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KISSsoft Instructions 072: Contact Analysis in the Cylindrical Gear Calculation

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1 Initial Situation

In Release 03/2011 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.

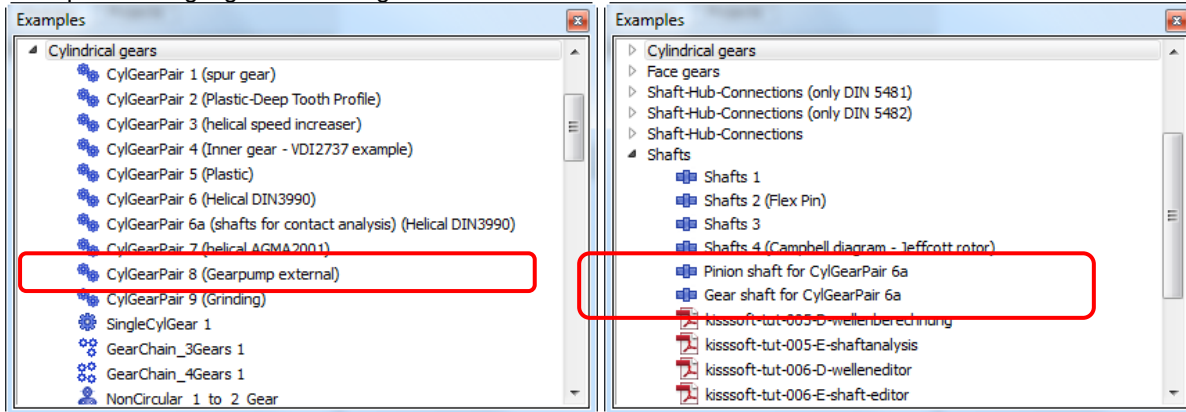


Figure 1.1-1: pre-defined calculation files for cylindrical gear pair and shaft analysis

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 $K_{H\beta}$, on tooth root stress $K_{F\beta}$ and on scuffing stress $K_{B\beta}$. The KISSsoft system has a number of different ways in which you can input $K_{H\beta}$:

- Input $K_{H\beta}$ directly, method A;
- Input deformation f_{sh} and manufacture tolerance f_{ma} : 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 $K_{H\beta}$ with the subsequent analysis results from steps 2 through 5.

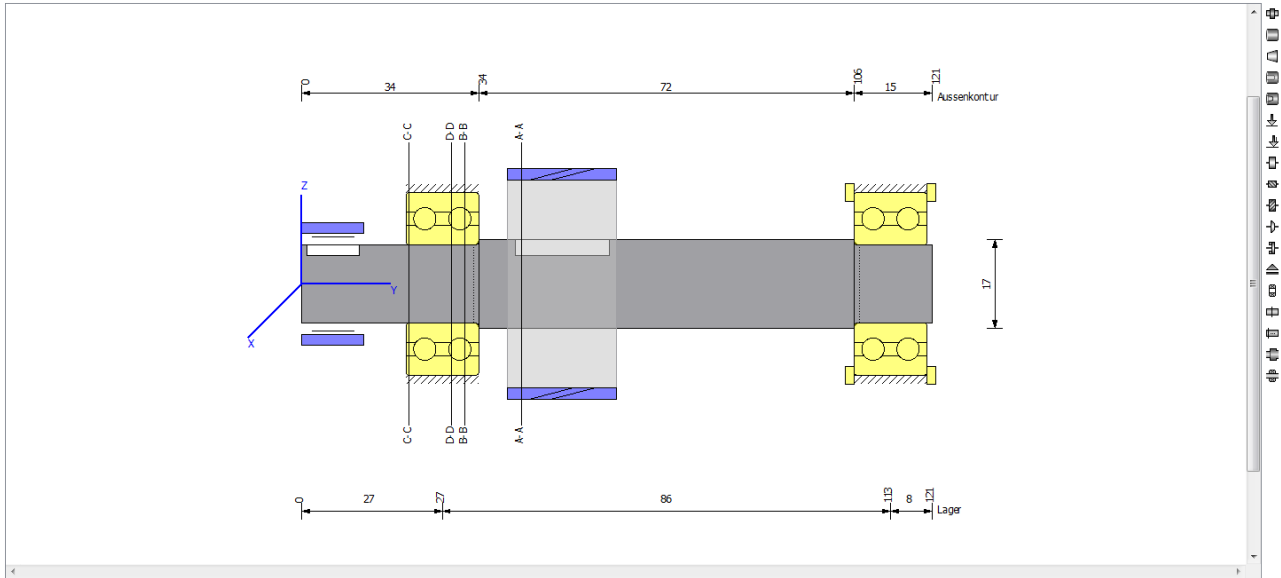


Figure 2.1-1: Pinion shaft dimensions and support

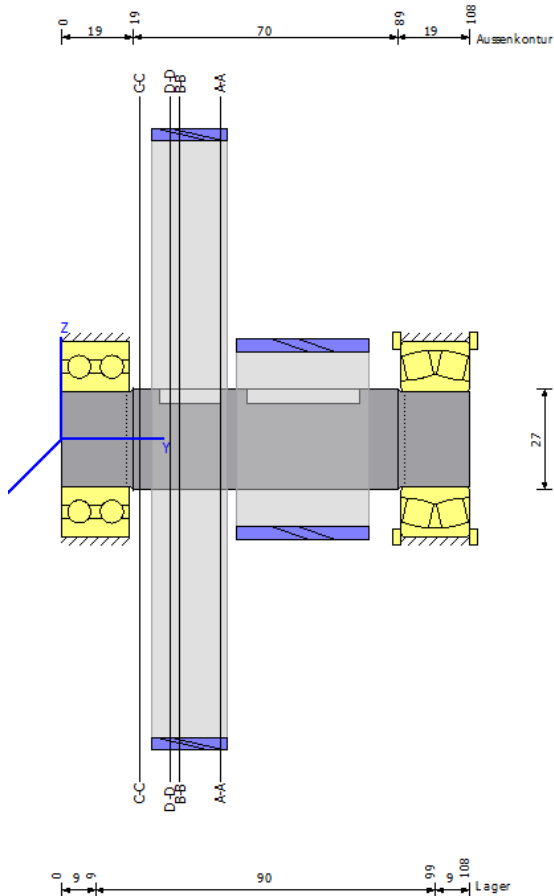


Figure 2.1-2: Gear shaft dimensions and support

To define the inputs for the face load factor, click the plus button to the right of the face load factor (see the button marked in the next figure).

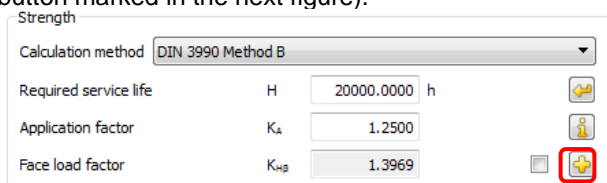


Figure 2.1-3: Defining the face load factor

The next figure shows the settings required to calculate the face load factor according to method C. The data you input here matches the dimensions of the pinion shaft as modeled in the shaft analysis.

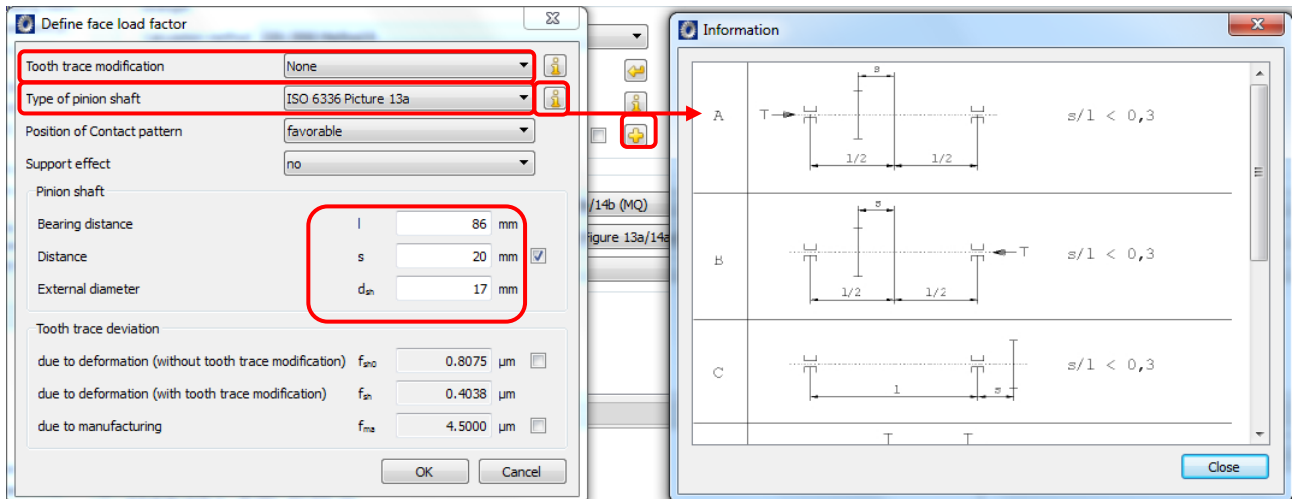


Figure 2.1-4: Inputs that take into account pinion dimensions (for method C)

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 (see also Figure 2.1-6). The following message appears when you run this calculation.

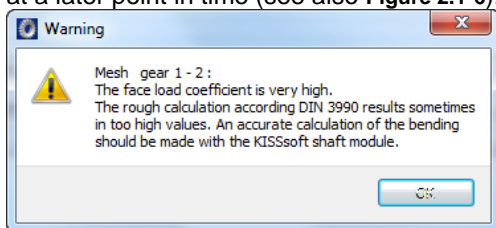


Figure 2.1-5: Warning message stating that the face load coefficient is too high

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.

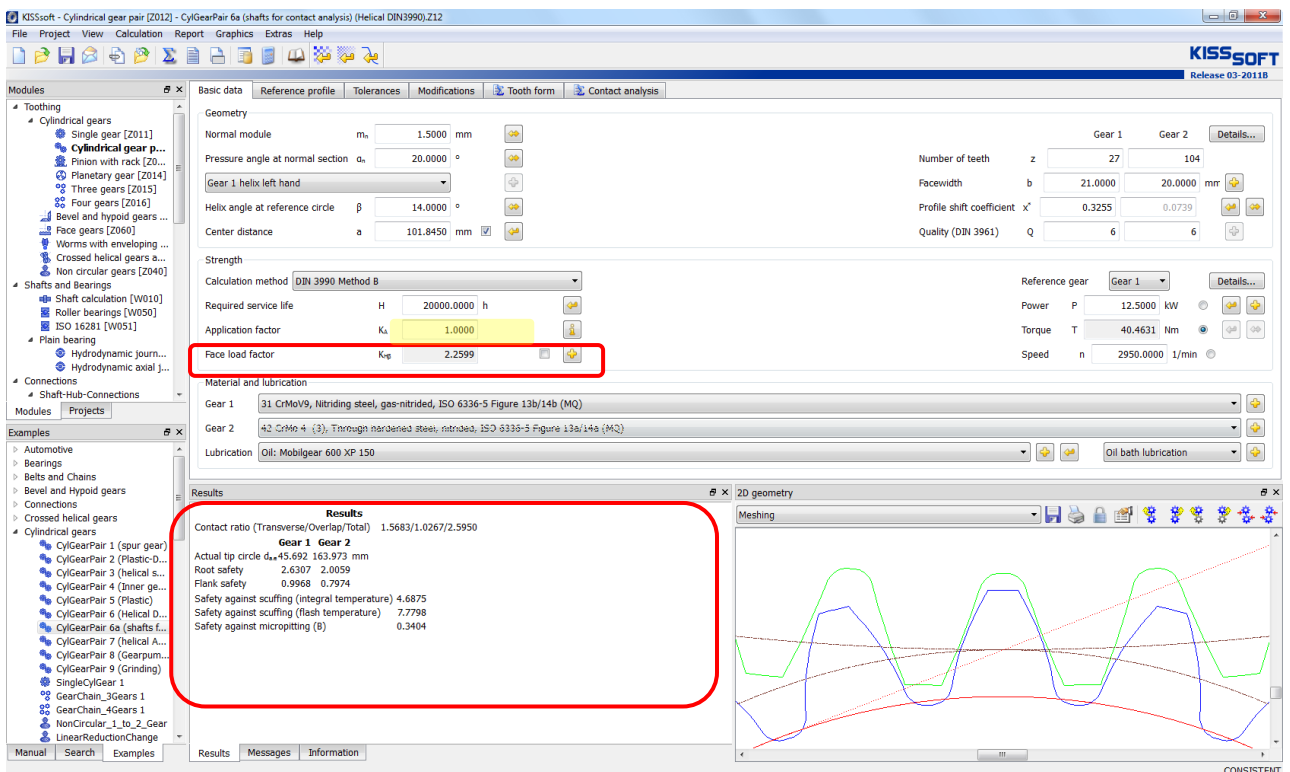


Figure 2.1-6: Calculation results according to the standard, method C, and taking into account the influence of pinion geometry

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.

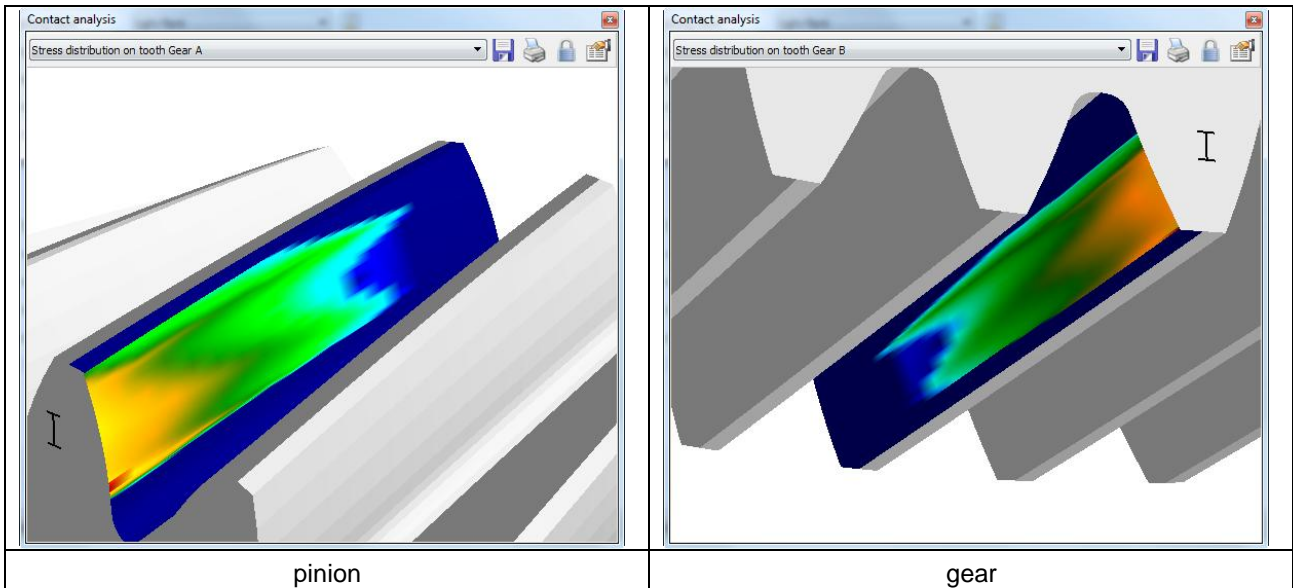


Figure 2.1-7: stress distribution calculated with $K_{H\beta} = 2.26$

2.1.2 Step 2 - Analyze the current situation, taking into account shaft deformation

A) Without actual contact analysis (Step 2a)

This calculation step determines the face load factor using the contact analysis in the KISSsoft cylindrical gear calculation functionality. First, open "Module specific settings" to make the following change to the scope of the calculation in the "Contact analysis" tab. In the selection list for "Extent of calculation", select "only face load factor $K_{H\beta}$ " as shown in this figure.

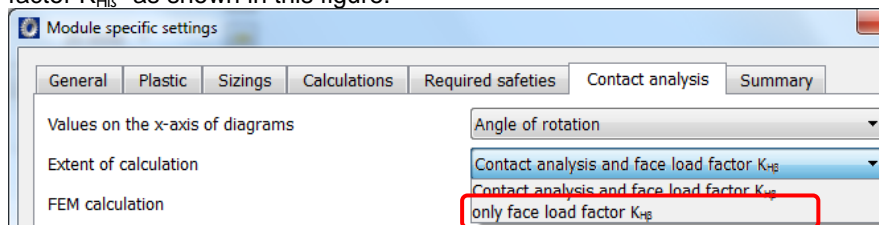


Figure 2.1-8: Module specific setting

If the "Contact analysis" tab is open, the calculation is performed and the following message appears.

