

---

---

## Gears — Calculation of load capacity of worm gears

*Engrenages — Calcul de la capacité de charge des engrenages à vis*

iTeh Standards  
(<https://standards.itih.ai>)  
Document Preview

[ISO/TS 14521:2020](https://standards.itih.ai/catalog/standards/iso/d09c2c9b-feaa-4504-9a3a-15de51b1bbd6/iso-ts-14521-2020)

<https://standards.itih.ai/catalog/standards/iso/d09c2c9b-feaa-4504-9a3a-15de51b1bbd6/iso-ts-14521-2020>



**iTeh Standards**  
**(<https://standards.iteh.ai>)**  
**Document Preview**

[ISO/TS 14521:2020](https://standards.iteh.ai/catalog/standards/iso/d09c2c9b-feaa-4504-9a3a-15de51b1bbd6/iso-ts-14521-2020)

<https://standards.iteh.ai/catalog/standards/iso/d09c2c9b-feaa-4504-9a3a-15de51b1bbd6/iso-ts-14521-2020>



**COPYRIGHT PROTECTED DOCUMENT**

© ISO 2020

All rights reserved. Unless otherwise specified, or required in the context of its implementation, no part of this publication may be reproduced or utilized otherwise in any form or by any means, electronic or mechanical, including photocopying, or posting on the internet or an intranet, without prior written permission. Permission can be requested from either ISO at the address below or ISO's member body in the country of the requester.

ISO copyright office  
CP 401 • Ch. de Blandonnet 8  
CH-1214 Vernier, Geneva  
Phone: +41 22 749 01 11  
Fax: +41 22 749 09 47  
Email: [copyright@iso.org](mailto:copyright@iso.org)  
Website: [www.iso.org](http://www.iso.org)

Published in Switzerland

# Contents

	Page
<b>Foreword</b> .....	<b>vi</b>
<b>Introduction</b> .....	<b>vii</b>
<b>1 Scope</b> .....	<b>1</b>
<b>2 Normative references</b> .....	<b>1</b>
<b>3 Terms, definitions and symbols</b> .....	<b>1</b>
3.1 Terms and definitions.....	1
3.2 Symbols.....	2
<b>4 General consideration</b> .....	<b>7</b>
4.1 Worm gear load capacity rating criteria.....	7
4.2 Basis of the method.....	8
4.3 Concept of absolute and relative parameters.....	8
4.4 Applicability.....	9
4.5 Validity.....	10
4.6 System considerations.....	11
4.7 Calculation methods A, B, C.....	11
4.7.1 Generality on methods A, B and C.....	11
4.7.2 Notes on numerical formulae.....	12
4.7.3 Base conditions, interaction.....	12
4.7.4 Other notes.....	13
4.8 Standard reference gear.....	13
<b>5 Required data for calculation</b> .....	<b>13</b>
5.1 Input variable.....	13
5.2 Safety factors.....	15
<b>6 Forces, speeds and parameters for the calculation of stresses</b> .....	<b>15</b>
6.1 General.....	15
6.2 Tooth forces.....	15
6.2.1 Application factor.....	15
6.2.2 Dynamic factor.....	15
6.2.3 Load distribution factor.....	15
6.2.4 Tooth force components.....	16
6.3 Sliding velocity at reference diameter.....	17
6.4 Physical parameters.....	17
6.4.1 Generality on physical parameters.....	17
6.4.2 Parameter for the mean Hertzian stress.....	18
6.4.3 Parameter for the mean lubricant film thickness.....	19
6.4.4 Parameter for the mean sliding path.....	20
6.5 Calculation of mean contact stress.....	21
6.6 Calculation of mean lubricant film thickness.....	22
6.7 Calculation of the wear path.....	23
6.8 Calculation of the lubricant kinematic viscosity.....	23
<b>7 Efficiency and power loss</b> .....	<b>23</b>
7.1 General.....	23
7.2 Total efficiency.....	24
7.2.1 Method A.....	24
7.2.2 Method B.....	24
7.3 Total power loss.....	24
7.3.1 Methods of calculation.....	24
7.3.2 Idle running power loss.....	25
7.3.3 Bearing load power loss.....	25
7.3.4 Sealing power loss.....	25
7.3.5 Adaptation of the calculation procedure to a specific test.....	26
7.4 Gear efficiency.....	26

