KISSSOFT
Calculation programs for machine design

RACK ANALYSIS (CYLINDRICAL GEAR)

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

Calculation method Plastic according to VDI 2545:1981 (YF Method C)
Steel wheels: calculated roughly according to DIN 3990!

		---- Pinion ----------	Rack -
Power (W)	[P]		285.000
Speed (1/min)	[n]	60.0	
Torque (Nm)	[T]	45.4	
Application factor	[KA]		1.00
Required service life (h)	[H]		5000.00
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)

		---- Pinion ----------	Rack -
Running centre distance (mm)	[a]		92.000
Centre distance tolerance	ISO 286:2010 Measure js7		
Rack height (mm)	[Hz]		50.000
Normal module (mm)	[mn]		3.0000
Pressure angle at normal section (°)	[alfn]		20.0000
Helix angle at reference circle (°)	[beta]		0.0000
Number of teeth	[z]	30	
Facewidth (mm)	[b]	30.00	30.00
Hand of gear	Spur gear		
Accuracy grade	[Q-DIN3961:1978]	6	6
Inner diameter (mm)	[di]	0.00	9094.01
Inner diameter of gear rim (mm)	[dbi]	0.00	0.00

Material
Gear 1: C45 (1), Through hardened steel, unalloyed, through hardened
ISO 6336-5 Figure 5/6 (MQ)
Gear 2: POM (VDI2545), Thermoplastic (POM, PPA, etc.), untreated
VDI2545[S B F Wd C]
Woehler line tooth root stress from file Z014-100.DAT
S-N curve (Woehler line) Hertzian pressure from file Z014-100.DAT

			------- GEAR 1 --------	GEAR 2 --
Surface hardness			HBW 186	HBW 0
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]	210.00	39.00
Strength against Hertzian pressure	at NL (N/mm²)	[σHadm]	678.88	41.80
Tensile strength (N/mm²)		[σB]	700.00	45.20
Yield point (N/mm²)		[σS]	490.00	41.00
Young's modulus (N/mm²)		[E]	206000	2100
Poisson's ratio		[v]	0.300	0.440
Roughness average value DS, flank (µm)		[RAH]	1.05	0.00

Roughness average value DS, root (µm)	[RAF]	3.00	0.00
Mean roughness height, Rz, flank (µm)	[RZH]	8.00	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]	10.7	19.5

Lubrication type Dry-running

Ambient temperature (°C)	[TU]	20.000

		---- Pinion ----------	Rack -
Transverse module (mm)	[mt]	3.000	
Pressure angle at pitch circle (°)	[alft]	20.000	
Working transverse pressure angle (°)	[alfwt]	20.000	
Working pressure angle at normal section (°)	[alfwn]	20.000	
Helix angle at operating pitch circle (°)	[betaw]	0.000	
Base helix angle (°)	[betab]	0.000	
Sum of profile shift coefficients	[Summexi]	0.0000	
Profile shift coefficient	[x]	0.0000	0.0000
Tooth thickness (Arc) (module) (module)	[sn*]	1.5708	1.5708
Tip alteration (mm)	[k*mn]	0.000	0.000
Reference diameter (mm)	[d]	90.000	47.000

