

Assessment of departures from roundness —

**Part 2: Specification for characteristics
of stylus instruments for measuring
variations in radius (including
guidance on use and calibration)**

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Foreword

This Part of this British Standard has been prepared under the direction of the Mechanical Engineering Standards Committee. It takes account of discussions within ISO/TC 57, Metrology and properties of surfaces, the results of which will be published as ISO 4291. At the time of publication the technical content of this Part of this standard was in agreement with the ISO draft.

This standard together with Parts 1 and 3 supersedes BS 3730:1964 which is now withdrawn.

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Summary of pages

This document comprises a front cover, an inside front cover, pages i and ii, pages 1 to 18, 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 Part of this British Standard specifies the characteristics of contact (stylus) instruments based on the method of determining departures from roundness by measuring variations in radius.

It relates to the assessment of the departures from ideal roundness of a workpiece through the medium of a profile transformation, obtained under reference conditions, expressed with respect to any one of the following centres:

- centre of the least squares circle;
- centre of the minimum zone circle;
- centre of the minimum circumscribed circle;
- centre of the maximum inscribed circle;

NOTE 1 Each of the foregoing centres may have its field of application. The position of the least squares centre can be calculated from a simple explicit formula given in Appendix E.

Departures of roundness from the measured profile, use of instrument, calibration and determination of systematic errors of rotation are dealt with in Appendix A to Appendix D, respectively. Appendix F gives rules for plotting and reading polar graphs.

NOTE 2 Reference conditions include the stylus, frequency limitations of an electric wave filter (if used), permissible eccentricity of the graphic or digital representation of the profile (generally 1/7 to 1/15 of its mean radius, see Appendix F) and the position of the measured section or sections relative to some feature of the workpiece.

NOTE 3 The titles of the publications referred to in this standard are listed on the inside back cover.

2 Definitions

For the purposes of this Part of BS 3730 the definitions given in BS 3730-1 apply, together with the following.

overall instrument error

the difference between the value of the parameter indicated, displayed or recorded by the instrument and the true value of the parameter. The value of this error is determined by measuring a test piece

3 Instruments

3.1 Instrument types and general requirements

3.1.1 General. Instruments of the stylus type employed for the determination of departures from ideal roundness shall be one of the following types:

- a stylus and transducer rotating round a stationary workpiece; *or*
- a rotating workpiece engaged by a stationary stylus and transducer.

NOTE By the character of the output information, instruments for the measurement of roundness fall into two groups:

- profile recording;
- direct display of the values of the parameters.

Both groups can be combined in one instrument.

Stylus instruments shall comply with 3.1.2 to 3.1.4.

3.1.2 Stylus types and dimensions. The surface characteristics of the part under examination are of primary importance in the choice of stylus and variations to comply with different requirements, depending upon the nature and magnitude of the irregularities that are to be taken into account, shall be as shown in Figure 1 to Figure 4 (see Appendix A).

NOTE No order of preference is implied by the order of Figure 1 to Figure 4.

