TECHNICAL REPORT

# ISO/TR 15144-2

First edition
2014-10-01

Corrected version
2015-01-15

# Calculation of micropitting load capacity of cylindrical spur and helical gears —

## Part 2: Examples of calculation for micropitting

*Calcul de la capacité de charge aux micropiqûres des engrenages cylindriques à dentures droite et hélicoïdale —*

*Partie 2: Exemples de calcul pour micropiqûres*



Reference number
ISO/TR 15144-2:2014(E)

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Published in Switzerland

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# Foreword

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The committee responsible for this document is ISO/TC 60, *Gears*, Subcommittee SC 2, *Gear capacity calculation*.

This corrected version of ISO/TR 15144-2:2014 incorporates the following corrections: errors in symbols and equations have been corrected.

ISO/TR 15144 consists of the following parts, under the general title *Calculation of micropitting load capacity of cylindrical spur and helical gears*:

— *Part 1: Introduction and basic principles*

— *Part 2: Examples of calculation for micropitting*

# Introduction

This part of ISO/TR 15144 provides worked examples for the application of the calculation procedures defined in ISO/TR 15144-1. The example calculations cover the application to spur and helical cyclindrical involute gears for both high-speed and low-speed operating conditions, determining the micropitting safety factor for each gear pair. The calculation procedures used are consistent with those presented in ISO/TR 15144-1. No additional calculations are presented here that are outside of the technical report.

Four worked examples are presented with the necessary input data for each gear set provided at the beginning of the calculation. The worked examples are based on real gear pairs where either laboratory or operational field performance data has been established, with the examples covering several applications. When available, pictures and measurements are provided of the micropitting wear, experienced on the gear sets when run under the conditions used in the worked examples. Calculation details are presented in full for several of the initial calculations after which only summarized results data are included. For better applicability, the numbering of the formulae follows ISO/TR 15144-1. Several of the worked examples are presented with the calculation procedures performed in accordance with the application of both methods A and B.

# Calculation of micropitting load capacity of cylindrical spur and helical gears —

# Part 2: Examples of calculation for micropitting

## 1 Scope

The example calculations presented here are provided for guidance on the application of the technical report ISO/TR 15144-1 only. Any of the values or the data presented should not be used as material or lubricant allowables or as recommendations for micro-geometry in real applications when applying this procedure. The necessary parameters and allowable film thickness values, $\lambda_{GFP}$, should be determined for a given application in accordance with the procedures defined in ISO/TR 15144-1.

## 2 Normative references

The following documents, in whole or in part, are normatively referenced in this document and are indispensable for its application. For dated references, only the edition cited applies. For undated references, the latest edition of the referenced document (including any amendments) applies.



ISO 1122-1:1998, *Vocabulary of gear terms — Part 1: Definitions related to geometry*

ISO 6336-1:2006, *Calculation of load capacity of spur and helical gears — Part 1: Basic principles, introduction and general influence factors*



ISO 6336-2:2006, *Calculation of load capacity of spur and helical gears — Part 2: Calculation of surface durability (pitting)*

ISO 21771:2007, *Gears — Cylindrical involute gears and gear pairs — Concepts and geometry*

ISO/TR 15144-1:2014, *Calculation of micropitting load capacity of cylindrical spur and helical gears — Part 1: Introduction and basic principles*

## 3 Terms, definitions, symbols, and units

### 3.1 Terms and definitions

For the purpose of this document, the terms and definitions given in ISO 1122-1, ISO 6336-1, and ISO 6336-2 apply.

### 3.2 Symbols and units

The symbols used in this technical report are given in Table 1. The units of length metre, millimetre, and micrometre are chosen in accordance with common practice. The conversions of the units are already included in the given formulae.

