

Ferrari F40, transmission analysis second gear, spur gears

f40_gears

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Description	Analysis of the second gear of the Ferrari F40, simplified with two equivalent spur gears
	ForEveryone (1113) KISSsoft Release 2022 -SP3

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1 Messages



The difference between the tooth mass temperature θ_M (109.4 °C) and the temperature (90.0 °C) used when the micropitting test process was performed is greater than (15.0 °C).
The results for micropitting should therefore be used with caution.

2 Overview

Calculation method	ISO 6336:2019		
Drawing or article number:			
Gear 1:	0.000.0		
Gear 2:	0.000.0		
		----- Gear 1 -----	Gear 2 -----
Power (kW)	[P]	94.248	
Speed (1/min)	[n]	3000.0	1750.0
Number of load cycles (in mio.)	[NL]	3600.000	2100.000
Torque (Nm)	[T]	300.0	514.3
Application factor	[KA]	1.25	
Required service life (h)	[H]	20000.00	
Gear driving (+) / driven (-)		+	-
Working flank Gear 1:	Right flank		
Gear 1 direction of rotation:	Clockwise		

3 Tooth geometry

Geometry calculation according to	ISO 21771:2007		
		----- Gear 1 -----	Gear 2 -----
Center distance (mm)	[a]	85.500	
Center distance tolerance	ISO 286:2010 Measure js6		
Normal module (mm)	[mn]	3.0000	
Normal pressure angle (°)	[αn]	20.0000	
Helix angle at reference circle (°)	[β]	0.0000	
Number of teeth	[z]	21	36
Facewidth (mm)	[b]	20.00	20.00
Hand of gear	Spur gear		
Accuracy grade	[Q-ISO 1328:2013]	A6	A6
Inner diameter (mm)	[di]	20.00	35.00
Inner diameter of gear rim (mm)	[dbi]	0.00	0.00

4 Materials

Gear 1

18CrNiMo7-6, Case hardening steel, case-hardened, ISO 6336-5 Figure 9/10 (MQ), Core hardness $\geq 25\text{HRC}$ Jominy J=12mm<HRC28

Gear 2

18CrNiMo7-6, Case hardening steel, case-hardened, ISO 6336-5 Figure 9/10 (MQ), Core hardness $\geq 25\text{HRC}$ Jominy J=12mm<HRC28

		----- Gear 1 -----	Gear 2 -----
Surface hardness		HRC 61	HRC 61
Material treatment according to ISO 6336:2006 Normal, Life factors Z_{NT} and $Y_{NT} \geq 0.85$			
Infinite life strength for tooth root stress (N/mm ²)	[σFlim]	430.00	430.00
Fatigue strength for Hertzian pressure (N/mm ²)	[σHlim]	1500.00	1500.00
Young's modulus (N/mm ²)	[E]	206000	206000
Poisson's ratio	[ν]	0.300	0.300

Tensile strength (N/mm ²)	[σB]	1200.00	1200.00
Yield point (N/mm ²)	[σS]	850.00	850.00

4.1 Roughnesses

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

4.2 Lubrication

Lubrication type	Oil bath lubrication		
Type of oil	Klübersynth GE 4 75 W 90 (API GL 5)		
Lubricant base	Synthetic oil based on Polyalphaolefin		
Oil nominal kinematic viscosity at 40°C (mm ² /s)	[v40]	130.00	
Oil nominal kinematic viscosity at 100°C (mm ² /s)	[v100]	18.00	
Specific density at 15°C (kg/dm ³)	[ρ]	0.860	
Oil temperature (°C)	[TS]	80.000	

5 Geometry

5.1 Reference profiles

Gear reference profile 1

Reference profile, Own Input	1.25 / 0.38 / 1.0 ISO 53:1998 Profil A		
Dedendum coefficient	[hfP*]	1.250	
Root radius factor	[pfP*]	0.380	
	[pfPmax*]	0.472	
Addendum coefficient	[haP*]	1.000	
Tip radius factor	[paP*]	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]	1.255 / 1.261	

Gear reference profile 2

Reference profile, Own Input	1.25 / 0.38 / 1.0 ISO 53:1998 Profil A		
Dedendum coefficient	[hfP*]	1.250	
Root radius factor	[pfP*]	0.380	
	[pfPmax*]	0.472	
Addendum coefficient	[haP*]	1.000	
Tip radius factor	[paP*]	0.000	
Protuberance height coefficient	[hprP*]	0.000	
Protuberance angle	[αprP]	0.000	
Tip form height coefficient	[hFaP*]	0.000	
Ramp angle	[αKP]	0.000	
	not topping		
Smallest radius of curvature, root rounding (mm)	[ρmin.e/i]	1.347 / 1.354	

