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**Geometrical product specifications  
(GPS) — Surface texture: Areal —**

Part 601:

**Nominal characteristics of contact  
(stylus) instruments**

*Spécification géométrique des produits (GPS) — État de surface:  
Surfacique —*

*Partie 601: Caractéristiques nominales des instruments à contact (à  
palpeur)*

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## 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.

International Standards are drafted in accordance with the rules given in the ISO/IEC Directives, Part 2.

The main task of technical committees is to prepare International Standards. Draft International Standards adopted by the technical committees are circulated to the member bodies for voting. Publication as an International Standard requires approval by at least 75 % of the member bodies casting a vote.

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.

ISO 25178-601 was prepared by Technical Committee ISO/TC 213, *Dimensional and geometrical product specifications and verification*.

ISO 25178 consists of the following parts, under the general title *Geometrical product specifications (GPS) — Surface texture: Areal*:

- *Part 2: Terms, definitions and surface texture parameters*
- *Part 3: Specification operators*
- *Part 6: Classification of methods for measuring surface texture*
- *Part 7: Software measurement standards*
- *Part 601: Nominal characteristics of contact (stylus) instruments*
- *Part 602: Nominal characteristics of non-contact (confocal chromatic probe) instruments*
- *Part 603: Nominal characteristics of non-contact (phase-shifting interferometric microscopy) instruments*
- *Part 701: Calibration and measurement standards for contact (stylus) instruments*

The following parts are under preparation:

- *Part 604: Nominal characteristics of non-contact (coherence scanning interferometry) instruments*
- *Part 605: Nominal characteristics of non-contact (point autofocusing) instruments*

## Introduction

This part of ISO 25178 is a geometrical product specification standard and is to be regarded as a general GPS standard (see ISO/TR 14638). It influences chain link 5 of the chain of standards on roughness profile, waviness profile, primary profile and areal surface texture.

For more detailed information of the relation of this standard to the GPS matrix model, see Annex C.

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# Geometrical product specifications (GPS) — Surface texture: Areal —

## Part 601: Nominal characteristics of contact (stylus) instruments

### 1 Scope

This part of ISO 25178 defines the metrological characteristics of contact (stylus) areal surface texture measuring instruments.

### 2 Normative references

The following referenced documents are indispensable for the application of this document. For dated references, only the cited editions apply. For undated references, the latest edition of the referenced document (including any amendments) applies.

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

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

ISO 10360-1, *Geometrical Product Specifications (GPS) — Acceptance and reverification tests for coordinate measuring machines (CMM) — Part 1: Vocabulary*

ISO/IEC Guide 99:2007, *International vocabulary of metrology — Basic and general concepts and associated terms (VIM)*

### 3 Terms and definitions

For the purposes of this document, the terms and definitions given in ISO 3274, ISO 4287, ISO 10360-1 and ISO/IEC Guide 99 and the following apply.

#### 3.1 General terms and definitions

##### 3.1.1

##### **coordinate system of the instrument**

right hand orthonormal system of axes (X,Y,Z) defined as:

- (X,Y) is the plane established by the areal reference guide of the instrument;
- Z-axis is in the plane of the stylus trajectory and is perpendicular to the (X,Y) plane (see Figure 1)

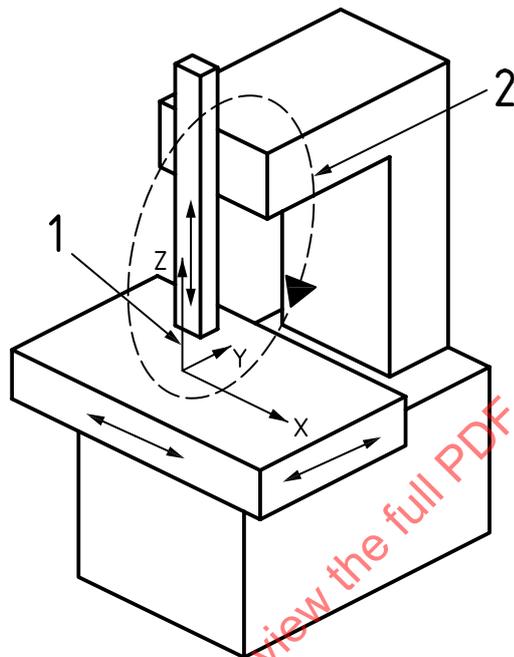
NOTE Normally, the X-axis is the tracing direction and the Y-axis is the stepping axis.

