]	0.93	0.93
Safety factor for contact stress at operating pitch circle			
	[SHw]	71.72	1.02
Transmittable power (W)	[WRating]	1573968.19	288.01

4a. WEAR

Line load at reference diameter (N/mm)	[w]	5.22
Line load at reference diameter (N/mm)	[K_A*K_γ*K_V*$K_{H\beta}$*$K_{H\alpha}$*w]	5.22
Loss factor	[H_V]	0.117
Calculation only for Gear 2		
Length of active flank (mm)	[l_{Fl}]	2.20
Wear factor (mm^3/Nm/10^6)	[k_W]	3.40000
Data from file k_W: Z014-PETG_VDI2736_BP.DAT		
Normal tooth thickness in pitch circle (mm)	[s_n]	1.79
Maximum permissible wear (%)	[W_{limit}]	15.00
Permissible wear on flank (mm)	[δ_{Wlimn}]	0.27
Wear removal (mm)	[δ_{Wn}]	0.00273
Wear removal (mg)	[=lFL*b*z*ro*δWn]	24.7
Required safety	[S_{Wmin}]	1.10
Safety against wear	[S_W]	97.97

Calculation for safety against shearing for plastics			
Normal tooth thickness in the active root diameter (mm)	[s_{dNf}-δWn]		2.37
Shearing stress (N/mm²)	[τ_{nom}]	2.20	
Notch effect coefficient	[K_T]	1.25	
Permitted shearing strength (N/mm²)	[τ_B]	4.85	
Required safety	[S_{Tmin}]	2.50	
Safety shearing	[S_T]	1.76	

$\tau_B = 0.557 * \sigma_{Fadm}$; $S_T = \tau_B / (\tau_{nom} * K_T)$

Calculation of local wear with speeds and load distribution according to method A:
Calculation was not carried out. (Contact analysis under load is required.)

Important note:
the kw wear coefficients are usually determined using a plastic/steel pairing..
The coefficients may be very different if pairings of other materials are used..
This calculation is designed to give an indication of possible service life,
however it has not yet been checked exhaustively in real life..

5. BENDING

For plastics:

Tooth deformation (µm)	[fa]	17.459
Permissible tooth deformation (µm)	[fazul]	87.500
Required safety	[Sdel]	1.000
Safety against deformation	[Sdelmin]	5.012

Experimental method using tooth stiffness according ISO6336:2006:

Tooth deformation (µm)	[faExp]	0.350	20.012
Permissible tooth deformation (µm)	[fazulExp]	151.874	151.874
Required safety	[Sdel]	1.000	
Safety against jamming	[SdelExp]	433.739	7.589

6. MEASUREMENTS FOR TOOTH THICKNESS

		------- Gear 1 ------	Gear 2 --
Tooth thickness deviation		DIN 3967 cd25	DIN 3967 cd25
Tooth thickness allowance (normal section) (mm)	[As.e/i]	-0.054 / -0.084	-0.095 / -0.145
Number of teeth spanned	[k]	4.000	12.000
Base tangent length (no backlash) (mm)	[Wk]	13.638	44.134
Actual base tangent length ('span') (mm)	[Wk.e/i]	13.588 / 13.560	44.045 / 43.998
(mm)	[ΔWk.e/i]	-0.051 / -0.079	-0.089 / -0.136
Diameter of measuring circle (mm)	[dMWk.m]	32.768	127.313
Theoretical diameter of ball/pin (mm)	[DM]	2.268	2.088
Effective diameter of ball/pin (mm)	[DMeff]	2.500	2.500
Radial single-ball measurement backlash free (mm)	[MrK]	18.329	65.833
Radial single-ball measurement (mm)	[MrK.e/i]	18.275 / 18.245	65.711 / 65.646
Diameter of measuring circle (mm)	[dMMr.m]	32.926	127.972
Diametral measurement over two balls without clearance (mm)	[MdK]	36.590	131.666
Diametral two ball measure (mm)	[MdK.e/i]	36.482 / 36.422	131.422 / 131.292
Diametral measurement over pins without clearance (mm)	[MdR]	36.658	131.666
Measurement over pins according to DIN 3960 (mm)	[MdR.e/i]	36.550 / 36.489	131.422 / 131.292
Measurement over 2 pins (free) according to AGMA 2002 (mm)	[dk2f.e/i]	36.479 / 36.418	0.000 / 0.000
Measurement over 2 pins (axial) according to AGMA 2002 (mm)	[dk2t.e/i]	36.615 / 36.554	0.000 / 0.000
Measurement over 3 pins (axial) according to AGMA 2002 (mm)	[dk3A.e/i]	36.550 / 36.489	131.422 / 131.292
Chordal tooth thickness (no backlash) (mm)	[sc]	2.235	1.785
Actual chordal tooth thickness (mm)	[sc.e/i]	2.181 / 2.151	1.690 / 1.640
Reference chordal height from da.m (mm)	[ha]	1.656	1.000
Tooth thickness (Arc) (mm)	[sn]	2.237	1.785
(mm)	[sn.e/i]	2.183 / 2.153	1.690 / 1.640
Backlash free center distance (mm)	[aControl.e/i]	79.796 / 79.685	
Backlash free center distance, allowances (mm)	[jta]	-0.204 / -0.315	
dNf.i with aControl (mm)	[dNf0.i]	30.294	125.101
Reserve (dNf0.i-dFf.e)/2 (mm)	[cF0.i]	-0.093	0.127
Tip clearance (mm)	[c0.i(aControl)]	0.128	0.072
Center distance allowances (mm)	[Aa.e/i]	0.015 / -0.015	
Circumferential backlash from Aa (mm)	[jtw_Aa.e/i]	0.011 / -0.011	

Radial backlash (mm)	[jrw.e/i]	0.330 /	0.189
Circumferential backlash (transverse section) (mm)	[jtw.e/i]	0.246 /	0.141
Normal backlash (mm)	[jnw.e/i]	0.226 /	0.130
Angle of rotation on input with fixed output.:			
Entire torsional angle (°)	[j.tSys]		0.8802/ 0.5059

7. GEAR ACCURACY

		------- GEAR 1	-------- GEAR 2 --
According to DIN 3961:1978			
Accuracy grade	[Q-DIN3961]	6	6
Profile form deviation (µm)	[ff]	6.00	6.00
Profile slope deviation (µm)	[fHa]	5.00	5.00
Total profile deviation (µm)	[Ff]	8.00	8.00
Helix form deviation (µm)	[fbf]	5.50	5.50
Helix slope deviation (µm)	[fHb]	9.00	9.00
Total helix deviation (µm)	[Fb]	10.00	10.00
Normal base pitch deviation (µm)	[fpe]	7.00	8.00
Single pitch deviation (µm)	[fp]	7.00	8.00
Adjacent pitch difference (µm)	[fu]	8.00	10.00
Total cumulative pitch deviation (µm)	[Fp]	19.00	29.00
Sector pitch deviation over z/8 pitches (µm)	[Fpz/8]	12.00	18.00
Runout (µm)	[Fr]	14.00	19.00
Tooth Thickness Variation (µm)	[Rs]	8.00	11.00
Single flank composite, total (µm)	[Fi']	22.00	30.00
Single flank composite, tooth-to-tooth (µm)	[fi']	10.00	11.00
Radial composite, total (µm)	[Fi"]	17.00	24.00
Radial composite, tooth-to-tooth (µm)	[fi"]	6.00	10.00
According to DIN 58405:1972 (Feinwerktechnik):			
Tooth-to-tooth composite error (µm)	[fi"]	7.00	9.00
Composite error (µm)	[Fi"]	20.00	25.00
Axis alignment error (µm)	[fp]	13.60	13.60
Flank direction error (µm)	[fbeta]	6.30	6.30
Runout (µm)	[Trk, Fr]	21.00	28.00

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

Maximum value for deviation error of axis (µm)	[fSigbet]	13.00 (Fb=13.00)
Maximum value for inclination error of axes (µm)	[fSigdel]	26.00