**Table 1 — Symbols and units**

| Symbol | Description | Unit |
|---|---|---|
| $a$ | centre distance | mm |
| $B_{M1}$ | thermal contact coefficient of pinion | $N/(m \cdot s^{0,5} \cdot K)$ |
| $B_{M2}$ | thermal contact coefficient of wheel | $N/(m \cdot s^{0,5} \cdot K)$ |
| $b$ | face width | mm |
| $C_{a1}$ | tip relief of pinion | µm |
| $C_{a2}$ | tip relief of wheel | µm |
| $c_{M1}$ | specific heat per unit mass of pinion | J/(kg·K) |
| $c_{M2}$ | specific heat per unit mass of wheel | J/(kg·K) |
| $c'$ | maximum tooth stiffness per unit face width (single stiffness) of a tooth pair | N/(mm·µm) |
| $c_{\gamma\alpha}$ | mean value of mesh stiffness per unit face width | N/(mm·µm) |
| $d_{a1}$ | tip diameter of pinion | mm |
| $d_{a2}$ | tip diameter of wheel | mm |
| $d_{b1}$ | base diameter of pinion | mm |
| $d_{b2}$ | base diameter of wheel | mm |
| $d_{w1}$ | pitch diameter of pinion | mm |
| $d_{w2}$ | pitch diameter of wheel | mm |
| $d_{Y1}$ | Y-circle diameter of pinion | mm |
| $d_{Y2}$ | Y-circle diameter of wheel | mm |
| $E_r$ | reduced modulus of elasticity | $N/mm^2$ |
| $E_1$ | modulus of elasticity of pinion | $N/mm^2$ |
| $E_2$ | modulus of elasticity of wheel | $N/mm^2$ |
| $F_{bt}$ | nominal transverse load in plane of action (base tangent plane) | N |
| $F_t$ | (nominal) transverse tangential load at reference cylinder per mesh | N |
| $G_M$ | material parameter | - |
| $g_Y$ | parameter on the path of contact (distance of point Y from point A) | mm |
| $g_\alpha$ | length of path of contact | mm |
| $H_v$ | load losses factor | - |
| $h_Y$ | local lubricant film thickness | µm |
| $K_A$ | application factor | - |
| $K_{H\alpha}$ | transverse load factor | - |
| $K_{H\beta}$ | face load factor | - |
| $K_v$ | dynamic factor | - |
| $n_1$ | rotation speed of pinion | $min^{-1}$ |
| $P$ | transmitted power | kW |
| $p_{et}$ | transverse base pitch on the path of contact | Mm |
| $p_{dyn,Y}$ | local Hertzian contact stress including the load factors K | $N/mm^2$ |
| $p_{H,Y}$ | local nominal Hertzian contact stress | $N/mm^2$ |
| $Ra$ | effective arithmetic mean roughness value | µm |
| $Ra_1$ | arithmetic mean roughness value of pinion | µm |
| $Ra_2$ | arithmetic mean roughness value of wheel | µm |
| $S_{GF,Y}$ | local sliding parameter | - |

