ISO 6336:2019
Changes and implications
Focus on root strength

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ISO

ICS › 21 › 21.200

ISO 6336-3:2019

Calculation of load capacity of spur and helical gears — Part 3: Calculatio of tooth bending strength

ABSTRACT

PREVIEW

This document specifies the fundamental formulae for use in tooth bending stress calculations for involute external or internal spur and helical gears with a rim thickness s_R › 0,5 h_t for external gears and s_R › 1,75 m_n for internal gears. In service, internal gears can experience failure modes other than tooth bending fatigue, i.e. fractures starting at the roo diameter and progressing radially outward. This document does not provide adequate safe against failure modes other than tooth bending fatigue. All load influences on the tooth roo stress are included in so far as they are the result of loads transmitted by the gears and in s far as they can be evaluated quantitatively.

This document includes procedures based on testing and theoretical studies such as those of Hirt[11], Strasser[14] and Brossmann[10]. The results are in good agreement with other

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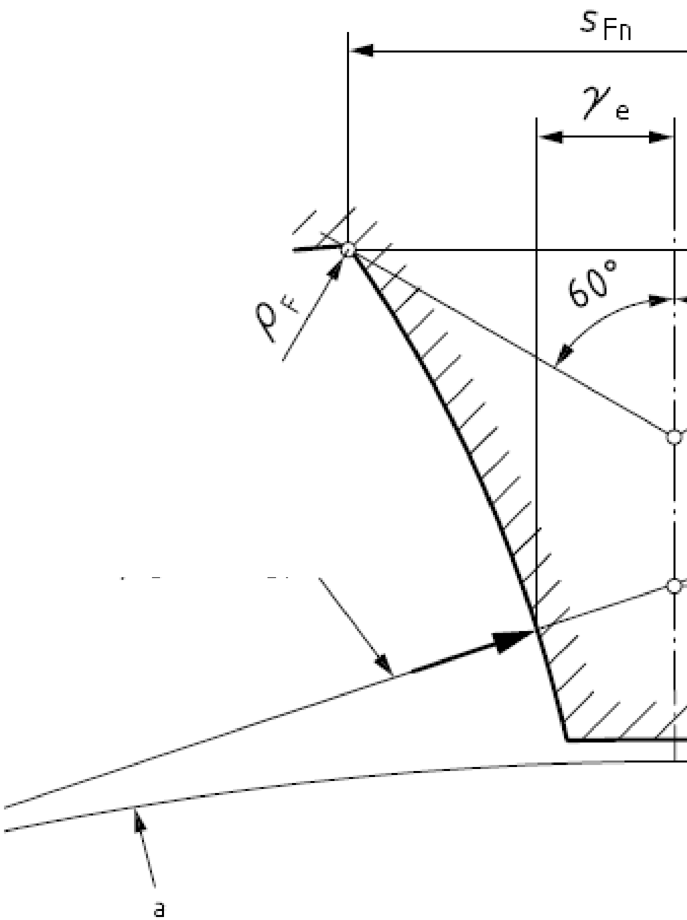
Presentation, sections



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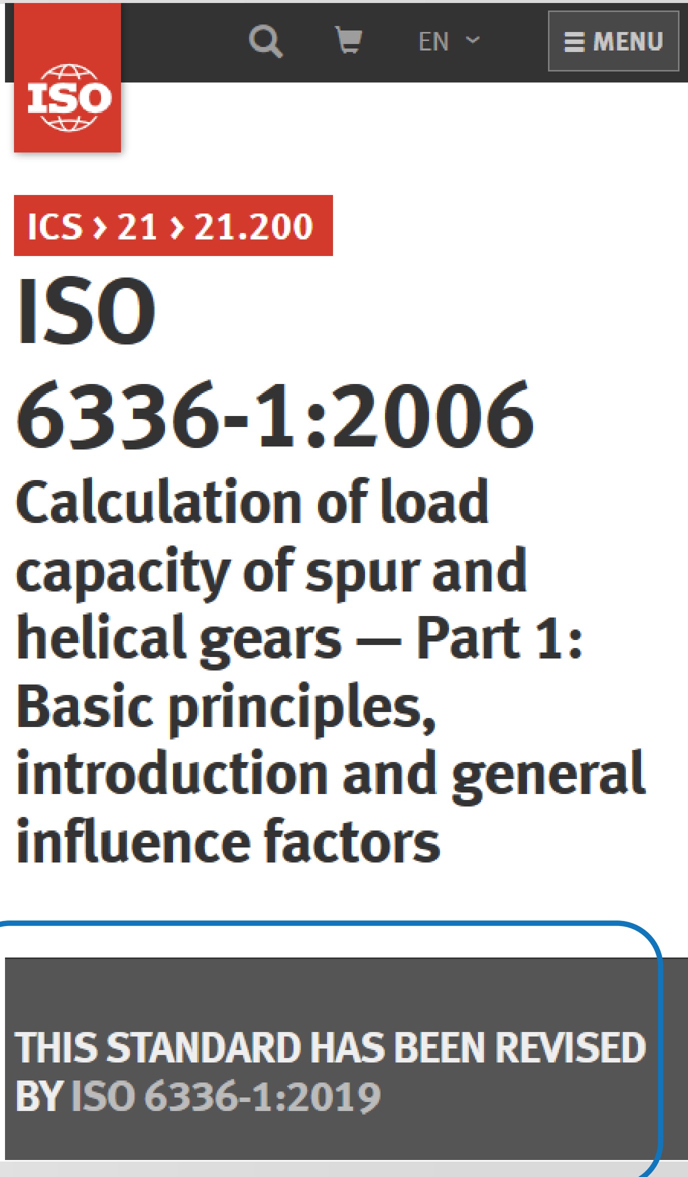
1. Current situation

ISO 6336:2019 is the only valid revision, other revisions are withdrawn

Previous versions of ISO 6336 are no longer valid. Refer to www.iso.org.

Contractual documents or certification guidelines that refer to ISO 6336 technically refer to the current revision (2019). Documents (calculation reports, contracts, specifications, certification guidelines, …) therefore need either to be specific (e.g. identifying the revision to be used) or updated.

It remains to be seen how the changes in the latest revision affect gear design procedures and customer requirements. It is recommended to gain experience with the 2019 revision of ISO 6336 by using both calculation methods (along revision 2006 and revision 2019) in parallel and to compare and assess the results.



ISO, ISO/TS, ISO/TR 6336 overview

ISO 6336 now consists of 5 parts, part 1, 2, 3, 5, 6

Parts 1, 2, 5, 6 are not changed with respect to resulting safety factors compared to previous version and are not discussed further here.

Note that part 4 is an ISO/TS

Parts 20, 21, 22 are also ISO/TS

Parts 30, 31 are ISO/TR

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 (also applicable to bevel and hypoid gears) — Flash temperature method (replaces: ISO/TR 13989-1)		X	
Part 21: Calculation of scuffing load capacity (also applicable to bevel and hypoid gears) — Integral temperature method (replaces: ISO/TR 13989-2)		X	
Part 22: Calculation of micropitting load capacity (replaces: ISO/TR 15144-1)		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 (replaces: ISO/TR 15144-2)			X

Comment on selected changes in Part 1

There is one change in ISO 6336-1:2019 that affects root strength rating too: Dynamic factor Kv is limited Kv≤2.00.

This has been implemented in KISSsoft for several years as a Kv value Kv≥2.00 does not make physical sense.

6.2.6 Application of internal dynamic factor for low loaded gears

Gears that are loaded with a line load of lower than $(F_t \cdot K_A . K_\gamma) / b = 100$ N/mm are typically defined as low loaded gears related to the internal dynamic factor. For gears that are loaded with a line load of lower than $(F_t \cdot K_A \cdot K_\gamma) / b = 50$ N/mm, a particular risk of vibration can exist dependant on gear accuracy and pitch line speeds.

Method B or C represents one model for the calculation of dynamic factor. This model is not valid for low loaded gears and values of $K_{v\text{-}B}$ or $K_{v\text{-}C} \geq 2$ might be calculated. When cases exist where $K_{v\text{-}B}$ or $K_{v\text{-}C} > 2$, the problem becomes significantly more complex as the possibility of tooth flank separation exists and the interaction with the entire dynamic system of stiffness and damping is highly influential.

If the gears are operated outside of their resonance condition and the calculated dynamic factor is $K_{v\text{-}B}$ or $K_{v\text{-}C} > 2$, the dynamic factor shall be set to $K_{v\text{-}B}$ or $K_{v\text{-}C} = 2$. This value shall be used for load capacity calculations according the ISO 6336 series, due to the described restrictions of the calculation model.

Comment on Part 2

A new auxiliary factor f_{ZCa} is introduced, influencing contact factors Z_B and Z_D as follows (see section 6.3).

This presentation focuses on root strength and in the examples below, f_{ZCa}=1.00 applies.

b) Helical gears with $\varepsilon_\alpha > 1$ and $\varepsilon_\beta \geq 1$:

$$Z_B = Z_D = \sqrt{f_{ZCa}} \tag{19}$$

with f_{ZCa} according to Table 3.

Table 3 — Factor f_{ZCa}

Helical gear sets with suitable profile and longitudinal modifications based on the 3D load distribution program, and with the maximum contact stress near mid-height and essentially uniform stress distribution	f_{ZCa} = 1,0
Helical gear sets with suitable flank modifications acc. to manufacturers experience	f_{ZCa} = 1,07
Helical gear sets without flank modifications	f_{ZCa} = 1,2

The factor f_{ZCa} is valid for the matched pinion and wheel. Consequently, the contact stresses at the beginning as well as at the end of the path of contact shall be considered.

c) Helical gears with $\varepsilon_\alpha > 1$ and $\varepsilon_\beta < 1$:

Z_B and Z_D are determined by linear interpolation between the values for spur and helical gearing with $\varepsilon_\beta \geq 1$:

$$\text{If } M_1 \leq 1 \text{ then } Z_B = 1 + \varepsilon_\beta \cdot \left(\sqrt{f_{ZCa}} - 1\right) \tag{20}$$

$$\text{If } M_1 > 1 \text{ then } Z_B = M_1 + \varepsilon_\beta \cdot \left(\sqrt{f_{ZCa}} - M_1\right) \tag{21}$$

$$\text{If } M_2 \leq 1 \text{ then } Z_D = 1 + \varepsilon_\beta \cdot \left(\sqrt{f_{ZCa}} - 1\right) \tag{22}$$

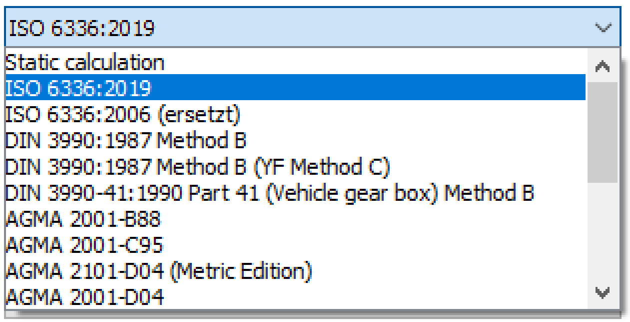
$$\text{If } M_2 > 1 \text{ then } Z_D = M_2 + \varepsilon_\beta \cdot \left(\sqrt{f_{ZCa}} - M_2\right) \tag{23}$$

If Z_B or Z_D are made equal to 1,0, the contact stresses calculated using Formula (4) or (5) are the values for the contact stress at the pitch cylinder.

2. Implementation in KISSsoft

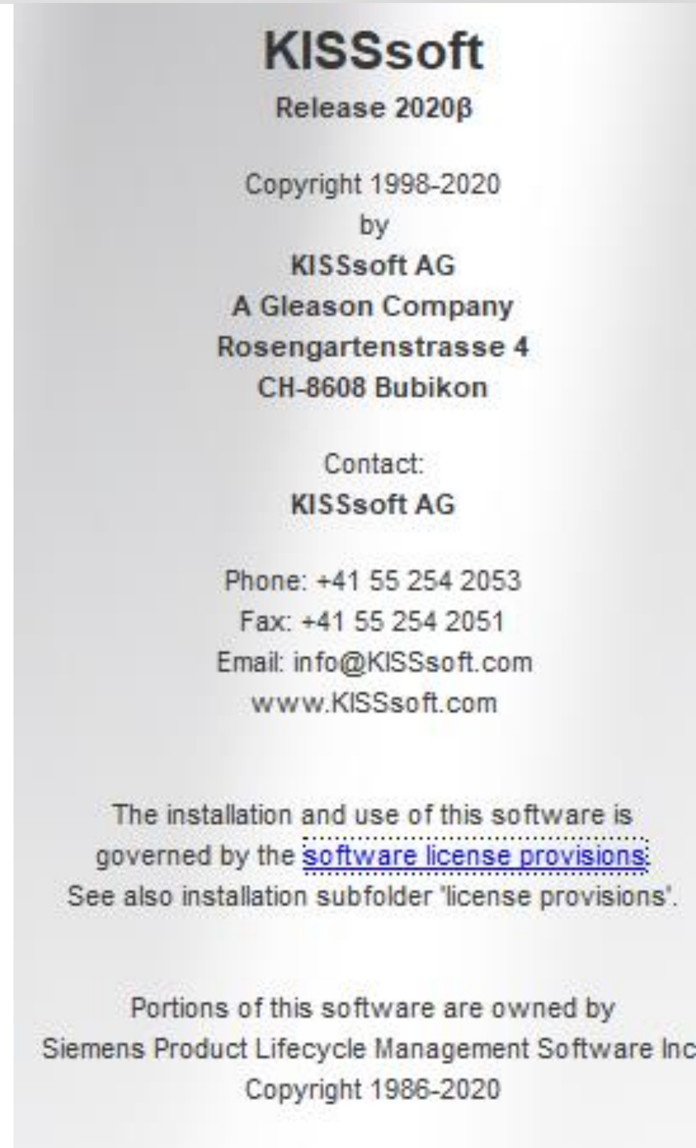
Software release 2020

Gear rating along ISO 6336:2019 for root and flank safety factors is implemented in KISSsoft for release 2020.



Also, scuffing rating, tooth flank fracture calculation and micropitting rating along the respective ISO 6336 or ISO/TS 6336 methods is included in KISSsoft.

