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Condition monitoring and diagnostics of machines — General guidelines on data interpretation and diagnostics techniques

Surveillance et diagnostic d'état des machines — Lignes directrices générales sur l'interprétation des données et les techniques de diagnostic

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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 2.

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

ISO 13379 was prepared by Technical Committee ISO/TC 108, *Mechanical vibration and shock*, Subcommittee SC 5, *Condition monitoring and diagnostics of machines*.

Introduction

This International Standard contains general procedures that can be used to determine the condition of a machine relative to a set of baseline parameters. Changes from the baseline values and comparison to alarm criteria are used to indicate anomalous behaviour and to generate alarms: this is usually designated as condition monitoring. Additionally, procedures that identify the cause(s) of the anomalous behaviour are given in order to assist in the determination of the proper corrective action: this is usually designated as diagnostics.

Condition monitoring and diagnostics of machines — General guidelines on data interpretation and diagnostics techniques

1 Scope

This International Standard gives guidance for data interpretation and diagnostics of machines. It is intended

— to allow the users and manufacturers of condition monitoring and diagnostics systems to share common concepts in the fields of machine diagnostics,

— to enable users to prepare the necessary technical characteristics that will be used for the further diagnosis of the condition of the machine, and

— to give an appropriate approach to achieve a diagnosis of machine faults.

Since it gives general guidelines, a list of the machine types addressed is not included. However, the machine sets covered by this International Standard will normally include industrial machines such as turbines, compressors, pumps, generators, electrical motors, blowers and fans.

2 Normative references

The following referenced documents are indispensable for the application 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, *Vibration and shock — Vocabulary*

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

3 Terms and definitions

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

3.1
alarm
operational signal or message designed to notify personnel when a selected anomaly, or a logical combination of anomalies, requiring corrective actions is encountered

NOTE An alarm is a more severe anomaly zone than an alert and should be identified with a red indicator.

3.2
anomaly
irregularity or abnormality in a system

3.3
descriptor
condition monitoring descriptor
data item derived from raw or processed parameters or an external observation

NOTE Descriptors are used to express symptoms and anomalies. The descriptors used for diagnostics are generally those obtained from the condition monitoring systems. However, operational parameters, like any other measurement, can be considered as descriptors.

3.4
failure
〈of a machine〉 termination of the ability of an item to perform a required function

NOTE Failure is an event as distinguished from fault, which is a state.

3.5
fault
〈of a component of a machine, in a machine〉 condition of a component that occurs when one of its components or assembly degrades or exhibits abnormal behaviour, which may lead to the failure of the machine

NOTE 1 Fault can be the result of a failure, but may exist without a failure.

NOTE 2 An event is not a fault if it is a result of planned actions or lack of external resources.

3.6
root cause
set of conditions and/or actions that occur at the beginning of a sequence of events that result in the initiation of a failure mode

3.7
symptom
〈of a fault〉 perception, made by means of human observations and measurements (descriptors), which may indicate the presence of one or more faults with a certain probability

3.8
syndrome
group of signs or symptoms that collectively indicate or characterize an abnormal condition

3.9
diagnosis confidence level
estimate of the likelihood that a calculated reliability will be achieved or bettered

NOTE 1 Reliability calculations are made on the basis of available evidence. The degree of trust that can be placed on the calculation is a function of the extent of the sample size.

NOTE 2 The diagnostic confidence level is a figure of merit that indicates the degree of certainty that the diagnosis is correct.

NOTE 3 The diagnostic confidence level is determined by the diagnostic confidence factor.

4 Condition monitoring set-up and diagnostics requirements

4.1 Role of diagnostics in operation and maintenance

Diagnostics has an essential role in decision making in operational and maintenance tasks. Hence, in order to be effective, diagnostics procedures should be set up according to the potential faults that may happen in the machine. Therefore, it is strongly recommended that a preliminary study be carried out when preparing the requirements for the condition monitoring and diagnostics system of a machine.

4.2 Establishing diagnostics needs

The principle of this study is shown in Figure 1. The “V” shape has been intentionally chosen to represent the high level concerns (maintenance: machine, risk assessment) and the “low level” ones (measurements: monitoring, periodical tests, data processing).

The right branch of the sketch corresponds to the condition monitoring and diagnostics activities that are normally undertaken after the machine has been commissioned. The left branch corresponds to the preliminary study which prepares, for a particular machine, the necessary data for condition monitoring and diagnostics. Each layer consists of a preparatory design phase (left) and a usage phase (right).