8. ADDITIONAL DATA

Maximal possible center distance (eps_a=1.0)	[aMAX]	80.833	
Mass (kg)	[m]	0.193	0.521
Total mass (kg)	[m]	0.714	
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]	2.537e-005	0.001049
System ((da+df)/2...di) (kg*m²)	[TraeghMom]	9.095e-005	
Coefficient of friction	[mum]	0.200	
Loss factor	[HV]	0.117	
Coefficient for frequency of running	[KstEDf]	1.000	
Casing surface (m²)	[Oberflache]	0.16961	
Gear power loss (W)	[PVZ]	6.138	

(Meshing efficiency (%)	[etaz]		97.656)	
Tooth root temperature (°C)	[TR]		70.0	70.0
Flank temperature (°C)	[TF]		70.0	70.0
Heat transfer coefficient, root	[KF]		0.0	0.0
Heat transfer coefficient, flank	[KH]		0.0	0.0
Indications for the manufacturing by wire cutting:				
Deviation from theoretical tooth trace (µm)		[WireErr]	317.1	79.5
Permissible deviation (µm)	[Fb/2]		5.0	5.0

9. MODIFICATIONS AND TOOTH FORM DEFINITION

Data for the tooth form calculation :

Calculation of Gear 1
Tooth form, Gear 1, Step 1: Automatic (final machining)
haP*= 1.070, hfP*= 1.250, rofP*= 0.380

Calculation of Gear 2
Tooth form, Gear 2, Step 1: Automatic (final machining)
haP*= 1.123, hfP*= 1.250, rofP*= 0.380

10. SERVICE LIFE, DAMAGE

Required safety for tooth root	[SFmin]	1.25	
Required safety for tooth flank	[SHmin]	0.93	
Required safety for wear	[SWmin]	1.10	
Service life (calculated with required safeties):			
System service life (h)	[Hatt]	71.886	
Tooth root service life (h)	[HFatt]	1e+006	131.7
Tooth flank service life (h)	[HHatt]	1e+006	71.89
Wear service life (h)	[HWatt]	1e+006	4275

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] (48.0 h)

F1%	F2%	H1%	H2%	W1%	W2%
0.00	36.4471	0.0000	66.7724	0.0000	1.1228

Damage calculated on basis of system service life [Hatt] (71.9 h)

F1%	F2%	H1%	H2%	W1%	W2%
0.00	54.5842	0.0000	100.0000	0.0000	1.6816

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

Gear		fac	b	t0	T	R(H)%
1	Tooth root	60000	1.7	9.654e+029	1.484e+030	100.00
1	Tooth flank	60000	1.3	9.014e+029	4.295e+030	100.00
2	Tooth root	15000	1.7	1.907e+006	2.931e+006	100.00
2	Tooth flank	15000	1.3	9.72e+005	4.631e+006	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.
- Calculation of steel/plastic pair:
  the steel gear's strength is calculated approximately, according to DIN 3990, to obtain an indication of the service life..

End of Report lines: 511

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File

Name : PETG_static_fin
Changed by: jsebe on: 22.05.2023 at: 08:43:33

Important hint: At least one warning has occurred during the calculation:

1-> Note:
For calculations in accordance with VDI, the face load factor KHb with 1.0 is assumed,
as plastics run in.
However a width/module ratio that is too large (b/mn > 10) should be avoided.
Or the face load factor needs to be checked.

CALCULATION OF A CYLINDRICAL SPUR GEAR PAIR

Drawing or article number:
Gear 1: 0.000.0
Gear 2: 0.000.0

Calculation method Plastic according to VDI 2736:2013 (YF Method C)

		------- GEAR 1	-------- GEAR 2 --
Power (kW)	[P]	1.330	
Speed (1/min)	[n]	1000.0	250.0
Torque (Nm)	[T]	12.7	50.8
Application factor	[KA]	1.00	
Required service life (h)	[H]	0.01	
Gear driving (+) / driven (-)		+	-

Working flank gear 1: Right flank
Sense of rotation gear 1 clockwise
Gearbox type: Gear with partly closed housing

1. TOOTH GEOMETRY AND MATERIAL

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

		------- GEAR 1	-------- GEAR 2 --
Center distance (mm)	[a]	80.000	
Center distance tolerance	ISO 286:2010 Measure js7		
Normal module (mm)	[mn]	1.2500	
Pressure angle at normal section (°)	[alfn]	20.0000	
Helix angle at reference circle (°)	[beta]	0.0000	
Number of teeth	[z]	25	100
Facewidth (mm)	[b]	30.00	30.00
Hand of gear		Spur gear	
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: PA66, Thermoplastic PA, untreated
3D printed material
Woehler line tooth root stress from file Z014-PA66_VDI2736_BP.DAT

S-N curve (Woehler line) Hertzian pressure from file Z014-PA66_VDI2736_BP.DAT

Gear 2: PA66, Thermoplastic PA, untreated

3D printed material

Woehler line tooth root stress from file Z014-PA66_VDI2736_BP.DAT

S-N curve (Woehler line) Hertzian pressure from file Z014-PA66_VDI2736_BP.DAT

		------- GEAR 1 --------	GEAR 2 --
Surface hardness		HBW 50	HBW 50
Tooth root temperature (°C)	[TR]	70.0	70.0
Flank temperature (°C)	[TF]	70.0	70.0
Tooth root strength at NL (N/mm²)	[σFadm]	31.30	32.90
Strength against Hertzian pressure at NL (N/mm²)	[σHadm]	31.30	32.90
Tensile strength (N/mm²)	[σB]	19.22	19.22
Yield point (N/mm²)	[σS]	17.33	17.33
Young's modulus (N/mm²)	[E]	560	560
Poisson's ratio	[v]	0.400	0.400
Roughness average value DS, flank (µm)	[RAH]	0.00	0.00
Roughness average value DS, root (µm)	[RAF]	0.00	0.00
Mean roughness height, Rz, flank (µm)	[RZH]	0.00	0.00
Mean roughness height, Rz, root (µm)	[RZF]	0.00	0.00

Gear reference profile 1 :

Reference profile	1.25 / 0.38 / 1.0 ISO 53:1998 Profil A	
Dedendum coefficient	[hfP*]	1.250
Root radius factor	[rhofP*]	0.380 (rhofPmax*=0.472)
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	1.25 / 0.38 / 1.0 ISO 53:1998 Profil A	
Dedendum coefficient	[hfP*]	1.250
Root radius factor	[rhofP*]	0.380 (rhofPmax*=0.472)
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	

Summary of reference profile gears:

Dedendum reference profile	[hfP*]	1.250	1.250
Tooth root radius Refer. profile	[rofP*]	0.380	0.380
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

Type of profile modification: none (only running-in)

