TECHNICAL REPORT

ISO/TR 17243-1

First edition
2014-12-01

Machine tool spindles — Evaluation of machine tool spindle vibrations by measurements on spindle housing —

Part 1: Spindles with rolling element bearings and integral drives operating at speeds between 600 min^{-1} and 30 000 min^{-1}

Broches pour machines-outils — Évaluation des vibrations d'une broche pour machine-outil par mesurages sur le logement de la broche —

Partie 1: Broches à roulements à billes et moteurs intégrés opérant à des vitesses comprises entre 600 min^{-1} et 30 000 min^{-1}

Reference number
ISO/TR 17243-1:2014(E)

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Published in Switzerland

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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.

The procedures used to develop this document and those intended for its further maintenance are described in the ISO/IEC Directives, Part 1. In particular the different approval criteria needed for the different types of ISO documents should be noted. This document was drafted in accordance with the editorial rules of the ISO/IEC Directives, Part 2 (see www.iso.org/directives).

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. Details of any patent rights identified during the development of the document will be in the Introduction and/or on the ISO list of patent declarations received (see www.iso.org/patents).

Any trade name used in this document is information given for the convenience of users and does not constitute an endorsement.

For an explanation on the meaning of ISO specific terms and expressions related to conformity assessment, as well as information about ISO's adherence to the WTO principles in the Technical Barriers to Trade (TBT), see the following URL: Foreword — Supplementary information.

The committee responsible for this document is ISO/TC 39, *Machine tools*, Subcommittee SC 2, *Test conditions for metal cutting machine tools*.

ISO/TR 17243 consists of the following parts, under the general title *Machine tool spindles — Evaluation of machine tool spindle vibrations by measurements on spindle housing*:

— *Part 1: Spindles with rolling element bearings and integral drives operating at speeds between 600 min^{-1} and 30 000 min^{-1}*

— *Part 2: Direct driven spindles and belt driven spindles with rolling element bearings operating at speeds between 600 min^{-1} and 30 000 min^{-1}*

Introduction

This part of ISO/TR 17243 provides specific guidance for assessing the severity of vibration measured on the spindle housing at customer site or at the machine tool manufacturer test facilities.

Machine tool spindles — Evaluation of machine tool spindle vibrations by measurements on spindle housing —

Part 1: Spindles with rolling element bearings and integral drives operating at speeds between 600 min^{-1} and 30 000 min^{-1}

1 Scope

This part of ISO/TR 17243 provides information on how to assess the severity of machine tool spindle vibrations measured on the spindle housing. The vibration criteria provided in this part of ISO/TR 17243 apply to spindles with integral drive intended for stationary machine tools with nominal operating speeds between 600 min^{-1} and 30 000 min^{-1}. This part of ISO/TR 17243 only applies to spindles with rolling element bearing types.

This part of ISO/TR 17243 applies to spindles assembled on metal cutting machine tools.

This part of ISO/TR 17243 is applicable for testing, periodic verification, and continuous monitoring.

Spindles with bearing types other than rolling element bearings are excluded from this part of ISO/TR 17243.

This part of ISO/TR 17243 does not address geometrical accuracy of axes of rotation (see ISO 230-7).

This part of ISO/TR 17243 does not address unacceptable cutting performance with regards to surface finish and accuracy.

This part of ISO/TR 17243 does not address vibration severity issues of machine tool spindles operating at speeds below 600 min^{-1} or exceeding 30 000 min^{-1} due to lack of supporting vibration data and limitations in many vibration measurement instruments. Also, due to lack of data, machine tool spindles with bearing types other than rolling element bearings are excluded from this part of ISO/TR 17243.

This part of ISO/TR 17243 does not address frequency domain analyses such as fast fourier transform (FFT) analyses, envelope analyses, or other similar techniques.

2 Normative references

The following documents, in whole or in part, are normatively referenced in this document and are indispensable for its application. For dated references, only the edition cited applies. For undated references, the latest edition of the referenced document (including any amendments) applies.

