

Specification for

Non-metallic spur gears

UDC 621.833.1 – 036

Confirmed
January 2011

NO COPYING WITHOUT BSI PERMISSION EXCEPT AS PERMITTED BY COPYRIGHT LAW



Document Sharing Hub

Committees responsible for this British Standard

The preparation of this British Standard was entrusted by the Machinery and Components Standards Committee (MCE/-) to Technical Committee MCE/5, upon which the following bodies were represented:

- Association of Consulting Engineers
- British Clock and Watch Manufacturers' Association
- British Coal
- British Gear Manufacturers' Association
- British Horological Institute
- British Railways Board
- Engineering Equipment and Materials Users' Association
- Federation of Manufacturers of Construction Equipment and Cranes
- Gauge and Tool Makers' Association
- Institution of Mechanical Engineers
- Institution of Production Engineers
- Lloyds Register of Shipping
- Machine Tool Industry Research Association
- Milling Cutter Association
- Ministry of Defence
- Society of Motor Manufacturers and Traders Limited

This British Standard, having been prepared under the direction of the Machinery and Components Standards Committee, was published under the authority of the Board of BSI and comes into effect on 31 March 1987

© BSI 04-2000

First published February 1982
First revision March 1987

The following BSI references relate to the work on this standard:
Committee reference MCE/5
Draft for comment 84/73218 DC

ISBN 0 580 15314 2

Amendments issued since publication

Amd. No.	Date of issue	Comments
6364	May 1991	Indicated by a sideline in the margin

Contents

	Page
Committees responsible	Inside front cover
Foreword	iv
1 Scope	1
2 Definitions and symbols	1
3 Basic rack tooth profile	3
4 Normal modules and normal diametral pitches	3
5 Fabrication	3
6 Accuracy	4
7 Measurement	5
8 Gear errors and tolerances	5
9 Hub and rim proportions	15
10 Allowances for thermal and hygroscopic expansion	16
11 Information to be given on drawings	17
Appendix A Materials	21
Appendix B Lubrication of plastics gears	22
Appendix C Tables of tolerance values	22
Appendix D Addendum modification	30
Appendix E Example calculations of maximum centre distance and total gear and housing expansion	32
Appendix F Recommended method for calculation of gear stresses	34
Figure 1 — Basic rack tooth profile for normal modules	4
Figure 2 — Limits of tip relief of modified basic rack tooth profile for normal modules	4
Figure 3 — Test loads	7
Figure 4 — Tolerance on cumulative tooth pitch error over k pitches F_{pk}	8
Figure 5 — Tolerance factor ϕ_p	9
Figure 6 — Adjacent pitch error (transverse) tolerance f_{pt}	9
Figure 7 — Radial run-out tolerance F_r	10
Figure 8 — Radial tooth-to-tooth composite error tolerance f_i''	11
Figure 9 — Radial composite error tolerance F_i''	11
Figure 10 — Radial indicator reading tolerance F_1	12
Figure 11 — Tolerance factor ϕ_f	13
Figure 12 — Tooth profile error tolerance f_f	14
Figure 13 — Tooth alignment tolerance on face width b , F_β	15
Figure 14 — Plastics moulding on metal hub	16
Figure 15 — Plastics moulding without hub	16
Figure 16 — Plastics moulding with hub	16
Figure 17 — Example of a typical drawing	18
Figure 18 — Thermal expansion rates	19
Figure 19 — Hygroscopic expansion rates	20
Figure 20 — Pinion with 10 teeth	32
Figure 21 — Tooth form factor Y_F as a function of number of teeth z for different values of addendum modification coefficient x	37
Figure 22 — Endurance limit for bending stress versus gear life (unlubricated PA 66)	38
Figure 23 — Endurance limit for bending stress versus gear life (unlubricated POM)	38

	Page
Figure 24 — Size factor Y_X as a function of gear module	39
Figure 25 — Young's modulus versus temperature	42
Figure 26 — Endurance limit for contact stress versus gear life (unlubricated PA 66)	43
Figure 27 — Endurance limit for contact stress versus gear life (unlubricated POM)	44
Table 1 — Normal modules	3
Table 2 — Normal diametral pitches	3
Table 3 — Gear errors and tolerances	6
Table 4 — Tolerance on cumulative tooth pitch error over a sector of k pitches (F_{pk}) or arc length L	6
Table 5 — Adjacent pitch error (transverse) tolerance f_{pt}	6
Table 6 — Radial run-out tolerance F_r	10
Table 7 — Radial tooth-to-tooth composite error tolerance f_i''	10
Table 8 — Radial composite error tolerance F_i''	10
Table 9 — Radial indicator reading tolerance F_1	12
Table 10 — Tooth profile error tolerance f_f	13
Table 11 — Tooth alignment error tolerance on face width b , F_β	14
Table 12 — Centre distance error tolerance f_a	14
Table 13 — Gear blanks tolerances	15
Table 14(a) — Cumulative tooth pitch error tolerance F_{pk} (metric units)	22
Table 14(b) — Cumulative tooth pitch error tolerance F_{pk} (imperial units)	23
Table 15(a) — Adjacent pitch error (transverse) tolerance f_{pt} (metric units)	23
Table 15(b) — Adjacent pitch error (transverse) tolerance f_{pt} (imperial units)	24
Table 16(a) — Radial run-out tolerance F_r (metric units)	24
Table 16(b) — Radial run-out tolerance F_r (imperial units)	25
Table 17(a) — Radial tooth-to-tooth composite error tolerance f_i'' (metric units)	25
Table 17(b) — Radial tooth-to-tooth composite error tolerance f_i'' (imperial units)	26
Table 18(a) — Radial composite error tolerance F_i'' (metric units)	26
Table 18(b) — Radial composite error tolerance F_i'' (imperial units)	27
Table 19(a) — Radial indicator reading tolerance F_1 (metric units)	27
Table 19(b) — Radial indicator reading tolerance F_1 (imperial units)	28
Table 20(a) — Tooth profile error tolerance f_f (metric units)	28
Table 20(b) — Tooth profile error tolerance f_f (imperial units)	29
Table 21(a) — Tooth alignment error tolerance F_β (metric units)	29
Table 21(b) — Tooth alignment error tolerance F_β (imperial units)	29
Table 22(a) — Tolerances on radial and axial run-out of reference surfaces of wheel blanks (metric units)	30
Table 22(b) — Tolerances on radial and axial run-out of reference surfaces of wheel blanks (imperial units)	30
Table 23(a) — Values of IT (metric units)	30
Table 23(b) — Values of IT (imperial units)	30
Table 24 — Coefficient of friction μ	35
Table 25 — Dimensionless experimental factor K_a	35

	Page
Table 26 — Correction coefficient K_b	36
Table 27 — Gear material constant K_M	36
Table 28 — Maximum bulk temperature for non-metallic materials for continuous operation	36
Table 29 — Application factor K_A for speed reducing gears	37
Table 30 — Poisson's ratio	40
Publications referred to	Inside back cover

Foreword

The revision of BS 6168 has been prepared under the direction of the Machinery and Components Standards Committee. The main change incorporated is the addition of an Appendix F to give recommendations on the limiting contact and bending stresses of non-metallic gears for general engineering applications. This appendix is for information only and does not form part of this standard.