**3.1.2 measurement loop**

closed chain which comprises all components connecting workpiece and the stylus tip, e.g. the means of positioning, the workholding fixture, the measuring stand, the drive unit, the probing system (pick-up)

See Figure 1.

NOTE The measurement loop will be subjected to external and internal disturbances which influence the measurement uncertainty.



- Key**
- 1 coordinate system of the instrument
  - 2 measurement loop

**Figure 1 — Coordinate system and measurement loop of the instrument**

**3.1.3 user adjustment**

(of a measuring instrument) adjustment employing only the means available to the user

NOTE This is an operation normally carried out by the user. It involves the use of a material measure, usually supplied with the instrument. The result of this operation automatically or manually adjusts certain parameters in order that the instrument operates correctly.

**3.1.4 residual correction error**

difference between the value of a quantity obtained after correcting the systematic error and the real value of this quantity

NOTE The residual error is composed of random errors and uncorrected systematic errors.

## 3.2 Terms and definitions relative to lateral scanning system

### 3.2.1

#### **lateral scanning system**

system that performs the scanning of the surface to be measured in the (X,Y) plane

NOTE Typically, the lateral scanning system is composed of the **drive unit X** (3.2.3) and **drive unit Y** (3.2.4).

### 3.2.2

#### **areal reference guide**

component of the instrument that generates the reference surface, in which the **probing system** (3.3.1) moves relative to the surface being measured according to a theoretically exact trajectory

NOTE In the case of areal surface texture measuring instruments, the reference guide establishes a reference surface (see ISO 25178-2). It can be achieved through the use of two perpendicular reference guides (see ISO 3274:1996, 3.3.2) or one reference surface guide.

### 3.2.3

#### **drive unit X**

component of the instrument that moves the **probing system** (3.3.1) or the surface to be measured along the reference guide on the X-axis and provides the horizontal position of the stylus tip in terms of the lateral X coordinate of the profile

### 3.2.4

#### **drive unit Y**

component of the instrument that moves the **probing system** (3.3.1) or the surface to be measured along the reference guide on the Y-axis and provides the horizontal position of the stylus tip in terms of the lateral Y coordinate of the profile

### 3.2.5

#### **lateral position sensor**

component of the drive unit that provides the lateral position of the pivot

NOTE 1 See Figure 2 for the definition of the pivot.

NOTE 2 The lateral position can be measured using, for example, a linear encoder, a laser interferometer, or a counting device coupled with a micrometer screw.

## 3.3 Terms and definitions relative to the probing system

### 3.3.1

#### **probing system**

(surface texture) component of the instrument consisting of the **stylus** (3.3.4), the pivot, the **probe** (3.3.2) and the **digitizing system** (3.3.3)

NOTE 1 The axis of rotation around the pivot is parallel to the Y axis.

NOTE 2 The probing system is commonly called a “pick up”.

### 3.3.2

#### **probe**

(surface texture) device that converts the height into a signal during measurement

NOTE In earlier standards this was termed a “transducer”.

### 3.3.3

#### **digitizing system**

device which converts analogue signals into digital ones

NOTE 1 The digital signal as a function of the  $x$  and  $y$  coordinates forms the extracted mechanical surface.

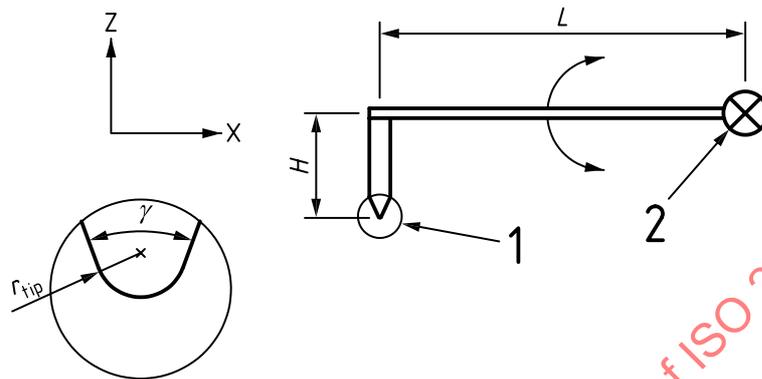
NOTE 2 The digitizing system should not cause any intentional surface modification.

NOTE 3 In a typical system, the digitizing system is usually an analogue to digital converter.