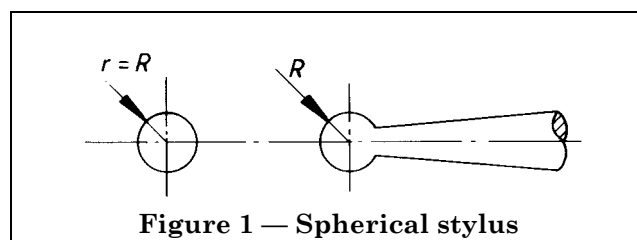


Figure 1 — Spherical stylus

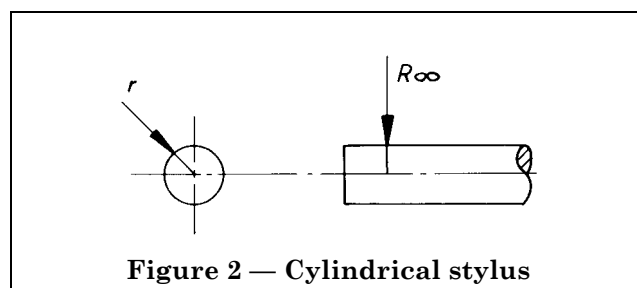


Figure 2 — Cylindrical stylus

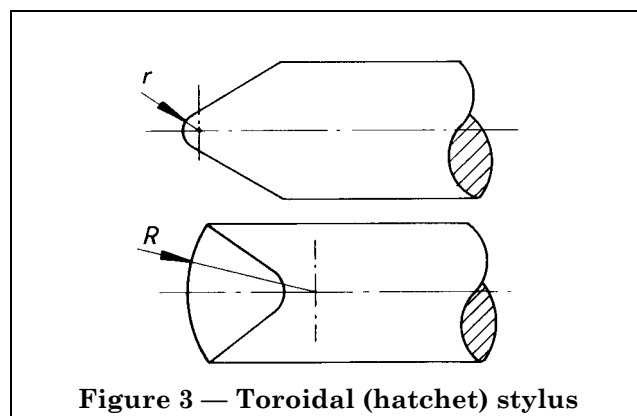


Figure 3 — Toroidal (hatchet) stylus

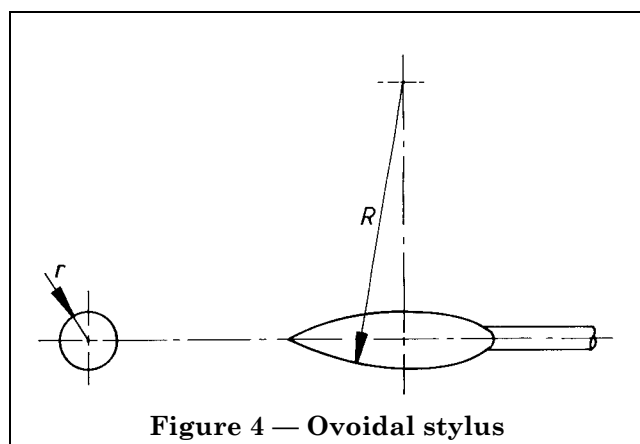


Figure 4 — Ovoidal stylus

The dimensions r and R of the various styli shall be selected from the following values:

0.25 mm, 0.8 mm, 2.5 mm and 8 mm.

3.1.3 Stylus static force. The force shall be adjustable up to 0.25 N and in use shall be adjusted down to the lowest value that will ensure continuous contact between the stylus and the surface being measured.

3.1.4 Instrument response for sinusoidal undulations. The range of periodic sinusoidal undulations per revolution (i.e. per 360°) of the workpiece to which the instrument responds shall be terminated by values taken from Table 1.

Table 1 — Limiting values of undulations per revolution

Filters transmitting from 1 undulation per revolution up to	Filters rejecting below
undulations per revolution	undulations per revolution
15	50
50	100
150	500
500	—
1 500	—

The response at the rated termination of the band shall be 75 % of the maximum transmission within the band except for 1 undulation per revolution which represents direct mechanical coupling between input and output (see note 5).

The transmission characteristics of the filter shall be equivalent to those produced by two independent CR networks of equal time constant (see Figure 5).

NOTE 1 These curves show only the amplitude attenuation characteristics and do not take phase shift into account. A phase corrected filter of known characteristics giving the same rate (or a higher rate) of attenuation may be used.

NOTE 2 When a filter attenuating high frequencies is required, the 2-CR form will generally be acceptable, distortion of the transmitted profile due to phase shift of the high frequencies relative to the low frequencies being generally unimportant.

When a filter attenuating low frequencies is required, distortion due to phase shift may be more significant and have to be taken into account or avoided by using a phase corrected filter.

NOTE 3 It is necessary to distinguish clearly between the undulations per revolution (i.e. per 360°) of the workpiece and the response of electronic circuits in the instrument in hertz.

