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Condition monitoring and diagnostics of machines — Vibration condition monitoring —

Part 1: General procedures

Surveillance des conditions et diagnostic des machines — Surveillance relative aux conditions des vibrations —

Partie 1: Procédures générales

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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 3.

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 part of ISO 13373 may be the subject of patent rights. ISO shall not be held responsible for identifying any or all such patent rights.

ISO 13373-1 was prepared by Technical Committee ISO/TC 108, *Mechanical vibration and shock*, Subcommittee SC 2, *Measurement and evaluation of mechanical vibration and shock as applied to machines, vehicles and structures*.

ISO 13373 consists of the following parts, under the general title *Condition monitoring and diagnostics of machines — Vibration condition monitoring*:

— *Part 1: General procedures*

— *Part 2: Data processing, analysis, diagnostics, display and general vibration*

Annexes A, B, C and D of this part of ISO 13373 are for information only.

Introduction

The principal purpose of vibration condition monitoring of machinery is to provide information on the operating condition of the machine for protection and predictive maintenance. An integral part of this process is the evaluation of the vibratory condition of the machine over operating time. The purpose of this part of ISO 13373 is to promote the use of well-accepted guidelines for acquiring and evaluating vibration measurements for condition monitoring.

In contrast to vibration testing used strictly for diagnostic or acceptance purposes, condition monitoring involves the acquisition of data which can be compared over a span of time, and emphasizes the changes in vibration behaviour rather than any particular behaviour by itself.

Changes in vibration behaviour may typically be caused by

— changes in balance,

— changes in alignment,

— wear of or damage to journals or anti-friction bearings,

— gear or coupling defects,

— cracks in the critical components,

— operational transients,

— fluid-flow disturbances in hydraulic machinery,

— transient excitations in electric machinery,

— rubbing, and

— mechanical looseness.

Vibration condition monitoring can provide information for the following purposes:

— to increase equipment protection;

— to improve safety for personnel;

— to improve maintenance procedures;

— to detect problems early;

— to avoid catastrophic failures;

— to extend equipment life;

— to enhance operations.

Vibration measurements for condition monitoring may take many forms from the very simple to the very complex, and can include continuous or periodic measurements. However, they all share the common goal of accurately and reliably assessing the condition of machinery. The instrumentation and procedures recommended in this part of ISO 13373 will assist in achieving that goal.

The measurement methods described in this part of ISO 13373 reflect current common methods of measurements utilizing seismic and non-contacting vibration transducers. However, it is recognized that other methods of assessing the vibration condition of machines are in development. Although not included at this time, this part of ISO 13373 does not preclude the use of such measurement techniques.

ISO/TC 108 is at present also in the process of developing new International Standards on the subject of Machinery Diagnostics. These International Standards are intended to provide guidance on the overall monitoring of the "health" of machines, including factors such as vibration, tribology, oil purity and thermography.

Condition monitoring and diagnostics of machines — Vibration condition monitoring —

Part 1:
General procedures

1 Scope

This part of ISO 13373 provides general guidelines for the measurement and data collection functions of machinery vibration for condition monitoring. It is intended to promote consistency of measurement procedures and practices, which usually concentrate on rotating machines.

Because of the diversity of approaches to condition monitoring, recommendations specific to a particular kind of monitoring programme will be addressed in additional parts of ISO 13373.

This part of ISO 13373 is a basic document which presents recommendations of a general nature, encompassing

— measurement methods,

— measurement parameters,

— transducer selection,

— transducer location,

— transducer attachment,

— data collection,

— machine operating conditions,

— vibration monitoring systems,

— signal conditioning systems,

— interfaces with data-processing systems,

— continuous monitoring, and

— periodic monitoring.

The vibratory conditions of a machine can be monitored by vibration measurements on the bearing or housing structure and/or by vibration measurements of the rotating elements of the machine. In addition, measurements can be continuous or non-continuous. This part of ISO 13373 provides guidance on the types of measurements recommended in both the continuous and the non-continuous modes.

It is emphasized that this part of ISO 13373 addresses only the procedures for vibration condition monitoring of machines. In many cases, the complete condition monitoring and diagnostics of a machine can also include other parameters, such as thermography, oil analysis, ferrography, process variations, temperatures and pressures. These non-vibratory parameters will be included in other International Standards.

