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Mechanical vibration — Evaluation of machine vibration by measurements on non-rotating parts —

Part 7: Rotodynamic pumps for industrial applications, including measurements on rotating shafts

Vibrations mécaniques — Évaluation des vibrations des machines par mesurages sur les parties non tournantes —

Partie 7: Pompes rotodynamiques pour applications industrielles, y compris mesurages sur les arbres tournants

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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.

International Standards are drafted in accordance with the rules given in the ISO/IEC Directives, Part 2.

The main task of technical committees is to prepare International Standards. Draft International Standards adopted by the technical committees are circulated to the member bodies for voting. Publication as an International Standard requires approval by at least 75 % of the member bodies casting a vote.

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.

ISO 10816-7 was prepared by Technical Committee ISO/TC 108, *Mechanical vibration, shock and condition monitoring*, Subcommittee SC 2, *Measurement and evaluation of mechanical vibration and shock as applied to machines, vehicles and structures*, in collaboration with ISO/TC 115 *Pumps*.

ISO 10816 consists of the following parts, under the general title *Mechanical vibration — Evaluation of machine vibration by measurements on non-rotating parts*:

— *Part 1: General guidelines*

— *Part 2: Land-based steam turbines and generators in excess of 50 MW with normal operating speeds of 1 500 r/min, 1 800 r/min, 3 000 r/min and 3 600 r/min*

— *Part 3: Industrial machines with nominal power above 15 kW and nominal speeds between 120 r/min and 15 000 r/min when measured* in situ

— *Part 4: Gas turbine sets with fluid-film bearings*

— *Part 5: Machine sets in hydraulic power generating and pumping plants*

— *Part 6: Reciprocating machines with power ratings above 100 kW*

— *Part 7: Rotodynamic pumps for industrial applications, including measurements on rotating shafts*

Introduction

Vibration measurements on rotodynamic pumps can be useful for many purposes, e.g. for the operational monitoring, acceptance test and for diagnostic or analytic investigation (condition monitoring).

General descriptions of the principles to be applied for the measurement and assessment of vibration on coupled industrial machines are given for vibration on non-rotating parts in ISO 10816-1 and for shaft vibration in ISO 7919-1.

This part of ISO 10816 is based on vibration data gathered from a survey of about 1 500 pumps operating both *in situ* and at various test facilities. This survey included pumps of different types, speed and power, operating over a wide range of flows. Due to the large number of vibration measurements, these data are considered to be representative of pumps that are operating satisfactorily, though there is a lack of information about the mean time between failure and operating conditions for the measured values.

Statistical evaluation of these data has been made for the preferred operating region, i.e. 70 % to 120 % of the best efficiency point (BEP), as well as evaluations of the flow and power dependency.

This vibration survey showed no significant differences between rigid and flexible supports, or between horizontal and vertical orientations of the pumps when measured at the positions defined in this part of ISO 10816. This is in contrast to other standards dealing with vibration measurements (e.g. ISO 10816-1, ISO 10816-3 and ISO 13709[10]) which do make these distinctions.

The statistical analysis showed a slight dependency of the vibration values with the power consumption of a pump. Consequently, this part of ISO 10816 distinguishes between pumps up to and above 200 kW.

Mechanical vibration — Evaluation of machine vibration by measurements on non-rotating parts —

Part 7:
Rotodynamic pumps for industrial applications, including measurements on rotating shafts

1 Scope

This part of ISO 10816 gives instructions for the evaluation of vibration on rotodynamic pumps for industrial applications with nominal power above 1 kW. It defines the special requirements for evaluation of vibration when the vibration measurements are made on non-rotating parts (bearing housing vibration). It provides specific guidance for assessing the severity of vibration measured on bearing housings of rotodynamic pumps *in situ* and for the acceptance test at the manufacturer's test facility or in the plant. This part of ISO 10816 also gives general information and guidelines for assessing relative shaft vibration of the rotating shaft.

This part of ISO 10816 specifies zones and limits for the vibration of horizontal and vertical pumps irrespective of their support flexibility. The general evaluation criteria are valid for operational monitoring of rotodynamic pumps and for acceptance tests[1] *in situ* or at the manufacturer's test facility if specified. For the acceptance test at the manufacturer's test facility, special conditions are given.

