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REMARKS AND CORRECTIONS TO THE STANDARD ISO 6336

Summary. The standard ISO 6336 for the calculation of load capacity of spur and helical gears was introduced in 2006. There were some later amendments, but several typographical and other errors. These can cause some misunderstandings during applications of the standard and are irritating for its users. This contribution seeks to highlight some aspects of the use of this standard, as well as drawing users' attention to the errors it contains and, at the same time, properly worded content. To fully appreciate this article, the reader is advised to have a copy of the standard itself. Parts 3 and 6 of the standard are covered in the contribution.
Keywords: ISO 6336; Part 3; Part 6; typos; errors; recommendations

1. INTRODUCTION

ISO 6336 is a key standard for gear checking and loading capacity assessment. It also addresses service life. In any task related to the design and optimization of the drive of mechanical systems, its application is absolutely necessary. Therefore, the standard cannot be misinterpreted or misunderstood. As such, this article highlights some of the mistakes and misinterpretations it contains. Due to the scale of this standard, only the third and sixth parts are addressed, as the other parts are highly effective. The results of this work will be immediately applied to the software.

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2. ISO 6336, PART 3

"Calculation of Tooth Bending Strength", which is the third part of the standard ISO 6336 on the calculation of load capacity of spur and helical gears, was introduced in 2006. This part was amended in 2008 with Technical Corrigendum 1, which is still valid. This is a basic standard and instruction for highly important calculations of bending stress in the roots of gear teeth. This chapter deals with some aspects of the use of this part of the standard. It also draws users' attention to the typographical and other errors it contains. At the same time, it highlights where the content is properly worded.

The latest edition of this part of the standard is considerably shorter (42 against 72 pages). It is interesting that the simplified calculation method C was fully removed from this part. In addition, some procedures for the calculations of some factors were changed. Of note is the revised procedure for calculating the form factor Y_{F2} for internal gearing. The tooth root's critical section (s_{Fn2}) starts from the root radius at a tangent point of the line inclined at 60° towards to the tooth axis; see Fig. 1 (it was 30° in the previous edition). Unfortunately, the new calculation of the tooth root's critical section s_{Fn2} shows a relatively large deviation from the exact value; see Tab. 1.

We can even say that the equations used, e.g., in the standard DIN 3990 for the calculation of the form factor Y_{F2} for internal gearing, give more accurate (although not entirely accurate) results than ISO 6336. Several comparative calculations for setting up the form factor Y_{F2} for internal gearing are given in Tab. 1, which compares the calculations from the latest version of ISO 6336 - 3 with the calculations made for exact geometric dimensions s_{Fn2} a h_{Fe2} (see Fig. 1). This geometrical calculation is quite easy (simple numerical calculation).

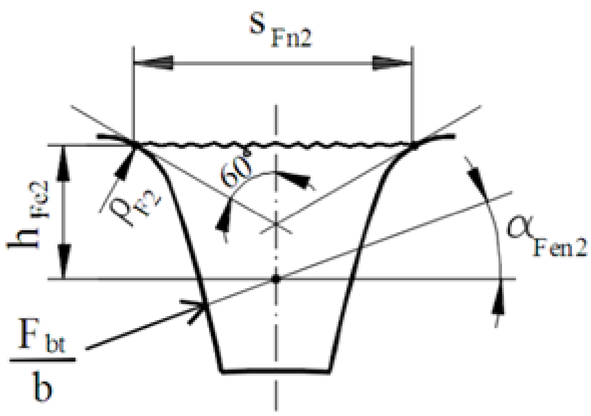

Fig. 1. Tooth root's critical section

There are examples for internal gear pairs in Tab. 1. These are concerned with manufacturing internal gearing with straight teeth, with a standard basic profile and the module m_n=1 [mm]. A tool is the standard pinion-type shaper cutter with z_0=25 teeth and a sharp addendum (ρ_{a02}=0). Its addendum modification coefficient is simply x_0=0. The mating pinion has always 20 teeth.

