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Condition monitoring and diagnostics of machines — Prognostics —

Part 1:
General guidelines

Surveillance et diagnostic des machines — Pronostic —

Partie 1: Lignes directrices générales

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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 13381-1 was prepared by Technical Committee ISO/TC 108, *Mechanical vibration and shock*, Subcommittee SC 5, *Condition monitoring and diagnostics of machines*.

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

— *Part 1: General guidelines*

Future parts are under preparation and are intended to outline modelling methods and techniques applicable to prognostics.

Introduction

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

- detection of problems (deviations from normal conditions);
- diagnosis of the faults and their causes;
- prognosis of future fault progression;
- recommendation of actions;
- post-mortems.

As far as the prognosis of machine health is concerned (which demands prophecies of future machine integrity and deterioration), there can be no exactitude in the process requiring statistical or testimonial approaches to be adopted. Standardization in prognosis of machine health therefore embodies guidelines, approaches and concepts rather than procedures or standard methodologies.

Prognosis of future fault progressions requires foreknowledge of the probable failure modes, future duties to which the machine will/might be subjected, and a thorough understanding of the relationships between failure modes and operating conditions. This can demand the collection of previous duty and cumulative duty parameters, along with condition and performance parameters, prior to extrapolations, projections and forecasts.

Also, there are a growing number of models for damage initiation and damage progression. Prognosis processes need to accommodate these and future analytical damage models.

As computing power increases and multiple parameter analysis becomes a reality, the ability to predict the initiation of a failure mode is not inconceivable if the initiation criteria, expressed as a set of parameter values for a given mode, are known as well as their future behaviour for a given set of conditions.

Condition monitoring and diagnostics of machines — Prognostics —

Part 1:
General guidelines

1 Scope

This International Standard provides guidance for the development of prognosis processes. It is intended

- to allow the users and manufacturers of condition monitoring and diagnostics systems to share common concepts in the fields of machinery fault prognosis,
- to enable users to determine the necessary data, characteristics and behaviour necessary for accurate prognosis,
- to outline an appropriate approach to prognosis development, and
- to introduce prognoses concepts in order to facilitate the development of future systems and training.

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

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 the following apply.

3.1
prognosis
estimation of time to failure and risk for one or more existing and future failure modes

3.2
confidence level
figure of merit that indicates the degree of certainty that the diagnosis/prognosis is correct

NOTE 1 It is expressed as a percentage.

NOTE 2 This value is essentially a figure representing 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.

3.3
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

3.4
failure modes effects analysis
FMEA
pre-production design and development process to help determine the ways that a machine could fail, and to assess the associated effects of such failure

NOTE The FMEA procedure is outlined in BS 5760-5.

3.5
failure modes effects criticality analysis
FMECA
process that adds an economic, financial and/or safety component to FMEA to assist in maintenance management decisions

NOTE The FMECA procedure is outlined in IEC 60812.

3.6
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 This process is outlined in ISO 13379.

3.7
estimated time to failure
ETTF
estimation of the period from the current point in time to the point in time when the monitored machine is deemed to be in the failed condition

4 Pre-requisite data required

For the general concepts for condition monitoring, see ISO 17359. These form the basis for the prognosis process and its pre-requisites. Prognosis requires collection of documented data covering the following:

a) the total population of plant, machinery and components under observation;

b) all monitored parameters and descriptors;

c) historical operation data, and maintenance and failure data;

d) future operating and maintenance environments, requirements and schedules;

e) initial diagnosis, including identification of all existing failure modes;

f) failure modelling processes 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) results of failure investigation;

k) reliability, availability, maintainability and safety data;

l) damage initiation data;

m) damage progression data.

The specific objectives of the collection of reliability data relating to current condition and field performance of machinery are

— to provide for a survey of 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, and

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

The specific objectives of the collection of data relating to current field duties and cumulative duties of machinery are

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

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

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

The specific objectives of the collection of cost data relating to monitoring equipment and usage, production losses, secondary damage losses, maintenance activities and stores inventories of machinery are

— to provide for a survey of the benefit-to-cost ratios of various alternative maintenance actions,

— to improve future maintenance decisions,

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

— to provide cost data (along with monitored data and performance data, and also with field duty data) 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 risk for one or more existing and future failure modes, and is normally intuitive and based on experience. Prognosis is usually effective for faults and failure modes with known, age-related, or progressive deterioration characteristics, the simplist of which is linear. Prognostics are most difficult for random failure modes.

A failure is defined in terms of the monitored parameters/descriptors. Monitoring data on their own is insufficient to produce a prognosis. The general conceptual basics of a prognosis process are

a) to define the end point (usually the trip set point),

b) to establish current severity,

c) to determine/estimate the parameter behaviour and the expected rate of deterioration, and

d) to determine the estimated time to failure (ETTF).

