KISSsoft
Drivetrain Design Solutions

Exercise Cylindrical 99

Changes in ISO 6336 from 2006 to 2019 version

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Sharing Knowledge

1 Document information

1.1 Document change record

Revision	Date	Author	Comments
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1.2 Table of content

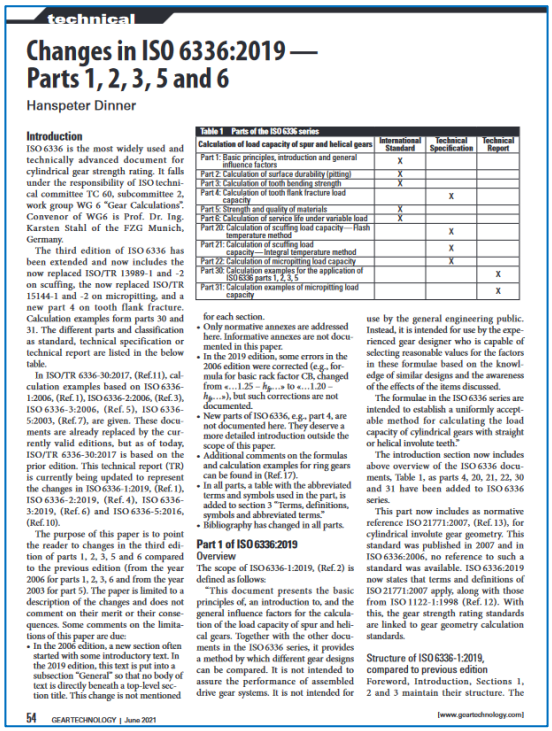
1.3 References

[1] KISSsoft software release 2021
[2] ISO 6336-1, 6336-2, 6336-3, 2006
[3] ISO 6336-1, 6336-2, 6336-3, 2019
[4] Paper comparing [2] and [3], www.kisssoft.com/en/products/publications/brochures/changes-in-iso-63362019-parts-1-2-3-5-and-6

2 Task description

2.1 Introduction

For pitting and bending rating, ISO 6336 series, in particular parts 1, 2, 3, 5 and 6 are commonly used. The revision of 2019 replaced the prior revision of 2006, bringing significant changes. Some of these changes and their effect are studied in this exercise:



technical

Changes in ISO 6336:2019 — Parts 1, 2, 3, 5 and 6

Hanspeter Dinner

Introduction

ISO 6336 is the most widely used and technically advanced document for cylindrical gear strength rating. It falls under the responsibility of ISO technical committee TC 60, subcommittee 2, work group WG 6 "Gear Calculations". Convenor of WG6 is Prof. Dr. Ing. Karsten Stahl of the FZG Munich, Germany.

The third edition of ISO 6336 has been extended and now includes the now replaced ISO/TR 13989-1 and -2 on scuffing, the now replaced ISO/TR 15144-1 and -2 on micropitting, and a new part 4 on tooth flank fracture. Calculation examples form parts 30 and 31. The different parts and classification as standard, technical specification or technical report are listed in the below table.

In ISO/TR 6336-30:2017, (Ref.11), calculation examples based on ISO 6336-1:2006, (Ref. 1), ISO 6336-2:2006, (Ref. 3), ISO 6336-3:2006, (Ref. 5), ISO 6336-5:2003, (Ref. 7), are given. These documents are already replaced by the currently valid editions, but as of today, ISO/TR 6336-30:2017 is based on the prior edition. This technical report (TR) is currently being updated to represent the changes in ISO 6336-1:2019, (Ref. 1), ISO 6336-2:2019, (Ref. 4), ISO 6336-3:2019, (Ref. 6) and ISO 6336-5:2016, (Ref. 10).