**3.3.4 stylus**

mechanical device consisting of a tip and an arm

NOTE The typical stylus is shown in Figure 2.



**Key**

- |                       |                                |
|-----------------------|--------------------------------|
| 1 stylus tip          | $H$ height of the stylus       |
| 2 pivot               | $r_{tip}$ radius of the tip    |
| $L$ length of the arm | $\gamma$ cone angle of the tip |

NOTE The above design is the most common. Other designs are also used, e.g. flexures, linear probes, etc.

**Figure 2 — Characterization of the typical stylus**

**3.3.5 error due to arcuate motion**

vector error generated by the rotation of the stylus (3.3.4) around the pivot

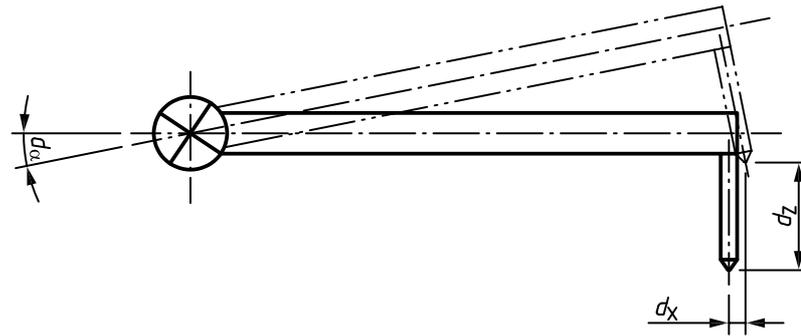
See Figure 3.

NOTE 1 The vector error consists of a lateral and horizontal component.

NOTE 2 The arcuate motion generates an error of the measured profile.

NOTE 3 The horizontal error which results from the arcuate motion is a function of the vertical displacement and may be neglected depending on the required accuracy.

NOTE 4 The probe only measures one quantity (typically Z or the angle of the stylus arm) which does not give enough information for the assessment of both X and Z quantities. The knowledge of the stylus geometry and either X or Z quantity allows this assessment by using a mathematical adjustment.

**Key**

- $d_\alpha$  rotation angle around the pivot  
 $d_x$  horizontal error function of  $d_z$  and stylus geometry  
 $d_z$  vertical displacement

**Figure 3 — Arcuate motion****3.4 Metrological characteristics of the instrument****3.4.1****measuring volume**

range of the instrument stated in terms of the limits on all three coordinates measured by the instrument

NOTE For areal surface texture measuring instruments, the measuring volume is defined by

- the measuring range of the **drive unit X** (3.2.3) and the **drive unit Y** (3.2.4),
- the measuring range of the **probing system** (3.3.1).

**3.4.2****response curve**

$F_x, F_y, F_z$

graphical representation of the function that describes the relation between the actual quantity and the measured quantity

See Figure 4.

NOTE 1 An actual quantity in X (respectively Y or Z) corresponds to a measured quantity  $x_m$  (respectively  $y_m$  or  $z_m$ ).

NOTE 2 The response curve can be used for adjustments and error corrections.

**3.4.3****amplification coefficient**

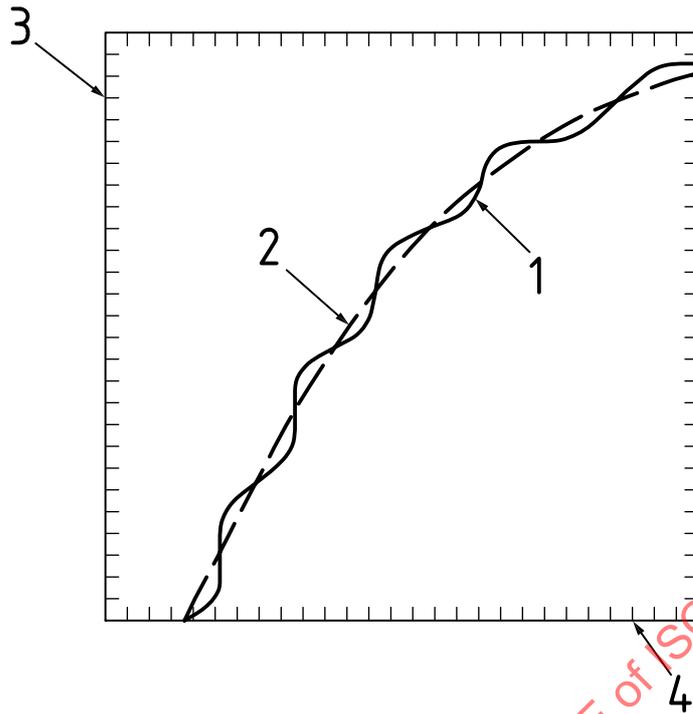
$\alpha_x, \alpha_y, \alpha_z$

slope of the linear regression curve obtained from the **response curve** (3.4.2)

See Figure 5.

