KISSsoft 03/2015 – Instructions 072

Contact Analysis in the Cylindrical Gear Calculation

Ho 06.05.11, Update 11.10.2011 Ho; Update 16.09.2013 Ho; Update 31.07.2015 Ho

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SHARING KNOWLEDGE

Contents

1 Initial Situation

Since the 2011 release it is now possible to include and take into account shaft deformation directly in cylindrical gear analysis. If you do so, the deformation that occurs is determined on the basis of the shaft dimensions and included directly in the cylindrical gear analysis. To illustrate this new functionality, KISSsoft is providing a number of pre-defined example analyses for cylindrical gears and the shafts associated with them. The relevant examples are highlighted in the figure below.

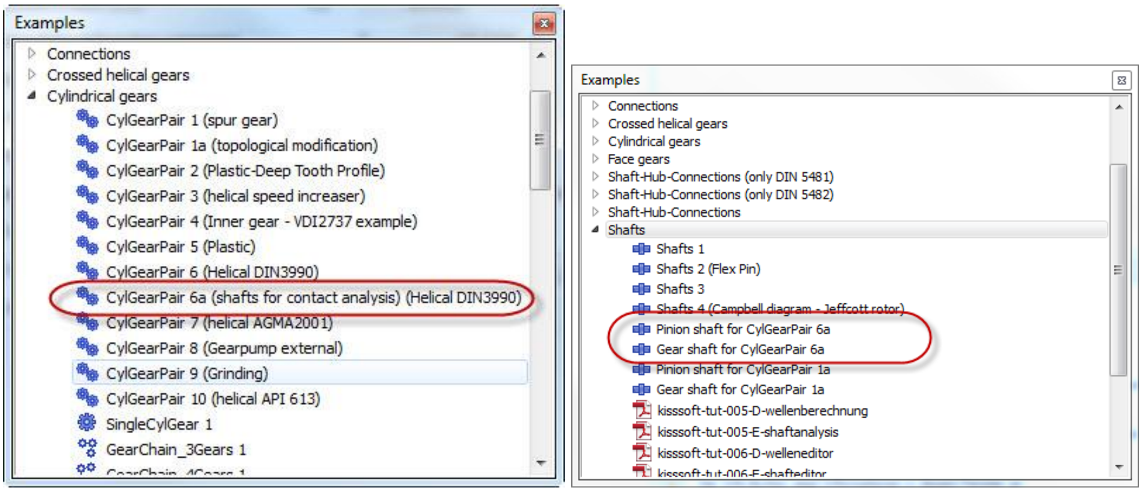


Figure 1. pre-defined calculation files for cylindrical gear pair and shaft analysis

1.1 Work steps

Work through the following steps with these examples:
Step 1: Analyze the current situation according to the relevant standard
Step 2: Analyze the current situation, taking into account the shaft deformation, with or without contact analysis
Step 3: Determine the necessary modifications for the tooth trace on the pinion and the gear
Step 4: Include the modifications in the cylindrical gear calculation
Step 5: Analyze the optimized situation, taking into account the shaft deformation

2 Solution

2.1 General notes

These work steps are designed to illustrate the basic procedure, to better identify and describe this new functionality.
The face load factors take into account the effect of unequal load distribution across facewidth on flank pressure $K_{Hß}$, on tooth root stress $K_{Fß}$ and on scuffing stress $K_{Bß}$. The KISSsoft system has a number of different ways in which you can input $K_{Hß}$:

- Input $K_{Hß}$ directly, method A;
- Input deformation fsh and manufacture tolerance fma: The KISSsoft shaft analysis functions can calculate the exact flank line variation due to deformation (torsion and bending) in the plane of action, method B;
- An approximate analysis according to ISO6336 (or DIN 3990). To do this, input the bearing distance l, the distance s of the pinion shaft, and the outside diameter of the pinion shaft, method C.

2.1.1 Step 1: Analyze the current situation

Load the current cylindrical gear calculation file CylGearPair 6a.Z12 into the cylindrical gear pair module. Compare the data inputs for the face load factor with the current dimensions taken from the shaft analysis of the pinion. Change the settings and compare the determined face load factors for $K_{Hß}$ with the subsequent analysis results from steps 2 through 5.

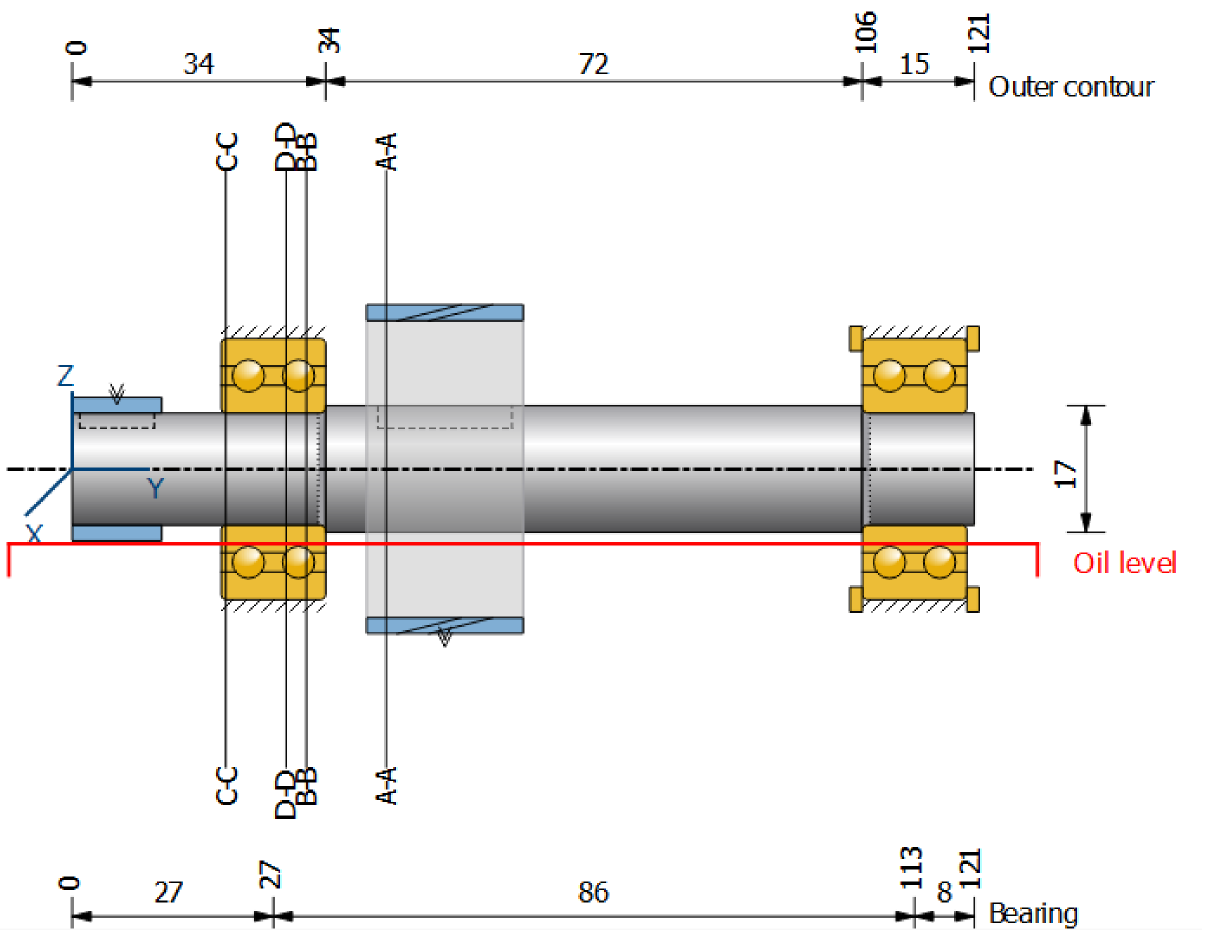


Figure 2. Pinion shaft dimensions and support

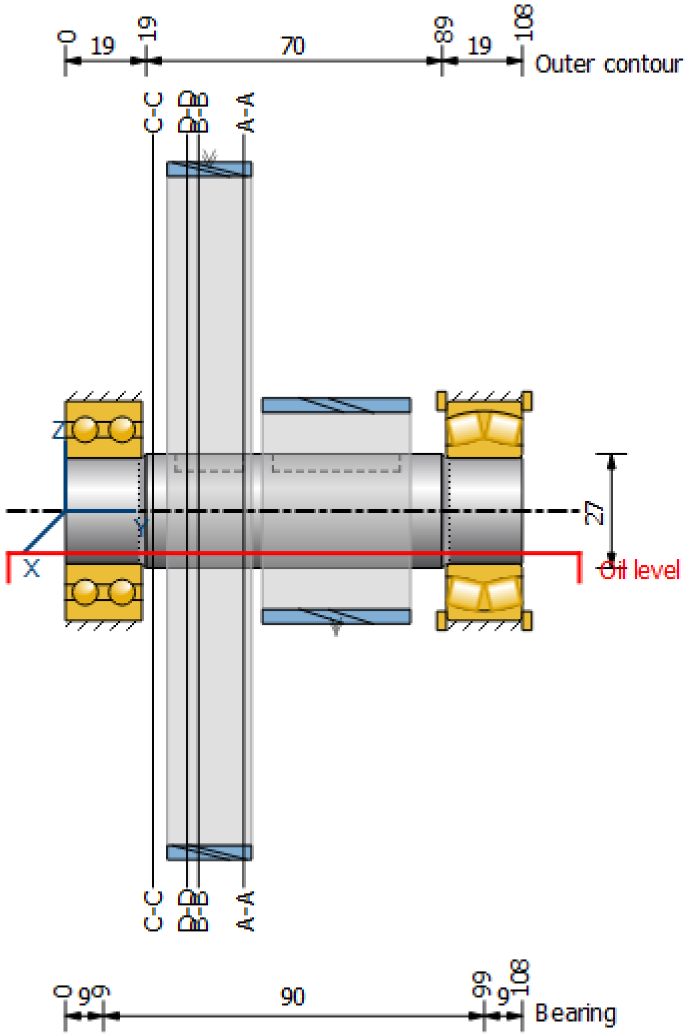


Figure 3. Gear shaft dimensions and support

To define the inputs for the face load factor, go to “Factors” tab. In the “Face load factor” section, first select “Calculation according calculation method” in the drop down list. Then click in the plus button on the right of the section to define more inputs for the load face factor.

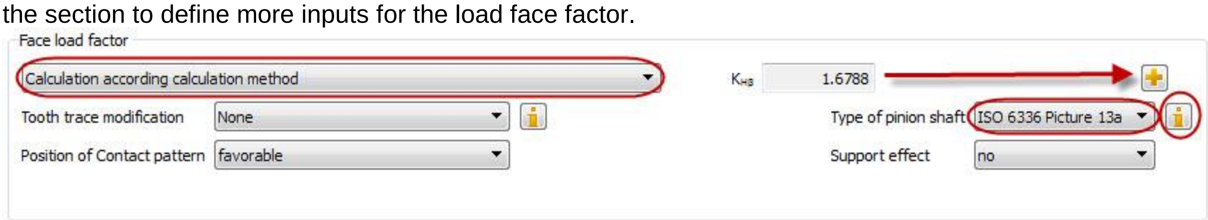


Figure 4. Defining the face load factor

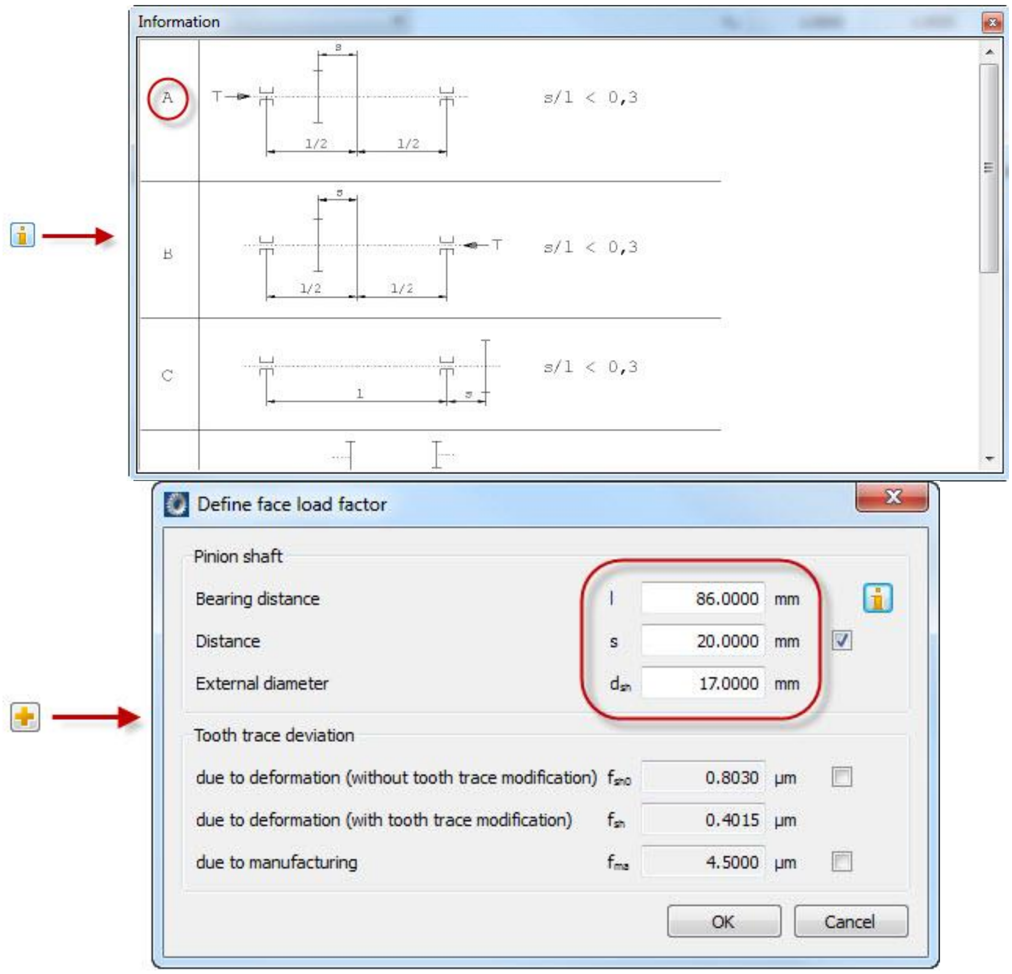


Figure 5. Inputs that take into account pinion dimensions (for method C)

The application factor K_A must be set to 1 so that it can be compared with the results of the subsequent analysis at a later point in time

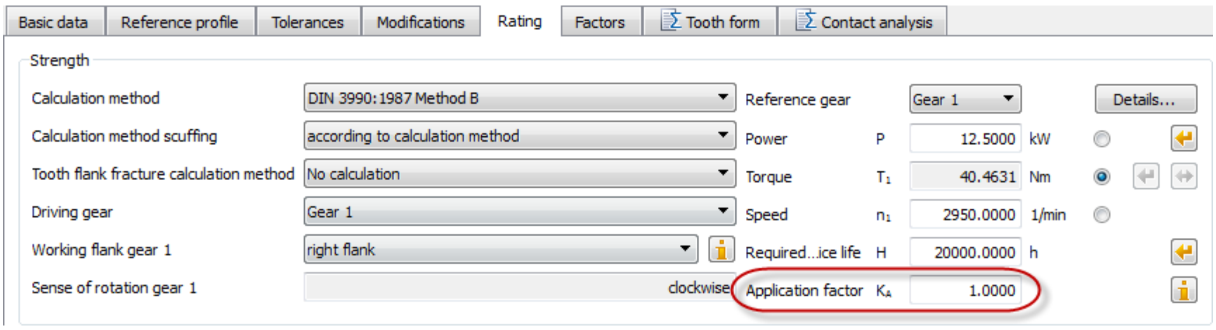


Figure 6. Application factor

The following message appears when you run this calculation.

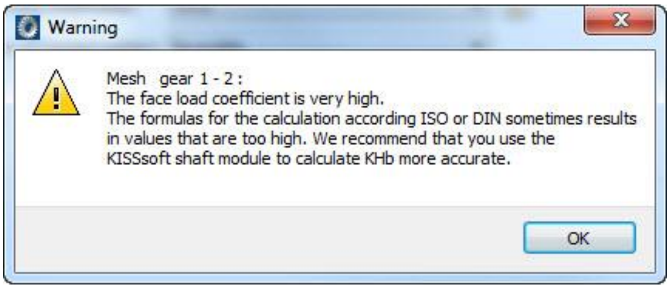


Figure 7. Warning message stating that the face load coefficient is too high

Note:

Any face load factor calculated according to method C which have a value greater than 1.5 must be checked in more detail. Method C is often very conservative. In other words, the calculated factor is too high and therefore the calculated safeties are too low. The factor should therefore be calculated in greater detail. You can do this by verifying the value more precisely. To do this, use the KISSsoft Shaft calculation module or the shaft analysis functions integrated in contact analysis in the KISSsoft cylindrical gear calculation functionality.

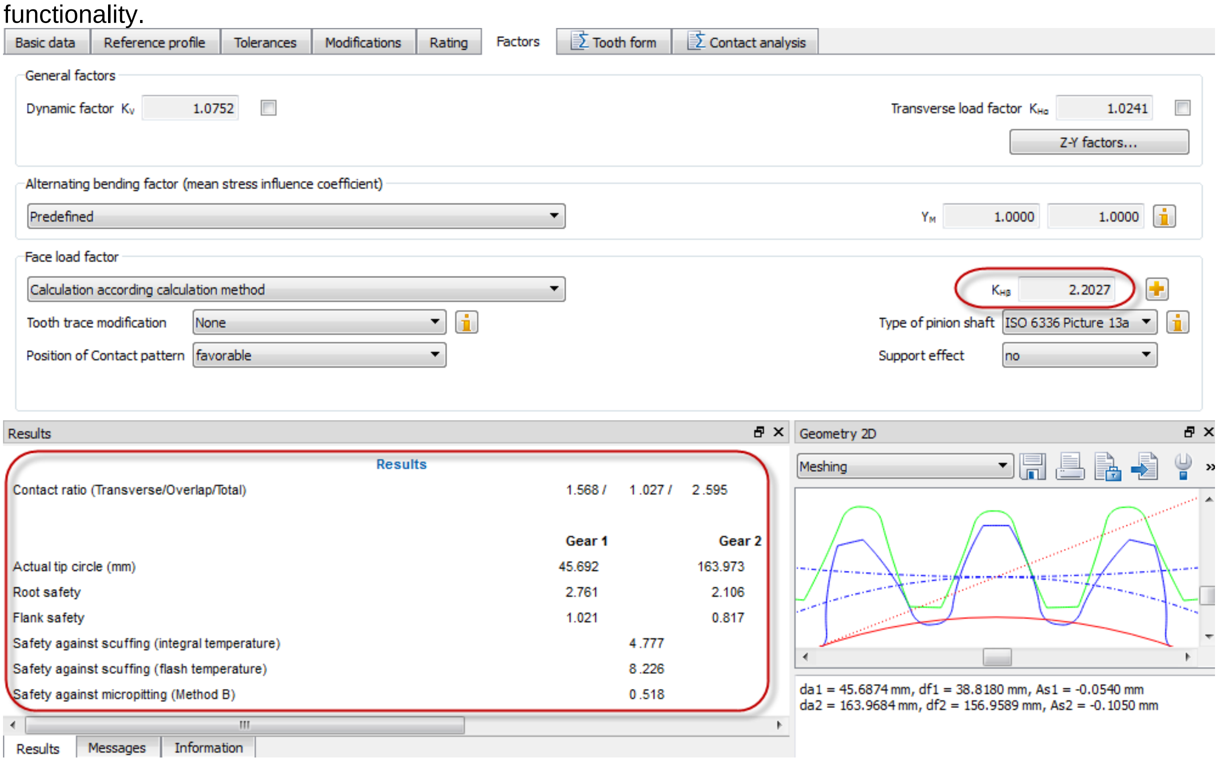
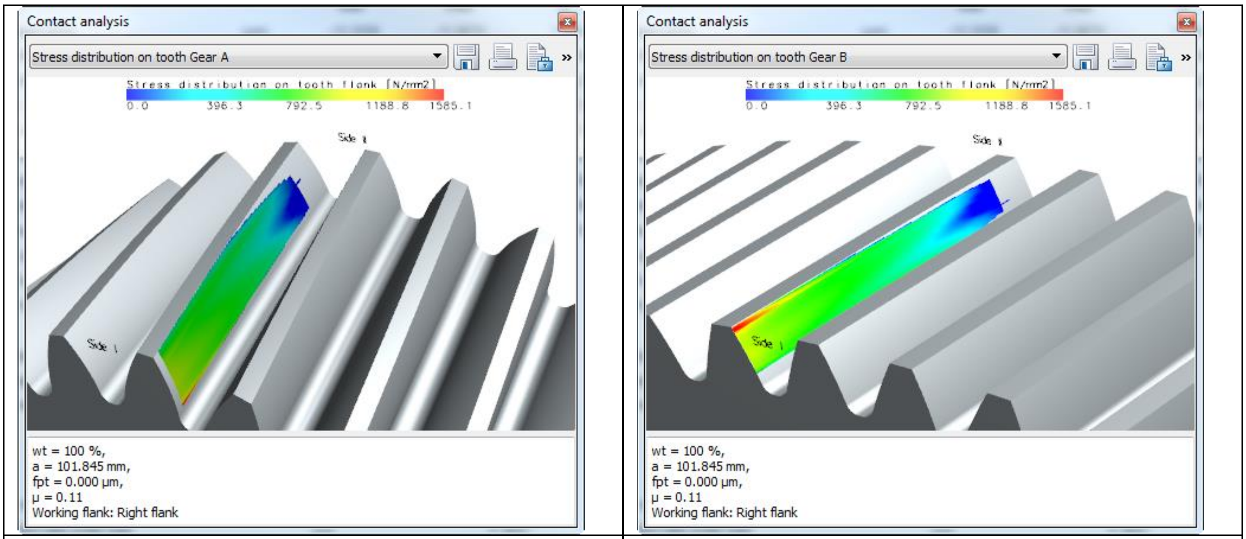


Figure 8. Calculation results according to the standard, method C, and taking into account the influence of pinion geometry

The result shows the calculation of $K_{H\beta}$ with the appropriate settings according to the standard. This calculation only includes the dimensions of the pinion shaft. However, the gear shaft will also deform when placed under load, and this method cannot take this effect (which is usually significantly smaller) into account.



