KISSsoft

Worm gear - worm wheel pair

01 Worm (DIN 3996 Example 1)

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	Non commercial version for demo and support purposes only ! (914)
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Contents

1 Messages

Calculation is consistent.

Worm
Facewidth is too small according to ISO 14521/DIN 3975 (60.000 mm < 92.594 mm)

2 Overview

Calculation method		DIN 3996:2012	
Geometry:		DIN 3975:2002	
Geometry calculation from axial module			
Drawing or article number:			
Worm:		0.000.0	
Worm wheel:		0.000.0	
		------- Worm ----------	Worm wheel -------
Worm driving			
Working flank Gear 1: Right flank			
Power (kW)	[P]	5.302	4.500
Speed (1/min)	[n]	1500.0	73.2
Number of load cycles (in mio.)	[NL]	2250.000	109.756
Torque (Nm)	[T]	33.754	587.282
Application factor	[KA]	1.00	
Required service life	[H]	25000.00	
Number of starts (1/h)	[Ns]	0.00	

3 Gear set data

Shape of flank: ZI (ISO/TR 10828:2015)

		------- Worm ----------	Worm wheel -------
Center distance (mm)	[a]	100.000	
Center distance tolerance		ISO 286:2010 Measure js7	
Shaft angle (°)	[Σ]	90.0000	
Normal module (mm)	[mn]	3.9047	
Transverse module (mm)	[mt]	4.0000	
Axial module (mm)	[mx]	4.0000	
Normal Diametral Pitch (1/in)	[Pnd]	6.50490	
Transverse Diametral Pitch (1/in)	[Ptd]	6.35000	
Normal pressure angle (°)	[αn]	20.0000	
Mean lead angle (°)	[γ]	12.5288	
Hand of gear		left	left
Number of teeth	[z]	2	41
Facewidth (mm)	[b1]	60.00	
Worm wheel rim width b2R (mm)	[b2R]		31.00
Worm gear wheel width b2H (mm)	[b2H]		31.00
Facewidth for calculation (mm)	[b1,b2]	60.00	30.83
Accuracy grade (manufacturing)	[Vqual]	6	7
Internal diameter gearbody (mm)	[di]	0.00	134.40

4 Materials

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

Worm wheel
CuSn12Ni2-C-GZ, Bronze, untreated, ISO 14521:2020

		------- Worm	---------- Worm wheel -------
Surface hardness		HRC 59	HBW 95
Pulsating shear strength (N/mm²)	[τFlim]	430.00	90.00
Fatigue strength for Hertzian pressure (N/mm²)	[σHlim]	1500.00	520.00
Material factor Y_W	[YW]	0.95	
Material lubrication coefficient	[WML_PolyG]	1.75	
Young's modulus (N/mm²)	[E]	206000	98100
Poisson's ratio	[v]	0.300	0.350
Tensile strength (N/mm²)	[σB]	1000.00	300.00
Yield point (N/mm²)	[σS]	695.00	180.00

4.1 Gear roughness

		------- Worm	---------- Worm wheel -------
Arithmetic mean roughness value R_a, flank (µm)	[RAH]	0.50	2.00
Arithmetic mean roughness value R_a, root (µm)	[RAF]	0.50	2.00
Mean peak-to-valley roughness R_z, flank (µm)	[RZH]	3.00	8.00
Mean peak-to-valley roughness R_z, root (µm)	[RZF]	3.00	8.00

4.2 Lubrication

Lubrication type	Oil bath lubrication	
Oil type, own input	ÖI: ISO-VG 220	
Lubricant base	Synthetic oil based on Polyglycol	
Oil nominal kinematic viscosity at 40°C (mm²/s)	[v40]	220.00
Oil nominal kinematic viscosity at 100°C (mm²/s)	[v100]	37.00
Specific density at 15°C (kg/dm³)	[ρ]	1.020
Oil temperature (°C)	[TS]	73.226
Ambient temperature (°C)	[TU]	20.000

5 Geometry

5.1 Reference profiles

Reference profile Gear 1

Reference profile	1.20 / 0.20 / 1.0 DIN 867:1986	
Dedendum coefficient	[hfP*]	1.200
Root radius factor	[ρfP*]	0.200
	[ρfPmax*]	0.498
Addendum coefficient	[haP*]	1.000
Tip radius factor	[ρaP*]	0.000
Protuberance height coefficient	[hprP*]	0.000
Protuberance angle	[αprP]	0.000
Tip form height coefficient	[hFaP*]	0.000
Ramp angle	[αKP]	0.000
	not topping	
Smallest radius of curvature, root rounding (mm)	[ρmin.e/i]	1.893 /1.893

