BRITISH STANDARD

BS 3730-3:
1982

Assessment of departures from roundness —

Part 3: Methods for determining departures from roundness using two- and three-point measurement

UDC 531.717.2:621.7.08

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Contents

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 4292. At the time of publication the technical content of this Part of this standard was in agreement with the ISO draft.

Appendix A gives worked examples of calculations for the departure from roundness.

This standard together with Parts 1 and 2 supersedes BS 3730:1964 which is now withdrawn.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.

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Summary of pages

This document comprises a front cover, an inside front cover, pages i and ii, pages 1 to 8, 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 describes methods for the numerical assessment of departures from roundness by the combination of two- and three-point measurement. The following methods are dealt with:

a) determination by means of two-point measurement (measurement of diameters);

b) determination by means of three-point measurement, summit (symmetrical or asymmetrical setting);

c) determination by means of three-point measurement, rider (symmetrical setting).

Any statement regarding an out-of-round section is incomplete unless the extent and nature of the departures from roundness is given and this is dealt with in Appendix A to D of BS 3730-2:1982.

For routine or in-process inspection, the requirements of BS 3730-2 may either be needlessly accurate or the items to be inspected may be too large to be accommodated.

The methods described in this Part of this standard may give faster and cheaper ways of assessing departures from roundness. This assessed value will deviate from the true value. The difference between the measured value and the true value can be estimated with help of Table 2 to Table 8, under the presumption that the undulation numbers are known and of sinusoidal nature. For non-sinusoidal undulations, a theory for estimating such deviations is not yet available.

NOTE 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 Part 1 apply, together with the following.

2.1
two-point measurement

measurement between coaxial anvils, one fixed and one moving in the direction of measurement (see Figure 1 and Figure 5)

2.2
three-point measurement

measurement between anvils, two fixed and one moving in the direction of measurement (see Figure 2, Figure 3, Figure 4, Figure 6, Figure 7 and Figure 8)

2.3
summit method

a three-point measurement in which the two fixed anvils are situated on one side and the measuring anvil is situated on the other side of the workpiece axis in the plane of measurement (see Figure 2, Figure 3, Figure 6, and Figure 7)

2.4
rider method

a three-point measurement in which the two fixed anvils are situated on the same side as the measuring anvil in the plane of measurement (see Figure 4 and Figure 8)

2.5
symmetrical (three-point) setting

a setting at which the direction of measurement coincides with the bisector angle between fixed anvils (see Figure 2, Figure 4, Figure 6 and Figure 8)

2.6
asymmetrical (three-point) setting

a setting at which the direction of measurement constitutes an angle with the bisector angle between fixed anvils (see Figure 3 and Figure 7)

3 Measuring conditions and instrument

3.1 Measuring anvil static force. The static measuring force shall not exceed 1 N.

NOTE 1 Preferably, the force should be adjustable and set at the lowest value that will ensure continuous contact between anvil and the surface being measured.

NOTE 2 For thin-walled workpieces, a high measuring force may affect the measuring result. Therefore it is necessary to reduce the force to the minimum value possible.

3.2 Measuring anvils. Depending on the form of the object, the measuring anvil shall be selected from Table 1.

NOTE Where the form of the object precludes the use of the anvils given in Table 1, other anvils may be used.

Table 1 — Types of anvil

Surface form	Anvil radius	Surface radius
	mm	mm
Convex surface	Spherical: 2.5	All
Convex edge	Cylindrical: 2.5	All
Concave surface	Spherical: 2.5	⩾ 10
Concave edge	Cylindrical: 2.5	⩾ 10
Concave surface	Spherical: 0.5	< 10
Concave edge	Cylindrical: 0.5	< 10

3.3 Fixed anvils. Point or line contact shall always be used.

NOTE The following is recommended:

a) External measurement. V-support with a small radius. The median plane of the V-support should be in the same plane as the plane of measurement.

b) Internal measurement. Sphere with a small radius. The median plane of the sphere should be in the same plane as the plane of measurement.

4 Procedure

In order to cover all possible form deviations and numbers of undulations always take one two-point measurement and two three-point measurements at different angles between fixed anvils.

NOTE The measurement procedures may, under certain preconditions, be amplified (see Table 2, Table 3 and Table 4).

Select the angles between fixed anvils from the following:

symmetrical setting:

α = 90° and 120° or α = 72° and 108°;

asymmetrical setting:

α 120°, β = 60°, or α = 60°, β – 30°;

where

- α is the angle between fixed anvils;
- β is the angle between the direction of measurement and bisector of angle between fixed anvils.

