# INTERNATIONAL STANDARD

# ISO 13373-3

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# Condition monitoring and diagnostics of machines — Vibration condition monitoring —

## Part 3:
## Guidelines for vibration diagnosis

*Surveillance et diagnostic d'état des machines — Surveillance des vibrations —*

*Partie 3: Lignes directrices pour le diagnostic des vibrations*



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# Foreword

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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).

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The committee responsible for this document is 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*.

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: Processing, analysis and presentation of vibration data*

— *Part 3: Guidelines for vibration diagnosis*

— *Part 9: Diagnostic techniques for electric motors*

 

# Introduction

This part of ISO 13373 has been developed as a set of guidelines for the general procedures to be considered when carrying out vibration diagnostics of machines. It is intended to be used by vibration practitioners, engineers and technicians and it provides them with useful diagnostic tools. These tools include diagnostic flowcharts, process tables and fault tables. The material contained herein presents a structured approach of the most basic, logical and intelligent steps to diagnose vibration problems associated with machines. However, this does not preclude the use of other diagnostic techniques.

ISO 13373-1 presents the basic procedures for vibration signal analysis. It includes: the types of transducers used, their ranges and their recommended locations on various types of machines, online and off-line vibration monitoring systems, and potential machinery problems.

ISO 13373-2 which leads to the diagnostics of machines includes: descriptions of the signal conditioning equipment that is required, time and frequency domain techniques, and the waveforms and signatures that represent the most common machinery operating phenomena or machinery faults that are encountered when performing vibration signature analysis.

The present part of ISO 13373 provides general guidelines for a range of machinery. Guidance for specific machines is provided in other parts of this International Standard (currently under development).

ISO 13373 does not define vibration limits; these are specified in ISO 7919 (all parts) for rotating shafts and ISO 10816 (all parts) for non-rotating parts.

# Condition monitoring and diagnostics of machines — Vibration condition monitoring —

# Part 3: Guidelines for vibration diagnosis

## 1 Scope

This part of ISO 13373 sets out guidelines for the general procedures to be considered when carrying out vibration diagnostics of rotating machines. It is intended to be used by vibration practitioners, engineers and technicians and provides a practical structured approach to fault diagnosis. In addition it gives examples of faults common to a wide range of machines.

NOTE Guidance for specific machines is provided in other parts of ISO 13373.

## 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,[1)] *Mechanical vibration — Balancing — Vocabulary*



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

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

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

ISO 13373-1, *Condition monitoring and diagnostics of machines — Vibration condition monitoring — Part 1: General procedures*

ISO 13373-2, *Condition monitoring and diagnostics of machines — Vibration condition monitoring — Part 2: Processing, analysis and presentation of vibration data*

## 3 Terms and definitions

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

## 4 Measurements

### 4.1 Vibration measurements

Reliable measurement is the essential basis of using this part of ISO 13373 (see Reference [1]).

1) To become ISO 21940-2 when revised.

In general, there are three types of vibration measurements:

a) vibration measurements made on the non-rotating structure of the machine, such as the bearing housings, machine casings or machine base, using e.g. accelerometers or velocity transducers (see ISO 2954);

b) relative motion measurements between the rotor and the stationary bearings or housing, using e.g. proximity probes (see ISO 10817-1);

c) measurements of the absolute vibratory motion of the rotating elements, using e.g. shaft riders or by combining the outputs of the methods described in items a) and b) (see ISO 10817-1).

International Standards have been written to help assess the vibration severity for these types of measurements, especially ISO 7919 and ISO 10816.

It is important to recognize that the appropriate transducer and measurement system should be used for the diagnosis of faults considering specific situations and machine types. For example, by taking into account the machines' particular operational duty, the required frequency range and the resolution of measurement are determined.

Description of transducer and measurement systems as well as specification of techniques are given in ISO 13373-1 and ISO 13373-2, which shall be considered for appropriate selection.

### 4.2 Machine operational parameter measurements

Operational parameters can significantly affect the vibration signature and therefore should be acquired alongside the vibration data in order to allow correlation for a diagnosis process. Examples are rotational speed, load, pressure and temperature.

It is good practice to obtain baseline vibration characteristics under a range of operating conditions and configurations as a basis for comparison with future vibration events.

Additional guidelines on using operational parameters are given in ISO 17359.



