TECHNICAL REPORT

ISO/TR 10064-4

First edition
1998-10-15

Cylindrical gears — Code of inspection practice

Part 4:
Recommendations relative to surface texture and tooth contact pattern checking

Engrenages cylindriques — Code pratique de réception —

Partie 4: Recommandations relatives à la rugosité de surface et au contrôle de la marque de portée

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Printed in Switzerland

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 main task of technical committees is to prepare International Standards, but in exceptional circumstances a technical committee may propose the publication of a Technical Report of one of the following types:

— type 1, when the required support cannot be obtained for the publication of an International Standard, despite repeated efforts;

— type 2, when the subject is still under technical development or where for any other reason there is a future but not immediate possibility of an agreement on an International Standard;

— type 3, when a technical committee has collected data of a different kind from that which is normally published as an International Standard ("state of the art", for example).

Technical Reports of types 1 and 2 are subject to review within three years of publication to decide whether they can be transformed into International Standards. Technical Reports of type 3 do not necessarily have to be reviewed until the data they provide are considered to be no longer valid or useful.

ISO/TR 10064-4, which is a Technical Report of type 3, was prepared by Technical Committee ISO/TC 60, *Gears*.

ISO 10064 consists of the following parts, under the general title *Cylindrical gears — Code of inspection practice*:

— *Part 1: Inspection of corresponding flanks of gear teeth*

— *Part 2: Inspection related to radial composite deviations, runout, tooth thickness and backlash*

— *Part 3: Recommendations relative to gear blanks, shaft centre distance and parallelism of axes*

— *Part 4: Recommendations relative to surface texture and tooth contact pattern checking*

Introduction

In the course of revising ISO 1328:1975, it was decided that descriptions and numerical values relative to surface texture and tooth contact pattern checking should be published under separate cover as a Technical Report, type 3. For the general replacement of ISO 1328:1975, a system of documents as listed in clause 2 (References), together with this Technical Report, has been established.

Cylindrical gears — Code of inspection practice

Part 4:
Recommendations relative to surface texture and tooth contact pattern checking

1 Scope

This part of ISO/TR 10064 provides recommendations on measurement considerations for surface roughness and tooth contact pattern checking of gear flanks.

Numerical values given in this document are not to be regarded as strict ISO accuracy criteria, but may serve as a guide for mutual agreements, for steel or iron components.

2 References

ISO 53:1998, *Cylindrical gears for general and heavy engineering — Standard basic rack tooth profile.*

ISO 1302:1992, *Technical drawings — Methods of indicating surface texture.*

ISO 1328-1:1995, *Cylindrical gears — ISO System of accuracy — Part 1: Definitions and allowable values of deviations relevant to corresponding flanks of gear teeth.*

ISO 1328-2:1996, *Cylindrical gears — ISO System of accuracy — Part 2: Definitions and allowable values of deviations relevant to radial composite deviations and runout.*

ISO 3274:1996, *Geometrical Product Specifications (GPS) — Surface texture: Profile method — Nominal characteristics of contact (stylus) instruments.*

ISO 4287:1997, *Geometrical Product Specifications (GPS) — Surface texture: Profile method — Terms, definitions and surface texture parameters.*

ISO 4288:1996, *Geometrical Product Specifications (GPS) — Surface texture: Profile method — Rules and procedures for the assessment of surface texture.*

ISO 11562:1996, *Geometrical Product Specifications (GPS) — Surface texture: Profile method — Metrological characteristics of phase correct filters.*

ISO 13565-1:1996, *Geometrical Product Specifications (GPS) — Surface texture: Profile method; Surfaces having stratified functional properties — Part 1: Filtering and general measurement conditions.*

ISO 13565-2:1996, *Geometrical Product Specifications (GPS) — Surface texture: Profile method; Surfaces having stratified functional properties — Part 2: Height characterization using the linear material ratio curve.*

3 Symbols and definitions

3.1 Symbols

Symbols used for deviations of individual element measurements are composed of lower case letters, such as "*f*", with subscripts, whereas symbols used for "total" deviations, which may represent combinations of several individual element deviations, are composed of capital letters, such as "*F*", also with subscripts. Only symbols for quantities used in this part of ISO/TR 10064 are given in Table 1.