NOTE 1 There will be amplification coefficients applicable to the X, Y and Z quantities.

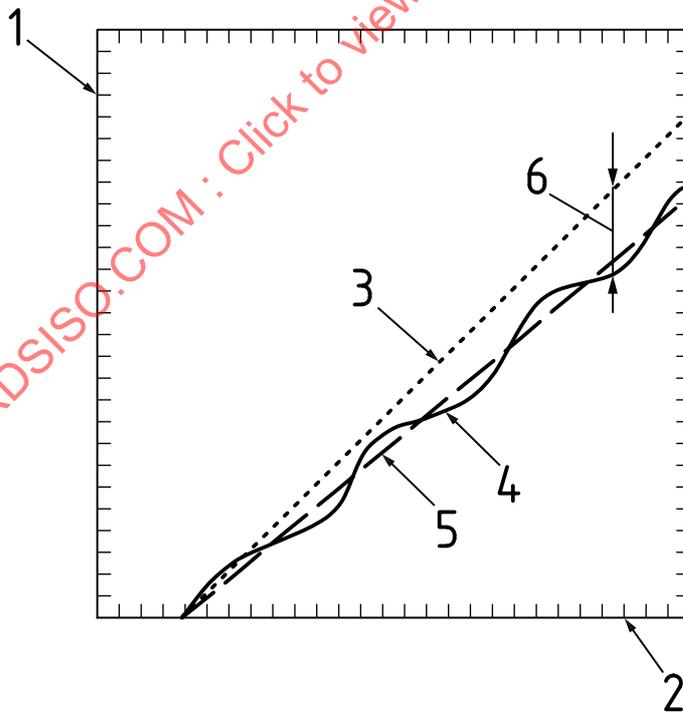
NOTE 2 The ideal response is a straight line with a slope equal to 1 which means that the values of the measurand are equal to the values of the input quantities.



**Key**

- 1 response curve
- 2 assessment of the response curve by polynomial approximation
- 3 measured quantities
- 4 input quantities

**Figure 4 — Example of a non-linear response curve**



**Key**

- 1 measured quantities
- 2 input quantities
- 3 ideal response curve
- 4 linearized response curve
- 5 straight line whose slope is the amplification coefficient  $\alpha$
- 6 local residual correction error before adjustment

**Figure 5 — Example of a linearization of a response curve**

**3.4.4****instrument noise**

internal noise added to the output signal caused by the instrument if ideally placed in a noise-free environment

NOTE 1 Internal noise can be due to electronic noise such as, e.g., amplifiers.

NOTE 2 This noise typically has high frequencies which limit the ability of the instrument to detect small scale surface texture.

NOTE 3 The S-filter specified in ISO 25178-3 may reduce this instrument noise.

**3.4.5****static noise**
 $N_s$ 

sum of the instrument and environmental noise on the output signal without any motion of the lateral scanning system

NOTE 1 Environmental noise is caused by, e.g., seismic, sonic and external electromagnetic disturbances.

NOTE 2 Notes 2 and 3 in 3.4.4 apply to 3.4.5 as well.

**3.4.6****dynamic noise**
 $N_d$ 

noise occurring during the motion of the drive units on the output signal

NOTE 1 Notes 2 and 3 in 3.4.4 apply to 3.4.6 as well.

NOTE 2 Dynamic noise includes the **static noise** (3.4.5).

**3.4.7****sampling interval in X**
 $D_x$ 

distance between two adjacent measured points along the X-axis

NOTE The sampling interval in X is usually determined by the **drive unit X** (3.2.3).

**3.4.8****sampling interval in Y**
 $D_y$ 

distance between two adjacent measured points along the Y-axis

NOTE The sampling interval in Y is usually determined by the **drive unit Y** (3.2.4).

**3.4.9****digitization step in Z**
 $D_z$ 

smallest height variation along the Z-axis between two ordinates of the extracted surface

NOTE According to the technology which is used, the digitization step can be determined by:

- the resolution of the analog to digital converter (ADC);
- the phase interpolation of the interferometer;
- the interpolation algorithm of the encoder.