Pinion	Gear

Figure 9. stress distribution calculated with $K_{H\beta}$ =2.2

2.1.2 Step 2: Analyze the current situation, considering shaft deformation

This calculation step determines the face load factor using the contact analysis in the KISSsoft cylindrical gear calculation functionality. You can perform the calculation with a complete contact analysis. In this case, the calculation will take significantly longer to run and the result for $K_{H\beta}$ is more accurate as it takes into account the shafts deformation.

The necessary shaft calculation files have already been assigned correctly in the CylGearPair 6a (…).Z12 cylindrical gear calculation file supplied with the system.

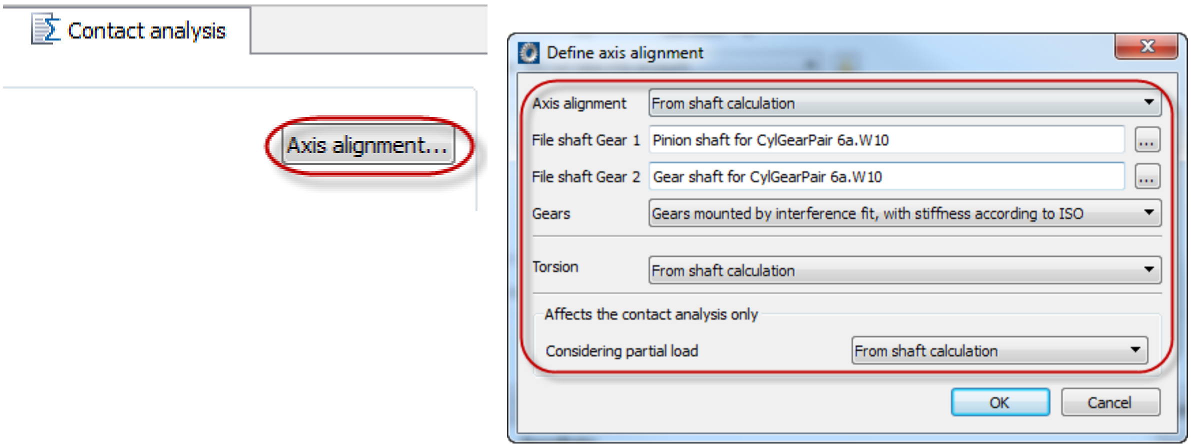


Figure 10. Determining $K_{H\beta}$ with contact analysis

Note:

a) If you want to consider tooth trace or profile corrections in the calculation, you must enable these modifications in the "Modifications" tab before running the contact analysis. If tooth trace corrections have been entered, you must enable them for this calculation step in the contact analysis. You do not need to enable profile corrections if only $K_{H\beta}$ is to be calculated

b) If the warning message does not appear, this means either that you have not input any modifications or that the modifications are already enabled.

To activate modifications in the "Modification" tab, enable the status as shown in the next figure.

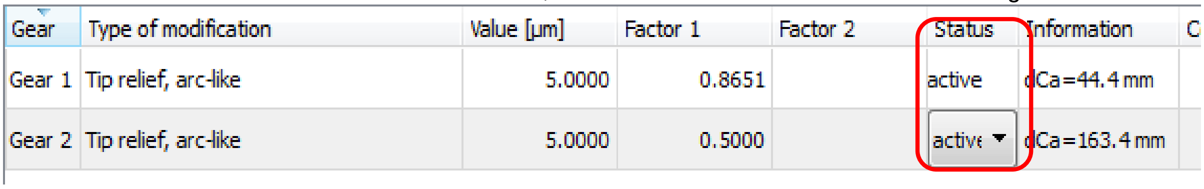


Figure 11. Enabling corrections in the "Modification" tab

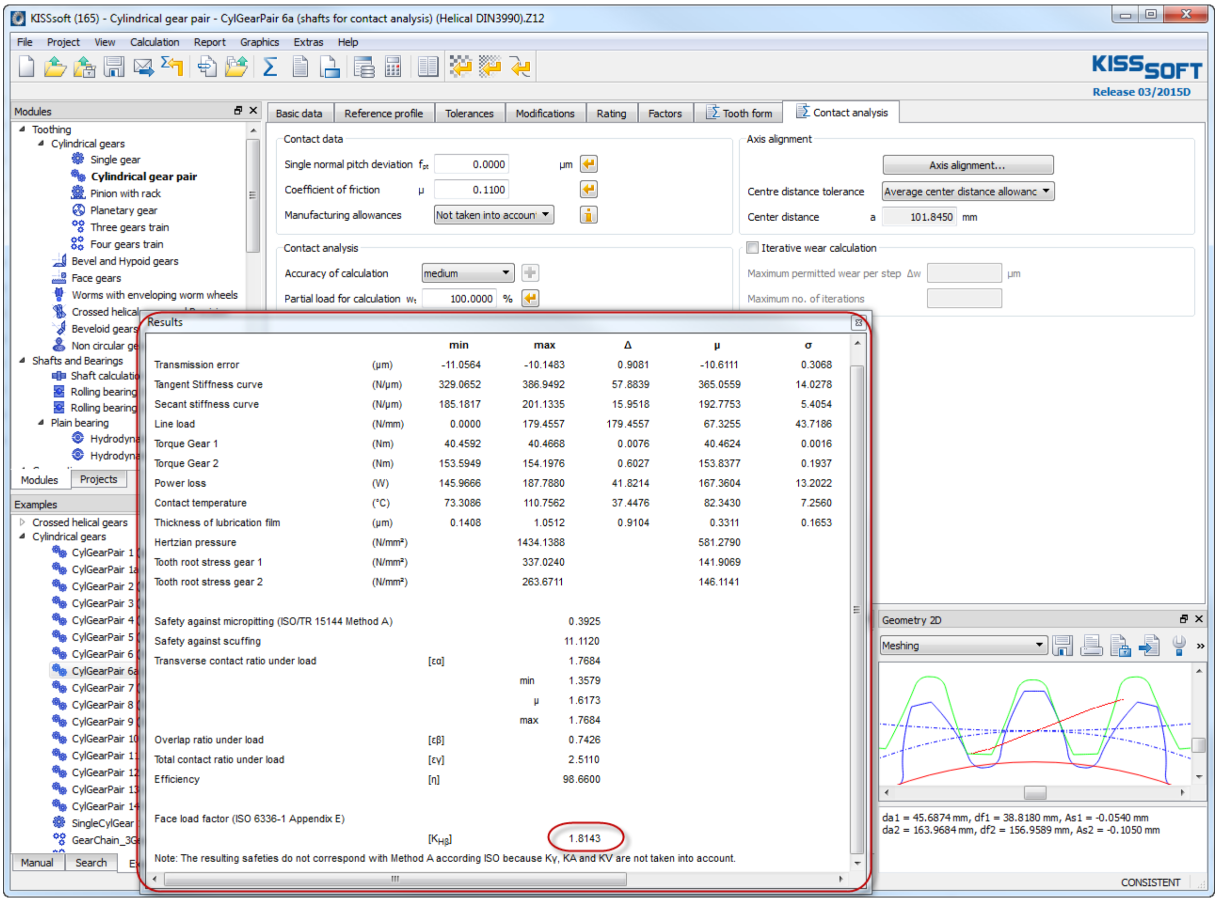
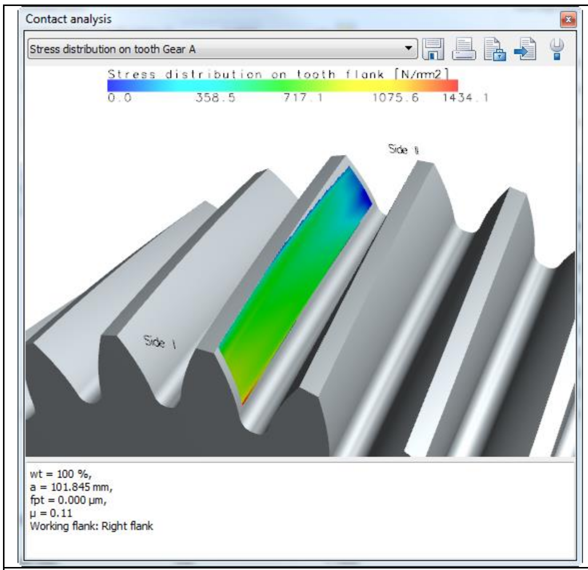
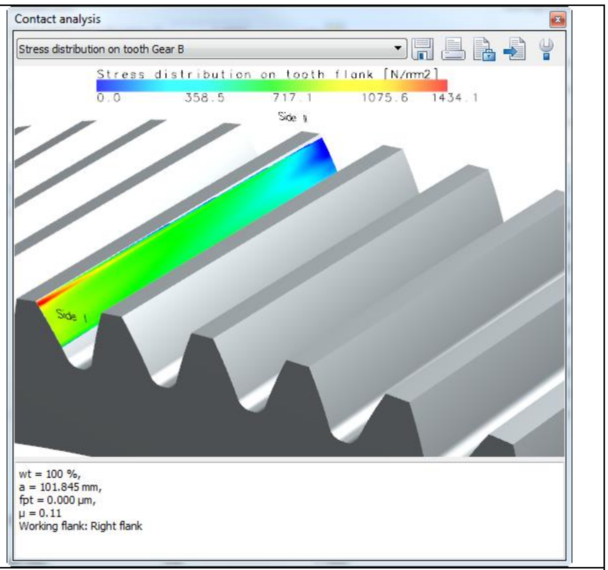


Figure 12. Results overview for a complete contact analysis without tooth trace modifications

In contrast to the calculation performed according to the equation in the standard, as shown in Step 1, the effective occurring face load factor changes to 1.81 in analysis step 2. This can now be used directly in the calculation. The safeties determined in the calculation then change accordingly.





Pinion	Gear

Figure 13. stress distribution calculated with $K_{Hß}$ =1.81

2.1.3 Step 3: Determine the necessary modifications for the tooth trace on the pinion and the gear

To do this, load the file ‘Pinion shaft for CylGearPair 6a.W10’ into the Shaft calculation module.
Then open the "Tooth trace modification" tab as shown in the figure below.

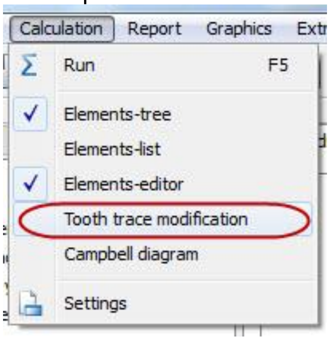


Figure 14. Calculating the tooth trace modification

Run the calculation after this. The next figure shows the results determined for the pinion. The calculation and modeling have been performed in such a way as to represent the counter gear as an idealized gear with infinite stiffness.

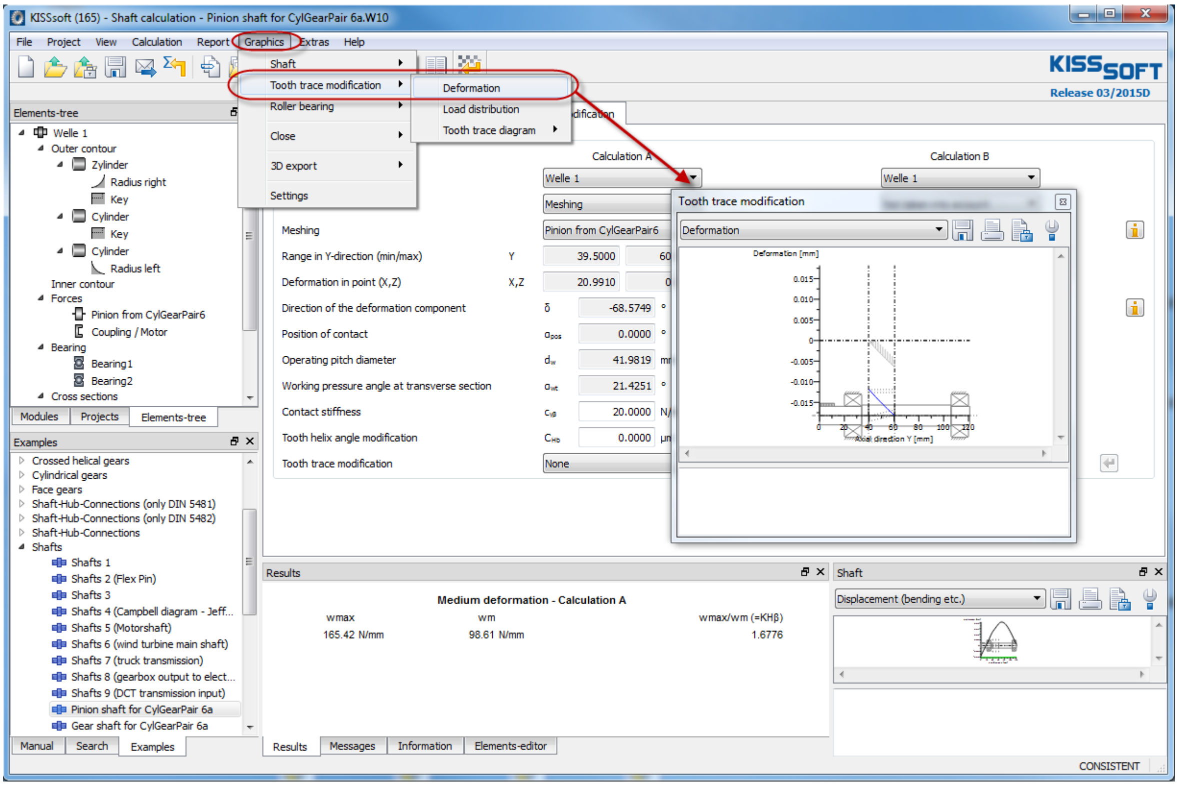


Figure 15. Results overview without tooth trace modification for the pinion

To reach an ideal modification, enter the helix angle modification $C_{H\beta}$ step-by-step. You can then check the result, i.e. the correct input for the size and the sign. The deformation graphic shows an optimum proposed value (shown here in gray). If values have been defined for the helix angle modification $C_{H\beta}$, the graphic also shows the defined correction (shown here in green). The value for $K_{H\beta}$ should be reduced (ideally to 1). The current value is then displayed in the results window.

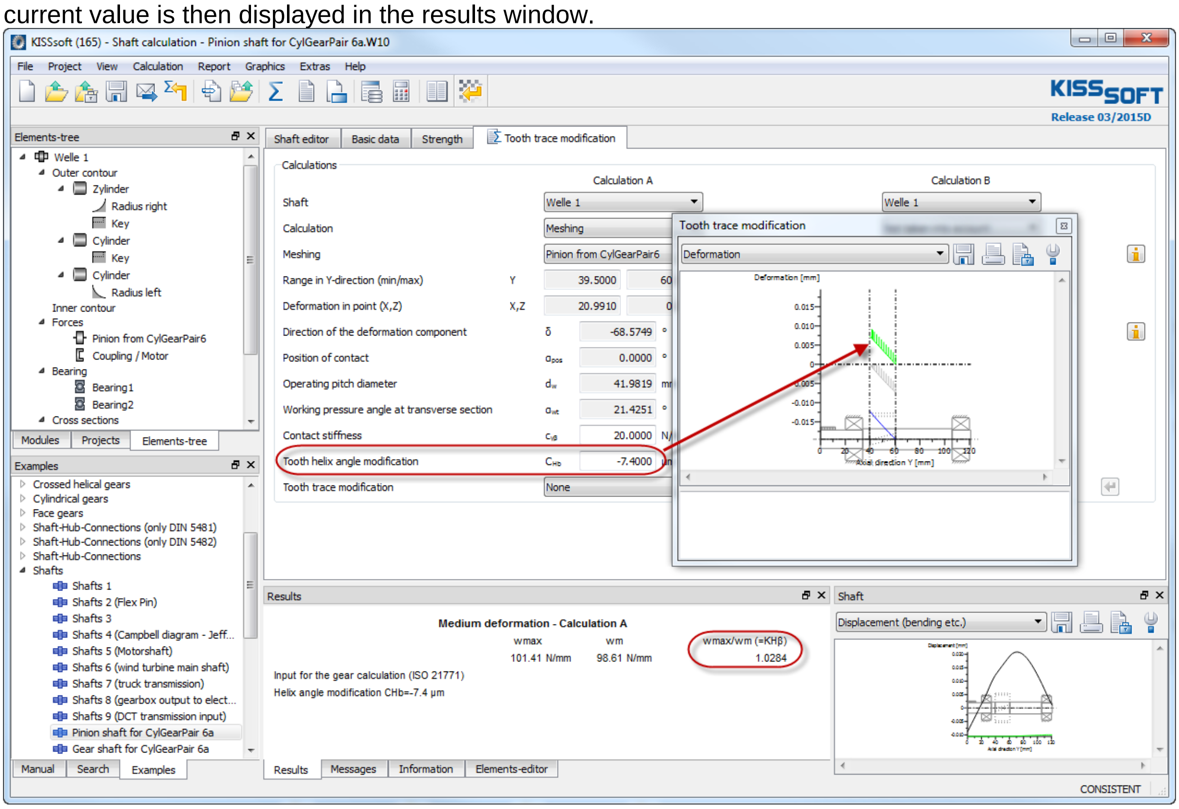


Figure 16. Results overview with enhanced tooth trace modification for the pinion

Since 2012th version, the sizing button is also available for this calculation. It runs an internal algorithm to get the optimum result. In the next image, it not possible to see the gray modification anymore as the green defined is now above it. Notice that the value is very close to the one reached before when trying step by step but there is also a small crowning to get is exact. Also the $K_{H\beta}$ is reduced to 1.0002.

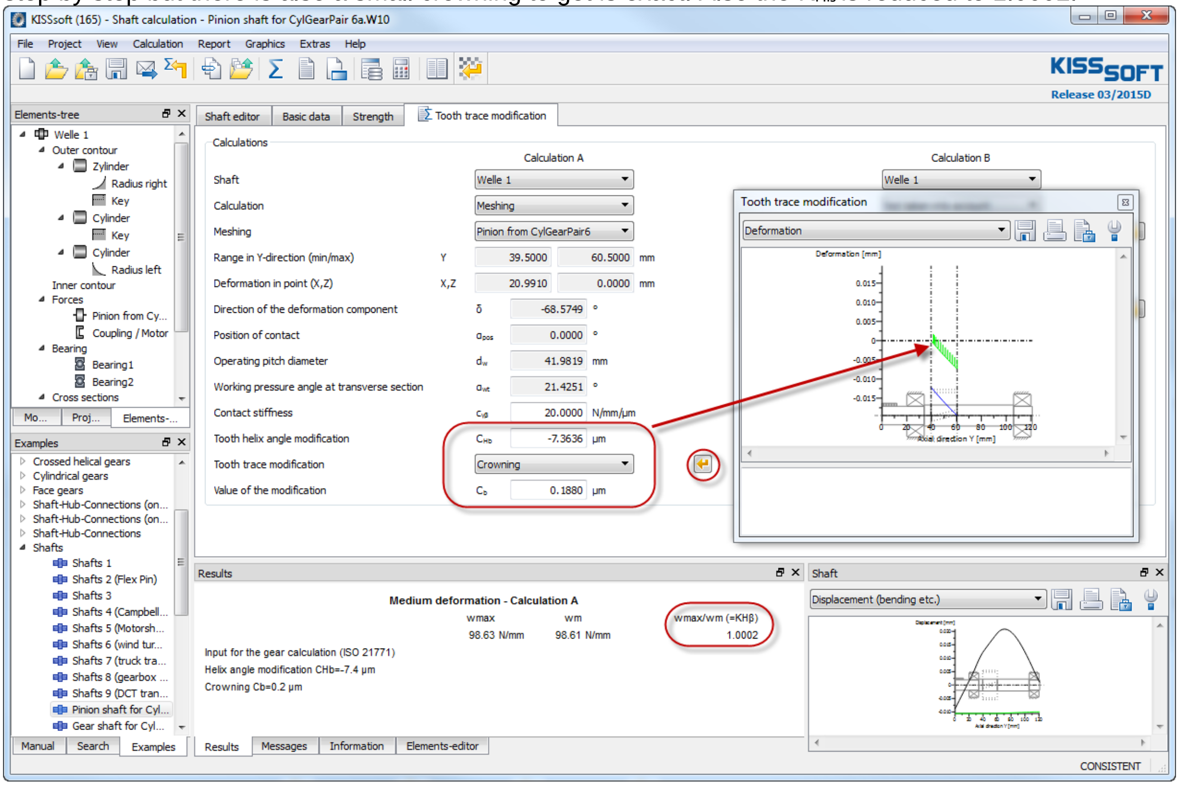


Figure 17. Results overview with optimum tooth trace modification for the pinion

The same should be done for the Gear. Load the file 'Pinion shaft for CylGearPair 6a.W10' and follow the same steps as decribed for the pinion.

