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## Condition monitoring and diagnostics of machines — Acoustic emission

*Surveillance et diagnostic d'état des machines — Émission acoustique*



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## Foreword

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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 22096 was prepared by Technical Committee ISO/TC 108, *Mechanical vibration, shock and condition monitoring*, Subcommittee SC 5, *Condition monitoring and diagnostics of machines*.

## Introduction

Acoustic emission (AE) technology can be used as a stand-alone condition monitoring technique that may also be employed to complement other condition monitoring techniques based on other technologies (e.g. vibration, infrared, etc.) used for machine condition analysis and diagnosis/prognosis. Due to the nature of AE, an understanding of the operating mechanics of the monitored machine is not essential, but such an understanding allows the maximum amount of data to be extracted from the results of the AE phenomena. As a diagnostic tool for machine condition monitoring, AE can be employed as a permanently installed, semi-permanent or portable system, depending on the criticality of the machine. Typically, an AE system would contain transducers, amplifiers, filters and data acquisition systems. Depending on the particular application, a range of AE characteristics can be extracted from the captured AE to provide indicators for machine condition monitoring.



 

# Condition monitoring and diagnostics of machines — Acoustic emission

## 1 Scope

This International Standard specifies the general principles required for the application of acoustic emission (AE) to condition monitoring and diagnostics of machinery operating under a range of conditions and environments. It is applicable to all machinery and associated components and covers structure-borne measurements only.

## 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 12718, *Non-destructive testing — Eddy current testing — Vocabulary*

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



ISO 18436-6, *Condition monitoring and diagnostics of machines — Requirements for training and certification of personnel — Part 6: Acoustic emission*

## 3 Terms and definitions

For the purposes of this document, the terms and definitions given in ISO 2041, ISO 12718, ISO 13372 and the following apply.

**3.1**
**acoustic emission**
⟨machine monitoring⟩ range of phenomena that results in the generation of structure-borne and fluid-borne (liquid, gas) propagating waves due to the rapid release of energy from localized sources within and/or on the surface of a material

NOTE 1 Such a release may be a result of a process such as crack propagation, friction, impact, and leakage.

NOTE 2 The definition of acoustic emission in this document conveys its broad application in machine monitoring.

**3.2**
**acoustic emission monitoring**
⟨machine monitoring⟩ detection and collection of information and acoustic emission data that indicate the state of a machine

NOTE The definition of acoustic emission monitoring in this document relates to the application in machine monitoring.

**3.3**
**acoustic emission sensor/receiver**
device containing a transducing element that converts elastic wave motion into an electrical signal

**3.4**
**acoustic emission signal**
electrical signal from an acoustic emission sensor resulting from acoustic emission

**3.5**
**acoustic emission characteristics**
set of specific characteristics describing acoustic emission associated with a machine or an acoustic emission source

NOTE The signature can be of a burst type, i.e. emission events which can be separated in time; or a continuous type, i.e. emissions which cannot be separated in time.

**3.6**
**acoustic emission waveguide**
device which allows the transfer of elastic waves from the machine to an acoustic emission sensor

**3.7**
**background noise**
false signals produced by causes other than acoustic emission, or by acoustic emission sources that are not relevant to the machine component being monitored

NOTE This can include signals of electrical, thermal and mechanical origins.



**3.8**
**couplant**
coupling media between an AE sensor and the object from which measurement is to be acquired



EXAMPLES Oil, grease, adhesive bond, water-soluble paste, wax.

**3.9**
**Hsu-Nielsen source**
pencil lead break device to simulate an acoustic emission event using the fracture of a brittle graphite lead in a suitable fitting

NOTE Changes in signal can be due to variations in the lead. Typically, lead 2H of diameter 0,5 mm (alternatively 0,3 mm) and length (3,0 ± 0,5) mm is used.

**3.10**
**machine**
mechanical system designed expressly to perform a specific task, such as the forming of material or the transference and transformation of motion, force or energy

NOTE This is also sometimes referred to as equipment.

**3.11**
**machine system**
machine train (deprecated)
mechanical system in which the principal subsystem is a specific machine (3.10) and whose other subsystems are components and auxiliaries whose individual functions are integrated to support the actions and work of the machine

 

# 4 Principle of the acoustic emission technology

## 4.1 Acoustic emission (AE) phenomenon

Acoustic emission is a physical phenomenon occurring within and/or on the surface of materials. The term "acoustic emission" is used to describe the spontaneous elastic energy released by a process in the form of transient elastic waves. Acoustic emissions generated within a material manifest as elastic waves on the surface of the material and cover a broad frequency range. Typically, the frequency content of detected acoustic emission signals falls within the range of 20 kHz to 1 MHz.

The waves associated with AE are detected by the use of a suitable sensor that converts the surface displacement of the material into an electrical signal. These electrical signals are processed by appropriate instrumentation and/or data processing techniques to characterize the system condition and to aid in detection of the early stages of loss of mechanical and structural integrity. The signal waveform from the sensor is affected by multiple path propagation and several wave modes that are generated in and/or on the material. As such, the sensor response for identical input sources that propagate through varying transmissions paths will be different.

## 4.2 Advantages and limitations of acoustic emission

AE offers the following advantages:

a) it is non-invasive;

b) it provides real-time process information;



c) due to its higher sensitivity, it may offer earlier fault detection than vibration analysis;

d) it offers monitoring of dynamic performance;



e) it may be applied to a wide range of rotational speeds with significant advantages at slow rotational speeds [of the order of less than 1 Hz (60 r/min)];

f) it allows for detection of the friction/wear process, for instance, rubbing between loose mating components or deterioration in lubricating condition.

Limitations of AE include

— susceptibility to attenuation,

— susceptibility to high operational background noise, and

— the inability to relate the resultant defect AE characteristics to the exact fault mechanism.