The manufacturing pair z_0=25, z_2=-40 with shifting coefficients x_0=0, x_2=-0.968 comprises the so-called pole gears (the pitch point lies on the tip of the circle of the wheel). In this case, a tool (pinion-type shaper cutter) does not create a root radius; rather, it only makes its "imprint" on the gear blank during manufacturing. Hence a "sharp" root is created: ρ_{f2}=0.

Tab. 1.

Calculation of the form factor Y_{F2}

z_2	x_2	ISO 6336 - 3				Exact geometric calculations				
		s_{Fn2}	h_{Fe2}	ρ_{F2}	Y_{F2}	s_{Fn2}	h_{Fe2}	ρ_{F2}	Y_{F2}	ΔY_{F2}
		[*mm*]	[*mm*]	[*mm*]	[-]	[*mm*]	[*mm*]	[*mm*]	[-]	[%]
-40	0	2.488	1.161	0.297	1.123	2.851	1.159	0.081	0.8539	31.5
-40	-0.968	2.857	1.500	0.560	1.065	3.019	1.305	0	0.830	28.3
-80	0	2.379	1.175	0.247	1.245	2.729	1.179	0.128	0.949	31.2
-80	-0.8	2.508	1.267	0.340	1.186	2.826	1.198	0.069	0.883	34.3

2.1. ISO 6336, Part 3: typographical and other errors

Page 3, Paragraph 3 - replace ... $Y_{DT.}$ with … $Y_{DT.}$

Page 8, in the middle - replace … *amount* m_n … with … *amount* $x_E \cdot m_n$ …

Page 16, under the figure - replace … $Y_\beta > 25°$… with … Y_β *for* $\beta > 25°$ …

Page 18, Line 2, from the top down - replace … $2 \leq \varepsilon_{\alpha n} <2,5$ … with … $2,05 \leq \varepsilon_{\alpha n}$ …

Page 21, note [b] - replace … Z_{NT} … with … Y_{NT} …

Page 21, note [b] - remove text … , *where pitting must be minimal*

Page 22 - number (49) belongs to the previous equation

Page 23, note [b] - replace … $\sigma_{S0,2}$. with … $\sigma_{0,2}$.

Page 24, Fig. 10 - one of the arrows at GG, GGG(ferr) belongs to the line above

Page 25, Fig. 12 - the curve for the material GTS is missing

Page 29, in the text and in Fig. 14 - data for the material GTS are missing

Page 29, Line 3, from the top down - replace … *(55) to (61).* with … *(56) to (62).*

Page 29 - what is $R_z > 40$ valid for?

Page 34, Line 7, from the bottom up - replace … $\sigma_{k\ lime}$ … with … $\sigma_{p\ lim}$ …

Page 36, Line 4, from the bottom up - replace … *of* Y_{Sa} *or* q_s *and the material, all relevant to the gear* … with … *of* q_s, *and the material of the gear* …

Subclauses A.6.3.2.2, A.6.4.2.2, A.7.2.2.2 and Fig. A1 - data for the material GTS are missing

Page 37, Eq. (A.15) - replace … $Y_{\delta k}$ = … with … Y_{δ} = …

Page 38, Eq. (A.17) - replace … Y_{Rk} = … with … $Y_{R\,rel\,k}$ = …

Page 39, Line 6, from the top down - replace … *1 μm < R_s < 40 μm* with … *1 μm ≤ R_s ≤ 40 μm*

Page 40, line 9, from the top down - replace … *1 > R > 0.* with … *-1.2 < R <0.*

Page 41, Line 2, from the top down - replace … *with R = 1* … with … *with R = -1* …

