SVENSK STANDARD
SS 728000-1:2014

Fastställd/Approved: 2014-06-30
Publicerad/Published: 2014-07-01
Utgåva/Edition: 1
Språk/Language: engelska/English
ICS: 25.040.20

Spindlar för verktygsmaskiner – Utvärdering av spindelvibrationer genom mätning på spindelhus – Del 1: Motorspindlar med rullelementlager och operativa varvtal mellan 600 min-1 och 30 000 min-1

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

Content

Introduction

SS 728000 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 speed between 600 min-1 and 30 000 min-1

Other than part 1 (this part) the following parts are under preparation;

Part 2: Direct driven spindles with rolling element bearings operating at speed between 600 min-1 and 30 000 min-1

Part 3: Geared spindles with rolling element bearings operating at speeds between 600 min-1 and 30 000 min-1

Part 4: Geared spindles with rolling element bearings operating at speeds below 600 min-1

Part 5: Spindles with magnetic bearings

1 Scope

This part of SS 728000 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 SS 728000 applies to spindles with integral drive intended for stationary machine tools with nominal operating speeds between 600 min-1 and 30 000 rpm-1. This part of SS 728000 only applies to spindles with rolling element bearing types.

This part of SS 728000 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.

This part of SS 728000 applies to spindles assembled in the machine tool.

This part of SS 728000 is applicable for testing, periodic verification and continuous monitoring.

Spindles with integral drive covered by this part of SS 728000 include spindle types intended for:

— Machining centers

— Milling machines

— Boring machines

— Grinding machines

— Turning centers

— Lathes

— Turning machines.

Spindles with bearing types other than rolling element bearings are excluded from this part of SS 728000.

This part of SS 728000 does not address geometrical accuracy of axes of rotation (see ISO 230-7:2006).

This part of SS 728000 does not address unacceptable cutting performance with regard to surface finish and accuracy.

This part of SS 728000 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.

2 Normative references

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

ISO/IEC Guide 98-3	*Uncertainty of measurement – Part 3: Guide to the expression of uncertainty in measurement (GUM:1995)*
SS-ISO 841, utg 2	*Industrial automation systems and integration – Numerical control of machines -Coordinate system and motion nomenclature (ISO 841:2001, IDT)*
SS-ISO 1925, utg 2	*Mechanical vibration – Balancing – Vocabulary (ISO 1925:2001, IDT)*
SS-ISO 1940-1, utg 2	*Mechanical vibration – Balance quality requirements for rotors in a constant (rigid) state – Part 1: Specification and verification of balance tolerances (ISO 1940-1:2003, IDT)*
SS-ISO 1940-1/Cor 1:2005	*Mechanical vibration – Balance quality requirements for rotors in a constant (rigid) state – Part 1: Specification and verification of balance tolerances (ISO 1940-1:2003/Cor 1:2005, IDT)*
SS-ISO 2041:2009	*Vibration and shock – Vocabulary (ISO 2041:2009, IDT)*
ISO 2954:2012	*Mechanical vibration of rotating and reciprocating machinery – Requirements for instruments for measuring vibration severity*
SS-ISO 13372:2012	*Condition monitoring and diagnostics of machines – Vocabulary (ISO 13372:2012, IDT)*

3 Terms and definitions

For the purposes of this document, the terms and definitions given in SS-ISO 1925, utg 2, SS-ISO 2041:2009, SS-ISO 13372:2012 and the following apply.

3.1
belt driven spindle
spindle where the power transmissions 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 less than 6 months

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 6 months or longer

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

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

3.8
spindle condition
RMS values for vibration velocity and acceleration of machine tool spindles

NOTE 1 to entry: Described in 6.1 and 6.2

3.9
STSC
Short Term Spindle Condition
parameter indicating the short term spindle condition of a machine tool spindle

3.10
LTSC
Long Term Spindle Condition
parameter indicating the long term spindle condition of a machine tool spindle

3.11
alert
condition where a significant change of vibration magnitude with respect to normal values has occurred

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

3.13
threshold for shutdown
condition where the vibration magnitude induces high dynamic load on the spindle bearings, substantial loss of bearing lifetime

3.14
steady-state operating temperature
<spindle condition monitoring> condition where machine tool spindle no longer is subjected to temperature changes as a result of being put in operation after being non-operational for time long enough to adopt ambient temperature

4 Preliminary operations

4.1 General

As for any vibration measurement the operational condition of the machine tool during measurement is of great importance. This part of SS 728000 is applicable to all normal operating conditions of the machine tool. That is any operational condition that the particular machine tool may be in when machining.