7.4.1	Efficiency calculation .....	26
7.4.2	Base coefficient of friction, $\mu_{OT}$ , of the standard reference gear .....	26
7.4.3	Size factor .....	28
7.4.4	Geometry factor .....	29
7.4.5	Material factor .....	29
7.4.6	Roughness factor .....	29
7.4.7	Adaptation of the calculation procedure to a specific test .....	29
7.5	Meshing power loss .....	30
7.5.1	Method A .....	30
7.5.2	Method B .....	30
7.5.3	Method C .....	30
<b>8</b>	<b>Wear load capacity .....</b>	<b>30</b>
8.1	General .....	30
8.2	Wear safety factor .....	30
8.3	Expected wear .....	31
8.3.1	Method A .....	31
8.3.2	Methods B, C .....	31
8.4	Permissible wear .....	35
8.5	Adaptation of the calculation procedure to a specific test .....	36
<b>9</b>	<b>Surface durability (pitting resistance) .....</b>	<b>36</b>
9.1	General .....	36
9.2	Pitting safety factor .....	36
9.3	Actual contact stress .....	37
9.3.1	Method A .....	37
9.3.2	Methods B, C .....	37
9.4	Limiting value of contact stress .....	37
9.5	Adaptation of the calculation procedure to specific test .....	38
<b>10</b>	<b>Deflection .....</b>	<b>38</b>
10.1	General .....	38
10.2	Deflection safety factor .....	39
10.3	Actual deflection .....	39
10.3.1	Method A .....	39
10.3.2	Method B .....	39
10.3.3	Method C .....	39
10.4	Limiting value of deflection .....	40
<b>11</b>	<b>Tooth root strength .....</b>	<b>40</b>
11.1	Safety factor for tooth breakage .....	40
11.2	Actual tooth root stress .....	40
11.2.1	Method A .....	40
11.2.2	Method B .....	40
11.2.3	Method C .....	40
11.3	Limiting value of shear stress at tooth root .....	42
11.3.1	General .....	42
11.3.2	Shear endurance limit, $\tau_{F \text{ lim } T}$ .....	42
11.3.3	Life factor, $Y_{NL}$ .....	42
11.4	Adaptation of the calculation procedure to a specific test .....	44
<b>12</b>	<b>Temperature safety factor .....</b>	<b>44</b>
12.1	Temperature safety factor for splash lubrication .....	44
12.1.1	General .....	44
12.1.2	Determination of oil sump temperature .....	45
12.1.3	Limiting values .....	46
12.2	Temperature safety factor for oil spray lubrication .....	46
12.2.1	General .....	46
12.2.2	Cooling capacity $P_K$ .....	46
<b>13</b>	<b>Determination of the wheel bulk temperature .....</b>	<b>47</b>