For monitoring the vibration values during long-term operation, two criteria are provided for assessing the machine vibration. One criterion considers the magnitude of the observed vibration and the second considers changes in magnitude. The evaluation criteria are applicable for the vibration produced by the pump itself and not for vibration which is transmitted to the pump from external sources. The criteria mainly serve to ensure a reliable, safe long-term operation of the pump, simultaneously minimizing harmful effects on connected devices. Additionally, recommendations are given for defining operational limits and setting alarm and trip values.

For pump units with integrated electrical motors (impeller directly on the motor shaft or impeller shaft rigidly connected to the motor shaft), this part of ISO 10816 applies to the whole coupled unit.

For flexibly coupled motors, this part of ISO 10816 is applicable for the pump only. Also, separately mounted drivers are not within the scope of this part of ISO 10816. Those drivers are dealt with in ISO 10816-3.

The following types of pumps are excluded from this part of ISO 10816:

— reciprocating and rotating positive displacement pumps;

— reciprocating engine driven pumps;

1) Wherever acceptance tests are mentioned in this part of ISO 10816 it should be taken into account that all the details about place, size and form of those test procedures are optional and need to be specified and agreed between both parties of a contract.

— pumps in hydraulic power generating and pumping plants with power above 1 MW (see ISO 7919-5[4] and ISO 10816-5);

— solids handling, slurry and submersible pumps.

Torsional vibration is not dealt with in this part of ISO 10816.

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

ISO 7919-1, *Mechanical vibration of non-reciprocating machines — Measurements on rotating shafts and evaluation criteria — Part 1: General guidelines*

ISO 10816-1:1995, *Mechanical vibration — Evaluation of machine vibration by measurements on non-rotating parts — Part 1: General guidelines*

3 Vibration measurement

3.1 Measurement quantity and procedure

The measurement quantity to be used for measuring the vibration of non-rotating parts[2)] of rotodynamic pumps is the root-mean-square (r.m.s.) vibration velocity in mm/s. For speeds below 600 r/min, it is additionally required to measure the peak-to-peak displacement in µm. The measurement procedure to be followed is specified in ISO 10816-1.

3.2 Measuring instrumentation and frequency range

3.2.1 General

The measuring instrumentation shall conform to the requirements set out in ISO 10816-1. The instrumentation shall be capable of measuring the r.m.s. vibration velocity in a broad frequency range reaching from at least 10 Hz to 1 000 Hz and shall be in accordance with the requirements of ISO 2954.

For pumps with operating speeds below 600 r/min, the lower frequency limit of the measuring instrumentation shall normally be 2 Hz so that the frequency of the vibration component at operating speed is well within the measured frequency range. In addition, the measuring instrumentation shall measure both r.m.s. vibration velocity (in millimetres per second) and peak-to-peak displacement (in micrometres).

Owing to the fact that the broad-band peak-to-peak displacement in the low-frequency range can be strongly influenced by stochastic, impulsive excitations due to the fluid flow, sometimes higher than normal values might occur and should then be analysed and explained e.g. by frequency filtering. In accordance with this it is recommended to measure the peak-to-peak displacement for the filtered values at 0,5 times, 1 times and 2 times the operating speed with a bandwidth of 1 Hz or less to evaluate the quality of a pump.

For very high-speed pumps or for diagnostic purposes (see e.g. ISO 13373-1[8] which specifies a more detailed analysis), it may be required to use measuring instrumentation which covers a wider frequency range, usually up to 2,5 times the blade-passing frequency so that the blade-passing frequency components are adequately accounted for.

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2) For measurements on rotating shafts, see Annex B.

3.2.2 Precautions

Care shall be taken to ensure that the measuring instrumentation is not influenced by factors such as:

— temperature variations,

— magnetic fields,

— sound fields,

— power source variations,

— earth loops,

— transducer cable length,

— transducer orientation.

Particular attention should be given to ensure that the vibration transducers are correctly mounted and that such mountings do not degrade the accuracy of the measurements. If vibration transducers with a magnetic base are used, the support surface at the measurement object should be prepared to avoid measurement errors. Appropriate mounting methods are shown in Figure 1.