Tip relief (µm)	[Ca]	19.6	19.6

Lubrication type		Dry-running	
Ambient temperature (°C)	[TU]	20.000	
		------- GEAR 1 --------	GEAR 2 --
Overall transmission ratio	[itot]	-4.000	
Gear ratio	[u]	4.000	
Transverse module (mm)	[mt]	1.250	
Pressure angle at pitch circle (°)	[alft]	20.000	
Working transverse pressure angle (°)	[alfwt]	23.412	
	[alfwt.e/i]	23.437 / 23.388	
Working pressure angle at normal section (°)	[alfwn]	23.412	
Helix angle at operating pitch circle (°)	[betaw]	0.000	
Base helix angle (°)	[betab]	0.000	
Reference center distance (mm)	[ad]	78.125	
Sum of profile shift coefficients	[Summexi]	1.6258	
Profile shift coefficient	[x]	0.5656	1.0602
Tooth thickness (Arc) (module) (module)	[sn*]	1.9825	2.3426
Tip alteration (mm)	[k*mn]	-0.157	-0.157
Reference diameter (mm)	[d]	31.250	125.000
Base diameter (mm)	[db]	29.365	117.462
Tip diameter (mm)	[da]	34.850	129.837
(mm)	[da.e/i]	34.850 / 34.825	129.837 / 129.797
Tip diameter allowances (mm)	[Ada.e/i]	0.000 / -0.025	0.000 / -0.040
Tip form diameter (mm)	[dFa]	34.850	129.837
(mm)	[dFa.e/i]	34.850 / 34.825	129.837 / 129.797
Active tip diameter (mm)	[dNa]	34.850	129.837
Active tip diameter (mm)	[dNa.e/i]	34.850 / 34.825	129.837 / 129.797
Operating pitch diameter (mm)	[dw]	32.000	128.000
(mm)	[dw.e/i]	32.006 / 31.994	128.024 / 127.976
Root diameter (mm)	[df]	29.539	124.526
Generating Profile shift coefficient	[xE.e/i]	0.5062/ 0.4732	0.9833/ 0.9393
Manufactured root diameter with xE (mm)	[df.e/i]	29.391 / 29.308	124.333 / 124.223
Theoretical tip clearance (mm)	[c]	0.312	0.312
Effective tip clearance (mm)	[c.e/i]	0.491 / 0.393	0.463 / 0.371
Active root diameter (mm)	[dNf]	30.504	125.718
(mm)	[dNf.e/i]	30.550 / 30.483	125.762 / 125.691
Root form diameter (mm)	[dFf]	30.311	125.151
(mm)	[dFf.e/i]	30.207 / 30.151	124.958 / 124.849
Reserve (dNf-dFf)/2 (mm)	[cF.e/i]	0.199 / 0.138	0.456 / 0.366
Addendum (mm)	[ha=mn*(haP*+x+k)]	1.800	2.418
(mm)	[ha.e/i]	1.800 / 1.787	2.418 / 2.398
Dedendum (mm)	[hf=mn*(hfP*-x)]	0.856	0.237
(mm)	[hf.e/i]	0.930 / 0.971	0.333 / 0.388
Roll angle at dFa (°)	[xsi_dFa.e/i]	36.616 / 36.526	26.984 / 26.938
Roll angle to dNa (°)	[xsi_dNa.e/i]	36.616 / 36.526	26.984 / 26.938
Roll angle to dNf (°)	[xsi_dNf.e/i]	16.438 / 15.960	21.916 / 21.820
Roll angle at dFf (°)	[xsi_dFf.e/i]	13.812 / 13.342	20.795 / 20.638
Tooth height (mm)	[h]	2.656	2.656
Virtual gear no. of teeth	[zn]	25.000	100.000
Normal tooth thickness at tip circle (mm)	[san]	0.829	0.976
(mm)	[san.e/i]	0.784 / 0.735	0.922 / 0.862
Normal tooth thickness on tip form circle (mm)	[sFan]	0.829	0.976
(mm)	[sFan.e/i]	0.784 / 0.735	0.922 / 0.862
Normal space width at root circle (mm)	[efn]	0.942	0.825
(mm)	[efn.e/i]	0.976 / 0.000	0.827 / 0.828
Max. sliding velocity at tip (m/s)	[vga]	0.396	0.292

Specific sliding at the tip	[zetaa]		0.403			0.403		
Specific sliding at the root	[zetaf]		-0.675			-0.675		
Mean specific sliding	[zetam]			0.403				
Sliding factor on tip	[Kga]		0.236			0.174		
Sliding factor on root	[Kgf]		-0.174			-0.236		
Pitch on reference circle (mm)	[pt]			3.927				
Base pitch (mm)	[pbt]			3.690				
Transverse pitch on contact-path (mm)	[pet]			3.690				
Length of path of contact (mm)	[ga, e/i]		5.256 (	5.293 /	5.148)			
Length T1-A, T2-A (mm)	[T1A, T2A]	4.128(	4.090/	4.212)	27.660(	27.660/	27.613)	
Length T1-B (mm)	[T1B, T2B]	5.693(	5.693/	5.670)	26.095(	26.057/	26.156)	
Length T1-C (mm)	[T1C, T2C]	6.358(	6.350/	6.365)	25.430(	25.400/	25.460)	
Length T1-D (mm)	[T1D, T2D]	7.818(	7.780/	7.903)	23.970(	23.970/	23.923)	
Length T1-E (mm)	[T1E, T2E]	9.383(	9.383/	9.360)	22.404(	22.367/	22.465)	
Length T1-T2 (mm)	[T1T2]		31.788 (	31.750 /	31.825)			
Diameter of single contact point B (mm)	[d-B]	31.496(	31.496/	31.479)	128.534(	128.503/	128.583)	
Diameter of single contact point D (mm)	[d-D]	33.269(	33.233/	33.349)	126.868(	126.868/	126.832)	
Addendum contact ratio	[eps]	0.820(	0.822/	0.812)	0.604(	0.612/	0.583)	
Minimal length of contact line (mm)	[Lmin]			30.000				
Transverse contact ratio	[eps_a]			1.424				
Transverse contact ratio with allowances	[eps_a.e/m/i]		1.434 /	1.415 /	1.395			
Overlap ratio	[eps_b]			0.000				
Total contact ratio	[eps_g]			1.424				
Total contact ratio with allowances	[eps_g.e/m/i]		1.434 /	1.415 /	1.395			

2. FACTORS OF GENERAL INFLUENCE

		------- GEAR 1	-------- GEAR 2 --
Nominal circum. force at pitch circle (N)	[Ft]	812.8	
Axial force (N)	[Fa]	0.0	
Radial force (N)	[Fr]	295.8	
Normal force (N)	[Fnorm]	865.0	
Nominal circumferential force per mm (N/mm)	[w]	27.09	
Only as information: Forces at operating pitch circle:			
Nominal circumferential force (N)	[Ftw]	793.8	
Axial force (N)	[Faw]	0.0	
Radial force (N)	[Frw]	343.7	
Circumferential speed reference circle (m/s)	[v]	1.64	
Circumferential speed operating pitch circle (m/s)	[v(dw)]	1.68	
Correction factor	[CM]	0.800	
Gear blank factor	[CR]	1.000	
Basic rack factor	[CBS]	0.975	
Material coefficient	[E/Est]	0.003	
Singular tooth stiffness (N/mm/µm)	[c']	0.043	
Meshing stiffness (N/mm/µm)	[cg]	0.057	
Dynamic factor	[KV]	1.000	
Face load factor - flank	[KHb]	1.000	
- Tooth root	[KFb]	1.000	
- Scuffing	[KBb]	1.000	
Transverse load factor - flank	[KHa]	1.000	
- Tooth root	[KFa]	1.000	

- Scuffing	[KBa]	1.000	
Number of load cycles (in mio.)	[NL]	0.001	0.000

3. TOOTH ROOT STRENGTH

Calculation of Tooth form coefficients according method: C

		------- GEAR 1	-------- GEAR 2 --
Calculated with manufacturing profile shift	[xE.m]	0.4897	0.9613
Tooth form factor	[YF]	2.08	1.97
Stress correction factor	[YS]	1.84	1.97
Load application angle (°)	[alfFen]	31.35	24.83
Bending moment arm (mm)	[hF]	2.38	2.36
Tooth thickness at root (mm)	[sFn]	2.79	2.95
Tooth root radius (mm)	[roF]	0.53	0.48

(hF* = 1.901/ 1.891 sFn* = 2.230/ 2.359 roF* = 0.423/ 0.381)
(den (mm) =
34.850/ 129.837 dsFn(mm) = 29.762/ 124.732 alfsFn(°) = 30.00/ 30.00 qs = 2.636/ 3.095)