This part of ISO 13373 covers rotating machines. However, many of the procedures included can be applied to other types of machines, for example reciprocating machines.

2 Normative references

The following normative documents contain provisions which, through reference in this text, constitute provisions of this part of ISO 13373. For dated references, subsequent amendments to, or revisions of, any of these publications do not apply. However, parties to agreements based on this part of ISO 13373 are encouraged to investigate the possibility of applying the most recent editions of the normative documents indicated below. For undated references, the latest edition of the normative document referred to applies. Members of ISO and IEC maintain registers of currently valid International Standards.

ISO 1925, *Mechanical vibration — Balancing — Vocabulary*

ISO 2041, *Vibration and shock — Vocabulary*

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

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

3 Terms and definitions

For the purposes of this part of ISO 13373, the terms and definitions given in ISO 1925 and ISO 2041 apply.

4 Vibration condition monitoring

4.1 General

Vibration monitoring is conducted to assist in the evaluation of the “health” of the machine during sustained operation. Depending on the machine type and the critical components to be monitored, one or more measurement parameters, and a suitable monitoring system, have to be selected. The objective of such a programme is to recognize an “unhealthy” condition in sufficient time to take remedial action before certain defects in the machine parts significantly decrease equipment operation or projected machine life, or fail completely, thereby establishing a cost-effective maintenance plan.

Several types of condition monitoring systems are described below; depending on the machine, the machine’s condition and other factors, any one of the systems, or combinations thereof, may be selected.

4.2 Types of vibration condition monitoring systems

4.2.1 General

Condition monitoring systems take many forms. They utilize permanently installed, semi-permanent or portable measuring equipment.

A decision to select the appropriate measuring system depends upon a number of factors, such as

— criticality of the machine operation,

— cost of machine down-time,

— cost of catastrophic failure,

— cost of the machine,

- rate of progress of the failure mode,
- accessibility for repair/maintenance (e.g. in nuclear plants or other remote locations),
- accessibility of the appropriate measurement positions,
- quality of the measurement/diagnostic system,
- operational modes of the machine (e.g. speed, power),
- cost of the monitoring system,
- safety, and
- environmental impacts.

4.2.2 Permanently installed systems

This type of system is one in which the transducers, signal conditioners, data-processing and data-storage equipment are permanently installed. Data may be collected either continuously or periodically. The application of permanently installed systems is usually limited to costly and critical machinery or to machines with complex monitoring tasks. Figure 1 shows a typical permanently installed on-line system.

4.2.3 Semi-permanent systems

The semi-permanent system is a cross between the permanent and portable systems. In this type of system the transducers are generally permanently installed, whereas the electronic data-acquisition components are intermittently connected.

4.2.4 Portable monitoring systems

A portable monitoring system performs similar functions as the "continuous" on-line system, but it is less elaborate and normally less expensive. With this arrangement, the data are recorded periodically either automatically or manually, with a portable data collector. This type of system is shown in Figure 2.

More commonly, portable monitoring systems are used to record manually measurements at preselected locations on the machine at periodic intervals (weekly, monthly, etc.). The data are usually entered and stored locally on a portable data collector. A preliminary cursory analysis can be done immediately; however, for more in-depth processing and analysis, the data is downloaded to a personal computer that has the appropriate software.

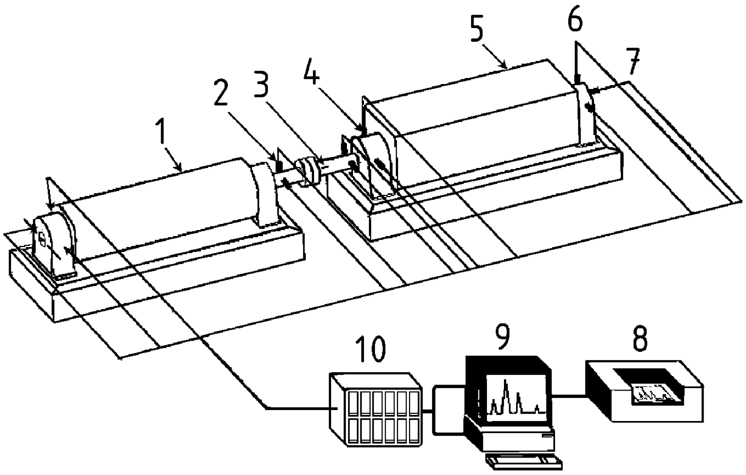
4.3 Data collection

4.3.1 General

Data may be collected on a continuous or periodic basis; and the data analysis may be driven by events or by intervals.