NOTE ISO 5348[2] contains information on the mechanical mounting of accelerometers which is, in general, also applicable to velocity transducers.

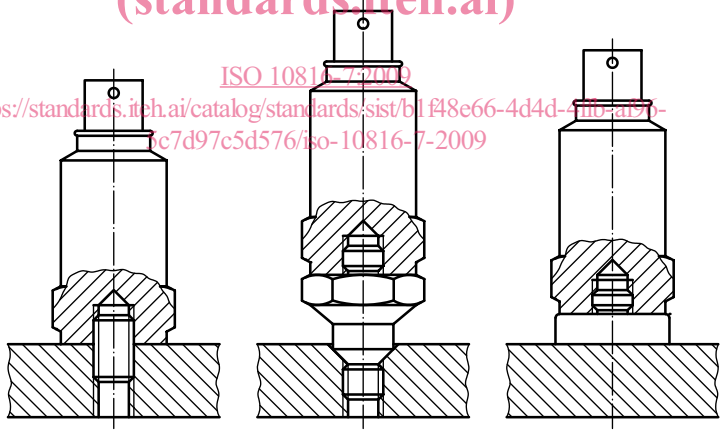


Figure 1 — Mounting methods for vibration transducers

3.2.3 Continuous and periodic monitoring

It is common practice on large or critical pumps to have permanently installed instrumentation for continuous on-line monitoring of vibration at key measurement locations. For many pumps, mainly those of small size or power, continuous monitoring of vibration is not necessarily carried out. Changes in unbalance, bearing performance, alignment, etc. can be detected with sufficient reliability from periodic vibration measurements with portable instrumentation.

When performing only periodic measurements on pumps, suddenly occurring defects will not be detected. This shall be especially taken into account when a pump is relevant to safety. In that case continuous on-line monitoring is recommended. The use of computers for trend analysis and warning against malfunctions is also becoming more common. Detailed information about procedures and instrumentation for vibration condition monitoring is given in ISO 13373-1[8].

3.3 Measurement locations and directions

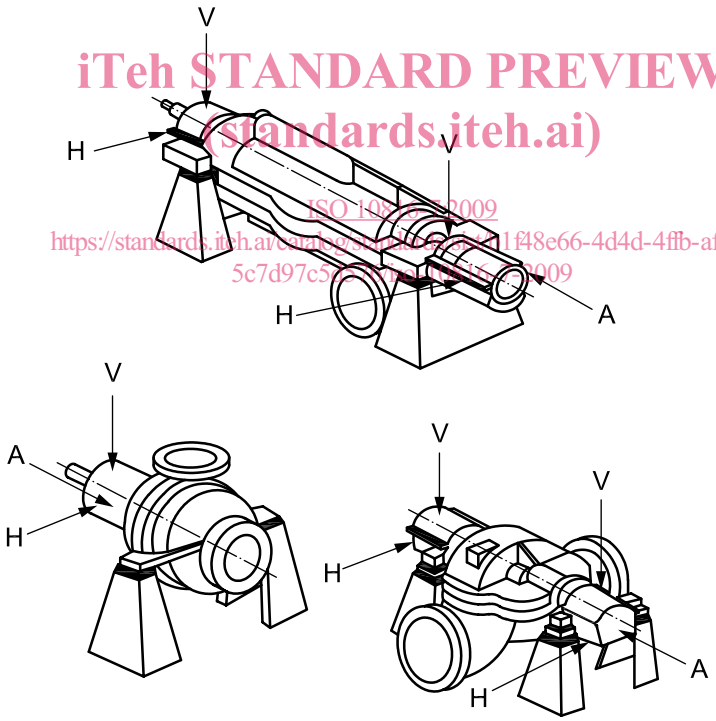
3.3.1 General measurements

The vibration of non-rotating parts of rotodynamic pumps shall be measured at the bearing housing of the pump. Vibration measurements are normally made on exposed parts of the pump that are accessible (see Figure 2 and Figure 3).