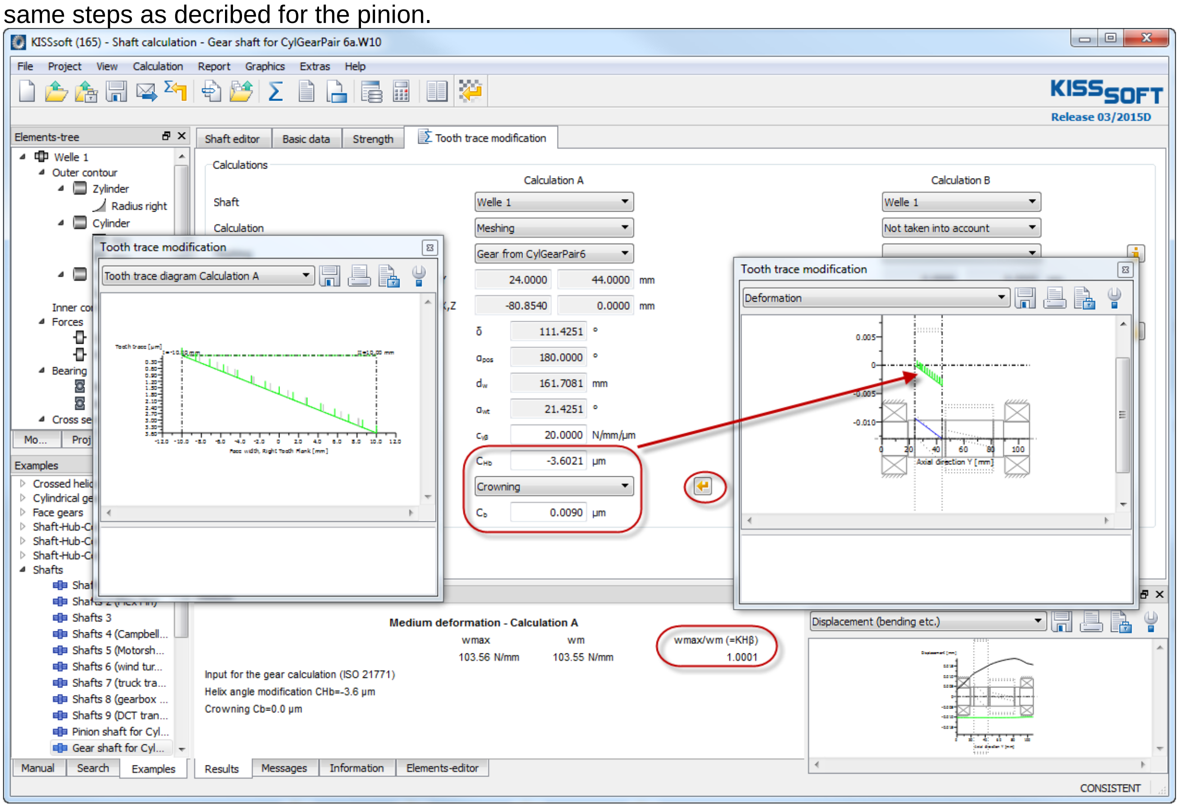


Figure 18. Results overview with optimum tooth trace modification for the gear

2.1.4 Step 4: Including modifications in the cylindrical gear calculation

The Shaft Analysis report and the "Deformation" figure both state the tooth flank for which the modification is to be performed. This is calculated from the direction of rotation and the direction of load. In this example, the modification is performed for the right tooth flank for both the pinion and the gear.

Explanations:
…
f.corr : Proposal for modification : Right tooth flank
…
Input data: Tooth trace crowned
$C_{H\beta}$=-7.4 µm, cβ=0.2 µm, rCrown=293287.1 mm

Notice:
The angle modification fHb corresponds to a helix angle modification -0.0189 °
(Helix angle 14.0591 °)
!! Use modification by helix angle modification only, if the direction of the rotation stays the same!

Figure 19. Report note with optimum tooth trace correction for the pinion

Explanations:
…
f.corr : Proposal for modification : Right tooth flank
…
Input data: Tooth trace crowned
$C_{H\beta}$=-3.6 µm, cβ=0.0 µm, rCrown=5581389.8 mm

Notice:
The angle modification fHb corresponds to a helix angle modification 0.0097 °
(Helix angle 14.0877 °)
!! Use modification by helix angle modification only, if the direction of the rotation stays the same!

Figure 20. Report note with optimum tooth trace modification for the gear

Now open the "Modifications" tab in the cylindrical gear calculation and enter the corrections. You should reduce the helix angle on the pinion and increase the helix angle on the gear.

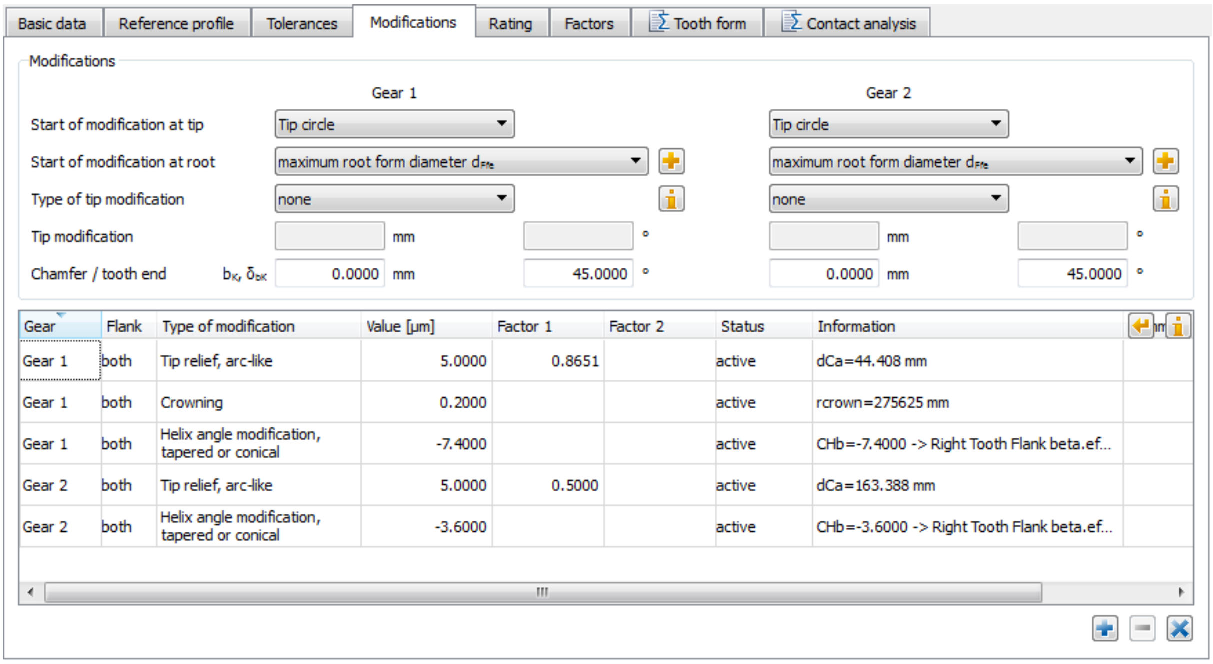


Figure 21. Inputting a conical helix angle and crowning for the gear and pinion in the Cylindrical gear calculation

The tip reliefs entered in Figure 21 are a good idea, but optional. They do not affect the result. The crowning calculated before by the sizing button is too small to have a real influence, but the optimal value is reached just if applying this modification. It was used also in the Cylindrial gear calculation, shown also in Figure 21 to show how the process works.

2.1.5 Step 5: Analyze the optimized situation taking into account the shaft deformation

The calculation of K_{Hb} in the "Contact analysis" tab now returns a much lower value than previously, due to the flank line modification that has just been applied. Both shaft deformations (pinion and gear) are now included here.

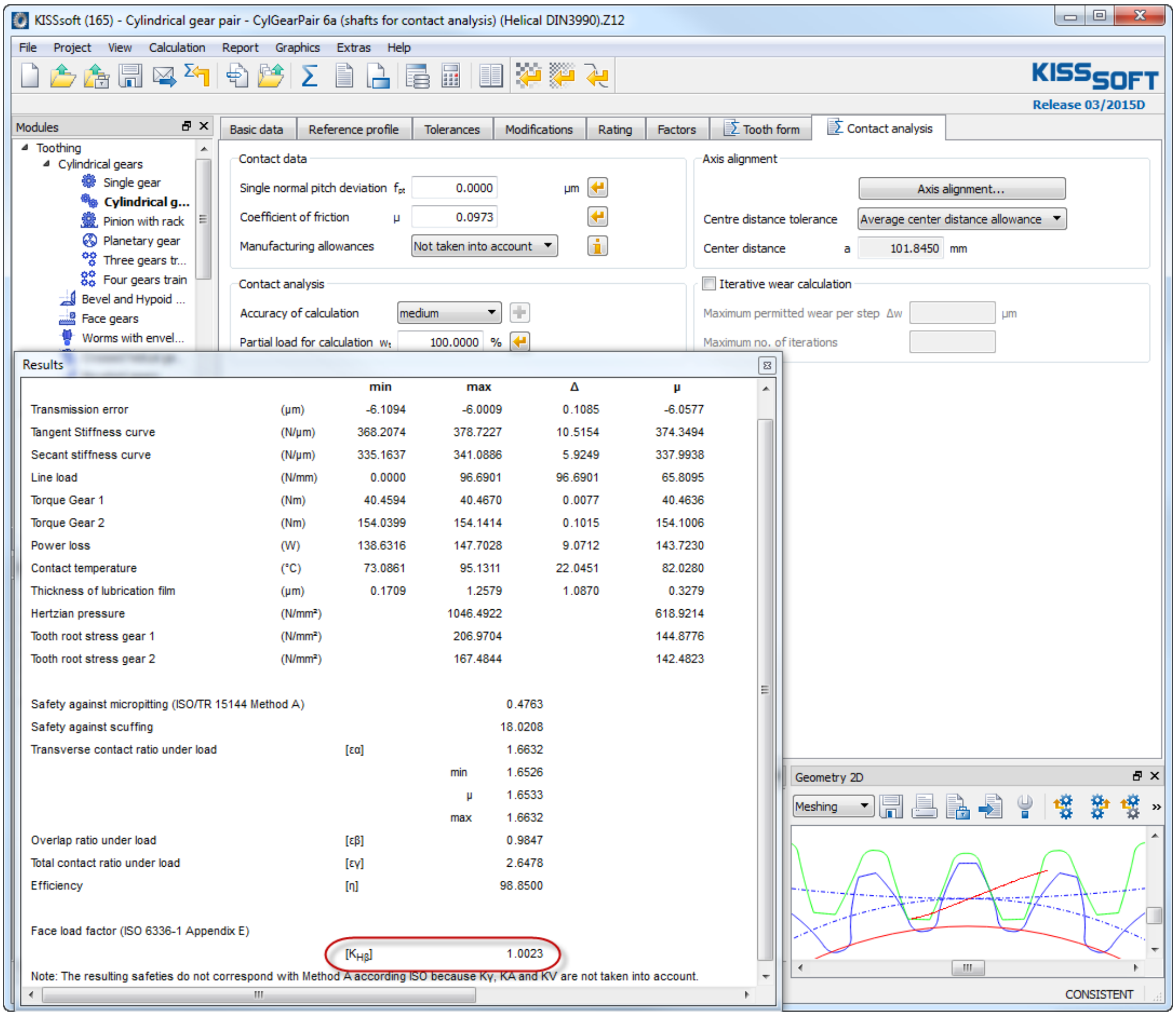


Figure 22. Results overview with optimum tooth trace modification

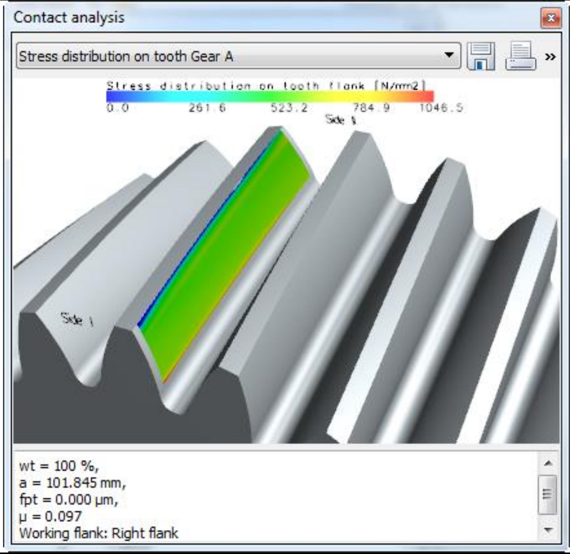
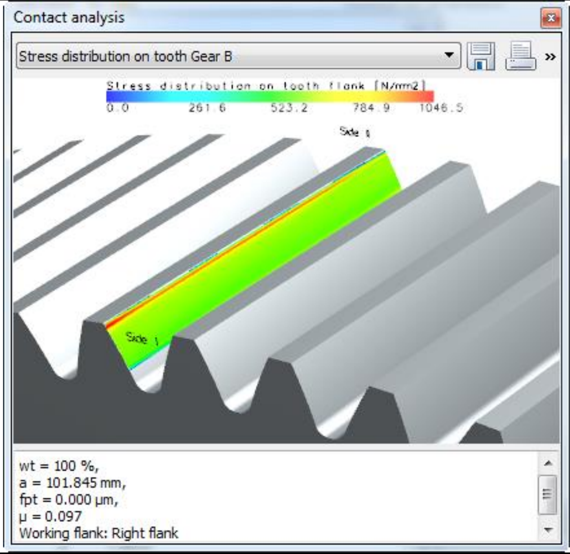
	
Pinion	Gear

Figure 23. stress distribution calculated with $K_{H\beta}$ =1.0023

Note:

Since 2014th version, the sizing function is also available for the gear pair calculation

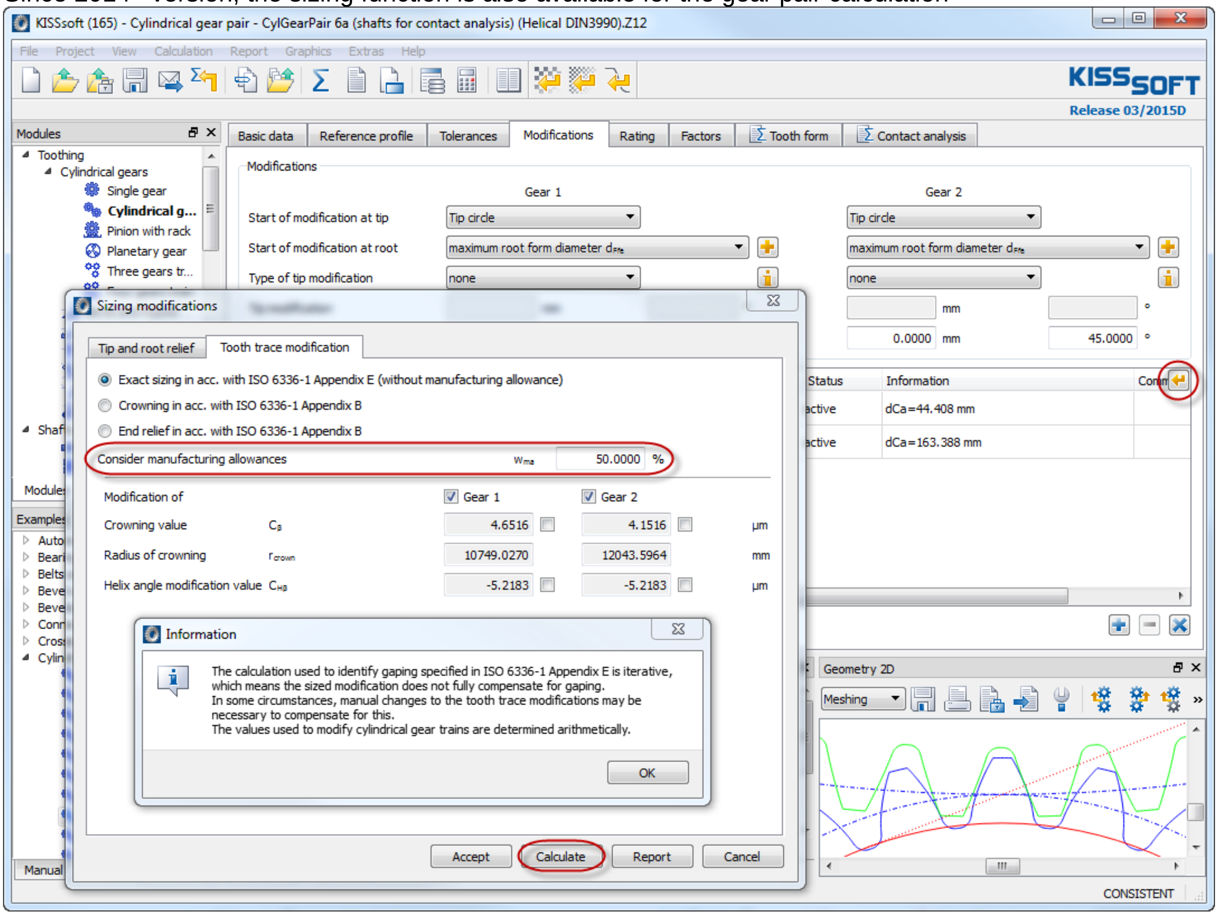


Figure 24. Sizing the tooth trace modification.

2.2 Summary

The table below contains an overview of the results.

Step	Face load factors on the	Pinion	Gear	Total	Note
1	$K_{Hß}$	2.203	(1.332)		determined in accordance with the standard
2	$K_{Hß}$			1.81	taking into account the shafts
3	$K_{Hß}$	1.678	1.35		without correction, calculated in the shaft analysis
4	$K_{Hß}$	1.029	1.019		with correction, calculated in the shaft analysis
4b	$K_{Hß}$	1.0002	1.0001		With optimum correction, calculated in the shaft analysis by sizing button
5	$K_{Hß}$			1.0023	with corrections, calculated in the cylindrical gear calculation, and taking into account both shafts

3 Results

3.1 Report of the contact analysis of the initial variant with main load stage

KISSsoft Release 03/2015 D

KISSsoft-Entwicklungs-Version KISSsoft AG CH-8608 BUBIKON

File

Filename: C:/KISSsoft 03-2015/example/CylGearPair 6a (shafts for contact analysis) (Helical DIN3990).Z12

Description: KISSsoft example

Changed by: mhoffmann am: 31.07.2015 um: 13:44:25

Contact Analysis

Meshing gear 1 - gear 2

Accuracy of calculation		Medium	
Partial load for calculation	**[w_t]**	**100.0000**	**(%)**

Note: In order to obtain contact analysis results for scuffing, micropitting and tooth flank fracture according to method A of ISO the calculation would have to be performed with w_t = 100*Kgam*KA*KV..

(w_t*Kgam*KA*KV = 107.52 %)

Working flank		Right tooth flank	
Center distance	[a]	101.8450	(mm)
Single pitch deviation	[f_{pt}]	0.0000	(µm)
Coefficient. of friction	[µ]	0.1073	
Deviation error of axis	[$f_{\Sigma\beta}$]	0.0000	(µm)
Inclination error of axis	[$f_{\Sigma\delta}$]	0.0000	(µm)
Torque	[T_1]	40.4631	(Nm)

Torsion from shaft calculation

		min	**max**	**Δ**	**µ**	**σ**
Transmission error	(µm)	-11.0588	-10.1505	0.9083	-10.6135	0.3069
Tangent Stiffness curve	(N/µm)	328.9452	386.7723	57.8271	364.9457	14.0022
Secant stiffness curve	(N/µm)	185.1894	201.1583	15.9689	192.7912	5.4121
Line load	(N/mm)	0.0000	179.4948	179.4948	67.3408	43.7285
Torque Gear 1	(Nm)	40.4592	40.4667	0.0076	40.4624	0.0016
Torque Gear 2	(Nm)	153.6476	154.2387	0.5910	153.8845	0.1903
Power loss	(W)	142.4653	183.2340	40.7687	163.3199	12.8687
Contact temperature	(°C)	73.3086	110.7638	37.4552	82.3447	7.2575
Thickness of lubrication film	(µm)	0.1408	0.9510	0.8102	0.3268	0.1471
Hertzian pressure	(N/mm²)		1434.2894		581.3539	
Tooth root stress gear 1	(N/mm²)		337.0271		141.9271	
Tooth root stress gear 2	(N/mm²)		263.4695		146.1006	

Safety against micropitting (ISO/TR 15144 Method A)			0.3924
Safety against scuffing			11.1099
Transverse contact ratio under load	[$\varepsilon\alpha$]		1.7684
		min	1.3579
		µ	1.6177
		max	1.7684
Overlap ratio under load	[$\varepsilon\beta$]		0.7426
Total contact ratio under load	[$\varepsilon\gamma$]		2.5110
Efficiency	[η]		98.6900

Face load factor (ISO 6336-1 Appendix E)

[$K_{H\beta}$] 1.8143

Note: The resulting safeties do not correspond with Method A according ISO because Kγ, KA and KV are not taken into account.