All calculations documented here were performed with KISSsoft, Release 2020β



Basic formulae for root strength

Nominal tooth root stress

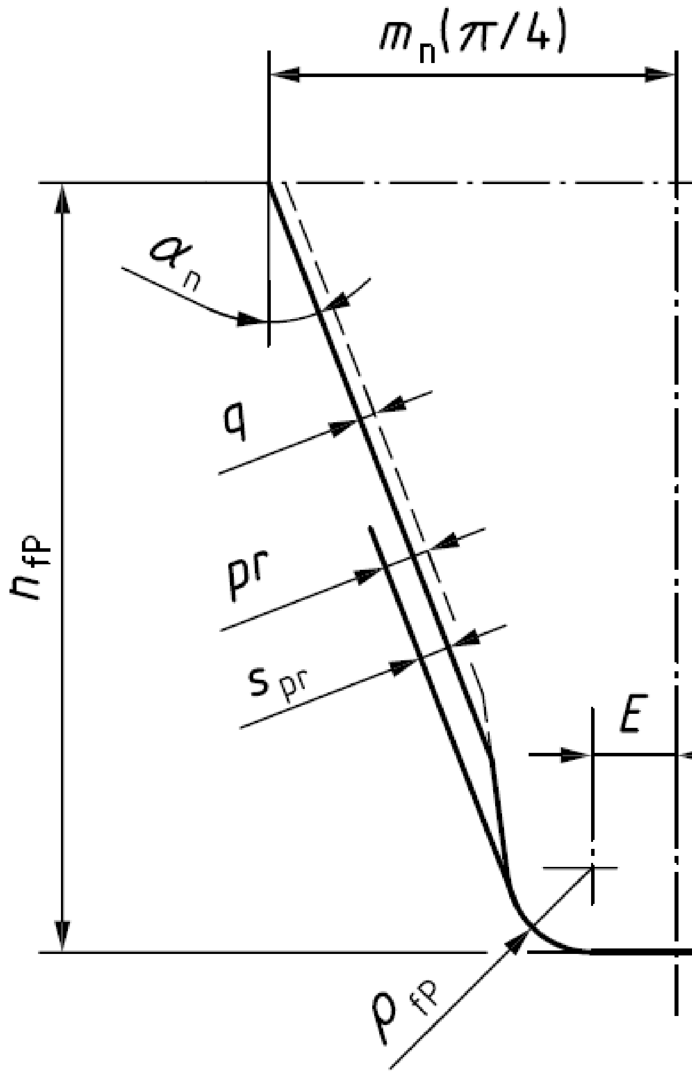
$$\sigma_{F0} = \frac{F_t}{b \cdot m_n} \cdot Y_F \cdot Y_S \cdot Y_\beta \cdot Y_B \cdot Y_{DT}$$

Tooth root stress

$$\sigma_F = \sigma_{F0} \cdot K_A \cdot K_\gamma \cdot K_v \cdot K_{F\beta} \cdot K_{F\alpha}$$

Permissible bending stress

$$\sigma_{FP} = \frac{\sigma_{F\,lim} \cdot Y_{ST} \cdot Y_{NT}}{S_{F\,min}} \cdot Y_{\delta\,rel\,T} \cdot Y_{R\,rel\,T} \cdot Y_X$$



The new revision ISO 6336:2019 replaces the previous revision ISO 6336:2006.
Changes are mainly affecting the root safety factor SF for external and internal gears.

Tooth form factor Y_F (see sections 4 and 5 below)

1) Influence of tooth form, cross sectional property of tooth. New factor f_ε considers the influence of load distribution between the teeth in mesh. → Affects the calculated root stresses.
2) For internal gears always **the shaper cutter data** is used. → Affects the calculated root stresses.
3) Manufacturing profile shift xE_i is used instead of x to calculate tooth thickness s_{Fn} (influencing YF and YS). → Affects the calculated root stresses.

Helix angle factor Y_β (see section 6 below)

Considers reduced stress due to oblique contact line, as function of helix angle at reference circle β and overlap ratio ε_β. → Affects the calculated root stresses.

Relative notch sensitivity factor $Y_{\delta relT}$ for static stress (see section 7 below)

Influence of the notch sensitivity relative to test gear. → Affects the permissible static stress number for bending.

4. Tooth form factor Y_F

Calculation of YF for different tooth thicknesses

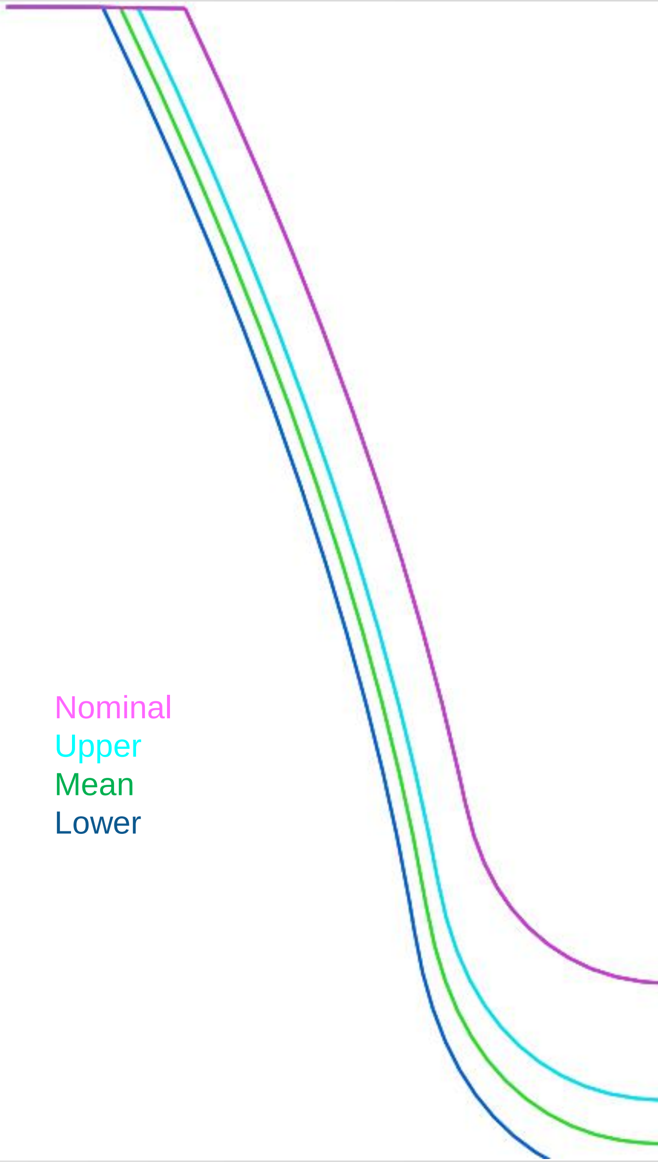
ISO 6336: 2006

YF is calculated from the nominal tooth form with the **theoretical profile shift coefficient x**.

If the tooth thickness deviation near the root results in a thickness reduction of more than 0.05*mn, this shall be taken into account, by taking the generated profile, x_E, relative to rack shift amount mn instead of the nominal profile.

ISO 6336: 2019

The tooth form factor is sensitive to the tooth thickness. When the manufactured geometry is measured, it should be used. If not, then, based on the tooth thickness tolerance, the **smallest generating profile shift, $x_{E\ min}$**, should be used to determine YF and YS.



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4. Tooth form factor Y_F

ISO 6336:2006

The following equation uses the symbols illustrated in Figures 3 and 4:

$$Y_F = \frac{\frac{6\, h_{Fe}}{m_n} \cos \alpha_{Fen}}{\left(\frac{s_{Fn}}{m_n}\right)^2 \cos \alpha_n} \quad (9)$$

In order to evaluate precise values, s_{Fn} and α_{Fen}, of h_{Fe} it is first necessary to derive a value of θ which is reasonably accurate, usually after five iterations of Equation (14). Determination of Y_F by graphical means is not recommended.

6.2.1 Tooth root normal chord, s_{Fn}, radius of root fillet, ρ_F, bending moment arm, h_{Fe} [4)]

First, determine the auxiliary values for Equation (9):

$$E = \frac{\pi}{4} m_n - h_{fP} \tan \alpha_n + \frac{s_{pr}}{\cos \alpha_n} - (1 - \sin \alpha_n) \frac{\rho_{fP}}{\cos \alpha_n} \quad (10)$$

ISO 6336:2019

$$Y_F = \frac{\frac{6 \cdot h_{Fe}}{m_n} \cdot \cos \alpha_{Fen}}{\left(\frac{s_{Fn}}{m_n}\right)^2 \cdot \cos \alpha_n} \cdot f_\varepsilon \quad (9)$$

In order to evaluate precise values, s_{Fn} and α_{Fen}, of h_{Fe} it is first necessary to derive a value of θ which is reasonably accurate, usually after five iterations of Formula (29). Determination of Y_F by graphical means is not recommended.

The factor f_ε considers the influence of load distribution between the teeth in the mesh. It provides more accurate results for gears with contact ratios $\varepsilon_{\alpha n} \geq 2{,}0$. Contact ratios of $\varepsilon_{\alpha n} \geq 2{,}0$ are calculated for gears with high helix angles, high contact ratios, ε_α, or both.

For spur gears with contact ratios $\varepsilon_{\alpha n} \leq 2{,}0$ the factor f_ε is equal to one according Formula (10). For helical gears with overlap ratio $\varepsilon_\beta \geq 1$ the factor is calculated according to Formula (14). Formulae (12) and (13) provide a smooth function for f_ε between Formulae (10) and (14).

If $\varepsilon_\beta = 0$ and $\varepsilon_{\alpha n} < 2$ then

$$f_\varepsilon = 1 \quad (10)$$

If $\varepsilon_\beta = 0$ and $\varepsilon_{\alpha n} \geq 2$ then

$$f_\varepsilon = 0{,}7 \quad (11)$$

If $0 < \varepsilon_\beta < 1$ and $\varepsilon_{\alpha n} < 2$ then

$$f_\varepsilon = \left(1 - \varepsilon_\beta + \frac{\varepsilon_\beta}{\varepsilon_{\alpha n}}\right)^{0{,}5} \quad (12)$$

$$\varepsilon_{\alpha n} = \frac{\varepsilon_\alpha}{(\cos \beta_b)^2}$$

If $0 < \varepsilon_\beta < 1$ and $\varepsilon_{\alpha n} \geq 2$ then

$$f_\varepsilon = \left(\frac{1 - \varepsilon_\beta}{2} + \frac{\varepsilon_\beta}{\varepsilon_{\alpha n}}\right)^{0{,}5} \quad (13)$$

If $\varepsilon_\beta \geq 1$ then

$$f_\varepsilon = \varepsilon_{\alpha n}^{-0{,}5} \quad (14)$$

4. Tooth form factor Y_F

Introduction of factor fε

ISO 6336: 2006

No such factor.

ISO 6336: 2019

The factor f_ε considers the influence of load distribution between the teeth in the mesh. It provides more accurate results for gears with contact ratios $\varepsilon_{\alpha n} \geq 2{,}0$. Contact ratios of $\varepsilon_{\alpha n} \geq 2{,}0$ are calculated for gears with high helix angles, high contact ratios, ε_α, or both. Note:

$$\varepsilon_{\alpha n} = \frac{\varepsilon_\alpha}{(\cos\beta_b)^2}$$

For spur gears with contact ratios $\varepsilon_{\alpha n} \leq 2{,}0$ the factor f_ε is equal to one according Formula (10). For helical gears with overlap ratio $\varepsilon_\beta \geq 1$ the factor is calculated according to Formula (14). Formulae (12) and (13) provide a smooth function for f_ε between Formulae (10) and (14).

If $\varepsilon_\beta = 0$ and $\varepsilon_{\alpha n} < 2$ then

$$f_\varepsilon = 1$$

If $\varepsilon_\beta = 0$ and $\varepsilon_{\alpha n} \geq 2$ then

$$f_\varepsilon = 0{,}7$$

If $0 < \varepsilon_\beta < 1$ and $\varepsilon_{\alpha n} < 2$ then

$$f_\varepsilon = \left(1 - \varepsilon_\beta + \frac{\varepsilon_\beta}{\varepsilon_{\alpha n}}\right)^{0{,}5}$$

If $0 < \varepsilon_\beta < 1$ and $\varepsilon_{\alpha n} \geq 2$ then

$$f_\varepsilon = \left(\frac{1 - \varepsilon_\beta}{2} + \frac{\varepsilon_\beta}{\varepsilon_{\alpha n}}\right)^{0{,}5}$$

