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

**Part 9:
Diagnostic techniques for electric
motors**

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

Partie 9: Techniques de diagnostic pour moteurs électriques



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ISO copyright office
Ch. de Blandonnet 8 • CP 401
CH-1214 Vernier, Geneva, Switzerland
Tel. +41 22 749 01 11
Fax +41 22 749 09 47
copyright@iso.org
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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.

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).

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For an explanation on 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 the following URL: 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.

Introduction

This document has been developed as guideline for the procedures to be considered when carrying out vibration diagnostics of electric motors. 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 and process tables and fault 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 7919 (rotating shafts), ISO 10816 (non-rotating parts) and ISO 20816 (both rotating shafts and non-rotating parts) series of International Standards contain acceptable vibration 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; online 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
- can be executed synchronous with monitoring from the beginning.

The present document considers only the former in which diagnostics is performed after an anomaly has been detected. Moreover, this document focuses mainly on the use of flowcharts and process tables as diagnostic tools, as well as fault 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 vibration data. 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 together with 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 electric motors.

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Condition monitoring and diagnostics of machines — Vibration condition monitoring —

Part 9: Diagnostic techniques for electric motors

1 Scope

This document specifies procedures to be considered when carrying out vibration diagnostics of various types of electric motors. The four motor types covered by this document are squirrel-cage induction, wound-rotor induction, salient-pole and DC motors.

NOTE The first two types are defined in ISO 20958.

This document is mostly applicable to motors with power above 15 kW.

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 a number of examples for a range of machine and component types and their associated fault symptoms.

The procedures presented in this document can, in some cases, be applied to other types of electrical machines, such as generators, but there can be other specific techniques associated with such machines that are not included in this document.

The use of non-vibration quantities, such as voltage and current, to identify and analyse vibration-related faults in electric motors is outside the scope of this document.

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 20958, *Condition monitoring and diagnostics of machine systems — Electrical signature analysis of three-phase induction motors*

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

IEC 60050, *International Electrotechnical Vocabulary*

3 Terms and definitions

For the purposes of this document, the terms and definitions given in ISO 2041, ISO 13372, ISO 20958, ISO 21940-2, IEC 60050 and the following apply.

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

- IEC Electropedia: available at <http://www.electropedia.org/>
- ISO Online browsing platform: available at <http://www.iso.org/obp>

3.1
DC armature
shaft with laminated, slotted core into which a two-layer winding is installed and connected to a commutator which is supplied with DC power via brushes

3.2
salient-pole rotor
shaft with solid or laminated poles having a winding on each pole

Note 1 to entry: The pole windings are connected together and to sliprings or a brushless exciter from which the required DC power supply is applied.

3.3
supply frequency
frequency of the power supply connected to AC motors

Note 1 to entry: The supply frequency is also called line frequency.

3.4
slip frequency
<induction motors> difference between the synchronous rotational speed and rotor rotational speed frequencies

3.5
number of stator poles
integer which is defined by the following formula:

$$\frac{2 n_{\text{syn}}}{60 f_{\text{supp}}}$$

where

n_{syn} is the synchronous rotational speed, in r/min;

f_{supp} is the supply frequency, in Hz.

Note 1 to entry: The number of pole pairs is the number of poles divided by 2.

3.6
pole passing frequency
<induction motors> rotor slip frequency times the number of poles

3.7
stator slot passing frequency
number of stator slots times the rotor rotational speed

3.8
rotor slot passing frequency
number of rotor slots times the rotor rotational speed

3.9
rotor bar passing frequency
number of bars in a squirrel-cage rotor times the rotor rotational speed

4 Measurements

4.1 Vibration measurements

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

- non-contacting, e.g. inductive, capacitive and eddy current probes used on rotating shafts;
- seismic transducers, e.g. accelerometers or velocity transducers used on non-rotating parts, such as bearing housings.

International Standards are available to help assess the vibration severity for the described types of measurement, in particular, ISO 7919, ISO 10816 and ISO 20816.

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 electric motors. For example, to detect rotor bar problems, high resolution in the spectrum is required to detect the slip frequency. In many cases, it is required to consider the grounding and electrical field of the machine before taking any measurement.

The 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

These are operational parameters, e.g. rotational speed, load, motor orientation (vertical or horizontal), mounting configuration (solid or flexible support arrangement) and temperatures, that can have an influence on the machine vibration characteristics and are therefore important to acquire in order to arrive at an appropriate 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 analysis should be performed using the guidelines given in ISO 13373-3:2015, Annex A. This analysis should identify safety concerns, the presence of high vibration, and if so, its vibration severity, past history, effects of operating parameters, consequences of not taking corrective actions and the need for a motor shutdown. Also, other factors such as motor mounting configuration, vibration from driven machinery, position relative to other rotating machines, building structure, environment, etc. should be considered during an initial analysis. See also ISO 13373-3:2015, Annexes B to D, for common faults such as from installation and bearing defects.

6 Motor specific analysis

Electric motors are used as drivers in many industrial applications such as pumps, fans and compressors. This document covers vibration diagnosis information for the most common types of electric motors. Symptoms of the most prevalent motor defects that cause excessive vibration magnitudes are given in [Annex A](#) which shall be considered. However, [Annex A](#) does not cover motor vibration from inadequate motor mounting, hydrodynamic bearing problems, or rolling element bearing problems which are addressed in ISO 13373-3:2015, Annexes B, C and D, respectively.