For any spindle vibration measurement intended to characterize the spindle condition according to this part of SS 728000 important operational conditions shall be recorded during spindle vibration measurements. Such operational conditions include, but are not limited to, characteristics listed in 4.2 to 4.12.

4.2 Process load

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

4.3 Spindle speed

This part of SS 728000 is applicable for every speed within the nominal speed range of the machine tool/spindle. Manufacturer may specify non-continuous speed ranges such as for instance 600 min-1 – 17 000 min-1 and 19 000 min-1 - 24 000 min-1 in order to avoid unreasonable limits at resonance speeds. A maximum of two such resonance speed ranges 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. The vibration acceleration parameter applies to any speed within the nominal speed range of the spindle.

When measuring vibration magnitude as a function of spindle speed, the spindle speed changes shall be made in such a way that a steady state vibration of the spindle is accomplished before recording the measurements. Typical methods are:

Step: Increasing or decreasing the spindle speed in steps not greater than 3 % of spindle maximum speed, with 10 seconds 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 minutes measurement time.

4.4 Thermal conditions

Thermal conditions should be agreed between manufacturer/supplier and user. If no conditions are specified the tests shall be made under conditions as near as possible to those of normal operation, as regards to lubrication and warm-up. The machine should make an idle running in accordance with the conditions of use and the instructions of the manufacturer until the machine/spindle has reached a steady-state operating temperature.

NOTE Refer to ISO 230-1:2012 for the installation of the machine before testing, warming up of the spindle and other moving components.

4.5 Spindle head position and direction

Spindle position, orientation and rotation for measurements shall be agreed between manufacturer/supplier and user.

Spindle position – this part of SS 728000 is applicable for all possible linear axis positions, including axial traversed.

Spindle orientation – this part of SS 728000 is applicable for all possible spindle orientations.

Spindle direction of rotation – for spindles that can be operated in either direction, this part of SS 728000 applies to both clockwise and counter clockwise spindle rotation.

4.6 Tool

4.6.1 General

A tool mounted in the spindle may influence the vibration measurements due to the unbalance of the tool itself. It shall be recorded whether a tool is used during the measurements or not. If used, the mass and balancing grade according to SS-ISO 1940-1, utg 2 of tool used during vibration measurements shall be recorded.

4.6.2 Spindle vibration measurements with a tool mounted in the spindle

Care should be taken to avoid errors introduced by the unbalance of the tool. Generally this implies that a balance quality grade of G2.5 or better according to SS-ISO 1940-1, utg 2 is required. If available, spindle manufacturer recommendations shall be referred to.

4.6.3 Spindle vibration measurements without tool

Spindles that can be operated throughout its entire operating speed range without any tool mounted and that do not require a tool for balance may be measured without a tool 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, should be recorded, as well as jaw positions.

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 shall be recorded as tool clamped, tool unclamped or tool improperly clamped. All spindle vibration measurements shall be performed with tool clamped or no tool, see 4.6.

4.10 Tool retaining force

If possible, the tools retaining force should be measured and recorded, in any circumstances spindle vibration measurements should only be performed if it is reasonably assured that the tool is properly fitted to the spindle.

4.11 Background vibration

If the measured vibration magnitude is greater than the acceptance criteria and background vibration is suspected, measurements shall be made with the machine shut down to determine the degree of external influence. If the vibration magnitude with the machine stationary exceeds 25 % of the value measured when the machine is running, corrective action shall be taken to reduce the effect of background vibration.

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

4.12 Idle operation

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

Idle spindle vibration measurements shall be taken at the same measurement locations/directions as running spindle vibration measurements, see 5.2.

5 Measurement and operational procedures

5.1 Measuring instruments

The measuring instrument shall comply with requirements of ISO 2954:2012. The frequency response of the measuring instrument shall be flat in the frequency range of 10 Hz – 10 000 Hz.

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

— Temperature variations

— Magnetic fields

— Sound pressure fields

— Sensor cable length

— Power supply noise

5.2 Measurement locations/directions

5.2.1 General

For vibration criteria presented in this part of SS 728000, measurements should be taken on the spindle housing at the front end of the spindle as well as at the back end. Sensor longitudinal locations should coincide with spindle bearing longitudinal locations as close as possible. Measurements should be taken in minimum two radial directions at both ends of the spindle and in axial direction in at least one end of the spindle, see figure 1.

NOTE The back end of the spindle may be hard to access, requiring dismantling of covers, etc.

The preferred sensor locations/directions ensure good mechanical coupling from the mechanical interface (the bearings) of rotating and non-rotating parts of the machine, and sensor locations. Therefore the preferred sensor locations/directions ensure low damping of vibration signals and good vibration signal quality.