4.3.2 Continuous data collection

A continuous data-collection system is one in which vibration transducers are installed permanently at key locations on the machine (as shown in Figure 1), and in which the vibration measurements are usually recorded and stored continuously, during operation of the machine. It can include automatic vibration monitoring systems with multiplex connections provided that the multiplexing rate is sufficiently rapid so that no significant data or trends are lost. The data may be processed to provide either broadband or spectral information which can be compared to previously acquired data. By setting "alert limits" on the stored data it is possible to inform the operator that the vibratory pattern of the machine has changed (the magnitude has either increased or decreased), and therefore diagnostic procedures are recommended.

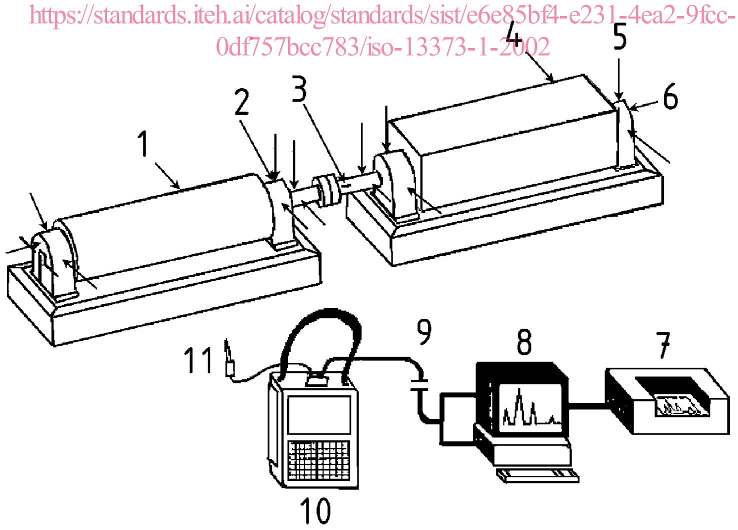


Key

1 Driver
2 Shaft displacement probes (typical)
3 Phase reference
4 Transducers on stationary bearing structure (typical)
5 Driven process machinery
6 Radial
7 Axial
8 Printer
9 Computer with data storage
10 Signal conditioner

NOTE This figure shows one typical arrangement. Alternative systems are permissible (e.g. microprocessor-based systems often have integral signal conditioning which may be carried out after the A/D conversion).

Figure 1 — Typical permanently installed on-line vibration condition monitoring system



Key

1 Driver
2 Data points (typical)
3 Phase reference
4 Driven process machinery
5 Radial
6 Axial
7 Printer
8 Computer with data storage
9 Computer link
10 Portable data logger
11 Transducer

Figure 2 — Typical portable monitoring system

A continuous data-collection system can be installed at the machine site for direct use by the machine operating crew, or it can be installed at remote sites with data transmitted to a central data analysis centre. The obvious advantage of a “continuous” system is the availability of on-line machine condition in real time.

In an automatic system, permanent vibration transducers are installed on the machine in much the same manner as with the continuous monitoring system. The system is programmed to record and store data automatically. The last data are compared with the previously stored data in order to determine whether an ALARM condition exists.

A decision to select a continuous data-collection system should be taken after consideration of the factors listed in 4.2.1.

4.3.3 Periodic data collection

Periodic data collection can be done with either permanent on-line or portable systems. On-line periodic systems may include automatic vibration monitoring systems with multiplexer connections. In this case all channels are cyclically scanned one after the other with respect to off-limit conditions. The measuring system is permanently in action but there are gaps in monitoring the individual measuring points, which are dependent on the number of channels monitored and the measuring period per channel. These systems are sometimes referred to as “scanning” or “intermittent” systems.

For machines for which permanent on-line systems cannot be justified, portable systems are usually used and they are in most cases suitable for periodic monitoring.

4.4 Condition monitoring programme

After selection of the equipment to be monitored, and determining the type of measurement system that is appropriate, it is recommended that a condition monitoring programme flowchart be developed. Figure 3 shows such a typical flowchart. However, since each plant and each system is unique, the data flow should be customized to provide the maximum benefits.