5 Expression of results

Calculate the corrected value of the departure from roundness δ from the formula:

$$\delta = \frac{\Delta}{F}$$

where

- Δ is the measured departure from roundness, which is largest value obtained from the preceding two or three combinations of angles received in the required measurements;
- F is the correction factor, with a value extracted from Table 2 to Table 8: as a first approximation F may be given a value of 2.

If the three-point measurement with symmetrical setting at 60° angles between fixed anvils is used when measuring workpieces with a known even or odd number of undulations, use the factor F given in Table 8.

NOTE This angle is useful as it gives measured values of higher correction factors than the other angles in this standard.

Table 5, Table 6 and Table 7 give true factors F for any given number of sinusoidal undulations and measuring method and if the number of sinusoidal undulations is known, calculate the departure from roundness by using the F factors directly from Table 5, Table 6 or Table 7 as indicated in Table 2, Table 3 or Table 4.

it is not possible to calculate exactly the departure from roundness if the number of undulations is unknown and in these cases calculate a maximum, average and minimum value of δ from the formula above using the largest Δ value and the factors obtained from Table 2, Table 3 or Table 4.

When selecting F, determine the limit on the maximum number of undulations per revolution, according to whether the number of undulations is known and whether this number is an odd or even value, from Table 2, Table 3 and Table 4.

NOTE 1 For 90° and 120° settings the maximum number of undulations per revolution is 22, which assumes that a greater number of undulations than this will not have any appreciable effect on the F factor.

For 72° and 108° settings the maximum number of undulations per revolution is determined by the fact that for 19 undulations the F factor cannot be determined.

NOTE 2 When using Table 5 to Table 8 other combinations of setting, besides those given in Table 2 to Table 4 can be made.