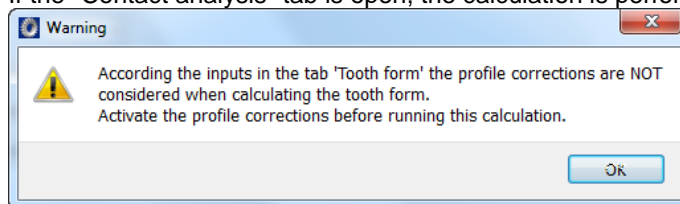


Figure 2.1-9: Warning message that profile corrections are not included in the calculation

Note:

- a) If you want to consider tooth trace or profile corrections in the calculation, you must enable these modifications in the "Tooth form" 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 "Tooth form" tab, enable the checkbox as shown in the next figure.

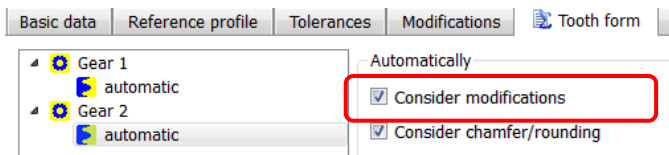


Figure 2.1-10: Enabling corrections in the "Tooth form" tab

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

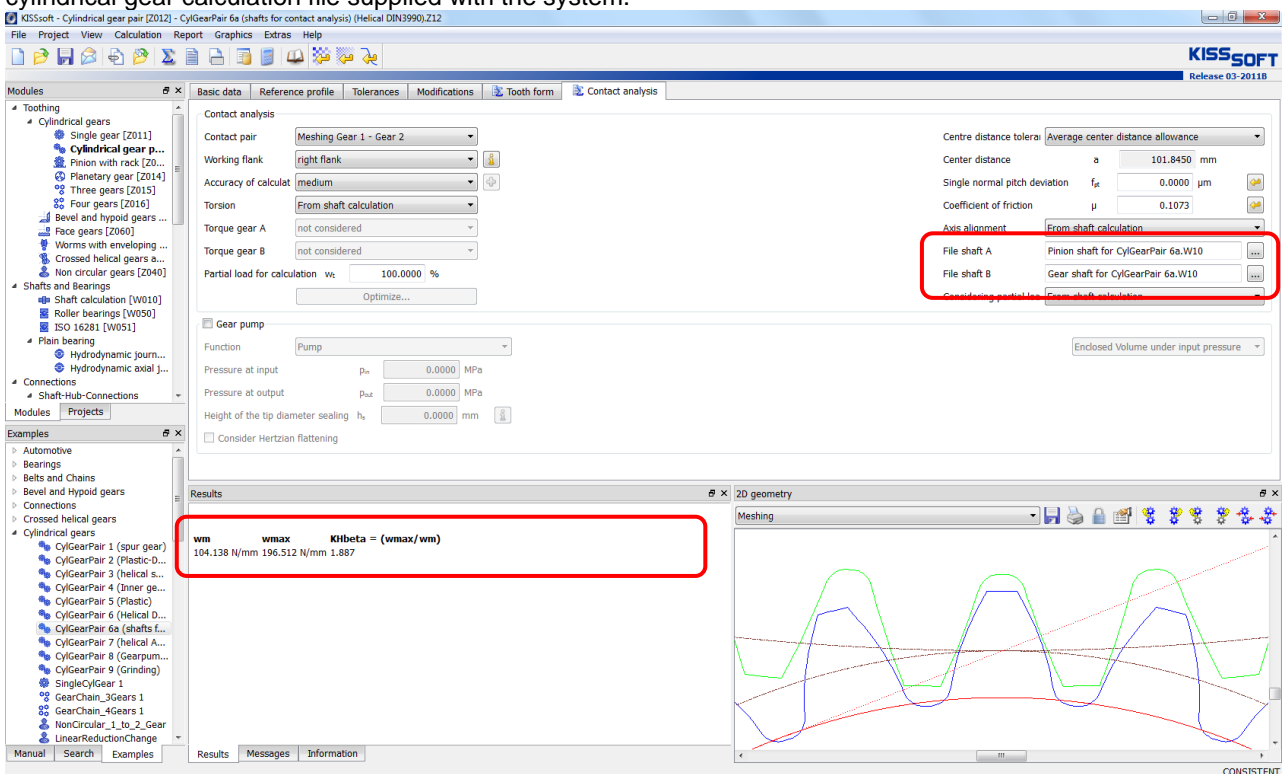


Figure 2.1-11: Determining $K_{H\beta}$ with contact analysis

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 1.887 in analysis step 2. This can now be used directly in the calculation. The safeties determined in the calculation then change accordingly.

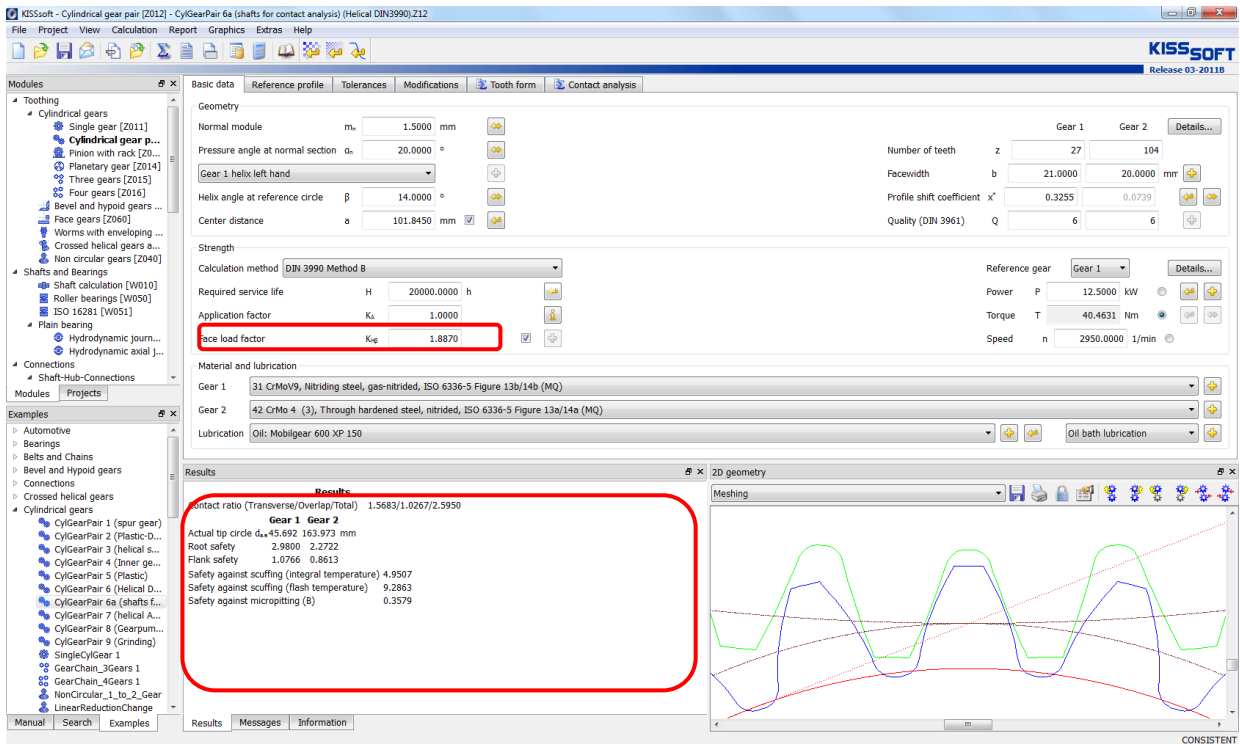


Figure 2.1-12: New safeties, taking shaft deformation into account

B) With contact analysis (Step 2b)

Alternatively, you can also 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 the same.

To perform a complete contact analysis, make the settings shown below.

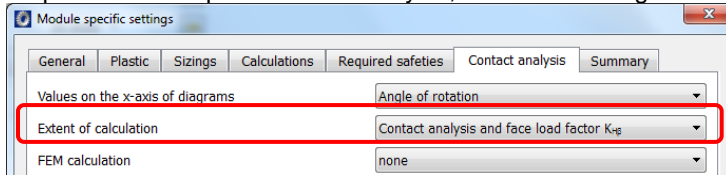


Figure 2.1-13: Setting for a complete contact analysis

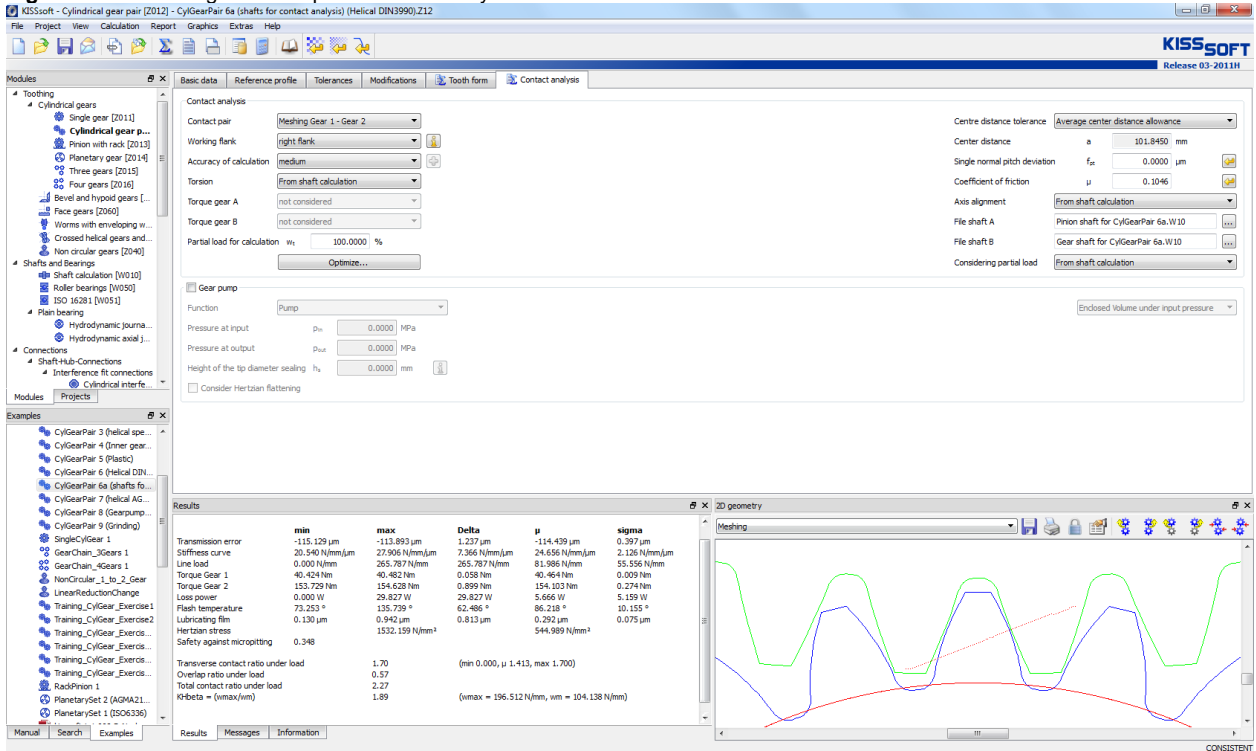


Figure 2.1-14: Results overview for a complete contact analysis without tooth trace modifications

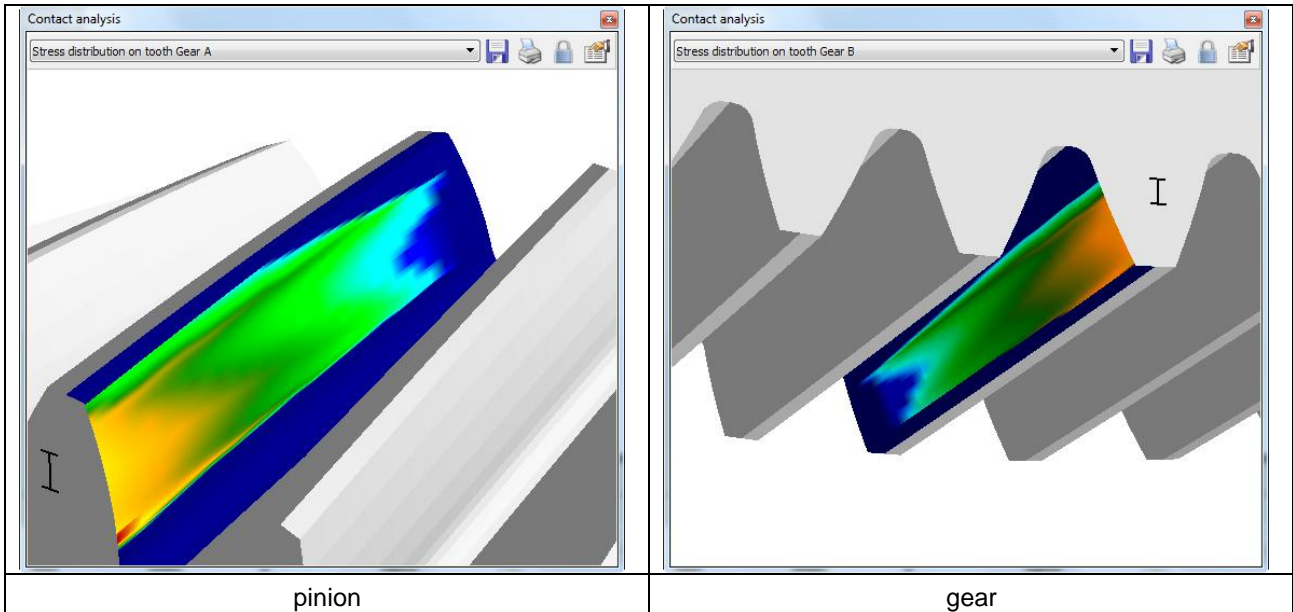


Figure 2.1-15: stress distribution calculated with $K_{HB} = 1.887$

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.

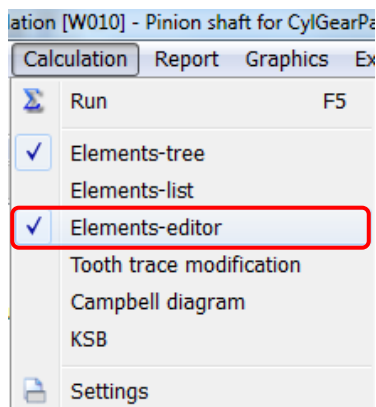


Figure 2.1-16: Calculating the tooth trace modification

The calculation is run 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.

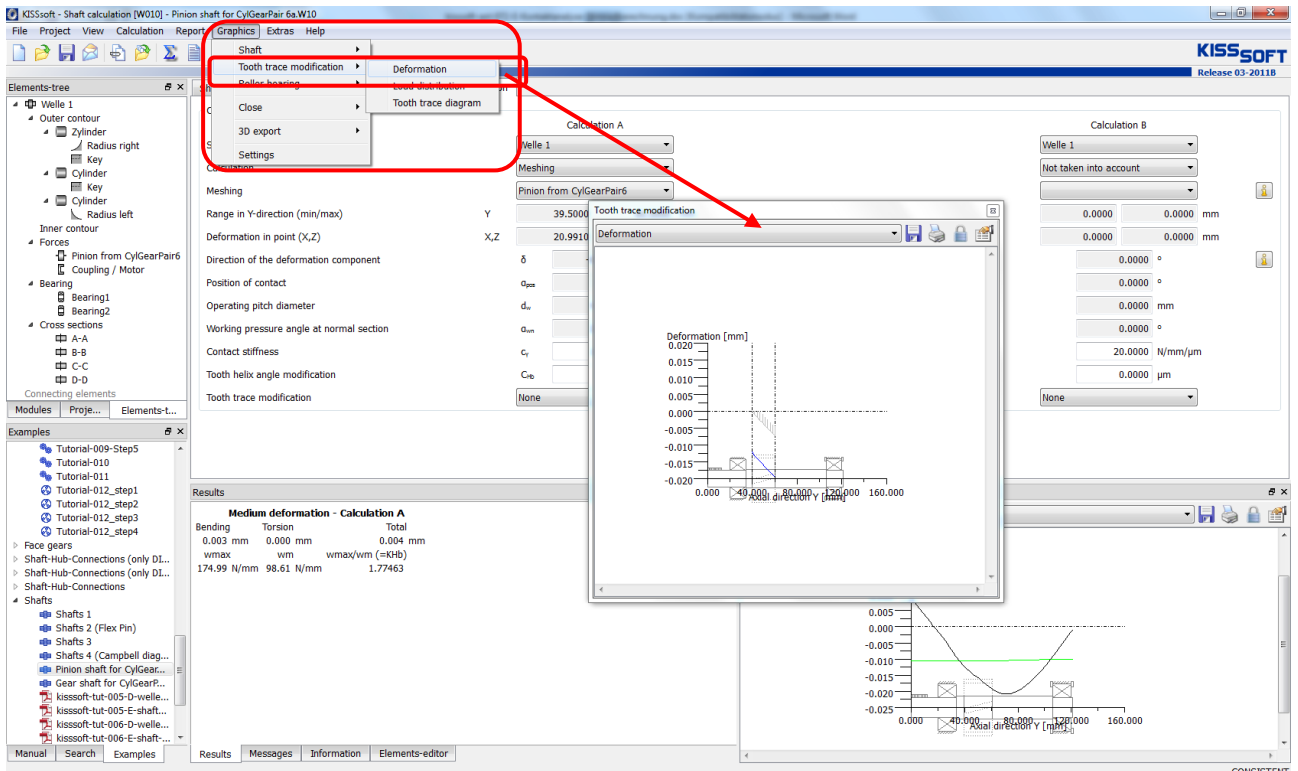


Figure 2.1-17: Results overview without tooth trace modification for the pinion

Enter the helix angle modification C_{Hb} 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_{Hb} , the graphic also shows the defined correction (shown here in green). The value for K_{Hb} should be reduced (ideally to 1). The current value is then displayed in the results window.