Amplitude spectrum of the transmission error

Harmonics	Amplitude (µm)
1	0.427
2	0.057
3	0.013
4	0.006
5	0.005
6	0.003
7	0.001
8	0.001
9	0.001
10	0.001

$K_{H\beta}$ Calculation - Gear 1 - Gear 2

Right flank

Shaft file A: C:/KISSsoft 03-2015/example/Pinion shaft for CylGearPair 6a.W10, selected gear: Pinion from CylGearPair6 (gears as masses and stiffness)

Shaft file B: C:/KISSsoft 03-2015/example/Gear shaft for CylGearPair 6a.W10, selected gear: Gear from CylGearPair6 (gears as masses and stiffness)

(Partial load for calculation w_t = 100 %)

f_{ma} = 0.000 µm , $f_{H\beta}$ = 0.000 µm

Result after i = 11 iterations of load distribution

Gear 1

Point in polar co-ordinates:

R = 20.991 mm , φ = 0.000 °

Displacement calculated in direction 111.425 °

	y	φ1.t	f1.t	f1.b	f1.tot	f1.C	f1.tot+f1.C
1	40.196 mm	0.0000°	-0.0045 µm	-0.0390 µm	-0.0435 µm	0.0000 µm	-0.0435 µm
2	40.588 mm	-0.0000°	0.0094 µm	0.0820 µm	0.0914 µm	0.0000 µm	0.0914 µm
3	40.980 mm	-0.0001°	0.0232 µm	0.2030 µm	0.2262 µm	0.0000 µm	0.2262 µm
4	41.373 mm	-0.0001°	0.0364 µm	0.3234 µm	0.3599 µm	0.0000 µm	0.3599 µm
5	41.765 mm	-0.0001°	0.0494 µm	0.4436 µm	0.4930 µm	0.0000 µm	0.4930 µm
6	42.157 mm	-0.0002°	0.0619 µm	0.5634 µm	0.6253 µm	0.0000 µm	0.6253 µm
7	42.549 mm	-0.0002°	0.0737 µm	0.6828 µm	0.7565 µm	0.0000 µm	0.7565 µm
8	42.941 mm	-0.0003°	0.0853 µm	0.8020 µm	0.8872 µm	0.0000 µm	0.8872 µm
9	43.333 mm	-0.0003°	0.0961 µm	0.9206 µm	1.0167 µm	0.0000 µm	1.0167 µm
10	43.725 mm	-0.0003°	0.1067 µm	1.0389 µm	1.1456 µm	0.0000 µm	1.1456 µm
11	44.118 mm	-0.0003°	0.1168 µm	1.1570 µm	1.2738 µm	0.0000 µm	1.2738 µm
12	44.510 mm	-0.0004°	0.1264 µm	1.2745 µm	1.4009 µm	0.0000 µm	1.4009 µm
13	44.902 mm	-0.0004°	0.1357 µm	1.3919 µm	1.5276 µm	0.0000 µm	1.5276 µm
14	45.294 mm	-0.0004°	0.1444 µm	1.5088 µm	1.6532 µm	0.0000 µm	1.6532 µm
15	45.686 mm	-0.0004°	0.1528 µm	1.6254 µm	1.7782 µm	0.0000 µm	1.7782 µm
16	46.078 mm	-0.0005°	0.1609 µm	1.7417 µm	1.9026 µm	0.0000 µm	1.9026 µm
17	46.471 mm	-0.0005°	0.1684 µm	1.8576 µm	2.0260 µm	0.0000 µm	2.0260 µm
18	46.863 mm	-0.0005°	0.1757 µm	1.9732 µm	2.1490 µm	0.0000 µm	2.1490 µm
19	47.255 mm	-0.0005°	0.1826 µm	2.0885 µm	2.2710 µm	0.0000 µm	2.2710 µm
20	47.647 mm	-0.0006°	0.1890 µm	2.2034 µm	2.3925 µm	0.0000 µm	2.3925 µm
21	48.039 mm	-0.0006°	0.1953 µm	2.3182 µm	2.5135 µm	0.0000 µm	2.5135 µm
22	48.431 mm	-0.0006°	0.2010 µm	2.4324 µm	2.6334 µm	0.0000 µm	2.6334 µm
23	48.824 mm	-0.0006°	0.2066 µm	2.5465 µm	2.7530 µm	0.0000 µm	2.7530 µm
24	49.216 mm	-0.0006°	0.2117 µm	2.6602 µm	2.8719 µm	0.0000 µm	2.8719 µm

25	49.608 mm	-0.0006°	0.2165 µm	2.7736 µm	2.9901 µm	0.0000 µm	2.9901 µm
26	50.000 mm	-0.0006°	0.2212 µm	2.8868 µm	3.1080 µm	0.0000 µm	3.1080 µm
27	50.392 mm	-0.0007°	0.2253 µm	2.9996 µm	3.2249 µm	0.0000 µm	3.2249 µm
28	50.784 mm	-0.0007°	0.2293 µm	3.1122 µm	3.3415 µm	0.0000 µm	3.3415 µm
29	51.176 mm	-0.0007°	0.2331 µm	3.2244 µm	3.4575 µm	0.0000 µm	3.4575 µm
30	51.569 mm	-0.0007°	0.2365 µm	3.3364 µm	3.5729 µm	0.0000 µm	3.5729 µm
31	51.961 mm	-0.0007°	0.2397 µm	3.4482 µm	3.6879 µm	0.0000 µm	3.6879 µm
32	52.353 mm	-0.0007°	0.2426 µm	3.5596 µm	3.8022 µm	0.0000 µm	3.8022 µm
33	52.745 mm	-0.0007°	0.2453 µm	3.6708 µm	3.9161 µm	0.0000 µm	3.9161 µm
34	53.137 mm	-0.0007°	0.2478 µm	3.7818 µm	4.0295 µm	0.0000 µm	4.0295 µm
35	53.529 mm	-0.0007°	0.2500 µm	3.8924 µm	4.1424 µm	0.0000 µm	4.1424 µm
36	53.922 mm	-0.0007°	0.2520 µm	4.0029 µm	4.2550 µm	0.0000 µm	4.2550 µm
37	54.314 mm	-0.0007°	0.2538 µm	4.1131 µm	4.3669 µm	0.0000 µm	4.3669 µm
38	54.706 mm	-0.0007°	0.2555 µm	4.2231 µm	4.4785 µm	0.0000 µm	4.4785 µm
39	55.098 mm	-0.0008°	0.2570 µm	4.3328 µm	4.5898 µm	0.0000 µm	4.5898 µm
40	55.490 mm	-0.0008°	0.2582 µm	4.4423 µm	4.7005 µm	0.0000 µm	4.7005 µm
41	55.882 mm	-0.0008°	0.2593 µm	4.5516 µm	4.8110 µm	0.0000 µm	4.8110 µm
42	56.275 mm	-0.0008°	0.2603 µm	4.6607 µm	4.9209 µm	0.0000 µm	4.9209 µm
43	56.667 mm	-0.0008°	0.2611 µm	4.7695 µm	5.0306 µm	0.0000 µm	5.0306 µm
44	57.059 mm	-0.0008°	0.2618 µm	4.8782 µm	5.1400 µm	0.0000 µm	5.1400 µm
45	57.451 mm	-0.0008°	0.2623 µm	4.9866 µm	5.2489 µm	0.0000 µm	5.2489 µm
46	57.843 mm	-0.0008°	0.2627 µm	5.0949 µm	5.3576 µm	0.0000 µm	5.3576 µm
47	58.235 mm	-0.0008°	0.2630 µm	5.2030 µm	5.4659 µm	0.0000 µm	5.4659 µm
48	58.627 mm	-0.0008°	0.2631 µm	5.3108 µm	5.5740 µm	0.0000 µm	5.5740 µm
49	59.020 mm	-0.0008°	0.2633 µm	5.4186 µm	5.6818 µm	0.0000 µm	5.6818 µm
50	59.412 mm	-0.0008°	0.2633 µm	5.5260 µm	5.7893 µm	0.0000 µm	5.7893 µm
51	59.804 mm	-0.0008°	0.2633 µm	5.6335 µm	5.8968 µm	0.0000 µm	5.8968 µm

Gear 2
Point in polar co-ordinates:
R = 80.854 mm , φ = 180.000 °
Displacement calculated in direction 111.425 °

	y	φ2.t	f2.t	f2.b	f2.tot	f2.C	f2.tot+f2.C
1	24.196 mm	-0.0000°	-0.0000 µm	0.0226 µm	0.0226 µm	0.0000 µm	0.0226 µm
2	24.588 mm	0.0000°	0.0000 µm	-0.0475 µm	-0.0475 µm	-0.0000 µm	-0.0475 µm
3	24.980 mm	0.0000°	0.0000 µm	-0.1176 µm	-0.1176 µm	-0.0000 µm	-0.1176 µm
4	25.373 mm	0.0000°	0.0001 µm	-0.1877 µm	-0.1876 µm	-0.0000 µm	-0.1876 µm
5	25.765 mm	0.0000°	0.0002 µm	-0.2578 µm	-0.2576 µm	-0.0000 µm	-0.2576 µm
6	26.157 mm	0.0000°	0.0003 µm	-0.3279 µm	-0.3275 µm	-0.0000 µm	-0.3275 µm
7	26.549 mm	0.0000°	0.0005 µm	-0.3979 µm	-0.3974 µm	-0.0000 µm	-0.3974 µm
8	26.941 mm	0.0000°	0.0007 µm	-0.4679 µm	-0.4672 µm	-0.0000 µm	-0.4672 µm
9	27.333 mm	0.0000°	0.0009 µm	-0.5379 µm	-0.5370 µm	-0.0000 µm	-0.5370 µm
10	27.725 mm	0.0000°	0.0011 µm	-0.6079 µm	-0.6068 µm	-0.0000 µm	-0.6068 µm
11	28.118 mm	0.0000°	0.0014 µm	-0.6779 µm	-0.6765 µm	-0.0000 µm	-0.6765 µm
12	28.510 mm	0.0000°	0.0017 µm	-0.7478 µm	-0.7461 µm	-0.0000 µm	-0.7461 µm
13	28.902 mm	0.0000°	0.0020 µm	-0.8178 µm	-0.8158 µm	-0.0000 µm	-0.8158 µm
14	29.294 mm	0.0000°	0.0024 µm	-0.8877 µm	-0.8853 µm	-0.0000 µm	-0.8853 µm
15	29.686 mm	0.0000°	0.0027 µm	-0.9576 µm	-0.9549 µm	-0.0000 µm	-0.9549 µm
16	30.078 mm	0.0000°	0.0031 µm	-1.0275 µm	-1.0244 µm	-0.0000 µm	-1.0244 µm
17	30.471 mm	0.0000°	0.0035 µm	-1.0974 µm	-1.0938 µm	-0.0000 µm	-1.0938 µm
18	30.863 mm	0.0000°	0.0040 µm	-1.1672 µm	-1.1633 µm	-0.0000 µm	-1.1633 µm
19	31.255 mm	0.0000°	0.0044 µm	-1.2371 µm	-1.2326 µm	-0.0000 µm	-1.2326 µm
20	31.647 mm	0.0000°	0.0049 µm	-1.3069 µm	-1.3020 µm	-0.0000 µm	-1.3020 µm
21	32.039 mm	0.0000°	0.0054 µm	-1.3767 µm	-1.3713 µm	-0.0000 µm	-1.3713 µm
22	32.431 mm	0.0000°	0.0060 µm	-1.4465 µm	-1.4406 µm	-0.0000 µm	-1.4406 µm
23	32.824 mm	0.0000°	0.0065 µm	-1.5163 µm	-1.5098 µm	-0.0000 µm	-1.5098 µm
24	33.216 mm	0.0000°	0.0071 µm	-1.5861 µm	-1.5790 µm	-0.0000 µm	-1.5790 µm

25	33.608 mm	0.0000°	0.0077 µm	-1.6558 µm	-1.6482 µm	-0.0000 µm	-1.6482 µm
26	34.000 mm	0.0000°	0.0083 µm	-1.7256 µm	-1.7173 µm	-0.0000 µm	-1.7173 µm
27	34.392 mm	0.0000°	0.0089 µm	-1.7953 µm	-1.7865 µm	-0.0000 µm	-1.7865 µm
28	34.784 mm	0.0000°	0.0095 µm	-1.8651 µm	-1.8555 µm	-0.0000 µm	-1.8555 µm
29	35.176 mm	0.0000°	0.0102 µm	-1.9348 µm	-1.9246 µm	-0.0000 µm	-1.9246 µm
30	35.569 mm	0.0000°	0.0108 µm	-2.0045 µm	-1.9936 µm	-0.0000 µm	-1.9936 µm
31	35.961 mm	0.0000°	0.0115 µm	-2.0742 µm	-2.0626 µm	-0.0000 µm	-2.0626 µm
32	36.353 mm	0.0000°	0.0122 µm	-2.1438 µm	-2.1316 µm	-0.0000 µm	-2.1316 µm
33	36.745 mm	0.0000°	0.0129 µm	-2.2135 µm	-2.2006 µm	-0.0000 µm	-2.2006 µm
34	37.137 mm	0.0000°	0.0137 µm	-2.2832 µm	-2.2695 µm	-0.0000 µm	-2.2695 µm
35	37.529 mm	0.0000°	0.0144 µm	-2.3528 µm	-2.3384 µm	-0.0000 µm	-2.3384 µm
36	37.922 mm	0.0000°	0.0152 µm	-2.4224 µm	-2.4073 µm	-0.0000 µm	-2.4073 µm
37	38.314 mm	0.0000°	0.0159 µm	-2.4921 µm	-2.4761 µm	-0.0000 µm	-2.4761 µm
38	38.706 mm	0.0000°	0.0167 µm	-2.5617 µm	-2.5449 µm	-0.0000 µm	-2.5449 µm
39	39.098 mm	0.0000°	0.0175 µm	-2.6313 µm	-2.6138 µm	-0.0000 µm	-2.6138 µm
40	39.490 mm	0.0000°	0.0183 µm	-2.7009 µm	-2.6825 µm	-0.0000 µm	-2.6825 µm
41	39.882 mm	0.0000°	0.0191 µm	-2.7705 µm	-2.7513 µm	-0.0000 µm	-2.7513 µm
42	40.275 mm	0.0000°	0.0200 µm	-2.8400 µm	-2.8201 µm	-0.0000 µm	-2.8201 µm
43	40.667 mm	0.0000°	0.0208 µm	-2.9096 µm	-2.8888 µm	-0.0000 µm	-2.8888 µm
44	41.059 mm	0.0000°	0.0216 µm	-2.9792 µm	-2.9575 µm	-0.0000 µm	-2.9575 µm
45	41.451 mm	0.0000°	0.0225 µm	-3.0487 µm	-3.0262 µm	-0.0000 µm	-3.0262 µm
46	41.843 mm	0.0000°	0.0234 µm	-3.1183 µm	-3.0949 µm	-0.0000 µm	-3.0949 µm
47	42.235 mm	0.0000°	0.0242 µm	-3.1878 µm	-3.1636 µm	-0.0000 µm	-3.1636 µm
48	42.627 mm	0.0000°	0.0251 µm	-3.2574 µm	-3.2323 µm	-0.0000 µm	-3.2323 µm
49	43.020 mm	0.0000°	0.0260 µm	-3.3269 µm	-3.3009 µm	-0.0000 µm	-3.3009 µm
50	43.412 mm	0.0000°	0.0269 µm	-3.3964 µm	-3.3696 µm	-0.0000 µm	-3.3696 µm
51	43.804 mm	0.0000°	0.0278 µm	-3.4659 µm	-3.4382 µm	-0.0000 µm	-3.4382 µm

Explanations:

y	: Width
φ.t	: Static torsion
f.t	: Displacement due to torsion
f.b	: Displacement due to bending
f.tot	: Total displacement (f.b+f.t)
f.C	: Change due to flank line modification

Load distribution

Contact stiffness = 18.895 N/mm/µm

Young's modulus = 206000.0/206000.0 N/mm²

	y	δ	g	w
1.	40.1961 mm	0.0000 µm	10.7505 µm	203.1328 N/mm
2.	40.5882 mm	0.2050 µm	10.5455 µm	199.2601 N/mm
3.	40.9804 mm	0.4099 µm	10.3406 µm	195.3882 N/mm
4.	41.3725 mm	0.6136 µm	10.1369 µm	191.5390 N/mm
5.	41.7647 mm	0.8167 µm	9.9338 µm	187.7008 N/mm
6.	42.1569 mm	1.0189 µm	9.7315 µm	183.8802 N/mm
7.	42.5490 mm	1.2200 µm	9.5305 µm	180.0804 N/mm
8.	42.9412 mm	1.4206 µm	9.3299 µm	176.2906 N/mm
9.	43.3333 mm	1.6199 µm	9.1306 µm	172.5253 N/mm
10.	43.7255 mm	1.8185 µm	8.9320 µm	168.7718 N/mm
11.	44.1176 mm	2.0164 µm	8.7341 µm	165.0328 N/mm
12.	44.5098 mm	2.2132 µm	8.5373 µm	161.3141 N/mm
13.	44.9020 mm	2.4095 µm	8.3410 µm	157.6045 N/mm
14.	45.2941 mm	2.6047 µm	8.1458 µm	153.9170 N/mm
15.	45.6863 mm	2.7992 µm	7.9513 µm	150.2414 N/mm
16.	46.0784 mm	2.9931 µm	7.7573 µm	146.5770 N/mm
17.	46.4706 mm	3.1860 µm	7.5645 µm	142.9333 N/mm
18.	46.8627 mm	3.3784 µm	7.3721 µm	139.2979 N/mm

19.	47.2549 mm	3.5698 µm	7.1807 µm	135.6805 N/mm
20.	47.6471 mm	3.7606 µm	6.9899 µm	132.0758 N/mm
21.	48.0392 mm	3.9509 µm	6.7996 µm	128.4802 N/mm
22.	48.4314 mm	4.1401 µm	6.6104 µm	124.9044 N/mm
23.	48.8235 mm	4.3290 µm	6.4215 µm	121.3359 N/mm
24.	49.2157 mm	4.5171 µm	6.2334 µm	117.7819 N/mm
25.	49.6078 mm	4.7044 µm	6.0460 µm	114.2412 N/mm
26.	50.0000 mm	4.8914 µm	5.8590 µm	110.7078 N/mm
27.	50.3922 mm	5.0775 µm	5.6730 µm	107.1924 N/mm
28.	50.7843 mm	5.2632 µm	5.4873 µm	103.6838 N/mm
29.	51.1765 mm	5.4482 µm	5.3023 µm	100.1875 N/mm
30.	51.5686 mm	5.6326 µm	5.1179 µm	96.7036 N/mm
31.	51.9608 mm	5.8166 µm	4.9338 µm	93.2258 N/mm
32.	52.3529 mm	5.9999 µm	4.7506 µm	89.7636 N/mm
33.	52.7451 mm	6.1828 µm	4.5677 µm	86.3081 N/mm
34.	53.1373 mm	6.3651 µm	4.3853 µm	82.8618 N/mm
35.	53.5294 mm	6.5469 µm	4.2036 µm	79.4276 N/mm
36.	53.9216 mm	6.7284 µm	4.0221 µm	75.9988 N/mm
37.	54.3137 mm	6.9091 µm	3.8413 µm	72.5828 N/mm
38.	54.7059 mm	7.0896 µm	3.6609 µm	69.1732 N/mm
39.	55.0980 mm	7.2697 µm	3.4808 µm	65.7703 N/mm
40.	55.4902 mm	7.4492 µm	3.3013 µm	62.3791 N/mm
41.	55.8824 mm	7.6284 µm	3.1221 µm	58.9924 N/mm
42.	56.2745 mm	7.8071 µm	2.9433 µm	55.6153 N/mm
43.	56.6667 mm	7.9855 µm	2.7650 µm	52.2446 N/mm
44.	57.0588 mm	8.1636 µm	2.5868 µm	48.8791 N/mm
45.	57.4510 mm	8.3412 µm	2.4092 µm	45.5233 N/mm
46.	57.8431 mm	8.5186 µm	2.2318 µm	42.1712 N/mm
47.	58.2353 mm	8.6956 µm	2.0548 µm	38.8265 N/mm
48.	58.6275 mm	8.8723 µm	1.8781 µm	35.4876 N/mm
49.	59.0196 mm	9.0489 µm	1.7016 µm	32.1523 N/mm
50.	59.4118 mm	9.2250 µm	1.5255 µm	28.8242 N/mm
51.	59.8039 mm	9.4011 µm	1.3493 µm	25.4963 N/mm

Explanations:
δ : Gap
g : Flank overlap
w : Line load

Force application point, Y direction: y = 46.444 mm (F = 2239.3 N)
To take into account the load distribution in the shaft calculation: Force center point offset: Δy = -3.556 mm

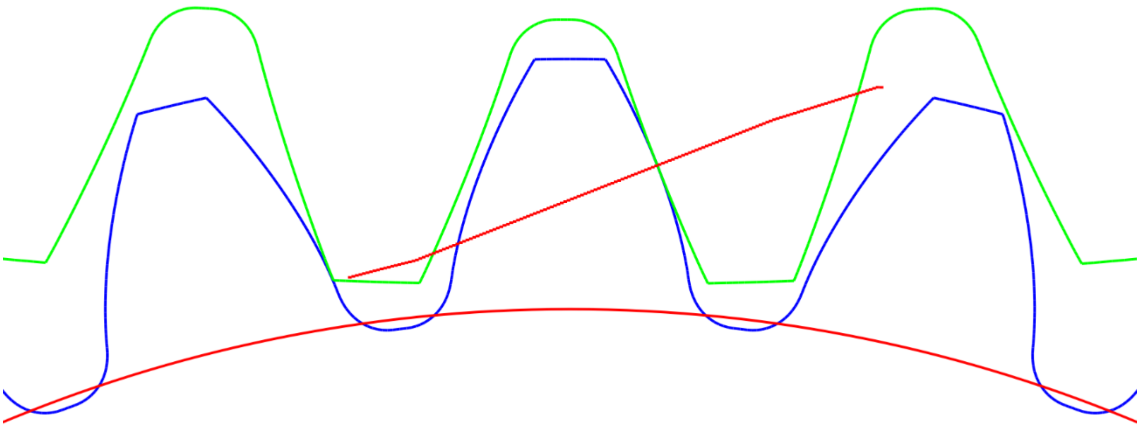
w_{max} = 203.133 N/mm, w_m = 111.964 N/mm
$w_m = K_V * K_A * K_\gamma * (F_t/b) / \cos(\alpha_{wt})$
K_V = 1.0752, K_A = 1.000, K_γ = 1.000
$K_{H\beta} = w_{max}/w_m$ = 1.8143 (Calculation according to ISO 6336-1, Appendix E)
Side I, II: w_I / w_m = 1.8143 wII / w_m = 0.2277

Notice: The influence of the exceeding facewidth is not taken into account in the calculation of $K_{H\beta}$.