5.1.1 Information on final machining

		----- Gear 1 -----	----- Gear 2 -----
Dedendum reference profile	[hfP*]	1.250	1.250
Tooth root radius Refer. profile	[pfP*]	0.380	0.380
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]	2.0 / 2.0	2.0 / 2.0

5.2 Basic data

Overall transmission ratio	[itot]	-1.714	
Gear ratio	[u]	1.714	
Transverse module (mm)	[mt]	3.000	
Transverse pressure angle (°)	[αt]	20.000	
Working pressure angle (°)	[αwt]	20.000	
(°)	[αwt.e/i]	20.020 / 19.980	
Working pressure angle at normal section (°)	[αwn]	20.000	
Base helix angle (°)	[βb]	0.000	
Helix angle at operating pitch circle (°)	[βw]	0.000	
Reference center distance (mm)	[ad]	85.500	
Sum of profile shift coefficients	[Σxi]	0.0000	
----- Gear 1 ----- Gear 2 -----			
Profile shift coefficient	[x]	0.2485	-0.2485
Generating profile shift coefficient	[xE.e/i]	0.2164/0.1981	-0.2806/-0.2989
Virtual gear no. of teeth	[zn]	21.000	36.000
Involute length (mm)	[l_dFa-l_dFf]	5.888	5.253

5.3 Diameters and their allowances

----- Gear 1 ----- Gear 2 -----			
Reference diameter (mm)	[d]	63.000	108.000
Base diameter (mm)	[db]	59.201	101.487
Tip alteration (mm)	[k*mn]	0.000	0.000
Tip diameter (mm)	[da]	70.491	112.509
(mm)	[da.e/i]	70.491 / 70.461	112.509 / 112.474
Tip diameter allowances (mm)	[Ada.e/i]	0.000 / -0.030	0.000 / -0.035
Tip form diameter (mm)	[dFa]	70.491	112.509
(mm)	[dFa.e/i]	70.491 / 70.461	112.509 / 112.474
Active tip diameter (mm)	[dNa]	70.491	112.509
(mm)	[dNa.e/i]	70.491 / 70.461	112.509 / 112.474
Operating pitch diameter (mm)	[dw]	63.000	108.000
(mm)	[dw.e/i]	63.008 / 62.992	108.014 / 107.986
Root diameter (mm)	[df]	56.991	99.009
Generated root diameter with xE (mm)	[df.e/i]	56.799 / 56.689	98.817 / 98.707
Active root diameter (mm)	[dNf]	60.026	103.481
(mm)	[dNf.e/i]	60.050 / 60.015	103.505 / 103.469
Root form diameter (mm)	[dFf]	59.789	102.595
(mm)	[dFf.e/i]	59.713 / 59.671	102.514 / 102.469

5.4 Tip clearances and tooth heights

----- Gear 1 ----- Gear 2 -----			
Theoretical tip clearance (mm)	[c]	0.750	0.750
Effective tip clearance (mm)	[c.e/i]	0.927 / 0.835	0.930 / 0.835
Reserve (dNf-dFf)/2 (mm)	[cF.e/i]	0.189 / 0.151	0.518 / 0.478
Addendum, $m_n(h_{aP}^*+x+k)$ (mm)	[ha]	3.745	2.255
(mm)	[ha.e/i]	3.745 / 3.730	2.255 / 2.237
Dedendum, $m_n(h_{fP}^*-x)$ (mm)	[hf]	3.005	4.495
(mm)	[hf.e/i]	3.101 / 3.156	4.592 / 4.647
Tooth height (mm)	[h]	6.750	6.750

5.5 Roll angle

		----- Gear 1 -----	Gear 2 -----
Roll angle at dFa (°)	[ξFa.e/i]	37.034 /36.981	27.419 /27.373
Roll angle to dNf (°)	[ξNf.e/i]	9.741 /9.538	11.483 /11.379
Roll angle at dFf (°)	[ξFf.e/i]	7.551 /7.240	8.172 /7.990

5.6 Tooth thickness and pitch

		----- Gear 1 -----	Gear 2 -----
Tooth thickness, arc, in module	[sn*]	1.7517	1.3899
Normal tooth thickness at tip circle (mm)	[san]	1.816	2.397
(mm)	[san.e/i]	1.757 /1.693	2.340 /2.282
Normal tooth thickness at tip form circle (mm)	[sFan]	1.816	2.397
(mm)	[sFan.e/i]	1.757 /1.693	2.340 /2.282
Normal space width at root circle (mm)	[efn]	0.000	0.000
(mm)	[efn.e/i]	0.000 /0.000	0.000 /0.000
Pitch on reference circle (mm)	[pt]	9.425	9.425
Base pitch (mm)	[pbt]	8.856	8.856
Transverse pitch on contact-path (mm)	[pet]	8.856	8.856

