An update on BSI and ISO machine tool accuracy standards

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Abstract

Up to the 1980s most standards on test conditions for machine tools, which represented most of the production of the MTE/1 (BSI) and TC39 (ISO) technical committees, were made following the same principle; they only dealt with geometric accuracy and, in order to provide some information on the cutting performance, with finishing cuts.

However, since that period, the emphasis has widened with the increased complexity of CNC and by demand from industry for different tests for assessing more thoroughly the machine performance.

Also, ten years ago, over 90% of BSI's standards were purely national, today, the tables have turned with over 90% of BSI's standards being either dual numbered or harmonized with European or International standards.

This paper describes the current status of the relevant BSI and ISO standards on machine tool testing and previews how, increasingly, harmonisation affects our national outlook on standards.

Definition

Standard

"Document, established by consensus and approved by a recognised body, that provides, for common and repeated use, rules, guidelines or characteristics for activities or their results, aimed at the achievement of the optimum degree of order in a given context." [1]
Background

At a meeting of the British Association for the Advancement of Science in August 1906, its Chairman, Sir John Wolfe Barry, stated that, "Standardisation is a rather barbarous word, but describes by a short cut and better than any paraphrase, an important departure which is of great interest to us all, the study and recognition of standard forms and qualities".

The British Engineering Standards Association, forerunner of BSI, was founded in 1901 to coordinate the development of national standards and represented, in that time, a major breakthrough in the history of technology and industrialisation. This foundation of BSI preceded by nearly 20 years that of other major national standards bodies.

In April 1926, those countries that had set up standards bodies met and formed the International Federation of the National Standardising Associations (ISA). The ISA lasted until 1939 when war broke out in Europe, it was eventually replaced by the International Organisation for Standardisation (ISO) that was formed on 23rd February 1947.

British Standards Institution (BSI)

BSI was incorporated by Royal Charter in 1929: a non-profit-distributing organisation, BSI remains independent of Government, industry or trade associations.

BSI plays a vital enabling role in the creation of standards. Interested parties representing the relevant industries, trade associations, consumer bodies, product testing organisations and local government are brought together by BSI to define the new British Standard.

One of the first British Standards, published in 1903, reduced the number of tramway rails manufactured from 75 to 5 - saving £1 million a year even then. Today, there are nearly 13,000 British Standards, with over 1,200 new standards produced each year. BSI's work is ensuring that, increasingly, they are being adopted worldwide. Equally, all safety related European Standards automatically become British Standards and all applicable International Standards are harmonised as British Standards.

International Organisation for Standardisation (ISO)

ISO is a worldwide federation of national standards bodies, comprising over 100 members. The object of ISO is to promote the development of standardisation and related activities in the world with a view to facilitating international exchange of goods and services, and to developing cooperation in the sphere of intelligent, scientific, technological and economic activity. The results of ISO technical work are published as International Standards.
Committee Structure

ISO

An International Standard is the result of an agreement between the member bodies of ISO and may be used as such, or may be implemented through incorporation in national standards of different countries. A member body is the national body "most representative of standardisation in its country". Member bodies pay subscription fees and are entitled to participate and exercise voting rights on any technical committee of ISO. Member bodies which decide to take an active part of a Technical Committee (or Subcommittee) are designated as P-members (participating). Member bodies which only wish to be kept informed of the work of a Technical Committee are registered as O-members (Observers). The Technical Committees are established by the Technical Management Board, who in turn establish the Subcommittee and Working Groups.

The Technical Committee responsible for producing ISO standards on all aspects of machine tools is TC39. One of the Subcommittees established by TC39 is SC2 (referred to as TC39/SC2) which is tasked with developing the test conditions for metal cutting machine tools. Normally Technical Committee TC39 delegates the technical aspects of producing standards to Working Groups. These working Groups deal with major projects, but in recent years has decided to speed up the work by establishing Ad Hoc Groups for specific short term issues under the leadership of a Project Leaders. Both the Working Group Convenor and Project Leaders function is to expedite the standards through the various Committee stages as efficiently and quickly as possible.

TC39/SC2 is presently assisted by three Working Groups, which are:

- WG 1 Revision of ISO 230-1
- WG 4 Test Conditions for Turning Centres (ISO 13041)
- WG 6 Evaluation of thermal effects (ISO 230-3).