The frequency in cycles per second (hertz) generated by the instrument will be given by:

sinusoidal undulations per 360° of the workpiece $\times$
revolutions per second of the spindle.

NOTE 4 Eccentricity will count as 1 undulation per revolution. A sinusoidal component of 1 undulation per revolution will be found when the periphery of the workpiece is assessed from a centre other than the centre of the least squares circle.

NOTE 5 When electronic circuits of instruments are required to respond to down to 1 undulation per revolution, they are often made responsive down to zero frequency (0 Hz), this being a natural way of avoiding phase distortion and permitting calibration by static means.

3.2 Instrument error

3.2.1 Overall instrument error. The overall instrument error, comprising systematic and random components from the spindle error, electric noise, vibration, magnification, etc., shall be expressed as a percentage of the upper limiting value of the measuring range used.

3.2.2 Errors of rotation of the instrument

3.2.2.1 General. The following errors of rotation shall be determined under reference conditions at assigned positions of measurement:

- a) *Radial instrument error:* the value of roundness parameter that would be indicated by the instrument when measuring a perfectly round and perfectly centred section of a test piece, in a direction perpendicular to the reference axis of rotation;
- b) *Axial instrument error:* the value derived from the zonal parameter displayed by the instrument when measuring on a perfectly flat test piece set perfectly perpendicular to the reference axis of rotation.

NOTE The components of errors of rotation are vector quantities and should not therefore be algebraically added to the measured value of a roundness parameter in an attempt to allow for errors of rotation.

3.2.2.2 Statements of errors of rotation. The displacements that the rotating member can exhibit, within the confines of its bearings, shall be divided into combinations of:

- a) radial displacements parallel to itself;
- b) axial displacements parallel to itself;
- c) tilt.

As the magnitude of the radial instrument error measured at the stylus depends on the position of the measurement plane along the axis of rotation and the magnitude of the axial instrument error depends on the radius at which the flat test piece is measured, the axial and radial positions selected for test shall be stated.

The radial instrument error shall be expressed at two stated and well separated positions along the axis, or at one position together with the rate of change of the radial instrument error along the axis. The axial instrument error shall be expressed on the axis and at one stated radius.

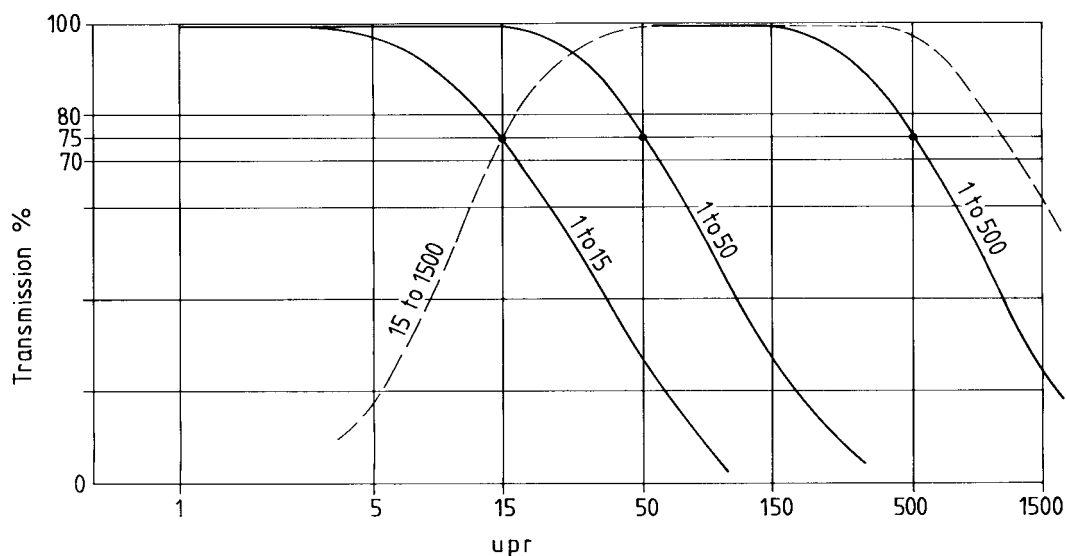


Figure 5 — Typical transmissions showing rate of attenuation given by two independent CR networks of equal time constant