If $\varepsilon_\beta \geq 1$ then

$$f_\varepsilon = \varepsilon_{\alpha n}^{-0{,}5}$$

Values for factor fε

	fε	virtual contact ratio of the virtual spur gear, εαn												
		1	1.1	1.2	1.3	1.4	1.5	1.6	1.7	1.8	1.9	2	2.1	2.2
Overlap ratio, εβ	0	1.0000	1.0000	1.0000	1.0000	1.0000	1.0000	1.0000	1.0000	1.0000	1.0000	0.7000	0.7000	0.7000
	0.1	1.0000	0.9954	0.9916	0.9884	0.9856	0.9832	0.9811	0.9792	0.9775	0.9760	0.7071	0.7054	0.7039
	0.2	1.0000	0.9909	0.9832	0.9767	0.9710	0.9661	0.9618	0.9579	0.9545	0.9515	0.7071	0.7037	0.7006
	0.3	1.0000	0.9863	0.9747	0.9648	0.9562	0.9487	0.9421	0.9362	0.9309	0.9262	0.7071	0.7020	0.6974
	0.4	1.0000	0.9816	0.9661	0.9527	0.9411	0.9309	0.9220	0.9139	0.9068	0.9003	0.7071	0.7003	0.6941
	0.5	1.0000	0.9770	0.9574	0.9405	0.9258	0.9129	0.9014	0.8911	0.8819	0.8736	0.7071	0.6986	0.6908
	0.6	1.0000	0.9723	0.9487	0.9282	0.9103	0.8944	0.8803	0.8677	0.8563	0.8460	0.7071	0.6969	0.6876
	0.7	1.0000	0.9677	0.9399	0.9157	0.8944	0.8756	0.8588	0.8437	0.8300	0.8176	0.7071	0.6952	0.6842
	0.8	1.0000	0.9630	0.9309	0.9030	0.8783	0.8563	0.8367	0.8189	0.8028	0.7881	0.7071	0.6935	0.6809
	0.9	1.0000	0.9582	0.9220	0.8901	0.8619	0.8367	0.8139	0.7934	0.7746	0.7574	0.7071	0.6918	0.6776
	1	1.0000	0.9535	0.9129	0.8771	0.8452	0.8165	0.7906	0.7670	0.7454	0.7255	0.7071	0.6901	0.6742
	1.1	1.0000	0.9535	0.9129	0.8771	0.8452	0.8165	0.7906	0.7670	0.7454	0.7255	0.7071	0.6901	0.6742
	1.2	1.0000	0.9535	0.9129	0.8771	0.8452	0.8165	0.7906	0.7670	0.7454	0.7255	0.7071	0.6901	0.6742
	1.3	1.0000	0.9535	0.9129	0.8771	0.8452	0.8165	0.7906	0.7670	0.7454	0.7255	0.7071	0.6901	0.6742
	1.4	1.0000	0.9535	0.9129	0.8771	0.8452	0.8165	0.7906	0.7670	0.7454	0.7255	0.7071	0.6901	0.6742
	1.5	1.0000	0.9535	0.9129	0.8771	0.8452	0.8165	0.7906	0.7670	0.7454	0.7255	0.7071	0.6901	0.6742
	1.6	1.0000	0.9535	0.9129	0.8771	0.8452	0.8165	0.7906	0.7670	0.7454	0.7255	0.7071	0.6901	0.6742
	1.7	1.0000	0.9535	0.9129	0.8771	0.8452	0.8165	0.7906	0.7670	0.7454	0.7255	0.7071	0.6901	0.6742
	1.8	1.0000	0.9535	0.9129	0.8771	0.8452	0.8165	0.7906	0.7670	0.7454	0.7255	0.7071	0.6901	0.6742
	1.9	1.0000	0.9535	0.9129	0.8771	0.8452	0.8165	0.7906	0.7670	0.7454	0.7255	0.7071	0.6901	0.6742
	2	1.0000	0.9535	0.9129	0.8771	0.8452	0.8165	0.7906	0.7670	0.7454	0.7255	0.7071	0.6901	0.6742
	2.1	1.0000	0.9535	0.9129	0.8771	0.8452	0.8165	0.7906	0.7670	0.7454	0.7255	0.7071	0.6901	0.6742

4. Tooth form factor Y_F, influence thereof, example

Example 1, spur gear

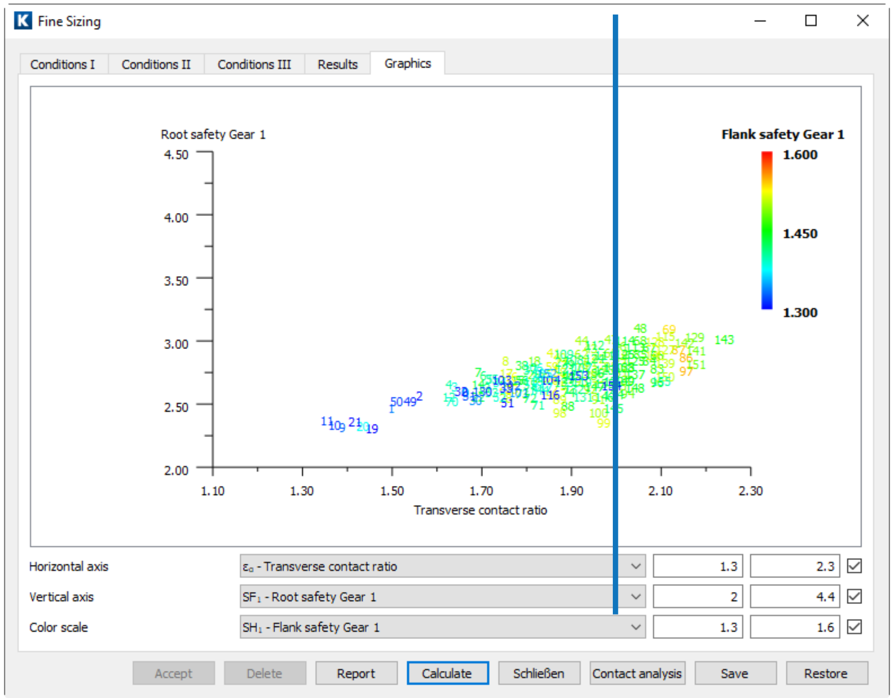
$h^*_{aP} = [1.0\,; 1.1, \ldots, 1.8]$ $h^*_{fP} = h^*_{aP} + 0.25$ $\rho^*_{fP} = 0.25$, addendum is varied

$\beta = 0°$

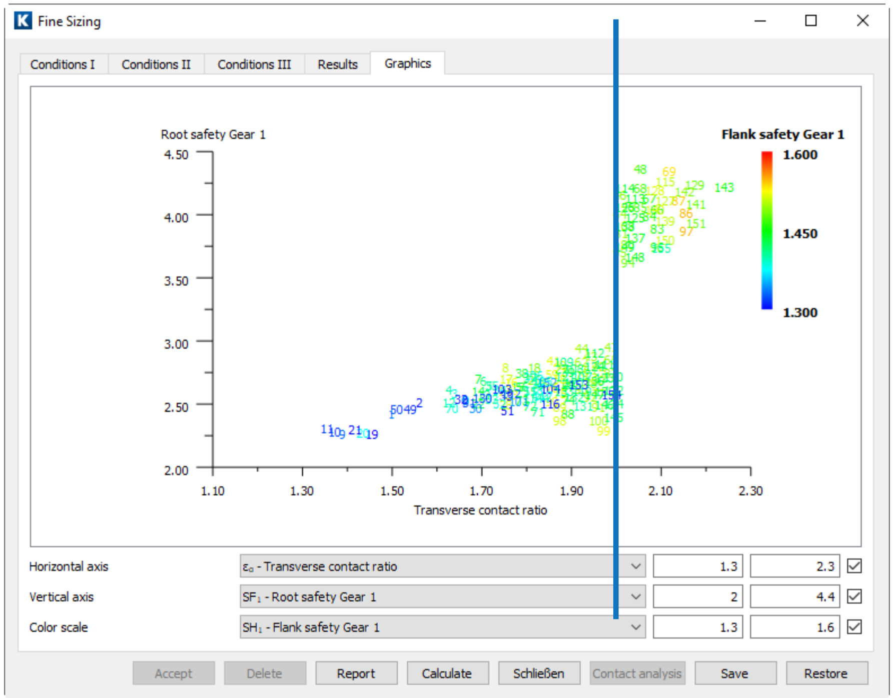
$a = 303\ mm$

$m_n = 6\ mm$

ISO 6336: 2006



ISO 6336: 2019



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4. Tooth form factor Y_F, influence thereof, example

Example 2, moderate helix angle

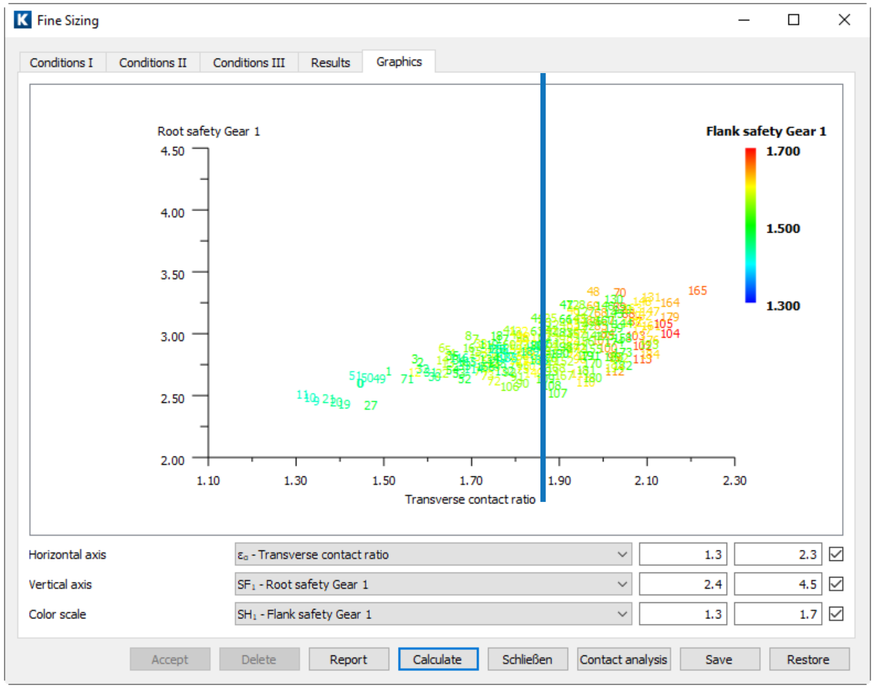
$h^*_{aP} = [1.0\,;1.1, \ldots, 1.8]$ $h^*_{fP} = h^*_{aP} + 0.25$ $\rho^*_{fP} = 0.25$, addendum is varied

$\beta = 15°$ ($\varepsilon_\beta = 0.75$) $Y_\beta = 1.026$ $\varepsilon_{\alpha n} / \varepsilon_\alpha = 0.94$

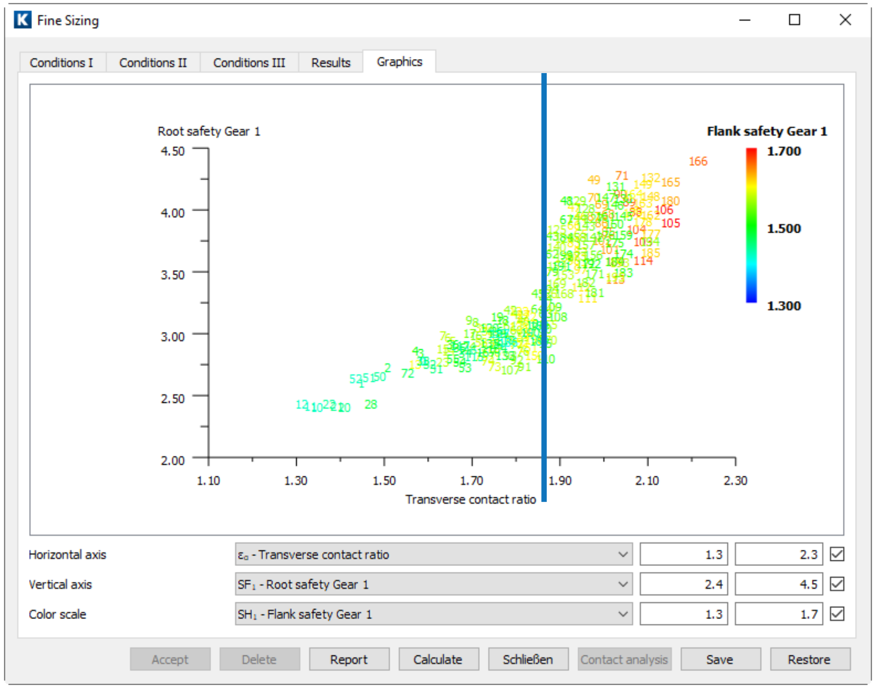
$a = 303\ mm$

$m_n = 5.8\ mm$

ISO 6336: 2006



ISO 6336: 2019



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Example 3, high helix angle

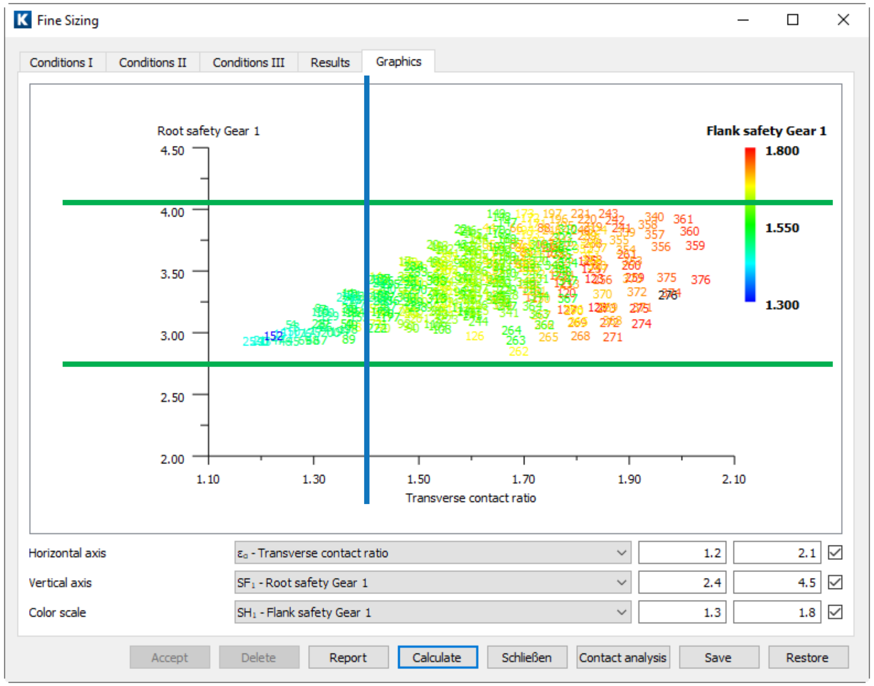
$h^*_{aP} = [1.0\,;1.1, \ldots, 1.8] \quad h^*_{fP} = h^*_{aP} + 0.25 \quad \rho^*_{fP} = 0.25$, addendum is varied

$\beta = 35°$ $(\varepsilon_\beta = 1.6)$ $Y_\beta = 1.155$ $\varepsilon_{\alpha n} / \varepsilon_\alpha = 0.71$