The information presented in Appendix F on the limiting contact and bending stresses of non-metallic gears is tentative. It is proposed to confirm the validity of the stressing formulae and failure data and to extend the range of non-metallic material for which accurate gear stressing is required. It is intended that the results of this work should be embodied in a future revision of BS 6168.

Certain quantities are expressed in both metric (SI) units and imperial units, the latter being given in recognition of the continuing demand for replacement gears manufactured to imperial dimensions. The retention of imperial units will be subject to review at the appropriate time.

This standard supersedes BS 6168:1982, which is withdrawn.

A British Standard does not purport to include all the necessary provisions of a contract. Users of British Standards are responsible for their correct application.

Compliance with a British Standard does not of itself confer immunity from legal obligations.

Summary of pages

This document comprises a front cover, an inside front cover, pages i to iv, pages 1 to 46, an inside back cover and a back cover.

This standard has been updated (see copyright date) and may have had amendments incorporated. This will be indicated in the amendment table on the inside front cover.

1 Scope

This British Standard specifies dimensional, accuracy and material requirements for spur gears made from non-metallic materials in pitch sizes of 0.50 module to 50 module (48 to 0.50 diametral pitch) and also gives guidance on lubrication and lists information to be given on drawings. The ranges of modules and diametral pitches employed include those specified in BS 436-1 and BS 436-2. The basic tooth form and the accuracy grades specified are selected from those specified in BS 436-1 and BS 436-2. Helical gears are not within the scope of this standard.

Surface finish requirements for thermoplastics gears are not specified in this standard as insufficient authoritative data on the subject exists at present.

NOTE 1 Information on the selection of materials and the lubrication of plastics gears is given in Appendix A and Appendix B, respectively. Tables of tolerance values are given in Appendix C. Recommendations for addendum modification and a recommended method of gear stressing are given in Appendix D and Appendix F. Example calculations are given in Appendix E and Appendix F.

NOTE 2 The titles of the publications referred to in this standard are listed on the inside back cover.

2 Definitions and symbols

2.1 Definitions

For the purposes of this British Standard, the definitions given in BS 2519-1 and PD 6457 apply.

2.2 Symbols

For the purposes of this British Standard, the following symbols apply.

NOTE This subclause is based on the symbols of BS 2519-2:1976.

Symbol	Designation	Imperial SI units units	
a	centre distance (theoretical)	in	mm
a_{ext}	centre distance (extension)	in	mm
a_{th}	centre distance thermal expansion	in	mm
a_{w}	centre distance (operating)	in	mm
b	facewidth	in	mm
d	reference diameter	in	mm
d_1	reference diameter of pinion	in	mm
d_2	reference diameter of wheel	in	mm
d_{a}	tip diameter	in	mm
e	spacewidth	in	mm
f_{a}	centre distance tolerance	in	μm

Symbol	Designation	Imperial SI units units	
f_{f}	profile error tolerance (maximum of pinion and wheel)	in	μm
f_{i}''	radial tooth-to-tooth composite error tolerance (dual flank)	in	μm
f_{pb}	normal individual base pitch error tolerance	in	μm
f_{pn}	adjacent pitch error tolerance (normal)	in	μm
f_{pt}	adjacent pitch error (transverse) tolerance	in	μm
f_{x}	axes parallelism error (inclination) tolerance	in	μm
f_{y}	axes parallelism error (deviation) tolerance	in	μm
h_{a}	dedendum	in	mm
h_{a0}	addendum of basic rack	in	mm
k	number of tooth pitches	—	—
m	module	—	mm
m_{n}	normal module	—	mm
n	rotational speed	min ⁻¹	min ⁻¹
r	radius	in	mm
r_{a}	tip radius	in	mm
r_{b}	base circle radius	in	mm
r_{hy}	radial hydroscopic expansion	in	mm
r_{th}	radial thermal expansion	in	mm
r_{tot1}	total pinion radial expansion	in	mm
r_{tot2}	total wheel radial expansion	in	mm
s	tooth thickness	in	mm
u	gear ratio	—	—
v	pitch line velocity	—	m/s
x	addendum modification coefficient	—	—
z	number of teeth	—	—
A	surface area of gearbox	in ²	m ²
E	Young's modulus of elasticity	—	GPa
F_{i}''	radial composite error tolerance (dual flank)	in	μm
F_{l}	radial indicator reading tolerance (width of tolerance band)	in	μm
F_{p}	total cumulative pitch error tolerance	in	μm
F_{pk}	tolerance on cumulative pitch error over k pitches	in	μm
F_{r}	radial tooth run-out tolerance	in	μm

Symbol	Designation	Imperial units	SI units	Symbol	Designation	Imperial units	SI units
F_t	nominal tangential force at reference circle	—	N	θ_2	temperature of wheel (surface and bulk)	—	°C
F_β	tooth alignment error tolerance on facewidth b	in	μm	μ	coefficient of friction	—	—
IT	tolerance grade value	in	mm	ν	Poisson's ratio	—	—
K_A	application factor	—	—	ρ_{a0}	tip radius of tool	in	mm
K_a	experimental factor for material temperature	—	—	σ_F	actual tooth root bending stress	—	MN/m ²
K_b	correction coefficient for material temperature	—	(m ² · °C)/W	$\sigma_{F \text{ lim}}$	endurance limit for bending stress for gears	—	MN/m ²
K_M	gear material constant	—	—	σ_H	actual contact stress (Hertzian pressure)	—	MN/m ²
L	length of arc round gear	in	mm	$\sigma_{H \text{ lim}}$	endurance limit for contact stress for gears	—	MN/m ²
P	diametral pitch	in ⁻¹	mm ⁻¹	ϕ_f	tolerance factor (adjacent pitch error)	—	—
P_n	normal diametral pitch	in ⁻¹	mm ⁻¹	ϕ_p	tolerance factor (profile)	—	—
P_T	transmitted power	—	kW	Δ_{hy}	hygroscopic expansion factor	—	—
R_a	arithmetic average roughness (CLA value)	—	—	Δ_{th}	thermal expansion factor	—	—
S	safety factor	—	—	ν	surface tension	—	N/M
S_F	actual safety factor for bending stress (against breakage)	—	—	Suffixes			
T	torque	—	N m	1	pinion		
T_1	pinion torque	—	N m	2	wheel		
T_2	wheel torque	—	N m	max	maximum		
Y	factor for bending stress	—	—	min	minimum		
Y_F	tooth form factor for bending stress	—	—	insp	inspected size or value		
Y_ϵ	contact ratio factor for bending stress	—	—	hy	hygroscopic expansion		
Y_x	size factor for bending stress	—	—	th	thermal expansion		
Z	factor for contact stress	—	—	tot	total		
Z_E	elasticity factor for contact stress	—	—	2.3 Material notation			
Z_ϵ	contact ratio factor for contact stress	—	—	for the purposes of this British Standard the following notation applies.			
Z_H	zone factor for Hertzian pressure at pitch point for contact stress	—	—	Notation	Chemical name	Common names	
α	pressure angle of basic rack	degree	degree	PA 6	Polyamide	Nylon	
α_t	transverse pressure angle at reference cylinder	degree	degree	PA 11			
α_w	pressure angle of operation	degree	degree	PA 12			
β	helix angle at reference cylinder	degree	degree	PA 66			
ϵ_α	transverse contact ratio	—	—	PBT	Polybutylene terephthalate	Thermoplastic polyester	
θ_0	initial temperature of gears	—	°C	PET	Polyethylene terephthalate	Thermoplastic polyester	
θ_1	temperature of pinion (surface and bulk)	—	°C	POM	Polyoxymethylene	Acetal	
				UHMWPE	Ultra-high molecular weight polyethylene	—	