ISO 1925, *Mechanical vibration — Balancing — Vocabulary*

ISO 1940-1, *Mechanical vibration — Balance quality requirements for rotors in a constant (rigid) state — Part 1: Specification and verification of balance tolerances*

ISO 2041, *Mechanical vibration, shock and condition monitoring — Vocabulary*

ISO 2954:2012, *Mechanical vibration of rotating and reciprocating machinery — Requirements for instruments for measuring vibration severity*

ISO 13372, *Condition monitoring and diagnostics of machines — Vocabulary*

3 Terms and definitions

For the purposes of this document, the terms and definitions given in ISO 1925, ISO 2041, ISO 13372, ISO 2954, and the following apply.

NOTE A concept limited to a special meaning in a particular context is indicated by designating the subject field in angle brackets (<, >) before the definition. For example, in the context of spindle condition monitoring for the term entry for alert, see 3.11.

3.1
belt driven spindle
spindle where the power transmission is achieved by a belt between the drive motor and the spindle

3.2
direct driven spindle
machine tool spindle in a motor-coupling-spindle configuration with no belts, gears, or other power transmitting elements in the power train

3.3
gear driven spindle
machine tool spindle with one or more power transmitting gear units in the power train

Note 1 to entry: Gear driven spindles may also incorporate coupling and/or belts in the power train.

3.4
spindle with integral drive
spindle unit where the rotor of the drive motor is the rotor of the spindle

3.5
short term
<spindle condition monitoring> time period of six months or shorter

Note 1 to entry: Time periods may differ for specific spindle types and/or operational conditions.

3.6
long term
<spindle condition monitoring> time period of longer than six months

Note 1 to entry: Time period may differ for specific spindle types and/or operational conditions.

3.7
machine condition monitoring
detection, collection, and interpretation of information and data that indicate the spindle condition of a machine tool spindle

3.8
spindle condition
root-mean-square (RMS) values for vibration velocity and acceleration of machine tool spindles as defined by specifications

3.9
short term spindle condition
STSC
parameter indicating the short term spindle condition of a machine tool spindle

3.10
long term spindle condition
LTSC
parameter indicating the long term spindle condition of a machine tool spindle

3.11
alert
<spindle condition monitoring> condition where a significant change in spindle vibration magnitude with respect to normal values has been detected

3.12
alarm
<spindle condition monitoring> condition where the vibration magnitude induces increased dynamic load on spindle bearings, reducing bearing lifetime

3.13
threshold for shutdown
<spindle condition monitoring> condition where the vibration magnitude induces high dynamic load on the spindle bearings potentially with substantial loss of bearing lifetime

3.14
steady-state operating temperature
<spindle condition monitoring> condition where machine tool spindle has been running for a sufficient time to reach a stable operating temperature

4 Preliminary operations

4.1 General

When measuring vibration, the operational condition of the machine tool is of great importance. This part of ISO/TR 17243 is applicable to all normal operational conditions that the machine tool could be in when machining.

For any spindle vibration measurement intended to characterize the spindle condition according to this part of ISO/TR 17243, important operational conditions should be recorded; such operational conditions include, but are not limited to, characteristics listed in 4.2 to 4.11.

When using vibration measurement results for evaluation of spindle condition, other factors contributing to or interfering with the measured signals should be taken into consideration. Such factors include spindle motor current control signals with their associated frequencies, influences of machine foundation and the position of the other moving components affecting the dynamic response of the overall system, and possible high level of scatter due to low energy content in the frequency range of interest. If such interfering signals or conditions are suspected, frequency analysis techniques can be used to differentiate bearing signals from other contributing factors.

4.2 Process load

All vibration measurements should be made under no-load conditions (no cutting, milling, or grinding).

4.3 Spindle speed

This part of ISO/TR 17243 is applicable for every speed within the nominal speed range of the machine tool/spindle. Manufacturer may specify non-continuous speed ranges like 600 min^{-1} to 17 000 min^{-1} and 19 000 min^{-1} to 24 000 min^{-1} in order to avoid unreasonable limits at resonance speeds. Two such resonance speed intervals are allowed together, occupying a maximum of 10 % of the nominal operating speed range of the spindle. The possibility to exclude certain speed ranges only applies to the vibration velocity parameter as defined in 6.1, i.e. indicators for long term spindle condition (LTSC). The vibration acceleration parameter as defined in 6.2, i.e. indicators for short term spindle condition (STSC), applies to any speed within the nominal speed range of the spindle.