**Table 1** *(continued)*

| Symbol | Description | Unit |
|---|---|---|
| $S_{\lambda}$ | safety factor against micropitting | - |
| $S_{\lambda,min}$ | minimum required safety factor against micropitting | - |
| $T_1$ | nominal torque at the pinion | Nm |
| $U_Y$ | local velocity parameter | - |
| $u$ | gear ratio | - |
| $v_{g,Y}$ | local sliding velocity | m/s |
| $v_{r1,Y}$ | local tangential velocity on pinion | m/s |
| $v_{r2,Y}$ | local tangential velocity on wheel | m/s |
| $v_{\Sigma,C}$ | sum of tangential velocities at pitch point | m/s |
| $v_{\Sigma,Y}$ | sum of tangential velocities at point Y | m/s |
| $W_W$ | material factor | - |
| $W_Y$ | local load parameter | - |
| $X_{but,Y}$ | local buttressing factor | - |
| $X_{Ca}$ | tip relief factor | - |
| $X_L$ | lubricant factor | - |
| $X_R$ | roughness factor | - |
| $X_S$ | lubrication factor | - |
| $X_Y$ | local load sharing factor | - |
| $Z_E$ | elasticity factor | $(N/mm^2)^{0,5}$ |
| $z_1$ | number of teeth of pinion | - |
| $z_2$ | number of teeth of wheel | - |
| $\alpha_t$ | transverse pressure angle | ° |
| $\alpha_{wt}$ | pressure angle at the pitch cylinder | ° |
| $\alpha_{\theta B,Y}$ | pressure-viscosity coefficient at local contact temperature | $m^2/N$ |
| $\alpha_{\theta M}$ | pressure-viscosity coefficient at bulk temperature | $m^2/N$ |
| $\alpha_{38}$ | pressure-viscosity coefficient at 38 °C | $m^2/N$ |
| $\beta_b$ | base helix angle | ° |
| $\varepsilon_{max}$ | maximum addendum contact ratio | - |
| $\varepsilon_{\alpha}$ | transverse contact ratio | - |
| $\varepsilon_{\alpha n}$ | virtual transverse contact ratio | - |
| $\varepsilon_{\beta}$ | overlap ratio | - |
| $\varepsilon_{\gamma}$ | total contact ratio | - |
| $\varepsilon_1$ | addendum contact ratio of the pinion | - |
| $\varepsilon_2$ | addendum contact ratio of the wheel | - |
| $\eta_{\theta B,Y}$ | dynamic viscosity at local contact temperature | $N{\cdot}s/m^2$ |
| $\eta_{\theta M}$ | dynamic viscosity at bulk temperature | $N{\cdot}s/m^2$ |
| $\eta_{\theta oil}$ | dynamic viscosity at oil inlet/sump temperature | $N{\cdot}s/m^2$ |
| $\eta_{38}$ | dynamic viscosity at 38 °C | $N{\cdot}s/m^2$ |
| $\theta_{B,Y}$ | local contact temperature | °C |
| $\theta_{fl,Y}$ | local flash temperature | °C |
| $\theta_M$ | bulk temperature | °C |



**Table 1** *(continued)*

| Symbol | Description | Unit |
|---|---|---|
| $\theta_{oil}$ | oil inlet/sump temperature | °C |
| $\lambda_{GF,min}$ | minimum specific lubricant film thickness in the contact area | - |
| $\lambda_{GF,Y}$ | local specific lubricant film thickness | - |
| $\lambda_{GFP}$ | permissible specific lubricant film thickness | - |
| $\lambda_{GFT}$ | limiting specific lubricant film thickness of the test gears | - |
| $\lambda_{M1}$ | specific heat conductivity of pinion | W/(m·K) |
| $\lambda_{M2}$ | specific heat conductivity of wheel | W/(m·K) |
| $\mu_m$ | mean coefficient of friction | - |
| $\nu_{\theta B,Y}$ | kinematic viscosity at local contact temperature | $mm^2/s$ |
| $\nu_{\theta M}$ | kinematic viscosity at bulk temperature | $mm^2/s$ |
| $\nu_1$ | Poisson's ratio of pinion | - |
| $\nu_2$ | Poisson's ratio of wheel | - |
| $\nu_{100}$ | kinematic viscosity at 100 °C | $mm^2/s$ |
| $\nu_{40}$ | kinematic viscosity at 40 °C | $mm^2/s$ |
| $\rho_{M1}$ | density of pinion | $kg/m^3$ |
| $\rho_{M2}$ | density of wheel | $kg/m^3$ |
| $\rho_{n,C}$ | normal radius of relative curvature at pitch diameter | mm |
| $\rho_{n,Y}$ | normal radius of relative curvature at point Y | mm |
| $\rho_{t,Y}$ | transverse radius of relative curvature at point Y | mm |
| $\rho_{t1,Y}$ | transverse radius of curvature of pinion at point Y | mm |
| $\rho_{t2,Y}$ | transverse radius of curvature of wheel at point Y | mm |
| $\rho_{\theta B,Y}$ | density of lubricant at local contact temperature | $kg/m^3$ |
| $\rho_{\theta M}$ | density of lubricant at bulk temperature | $kg/m^3$ |
| $\rho_{15}$ | density of lubricant at 15 °C | $kg/m^3$ |
| **Subscripts to symbols** | | |
| Y | Parameter for any contact point Y in the contact area for method A and on the path of contact for method B (all parameters subscript Y has to be calculated with local values). | |