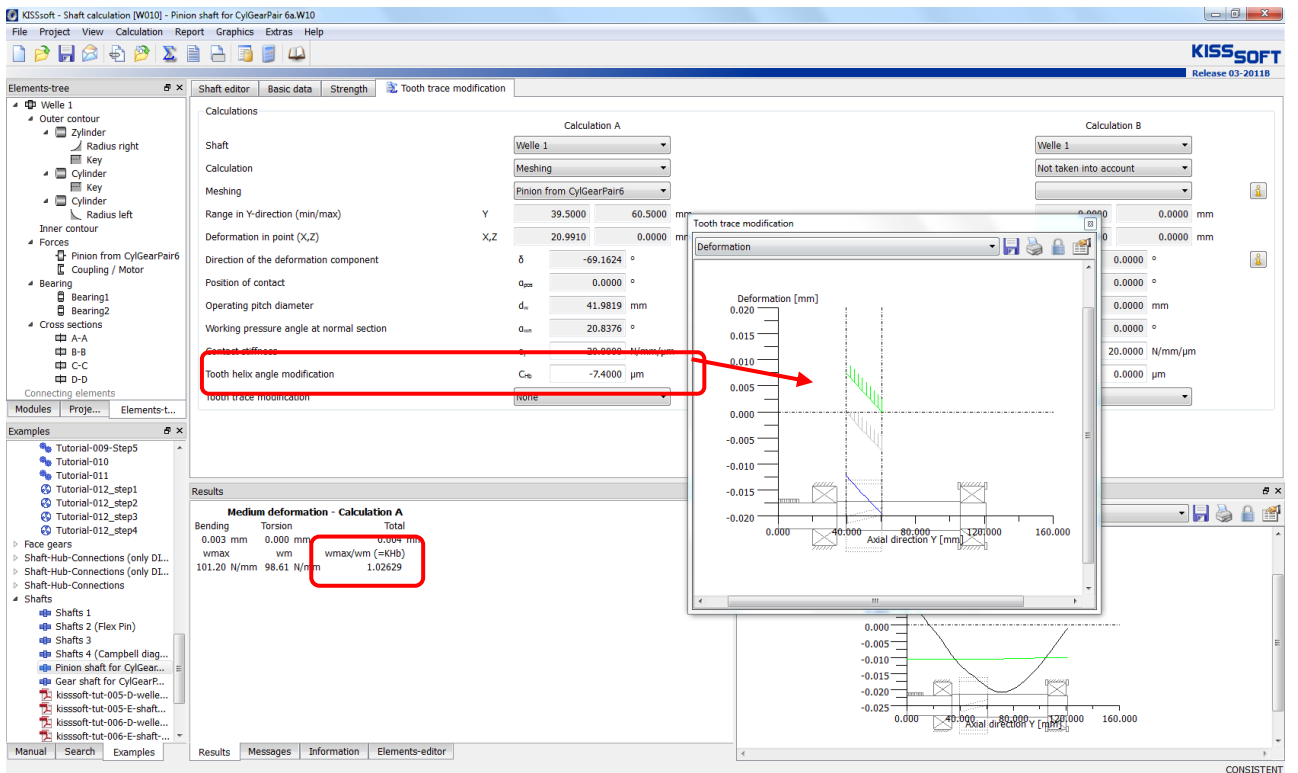


Figure 2.1-18: Results overview with optimum tooth trace modification for the pinion

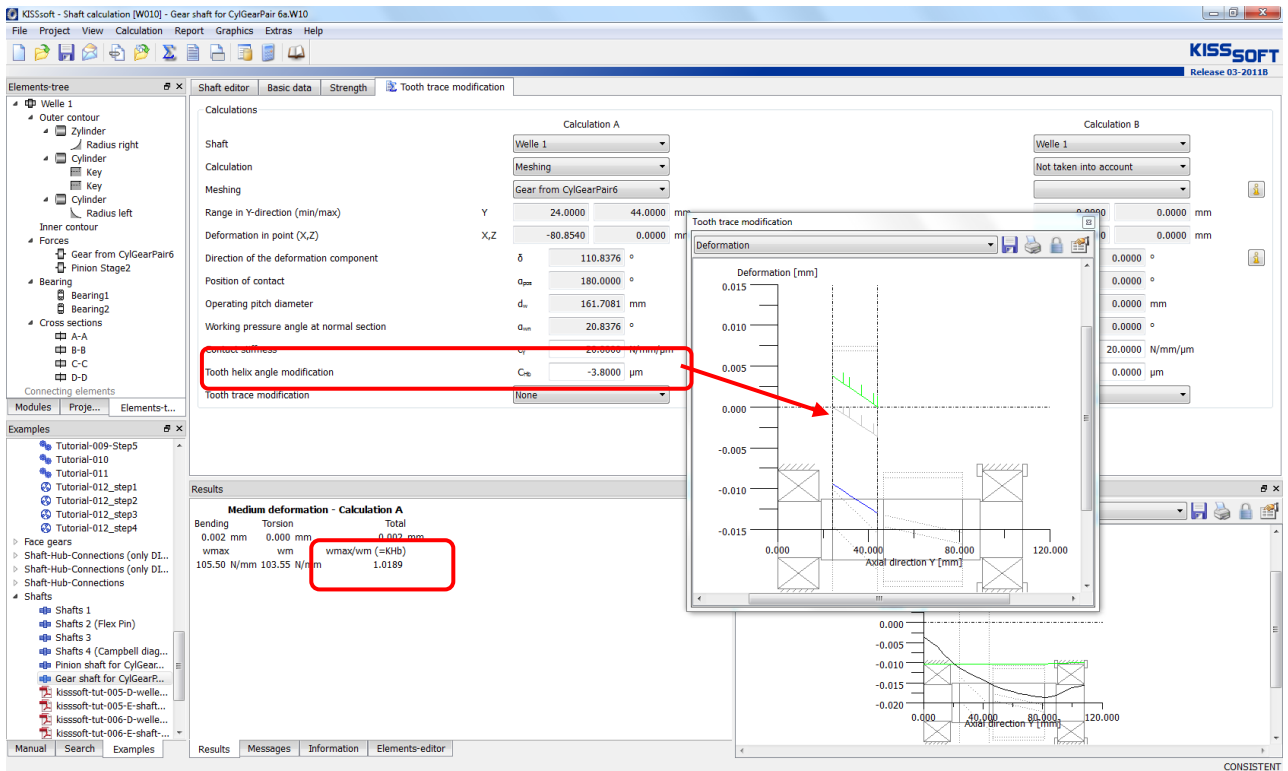


Figure 2.1-19: Results overview with optimum tooth trace modification for the gear

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.

```

For gear calculation: Right Tooth Flank
...

Input data: Tooth trace modification
CHb= -7.4 µm

Note:
The angle modification fHb corresponds to a helix angle modification -0.0190 °
(Helix angle 14.0590 °)
!! Use modification by helix angle modification only if the direction of the rotation stays the same!

```

Figure 2.1-20: Report note with optimum tooth trace correction for the pinion

```

For gear calculation: Right Tooth Flank
...

Input data: Tooth trace modification
CHb= -3.8 µm

Note:
The angle modification fHb corresponds to a helix angle modification 0.0102 °
(Helix angle 14.0882 °)
!! Use modification by helix angle modification only if the direction of the rotation stays the same!

```

Figure 2.1-21: 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 must reduce the helix angle on the pinion and increase the helix angle on the gear.

Gear	Type of modification	Value [µm]	Coefficient 1	Coefficient 2	Status	Comment
Gear 1	Tip relief, linear	5.0000	0.8651		active	
Gear 1	Helix angle modification, t...	-7.4000			active	CHb=-7.4 -> Right Tooth Flank beta.eff = 13.981°-left Left Tooth Flank beta.eff = 14.019°-left
Gear 2	Tip relief, linear	5.0000	0.2500		active	
Gear 2	Helix angle modification, t...	-3.8000			active	CHb=-3.8 -> Right Tooth Flank beta.eff = 14.010°-right Left Tooth Flank beta.eff = 13.990°-right

Figure 2.1-22: Inputting a conical helix angle for the gear and pinion in the Cylindrical gear calculation:

The tip reliefs entered in Figure 2.1-22 are a good idea, but optional. They do not affect the result.

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.

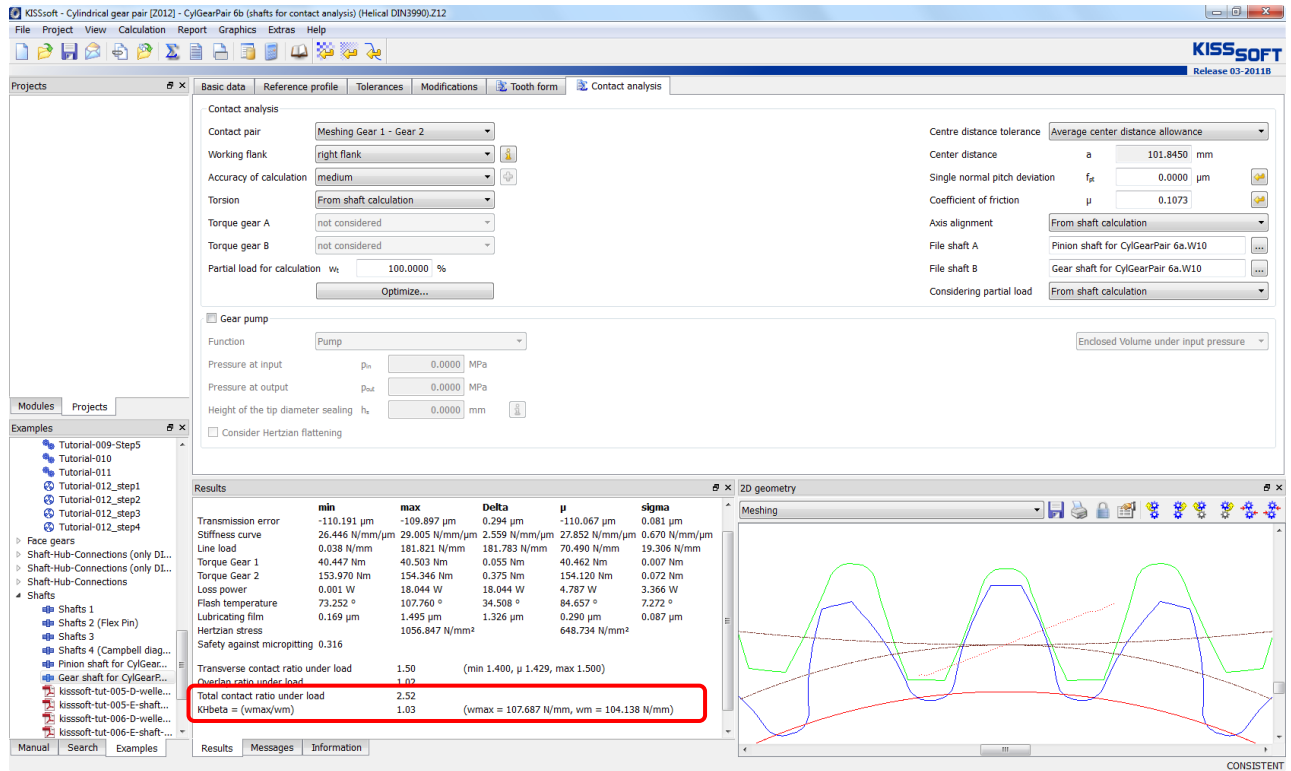


Figure 2.1-23: Results overview with optimum tooth trace modification

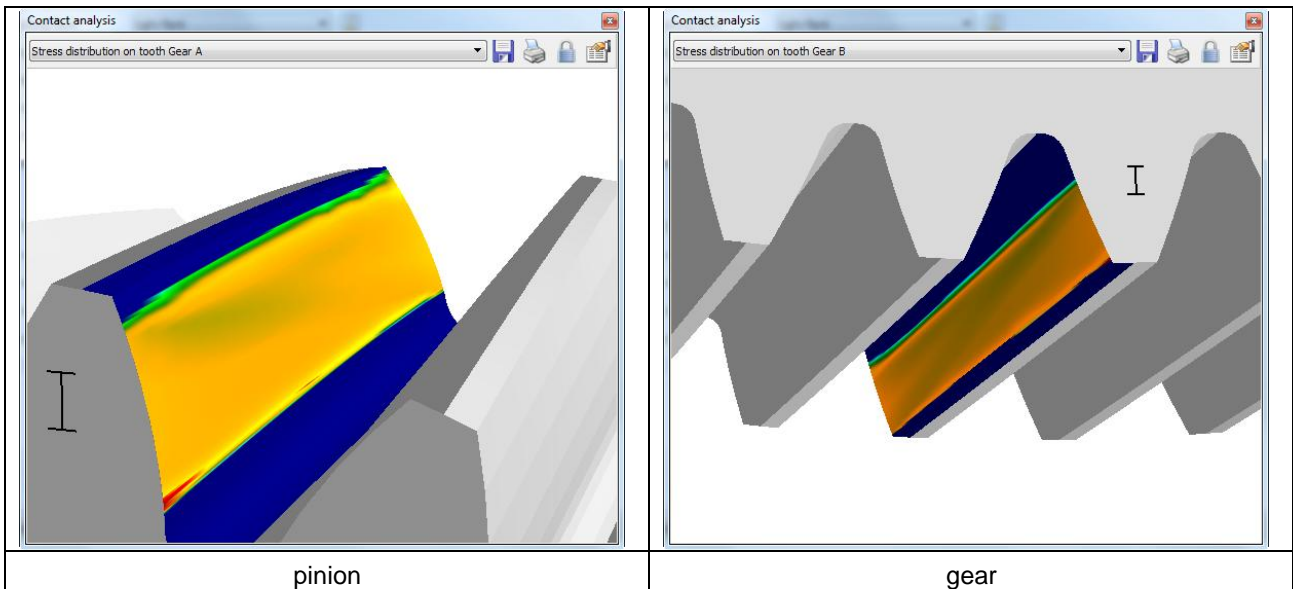


Figure 2.1-24 stress distribution calculated with $K_{Hb} = 1.034$

2.2 Summary

The table below contains an overview of the results.