The purpose of this paper is to point the reader to changes in the third edition of parts 1, 2, 3, 5 and 6 compared to the previous edition (from the year 2006 for parts 1, 2, 3, 6 and from the year 2003 for part 5). The paper is limited to a description of the changes and does not comment on their merit or their consequences. Some comments on the limitations of this paper are due:

- In the 2006 edition, a new section often started with some introductory text. In the 2019 edition, this text is put into a subsection "General" so that no body of text is directly beneath a top-level section title. This change is not mentioned for each section.
- Only normative annexes are addressed here. Informative annexes are not documented in this paper.
- In the 2019 edition, some errors in the 2006 edition were corrected (e.g., formula for basic rack factor CB, changed from «…1.25 – h_{fP}…» to «…1.20 – h_{fP}…»), but such corrections are not documented.
- New parts of ISO 6336, e.g., part 4, are not documented here. They deserve a more detailed introduction outside the scope of this paper.
- Additional comments on the formulas and calculation examples for ring gears can be found in (Ref. 17).
- In all parts, a table with the abbreviated terms and symbols used in the part, is added to section 3 "Terms, definitions, symbols and abbreviated terms."
- Bibliography has changed in all parts.

Table 1 Parts of the ISO 6336 series

Calculation of load capacity of spur and helical gears	International Standard	Technical Specification	Technical Report
Part 1: Basic principles, introduction and general influence factors	X		
Part 2: Calculation of surface durability (pitting)	X		
Part 3: Calculation of tooth bending strength	X		
Part 4: Calculation of tooth flank fracture load capacity		X	
Part 5: Strength and quality of materials	X		
Part 6: Calculation of service life under variable load	X		
Part 20: Calculation of scuffing load capacity—Flash temperature method		X	
Part 21: Calculation of scuffing load capacity—Integral temperature method		X	
Part 22: Calculation of micropitting load capacity		X	
Part 30: Calculation examples for the application of ISO 6336 parts 1, 2, 3, 5			X
Part 31: Calculation examples of micropitting load capacity			X

Part 1 of ISO 6336:2019

Overview

The scope of ISO 6336-1:2019, (Ref. 2) is defined as follows:

"This document presents the basic principles of, an introduction to, and the general influence factors for the calculation of the load capacity of spur and helical gears. Together with the other documents in the ISO 6336 series, it provides a method by which different gear designs can be compared. It is not intended to assure the performance of assembled drive gear systems. It is not intended for use by the general engineering public. Instead, it is intended for use by the experienced gear designer who is capable of selecting reasonable values for the factors in these formulae based on the knowledge of similar designs and the awareness of the effects of the items discussed.

The formulae in the ISO 6336 series are intended to establish a uniformly acceptable method for calculating the load capacity of cylindrical gears with straight or helical involute teeth."

The introduction section now includes above overview of the ISO 6336 documents, Table 1, as parts 4, 20, 21, 22, 30 and 31 have been added to ISO 6336 series.

This part now includes as normative reference ISO 21771:2007, (Ref. 13), for cylindrical involute gear geometry. This standard was published in 2007 and in ISO 6336:2006, no reference to such a standard was available. ISO 6336:2019 now states that terms and definitions of ISO 21771:2007 apply, along with those from ISO 1122-1:1998 (Ref. 12). With this, the gear strength rating standards are linked to gear geometry calculation standards.

Structure of ISO 6336-1:2019, compared to previous edition

Foreword, Introduction, Sections 1, 2 and 3 maintain their structure. The

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Figure 2.1-1 Paper describing the changes in detail, **Fehler! Verweisquelle konnte nicht gefunden werden.**

2.2 Given data

Complete the following task. Start with the example file shown below, pay attention not to overwrite / save the original example file. In all tasks, we look at the pitting safety factors SH1 (for the sun), SH2 (for the planet) and SH3 for the ring gear as well as at the bending safety factors SF1 (for the sun), SF2 (for the planet) and SF3 (for the ring ear).

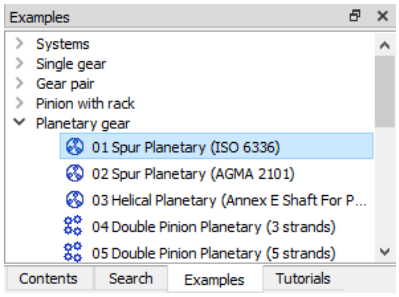

Figure 2.2-1 Example file to start with for all tasks.