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

However, prognostics is focussed on the future and, therefore, the following need to be considered:

— existing 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 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; the conditions or assumptions under which prognoses remains valid.

The general relationship concepts may be graphically represented using causal tree modelling as shown in Figure 1 (FM stands for failure mode).

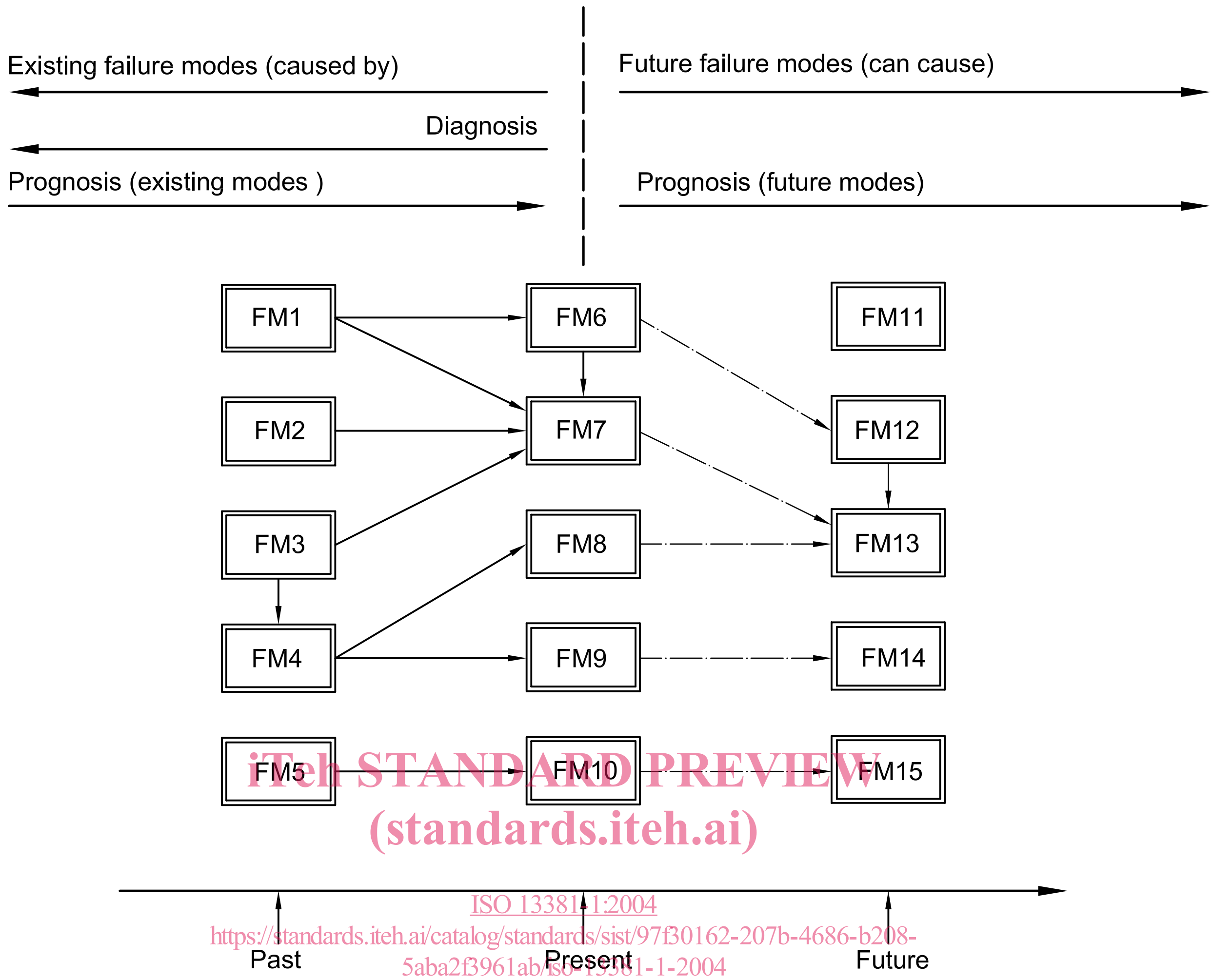

Figure 1 — Causal tree relationships

5.2 Influence factors

Influence factors are parameters that effect the deterioration rate of a failure mode, such as temperature, viscosity, clearance, load and speed. Each influence factor may be considered to be a symptom of an existing failure mode and is represented in Figure 1 by the solid lines that connect existing failure mode trends. Influence factors also have effects on the progression and initiation of other either existing or future faults (see Figure 2).

An example of a situation as described by Figure 2 is where the initial parameter of vibration, due to 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 progresses to failure, the leakage results in 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.