Reference profile Gear 2

Reference profile	1.20 / 0.20 / 1.0 DIN 867:1986	
Dedendum coefficient	[hfP*]	1.200
Root radius factor	[ρfP*]	0.200
	[ρfPmax*]	0.498
Addendum coefficient	[haP*]	1.000
Tip radius factor	[ρaP*]	0.000
Protuberance height coefficient	[hprP*]	0.000
Protuberance angle	[αprP]	0.000
Tip form height coefficient	[hFaP*]	0.000
Ramp angle	[αKP]	0.000
	not topping	
Smallest radius of curvature, root rounding (mm)	[ρmin.e/i]	0.975 /0.980

5.1.1 Information on final machining

		------- Worm	---------- Worm wheel -------
Dedendum reference profile	[hfP*]	1.200	1.200
Tooth root radius reference profile	[ρfP*]	0.200	0.200
Addendum reference profile	[haP*]	1.000	1.000
Protuberance height coefficient	[hprP*]	0.000	0.000
Protuberance angle (°)	[αprP]	0.000	0.000
Tip form height coefficient	[hFaP*]	0.000	0.000

Ramp angle (°)	[αKP]	0.000	0.000
Type of profile modification:	none (only running-in)		
Tip relief by running in (µm)	[Ca L/R]	0.0 /0.0	0.0 /0.0

5.2 Basic data

		------- Worm	---------- Worm wheel -------
Overall transmission ratio	[itot]	-20.500	
Gear ratio	[u]	20.500	
Generating angle (°)	[α0]	20.000	
Normal pressure angle (°)	[αn]	20.000	
Base helix angle (°)	[βb]	11.762	
Reference center distance (mm)	[ad]	100.000	
Diametral factor q	[q]	9.000	
Sum of profile shift coefficients	[Σxi]	0.0000	
Lead height (mm)	[pz]	25.133	
Axial pitch (mm)	[px]	12.566	
For ZI-worms:			
Base lead angle (°)	[γb]	23.463	
Base pitch (mm)	[pb]	11.527	
Profile shift coefficient	[x]	0.0000	0.0000
Profile shift (mm)	[x*mx]	0.0000	0.0000
The profile shift relates to the worm's axial module as specified in ISO/TR 14521:2020/DIN 3975:2002.			
Tooth thickness modification coefficient	[xs]	0.0000	0.0000
Generating profile shift coefficient	[xE.e/i]		-0.0450/-0.0591
Theoretical tip clearance (mm)	[c]	0.800	0.800
Effective tip clearance (mm)	[c.e/i]	1.059 /0.963	0.877 /0.782
Transverse contact ratio (guide value in accordance with Thomas-Charchut)			
	[εα]	1.911	

5.3 Diameters and their allowances

		------- Worm	---------- Worm wheel -------
Reference operating diameter (mm)	[dm]	36.000	164.000
Reference diameter (mm)	[d]		164.000
Base diameter (mm)	[db]		153.666
Tip alteration (mm)	[k*mn]	0.000	0.000
Tip diameter (mm)	[da]	44.000	172.000
Tip diameter allowances (mm)	[Ada.e/i]	0.000 /-0.010	0.000 /-0.010
Tip form diameter (mm)	[dFa]	44.000	172.000
(mm)	[dFa.e/i]	44.000 /43.990	172.000 /171.990
Root diameter (mm)	[df]	26.400	154.400
(mm)	[df.e/i]	26.400 /26.290	154.040 /153.927
For ZI-worms:			
Base diameter (mm)	[db]	18.431	

5.4 Details for the manufacturing of the worm wheel according to ISO 14521:2020

Only valid for worm wheels that were manufactured using a cutter that is similar to a worm.