Table 1 — Symbols used within ISO/TR 10064-4

Symbol	Term	Units
$f_{w\beta}$	amplitude of undulation	µm
b_{c1}	larger length of contact pattern	%
b_{c2}	smaller length of contact pattern	%
h_{c1}	larger height of contact pattern	%
h_{c2}	smaller height of contact pattern	%
lr	sampling length for roughness profile	mm
ln	evaluation length (Default is normally *ln* = 5 x *lr*	mm
	— see ISO 4287:1997, table C.2 and ISO 4288:1996, 4.4.)	
Mr	material length	mm
*Mr*1 & *Mr*2	material portion	%
Ra	arithmetical mean deviation of the roughness profile	µm
Rk	core roughness depth	µm
Rpk	reduced peak height	—
Rvk	reduced valley depth	—
Rz	maximum height of the roughness profile (see ISO 4287)	µm
Z(x)	ordinate value	µm
λ	wavelength	mm
λ*c*	wavelength cutoff (and short wave cut-off for waviness)	mm
λ*s*	short wavelength cutoff for roughness	mm

3.2 Terms and definitions

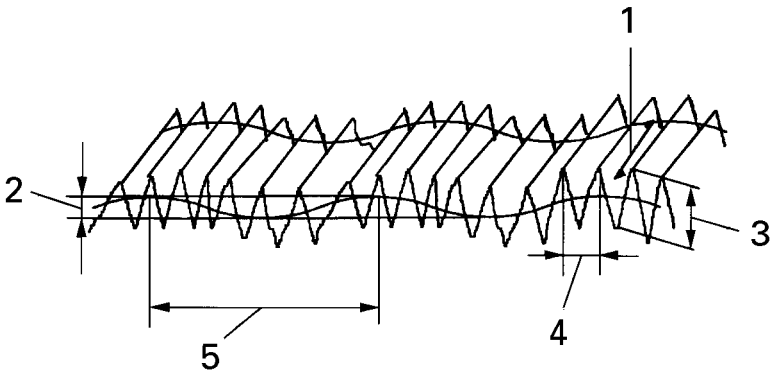
3.2.1 General terms

3.2.1.1
surface lay
The direction of the predominant surface pattern (see Figure 1a).

NOTE Surface lay is ordinarily determined by the production method used.

3.2.1.2
roughness
The irregularities of the roughness profile (see 3.2.2.1). It is the component of surface texture inherent in the production process but excluding waviness and deviation of form.

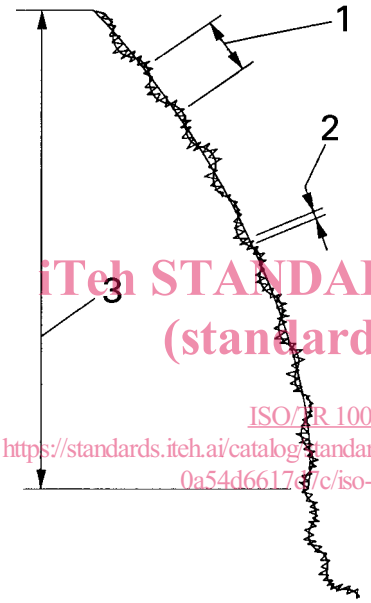
3.2.1.3
waviness
The irregularities of the waviness profile (see 3.2.2.2). That component of surface texture upon which roughness is superimposed (see Figures 1a, 1b, 1c). In general, for machined gear tooth surfaces the waviness spacing is significantly greater than the roughness spacing.