NOTE For convenience, these notations have been used, as appropriate, in graphs and stress calculations. For other materials for use in gears see Appendix A.

3 Basic rack tooth profile

The basic rack tooth profile shall comply with the requirements of BS 436-1 and BS 436-2, see Figure 1.

In practice, the basic rack is usually modified but the extent of modification shall be in accordance with the following requirements.

- a) Variation of the root radius shall be within the limits $0.38m$ to $0.45m$.

NOTE Values of root radius within these limits may be employed, conditions of meshing permitting, without alteration to the total depth of tooth.

- b) For maximum tooth strength, the root radius shall be $0.38m$.

- c) Application of tip relief shall be within the limits shown in Figure 2.

4 Normal modules and normal diametral pitches

Normal modules and normal diametral pitches shall be selected from the values given in Table 1 and Table 2, respectively. Where possible, selection shall be made from the values given in column 1.

NOTE The values in Table 1 and Table 2 include the values given in BS 436-1 and BS 436-2, with additional values below 1 module (see Table 1) and above 20 diametral pitch (see Table 2).

Table 1 — Normal modules

1	2
Normal module m_n	
Preferred modules	Second choice modules
mm	mm
0.50	
0.60	
0.80	0.70
1	0.90
1.25	1.125
1.50	1.375
2	1.75
2.50	2.25
3	2.75
4	3.50
5	4.50
6	5.50
	6.50
8	
10	7
12	9
16	11
20	14
25	18
32	22
40	28
50	36
	45

Table 2 — Normal diametral pitches

1	2
Normal diametral pitch P_n	
Preferred diametral pitches	Second choice diametral pitches
in	in
48	
40	
32	36
24	28
20	
16	18
12	14
10	11
8	9
6	7
5	5.50
4	4.50
3	3.50
2.50	2.75
2	2.25
1.50	1.75
1.25	
1	0.875
0.75	
0.625	
0.50	

5 Fabrication

5.1 Moulded gears

Moulded gears shall be free from defects such as:

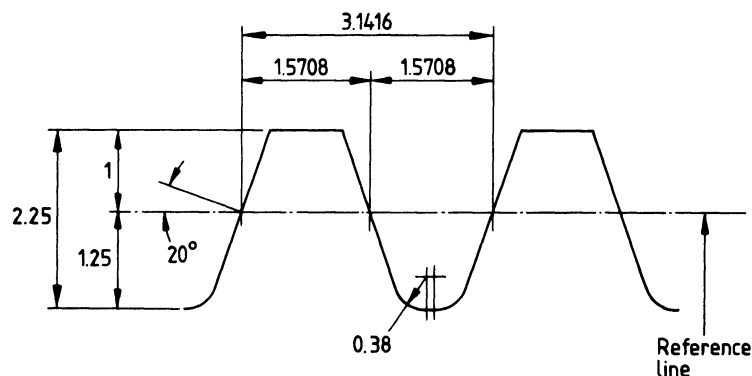
- weld lines on the surface;
- voids within the body of the moulding;
- flow lines;
- burn marks;
- sink marks.

NOTE 1 The design of tooling and the moulding conditions employed can have a significant effect on the life of moulded gears. The purchaser should, therefore, discuss with the moulder any defects which could arise and affect gear performance. Methods are not currently available for quantifying all such defects.

NOTE 2 The moulder should seek advice from the material supplier regarding moulding techniques.

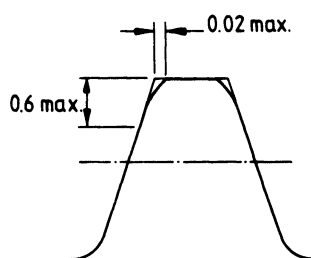
5.2 Cut thermoplastics gears

Thermoplastics gears cut from semi-finished plastics rod and sheet shall be free from the defects listed in 5.1.



All linear dimensions are in millimetres.

Figure 1 — Basic rack tooth profile for normal modules



All dimensions are in millimetres.

Figure 2 — Limits of tip relief of modified basic rack tooth profile for normal modules

5.3 Phenolic fabric gears

To ensure that the plane of shear stress in the gear tooth is not co-planar with the laminated layer, phenolic fabric gears shall be cut from laminated sheets and not from laminated-rolled and moulded rods.

6 Accuracy

6.1 Housing alignment

The gear housing alignment shall be such that the loading across the tooth face is within the specified limits of the grade chosen. Additionally, the large coefficient of thermal expansion of some plastics and the hygroscopic expansion of others shall be taken into account (see clause 10).

NOTE 1 The position of "gates" on injection moulded glass reinforced materials has a significant effect on the dimensional accuracy of the mould materials.

NOTE 2 It should be noted that excessive thinning of gear teeth below that of the rack form could result in a significant reduction of the calculated load carrying capacity (see D.5).

6.2 Grades of gears

The four grades of accuracy of gears shall be grades 6, 8, 10 and 12 of BS 436-1 and BS 436-2. The coarsest grade compatible with the duty required shall be chosen.

NOTE 1 See 7.3 regarding tip interference when dual flank testing of coarser grades is carried out.

NOTE 2 Grade 12 is the coarsest grade specified in this standard. If this grade is used for any tooth size less than 1 module (24 diametral pitch), the contact ratio may fall below an acceptable minimum of 1.2 for minimum material conditions (see E.1 for a worked example of a 0.6 module pinion of grade 8 meshing with a grade 8 wheel).