5.7 Sliding

		----- Gear 1 -----	Gear 2 -----
Max. sliding velocity at tip (m/s)	[vga]	4.158	2.892
Specific sliding at the tip	[ζa]	0.692	0.650
Specific sliding at the root	[ζf]	-1.856	-2.244
Mean specific sliding	[ζm]	0.675	
Sliding factor on tip	[Kga]	0.420	0.292
Sliding factor on root	[Kgf]	-0.292	-0.420

5.8 Contact ratios

		----- Pair -----	
Minimal length of contact line (mm)	[Lmin]	20.000	
Transverse contact ratio	[εα]	1.600	
	[εα.e/m/i]	1.604 /1.597/1.589	
Overlap ratio	[εβ]	0.000	
Total contact ratio	[εγ]	1.600	
	[εγ.e/m/i]	1.604 /1.597/1.589	
Length of path of contact (mm)	[ga]	14.173	
(mm)	[ga.e/i]	14.206 /14.073	
		----- Gear 1 -----	Gear 2 -----
Addendum contact ratio	[ε]	0.944	0.656
	[ε.e/i]	0.945 /0.939	0.659 /0.650
Length T1-A and T2-A (mm)	[T1A,T2A]	4.959	24.283
(mm)	[.e/i]	4.927 / 5.032	24.283 /24.243
Length T1-B and T2-B (mm)	[T1B,T2B]	10.276	18.966
(mm)	[.e/i]	10.276 /10.249	18.934 /19.026
Length T1-C and T2-C (mm)	[T1C,T2C]	10.774	18.469
(mm)	[.e/i]	10.762 /10.785	18.449 /18.489
Length T1-D and T2-D (mm)	[T1D,T2D]	13.816	15.427
(mm)	[.e/i]	13.784 /13.889	15.427 /15.386
Length T1-E and T2-E (mm)	[T1E,T2E]	19.133	10.110
(mm)	[.e/i]	19.133 /19.105	10.078 /10.170
Length T1-T2 (mm)	[T1T2]	29.243	
(mm)	[.e/i]	29.211 /29.275	
Diameter of single contact point B (mm)	[d-B]	62.667	108.344
(mm)	[d-B.e/i]	62.667 /62.649	108.322 /108.386
Diameter of single contact point D (mm)	[d-D]	65.332	106.073
(mm)	[d-D.e/i]	65.304 /65.393	106.073 /106.050

6 General influence factors

6.1 Forces and circumferential speed

		----- Gear 1 -----	Gear 2 -----
Nominal circum. force at pitch circle (N)	[Ft]	9523.8	
Axial force (N)	[Fa]	0.0	0.0
Radial force (N)	[Fr]	3466.4	3466.4
Normal force (N)	[Fnorm]	10135.0	10135.0
Nominal circumferential force per mm (N/mm)	[w]	476.19	
Only as information: Forces at operating pitch circle:			
Nominal circumferential force (N)	[Ftw]	9523.8	
Axial force (N)	[Faw]	0.0	0.0
Radial force (N)	[Frw]	3466.4	
Circumferential speed reference circle (m/s)	[v]	9.90	
Circumferential speed operating pitch circle (m/s)	[v(dw)]	9.90	

6.2 Contact stiffness

Running-in value (μm)	[yp]	0.6	
Running-in value (μm)	[yf]	0.7	
Correction factor	[CM]	0.800	
Gear blank factor	[CR, bs/b, sr/mn]	0.918	(0.250,6.115)
Basic rack factor	[CBS]	0.975	
Material coefficient	[E/Est]	1.000	
Singular tooth stiffness (N/mm/ μm)	[c']	11.661	
Meshing stiffness (N/mm/ μm)	[cy α]	16.912	
Meshing stiffness (N/mm/ μm)	[cy β]	14.375	
Reduced mass (kg/mm)	[mRed]	0.01033	
Resonance speed (min-1)	[nE 1]	18401	
Resonance ratio (-)	[N]	0.163	
Subcritical range			

6.3 Calculation of K factors

Running-in value (μm)	[y α]	0.7
Bearing distance l of pinion shaft (mm)	[l]	40.000
Distance s of pinion shaft (mm)	[s]	4.000
Outside diameter of pinion shaft (mm)	[dsh]	20.000
Load in accordance with Figure 13, ISO 6336-1:2006 0:a), 1:b), 2:c), 3:d), 4:e)	[-]	4
Coefficient K' according to Figure 13, ISO 6336-1:2006	[K']	-0.60
With stiffening		
Tooth trace deviation (active) (μm)	[F β y]	3.61
from deformation of shaft (μm)	[fsh*B1]	2.88
fsh (μm)	[fsh]	2.88
B1	[B1]	1.00
fH β 5 (μm)	[fH β 5]	6.00
Tooth without flank line modification		
Position of contact pattern:	favorable	
from production tolerances (μm)	[fma*B2]	12.02
B ₂ =1.00		
Tooth trace deviation, theoretical (μm)	[F β x]	4.25
Running-in value (μm)	[y β]	0.64

