# INTERNATIONAL STANDARD

# ISO 13381-1

Second edition
2015-09-15

# Condition monitoring and diagnostics of machines — Prognostics —

## Part 1: General guidelines

*Surveillance et diagnostic des machines — Pronostic —*

*Partie 1: Lignes directrices générales*



Reference number
ISO 13381-1:2015(E)

# 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 on the meaning of ISO specific terms and expressions related to conformity assessment, as well as information about ISO's adherence to the WTO principles in the Technical Barriers to Trade (TBT) see the following URL: Foreword - Supplementary information



The committee responsible for this document is ISO/TC 108, *Mechanical vibration, shock and condition monitoring*, Subcommittee SC 5, *Condition monitoring and diagnostics of machine systems*.



This second edition cancels and replaces the first edition (ISO 13381-1:2004), which has been technically revised.

ISO 13381 consists of the following parts, under the general title *Condition monitoring and diagnostics of machines — Prognostics*:

— *Part 1: General guidelines*

The following parts are planned:

— *Part 2: Performance based approaches*

— *Part 3: Cyclic-driven life usage techniques*

— *Part 4: Useful-life-remaining prediction models*

 

# Introduction

The complete process of machine condition monitoring consists of five distinct phases:

— detection of problems (deviations from normal conditions);

— diagnosis of the faults and their causes;

— prognosis of future fault progression;

— recommendation of actions;

— post-mortems.

Machine health prognosis demands prediction of future machine integrity and deterioration so there can be no exactitude in the process. Instead, prognosis requires statistical or testimonial approaches to be adopted. Standardization in machine health prognosis therefore embodies guidelines, approaches, and concepts rather than strict procedures or standard methodologies.

Prognosis of future fault progressions requires foreknowledge of the probable failure modes, future duties to which the machine will or might be subjected, and a thorough understanding of the relationships between failure modes and operating conditions. This may require an understanding of the physics underlying the fault modes and demand the collection of previous duty and cumulative duty parameters, previous maintenance history, inspection results, run-to-failure data, trajectories and associated operational data, along with condition and performance parameters prior to extrapolations, projections and forecasts.



Prognosis processes need to be able to accommodate analytical damage models.

As computing power increases, and data storage decreases in cost, multiple-parameter analysis becomes more complex and modelling becomes more sophisticated. Thus, the ability to predict the progression of damage accumulation is achievable if the initiation criterion is known (expressed as a set of parameter values for a given mode) in addition to future behaviour for a given set of conditions.

# Condition monitoring and diagnostics of machines — Prognostics —

## Part 1: General guidelines

## 1 Scope

This part of ISO 13381 provides guidance for the development and application of prognosis processes. It is intended to

— allow developers, providers, users and manufacturers to share common concepts of prognostics,

— enable users to determine the data, characteristics, processes and behaviours necessary for accurate prognosis,

— outline appropriate approaches and processes to prognostics development, and

— introduce prognostics concepts in order to facilitate future systems and training.



Other parts will include the introduction of concepts of the following forms of prognostic approaches: performance changes (trending) approaches (ISO 13381-2), cyclic-driven life usage techniques (ISO 13381-3), and useful-life-remaining models (ISO 13381-4).



## 2 Normative references

The following documents, in whole or in part, are normatively referenced in this document and are indispensable for its application. For dated references, only the edition cited applies. For undated references, the latest edition of the referenced document (including any amendments) applies.

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

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

ISO 13379-1, *Condition monitoring and diagnostics of machines — Data interpretation and diagnostics techniques — Part 1: General guidelines*

ISO 17359, *Condition monitoring and diagnostics of machines — General guidelines*

## 3 Terms and definitions

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

**3.1**
**prognosis**
estimation of time to failure and risk for one or more incipient failure modes

[SOURCE: ISO 13372:2012, 10.2]

**3.2**
**prognostics**
analysis of the symptoms of faults to predict future condition and residual life within design parameters

[SOURCE: ISO 13372:2012, 1.15]

**3.3**
**confidence level**
figure of merit (e.g. percentage) that indicates the degree of certainty that the diagnosis/prognosis is correct

Note 1 to entry: This figure essentially represents the cumulative effect of error sources on the final certainty or confidence in the accuracy of the outcome. Such a figure can be determined algorithmically or via a weighted assessment system.

**3.4**
**root cause**
set of conditions or actions that occur at the beginning of a sequence of events that result in the initiation of a failure mode

[SOURCE: ISO 13372:2012, 8.9]

**3.5**
**failure modes effects analysis**
**FMEA**
structured procedure to determine equipment functions and functional failures, with each failure being assessed as to the cause of the failure and the effects of the failure on the system



Note 1 to entry: The technique may be applied to a new system based on analysis or an existing system based on historical data.

Note 2 to entry: A FMEA procedure is outlined in IEC 60812.[3]



[SOURCE: ISO 13372:2012, 8.2]

**3.6**
**failure modes effects criticality analysis**
**FMECA**
FMEA with a classification process based on the severity of the faults

Note 1 to entry: This is in comparison with the criticality thresholds.

Note 2 to entry: A FMECA procedure is also outlined in IEC 60812.[3]

[SOURCE: ISO 13372:2012, 8.3]

**3.7**
**failure modes symptoms analysis**
**FMSA**
process based on FMECA that documents the symptoms produced by each mode and the most effective detection and monitoring techniques in order to develop and optimize a monitoring programme

Note 1 to entry: This process is outlined in ISO 13379-1.