## 5 Structured diagnostic approach

The tools used in this part of ISO 13373 to guide the diagnostic process are flowcharts, process tables and fault tables. The flowcharts and the process tables are essentially a step-by-step question and answer procedure that guides the user in the diagnosis process. The flowcharts are used for an overview of the vibration events and characterize the features, while the process tables are used for more in-depth analysis. The fault tables are used to illustrate common machinery events and how they manifest themselves.

Annex A specifies the systematic approach to the vibration analysis of machines:

a) A.1 is used to gather background information regarding the machine, nature and severity of the vibration.

b) A.2 is used to answer a set of questions aimed at arriving at a probable diagnosis of such common faults as unbalance, misalignment and rubs.

c) A.3 is used to set out certain considerations when recommending actions following a probable diagnosis.

In addition, approaches for faults common to a wide range of machines are shown in other annexes:

— Installation faults and examples are described in Annex B.

— Radial hydrodynamic fluid-film bearing faults and examples are described in Annex C.

— Rolling element bearing faults and examples are described in Annex D.

 

Guidance for specific machines is provided in other parts of ISO 13373.

This approach is considered to be good practice put together by experienced users, although it is acknowledged that other approaches can exist.

A word of caution to all users: in some cases the vibration diagnosis can point to several root causes. It is recommended to consult with the manufacturer under these circumstances.

# 6 Additional analysis and testing

## 6.1 General

After using the relevant flowcharts, process tables and fault tables, further testing can be necessary to establish the cause and effect mechanism. In some circumstances, with approval of the plant operator, a physical change to the machine can be required to observe an influence.

Typical tests and analysis techniques are described 6.2 to 6.4.

## 6.2 Not requiring changes to operating parameters

### 6.2.1 General

These tests can be carried during normal operation, i.e. no changes to the characteristics of the machine.



### 6.2.2 Trend analysis

The objective of trend analysis is to track changes in machine condition with time. This can be achieved through continuous or periodic measurements. Trending is done with operational parameters as well as vibration parameters. Vibration is trended as an overall value either peak or r.m.s. value in a certain frequency band, or as a filtered value in a number of smaller bands. More elaborate analysis can include regression analysis of trended data, as well as possible extrapolation.



### 6.2.3 Phase analysis

Phase is an important diagnostic tool for which a reference signal is required. For example, phase is a useful tool to distinguish between misalignment, resonance, rubs and unbalance.

### 6.2.4 Resonance test

In a resonance test, e.g. impact test, shaker test, the object is to find any natural frequencies or resonance speeds that can be excited by the machine. Usually, an impact test is conducted on the machine to determine the natural frequencies of stationary parts, while a resonance speed test is required to determine the natural frequencies of rotor/rotor train. An impact test is usually done while the machine is not running. However if resonance speed information is sought, then a run-up or coast-down test would be recommended (see 6.3.1).

### 6.2.5 Measurement of operational deflection shape

The operational deflection shape (ODS) measurement is an actual visualization of the machine behaviour, at any frequency (but usually at the running speed), under its normal operating conditions. It is important to measure not only the amplitude of vibration, but also the phase at all points on the machine. This allows the visualization of the actual relative deflection of the machine at its operating condition.

### 6.2.6 Long-time waveform capture

This technique is used to capture raw time data that would otherwise not be captured in conventional vibration measurement. The time period will be dependent upon the particular application. Usually multiple measurements are conducted simultaneously, including operating parameter measurement. This measurement can assist in capturing fast events or allow post-analysis of a raw signal.

## 6.3 Requiring changes to operating parameters

### 6.3.1 Changes to operating conditions

Changes to operating conditions should always be discussed with the plant operator. Operating conditions outside the manufacturer's recommended limits should be treated with special care and will need the acceptance of all parties.

The following are examples:

— change of machine speed, e.g. run up, run down;

— vibration measurements during variation of parameters, e.g. change of oil temperature, change of load.

### 6.3.2 Complete experimental modal analysis

Modal testing is a very powerful tool to obtain the machine and structure modal parameters, including natural frequencies, damping ratios and mode shapes. This is an expensive and time-consuming test that requires extensive instrumentation and experience, and should only be used when absolutely necessary. Normally the machine must be shut down for this test. The characteristics of the machine obtained from a test at rest can be different from the characteristics at operating speed, particularly for machines with hydrodynamic bearings.



## 6.4 Changes to the physical state of the machine



Changes to the physical state are recognized as being intrusive and can involve changing position, mass or stiffness characteristics. It is advisable to have a measurement before and after making any changes in the physical state of the machine and to carry out a risk assessment.

