

KISSsoft Exercise 2

Bevel Gear 02

Strength rating of a bevel gearset

1 Purpose of exercise

In this exercise, we will do a strength rating of a Face milling bevel gearset, using the ISO 10300:2014

- General setting for strength calculation
- Root bending strength: root radius optimization, cutter head size, tooth thickness modification factor
- Scuffing: running-in, lubrication, phosphating
- Tooth flank fracture: increase hardening depth
- Load spectra applied

2 Task

Use Sample: 12 Bevel (GEMS Example 2 FM).

2.1 Analysis of general settings for strength

2.1.1 Effective face width

The current effective face width is entered with 0.92. This is an optimized value. Enter the value of 0.85, which is the default value and check the effect on the safety numbers.

2.1.2 Profile crowning

The setting for load distribution is selected with 'low'. Change the setting to 'high' and check the effect on the safety numbers.

2.1.3 Life factor

The life factor ZNT, YNT are defined with the reduction of the number to 0.85 at number of cycles at 10^{10} . This is a conservative calculation. Change the setting to 1 at number of cycles at 10^{10} and check the effect on the safety numbers.

2.1.4 Mounting factor

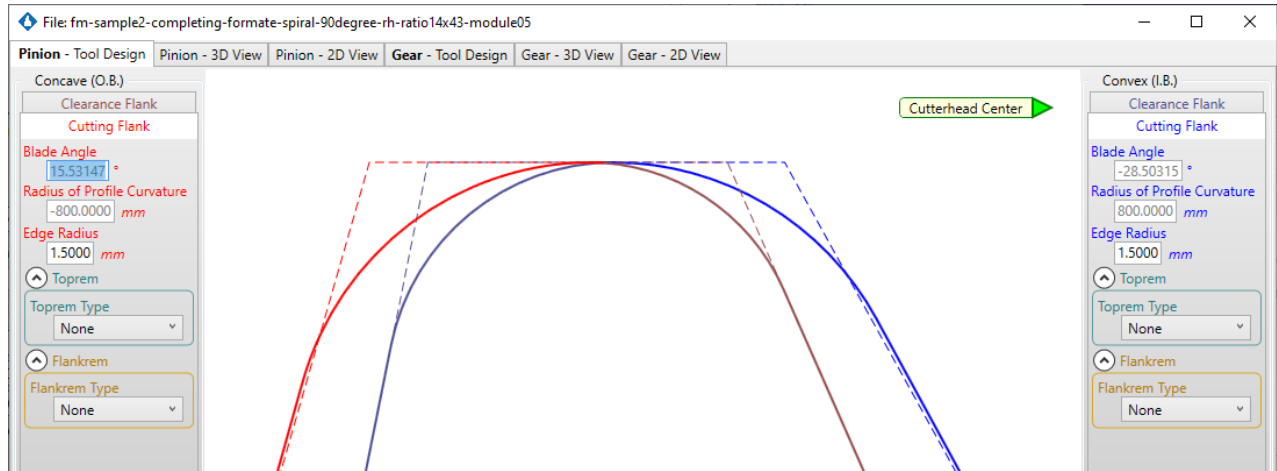
The mounting factor is selected as 1.1. As a sample, all the bevel gearsets are tested under full load. This results in a mounting factor of 1. Enter the new number and check the effect on the safety numbers.

Change	Previous flank safety		Previous root safety		New flank safety		New root safety	
	G1	G2	G1	G2	G1	G2	G1	G2
Change effective face width beff from 0.92 to 0.85 (default value)	0.97	1.0	1.352	1.308				
Change profile crowning from low to high	0.97	1.0	1.352	1.308				
Change life factors ZNT, YNT from 0.85 to 1	0.97	1.0	1.352	1.308				
Change mounting factor from 1.1 to 1.0	0.97	1.0	1.352	1.308				

2.2 Root bending strength improvement

2.2.1 Edge radius of blade

As a sample, in the GEMS software, the edge radius at pinion was reduced from 1.5 mm to 1.2 mm. Enter the data in KISSsoft and check the effect on the safety number.



2.2.2 Cutter head size

The cutter head size of the bevel gearset is to be selected smaller, to find a benefit in root bending strength. Select the cutter head size = 3" and check the effect on the safety number. Is the cutter head size still within the application limits, so that manufacturing problem can be avoided?

2.2.3 Tooth thickness modification

The tooth root strength between pinion and ring gear should be balanced by modified tooth thickness factor xsm1 and xsm2 for equal life. Check in the report, what lifetime is achieved with the current settings and balance the life time by modifying the tooth thickness modification factor xsm1 and xsm2 (note that the backlash has to remain).