Base diameter (mm)	[db]	84.572			
Tip diameter (mm)	[da,Hz]	96.000		50.000	
(mm)	[da,Hz.e/i]	96.000 /	95.990	50.000 /	49.995
Tip diameter allowances (mm)	[Ada,AHz.e/i]	0.000 /	-0.010	0.000 /	-0.005
Tip form diameter (mm)	[dFa]	96.000		50.000	
(mm)	[dFa.e/i]	96.000 /	95.990	50.000 /	49.995
Active tip diameter (mm)	[dNa.e/i]	96.000 /	95.990	50.000 /	49.995
Operating pitch diameter (mm)	[dw]	90.000		47.000	
Root diameter (mm)	[df]	82.500		43.250	
Generating Profile shift coefficient	[xE.e/i]	-0.0321 /	-0.0504	-0.0321 /	-0.0504
Manufactured root diameter with xE (mm)	[df.e/i]	82.308 /	82.198	43.154 /	43.099
Theoretical tip clearance (mm)	[c]	0.750		0.750	
Effective tip clearance (mm)	[c.e/i]	0.924/	0.829	0.924/	0.829
Active root diameter (mm)	[dNf]	85.595		44.490	
(mm)	[dNf.e/i]	85.616 /	85.580	44.512 /	44.473
Root form diameter (mm)	[dFf]	85.602		44.261	
(mm)	[dFf.e/i]	85.517 /	85.470	44.165 /	44.109
Reserve (dNf-dFf)/2 (mm)	[cF.e/i]	0.073 /	0.031	0.402 /	0.308
Addendum (mm)	[ha = mn * (haP*+x)]	3.000		3.000	
(mm)	[ha.e/i]	3.000 /	2.995	3.000 /	2.995
Dedendum (mm)	[hf = mn * (hfP*-x)]	3.750		3.750	
(mm)	[hf.e/i]	3.846 /	3.901	3.846 /	3.901
Roll angle at dFa (°)	[xsi_dFa.e/i]	30.775 /	30.761		
Roll angle to dNa (°)	[xsi_dNa.e/i]	30.775 /	30.761		
Roll angle to dNf (°)	[xsi_dNf.e/i]	9.028 /	8.870		
Roll angle at dFf (°)	[xsi_dFf.e/i]	8.589 /	8.371		
Tooth height (mm)	[h]	6.750		6.750	
Virtual gear no. of teeth	[zn]	30.000			
Normal tooth thickness at tip circle (mm)	[san]	2.212		2.529	
(mm)	[san.e/i]	2.143 /	2.095	2.462 /	2.419
Normal space width at root circle (mm)	[efn]	0.000		1.983	
(mm)	[efn.e/i]	0.000 /	0.000	1.959 /	1.946
Max. sliding velocity at tip (m/s)	[vga]	0.046		0.055	
Specific sliding at the tip	[zetaa]	0.319		0.569	
Specific sliding at the root	[zetaf]	-1.320		-0.469	
Sliding factor on tip	[Kga]	0.161		0.193	
Sliding factor on root	[Kgf]	-0.193		-0.161	
Pitch on reference circle (mm)	[pt]	9.425			
Base pitch (mm)	[pbt]	8.856			
Transverse pitch on contact-path (mm)	[pet]	8.856			
Length of path of contact (mm)	[ga, e/i]	16.116 (	16.167/	16.039)	
Length T1-A (mm)	[T1A]	6.597 (	6.546/	6.663)	
Length T1-B (mm)	[T1B]	13.857 (	13.857/	13.846)	
Length T1-C (mm)	[T1C]	15.391 (	15.391/	15.390)	
Length T1-D (mm)	[T1D]	15.454 (	15.403/	15.520)	
Length T1-E (mm)	[T1E]	22.713 (	22.713/	22.702)	
Diameter of single contact point B (mm)	[d-B]	88.997 (	88.997/	88.991)	
Diameter of single contact point D (mm)	[d-D]	90.043 (	90.008/	90.088)	

Transverse contact ratio	[eps_a]	1.820		
Transverse contact ratio with allowances	[eps_a.e/m/i]	1.825 /	1.818 /	1.811
Overlap ratio	[eps_b]	0.000		
Total contact ratio	[eps_g]	1.820		
Total contact ratio with allowances	[eps_g.e/m/i]	1.825 /	1.818 /	1.811