6.4 K factors

Dynamic factor	[Kv]	1.055
Width factors		
- Flank	[KH β]	1.041
- Tooth root	[KF β]	1.028
- Scuffing	[KB β]	1.041

Transverse load factors		
- Flank	[KH α]	1.000
- Tooth root	[KF α]	1.000
- Scuffing	[KB α]	1.000
Application factor	[KA]	1.250
Distribution factor	[K γ]	1.000

7 Calculation of tooth root strength (fracture)

Calculation of Tooth form coefficients according method: B

		----- Gear 1 -----	Gear 2 -----
Calculated with generating profile shift coefficient	[xE.i]	0.1981	-0.2989
Tooth form factor	[YF]	1.41	1.81
Stress correction factor	[YS]	1.99	1.69
Load application angle (°)	[α Fen]	21.21	18.41
Load distribution influence factor	[f ϵ]		1.000
Load application diameter (mm)	[d _{en}]	65.332	108.344
Bending moment arm (mm)	[hF]	3.04	3.53
Tooth thickness at root (mm)	[sFn]	6.21	5.96
Tooth root radius (mm)	[ρ F]	1.51	1.91
Bending moment arm (-)	[hF/mn]	1.013	1.177
Tooth thickness at root (-)	[sFn/mn]	2.069	1.987
Tooth root radius (-)	[ρ F/mn]	0.504	0.637
Calculation cross section diameter (mm)	[d _{sFn}]	57.761	100.075
Tangents on calculation cross section (°)	[α sFn]	30.000	30.000
Notch parameter	[q _s]	2.053	1.561
Helix angle factor	[Y β]		1.000
Deep tooth factor	[YDT]		1.000
Gear rim factor	[YB]	1.00	1.00
Effective facewidth (mm)	[beff]	20.00	20.00
Nominal stress at tooth root (N/mm²)	[σ F0]	445.71	483.70
Tooth root stress (N/mm²)	[σ F]	604.52	656.04
Permissible bending stress at root of Test-gear			
Notch sensitivity factor	[Y _{drel} T]	0.996	0.990
Surface factor	[Y _{Rrel} T]	0.957	0.957
Size factor, tooth root	[YX]	1.000	1.000
Life factor	[YNT]	0.868	0.877
Y _{drel} T*Y _{Rrel} T*Y _X *Y _{NT}		0.826	0.831
Alternating bending factor, mean stress influence coefficient	[YM]	1.000	1.000
Stress correction factor	[YST]		2.00
YST* σ Flim (N/mm²)	[σ FE]	860.00	860.00
Permissible tooth root stress σ FG/SFmin (N/mm²)	[σ FP]	507.65	510.43
Limit strength tooth root (N/mm²)	[σ FG]	710.71	714.60

7.1 Safety factors

		----- Gear 1 -----	Gear 2 -----
Required safety	[SFmin]	1.40	1.40
Safety for tooth root stress	[SF= σ FG/ σ F]	1.18	1.09
Transmittable power (kW)	[kWRating]	79.15	73.33

8 Calculation of flank strength (pitting)

		----- Gear 1 -----	Gear 2 -----
Zone factor	[ZH]		2.495
Elasticity factor ($\sqrt{N/mm^2}$)	[ZE]		189.812
Contact ratio factor	[Z ϵ]		0.894
Helix angle factor	[Z β]		1.000
Effective facewidth (mm)	[beff]		20.00
Nominal contact stress (N/mm²)	[σ H0]		1465.00
Contact stress at operating pitch circle (N/mm²)	[σ Hw]		1716.82
Single tooth contact factor	[ZB,ZD]	1.01	1.00
Contact stress (N/mm²)	[σ HB, σ HD]	1734.66	1716.82

Lubricant coefficient for N_L	[ZL]	0.982	0.982
Speed factor at N_L	[ZV]	1.000	1.000
Roughness factor for N_L	[ZR]	0.953	0.953
Material hardening factor for N_L	[ZW]	1.000	1.000
Life factor	[ZNT]	0.877	0.892
	[ZL*ZV*ZR*ZNT]	0.821	0.835
Limited pitting is permissible:	No		
Size factor (flank)	[ZX]	1.000	1.000
Permissible contact stress, $\sigma_{HG}/\sigma_{Hmin}$ (N/mm ²)	[σ_{HP}]	1231.59	1252.12
Pitting stress limit (N/mm ²)	[σ_{HG}]	1231.59	1252.12

8.1 Safety factors

		----- Gear 1 -----	Gear 2 -----
Required safety	[SHmin]	1.00	1.00
Safety factor for contact stress on operating pitch circle	[SHw]	0.72	0.73
Safety against pressure, σ_{HG}/σ_{HBD} Single contact	[SHBD]	0.71	0.73
Safety regarding transmittable torque	[SHBD ²]	0.50	0.53
Transmittable power (kW)	[kWRating]	47.51	50.13

