BRITISH STANDARD

BS ISO 16587:2004

Mechanical vibration and shock — Performance parameters for condition monitoring of structures

ICS 17.160; 91.120.25

British Standards

National foreword

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The UK participation in its preparation was entrusted by Technical Committee GME/21, Mechanical vibration and shock, to Subcommittee GME/21/3, Measurement and evaluation of mechanical vibration and shock, which has the responsibility to:

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— present to the responsible international/European committee any enquiries on the interpretation, or proposals for change, and keep the UK interests informed;

— monitor related international and European developments and promulgate them in the UK.

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Summary of pages

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INTERNATIONAL STANDARD

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Mechanical vibration and shock — Performance parameters for condition monitoring of structures

Vibrations et chocs mécaniques — Paramètres de performance pour la surveillance des structures

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Foreword

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ISO 16587 was prepared by Technical Committee ISO/TC 108, *Mechanical vibration and shock*.

Introduction

This International Standard provides general guidelines for the condition monitoring of structures, using parameters typically used to measure or monitor structure performance, such as displacement, strain, vibration, settlement, rotation, temperature, and foundation pore pressure.

It has been structured to be consistent with ISO 13380 and ISO 17359 in order to facilitate a consistent approach to the condition monitoring of systems.

The information provided in this International Standard will be supplemented by ISO 18431 which will be published in several parts.

Mechanical vibration and shock — Performance parameters for condition monitoring of structures

1 Scope

This International Standard describes the performance parameters for assessing the condition of structures, including types of measurement, factors for setting acceptable performance limits, data acquisition parameters for constructing uniform databases, and internationally accepted measurement guidance (e.g. terminology, transducer calibration, transducer mounting and approved transfer function techniques).

The procedures relate to in-service monitoring of structures, and include all components and sub-assemblies necessary to provide the functioning of the structure as a complete entity. The monitoring is intended to be ongoing in nature through the lifecycle of the structure.

NOTE 1 Figure 1 is a flowchart showing how this International Standard takes the user from the initial client need for condition monitoring of structures through to the point where the corresponding performance parameters have been chosen. Subsequent standards will deal with how these parameters are measured and processed.

This International Standard presupposes that a “high level” need for condition monitoring of structures already exists.

NOTE 2 Some useful guidance on identifying this need, by the use of asset identification and reliability/criticality audits, is contained in ISO 17359.

The target industries for this International Standard include

— construction,

— infrastructure,

— transportation,

— power generation,

— oil and gas, and

— leisure and entertainment.

This International Standard is applicable to stationary structures, such as

— buildings,

— bridges and tunnels,

— towers, masts and antennae,

— tanks and silos,

— retaining walls and dams,

— jetties and other shore-side structures,

— offshore platforms,

— pressure vessels, and

— pipelines.

Non-stationary structures (e.g. self-propelled ships) and mobile structures (e.g. offshore jack-up platforms) are excluded from this International Standard.

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 2041:1990, *Vibration and shock — Vocabulary*

3 Terms and definitions

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

3.1
defect
structural defect
event occurring when the condition of any of the components of a structure or their assembly is degraded or exhibits abnormal behaviour

NOTE This may lead to failure of the structure.

3.2
failure
structural failure
termination of the ability of a structure to perform its required function

NOTE This generally happens when one or more of the components of a structure are in a defective condition, either at a service or ultimate limit state. Also, failure is an event as distinguished from fault, which is a state.

3.3
performance parameter
structural performance parameter
one or more characteristic quantities such as displacement, strain, velocity, settlement, rotation and acceleration

NOTE Performance is derived by measurement and calculation of one or more parameters, which singly or together provide information on the characteristic quantity. Performance may be described in terms of static, quasi-static or dynamic parameters, depending on the type of loading being experienced.

3.4
baseline values
parameters or derived quantities, determined under specific loading configurations and specified environmental conditions, which may be stored or kept as reference values or characteristic profiles

NOTE Baseline values are normally strongly dependent on temperature.

3.5
structure
stationary structure
stationary engineering artefact

EXAMPLES

— land-based structure, such as a building or bridge;

— coastal structure, such as a jetty;

— offshore structure, such as a fixed oil production platform and pipelines.

3.6
limit state
boundary of a domain within which the structure is assumed to satisfy the design criteria

NOTE Limit states are classified into ultimate limit states and service limit states.