**3.4.10****lateral resolution**
 $R_l$ 

smallest separation distance between two features which can be detected

**3.4.11**  
**width limit for full height transmission**

$W_l$   
 width of the narrowest rectangular groove whose measured height remains unchanged by the measurement

NOTE 1 The width limit of transmission of height is a function of the shape (see Figure 6).

NOTE 2 The width limit of transmission of height is mainly dependent on the stylus geometry ( $r_{tip}$  and  $\gamma$ ).

NOTE 3 Metrological characteristics including:

- the **sampling interval in X** (3.4.7) and the **sampling interval in Y** (3.4.8);
- the **digitization step in Z** (3.4.9);
- the filter use;

should be adapted in such a way that they do not influence the **lateral resolution** (3.4.10) and the width limit for full height transmission.

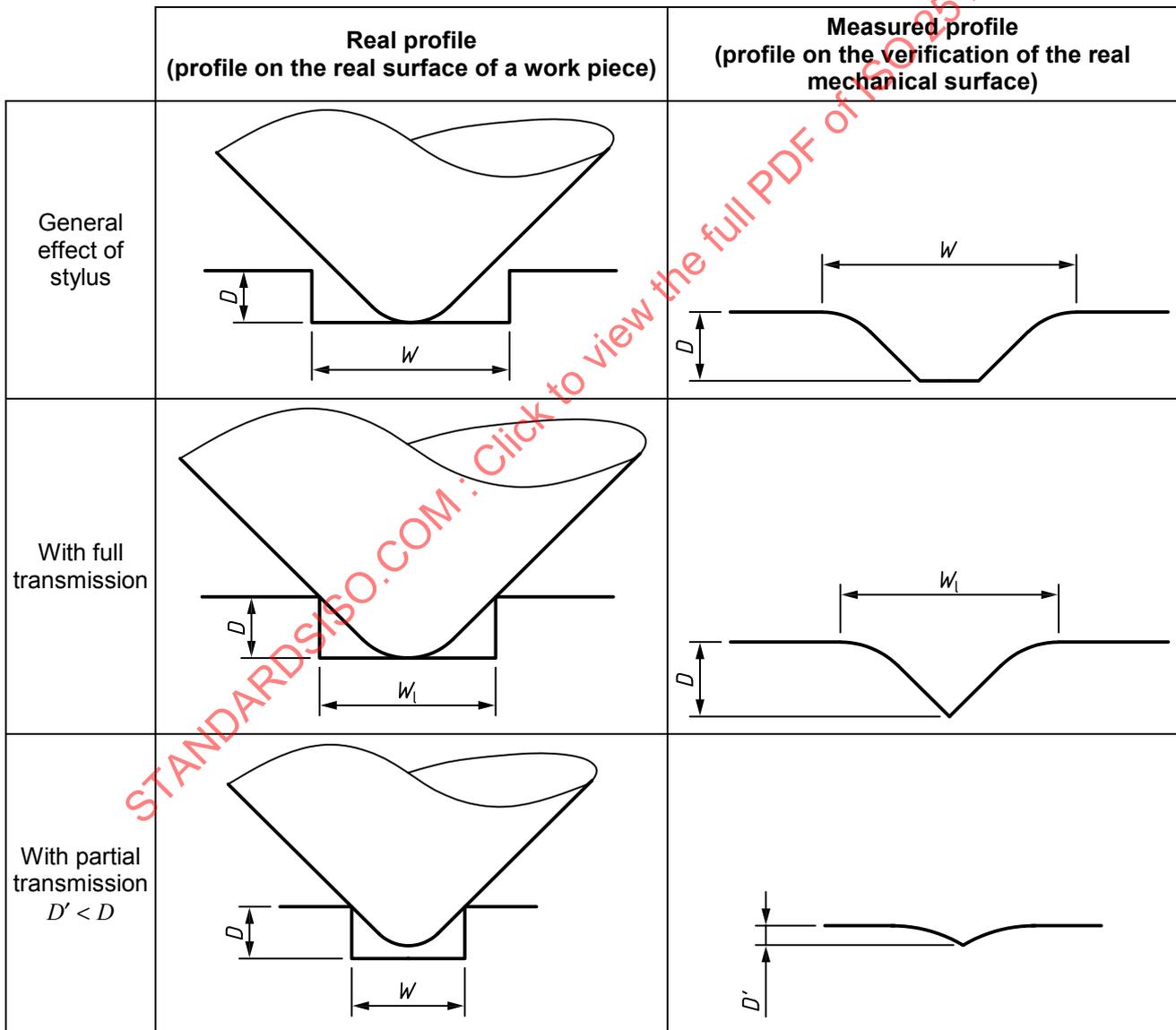


Figure 6 — Width limit of transmission of height

**3.4.12****maximum local slope**

greatest local slope of a surface feature that can be assessed by the probing system

NOTE 1 The term “local slope” is defined in ISO 4287.