Key

1 Lay (direction of dominant pattern)
2 Waviness
3 Roughness
4 Roughness spacing
5 Waviness spacing

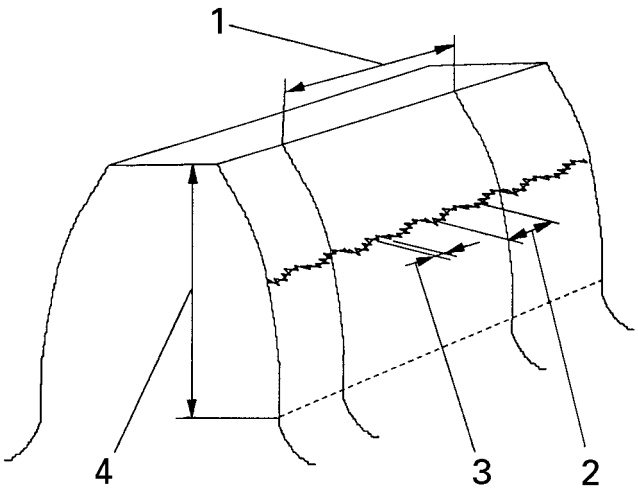
Figure 1a — Surface characteristics and terms



Key

1 Waviness spacing
2 Roughness spacing
3 Working tooth depth

Figure 1b — Enlarged example of the surface texture profile of an involute tooth



Key

1 Distance equal to working tooth depth
2 Waviness
3 Roughness
4 Working tooth depth

Figure 1c — Enlarged example of the surface texture profile along a tooth

3.2.2 Terms associated with the assessment of surface profile

3.2.21
roughness profile
The transmission band for roughness profiles is defined by the λ*c* and λ*s* profile filters (see ISO 11562:1996, clause 3), see Figure 1.

NOTE 1 The roughness profile is the basis for evaluation on the roughness profile parameters.

NOTE 2 The default relationship between λ*c* and λ*s* is given in ISO 11562:1996, clause 3.2.

3.2.2.2
waviness profile
The periodic part of the long wave component after the use of the profile filter λ*c*.

3.2.2.3
mean line for the roughness profile
The mean line is the long wave profile component suppressed by the profile filter λ*c* (see ISO 11562:1996, 3.2.1).

NOTE The mean line for the roughness profile is the reference line from which the profile ordinate *Z*(*x*) is measured, see Figure 2.

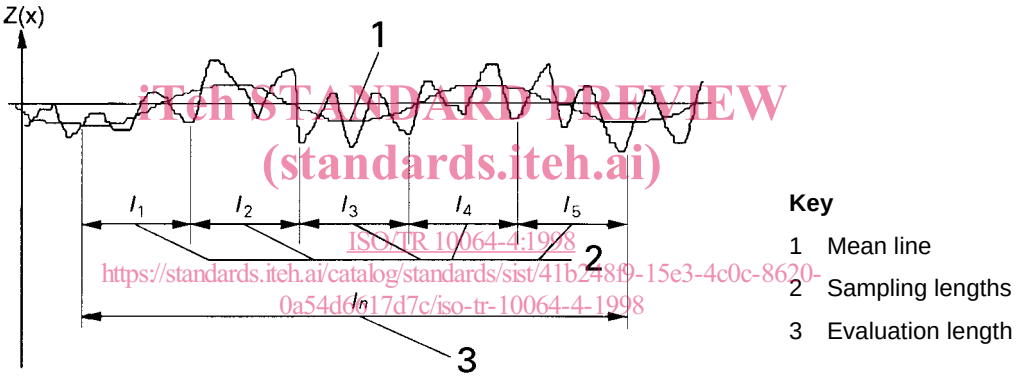


Figure 2 — Measurement lengths

3.2.2.4
ordinate value
The height of the assessed profile at any position *x*.

3.2.2.5
sampling length, *lr*, for roughness
The length in the direction of the x-axis used for identifying the irregularities characterizing the profile under evaluation. The sampling length for roughness *lr* is numerically equal to the characteristic wavelength of the profile filter λ*c* (see ISO 4287).