NOTE 3 Grade 10 is suitable for commercially moulded plastics gears. Poor contact ratio should be checked for the finer pitches [less than 1 module (24 diametral pitch)].

NOTE 4 Grade 8 is suitable for good quality moulded plastics gears and most normal applications. A satisfactory contact ratio is usually obtainable for all tooth sizes (with standard addendum modifications below 17 teeth).

NOTE 5 Grade 6 should only be used where extreme accuracy is justified. Asymmetrical cams, ribs or other departures from plain cylindrical shapes (even "D" holes in small gears) can cause eccentricity beyond the limits of this grade.

6.3 Transverse contact ratio

As the transverse contact ratio will vary according to the centre distance, tip diameter and run-out tolerances allowed within the chosen grade, two conditions defining the worst and best contact ratio, i.e. the length of the contact along the line of action divided by the base pitch, shall be calculated from the minimum material/maximum centre distance and maximum material/minimum centre distance conditions respectively, using the following equation:

$$\epsilon_{\alpha} = \frac{\sqrt{(r_{a1}^2 - r_{b1}^2)} + \sqrt{(r_{a2}^2 - r_{b2}^2)} - a_w \sin \alpha_w}{\pi m \cos \alpha_t} \quad (1)$$

where

$$\alpha_w = \cos^{-1} \left(\frac{a \cos \alpha_t}{a_w} \right) \quad (2a)$$

in which

$$a_w = \frac{1}{2} m (z_1 + z_2) \quad (2b)$$

The tip radius to be used shall be calculated as the minimum/maximum theoretical value less half the tip run-out tolerance, i.e. $r_a - IT \text{ value}^{1)/2}$.

The base diameter, ignoring correction, shall be calculated as:

$$z m \cos \alpha \quad (3)$$

The centre distance used shall be the minimum/maximum value with due allowance for expansion or contraction of the gear support frame or housing.

NOTE For example calculation of maximum centre distance see E.1.

7 Measurement

7.1 Measurement methods

The gear accuracy (see 6.2) shall be verified by a recognized test method, e.g.:

- a) dual flank checks;
- b) single flank checks;
- c) size over pin checks;
- d) base tangent measurements.

NOTE Dual flank rolling checks and size over pin checks are most common for non-metallic gears.

7.2 Pin measurements

The basic pitch diameter shall be checked by a recognized test method, e.g. by checking of the size over pins lodged at or around the pitch line of opposite gear teeth, to establish basic pitch diameter measurements.

NOTE Van Keuren tables provide the basic data for these checks to be carried out using standardized checking pin diameters.

This method does not however give any guide as to the gear pitch circle diameter radial run-out, which shall be checked by a recognized method, e.g. by an additional check upon a gear mounted about its axis with a gauge pin between each successive pair of teeth and a height comparator to check the pin radius that will enable radial run-out errors to be determined.

7.3 Dual flank rolling check

7.3.1 General. For coarser grades of gear, the master gear teeth tip radii and the test gear teeth shall be compatible as bottoming of the tips of the master gear teeth into the roots of the non-metallic gear under test can otherwise occur, giving rise to erroneous measurements.

7.3.2 Test loads. Test loads for use when checking non-metallic gears with a gear tooth face width of 25 mm shall be as shown in Figure 3. Test loads for other face widths shall be in direct proportion to the alteration in face width from 25 mm, e.g. if the face width employed is 12.5 mm, the values in Figure 3 shall be halved.

NOTE 1 The dual flank rolling check provides a ready method of determining gear tooth quality and size. Due to the greater flexibility of non-metallic gear materials, reduced test loads between the master gear or worm and the gear under test should be used compared to those used for metallic materials.

NOTE 2 In certain circumstances, e.g. to avoid or reduce distortion of the gear under test, it may be necessary, by agreement between the supplier and the customer, to deviate from the values specified in Figure 3.

8 Gear errors and tolerances

8.1 Tolerances

The tolerances specified in this standard for control of errors in gear elements shall be appropriate to the grades of gear selected (see 6.2) and the values of tolerance shall be in accordance with 8.4 to 8.15.

For ease of reference, the numerical values of tolerance are shown in tabular form in Appendix C and these values shall take precedence over any values obtained by direct application of the formulae specified in 8.4 to 8.15.

NOTE For values of m from 0.50 module to 1.0 module (48 diametral pitch to 24 diametral pitch) only, the tolerance values in the tables in Appendix A have been extrapolated using the Renard R20 series.

8.2 Gear errors

The gear errors given in Table 3 shall be checked.

8.3 Accuracy

The accuracy grades associated with each gear element shall be in accordance with BS 436-2.

8.4 Cumulative tooth pitch error

8.4.1 The tolerance on cumulative tooth pitch error over a sector of k pitches (F_{pk}) or arc length L where L (in mm) = $k\pi m$ or L (in in) = $k\pi/P$, shall be as given in Table 4 and shown in Figure 4.

¹⁾ See Table 13.

The maximum admissible cumulative error on any length of arc $L = k$ pitches or of any number k of pitches ($L_{\max} = \frac{1}{2}$ circumference) shall be determined in accordance with Table 4 and Figure 4. The grade of teeth shall be determined by the most unfavourable sector.

The numerical values of tolerance given in Table 14(a) and Table 14(b) shall take precedence over any values obtained by direct application of the formulae given in Table 4.

8.4.2 The total cumulative pitch error tolerance F_p is equal to F_{pk} for $L = \frac{1}{2}$ circumference (i.e. $k = z/2$) [see Table 14(a) and Table 14(b)].

Table 3 — Gear errors and tolerances

Errors to be checked		Tolerances
Teeth	Adjacent pitch error:	
	transverse	$\pm f_{pt}$
	normal	$\pm f_{pn}$
	Normal individual base pitch error	$\pm f_{pb}$
	Cumulative tooth pitch error over a sector of k pitches	F_{pk}
	Total cumulative pitch error	F_p
	Radial run-out	$\pm F_r$
	Profile error (max. of pinion and wheel)	f_f
Gear pair	Tooth alignment error	F_β
	Radial composite error	$F_{I''}$
	Radial tooth-to-tooth composite error	$f_{I''}$
	Radial indicator reading	F_I
	Centre distance error	$\pm f_a$
	Inclination error	f_x
	Deviation error	f_y

NOTE Generally, the elements of a pair of mating gears are of identical grades but, by agreement between the purchaser and the manufacturer, a finer or coarser grade of accuracy may be adopted for one or more elements (e.g. because of the statistical character of the values given in the formulae and the relative importance of their possible variation depending on the manufacturing process) but with the reservation that, for the gear elements in the following groups, the accuracy grades for all elements in any one group should be identical.