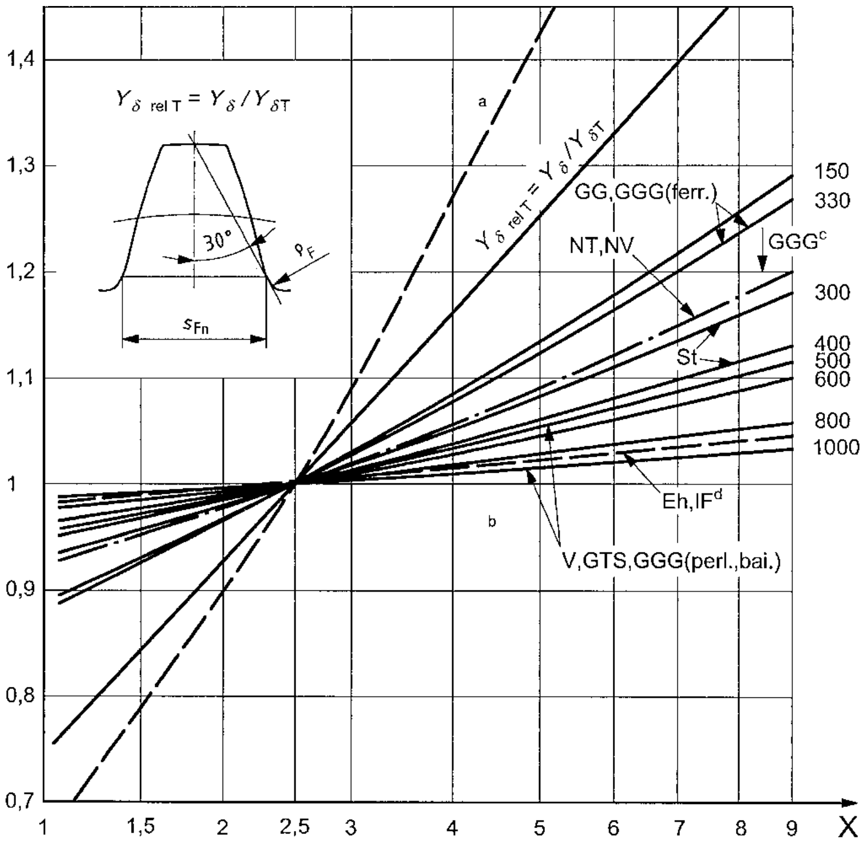

Fig. 2. Current Fig. 10

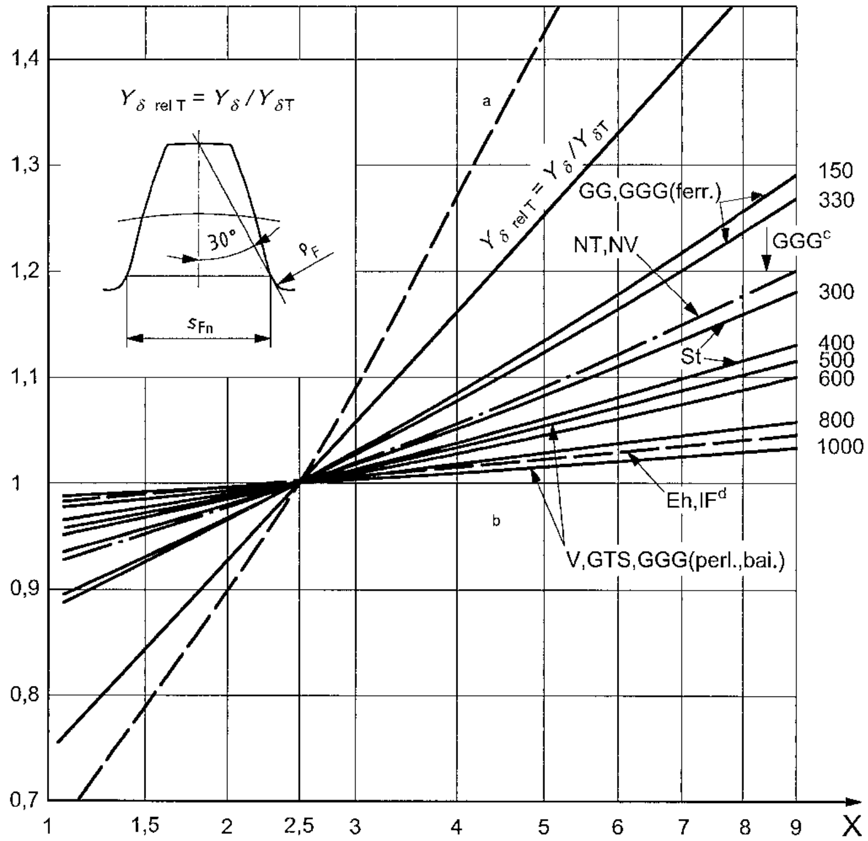

Fig. 3. Corrected Fig. 10

2.2. ISO 6336, Part 3: conclusion

The latest edition of the third part of the standard ISO 6336 improves on the previous edition. Firstly, it is shorter and more readable. However, the simplified calculation method C was apparently omitted. There is no need to simplify a calculation for bending stress. But it is a pity that not all errors were caught by Technical Corrigendum 1. That said, we can say that this part of the standard is still of great benefit to users, although it is advisable to consider modifying the calculation of the form factor Y_{F2} for internal gearing.

3. ISO 6336, PART 6

"Calculation of Service Life Under Variable Load", which is the sixth part of the standard ISO 6336 for the calculation of load capacity of spur and helical gears, was introduced in 2004. This part was updated in 2006 and is still valid. This is a fairly effective tool, which defines the procedure for processing a gear pair loading spectrum using stress levels method. On this basis, we can numerically calculate service life or safety factors for the required service life. This chapter also seeks to highlight some aspects of the use of this standard, as well as draw users' attention to the typographical and other errors. At the same time, we point out where the wording is properly worded.

The standard firstly describes the so-called the Palmgren-Miner's rule, which states that the order in which each stress cycle is applied is not considered significant and the damage accumulation takes place linearly. Failure should be expected when the sum equals 1. The standard further mentions that, when stress is calculated, for each level, all factors K (for contact and bending) should be separately determined. The rotational speed for the concerned level is the mean one. For the determination of the resulting safety factors for the required service life, the standard provides a graphic algorithm for the necessary numerical calculation (Fig. 4 in the standard).