3.2.2.6
evaluation length, *ln*
The length in the direction of the x-axis used for assessng the profile under evaluation. The evaluation length may contain one or more sampling lengths (see ISO 4287).

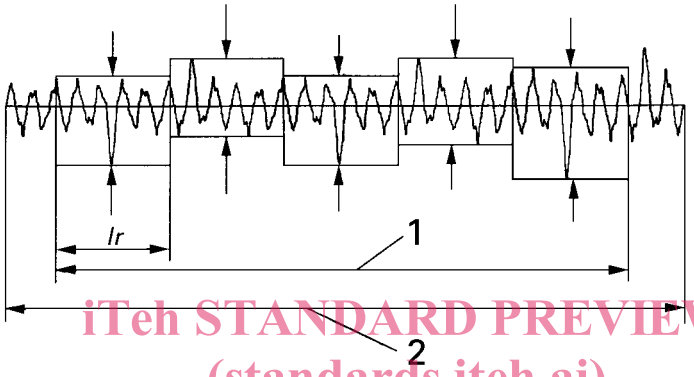
3.2.2.7
cut-off wavelength, λ*c*, of profile filters (phase, correct, gaussian)
The wave length of a sinusoidal profile of which 50% of the amplitude is transmitted by the profile filter (see ISO 11562).

3.2.2.8
cut-off ratio
The ratio of the long wave length characteristic cut-off to the short wave length characteristic cut-off of a given transmission band (see ISO 11562).

3.2.3 Terms related to surface roughness parameters

3.2.3.1
maximum heights of roughness profile, *Rz*
The sum of the height of the largest profile peak height, *Zp*, and the largest profile valley depth, *Zv*, within a sampling length (see ISO 4287:1997, 4.1.3 and Figure 9).

NOTE Usually this parameter is measured as a mean value of five adjacent sampling lengths. The evaluation length then consists of five sampling lengths (see Figure 3).



Key
1 Evaluation length, *ln*
2 Traversed length

Figure 3 — Maximum height of roughness profile

3.2.3.2
arithmetical mean deviations of the roughness profile, *Ra*
The arithmetical mean of the absolute ordinate values *Z*(x) within a sampling length (see ISO 4287:1997, 4.2.1).

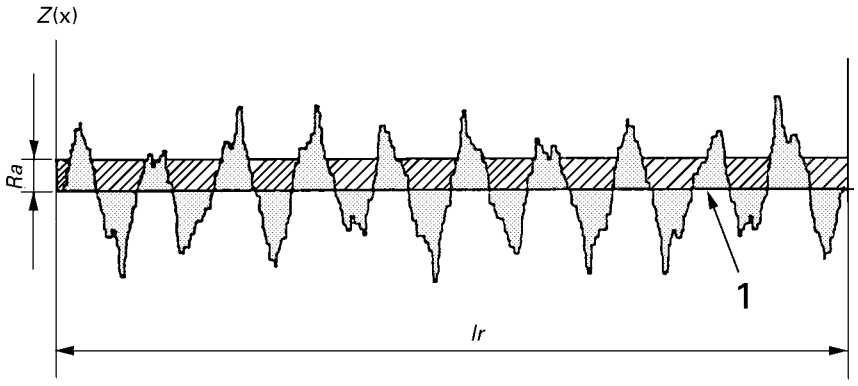
$$Ra = \frac{1}{lr}\int_0^{lr} \left| z(x) \right| dx \qquad (1)$$

where

lr is the sampling length for *Ra*;

$Z(x)$, Z_i are the ordinate values.

NOTE The arithmetical mean deviation, *Ra*, is determined by an evaluation length of five adjacent sampling lengths (see Figure 4 and ISO 4288).