Change the following parameters in tab “Basic data”:
Set the face width to 15mm for sun, planet and ring gear:

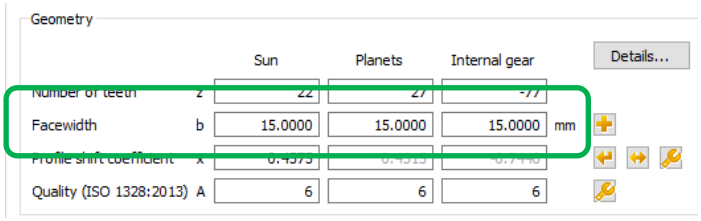

Figure 2.2-2 Change the face width to 15mm for all gears

In the tab “Strength”, change the power and switch off all calculations except for pitting and bending:

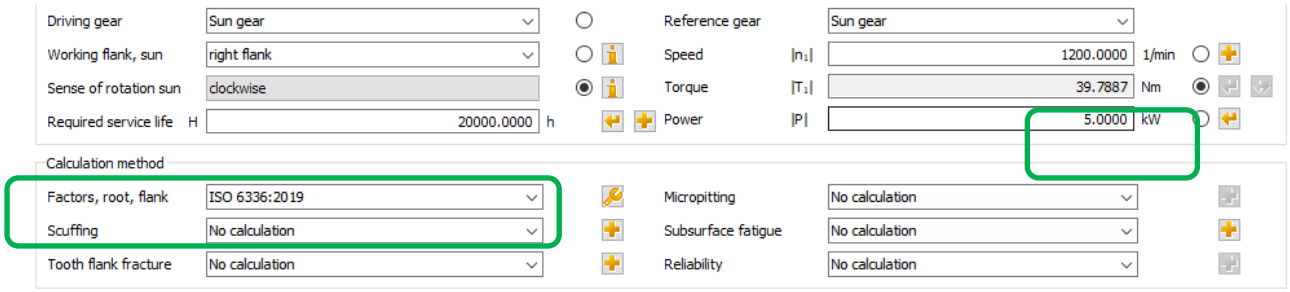

Figure 2.2-3 Change the power to 5.00 kW and activate only pitting and bending rating

In tab “Factors”, set all K factors to unity, except for the mean stress influence factor of the planet at 0.70:

Figure 2.2-4 Setting all K factors to = 1.00

Run the calculation and accept below proposal by pressing “Yes”:

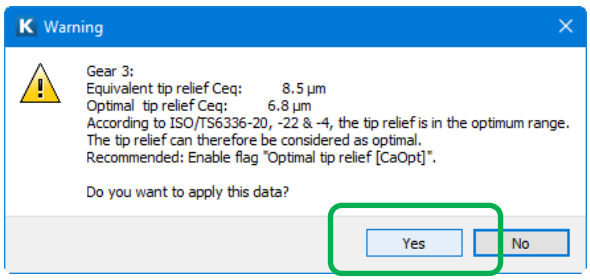

Figure 2.2-5 Accept the proposal by pressing “Yes”.

Save the file, see file “Exercise-Cyindrical-99-ISO_6336_bending_pitting_changes_start-en-v2100-hd-public.z14”.

2.3 Tasks

Task 1: Save a copy of the file “Exercise-Cyindrical-99-ISO_6336_bending_pitting_changes_start-en-v2100-hd-public.z14” as “Exercise-Cyindrical-99-ISO_6336_bending_pitting_changes_task_1-en-v2100-hd-public.z14”. Run pitting and bending strength calculation using ISO 6336:2006 and ISO 6336:2019. Compare the results.

Task 2: Save a copy of the file “Exercise-Cyindrical-99-ISO_6336_bending_pitting_changes_start-en-v2100-hd-public.z14” as “Exercise-Cyindrical-99-ISO_6336_bending_pitting_changes_task_2-en-v2100-hd-public.z14”. Change the helix angle to such that εβ=1.00 results. Adjust the center distance accordingly and compare the two calculation methods.