NOTE 2 The maximum local slope is limited by the angle and the arcuate motion of the stylus.

**3.4.13****speed of measurement**
 $v_x$ 

speed of the probing system relatively to the surface to be measured during the measurement along the X-axis

**3.4.14****dynamic of the probing system**
 $d_{yn}$ 

mechanical and electrical dynamic properties of the probing system which together influence the output signal

**3.4.15****critical dynamic of the probing system**
 $v_{dyn,c}$ 

maximum value of the tracing speed above which the output signal is distorted

NOTE 1 The critical dynamic is dependant on the mechanical inertia of the moving parts and the surface to be measured.

NOTE 2 Below the critical dynamic, a range of speeds of measurement are generally acceptable.

**4 Summary of metrological characteristics**

Typical metrological characteristics which influence the measurement uncertainty for areal surface texture measuring instruments are given in Table 1.

Table 1 indicates the axes which are affected by deviations of metrological characteristics.

Table 1 — Metrological characteristics

Component	Element	Metrological characteristic(s)	Error along	
Probing system	Stylus	$H$	vertical height from the pivot to the stylus tip	X and Z
		$L$	horizontal length from the pivot to the stylus tip	X and Z
		$r_{\text{tip}}$	tip radius	X, Y and Z
		$\gamma$	cone angle	X, Y and Z
		$R_l$	lateral resolution	X and Y
		$W_l$	width limit of transmission of height	Z
	Probe	$\alpha_z$	amplification coefficient	Z
		$D_z$	vertical digitization step	Z
	Probe and pivot	$z_{\text{HYS}}$	vertical hysteresis	Z
		$v_{\text{dyn,c}}$	critical dynamic of the probing system	X and Z
		$F_z$	response curve	Z
Pivot	$J_y$	lateral component of the Y tracking error of the stylus in respect to the pivot	X and Y	
Lateral scanning system	Position sensor (linear encoder, micrometric screw, ...)	$F_x, F_y$	response curves	X (or Y)
		$\alpha_x, \alpha_y$	amplification coefficients	X (or Y)
		$D_x, D_y$	lateral sampling intervals	X (or Y)
		$x_{\text{HYS}}$	hysteresis of repositioning in X, between two adjacent profiles	X
		$y_{\text{HYS}}$	hysteresis of repositioning in Y	Y
	Areal reference guide (height component)	$z_{\text{FLT(X,Y)}}$	height component of the flatness deviation of the movement in the XY plane $z_{\text{FLT(X,Y)}}$ contains in particular:	Z
		$z_{\text{STR(X)}}$	height component of the straightness deviation along the X-axis	
		$z_{\text{STR(Y)}}$	height component of the straightness deviation along the Y-axis	
	Areal reference guide (lateral component)	$\lambda_{\text{PER}}$	perpendicularity deviation between X and Y axes	X and Y
		$y_{\text{STR(X)}}$	lateral component Y of the straightness along the X-axis	X and Y
$x_{\text{STR(Y)}}$		lateral component X of the straightness along the Y-axis	X and Y	
Instrument	$N_s$	static noise	Z	
	$N_d$	dynamic noise	Z	

**Annex A**  
(normative)

**Classification of the different configurations for areal surface texture scanning instruments**

There are essentially four aspects to a surface texture scanning instrument system: the X-axis drive, the Y-axis drive, the Z-measurement probe and the surface to be measured. There are different ways in which these may be configured and thus there will be a difference between different configurations as explained in Table A.1.

NOTE Whilst this part of ISO 25178 is concerned with contact probing systems, the lateral scanning system may also be suitable for a non-contact single point probing system.