Contact ratio factor	[Yeps]		0.777	
Helix angle factor	[Ybet]		1.000	
Effective facewidth (mm)	[beff]	30.00		30.00
Nominal stress at tooth root (N/mm²)	[sigF0]	64.42		65.36
Tooth root stress (N/mm²)	[sigF]	64.42		65.36
Permissible bending stress at root from data tables				
Notch sensitivity factor	[YdrelT]	1.000		1.000
Surface factor	[YRrelT]	1.000		1.000
size factor (Tooth root)	[YX]	1.000		1.000
Notice: When using Wohler lines from data files, the factors YdrelT, YRrelT, YX will be interpolated according to the breakpoints NLstatic and NLendurance following ISO.				
Finite life factor	[YNT]	1.000		1.000
	[YdrelT*YRrelT*YX*YNT]	1.000		1.000
Alternating bending factor (mean stress influence coefficient)	[YM]	1.000		1.000
Stress correction factor	[Yst]		2.00	
Yst*sigFlim (N/mm²)	[sigFE]	62.60		65.80
Permissible tooth root stress (N/mm²)	[sigFP=sigFG/SFmin]	50.08		52.64
Limit strength tooth root (N/mm²)	[sigFG]	62.60		65.80
Required safety	[SFmin]	1.25		1.25
Safety for tooth root stress	[SF=sigFG/sigF]	0.97		1.01
Transmittable power (kW)	[kWRating]	1.03		1.07

4. SAFETY AGAINST PITTING (TOOTH FLANK)

		------- GEAR 1	-------- GEAR 2 --
Zone factor	[ZH]		2.287
Elasticity factor (√N/mm²)	[ZE]		10.301
Young's modulus for tooth flank (N/mm²)	[E]	560	560
Contact ratio factor	[Zeps]		0.927
Helix angle factor	[Zbet]		1.000
Effective facewidth (mm)	[beff]		30.00
Nominal contact stress (N/mm²)	[sigH0]		22.73
Contact stress at operating pitch circle (N/mm²)	[sigHw]		22.73

Lubrication coefficient at NL	[ZL]	1.000	1.000
Speed coefficient at NL	[ZV]	1.000	1.000
Roughness coefficient at NL	[ZR]	1.000	1.000
Material pairing coefficient at NL	[ZW]	1.000	1.000
Notice: When using Wohler lines from data files, the factors ZL, ZV, ZR, ZW will be interpolated according to the breakpoints NLstatic and NLendurance following ISO.			
Finite life factor	[ZNT]	1.000	1.000
	[ZL*ZV*ZR*ZNT]	1.000	1.000
Limited pitting is permitted:	No		
Size factor (flank)	[ZX]	1.000	1.000
Permissible contact stress (N/mm²)	[sigHP=sigHG/SHmin]	33.84	35.57
Pitting stress limit (N/mm²)	[sigHG]	31.30	32.90
Required safety	[SHmin]	0.93	0.93
Safety factor for contact stress at operating pitch circle			
	[SHw]	1.38	1.45
Transmittable power (kW)	[kWRating]	1.98	2.08

4a. WEAR

Line load at reference diameter (N/mm)	[w]	27.09	
Line load at reference diameter (N/mm)	[K_A*K_γ*K_V*$K_{H\beta}$*$K_{H\alpha}$*w]	27.09	
Loss factor	[H_V]	0.096	
Length of active flank (mm)	[l_{Fl}]	2.39	2.22
Wear factor (mm^3/Nm/10^6)	[k_W]	9.80000	9.80000
Data from file k_{W1}: Z014-PA66_VDI2736_BP.DAT			
Data from file k_{W2}: Z014-PA66_VDI2736_BP.DAT			
Normal tooth thickness in pitch circle (mm)	[s_n]	2.48	2.93
Maximum permissible wear (%)	[W_{limit}]	15.00	
Permissible wear on flank (mm)	[δ_{Wlimn}]	0.37	0.44
Wear removal (mm)	[δ_{Wn}]	0.00003	0.00001
Wear removal (mg)	[=lFL*b*z*ro*δWn]	0.1	0.1
Required safety	[S_{Wmin}]	1.10	
Safety against wear	[S_W]	999.99	999.99

Calculation for safety against shearing for plastics			
Normal tooth thickness in the active root diameter (mm)	[s_{dNf}-δWn]	2.60	2.59
Shearing stress (N/mm²)	[τ_{nom}]	10.44	10.46
Notch effect coefficient	[K_T]	1.25	1.25
Permitted shearing strength (N/mm²)	[τ_B]	17.43	18.33
Required safety	[S_{Tmin}]	2.50	
Safety shearing	[S_T]	1.34	1.40

$\tau_B = 0.557 * \sigma_{Fadm}$; $S_T = \tau_B / (\tau_{nom} * K_T)$

Calculation of local wear with speeds and load distribution according to method A:
Calculation was not carried out. (Contact analysis under load is required.)

Important note:
the kw wear coefficients are usually determined using a plastic/steel pairing..
The coefficients may be very different if pairings of other materials are used..
This calculation is designed to give an indication of possible service life,
however it has not yet been checked exhaustively in real life..

5. BENDING

For plastics:			
Tooth deformation (µm)	[fa]	725.714	
Permissible tooth deformation (µm)	[fazul]	87.500	
Required safety	[Sdel]	1.000	
Safety against deformation	[Sdelmin]	0.121	
Experimental method using tooth stiffness according	ISO6336:2006:		
Tooth deformation (µm)	[faExp]	546.134	391.791
Permissible tooth deformation (µm)	[fazulExp]	549.223	549.223
Required safety	[Sdel]	1.000	
Safety against jamming	[SdelExp]	1.006	1.402

6. MEASUREMENTS FOR TOOTH THICKNESS

		------- Gear 1	------ Gear 2 --
Tooth thickness deviation		DIN 3967 cd25	DIN 3967 cd25
Tooth thickness allowance (normal section) (mm)	[As.e/i]	-0.054 / -0.084	-0.070 / -0.110
Number of teeth spanned	[k]	4.000	13.000
Base tangent length (no backlash) (mm)	[Wk]	13.837	48.784
Actual base tangent length ('span') (mm)	[Wk.e/i]	13.786 / 13.758	48.719 / 48.681
(mm)	[ΔWk.e/i]	-0.051 / -0.079	-0.066 / -0.103
Diameter of measuring circle (mm)	[dMWk.m]	32.434	127.157
Theoretical diameter of ball/pin (mm)	[DM]	2.454	2.275
Effective diameter of ball/pin (mm)	[DMeff]	2.500	2.500
Radial single-ball measurement backlash free (mm)	[MrK]	18.202	65.803
Radial single-ball measurement (mm)	[MrK.e/i]	18.151 / 18.122	65.724 / 65.678
Diameter of measuring circle (mm)	[dMMr.m]	32.611	127.892
Diametral measurement over two balls without clearance (mm)	[MdK]	36.337	131.606
Diametral two ball measure (mm)	[MdK.e/i]	36.235 / 36.178	131.447 / 131.356
Diametral measurement over pins without clearance (mm)	[MdR]	36.337	131.606
Measurement over pins according to DIN 3960 (mm)	[MdR.e/i]	36.235 / 36.178	131.447 / 131.356
Measurement over 3 pins (axial) according to AGMA 2002 (mm)			
	[dk3A.e/i]	36.235 / 36.178	131.447 / 131.356
Dimensions over 3 pins without clearance (mm)	[Md3R]	36.270	0.000
Effective dimensions over 3 pins (mm)	[Md3R.e/i]	36.168 / 36.112	0.000 / 0.000
Chordal tooth thickness (no backlash) (mm)	[sc]	2.476	2.928
Actual chordal tooth thickness (mm)	[sc.e/i]	2.422 / 2.392	2.858 / 2.818
Reference chordal height from da.m (mm)	[ha]	1.843	2.425
Tooth thickness (Arc) (mm)	[sn]	2.478	2.928
(mm)	[sn.e/i]	2.424 / 2.394	2.858 / 2.818
Backlash free center distance (mm)	[aControl.e/i]	79.853 / 79.769	
Backlash free center distance, allowances (mm)	[jta]	-0.147 / -0.231	
dNf.i with aControl (mm)	[dNf0.i]	30.207	125.305
Reserve (dNf0.i-dFf.e)/2 (mm)	[cF0.i]	0.000	0.173
Tip clearance (mm)	[c0.i(aControl)]	0.177	0.155
Center distance allowances (mm)	[Aa.e/i]	0.015 / -0.015	
Circumferential backlash from Aa (mm)	[jtw_Aa.e/i]	0.013 / -0.013	
Radial backlash (mm)	[jrw.e/i]	0.246 / 0.132	
Circumferential backlash (transverse section) (mm)	[jtw.e/i]	0.212 / 0.114	
Normal backlash (mm)	[jnw.e/i]	0.199 / 0.107	