Clear descriptions of operating conditions, such as speed, load or temperature, should accompany any vibration data collected. As a minimum, such descriptions should include shaft speed (r/min) and machine load (power, flow, pressure, etc.) and any other operating parameter that can affect the measured vibration.

In general, during data acquisition it is strongly emphasized that the operating conditions should approximate the normal operating conditions of the machine as closely as possible, to ensure consistency and valid comparability of the data. When this is not possible, the characteristics of the machine must be well known in order to evaluate any differences in the data.

Since the procedure of condition monitoring includes the process of “trending”, which examines the rate at which vibration values change with operating time, it is especially important that the operating conditions during successive measurements remain the same, in order for such trending to be valid. For example, in the case of pumps, the vibration values can vary significantly between “normal” and “off-normal” operating loads. Thus, a change in vibration response due to a change in operating conditions could easily be incorrectly interpreted as a change due to an impending problem.

In addition, the time rate of data acquisition need not to be constant. As pointed out in 7.3, it depends on the current condition of the machine.

Data under other conditions may also need to be collected depending on the complexity of the machine and the purpose of the measurement. For example, where problems with unbalance, rubbing, shaft cracks or oil whirl are suspected, testing during transient operating conditions such as start-up and shut-down is recommended.

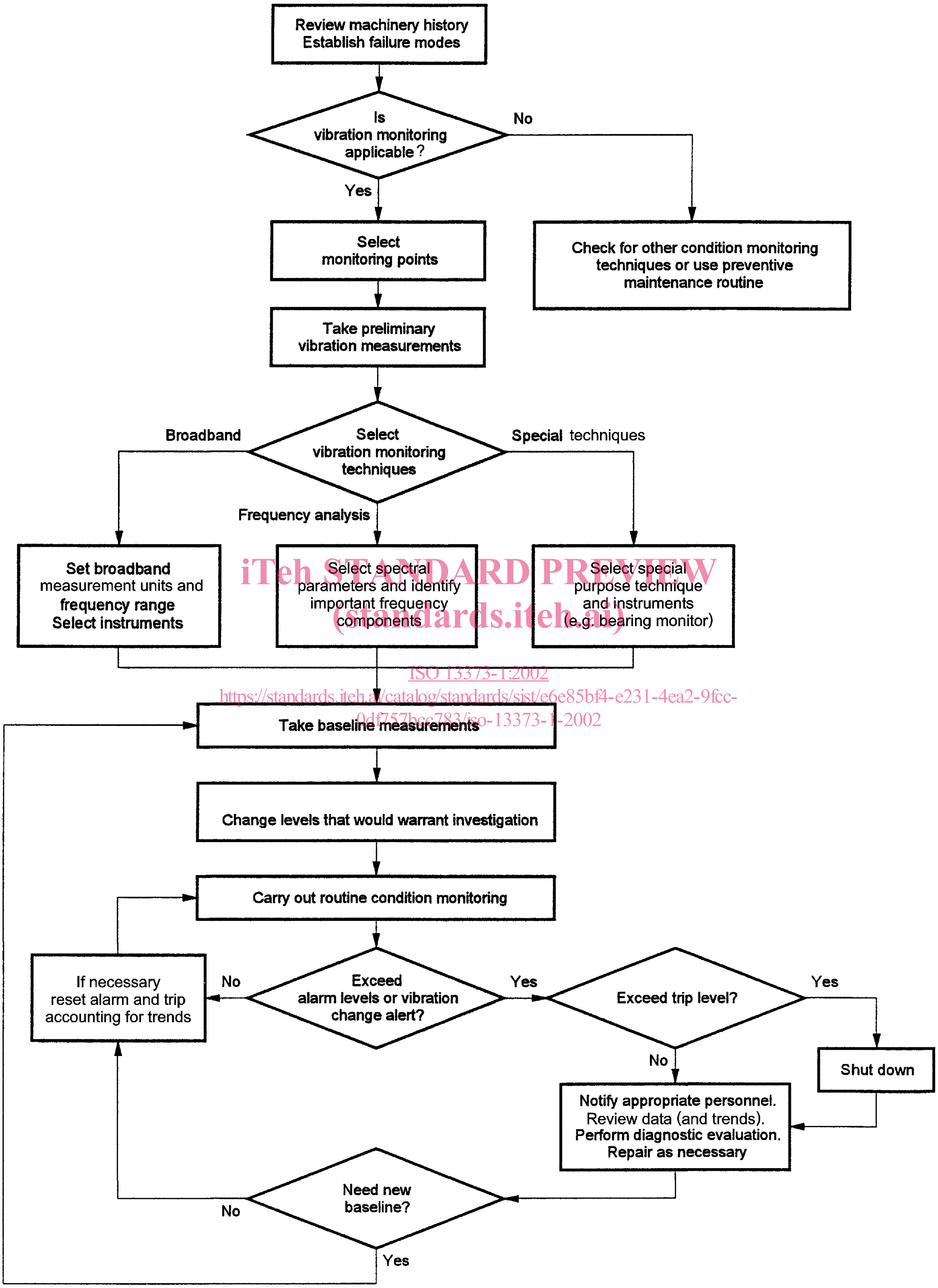


Figure 3 — Vibration condition monitoring flowchart

5 Measurements

5.1 General

This clause provides information on the types of measurements and the measurement quantities recommended for vibration condition monitoring. Annex B lists the typically required information to be recorded for each machine and measurement.

5.2 Types of measurements

5.2.1 General considerations

In general, there are three types of measurements that may be employed for machine vibration condition monitoring, as follows:

a) vibration measurements made on the non-rotating structure of the machine, such as the bearing housings, machine casing or machine base;

b) relative motion between the rotor and the stationary bearings or housing;

c) absolute vibratory motion of the rotating elements.

Vibration measurements on structures would normally use r.m.s. velocity often combined with r.m.s. displacement or acceleration (see ISO 10816-1). If the vibration is predominantly sinusoidal, vibratory displacement (zero-to-peak or peak-to-peak) may also be used.