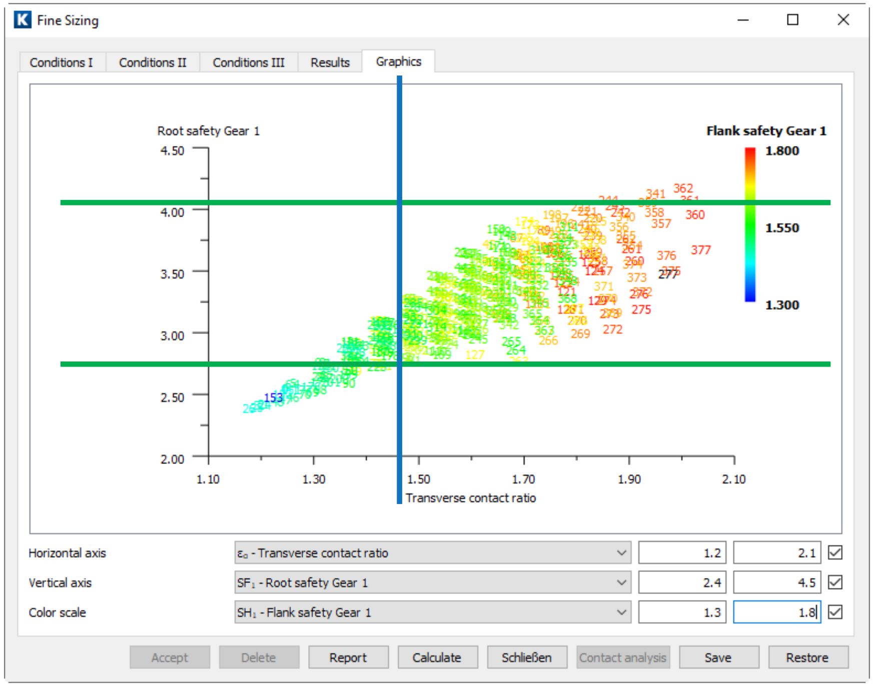
$a = 303\ mm$

$m_n = 4.9\ mm$

ISO 6336: 2006



ISO 6336: 2019



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Calculation of YF for internal gears

ISO 6336: 2006

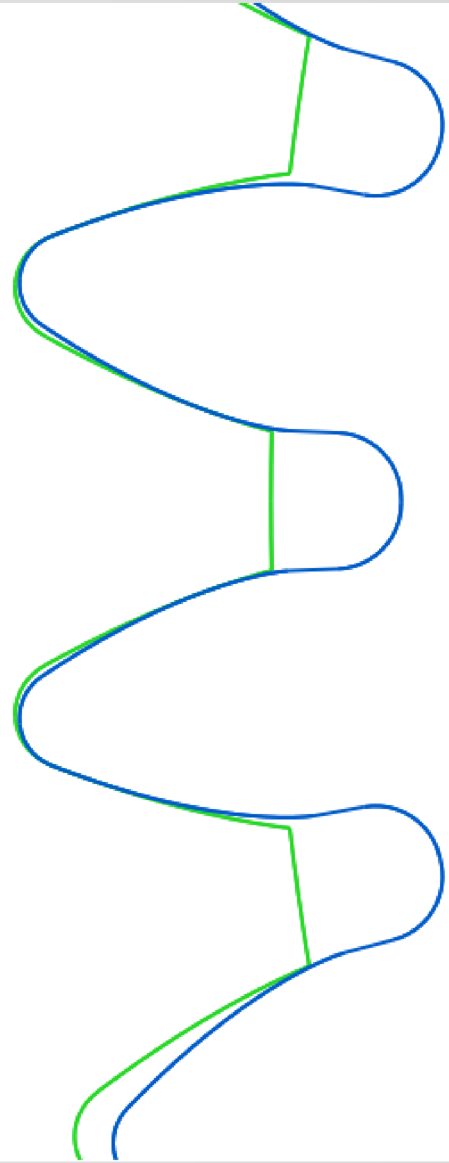
For internal gears, a **virtual basic rack profile** is used which differs from the basic rack profile in the root radius ρfP.

ISO 6336: 2019

For internal gears always the **shaper cutter** data is used. The same formulas as in VDI 2737 “Calculation of the load capacity of the tooth root in internal toothings with influence of the gear rim”, 2016.

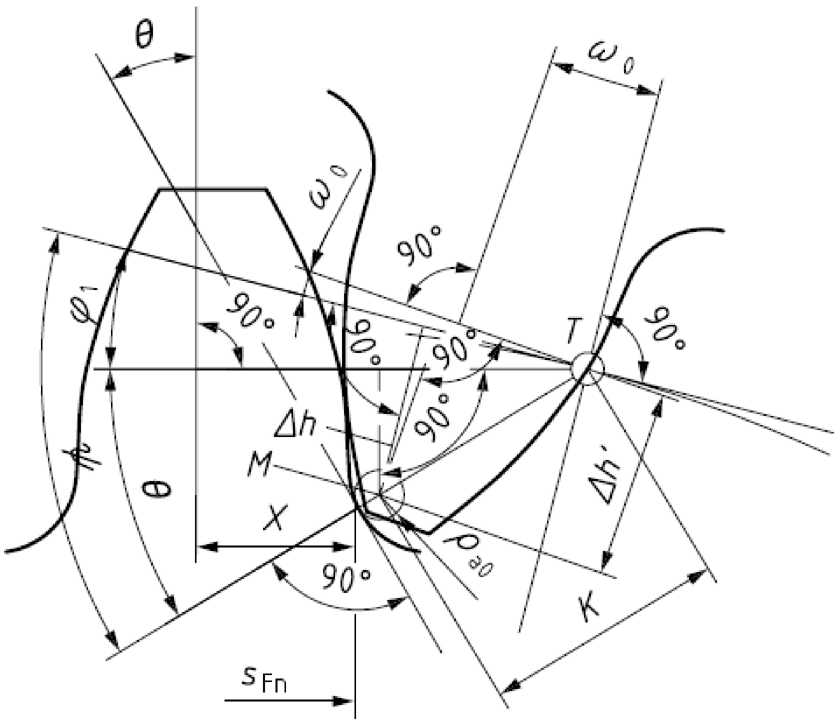
ICS 21.200	VDI-RICHTLINIEN	Dezember 2016 December 2016

VEREIN DEUTSCHER INGENIEURE	Berechnung der Zahnfußtragfähigkeit von Innenverzahnungen mit Zahnkranzeinfluss Calculation of the load capacity of the tooth root in internal toothings with influence of the gear rim	VDI 2737 Ausg. deutsch/englisch Issue German/English



5. Tooth form factor Y_F when shaper cutter is used

For internal gears only the shaper cutter data is used.



a) Shaper cutter

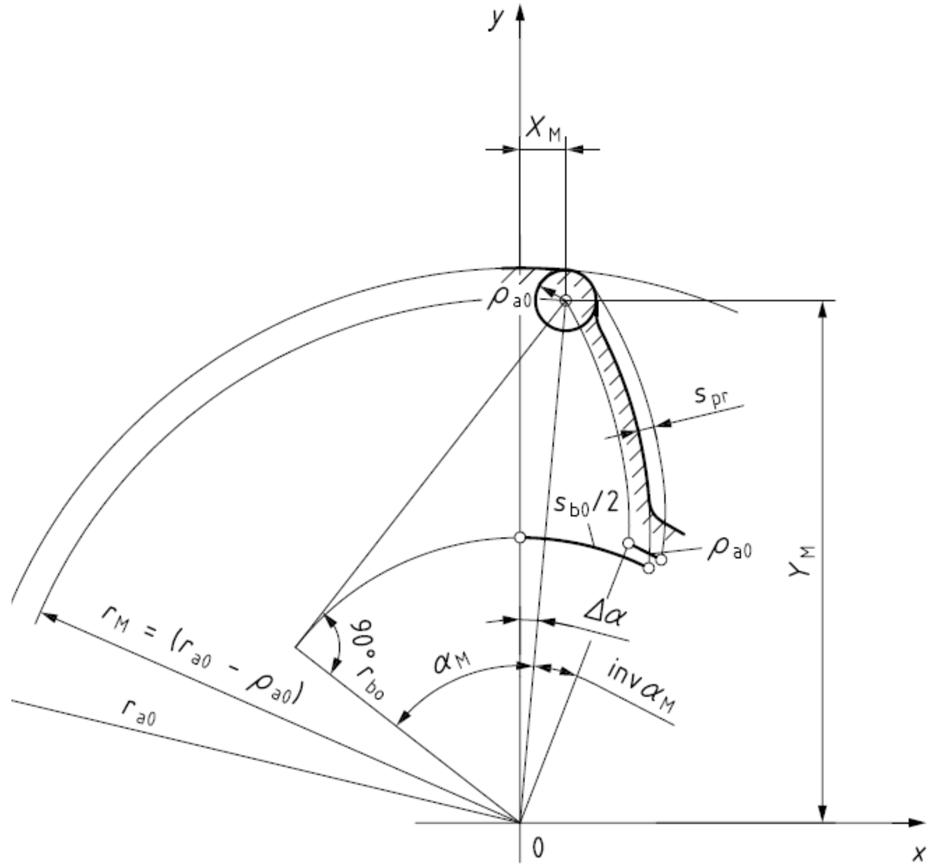


Figure 6 — Quantities at the shaper cutter

5. Tooth form factor Y_F when shaper cutter is used

Main problem is the error in the root fillet calculation in ISO 6336-3:2006

The following table illustrates the resulting root fillet for

- ISO 6336-3:2006 & corrigendum 2007, root fillet calculation
- ISO 6336 (2007-04)
- Effective root fillet based on manufacturing simulation
- VDI 2737 and ISO 6336-3:2019

gear x*	pinion cutter x0	ρ_{fP}	ρ_{fPv}	ρ_F 2006 / 2007-02	ρ_F 2007-04	ρ_F measured	ρ_F VDI 2736	ρ_F ISO 6336 2019	Deviation % (2007/2019)
-0.75	0.1	0.2	0.32	0.201	0.426	0.233	0.233	**0.233**	45%
-0.75	0.0	0.2	0.296	0.175	0.403	0.220	0.220	**0.220**	45%
0.00	0.1	0.2	0.332	0.298	0.364	0.284	0.286	**0.286**	21%
0.00	0.0	0.2	0.310	0.274	0.343	0.265	0.264	**0.264**	23%

ISO 6336-3:2019 uses the same formulae as in VDI 2737.

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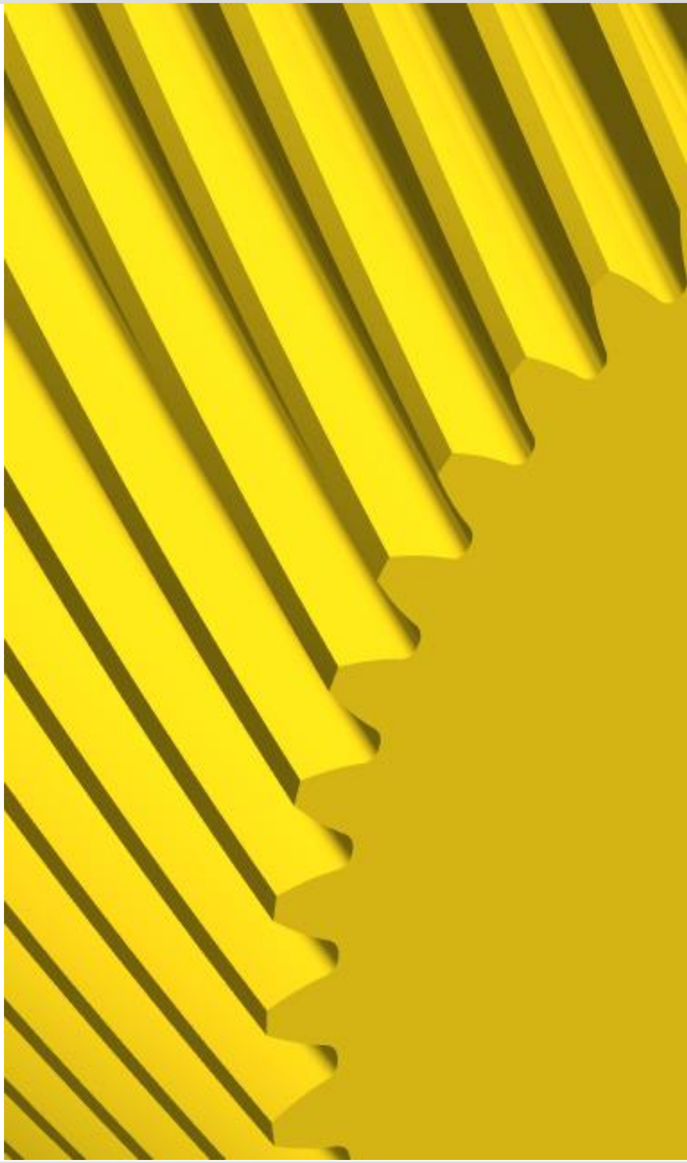
6. Changes in helix angle factor Y_β

Use of the helix angle factor

See ISO 6336-3:2019 which states

“The tooth root stress of a virtual spur gear, calculated as a preliminary value, is converted by means of the helix factor, Y_β, to that of the corresponding helical gear. By this means, the oblique orientation of the lines of the mesh contact is taken into account (less tooth root stress).”

The factor is a function of the helix angle β and the overlap contact ratio ε_β. Note that β is limited to 30° and ε_β is limited to 1.00 for the calculation of this factor.



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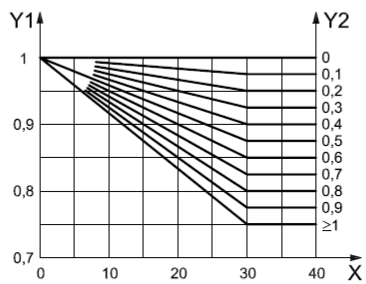
6. Changes in helix angle factor Y_β

ISO 6336: 2006

8.1 Graphical value

Y_β may be read from Figure 6 as a function of the helix angle, β, and the overlap ratio, ε_β.



Key

X reference helix angle, β, degrees
Y1 helix factor, Y_β
Y2 overlap ratio, ε_β

Helix factors $Y_\beta > 25°$ shall be confirmed by experience.

Figure 6 — Helix factor, Y_β

8.2 Determination by calculation

The factor Y_β can be calculated using Equation (40), which is consistent with the curves illustrated in Figure 6.

$$Y_\beta = 1 - \varepsilon_\beta \frac{\beta}{120°} \quad (40)$$

where β is the reference helix angle, in degrees.

The value 1,0 is substituted for ε_β when $\varepsilon_\beta > 1{,}0$, and 30° is substituted for β when $\beta > 30°$.