Angle of rotation on input with fixed output.:

Entire torsional angle (°)	[j.tSys]	0.7579/ 0.4082

7. GEAR ACCURACY

		GEAR 1	GEAR 2
According to DIN 3961:1978			
Accuracy grade	[Q-DIN3961]	6	6
Profile form deviation (µm)	[ff]	6.00	6.00
Profile slope deviation (µm)	[fHa]	5.00	5.00
Total profile deviation (µm)	[Ff]	8.00	8.00
Helix form deviation (µm)	[fbf]	5.50	5.50
Helix slope deviation (µm)	[fHb]	9.00	9.00
Total helix deviation (µm)	[Fb]	10.00	10.00
Normal base pitch deviation (µm)	[fpe]	7.00	7.00
Single pitch deviation (µm)	[fp]	7.00	7.00
Adjacent pitch difference (µm)	[fu]	8.00	9.00
Total cumulative pitch deviation (µm)	[Fp]	19.00	25.00
Sector pitch deviation over z/8 pitches (µm)	[Fpz/8]	12.00	15.00
Runout (µm)	[Fr]	14.00	16.00
Tooth Thickness Variation (µm)	[Rs]	8.00	10.00
Single flank composite, total (µm)	[Fi']	22.00	26.00
Single flank composite, tooth-to-tooth (µm)	[fi']	10.00	11.00
Radial composite, total (µm)	[Fi"]	17.00	20.00
Radial composite, tooth-to-tooth (µm)	[fi"]	6.00	8.00
According to DIN 58405:1972 (Feinwerktechnik):			
Tooth-to-tooth composite error (µm)	[fi"]	7.00	9.00
Composite error (µm)	[Fi"]	20.00	25.00
Axis alignment error (µm)	[fp]	13.60	13.60
Flank direction error (µm)	[fbeta]	6.30	6.30
Runout (µm)	[Trk, Fr]	21.00	28.00

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

Maximum value for deviation error of axis (µm)	[fSigbet]	12.00 (Fb=12.00)
Maximum value for inclination error of axes (µm)	[fSigdel]	24.00

8. ADDITIONAL DATA

Maximal possible center distance (eps_a=1.0)	[aMAX]	80.635	
Mass (g)	[m]	27.60	430.66
Total mass (g)	[m]	458.26	
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]	3.575e-006	0.0008707
System ((da+df)/2...di) (kg*m²)	[TraeghMom]	5.8e-005	
Coefficient of friction	[mum]	0.400	
Loss factor	[HV]	0.096	
Coefficient for frequency of running	[KstEDf]	1.000	
Casing surface (m²)	[Oberflache]	0.16539	
Gear power loss (kW)	[PVZ]	0.051	
(Meshing efficiency (%)	[etaz]	96.147)	
Tooth root temperature (°C)	[TR]	70.0	70.0
Flank temperature (°C)	[TF]	70.0	70.0

Heat transfer coefficient, root	[KF]	0.0	0.0
Heat transfer coefficient, flank	[KH]	0.0	0.0

9. MODIFICATIONS AND TOOTH FORM DEFINITION

Data for the tooth form calculation :

Calculation of Gear 1
Tooth form, Gear 1, Step 1: Automatic (final machining)
haP*= 0.945, hfP*= 1.250, rofP*= 0.380

Calculation of Gear 2
Tooth form, Gear 2, Step 1: Automatic (final machining)
haP*= 0.965, hfP*= 1.250, rofP*= 0.380

10. SERVICE LIFE, DAMAGE

Required safety for tooth root	[SFmin]	1.25
Required safety for tooth flank	[SHmin]	0.93
Required safety for wear	[SWmin]	1.10

Service life (calculated with required safeties):

System service life (h)	[Hatt]	0.000

Tooth root service life (h)	[HFatt]	0	0
Tooth flank service life (h)	[HHatt]	4.058	16.23
Wear service life (h)	[HWatt]	134.2	587.5

Damage calculated on the basis of the required service life [H] (0.0 h)

F1%	F2%	H1%	H2%	W1%	W2%
9999.99	9999.9900	0.2464	0.0616	0.0074	0.0017

Damage calculated on basis of system service life [Hatt] (0.0 h)

F1%	F2%	H1%	H2%	W1%	W2%
100.00	100.0000	0.0000	0.0000	0.0000	0.0000

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

Gear		fac	b	t0	T	R(H)%
1	Tooth root	60000	1.7	0	0	0.00
1	Tooth flank	60000	1.3	2.195e+005	1.046e+006	100.00
2	Tooth root	15000	1.7	0	0	0.00
2	Tooth flank	15000	1.3	2.195e+005	1.046e+006	100.00

Reliability of the configuration for required service life (%) 0.00 (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.

End of Report lines: 502

KISSsoft Release 03/2018 C

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File

Name : Nylon_dynamic_3d
Changed by: jsebe on: 26.05.2023 at: 12:41:24

Important hint: At least one warning has occurred during the calculation:

1-> Note:
For calculations in accordance with VDI, the face load factor KHb with 1.0 is assumed,
as plastics run in.
However a width/module ratio that is too large (b/mn > 10) should be avoided.
Or the face load factor needs to be checked.

CALCULATION OF A HELICAL GEAR PAIR

Drawing or article number:
Gear 1: 0.000.0
Gear 2: 0.000.0

Calculation method Plastic according to VDI 2736:2013 (YF Method C)
Steel wheels: calculated roughly according to DIN 3990!

		------- GEAR 1	-------- GEAR 2 --
Power (W)	[P]	418.879	
Speed (1/min)	[n]	1000.0	250.0
Torque (Nm)	[T]	4.000	16.000
Application factor	[KA]	1.00	
Required service life (h)	[H]	48.00	
Gear driving (+) / driven (-)		+	-

Working flank gear 1: Right flank
Sense of rotation gear 1 clockwise
Gearbox type: Gear with partly closed housing

1. TOOTH GEOMETRY AND MATERIAL

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

		------- GEAR 1	-------- GEAR 2 --
Center distance (mm)	[a]	80.000	
Center distance tolerance	ISO 286:2010 Measure js7		
Normal module (mm)	[mn]	1.2500	
Pressure angle at normal section (°)	[alfn]	20.0000	
Helix angle at reference circle (°)	[beta]	12.0000	
Number of teeth	[z]	25	100
Facewidth (mm)	[b]	30.00	30.00
Hand of gear		left	right
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 >=25HRC Jominy J=12mm<HRC28

Gear 2: PA66, Thermoplastic PA, untreated

3D printed material

Woehler line tooth root stress from file Z014-PA66_VDI2736_BP.DAT

S-N curve (Woehler line) Hertzian pressure from file Z014-PA66_VDI2736_BP.DAT

			------- GEAR 1 --------	GEAR 2 --
Surface hardness			HRC 61	HBW 50
Tooth root temperature (°C)	[TR]		70.0	70.0
Flank temperature (°C)	[TF]		70.0	70.0
Tooth root strength at NL (N/mm²)	[σFadm]		432.01	16.20
Strength against Hertzian pressure at NL (N/mm²)	[σHadm]		1861.40	16.20
Tensile strength (N/mm²)	[σB]		1200.00	19.22
Yield point (N/mm²)	[σS]		850.00	17.33
Young's modulus (N/mm²)	[E]		206000	560
Poisson's ratio	[v]		0.300	0.400
Roughness average value DS, flank (µm)	[RAH]		0.60	0.00
Roughness average value DS, root (µm)	[RAF]		3.00	0.00
Mean roughness height, Rz, flank (µm)	[RZH]		4.80	0.00
Mean roughness height, Rz, root (µm)	[RZF]		20.00	0.00