BSI

Technical committee MTE/1 has the overall responsibility for the direction and coordination of work carried out on the national and international field of machine tool standardisation. Recognition of the importance of international work has reduced the demand for British Standards developed on a purely national basis. Resources devoted to national work have declined with the consequential decline in the Committee structure. The majority of MTE/1's work is to shadow the development of new standards at International and European level and maintenance of existing British Standards for which no international or European equivalents are in view. To achieve this reduced role, MTE/1 is supported by 3 subcommittees and a number of working panels.
Standards Development

International standards are developed on the basis of a project approach through several stages; proposal stage, committee stage, enquiry stage and approval stage. Each stage has a time limit and the project can effectively be cancelled if the time limits are not met.

Proposal Stage This initial stage identifies the requirement, which can be either a new ISO standard or the revision of an existing standard. In some instances this can be in the form of first working draft (WD) offered by a member country or, as in the case of ISO 230-2 "Determination of accuracy and repeatability of positioning", by a member organisation (BSI) offering a national standard (BS 4656:Part 16).

During this stage the priority is determined, the target dates are set and a Project Leader identified. The time limit for this stage is six months.

Committee Stage Once the proposal has been accepted, TC39 will pass the work to an existing Working Group or establish an Ad Hoc group comprising of the relevant experts. Whichever group undertakes the work has two years to produce the first committee draft (CD).

Enquiry Stage When agreement is reached within the committee, the CD becomes a Draft International Standard (DIS) which is circulated as an enquiry draft to all member bodies for voting. This voting stage must be completed within five months.

Approval Stage If this draft meets the acceptance criteria, it is circulated as a Final Draft International Standard (FDIS) for a two-month unconditional vote and, if accepted, is published as an International Standard. The timescale for producing the FDIS is three years.

With harmonisation, MTE/1 now has a policy of adopting all ISO standards that are coming through for publication, although it has the authority to disregard the eventual ISO standard if the content is totally different from an existing BSI standard.

Current Status of Standards

For the purpose of this paper, only those new standards being worked on by TC39/SC2 and their consequences for BS standards will be discussed here.

BS ISO 230 (BS 3800) - Test Code for Machine Tools

This series of standards is reproduced verbatim from the ISO 230 series, with only one exception namely BS 3800:Part 3, whose ISO equivalent has yet to be published. These standards are regarded as the reference book for machine tool
testing, they detail all the methods and instruments that may be applied to particular tests but it do not include permissible deviations. To simplify matters, the old BS 3800 parts that were superseded are mentioned.

BS ISO 230 will consist of the following parts, under the general title "Test code for machine tools":

- **Part 1**: Geometric accuracy of machines operating under no-load or finishing conditions
- **Part 2**: Determination of accuracy and repeatability of positioning of numerically controlled machine tool axes
- **Part 3**: Determination of thermal effects
- **Part 4**: Circular tests for numerically controlled machine tools
- **Part 5**: Determination of noise emission
- **Part 6**: Diagonal displacement tests

**BS ISO 230-1 : 1996 - "Geometric accuracy of machines operating under no-load or finishing conditions".**

The aim of this part, which supersedes BS 3800: Part 1:1990 which in turn superseded BS 3800: Part 1:1964, is to standardise methods of testing the accuracy of all types of metalworking machine tools by means of geometrical and practical tests such as straightness, flatness, parallelism and squareness. It relates only to testing of geometrical accuracy and not with the checking of the running of the machine tool, e.g. vibrations, abnormal noises, nor with speeds and feeds etc.

This part also provides information on definitions, testing methods, and the use of checking instruments and tolerances. In addition to a description and precautions for use on the various checking instruments such as straightedges, precision levels and lasers.

It describes preliminary checking operations and geometrical checks as well as some special checks such as circularity, cylindricity and consistency of machined diameters. There is no change in this standard from the superseded BS 3800:Part 1.

**BS ISO 230-2 : 1997 - "Determination of accuracy and repeatability of positioning of numerically controlled machine tool axes"**


It uses statistical treatment of measured values to define various parameters related to the accuracy and repeatability of numerically controlled
machine tools and related accessories by direct measurements on the machine. The methods described are only for linear and rotary positioning errors.

The methods involve repeat measurements at a series of random target positions along the length of the axis under test. The number of measurements and the nature of the errors does not allow the confidence level of the results to be estimated accurately. Nevertheless the methods chosen have been shown in practice to have an adequate confidence level and, provided the procedure is followed, will give acceptable results.

