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Condition monitoring and diagnostics of machines — General guidelines on using performance parameters

Surveillance et diagnostic d'état des machines — Recommandations générales sur l'utilisation des paramètres de performance

Reference number
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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 International Standard may be the subject of patent rights. ISO shall not be held responsible for identifying any or all such patent rights.

ISO 13380 was prepared by Technical Committee ISO/TC 108, *Mechanical vibration and shock*, Subcommittee SC 5, *Condition monitoring and diagnostics of machines*.

Annexes A to D of this International Standard are for information only.

Introduction

This International Standard provides guidance for condition monitoring and diagnostics of machines using parameters such as temperatures, flow rates, contamination, power and speed, typically associated with performance, condition, safety and quality criteria. The evaluation of machine function and condition may be based on performance, condition, product quality or safety.

It is part of a series of standards developed under the general title *Condition monitoring and diagnostics of machines.*

Condition monitoring and diagnostics of machines — General guidelines on using performance parameters

1 Scope

This International Standard describes the general conditions and procedures for recording, assessment, evaluation and diagnostics of machine condition by measuring parameters related to machine performance, condition and safety, including thermal, electrical and hydraulic parameters where applicable.

The procedures relate to operational monitoring of machines, and include all components and sub-assemblies necessary to provide the functional operation of the machine.

2 Normative references

The following normative documents contain provisions which, through reference in this text, constitute provisions of this International Standard. For dated references, subsequent amendments to, or revisions of, any of these publications do not apply. However, parties to agreements based on this International Standard 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 13379, *Condition monitoring and diagnostics of machines — General guideleines on data interpretation and diagnostic techniques*

3 Terms and definitions

For the purposes of this International Standard, the terms and definitions given in ISO 1925, ISO 2041 and the following apply.

NOTE A terminology standard for condition monitoring and diagnostics of machines (ISO 13372) is in course of preparation.

3.1
fault
⟨in a machine⟩ condition of a machine when any of its components or their assembly is degraded or exhibits an abnormal behaviour

NOTE This may lead to failure of the machine.

3.2
failure
⟨of a machine⟩ condition of a machine when one or more of its principle functions are no longer available

NOTE This generally happens when one or more of its components is in a fault condition.

3.3
performance
〈of a machine〉 capability of a machine defined by one or more characteristic quantities such as power, flow, efficiency or speed

NOTE Performance is derived by measurement and calculation of one or more parameters which singly or together provide information on the characteristic quantity. Performance characteristics are reference quantities or envelopes.

3.4
baseline
parameters or derived quantities made under specific equipment configurations and specified operating conditions

NOTE They can be stored or kept as reference values or characteristic profiles. These reference values are called baselines.

3.5
machine
device using or applying mechanical power

3.6
compressor
machine or component which increases the pressure of the working fluid

NOTE This can be a rotating or reciprocating machine with one or more stages.

3.7
turbine
component which produces power from the expansion of the working fluid

3.8
gas turbine
machine which converts thermal energy of a combustion gas into mechanical work

NOTE It consists of one or several rotating compressors, one or more thermal devices which heat the working fluid, one or more turbines, a control system and essential auxiliary equipment. Any heat exchangers (excluding waste heat recovery exchangers) in the main working fluid circuit are considered to be part of the gas turbine.

3.9
gas generator
assembly of gas turbine components which produces heated pressurized gas to a process or to a power turbine

NOTE It consists of one or more rotating compressors, one or more thermal devices heating the working fluid, one or more compressor-driven turbines, a control system and essential auxiliary equipment.

3.10
gas turbine power plant
gas turbine and all essential equipment necessary for the production of power in a useful form (e.g. electrical, mechanical or thermal)

3.11
steam turbine
machine which converts thermal energy of steam into mechanical work

NOTE It consists of one or more turbines, a control system and essential auxiliary equipment.

3.12
electric motor
machine which converts electrical energy into mechanical work

NOTE It consists of one or more rotors and stators, a starting and control system, and essential auxiliary equipment.

3.13
pump
component which increases the pressure of the working fluid

NOTE It consists of a mechanical work input coupling and one or more rotors.

