INTERNATIONAL STANDARD

ISO 13373-4

First edition
2021-11

Condition monitoring and diagnostics of machines — Vibration condition monitoring —

Part 4:
Diagnostic techniques for gas and steam turbines with fluid-film bearings

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

Partie 4: Techniques de diagnostic pour turbines à gaz et turbines à vapeur à paliers à film fluide

Reference number
ISO 13373-4:2021(E)

ISO copyright office
CP 401 • Ch. de Blandonnet 8
CH-1214 Vernier, Geneva
Phone: +41 22 749 01 11
Email: copyright@iso.org
Website: www.iso.org

Published in Switzerland

Contents

Page

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 of the voluntary nature of standards, the meaning of ISO specific terms and expressions related to conformity assessment, as well as information about ISO's adherence to the World Trade Organization (WTO) principles in the Technical Barriers to Trade (TBT), see www.iso.org/iso/foreword.html.

This document 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*.

A list of all parts in the ISO 13373 series can be found on the ISO website.

Any feedback or questions on this document should be directed to the user's national standards body. A complete listing of these bodies can be found at www.iso.org/members.html.

Introduction

This document provides guidelines for the procedures to be considered when carrying out vibration diagnostics of gas turbines and steam turbines on fluid-film bearings. It is intended to be used by vibration practitioners, engineers and technicians and it provides them with useful diagnostic tools. These tools include the use of diagnostic flowcharts, process tables, fault tables and symptom tables. The material contained in this document presents the most basic, logical, and intelligent steps that should be taken when diagnosing problems associated with these particular types of machines.

The ISO 20816 series of standards contains acceptable vibration magnitudes and zones for various types and sizes of machines, ranging from new and well-running machines to machines that are in danger of failing.

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

ISO 13373-2 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.

ISO 13373-3 provides some procedures to determine the causes of vibration problems common to all types of rotating machines. It includes: systematic approaches to characterize vibration effects; the diagnostic tools available; which tools are needed for particular applications; and recommendations on how the tools are to be applied to different machine types and components. However, this does not preclude the use of other diagnostic techniques.

It should be noted that ISO 17359 indicates that diagnostics can be

— started as a succeeding activity after detection of an anomaly during monitoring, or

— executed synchronous with monitoring from the beginning.

This document considers only the former in which diagnostics is performed after an anomaly has been detected. Moreover, this document focusses mainly on the use of flowcharts and process tables as diagnostic tools, as well as fault tables and symptom tables, since it is felt that these are the tools that are most appropriate for use by practitioners, engineers and technicians in the field.

The flowchart and diagnostic process table methodology presents a structured procedure for a person in the field to diagnose a fault and find its cause. This step-by-step procedure should be able to guide the practitioner in the vibration diagnostics of the machine anomaly, in order to reach the probable root cause of this anomaly.

The fault tables present a list of the most common faults in machinery, as well as their manifestations in the machine and vibration data. The symptom tables contain the main distinguishing vibration features of the main faults. When used with the flowcharts, the tables assist with the identification of machinery faults.

When approaching a machinery problem that manifests itself as a high or erratic vibration signal, the diagnosis of the problem should be done in a well thought out, systematic manner. This document and ISO 13373-3 achieve that purpose by providing to the analyst guidance on the selection of the proper measuring tools, the analysis tools and their use, and the step-by-step recommended procedures for the diagnosis of problems associated with various types of gas and steam turbines with fluid-film bearings.

VDI 3839-4 provides typical vibration patterns in steam and gas turbines, and can be a useful reference.

Condition monitoring and diagnostics of machines — Vibration condition monitoring —

Part 4: Diagnostic techniques for gas and steam turbines with fluid-film bearings

1 Scope

This document sets out guidelines for the specific procedures to be considered when carrying out vibration diagnostics of various types of gas and steam turbines with fluid-film bearings.

This document is intended to be used by condition monitoring practitioners, engineers and technicians and provides a practical step-by-step vibration-based approach to fault diagnosis. In addition, it gives examples for a range of machine and component types and their associated fault symptoms.

The approach given in this document is based on established good practice, put together by experienced users, although it is acknowledged that other approaches can exist. Recommended actions for a particular diagnosis depend on individual circumstances, the degree of confidence in the fault diagnosis (e.g. has the same diagnosis been made correctly before for this machine), the experience of the practitioner, the fault type and severity as well as on safety and commercial considerations. It is neither possible nor the aim of this document to recommend actions for all circumstances.