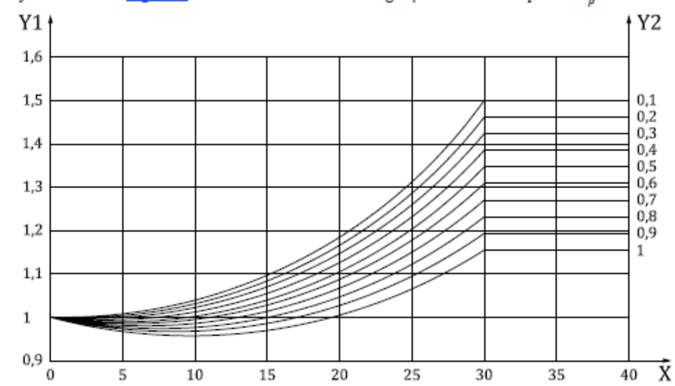
ISO 6336: 2019

8.1 General

The tooth root stress of a virtual spur gear, calculated as a preliminary value, is converted by means of the helix factor, Y_β, to that of the corresponding helical gear. By this means, the oblique orientation of the lines of the mesh contact is taken into account (less tooth root stress).

8.2 Graphical value

Y_β may be read from Figure 8 as a function of the helix angle, β and the overlap ratio, ε_β.



Key

X reference helix angle, β, degrees
Y1 helix factor, Y_β
Y2 overlap ratio, ε_β

Figure 8 — Helix factor, Y_β

Helix factors Y_β for $\beta > 25°$ shall be confirmed by experience.

8.3 Determination by calculation

The factor Y_β can be calculated using Formula (66) which is consistent with the curves illustrated in Figure 8.

$$Y_\beta = \left(1 - \varepsilon_\beta \cdot \frac{\beta}{120°}\right) \cdot \frac{1}{\cos^3 \beta} \quad (66)$$

where β is the reference helix angle, in degrees and

$$\varepsilon_\beta > 0 \quad (67)$$

The value 1,0 is substituted for ε_β when $\varepsilon_\beta > 1{,}0$, and 30° is substituted for β when $\beta > 30°$.

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6. Changes in helix angle factor Y_β

Values for factor Yβ

Yβ	reference helix angle, β												
Overlap ratio, εβ	0	3	6	9	12	15	18	21	24	27	30	33	36
0	1.0000	1.0041	1.0166	1.0379	1.0685	1.1096	1.1625	1.2290	1.3116	1.4137	1.5396	1.5396	1.5396
0.1	1.0000	1.0016	1.0115	1.0301	1.0578	1.0957	1.1450	1.2075	1.2854	1.3819	1.5011	1.5011	1.5011
0.2	1.0000	0.9991	1.0064	1.0223	1.0472	1.0819	1.1276	1.1860	1.2592	1.3501	1.4626	1.4626	1.4626
0.3	1.0000	0.9966	1.0014	1.0145	1.0365	1.0680	1.1102	1.1645	1.2329	1.3183	1.4241	1.4241	1.4241
0.4	1.0000	0.9941	0.9963	1.0067	1.0258	1.0541	1.0927	1.1430	1.2067	1.2865	1.3856	1.3856	1.3856
0.5	1.0000	0.9916	0.9912	0.9989	1.0151	1.0403	1.0753	1.1214	1.1805	1.2547	1.3472	1.3472	1.3472
0.6	1.0000	0.9891	0.9861	0.9912	1.0044	1.0264	1.0578	1.0999	1.1542	1.2229	1.3087	1.3087	1.3087
0.7	1.0000	0.9866	0.9810	0.9834	0.9937	1.0125	1.0404	1.0784	1.1280	1.1910	1.2702	1.2702	1.2702
0.8	1.0000	0.9840	0.9760	0.9756	0.9830	0.9986	1.0230	1.0569	1.1018	1.1592	1.2317	1.2317	1.2317
0.9	1.0000	0.9815	0.9709	0.9678	0.9724	0.9848	1.0055	1.0354	1.0755	1.1274	1.1932	1.1932	1.1932
1	1.0000	0.9790	0.9658	0.9600	0.9617	0.9709	0.9881	1.0139	1.0493	1.0956	1.1547	1.1547	1.1547
1.1	1.0000	0.9790	0.9658	0.9600	0.9617	0.9709	0.9881	1.0139	1.0493	1.0956	1.1547	1.1547	1.1547
1.2	1.0000	0.9790	0.9658	0.9600	0.9617	0.9709	0.9881	1.0139	1.0493	1.0956	1.1547	1.1547	1.1547
1.3	1.0000	0.9790	0.9658	0.9600	0.9617	0.9709	0.9881	1.0139	1.0493	1.0956	1.1547	1.1547	1.1547
1.4	1.0000	0.9790	0.9658	0.9600	0.9617	0.9709	0.9881	1.0139	1.0493	1.0956	1.1547	1.1547	1.1547
1.5	1.0000	0.9790	0.9658	0.9600	0.9617	0.9709	0.9881	1.0139	1.0493	1.0956	1.1547	1.1547	1.1547
1.6	1.0000	0.9790	0.9658	0.9600	0.9617	0.9709	0.9881	1.0139	1.0493	1.0956	1.1547	1.1547	1.1547
1.7	1.0000	0.9790	0.9658	0.9600	0.9617	0.9709	0.9881	1.0139	1.0493	1.0956	1.1547	1.1547	1.1547
1.8	1.0000	0.9790	0.9658	0.9600	0.9617	0.9709	0.9881	1.0139	1.0493	1.0956	1.1547	1.1547	1.1547
1.9	1.0000	0.9790	0.9658	0.9600	0.9617	0.9709	0.9881	1.0139	1.0493	1.0956	1.1547	1.1547	1.1547
2	1.0000	0.9790	0.9658	0.9600	0.9617	0.9709	0.9881	1.0139	1.0493	1.0956	1.1547	1.1547	1.1547
2.1	1.0000	0.9790	0.9658	0.9600	0.9617	0.9709	0.9881	1.0139	1.0493	1.0956	1.1547	1.1547	1.1547

Example 4

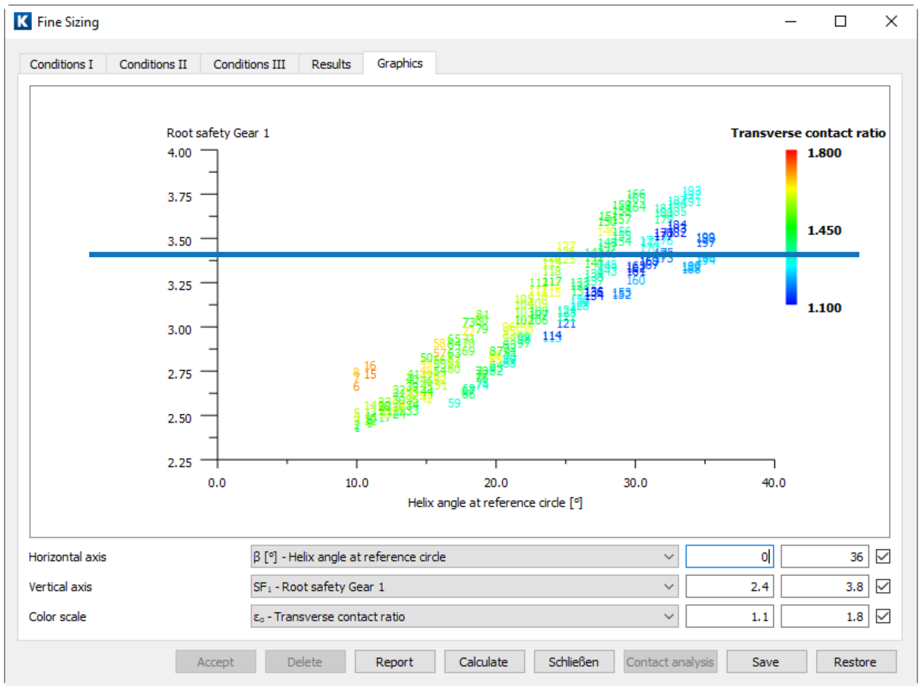
$h^*_{aP} = 1.0 \quad h^*_{fP} = h^*_{aP} + 0.25 \quad \rho^*_{fP} = 0.25$

$\beta = [10°, 11°, \dots, 35°]$, helix angle is varied

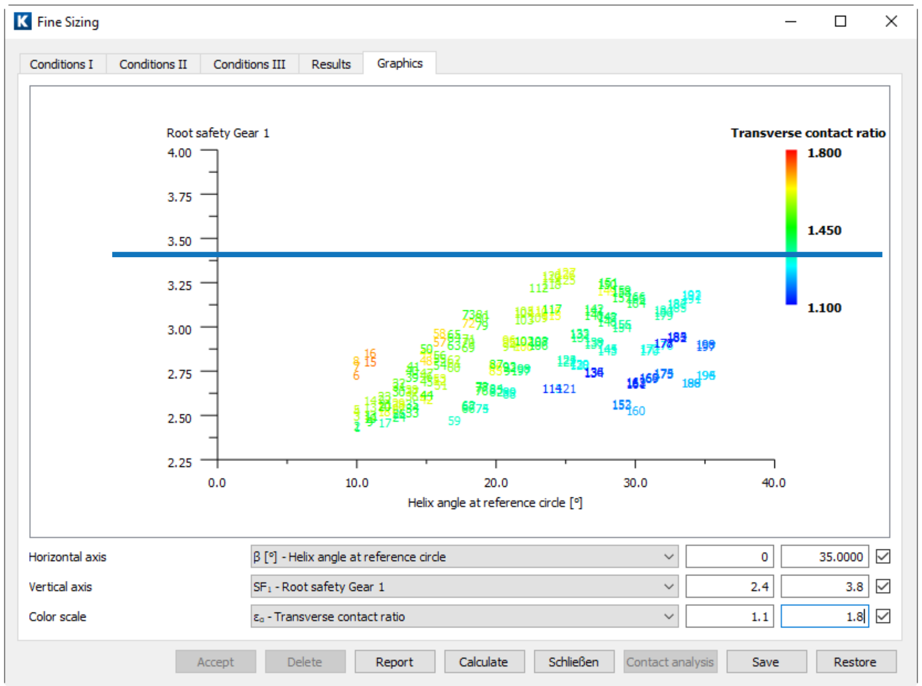
$a = 303\ mm$

$m_n = 6\ mm$

ISO 6336: 2006



ISO 6336: 2019



Influence of both tooth form factor Y_F and helix angle factor Y_β

Example 5

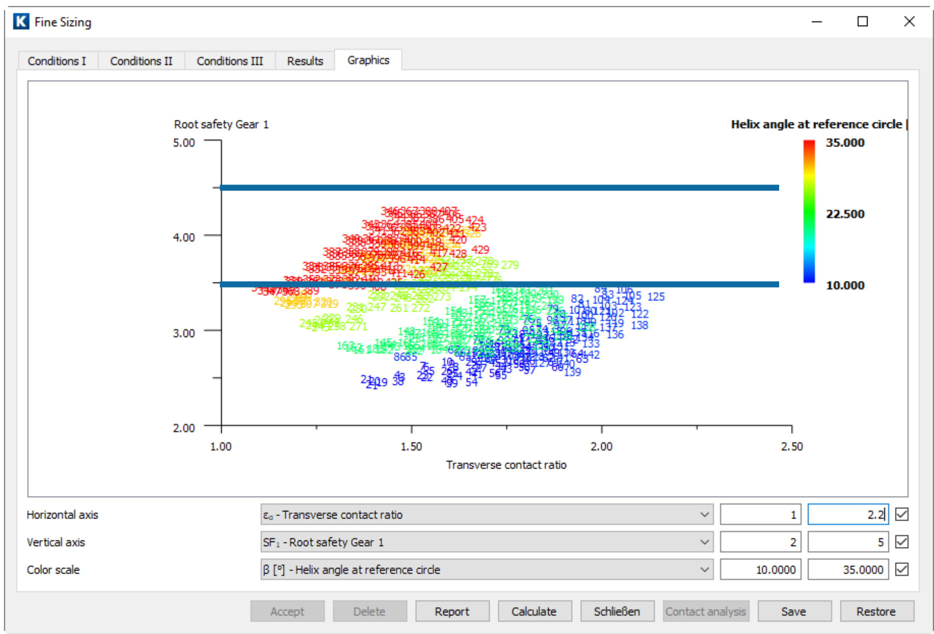
$h^*_{aP} = [1.0\,;1.1, \dots, 1.8]$ $\quad h^*_{fP} = h^*_{aP} + 0.25$ $\quad \rho^*_{fP} = 0.25$, addendum is varied

$\beta = [10°, 15°, \dots, 35°]$, helix angle is varied

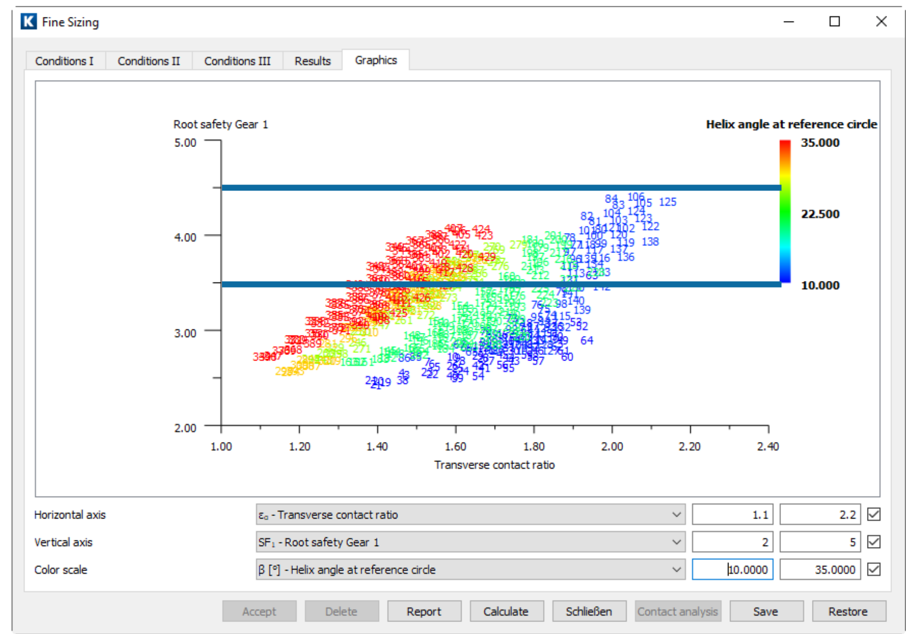
$a = 303\ mm$

$m_n = 6\ mm$

ISO 6336: 2006



ISO 6336: 2019



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7. Relative notch sensitivity factor $Y_{\delta relT}$