Gear reference profile	1 :		
Reference profile	1.25 / 0.38 / 1.0 ISO 53:1998 Profil A		
Dedendum coefficient		[hfP*]	1.250
Root radius factor		[rhofP*]	0.380 (rhofPmax*=0.472)
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	1.25 / 0.38 / 1.0 ISO 53:1998 Profil A		
Dedendum coefficient		[hfP*]	1.250
Root radius factor		[rhofP*]	0.380 (rhofPmax*=0.472)
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

Summary of reference profile gears:

Dedendum reference profile	[hfP*]	1.250	1.250
Tooth root radius Refer. profile	[rofP*]	0.380	0.380
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

Type of profile modification:	none (only running-in)		
Tip relief (µm)	[Ca]	2.0	19.6

Lubrication type Dry-running

Ambient temperature (°C)	[TU]	20.000	
		------- GEAR 1 --------	GEAR 2 --
Overall transmission ratio	[itot]	-4.000	
Gear ratio	[u]	4.000	
Transverse module (mm)	[mt]	1.278	
Pressure angle at pitch circle (°)	[alft]	20.410	
Working transverse pressure angle (°)	[alfwt]	20.658	
	[alfwt.e/i]	20.687 / 20.630	
Working pressure angle at normal section (°)	[alfwn]	20.243	
Helix angle at operating pitch circle (°)	[betaw]	12.019	
Base helix angle (°)	[betab]	11.267	
Reference center distance (mm)	[ad]	79.870	
Sum of profile shift coefficients	[Summexi]	0.1043	
Profile shift coefficient	[x]	0.3003	-0.1960
Tooth thickness (Arc) (module) (module)	[sn*]	1.7894	1.4281
Tip alteration (mm)	[k*mn]	-0.001	-0.001
Reference diameter (mm)	[d]	31.948	127.793
Base diameter (mm)	[db]	29.942	119.770
Tip diameter (mm)	[da]	35.197	129.801
(mm)	[da.e/i]	35.197 / 35.172	129.801 / 129.761
Tip diameter allowances (mm)	[Ada.e/i]	0.000 / -0.025	0.000 / -0.040
Tip form diameter (mm)	[dFa]	35.197	129.801
(mm)	[dFa.e/i]	35.197 / 35.172	129.801 / 129.761
Active tip diameter (mm)	[dNa]	35.197	129.801
Active tip diameter (mm)	[dNa.e/i]	35.197 / 35.172	129.801 / 129.761
Operating pitch diameter (mm)	[dw]	32.000	128.000
(mm)	[dw.e/i]	32.006 / 31.994	128.024 / 127.976
Root diameter (mm)	[df]	29.574	124.178
Generating Profile shift coefficient	[xE.e/i]	0.2409/ 0.2080	-0.3004/ -0.3553
Manufactured root diameter with xE (mm)	[df.e/i]	29.425 / 29.343	123.917 / 123.779
Theoretical tip clearance (mm)	[c]	0.313	0.313
Effective tip clearance (mm)	[c.e/i]	0.539 / 0.428	0.463 / 0.372
Active root diameter (mm)	[dNf]	30.621	125.637
(mm)	[dNf.e/i]	30.662 / 30.604	125.677 / 125.612
Root form diameter (mm)	[dFf]	30.563	125.061
(mm)	[dFf.e/i]	30.480 / 30.437	124.848 / 124.737
Reserve (dNf-dFf)/2 (mm)	[cF.e/i]	0.112 / 0.062	0.470 / 0.382
Addendum (mm)	[ha=mn*(haP*+x+k)]	1.624	1.004
(mm)	[ha.e/i]	1.624 / 1.612	1.004 / 0.984
Dedendum (mm)	[hf=mn*(hfP*-x)]	1.187	1.807
(mm)	[hf.e/i]	1.261 / 1.303	1.938 / 2.007
Roll angle at dFa (°)	[xsi_dFa.e/i]	35.401 / 35.310	23.936 / 23.886
Roll angle to dNa (°)	[xsi_dNa.e/i]	35.401 / 35.310	23.936 / 23.886
Roll angle to dNf (°)	[xsi_dNf.e/i]	12.633 / 12.109	18.217 / 18.112
Roll angle at dFf (°)	[xsi_dFf.e/i]	10.908 / 10.456	16.861 / 16.672
Tooth height (mm)	[h]	2.811	2.812
Virtual gear no. of teeth	[zn]	26.573	106.291
Normal tooth thickness at tip circle (mm)	[san]	0.789	1.030
(mm)	[san.e/i]	0.745 / 0.697	0.950 / 0.883
Normal tooth thickness on tip form circle (mm)	[sFan]	0.789	1.030
(mm)	[sFan.e/i]	0.745 / 0.697	0.950 / 0.883
Normal space width at root circle (mm)	[efn]	0.000	0.950
(mm)	[efn.e/i]	0.000 / 0.000	0.971 / 0.983
Max. sliding velocity at tip (m/s)	[vga]	0.472	0.319
Specific sliding at the tip	[zetaa]	0.487	0.487

Specific sliding at the root	[zetaf]		-0.951			-0.950		
Mean specific sliding	[zetam]			0.487				
Sliding factor on tip	[Kga]		0.282			0.190		
Sliding factor on root	[Kgf]		-0.190			-0.282		
Pitch on reference circle (mm)	[pt]			4.015				
Base pitch (mm)	[pbt]			3.763				
Transverse pitch on contact-path (mm)	[pet]			3.763				
Lead height (mm)	[pz]		472.195			1888.778		
Axial pitch (mm)	[px]			18.888				
Length of path of contact (mm)	[ga, e/i]		6.044 (	6.086 /	5.926)			
Length T1-A, T2-A (mm)	[T1A, T2A]	3.206(	3.164/	3.301)	25.017(	25.017/	24.965)	
Length T1-B (mm)	[T1B, T2B]	5.488(	5.488/	5.464)	22.736(	22.693/	22.802)	
Length T1-C (mm)	[T1C, T2C]	5.645(	5.636/	5.653)	22.579(	22.545/	22.613)	
Length T1-D (mm)	[T1D, T2D]	6.969(	6.927/	7.064)	21.255(	21.255/	21.203)	
Length T1-E (mm)	[T1E, T2E]	9.250(	9.250/	9.226)	18.973(	18.931/	19.040)	
Length T1-T2 (mm)	[T1T2]		28.224 (	28.181 /	28.266)			
Diameter of single contact point B (mm)	[d-B]	31.890(	31.890/	31.874)	128.111(	128.081/	128.158)	
Diameter of single contact point D (mm)	[d-D]	33.028(	32.992/	33.108)	127.090(	127.090/	127.055)	
Addendum contact ratio	[eps]	0.958(	0.961/	0.950)	0.648(	0.657/	0.625)	
Minimal length of contact line (mm)	[Lmin]			46.013				
Transverse contact ratio	[eps_a]			1.606				
Transverse contact ratio with allowances	[eps_a.e/m/i]		1.618 /	1.596 /	1.575			
Overlap ratio	[eps_b]			1.588				
Total contact ratio	[eps_g]			3.195				
Total contact ratio with allowances	[eps_g.e/m/i]		3.206 /	3.185 /	3.163			