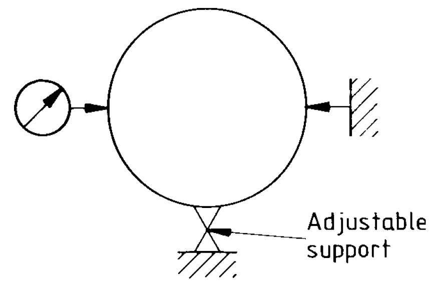

Figure 1 — Two-point measurement

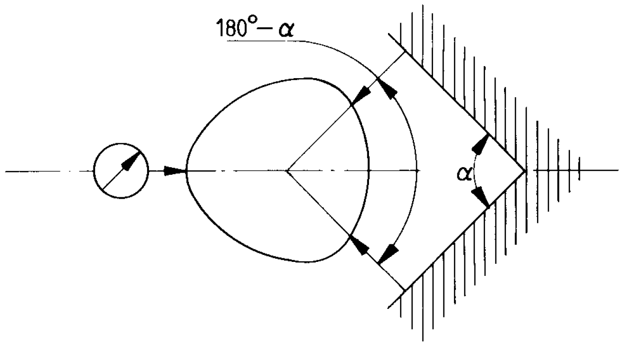

Figure 2 — Three-point measurement, summit method, symmetrical setting

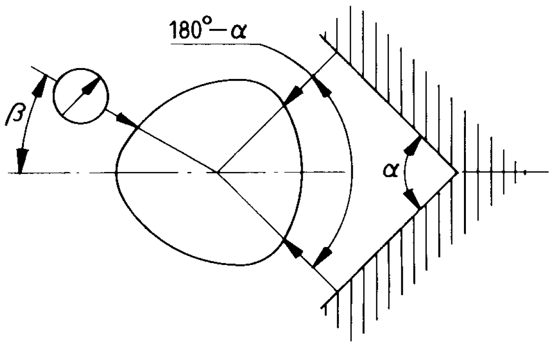

Figure 3 — Three-point measurement, summit method, asymmetrical setting

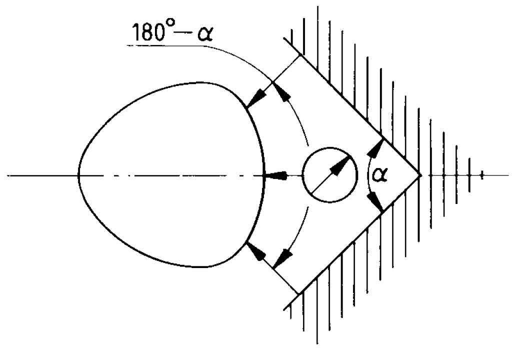

Figure 4 — Three-point measurement, rider method, symmetrical setting

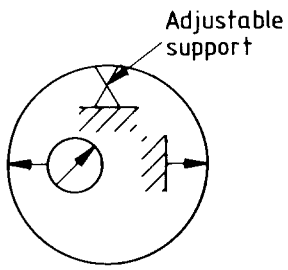

Figure 5 — Two-point measurement

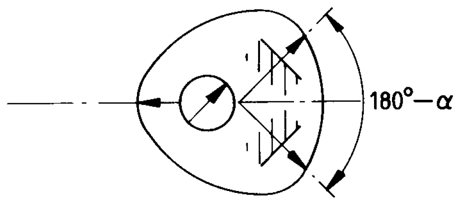

Figure 6 — Three-point measurement, summit method, symmetrical setting

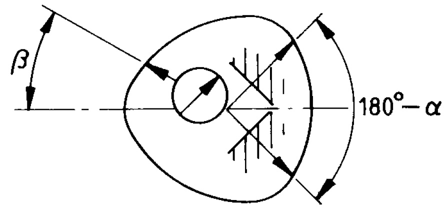

Figure 7 — Three-point measurement, summit method, asymmetrical setting

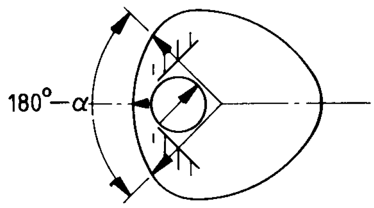

Figure 8 — Three-point measurement, rider method, symmetrical setting

Table 2 — Values of factor *F* for α = 90° and α = 120°, symmetrical setting

Number of undulations, n_s	Combination of settings[a]				
	2, 3S 90° and 3S 120°	2, 3R 90° and 3R 120°	2	3S 90° and 3S 120°	3R 90° and 3R 120°
	Factor, *F*				
n_s unknown, but assumed to be $2 \leqslant n_s \leqslant 22$	max. 2.41 av. 1.94 min. 1.00	max. 2.41 av. 1.96 min. 1.00	—	—	—
n_s even but unknown, but assumed to be $2 \leqslant n_s \leqslant 22$	—	—	2.00	max. 2.41 av. 2.08 min. 2.00	max. 2.41 av. 2.17 min. 1.58
n_s odd but unknown, but assumed to be $3 \leqslant n_s \leqslant 21$	—	—	—	max. 2.00 av. 1.80 min. 1.00	max. 2.00 av. 1.80 min. 1.00
n_s known and even	—	—	2.00	exact[b]	exact[b]
n_s known and odd	—	—	—	exact[b]	exact[b]

[a] The abbreviations in the table represent the following situations:
2 = two-point measurement;
3S 90° = three-point measurement, summit, α = 90°;
3S 120° = three-point measurement, summit, α = 120°;
3R 90° = three-point measurement, rider, α = 90°;
3R 120° = three-point measurement, rider, α = 120°.
[b] If multiplied by *F* factors given in Table 5.

Table 3 — Values of factor *F* for α = 72° and α = 108°, symmetrical setting

Number of undulations, n_s	Combination of settings[a]				
	2, 3S 72° and 3S 108°	2, 3R 72° and 3R 108°	2	3S 72° and 3S 108°	3R 72° and 3R 108°
	Factor, *F*				
n_s unknown, but assumed to be $2 \leqslant n_s \leqslant 18$	max. 2.70 av. 2.16 min. 2.00	max. 2.62 av. 2.11 min. 1.38	—	—	—
n_s even but unknown, but assumed to be $2 \leqslant n_s \leqslant 22$	—	—	2	max. 2.70 av. 2.16 min. 2	max. 2.70 av. 2.13 min. 2
n_s odd but unknown, but assumed to be $3 \leqslant n_s \leqslant 17$	—	—	—	max. 2.62 av. 2.06 min. 1.38	max. 2.62 av. 2.06 min. 1.38
n_s known and even	—	—	2	exact[b]	exact[b]
n_s known and odd	—	—	—	exact[b]	exact[b]

[a] The abbreviations in the table represent the following situations:
2 = two-point measurement;
3S 72° = three-point measurement, summit, α = 72°;
3S 108° = three-point measurement, summit, α = 108°;
3R 72° = three-point measurement, rider, α = 72°;
3R 108° = three-point measurement, rider, α = 108°;
[b] If multiplied by *F* factors given in Table 6.

