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Machine tool ball screws —

**Part 2: Specification for accuracy,
including geometrical tests**

Committees responsible for this British Standard

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- Advanced Manufacturing Technology Research Institute
- Cranfield Institute of Technology
- Department of Trade and Industry [Mechanical Engineering and Manufacturing Technology Division (Mmt)]
- Federation of British Engineers' Tool Manufacturers
- Health and Safety Executive
- Ministry of Defence
- Society of British Aerospace Companies
- Individual experts

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Foreword

This Part of BS 6101 has been prepared under the direction of the Machine, Engineers and Hand Tools Standards Policy Committee in response to requests from machine tool manufacturers who use ball screws in their machines.

This edition supersedes BS 6101-2:1982 which is withdrawn.

This Part of BS 6101 is based on, but is not identical to, ISO/DIS 3408-3 prepared by the International Organization for Standardization (ISO).

It is limited to ball screws of up to 2 500 mm travel which suits the UK home and export requirements. DIS 3408 goes beyond that and up to 6 300 mm travel.

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 and ii, pages 1 to 14, 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 requirements for accuracy and describes geometrical tests for re-circulating ball screws for use in machine tool applications.

This standard is applicable to re-circulating ball screw assemblies having the shafts and nuts manufactured from hardened steel. It deals only with the verification of accuracy of ball screw assemblies before mounting in the machine tool. It does not apply to testing the running of the machine tool.

Complementary tables are given in Appendix A. Appendix B describes a method of measuring the error in the balltrack.

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

2 Definitions

for the purposes of this Part of BS 6101, the definitions given in BS 6101-3 apply

NOTE See Figure 1.

3 Application of test methods

3.1 The tests in Table 3 may be applied in any order that is practicable and that makes for ease of mounting of instruments or gauging. The sequence in which the geometrical tests are listed in Table 3 is not intended to impose the practical order in which the tests are to be done.

3.2 For tests G5 to G11, the shaft shall be set parallel to the surface on which the tests are carried out. For the purposes of these tests, it is assumed that the balltrack has been checked to prove its concentricity with the outside diameter of the screwed portion of the shaft, therefore the use of this outside diameter for reference purposes is acceptable. If the balltrack is found not to be concentric, then the error shall be taken into account when measuring the permissible deviation. (See Appendix B.)

4 Abbreviations

For the purposes of this standard, the use of “per” in column 4 of Table 1 has a specific meaning as follows.

--- per --- This type of expression applies to deviations of straightness and parallelism, and is used to recommend a measurement length, but in this case the proportionality rule comes into operation if the measurement length differs from that indicated.

5 Accuracy grades

5.1 General

The tests are graded in five standard tolerance grades (see Table 1) in compliance with BS 4500-1 and Table 2 of ISO/R 1938:1971. The value v_{300} (test G3) of the travel variation, v , within 300 mm travel served as a basis for the classification.

Table 1 — Standard tolerance grades

Standard tolerance grade	IT1 IT3 IT5 IT7 IT10	↑	Increasing requirements on accuracy and function
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5.2 Geometrical tests

5.2.1 Tolerances

Tolerances on specified travel, e_p , for the useful travel, l_u (tests G1.1 and G1.2), are taken directly from Tables 2 and 2A of ISO/R 1938:1971.

Tolerances on travel variation, v_{up} , in micrometres, within the useful travel, l_u , were evaluated using the following equations:

$$\text{Grade IT1: } v_{up} = 0.0045 \bar{l}_u + 4.6$$

$$\text{Grade IT3: } v_{up} = 0.009 \bar{l}_u + 9.2$$

$$\text{Grade IT5: } v_{up} = 0.018 \bar{l}_u + 18.4$$

where $\bar{l}_u$ is the geometrical mean, in millimetres, of the extreme lengths of each step:

$$\bar{l}_u = \sqrt{(l_{u \max} \times l_{u \min})}$$

Run-out tolerances and orientation tolerances were determined from experience.

5.2.2 Travel deviations

5.2.2.1 General

Depending on the type of ball screw considered (positioning or transport ball screw) the tests given in Table 2 shall apply.

The basic measuring principle is illustrated in Figure 2.

Tests and tolerances refer to the ball nut body displacement relative to the ball screw shaft.

A pitch-to-pitch measurement may be carried out using a measuring ball by touching the ball track of a non-rotating ball screw shaft. For the measuring intervals, see Table 4.

The travel variation $v_{2\pi}$ within 2π rad is determined over nine measurements ($8 \times 45^\circ$) per revolution or continuously within one thread (at the start, in the middle and at the end of useful travel), provided that this test has been the subject of a special agreement.

Table 2 — Travel deviation tests

Travel deviations per reference length	Type of ball screw	
	Positioning	Transport
	Test	
Travel compensation c for useful travel l_u	Specified by user	$c = 0$
Tolerance on specified travel e_p	G11	G12
Permissible travel variation v_{up} within useful travel	G2	—
Permissible travel variation v_{300p} within 300 mm travel	G3	G3
Permissible travel variation $v_{2\pi p}$ within 2π rad	G4	—

5.2.2.2 Evaluation of the measuring diagrams**5.2.2.2.1 Choice of methods**

To determine the actual mean travel deviation within the useful travel, one may use either a mathematical method, which is precise by its very nature, or a graphical method, which is simple and quick and is recommended as an approximation method suitable for every day evaluations.

5.2.2.2.2 Mathematical method

The actual mean travel deviation, e_a , is given by the formula

$$e_a = a + by$$

where

$$a = \frac{\sum \gamma_i^2 \sum e_i - \sum \gamma_i \sum \gamma_i e_i}{n \sum \gamma_i^2 - \sum \gamma_i \sum \gamma_i}$$

$$b = \frac{n \sum \gamma_i e_i - \sum \gamma_i \sum e_i}{n \sum \gamma_i^2 - \sum \gamma_i \sum \gamma_i}$$

e_a is the actual mean travel deviation in relation to the specified or nominal travel, as appropriate;

γ is the angle of rotation (specified or nominal travel, as appropriate);

γ_i is the angle of rotation (specified or nominal travel, as appropriate) corresponding to the i th measuring point;

e_i is the travel deviation (or travel) in relation to the specified or nominal travel for the angle of rotation (or travel) corresponding to the i th measuring point;

n is the number of measuring points.

5.2.2.2.3 Graphical method [see Figure 3(a) and Figure 3(b)]

The determination of the actual mean travel deviation from the travel deviation diagram is carried out as follows:

- draw one or several tangents to the actual travel deviation curve at at least two upper peaks ($l_1, l_2, \dots$) and repeat this procedure for the lower peaks ($l_3, \dots$);
- determine the respective largest deviations ($e_1, e_2, e_3, \dots$) parallel to the ordinate, and select from these the smallest deviation (e_2 in the example);
- draw a straight line through this point of minimum deviation that is parallel to the corresponding peak line (l'_2 parallel to l_2 in the example).

The actual mean travel deviation, e_a , is the centreline between these parallel lines (l_2 and l'_2) and the band width within the useful travel, v_{ua} , is the distance between these parallel lines, e_2 , measured parallel to the ordinate.