The methodology for vibration diagnosis of electric motors is given in [Annex B](#), while case studies illustrating the methodology are provided in [Annex C](#). The techniques used in vibration diagnosis of electric motors include visual inspections, vibration magnitudes, spectral analysis, time waveform analysis, phase analysis and operational deflection shape (ODS) analysis. The use of these techniques is described in [B.2](#).

Annex A (normative)

Systematic approach to vibration analysis of electric motors

The systematic approach to vibration analysis of electric motors is given by the fault table in [Table A.1](#).

NOTE Most of the theory as to why specific defects can be identified by certain vibration frequencies and other characteristics can be found in References [\[15\]](#) and [\[16\]](#).

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Table A.1 — Fault table for vibration analysis of electric motors

Defect	Measurement conditions under which change occurs	Initial rate of change of vibration amplitude	Major frequency component of changed vibration amplitude and phase angles	Subsequent behaviour of vibration with time	Effect on resonance speed	Effect of cutting power	Repeatability	Comments
Loose stator coils (synchronous motors)	Usually gradually develops with time	Slow rate of change	(Number of stator coils) times (1× rotational speed) with 1× rotational speed sidebands	Magnitudes increase with time	None	Immediate drop in vibration magnitudes	Yes	Unlikely to occur if stator winding is global vacuum pressure impregnated
Bent shaft extension	Usually after failure of driven equipment, or if high radial load is imposed	Fast rate of change	Mainly 1× rotational speed, but exhibit 2× supply frequency and modulation of this at 2× slip frequency in 2-pole squirrel-cage motors if bent shaft leads to non-uniform air gap	If due to high radial load on shaft extensions can increase with time and vary with load	None	Some initial drop in the 2× supply frequency component, but then slowly increases with time	Magnitudes can change with load and temperature	Can be confirmed by total indicated runout measurement on shaft extension
Rotor running off magnetic centre	After motor installation, or axial realignment with driven equipment	Depends on how far rotor is off its axial magnetic centre	High axial 1×, 2× or 3× rotational speed frequency with much lower radial vibration	Can change with load	None	Immediate drop in vibration magnitudes	Magnitudes can change with load and temperature	Higher magnitudes on motors with radial cooling ducts on stator and rotor

Table A.1 (continued)

Defect	Measurement conditions under which vibration change occurs	Initial rate of change of vibration amplitude	Major frequency component of changed vibration amplitude and phase angles	Subsequent behaviour of vibration with time	Effect on resonance speed	Effect of cutting power	Repeatability	Comments
Cracked or broken rotor bars	After motor starting, unless due to voids in diecast rotor bars	Slow if fabricated rotor bars	High $1 \times$ rotational speed frequency with sidebands at $\pm$ slip frequency times number of poles. Also harmonics of these frequencies. Vibration amplitude can vary at slip frequency times number of poles and increase with load. Can also be a high $4 \times$ rotational speed axial vibration	Vibration will increase if more rotor bars break. Also unbalance and vibration due to thermal bow will develop	Will change response	Immediate drop in vibration magnitudes	Magnitudes will change if more rotor bars break	Motor will become noisy during starting and starting time will increase due to reduction in motor torque. Can usually be confirmed by current signature analysis and $2 \times$ slip frequency sidebands around supply frequency

Table A.1 (continued)

Defect	Measurement conditions under which vibration change occurs	Initial rate of change of vibration amplitude	Major frequency component of changed vibration amplitude and phase angles	Subsequent behaviour of vibration with time	Effect on resonance speed	Effect of cutting power	Repeatability	Comments
Loose rotor bars	Unless bars were loose from manufacture will usually start to develop some time after motor is placed in service	For developing looseness with service, rate of change will be slow	2× supply frequency sidebands on 1×, 2× or 3× rotor slot passing frequency components	Vibration magnitudes will increase with time and can vary with load if more bars become loose	Varies with load	Rotor slot passing frequencies will immediately disappear. Unbalance effect frequency component can suddenly disappear at some lower speed	Yes	Excessive looseness and rotor thermal bow can cause mechanical unbalance in higher speed motors
Non-uniform air gap	Steady load conditions	Can develop slowly with time	2× supply frequency, may have beating with 2× rotational speed in 2-pole motors	Will likely not change with time or load	Not applicable	Immediate drop in vibration magnitude	Yes	Can be due to soft foot or flexible stator, sometimes induced by misalignment
Unbalanced power supply voltages	Steady load conditions	Depends on amount of voltage unbalance	2× power supply frequency radial, with 1/3× supply frequency sidebands, with perhaps an amplitude beat	Vibration magnitudes will increase with the amount of voltage unbalance	Not applicable	Drops rapidly unless there is a resonance speed below rotational speed	May not be repeatable, if due to a loose connection	Voltage unbalance can be from supply unbalance, or loose connection at motor terminals

Table A.1 (continued)