It should be confirmed that the measurements represent the bearing housing vibration correctly and are not degraded by any local resonance or amplification. The measurement locations and transducer orientations shall be such that the dynamic forces of the pump are represented with sufficient sensitivity. These locations are normally close to the centreline of the bearings. To ensure this, measurements shall normally be made at each bearing housing in two orthogonal radial directions and possibly one axial direction (see 3.3.2) as shown in Figure 2 and Figure 3.

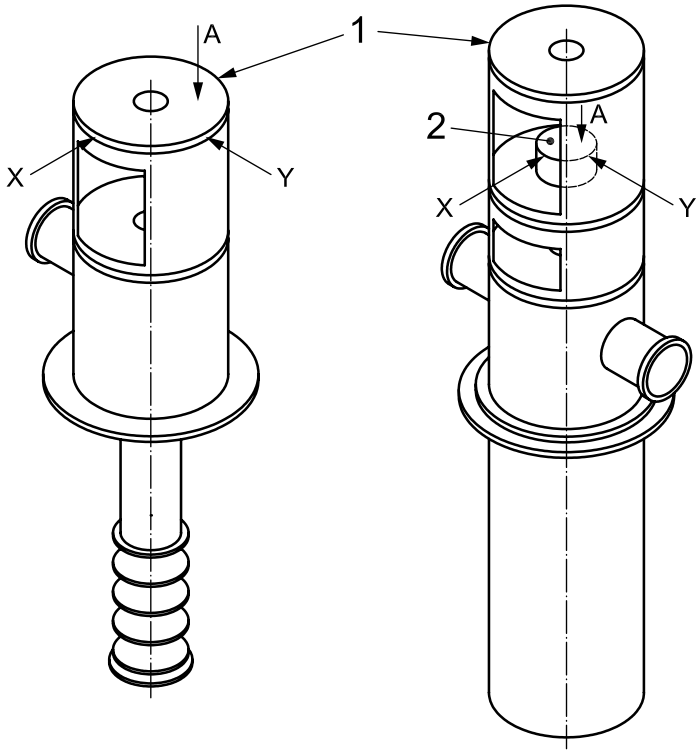
For pumps with horizontal shafts, usually the horizontal and vertical directions are preferred and, if possible, also the axial direction. For pumps with vertical or inclined shaft arrangements, the measurement locations shall be chosen in such a way as to ensure the maximum reading. In most of the cases it will lie towards the direction of the largest flexibility and 90° away from it.

The measurement locations and directions used shall be listed in the measurement report.



NOTE H, V (horizontal, vertical) are the two orthogonal radial measurement directions; A is the axial measurement direction.

Figure 2 — Measurement locations on horizontal pumps



Key

1 driver mounting surface/lower motor bearing

2 pump bearing housing. Preferably this location has to be chosen if within reach, otherwise the lower motor bearing housing can be used.

NOTE X, Y are the two orthogonal radial measurement directions; A is the axial measurement direction.

Figure 3 — Measurement locations on vertical pumps

3.3.2 Special axial measurements

It is not common practice to measure axial vibration on main radial load-carrying bearings during continuous operational monitoring. Such axial measurements are primarily used during periodic vibration surveys or for diagnostic purposes. However, certain faults are more easily detected in the axial direction. Axial vibration criteria are at present only given for thrust bearings where axial vibration correlates with axial pulsation which could cause damage to the axial load-carrying surfaces. The criteria given in Table A.1 and Table A.2 apply to radial vibration on all bearings and to axial vibration on thrust bearings.

3.4 Installation and operating conditions

For the installation of pumps, it is important that the system designer, pump manufacturer and user take special care to avoid resonance in the connected piping systems and foundations with the main excitation frequencies (e.g. rotational frequency, twice rotational frequency or blade-passing frequency) since such a resonance can cause excessive vibration.

Measurements shall be carried out when the rotor and the main bearings have reached their normal steady-state operating temperatures. The pump shall be operated under the specified operating conditions, i.e. at the nominal values for rate of flow, delivery head, and speed, which should lie within the preferred operating range (see Figure 4). This part of ISO 10816 also gives guidelines for operating within the whole allowable operating range.