Of interest is Annex A, which contains a technique to determine the application factor K_A without knowledge of an endurance limit. For the calculation of K_A from a loading spectrum, it is enough to know the values of the slope of the Wöhler damage line p and the endurance limit cycles N_{lim}.

There is also presented a classical calculation for an equivalent torque T_{eq} in the form of an equation (Eq. A2 in the standard). Standard ISO 6336 rightly points out that this principle is incorrect. The limit cycles N_{lim} are achieved in the same way as described earlier; see Figs. 3 and A2 in the standard. In other words, using Eq. A2 leads to the application of a greater number of cycles in the calculation (this technique is not correct). For potential applications, precise values of an equivalent torque for loading spectra, according to Tab. A2, are as follows:

According to Eq. A2, ... T_{eq} = 1138,4 K_A = 1,198

According to the Fig. A2, ... T_{eq} =1124,9 K_A = 1,184

This means that the gear design according to Eq. A2 would give a greater gear pair.

3.1. ISO 6336, Part 6: typographical and other errors

Tab. 3 - replace N_{38} with n_{38}; replace N_{39} with n_{39}
Under Fig. 3 - replace de *damage* with *damage*
Eq. (5) - replace $KF_{\alpha ii}$ with $KF_{\alpha i}$
Fig. 4 - fourth box from above, replace ... *to 5.1 to 5.3* with ... *to 5.1 to 5.4*
Page 10 - fourth line from below, replace ... *in A.2.2 shall* ... with ... *in A.3.2 shall*
Under Fig. A.2 - replace (T_{2e}, N_{2e}) with (T_2, N_{2e})
Page 12 - second line from below - replace ... *cycles* N_L ... with ... *cycles* N_{Lref}
Tab. A.2 - heading for the fourth column - replace $\frac{h}{L}$ with $\frac{L}{h}$
Tab. B3 - replace *calendars* with *calenders*; should *sleve* be *slave*?
Tab. B4 - change *Moderate* to *Light*; change *Medium* to *Moderate*
Tab. C1 - see Tabs. 2 and 3 in all columns