Defect	Measurement conditions under which vibration change occurs	Initial rate of change of vibration amplitude	Major frequency component of changed vibration amplitude and phase angles	Subsequent behaviour of vibration with time	Effect on resonance speed	Effect of cutting power	Repeatability	Comments
Rotor shaft crack	Steady load conditions	Slow initially	1× plus 2×, 3× mainly radial, some axial dependent upon type of crack	1× component increases exponentially with time, while 2× magnitude and phase unsteady	Frequency can reduce and split into two peaks	Can be initial drop due to loss of magnetic attraction between rotor and stator then slow decline afterwards	May not be repeatable	Steady-state vibration changes can be insignificant. Larger amplitudes can be evident on rundown through resonance speeds leading to acceleration of damage. Observe trends of harmonic vibration components. Compare historic slow-roll runout and changes in 1× and some 2× characteristics
Proximity of rotor resonance speed to operating speed	Normal operating conditions, but can pass through resonance speed during start up	Immediately evident	1× rotational speed mainly radial	Will likely not change with time	Not applicable	Drops rapidly unless there is a resonance speed below rotational speed	Yes	Shaft displacement measurements are best for detecting this problem

Table A.1 (continued)

Defect	Measurement conditions under which vibration change occurs	Initial rate of change of vibration amplitude	Major frequency component of changed vibration amplitude and phase angles	Subsequent behaviour of vibration with time	Effect on resonance speed	Effect of cutting power	Repeatability	Comments
Proximity of structural resonances to operating speed	Normal operating conditions, but can pass through resonance speed during start up	Immediately evident	1× rotational speed radial or axial, but will dominate in one plane	Will likely not change with time	Not applicable	Drops rapidly unless there is a resonance speed below rotational speed	Yes	
Salient-pole rotor shorted turns	Steady load conditions	Immediately evident	Rotational speed times number of poles. Magnitude proportional to the number of shorted turns and field current. Mainly radial vibration mode	Will increase if more shorted turns develop	Can change resonance speed due to increase in radial bearing loading from unbalanced magnetic pull between rotor and stator	Immediate drop in vibration magnitude	Yes	Sometimes difficult to confirm since turn shorts can disappear when centrifugal forces present during running are not present with the rotor at standstill
Loose salient-poles	Steady load and during starting and stopping	Can develop slowly with time	Rotational speed times number of poles with 1× speed sidebands mainly radial	Will increase with further pole looseness	Can change resonance speed	Drops slowly with speed	Yes	

Table A.1 (continued)

Defect	Measurement conditions under which vibration change occurs	Initial rate of change of vibration amplitude	Major frequency component of changed vibration amplitude and phase angles	Subsequent behaviour of vibration with time	Effect on resonance speed	Effect of cutting power	Repeatability	Comments
Stator shorts	Steady load conditions	Can develop slowly with time	2× supply frequency and multiples	Will increase if shorted area increases	Not applicable	Immediate drop in vibration magnitude	Yes	
DC motor broken field windings and loose connections	Steady load conditions	Can develop slowly with time	Usually 6× solid state AC to DC power rectifier firing frequency (mainly radial)	Can increase with increased connection looseness	Not applicable	Immediate drop in vibration magnitude	Yes	
Misalignment with driven equipment	See ISO 13373-3:2015, Annex B							

Annex B (informative)

Methodology for vibration diagnosis of faults in electric motors

B.1 General

A methodology for vibration diagnosis of faults in electric motors is given by the flowcharts in [Figures B.1](#) to [B.4](#). Relevant International Standards for vibration magnitudes are in particular ISO 7919, ISO 10816 and ISO 20816.

NOTE ODS stands for operational deflection shape.