2. FACTORS OF GENERAL INFLUENCE

		------- GEAR 1	-------- GEAR 2 --
Nominal circum. force at pitch circle (N)	[Ft]	250.4	
Axial force (N)	[Fa]	53.2	
Radial force (N)	[Fr]	93.2	
Normal force (N)	[Fnorm]	272.4	
Nominal circumferential force per mm (N/mm)	[w]	8.35	
Only as information: Forces at operating pitch circle:			
Nominal circumferential force (N)	[Ftw]	250.0	
Axial force (N)	[Faw]	53.2	
Radial force (N)	[Frw]	94.3	
Circumferential speed reference circle (m/s)	[v]	1.67	
Circumferential speed operating pitch circle (m/s)	[v(dw)]	1.68	
Correction factor	[CM]	0.800	
Gear blank factor	[CR]	1.000	
Basic rack factor	[CBS]	0.975	
Material coefficient	[E/Est]	0.005	
Singular tooth stiffness (N/mm/µm)	[c']	0.077	
Meshing stiffness (N/mm/µm)	[cg]	0.112	
Dynamic factor	[KV]	1.000	
Face load factor - flank	[KHb]	1.000	
- Tooth root	[KFb]	1.000	
- Scuffing	[KBb]	1.000	
Transverse load factor - flank	[KHa]	1.000	

- Tooth root	[KFa]	1.000	
- Scuffing	[KBa]	1.000	

Number of load cycles (in mio.)	[NL]	2.880	0.720

3. TOOTH ROOT STRENGTH

Calculation of Tooth form coefficients according method: C

		------- GEAR 1	-------- GEAR 2 --
Calculated with manufacturing profile shift	[xE.m]	0.2245	-0.3278
Tooth form factor	[YF]	2.46	2.47
Stress correction factor	[YS]	1.69	1.67
Load application angle (°)	[alfFen]	30.03	21.84
Bending moment arm (mm)	[hF]	2.53	2.54
Tooth thickness at root (mm)	[sFn]	2.67	2.76
Tooth root radius (mm)	[roF]	0.61	0.66

(hF* = 2.024/ 2.034 sFn* = 2.135/ 2.208 roF* = 0.487/ 0.529)
(den (mm) =
36.465/ 134.872 dsFn(mm) = 29.845/ 124.383 alfsFn(°) = 30.00/ 30.00 qs = 2.193/ 2.088)

Contact ratio factor	[Yeps]	0.717	
Helix angle factor	[Ybet]	0.900	
Effective facewidth (mm)	[beff]	30.00	30.00
Nominal stress at tooth root (N/mm²)	[sigF0]	17.24	17.82
Tooth root stress (N/mm²)	[sigF]	17.24	17.82

Permissible bending stress at root from data tables

Notch sensitivity factor	[YdrelT]	0.998	1.000
Surface factor	[YRrelT]	0.957	1.000
size factor (Tooth root)	[YX]	1.000	1.000

Notice: When using Wohler lines from data files, the factors YdrelT, YRrelT, YX
will be interpolated according to the breakpoints NLstatic and NLendurance following ISO.

Finite life factor	[YNT]	1.005	1.000	
	[YdrelT*YRrelT*YX*YNT]	0.959	1.000	
Alternating bending factor (mean stress influence coefficient)	[YM]	1.000		1.000
Stress correction factor	[Yst]	2.00		
Yst*sigFlim (N/mm²)	[sigFE]	860.00	32.40	
Permissible tooth root stress (N/mm²)	[sigFP=sigFG/SFmin]	659.96	25.92	
Limit strength tooth root (N/mm²)	[sigFG]	824.95	32.40	
Required safety	[SFmin]	1.25	1.25	
Safety for tooth root stress	[SF=sigFG/sigF]	47.85	1.82	
Transmittable power (W)	[WRating]	16034.00	609.18	

4. SAFETY AGAINST PITTING (TOOTH FLANK)

		------- GEAR 1	-------- GEAR 2 --
Zone factor	[ZH]	2.434	
Elasticity factor (√N/mm²)	[ZE]	14.546	
Young's modulus for tooth flank (N/mm²)	[E]	206000	560
Contact ratio factor	[Zeps]	0.789	
Helix angle factor	[Zbet]	1.000	
Effective facewidth (mm)	[beff]	30.00	
Nominal contact stress (N/mm²)	[sigH0]	15.96	

Contact stress at operating pitch circle (N/mm²)	[sigHw]	15.96	
Lubrication coefficient at NL	[ZL]	1.020	1.000
Speed coefficient at NL	[ZV]	0.954	1.000
Roughness coefficient at NL	[ZR]	1.000	1.000
Material pairing coefficient at NL	[ZW]	1.000	1.000
Notice: When using Wohler lines from data files, the factors ZL, ZV, ZR, ZW will be interpolated according to the breakpoints NLstatic and NLendurance following ISO.			
Finite life factor	[ZNT]	1.241	1.000
	[ZL*ZV*ZR*ZNT]	1.208	1.000
Limited pitting is permitted:	No		
Size factor (flank)	[ZX]	1.000	1.000
Permissible contact stress (N/mm²)	[sigHP=sigHG/SHmin]	1959.32	17.51
Pitting stress limit (N/mm²)	[sigHG]	1812.38	16.20
Required safety	[SHmin]	0.93	0.93
Safety factor for contact stress at operating pitch circle			
	[SHw]	114.81	1.01
Transmittable power (W)	[WRating]	6452569.76	459.60

4a. WEAR

Line load at reference diameter (N/mm)	[w]	8.35
Line load at reference diameter (N/mm)	[K_A*K_γ*K_V*$K_{H\beta}$*$K_{H\alpha}$*w]	8.35
Loss factor	[H_V]	0.117
Calculation only for Gear 2		
Length of active flank (mm)	[l_{Fl}]	2.20
Wear factor (mm^3/Nm/10^6)	[k_W]	9.80000
Data from file k_W: Z014-PA66_VDI2736_BP.DAT		
Normal tooth thickness in pitch circle (mm)	[s_n]	1.79
Maximum permissible wear (%)	[W_{limit}]	15.00
Permissible wear on flank (mm)	[δ_{Wlimn}]	0.27
Wear removal (mm)	[δ_{Wn}]	0.01261
Wear removal (mg)	[=lFL*b*z*ro*δWn]	94.0
Required safety	[S_{Wmin}]	1.10
Safety against wear	[S_W]	21.24

Calculation for safety against shearing for plastics		
Normal tooth thickness in the active root diameter (mm)	[s_{dNf}-δWn]	2.36
Shearing stress (N/mm²)	[τ_{nom}]	3.54
Notch effect coefficient	[K_T]	1.25
Permitted shearing strength (N/mm²)	[τ_B]	9.02
Required safety	[S_{Tmin}]	2.50
Safety shearing	[S_T]	2.04

$\tau_B = 0.557 * \sigma_{Fadm}$; $S_T = \tau_B / (\tau_{nom} * K_T)$

Calculation of local wear with speeds and load distribution according to method A:
Calculation was not carried out. (Contact analysis under load is required.)

Important note:
the kw wear coefficients are usually determined using a plastic/steel pairing..
The coefficients may be very different if pairings of other materials are used..
This calculation is designed to give an indication of possible service life,
however it has not yet been checked exhaustively in real life..