9 Micropitting

Calculation method according to ISO/TS 6336-22:2018
 Lubricant load according to FVA Info sheet 54/7 10, Klübersynth GE 4 75 W 90 (API GL 5)
 Reference data FZG-C Test:

Torque (Nm)	[T1Ref]	265.100
Line load at contact point A (N/mm)	[FbbRef,A]	236.300
Oil temperature (°C)	[θ_{OilRef}]	90.000
Tooth mass temperature (°C)	[θ_{MRef}]	122.236
Contact temperature (°C)	[$\theta_{BRef,A}$]	222.179
Lubrication gap thickness (µm)	[hRef,A]	0.046
Specific film thickness in test	[λ_{GFT}]	0.092

		----- Gear 1 -----	Gear 2 -----
Calculation of permissible specific film thickness			
Material coefficient	[WW]	1.000	
Permissible specific film thickness	[λ_{GFP}]	0.129	

Interim results in accordance with ISO/TS 6336-22:2018

Coefficient of friction	[μ_m]	0.063
Lubricant factor	[XL]	0.800
Roughness factor	[XR]	1.199
Lubrication coefficient for lubrication type	[XS]	1.000
Tooth mass temperature (°C)	[θ_M]	109.392
Tip relief factor	[XCa(A)]	1.000
Loss factor	[HV]	0.171
Equivalent Young's modulus (N/mm ²)	[Er]	226373.626
Pressure-viscosity coefficient (m ² /N)	[α_{38}]	0.01317
Dynamic viscosity (Ns/m ²)	[$\eta_t M$]	11.551
Roughness average value (µm)	[Ra]	0.600

Calculation of speeds, load distribution and flank curvature according to method B following ISO/TS 6336-22:2018.

C_a taken as optimal in the calculation. 0=no, 1=yes	0	0
Calculation at point (0:A, 1:AB, 2:B, 3:C, 4:D, 5:DE, 6:E, -1:No Point)	0	
Diameter (mm)	[dy]	60.026 112.509
Relative radius of curvature (mm)	[pred]	4.118
Load sharing factor	[XY]	0.333
Contact stress (N/mm ²)	[pH]	1215.619
Contact stress (N/mm ²)	[pdy]	1424.569
Minimal specific film thickness	[λ_{GFY}]	0.111 ($h_v=0.066 \mu m$)
Safety against micropitting	[$\lambda(B)$]	0.854
For interim results, refer to file:	Micropitting_12.tmp	

10 Safety of hardened layer (subsurface fatigue)

CHD according to	DNV 41.2:2012		
		----- Gear 1 -----	Gear 2 -----
Required hardening depth EHT (mm)	[t550]	0.50 /0.60	0.50 /0.60
Required hardness at t550 (HV)	[HV.t]	550	550
Required hardening depth EHT (mm)	[t400]	0.90 /1.10	0.90 /1.10
Required hardness at t400 (HV)	[HV.t]	400	400
Required hardening depth EHT (mm)	[t300]	1.30 /1.60	1.30 /1.60
Required hardness at t300 (HV)	[HV.t]	300	300
Condition for hardness on the surface (HV)	[HV.0] >	768 , HRC	63> 768, HRC 63
HV.0 is calculated with $t_z/a_H = 0.5$, $S_H = \min(S_{EHT}, S_{Hssmin})$			
Safety of the hardened layer	[SEHT]	0.00	0.00
Required safety	[SHssmin]	1.00	1.00
Result		1	1
-1: Not checked, 0: CHD too small, 1: CHD too large or HV.0 too deep, 2: CHD too large ($> 0.25 \cdot m_n$, $t > s_{an}/3$)			
3: Check performed, 4: Check performed with insufficient hardening depths ($t_z/a_H < 0.5$, $t_z/a_{Hst} < 0.6$)			
5: EHT to large, tooth tip through hardend ($> 0.50 \cdot m_n$, $t > 2 \cdot s_{an}/3$)			

11 Tooth flank fracture

Calculation method according to	ISO/TS 6336-4 (2019)		
Calculation according to Method B			
		----- Gear 1 -----	Gear 2 -----
Calculation at point (0:A, 1:AB, 2:B, 3:C, 4:D, 5:DE, 6:E, -1:No Point)		2	2
Diameter (mm)	[dy]	62.667	108.344
Relative radius of curvature (mm)	[pred]	6.665	6.665
Load sharing factor	[XCP]	1.000	1.000
Contact stress (N/mm ²)	[pH]	1655.071	1655.071
Contact stress (N/mm ²)	[pdyn]	1939.558	1939.558
Required hardening depth EHT (mm)	[t550]	0.50 /0.60	
Required hardening depth EHT (mm)	[t550]		0.50 /0.60
The calculation will be performed with the minimum hardening depth			
Core hardness (HV)	[HV _{core}]	342	342
Hardness curve from:			
HV(y) gear 1	ISO/TS 6336-4, chapter 7.3.3, Method C1		
HV(y) gear 2	ISO/TS 6336-4, chapter 7.3.3, Method C1		
Maximum material exposure	[AFFmax]	0.828	0.828
Depth of maximum load (mm)	[y]	-1.050	-1.050
Material coefficient	[K _{material}]	1.131	1.131
Material shearing strength (N/mm ²)	[τ_{per}]	164.250	164.250
Equivalent stress state (N/mm ²)	[τ_{eff}]	129.419	129.419
Safety factor	[SFF]	1.173	1.173
$(S_{FF} = 1/(A_{FF,max} + 0.2) + 0.2)$			