3.2.4
gear tooth undulations
Undulations are periodic waviness in a tooth surface. A special form of undulations meets the following criteria:

— the lay is approximately parallel to the lines of contact (with the mating gear);

— the number of waves projected on a pitch circle (in a plane of rotation) is an integer, see Figure 5;

— they are a likely cause of noise.

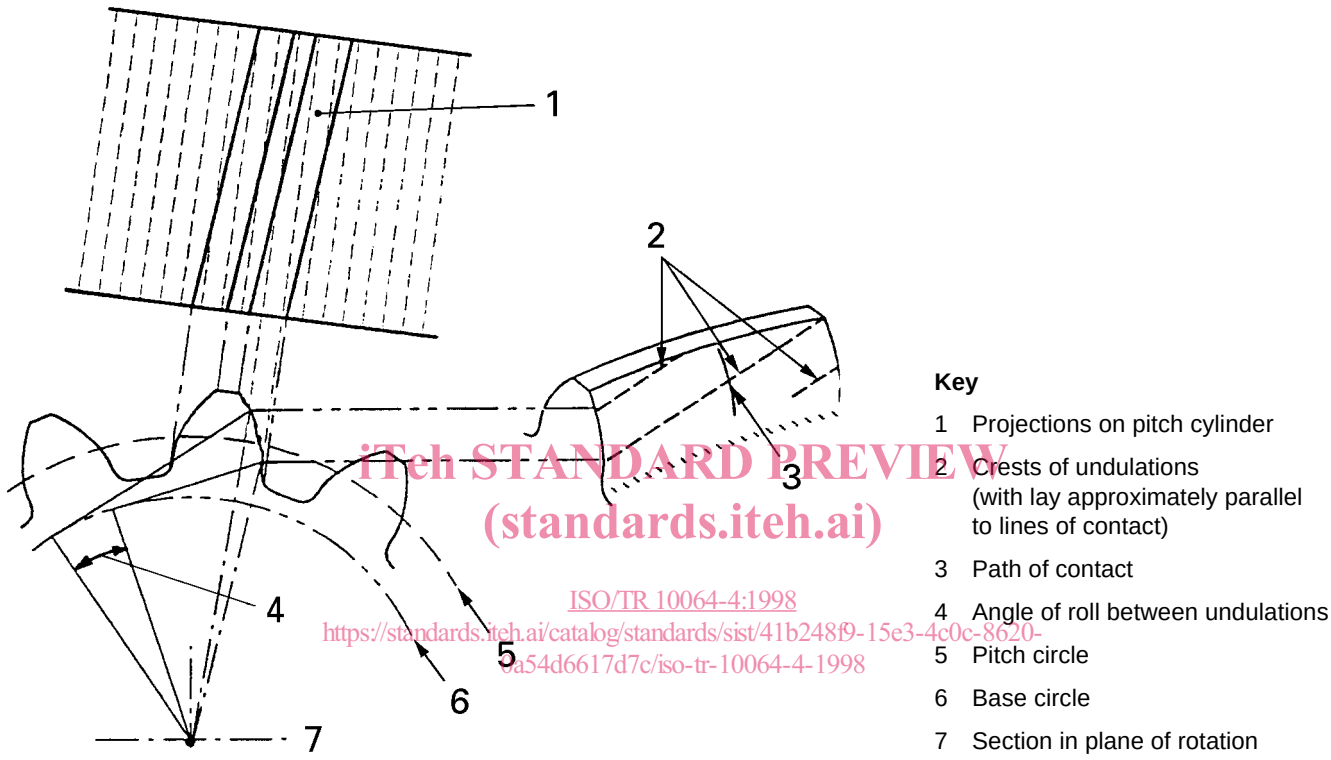


Figure 5 — Undulations in a helical gear

4 Surface texture

Experimental investigations and service experience indicate that a relationship exists between grades of surface texture and aspects of gear load capacity. The influence of surface roughness on the pitting resistance and bending strength of gear teeth is addressed in ISO 6336, Parts 2 and 3 respectively; its influence on scuffing is discussed in ISO/TR 13989.