3.14
RIC engine
reciprocating internal combustion engine
machine which converts chemical energy into rotational mechanical work

NOTE It consists of one or more pistons and cylinders arranged in Vee, in-line or horizontally opposed configurations connected to one or more crankshafts and an output coupling, a starting and control system and essential auxiliary equipment.

3.15
generator
rotating machine which converts mechanical work into electrical energy

NOTE It consists of a mechanical work input coupling, one or more rotors and stators, excitation equipment, a starting and control system and essential auxiliary equipment.

4 Monitored parameters

4.1 Type of parameters

A large range of performance parameters can be measured for the purposes of establishing performance criteria, both for acceptance testing and for through-life monitoring. The parameters to be considered are those which will indicate a fault condition either by an increase or decrease in overall measured value, or by some other change to a characteristic value, such as pump or compressor performance curves, reciprocating internal combustion engine pressure-volume curves or other performance curves.

4.2 Type of measurement

Measured parameters can be simple measurements of overall values, or values averaged over time. For certain parameters, such as current, voltage and vibration, simple measurements of overall values may not be sufficient to show the occurrence of a fault. Techniques such as spectral and phase measurement may be required to reveal changes caused by faults.

Examples of performance parameters useful to consider for a number of machine types are given in annex A. Examples of standards which may be useful to identify particular measurement methods and parameters for different machine types are included in the Bibliography.

4.3 Accuracy of monitored parameters

The accuracy required of performance parameters to be used for machine condition monitoring and diagnosis is not so absolute as the accuracy which may be required for performance measurement. Methods utilizing trending of values can be effective, where repeatability of measurement is more important than absolute accuracy of measurement. Correction of measured parameters, for example to ISO standard conditions of pressure and temperature, is not necessarily required for gas turbines for routine condition monitoring. Where this is required, advice is given in the appropriate acceptance testing standard; a list of some typical standards is included in the Bibliography.

4.4 Other causes of change to measured values

Measured values and baselines can change due to maintenance work, including component change, adjustment or duty change. In certain cases the baseline may need to be re-established following such changes.

It should be noted that changes in measured values can also be due to normal or controlled changes in the operating conditions, and do not necessarily indicate a fault condition.

5 Measurement procedure

5.1 Feasibility of measurement

Consideration should be given to the practicability of measuring the parameters, and whether surveillance or control systems exist which are already measuring parameters of interest. Examples of faults, and the parameters to be measured to detect them, are given by machine type in annex C. Although presented by machine type, it is recommended that the complete machine train be included in the decision and monitoring process.

5.2 Operating conditions during measurements

Measurements of different parameters should be taken wherever possible at the same time, or under the same operating conditions. For variable duty or variable speed machines, it may be possible to achieve similar measurement conditions by varying speed, load or some other control parameter.

Monitoring should be taken where possible when the machine has reached a predetermined set of operating conditions (e.g. normal operating temperature) or, for transients, a predetermined start and finish condition and operating profile (e.g. coast down). These are also conditions which may be used for a specific machine configuration to establish baselines. Subsequent measurements are compared to the baseline values to detect changes. The trending of measurements is useful in highlighting the development of faults.

5.3 Measurement interval

Consideration should be given to the interval between measurements, and whether continuous or periodic sampling is required. The measurement interval primarily depends on the type of fault and its rate of progression (and thus the rate of change of the relevant parameters). However, the measurement interval is also influenced by factors such as duty cycles, cost and criticality.

5.4 Data acquisition rate

For steady-state conditions, the data acquisition rate should be fast enough to capture a complete set of data before conditions change. During transients, high-speed data acquisition may be necessary.

5.5 Record of monitored parameters

Records of monitored parameters should include as a minimum the following information:

— essential data describing the machine;

— the measurement position;

— the measured quantity units and processing; and

— date and time information.

Other information useful to allow comparison include details of the measuring systems used, and the accuracy of each measuring system. It is recommended that details of machine configuration and any component changes are also included. Annex B gives typical information which should be recorded when monitoring. An example of a typical recording format is shown for information in annex D.