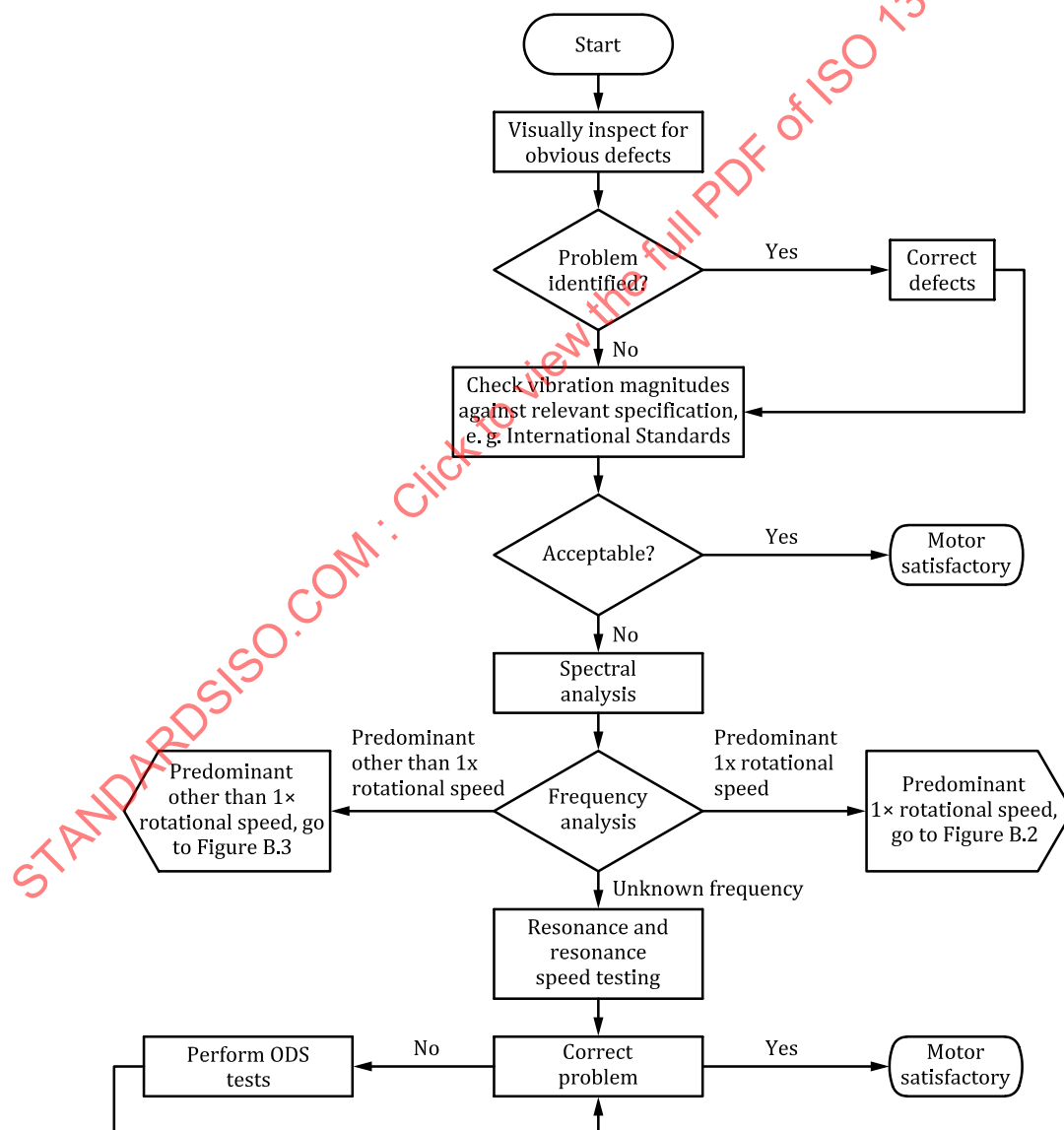


Figure B.1 — Start procedure

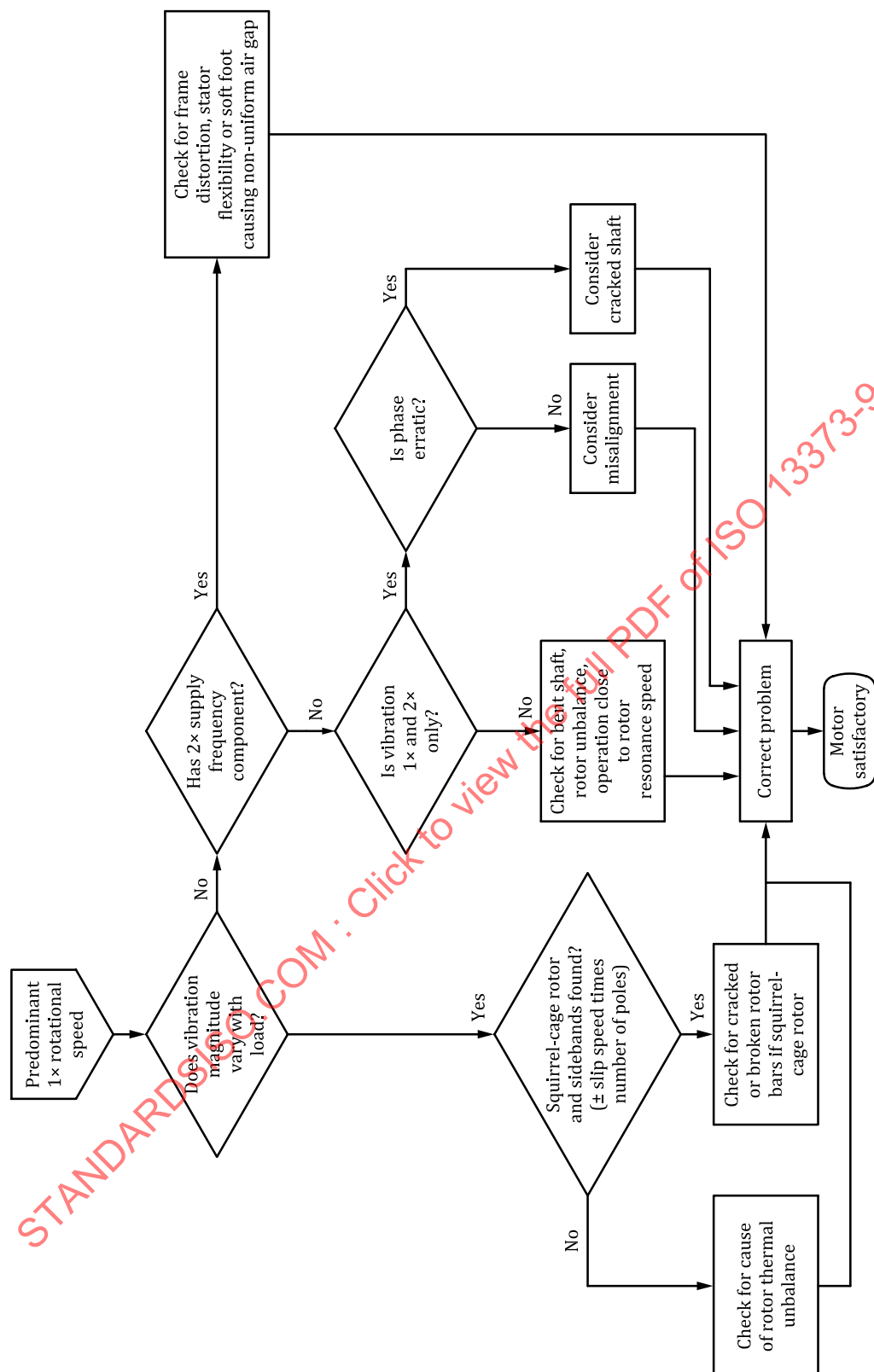


Figure B.2 — Procedure for predominant 