**Table A.1 — Reference guides (X and Y)**

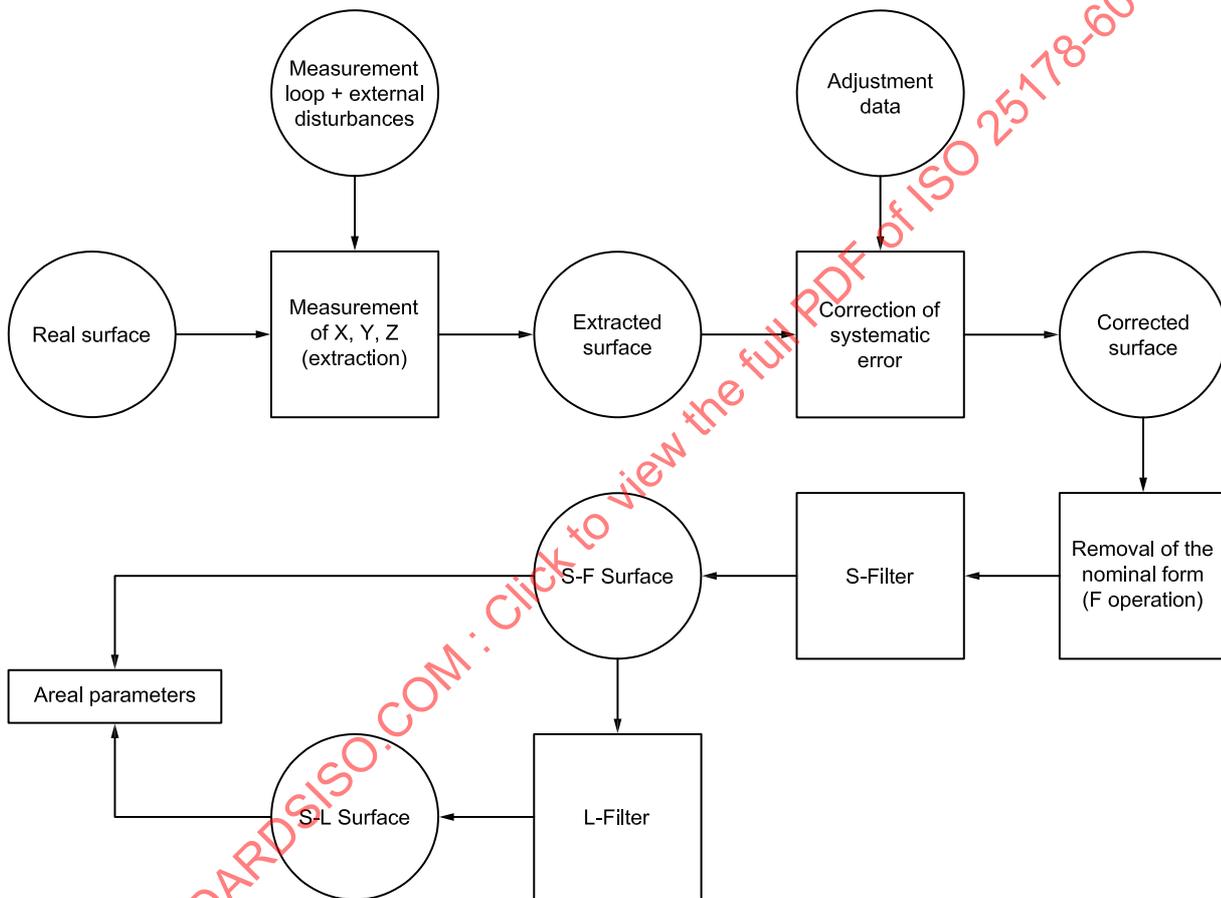
		Drive unit				
		Two reference guides (X and Y)			One areal reference guide	
		PX ◦ CY <sup>a</sup>	PX ◦ PY <sup>a</sup>	CX ◦ CY <sup>a</sup>	PXY <sup>a</sup>	CXY <sup>a</sup>
<b>Probing system</b>	Without arcuate error correction	PX ◦ CY – A	PX ◦ PY – A	CX ◦ CY – A	PXY – A	CXY – A
	Without arcuate error or with corrected arcuate error	PX ◦ CY – S	PX ◦ PY – S	CX ◦ CY – S	PXY – S	CXY – S
NOTE For two given functions <i>f</i> and <i>g</i> , <i>f</i> ◦ <i>g</i> is the composite function of <i>f</i> and <i>g</i> .						
<sup>a</sup> PX = probing systems moving along the X-axis PY = probing systems moving along the Y-axis PX ◦ CY = probing system moving along the X-axis and component moving along the Y-axis PX ◦ PY = probing systems moving along the X and Y axes PXY = probing systems moving in the XY plane CX = component moving along the X-axis CY = component moving along the Y-axis CX ◦ CY = component moving along the X and Y axes CXY = Component moving in the XY plane.						