# 5 Applications of the acoustic emission technique

## 5.1 Machinery monitored by acoustic emission

Acoustic emission technology may be applied to a wide range of machinery, provided a transmission path from the position of the sensor to the region of interest exists. This is particularly important for structure-borne AE monitoring; some examples are detailed in Table 1. The method does not rely on absolute quantities of measured AE parameters but on trends of AE parameters that are measured during a specified operational condition. For instance, an increasing trend in the detected AE signal level under steady operating conditions is indicative of machine deterioration; AE signal amplitude modulated at a bearing defect frequency is indicative of early stages of bearing element defect, which may not be detectable with vibration or shock pulse monitoring. It should be noted that AE activity will vary for differing machines, operating conditions and machine loading.

**Table 1 — Examples of applications of AE to machine condition monitoring**

| Machine type | Fault | | | | | | |
|---|---|---|---|---|---|---|---|
| | **Bearing deterioration** | **Mechanical seal rubbing** | **Wear** | **Lubricant contamination and loss of lubricant** | **Severe misalignment** | **Mounting faults** | **Process monitoring, including leakage, performance, etc.** |
| Pump | • | • | • | • | • | • | • |
| Gear box | • | | • | • | • | • | • |
| Electric motor | • | | | • | • | • | |
| Steam turbine | • | • | | • | • | • | • |
| Industrial gas turbine | • | • | | • | • | • | • |
| Electric generator | • | | | • | • | • | |
| Diesel engine | | | • | | | | • |
| Machining processes | • | | • | • | | | |
| Fan or blower | • | | | • | • | | • |
| Slow-speed rotating machine (typically < 60 r/min) | • | | | • | • | • | • |
| Machine components, e.g. valves, heat exchangers | | | • | • | | • | • |
| Compressors (air, gas, etc.) | • | • | • | • | • | • | • |



## 5.2 Interference factors

Prior to performing an AE measurement, it is very important to be aware of potential noise sources, such as electronic noise (electromagnetic and radio frequency interference), airborne noise (such as gas leaks or the impact of sand particles on the machine in windy environments), operational background noise (flow of fluids in pipes) and mechanical background noise, whose presence might affect the AE measurement.

# 6 Data acquisition

## 6.1 Installing a system

A schematic diagram of a typical structure-borne AE data acquisition system is illustrated in Figure 1. Typically the sensor is coupled to the machine under observation. This in turn is usually connected to a pre-amplifier, which is connected to an acquisition system. Some AE sensors have built-in pre-amplifiers. The data shall be acquired while the machine is operational and the amount of data acquired and extent of analysis depends upon the particular application. The system can be permanent, semi-permanent or portable.

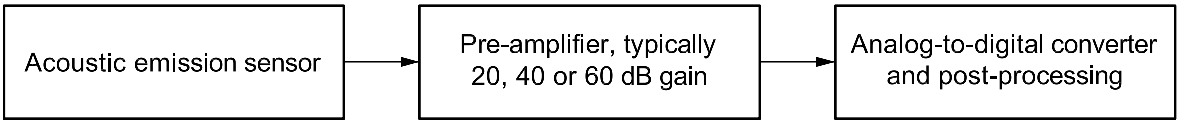


**Figure 1 – Schematic diagram of an acquisition system**

## 6.2 AE instrumentation and sensors

Detection is the most important part of an AE chain and every attempt should be undertaken to overcome poor installation and acoustical coupling. Furthermore, the effects of incorrect frequency selection for filters, sensors, acquisition rates, etc, should be considered. Instruments and sensors may be characterized and calibrated to EN 13477-1, EN 13477-2, ASTM E 1106-86 and ASTM E976-05. In addition, sensor parameters that shall be considered include size, sensitivity, frequency response and environment. In circumstances where appropriate, for instance large circular bearings, an array of transducers may be necessary for source location. Location could be achieved by a number of methods; AE wave arrival time is one such method.



## 6.3 Sensor installation and coupling media for structure-borne monitoring

For structure-borne monitoring, the purpose of the mounting arrangement is to ensure the sensor is fixed onto a structure with an adequate coupling media (couplant). Mounting methods will be either a mechanical arrangement (compression force applied with a magnet, mechanical clamp, etc.) or the use of an adhesive. In the latter instance, the adhesive also serves as the couplant.

The location of the AE sensor should ensure a transmission path to the machine component under observation. This path can include surface discontinuities (a discontinuity is defined as an interface, for instance, the interface between a bolt head and the clamped component). However, these surfaces should be in contact either directly or across a couplant (e.g. a transmission path across a plain journal bearing where the lubricating and cooling oil serves as the couplant for transmission). In addition, the surface onto which the sensor is placed shall be clean. The signal transmission path can be improved by removing any surface paint to expose the metal substrate; however removal of any coat should not degrade the machine integrity or performance. Every attempt shall be made to ensure that the face of the sensor is fixed flat onto the surface, avoiding surface curvature, contaminating particles or surface discontinuities. The primary purpose of this procedure is to improve transmission paths and to ensure repeatability.

Under certain conditions, the AE sensor may be installed on a waveguide. Usually the waveguide is constructed to ensure a more direct transmission path between the sensor and machine component under observation and/or to effect a reduction in the temperature experienced by the AE sensor. The waveguide can affect the acquired AE wave, for instance, attenuation, waveform shape, etc.

The couplant may be applied by placing a small amount in the centre of the intended position of the sensor, which is then carefully pressed onto the surface, spreading the couplant uniformly. The thickness of the couplant can alter the sensitivity of the sensor.

In conditions where the use of a couplant is impractical, a dry contact may be used. In this case, the necessary contact pressure shall be determined experimentally, for instance, with the Hsu-Nielsen source.