5. BENDING

For plastics:

Tooth deformation (µm)	[fa]	114.596
Permissible tooth deformation (µm)	[fazul]	87.500
Required safety	[Sdel]	1.000
Safety against deformation	[Sdelmin]	0.764

Experimental method using tooth stiffness according ISO6336:2006:

Tooth deformation (µm)	[faExp]	0.560	132.473
Permissible tooth deformation (µm)	[fazulExp]	210.901	210.901
Required safety	[Sdel]	1.000	
Safety against jamming	[SdelExp]	376.447	1.592

6. MEASUREMENTS FOR TOOTH THICKNESS

		------- Gear 1 ------	Gear 2 --
Tooth thickness deviation		DIN 3967 cd25	DIN 3967 cd25
Tooth thickness allowance (normal section) (mm)	[As.e/i]	-0.054 / -0.084	-0.095 / -0.145
Number of teeth spanned	[k]	4.000	12.000
Base tangent length (no backlash) (mm)	[Wk]	13.638	44.134
Actual base tangent length ('span') (mm)	[Wk.e/i]	13.588 / 13.560	44.045 / 43.998
(mm)	[ΔWk.e/i]	-0.051 / -0.079	-0.089 / -0.136
Diameter of measuring circle (mm)	[dMWk.m]	32.768	127.313
Theoretical diameter of ball/pin (mm)	[DM]	2.268	2.088
Effective diameter of ball/pin (mm)	[DMeff]	2.500	2.500
Radial single-ball measurement backlash free (mm)	[MrK]	18.329	65.833
Radial single-ball measurement (mm)	[MrK.e/i]	18.275 / 18.245	65.711 / 65.646
Diameter of measuring circle (mm)	[dMMr.m]	32.926	127.972
Diametral measurement over two balls without clearance (mm)	[MdK]	36.590	131.666
Diametral two ball measure (mm)	[MdK.e/i]	36.482 / 36.422	131.422 / 131.292
Diametral measurement over pins without clearance (mm)	[MdR]	36.658	131.666
Measurement over pins according to DIN 3960 (mm)	[MdR.e/i]	36.550 / 36.489	131.422 / 131.292
Measurement over 2 pins (free) according to AGMA 2002 (mm)	[dk2f.e/i]	36.479 / 36.418	0.000 / 0.000
Measurement over 2 pins (axial) according to AGMA 2002 (mm)	[dk2t.e/i]	36.615 / 36.554	0.000 / 0.000
Measurement over 3 pins (axial) according to AGMA 2002 (mm)	[dk3A.e/i]	36.550 / 36.489	131.422 / 131.292
Chordal tooth thickness (no backlash) (mm)	[sc]	2.235	1.785
Actual chordal tooth thickness (mm)	[sc.e/i]	2.181 / 2.151	1.690 / 1.640
Reference chordal height from da.m (mm)	[ha]	1.656	1.000
Tooth thickness (Arc) (mm)	[sn]	2.237	1.785
(mm)	[sn.e/i]	2.183 / 2.153	1.690 / 1.640
Backlash free center distance (mm)	[aControl.e/i]	79.796 / 79.685	
Backlash free center distance, allowances (mm)	[jta]	-0.204 / -0.315	
dNf.i with aControl (mm)	[dNf0.i]	30.294	125.101
Reserve (dNf0.i-dFf.e)/2 (mm)	[cF0.i]	-0.093	0.127
Tip clearance (mm)	[c0.i(aControl)]	0.128	0.072
Center distance allowances (mm)	[Aa.e/i]	0.015 / -0.015	
Circumferential backlash from Aa (mm)	[jtw_Aa.e/i]	0.011 / -0.011	

Radial backlash (mm)	[jrw.e/i]	0.330 /	0.189
Circumferential backlash (transverse section) (mm)	[jtw.e/i]	0.246 /	0.141
Normal backlash (mm)	[jnw.e/i]	0.226 /	0.130
Angle of rotation on input with fixed output.:			
Entire torsional angle (°)	[j.tSys]		0.8802/ 0.5059

7. GEAR ACCURACY

		------- GEAR 1	-------- GEAR 2 --
According to DIN 3961:1978			
Accuracy grade	[Q-DIN3961]	6	6
Profile form deviation (µm)	[ff]	6.00	6.00
Profile slope deviation (µm)	[fHa]	5.00	5.00
Total profile deviation (µm)	[Ff]	8.00	8.00
Helix form deviation (µm)	[fbf]	5.50	5.50
Helix slope deviation (µm)	[fHb]	9.00	9.00
Total helix deviation (µm)	[Fb]	10.00	10.00
Normal base pitch deviation (µm)	[fpe]	7.00	8.00
Single pitch deviation (µm)	[fp]	7.00	8.00
Adjacent pitch difference (µm)	[fu]	8.00	10.00
Total cumulative pitch deviation (µm)	[Fp]	19.00	29.00
Sector pitch deviation over z/8 pitches (µm)	[Fpz/8]	12.00	18.00
Runout (µm)	[Fr]	14.00	19.00
Tooth Thickness Variation (µm)	[Rs]	8.00	11.00
Single flank composite, total (µm)	[Fi']	22.00	30.00
Single flank composite, tooth-to-tooth (µm)	[fi']	10.00	11.00
Radial composite, total (µm)	[Fi"]	17.00	24.00
Radial composite, tooth-to-tooth (µm)	[fi"]	6.00	10.00
According to DIN 58405:1972 (Feinwerktechnik):			
Tooth-to-tooth composite error (µm)	[fi"]	7.00	9.00
Composite error (µm)	[Fi"]	20.00	25.00
Axis alignment error (µm)	[fp]	13.60	13.60
Flank direction error (µm)	[fbeta]	6.30	6.30
Runout (µm)	[Trk, Fr]	21.00	28.00

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

Maximum value for deviation error of axis (µm)	[fSigbet]	13.00 (Fb=13.00)
Maximum value for inclination error of axes (µm)	[fSigdel]	26.00

8. ADDITIONAL DATA

Maximal possible center distance (eps_a=1.0)	[aMAX]	80.833	
Mass (kg)	[m]	0.193	0.429
Total mass (kg)	[m]	0.623	
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]	2.537e-005	0.0008655
System ((da+df)/2...di) (kg*m²)	[TraeghMom]	7.946e-005	
Coefficient of friction	[mum]	0.200	
Loss factor	[HV]	0.117	
Coefficient for frequency of running	[KstEDf]	1.000	
Casing surface (m²)	[Oberflache]	0.16961	
Gear power loss (W)	[PVZ]	9.821	

(Meshing efficiency (%)	[etaz]		97.656)	
Tooth root temperature (°C)	[TR]		70.0	70.0
Flank temperature (°C)	[TF]		70.0	70.0
Heat transfer coefficient, root	[KF]		0.0	0.0
Heat transfer coefficient, flank	[KH]		0.0	0.0
Indications for the manufacturing by wire cutting:				
Deviation from theoretical tooth trace (µm)		[WireErr]	317.1	79.5
Permissible deviation (µm)	[Fb/2]		5.0	5.0

9. MODIFICATIONS AND TOOTH FORM DEFINITION

Data for the tooth form calculation :

Calculation of Gear 1
Tooth form, Gear 1, Step 1: Automatic (final machining)
haP*= 1.070, hfP*= 1.250, rofP*= 0.380

Calculation of Gear 2
Tooth form, Gear 2, Step 1: Automatic (final machining)
haP*= 1.123, hfP*= 1.250, rofP*= 0.380

10. SERVICE LIFE, DAMAGE

Required safety for tooth root	[SFmin]	1.25	
Required safety for tooth flank	[SHmin]	0.93	
Required safety for wear	[SWmin]	1.10	
Service life (calculated with required safeties):			
System service life (h)	[Hatt]	71.595	
Tooth root service life (h)	[HFatt]	1e+006	254.9
Tooth flank service life (h)	[HHatt]	1e+006	71.59
Wear service life (h)	[HWatt]	1e+006	926.9

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] (48.0 h)

F1%	F2%	H1%	H2%	W1%	W2%
0.00	18.8277	0.0000	67.0440	0.0000	5.1783

Damage calculated on basis of system service life [Hatt] (71.6 h)

F1%	F2%	H1%	H2%	W1%	W2%
0.00	28.0825	0.0000	100.0000	0.0000	7.7237

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

Gear		fac	b	t0	T	R(H)%
1	Tooth root	60000	1.7	9.654e+029	1.484e+030	100.00
1	Tooth flank	60000	1.3	9.014e+029	4.295e+030	100.00
2	Tooth root	15000	1.7	3.692e+006	5.673e+006	100.00
2	Tooth flank	15000	1.3	9.68e+005	4.612e+006	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.
- Calculation of steel/plastic pair:
  the steel gear's strength is calculated approximately, according to DIN 3990, to obtain an indication of the service life..

End of Report lines: 511