Step	Face load factors on the	Pinion	Gear	Total	Note
1	K_{HB}	2.599	(1.369)		determined in accordance with the standard
2a	K_{HB}			1.887	taking into account the shafts
2b	K_{HB}			1.887	no change
3	K_{HB}	1.775	1.350		without correction, calculated in the shaft analysis
3	K_{HB}	1.026	1.019		with correction, calculated in the shaft analysis
5	K_{HB}			1.034	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 03-2011H
 KISSsoft-Entwicklungs-Version KISSsoft AG CH-8634 HOMBRECHTIKON

File
 Name : CylGearPair 6a (shafts for contact analysis) (Helical DIN3990)
 Description: KISSsoft example
 Changed by : ho on: 11.10.2011 at: 15:36:55

Calculation of path of contact under load

Mesh gear 1 - gear 2 (Right Tooth Flank)
 Shaft file A: C:/Program Files (x86)/KISSsoft 03-2011/example/Pinion shaft for CylGearPair 6a.W10,
 selected gear: Pinion from CylGearPair6
 Shaft file B: C:/Program Files (x86)/KISSsoft 03-2011/example/Gear shaft for CylGearPair 6a.W10,
 selected gear: Gear from CylGearPair6

Partial load for calculation		100.00	%
Center distance	[a]	101.85	mm
Single pitch deviation	[fpt]	0.00	µm
Coefficient of friction	[µ]	0.10	
Torque	[T1]	40.46	Nm

		min	max	Delta	µ	sigma
Transmission error	(µm)	-115.1292	-113.8927	1.2365	-114.4387	0.3972
Stiffness curve	(N/mm/µm)	20.5404	27.9063	7.3659	24.6558	2.1262
Line load	(N/mm)	0.0000	265.7870	265.7870	81.9860	55.5559
Torque Gear 1	(Nm)	40.4236	40.4816	0.0580	40.4640	0.0088
Torque Gear 2	(Nm)	153.7294	154.6284	0.8990	154.1034	0.2739
Loss power	(W)	0.0000	29.8268	29.8268	5.6659	5.1591
Flash temperature	(°)	73.2528	135.7389	62.4862	86.2179	10.1547
Lubricating film	(µm)	0.1296	0.9424	0.8128	0.2918	0.0749
Hertzian stress	(N/mm ²)		1532.1587		544.9891	
Safety against micropitting		0.3479				

Transverse contact ratio under load[Epsa']	1.70
Overlap ratio under load [Epsb']	0.57
Total contact ratio under load[Epsg']	2.27

KHbeta Calculation

Gear 1
 Point in polar co-ordinates:
 R = 20.991 mm , phi = 0.000 °
 Displacement calculated in direction 111.425 °

	y	phi1.t	f1.t	f1.b	f1.tot	f1.C
1	40.4762 mm	-0.0000°	-0.0000 mm	0.0119 mm	0.0119 mm	0.0000 mm
2	41.4286 mm	-0.0001°	-0.0001 mm	0.0122 mm	0.0122 mm	0.0000 mm
3	42.3810 mm	-0.0002°	-0.0001 mm	0.0125 mm	0.0124 mm	0.0000 mm
4	43.3333 mm	-0.0003°	-0.0001 mm	0.0128 mm	0.0127 mm	0.0000 mm
5	44.2857 mm	-0.0003°	-0.0001 mm	0.0131 mm	0.0129 mm	0.0000 mm
6	45.2381 mm	-0.0004°	-0.0001 mm	0.0133 mm	0.0132 mm	0.0000 mm
7	46.1905 mm	-0.0004°	-0.0002 mm	0.0136 mm	0.0134 mm	0.0000 mm
8	47.1429 mm	-0.0005°	-0.0002 mm	0.0139 mm	0.0137 mm	0.0000 mm
9	48.0952 mm	-0.0005°	-0.0002 mm	0.0141 mm	0.0139 mm	0.0000 mm
10	49.0476 mm	-0.0005°	-0.0002 mm	0.0144 mm	0.0142 mm	0.0000 mm
11	50.0000 mm	-0.0006°	-0.0002 mm	0.0147 mm	0.0145 mm	0.0000 mm
12	50.9524 mm	-0.0006°	-0.0002 mm	0.0149 mm	0.0147 mm	0.0000 mm
13	51.9048 mm	-0.0006°	-0.0002 mm	0.0152 mm	0.0150 mm	0.0000 mm
14	52.8571 mm	-0.0006°	-0.0002 mm	0.0155 mm	0.0152 mm	0.0000 mm
15	53.8095 mm	-0.0006°	-0.0002 mm	0.0157 mm	0.0155 mm	0.0000 mm
16	54.7619 mm	-0.0007°	-0.0002 mm	0.0160 mm	0.0157 mm	0.0000 mm
17	55.7143 mm	-0.0007°	-0.0002 mm	0.0162 mm	0.0160 mm	0.0000 mm
18	56.6667 mm	-0.0007°	-0.0002 mm	0.0165 mm	0.0162 mm	0.0000 mm
19	57.6190 mm	-0.0007°	-0.0002 mm	0.0167 mm	0.0165 mm	0.0000 mm
20	58.5714 mm	-0.0007°	-0.0002 mm	0.0170 mm	0.0167 mm	0.0000 mm
21	59.5238 mm	-0.0007°	-0.0002 mm	0.0172 mm	0.0170 mm	0.0000 mm

Gear 2
 Point in polar co-ordinates:
 R = 80.854 mm , phi = 0.000 °
 Displacement calculated in direction 291.425 °

	y	phi2.t	f2.t	f2.b	f2.tot	f2.C
1	24.4762 mm	0.0000°	0.0000 mm	-0.0095 mm	-0.0095 mm	0.0000 mm
2	25.4286 mm	0.0000°	0.0000 mm	-0.0096 mm	-0.0096 mm	0.0000 mm
3	26.3810 mm	0.0000°	0.0000 mm	-0.0098 mm	-0.0098 mm	0.0000 mm

4	27.3333 mm	0.0000°	0.0000 mm	-0.0100 mm	-0.0100 mm	0.0000 mm
5	28.2857 mm	0.0000°	0.0000 mm	-0.0102 mm	-0.0102 mm	0.0000 mm
6	29.2381 mm	0.0000°	0.0000 mm	-0.0103 mm	-0.0103 mm	0.0000 mm
7	30.1905 mm	0.0000°	0.0000 mm	-0.0105 mm	-0.0105 mm	0.0000 mm
8	31.1429 mm	0.0000°	0.0000 mm	-0.0107 mm	-0.0107 mm	0.0000 mm
9	32.0952 mm	0.0000°	0.0000 mm	-0.0108 mm	-0.0108 mm	0.0000 mm
10	33.0476 mm	0.0000°	0.0000 mm	-0.0110 mm	-0.0110 mm	0.0000 mm
11	34.0000 mm	0.0000°	0.0000 mm	-0.0112 mm	-0.0112 mm	0.0000 mm
12	34.9524 mm	0.0000°	0.0000 mm	-0.0113 mm	-0.0113 mm	0.0000 mm
13	35.9048 mm	0.0000°	0.0000 mm	-0.0115 mm	-0.0115 mm	0.0000 mm
14	36.8571 mm	0.0000°	0.0000 mm	-0.0117 mm	-0.0117 mm	0.0000 mm
15	37.8095 mm	0.0000°	0.0000 mm	-0.0118 mm	-0.0118 mm	0.0000 mm
16	38.7619 mm	0.0000°	0.0000 mm	-0.0120 mm	-0.0120 mm	0.0000 mm
17	39.7143 mm	0.0000°	0.0000 mm	-0.0122 mm	-0.0122 mm	0.0000 mm
18	40.6667 mm	0.0000°	0.0000 mm	-0.0123 mm	-0.0123 mm	0.0000 mm
19	41.6190 mm	0.0000°	0.0000 mm	-0.0125 mm	-0.0125 mm	0.0000 mm
20	42.5714 mm	0.0000°	0.0000 mm	-0.0127 mm	-0.0127 mm	0.0000 mm
21	43.5238 mm	0.0000°	0.0000 mm	-0.0129 mm	-0.0128 mm	0.0000 mm

Explanations:

y : Width
 phi's : Static torsion
 fat : Displacement due to torsion
 fib : Displacement due to bending
 f.tot : Total displacement (f.b+f.t)
 f.C : Change due to tooth trace modification

Load distribution

Contact stiffness = 20.257 N/mm/μm

	y	g	w
1.	40.4762 mm	9.7010 μm	196.5123 N/mm
2.	41.4286 mm	9.2194 μm	186.7568 N/mm
3.	42.3810 mm	8.7425 μm	177.0969 N/mm
4.	43.3333 mm	8.2708 μm	167.5416 N/mm
5.	44.2857 mm	7.8034 μm	158.0722 N/mm
6.	45.2381 mm	7.3403 μm	148.6912 N/mm
7.	46.1905 mm	6.8813 μm	139.3945 N/mm
8.	47.1429 mm	6.4263 μm	130.1781 N/mm
9.	48.0952 mm	5.9751 μm	121.0377 N/mm
10.	49.0476 mm	5.5275 μm	111.9694 N/mm
11.	50.0000 mm	5.0831 μm	102.9689 N/mm
12.	50.9524 mm	4.6421 μm	94.0352 N/mm
13.	51.9048 mm	4.2040 μm	85.1604 N/mm
14.	52.8571 mm	3.7686 μm	76.3404 N/mm
15.	53.8095 mm	3.3357 μm	67.5708 N/mm
16.	54.7619 mm	2.9051 μm	58.8475 N/mm
17.	55.7143 mm	2.4765 μm	50.1664 N/mm
18.	56.6667 mm	2.0498 μm	41.5231 N/mm
19.	57.6190 mm	1.6248 μm	32.9135 N/mm
20.	58.5714 mm	1.2012 μm	24.3334 N/mm
21.	59.5238 mm	0.7789 μm	15.7783 N/mm

Explanations:

g : Flank overlap
 w : Line load

wmax = 196.512 N/mm, wm = 104.138 N/mm

wm = (Ft/b)/cos(a_wt)

KHb = wmax/wm = 1.887 (Calculation according to ISO 6336-1, Appendix E)

Notice: The influence of the exceeding tooth width is not taken into account in the calculation of KHbeta.

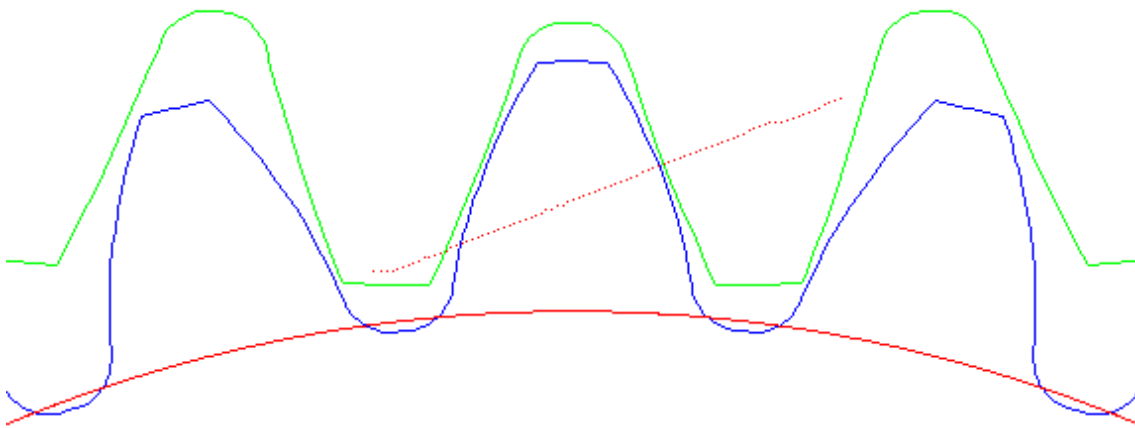
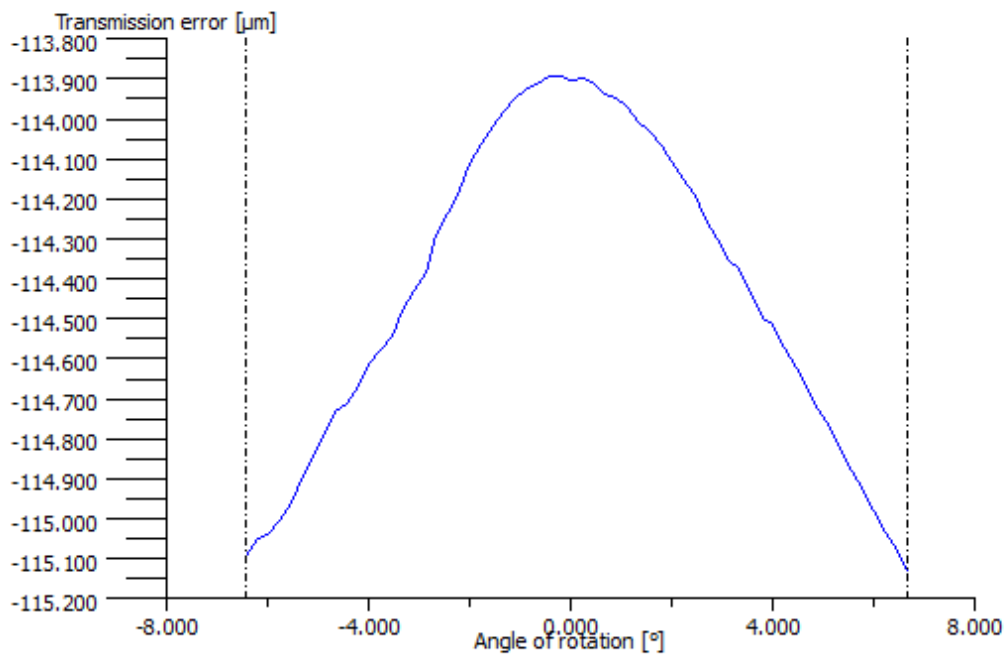
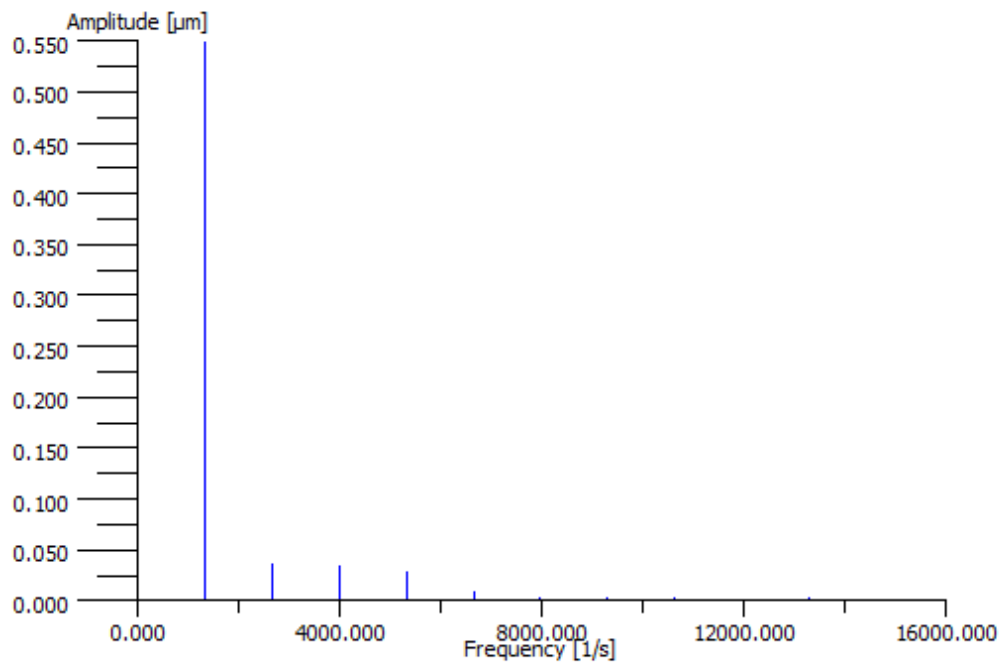