- a) Group 1: F_{pk} , F_p , F_r , $F_{I''}$.
b) Group 2: f_{pt} , f_{pn} , f_{pb} , $f_{I''}$.
c) Group 3: F_β , f_x , f_y .

Table 4 — Tolerance on cumulative tooth pitch error over a sector of k pitches (F_{pk}) or arc length L

Accuracy grade	Cumulative tooth pitch error tolerance F_{pk}	
	(where L is in mm)	(where L is in in)
	μm	10^{-3} in
6	$2.5 \sqrt{L} + 6.3$	$0.50 \sqrt{L} + 0.25$
8	$5 \sqrt{L} + 12.5$	$1 \sqrt{L} + 0.5$
10	$10 \sqrt{L} + 25$	$2 \sqrt{L} + 1$
12	$20 \sqrt{L} + 50$	$4 \sqrt{L} + 2$

8.5 Adjacent pitch error

8.5.1 Tolerance factor. Adjacent pitch error is related to a tolerance factor ϕ_p , values of which are shown in Figure 5, which shall be calculated using the following equations.

a) In metric units:

$$\phi_p = m + 0.25 \sqrt{d} \quad (4a)$$

b) In imperial units:

$$\phi_p = \frac{25.4}{P} + 1.25 \sqrt{d} \quad (4b)$$

8.5.2 Adjacent pitch error (transverse). The adjacent pitch error (transverse) tolerance f_{pt} (+ or -) shall be as given in Table 5 and shown in Figure 6. The value to retain for f_{pt} shall be the smaller of the two values from Table 5 or Table 4 for L equal to one pitch (equal to πm or π/P).

The numerical values of tolerance given in Table 15(a) and Table 15(b) shall take precedence over any values obtained by direct application of the formulae given in Table 5.

8.5.3 Adjacent pitch error (normal). The adjacent pitch error (normal) tolerance f_{pn} shall be calculated from the following equation

$$f_{pn} (+ \text{ or } -) = f_{pt} \cos \beta \quad (5)$$

Table 5 — Adjacent pitch error (transverse) tolerance f_{pt}

Accuracy grade	Adjacent pitch error (transverse) tolerance f_{pt} (+ or -)	
	μm	10^{-3} in
6	$0.63 \phi_p + 8$	$0.025 \phi_p + 0.315$
8	$1.25 \phi_p + 16$	$0.050 \phi_p + 0.63$
10	$2.5 \phi_p + 31.5$	$0.10 \phi_p + 1.25$
12	$5 \phi_p + 63$	$0.20 \phi_p + 2.5$