ISO 6336: 2006

13.3.2.1.1 $Y_{\delta \text{rel T}}$ for static stress

$Y_{\delta \text{rel T}}$ can be calculated using Equations (50) to (54). These are consistent with the curves in Figure 11 (see ISO 6336-1:2006, Table 2, for an explanation of the abbreviations used).

a) For St with well defined yield point:

$$Y_{\delta \text{rel T}} = \frac{1 + 0{,}93\,(Y_S - 1)\sqrt[4]{\frac{200}{\sigma_S}}}{1 + 0{,}93\sqrt[4]{\frac{200}{\sigma_S}}} \tag{50}$$

b) For St with steadily increasing elongation curve and 0,2 % proof stress, V and GGG (perl., bai.):

$$Y_{\delta \text{rel T}} = \frac{1 + 0{,}82\,(Y_S - 1)\sqrt[4]{\frac{300}{\sigma_{0,2}}}}{1 + 0{,}82\sqrt[4]{\frac{300}{\sigma_{0,2}}}} \tag{51}$$

These values are only valid if the local stresses do not reach the yield point.

c) For Eh and IF(root) with stress up to crack initiation:

$$Y_{\delta \text{rel T}} = 0{,}44\,Y_S + 0{,}12 \tag{52}$$

d) For NT and NV with stress up to crack initiation:

$$Y_{\delta \text{rel T}} = 0{,}20\,Y_S + 0{,}60 \tag{53}$$

e) For GG and GGG (ferr.) with stress up to fracture limit:

$$Y_{\delta \text{rel T}} = 1{,}0 \tag{54}$$

ISO 6336: 2019

Values for GTS (black malleable cast iron (perlitic structure) added

13.3.2.2 $Y_{\delta \text{rel T}}$ for static stress

$Y_{\delta \text{rel T}}$ can be calculated using Formulae (78) to (83). These are consistent with the curves in Figure 13.

a) For St with well-defined yield point:

$$Y_{\delta \text{rel T}} = \frac{1 + 0{,}93 \cdot (Y_S - 1) \cdot \sqrt[4]{\frac{200}{\sigma_S}}}{1 + 0{,}93 \cdot \sqrt[4]{\frac{200}{\sigma_S}}} \tag{78}$$

b) For St with steadily increasing elongation curve and 0,2 % proof stress, V and GGG (perl., bai.):

$$Y_{\delta \text{rel T}} = \frac{1 + 0{,}82 \cdot (Y_S - 1) \cdot \sqrt[4]{\frac{300}{\sigma_{0,2}}}}{1 + 0{,}82 \cdot \sqrt[4]{\frac{300}{\sigma_{0,2}}}} \tag{79}$$

These values are only valid if the local stresses do not reach the yield point.

c) For Eh and IF(root) with stress up to crack initiation:

$$Y_{\delta \text{rel T}} = 0{,}44 \cdot Y_S + 0{,}12 \tag{80}$$

d) For NT and NV with stress up to crack initiation:

$$Y_{\delta \text{rel T}} = 0{,}20 \cdot Y_S + 0{,}60 \tag{81}$$

e) For GTS with stress up to crack initiation:

$$Y_{\delta \text{rel T}} = 0{,}075 \cdot Y_S + 0{,}85 \tag{82}$$

f) For GG and GGG (ferr.) with stress up to fracture limit:

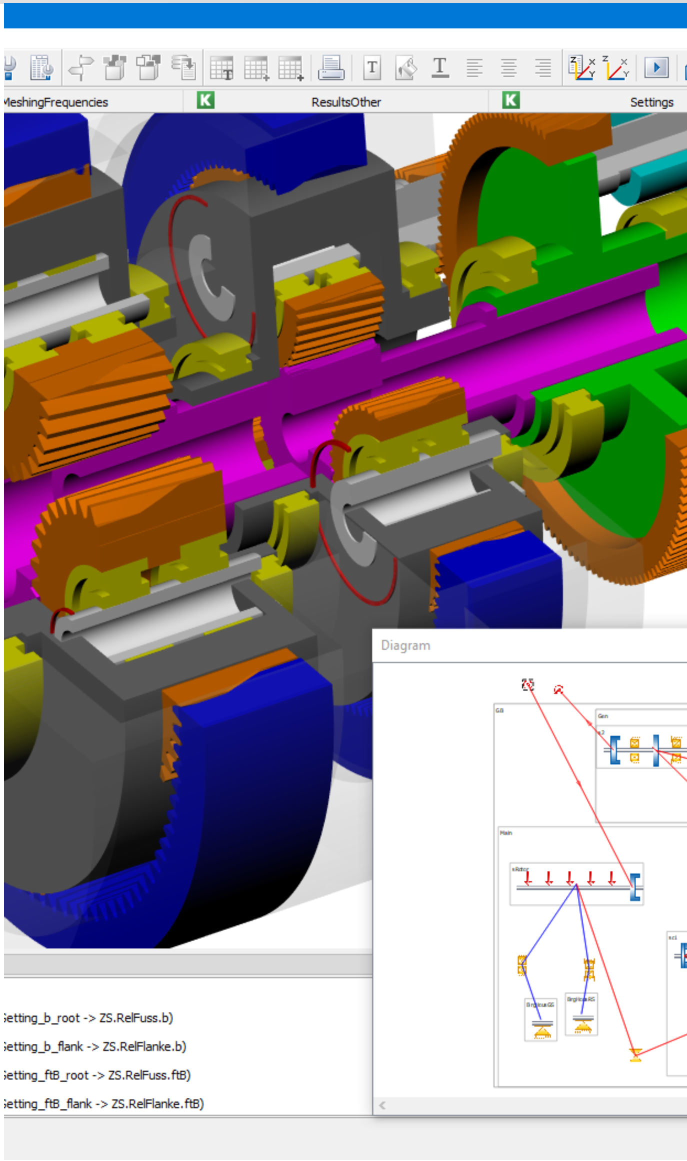
$$Y_{\delta \text{rel T}} = 1{,}0 \tag{83}$$

Method

Four different wind turbine gearboxes were analyzed. For each stage, the cylindrical gear rating along ISO 6336:2006 and ISO 6336:2019 was performed. Resulting root and flank safety factors SF and SH are compared.

The choice of gearboxes was not systematic, and the results are therefore not to be taken as guidelines. The results illustrate that deviations can be significant. Deviations can be such that safety factors are greater or smaller when using ISO 6336:2019 compared to 2006 version.

It is recommended to use the ISO 6336:2019 method in parallel to the 2006 method to gain experience with the new standard version.

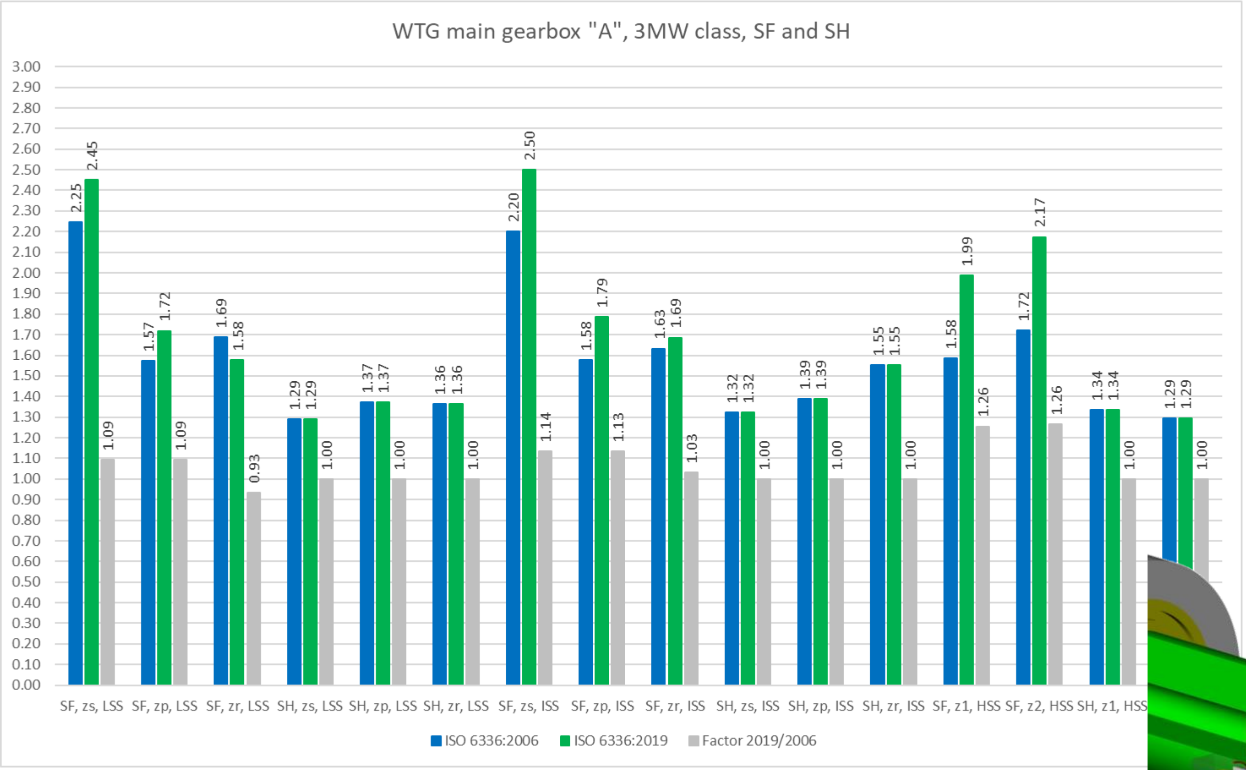


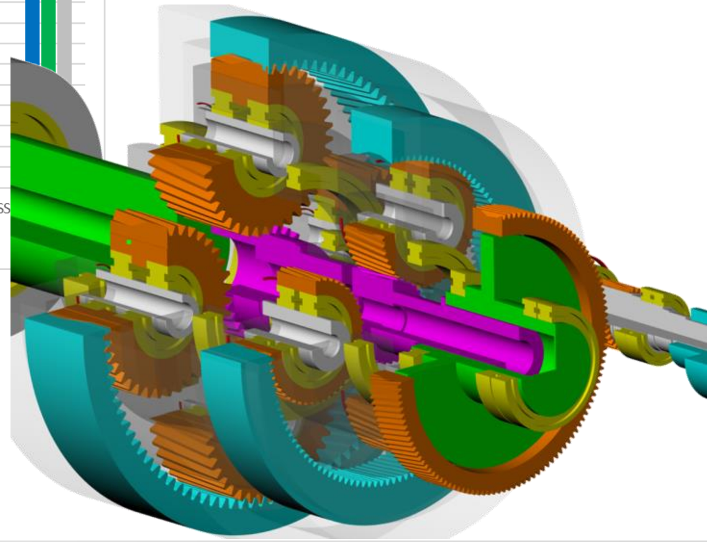
Four gearboxes A, B, C, D

The following four gearboxes were rated along ISO 6336:2006 and ISO 6336:2019, for root and flank safety factor SF and SH

Designation	Arrangement	Power	Origin	Remarks
A	LSS=Planetary ISS=Planetary HSS=Helical	3.1 MW	European	Four planets in LSS, three planets in ISS Helical
B	LSS=Planetary ISS=Planetary HSS=none	3.0 MW	European	Four planets in LSS, three planets in ISS Helical
C	LSS=Planetary ISS=Planetary HSS=none	7.5 MW	European	Five planets in LSS, three planets in ISS Spur
D	LSS=Planetary ISS=Planetary HSS=Helical	3.3 MW	Chinese	Five planets in LSS, three planets in ISS Helical