Task 3: Save a copy of the file “Exercise-Cyindrical-99-ISO_6336_bending_pitting_changes_start-en-v2100-hd-public.z14” as “Exercise-Cyindrical-99-ISO_6336_bending_pitting_changes_task_3-en-v2100-hd-public.z14”. Consider two tooth thickness tolerances, once as in the original file and once as zero. Compare the ratings for root strength only.

Task 4: Save a copy of the file “Exercise-Cyindrical-99-ISO_6336_bending_pitting_changes_start-en-v2100-hd-public.z14” as “Exercise-Cyindrical-99-ISO_6336_bending_pitting_changes_task_4-en-v2100-hd-public.z14”. Change the tooth height such that a transverse contact ratio of εα=2.05 results. Compare the ratings for the original contact ratio (based on file …_start-…) and the high contact ratio (based on file …_task_4-…). Use a reduced pressure angle of α = 15° and ρfP* = 0.10 for sun and planet for all calculations.

3 Task 1

3.1 Calculation with ISO 6336:2006

In the file, the calculation method along ISO 6336:2019 is selected. Change it to ISO 6336: 2006 as shown below. Run the calculation to find the pitting and bending safety factors for z1 (sun), z2 (planets), z3 (ring gear):

Figure 3.1-1 Calculation method selected as ISO 6336:2019.

Run the calculation by pressing F5 command on the keyboard to find:

Results (basic calculation)

Contact ratios, Sun - Planets	$[\varepsilon_{\alpha m}/\varepsilon_{\beta}/\varepsilon_{\gamma m}]$	1.354 / 0.000 / 1.354		
Contact ratios, Planets - Internal gear	$[\varepsilon_{\alpha m}/\varepsilon_{\beta}/\varepsilon_{\gamma m}]$	1.586 / 0.000 / 1.586		
		Sun	**Planets**	**Internal gear**
Actual tip circle (mm)		24.737	29.685	76.489
Root safety		2.788	1.994	1.906
Flank safety		1.130	1.215	0.943

3.2 Calculation with ISO 6336:2019

Change the calculation method to ISO 6336:2019 and re-run the calculation:

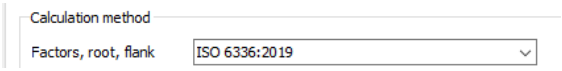

Figure 3.2-1 Change calculation method to ISO 6336:2006.

You will find the results:

Results (basic calculation)				
Contact ratios, Sun - Planets	[$\varepsilon_{\alpha m}/\varepsilon_{\beta}/\varepsilon_{\gamma m}$]	1.354 / 0.000 / 1.354		
Contact ratios, Planets - Internal gear	[$\varepsilon_{\alpha m}/\varepsilon_{\beta}/\varepsilon_{\gamma m}$]	1.586 / 0.000 / 1.586		
		Sun	**Planets**	**Internal gear**
Actual tip circle (mm)		24.737	29.685	76.489
Root safety		2.788	1.994	1.906
Flank safety		1.130	1.215	0.943

Figure 3.2-2 Change calculation method to ISO 6336:2006.

3.3 Findings

For spur gear of typical transverse contact ratio around 1.50, the changes are visible on the root but not on the flank rating. Note that in Task 3, an influence on the flank rating is visible in case that helical gears are used.

4 Task 2

4.1 Set up

Use the conversion button for the helix angle and select that the overlap contact ratio should be εβ=1.00. This will give the required helix angle:

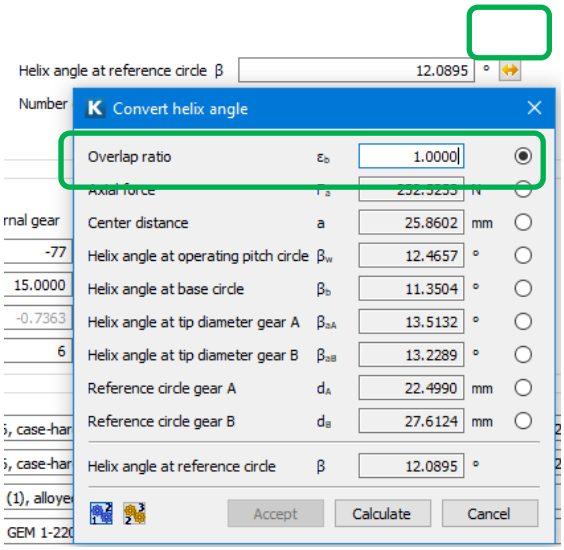

Figure 4.1-1 Change calculation method to ISO 6336:2006.