Appendix A Departure from roundness of the measured profile of the workpiece

In this Part of this standard, the departure from ideal roundness is assessed as the difference between the largest and the smallest radii of the measured profile of the workpiece, measured from one or other of the following centres.

- a) *Least squares centre (LSC)*: the centre of the least squares mean circle (see Figure 6).
- b) *Minimum zone centre (MZC)*: the centre of the minimum zone circle (see Figure 7).
- c) *Minimum circumscribed circle centre (MCC)*: the centre of the minimum circumscribed circle for external surfaces (see Figure 8).

- d) *Maximum inscribed circle centre (MIC)*: the centre of the maximum inscribed circle for internal surfaces (see Figure 9).

The largest and smallest radius, in each case, is commonly used to define a concentric zone. The kind of zone may be designated by the letter *z*, together with a suffix denoting its centre. For the purposes of this standard the following suffices are used:

- e) least squares: suffix *q*, thus Z_q ;
- f) minimum width: suffix *z*, thus Z_z ;
- g) minimum circumscribed: suffix *c*, thus Z_c ;
- h) maximum inscribed: suffix *i*, thus Z_i .

NOTE The use of circles drawn on the chart to represent circles fitting the profile of the workpiece assumes that the workpiece is sufficiently well centred on the axis of the instrument (see B.1.1, Figure 10 and Appendix F).

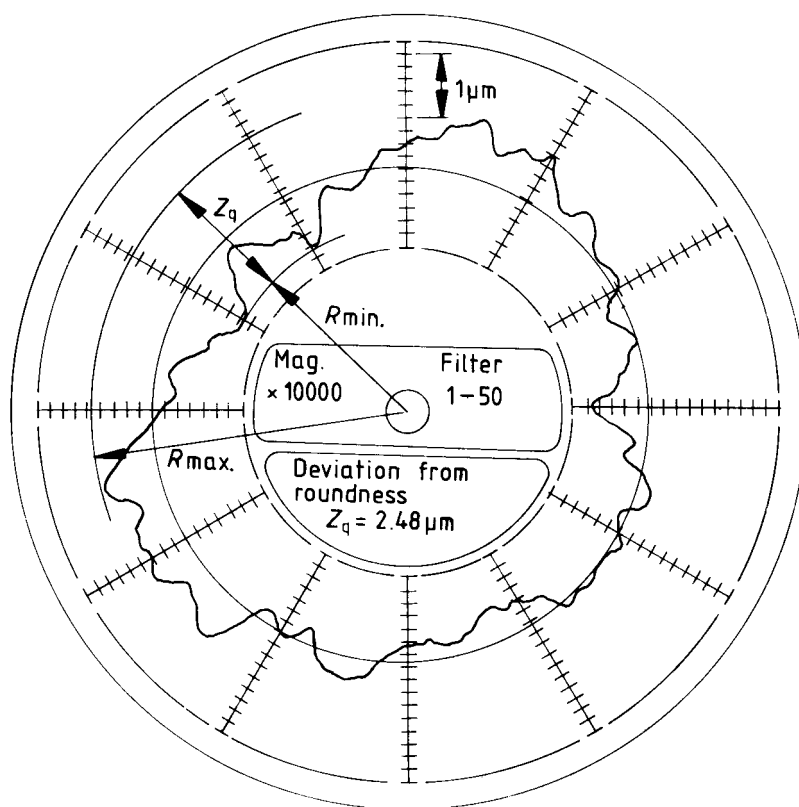


Figure 6 — Assessment of roundness from least squares centre (Z_q)