13.1	Wheel bulk temperature with splash lubrication.....	47
13.1.1	General.....	47
13.1.2	Method A.....	48
13.1.3	Method B.....	48
13.1.4	Method C.....	48
13.2	Wheel bulk temperature with spray lubrication.....	48
13.2.1	General.....	48
13.2.2	Method A.....	48
13.2.3	Method B.....	48
13.2.4	Method C.....	49
<b>Annex A (informative) Notes on physical parameters.....</b>		<b>50</b>
<b>Annex B (normative) Methods for the determination of the parameters.....</b>		<b>51</b>
<b>Annex C (normative) Lubricant film thickness according to the Elasto Hydrodynamic Lubrication (EHL) theory.....</b>		<b>56</b>
<b>Annex D (normative) Wear path definition.....</b>		<b>58</b>
<b>Annex E (informative) Notes on calculation wear.....</b>		<b>61</b>
<b>Annex F (informative) Notes on tooth root strength.....</b>		<b>62</b>
<b>Annex G (informative) Adaptation of formulae for the reference gear with results from testing.....</b>		<b>63</b>
<b>Annex H (informative) Life time estimation for worm gears with a high risk of pitting damage.....</b>		<b>66</b>
<b>Annex I (informative) Examples.....</b>		<b>68</b>
<b>Annex J (informative) Examples of limit load capacity in a range of working conditions.....</b>		<b>84</b>
<b>Bibliography.....</b>		<b>87</b>

## Document Preview

[ISO/TS 14521:2020](https://standards.iteh.ai)

<https://standards.iteh.ai/catalog/standards/iso/d09c2e9b-feaa-4504-9a3a-15de51b1bbd6/iso-ts-14521-2020>

## Foreword

ISO (the International Organization for Standardization) is a worldwide federation of national standards bodies (ISO member bodies). The work of preparing International Standards is normally carried out through ISO technical committees. Each member body interested in a subject for which a technical committee has been established has the right to be represented on that committee. International organizations, governmental and non-governmental, in liaison with ISO, also take part in the work. ISO collaborates closely with the International Electrotechnical Commission (IEC) on all matters of electrotechnical standardization.

The procedures used to develop this document and those intended for its further maintenance are described in the ISO/IEC Directives, Part 1. In particular, the different approval criteria needed for the different types of ISO documents should be noted. This document was drafted in accordance with the editorial rules of the ISO/IEC Directives, Part 2 (see [www.iso.org/directives](http://www.iso.org/directives)).

Attention is drawn to the possibility that some of the elements of this document may be the subject of patent rights. ISO shall not be held responsible for identifying any or all such patent rights. Details of any patent rights identified during the development of the document will be in the Introduction and/or on the ISO list of patent declarations received (see [www.iso.org/patents](http://www.iso.org/patents)).

Any trade name used in this document is information given for the convenience of users and does not constitute an endorsement.

For an explanation of the voluntary nature of standards, the meaning of ISO specific terms and expressions related to conformity assessment, as well as information about ISO's adherence to the World Trade Organization (WTO) principles in the Technical Barriers to Trade (TBT) see [www.iso.org/iso/foreword.html](http://www.iso.org/iso/foreword.html).

This document was prepared by Technical committee ISO/TC 60, *Gears*, Subcommittee SC 1, *Nomenclature and wormgearing*.

This first edition cancels and replaces ISO/TR 14521:2010, which has been technically revised.

The main changes compared to the previous edition are as follows:

- the original [Clause 6](#) which focused on geometry has been deleted and ISO/TR 10828 has been referenced.

Any feedback or questions on this document should be directed to the user's national standards body. A complete listing of these bodies can be found at [www.iso.org/members.html](http://www.iso.org/members.html).

## Introduction

This document was developed for the rating and design of enclosed or open single enveloping worm gears with cylindrical worms, and worm-gearred motors having either solid or hollow output shafts.

This document is only applicable when the flanks of the worm wheel teeth are conjugate to those of the worm threads.

The particular shapes of the rack profiles from tip to root do not affect the conjugacy when the worm and worm wheel hobs have the same profiles; thus worm wheels have proper contact with worms and the motions of worm gear pairs are uniform.

This document can apply to wormgearing with cylindrical helicoidal worms as defined in ISO/TR 10828 having the following thread forms: A, C, I, N, K.

Other than those mentioned in the three preceding paragraphs, no restrictions are placed on the manufacturing methods used.

In order to ensure proper mating and because of the many different thread profiles in use, it is generally desirable that worms and worm wheels be supplied by the same manufacturer.