Change	Previous root safety		New root safety	
	G1	G2	G1	G2
Pinion (G1), Ring gear (G2)				
Edge radius of blade	1.352	1.308		
Cutter head size from 3.75" to 3"	1.352	1.308		
Tooth thickness modification for equal life	1.352	1.308		

2.3 Scuffing

2.3.1 Running-in

Activate resp. de-activate the running-in option and check the effect on the safety number.

2.3.2 Lubrication

Increase the load stage scuffing test number from 12 to 13 and check the effect on the safety number.

2.3.3 Phosphating

The ring gear is phosphated to have higher resistance against scuffing. Enter the corresponding number in KISSsoft and check the effect on the safety number.

2.3.4 Crowning

Enter profile crowning and check the effect on the safety number.

Change	Previous scuffing safety	New scuffing safety
	Gearset	Gearset
Running-in was active / inactive.	1.703	
Load stage scuffing test from 12 to 13	1.703	
Phosphating of ring gear	1.703	
Profile crowning added	1.703	

2.4 Tooth flank fracture

2.4.1 Hardening depth

Do a calculation with a recommended hardening depth value of 0.66 mm. Increase the hardening depth to 0.9 mm and check the effect on the flank fracture safety number.

Change	Previous tooth flank fracture safety	New tooth flank fracture safety
	Gearset	Gearset
Increased the hardening depth from 0.66 to 0.9 mm	0.932	

3 Solution

3.1 Analysis of general settings for strength

3.1.1 Effective face width

K Details for root and flank strength calculation

Allow simplified calculation according to DIN 3990/ISO 6336 (for plastics)

Profile modification: Without (only running-in)

Life factors Z_{NT} , Y_{NT} according to ISO 6336: Normal (reduction to 0.85 at 10^{10} cycles)

Modification of S-N curve (Woehler line) in the range of endurance limit: according standard (ISO, AGMA or DIN)

Consider load bins with 0% frequency: Yes

Tooth flank with load spectra: Consider all negative load bins as positive

Tooth root with load spectra: Consider all negative load bins as positive

Profile crowning: low (automotive gears)

Limited pitting is permitted: No

Effective facewidth (ISO 10300) calculated with b_{eff}/b : 0.85

OK Cancel

Change	Previous flank safety		Previous root safety		New flank safety		New root safety	
	G1	G2	G1	G2	G1	G2	G1	G2
Pinion (G1), Ring gear (G2)								
Change effective face width b_{eff} from 0.92 to 0.85 (default value)	0.97	1.0	1.352	1.308	0.903	0.934	1.302	1.26

3.1.2 Profile crowning

K Details for root and flank strength calculation

Allow simplified calculation according to DIN 3990/ISO 6336 (for plastics)

Profile modification: Without (only running-in)

Life factors Z_{NT} , Y_{NT} according to ISO 6336: Normal (reduction to 0.85 at 10^{10} cycles)

Modification of S-N curve (Woehler line) in the range of endurance limit: according standard (ISO, AGMA or DIN)

Consider load bins with 0% frequency: Yes

Tooth flank with load spectra: Consider all negative load bins as positive

Tooth root with load spectra: Consider all negative load bins as positive

Profile crowning: high (industry gears)

Limited pitting is permitted: No

Effective facewidth (ISO 10300) calculated with b_{eff}/b : 0.9200

OK Cancel

Change	Previous flank safety		Previous root safety		New flank safety		New root safety	
	G1	G2	G1	G2	G1	G2	G1	G2
Pinion (G1), Ring gear (G2)								
Change profile crowning from low to high	0.97	1.0	1.352	1.308	0.96	0.994	1.334	1.29

3.1.3 Life factor

K Details for root and flank strength calculation

Allow simplified calculation according to DIN 3990/ISO 6336 (for plastics)

Profile modification: Without (only running in)

Life factors Z_{NT} , Y_{NT} according to ISO 6336: With optimum quality and experience (always 1.0)

Modification of S-N curve (Woehler line) in the range of endurance limit: according standard (ISO, AGMA or DIN)

Consider load bins with 0% frequency: Yes

Tooth flank with load spectra: Consider all negative load bins as positive

Tooth root with load spectra: Consider all negative load bins as positive

Profile crowning: low (automotive gears)

Limited pitting is permitted: No

Effective facewidth (ISO 10300) calculated with b_{eff}/b : 0.9200

OK Cancel

Change	Previous flank safety		Previous root safety		New flank safety		New root safety	
	G1	G2	G1	G2	G1	G2	G1	G2
Pinion (G1), Ring gear (G2) Change life factors Z_{NT} , Y_{NT} from 0.85 to 1	0.97	1.0	1.352	1.308	1.08	1.08	1.538	1.455