		------- Worm	---------- Worm wheel -------
Mean lead angle of the worm (°)	[γ]	12.5288	
Transverse module (mm)	[mt]	4.0000	
Reference diameter (mm)	[d]		164.000
Reference operating diameter (mm)	[dm]		164.000
Throat radius (mm)	[rk]		14.000
Throat center distance (mm)	[ark]	100.000	
Facewidth chamfer angle (°)	[θ]		0.0000
Chamfering center distance (mm)	[aθ]	100.000	
External diameter (mm)	[de]		181.410
Tip diameter (mm)	[da]		172.000
Profile shift coefficient	[x]		0.0000
Transverse pitch (mm)	[pt]	12.566	

5.5 Values for manufacturing the worm wheel as a cylindrical gear or for mold making

These values are only intended to be an indication. Use the crossed helical gear calculation to calculate the exact geometry!

		------- Worm	---------- Worm wheel -------
Transverse pressure angle (°)	[αt]	59.205	20.448
Axial pressure angle (°)	[αχ]	20.448	59.205
Helix angle at reference circle (°)	[β]	77.471	12.529
Lead angle at reference diameter (°)	[γ]	12.529	77.471
Transverse module (mm)	[mt]	18.000	4.000
Axial module (mm)	[mx]	4.000	18.000
Helix angle at operating pitch circle (°)	[βs]	77.471	12.529
Operating pitch diameter (mm)	[dw]	36.000	164.000
Profile shift coefficient	[x-DIN3960]	0.000	0.000

6 General influence factors

		------- Worm	---------- Worm wheel -------
Nominal circum. force at pitch circle (N)	[Ft]	1875.2	7162.0
Axial force (N)	[Fa]	-7162.0	-1875.2
Radial force (N)	[Fr]	2847.3	-2847.3
Normal force (N)	[Fn]	8343.7	
Circumferential speed reference circle (m/s)	[v]	2.827	0.628
Sliding velocity an mean circle (m/s)	[vgm]	2.896	

Data of reference gearbox:

Equivalent Young's modulus (N/mm²)	[EredT]	150622.00	
Surface roughness of worm (µm)	[RaT]	0.500	
Center distance (mm)	[aT]	100.000	
Transmission ratio	[uT]	20.500	
Reference operating diameter (mm)	[dm1T,dm2T]	36.000	164.000
Characteristic value for mean Hertzian pressure	[pmT*]	0.962	
Characteristic value for mean lubricant gap thickness	[hT*]	0.070	
Characteristic value for mean sliding path	[sT*]	30.800	

Physical characteristic values:

Characteristic value for mean lubrication Space width	[h*]	0.0692
Characteristic value for mean Hertzian pressure	[pm*]	0.9470
Characteristic value for mean sliding path	[s*]	30.2850
Equivalent Young's modulus (N/mm²)	[Ered]	149673.38
Mean contact stress (N/mm²)	[σHm]	367.36

6.1 Efficiency according method C

Rolling bearing with set support

Bearing loss-power (kW)	[PVLP]	0.126
Number of sealing gaskets (integral worm shaft)	[nVD]	2
Sealing power loss (kW)	[PVD]	0.046
Idle power loss (kW)	[PV0]	0.153
Base friction number	[µOT]	0.0245
Size factor	[YS]	1.000
Geometry factor	[YG]	1.006
Roughness factor	[YR]	1.000
Material Coefficient YW	[YW]	0.950
Mean tooth friction number	[µzm]	0.0234
Tooth friction angle (°)	[ρz]	1.341
Meshing efficiency (%)	[ηz]	90.002
Meshing power loss (kW)	[PVZ]	0.477
Total power loss (kW)	[PV]	0.802
Total efficiency (%)	[ηGes]	84.872

6.2 Wheel bulk temperature

Lubrication type	Oil bath lubrication	
For immersed worm wheel		
Cooled surface of the gear set (cm²)	[AR]	50.840
Heat transition coefficient wheels (W/m²/K)	[αL]	24440.000
Wheel bulk temperature (°C)	[θM]	77.1
Oil sump temperature (°C)	[θS]	73.2