6 Fault diagnosis

6.1 Procedure for fault diagnosis

The possibility of carrying out fault diagnosis will depend on the machine type, configuration and operating conditions. A fault may be indicated by a change in one or more of the measured or derived parameters from the baseline values. For fault diagnosis procedures, see ISO 13379.

6.2 Criteria for fault diagnosis

The following methods may be used to perform fault diagnosis:

a) experience with similar machines, or by statistical analysis;

b) studies of deviations from required minimum or maximum values;

c) discussions between the manufacturer and customer.

For the machine types shown at annex A, examples of faults and their associated symptoms or measured parameters are given for each machine type considered in annex C. As and when circumstances permit, further examples of machine type and faults shown by performance parameter monitoring may be added to this International Standard. Until such time, fault parameter identification may be found using experience or the results of operation, and the interpretation should be agreed between the manufacturer and customer.

Annex A
(informative)

Examples of parameters related to performance for a range of machine types

Table A.1 — Performance parameters by machine type

Performance parameter	Machine type								
	Electric motor	Steam turbine	Aero gas turbine	Industrial gas turbine	Pump	Com-pressor	Electric generator	RIC engine	Fan
Temperature	•	•	•	•	•	•	•	•	•
Pressure		•	•	•	•	•	•	•	•
Pressure (head)					•				
Pressure ratio			•	•		•			
Air flow			•			•		•	•
Fuel flow			•	•				•	
Fluid flow		•			•	•			
Current	•						•		
Voltage	•						•		
Resistance	•						•		
Input power	•				•	•	•		•
Output power	•	•		•			•	•	
Noise	•	•	•	•	•	•	•	•	•
Vibration	•	•	•	•	•	•	•	•	•
Oil pressure	•	•	•	•	•	•	•	•	•
Oil consumption	•	•	•	•	•	•	•	•	•
Oil (tribology)	•	•	•	•	•	•	•	•	•
Torque	•	•				•	•	•	
Speed	•	•	•	•	•	•	•	•	•
Length		•							
Angular position		•	•	•		•			
Efficiency (derived)		•	•	•	•	•		•	

• Indicates measurement of performance parameter may be applicable for condition monitoring.

Annex B
(informative)

Typical information to be recorded when monitoring

B.1 Machine details

For each machine being monitored, the following information should be recorded:

— unique machine identifier: e.g. equipment code

— machine type: motor/generator/turbine/compressor/pump/fan

— powered: electric/steam/gas/RIC/diesel/hydraulic

— configuration: direct, belt or shaft driven

— rated speed: in r/min or Hz

— rated power: in kW

The following information may also be recorded:

— function: driver or driven

— mounting: rigid or resiliently mounted

— coupling: rigid or flexible

— number of cylinders: 1/2/3/4/5/6/8/12/16 cylinders

— working cycle: two or four stroke, or single or double effect

B.2 Measurements

For each measuring system, the following information should be recorded:

— date, time (including time zone) of measurement;

— instrument and transducer type;

— measurement location and method of attachment;

— measurement value, units and processing method.

The following information may also be recorded:

— speed during measurement: in r/min or Hz

— power during measurement: in kW

— calibration requirement, type and date of last or next required calibration.

B.3 Other information

Extra information on the machine and the measurements may be recorded in addition to the above, for example historical maintenance data. Other information such as lubricant type and ambient conditions may be useful.

Annex C
(informative)

Examples of faults indicated by performance parameter change

Tables C.1 to C.9 show a range of typical faults for each selected machine type. The faults are then correlated with a range of symptoms or parameters which can change or be influenced if the fault occurs.

Table C.1 — Electric motors

Machine type: Electric motor	**Symptom or parameter change**												
Fault	Current	Voltage	Resistance	Partial discharge	Power	Torque	Speed	Vibration	Temperature	Coast down time	Axial flux	Oil debris	Cooling gas
Rotor windings	•				•	•	•	•	•		•		•
Stator windings	•								•		•		•
Eccentric rotor	•							•			•		
Brush(es) fault	•	•			•	•			•				
Bearing damage						•		•	•	•		•	
Insulation deterioration	•	•	•	•									•
Loss of input power phase	•	•						•			•		
Unbalance								•					
Misalignment								•					

• Indicates symptom may occur or parameter may change if fault occurs.