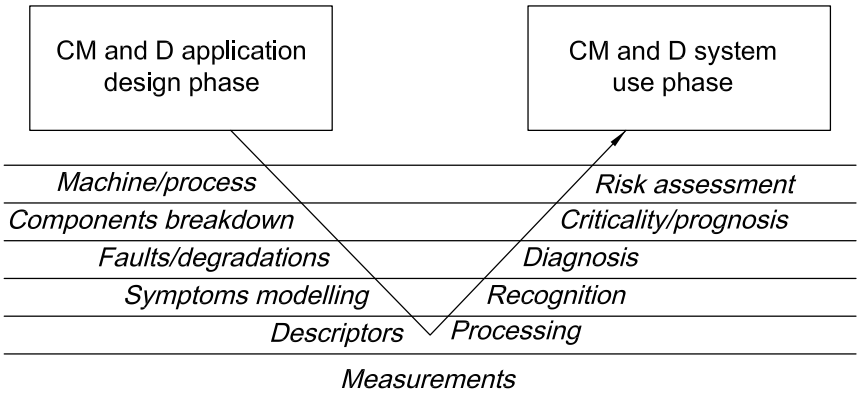

Figure 1 — Condition monitoring and diagnostics (CM and D) cycle: Design and use of the application on a machine

The generic steps of the diagnostics study include the following:

a) analyse the machine availability, maintainability and criticality with respect to the whole process;

b) list the major components and their functions;

c) analyse the failure modes and their causes as component faults;

d) express the criticality, taking into account the gravity (safety, availability, maintenance costs, production quality) and the occurrence;

e) decide accordingly which faults should be covered by diagnostics (“diagnosable”);

f) analyse under which operating conditions the different faults can be best observed and define reference conditions;

g) express the symptoms that can serve in assessing the condition of the machine, and that will be used for diagnostics;

h) list the descriptors that will be used to evaluate (recognize) the different symptoms;

i) identify the necessary measurements and transducers from which the descriptors will be derived or computed.

The steps given in a), b), c) and d) may be followed using maintenance optimization such as FMEA (Failure Modes and Effects Analysis), FMECA (Failure Modes, their Effects and Criticality Analysis). They may be also accomplished within a more general process of maintenance optimization like RCM (Reliability Centred Maintenance).

NOTE FMEA and FMECA procedures are outlined in BS 5760 and IEC 60812.

The steps given in c), d), e), f), g), h) and i) may be followed using the FMSA (Failure Mode Symptoms Analysis) methodology explained in 4.3.

4.3 Failure Mode Symptoms Analysis (FMSA)

4.3.1 FMSA process

The aim of this process is to select monitoring technologies and strategies that maximize the confidence level in the diagnosis and prognosis of any given failure mode.

This methodology is designed to assist with the selection of monitoring techniques that will provide the greatest sensitivity to detection and rate of change of a given symptom. Where the confidence in a technique's sensitivity and resulting diagnosis/prognosis accuracy is questionable, then the use of additional techniques for further correlation should be recommended.

This process is essentially a modification of an FMECA process with a focus on the symptoms produced by each identified failure mode and the subsequent selection of the most appropriate detection and monitoring techniques and strategies.

This tool should be used in conjunction with an existing FMECA analysis that has already identified and ranked possible failure modes.

4.3.2 Guide for usage

This process is best represented by Table A.1. The essential items are as follows:

— listing the components involved;

— listing the possible failure modes for each component;

— listing the effects of each failure mode;

— listing the causes of each failure mode;

— listing the symptoms produced by each failure mode;

— ranking each failure mode by detection, severity, diagnosis confidence and prognosis confidence resulting in the Monitoring Priority Number;

— listing the most appropriate monitoring technique;

— listing the estimated frequency of monitoring;

— listing the most appropriate correlation techniques;

— listing the frequency of monitoring for the correlation techniques.

The greatest difficulty arises in establishing the correct terms for failure mode, effect and cause. The failure mode is a definition of how the failure would be observed; i.e. bent, corroded, etc. In the FMECA processes that should have been carried out prior to the FMSA process, there are areas of overlap between the terms used for the failure modes, effects and causes. An item may appear as a "cause of failure" in one line when considering a component and as a "failure mode" in another. A term may also appear as an "effect" in one line when dealing with a component and as a "failure mode" when dealing with an assembly. This is also true for the FMSA process.