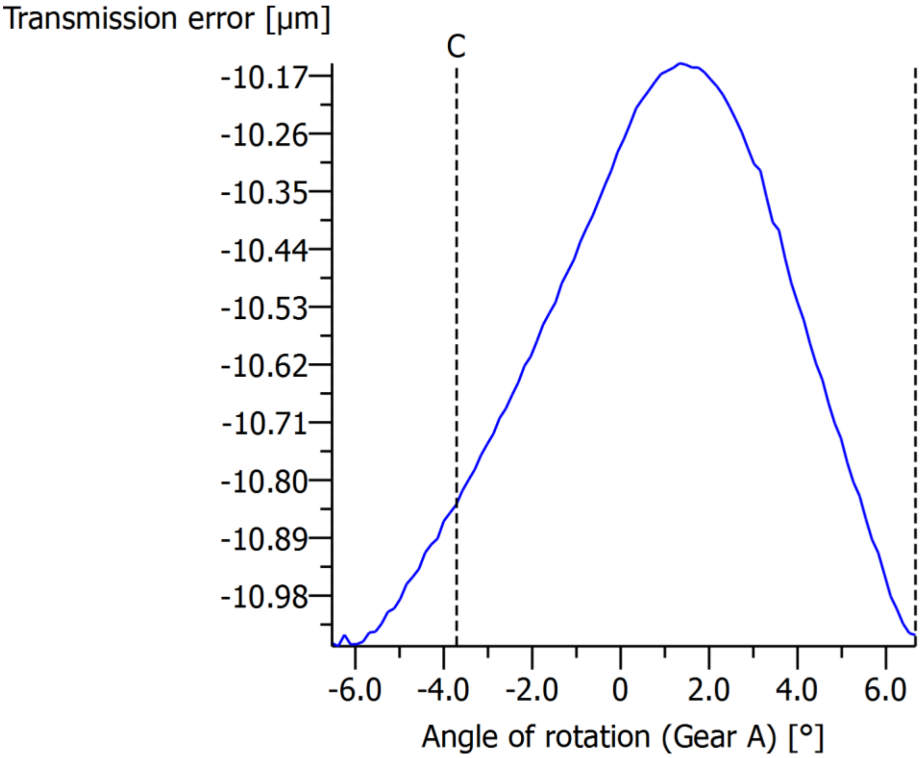
Calculation of the 'equivalent' linear misalignment of the shafts

a) Calculation of the 'equivalent' linear misalignment, so that $K_{H\beta}$ remains the same
Linear misalignment in the plane of action, Gear 1: [$F_{\beta x1}$] 6.18 µm ($K_{H\beta 1}$ = 1.5211)
Linear misalignment in the plane of action, Gear 2: [$F_{\beta x2}$] 3.47 µm ($K_{H\beta 2}$ = 1.2931)
Axis alignment: Deviation error of axis/Inclination error of axis fΣβ/fΣδ: 8.98 µm/3.52 µm ($F_{\beta x}$ = 9.65 µm)
The deformation due to tosrion is included in the specification of fΣβ/fΣδ.

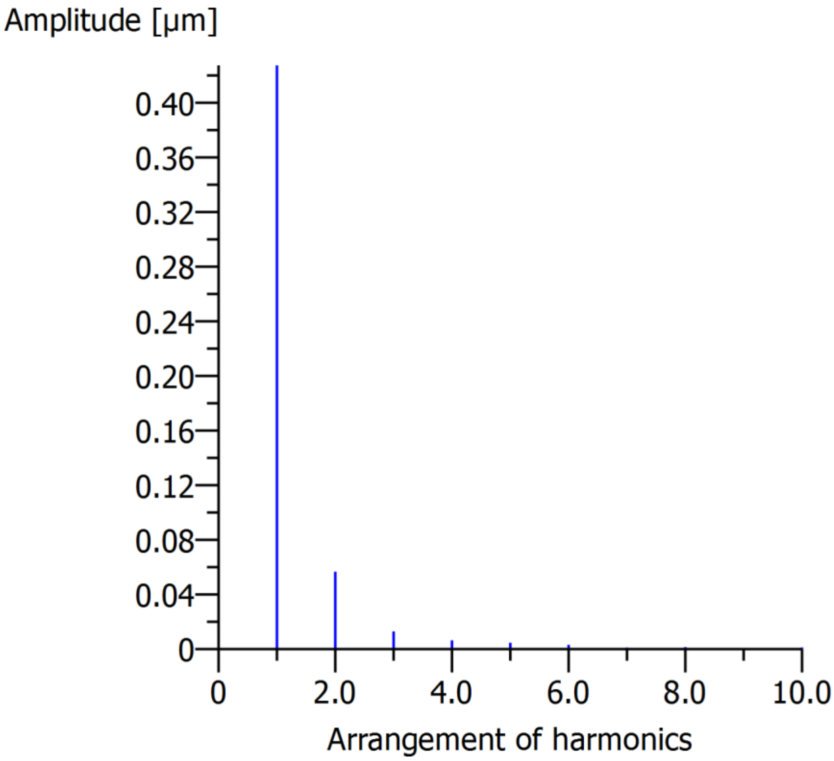
b) Linear misalignment due to connection of the gap from side I to II
Linear misalignment in the plane of action, Gear 1: [$F_{\beta x1}$] 5.94 µm
Linear misalignment in the plane of action, Gear 2: [$F_{\beta x2}$] 3.46 µm
Axis alignment: Deviation error of axis/Inclination error of axis fΣβ/fΣδ: 8.75 µm/3.43 µm (${F_{\beta x}}$ = 9.40 µm)
The deformation due to tosrion is included in the specification of fΣβ/fΣδ.



da1 = 45.6874 mm, df1 = 38.8180 mm, As1 = -0.0540 mmda2 = 163.9684 mm, df2 = 156.9589 mm, As2 = -0.1050 mm
Figure: Path of contact



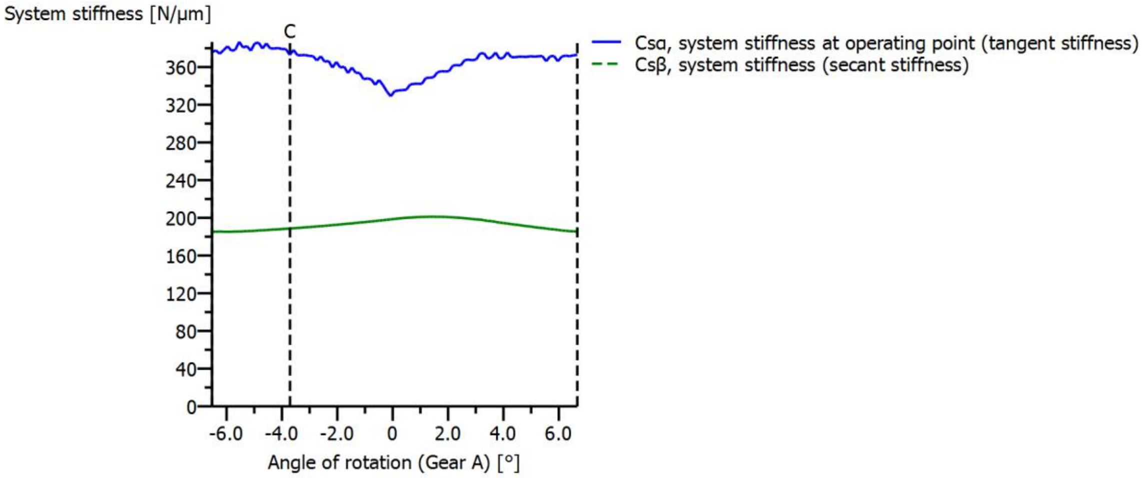
wt = 100 %, a = 101.845 mm,fpt = 0.000 µm,µ = 0.107Working flank: Right flank
Figure: Transmission error



Arrangement of harmonics Amplitude [µm]1. 0.4273782. 0.0566563. 0.0129554. 0.0064075. 0.0046326. 0.0031277. 0.0011528. 0.0014699. 0.00062510. 0.001185

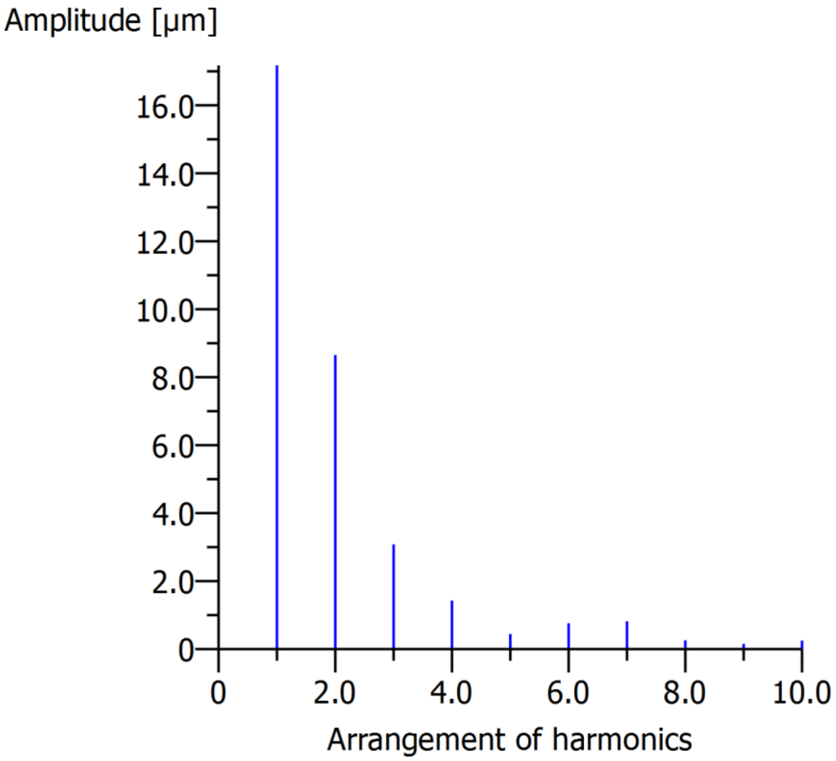
wt = 100 %, a = 101.845 mm,fpt = 0.000 µm,µ = 0.107Working flank: Right flank

Figure: Amplitude spectrum of transmission error



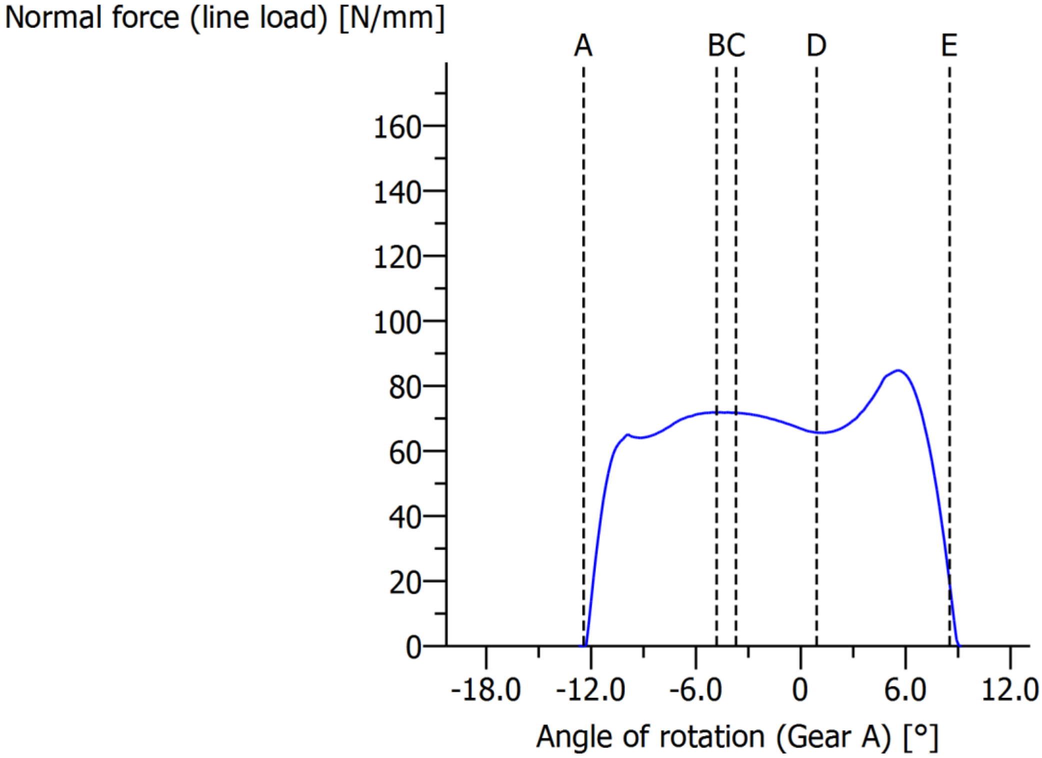
wt = 100 %, a = 101.845 mm,fpt = 0.000 µm,µ = 0.107Working flank: Right flankCsα_mean = 364.8450387 N/µmCsβ_mean = 192.8693904 N/µmCsα = Cγα * bCsβ = Cγβ * b

Figure: Stiffness curve



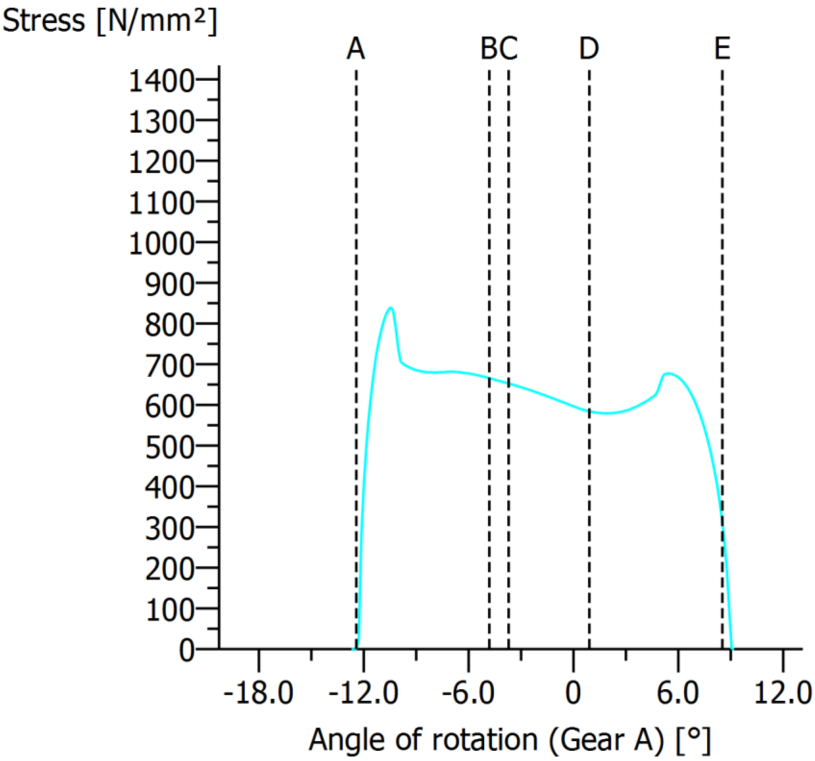
Arrangement of harmonics Amplitude [N/mm/µm]1. 17.1747232. 8.6523893. 3.0807524. 1.4289105. 0.4439176. 0.7597007. 0.8163658. 0.2592859. 0.15542010. 0.251625 wt = 100 %, a = 101.845 mm,fpt = 0.000 µm,µ = 0.107Working flank: Right flank

Figure: Amplitude spectrum of contact stiffness



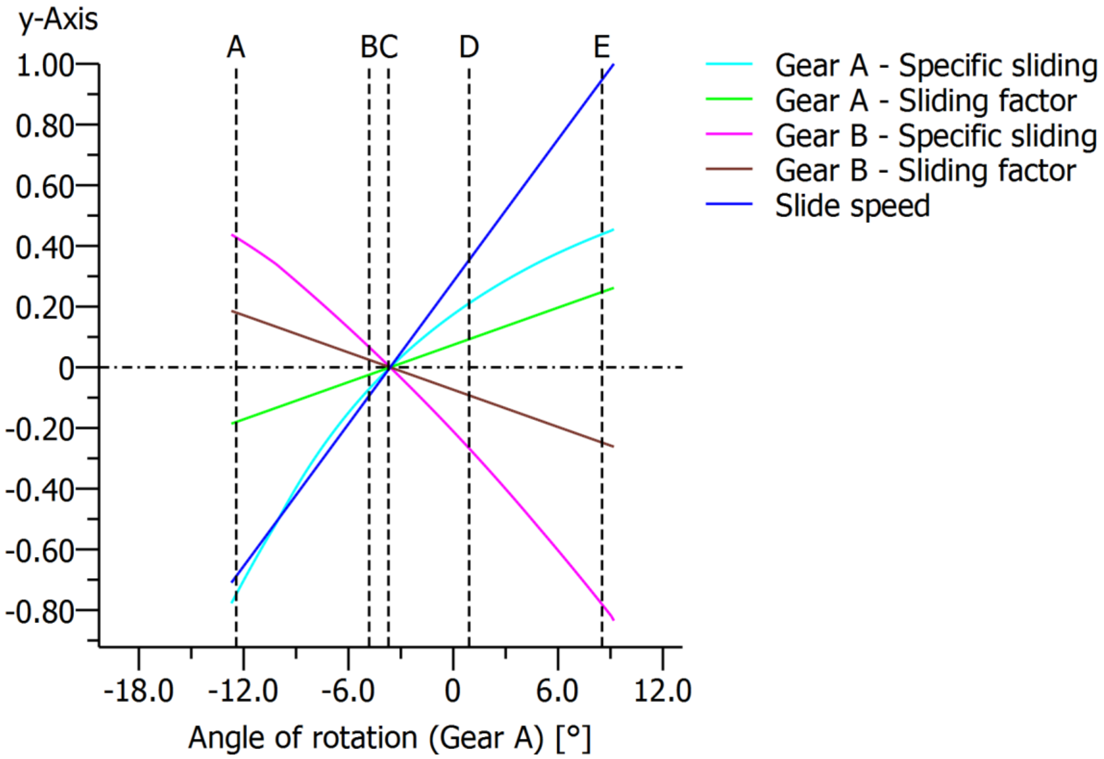
wt = 100 %, a = 101.845 mm,fpt = 0.000 µm,µ = 0.107Working flank: Right flank

Figure: Normal force curve (Line load)



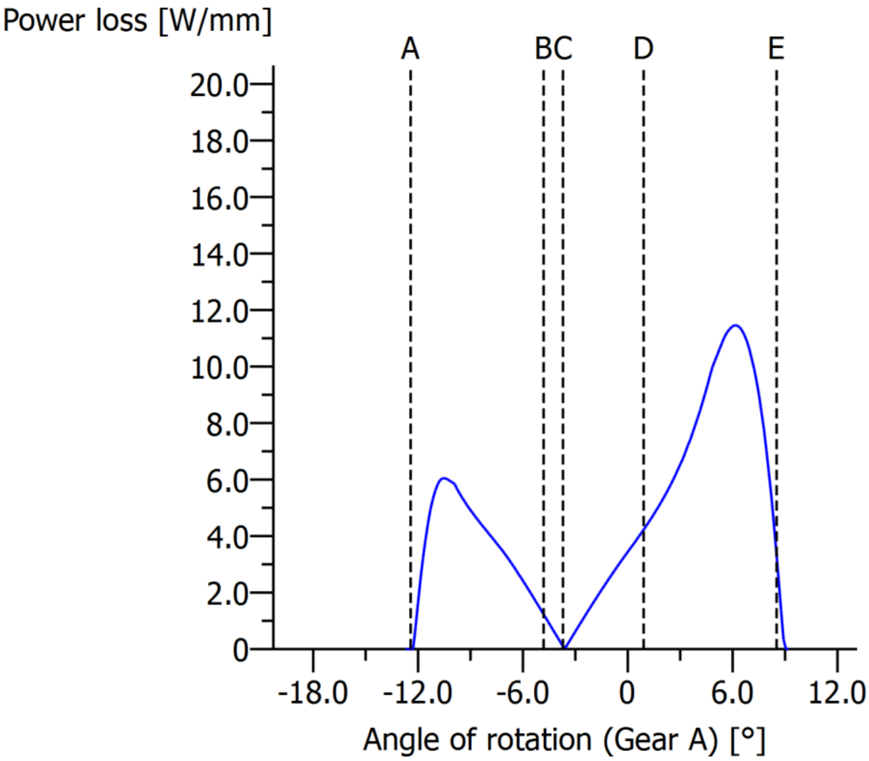
wt = 100 %, a = 101.845 mm,fpt = 0.000 µm,µ = 0.107Working flank: Right flank