2 Normative references

The following documents are referred to in the text in such a way that some or all of their content constitutes requirements 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 2041, *Mechanical vibration, shock and condition monitoring — Vocabulary*

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*

ISO 13373-3:2015, *Condition monitoring and diagnostics of machines — Vibration condition monitoring — Part 3: Guidelines for vibration diagnosis*

ISO 21940-2, *Mechanical vibration — Rotor balancing — Part 2: Vocabulary*

3 Terms and definitions

For the purposes of this document, the terms and definitions given in ISO 2041, ISO 13372 and ISO 21940-2 apply.

ISO and IEC maintain terminological databases for use in standardization at the following addresses:

— ISO Online browsing platform: available at https://www.iso.org/obp

— IEC Electropedia: available at https://www.electropedia.org/

4 Measurements

4.1 Vibration measurements

Vibration measurements may be obtained using two main categories of transducers:

a) non-contacting, e.g. inductive, capacitive and eddy current probes used on rotating shafts;

b) seismic transducers, e.g. accelerometers or velocity transducers used on non-rotating parts, such as bearing housings.

International Standards have been written to help in assessing the vibration severity for both of these types of measurements, for instance the ISO 7919 series, the ISO 10816 series and the ISO 20816 series.

Guidance for the selection of the appropriate International Standard to use is given in ISO/TR 19201.

It is important to recognize that the appropriate transducer, signal conditioning, measurement and analysis system should be used for the diagnosis of faults considering specific situations in gas and steam turbines with fluid-film bearings. Before any measurements are taken, it is good practice to consider whether the grounding and electrical fields of the machine will have any effect on them.

Descriptions of transducers, measurement systems and analysis techniques are given in ISO 13373-1 and ISO 13373-2, which shall be considered for appropriate selection.

4.2 Machine operational parameter measurement

Operational parameters [e.g. rotational speed, load, mounting configuration (rigid or flexible support arrangement) and temperature], that can have an influence on machine vibration characteristics are important in order to arrive at an appropriate fault diagnosis. For a given machine, these parameters can be associated with a range of steady-state and transient operating conditions.

5 Initial analysis

An initial fault analysis shall be performed using the guidelines given in ISO 13373-3:2015, Annex A and shall identify any safety concerns such as the

a) presence and severity of any high vibration,

b) past history of the machine,

c) effects of the machine operating parameters,

d) consequence of not taking any necessary corrective action to reduce machine vibration, and

e) shutting the turbine down to prevent damage.

In addition, other factors such as the

f) measurement transducer mounting configuration,

g) effect of any nearby rotating machines, and

h) effect of the building and the machine foundation [e.g. platform foundation (onshore and offshore) environment] on the machine under consideration should be taken into account during the initial analysis of machine performance.

Also see ISO 13373-3:2015, Annexes B to D for a description of some common machine faults (e.g. installation and bearing defects).

6 Specific analysis of gas and steam turbines with fluid-film bearings

The systematic procedure used in the ISO 13373 series includes usage of fault tables, symptom tables and a step-by-step methodology of vibration diagnosis of faults. For this document, the fault table for the diagnosis of gas and steam turbines with fluid-film bearings to be used is given by Table A.1, the symptom table is given in Table A.2, while the methodology of vibration diagnosis is presented in Annex B. Examples of the use of the fault table, symptom table and methodology of vibration diagnosis of gas and steam turbines with fluid-film bearings are given in Annex C. Note that these annexes do not cover turbine vibration from hydrodynamic bearing problems which are addressed in ISO 13373-3:2015, Annex C.

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

It should be noted that in some cases the vibration diagnosis can point to several root causes and it is recommended that an expert is consulted in order to establish the most probable fault.

7 Considerations when recommending actions

A number of factors influence any remedial or corrective actions to be taken, such as

a) their safety,

b) commercial considerations,

c) incorrect machine design, and

d) machine assembly issues.

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

Recommended actions 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 document to recommend actions for all circumstances.

Annex A
(normative)

Systematic approach for vibration analysis of gas and steam turbines with fluid-film bearings

A systematic approach to vibration analysis of gas and steam turbines with fluid-film bearings is given by the fault table in Table A.1, and the symptom table given in Table A.2. The information included in Table A.1 is not intended to be exhaustive, but includes the most prevalent faults associated with steam and gas turbines with fluid film bearings.