1x rotational speed

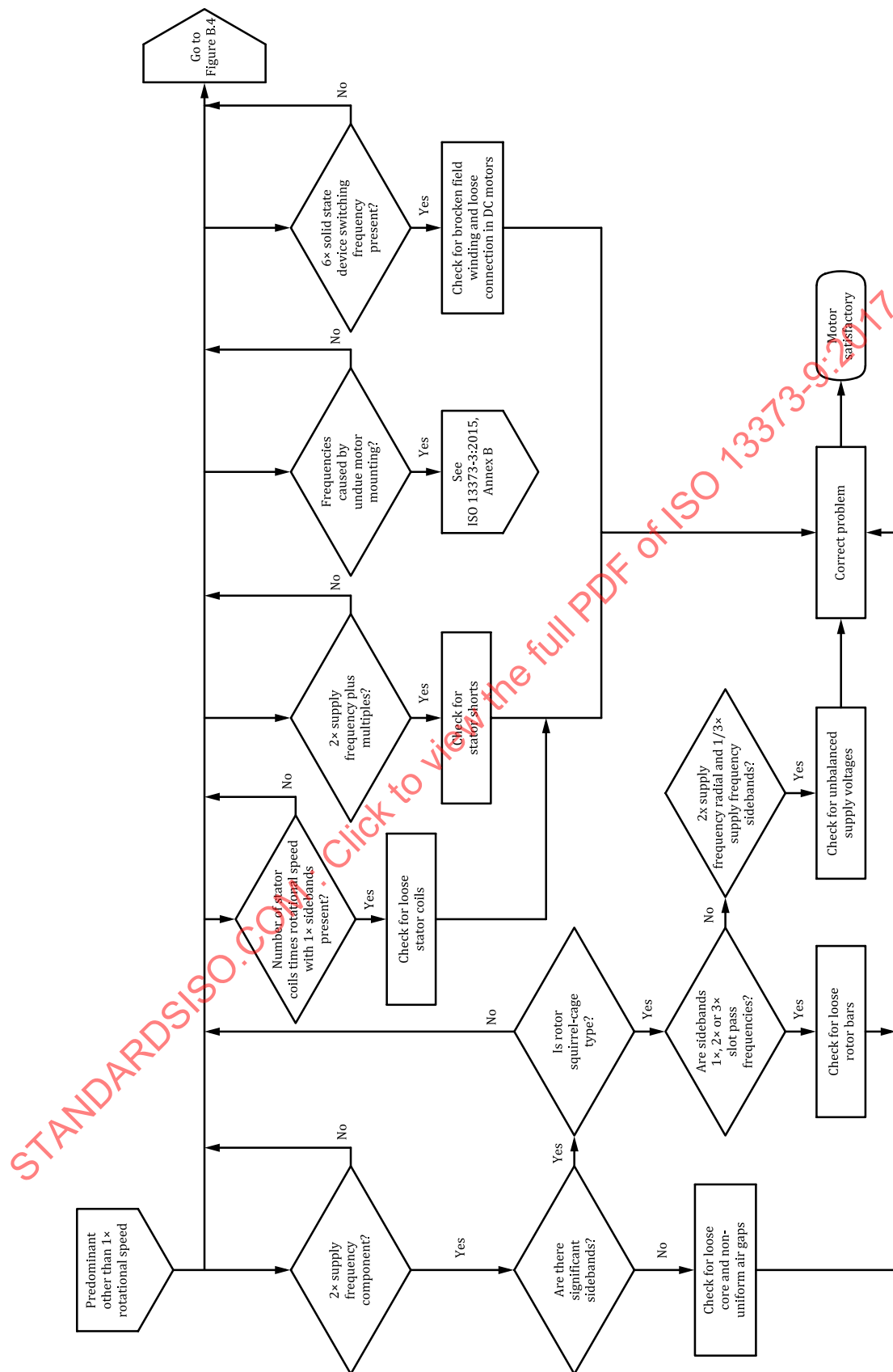


Figure B.3 — Procedure for predominant other than 1× rotational speed (first part)