Figure: Stress curve



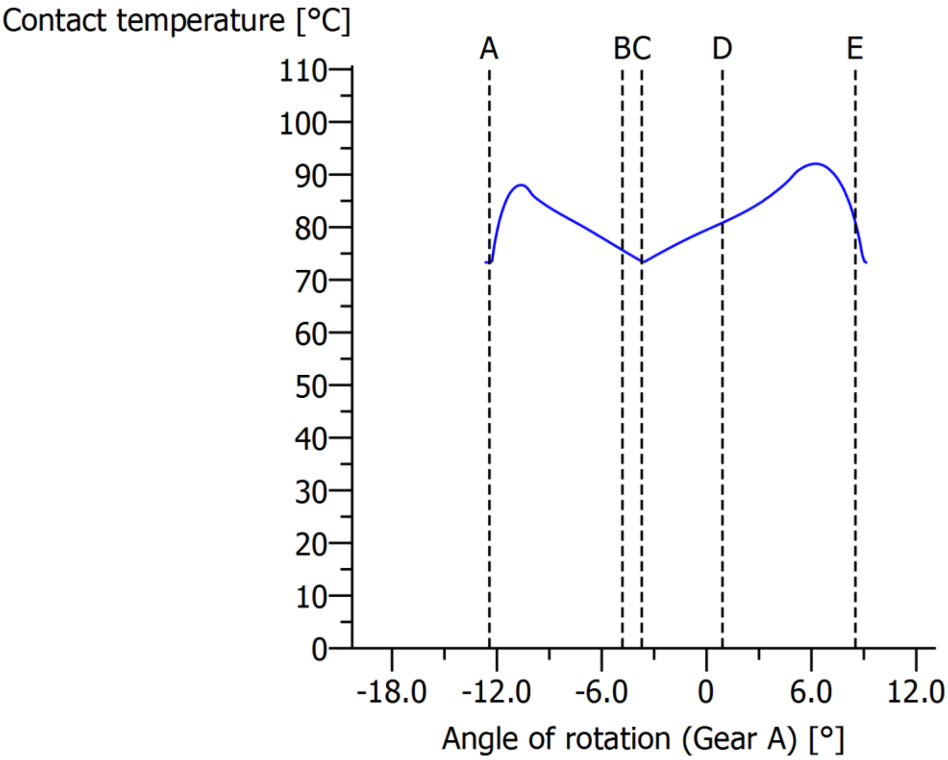
wt = 100 %, a = 101.845 mm,fpt = 0.000 µm,µ = 0.107Working flank: Right flankMaximum sliding velocity: 1.790 m/s

Figure: Kinematics



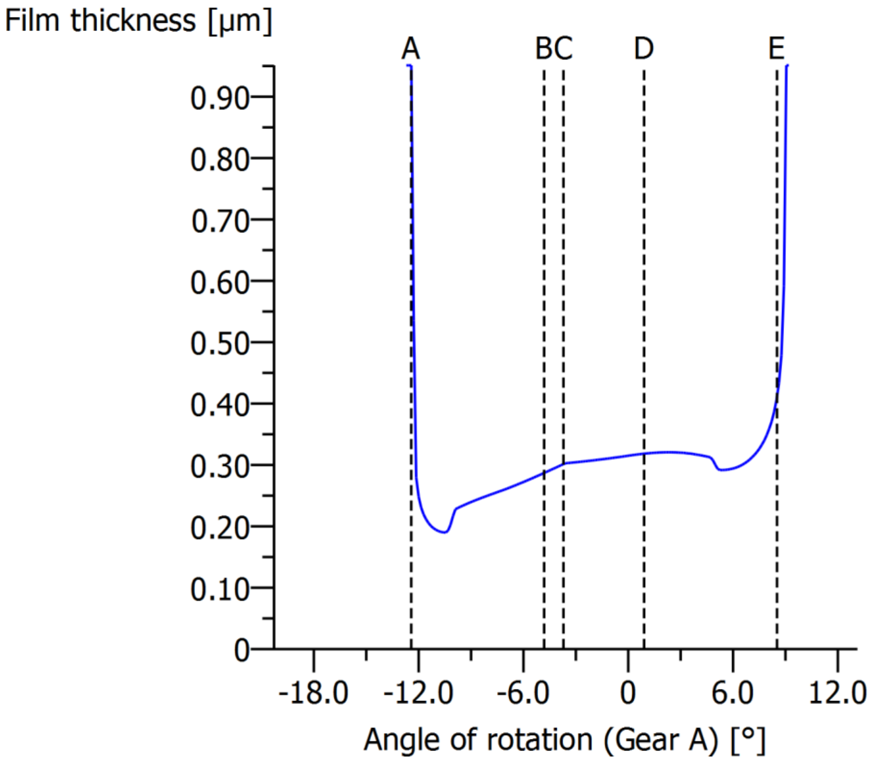
wt = 100 %, a = 101.845 mm,fpt = 0.000 µm,µ = 0.107Displaying power losses per mm facewidthWorking flank: Right flank

Figure: Specific Power Loss



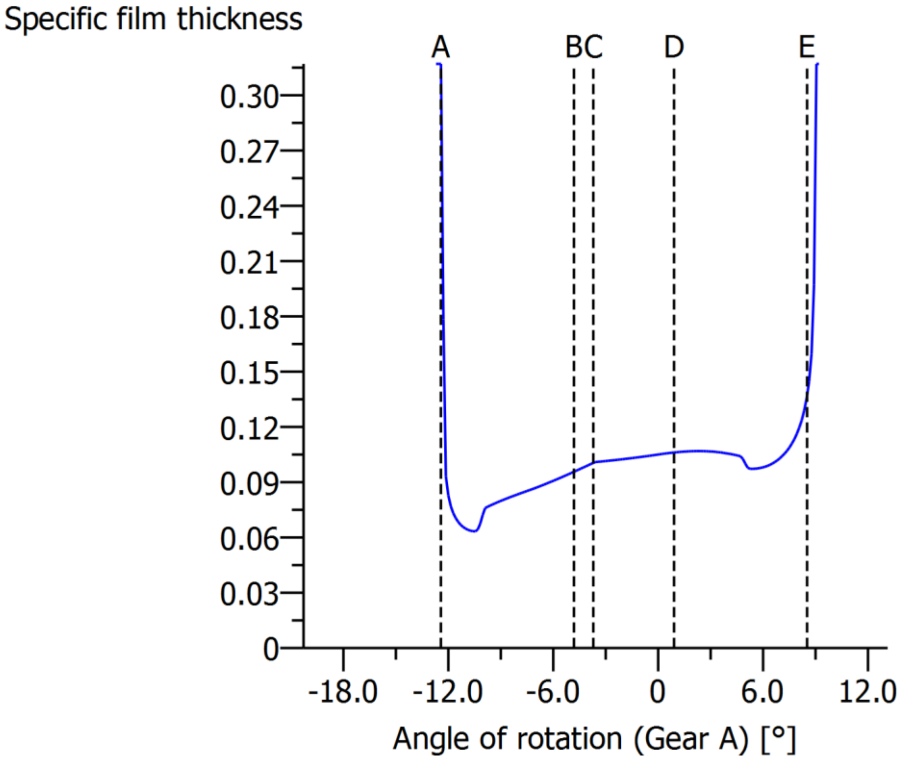
wt = 100 %, a = 101.845 mm,fpt = 0.000 µm,µ = 0.107the0il = 70.0 °C, theM = 73.3 °C, etaM = 28.55 mPa*sWorking flank: Right flank

Figure: Contact temperature



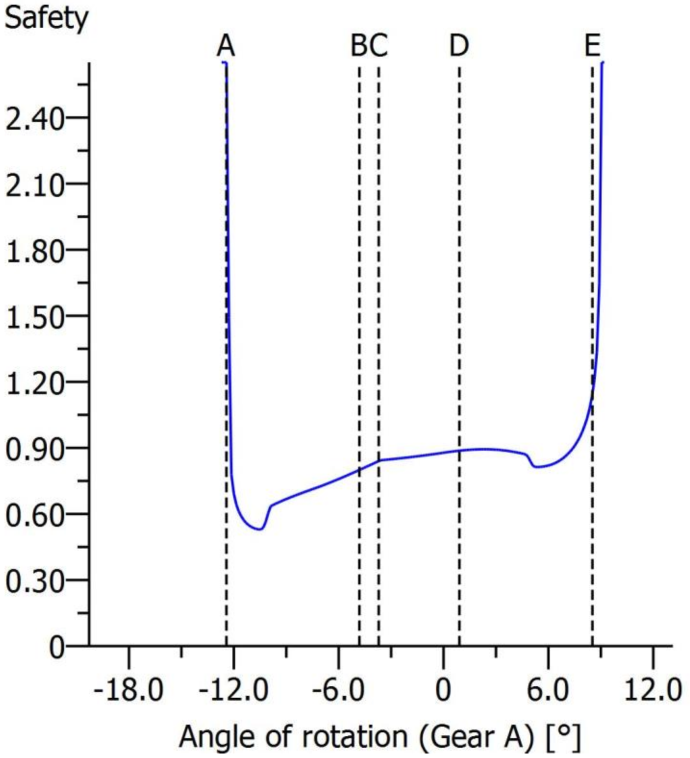
wt = 100 %, a = 101.845 mm,fpt = 0.000 µm,µ = 0.107the0il = 70.0 °C, theM = 73.3 °C, etaM = 28.55 mPa*shMini(ISO) = 0.141 µm, Ra = 3.000 µmWorking flank: Right flank

Figure: Lubricating film (ISO TR 15144)



wt = 100 %, a = 101.845 mm,fpt = 0.000 µm,µ = 0.107the0il = 70.0 °C, theM = 73.3 °C, etaM = 28.55 mPa*shMini(ISO) = 0.141 µm, Ra = 3.000 µm, lamGFmin = 0.047Working flank: Right flank

Figure: Specific film thickness (ISO TR 15144)



wt = 100 %, a = 101.845 mm,fpt = 0.000 µm,µ = 0.107the0il = 70.0 °C, theM = 73.3 °C, etaM = 28.55 mPa*sSlam(ISO) = 0.392, Ra = 3.000 µmWorking flank: Right flank

Figure: Safety against micropitting (ISO TR 15144)

End of Report lines: 312

3.2 Report of contact analysis of the end variant with main load stage

KISSsoft Release 03/2015 D

KISSsoft-Entwicklungs-Version KISSsoft AG CH-8608 BUBIKON

File

Filename: C:/KISSsoft 03-2015/example/CylGearPair 6a (shafts for contact analysis) (Helical DIN3990).Z12

Description: KISSsoft example

Changed by: mhoffmann am: 31.07.2015 um: 13:55:53

Contact Analysis

Meshing gear 1 - gear 2

Accuracy of calculation		Medium	
Partial load for calculation	**[w_t]**	**100.0000**	**(%)**

Note: In order to obtain contact analysis results for scuffing, micropitting and tooth flank fracture according to method A of ISO the calculation would have to be performed with w_t = 100*Kgam*KA*KV..

(w_t*Kgam*KA*KV = 107.52 %)

Working flank		Right tooth flank	
Center distance	[a]	101.8450	(mm)
Single pitch deviation	[f_{pt}]	0.0000	(µm)
Coefficient. of friction	[µ]	0.0973	
Deviation error of axis	[$f_{\Sigma\beta}$]	0.0000	(µm)
Inclination error of axis	[$f_{\Sigma\delta}$]	0.0000	(µm)
Torque	[T_1]	40.4631	(Nm)

Torsion from shaft calculation

		min	**max**	**Δ**	**µ**	**σ**
Transmission error	(µm)	-6.1094	-6.0009	0.1085	-6.0577	0.0385
Tangent Stiffness curve	(N/µm)	368.2074	378.7227	10.5154	374.3494	3.3633
Secant stiffness curve	(N/µm)	335.1637	341.0886	5.9249	337.9938	2.0914
Line load	(N/mm)	0.0000	96.6901	96.6901	65.8095	20.9818
Torque Gear 1	(Nm)	40.4594	40.4670	0.0077	40.4636	0.0020
Torque Gear 2	(Nm)	154.0399	154.1414	0.1015	154.1006	0.0283
Power loss	(W)	138.6316	147.7028	9.0712	143.7230	2.8966
Contact temperature	(°C)	73.0861	95.1311	22.0451	82.0280	5.5623
Thickness of lubrication film	(µm)	0.1709	1.2579	1.0870	0.3279	0.1946
Hertzian pressure	(N/mm²)		1046.4922		618.9214	
Tooth root stress gear 1	(N/mm²)		206.9704		144.8776	
Tooth root stress gear 2	(N/mm²)		167.4844		142.4823	

Safety against micropitting (ISO/TR 15144 Method A)			0.4763
Safety against scuffing			18.0208
Transverse contact ratio under load	[εα]		1.6632
		min	1.6526
		µ	1.6533
		max	1.6632
Overlap ratio under load	[εβ]		0.9847
Total contact ratio under load	[εγ]		2.6478
Efficiency	[η]		98.8500

Face load factor (ISO 6336-1 Appendix E)

[$K_{H\beta}$] 1.0023

Note: The resulting safeties do not correspond with Method A according ISO because Kγ, KA and KV are not taken into account.

Amplitude spectrum of the transmission error

Harmonics	Amplitude (µm)
1	0.052
2	0.011
3	0.010
4	0.001
5	0.003
6	0.002
7	0.000
8	0.001
9	0.001
10	0.001

$K_{H\beta}$ Calculation - Gear 1 - Gear 2

Right flank

Shaft file A: C:/KISSsoft 03-2015/example/Pinion shaft for CylGearPair 6a.W10, selected gear: Pinion from CylGearPair6 (gears as masses and stiffness)

Shaft file B: C:/KISSsoft 03-2015/example/Gear shaft for CylGearPair 6a.W10, selected gear: Gear from CylGearPair6 (gears as masses and stiffness)

(Partial load for calculation w_t = 100 %)

f_{ma} = 0.000 µm , $f_{H\beta}$ = 0.000 µm

Result after i = 2 iterations of load distribution

Gear 1

Point in polar co-ordinates:

R = 20.991 mm , φ = 0.000 °

Displacement calculated in direction 111.425 °

	y	φ1.t	f1.t	f1.b	f1.tot	f1.C	f1.tot+f1.C
1	40.196 mm	0.0000°	-0.0045 µm	-0.0445 µm	-0.0490 µm	0.0000 µm	-0.0490 µm
2	40.588 mm	-0.0000°	0.0094 µm	0.0935 µm	0.1029 µm	-0.1515 µm	-0.0486 µm
3	40.980 mm	-0.0001°	0.0233 µm	0.2315 µm	0.2548 µm	-0.3030 µm	-0.0482 µm
4	41.373 mm	-0.0001°	0.0368 µm	0.3691 µm	0.4059 µm	-0.4535 µm	-0.0476 µm
5	41.765 mm	-0.0001°	0.0502 µm	0.5065 µm	0.5567 µm	-0.6038 µm	-0.0471 µm
6	42.157 mm	-0.0002°	0.0632 µm	0.6437 µm	0.7069 µm	-0.7534 µm	-0.0465 µm
7	42.549 mm	-0.0002°	0.0759 µm	0.7805 µm	0.8564 µm	-0.9024 µm	-0.0460 µm
8	42.941 mm	-0.0003°	0.0884 µm	0.9172 µm	1.0056 µm	-1.0511 µm	-0.0455 µm
9	43.333 mm	-0.0003°	0.1005 µm	1.0534 µm	1.1539 µm	-1.1989 µm	-0.0450 µm
10	43.725 mm	-0.0003°	0.1123 µm	1.1895 µm	1.3018 µm	-1.3463 µm	-0.0445 µm
11	44.118 mm	-0.0004°	0.1239 µm	1.3253 µm	1.4492 µm	-1.4932 µm	-0.0440 µm
12	44.510 mm	-0.0004°	0.1351 µm	1.4607 µm	1.5958 µm	-1.6394 µm	-0.0436 µm
13	44.902 mm	-0.0004°	0.1462 µm	1.5960 µm	1.7421 µm	-1.7852 µm	-0.0431 µm
14	45.294 mm	-0.0005°	0.1568 µm	1.7308 µm	1.8876 µm	-1.9303 µm	-0.0427 µm
15	45.686 mm	-0.0005°	0.1671 µm	1.8654 µm	2.0326 µm	-2.0749 µm	-0.0424 µm
16	46.078 mm	-0.0005°	0.1773 µm	1.9998 µm	2.1771 µm	-2.2191 µm	-0.0420 µm
17	46.471 mm	-0.0005°	0.1870 µm	2.1338 µm	2.3208 µm	-2.3624 µm	-0.0417 µm
18	46.863 mm	-0.0006°	0.1965 µm	2.2676 µm	2.4641 µm	-2.5054 µm	-0.0413 µm
19	47.255 mm	-0.0006°	0.2057 µm	2.4010 µm	2.6067 µm	-2.6478 µm	-0.0411 µm
20	47.647 mm	-0.0006°	0.2145 µm	2.5341 µm	2.7487 µm	-2.7896 µm	-0.0409 µm
21	48.039 mm	-0.0007°	0.2232 µm	2.6671 µm	2.8903 µm	-2.9310 µm	-0.0407 µm
22	48.431 mm	-0.0007°	0.2314 µm	2.7996 µm	3.0310 µm	-3.0715 µm	-0.0405 µm
23	48.824 mm	-0.0007°	0.2395 µm	2.9319 µm	3.1713 µm	-3.2117 µm	-0.0404 µm
24	49.216 mm	-0.0007°	0.2472 µm	3.0639 µm	3.3110 µm	-3.3513 µm	-0.0403 µm
25	49.608 mm	-0.0007°	0.2545 µm	3.1955 µm	3.4500 µm	-3.4903 µm	-0.0402 µm
26	50.000 mm	-0.0008°	0.2617 µm	3.3270 µm	3.5887 µm	-3.6289 µm	-0.0402 µm
27	50.392 mm	-0.0008°	0.2684 µm	3.4580 µm	3.7264 µm	-3.7666 µm	-0.0402 µm

28	50.784 mm	-0.0008°	0.2750 µm	3.5888 µm	3.8638 µm	-3.9040 µm	-0.0403 µm
29	51.176 mm	-0.0008°	0.2812 µm	3.7192 µm	4.0005 µm	-4.0408 µm	-0.0404 µm
30	51.569 mm	-0.0008°	0.2871 µm	3.8494 µm	4.1365 µm	-4.1770 µm	-0.0405 µm
31	51.961 mm	-0.0009°	0.2928 µm	3.9793 µm	4.2721 µm	-4.3128 µm	-0.0407 µm
32	52.353 mm	-0.0009°	0.2981 µm	4.1088 µm	4.4069 µm	-4.4478 µm	-0.0409 µm
33	52.745 mm	-0.0009°	0.3031 µm	4.2381 µm	4.5412 µm	-4.5824 µm	-0.0412 µm
34	53.137 mm	-0.0009°	0.3079 µm	4.3671 µm	4.6750 µm	-4.7165 µm	-0.0415 µm
35	53.529 mm	-0.0009°	0.3123 µm	4.4957 µm	4.8080 µm	-4.8498 µm	-0.0418 µm
36	53.922 mm	-0.0009°	0.3165 µm	4.6241 µm	4.9406 µm	-4.9828 µm	-0.0422 µm
37	54.314 mm	-0.0009°	0.3203 µm	4.7521 µm	5.0724 µm	-5.1151 µm	-0.0427 µm
38	54.706 mm	-0.0009°	0.3239 µm	4.8798 µm	5.2037 µm	-5.2468 µm	-0.0431 µm
39	55.098 mm	-0.0010°	0.3272 µm	5.0073 µm	5.3345 µm	-5.3781 µm	-0.0436 µm
40	55.490 mm	-0.0010°	0.3301 µm	5.1344 µm	5.4645 µm	-5.5087 µm	-0.0442 µm
41	55.882 mm	-0.0010°	0.3328 µm	5.2613 µm	5.5941 µm	-5.6389 µm	-0.0448 µm
42	56.275 mm	-0.0010°	0.3351 µm	5.3878 µm	5.7229 µm	-5.7683 µm	-0.0454 µm
43	56.667 mm	-0.0010°	0.3372 µm	5.5140 µm	5.8512 µm	-5.8973 µm	-0.0461 µm
44	57.059 mm	-0.0010°	0.3390 µm	5.6400 µm	5.9791 µm	-6.0259 µm	-0.0468 µm
45	57.451 mm	-0.0010°	0.3405 µm	5.7656 µm	6.1060 µm	-6.1536 µm	-0.0476 µm
46	57.843 mm	-0.0010°	0.3417 µm	5.8910 µm	6.2326 µm	-6.2810 µm	-0.0483 µm
47	58.235 mm	-0.0010°	0.3425 µm	6.0160 µm	6.3585 µm	-6.4077 µm	-0.0492 µm
48	58.627 mm	-0.0010°	0.3431 µm	6.1407 µm	6.4838 µm	-6.5338 µm	-0.0500 µm
49	59.020 mm	-0.0010°	0.3435 µm	6.2652 µm	6.6087 µm	-6.6596 µm	-0.0509 µm
50	59.412 mm	-0.0010°	0.3436 µm	6.3893 µm	6.7329 µm	-6.7846 µm	-0.0517 µm
51	59.804 mm	-0.0010°	0.3436 µm	6.5134 µm	6.8570 µm	-6.9094 µm	-0.0525 µm