Care should be taken to avoid duplication of failure mode and cause on the same line. For any one item, the failure mode, effect and cause should read logically across the page. It can help to use the following format:

— a "failure mode" could result in an "effect" due to a "cause".

When considering monitoring strategies, the following format can also be used:

— a “failure mode” produces “symptoms” which are best detectable by a “primary monitoring technique” resulting in a high diagnosis and prognosis confidence when monitored at a given “monitoring frequency”;

— increased diagnosis and prognosis confidence can be gained by using “correlation techniques” when monitored at a given “monitoring frequency”.

4.3.3 Guide for rating

4.3.3.1 General

A rating is assigned to each column which estimated the probability of detection and prognosis accuracy, and the degree of severity. Provided that a user applies a consistent rating throughout all analyses, the higher risk categories reflect a higher Monitoring Priority Number.

4.3.3.2 Rating detection (DET)

The probability of detection is rated from 1 to 5 and is designed to reflect the overall detectability of a failure mode irrespective of the following accuracy of diagnosis or prognosis. This rating is designed to highlight failure modes that

— produce symptoms that are detectable but unrepeatable,

— produce symptoms that are undetectable,

— produce symptoms that are not measurable in practice, or

— produce symptoms that may be masked by other failure mode symptoms.

This is estimated on a scale of 1 to 5, as follows.

1 means “There is a REMOTE PROBABILITY that this failure mode will be detected.”

2 means “There is a LOW PROBABILITY that this failure mode will be detected.”

3 means “There is a MODERATE PROBABILITY that this failure mode will be detected.”

4 means “There is a HIGH PROBABILITY that this failure mode will be detected.”

5 means “It is CERTAIN that this failure mode will be detected.”

4.3.3.3 Severity of failure (SEV)

This ranking should reflect any previous FMECA analysis and is designed to rank individual failure modes by risk.

This is estimated on a scale of 1 to 4, as follows.

1 means “Any event which could cause degradation of system performance function(s) resulting in negligible damage to either system or its environment; and no damage to life or limb.”

2 means “Any event which degrades system performance function(s) without appreciable damage to either system or life or limb.”

3 means “Any event which could potentially cause the loss of primary system function(s) resulting in significant damage to the said system or its environment and negligible hazard to life or limb.”

4 means “Any event which could potentially cause the loss of primary system function(s) resulting in significant damage to the system or its environment, and or cause the loss of life or limb.”

4.3.3.4 Diagnosis confidence (DGN)

The predicted accuracy of the diagnosis is also rated from 1 to 5. This rating is designed to identify failure modes with

— detectable but unrepeatable symptoms,

— unknown symptoms, or

— symptoms that are not distinguishable from other failure mode symptoms.

This is estimated on a scale of 1 to 5, as follows.

1 means “There is a REMOTE PROBABILITY of this failure mode diagnosis being accurate.”

2 means “There is a LOW PROBABILITY of this failure mode diagnosis being accurate.”

3 means “There is a MODERATE PROBABILITY of this failure mode diagnosis being accurate.”

4 means “There is a HIGH PROBABILITY of this failure mode diagnosis being accurate.”

5 means “It is CERTAIN that this failure mode diagnosis will be accurate.”

4.3.3.5 Prognosis confidence (PGN)

The predicted accuracy of the prognosis is also rated from 1 to 5. This rating is designed to identify failure modes with

— detectable but unrepeatable symptoms,

— symptoms that are not sensitive to changes in degradation,

— unknown failure rates, or

— symptoms that are not distinguishable from other failure mode symptoms.

This is estimated on a scale of 1 to 5, as follows.

1 means “There is a REMOTE PROBABILITY of this failure mode prognosis being accurate.”

2 means “There is a LOW PROBABILITY of this failure mode prognosis being accurate.”

3 means “There is a MODERATE PROBABILITY of this failure mode prognosis being accurate.”

4 means “There is a HIGH PROBABILITY of this failure mode prognosis being accurate.”

5 means “It is CERTAIN that this failure mode prognosis will be accurate.”

The frequency of monitoring also contributes to the determination of the accuracy of expected prognosis i.e. the greater the frequency of monitoring used the higher the confidence in the expected failure rate and prognosis.

4.3.3.6 Monitoring Priority Number (MPN)

This ranking is the multiplication of the four preceding rankings and results in an overall rating of each failure mode.

A high MPN value indicates that the nominated technique is the most suitable for the detection, diagnosis and prognosis of the associated failure mode.