Figure: Path of contact



wt = 100 %, a = 101.845 mm, fpt = 0 μm, μ = 0.1045744304

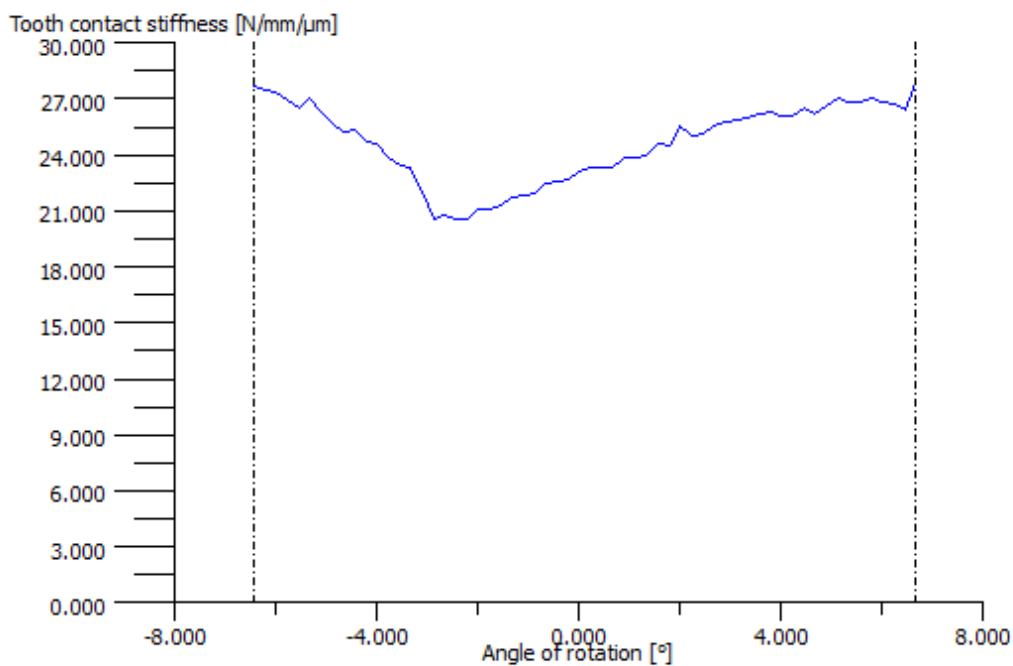
Figure: Transmission error



1st Harmonic frequency [1/s] : 1327.5

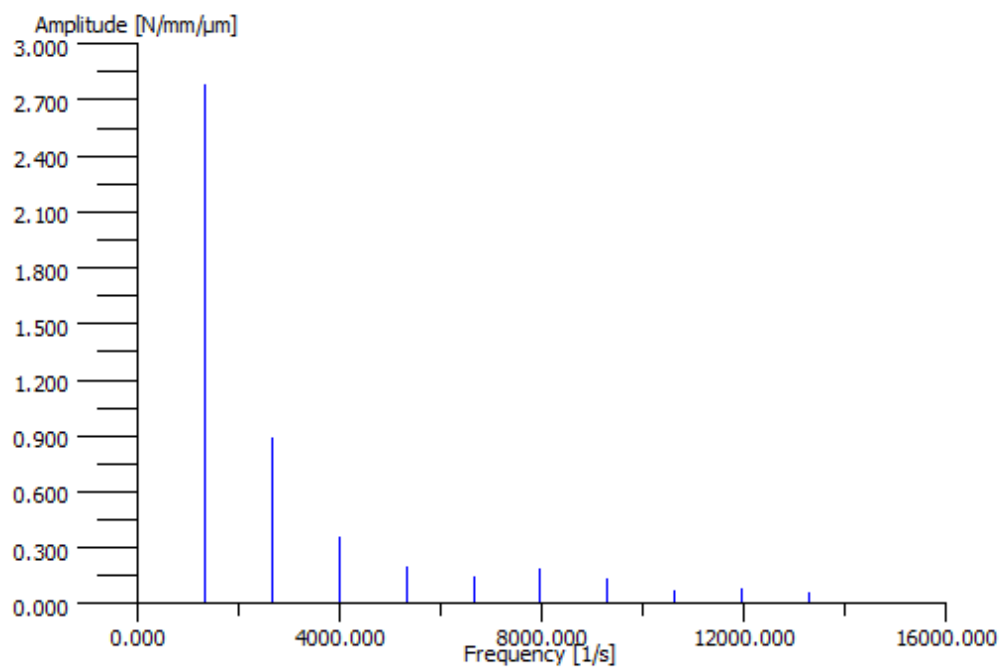
Harmonics	Amplitude [µm]
1.	0.5486216457
2.	0.03685609114
3.	0.03335540985
4.	0.0287800975
5.	0.009420966509
6.	0.00340156935
7.	0.00375244981
8.	0.002837216931
9.	0.001215368683
10.	0.002461946971

Figure: FFT of transmission error



wt = 100 %, a = 101.845 mm, fpt = 0 µm, μ = 0.1045744304

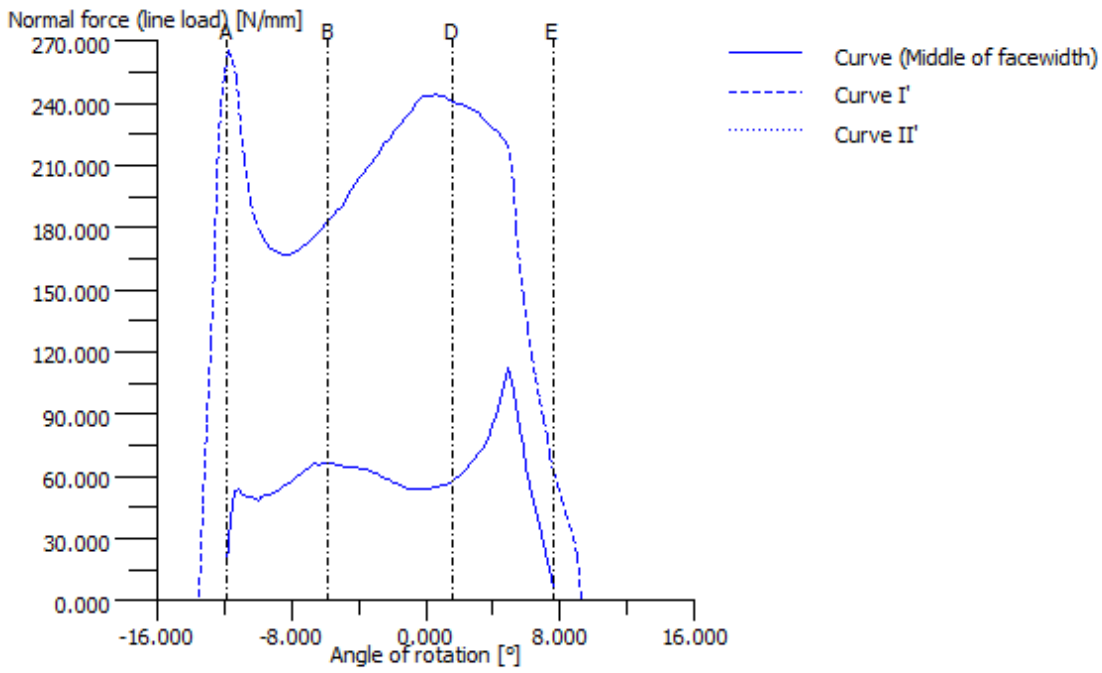
Figure: Stiffness curve



1st Harmonic frequency [1/s] : 1327.5

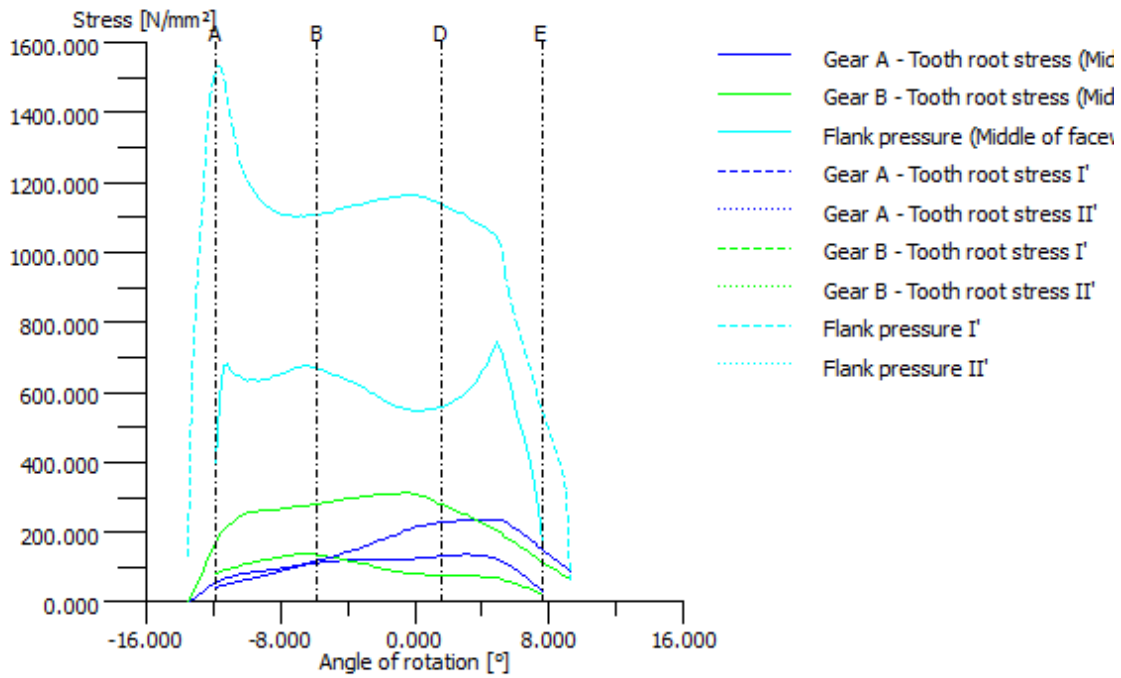
Harmonics	Amplitude [N/mm/μm]
1.	2.774274825
2.	0.8831922244
3.	0.3542622037
4.	0.2004177811
5.	0.1388579043
6.	0.1805263486
7.	0.1304893865
8.	0.06698245069
9.	0.0749695955
10.	0.0532773082

Figure: FFT of contact stiffness



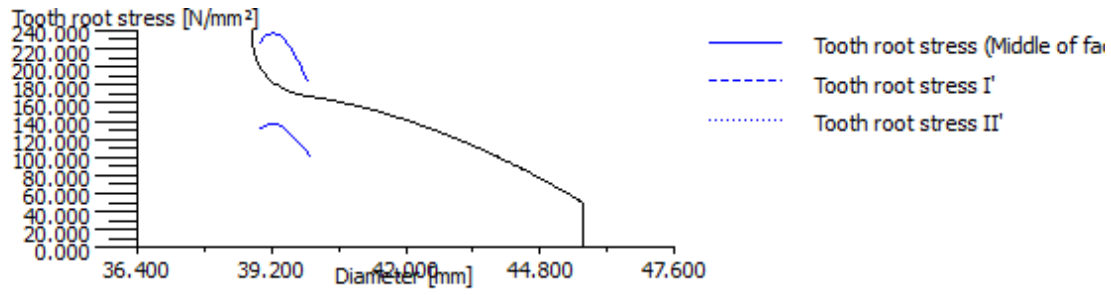
wt = 100 %, a = 101.845 mm, fpt = 0 μm, μ = 0.1045744304

Figure: Normal force curve (Line load)



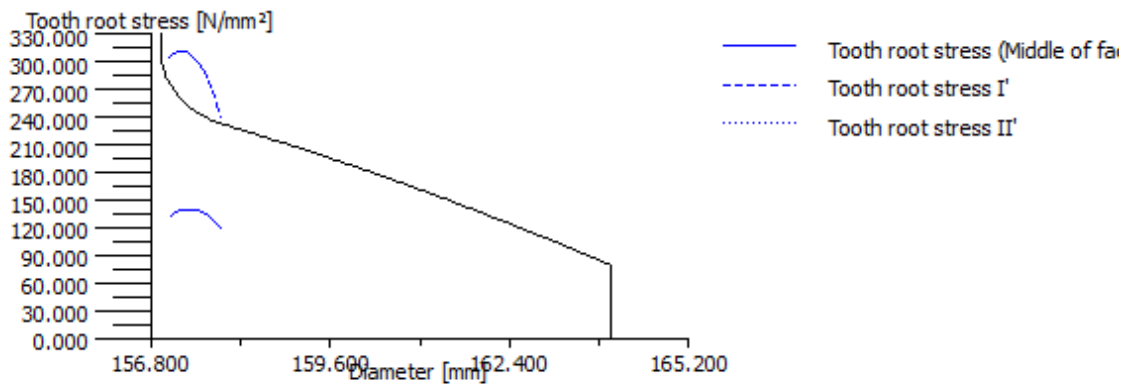
wt = 100 %, a = 101.845 mm, fpt = 0 μm, μ = 0.1045744304

Figure: Stress curve



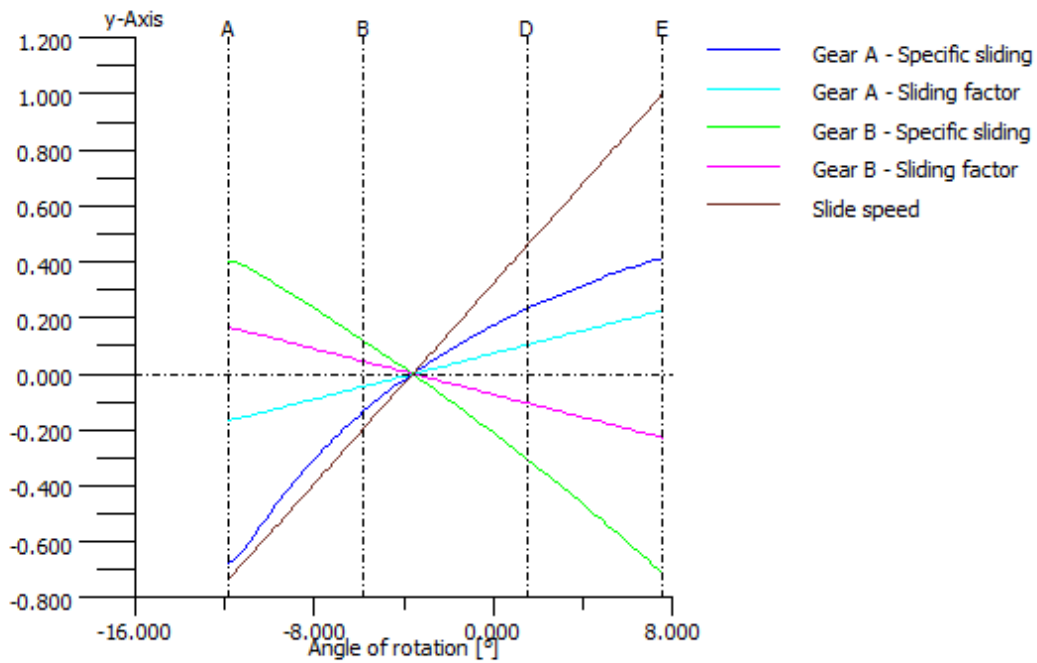
wt = 100 %, a = 101.845 mm, fpt = 0 μ m, μ = 0.1045744304

Figure: Stress curve Gear A



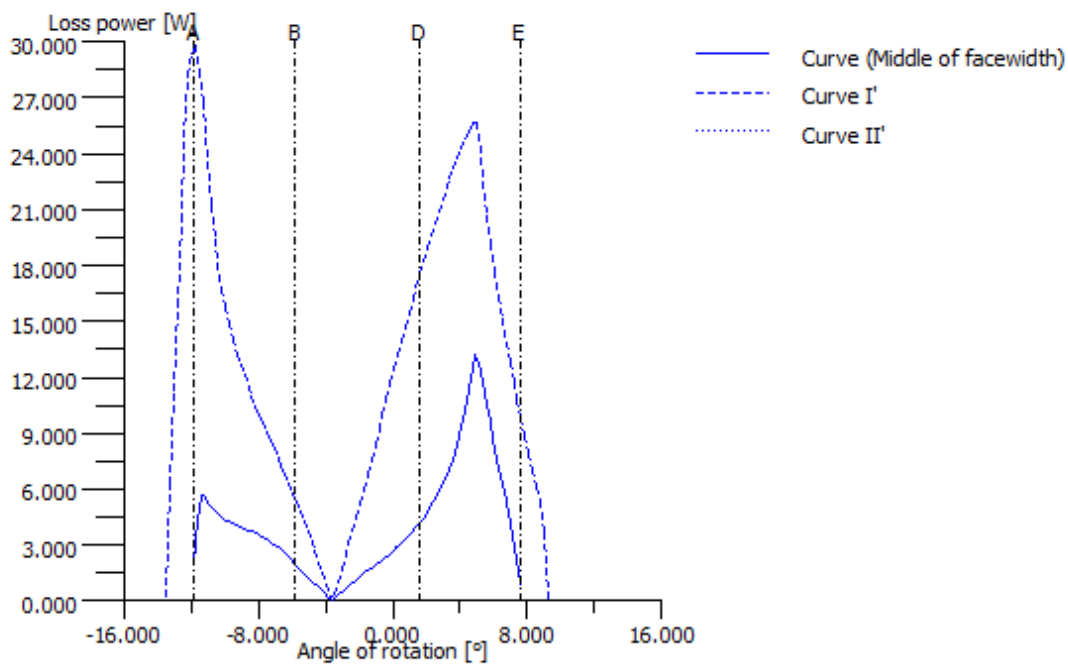
wt = 100 %, a = 101.845 mm, fpt = 0 μ m, μ = 0.1045744304