**3.8**
**estimated time to failure**
**ETTF**
estimation of the period from the current point in time to the point in time where the monitored machine is deemed to be in the failed condition

Note 1 to entry: Defined in Figure 2.

**3.9**
**remaining useful life**
**RUL**
remaining time before system health falls below a defined failure threshold

**3.10**
**predictive horizon**
threshold for prediction of lead time to failure as desired by the user

## 4 Data requirements

**4.1** The general concepts for condition monitoring are outlined in ISO 17359 and form the basis for the prognostic process and its pre-requisites. Prognostics may require the collection of documented data covering

a) the total population of plant, machinery and components under observation along with original equipment specifications,

b) all monitored parameters and descriptors,

c) expert knowledge of baseline, commissioning, historical operation, maintenance, inspection and failure data,

d) current and future operating and maintenance environments, regimes, requirements and schedules,

e) initial diagnosis inclusive of identification of all existing failure modes,

f) failure models including single and multiple failure modes that can include statistics, existing and future failure mode influence factors, initiation criteria, and failure definition set points for all parameters, and descriptors,

g) curve fitting, projection and superimposition techniques,

h) alarm limits,

i) trip (shut-down) limits,

j) performance thresholds relating to system health,

k) failure investigation results,

l) reliability, availability, maintainability, cost and safety data,

m) damage initiation data,

n) damage progression data,

o) manufacturing configuration state (lot number, batch number, etc.), and

p) environmental data that has an impact on component health.

All this information may not be available in some applications and cases.



**4.2** There are specific objectives for the collection of reliability data relating to current condition and field performance of machinery:

— survey the actual reliability and, hence, to enable the predicted reliability characteristics of an item to be made and compared with field data, and damage models and thereby to improve future predictions;

— provide data for improving the reliability of both the current item and future developments;

— provide data for verifying and validating models and algorithms.

**4.3** There are specific objectives for the collection of data relating to current field duties and cumulative duties of machinery:

— survey the relationship between the actual reliability and the work done, hence, to enable the comparison of damage initiation and progression models with field data;

— provide data for improving the damage estimation models of both the current item and future developments;

— provide data for extending the range of applications for damage estimation models.

**4.4** There are specific objectives for the collection of cost data relating to monitoring equipment and usage, production losses, secondary damage losses, maintenance activities and inventories of machinery:

— survey the benefit-to-cost ratios of various alternative maintenance actions;

— improve future maintenance decisions;

— provide data for reducing the operating and maintenance costs of both the current item and future embodiments;

— provide cost data (along with monitored data and performance data, and also field duty data, see 4.3) for the optimal organization and management of any maintenance operation (on-condition maintenance, scheduled preventive maintenance, corrective maintenance, service personnel, spare parts stores, etc.).



# 5 Prognosis concepts

## 5.1 Basic concepts



Prognosis is an estimation of time to failure and the probability of one or more existing and future failure modes. It is based on detailed knowledge and experience of the fault propagation process. The goal of prognostics is to provide the user with the capability to predict remaining useful life (RUL) with a satisfactory level of confidence. This information can be used to drive operators' decisions in order to avert the failure, extend life through appropriate operational changes, or simply to allow time to prepare for the impending failure. The effectiveness of prognosis is determined by the degree to which faults and failure modes have known, age-related, performance-related or progressive deterioration characteristics that are well-understood and supported by models.

A failure has to be defined in terms of the monitored parameters and descriptors. Monitoring data on its own is insufficient to produce a prognosis.

The general conceptual basics of a prognosis process are

a) define the end point,

b) determine or estimate the parameter or descriptor behaviours and the expected rate of deterioration,

c) estimate current state of deterioration,

d) estimate the expected remaining life or expected time to failure,

e) define level of confidence, and

f) establish the desired prognostic event horizon.

It is important to understand that diagnostics is retrospective in nature in that it focuses on existing data at a given point in time.

Prognostics, however, focuses on the future and so must consider

- — existing single and multiple failure modes and deterioration rates,
- — the initiation criteria for future failure modes,
- — the role of existing failure modes in the initiation of future failure modes,
- — the influence between existing and future failure modes and their deterioration rates,
- — the sensitivity to detection and change of existing and future failure modes by the current monitoring techniques,
- — the design and variation of monitoring strategies to suit all of the above,
- — the effect of maintenance actions and/or operating conditions, and
- — the conditions or assumptions under which prognoses remains valid.

The sub-domains of interest are: performance degradation, cyclic usage and RUL prediction models.

Figure 1 a) shows the general relationship concepts between prognostics and diagnostics across the failure progression timeline. Figure 1 b) shows another perspective of the relationship between diagnostic and prognostic processes.

## 5.2 Influence factors



Influence factors are parameters that affect the deterioration rate of a failure mode; for example, temperature, viscosity, clearance, load, speed, operating conditions, etc. Each influence factor can be considered a contributing driver of an existing failure mode. Influence factors also affect the progression and initiation of other existing or future faults.

One example, as shown in Figure 2, is when the initial parameter of vibration, caused by a fault in a lubricating oil pump bearing (primary failure mode), influences the initiation of a seal failure (secondary failure mode), which has a faster deterioration rate than the bearing. As this seal fails, the leakage of oil creates a loss of oil delivery pressure, which influences the initiation of an impeller failure in the pump (tertiary failure mode), which has a slower deterioration rate.