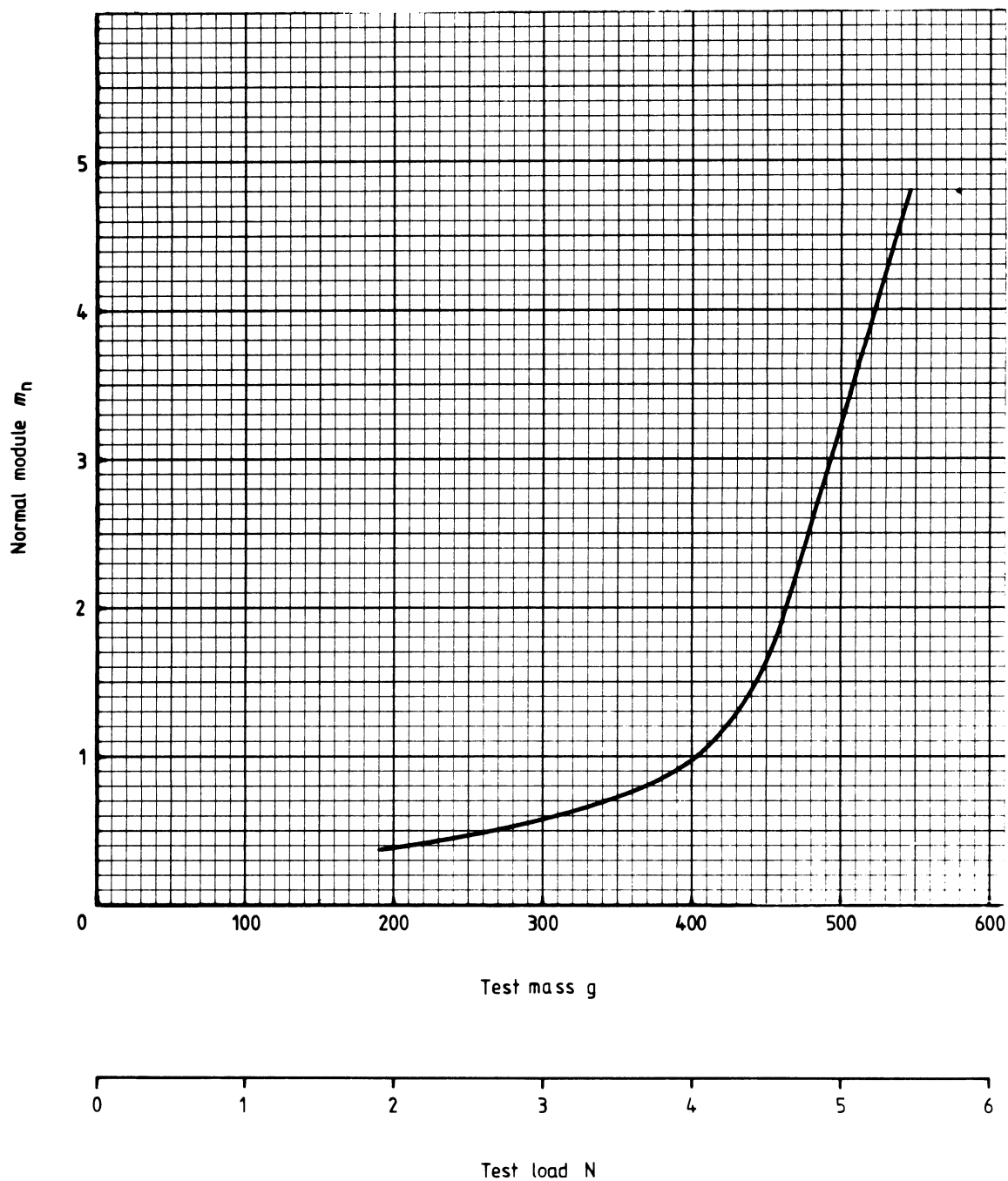


Figure 3 — Test loads

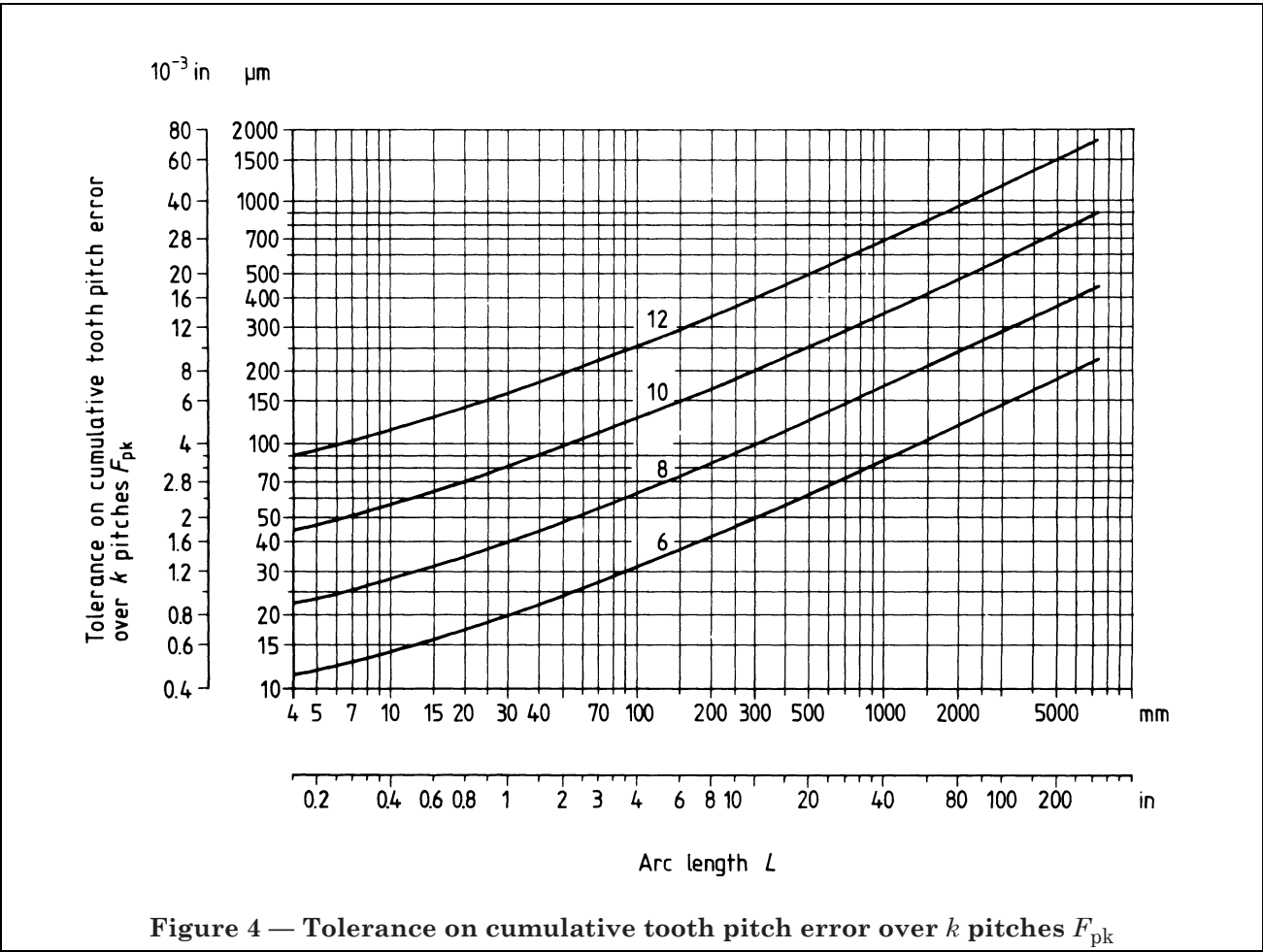
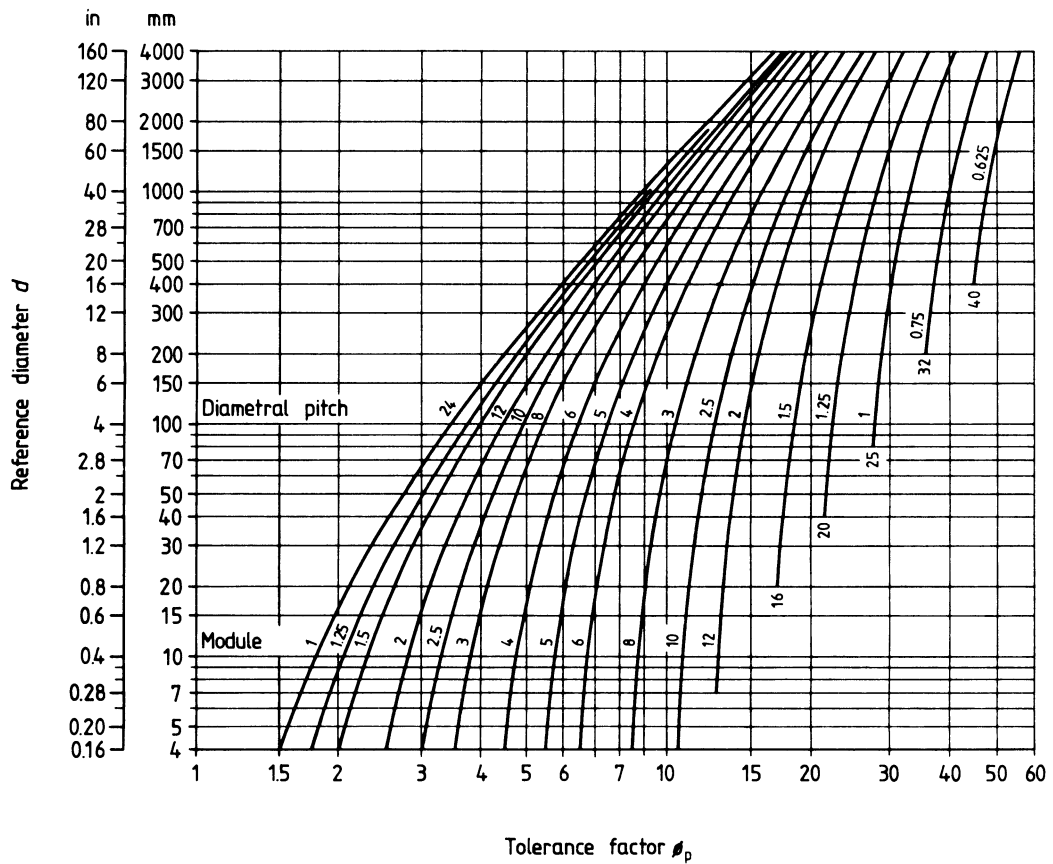
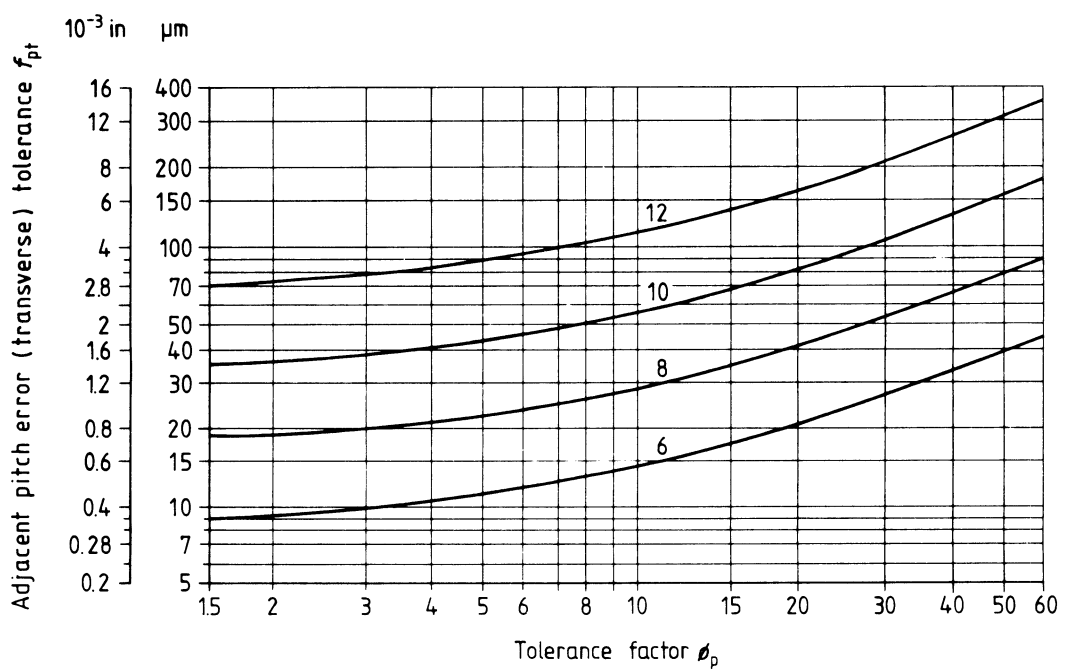