Figure: Stress curve Gear B



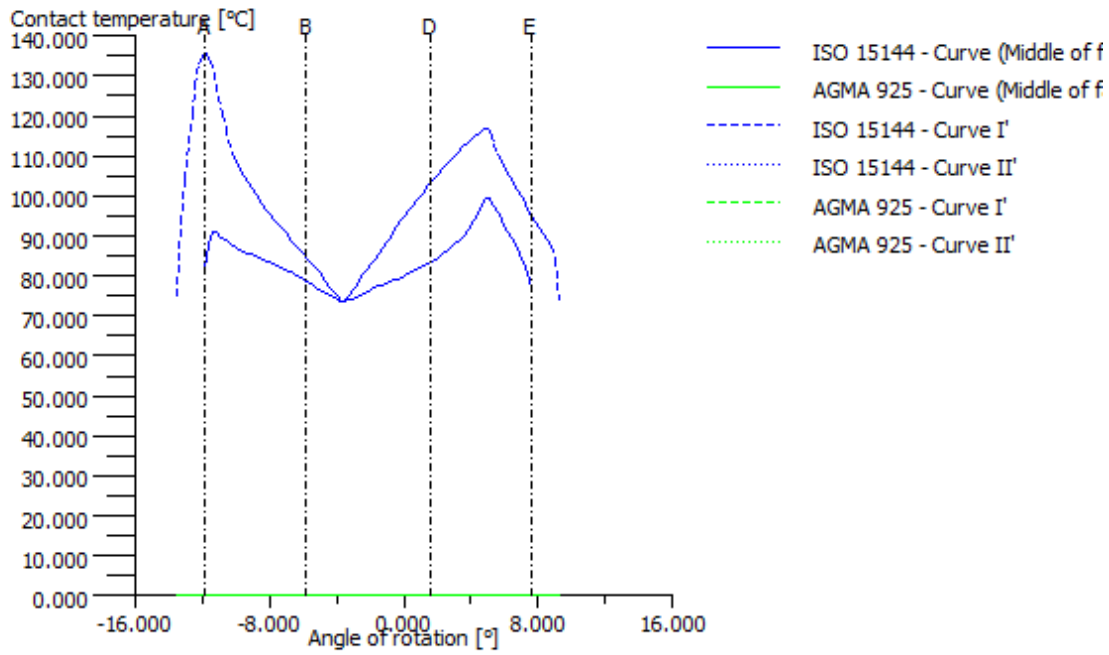
wt = 100 %, a = 101.845 mm, fpt = 0 μ m, μ = 0.1045744304
 vg: 1.0 = 1.481 m/s

Figure: Kinematics



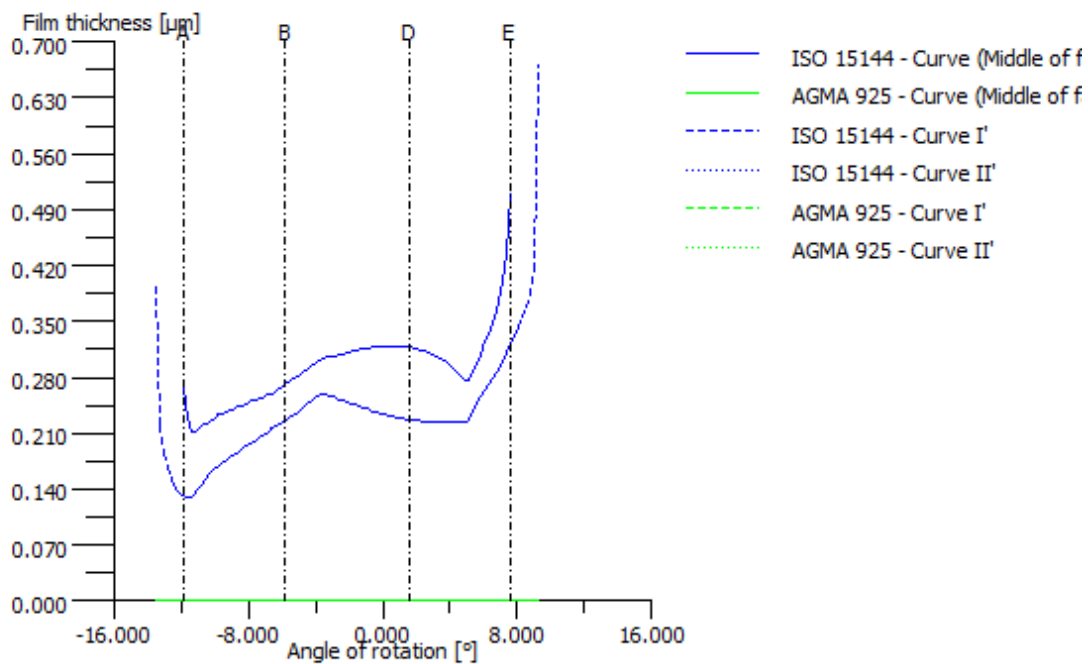
wt = 100 %, a = 101.845 mm, fpt = 0 μ m, μ = 0.1045744304

Figure: Loss power



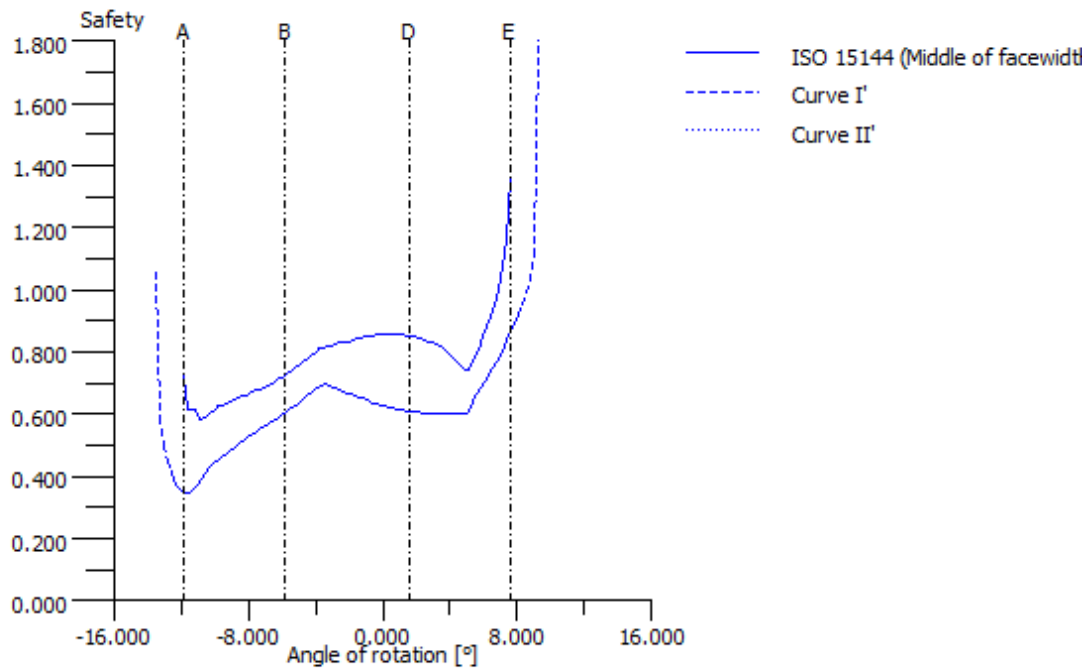
wt = 100 %, a = 101.845 mm, fpt = 0 μm , μ = 0.1045744304
theOil = 70.0 °C, theM = 73.3 °C, etaM = 28.45 mPa*s

Figure: Flash temperature (ISO TR 15144)



wt = 100 %, a = 101.845 mm, fpt = 0 μm , μ = 0.1045744304
theOil = 70.0 °C, theM = 73.3 °C, etaM = 28.45 mPa*s
hmin(ISO) = 0.130 μm , Ra = 3.000 μm

Figure: Lubricating film (ISO TR 15144)



wt = 100 %, a = 101.845 mm, fpt = 0 μ m, μ = 0.1045744304
theOil = 70.0 °C, theM = 73.3 °C, etaM = 28.45 mPa*s
Slam(ISO) = 0.348, Ra = 3.000 μ m

Figure: Safety against micropitting (ISO TR 15144)

Remark:

The report contains only the important graphics.
The other graphics can be found in menu 'Graphics' -> 'Contact analysis'.

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

KISSsoft - Release 03-2011H
 KISSsoft-Entwicklungs-Version KISSsoft AG CH-8634 HOMBRECHTIKON

File
 Name : CylGearPair 6a (shafts for contact analysis) (Helical DIN3990)_finale
 Description: KISSsoft example
 Changed by : ho on: 11.10.2011 at: 15:54:27

Calculation of path of contact under load

Mesh gear 1 - gear 2 (Right Tooth Flank)
 Shaft file A: C:/Program Files (x86)/KISSsoft 03-2011/example/Pinion shaft for CylGearPair 6a.W10,
 selected gear: Pinion from CylGearPair6
 Shaft file B: C:/Program Files (x86)/KISSsoft 03-2011/example/Gear shaft for CylGearPair 6a.W10,
 selected gear: Gear from CylGearPair6

Partial load for calculation		100.00	%
Center distance	[a]	101.85	mm
Single pitch deviation	[fpt]	0.00	µm
Coefficient of friction	[µ]	0.10	
Torque	[T1]	40.46	Nm

		min	max	Delta	µ	sigma
Transmission error	(µm)	-110.1883	-109.9462	0.2421	-110.0797	0.0749
Stiffness curve	(N/mm/µm)	26.3787	29.0513	2.6727	27.7832	0.6873
Line load	(N/mm)	0.2833	147.4778	147.1945	70.5199	18.2483
Torque Gear 1	(Nm)	40.4501	40.5035	0.0534	40.4643	0.0095
Torque Gear 2	(Nm)	154.0368	154.3706	0.3339	154.1726	0.0767
Loss power	(W)	0.0007	17.7381	17.7374	4.6684	3.2493
Flash temperature	(°)	73.2520	107.6581	34.4060	84.7400	7.2663
Lubricating film	(µm)	0.1676	0.7535	0.5859	0.2826	0.0528
Hertzian stress	(N/mm ²)		1046.6853		653.7907	
Safety against micropitting		0.4613				

Transverse contact ratio under load[Epsa']	1.50
Overlap ratio under load [Epsb']	1.03
Total contact ratio under load[Epsg']	2.53

KHbeta Calculation

Gear 1
 Point in polar co-ordinates:
 R = 20.991 mm , phi = 0.000 °
 Displacement calculated in direction 111.425 °

	y	phi1.t	f1.t	f1.b	f1.tot	f1.C
1	40.4762 mm	-0.0000°	-0.0000 mm	0.0125 mm	0.0125 mm	-0.0003 mm
2	41.4286 mm	-0.0001°	-0.0001 mm	0.0129 mm	0.0128 mm	-0.0007 mm
3	42.3810 mm	-0.0002°	-0.0001 mm	0.0132 mm	0.0131 mm	-0.0010 mm
4	43.3333 mm	-0.0003°	-0.0001 mm	0.0135 mm	0.0134 mm	-0.0014 mm
5	44.2857 mm	-0.0004°	-0.0001 mm	0.0139 mm	0.0137 mm	-0.0017 mm
6	45.2381 mm	-0.0004°	-0.0002 mm	0.0142 mm	0.0140 mm	-0.0020 mm
7	46.1905 mm	-0.0005°	-0.0002 mm	0.0145 mm	0.0143 mm	-0.0024 mm
8	47.1429 mm	-0.0006°	-0.0002 mm	0.0149 mm	0.0146 mm	-0.0027 mm
9	48.0952 mm	-0.0006°	-0.0002 mm	0.0152 mm	0.0150 mm	-0.0030 mm
10	49.0476 mm	-0.0007°	-0.0002 mm	0.0155 mm	0.0153 mm	-0.0034 mm
11	50.0000 mm	-0.0007°	-0.0003 mm	0.0158 mm	0.0156 mm	-0.0037 mm
12	50.9524 mm	-0.0008°	-0.0003 mm	0.0161 mm	0.0159 mm	-0.0040 mm
13	51.9048 mm	-0.0008°	-0.0003 mm	0.0165 mm	0.0162 mm	-0.0044 mm
14	52.8571 mm	-0.0008°	-0.0003 mm	0.0168 mm	0.0165 mm	-0.0047 mm
15	53.8095 mm	-0.0009°	-0.0003 mm	0.0171 mm	0.0168 mm	-0.0050 mm
16	54.7619 mm	-0.0009°	-0.0003 mm	0.0174 mm	0.0171 mm	-0.0054 mm
17	55.7143 mm	-0.0009°	-0.0003 mm	0.0177 mm	0.0174 mm	-0.0057 mm
18	56.6667 mm	-0.0009°	-0.0003 mm	0.0180 mm	0.0177 mm	-0.0060 mm
19	57.6190 mm	-0.0009°	-0.0003 mm	0.0183 mm	0.0180 mm	-0.0064 mm
20	58.5714 mm	-0.0010°	-0.0003 mm	0.0186 mm	0.0183 mm	-0.0067 mm
21	59.5238 mm	-0.0010°	-0.0003 mm	0.0189 mm	0.0186 mm	-0.0071 mm

Gear 2
 Point in polar co-ordinates:
 R = 80.854 mm , phi = 0.000 °
 Displacement calculated in direction 291.425 °

	y	phi2.t	f2.t	f2.b	f2.tot	f2.C
1	24.4762 mm	0.0000°	0.0000 mm	-0.0094 mm	-0.0094 mm	-0.0001 mm
2	25.4286 mm	0.0000°	0.0000 mm	-0.0096 mm	-0.0096 mm	-0.0003 mm
3	26.3810 mm	0.0000°	0.0000 mm	-0.0098 mm	-0.0098 mm	-0.0005 mm
4	27.3333 mm	0.0000°	0.0000 mm	-0.0100 mm	-0.0100 mm	-0.0006 mm
5	28.2857 mm	0.0000°	0.0000 mm	-0.0101 mm	-0.0101 mm	-0.0008 mm
6	29.2381 mm	0.0000°	0.0000 mm	-0.0103 mm	-0.0103 mm	-0.0010 mm
7	30.1905 mm	0.0000°	0.0000 mm	-0.0105 mm	-0.0105 mm	-0.0012 mm
8	31.1429 mm	0.0000°	0.0000 mm	-0.0107 mm	-0.0107 mm	-0.0014 mm

9	32.0952 mm	0.0000°	0.0000 mm	-0.0108 mm	-0.0108 mm	-0.0015 mm
10	33.0476 mm	0.0000°	0.0000 mm	-0.0110 mm	-0.0110 mm	-0.0017 mm
11	34.0000 mm	0.0000°	0.0000 mm	-0.0112 mm	-0.0112 mm	-0.0019 mm
12	34.9524 mm	0.0000°	0.0000 mm	-0.0114 mm	-0.0113 mm	-0.0021 mm
13	35.9048 mm	0.0000°	0.0000 mm	-0.0115 mm	-0.0115 mm	-0.0023 mm
14	36.8571 mm	0.0000°	0.0000 mm	-0.0117 mm	-0.0117 mm	-0.0024 mm
15	37.8095 mm	0.0000°	0.0000 mm	-0.0119 mm	-0.0119 mm	-0.0026 mm
16	38.7619 mm	0.0000°	0.0000 mm	-0.0120 mm	-0.0120 mm	-0.0028 mm
17	39.7143 mm	0.0000°	0.0000 mm	-0.0122 mm	-0.0122 mm	-0.0030 mm
18	40.6667 mm	0.0000°	0.0000 mm	-0.0124 mm	-0.0124 mm	-0.0032 mm
19	41.6190 mm	0.0000°	0.0000 mm	-0.0126 mm	-0.0125 mm	-0.0033 mm
20	42.5714 mm	0.0000°	0.0000 mm	-0.0127 mm	-0.0127 mm	-0.0035 mm
21	43.5238 mm	0.0000°	0.0000 mm	-0.0129 mm	-0.0129 mm	-0.0037 mm

Explanations:

y : Width
 phi's : Static torsion
 fat : Displacement due to torsion
 fib : Displacement due to bending
 f.tot : Total displacement (f.b+f.t)
 f.C : Change due to tooth trace modification

Load distribution

Contact stiffness = 20.257 N/mm/ μ m

	y	g	w
1.	40.4762 mm	5.1678 μ m	104.6846 N/mm
2.	41.4286 mm	5.1454 μ m	104.2302 N/mm
3.	42.3810 mm	5.1259 μ m	103.8349 N/mm
4.	43.3333 mm	5.1097 μ m	103.5066 N/mm
5.	44.2857 mm	5.0963 μ m	103.2365 N/mm
6.	45.2381 mm	5.0861 μ m	103.0289 N/mm
7.	46.1905 mm	5.0790 μ m	102.8844 N/mm
8.	47.1429 mm	5.0750 μ m	102.8034 N/mm
9.	48.0952 mm	5.0741 μ m	102.7861 N/mm
10.	49.0476 mm	5.0764 μ m	102.8330 N/mm
11.	50.0000 mm	5.0819 μ m	102.9444 N/mm
12.	50.9524 mm	5.0908 μ m	103.1239 N/mm
13.	51.9048 mm	5.1029 μ m	103.3685 N/mm
14.	52.8571 mm	5.1182 μ m	103.6784 N/mm
15.	53.8095 mm	5.1367 μ m	104.0538 N/mm
16.	54.7619 mm	5.1585 μ m	104.4949 N/mm
17.	55.7143 mm	5.1835 μ m	105.0018 N/mm
18.	56.6667 mm	5.2118 μ m	105.5747 N/mm
19.	57.6190 mm	5.2433 μ m	106.2137 N/mm
20.	58.5714 mm	5.2781 μ m	106.9189 N/mm
21.	59.5238 mm	5.3160 μ m	107.6866 N/mm

Explanations:

g : Flank overlap
 w : Line load

wmax = 107.687 N/mm, wm = 104.138 N/mm

wm = (Ft/b)/cos(a_{wt})

KHb = wmax/wm = 1.034 (Calculation according to ISO 6336-1, Appendix E)

Notice: The influence of the exceeding tooth width is not taken into account in the calculation of KHbeta.