2. FACTORS OF GENERAL INFLUENCE

		---- Pinion ----------	Rack -
Nominal circum. force at pitch circle (N)	[Ft]		1008.0
Axial force (N)	[Fa]		0.0
Radial force (N)	[Fr]		366.9
Normal force (N)	[Fnorm]		1072.7
Nominal circumferential force per mm (N/mm)	[w]		33.60
Only as information: Forces at operating pitch circle:			
Nominal circumferential force (N)	[Ftw]		1008.0
Axial force (N)	[Faw]		0.0
Radial force (N)	[Frw]		366.9
Circumferential speed reference circle (m/s)	[v]		0.28
Circumferential speed operating pitch circle (m/s)	[v(dw)]		0.28
Correction coefficient	[CM]		0.800
Gear body coefficient	[CR]		1.000
Basic rack factor	[CBS]		0.975
Material coefficient	[E/Est]		0.020
Singular tooth stiffness (N/mm/µm)	[c']		0.300
Meshing stiffness (N/mm/µm)	[cg]		0.485
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]	18.000	1.106
Rack length (mm)	[l]		4600.000

3. TOOTH ROOT STRENGTH

Calculation of Tooth form coefficients according method: C

		---- Pinion ----------	Rack -
Calculated with profile shift	[x]	0.0000	0.0000
Tooth form factor	[YF]	2.53	1.99
Stress correction factor	[YS]	1.00	1.00
Working angle (°)	[alfFen]	26.92	20.00
Bending moment arm (mm)	[hF]	5.69	5.72
Tooth thickness at root (mm)	[sFn]	6.20	7.20
Tooth root radius (mm)	[roF]	1.65	1.14

(hF* = 1.895/ 1.907 sFn* = 2.066/ 2.398 roF* = 0.549/ 0.380)
(den/hen (mm) = 96.000/ 50.000 dsFn/hsFn(mm) = 83.708/ 43.820 alfsFn(°) = 30.00/ 30.00 qs = 1.881/ 3.156)

Contact ratio factor	[Yeps]	0.550	
Helix angle factor	[Ybet]	1.000	
Effective facewidth (mm)	[beff]	30.00	30.00
Nominal stress at tooth root (N/mm²)	[sigF0]	30.44	12.24
Tooth root stress (N/mm²)	[sigF]	30.44	12.24

Permissible bending stress at root from data tables				
Notch sensitivity factor	[YdrelT]	0.983	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]	1.000	1.000	
	[YdrelT*YRrelT*YX*YNT]	0.940	1.000	
Alternating bending factor (mean stress influence coefficient)	[YM]	1.000		1.000
Stress correction factor	[Yst]	1.00		
Yst*sigFlim (N/mm²)	[sigFE]	210.00	39.00	
Permissible tooth root stress (N/mm²)	[sigFP=sigFG/SFmin]	282.05	27.86	
Limit strength tooth root (N/mm²)	[sigFG]	394.87	39.00	
Required safety	[SFmin]	1.40	1.40	
Safety for tooth root stress	[SF=sigFG/sigF]	12.97	3.19	
Transmittable power (W)	[WRating]	2640.81	648.62	

4. SAFETY AGAINST PITTING (TOOTH FLANK)

		---- Pinion ----------	Rack -	
Zone factor	[ZH]	2.495		
Elasticity factor (√N/mm²)	[ZE]	28.627		
Contact ratio factor	[Zeps]	0.853		
Helix angle factor	[Zbet]	1.000		
Effective facewidth (mm)	[beff]	30.00		
Nominal contact stress (N/mm²)	[sigH0]	37.01		
Contact stress at operating pitch circle (N/mm²)	[sigHw]	37.01		
Lubrication coefficient at NL	[ZL]	0.931	1.000	
Speed coefficient at NL	[ZV]	0.935	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]	1.257	1.000	
	[ZL*ZV*ZR*ZNT]	1.095	1.000	
Limited pitting is permitted:		Yes		
Size factor (flank)	[ZX]	1.000	1.000	
Permissible contact stress (N/mm²)	[sigHP=sigHG/SHmin]	591.35	41.80	
Pitting stress limit (N/mm²)	[sigHG]	591.35	41.80	
Required safety	[SHmin]	1.00	1.00	
Safety factor for contact stress at operating pitch circle				
	[SHw]	15.98	1.13	
Transmittable power (W)	[WRating]	65437.21	321.87	