Table C.2 — Steam turbines

Machine type: Steam turbines	**Symptom or parameter change**									
Fault	Steam leakage	Length measure-ment	Power	Pressure or vacuum	Speed	Vibration	Temper-ature	Coast down time	Oil debris	Oil leakage
Damaged rotor blade	•		•			•	•	•	•	
Damaged labyrinth	•		•	•	•	•	•	•		
Eccentric rotor	•					•		•		
Bearing damage		•	•	•		•	•	•	•	•
Bearing wear	•	•				•	•	•	•	•
Hogging or sagging rotor	•					•		•	•	
Unequal expansion	•	•				•	•			
Unbalance						•				
Misalignment						•				

• Indicates symptom may occur or parameter may change if fault occurs.

Table C.3 — Aero gas turbine

Machine type: Aero gas turbine	**Symptom or parameter change**											
Fault	Compressor temperature	Compressor press/ press ratio	Air flow	Fuel pressure/ fuel flow	Speed	Gas generator temperature	Pressure/ pressure ratio	Power turbine temperature	Exhaust temperature	Vibration	Oil debris	Oil leakage/ consumption
Air inlet blockage	•	•	•		•							
Compressor fouled	•	•	•	•	•	•	•	•	•	•	•	
Compressor damaged	•	•		•	•	•	•	•	•	•	•	
Compressor stall					•		•			•		
Fuel filter blockage		•		•	•		•					
Seal leakage						•	•				•	•
Combustion chamber holed				•	•				•			
Burner blocked				•	•		•					
Power turbine dirty	•	•	•		•		•	•		•		
Power turbine damage	•	•	•		•		•			•	•	
Bearing wear/ damage										•	•	•
Gear defects										•	•	
Unbalance										•		
Misalignment										•		

• Indicates symptom may occur or parameter may change if fault occurs.

Table C.4 — Industrial gas turbine

Machine type: Industrial gas turbine	**Symptom or parameter change**											
Fault	Compressor temperature	Compressor pressure	Air flow	Fuel pressure Fuel flow	Speed	Exhaust temperature	Vibration	Output power	Compressor efficiency	Turbine efficiency	Oil debris/ contamination	Oil consumption
Air inlet blockage		•	•		•			•				
Compressor fouled	•	•	•	•	•			•	•			
Compressor damaged	•	•	•	•	•		•	•	•		•	
Fuel filter blockage		•		•	•			•				
Combustion chamber holed				•	•			•				
Burner blocked				•	•	•		•				
Power turbine damaged					•	•	•	•		•	•	
Bearing wear							•				•	•
Unbalance							•					
Misalignment							•					

• Indicates symptom may occur or parameter may change if fault occurs.

Table C.5 — Pumps

Machine type: Pumps	**Symptom or parameter change**									
Fault	Fluid leakage	Length meas-urement	Power	Pressure or vacuum	Speed	Vibration	Temp-erature	Coast down time	Oil debris	Oil leakage
Damaged impeller		•	•	•	•	•	•	•	•	
Damaged seals	•	•		•	•	•				
Eccentric impeller			•	•	•	•	•	•		
Bearing damage		•	•		•	•	•	•	•	•
Bearing wear		•				•	•	•	•	
Mounting fault						•				
Unbalance						•				
Misalignment		•				•				

• Indicates symptom may occur or parameter may change if fault occurs.

Table C.6 — Compressors

Machine type: Compressors	**Symptom or parameter change**									
Fault	Fluid leakage	Length meas-urement	Power	Pressure or vacuum	Speed	Vibration	Temp-erature	Coast down time	Oil debris	Oil leakage
Damaged impeller		•	•	•	•	•	•	•	•	
Damaged seals	•	•		•	•				•	
Eccentric impeller			•	•	•	•	•	•		
Bearing damage		•	•		•	•	•	•	•	•
Bearing wear		•				•	•	•	•	
Cooling system fault	•			•			•		•	
Valve fault	•			•		•	•			
Mounting fault						•				
Compressor stall		•			•	•				
Unbalance						•				
Misalignment		•				•				

• Indicates symptom may occur or parameter may change if fault occurs.