The following are examples of changes to physical state:

— unbalance test;

— 180° turning of coupling;

— running the machine uncoupled;

— additional measurements, e.g. alignment, rotor position in bearing, temperature of stator.

# 7 Additional diagnostic techniques

The main emphasis of this part of ISO 13373 is a logical framework based upon experience. However, other diagnostic techniques are available, such as the following:

— artificial intelligence;

— knowledge-based;

— pattern recognition;

— neural networks.

These techniques are identified in ISO 13379-1.

 

## 8 Considerations when recommending actions

A number of factors will influence remedial or corrective actions including the following:

— safety;

— commercial;

— incorrect design.

Clearly, the appropriate action(s) for a particular diagnosis will depend on individual circumstances and it is beyond the scope of this part of ISO 13373 to make specific recommendations. Nevertheless, it is important for the diagnostic engineer to consider possible actions resulting from their diagnosis and the implications of those actions.

Recommended actions will depend on the degree of confidence in the fault diagnosis (e.g. has the same diagnosis been made correctly before for this machine?), the fault type and severity as well as on safety and commercial considerations. It is neither possible nor the aim of this part of ISO 13373 to recommend actions for all circumstances. Nevertheless, there are several questions that should be considered when recommending actions, some of which are indicated in A.3.

# Annex A
(normative)

# Process tables for the systematic approach to vibration analysis of machines

## A.1 Initial questions

Initial questions which comprise information gathering and verification are summarized in Table A.1.

**Table A.1 — Initial questions**

| Step | Description | Details | Next step |
|---|---|---|---|
| 1 | What is the machine type? | Establish the machine elements (driver, driven, coupling, bearings, fixed or variable speed, etc.)<br>Is the practitioner familiar with this type of machine?<br>Is there any operating experience of this or similar design of machine/plant?<br>Where is the plant and what is the unit number? | 2 |
| 2 | Is there a machine integrity concern? | Is the machine operating now?<br>Is it advisable to continue to operate?<br>Is it advisable to restart the machine?<br>Has a risk analysis taken place to assess whether the integrity of the machine will be maintained during continued operation while the diagnostic process is carried out? | 3 |
| 3 | Is there a vibration anomaly? | Can vibration data be obtained?<br>What is the normal operating vibration behaviour of this machine? | 4 |
| 4 | How was the anomaly found? | Is there a vibration alarm?<br>Did online vibration data show a significant change?<br>Is there a significant deviation from a previous vibration survey?<br>Was there an uncharacteristic noise from the machine?<br>Did visual inspection show a defect, e.g. a gas/oil/steam/water leak? | 5 |



 

**Table A.1** *(continued)*

| Step | Description | Details | Next step |
|---|---|---|---|
| 5 | Is the indicated vibration valid? | Check signal time/spectral characteristics.<br>Are they as expected?<br>Do they show symptoms of signal faults (e.g. zero output, DC offset, erratic low-frequency components)?<br>Is the transducer mounting correct?<br>Is the cable integrity acceptable?<br>Is the signal conditioning operating correctly?<br>Consider taking hand-held independent measurements, e.g. pedestal mounted or shaft rider.<br>Check whether non-vibration symptoms are evident (e.g. oil/bearing temperature changes, shaft position changes, unusual noises, etc.).<br>Is the vibration anomaly isolated to one transducer (see step 6)? | 6 |
| 6 | Is the vibration anomaly isolated to one transducer? | Check orthogonal directions<br>Check other axial positions<br>Compare pedestal and shaft vibration<br>Inspect transducer and measurement chain<br>Consider swapping channels or components of measurement chain | 7 |
| 7 | Is there a vibration severity concern? | How do the overall (broadband) vibration values compare with appropriate standards e.g. ISO 7919 or ISO 10816 zones. If these values are excessive (e.g. are within zones C or D) and abnormal then consider rapid plant action (subject to steps 5 and 6). If not then proceed to step 8. | 8 |
| 8 | Vibration signal characteristics: what is the signal content? | Overall magnitude (broadband)<br>Amplitude and phase of the 1x component<br>Amplitude and phase of the 2x component<br>Spectral content of the signal and amplitude of other components (e.g. blade pass, rotor bar pass, subsynchronous frequencies) as appropriate for machine type<br>Shaft position/shaft centreline/shaft orbit | 9 |
| 9 | Has this type of anomaly been observed before? | What was the experience gained, e.g. how long did the anomaly last, was the cause determined, was there a failure? | 10 |