When measuring vibration magnitude as a function of spindle speed, it is important to execute the spindle speed changes in such a way that a steady-state vibration of the spindle is reached before recording the measurements. The following are typical methods.

— Step: Increasing or decreasing the spindle speed in steps not greater than 3 % of spindle maximum speed with 10 s of constant speed at each such selected speed.

— Acceleration: Increasing or decreasing the spindle speed with a rate of not more than 20 % of maximum spindle speed per minute.

Both the above methods will result in approximately 5 min measurement time.

4.4 Thermal conditions

Thermal conditions have to be agreed upon between manufacturer/supplier and user. If no conditions are specified, the tests should be made under conditions as near as possible to those of normal operation with regards to lubrication and warm-up. Therefore, the machine should have an idle running performance in accordance with the conditions of use and the instructions of the manufacturer until the machine/spindle has reached steady-state operating temperature. Refer to ISO 230-1 for the installation of the machine before testing and warming up of the spindle and other moving components.

4.5 Spindle position and orientation

Spindle position: ISO/TR 17243-1 is applicable for all possible linear axis positions.

Spindle orientation: ISO/TR 17243-1 is applicable for all possible spindle orientations.

Spindle direction of rotation: For spindles that can be operated in either direction, ISO/TR 17243-1 applies to both clockwise and counter clockwise spindle rotation.

Spindle position, orientation, and direction of rotation for vibration measurements have to be agreed upon between manufacturer/supplier and user.

4.6 Tool or workpiece balancing

A tool or workpiece mounted in the spindle might influence the vibration measurements due to the unbalance of the tool or workpiece itself. It should be recorded whether a tool/workpiece is used during the measurements or not. If used, the mass and balancing grade according to ISO 1940-1 of tool/workpiece used during vibration measurements should be recorded.

4.6.1 Spindle vibration measurements with a tool/workpiece mounted in the spindle

Care should be taken to avoid errors introduced by the unbalance of the tool/workpiece. For most machine tools/spindles, this implies that a balance quality grade of G2.5 or better, according to ISO 1940-1, is required. If available, refer to spindle manufacturer recommendations.

4.6.2 Spindle vibration measurements without tool/workpiece

Spindles that can be operated throughout their entire operating speed range without any tool/workpiece mounted and do not require tool/workpiece for balance can be measured without a tool/workpiece mounted in the spindle.

4.7 Spindle chuck

Spindle chuck mechanical settings such as chuck front end position with respect to spindle gauge line for clamped and unclamped positions, as well as jaw positions, should be recorded.

4.8 Spindle cooling

The spindle cooling system settings should be set appropriately and the performance confirmed. All settings should be recorded.

4.9 Drawbar

The drawbar status should be recorded as tool clamped, tool unclamped, or tool improperly clamped. It is recommended that all spindle vibration measurements be performed with tool clamped or no tool. Refer to 4.6.

4.10 Background vibration

If the measured vibration magnitude is greater than an acceptance criterion established by mutual agreement between manufacturer/supplier and user and background vibration is suspected, measurements should be made with the machine shut down to determine the degree of external influence. If the vibration magnitude with the machine shut down exceeds 10 % of the value measured when the machine is running, corrective action might be necessary to reduce the effect of background vibration.

NOTE In some cases, the effect of background vibration can be nullified by spectrum analysis or by eliminating the offending external source.

4.11 Idle operation

It can be beneficial to conduct vibration measurements with the spindle idle but other machine tool systems, such as pumps, fans, and hydraulic systems, active. Vibration data acquired this way can be useful when comparing spindle vibration changes over time.

Idle spindle vibration measurements should be taken at the same measurement locations/directions as running spindle vibration measurements. Refer to 5.2.

5 Measurement and operational procedures

5.1 Measuring instruments

The measuring instrument should comply with requirements of ISO 2954 for a specified frequency range of 10 Hz to 10 kHz.

Various methods exist to compute the rms value of a specified frequency band. Refer to ISO 2954, Annex A for further information on how to test the rms indicator of any measuring instrument.

Care should be taken to ensure that the measurements are not influenced by environmental factors or other external factors including, but not limited to, the following:

— temperature variations;

— magnetic fields;

— sound pressure fields;

— sensor cable length;

— power supply noise.

Refer to 5.3 for further information on sensor mounting procedures.