## 4 Example calculation

The following presents examples for the calculation of the safety factor against micropitting, $S_\lambda$. Each example is first calculated according to method B and examples 1, 3, and 4 subsequently calculated according to method A. The calculation sequence for method B has been provided to follow a logical approach in relation to the input data. Beside the formulae itself, the formula numbers related to ISO/TR 15144-1 are given.

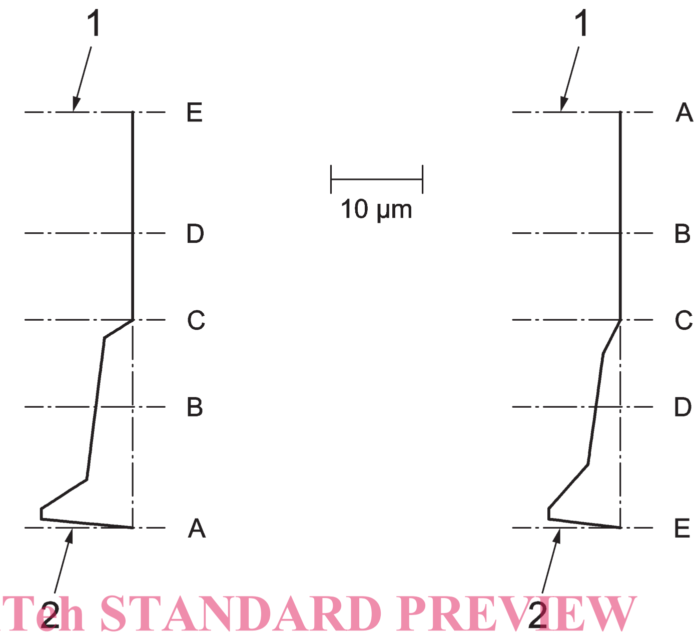
The examples calculate the safety factor $S_\lambda$ of a specific gear set when compared to an allowable $\lambda_{GFP}$ value. For the examples 1, 2, and 4, the permissible specific oil film thickness, $\lambda_{GFP}$, was determined from the test result of the lubricant in the FZG-FVA micropitting test.[1] For these calculations medium values for the standard FZG back-to-back test rig and standard test conditions for $K_{H\beta}$ and $K_v$ were used ($K_{H\beta}$ = 1,10 and $K_v$ = 1,05). The calculation of the $\lambda_{GFP}$ value from the test result of the FZG-FVA micropitting test[1] (method B) is shown exemplary on the basis of the first example. For example 3, the permissible specific oil film thickness, $\lambda_{GFP}$, was determined from a bench test.

NOTE The calculations were performed computer-based. If the calculations are performed manually, small differences between the results can appear.

## 4.1 Example 1 — Spur gear

The result of this example is confirmed by experimental investigations. The gears were obviously micropitted and had profile deviations of approximately 8 to 10 µm. Figure 1 shows a diagram of the observed location and severity of micropitting for pinion and wheel of example 1.