12 Scuffing load capacity

Calculation method according to	ISO/TS 6336-20/21:2017		
		----- Gear 1 -----	Gear 2 -----
Thermal contact coefficient (N/mm/s ^{0.5} /K)	[BM]	13.780	13.780
Relevant tip relief (μ m)	[Ca]	2.00	2.00
Optimal tip relief (μ m)	[Ceff]	51.05	
C _a taken as optimal in the calculation. 0=no, 1=yes		0	0
		----- Pair -----	
Helical load factor for scuffing	[KBy]	1.000	

Lubrication coefficient for lubrication type	[XS]	1.000	
Scuffing test and load stage	[FZGtest]	FZG - Test A / 8.3 / 90 (ISO 14635 - 1)	14
Multiple meshing factor	[Xmp]	1.000	
Relative structural factor, scuffing	[XWrelT]	1.000	
Effective facewidth (mm)	[beff]	20.000	
Applicable circumferential force/facewidth (N/mm)	[wBt]	653.963	
$K_{By} = 1.000$, $w_{Bt} \cdot K_{By} = 653.963$			
Angle factor	[Xαβ]	0.978	
$\varepsilon_1 = 0.944$, $\varepsilon_2 = 0.656$			

12.1 Flash temperature-criteria

		Pair	
Lubricant factor	[XL]	0.681	
Tooth mass temperature (°C)	[θMi]	99.35	
$\theta_{Mi} = \theta_{oil} + X_S \cdot 0.47 \cdot X_{mp} \cdot \theta_{lim}$			
Average flash temperature (°C)	[θflm]	41.16	
Scuffing temperature (°C)	[θS]	380.51	
Γ coordinates (point of highest temperature)	[Γ]	0.723	
[Γ.A]= -0.540, [Γ.E]= 0.776			
Maximum contact temperature (°C)	[θB]	165.34	
Flash factor (°K*N ⁻¹ ·s ⁻¹ ·m ⁻¹ ·mm)	[XM]	50.058	
Approach factor	[XJ]	1.000	
Load sharing factor	[XΓ]	0.369	
Dynamic viscosity (mPa*s)	[ηM]	24.75	(80.0 °C)
Coefficient of friction	[μm]	0.054	
Required safety	[SBmin]	2.000	
Margin of safety for scuffing, flash temperature	[SB]	3.521	

12.2 Integral temperature-criteria

		Pair	
Lubricant factor	[XL]	0.800	
Tooth mass temperature (°C)	[θMC]	107.13	
$\theta_{MC} = \theta_{oil} + X_S \cdot 0.70 \cdot \theta_{flint}$			
Integral scuffing temperature (°C)	[θSint]	381.92	
Flash factor (°K*N ⁻¹ ·s ⁻¹ ·m ⁻¹ ·mm)	[XM]	50.058	
Running-in factor, well run in	[XE]	1.000	
Contact ratio factor	[Xε]	0.239	
Dynamic viscosity (mPa*s)	[ηOil]	24.75	(80.0 °C)
Mean coefficient of friction	[μm]	0.062	
Geometry factor	[XBE]	0.438	
Meshing factor	[XQ]	1.000	
Tip relief factor	[XCa]	1.105	
Mean flash temperature (°C)	[θflaint]	38.75	
Integral tooth flank temperature (°C)	[θint]	165.25	
Required safety	[SSmin]	1.800	
Safety factor for scuffing (intg.-temp.)	[SSint]	2.311	
Safety factor for transmitted moment (int.-T.)	[SSL]	3.542	

13 Measurements for tooth thickness

13.1 Tooth thickness tolerances

		Gear 1	Gear 2
Tooth thickness tolerance		DIN 3967 cd25	DIN 3967 cd25
Tooth thickness allowance (normal section) (mm)	[As.e/i]	-0.070 /-0.110	-0.070 /-0.110