3.7
ultimate limit state
state associated with collapse or with other forms of structural failure, which may endanger structural safety

NOTE The passage of an ultimate limit state is considered to cause failure.

3.8
service limit state
state associated with specified service criteria for normal use

NOTE In the case of permanent damage or permanent unacceptable deformations, the first passage of a service limit state is irreversible and is considered to cause failure. In other cases (such as temporary damage, temporary deformations or vibrations), the passage of a service limit state may be reversible and then a passage of a limit state does not always cause failure.

4 Monitored parameters and limits

4.1 Type of performance parameter

A large range of performance parameters may 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 defect condition either by an increase or decrease in overall measured value, or by some other change to a characteristic value. The parameters may be either quasi-static (varying with time relatively slowly) or dynamic (varying with time relatively rapidly) in nature. The parameters may be identified with the assistance of reliability/criticality audits. Examples include displacement, strain, vibration, temperature, and stress waves.

Condition monitoring of structures will usually be carried out at the serviceability limit state. Any extrapolation to ultimate limit state performance requires careful consideration.

4.2 Type of measurement and diagnosis

Examples of performance parameters, and measurement transducers and systems, useful to consider for a number of structure types are given in Annex A. Measurement transducers and systems shall be appropriately calibrated (for example in accordance with the relevant part of ISO 5347 or ISO 16063), mounted (for example in accordance with ISO 5348) and experimentally determined (for example in accordance with ISO 7626). When monitoring structures, features must be extracted from the measured performance parameters. These may be overall values, or values averaged over time in simple cases. In most cases, these simple features or descriptors are not useful as symptoms for the occurrence of defects. Signal-processing techniques may be required to reveal changes caused by emerging defects. These data-processing techniques, which are diagnostic in nature, include narrow-band vibration analysis, transfer-function analysis (e.g. mechanical mobility), broad-band vibration analysis, structural-damping analysis (both time domain and spatial domain), mechanical power-flow, complex wave number analysis, etc.

Condition monitoring systems can take many forms. They can utilize permanently installed, semi-permanent or portable measuring instrumentation, or can involve methods for remote or local analysis.

4.3 Measurement uncertainty of monitored parameters

The measurement uncertainty (accuracy) required of monitored parameters to be used for structure condition monitoring and diagnosis is not so absolute as the accuracy that may be required for performance measurement. Methods utilizing trending of values can be effective when 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 routine condition monitoring. Where this is required, advice is given in the appropriate acceptance testing standard. It should be noted, however, that some parameters can be strongly dependent on temperature.

4.4 Sources of error and uncertainty

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

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

Examples of error and uncertainty include calibration uncertainties, uncertainty induced by transducer mounting, instrumentation measurement uncertainty, and uncertainty in calibration from environmental effects on measurement systems. Such errors and uncertainties can be minimized by the proper application of standards such as ISO 5347, ISO 5348, ISO 7626 and ISO 16063.

4.5 Factors affecting the setting of limits

As may be seen from Figure 1, the acceptable limits should be chosen by suitably experienced personnel, based on the following:

- design, construction, operation and maintenance codes, standards and criteria;
- type and magnitude of loading;
- service limit state and ultimate limit state characteristics;
- anticipated structural failure modes, either based on experience or on finite element models.

Many of the chosen limits may be preliminary, and may have to be improved iteratively after a period of monitoring (“trial and error”).