Tab. 2.
C1 (incorrect)

Item	Pinion	Wheel	Unit
No. of teeth, z	17	80	-
Gear ratio, u	3,529 41		mm
Normal module, m_n	8,467		°
Normal pressure angle, α_n	25		°
Helix angle, β	15,5		mm
Centre distance, α	339,727		mm
Face width, b	152,4		mm
Tip diameter, d_a	169,212	544,132	mm
Profile shift coefficient, x	0,172 0	0,001 5	-

Tab. 3.
C1 (correct)

Item	Pinion	Wheel	Unit
No. of teeth, z	17	80	-
Gear ratio, u	3,529 41		-
Normal module, m_n	8,467		mm
Normal pressure angle, α_n	25		°
Helix angle, β	15,5		°
Centre distance, a	339,738		mm
Face width, b	152,4		mm
Tip diameter, d_a	169,192	544,127	mm
Profile shift coefficient, x	0,172 0	0,001 5	-

Page 19 - 10th line - replace ... *(14), and ISO 6336-3:2006, Eq. (7).* with ... *(11), and ISO 6336-3:2006, Eq. (8).*
Page 19 - sixth line from below - replace *Using the nominal* ... with *Using the reference* ...

Page 20 - fourth line - replace ... *Fig. 9).* with ... *Fig. 9.*
Page 20 - fifth line - replace ... *5.3.3.2, and* ... with ... *5.4.3.2, and* ...
Page 20 - fifth line from below - replace ... *Fig. 7,* with ... *Fig. 4,*
Page 20 - second line from below - replace ... *1,428* ... with ... *1,3355* ...
Page 20 - second line from below - replace ... *1,324* ... with ... *1,677* ...
Page 20 - incorrect set of equations

For contact stress:

$$Z_{NT\,i} = \frac{\sigma_{H\,i}}{\sigma_{HP\,i}} \quad (1) \qquad U_i = \frac{n_i}{N_{ii}} \quad (2)$$

$$N_i = \left(\frac{Z_{NT\,i}}{1{,}6}\right)^{-13{,}222469} \times 10^5 \ (if\ Z_{NT\,i} > 1),\ N_i = \left(Z_{NT\,i}\right)^{-32.60122926} \times 5 \times 10^7 \ (if\ Z_{NT\,i} \le 1) \quad (3)$$

For bending stress:

$$Y_{NT\,i} = \frac{\sigma_{F\,i}}{\sigma_{FP\,i}} \quad (4) \qquad U_i = \frac{n_i}{N_{ii}} \quad (5)$$

$$N_i = \left(\frac{Y_{NT\,i}}{2{,}5}\right)^{-8{,}737\,24908} \times 10^3 \ (if\ Y_{NT\,i} \ge 1),\ N_i = \left(Y_{NT\,i}\right)^{-49.91250338} \times 3 \times 10^6 \ (if\ Y_{NT\,i} < 1) \quad (6)$$

Page 20: correct set of equations

For contact stress:

$$Z_{N\,i} = \frac{\sigma_{H\,i}}{\sigma_{HP\,ref}} \qquad (7) \qquad\qquad U_i = \frac{n_i}{N_i} \qquad (8)$$

$$N_i = \left(\frac{Z_{N\,i}}{1{,}6}\right)^{-13{,}222469} \times 10^5 \ (if\ Z_{N\,i} \geq 1),\ N_i = \left(Z_{N\,i}\right)^{-32.60122926} \times 5 \times 10^7 \ (if\ Z_{N\,i} < 1) \qquad (9)$$

For bending stress:

$$Y_{N\,i} = \frac{\sigma_{F\,i}}{\sigma_{FP\,ref}} \qquad (10) \qquad\qquad U_i = \frac{n_i}{N_i} \qquad (11)$$

$$N_i = \left(\frac{Y_{N\,i}}{2{,}5}\right)^{-8{,}73724908} \times 10^3 \ (if\ Y_{N\,i} \geq 1),\ N_i = \left(Y_{N\,i}\right)^{-49.91250338} \times 3 \times 10^6 \ (if\ Y_{N\,i} < 1) \qquad (12)$$

Tab. 4.