In this document, the permissible torque for a worm gear is limited by considerations of surface stress (conveniently referred to as wear or pitting) or bending stress (referred to as strength) in both worm threads and worm wheel teeth, deflection of worm or thermal limitation.

Consequently, the load capacity of a pair of gears is determined using calculations concerned with all criteria described in the scope and 6.4. The permissible torque on the worm wheel is the least of the calculated values.

## Document Preview

[ISO/TS 14521:2020](https://standards.iteh.ai/standards/iso/d09c2c9b-feaa-4504-9a3a-15de51b1bbd6/iso-ts-14521-2020)

<https://standards.iteh.ai/catalog/standards/iso/d09c2c9b-feaa-4504-9a3a-15de51b1bbd6/iso-ts-14521-2020>





# Gears — Calculation of load capacity of worm gears

## 1 Scope

This document specifies formulae for calculating the load capacity of cylindrical worm gears and covers load ratings associated with wear, pitting, worm deflection, tooth breakage and temperature. Scuffing and other failure modes are not covered by this document.

The load rating and design procedures are only valid for tooth surface sliding velocities,  $\bar{v}_g$ , less than or equal to 25 m/s and contact ratios greater than 2,1. For wear, load rating and design procedures are only valid for tooth surface sliding velocities which are above 0,1 m/s. The rules and recommendations for the dimensioning, lubricants or materials selected by this document only apply to centre distances of 50 mm and larger. For centre distances below 50 mm, method A applies.

The choice of appropriate methods of calculation requires knowledge and experience. This document is intended for use by experienced gear designers who can make informed judgements concerning factors. It is not intended for use by engineers who lack the necessary experience. See 4.7.

**WARNING — The geometry of worm gears is complex, therefore the user of this document is encouraged to make sure that a valid working geometry has been established.**

## 2 Normative references

The following documents are referred to in the text in such a way that some or all of their content constitutes requirements of this document. For dated references, only the edition cited applies. For undated references, the latest edition of the referenced document (including any amendments) applies.

ISO 1122-1, *Vocabulary of gear terms — Part 1: Definitions related to geometry*

ISO 1122-2, *Vocabulary of gear terms — Part 2: Definitions related to worm gear geometry*

ISO 6336-6, *Calculation of load capacity of spur and helical gears — Part 6: Calculation of service life under variable load*

DIN 3974-1, *Accuracy of worms and wormgears — Part 1: General bases*

DIN 3974-2, *Accuracy of worms and wormgears — Part 2: Tolerances for individual errors*

## 3 Terms, definitions and symbols

### 3.1 Terms and definitions

For the purposes of this document, the terms and definitions given in ISO 1122-1, ISO 1122-2 and the following apply.

ISO and IEC maintain terminological databases for use in standardization at the following addresses:

— ISO Online browsing platform: available at <https://www.iso.org/obp>

— IEC Electropedia: available at <http://www.electropedia.org/>

#### 3.1.1

##### **actual gear**

worm gear set designed by this document

3.2 Symbols

NOTE Where applicable, the symbols are in accordance with ISO 701.