a) pinion b) wheel

**Key**

1 tip

2 root



**Figure 1 — Diagram of schematic profile deviations of pinion and wheel for example 1**

### 4.1.1 Input data

**Table 2 — Input data for Example 1**

| | Symbol | Description | Unit | Example 1 pinion | Example 1 wheel |
|---|---|---|---|---|---|
| | | | | comb. | |
| Geometry | $z$ | number of teeth | - | 18 | 18 |
| | - | driving gear | - | x | |
| | $m_n$ | normal module | mm | 10,93 | |
| | $\alpha_n$ | normal pressure angle | ° | 20 | |
| | $\beta$ | helix angle | ° | 0 | |
| | $b$ | face width | mm | 21,4 | |
| | $a$ | centre distance | mm | 200 | |
| | $x$ | addendum modification factor | - | 0,158 | 0,158 |
| | $d_a$ | tip diameter of pinion | mm | 221,4 | 221,4 |
| | - | tooth flank modifications | - | no modifications | |
| | $Q$ | gear quality | - | 5 | 5 |
| | $Ra$ | arithmetic mean roughness value | µm | 0,90 | 0,90 |
| Material | - | material | - | Eh | Eh |
| | $E$ | modulus of elasticity | N/mm² | 206 000 | 206 000 |
| | $\nu$ | Poisson’s ratio | - | 0,3 | 0,3 |
| | $\lambda_M$ | specific heat conductivity | W/(m·K) | 45 | 45 |
| | $c_M$ | specific heat per unit mass | J/(kg·K) | 440 | 440 |
| | $\rho_M$ | density | kg/m³ | 7 800 | 7 800 |
| | $W_W$ | material factor according to ISO/TR 15144-1:2014, Table A.1 (for matching case carburised/case carburised) | - | 1,0 | |
| Application | $K_A$ | application factor | - | 1,0 | |
| | $K_v$ | dynamic factor | - | 1,15 | |
| | $K_{H\alpha}$ | transverse load factor | - | 1,0 | |
| | $K_{H\beta}$ | face load factor | - | 1,10 | |
| Load | $T_1$ | nominal torque at the pinion | Nm | 1 878 | |
| | $n_1$ | rotation speed of the pinion | min⁻¹ | 3 000 | |
| Lubricant | $\theta_{oil}$ | oil inlet temperature (injection lubrication) | °C | 90 | |
| | $\nu_{40}$ | kinematic viscosity at 40 °C | mm²/s | 210 | |
| | $\nu_{100}$ | kinematic viscosity at 100 °C | mm²/s | 18,5 | |
| | $\rho_{15}$ | density of the lubricant at 15 °C | kg/m³ | 895 | |
| | - | oil type | - | mineral oil | |
| | - | failure load stage at test temperature (90 °C) according to FVA 54/7 | - | SKS 8 | |
| | $\lambda_{GFP}$ | permissible lubricant film thickness (see 4.1.4 for calculation) | - | 0,211 | |

### 4.1.2 Calculation according to method B

#### 4.1.2.1 Calculation of gear geometry (according to ISO 21771)

Basic values:

$$m_t = \frac{m_n}{\cos\beta}$$ $m_t$ = 10,93 mm

$$d_1 = z_1 \cdot m_t$$ $d_1$ = 196,74 mm

$$d_2 = z_2 \cdot m_t$$ $d_2$ = 196,74 mm

$$u = \frac{z_2}{z_1}$$ $u = 1$

$$\alpha_t = \arctan\left(\frac{\tan\alpha_n}{\cos\beta}\right)$$ $\alpha_t = 20\ °$

$$d_{b1} = d_1 \cos\alpha_t$$ $d_{b1}$ = 184,875 mm

$$d_{b2} = d_2 \cos\alpha_t$$ $d_{b2}$ = 184,875 mm



$$d_{w1} = \frac{2 \cdot a}{u+1}$$ $d_{w1}$ = 200 mm

$$d_{w2} = 2 \cdot a - d_{w1}$$ $d_{w2}$ = 200 mm



$$\alpha_{wt} = \arccos\left[\frac{(z_1 + z_2) \cdot m_t \cdot \cos\alpha_t}{2 \cdot a}\right]$$ $\alpha_{wt} = 22{,}426\ °$

$$\beta_b = \arcsin(\sin\beta \cdot \cos\alpha_n)$$ $\beta_b = 0\ °$ $\beta_b = 0\ °$