3.1.4 Mounting factor

Reference profile Manufacturing Tolerances Modifications Strength Factors

General factors

Application factor K_A : 1.1000

Dynamic factor K_v : 1.0244

Transverse load factor $K_{H\alpha}$: 1.0051

Mounting factor (Load distribution modifier) $K_{H\beta-be}$: 1.0000

Alternating bending factor (mean stress influence coefficient)

Method: Predefined

Alternating bending factor Y_M : 1.0000

Change	Previous flank safety		Previous root safety		New flank safety		New root safety	
	G1	G2	G1	G2	G1	G2	G1	G2
Change mounting factor from 1.1 to 1.0	0.97	1.0	1.352	1.308	1.012	1.047	1.48	1.43

3.2 Root bending strength improvement

3.2.1 Edge radius of blade

Basic data		Process		Reference profile		Manufacturing	
Machining step Gear 1							
Pre- and final machining		Final machining (without pre-mac					
Final machining Gear 1							
Tool selection	Reference profile gear						
Input	Lengths						
Select reference profile	Own input						
Designation	25 / 0.30 / 1.0 ISO 53:1998 Profil B						
Dedendum	h_{FP}		5.0000	mm			
Root radius	ρ_{FP}		1.2000	mm			
Addendum	h_{aP}		4.0809	mm			
Protuberance height	h_{pP}		0.0000	mm			
Protuberance angle	α_{pP}		0.0000	°			
Tip form height	h_{FaP}		0.0000	mm			
Profile angle of the chamfer involute	α_{KP}		0.0000	°			

Change	Previous root safety		New root safety	
	G1	G2	G1	G2
Pinion (G1), Ring gear (G2)				
Edge radius of blade	1.352	1.308	1.295	1.308

3.2.2 Cutter head size

Basic data		Process		Reference profile		Manufacturing		Tolerances		Modification		
Manufacturing process												
		Gear 1		Gear 2								
Manufacture type	generate	formate										
Process	lapped											
Manufacturer's data for spiral teeth												
Manufacturing	Face Milling (single indexing method)											
						Cutter radius r_{c0}		3.0		in		

The cutter head size is still within the recommended range of 0,95 ..1,1. No problems in manufacturing are to be expected. Note, that the recommended blank angles slightly change.

Change	Previous root safety		New root safety	
	G1	G2	G1	G2
Pinion (G1), Ring gear (G2)				
Cutter head size from 3.75" to 3"	1.352	1.308	1.416	1.370

3.2.3 Tooth thickness modification

Currently, the tooth root strength is limited by the ring gear with 685 hours. This is also the system service life.

Profile shift coefficient	X_{hmn}	0.5185	-0.5185	↶ ↷
Tooth thickness modification factor	X_{sm}	0.0317	-0.0484	<input checked="" type="checkbox"/>
Quality (ISO 17485)	Q	6	6	🔧

15 Service life, damage

Required safety for tooth root	$[S_{rmin}]$	1.40
Required safety for tooth flank	$[S_{Hmin}]$	1.00
Required service life	[H]	20000.00

Service life (calculated with required safeties):
System service life (h)

[H_{att}] 685

Tooth root service life (h)
Tooth flank service life (h)

	Gear 1	Gear 2
[H _{Fatt}]	3545	685.2
[H _{Hatt}]	6722	2.064e+04

After (manually) balancing the values for tooth thickness modifications x_{sm1} and x_{sm2} , the system service life is increased to 1580 hours, which is more than factor 2.3 of the previous lifetime.

Profile shift coefficient	X_{hmn}	0.5185	-0.5185	↶ ↷
Tooth thickness modification factor	X_{sm}	0.0187	-0.0354	<input checked="" type="checkbox"/>
Quality (ISO 17485)	Q	6	6	🔧