Table 1 — Symbols for worm gears

Symbols	Description	Unit	Figure	Formula
$a$	centre distance	mm	<a href="#">Figure 1</a>	
$a_1$	centre distance of the gear concerned	mm	<a href="#">Figure 1</a>	
$a_0, a_1, a_2$	oil sump temperature coefficients			<a href="#">(118)</a> to <a href="#">(124)</a>
$a_T$	centre distance of standard reference gear	mm	<a href="#">Figure 1</a>	
$a_V$	centre distance of a gear operating or test experiences are available	mm	<a href="#">Table 4</a>	
$b_{2H}$	effective wheel facewidth	mm		
$b_{2H, std}$	standard effective worm wheel facewidth	mm		<a href="#">(10)</a>
$b_{2R}$	wheel rim width	mm		<a href="#">(132)</a>
$b_H$	half Hertzian contact width	mm	<a href="#">Annex D</a>	<a href="#">(D.2)</a>
$c_k$	coefficient for heat transition coefficient			<a href="#">(133)</a>
$c_{oil}$	specific heat capacity of the oil (for temperature calculation with spray lubrication)	Ws/(kg.K)		<a href="#">(128)</a>
$c_\alpha$	proximity value for the viscosity pressure exponent $\alpha$	m <sup>2</sup> /N		<a href="#">(22)</a> / <a href="#">(24)</a>
$d_{a1}$	worm tip diameter	mm		<a href="#">(89)</a>
$d_{a2}$	worm wheel throat diameter	mm		
$d_{e2}$	worm wheel outside diameter	mm		
$\bar{d}F$	force transmitted by a segment of the contact line	N	<a href="#">Figure B.2</a>	<a href="#">(B.3)</a>
$dl$	length of contact line segment	mm		<a href="#">(B.1)</a> to <a href="#">(B.6)</a>
$d_{f1}$	worm root diameter	mm		<a href="#">(104)</a>
$d_{f2}$	worm wheel root diameter	mm		<a href="#">(111)</a>
$d_{m1}$	worm reference diameter	mm		
$d_{m2}$	worm wheel reference diameter	mm		<a href="#">(41)</a> to <a href="#">(43)</a>
$d_{m1T}$	reference diameter of the worm, from standard reference gear	mm	<a href="#">Table 4</a>	<a href="#">(44)</a> , <a href="#">(45)</a>
$d_{m2T}$	reference diameter of the wheel, from standard reference gear	mm	<a href="#">Table 4</a>	
$\bar{e}_x$	unit vector pointing in direction of the x-axis	mm		<a href="#">(B.4)</a>
$f_h$	worm wheel face width factor for the parameter for the minimum mean lubricant film thickness	—		<a href="#">(16)</a>
$f_p$	worm wheel face width factor for the parameter for the mean Hertzian stress	—		<a href="#">(17)</a>
$\Delta f$	relative deviation between a quantity of the gear concerned and a reference gear	—	<a href="#">Figure 1</a>	
$\Delta f_T$	relative deviation between the centre distance of the gear concerned and the standard reference gear	—	<a href="#">Figure 1</a>	
$\Delta f_V$	relative deviation between the centre distance of the gear concerned and a gear operating or test experiences are available	—	<a href="#">Figure 1</a>	

Table 1 (continued)