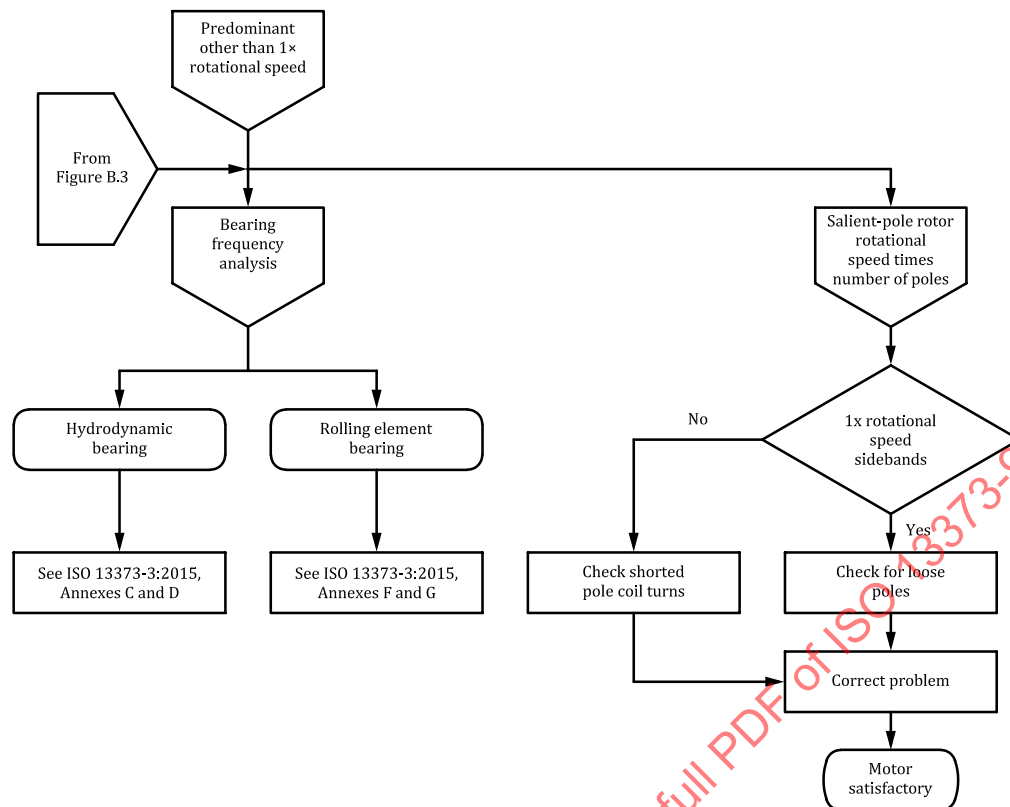


Figure B.4 — Procedure for predominant other than 1x rotational speed (second part)

B.2 Methodology description

B.2.1 General

The recommended methodology is illustrated in [Figures B.1 to B.4](#), which indicates that the diagnosis of motor problems should consist of visual inspection, spectral analysis^[15] and resonance testing, as being the main components of the vibration analysis of the installed motor. In addition, time waveform analysis, phase analysis and operational deflection shape (ODS) analysis should be used if and when judged necessary. It is important to also note the effects of cutting power to the motor, as indicated in [Table A.1](#), when analysing possible causes of excessive vibration.

B.2.2 Visual inspections

It is recommended that before any testing of installed motors is performed, a visual inspection of the motor and the site be completed. For example, the presence of motor mounting or support base looseness and/or piping strain would be evident to the naked eye. It is suggested that all motor and any mounting base bolts be tightened before testing an installed machine. Also, all piping connections to the motor should be checked before testing. All flanged connections to motor auxiliary systems such as water supplies to coolers and separate oil lubrication systems should be checked to make sure that connecting bolts pass through the flanges without any restriction, thus causing no piping strain. Also, since certain motor defects create specific types of noise during starting and normal running, note should be taken of any unusual noise emitted from the motor both during starting and normal running, if present.

B.2.3 Vibration magnitudes

Before continuing with the diagnostic process, vibration magnitudes should be compared with the values given in ISO 7919, ISO 10816 and ISO 20816.

B.2.4 Spectral analysis

Spectral analysis is the core of the diagnosis of rotating machinery (see [Figures C.1, C.2, C.4, C.6 and C.7](#)). Spectral data are usually taken as velocity data, but also as acceleration data for high-speed machines and as displacement data for compressors and low-speed machines. In addition, shaft displacement probe measurements are also useful when exploring the possibility of problems with rotor lateral resonance speeds and hydrodynamic bearings.

These spectral data should be measured on all motor bearings, in all three directions, horizontal, vertical and axial. Complete knowledge of the motor type and construction should be available to identify characteristic frequencies. In particular, it is important to know the type of rotor winding since some vibration frequencies are specific to certain types of rotor winding faults. The purpose of the spectral analysis is to identify the frequencies causing the machine to vibrate. If all vibration amplitudes are within acceptable limits, then the machine would be accepted as normal. However, if any of the spectral components has a high amplitude, then spectral analysis is used to correlate the frequency of the high-amplitude vibration to the motor rotational frequency and in some cases to the motor power supply frequency. It should, however, be noted that changes in spectral behaviour can indicate faults which are not necessarily related to high amplitudes.