Gear 2
Point in polar co-ordinates:
R = 80.854 mm , φ = 180.000 °
Displacement calculated in direction 111.425 °

	y	φ2.t	f2.t	f2.b	f2.tot	f2.C	f2.tot+f2.C
1	24.196 mm	-0.0000°	-0.0000 µm	0.0230 µm	0.0230 µm	0.0000 µm	0.0230 µm
2	24.588 mm	0.0000°	0.0000 µm	-0.0484 µm	-0.0483 µm	0.0706 µm	0.0222 µm
3	24.980 mm	0.0000°	0.0000 µm	-0.1197 µm	-0.1197 µm	0.1412 µm	0.0215 µm
4	25.373 mm	0.0000°	0.0001 µm	-0.1911 µm	-0.1910 µm	0.2118 µm	0.0208 µm
5	25.765 mm	0.0000°	0.0001 µm	-0.2624 µm	-0.2623 µm	0.2824 µm	0.0200 µm
6	26.157 mm	0.0000°	0.0002 µm	-0.3338 µm	-0.3336 µm	0.3529 µm	0.0194 µm
7	26.549 mm	0.0000°	0.0003 µm	-0.4051 µm	-0.4048 µm	0.4235 µm	0.0187 µm
8	26.941 mm	0.0000°	0.0004 µm	-0.4764 µm	-0.4760 µm	0.4941 µm	0.0181 µm
9	27.333 mm	0.0000°	0.0005 µm	-0.5477 µm	-0.5472 µm	0.5647 µm	0.0175 µm
10	27.725 mm	0.0000°	0.0007 µm	-0.6190 µm	-0.6183 µm	0.6353 µm	0.0170 µm
11	28.118 mm	0.0000°	0.0009 µm	-0.6903 µm	-0.6894 µm	0.7059 µm	0.0165 µm
12	28.510 mm	0.0000°	0.0010 µm	-0.7615 µm	-0.7605 µm	0.7765 µm	0.0160 µm
13	28.902 mm	0.0000°	0.0012 µm	-0.8328 µm	-0.8315 µm	0.8471 µm	0.0155 µm
14	29.294 mm	0.0000°	0.0015 µm	-0.9040 µm	-0.9026 µm	0.9176 µm	0.0151 µm
15	29.686 mm	0.0000°	0.0017 µm	-0.9752 µm	-0.9735 µm	0.9882 µm	0.0147 µm
16	30.078 mm	0.0000°	0.0020 µm	-1.0465 µm	-1.0445 µm	1.0588 µm	0.0143 µm
17	30.471 mm	0.0000°	0.0022 µm	-1.1177 µm	-1.1154 µm	1.1294 µm	0.0140 µm
18	30.863 mm	0.0000°	0.0025 µm	-1.1889 µm	-1.1863 µm	1.2000 µm	0.0137 µm
19	31.255 mm	0.0000°	0.0028 µm	-1.2600 µm	-1.2572 µm	1.2706 µm	0.0134 µm
20	31.647 mm	0.0000°	0.0032 µm	-1.3312 µm	-1.3280 µm	1.3412 µm	0.0131 µm
21	32.039 mm	0.0000°	0.0035 µm	-1.4023 µm	-1.3988 µm	1.4118 µm	0.0129 µm
22	32.431 mm	0.0000°	0.0039 µm	-1.4735 µm	-1.4696 µm	1.4824 µm	0.0127 µm
23	32.824 mm	0.0000°	0.0043 µm	-1.5446 µm	-1.5404 µm	1.5529 µm	0.0126 µm
24	33.216 mm	0.0000°	0.0047 µm	-1.6157 µm	-1.6111 µm	1.6235 µm	0.0125 µm
25	33.608 mm	0.0000°	0.0051 µm	-1.6868 µm	-1.6817 µm	1.6941 µm	0.0124 µm
26	34.000 mm	0.0000°	0.0055 µm	-1.7579 µm	-1.7524 µm	1.7647 µm	0.0123 µm
27	34.392 mm	0.0000°	0.0060 µm	-1.8290 µm	-1.8230 µm	1.8353 µm	0.0123 µm

28	34.784 mm	0.0000°	0.0065 µm	-1.9001 µm	-1.8936 µm	1.9059 µm	0.0123 µm
29	35.176 mm	0.0000°	0.0069 µm	-1.9711 µm	-1.9642 µm	1.9765 µm	0.0123 µm
30	35.569 mm	0.0000°	0.0075 µm	-2.0421 µm	-2.0347 µm	2.0471 µm	0.0124 µm
31	35.961 mm	0.0000°	0.0080 µm	-2.1132 µm	-2.1052 µm	2.1176 µm	0.0125 µm
32	36.353 mm	0.0000°	0.0085 µm	-2.1842 µm	-2.1756 µm	2.1882 µm	0.0126 µm
33	36.745 mm	0.0000°	0.0091 µm	-2.2552 µm	-2.2461 µm	2.2588 µm	0.0127 µm
34	37.137 mm	0.0000°	0.0097 µm	-2.3262 µm	-2.3165 µm	2.3294 µm	0.0129 µm
35	37.529 mm	0.0000°	0.0103 µm	-2.3971 µm	-2.3869 µm	2.4000 µm	0.0131 µm
36	37.922 mm	0.0000°	0.0109 µm	-2.4681 µm	-2.4572 µm	2.4706 µm	0.0134 µm
37	38.314 mm	0.0000°	0.0115 µm	-2.5390 µm	-2.5275 µm	2.5412 µm	0.0137 µm
38	38.706 mm	0.0000°	0.0122 µm	-2.6100 µm	-2.5978 µm	2.6118 µm	0.0140 µm
39	39.098 mm	0.0000°	0.0129 µm	-2.6809 µm	-2.6680 µm	2.6824 µm	0.0143 µm
40	39.490 mm	0.0000°	0.0136 µm	-2.7518 µm	-2.7383 µm	2.7529 µm	0.0147 µm
41	39.882 mm	0.0000°	0.0143 µm	-2.8227 µm	-2.8085 µm	2.8235 µm	0.0151 µm
42	40.275 mm	0.0000°	0.0150 µm	-2.8936 µm	-2.8786 µm	2.8941 µm	0.0155 µm
43	40.667 mm	0.0000°	0.0157 µm	-2.9645 µm	-2.9487 µm	2.9647 µm	0.0160 µm
44	41.059 mm	0.0000°	0.0165 µm	-3.0353 µm	-3.0188 µm	3.0353 µm	0.0165 µm
45	41.451 mm	0.0000°	0.0173 µm	-3.1062 µm	-3.0889 µm	3.1059 µm	0.0170 µm
46	41.843 mm	0.0000°	0.0181 µm	-3.1770 µm	-3.1589 µm	3.1765 µm	0.0176 µm
47	42.235 mm	0.0000°	0.0189 µm	-3.2478 µm	-3.2289 µm	3.2471 µm	0.0181 µm
48	42.627 mm	0.0000°	0.0197 µm	-3.3186 µm	-3.2989 µm	3.3176 µm	0.0188 µm
49	43.020 mm	0.0000°	0.0206 µm	-3.3894 µm	-3.3688 µm	3.3882 µm	0.0194 µm
50	43.412 mm	0.0000°	0.0215 µm	-3.4602 µm	-3.4387 µm	3.4588 µm	0.0201 µm
51	43.804 mm	0.0000°	0.0223 µm	-3.5310 µm	-3.5086 µm	3.5294 µm	0.0208 µm

Explanations:

y	: Width
φ.t	: Static torsion
f.t	: Displacement due to torsion
f.b	: Displacement due to bending
f.tot	: Total displacement (f.b+f.t)
f.C	: Change due to flank line modification

Load distribution

Contact stiffness = 18.895 N/mm/µm

Young's modulus = 206000.0/206000.0 N/mm²

	y	δ	g	w
1.	40.1961 mm	0.0012 µm	5.9378 µm	112.1957 N/mm
2.	40.5882 mm	0.0024 µm	5.9366 µm	112.1737 N/mm
3.	40.9804 mm	0.0036 µm	5.9354 µm	112.1516 N/mm
4.	41.3725 mm	0.0048 µm	5.9341 µm	112.1273 N/mm
5.	41.7647 mm	0.0061 µm	5.9329 µm	112.1034 N/mm
6.	42.1569 mm	0.0073 µm	5.9317 µm	112.0803 N/mm
7.	42.5490 mm	0.0085 µm	5.9305 µm	112.0582 N/mm
8.	42.9412 mm	0.0096 µm	5.9294 µm	112.0366 N/mm
9.	43.3333 mm	0.0107 µm	5.9283 µm	112.0163 N/mm
10.	43.7255 mm	0.0118 µm	5.9272 µm	111.9966 N/mm
11.	44.1176 mm	0.0128 µm	5.9262 µm	111.9777 N/mm
12.	44.5098 mm	0.0137 µm	5.9253 µm	111.9597 N/mm
13.	44.9020 mm	0.0146 µm	5.9244 µm	111.9423 N/mm
14.	45.2941 mm	0.0154 µm	5.9236 µm	111.9273 N/mm
15.	45.6863 mm	0.0162 µm	5.9228 µm	111.9127 N/mm
16.	46.0784 mm	0.0170 µm	5.9220 µm	111.8985 N/mm
17.	46.4706 mm	0.0176 µm	5.9214 µm	111.8861 N/mm
18.	46.8627 mm	0.0182 µm	5.9208 µm	111.8744 N/mm
19.	47.2549 mm	0.0187 µm	5.9202 µm	111.8646 N/mm
20.	47.6471 mm	0.0192 µm	5.9198 µm	111.8557 N/mm
21.	48.0392 mm	0.0196 µm	5.9193 µm	111.8476 N/mm

22.	48.4314 mm	0.0200 µm	5.9190 µm	111.8412 N/mm
23.	48.8235 mm	0.0203 µm	5.9187 µm	111.8355 N/mm
24.	49.2157 mm	0.0205 µm	5.9185 µm	111.8312 N/mm
25.	49.6078 mm	0.0206 µm	5.9184 µm	111.8288 N/mm
26.	50.0000 mm	0.0207 µm	5.9183 µm	111.8274 N/mm
27.	50.3922 mm	0.0207 µm	5.9183 µm	111.8271 N/mm
28.	50.7843 mm	0.0207 µm	5.9183 µm	111.8279 N/mm
29.	51.1765 mm	0.0206 µm	5.9184 µm	111.8305 N/mm
30.	51.5686 mm	0.0203 µm	5.9187 µm	111.8346 N/mm
31.	51.9608 mm	0.0201 µm	5.9189 µm	111.8395 N/mm
32.	52.3529 mm	0.0197 µm	5.9193 µm	111.8464 N/mm
33.	52.7451 mm	0.0193 µm	5.9197 µm	111.8541 N/mm
34.	53.1373 mm	0.0188 µm	5.9202 µm	111.8629 N/mm
35.	53.5294 mm	0.0183 µm	5.9207 µm	111.8738 N/mm
36.	53.9216 mm	0.0176 µm	5.9214 µm	111.8856 N/mm
37.	54.3137 mm	0.0169 µm	5.9221 µm	111.8996 N/mm
38.	54.7059 mm	0.0161 µm	5.9229 µm	111.9142 N/mm
39.	55.0980 mm	0.0153 µm	5.9237 µm	111.9294 N/mm
40.	55.4902 mm	0.0144 µm	5.9246 µm	111.9474 N/mm
41.	55.8824 mm	0.0134 µm	5.9256 µm	111.9664 N/mm
42.	56.2745 mm	0.0123 µm	5.9267 µm	111.9866 N/mm
43.	56.6667 mm	0.0112 µm	5.9278 µm	112.0081 N/mm
44.	57.0588 mm	0.0100 µm	5.9290 µm	112.0306 N/mm
45.	57.4510 mm	0.0087 µm	5.9303 µm	112.0549 N/mm
46.	57.8431 mm	0.0073 µm	5.9316 µm	112.0800 N/mm
47.	58.2353 mm	0.0059 µm	5.9331 µm	112.1068 N/mm
48.	58.6275 mm	0.0044 µm	5.9346 µm	112.1349 N/mm
49.	59.0196 mm	0.0029 µm	5.9361 µm	112.1638 N/mm
50.	59.4118 mm	0.0015 µm	5.9375 µm	112.1914 N/mm
51.	59.8039 mm	0.0000 µm	5.9390 µm	112.2188 N/mm

Explanations:

δ : Gap

g : Flank overlap

w : Line load

Force application point, Y direction: y = 50.000 mm (F = 2239.3 N)

To take into account the load distribution in the shaft calculation: Force center point offset: Δy = -0.000 mm

w_{max} = 112.219 N/mm, w_m = 111.964 N/mm

$w_m = K_v * K_A * K_\gamma * (F_t/b) / \cos(\alpha_{wt})$

K_v = 1.0752, K_A = 1.000, K_γ = 1.000

$K_{H\beta} = w_{max}/w_m$ = 1.0023 (Calculation according to ISO 6336-1, Appendix E)

Side I, II: w_I / w_m = 1.0021 w_{II} / w_m = 1.0023

Notice: The influence of the exceeding facewidth is not taken into account in the calculation of $K_{H\beta}$.

Calculation of the 'equivalent' linear misalignment of the shafts

IMPORTANT: The flank line modifications are taken into account.

a) Calculation of the 'equivalent' linear misalignment, so that $K_{H\beta}$ remains the same

Linear misalignment in the plane of action, Gear 1: [$F_{\beta x1}$] 0.02 µm ($K_{H\beta 1}$ = 1.0014)

Linear misalignment in the plane of action, Gear 2: [$F_{\beta x2}$] 7.07 µm ($K_{H\beta 2}$ = 1.5969)

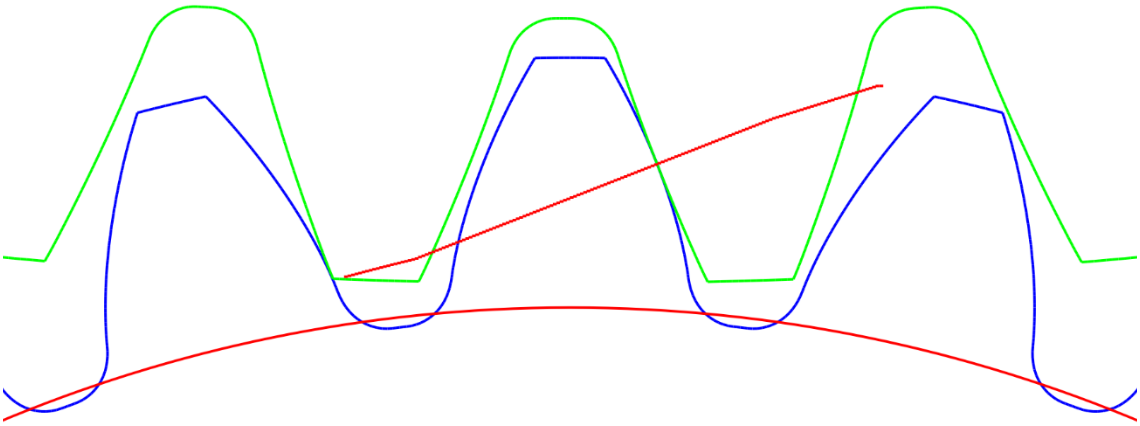
Axis alignment: Deviation error of axis/Inclination error of axis fΣβ/fΣδ: 0.03 µm/0.01 µm ($F_{\beta x}$ = 0.03 µm)

The deformation due to tosrion is included in the specification of fΣβ/fΣδ.

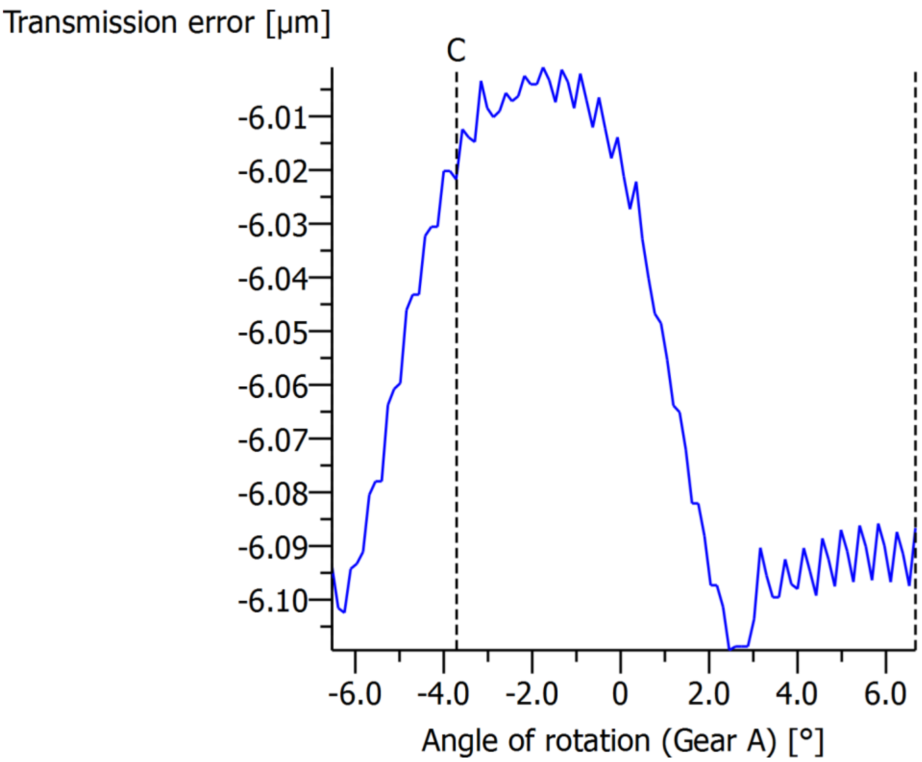
b) Linear misalignment due to connection of the gap from side I to II

Linear misalignment in the plane of action, Gear 1: [$F_{\beta x1}$] 0.00 µm

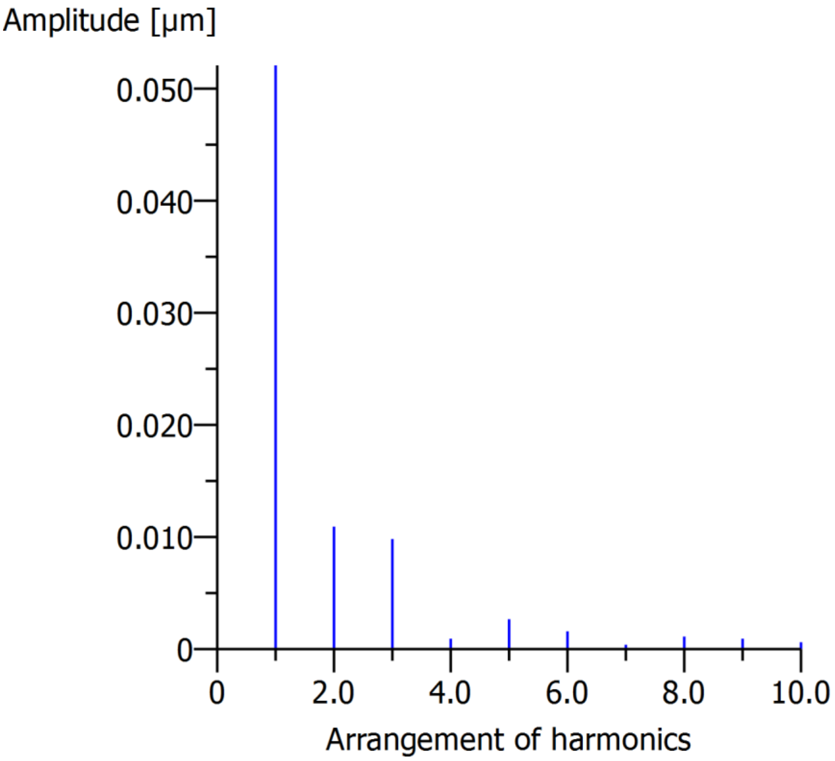
Linear misalignment in the plane of action, Gear 2: [$F_{\beta x2}$] 7.06 µm
Axis alignment: Deviation error of axis/Inclination error of axis fΣβ/fΣδ: -0.00 µm/-0.00 µm (${F_{\beta x}}$ = -0.00 µm)
The deformation due to tosrion is included in the specification of fΣβ/fΣδ.



da1 = 45.6874 mm, df1 = 38.8180 mm, As1 = -0.0540 mmda2 = 163.9684 mm, df2 = 156.9589 mm, As2 = -0.1050 mm
Figure: Path of contact



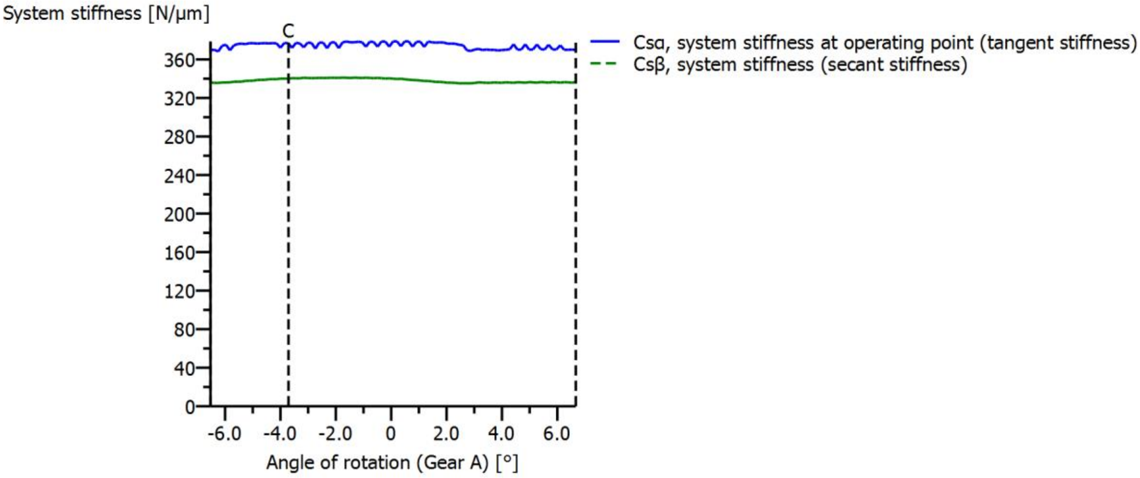
wt = 100 %, a = 101.845 mm,fpt = 0.000 µm,µ = 0.097Working flank: Right flank
Figure: Transmission error



Arrangement of harmonics   Amplitude [µm]1.   0.0520762.   0.0109263.   0.0098204.   0.0009285.   0.0026666.   0.0015867.   0.0003898.   0.0011189.   0.00092910.   0.000615