Symbols	Description	Unit	Figure	Formula
$h_{am1}$	worm tooth reference addendum in axial section	mm		(86)
$h_{min}$	minimum lubricant film thickness	$\mu\text{m}$		(C.1)
$h_{min\ m}$	minimum mean lubricant film thickness	$\mu\text{m}$		(21)
$h^*$	parameter for minimum mean lubricant film thickness	—		(14)/(15)
$h_T^*$	parameter for minimum mean lubricant film thickness of the standard reference gear	—	Table 4	
$k$	lubricant constant	1/K		(27)/(29)
$l_1$	spacing of the worm shaft bearings	mm		(103)
$l_{11}, l_{12}$	bearing spacing of the worm shaft	mm	Figure 5	(103)
$m_{x1}$	axial module	mm		
$\Delta m_{lim}$	material loss limit	mg		(88)
$\Delta s$	tooth thickness loss	mm		(111)
$\Delta s_{lim}$	allowable tooth thickness loss	mm		(87)
$\vec{n}$	normal vector			(B.5)
$n_1$	rotational speed of the worm shaft	$\text{min}^{-1}$		
$p_H$	Hertzian stress	$\text{N}/\text{mm}^2$		(B.1)/(B.6)
$p_{Hm}$	Hertzian stress; mean value for the total contact area	$\text{N}/\text{mm}^2$		(B.7)
$p_m^*$	parameter for the mean Hertzian stress	—		(11)/(12)/(B.8)
$p_{mT}^*$	parameter for the mean Hertzian stress of the standard reference gear	—	Table 4	
$q_1$	diameter quotient	mm		
$\vec{r}$	radius from the axis of the worm wheel to the contact point B	mm		(B.4)
$s_{f2}$	mean tooth root thickness of the wheel teeth in the spur section	mm		(111)
$s_{ft2}$	mean tooth root thickness of the wheel teeth in the spur section	mm		(111)
$s_{gB}$	sliding path of the worm flanks within the Hertzian contact of the wheel flank per number of cycles of the wheel, around the contact point (local value)	mm		(D.3)/(D.5)
$s_{gm}$	mean sliding path	mm		(D.7)
$s_{m2}$	tooth thickness at the reference diameter of the worm wheel	mm		(111)
$s_K$	rim thickness	mm	Figure 6	(113)
$s_{Wm}$	wear path inside of the required life expectancy	mm		(30)/(D.1)
$s_{mx1}$	worm tooth thickness in axial section	mm		
$s_{mx1}^*$	worm tooth thickness in axial section coefficient	—		(111)
$s^*$	parameter for the mean sliding path	—		(17)/(18)/(D.8)
$s_T^*$	parameter for the mean sliding path of the standard reference gear	—	Table 4	
$\Delta s$	tooth thickness loss			(111)

Table 1 (continued)

Symbols	Description	Unit	Figure	Formula
$\Delta s_{lim}$	allowable tooth thickness loss			(87)/(111)
$t_{contact}$	time of contact	s		(D.2)
$u$	gear ratio			(1)
$u_T$	gear ratio of the standard reference gear		Table 4	
$\vec{v}_1$	velocity of a flank point of the worm	m/s	Figure B.1	
$\vec{v}_2$	velocity of a flank point of a worm wheel	m/s	Figure B.1	
$v_{1n}$	worm velocity component normal to the contact line	m/s	Figure B.2	
$v_{2n}$	wheel velocity component normal to the contact line	m/s	Figure B.2	(D.2)
$\vec{v}_{gB}$	sliding velocity normal to the line of contact in flank direction	m/s		(D.3)/(D.5)/(D.6)
$v_g$	sliding velocity at reference diameter	m/s		(9)/(49)/(50)/(51)/(H.2)/(H.3)/(H.5)
$v_{ref}$	reference sliding velocity	m/s		(H.2) to (H.5)
$v_{\Sigma n}$	sum velocity in normal direction	m/s		(11)/(C.4)
$x_2$	worm wheel profile shift coefficient	—		
$z_1$	number of threads in worm	—		
$z_2$	number of teeth in worm wheel	—		
$A$	coefficient for kinematic viscosity			(33)
$A_{fl}$	total flank surface of the worm wheel	mm <sup>2</sup>		(89)
$A_R$	dominant cooled surface of the gear set	m <sup>2</sup>		(132)
$B$	coefficient for kinematic viscosity	—		(34)
$B$	coefficient for $h^*$	mm		(14)
$E_1$	modulus of elasticity of the worm	N/mm <sup>2</sup>		
$E_2$	modulus of elasticity of the worm wheel	N/mm <sup>2</sup>		
$E_{red}$	equivalent modulus of elasticity	N/mm <sup>2</sup>	Table 4	(20)
$F_{xm1}$	axial force to the worm shaft	N		(4)/(7)
$F_{xm2}$	axial force to the worm wheel	N		(3)/(6)
$F_{rm1}$	radial force to the worm shaft	N		(5)
$F_{rm2}$	radial force to the worm wheel	N		(11)
$F_{tm1}$	circumferencial or tangential force to the worm shaft	N		(4)/(6)
$F_{tm2}$	circumferencial or tangential force to the worm wheel	N		(3)/(7)
$dF/dl$	specific loading	N/mm		(C.5)
$J_{OT}$	reference wear intensity	—	Figure 4	(69) to (79)
$J_{OI}, J_{OII}, J_{OIII}$	reference wear intensity for stage I, II, III	—		(H.6) to (H.7)
$J_W$	wear intensity	—		(68)
$J_{WP}$	wear intensity	—		(H.6)
$K_n$	rotational speed factor/wheel bulk temperature	—		(135)
$K_{H\alpha}$	transverse load distribution factor	—		6.2.3
$K_{H\beta}$	longitudinal load distribution factor	—		6.2.3
$K_S$	size factor/wheel bulk temperature	—		(137)