Root safety factor changes using ISO 6336:2019: +26%, -7%





LSS: low speed stage

ISS: intermediate speed stage

HSS: high speed stage

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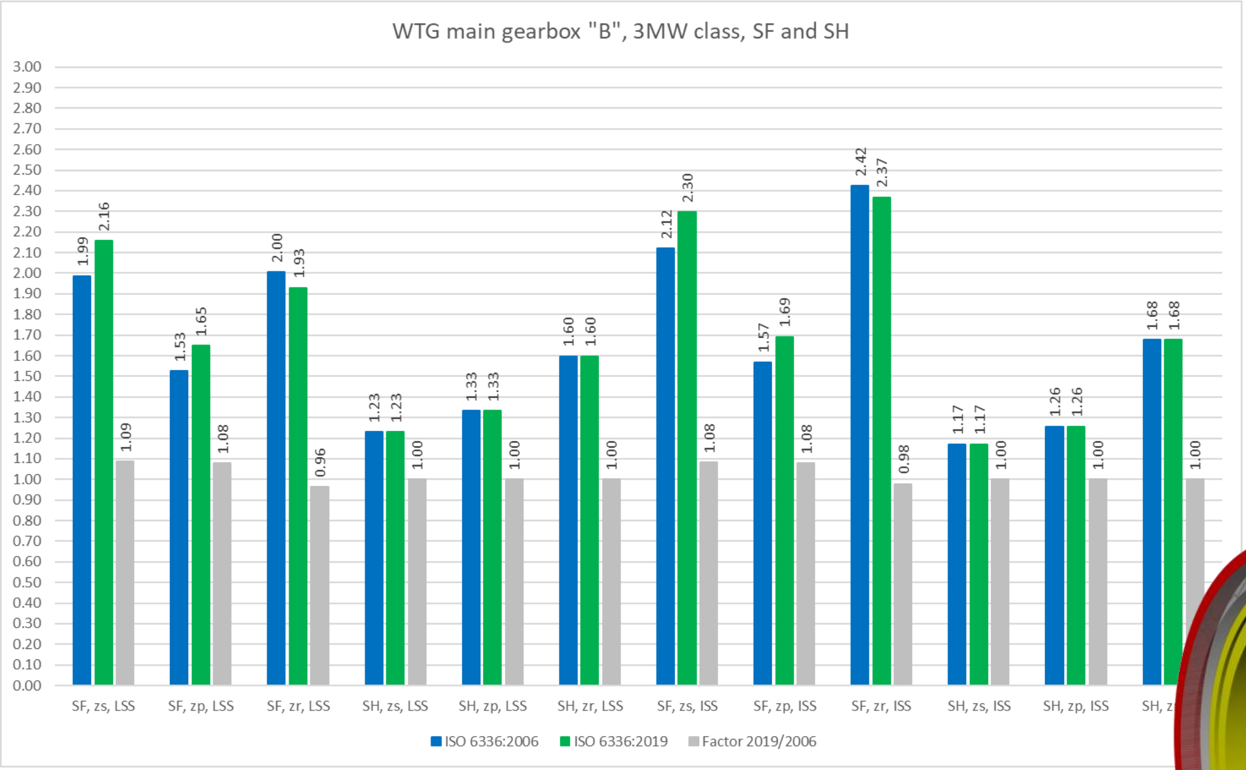
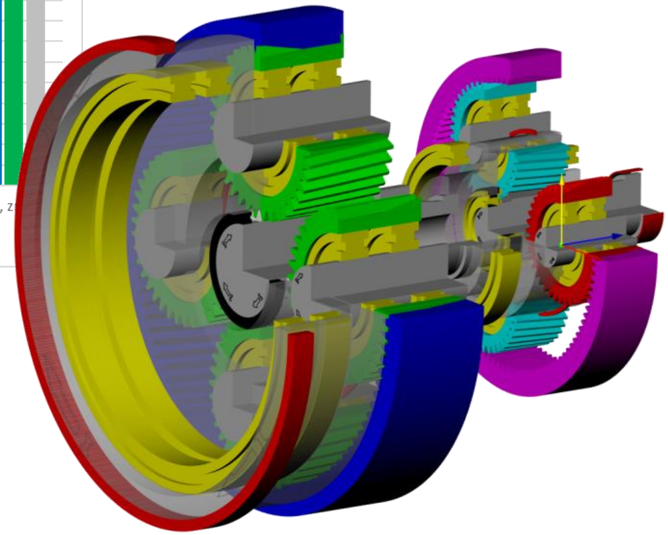
Root safety factor changes using ISO 6336:2019: +9%, -4%





LSS: low speed stage

ISS: intermediate speed stage

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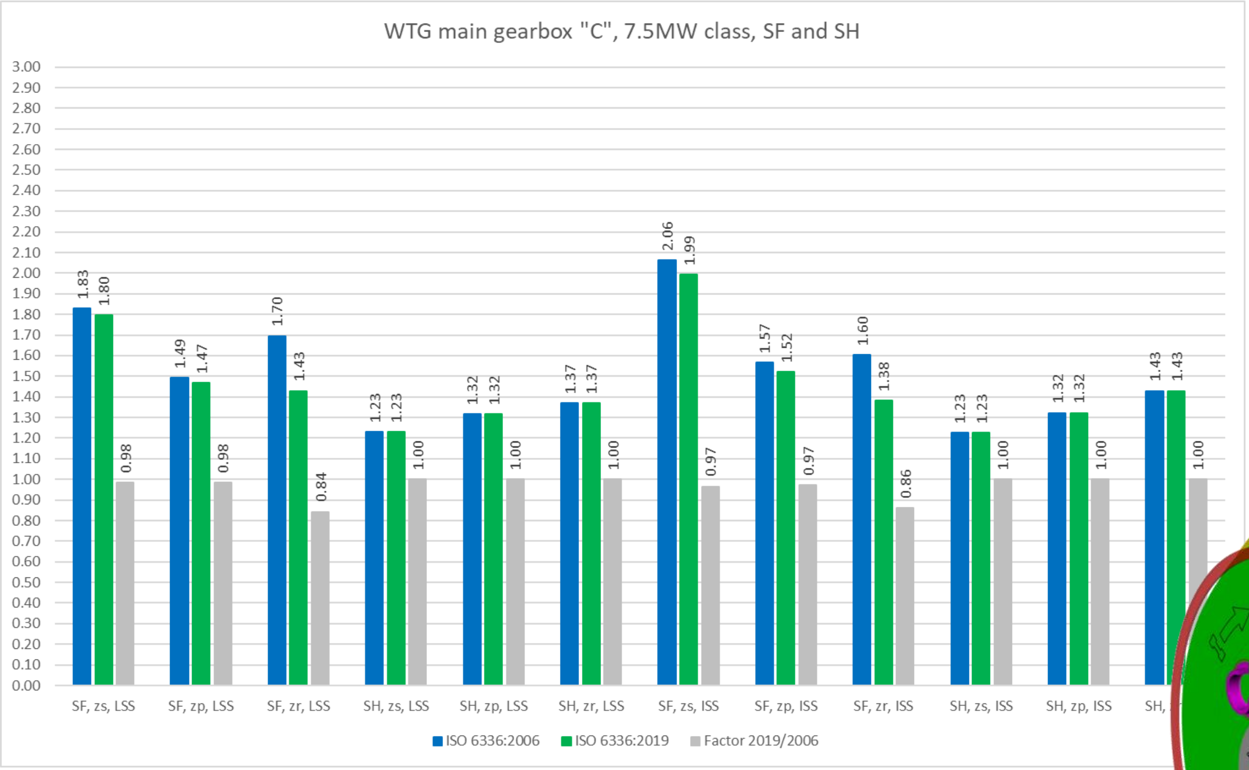
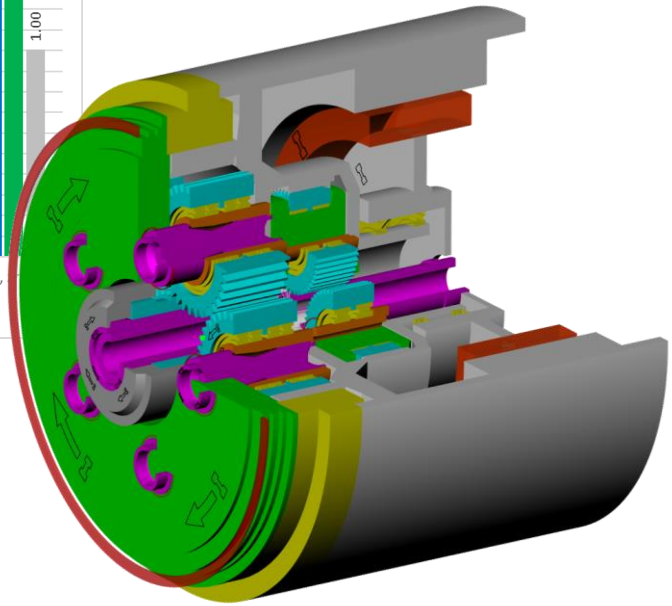
Root safety factor changes using ISO 6336:2019: +0%, -16%





LSS: low speed stage

ISS: intermediate speed stage

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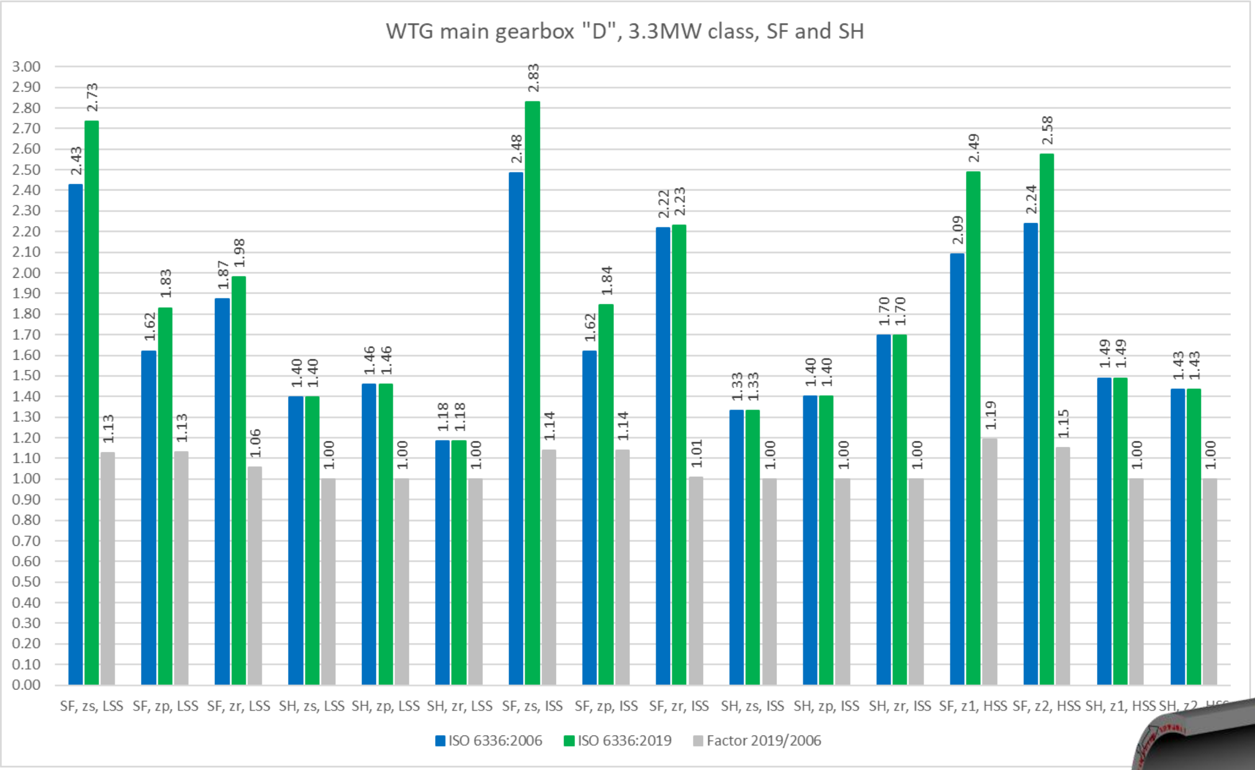
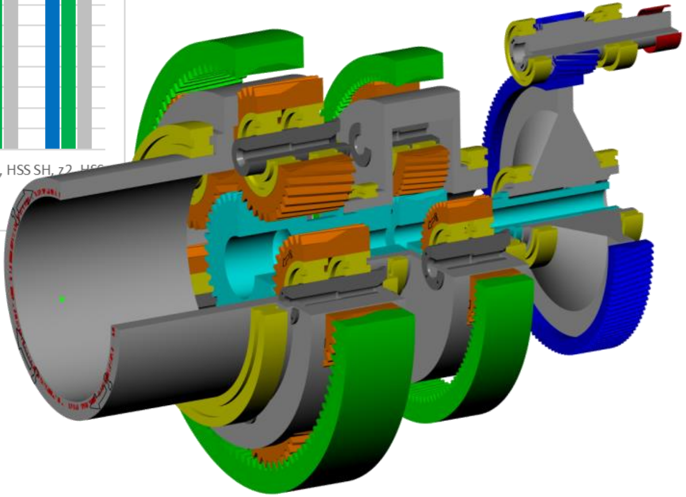
Root safety factor changes using ISO 6336:2019: +19%, -0%





LSS: low speed stage

ISS: intermediate speed stage

HSS: high speed stage

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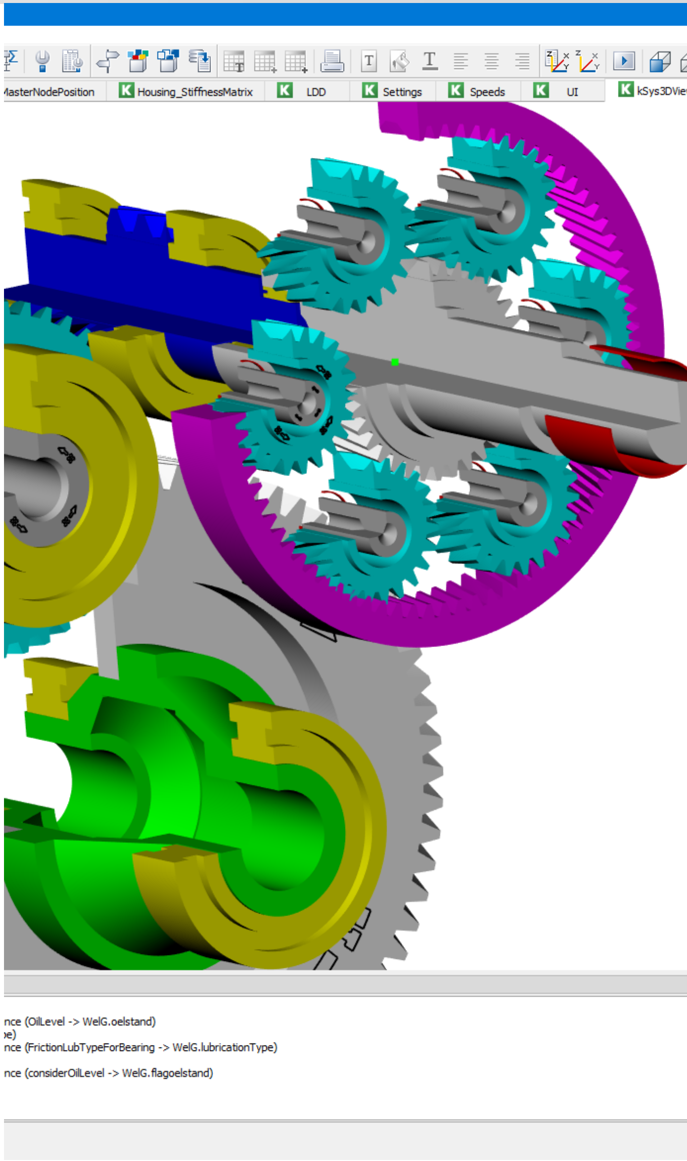
Method

The three stages of an EV transmission are rated along ISO 6336:2006 and ISO 6336:2019. Resulting root and flank safety factors SF and SH are compared.

It is recommended to use the ISO 6336:2019 method in parallel to the 2006 method to gain experience with the new standard version in the design of EV transmission since they typically use gears with high contact ratio.