15 Service life, damage

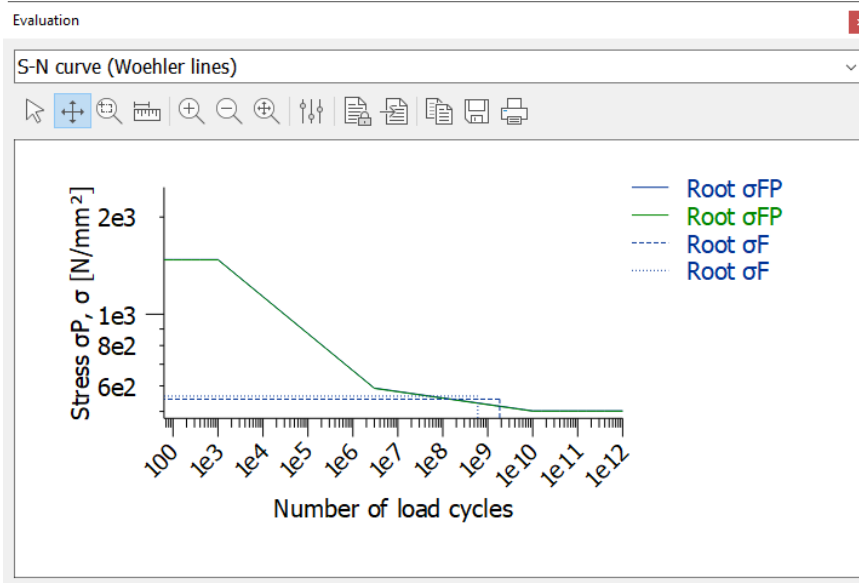
Required safety for tooth root	$[S_{rmin}]$	1.40
Required safety for tooth flank	$[S_{Hmin}]$	1.00
Required service life	[H]	20000.00

Service life (calculated with required safeties):
System service life (h)

[H_{att}] 1586

Tooth root service life (h)
Tooth flank service life (h)

	Gear 1	Gear 2
[H _{Fatt}]	1689	1586
[H _{Hatt}]	6722	2.064e+04



Change	Previous root safety		New root safety	
	G1	G2	G1	G2
Pinion (G1), Ring gear (G2)				
Tooth thickness modification for equal life	1.352	1.308	1.332	1.331

3.3 Scuffing

3.3.1 Running-in

Details for scuffing calculation

Peak overload factor according to DNV 41.2 (for short period torque peaks)

Define mass temperature

Lubricant factor X_L

Toothing is well run in No

Relative structural factor X_{WreIT}

Oil level h_{oil} Gear 1 Gear 2 mm

Change	Previous scuffing safety	New scuffing safety
	Gearset	Gearset
Running-in was active / inactive	1.703	1.279

3.3.2 Lubrication

Define lubricant

Own Input

Comment

Oil/ Grease

Density oil ρ kg/dm³

Nominal kinematic viscosity at 40°C ν_{40} mm²/s

Nominal kinematic viscosity at 100°C ν_{100} mm²/s

Lower limit service temperature θ_{min} °C

Upper limit service temperature θ_{max} °C

Lubricant base

Test procedure scuffing

Load stage scuffing test 13

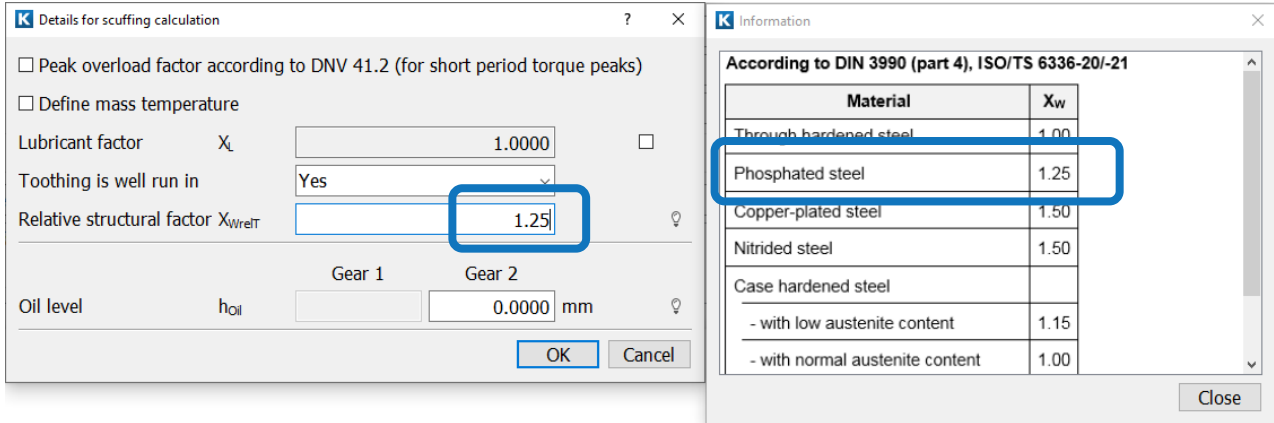
Test procedure micropitting

k factor for pressure-viscosity coefficient (AGMA 925) k

s factor for pressure-viscosity coefficient (AGMA 925) s

Change	Previous scuffing safety	New scuffing safety
	Gearset	Gearset
Load stage scuffing test from 12 to 13	1.703	1.986