4a. WEAR

Line load at reference diameter (N/mm)	[w]	33.60
Line load at reference diameter (N/mm)	[K_A*K_γ*K_V*$K_{H\beta}$*$K_{H\alpha}$*w]	33.60
Loss factor	[H_V]	0.088
Calculation only for Gear 2		
Length of active flank (mm)	[l_{Fl}]	5.84
Wear factor ($mm^3/Nm/10^6$)	[k_w]	3.40000
Data from file k_w: Z014-100.DAT		

Normal tooth thickness in pitch circle (mm)	[s_n]	4.71
Maximum permissible wear (%)	[W_{limit}]	15.00
Permissible wear on flank (mm)	[δ_{Wlimn}]	0.71
Wear removal (mm)	[δ_{Wn}]	0.01797
Wear removal (mg)	[=lFL*b*z*ro*δWn]	13411.1
Required safety	[S_{Wmin}]	1.10
Safety against wear	[S_W]	39.34

Calculation for safety against shearing for plastics

Normal tooth thickness in the active root diameter (mm)	[s_{dNf}-δWn]	6.44
Shearing stress (N/mm²)	[τ_{nom}]	5.21
Notch effect coefficient	[K_T]	1.25
Permitted shearing strength (N/mm²)	[τ_B]	21.72
Required safety	[S_{Tmin}]	2.50
Safety shearing	[S_T]	3.33

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

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

According to VDI2545:1981

Tooth deformation (µm)	[fa]	165.752	
Permissible tooth deformation (µm)	[fazul]	300.000	
Required safety	[Sdel]	1.000	
Safety against deformation	[Sdelmin]	1.810	

Experimental method using tooth stiffness according ISO6336:2006:

Tooth deformation (µm)	[faExp]	1.718	168.557
Permissible tooth deformation (µm)	[fazulExp]	192.362	192.362
Required safety	[Sdel]	1.000	
Safety against clamping	[SdelExp]	111.949	1.141

6. MEASUREMENTS FOR TOOTH THICKNESS

		---- Pinion	---------- Rack -
Tooth thickness deviation		DIN 3967 cd25	DIN 3967 cd25
Tooth thickness allowance (normal section) (mm)	[As.e/i]	-0.070 / -0.110	-0.070 / -0.110
Number of teeth spanned	[k]	4.000	
(Internal toothing: k = (Measurement gap number)			
Base tangent length (no backlash) (mm)	[Wk]	32.258	
Actual base tangent length ('span') (mm)	[Wk.e/i]	32.192 / 32.155	
(mm)	[ΔWk.e/i]	-0.066 / -0.103	
Diameter of contact point (mm)	[dMWk.m]	90.485	
Theoretical diameter of ball/pin (mm)	[DM]	5.117	5.833
Effective diameter of ball/pin (mm)	[DMeff]	5.250	6.000
Radial single-ball measurement backlash free (mm)	[MrK]	48.731	52.298

Radial single-ball measurement (mm)	[MrK.e/i]	48.649 / 48.601	52.202 / 52.147
Diameter of contact point (mm)	[dMMr.m]	90.062	
Diametral measurement over two balls without clearance (mm)	[MdK]	97.463	
Diametral two ball measure (mm)	[MdK.e/i]	97.297 / 97.202	
Diametral measurement over pins without clearance (mm)	[MdR]	97.463	
Measurement over pins according to DIN 3960 (mm)	[MdR.e/i]	97.297 / 97.202	
Measurement over 3 pins (axial) according to AGMA 2002 (mm)	[dk3A.e/i]	97.297 / 97.202	
Chordal tooth thickness (no backlash) (mm)	[sc]	4.710	4.712
Actual chordal tooth thickness (mm)	[sc.e/i]	4.640 / 4.600	4.642 / 4.602
Reference chordal height from da.m (mm)	[ha]	3.059	2.997
Tooth thickness (Arc) (mm)	[sn]	4.712	4.712
(mm)	[sn.e/i]	4.642 / 4.602	4.642 / 4.602
Backlash free center distance (mm)	[aControl.e/i]	91.808 / 91.698	
Backlash free center distance, allowances (mm)	[jta]	-0.192 / -0.302	
Tip clearance (mm)	[c0.i(aControl)]	0.544	0.544
Centre distance allowances (mm)	[Aa.e/i]	-0.018 / 0.018	
Circumferential backlash from Aa (mm)	[jtw_Aa.e/i]	0.013 / -0.013	
Radial clearance (mm)	[jrw]	0.320 / 0.175	
Circumferential backlash (transverse section) (mm)	[jtw]	0.233 / 0.127	
Normal backlash (mm)	[jnw]	0.219 / 0.120	
Torsional angle for fixed rack:			
Entire torsional angle (°)	[j.tSys]	0.0030/ 0.0016	