13.2 Base tangent lengths

		Gear 1	Gear 2
Number of teeth spanned	[k]	3.000	4.000
Base tangent length (no backlash) (mm)	[Wk]	23.533	32.000
Base tangent length with allowance (mm)	[Wk.e/i]	23.468 /23.430	31.934 /31.897
(mm)	[ΔWk.e/i]	-0.066 /-0.103	-0.066 /-0.103
Diameter of measuring circle (mm)	[dMWk.m]	63.675	106.387

13.3 Measurement over balls and pins

		----- Gear 1 -----	Gear 2 -----
Theoretical diameter of ball/pin (mm)	[DM]	5.495	4.981
Effective diameter of ball/pin (mm)	[DMeff]	5.500	5.000
Radial single-ball measurement backlash free (mm)	[MrK]	36.186	56.590
Radial single-ball measurement (mm)	[MrK.e/i]	36.115 /36.074	56.494 /56.439
Diameter of measuring circle (mm)	[dMMr.m]	64.343	106.335
Diametral measurement over two balls without clearance (mm)	[MdK]	72.185	113.180
Diametral measurement over two balls (mm)	[MdK.e/i]	72.044 /71.962	112.989 /112.878
Diametral measurement over pins without clearance (mm)	[MdR]	72.185	113.180
Measurement over pins according to DIN 3960 (mm)	[MdR.e/i]	72.044 /71.962	112.989 /112.878
Measurement over 3 pins without play (mm)	[Md3R]	71.999	0.000
Measurement over 3 pins (mm)	[Md3R.e/i]	71.858 /71.776	0.000 /0.000

13.4 Tooth thickness

		----- Gear 1 -----	Gear 2 -----
Reference chordal height from da.m (mm)	[ha]	3.848	2.286
Chordal tooth thickness (mm)	[sc]	5.249	4.169
(mm)	[sc.e/i]	5.181 /5.142	4.100 /4.060
Tooth thickness, arc (mm)	[sn]	5.255	4.170
(mm)	[sn.e/i]	5.185 /5.145	4.100 /4.060

13.5 Backlash

		----- Pair -----
Circumferential backlash from Aa (mm)	[jtw_Aa.e/i]	0.008 /-0.008
Radial backlash (mm)	[jrw.e/i]	0.317 /0.183
Circumferential backlash (transverse section) (mm)	[jtw.e/i]	0.228 /0.132
Normal backlash (mm)	[jn.e/i]	0.214 /0.124
Center distance allowances (mm)	[Aa.e/i]	0.011 /-0.011
Backlash free center distance (mm)	[aControl.e/i]	85.306 /85.194
Backlash free center distance, allowances (mm)	[jta]	-0.194 /-0.306
		----- Gear 1 ----- Gear 2 -----
dNf.i with aControl (mm)	[dNf0.i]	59.752 103.142
Reserve (dNf0.i-dFf.e)/2 (mm)	[cF0.i]	0.020 0.314
Tip clearance (mm)	[c0.i(aControl)]	0.540 0.540
Torsional angle on input with output fixed:		
Total torsional angle (°)	[j.tSys]	0.4147/0.2401

14 Toothing tolerances

		----- Gear 1 -----	Gear 2 -----
According to ISO 1328-1:2013, ISO 1328-2:1997			
Accuracy grade	[Q]	A6	A6
Single pitch deviation (µm)	[fptT]	9.00	9.00
Base circle pitch deviation (µm)	[fpbT]	8.46	8.46
Sector pitch deviation over k/8 pitches (µm)	[Fpk/8T]	19.00	20.00
Profile form deviation (µm)	[ffαT]	9.50	9.50
Profile slope deviation (µm)	[fHαT]	7.50	7.50
Total profile deviation (µm)	[FαT]	12.00	12.00
Helix form deviation (µm)	[ffβT]	9.50	9.50
Helix slope deviation (µm)	[fHβT]	8.50	8.50
Total helix deviation (µm)	[FβT]	13.00	13.00
Total cumulative pitch deviation (µm)	[FpT]	26.00	28.00
Adjacent pitch difference (µm)	[fuT]	13.00	13.00
Runout (µm)	[FrT]	24.00	25.00
Single flank composite, total (µm)	[FisT]	35.00	37.00
Single flank composite, tooth-to-tooth (µm)	[fisT]	8.50	8.50
Radial composite, total (µm)	[FidT]	36.00	36.00

Radial composite, tooth-to-tooth (μm) [fidT] 14.00 14.00
FidT (Fi") and fidT (fi") according to ISO 1328:1997 calculated with the geometric mean values for m_n and d.

According to ISO 1328-2:2020

Accuracy grade	[Q]	R39	R40
Radial composite, total (μm)	[FidT]	29.00	36.00
Radial composite, tooth-to-tooth (μm)	[fidT]	14.00	16.00

Axis alignment tolerances recommendation acc. to ISO TR 10064-3:1996, Quality 6
Maximum value for deviation error of axis (μm) [f $\Sigma\beta$] 13.00 ($F_\beta=13.00$)
Maximum value for inclination error of axes (μm) [f $\Sigma\delta$] 26.00

15 Modifications and determination of the tooth form

15.1 Data for the tooth form calculation

Data not available.