For high-speed machines/gears and machines with anti-friction bearings, peak acceleration is often used for monitoring in combination with r.m.s. velocity. In addition, increasing use is being made of other more sophisticated techniques which enable greater use to be made of the information contained within the vibration signal.

Absolute and relative displacement of the rotating components are further defined by several different displacement quantities, each of which is now in widespread use and is defined in ISO 7919-1. These include

— S_{max}, the maximum value of shaft displacement from the time-integrated zero mean position, and

— S_{p-p}, the vibratory peak-to-peak displacement in the direction of measurement.

Each of these displacement quantities may be used for measurement of shaft vibration. However, the quantities shall be clearly identified so as to ensure correct interpretation of the measurements.

It should be noted that the ISO 7919 and ISO 10816 series address broadband measurements only. However, condition monitoring may include additional vibration measurements and analyses such as

— spectral analysis,

— filtering,

— time wave forms and orbits,

— vector analysis with magnitude and phase, and

— analysis of the high-frequency vibration envelope.

5.2.2 Transducer locations

The locations of transducers for the purposes of condition monitoring depend on the particular machine and the specific parameters to be measured. Before specifying “location”, it is first necessary to identify which parameters should be monitored, i.e.

— the absolute vibration of the machine housing,

— the vibratory motion of the rotor relative to the housing,

— the position of the shaft relative to the housing during machine operation, and

— the absolute motion of the shaft.

In general, the transducers should be located at or near the bearings. However, if experience is available for a particular type of machine and if such transducer locations are practical, it could be useful to locate transducers at other positions than the bearings, as follows:

a) at the positions which are most likely to provide maximum values of vibration (such as intermediate shaft mid-span of large gas turbine units);

b) at the positions where a small clearance exists between the static and rotating parts and rubbing may occur.

Whatever the plane chosen for the vibration measurement, transducers should be located at those angular positions which are most likely to provide early indications of wear or failure.

5.2.3 Transducer locations for typical machines

Annex A includes a table showing recommended locations for obtaining meaningful vibration data for various types of machines. These locations and directions provide for shaft measurements near the bearings.