7. GEAR ACCURACY

		---- Pinion ----------	Rack -
According to DIN 3961:1978			
Accuracy grade	[Q-DIN3961]	6	6
Profile form deviation (µm)	[ff]	8.00	8.00
Profile slope deviation (µm)	[fHa]	6.00	6.00
Total profile deviation (µm)	[Ff]	10.00	10.00
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]	8.00	8.00
Single pitch deviation (µm)	[fp]	8.00	8.00
Adjacent pitch difference (µm)	[fu]	10.00	10.00
Total cumulative pitch deviation (µm)	[Fp]	27.00	27.00
Sector pitch deviation over z/8 pitches (µm)	[Fpz/8]	17.00	17.00
Runout (µm)	[Fr]	19.00	19.00
Tooth Thickness Variation (µm)	[Rs]	11.00	11.00
Single flank composite, total (µm)	[Fi']	30.00	30.00
Single flank composite, tooth-to-tooth (µm)	[fi']	13.00	13.00
Radial composite, total (µm)	[Fi"]	22.00	22.00
Radial composite, tooth-to-tooth (µm)	[fi"]	9.00	9.00
According to DIN 58405:1972 (Feinwerktechnik):			
Tooth-to-tooth composite error (µm)	[fi"]	9.00	9.00
Composite error (µm)	[Fi"]	25.00	25.00
Axis alignment error (µm)	[fp]	15.64	15.64
Flank direction error (µm)	[fbeta]	6.30	6.30
Runout (µm)	[Trk, Fr]	24.00	24.00

(Tolerances of rack following DIN 3961:1978 mit der Zähnezahl und dem Teilkreis des Ritzels berechnet)

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

Maximum value for deviation error of axis (µm)	[fSigbet]	24.00 (Fb=24.00)
Maximum value for inclination error of axes (µm)	[fSigdel]	48.00

8. ADDITIONAL DATA

Exponent kappa (temperature calculation)	[ExpKappa]	0.400	
Coefficient of friction	[mum]	0.200	
Loss factor	[HV]	0.088	
Coefficient for frequency of running	[KstEDf]	1.000	
Casing surface (m²)	[Oberflache]	369.36000	
Gear power loss (W)	[PVZ]	5.021	
(Meshing efficiency (%)	[etaz]	98.238)	
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 :
Data not available.

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]	10809

Tooth root service life (h)	[HFatt]	1e+006	1e+006
Tooth flank service life (h)	[HHatt]	1e+006	1.081e+004
Wear service life (h)	[HWatt]	1e+006	1.788e+005

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] (5000.0 h)

F1%	F2%	H1%	H2%	W1%	W2%
0.00	0.00	0.00	46.26	0.00	2.80

Damage calculated on basis of system service life [Hatt] (10809.5 h)

F1%	F2%	H1%	H2%	W1%	W2%
0.00	0.00	0.00	100.00	0.00	6.05

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

Gear		fac	b	t0	T	R(H)%

1	Tooth root	3600	1.7	9.654e+029	1.484e+030	100.00
1	Tooth flank	3600	1.3	9.014e+029	4.295e+030	100.00
2	Tooth root	221	1.7	9.654e+029	1.484e+030	100.00
2	Tooth flank	221	1.3	2.156e+006	1.027e+007	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: 475