Table 1 (continued)

Symbols	Description	Unit	Figure	Formula
$K_A$	application factor	—		<a href="#">6.2.1</a>
$K_V$	dynamic factor	—		<a href="#">6.2.2</a>
$K_W$	lubricant film thickness parameter	—		<a href="#">(80)</a>
$K_\nu$	viscosity factor/wheel bulk temperature	—		<a href="#">(136)</a>
$K_1$	factor	—		<a href="#">(G.5)</a>
$L_h$	life time	h		
$N_L$	number of stress cycles of the worm wheel	—		<a href="#">(31)</a>
$N_{LI}, N_{LII}, N_{LIII}$	number of stress cycles of the worm wheel for stage I to III	—		<a href="#">(H.1)</a>
$N_S$	number of starts per hour	—		<a href="#">(70)</a>
$P_1$	input power to the worm shaft	W		
$P_2$	output power from the worm wheel shaft	W		
$P_K$	cooling capacity of the oil with spray lubrication	W		<a href="#">(127)</a> <a href="#">(125)</a>
$P_V$	total power loss of the worm gear unit	W		<a href="#">(38)</a>
$P_{VO}$	idle running power loss	W		<a href="#">(38)</a> / <a href="#">(39)</a> / <a href="#">(G.1)</a>
$P_{Vz1-2}$	meshing power loss in reducer	W		<a href="#">(62)</a>
$P_{Vz2-1}$	meshing power loss in increaser	W		<a href="#">(64)</a>
$P_{VD}$	sealing power loss	W		<a href="#">(44)</a> / <a href="#">(45)</a>
$P_{VLP}$	bearing power loss through loading	W		<a href="#">(40)</a> to <a href="#">(43)</a>
$Q_{oil}$	spray quantity	m <sup>3</sup> /s		<a href="#">(127)</a>
$Ra_1$	arithmetic mean roughness for worm	µm	<a href="#">Table 4</a>	
$Ra_T$	arithmetic mean roughness for reference gear	µm		<a href="#">(62)</a>
$Rz_1$	mean roughness depth	µm		<a href="#">7.4.6</a>
$S_F$	tooth breakage safety factor	—		<a href="#">(106)</a>
$S_{Fmin}$	minimum tooth breakage safety factor	—		<a href="#">(107)</a>
$S_H$	pitting safety factor	—		<a href="#">(91)</a>
$S_{Hmin}$	minimum pitting safety factor	—		<a href="#">(92)</a>
$S_T$	temperature safety factor	—		<a href="#">(115)</a> / <a href="#">(125)</a>
$S_{Tmin}$	minimum temperature safety factor	—		<a href="#">(116)</a> / <a href="#">(126)</a>
$S_W$	wear safety factor	—		<a href="#">(65)</a>
$S_{Wmin}$	minimum wear safety factor	—		<a href="#">(66)</a>
$S_\delta$	deflection safety factor	—		<a href="#">(101)</a>
$S_{\delta min}$	limit of deflection safety factor	—		<a href="#">(102)</a>
$T_1$	input torque to the worm shaft	Nm		<a href="#">(1)</a>
$T_{1N}$	nominal input torque to the worm shaft	Nm		<a href="#">(1)</a>
$T_2$	output torque from the worm wheel	Nm		<a href="#">(2)</a> / <a href="#">(B.4)</a> / <a href="#">(B.5)</a>
$T_{2N}$	nominal output torque from the worm wheel	Nm		<a href="#">(2)</a>
$V_{SUMn}$	sum of velocities at contact point			<a href="#">(C.1)</a>
$W_H$	—			<a href="#">(84)</a> / <a href="#">(85)</a>
$W_{ML}$	material — lubricant factor	—	<a href="#">Table 7</a>	
$W_{NS}$	start factor	—		<a href="#">(83)</a>
$W_P$	damage factor	—		<a href="#">(H.8)</a>
$W_S$	lubricant structure factor	—		<a href="#">(81)</a> / <a href="#">(82)</a>