$$p_{et} = m_t \cdot \pi \cdot \cos\alpha_t$$ $p_{et}$ = 32,267 mm

$$\varepsilon_1 = \frac{z_1}{2 \cdot \pi} \cdot \left[\sqrt{\left(\frac{d_{a1}}{d_{b1}}\right)^2 - 1} - \tan\alpha_{wt}\right]$$ $\varepsilon_1 = 0{,}705$

$$\varepsilon_2 = \frac{z_2}{2 \cdot \pi} \cdot \left[\sqrt{\left(\frac{d_{a2}}{d_{b2}}\right)^2 - 1} - \tan\alpha_{wt}\right]$$ $\varepsilon_2 = 0{,}705$

$$\varepsilon_\alpha = \frac{1}{p_{et}} \cdot \left(\sqrt{\frac{{d_{a1}}^2}{4} - \frac{{d_{b1}}^2}{4}} + \sqrt{\frac{{d_{a2}}^2}{4} - \frac{{d_{b2}}^2}{4}} - a \cdot \sin\alpha_{wt}\right)$$ $\varepsilon_\alpha = 1{,}411$

$$\varepsilon_\beta = \frac{b \cdot \sin\beta}{m_n \cdot \pi}$$ $\varepsilon_\beta = 0$

$\varepsilon_\gamma = \varepsilon_\alpha + \varepsilon_\beta$ $\varepsilon_\gamma = 1{,}411$

$$g_\alpha = 0{,}5 \cdot \left( \sqrt{d_{a1}{}^2 - d_{b1}{}^2} + \sqrt{d_{a2}{}^2 - d_{b2}{}^2} \right) - a \cdot \sin\alpha_{wt}$$ $g_\alpha = 45{,}519$ mm

Coordinates of the basic points (A, AB, B, C, D, DE, E) on the line of action:

$$g_A = 0 \text{ mm} \qquad (34)$$ $g_A = 0$ mm

$$g_{AB} = \frac{g_\alpha - p_{et}}{2} \qquad (35)$$ $g_{AB} = 6{,}626$ mm

$$g_B = g_\alpha - p_{et} \qquad (36)$$ $g_B = 13{,}253$ mm

$$g_C = \frac{d_{b1}}{2} \cdot \tan\alpha_{wt} - \sqrt{\frac{d_{a1}{}^2}{4} - \frac{d_{b1}{}^2}{4}} + g_\alpha \qquad (37)$$ $g_C = 22{,}760$ mm

$$g_D = p_{et} \qquad (38)$$ $g_D = 32{,}267$ mm



$$g_{DE} = \frac{g_\alpha - p_{et}}{2} + p_{et} \qquad (39)$$ $g_{DE} = 38{,}893$ mm



$$g_E = g_\alpha \qquad (40)$$ $g_E = 45{,}519$ mm

$$d_{A1} = 2 \cdot \sqrt{\frac{d_{b1}{}^2}{4} + \left( \sqrt{\frac{d_{a1}{}^2}{4} - \frac{d_{b1}{}^2}{4}} - g_\alpha + g_A \right)^2} \qquad (41)$$ $d_{A1} = 187{,}419$ mm

$d_{AB1} = 190{,}046$ mm $d_{B1} = 193{,}546$ mm $d_{C1} = 200{,}000$ mm

$d_{D1} = 207{,}998$ mm $d_{DE1} = 214{,}394$ mm $d_{E1} = 221{,}400$ mm

$$d_{A2} = 2 \cdot \sqrt{\frac{d_{b2}{}^2}{4} + \left( \sqrt{\frac{d_{a2}{}^2}{4} - \frac{d_{b2}{}^2}{4}} - g_A \right)^2} \qquad (42)$$ $d_{A2} = 221{,}400$ mm

$d_{AB2} = 214{,}394$ mm $d_{B2} = 207{,}998$ mm $d_{C2} = 200{,}000$ mm

$d_{D2} = 193{,}546$ mm $d_{DE2} = 190{,} 046$ mm $d_{E2} = 187{,}419$ mm

Normal radius of relative curvature:

$$\rho_{n,A} = \frac{\rho_{t,A}}{\cos\beta_b} \qquad (45)$$ $\rho_{n,A} = 12{,}285$ mm