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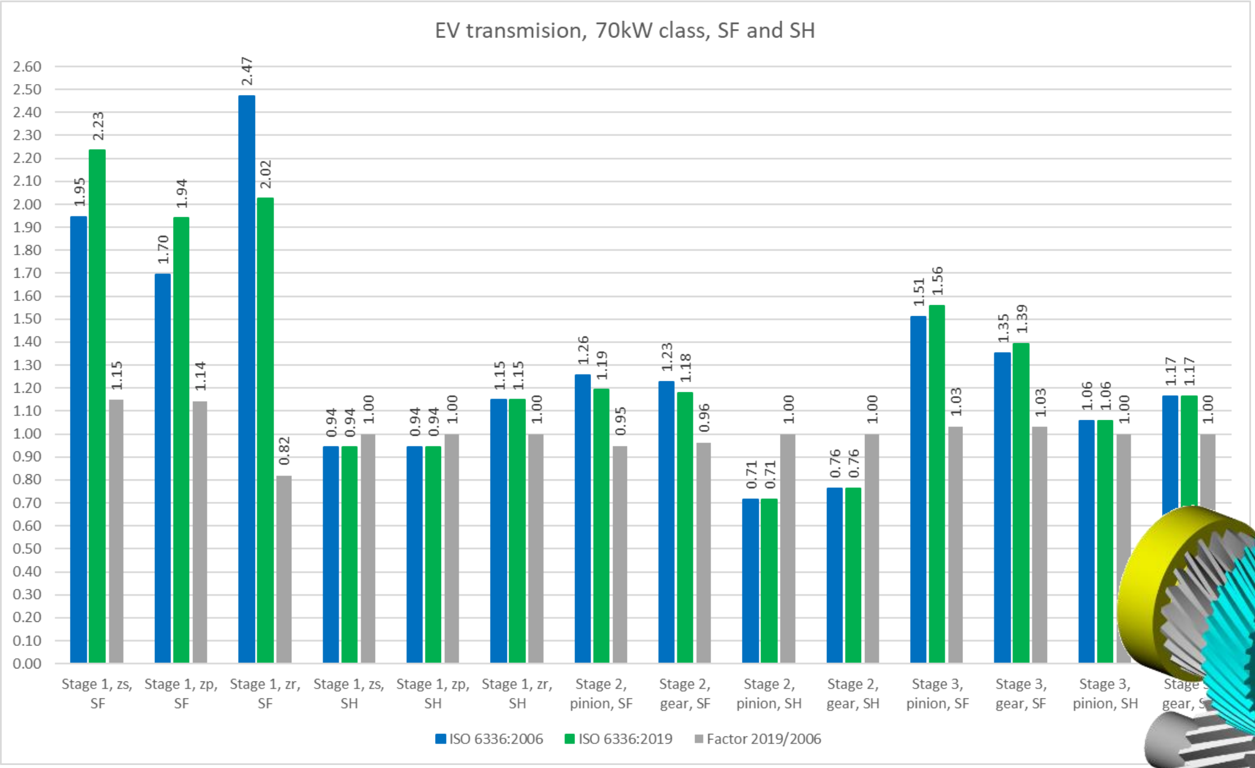
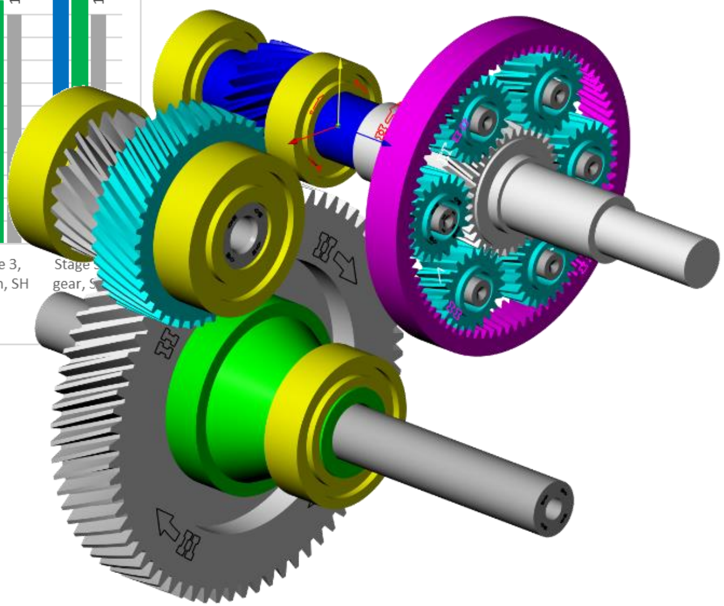
Root safety factor changes using ISO 6336:2019: +15%, -18%





Stage 1: planetary stage

Stage 2: intermediate stage

Stage 3: output stage

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Examples from ISO/TR 6336-30, compared

There are eight examples listed and solved:

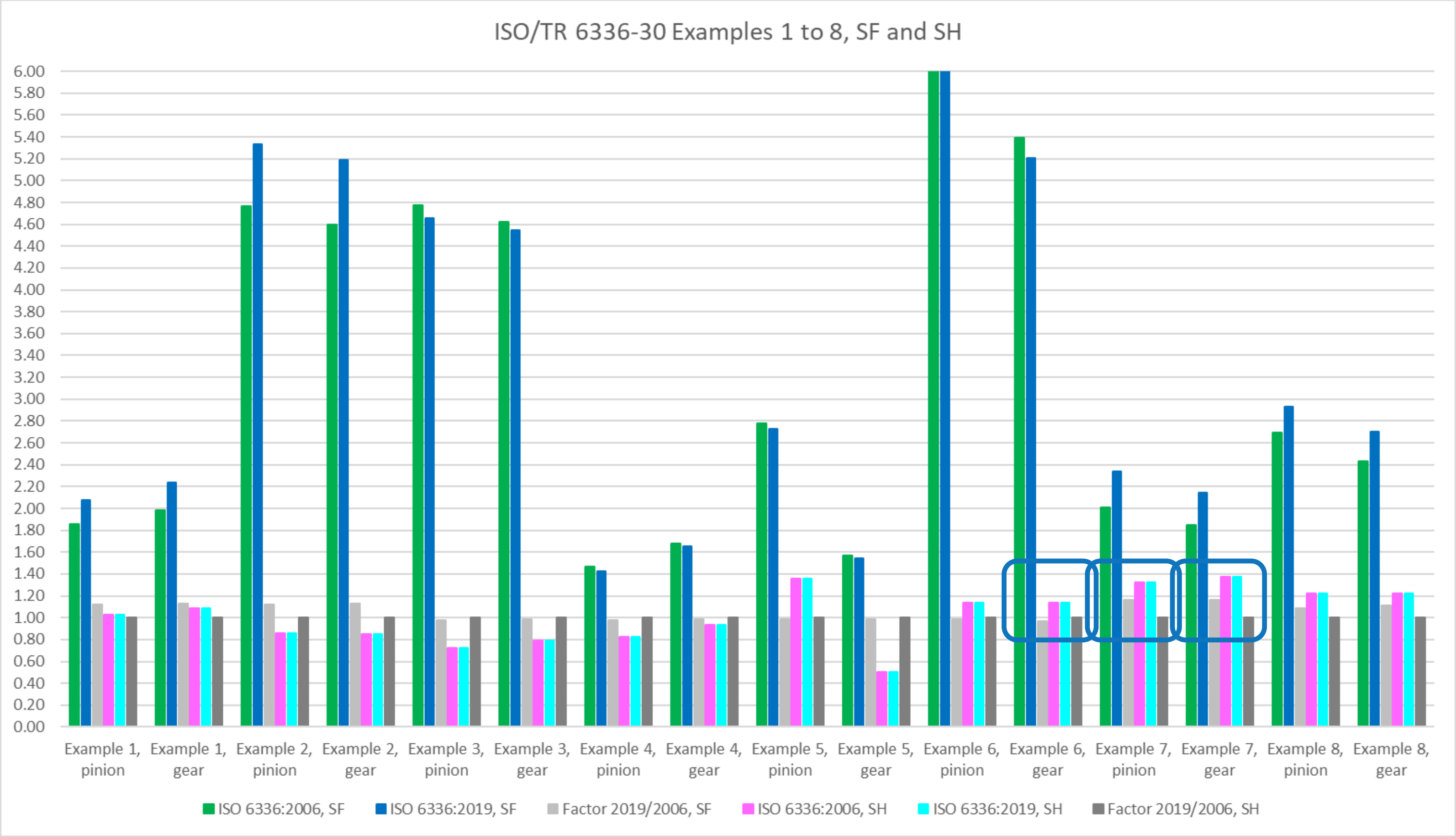
Example 1: Single helical case carburized gear pair
Example 2: Single helical through-hardened gear pair
Example 3: Spur through-hardened gear pair
Example 4: Spur case carburized gear pair
Example 5: Spur gear pair with an induction hardened pinion and through-hardened cast gear
Example 6: Spur internal through-hardened gear pair
Example 7: Double helical through-hardened gear pair
Example 8: Single helical case carburized gear pair

ISO/TR 6336-30:2017(en) Calculation of loa
ISO 6336 parts 1,

Table of contents

Examples from ISO/TR 6336-30, compared.

No changes in SH. SF changes by -3%, +16% (Example 6 and 7)



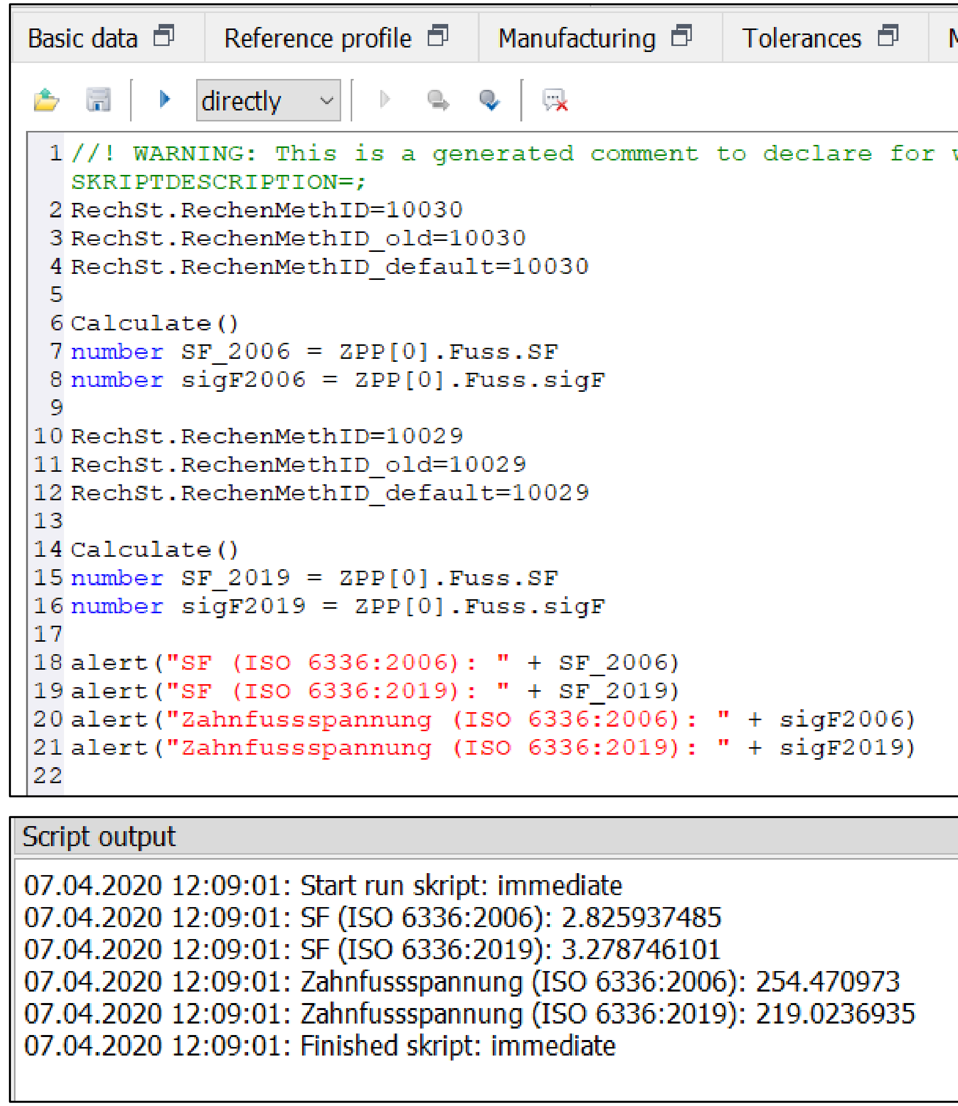
KISSsoft scripting language

KISSsoft Release 2020 provides a scripting possibility.

Per one click, the user finds the results for root safety calculated with ISO 6336:2006 and ISO 6336:2019.

Customized evaluations by exporting data, intermediate parameter results, comparisons of results etc. are possible by the user.

Other samples for scripting applications are available on request.



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Conclusions are preliminary

Helical gears: SF↑, in tendency

Helical gears: Influence of higher transverse contact ratio is stronger

Spur external gears: SF↓, smaller tooth thickness.

Spur internal gears : SF↓, smaller root rounding (?)

Spur gears with contact ratio ≥ 2.00, jump in results are questionable

Flank safety factor remain (changed in ISO 6336-2:2006, corrigendum 2008) Replace Equation (36) with the following:

$$Z_\beta = \frac{1}{\sqrt{\cos \beta}}$$

Thank you for your attention!

Sharing Knowledge

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ISO

ICS › 21 › 21.200

ISO 6336-3:2019

Calculation of load capacity of spur and helical gears — Part 3: Calculatio of tooth bending strength

ABSTRACT

PREVIEW

This document specifies the fundamental formulae for use in tooth bending stress calculations for involute external or internal spur and helical gears with a rim thickness s_R > 0,5 h_t for external gears and s_R > 1,75 m_n for internal gears. In service, internal gears can experience failure modes other than tooth bending fatigue, i.e. fractures starting at the roo diameter and progressing radially outward. This document does not provide adequate safe against failure modes other than tooth bending fatigue. All load influences on the tooth roo stress are included in so far as they are the result of loads transmitted by the gears and in s far as they can be evaluated quantitatively.

This document includes procedures based on testing and theoretical studies such as those of Hirt[11], Strasser[14] and Brossmann[10]. The results are in good agreement with other

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