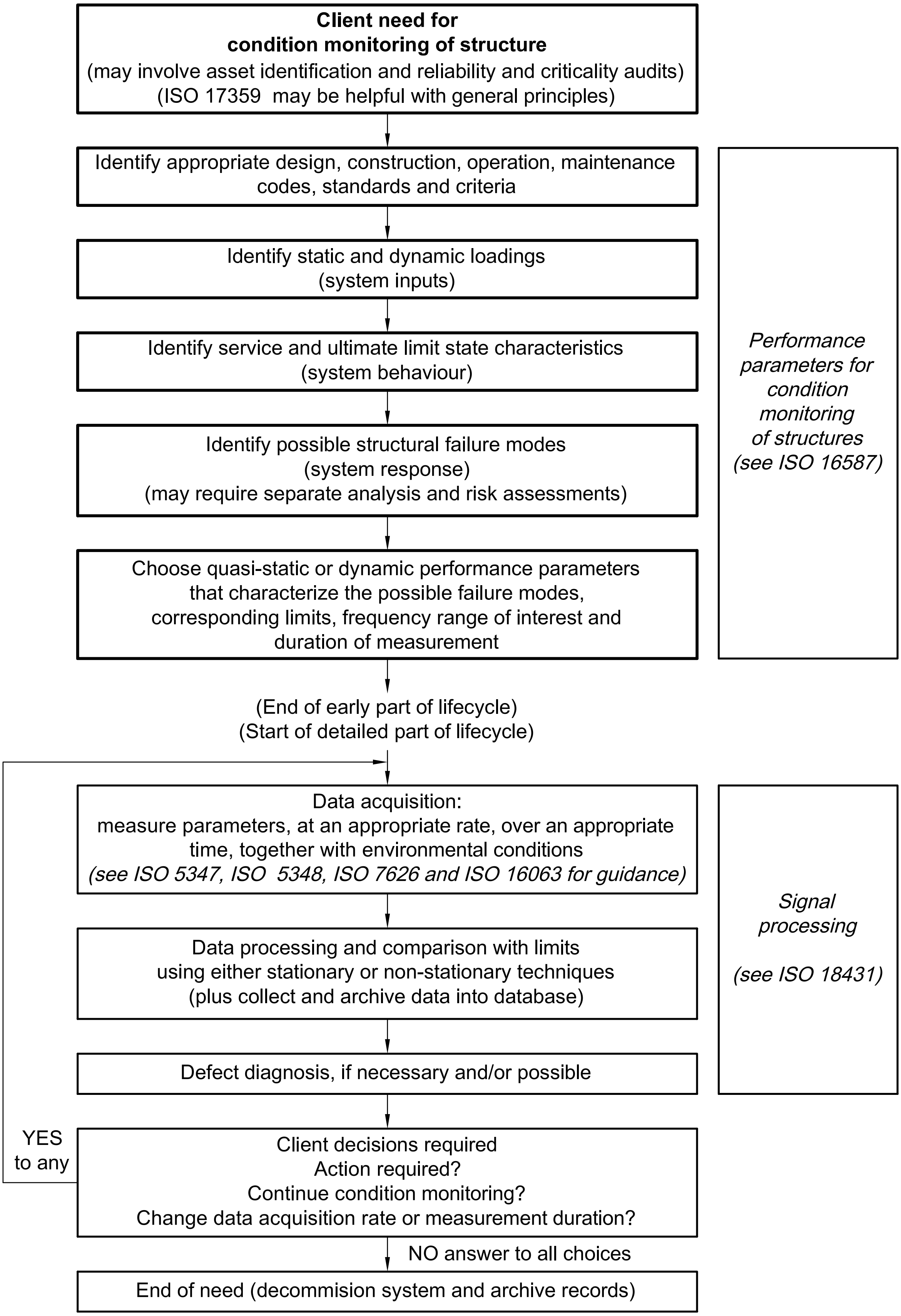

Figure 1 — Flowchart illustrating an idealized condition-monitoring lifecycle

5 Measurement procedure and data processing

5.1 Measurement techniques

For the particular measurable parameter considered applicable, one or more measurement techniques may be appropriate. The particular technique chosen should then be assessed as to the practicalities of implementation, and the type of condition monitoring system required. Where appropriate, measurement techniques specified in currently approved International Standards should be followed (for example, the ISO 7626 series outline the appropriate techniques for conducting mechanical mobility measurements).

5.2 Feasibility of measurement

Consideration should be given to the feasibility of acquiring the measurements, including ease of access, complexity of required data acquisition system, level of required data processing, safety requirements, cost, and whether surveillance or control systems exist which are already measuring parameters of interest.

5.3 Environmental conditions during measurements

Measurements of different parameters should be taken wherever possible at the same time, or under the same environmental conditions. For variable loadings (duty), it may be possible to achieve similar measurement conditions by varying the extent, speed and/or density of the loading. Loads due to environmental conditions, such as wind, wave, temperature and humidity, should be considered.

Monitoring should be taken, where possible, when the structure has reached a predetermined set of environmental conditions, such as seasonal midday temperature (which will vary from summer to winter), prescribed water height (such as high tide), and ground conditions (e.g. prescribed water table level). These are also conditions that may be used to establish baselines for a specific structure configuration. Many engineering structures and their baseline parameters show a very strong dependency on temperature, hence measurements should either be taken under the same temperature conditions or the dependency of the baseline parameters on temperature should be known. Subsequent measurements should be compared to the baseline values to detect changes. The trending of measurements is useful in highlighting the development of defects.