This standard differs from the BS 3800:Part 2 in a number of significant ways; it deletes the requirement to treat angular and straightness errors in a statistical manner and follows the recommendations provided by the Guide to the expression of uncertainty of measurement. The first recommendation is related to the assumption of the type of distribution of the positional deviations. The modified definitions in this standard use no assumptions for the shape of the distributions by referring to 'standard uncertainties' rather than 'standard deviation'. The new definition of expanded uncertainty with a coverage factor of 2 instead of 3 is also used.

Secondly, in order to highlight the systematic behaviour of machine tools, new definitions of 'E' (corresponding to the term Accuracy in ANSI B5.54) and M (corresponding to the term Positional Deviation P in VDI 3441).

ISO 230-3 Determination of thermal effects
After discussion at Kyoto, 1998, the modified draft will be distributed to members before it is registered as an FDIS. Once published it will be harmonized as BS ISO 230-3 Determination of thermal effects and will supersede BS 3800:Part 3.

BS 3800: Part 3: 1990 - "Method of testing performance of machines operating under loaded conditions in respect of thermal distortion". This part gives methods for assessing the contribution to workpiece inaccuracy arising from thermal behaviour of the machine, due to internal heat sources, in respect of:

(a) distortion of the structure; and
(b) drift of the axis drives.

The tests for thermal distortion of the structure are applicable to any machine which incorporates a rotating spindle or spindles supporting the tool or workpiece.

The tests are designed to establish the relative displacements occurring between the tool and workpiece sides of the structure as a result of thermal expansion or contraction of key structural elements.

The tests for thermal drift of the axis drives are applicable to numerically controlled machines only and are designed to quantify the effects on positioning accuracy and repeatability of thermal expansion and contraction of axis drives.

The standard specified that the test mandrel and fixture used for the test on the structure should be constructed from a low-expansion alloy material. It also indicated a presentation format for the resultant data.
This part specifies methods of testing and evaluating the circular hysteresis and the circular and radial deviation of circular paths that are produced by the simultaneous movements of two linear axes. It includes definitions, test conditions, test parameters and procedures, as well as a presentation of the results. There was no previous BS 3800 part.

ISO 230-5 - "Determination of the noise emission"
This standard is currently at the DIS stage. Once published it will be harmonized as BS ISO 230-4 Determination of the noise emissions.

This part specifies methods for noise testing stationary floor mounted machine tools and related auxiliary equipment directly on the shop floor. The purpose of the measurements is to permit comparison of the performance of different units of a given family of machine tools or equipment, under defined environmental conditions and standardized mounting and operating conditions. There was no previous BS 3800 part.

ISO 230-6 - "Diagonal displacement test"
This standard is currently at the third WD stage. When eventually published it will be harmonized as BS ISO 230-6 Diagonal displacement test.

As this part is still at the WD stage it is highly likely to change from its present form. However, currently it is used for the estimation of the volumetric performance of a machine tool. The test procedure is conceptually similar to that described in BS ISO 230-2 for linear axes except that linear displacements are not measured parallel to a linear axis but along the diagonal of the working volume of the machine. These measurements shall be carried out in the four body diagonals of the working volume. On turning machines, face diagonals are used instead of body diagonals. There was no previous BS 3800 part.

BS 4656 'Accuracy of Machine Tools and Methods of Test'

This standard gives both methods of test and permissible deviations for each individual test with references made to the applicable BS 3800 (BS ISO 230) series. Which, as previously stated, is very much in the format of Schlesinger\(^\text{5}\), BS 4656 is primarily intended for developing and verifying individual machine specifications.

This is probably the backbone of BSI's machine tool testing standards. There was 38 parts to this standard, with each part relating to a specific machine type, with the exception of a few parts. However, harmonisation has resulted in the following parts being replaced by the ISO equivalent:

- Part 8 Internal cylindrical grinding machines with horizontal spindle (replaced by BS ISO 2407:1997)
ISO 10791 - Test Code for Machining Centres

This standard specifies with reference to the relevant parts of (BS) ISO 230, several families of tests for machining centres with horizontal or vertical spindle or universal heads of different types. The machines may be stand-alone or integrated into flexible manufacturing systems. It establishes the tolerances corresponding to general purpose and normal accuracy machines. The standard is also applicable to numerically controlled milling or boring machines when their configurations, components and movements are compatible with the tests so described. Currently this standard is made up of 11 parts, although new parts covering such features as tests under load, checking performance and stiffness of the machine under specified loads are being proposed. Once all parts are published, it will supersede BS 4656:Part 30. Where the British Standard has already been published then it shall be quoted otherwise the ISO version is quoted. Currently the title and status of each part is as follows:-