The result of the spectral analysis of the high-amplitude vibration is one of three cases:

a) at $1\times$ rotational frequency

There are many motor related problems that lead to high $1\times$ vibration. Amongst these faults are rotor mechanical and thermal unbalance, bent shaft and rotor lateral resonance speed close to rotational speed. In this case, special vibration measurements have to be conducted on the machine to describe the nature of this $1\times$ vibration, and to distinguish between the different $1\times$ faults. These measurements include time waveform measurement, phase measurement, and measurement of the ODS.

b) at a frequency other than motor rotational speed ($1\times$) that can be related to a known cause

Examples are decreasing amplitude of harmonics of the rotational speed in the spectrum. This spectrum shape is usually correlated with looseness in the bearings or mounting skid. $2\times$ supply frequency vibration is commonly found in three phase AC motors and possible causes of this are identified in [Annex A](#) and [B.1](#).

c) at a frequency that cannot be related to commonly known motor defects

In such cases, additional testing is required to determine the source of these frequencies. This could include resonance testing^[15] (including impact test and transient testing) and modal testing^[18]. The purpose of the resonance testing is to correlate the observed frequency to natural frequencies (stationary components) or resonance speeds (rotating components) of the machine. Modal testing is a more advanced form of resonance testing, where all the modal characteristics of the machine are determined, including natural frequencies, damping ratios, and mode shapes. Modal testing is rarely used in the field, as it is an elaborate testing method, and is usually time consuming and costly. However, when justified, it can be a very powerful tool to obtain the machine characteristics and identify clearly the observed frequency in the spectrum, and suggest a solution to the problem^[18]. As can be seen from [Table A.1](#) and the flowcharts in [Figures B.1 to B.4](#), variation of motor load and the effects of cutting the motor power supply can also help identify possible causes.

B.2.5 Time waveform analysis

The time-waveform measurement can be used to distinguish between misalignment, non-uniform air gaps, stator frame distortion and stator winding faults.

B.2.6 Phase analysis

The phase analysis is used to diagnose unbalance, misalignment, bent shaft and casing distortion. In many cases, misalignment (the main installation anomaly) manifests itself as vibration at $1\times$ only. One

of the ways to distinguish between $1\times$ vibration due to unbalance and $1\times$ vibration due to misalignment is to measure phase across the coupling.

- a) If there is a 180° phase shift across the coupling, then the problem is misalignment. If no phase shift occurs across the coupling, then the problem is unbalance. In special cases, if a resonance condition occurs and the node happens to be at the coupling, care should be exercised to evaluate the phase shift.
- b) Casing distortion can be identified by 180° phase shift across the machine (side-to-side or end-to-end) in the horizontal, vertical and/or axial directions.
- c) When a rotor has a resonance speed, there will be theoretically a 180° phase shift when it runs through this. In reality, due to damping and other resonance speeds, the phase shift will be less than 180° .

A cocked bearing can be identified by measuring phase around the bearing housing and noticing the phase shift due to the wobbly action of the cocked bearing. In many cases, a coupled time-waveform-phase analysis is quite useful in visualizing the vibration pattern and identifying the problem.

B.2.7 Operational deflection shape (ODS) analysis

If the $1\times$ vibration problem is still not solved after time waveform and phase analysis, then an ODS analysis should be performed. The ODS analysis is useful in identifying problems of tilted foundation, skid levelling, motor support base looseness or structural resonance (see [Figures C.7 to C.9](#)), and shafts that are not parallel (lateral and angular misalignment). In the ODS measurement, phase-referenced vibration, at the appropriate frequency, is measured at grid points on the machine structure or skid. This reveals the actual deflection shape of the machine under the operating load, and at the operating speed. Note that the ODS is not a mode shape of the machine or structure, unless the machine is in resonance, but it can be considered as a summation of the contributions of all of the modes of vibration. ODS analysis can be useful in identifying problems, as it provides a visualization of the actual vibration pattern of the machine and/or skid (see [Figures C.7 and C.9](#)). In particular, if a machine skid exhibits a node in its ODS, then this is a clear indication of a tilted foundation or a levelling problem in the skid. Accurate measurement of skid and/or foundation levels would then be required to confirm the results of the ODS analysis.

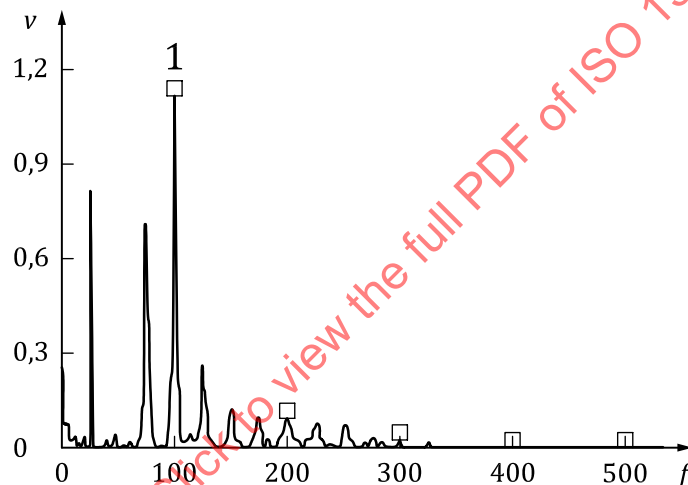
If the analyst follows the above described methodology and still the problem diagnosis has not yet been reached, then an expert should be invited to analyse the problem.

Annex C (informative)

Examples of vibration problems in electric motors

C.1 Case Study 1 — Non-uniform air gap

A 75 kW, 4-pole 50 Hz squirrel-cage induction motor driving a fan shows high vibration magnitudes. To investigate this problem, high-resolution spectral vibration plots were taken and the 100 Hz component with an r.m.s. magnitude of 1,12 mm/s was found (see [Figure C.1](#)). Current signature analysis confirms that this motor had air gap eccentricity. This air gap problem was corrected and the overall and 100 Hz vibration magnitudes reduced to acceptable values.