Please run the calculation in the "Tooth form" tab and open the main report again.

16 Supplementary data

Maximal possible center distance (eps_a=1.0) [aMAX] 87.461

16.1 Masses, stiffnesses and moments of inertia

		----- Gear 1 -----	----- Gear 2 -----
Mass (kg)	[m]	0.451	1.225
Total mass (kg)	[mGes]	1.676	
Moment of inertia for system, relative to the input: calculation without consideration of the exact tooth shape			
Gears individually ((da+df)/2...di) ($\text{kg}\cdot\text{m}^2$)	[J]	0.0002513	0.0019
System (da+df)/2...di ($\text{kg}\cdot\text{m}^2$)	[J]	0.000898	

16.2 Wear, power loss, sound pressure level

Torsional stiffness at driving gear with fixed driven gear:

Torsional stiffness (MNm/rad)	[cr]	0.252
Torsion when subjected to nominal torque (°)	[δcr]	0.068
Average coefficient of friction according to Niemann	[μ_m]	0.062
Wear sliding coef. by Niemann	[ζ_w]	1.080
Loss factor	[HV]	0.171
Gear power loss (kW)	[PVZ]	1.000
Meshing efficiency (%)	[η_z]	98.939
Sound pressure level based on Masuda, without PPTE/ δ_s	[dB(A)]	79.553

17 Service life, damage

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

Service life (calculated with required safeties):

System service life (h)	[H _{att}]	8.909
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		----- Gear 1 -----	----- Gear 2 -----
Tooth root service life (h)	[H _{Fatt}]	12.71	8.909
Tooth flank service life (h)	[H _{Hatt}]	23.96	46.32

17.1 Damage

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

F ₁ (%)	F ₂ (%)	H ₁ (%)	H ₂ (%)
--------------------	--------------------	--------------------	--------------------

9999.9900	9999.9900	9999.9900	9999.9900
	0		0

Damage relative to the system service life (H_{alt} , 8.9 h)

F_1 (%)	F_2 (%)	H_1 (%)	H_2 (%)
70.0972	100.0000	37.1749	19.2348

18 Reliability calculation

18.1 Calculation method

Calculation method according to B. Bertsche, Reliability in Automotive and Mechanical Engineering, Springer-Verlag Berlin Heidelberg 2008

18.2 Factors

Reliability of material data for σ_{Hlim} (%)	$[R\sigma_{\text{Hlim}}]$	99.00
Reliability of material data for σ_{Flim} (%)	$[R\sigma_{\text{Flim}}]$	99.00

Calculation of coefficients for reliability $R(t)$

$$R(t) = 100 * \text{Exp}(-((t * \text{fac} - t_0) / (T - t_0))^\beta) \text{ (%)}$$

Gear	Type	fac	β	t_0	T	R(H)
		cycles/h		cycles	cycles	%
1	Tooth root	180000	1.700e+00	2.208e+06	3.394e+06	0.0000
1	Tooth flank	180000	1.300e+00	3.888e+06	1.853e+07	0.0000
2	Tooth root	105000	1.700e+00	9.030e+05	1.388e+06	0.0000
2	Tooth flank	105000	1.300e+00	4.384e+06	2.089e+07	0.0000

fac = Number of load cycles per hour

β = Weibull shape parameter

t_0 = Failure-free number of load cycles

T = Characteristic service life (in load cycles) for 63.2% failure probability

R(H) = Reliability for required service life

18.3 Resulting reliabilities and service lives

Required service life (h)	$[H_{\text{min}}]$	20000.0000
Reliability R, tooth roots subsystem (%)	$[R_{\text{subF}}]$	0.0000
Reliability R, tooth flanks subsystem (%)	$[R_{\text{subH}}]$	0.0000
Reliability R, gears subsystem (%)	$[R_{\text{subG}}]$	0.0000
Required reliability (%)	$[R_{\text{min}}]$	99.0000
Service life H, tooth roots subsystem (h)	$[H_{\text{subF}}]$	8.9088
Service life H, tooth flanks subsystem (h)	$[H_{\text{subH}}]$	23.9644
Service life H, gears subsystem (h)	$[H_{\text{subG}}]$	8.9088

19 Remarks

19.1 Conventions

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

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

19.2 Calculations and factors

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

f_{ma} according to equation 66, f_{sh} according to 59/60, $F_{\beta x}$ according to 54/55/57

K_{Ha} , K_{Fa} according to Method B

- The logarithmically interpolated value must be entered for factors Z_L , Z_V , Z_R , Z_W , Z_X , Y_{drelT} , Y_{RrelT} and Y_X . This value is calculated from the infinite life strength and static strength values, based on the number of load cycles.

End of report (lines: 743)