BS ISO 10791-1:1998 "Geometric tests for machining centres with horizontal spindle and with accessory heads (Z axis - horizontal)"

Part 2 "Geometric tests for machining centres with vertical spindle or universal heads with vertical primary rotary axis (Z axis - vertical)"
Currently at DIS stage

BS ISO 10791-3:1999 "Geometric tests for machining centres with integral universal heads with horizontal primary rotary axis B (Z axis - vertical)"

BS ISO 10791-4:1999 "Accuracy and repeatability of positioning of linear and rotary axes"

BS ISO 10791-5:1998 "Accuracy and repeatability of work-holding pallets"
Laser Metrology and Machine Performance

BS ISO 10791-6:1998 "Accuracy of speeds, feeds and interpolations"

BS ISO 10791-7:1998 "Accuracy of finished test piece"

Part 8 "Global evaluation by means of circular tests"
Currently at DIS stage

Part 9 "Evaluation of the operating times of tool change and pallet change"
Currently at DIS stage

Part 10 "Evaluation of the thermal distortions"
Currently at CD stage, awaiting finalisation of ISO 230-3

Part 11 "Noise tests"
Currently at CD stage, awaiting finalisation of ISO 230-5

Part 12 "Evaluation of the vibration severity"
Deleted from project (Resolution 10, Prague 1998), however Resolution 8, Kyoto 1998 agreed that there is a need for a uniform approach to the methods of test and consequently appointed a US member to lead this effort. The outcome is likely to be the publication of a new part of the (BS) ISO 230 series before the work on Part 12 is restarted.

ISO 13041 - Test Code for Turning Centres

The object of ISO 13041 is to supply information as wide and comprehensive as possible on geometric, positional, contouring, thermal and machining tests which can be carried out turning centres and numerically controlled (NC) turning machines.

ISO 13041 specifies, with reference to the relevant parts of (BS) ISO 230, tests on machines that are stand alone or integrated into flexible manufacturing systems and with or without tailstocks. ISO 13041 also establishes the tolerances or maximum permissible deviations for the test results corresponding to general purpose and normal accuracy machines for three size ranges up to a swing diameter of 1,000 mm.

It gives definitions and terminology associated with both turning centres and NC turning machines as well as displaying examples of different turret and spindle configurations. As with most standards, for simplicity the diagrams used in the individual tests are based on only one machine type.

Currently at DIS stage, the standard will follow the BS 4656: Part 30 format (i.e. all in one document) rather than the ISO 10791 format (i.e. divided into many parts). The DIS draft has been distributed to member bodies for comment and is due for discussion at the next SC2 meeting in Stockholm, Sweden on November 1999.
Status of other ISO work

- **DIS/ISO 1984-1**: Test conditions for milling machines with table of fixed height - machines with horizontal spindle.
- **DIS/ISO 1984-2**: Test conditions for milling machines with table of fixed height - machines with vertical spindle.
- **DIS/ISO 1986-1**: Test conditions for surface grinding machines with horizontal grinding wheel spindle and reciprocating table - machines with table length of up to 1600 mm.
- **WD/ISO 1986-2**: Test conditions for surface grinding machines with horizontal grinding wheel spindle and reciprocating table - table length larger than 1600 mm.
- **DIS/ISO 2433**: Test conditions for external cylindrical grinding machines with a moveable table.
- **DIS/ISO 3686-1**: Test conditions for high accuracy turret and single spindle coordinate drilling and boring machines with table of fixed height with vertical spindle - single column type machines.
- **DIS/ISO 3686-1**: Test conditions for high accuracy turret and single spindle coordinate drilling and boring machines with table of fixed height with vertical spindle - bridge type machines.
- **DIS/ISO 4703**: Test conditions for surface grinding machines with two columns for grinding slideways.
- **DIS/ISO 8636-1**: Test conditions for plano-milling machines - portal type.
- **FDIS/ISO 11090-2**: Test conditions for die sinking electro-discharge machines - two column machines.
- **DIS/ISO 14137**: Test conditions for wire electro-discharge machines.

References

1. BS 0:PART 1:1991 "A STANDARD FOR STANDARDS"