Use the sizing function to determine the new center distance such that the profile shifts do not change:

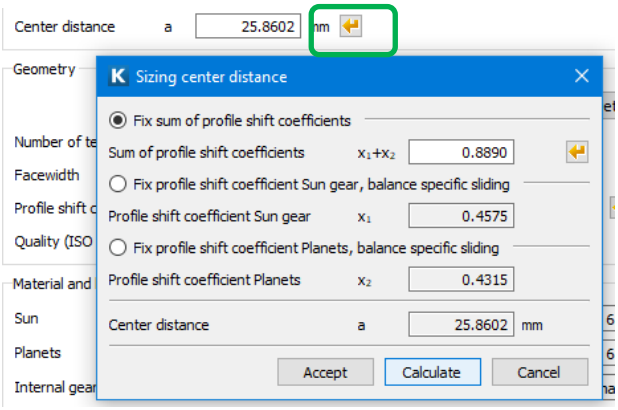

Figure 4.1-2 Re-calculate center distance, it increases from 25.3000 mm to 25.3038 mm.

4.2 Calculation with ISO 6336:2006

Select ISO 6336:2006 as calculation method and run the calculation to find:

Results (basic calculation)				
Contact ratios, Sun - Planets	$[\varepsilon_{\alpha m}/\varepsilon_{\beta}/\varepsilon_{\gamma m}]$	1.323 / 1.000 / 2.323		
Contact ratios, Planets - Internal gear	$[\varepsilon_{\alpha m}/\varepsilon_{\beta}/\varepsilon_{\gamma m}]$	1.541 / 1.000 / 2.541		
		Sun	**Planets**	**Internal gear**
Actual tip circle (mm)		25.244	30.305	78.219
Root safety		3.297	2.351	2.777
Flank safety		1.294	1.347	1.084

Note that the factor fZCa as shown in next section does not exist in ISO 6336:2006, hence, there is no influence from it and only one set of result is available.

4.3 Calculation with ISO 6336:2019

Select ISO 6336:2019 as calculation method and run the calculation to find:

Results (basic calculation)				
Contact ratios, Sun - Planets	$[\varepsilon_{\alpha m}/\varepsilon_{\beta}/\varepsilon_{\gamma m}]$	1.323 / 1.000 / 2.323		
Contact ratios, Planets - Internal gear	$[\varepsilon_{\alpha m}/\varepsilon_{\beta}/\varepsilon_{\gamma m}]$	1.541 / 1.000 / 2.541		
		Sun	**Planets**	**Internal gear**
Actual tip circle (mm)		25.244	30.305	78.219
Root safety		3.530	2.521	2.556
Flank safety		1.181	1.230	1.084

Now, go to tab “Strength”, to the settings for ISO 6336:20019 rating and change fCZa from fCZa = 1.20 to fCZa = 1.00. Repeat the calculation to find:

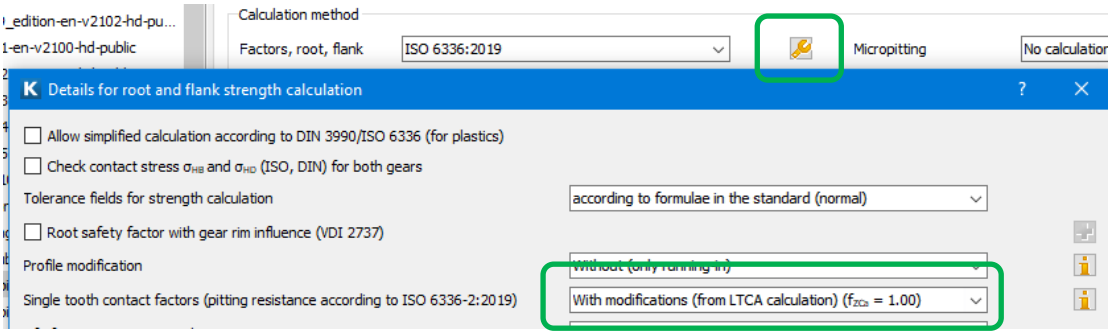

Figure 4.3-1 Change setting for calculation of zone factors, by changing fCZa from fCZa = 1.20 (if no modifications are present for helical gears) to fCZa = 1.00 (applicable if LTCA is used to optimize flank modifications in lead and profile direction).

Now, the calculation results are again the same as if ISO 6336:2006 was used:

Results (basic calculation)				
Contact ratios, Sun - Planets	[$\varepsilon_{\alpha m}/\varepsilon_{\beta}/\varepsilon_{\gamma m}$]	1.323 / 1.000 / 2.323		
Contact ratios, Planets - Internal gear	[$\varepsilon_{\alpha m}/\varepsilon_{\beta}/\varepsilon_{\gamma m}$]	1.541 / 1.000 / 2.541		
		Sun	**Planets**	**Internal gear**
Actual tip circle (mm)		25.244	30.305	78.219
Root safety		3.530	2.521	2.556
Flank safety		1.294	1.347	1.084

4.4 Findings

When having helical gears, in particular if overlap contact ratio is 1.00 or higher, a new factor fCZa influences the flank rating but not the root rating, only when using ISO 6336:2019. The value of the factor is determined by three options, these are

- No gear modifications are applied
- Gear modifications are suitably applied, based on experience
- Gear modifications are suitably applied, based on loaded tooth contact analysis LTCA

Note that by default, KISSsoft uses a conservative approach which may result in quite different flank rating values between ISO 6336:2006 and ISO 6336:2019 ratings.

5 Task 3

5.1 Calculation with ISO 6336:2006

Run the calculation with the tooth thickness tolerances as present in the original file to find:

Results (basic calculation)				
Contact ratios, Sun - Planets	[$\varepsilon_{\alpha m}/\varepsilon_{\beta}/\varepsilon_{\gamma m}$]	1.354 / 0.000 / 1.354		
Contact ratios, Planets - Internal gear	[$\varepsilon_{\alpha m}/\varepsilon_{\beta}/\varepsilon_{\gamma m}$]	1.586 / 0.000 / 1.586		
		Sun	**Planets**	**Internal gear**
Actual tip circle (mm)		24.737	29.685	76.489
Root safety		2.860	2.042	2.457

Now, set the tooth thickness tolerances for the sun, the planet(s) and the ring gear to zero (backlash-free condition):

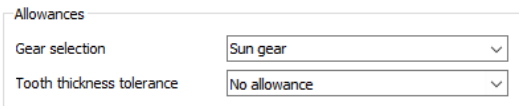

Figure 5.1-1 Set tooth thickness tolerance to zero, for all gears (sun, planet(s), ring gear).

Re-run the calculation to find:

Results (basic calculation)				
Contact ratios, Sun - Planets	$[\varepsilon_{\alpha m}/\varepsilon_{\beta}/\varepsilon_{\gamma m}]$	1.354 / 0.000 / 1.354		
Contact ratios, Planets - Internal gear	$[\varepsilon_{\alpha m}/\varepsilon_{\beta}/\varepsilon_{\gamma m}]$	1.586 / 0.000 / 1.586		
		Sun	**Planets**	**Internal gear**
Actual tip circle (mm)		24.737	29.685	76.489
Root safety		2.995	2.132	2.544

5.2 Calculation with ISO 6336:2019

Run the calculation with the tooth thickness tolerances as present in the original file to find:

Results (basic calculation)				
Contact ratios, Sun - Planets	$[\varepsilon_{\alpha m}/\varepsilon_{\beta}/\varepsilon_{\gamma m}]$	1.354 / 0.000 / 1.354		
Contact ratios, Planets - Internal gear	$[\varepsilon_{\alpha m}/\varepsilon_{\beta}/\varepsilon_{\gamma m}]$	1.586 / 0.000 / 1.586		
		Sun	**Planets**	**Internal gear**
Actual tip circle (mm)		24.737	29.685	76.489
Root safety		2.788	1.994	1.906

Now, set the tooth thickness tolerances for the sun, the planet(s) and the ring gear to zero (backlash-free condition):

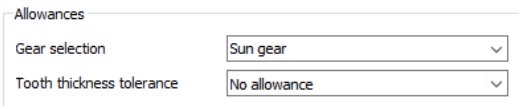

Figure 5.2-1 Set tooth thickness tolerance to zero, for all gears (sun, planet(s), ring gear).

Re-run the calculation to find:

Results (basic calculation)				
Contact ratios, Sun - Planets	$[\varepsilon_{\alpha m}/\varepsilon_{\beta}/\varepsilon_{\gamma m}]$	1.354 / 0.000 / 1.354		
Contact ratios, Planets - Internal gear	$[\varepsilon_{\alpha m}/\varepsilon_{\beta}/\varepsilon_{\gamma m}]$	1.586 / 0.000 / 1.586		
		Sun	**Planets**	**Internal gear**
Actual tip circle (mm)		24.737	29.685	76.489
Root safety		2.995	2.132	2.021

5.3 Findings

For external gears, if tooth thickness allowance is set to zero, the results are the same for ISO 6336:2006 and ISO 6336:2019. However, if tooth thickness allowances are not zero, the results are different. Note that for ISO 6336:2019, root strength is reduced as the lowest tooth thickness is considered (which is more conservative compared to ISO 6336:2006 approach).

For the ring gear, the results are different anyway as the root strength calculation for ring gears has changed considerably from ISO 6336:2006 to ISO 6336:2019.

6 Task 4

6.1 Calculation with ISO 6336:2006

Run the calculation with the original file "…_start-…", with the pressure angle changed to α = 15° and the original tooth height to find:

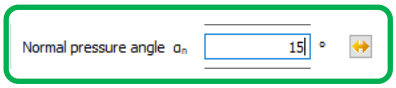

Figure 6.1-1 Change the pressure angle.

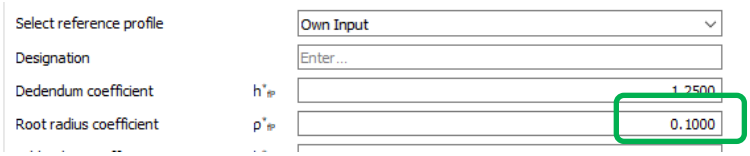

Figure 6.1-2 Change root rounding factor for sun, planet and ring gear to 0.10.

Results (basic calculation)				
Contact ratios, Sun - Planets	$[\varepsilon_{\alpha m}/\varepsilon_{\beta}/\varepsilon_{\gamma m}]$	1.428 / 0.000 / 1.428		
Contact ratios, Planets - Internal gear	$[\varepsilon_{\alpha m}/\varepsilon_{\beta}/\varepsilon_{\gamma m}]$	1.768 / 0.000 / 1.768		
		Sun	**Planets**	**Internal gear**
Actual tip circle (mm)		24.603	29.686	76.645
Root safety		2.044	1.453	2.201
Flank safety		1.061	1.149	0.879

Now, change the tooth height in the tab "Reference profile" by using the sizing function as shown below:

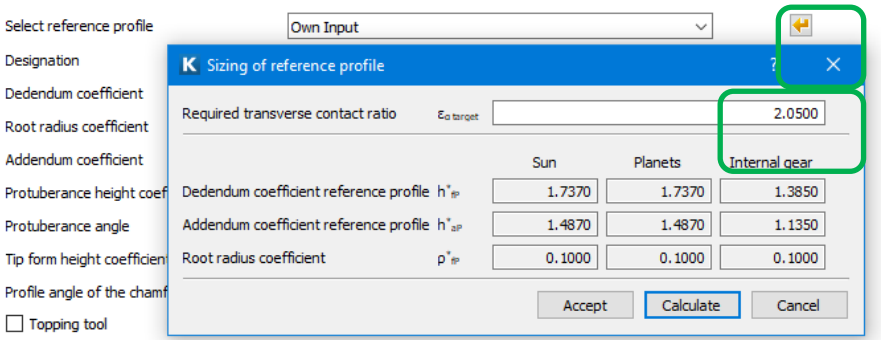

Figure 6.1-3 Sizing function for high contact ratio HCR gears, targeting transverse contact ratio of 2.05.

Enter the reference profile for the ring gear manually:

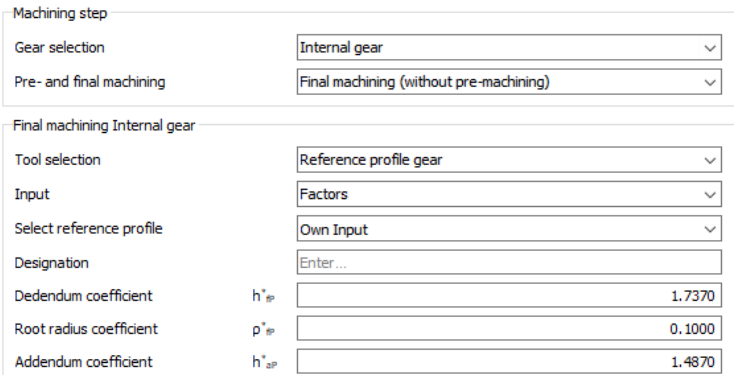

Figure 6.1-4 Input of reference profile for ring gear.

Repeat the calculation with the HCR gear to find:

Results (basic calculation)				
Contact ratios, Sun - Planets	$[\varepsilon_{\alpha m}/\varepsilon_{\beta}/\varepsilon_{\gamma m}]$	2.037 / 0.000 / 2.037		
Contact ratios, Planets - Internal gear	$[\varepsilon_{\alpha m}/\varepsilon_{\beta}/\varepsilon_{\gamma m}]$	2.438 / 0.000 / 2.438		
		Sun	**Planets**	**Internal gear**
Actual tip circle (mm)		25.577	30.660	75.671
Root safety		2.041	1.508	3.061
Flank safety		1.268	1.319	1.131

6.2 Calculation with ISO 6336:2019

Change the calculation method and calculate the gear set for the two conditions, as a low contact ratio gear LCR and as a high contact ratio gear HCR:

Results (basic calculation)				
Contact ratios, Sun - Planets	$[\varepsilon_{\alpha m}/\varepsilon_{\beta}/\varepsilon_{\gamma m}]$	1.428 / 0.000 / 1.428		
Contact ratios, Planets - Internal gear	$[\varepsilon_{\alpha m}/\varepsilon_{\beta}/\varepsilon_{\gamma m}]$	1.768 / 0.000 / 1.768		
		Sun	**Planets**	**Internal gear**
Actual tip circle (mm)		24.603	29.686	76.645
Root safety		2.002	1.431	1.590
Flank safety		1.061	1.149	0.879

Results (basic calculation)				
Contact ratios, Sun - Planets	$[\varepsilon_{\alpha m}/\varepsilon_{\beta}/\varepsilon_{\gamma m}]$	2.037 / 0.000 / 2.037		
Contact ratios, Planets - Internal gear	$[\varepsilon_{\alpha m}/\varepsilon_{\beta}/\varepsilon_{\gamma m}]$	2.438 / 0.000 / 2.438		
		Sun	**Planets**	**Internal gear**
Actual tip circle (mm)		25.577	30.660	75.671
Root safety		2.810	2.093	2.647
Flank safety		1.268	1.319	1.131

6.3 Findings

For ISO 6336:2006, the influence of a higher contact ratio on the root strength is small (for the external gears) while it is large for ISO 6336:2019. This means that the positive effect of a higher contact ratio is more strongly considered in ISO 6336:2019.