As well as roughness, waviness and other features of surface texture can influence the surface fatigue resistance of materials. Because of this, it is prudent to make an unfiltered profile recording of the surface texture of the teeth of gears when high standards of performance and reliability are demanded.

In this Technical Report no recommendations are made concerning the grades of surface roughness, waviness and form or type of lay suitable for specific purposes, nor are causes of such irregularities identified.

CAUTION It is strongly recommended that before prescribing limits for features of the surface texture of gear teeth, designers of gears and gear engineers should familiarize themselves with ISO standards and other literature on the subject. See references in clause 2.

5 Functional considerations

The functional characteristics of gear teeth that are affected by surface texture can be separated into categories:

— transmission accuracy (noise and vibration);

— surface load carrying ability (such as pitting, scuffing, and wear);

— bending strength (root fillet condition).

5.1 Transmission accuracy

Surface texture can be described as having two major forms: roughness and waviness.

Transmission errors can be caused by surface waviness or undulations in the tooth surface. The effect depends on the direction of the lay of the waves relative to the instantaneous line of contact and its path. If the lay of the waves is parallel to the instantaneous line or area of contact (perpendicular to the path of contact), a high pitched whine can occur in the gear mesh (ghost harmonics above mesh frequency).

In a few cases, surface roughness can make a difference in the character of gear noise (smooth vs. rough quality). It does not normally contribute to the noise occurring at gear mesh frequency and its harmonics.

5.2 Load carrying ability

Surface texture can affect the gear tooth endurance in two general areas: surface deterioration and tooth breakage.

5.2.1 Surface deterioration

Surface deterioration is described in terms of wear, scuffing or scoring, pitting, etc. Surface roughness and waviness on the tooth profile is of concern. The surface texture, temperature and lubricant determine the elasto-hydrodynamic (EHD) film thickness, which affects the endurance of the tooth surface.

5.2.2 Bending strength

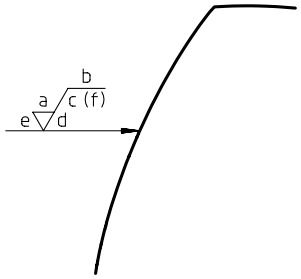
Tooth breakage can be the result of fatigue (high cyclic stress). Surface texture effect on stress in the fillet region is of concern as an influential factor.

5.3 Effect on measurement method

The measurement method instrumentation, location, direction, and analysis (filter, etc.) must be chosen to represent the functional area of the tooth and the path of contact.

6 Data given in drawings

When specified by the customer, or when design and operational requirements make it necessary, an appropriate value of surface roughness for the finished condition is to be stated in the drawing as shown in Figures 6a and 6b.



a = *Ra* or *Rz*, µm

b = production process, surface treatment etc.

c = sampling length

d = direction of lay

e = machining allowance

f = other roughness values (in brackets)

Figure 6a — Symbols for surface texture

Key

1 Tooth flank excluding fillet

2 Tooth flank including fillet

Figure 6b — Symbols for roughness and direction of lay

7 Measuring instruments

Stylus type measuring instruments are commonly used for the measurement of roughness. The measurement can be taken with the following equipment, that includes characteristics that influence the uncertainty of measurement (see Figure 7):

a) one skid or by a pair of skids which slide over the surface to be measured (instrument with a straight reference plane);

b) a skid which slides over a reference plane having the form of the nominal surface;

c) an adjustable or programmable reference line generator in combination with a skid, e. g. realized by a coordinate measuring machine;

d) assessment of form, waviness and roughness by a skidless pickup and straight datum combined with a large measuring range.

To comply with ISO standards, the tip radius of the stylus is to be 2 µm, or 5 µm, or 10 µm. The stylus angle may be 60° or 90°. Further details of instrument features can be found in ISO 3274. The report of the surface measurement should indicate tip radius and angle of stylus.