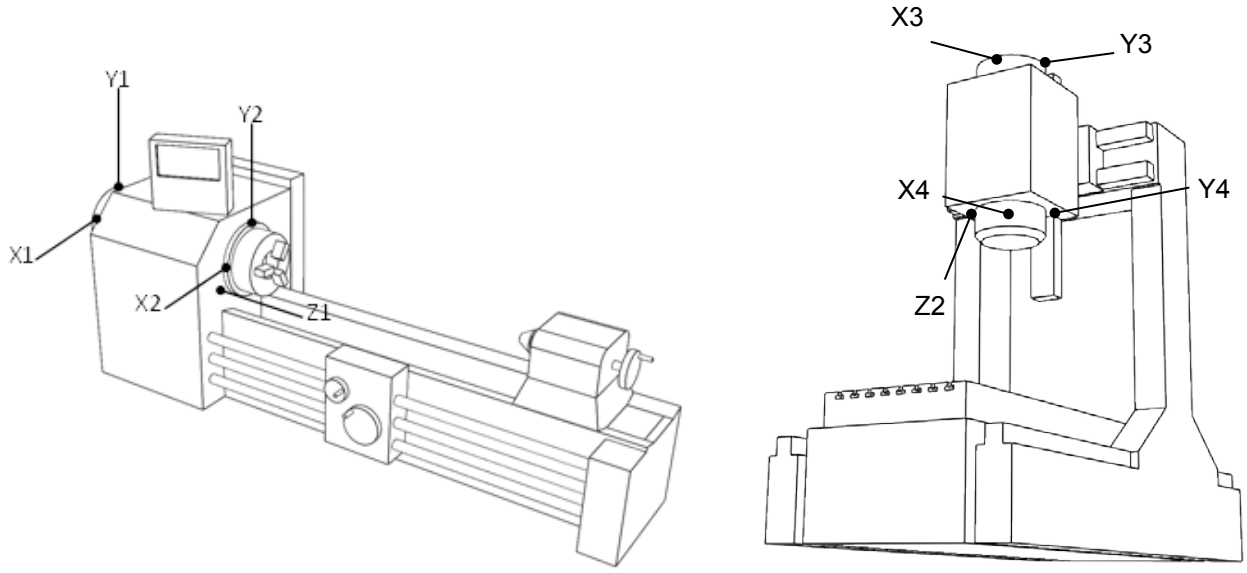
If for practical reasons some of the preferred sensor locations are not deemed possible to access, these sensor locations may be omitted or alternative sensor positions be established by mutual agreement between manufacturer/supplier and user. If alternative sensor locations are selected, the evaluation zone boundary values in 8.4.2 and 8.4.3 shall be agreed between manufacturer/supplier and user.

The two radial measurement directions should be perpendicular to each other and coincide with the movement axes of the machine tool, such as X and Y or any other axes defined by SS-ISO 841, utg 2. See figure 1 for examples on common machine types.

For some machine tool designs other measurement directions may be preferred.

The vibration sensor should be positioned at the preferred measurement locations of Figure 1. For periodic measurements where the main interest is observing changes in the vibration related parameters over time, a single tri-axial sensor can be used. In this last case, a fixed threaded installation of the vibration sensor, see 5.3, should be used to ensure measurement repeatability.

All sensor locations/directions used for vibration measurements shall be recorded.



Key

X1, X2, X3, X4	Preferred radial measurement locations in X-axis direction of machine.
Y1, Y2, Y3, Y4	Preferred radial measurement locations in Y-axis direction of machine.
Z1, Z2	Preferred axial measurement locations in Z-axis direction of machine.

Figure 1 — Examples of preferred measurement locations and possible naming conventions of common machine/spindle configurations

5.2.2 Naming convention for measurement locations

Spindles with integral drive covered by this part of SS 728000 are used in many different machine tool types and applications. Therefore no obvious naming convention exists for assigning names to the measurement locations/directions.

The terminology shall be according to SS-ISO 841, utg 2 when referring to directions coinciding with movement axes of machine types covered by SS-ISO 841, utg 2. Possible measurement location names include:

“Spindle front end X”

“Spindle back end Y”

In any case where measurement location/direction names could be misinterpreted, additional data shall be supplied (i.e. a simple drawing).

5.3 Sensor mounting procedures

The sensor mounting shall be as rigid as possible, ensuring that the mounting procedure does not influence the measured value in any significant way.

For acceptance testing of new or overhauled machine tools or spindles chemical bonding or threaded sensor mounting should be used since these mounting procedures will ensure best possible measurement results for all parameters defined in this part of SS 728000.

For periodic measurements wax or sensors mounted with a magnetic base may be considered, due to practical considerations.