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, and should also cover the frequency range of interest. During transients, high-speed data acquisition may be necessary. Consideration should also be given to the duration of the measurement, the interval between measurements, and whether periodic or continuous sampling is required. A preliminary estimate should be made, based on an analysis of how the structure is likely to perform, and the type of defects and their rate of propagation. Subsequently, the duration may need to be revised as the monitoring proceeds, if the structural performance differs significantly from that anticipated.

5.5 Record of monitored parameters

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

— essential data describing the structure;

— measurement position;

— measured quantity units and processing;

— information on date and time;

— details of the environmental conditions at the time of measurement.

Other information useful to permit comparison includes details of the measuring systems used and the measurement uncertainty. It is recommended that details of structure configuration and any component changes also be included.

5.6 Measurement locations

Measurement locations should be chosen to give the best possibility to locate defects. A good way to determine these locations is by using a numerical model. Measurement points should be identified uniquely. The use of a permanent label, or identification mark, is recommended.

Factors to take into consideration are

- safety,
- high sensitivity to change in the defect condition,
- reduced sensitivity to other influences,
- repeatability of measurement,
- attenuation or loss of signal,
- accessibility,
- environment, and
- cost.

Where appropriate, analytical methods (e.g. finite element modelling, statistical energy analysis modelling, and boundary-element modelling) for the dynamic analysis of structural systems should be used to identify critical high-stress locations in the structure that should be periodically monitored for early warning.

6 Defect diagnosis

6.1 Procedure for defect diagnosis

The possibility of carrying out defect diagnosis will depend on the structure type, configuration and environmental conditions. A defect may be indicated by a change in one or more of the baseline values which is statistically significant.

6.2 Criteria for defect diagnosis

The following methods may be used to perform defect diagnosis:

- experience with similar structures;
- realistic statistical and/or other numerical models;
- studies of deviations from required minimum or maximum values;
- discussions between the builder (constructor) and the owner (operator).

NOTE When circumstances permit, examples of structure type and defects shown by performance parameter monitoring may be included in this International Standard. Until such time, defect parameter identification is found using experience, numerical modelling or results.

Annex A
(informative)

Examples of performance parameters and measurement transducers and systems

Performance parameter	Suitable structures	Suitable load conditions	Instrumentation systems	Type of equipment	Remarks
Displacement	No restriction	Static Dynamic	Linear voltage displacement transducer (LVDT)	Electrical	Rigid mounting required
Displacement	No restriction	Static Dynamic	Deflection pole	Electrical	Quick to set up, very efficient data recording
Displacement	No restriction	Static	Dial gauge	Mechanical	Manual reading and rigid mounting required
Displacement related	No restriction	Static Dynamic	Laser theodolite systems	Laser	Good for two dimensional displacement
Strain	No restriction	Static	Vibrating wire strain gauge	Acoustic	Easy to glue, accurate, can be temperature sensitive
Strain	Metal Concrete Composites	Static Dynamic	Electrical resistance (ER) strain gauge	Electrical	Accurate and reliable but costly; requires special skills
Strain	Masonry Metal Timber	Static Dynamic	Demountable ER strain gauge	Electrical	Accurate and reliable but not widely used
Strain	Metal	Static Dynamic	Mobile strain transducer	Electrical	Used with deflection pole system
Strain	No restriction	Static	Demec gauge	Mechanical	Easy to use but error can be significant
Vibration (displacement, velocity or acceleration)	No restriction	Dynamic	Accelerometers (and velocity transducers)	Electrical	Accurate if used correctly in conjunction with the frequency response curve of the transducer
Temperature	No restriction	Static Dynamic	Thermocouples and thermography	Electrical	Easy to make and use on site
Rotation	No restriction	Static Dynamic	Tiltmeters and slope indicators	Electrical	Accurate if used correctly
Various	Selected structures and foundations	Static Dynamic	Fibre optic, GPS and/or pore pressure systems	Various	Emerging techniques
Stress wave (acoustic emission)	Metal Composites	Static Dynamic	Acoustic emission monitoring	Electrical	Requires special skills

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