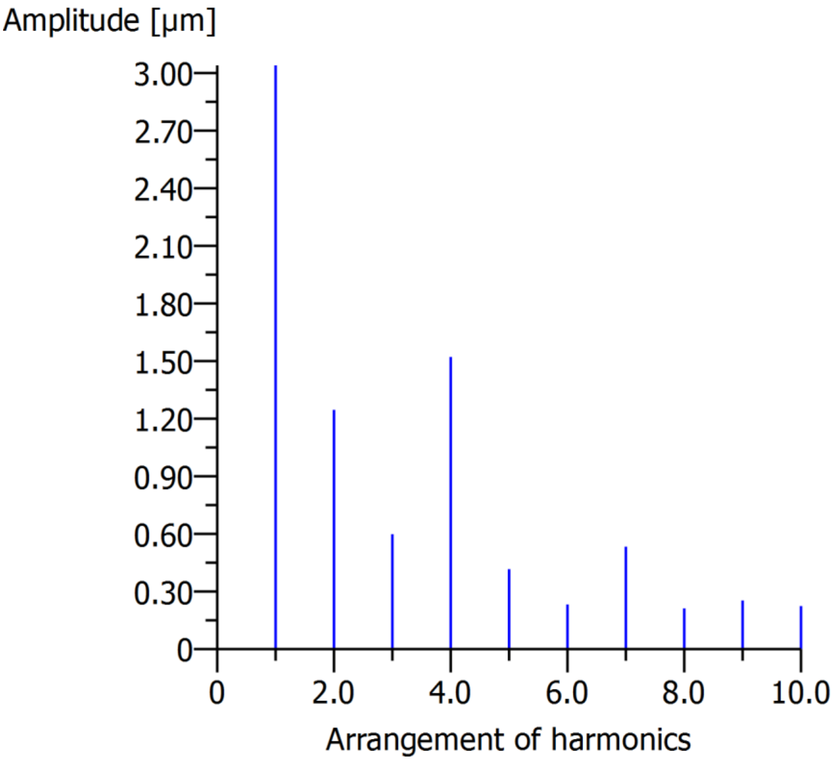
wt = 100 %, a = 101.845 mm,fpt = 0.000 µm,µ = 0.097Working flank: Right flank

Figure: Amplitude spectrum of transmission error



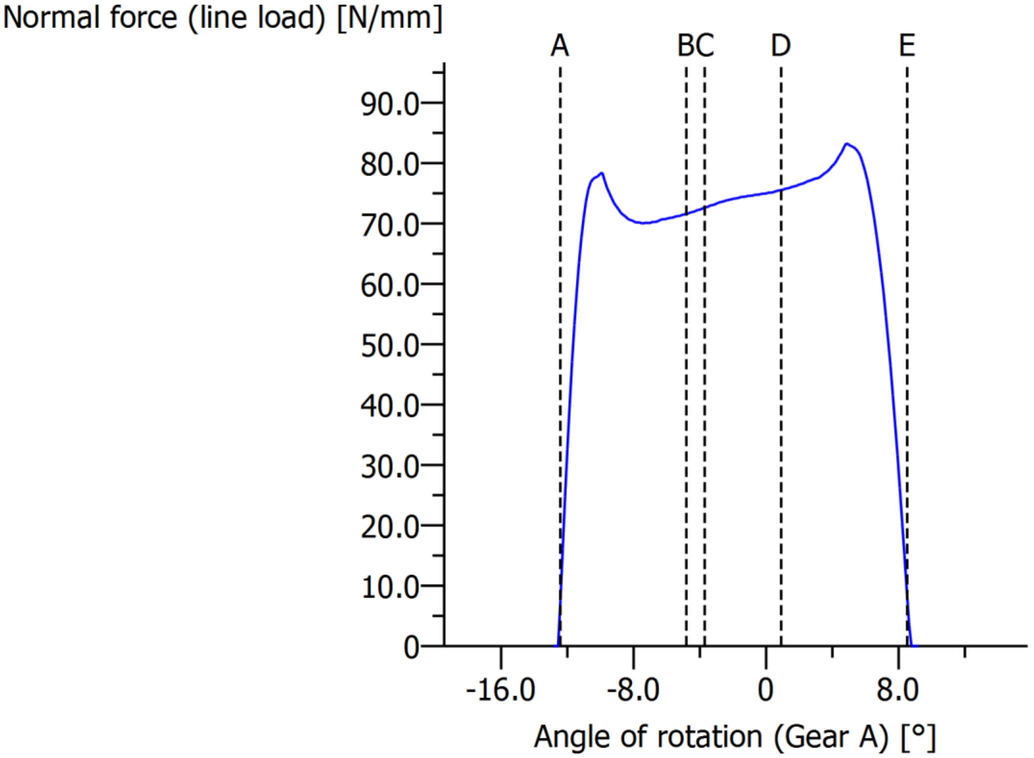
wt = 100 %, a = 101.845 mm,fpt = 0.000 µm,µ = 0.097Working flank: Right flankCsα_mean = 374.3984863 N/µmCsβ_mean = 338.0123363 N/µmCsα = Cγα * bCsβ = Cγβ * b

Figure: Stiffness curve



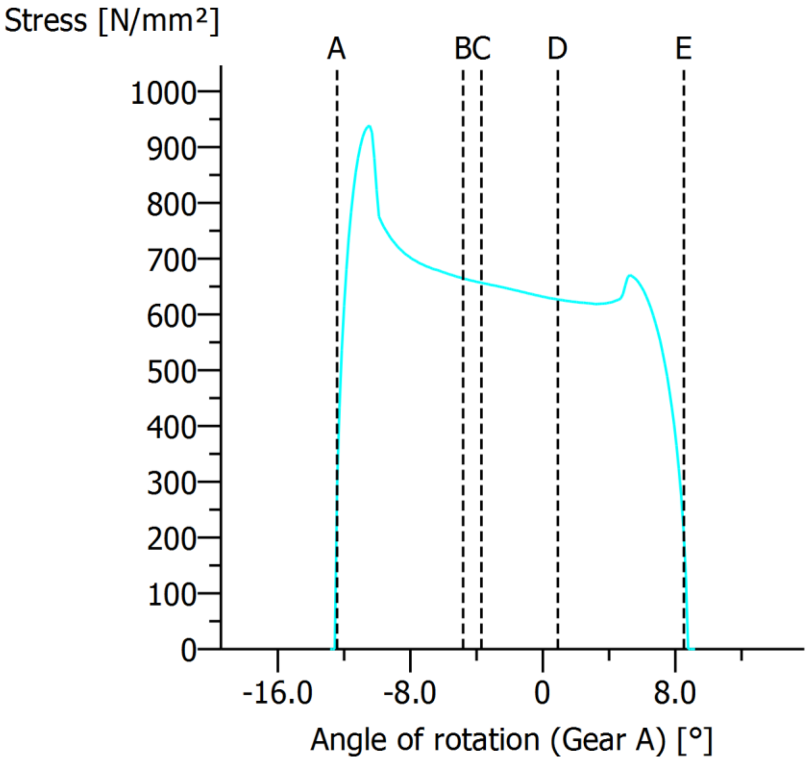
Arrangement of harmonics Amplitude [N/mm/µm]1. 3.0399272. 1.2459713. 0.5984794. 1.5214215. 0.4163106. 0.2324517. 0.5334218. 0.2120979. 0.25316210. 0.224151 wt = 100 %, a = 101.845 mm, fpt = 0.000 µm,µ = 0.097Working flank: Right flank

Figure: Amplitude spectrum of contact stiffness



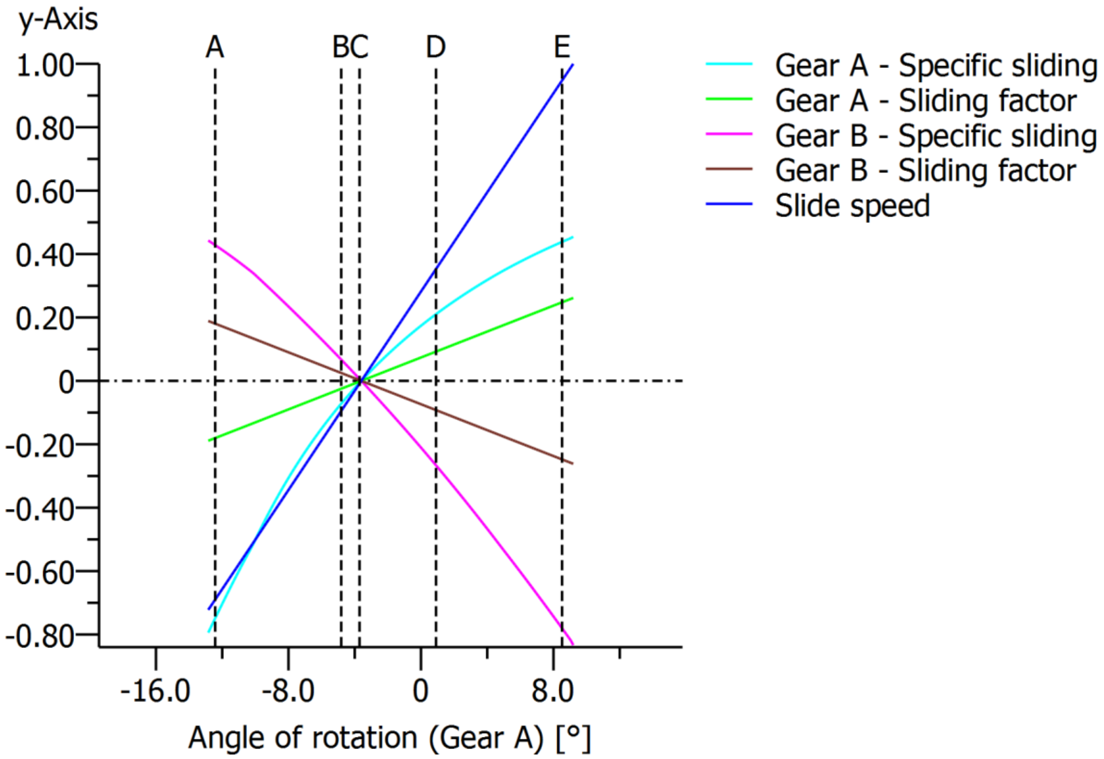
wt = 100 %, a = 101.845 mm,fpt = 0.000 µm,µ = 0.097Working flank: Right flank

Figure: Normal force curve (Line load)



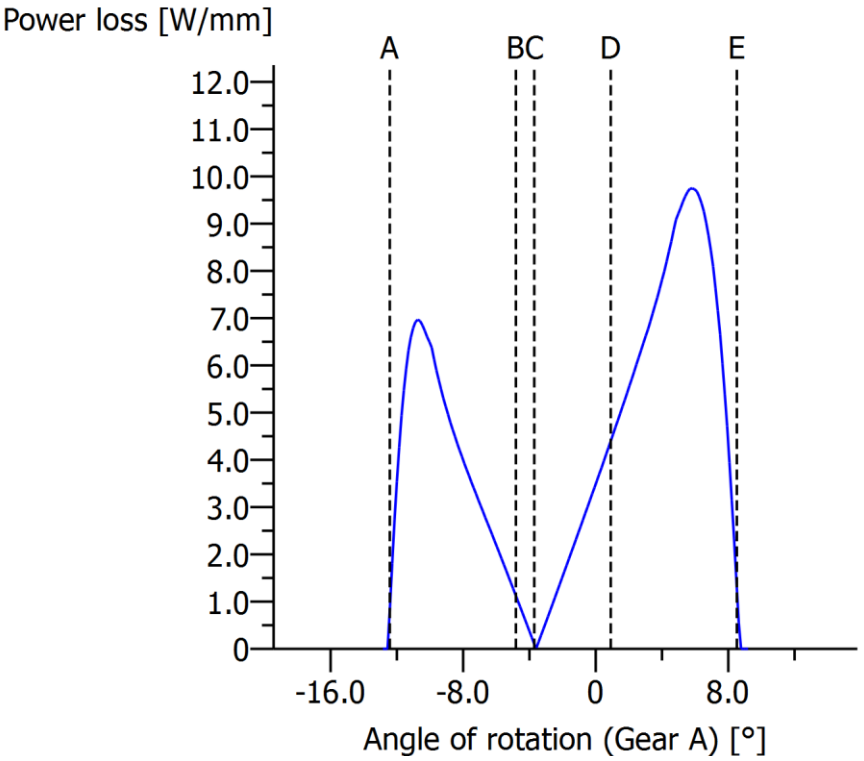
wt = 100 %, a = 101.845 mm,fpt = 0.000 µm,µ = 0.097Working flank: Right flank

Figure: Stress curve



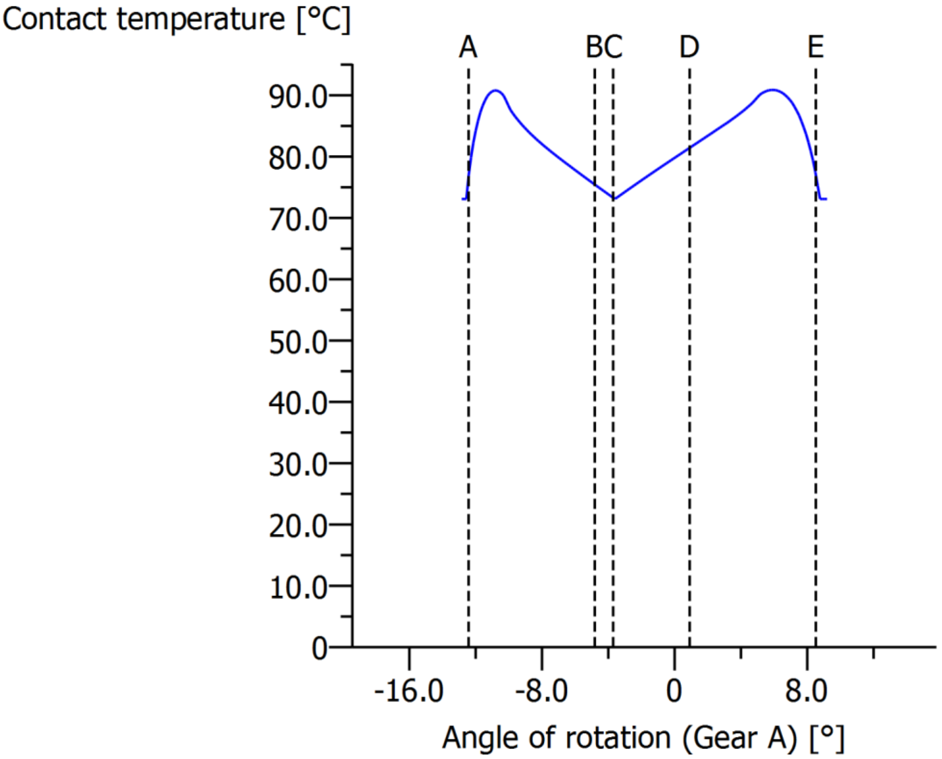
wt = 100 %, a = 101.845 mm,fpt = 0.000 µm,µ = 0.097Working flank: Right flankMaximum sliding velocity: 1.694 m/s

Figure: Kinematics



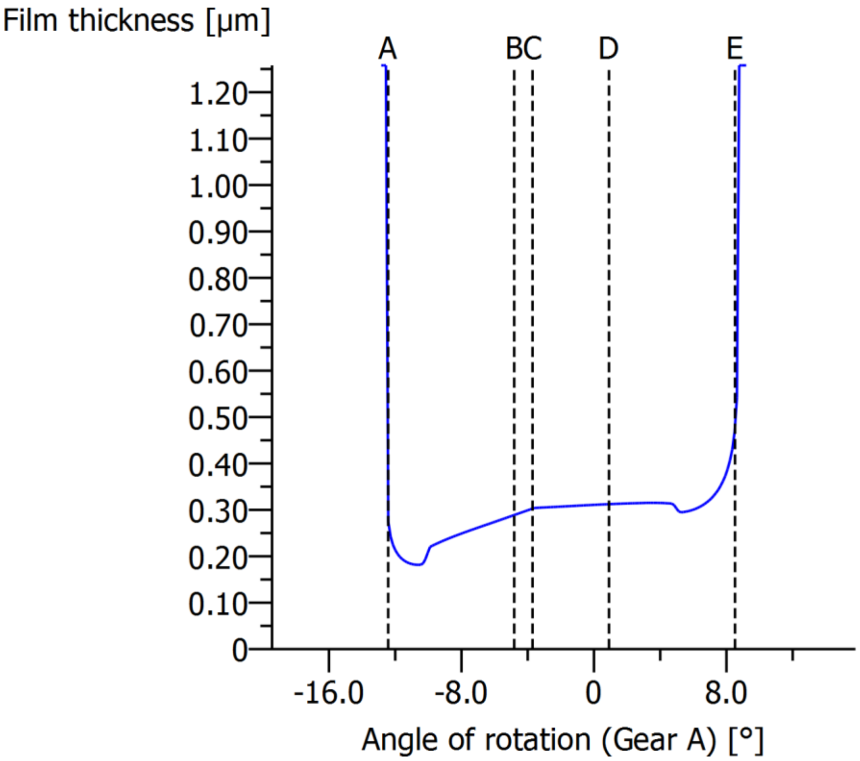
wt = 100 %, a = 101.845 mm,fpt = 0.000 µm,µ = 0.097Displaying power losses per mm facewidthWorking flank: Right flank

Figure: Specific Power Loss



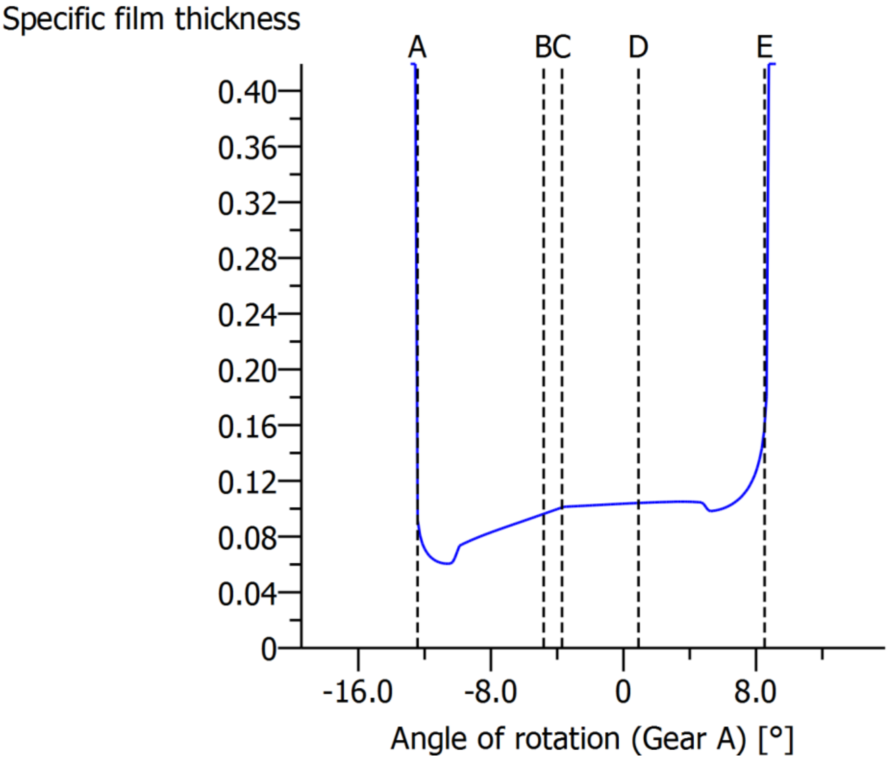
wt = 100 %, a = 101.845 mm,fpt = 0.000 µm,µ = 0.097the0il = 70.0 °C, theM = 73.1 °C, etaM = 28.79 mPa*sWorking flank: Right flank

Figure: Contact temperature



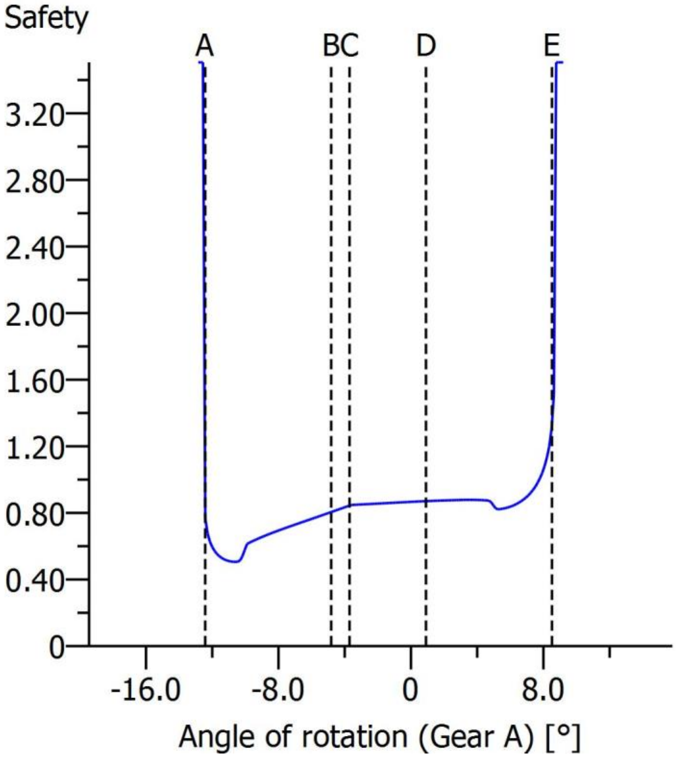
wt = 100 %, a = 101.845 mm,fpt = 0.000 µm,µ = 0.097the0il = 70.0 °C, theM = 73.1 °C, etaM = 28.79 mPa*shMini(ISO) = 0.171 µm, Ra = 3.000 µmWorking flank: Right flank

Figure: Lubricating film (ISO TR 15144)



wt = 100 %, a = 101.845 mm,fpt = 0.000 µm,µ = 0.097the0il = 70.0 °C, theM = 73.1 °C, etaM = 28.79 mPa*shMini(ISO) = 0.171 µm, Ra = 3.000 µm, lamGFmin = 0.057Working flank: Right flank

Figure: Specific film thickness (ISO TR 15144)



wt = 100 %, a = 101.845 mm,fpt = 0.000 µm,µ = 0.097the0il = 70.0 °C, theM = 73.1 °C, etaM = 28.79 mPa*sSlam(ISO) = 0.476, Ra = 3.000 µmWorking flank: Right flank

Figure: Safety against micropitting (ISO TR 15144)

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