Replacing ... *1,428* with ... *1,3355* - incorrect first row

				Stress cycles in 30 years N	Face load factor $K_{H\beta}$	Contact stress $\sigma_H \cdot S_H$ N/mm^2	Life factor Z_{NT}	Cycles to failure N_f	Damage parts U_i (N/N_f)

Tab. 5.

Correct first row

				Stress cycles in 30 years n	Face load factor $K_{H\beta}$	Contact stress $\sigma_H \cdot S_H$ N/mm^2	Life factor Z_N	Cycles to failure N	Damage parts U_i (n/N)

Tab. 5.

Replacing ... *1,324* with ... *1,677* - incorrect first row

				Stress cycles in 30 years N	Face load factor $K_{F\beta}$	Bending stress $\sigma_F \cdot S_F$ N/mm^2	Life factor Y_{NT}	Cycles to failure N_f	Damage parts U_i (N/N_f)

Tab. 6.

Correct first row

				Stress cycles in 30 years n	Face load factor $K_{F\beta}$	Bending stress $\sigma_F \cdot S_F$ N/mm²	Life factor Y_N	Cycles to failure N	Damage parts U_i (n/N)

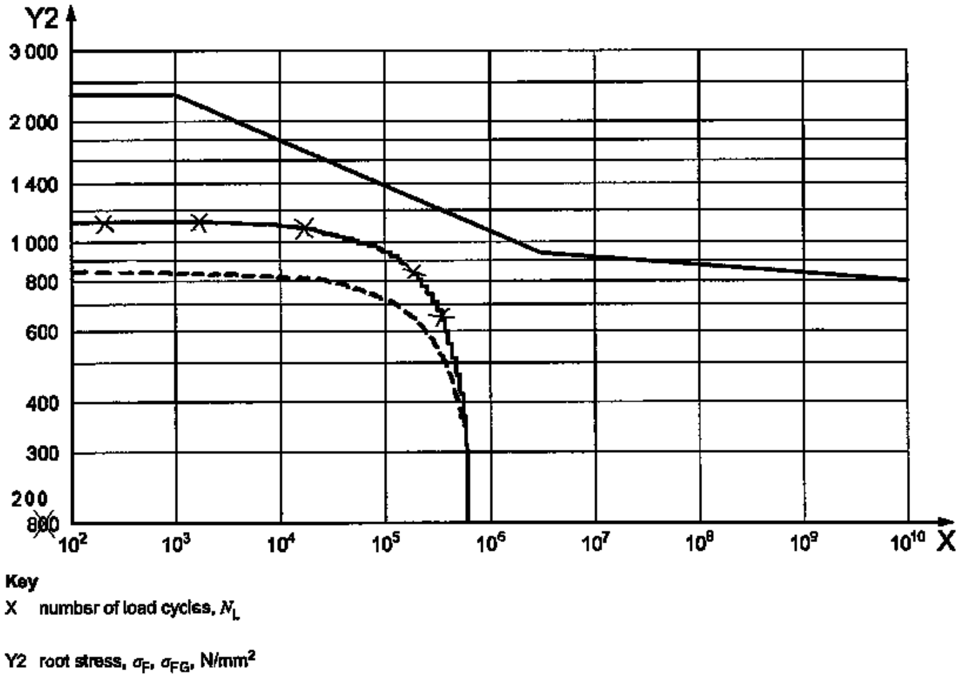

Fig. 4. Wöhler damage curve for bending: corrected curve (dashed) of the spectrum and one value of the scale y2

3.2. ISO 6336, Part 6: conclusion

Lifetime calculations of gear pairs for a given safety factor are standard requests when they are being designed or checked. The standard ISO 6336 - 6 makes progress towards satisfying these demands. But, despite some minor confusion and mistakes, it is a very useful tool for designers. To this extent, this article seeks to improve the readability of this part of the standard ISO 6336, while taking into account Technical Corrigendum 1 (2007).

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