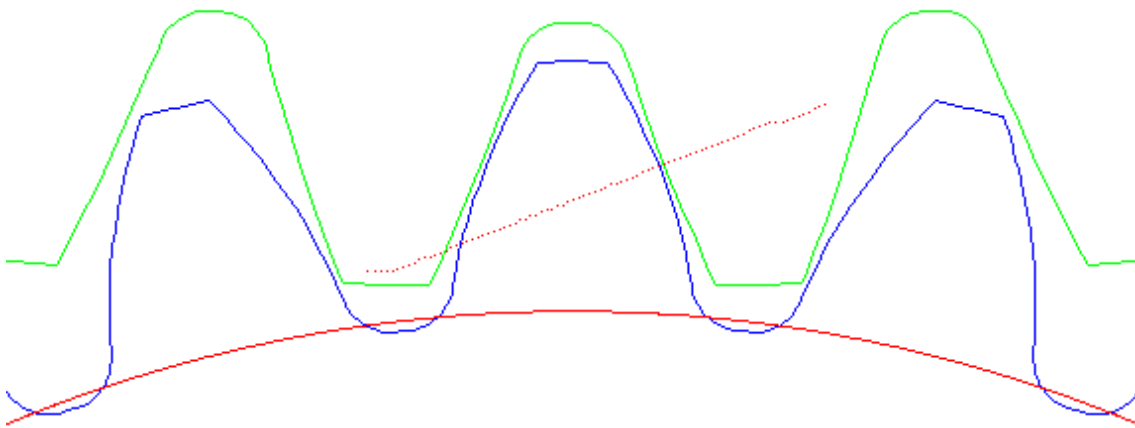
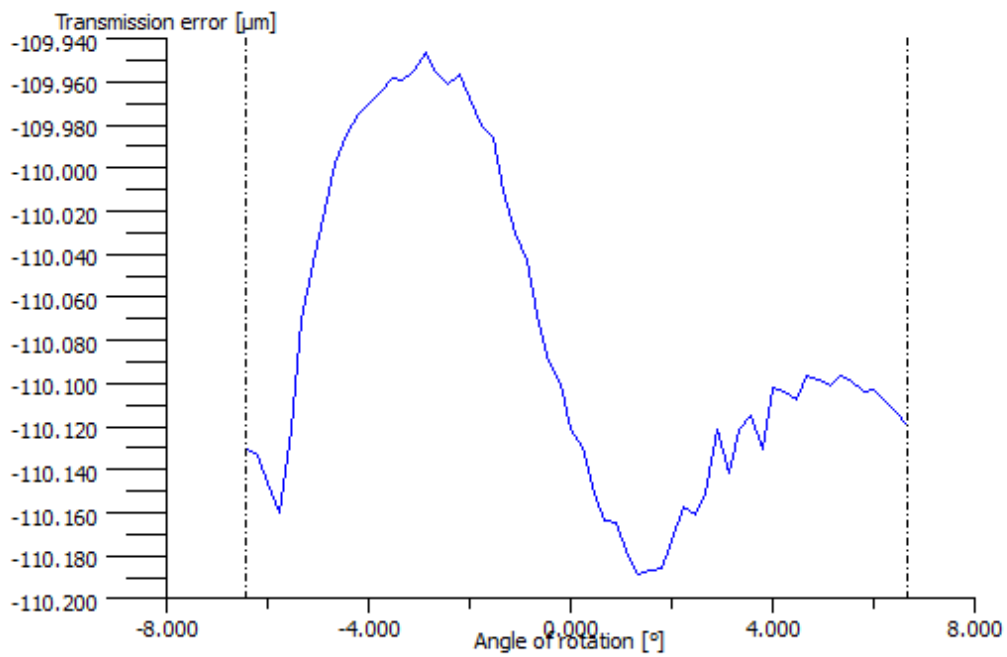
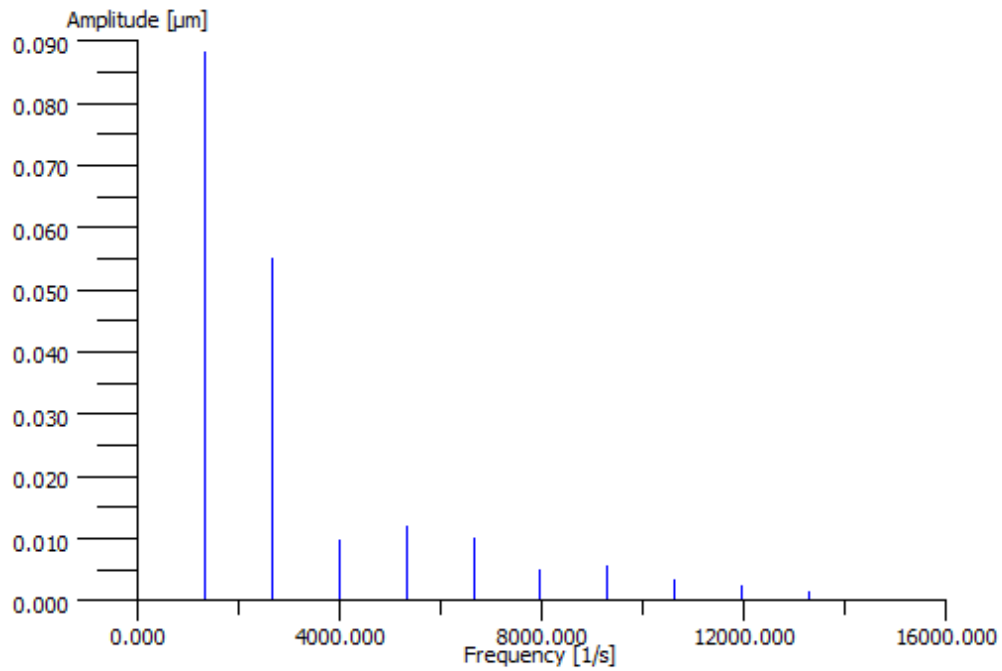


Figure: Path of contact



wt = 100 %, a = 101.845 mm, fpt = 0 µm, $\mu = 0.1045744304$

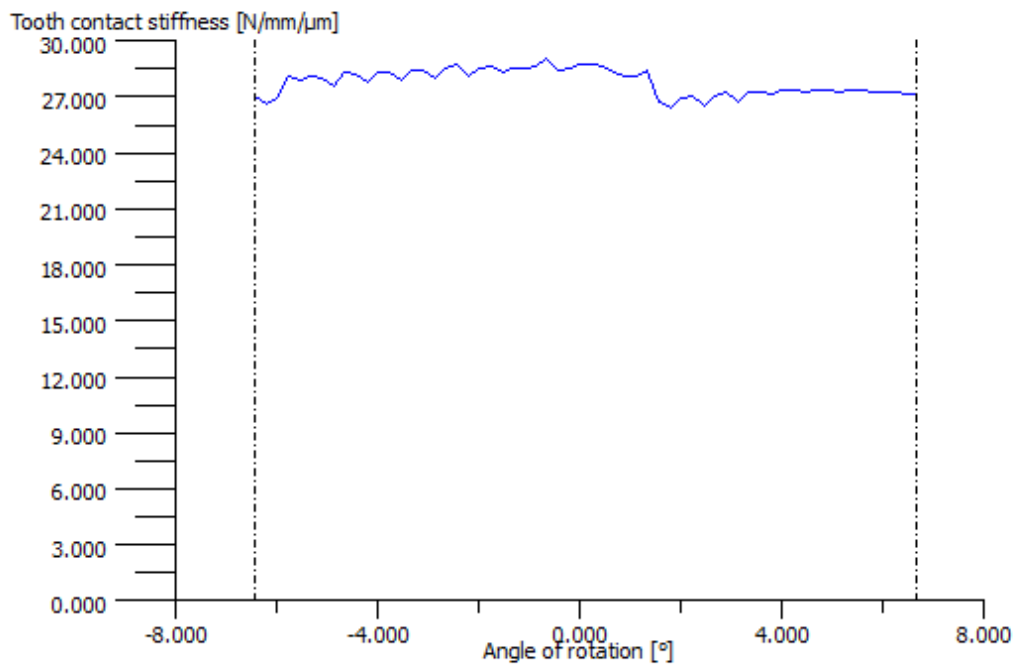
Figure: Transmission error



1st Harmonic frequency [1/s] : 1327.5

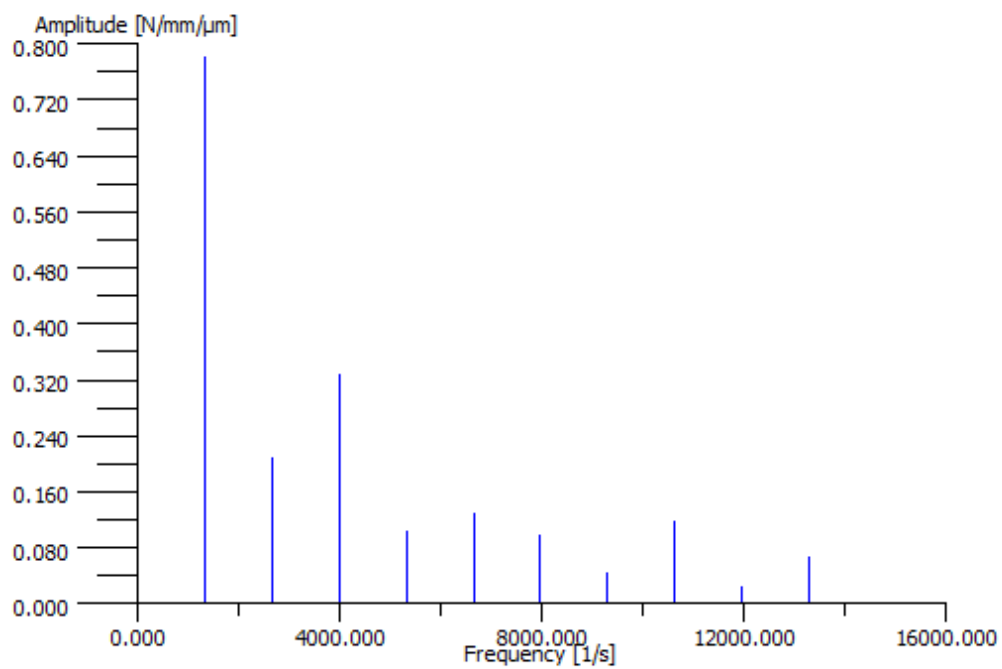
Harmonics	Amplitude [μm]
1.	0.08822548272
2.	0.05514285821
3.	0.009550383155
4.	0.01180416022
5.	0.009924881985
6.	0.004873826334
7.	0.005528190247
8.	0.003199683043
9.	0.002210586162
10.	0.001545248804

Figure: FFT of transmission error



wt = 100 %, a = 101.845 mm, fpt = 0 μm, μ = 0.1045744304

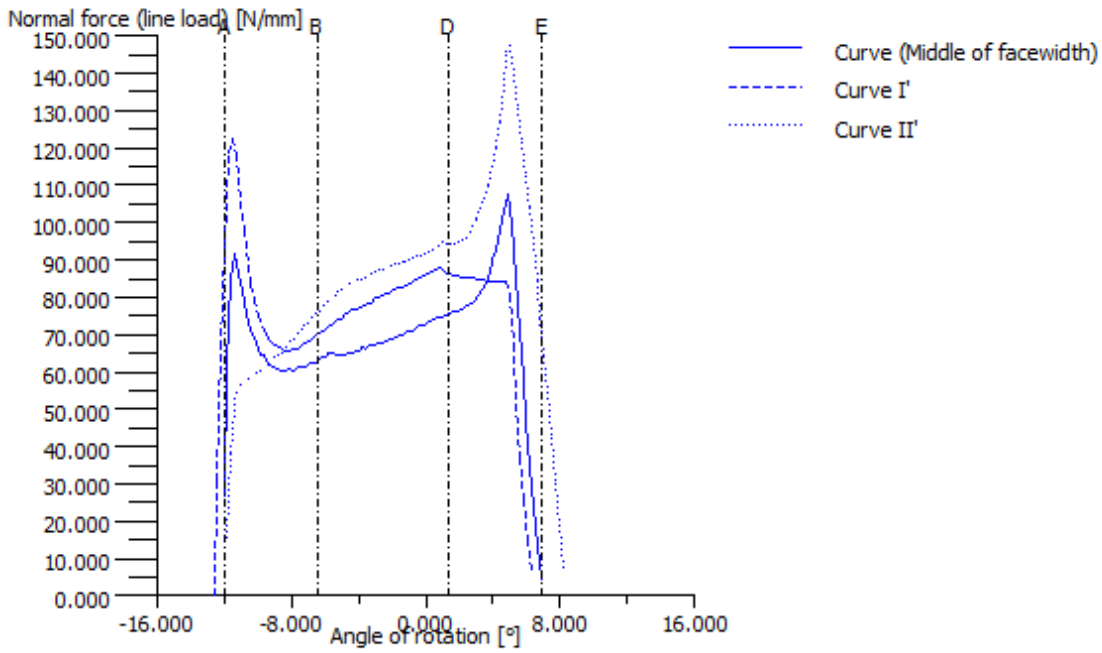
Figure: Stiffness curve



1st Harmonic frequency [1/s] : 1327.5

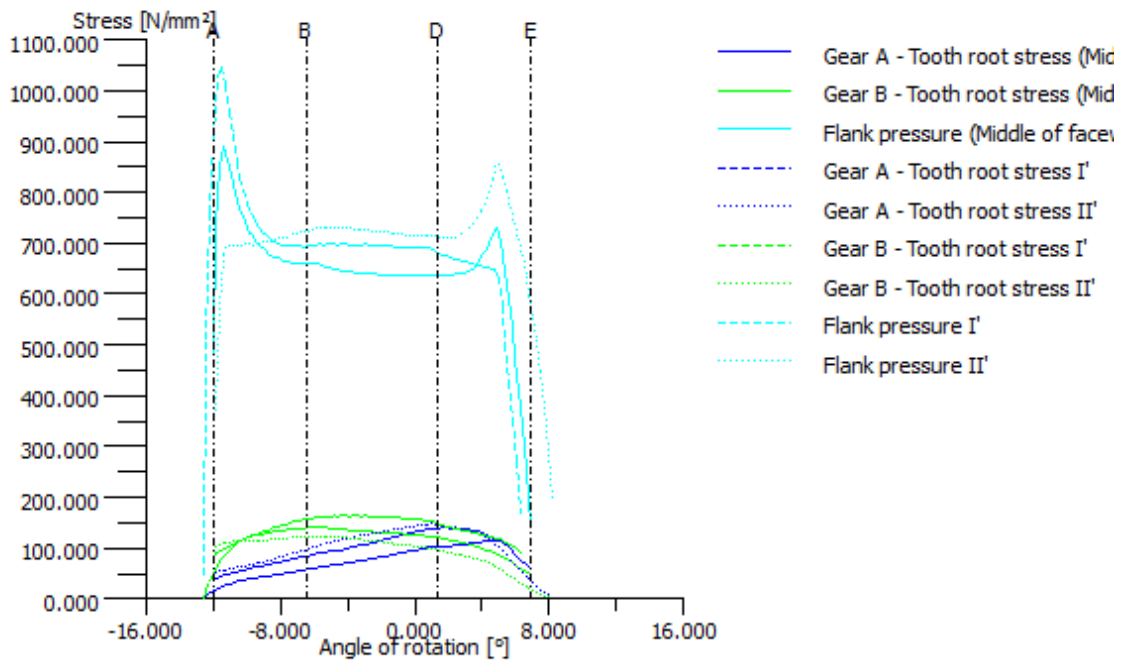
Harmonics	Amplitude [N/mm/μm]
1.	0.7812834537
2.	0.2095175289
3.	0.3261955402
4.	0.1024535954
5.	0.1285213218
6.	0.09802182462
7.	0.04279885289
8.	0.1177815205
9.	0.02437144185
10.	0.06627046822