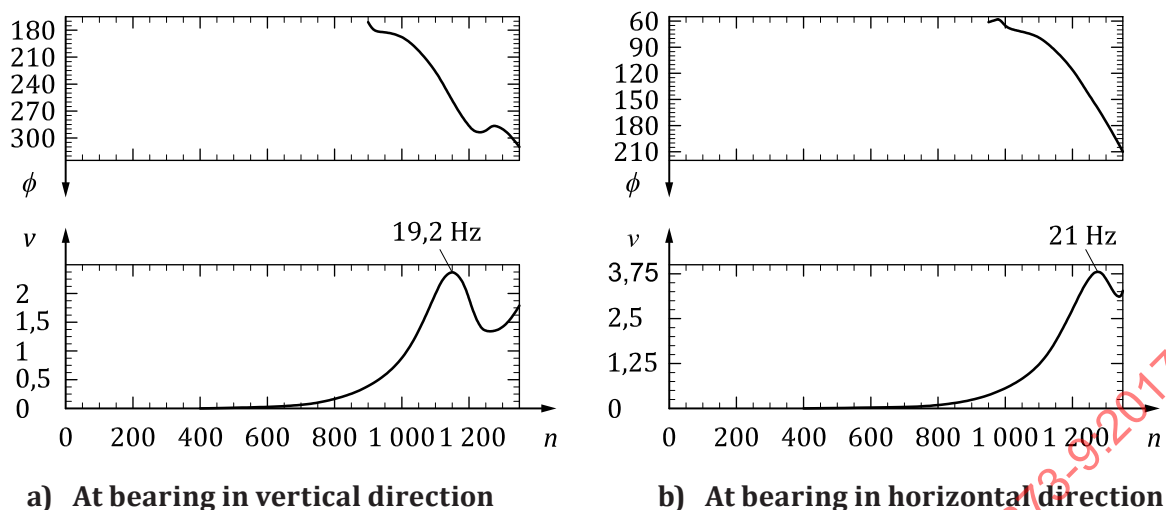
Key

- f frequency, in Hz
- v r.m.s. vibration magnitude, in mm/s
- 1 100 Hz vibration

Figure C.1 — High-magnitude 100 Hz vibration from non-uniform air gap

C.2 Case Study 2 — Vertical electric motor with natural frequency problem (Reference [18])

A 6-pole vertical induction pump motor when factory coast down tested on a massive foundation had two different directional natural frequencies 90° apart, both of which were very close to rotational frequency of about 20 Hz (see [Figure C.2](#)). This would have caused vibration problems if the foundation stiffness was similar when it was bolted to the mounting base of the pump it was driving. However, the motor pump mounting base was much more flexible than the factory one and this brought the natural frequency in both directions well below 20 Hz and so no in-service vibration problems from structural resonance were experienced.

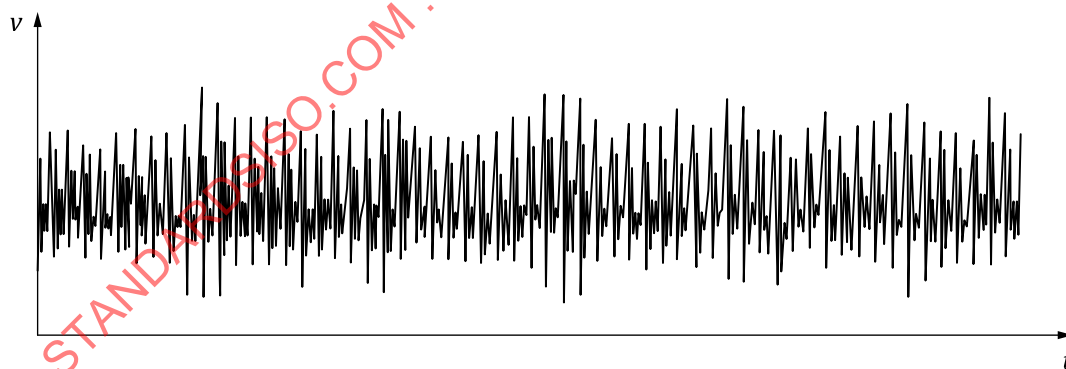
**Key**

- ϕ phase lag, in degrees ($^{\circ}$)
- n rotational speed, in r/min
- v vibration velocity magnitude, in mm/s

Figure C.2 — Two natural frequencies 90° apart close to motor rotational speed of 1 200 r/min

C.3 Case Study 3 — Stator winding fault: Stator shorts (Reference [18])

Figure C.3 shows the vibration velocity time waveform from a 200 kW, 12-pole 60 Hz motor with a stator winding fault. The time waveform shows a $2\times$ supply frequency (120 Hz) modulated vibration (see Figure C.3) while the spectrum, i.e. vibration versus frequency plot, shows a significant $2\times$ supply frequency component and multiples of this (see Figure C.4) which are common symptoms of this problem.

**Key**

- t time
- v vibration velocity

Figure C.3 — Time waveform showing 120 Hz vibration modulation