Figure 4 — Tolerance on cumulative tooth pitch error over k pitches F_{pk}

Figure 5 — Tolerance factor ϕ_p Figure 6 — Adjacent pitch error (transverse) tolerance f_{pt}

8.6 Normal base pitch error

The normal base pitch error tolerance f_{pb} (+ or -) shall be calculated from the following equation:

$$f_{pb} \text{ (+ or -)} = f_{pt} \cos\alpha \tag{6}$$

NOTE In practice, f_{pb} does not differ appreciably from f_{pn} .

8.7 Radial run-out

The radial run-out tolerance F_r (+ or -), as measured by an indicator on a pin resting in tooth spaces around a gear mounted on a fixed arbor, shall be as given in Table 6 and Figure 7. Numerical values of tolerance given in Table 16(a) and Table 16(b) shall take precedence over any values obtained by direct application of the formulae given in Table 6.

Table 6 — Radial run-out tolerance F_r

Accuracy grade	Radial run-out tolerance F_r (+ or -)	
	μm	10^{-3} in
6	$2.24 \phi_p + 28$	$0.090 \phi_p + 1.12$
8	$4 \phi_p + 50$	$0.16 \phi_p + 2.0$
10	$6.3 \phi_p + 80$	$0.25 \phi_p + 3.15$
12	$10 \phi_p + 125$	$0.40 \phi_p + 5$

8.8 Radial tooth-to-tooth composite error

The radial tooth-to-tooth composite error tolerance f_i'' , as measured by the dual flank or single flank rolling tests, shall be as given in Table 7 and shown in Figure 8. The numerical values of tolerance given in Table 17(a) and Table 17(b) shall take precedence over any values obtained by direct application of the formulae given in Table 7.

Table 7 — Radial tooth-to-tooth composite error tolerance f_i''

Accuracy grade	Radial tooth-to-tooth composite error tolerance f_i''	
	μm	10^{-3} in
6	$0.9 \phi_p + 11.2$	$0.0355 \phi_p + 0.45$
8	$1.8 \phi_p + 22.4$	$0.071 \phi_p + 0.9$
10	$2.8 \phi_p + 35.5$	$0.112 \phi_p + 1.4$
12	$4.5 \phi_p + 56$	$0.18 \phi_p + 2.24$

8.9 Radial composite error

The radial composite error tolerance F_i'' , as measured by the dual flank or single flank rolling tests, shall be as given in Table 8 and shown in Figure 9. The numerical values of tolerance given in Table 18(a) and Table 18(b) shall take precedence over any values obtained by direct application of the formulae given in Table 8.

Table 8 — Radial composite error tolerance F_i''

Accuracy grade	Radial composite error tolerance F_i''	
	μm	10^{-3} in
6	$3.15 \phi_p + 40$	$0.125 \phi_p + 1.6$
8	$5.6 \phi_p + 71$	$0.224 \phi_p + 2.8$
10	$9 \phi_p + 112$	$0.355 \phi_p + 4.5$
12	$14 \phi_p + 180$	$0.56 \phi_p + 7.1$