Figure: FFT of contact stiffness



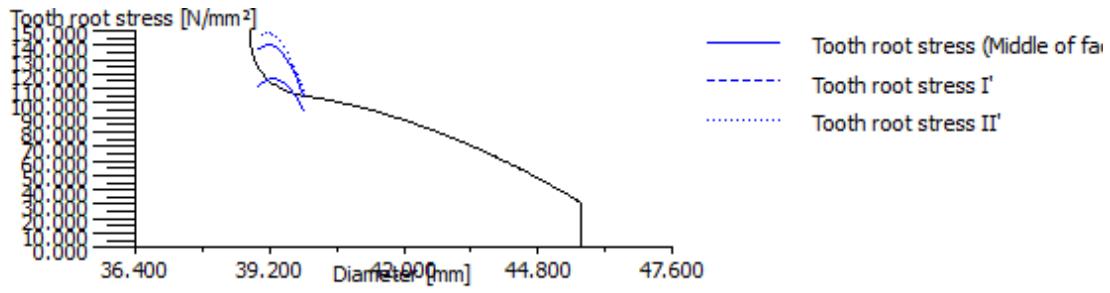
wt = 100 %, a = 101.845 mm, fpt = 0 μm, μ = 0.1045744304

Figure: Normal force curve (Line load)



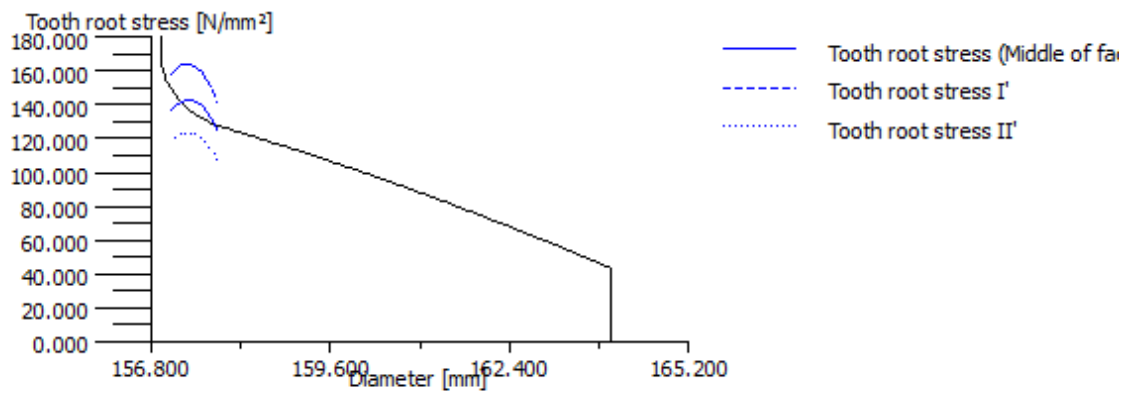
wt = 100 %, a = 101.845 mm, fpt = 0 μm, μ = 0.1045744304

Figure: Stress curve



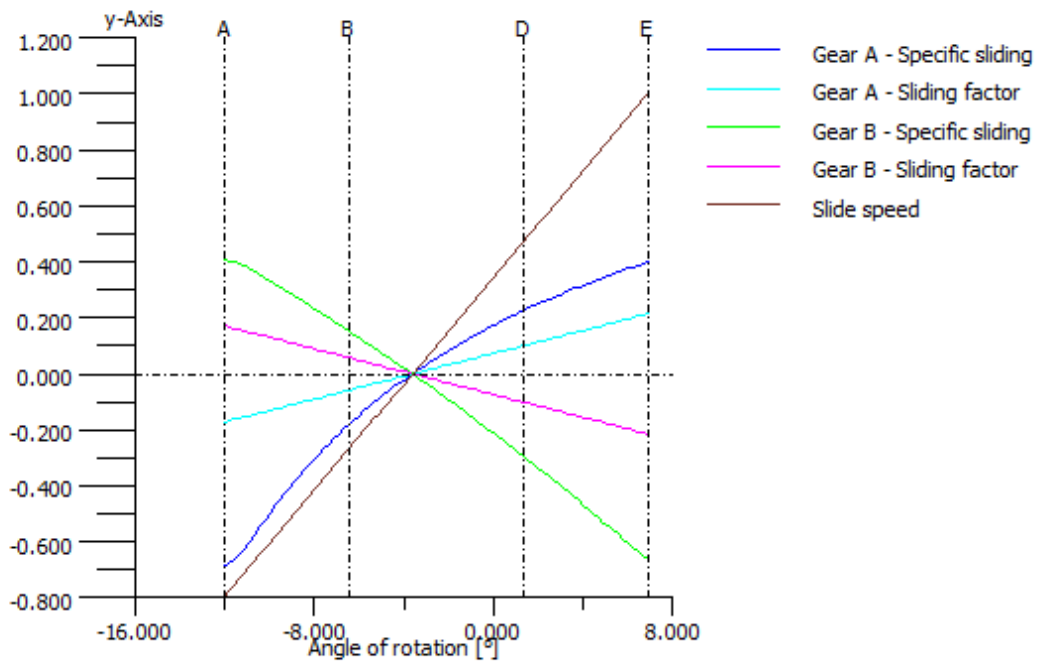
wt = 100 %, a = 101.845 mm, fpt = 0 μ m, μ = 0.1045744304

Figure: Stress curve Gear A



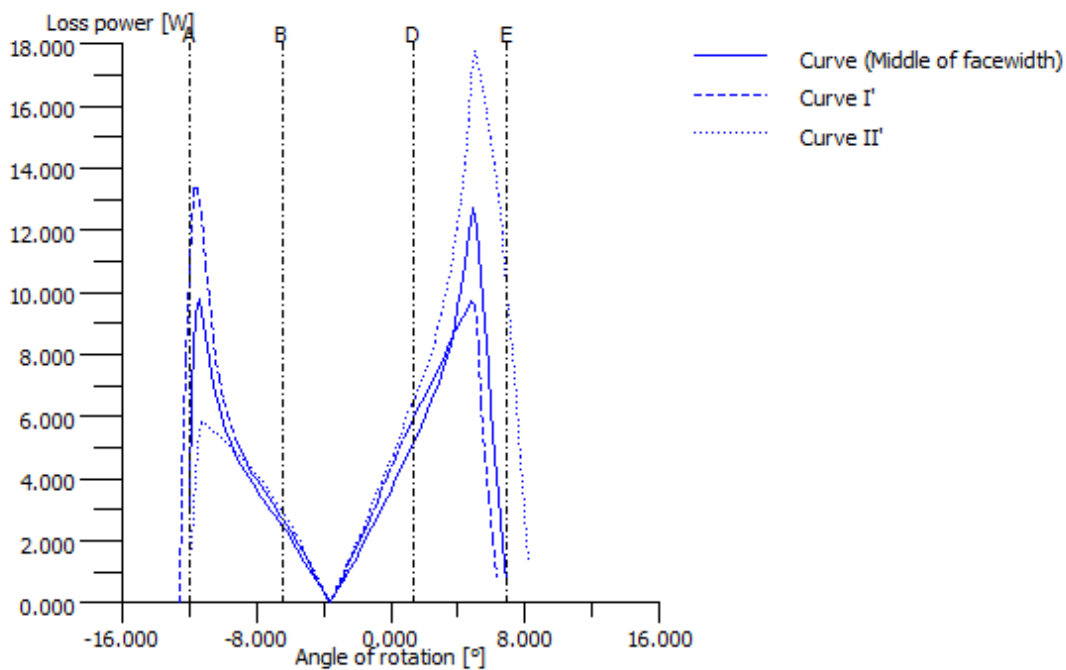
wt = 100 %, a = 101.845 mm, fpt = 0 μ m, μ = 0.1045744304

Figure: Stress curve Gear B



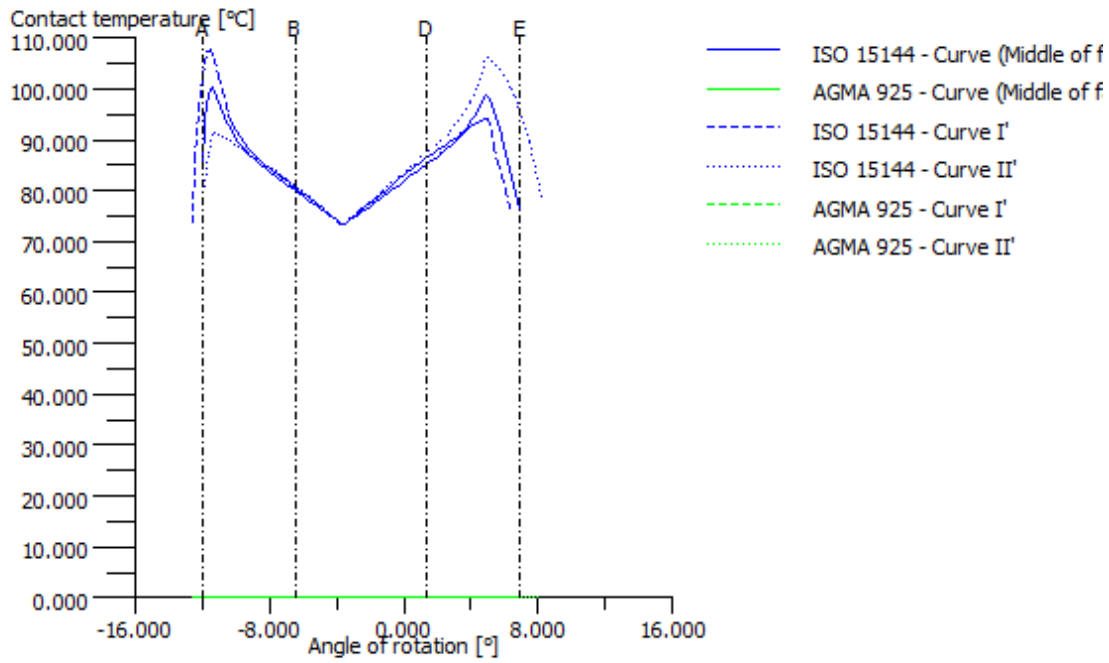
wt = 100 %, a = 101.845 mm, fpt = 0 μ m, μ = 0.1045744304
 vg: 1.0 = 1.394 m/s

Figure: Kinematics



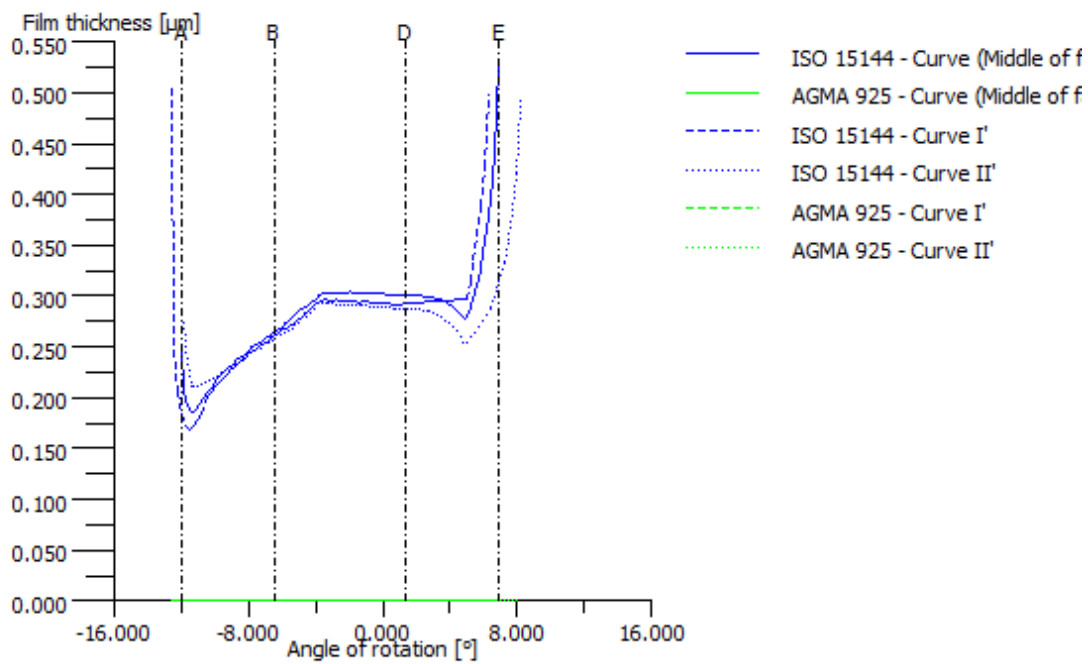
wt = 100 %, a = 101.845 mm, fpt = 0 μ m, μ = 0.1045744304

Figure: Loss power



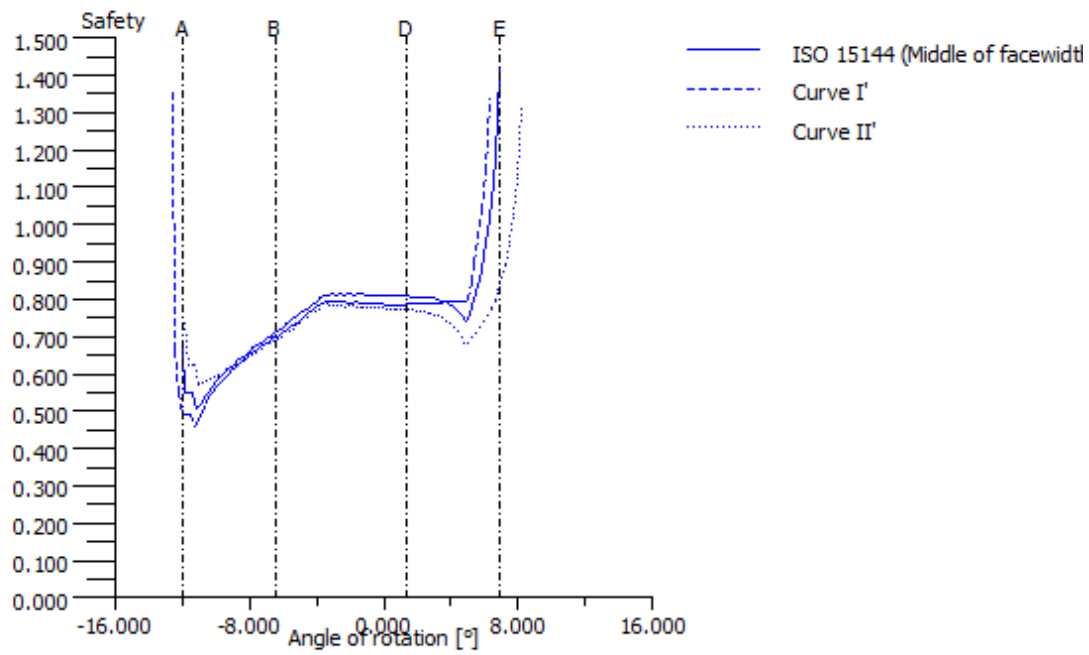
wt = 100 %, a = 101.845 mm, fpt = 0 μm , μ = 0.1045744304
 theOil = 70.0 $^{\circ}\text{C}$, theM = 73.3 $^{\circ}\text{C}$, etaM = 28.45 mPa*s

Figure: Flash temperature (ISO TR 15144)



wt = 100 %, a = 101.845 mm, fpt = 0 μm , μ = 0.1045744304
 theOil = 70.0 $^{\circ}\text{C}$, theM = 73.3 $^{\circ}\text{C}$, etaM = 28.45 mPa*s
 hmin(ISO) = 0.168 μm , Ra = 3.000 μm

Figure: Lubricating film (ISO TR 15144)



wt = 100 %, a = 101.845 mm, fpt = 0 μ m, μ = 0.1045744304
 theOil = 70.0 °C, theM = 73.3 °C, etaM = 28.45 mPa*s
 Slam(ISO) = 0.461, Ra = 3.000 μ m

Figure: Safety against micropitting (ISO TR 15144)

Remark:

The report contains only the important graphics.
 The other graphics can be found in menu 'Graphics' -> 'Contact analysis'.