7 Wear strength according method B,C

		------- Worm	---------- Worm wheel -------
Mean lubricant gap thickness (µm)	[hminm]	0.2480	
h_{minm} calculated with:			
-Dynamic viscosity (Ns/m²)	[ηOM]	0.0642	
-Wheel bulk temperature (°C)	[θM]	77.0676	
Pressure factor	[WH]	1.0000	
Factor for lubricant structure	[WS]	2.6140	
Factor for start	[WNS]	1.0000	
Characteristic value	[Kw]	0.6484	
Reference wear intensity	[JOT]	5.10181e-10	
Wear intensity	[Jw]	8.92817e-10	
Wear path (m)	[sWm]	815830	
Wear removal (mm)	[δWn]	0.728	
Permissible tooth thickness reduction (coefficient in module)	[ΔS]	0.300	
Permissible mass decrease (kg)			
Normal tooth thickness at tip circle (mm)	[san]		2.907
(mm)	[san.e/i]		2.778 /2.731
Permissible wear on flank (mm)	[δWlimn]	1.171	
Limited by: Permissible tooth thickness decrease			
Safety against wear	[SW]	1.608	
Required safety	[SWmin]	1.100	
As information:			
Achievable service life, with S_W=1.100 (h)	[Lh]	36551.05	

8 Pitting resistance according to Method B or C

		------- Worm	---------- Worm wheel -------
Mean contact stress (N/mm²)	[σHm]	367.36	
Life coefficient	[Zh]		1.000
Speed factor	[ZV]		0.851
Size factor	[ZS]		1.000
Lubrication factor	[Zoil]		1.000
Ratio factor	[Zu]	1.000	
Boundary value of average contact stress (N/mm²)	[σHG]		442.766
Safety factor for contact stress	[SH]		1.205
Required safety	[SHmin]		1.000
As information:			
Achievable service life, with S_{Hmin}=1.000 (h)	[Lh]	76640.71	

9 Deflection safety

Worm shaft bearing distance l_1 (mm)	[l1]	150.000
Bearing distances in worm shaft l_{11} (mm)	[l11]	75.000
Deflection (mm)	[δm]	0.030
Boundary value bending (mm)	[δlim]	0.080
Safety for deflection	[Sδ]	2.632
Required safety	[Sδmin]	1.000

10 Calculation of strength (fracture) according to Method C

Calculation taking into account the decrease of the tooth-thickness due to wear, with minimum, δ_{Wn}, δ_{Wlimn}

		------- Worm	---------- Worm wheel -------
Tooth thickness at root (mm)	[sft2]		9.663
Tooth form factor	[YF2]		1.200
Contact ratio factor	[Yε]	0.500	
Lead coefficient	[Yγ]	1.024	
Rim thickness (mm)	[sk2]		10.000
Rim thickness coefficient	[YK2]		1.000
Nominal shear stress at tooth root (N/mm²)	[τF2]		35.51

No Quality reduction by small plastic deformation is accepted.

Life coefficient	[YNL]	1.000
Boundary value of shear stress at tooth root (N/mm²)	[τFG]	90.00
Safety for tooth root stress	[SF]	2.534
Required safety	[SFmin]	1.100

11 Temperature safety according to Method C

Housing with cooler

Ambient temperature (°C)	[TU]	20.0
Oil temperature (°C)	[θOil]	73.2
Boundary value oil temperature (°C)	[θSlim]	100.0
Required safety	[STmin]	1.100
Oil sump temperature (°C)	[θS]	73.2
Temperature safety	[ST=θSlim/θS]	1.366

12 Allowances for tooth thickness

		------- Worm	------------------ Worm wheel -------
Tooth thickness tolerance		Own Input	Own Input
Tooth thickness allowance (normal section) (mm)	[Asn.e/i]	0.000 /-0.040	-0.128 /-0.168

12.1 Base tangent lengths

		------- Worm	------------------ Worm wheel -------
Number of teeth spanned	[k]		5.000
Base tangent length (mm)	[Wk]		54.275
Base tangent length with allowance (mm)	[Wk.e/i]		54.155 /54.117
Diameter of measuring circle (mm)	[dMWk.m]		162.549

Base tangent length (span): Can only be measured, if the worm-wheel is manufactured like a cylindrical gear!