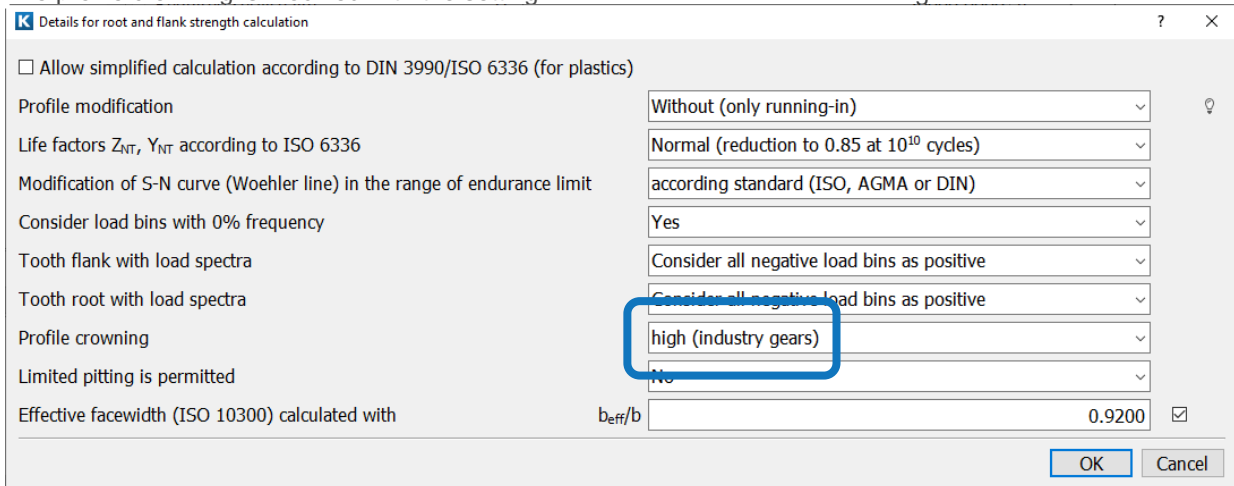
3.3.3 Phosphating



Change	Previous scuffing safety	New scuffing safety
	Gearset	Gearset
Phosphating of ring gear	1.703	2.017

3.3.4 Crowning

The profile crowning is modified with the setting in 'Details for root and flank strength calculation'.

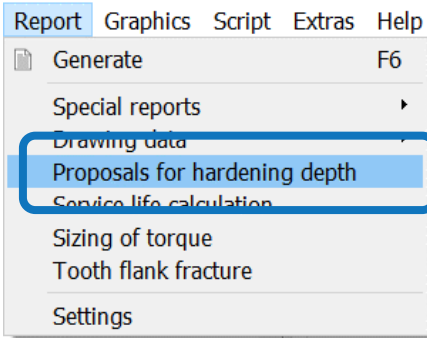


Change	Previous scuffing safety	New scuffing safety
	Gearset	Gearset
Profile crowning added	1.703	2.066

3.4 Tooth flank fracture

3.4.1 Hardening depth

Activate the hardening depth calculation. Enter the values from the special report 'Proposals for hardening depth' into KISSsoft (MQ steel is applied here).



Propositions ISO 6336 part 5 (p.21-23)

Recommended case depth to avoid pitting

[Ehtmax] 1.87 mm
 [EhtHopt] 0.70 mm

Recommended case depth to avoid case-crushing

Quality ML [EhtcML] 1.00 mm
 Quality MQ/ME [EhtcMQ] 0.66 mm

Calculation method

Factors, root, flank Bevel gear ISO 10300:2014, Method B1

Scuffing ISO/TS 10300-20:2021

Tooth flank fracture ISO/DTS 10300-4 (draft)

K Details for flank fracture calculation

	Gear 1		Gear 2		
	min	max	min	max	
Hardening depth t_{550}	0.6600	0.6600	0.6600	0.6600	mm
Hardening depth t_{400}	0.0000	0.0000	0.0000	0.0000	mm
Hardening depth t_{300}	0.0000	0.0000	0.0000	0.0000	mm
Core hardness HV_{core}	342.0000		342.0000		HV
Hardness curve	ISO/TS 6336-4 Method C1		ISO/TS 6336-4 Method C1		

OK Cancel

Enter an increased hardening depth of 0.9 mm. The safety number increases from 0.932 to 1.123.

Change	Previous tooth flank fracture safety	New tooth flank fracture safety
	Gearset	Gearset
Increased the hardening depth from 0.66 to 0.9 mm	0.932	1.123