Table 1 (continued)

Symbols	Description	Unit	Figure	Formula
$Y_F$	form factor/tooth breakage	—		(110)
$Y_G$	geometry factor/coefficient of friction	—		(59)/(60)
$Y_K$	rim thickness factor/tooth breakage	—		(113)
$Y_{NL}$	life factor/tooth breakage	—	Figure 7 a)/b)	Table 11
$Y_R$	roughness factor/coefficient of friction	—		(61)/(62)
$Y_S$	size factor/coefficient of friction	—		(57)/(58)
$Y_W$	material factor/coefficient of friction	—		
$Y_\varepsilon$	contact factor/tooth breakage	—		(109)
$Y_\gamma$	lead factor/tooth breakage	—		(112)
$Z_h$	life factor/pitting	—		(94)
$Z_{oil}$	lubricant factor/pitting	—		(100)
$Z_S$	size factor/pitting	—		(96)/(97)
$Z_u$	gear ratio factor	—		(98)/(99)
$Z_v$	velocity factor/pitting	—		(95)
$\alpha$	pressure viscosity factor	m <sup>2</sup> /N		6.6
$\alpha_L$	heat transition coefficient for immersed wheel teeth	W/(m <sup>2</sup> K)		(133)
$\alpha_n$	normal pressure angle	°		
$\alpha_0$	normal pressure angle			(5), (86)
$\gamma_{m1}$	reference lead angle of worm	°		(86)
$\delta_{lim}$	limiting value of deflection	mm		(105)
$\delta_m$	incurred deflection	mm		(103)/(104)
$\delta_{Wn}$	flank loss from wheel through abrasive wear in the normal section	mm		(67)
$\delta_{Wlim}$	limiting value of flank loss	mm		(90)
$\delta_{Wlimn}$	limiting value of flank loss in normal section	mm		(86) to (88)
$\eta_{ges}$	total efficiency in reducer	—		(35)
$\eta_{ges1-2}$	total efficiency worm driving wheel	—		(35)
$\eta_{ges2-1}$	total efficiency wheel driving worm	—		(36)
$\eta'_{ges}$	total efficiency in increaser	—		(36)
$\eta_{z1-2}$	gear efficiency in reducer	—		(46)/(63)
$\eta_{z2-1}$	gear efficiency in increaser	—		(47)/(64)
$\eta_{0M}$	dynamic viscosity of lubricant at ambient pressure and wheel bulk temperature	Ns/m <sup>2</sup>		(25)/(C.1)
$\theta$	temperature	°C		
$\Delta\theta$	temperature difference between oil sump and worm wheel bulk temperature	°C		(131)
$\theta_{in}$	oil entrance temperature	°C		(129)
$\theta_0$	ambient temperature	°C		
$\theta_{oil}$	spray temperature	°C		(129)
$\Delta\theta_{oil}$	oil temperature difference between input and output cooling system	°C		(129)
$\theta_M$	wheel bulk temperature	°C		(130)/(134)
$\theta_S$	oil sump temperature	°C		(117)/(119)
$\theta_{Slim}$	limiting value of oil sump temperature	°C		(115)