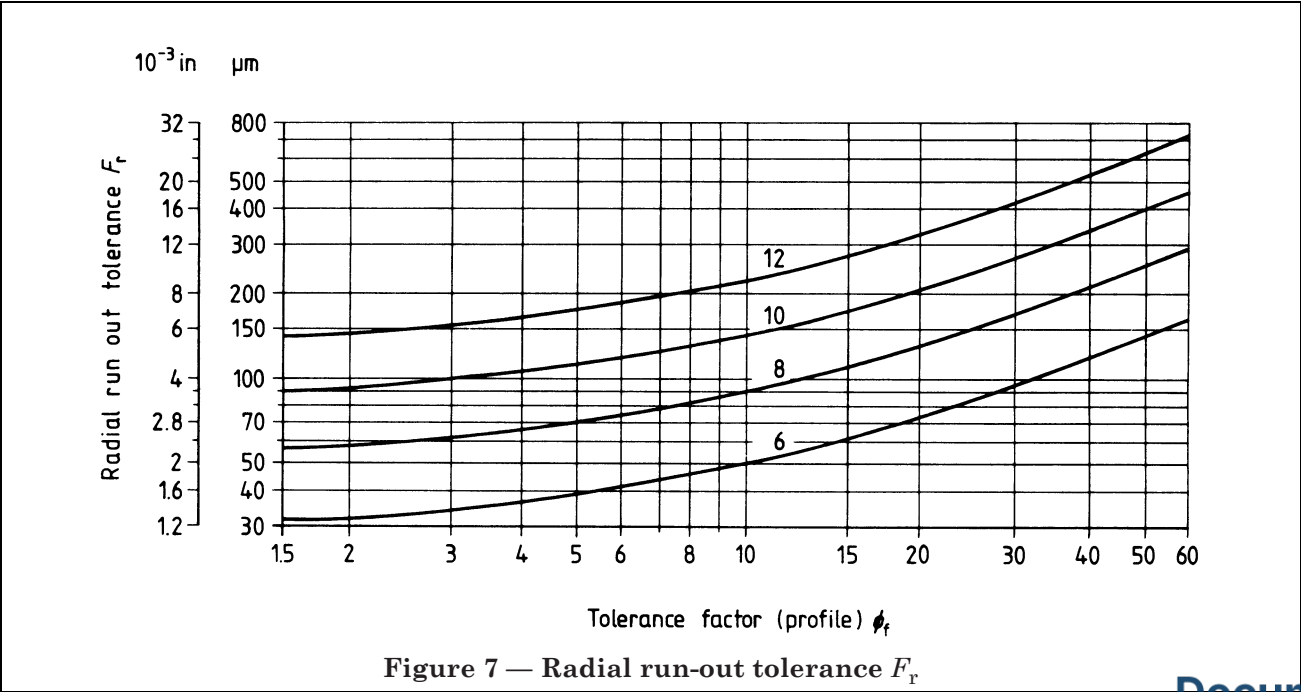
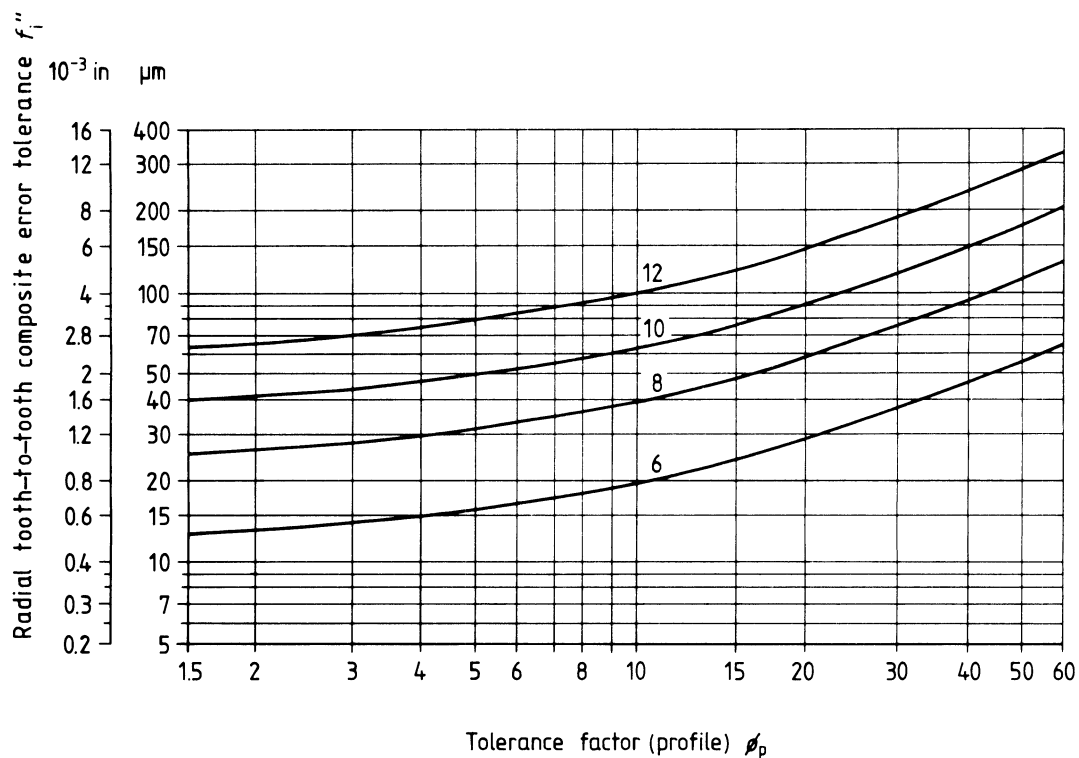
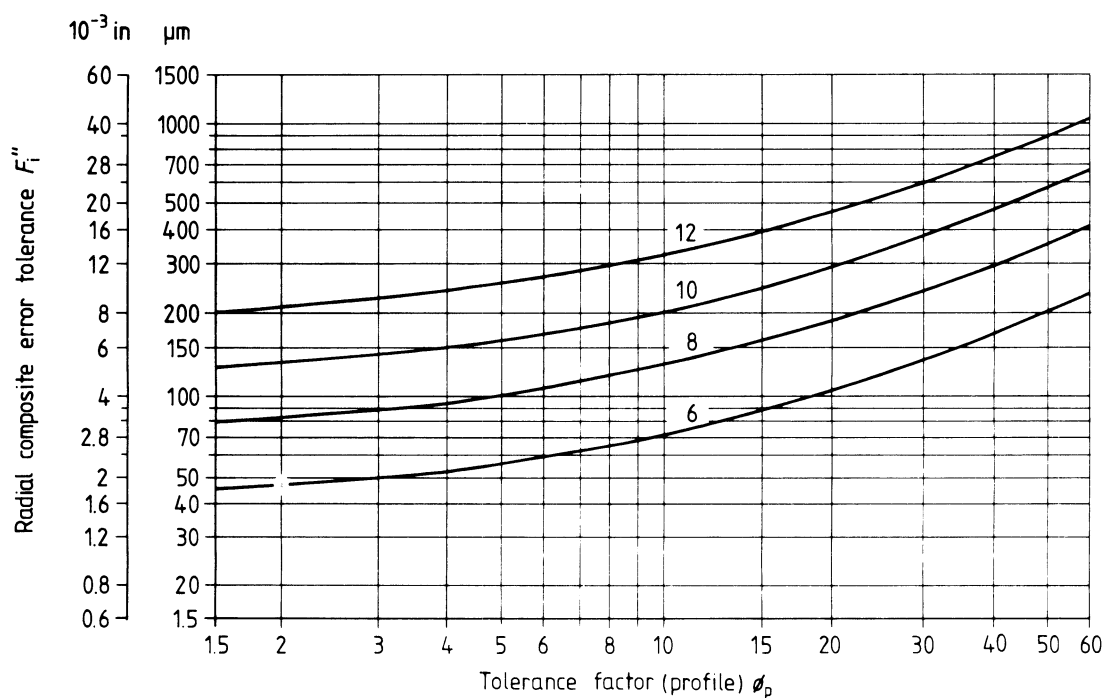


Figure 7 — Radial run-out tolerance F_r

Figure 8 — Radial tooth-to-tooth composite error tolerance f_i'' Figure 9 — Radial composite error tolerance F_i''