12.2 Measurement over balls and pins

		------- Worm	------------------ Worm wheel -------
Theoretical diameter of ball/pin (mm)	[dm]	6.565	6.615
Effective diameter of ball/pin (mm)	[DMeff]	7.000	7.000
Radial single-ball measurement, no backlash (mm)	[MrK]		87.190
Radial single-ball measurement (mm)	[MrK.e/i]		87.034 /86.985
Diameter of measuring circle (mm)	[dMMr.m]	37.166	164.455
Diametral measurement over two balls, no backlash (mm)			[MdK] 174.257
Diametral measurement over two balls (mm)	[MdK.e/i]		173.946 /173.848
Dimensions over 3 pins, no backlash (mm)	[Md3R]	46.559	
Measurement over 3 pins with allowance (mm)	[Md3R.e/i]	46.559 /46.452	

12.3 Tooth thickness

		------- Worm	------------------ Worm wheel -------
Normal tooth thickness (chord) in the reference circle (mm)			
	[sc]	6.133	6.132
(mm)	[sc.e/i]	6.133 /6.093	6.003 /5.962
Tooth thickness in the transverse section (chord) in the reference circle (mm)			
	['st]		6.282
(mm)	['st.e/i]		6.151 /6.110
Tooth thickness in the transverse section (arc) in the reference circle (mm)			
	[st]		6.283
(mm)	[st.e/i]		6.152 /6.111
Tooth thickness in the axial section (mm)	[smx]	6.283	
(mm)	[smx.e/i]	6.283 /6.242	
Tooth space in the axial section (mm)	[emx]	6.283	
(mm)	[emx.e/i]	6.283 /6.324	
Reference chordal height from da.m (mm)	[ham1,ha2]	3.997	4.052

12.4 Backlash

		Pair
Backlash free center distance (mm)	[aControl]	99.820 /99.707
Backlash free center distance, allowances (mm)	[jta]	-0.180 /-0.293
Center distance allowances (mm)	[Aa.e/i]	0.018 /-0.018
Circumferential backlash, transverse section (mm)	[jt]	0.226 /0.118
Normal backlash (mm)	[jn]	0.207 /0.108
Torsional angle on input with fixed output:		
Total torsional angle (°)	[j.tSys]	3.2390/1.6913 (3°14'20"/ 1°41'29")

13 Toothing tolerances

		Worm	Worm wheel
According to DIN 3974:1995			
Accuracy grade	[Vqual]	6	7
Single pitch deviation (µm)	[fpx,fp2]	8.50	13.00
Adjacent pitch difference (µm)	[fux,fu2]	11.00	16.00
Total deviation of the slope (µm)	[Fpz]	11.00	
Total cumulative pitch deviation (µm)	[Fp2]		51.00
Profile slope deviation (µm)	[fHα]	7.50	11.00
Profile form deviation (µm)	[ffα]	11.00	15.00
Total profile deviation (µm)	[Fα]	13.00	19.00
Runout (µm)	[Fr]	18.00	35.00
Single flank composite, total (µm)	[Fi']	29.00	56.00
Single flank composite, tooth-to-tooth (µm)	[fi']	15.00	22.00

14 Supplementary data

		Worm	Worm wheel
Mass - calculated with da (kg)	[m]	0.456	1.812
Start under load: Worm driving			
Tooth friction number, acc. to Niemann	[µzmS]	0.140	
Torque (Nm)	[T1S]	48.195	587.282

15 Service life, damage

Required safety for tooth root	[S_{Fmin}]	1.1000
Required safety for tooth flank	[S_{Hmin}]	1.0000
Required service life	[H]	25000.0000
Service life (calculated with required safeties):		
System service life (h)	[H_{att}]	36551

		Worm	Worm wheel
Tooth root service life (h)	[H_{Fatt}]	1e+06	1e+06
Tooth flank service life (h)	[H_{Hatt}]	1e+06	7.665e+04

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

15.1 Damage

Damage relative to the required service life (H, 25000.0 h)

F_1 (%)	F_2 (%)	H_1 (%)	H_2 (%)
0.0000	0.0000	0.0000	32.6166

Damage relative to the system service life (H_{att}, 36551.0 h)

F_1 (%)	F_2 (%)	H_1 (%)	H_2 (%)
0.0000	0.0000	0.0000	47.6869

16 Remarks

16.1 Conventions

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

- The circumferential backlash specification and the backlash-free center distance for the tooth thickness check have not been checked accurately. They are only guide values.
- The normal chordal tooth thickness value, calculated according to ISO TR 14521:2020/DIN 3975:2002, without taking into account the exact shape of flank, is imprecise. It is only a guide value.
- ISO 14521 and DIN 3996 do not always provide the necessary data for every material. In these cases, this message is displayed: "Not calculated, material data missing".

End of report (lines: 473)