**Annex B**  
(informative)

**Features of an areal surface texture measuring instrument**

**B.1 General**

Surface texture instruments enable the assessment of quantities in X, Y and Z from which areal surface texture parameters are calculated (see Figure B.1).



**Figure B.1** — Typical measurement method applied to an areal surface texture measuring instrument

Quantities in X and Y characterize the lateral position of the measured point.

The quantity Z characterizes the height of the measured point.

The knowledge of these three quantities gives the ability to calculate various areal surface texture parameters.

NOTE The extracted surface is equivalent to the traced surface as defined in ISO 3274.

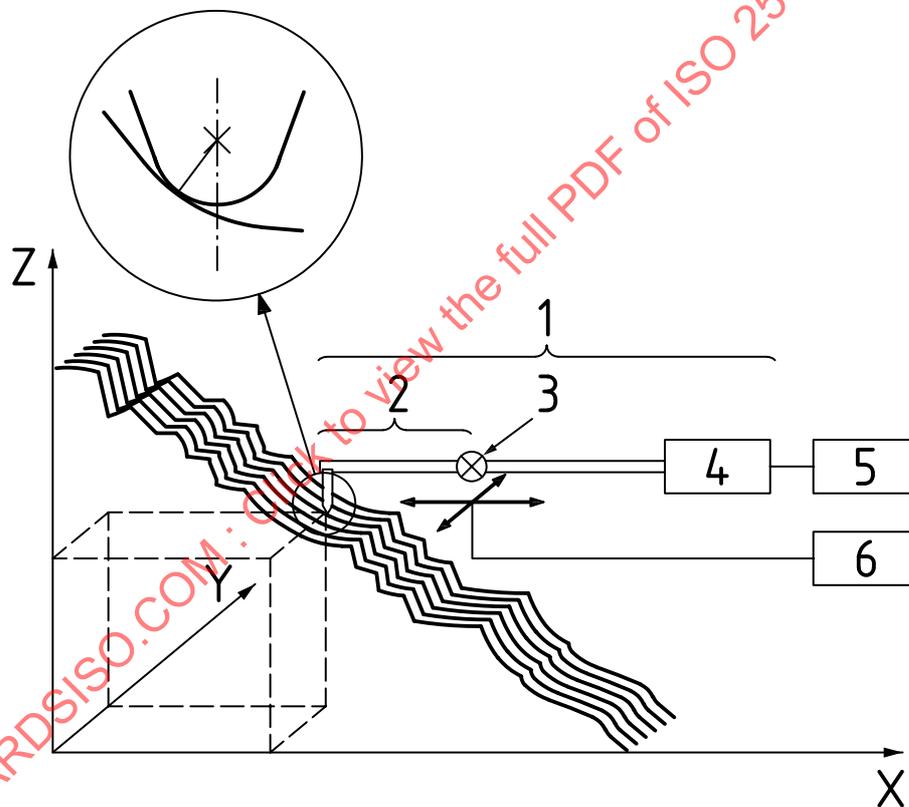
## B.2 Contact (stylus) areal surface texture measuring instruments

An areal surface texture measuring instrument is composed of a lateral scanning system and a probing system.

Contact (stylus) areal surface measuring instruments use a contact probing system equipped with a stylus for determining heights.

Such instruments are also able to perform profile measurements. There are two types of instrument:

- instruments whose vertical range of measurement allows only the measurement of the surface texture on flat workpieces or on surfaces with small form deviation; typically, the vertical measuring range is less than 1 mm;
- instruments whose vertical range of measurement allows measurement of the surface texture on surfaces intentionally not flat, with large form deviation or measurement of contour; typically, the vertical measuring range is several millimetres;



### Key

- 1 probing system
- 2 stylus
- 3 pivot
- 4 probe
- 5 digitizing system
- 6 drive units (including areal reference guide and lateral position sensors)

NOTE 1 The contact point may occur at any position on the spherical portion of the tip.

NOTE 2 The measurement of the surface using a ball is equivalent to applying a morphological operation as defined in ISO/TS 16610-40<sup>[4]</sup>.

Figure B.2 — Contact (stylus) areal surface texture instruments