Table C.7 — Reciprocating internal combustion engine

Machine type: RIC engine	**Symptom or parameter change**											
Fault	Engine temperature	Cylinder pressure	Air flow	Fuel pressure	Fuel flow	Exhaust temperature	Exhaust pressure	Vibration	Output Power	Oil Consumption	Oil debris	Cooling fluid leak
Air inlet blockage	•	•	•				•					
Fuel injector fault	•	•	•		•	•		•	•	•		
Ignition fault	•	•			•	•		•	•	•		
Bearing wear								•			•	
Fuel filter blockage				•	•		•					
Seal leakage						•	•			•		
Piston ring fault		•							•	•	•	
Cooling system fault					•		•			•	•	•
Secondary balance gear fault								•				
Gear Defects								•			•	
Flywheel damage								•			•	
Mounting fault								•				
Unbalance								•				
Misalignment								•				

• Indicates symptom may occur or parameter may change if fault occurs.

Table C.8 — Electric generators

Machine type: Electric generators	**Symptom or parameter change**												
Fault	Current	Voltage	Resistance	Partial discharge	Power	Torque	RF (Radio Frequency) emissions	Vibration	Temperature	Coast down	Axial flux	Oil debris	Cooling gas
Rotor windings	•							•	•		•		•
Stator windings	•							•	•		•		•
Eccentric rotor	•							•			•		
Brush(es) fault	•	•			•	•	•		•				
Bearing damage						•		•	•	•		•	
Insulation deterioration	•	•	•	•									•
Loss of output power phase	•	•						•					
Unbalance								•					
Misalignment								•					

• Indicates symptom may occur or parameter may change if fault occurs.

Table C.9 — Fans

Machine type: Fans	**Symptom or parameter change**									
Fault	Air leakage	Length meas-urement	Power	Pressure or vacuum	Speed	Vibration	Temp-erature	Coast down time	Oil debris	Oil leakage
Damaged impeller		•	•	•	•	•	•	•	•	
Damaged oil seals		•		•	•				•	•
Damaged bellows	•									
Eccentric impeller			•	•	•	•	•	•		
Bearing damage		•	•		•	•	•	•	•	•
Bearing wear		•				•	•	•	•	
Mounting fault						•				
Rotor fouled						•				
Unbalance						•				
Misalignment		•				•				

• Indicates symptom may occur or parameter may change if fault occurs.

Annex D
(informative)

Form for recording typical machine details

General

Record No.: _____ Installation site: _____

Date: _____ Measured by: _____

Details of machine/train

Unique Machine ID No.: _____ Type/Serial No.: _____

Type: motor/generator/turbine/comp./pump/fan[1)] Powered: electric/steam/gas/ric/diesel/hydraulic[1)]

Configuration: direct/belt/shaft[1)] drive/driven[1)] Function: driver/driven[1)] Coupling: rigid/flexible[1)]

Rated speed: _____ r/min Rated power: _____ kW

Actual speed: _____ r/min Power during measurement: _____ kW

Mounting: rigid/resilient[1)] directly/on baseplate[1)] Running hours: _____

Manufacturer: _____ Bearing type(s): _____

Details of each measuring system

Instrument type: _____ Make: _____

Transducer type: _____ Make: _____ Attachment: _____ Units: _____

Transducer type: _____ Make: _____ Attachment: _____ Units: _____

For reciprocating machine:

Number of cylinders: 2/3/4/5/6/8/12/16[1)] Working cycle: two/four/single/double[1)] stroke/effect[1)]

Diagram Sketch machine below:

Measurement records, readings, diagrams, etc. should be attached giving locations and points of measurement, and the conditions at the time of measurement, if applicable.

1) Delete/supplement as appropriate.

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