Table 4 — Values of factor *F* for α = 60°/β = 30° and α = 120°/β = 60°, asymmetrical setting and α = 90° symmetrical setting

Number of undulations, n_s	Combination of settings[a]						
	2, and 3S 60°/30°	2, and 3S 60°/30° and 3S 90°	2, and 3S 120°/60°	2, and 3S 120°/60° and 3S 90°	2	3S 60°/30°	3S 120°/60°
	Factor, *F*						
n_s unknown but assumed to be $2 \leqslant n_s \leqslant 10$	2	max. 2.41 av. 2.04 min. 2	max. 2.38 av. 2.08 min. 2	max. 2.41 av. 2.13 min. 2	—	max. 2 av. 1.6 min. 0.73	max. 2.38 av. 1.69 min. 0.42
n_s unknown but assumed to be $2 \leqslant n_s \leqslant 22$	—	max. 2.41 av. 2.04 min. 2	—	max. 2.41 av. 2.09 min. 2	—	—	—
n_s even but unknown and assumed to be $2 \leqslant n_s \leqslant 22$	—	—	—	—	2	max. 1.41 av. 1.22 min. 0.73	max. 2.38 av. 1.22 min. 0.42
n_s odd but unknown and assumed to be $3 \leqslant n_s \leqslant 9$	2	2	2	2	—	2	2
n_s odd but unknown and assumed to be $3 \leqslant n_s \leqslant 21$	—	2	—	2	—	—	—
n_s even and known	—	—	—	—	2	exact[b]	exact[b]
n_s odd and known	—	—	—	—	—	exact[b]	exact[b]

[a] The abbreviations in the table represent the following situations:
2 = two-point measurement;
3S 60°/30° = three-point measurement, summit, α = 60°, β = 30°;
3S 120°/60° = three-point measurement, summit, α = 120°, β = 60°;
3S 90° = three-point measurement, summit, α = 90° (symmetrical setting).

[b] If multiplied by *F* factors given in Table 7.

Table 5 — Values of factor *F* for α = 90° and α = 120°, symmetrical setting, for n_s = 2 to n_s = 22

Number of undulations, n_s	Combination of settings[a]				
	2	3S 90°	3S 120°	3R 90°	3R 120°
	Factor, F				
2	2	1	1.58	1	0.42
3	[b]	2	1	2	1
4	2	0.41	0.42	2.41	1.58
5	[b]	2	2	2	2
6	2	1	[b]	1	2
7	[b]	[b]	2	[b]	2
8	2	2.41	0.42	0.41	1.58
9	[b]	[b]	1	[b]	1
10	2	1	1.58	1	0.42
11	[b]	2	[b]	2	[b]
12	2	0.41	2	2.41	[b]
13	[b]	2	[b]	2	[b]
14	2	1	1.58	1	0.42
15	[b]	[b]	1	[b]	1
16	2	2.41	0.42	0.41	1.58
17	[b]	[b]	2	[b]	2
18	2	1	[b]	1	2
19	[b]	2	2	2	2
20	2	0.41	0.42	2.41	1.58
21	[b]	2	1	2	1
22	2	1	1.58	1	0.42

[a] See asterisk footnote to Table 2.
[b] In this case the method gives no indication of deviation from roundness.

Table 6 — Values of factor *F* for α = 72° and α = 108°, symmetrical setting, for n_s = 2 to n_s = 22

Number of undulations, n_s	Combination of settings[a]				
	2	3S 72°	3S 108°	3R 72°	3R 108°
	Factor, F				
2	2	0.47	1.38	1.53	0.62
3	[b]	2.62	1.38	2.62	1.38
4	2	0.38	[b]	2.38	2
5	[b]	1	2.24	1	2.24
6	2	2.38	[b]	0.38	2
7	[b]	0.62	1.38	0.62	1.38
8	2	1.53	1.38	0.47	0.62
9	[b]	2	[b]	2	[b]
10	2	0.70	2.24	2.70	0.24
11	[b]	2	[b]	2	[b]
12	2	1.53	0.38	0.47	0.62
13	[b]	0.62	1.38	0.62	1.38
14	2	2.38	[b]	0.38	2
15	[b]	1	2.24	1	2.24
16	2	0.38	[b]	2.38	2
17	[b]	2.62	1.38	2.62	1.38
18	2	0.47	1.38	1.53	0.62
19	[b]	[b]	[b]	[b]	[b]
20	2	2.70	2.24	0.70	0.24
21	[b]	[b]	[b]	[b]	[b]
22	2	0.47	1.38	1.53	0.62

[a] See asterisk footnote to Table 3.
[b] In this case the method gives no indication of deviation from roundness.