$\rho_{n,AB} = 15{,}663$ mm $\rho_{n,B} = 17{,}890$ mm $\rho_{n,C} = 19{,}074$ mm

$\rho_{n,D} = 17{,}890$ $\rho_{n,DE} = 15{,}663$ mm $\rho_{n,E} = 12{,}285$ mm

#### 4.1.2.2 Calculation of material data

$$E_r = 2 \cdot \left( \frac{1-\nu_1^2}{E_1} + \frac{1-\nu_2^2}{E_2} \right)^{-1} \quad (6) \qquad E_r = 226\,374\ \mathrm{N/mm^2}$$

$$B_{M1} = \sqrt{\lambda_{M1} \cdot \rho_{M1} \cdot c_{M1}} \quad (82) \qquad B_{M1} = 12\,427{,}4\ \mathrm{N/(ms^{0,5}K)}$$

$$B_{M2} = \sqrt{\lambda_{M2} \cdot \rho_{M2} \cdot c_{M2}} \quad (83) \qquad B_{M2} = 12\,427{,}4\ \mathrm{N/(ms^{0,5}K)}$$

#### 4.1.2.3 Calculation of operating conditions

Loading:

$$P = 2 \cdot \pi \cdot \frac{n_1}{60} \cdot \frac{T_1}{1\,000} \quad (85) \qquad P = 590\ \mathrm{kW}$$

$$F_t = 2\,000 \cdot \frac{T_1}{d_1} \qquad F_t = 19\,091\ \mathrm{N}$$

$$F_{bt} = 2\,000 \cdot \frac{T_1}{d_{b1}} \qquad F_{bt} = 20\,316\ \mathrm{N}$$



Local load sharing factor:



NOTE No tooth flank modifications, spur gears, gear quality ≤7 (see ISO/TR 15144-1:2014, Figure 2).

$$X_A = \frac{Q-2}{15} + \frac{1}{3} \cdot \frac{g_A}{g_B} \quad (46) \qquad X_A = 0{,}333$$

$X_{AB} = 0{,}500$ $X_B = 1{,}000$ $X_C = 1{,}000$

$X_D = 1{,}000$ $X_{DE} = 0{,}500$ $X_E = 0{,}333$

Elasticity factor:

$$Z_E = \sqrt{\frac{E_r}{2 \cdot \pi}} \quad (26) \qquad Z_E = 189{,}812\ (\mathrm{N/mm^2})^{0,5}$$

Local Hertzian contact stress:

$$p_{H,A,B} = Z_E \cdot \sqrt{\frac{F_t \cdot X_A}{b \cdot \rho_{n,A} \cdot \cos\alpha_t \cdot \cos\beta_b}} \quad (25) \qquad p_{H,A,B} = 963\ \mathrm{N/mm^2}$$

$p_{H,AB,B} = 1\,045\ \mathrm{N/mm^2}$ $p_{H,B,B} = 1\,383\ \mathrm{N/mm^2}$ $p_{H,C,B} = 1\,339\ \mathrm{N/mm^2}$

$p_{H,D,B} = 1\,383\ \mathrm{N/mm^2}$ $p_{H,DE,B} = 1\,045\ \mathrm{N/mm^2}$ $p_{H,E,B} = 963\ \mathrm{N/mm^2}$

$$p_{dyn,A,B} = p_{H,A,B} \cdot \sqrt{K_A \cdot K_V \cdot K_{H\alpha} \cdot K_{H\beta}} \quad (24) \qquad p_{dyn,A,B} = 1\,084\ \mathrm{N/mm^2}$$

$p_{dyn,AB,B} = 1\,175\ \mathrm{N/mm^2}$ $p_{dyn,B,B} = 1\,555\ \mathrm{N/mm^2}$ $p_{dyn,C,B} = 1\,506\ \mathrm{N/mm^2}$