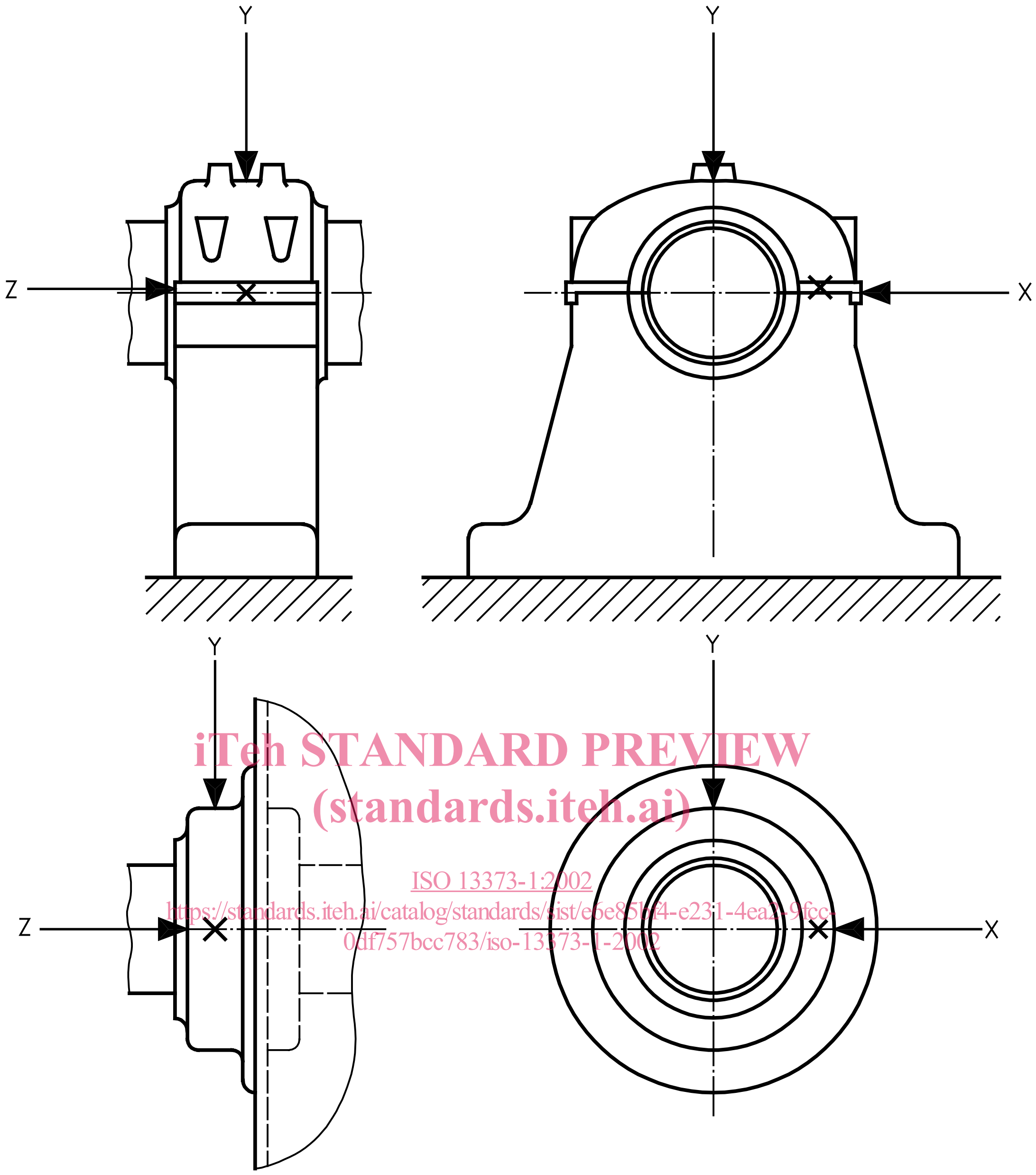
5.2.4 Transducer orientation and identification

The locations of the transducers should be clearly marked and identified to ensure repeatability of location during successive measurements. It is important to establish a consistent naming convention for assets and measurement points. Annex D provides an example of a typical convention for transducer orientation and identification.

5.2.5 Measurements on non-rotating structures

The ISO 10816 series provides specific procedures and instrumentation for different classes of machinery and identifies r.m.s. vibration velocity (in millimetres per second) as the preferred evaluation parameter. Measurements may be made either directly by a velocity transducer or by an accelerometer with an integrating circuit.

Typical locations for these types of measurements for horizontal machines are on each bearing housing or pedestal as shown in Figure 4. For vertical machines, see Figure 5.



X horizontal
Y vertical
Z axial

Figure 4 — Schematic diagram of typical transducer locations for vibration measurements on horizontal machines