Table 7 — Values of factor F for $\alpha = 60°/\beta = 30°$ and $\alpha = 120°/\beta = 60°$, asymmetrical setting, for $n_s = 2$ to $n_s = 22$

Number of undulations, n_s	Combination of settings[a]		
	2	3S 60°/30°	3S 120°/60°
	Factor, F		
2	2	1.41	2.38
3	[b]	2	2
4	2	1.41	1.01
5	[b]	2	2
6	2	0.73	0.42
7	[b]	2	2
8	2	1.41	1.01
9	[b]	2	2
10	2	1.41	2.38
11	[b]	[b]	[b]
12	2	0.73	1.01
13	[b]	[b]	[b]
14	2	1.41	0.42
15	[b]	2	2
16	2	1.41	1.01
17	[b]	2	2
18	2	0.73	2.38
19	[b]	2	2
20	2	1.41	1.01
21	[b]	2	2
22	2	1.41	0.42

[a] See asterisk footnote to Table 4.
[b] In this case the method gives no indication of deviation from roundness.

Table 8 — Values of factor F for $\alpha = 60°$, symmetrical setting

Number of undulations, n_s	Combination of settings[a]	
	3S 60°	3R 60°
	Factor, F	
2	[b]	2
3	3	3
4	[b]	2
5	[b]	[b]
6	3	1
7	[b]	[b]
8	[b]	2
9	3	3
10	[b]	2
11	[b]	[b]
12	3	1
13	[b]	[b]
14	[b]	2
15	3	3
16	[b]	2
17	[b]	[b]
18	3	1
19	[b]	[b]
20	[b]	2
21	3	3
22	[b]	4

[a] The abbreviations in the table represent the following situations:
3S 60° = three-point measurement, summit, $\alpha = 60°$;
3R 60° = three-point measurement, rider, $\alpha = 60°$.
[b] In this case the method gives no indication of deviation from roundness.

Appendix A Worked examples

Example 1. A centreless ground workpiece is to be verified. It is known that a three-lobed shape is present.

Available measuring equipment measures two-point, 3S 72° and 3S 108°.

Measured results obtained:

$\Delta_{2\text{-point}} = 1\ \mu m$;

$\Delta_{3S\ 72°} = 8\ \mu m$;

$\Delta_{3S\ 108°} = 3\ \mu m$.

Calculation of the departure from roundness: for 3 sinusoidal undulations, Table 6 shows:

$F_{2\text{-point}}$ (not applicable)

$F_{3s\ 72°} = 2.62$

$F_{3s\ 108°} = 1.38$

$\delta_{2\text{-point}}$ (not applicable)

$$\delta_{3S\ 72°} = \frac{\Delta_{3S\ 72°}}{F_{3S\ 72°}} = \frac{8}{2.62} \approx 3\ \mu m$$

$$\delta_{3S\ 108°} = \frac{\Delta_{3S\ 108°}}{F_{3S\ 108°}} = \frac{3}{1.38} \approx 2\ \mu m$$

$$\delta = \delta_{max} = \delta_{3S\ 72°} \sim 3\ \mu m$$

Approximation of the departure from roundness:

$$F = 2$$

$$\delta = \frac{\Delta_{max}}{2} = \frac{8}{2} = 4\ \mu m$$

Example 2. A turned cylindrical bore is to be verified.

Available measuring equipment measures two-point, 3S 90° and 3S 120°.

Measured results obtained:

$\Delta_{2\text{-point}} = 2\ \mu m$;

$\Delta_{3S\ 90°} = 30\ \mu m$;

$\Delta_{3S\ 120°} = 27\ \mu m$.

Calculation of the departure from roundness: by comparing the results obtained with the given *F*-factors (2-point near zero value, 90° and 120° values almost equal), Table 5 indicates that there are 5 or 19 sinusoidal undulations.

For 5 and 19 lobes the following *F*-factors are given in Table 5:

$F_{2\text{-point}}$ (not applicable)

$F_{3S\ 90°} = 2$

$F_{3S\ 120°} = 2$

$\delta_{2\text{-point}}$ (not applicable)

$$\delta_{3S\ 90°} = \frac{30}{2} = 15\ \mu m$$

$$\delta_{3S\ 120°} = \frac{27}{2} = 14\ \mu m$$

$$\delta = \delta_{max} = \delta_{3S\ 90°} = 15\ \mu m$$

Approximation of the departure from roundness:

$$F = 2$$

$$\delta = \frac{\Delta_{max}}{2} = \frac{30}{2} = 15\ \mu m$$

Publications referred to

BS 3730, *Assessment of departures from roundness.*

BS 3730-1, *Glossary of terms relating to roundness measurement.*

BS 3730-2, *Specification for characteristics of stylus instruments for measuring variations in roundness (including guidance on use and calibration).*

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