Table A.1 — Fault table for vibration analysis of gas and steam turbines with fluid-film bearings

Fault	Conditions under which the vibration change occurs	Initial rate of change of vibration amplitude	Major frequency component of changed vibration amplitude	Subsequent behaviour of vibration with time	Effect on resonance speed	Behaviour on barring	Repeatability	Comments
Shaft unbalance	Steady state	Immediately evident	1x	Steady	None	Not affected	Repeatable	None
Shaft unbalance resulting from rotating component material loss	Usually steady state but can be transient	Step change or series of changes	1x	Steady following step change	Vibration level significantly changed	Rubbing can be heard in extreme cases	None	For turbines consisting of multiple rotors in tandem, the largest changes usually occur at the bearings of the affected rotor. Rotor unbalance may be due to blade erosion.
Bearing elevation change	Following operational transient	Slow, unless oil whirl is predominant	Predominantly 1x. Less than 1x can be exhibited (see oil whirl)	Under steady conditions a new steady level will be reached	May increase or decrease depending on whether the bearing elevation is raised or lowered. Adjacent rotors may experience the opposite effect	None	Trends, but not necessarily amplitudes will tend to repeat following similar transients	Reversal of transient will not immediately reverse the vibration change. Correlate with bearing wedge pressures and metal temperatures. This fault is typically limited to turbines with two bearings per rotor. Turbines with a single bearing per rotor tend to be less susceptible to this fault.

NOTES:

a) Light rubbing tends to occur between the shaft and the stationary seals, which are locations where the clearances are small by design and steps are taken by the manufacturer in the design of the seals to minimise the effects of rubbing, e.g. through the use of spring-backed segmented seal rings and/or brass/bronze seal fins.

b) Hard rubbing tends to occur at other locations where rubbing is not generally intended to occur by design and therefore more substantial contact can occur.

c) The Morton effect refers to a vibration condition where viscous heating of the shaft surface occurs due to shearing of the oil in a narrow oil film of a fluid-film bearing, leading to a temporary thermal bend of the shaft.

Table A.1 *(continued)*

Fault	Conditions under which the vibration change occurs	Initial rate of change of vibration amplitude	Major frequency component of changed vibration amplitude	Subsequent behaviour of vibration with time	Effect on resonance speed	Behaviour on barring	Repeatability	Comments
Permanent bend in the shaft	During or following a transient, large temperature drop or change in rotor to casing position	Rapid – often large	1x	Reduces with speed reduction, except when passing through resonance speed. Will stabilize at new steady level	Vibration level significantly changed	Slow roll run-out will generally increase to a new, higher steady level	Yes	With severe bends barring motor will not engage.
Transient bend in the shaft with no rubbing	During temperature change	Closely follows temperature change. Depends on rotor construction	1x	Will revert to previous value following stabilization of temperature	Vibration level can be significantly changed	Slow roll run-out will decay to previous normal level over a period of time	Repeats at each start for the same operating conditions	Can be caused by the bi-metal effect and differential emissivity of the shaft materials.
Transient bend in the shaft with hard rubbing	Speed or load change. Stationary and rotating parts contact	Variable. If rapid a permanent bend will almost certainly develop	1x, heavy contact, apparent as flat spots on orbits, might also cause responses at natural frequencies and higher harmonics	Cyclic amplitude with phase rotation or variation	Vibration level can be significantly changed	Slow roll can be higher immediately after rundown and will decay to previous level over a period of time	Not necessarily repeatable each time the transient is undergone	Reversal of speed or load change will restore previous vibration levels fairly quickly. Vector will rotate with a period of typically 1/2 h to 3 h. Depends on construction.

NOTES:

a) Light rubbing tends to occur between the shaft and the stationary seals, which are locations where the clearances are small by design and steps are taken by the manufacturer in the design of the seals to minimise the effects of rubbing, e.g. through the use of spring-backed segmented seal rings and/or brass/bronze seal fins.

b) Hard rubbing tends to occur at other locations where rubbing is not generally intended to occur by design and therefore more substantial contact can occur.

c) The Morton effect refers to a vibration condition where viscous heating of the shaft surface occurs due to shearing of the oil in a narrow oil film of a fluid-film bearing, leading to a temporary thermal bend of the shaft.