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Mechanical vibration — Measurement of vibration on ships —

Part 3: Pre-installation vibration measurement of shipboard equipment

Vibrations mécaniques — Mesurage des vibrations à bord des navires —
Partie 3: Mesurage des vibrations des équipements de bord avant leur installation

Reference number
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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 20283-3 was prepared by Technical Committee ISO/TC 108, *Mechanical vibration and shock*, Subcommittee SC 2, *Measurement and evaluation of mechanical vibration and shock as applied to machines, vehicles and structures*.

ISO 20283 consists of the following parts, under the general title *Mechanical vibration — Measurement of vibration on ships*:

— *Part 3: Pre-installation vibration measurement of shipboard equipment*

The following parts are under preparation:

— *Part 2: Measurement of structural vibration on ships*

General guidelines and measurement and evaluation of ship propulsion machinery vibration are to form the subjects of future parts 1 and 4.

Introduction

Operating machinery and equipment aboard ships can create vibration and excessive structure-borne sound. As a result, the limits for sound pressure levels specified by contracting partners for spaces occupied by crew and passengers may be exceeded. Where it is anticipated that structure-borne sound from machinery can adversely affect occupied spaces, this part of ISO 20283 can be applied with the aim of selecting low-vibration machinery.

Measurement of the vibration of individual equipment units, conducted according to standardized procedures and compared with contractually agreed-on acceptance criteria, will provide the requisite information to the shipbuilder for the proper selection and installation of the equipment.

Mechanical vibration — Measurement of vibration on ships —

Part 3:
Pre-installation vibration measurement of shipboard equipment

1 Scope

This part of ISO 20283 gives guidelines, requirements and procedures for the measurement of vibration generated by types of shipboard equipment, and which can be transmitted into a ship structure as structure-borne sound, as part of the factory acceptance test (FAT) of the equipment unit. It specifies the measurements to be conducted for well-defined operating and mounting conditions of the unit, e.g. in the supplier's test rig.

This part of ISO 20283 is a framework for providing representative test results. It is applicable to shipboard equipment intended for passenger ships, merchant ships, yachts and high-speed craft.

This part of ISO 20283 is concerned with translational vibration, since rotational vibration is not considered to be a substantial contributor to structure-borne sound. However, it does not provide numerical limits for equipment vibration or transmitted structure-borne sound.

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 31-7, *Quantities and units — Part 7: Acoustics*

ISO 1683, *Acoustics — Preferred reference quantities for acoustic levels*

ISO 2041, *Vibration and shock — Vocabulary*

ISO 5348, *Mechanical vibration and shock — Mechanical mounting of accelerometers*

ISO/TR 13298, *Ships and marine technology — Vocabulary of general terms*

3 Terms and definitions

For the purposes of this document, the terms and definitions given in ISO 31-7, ISO 2041, ISO/TR 13298 and the following apply.

3.1
equipment
any machine, system, subsystem or part thereof which causes vibration and is intended to be installed aboard ships

EXAMPLE 1 Main propulsion plant: diesel engine, gas turbine, main reduction gear, electric propulsion motor.

EXAMPLE 2 Mechanical ventilation as well as heating, ventilation and air-conditioning (HVAC) system: air supply and exhaust fans, air-conditioning units, air-conditioning water cooling units, fresh water pumps, etc.

EXAMPLE 3 Auxiliary equipment: diesel engine or gas turbine driven generators, hydraulic plants, electric motors, etc.

NOTE Excluded are pumps directly fitted to reduction gears, diesel engines, etc., fans directly fitted to electric propulsion motors, generators, electric motors, etc., and any other auxiliary equipment attached to larger units that are subject to the pre-testing procedure.

3.2
resilient mount
device with elastic properties used to reduce transmission of structure-borne vibration

NOTE This is typically a shaped block of rubber or similar elastic material used at discrete locations at the component attachment point(s) for the purpose of supporting the component and providing vibration isolation between the component and the support foundation or structure. Use of these devices approximates a **practically free condition** (3.12) within a broad frequency range.

3.3
compound mount
double-resilient mount
three-element system consisting of an intermediate mass, the amount of which is comparable to that of the mounted equipment contained between two sets of resilient elements

NOTE Compound mounts are used to achieve greater vibration attenuation than is available with the use of simple resilient mounts. The isolated equipment is supported by the three-element system.

3.4
rigidly mounted equipment
equipment which is solidly attached to the support structure

3.5
support structure
mechanical structure of various types upon which equipment is installed

3.5.1
mounting fixture
support structure mainly intended to be used for rigidly mounted equipment with relatively light framework or structure for the purpose of vibration testing, and which is used above resilient mounts

EXAMPLE Common base frame.

NOTE The fixture can also be used for resiliently mounted equipment for the purpose of vibration testing.

3.5.2
foundation
support structure which is used below the resilient mounts and which may or may not resemble the ship structure

3.5.3
subbase
bedplate
support structure required for shipboard installation and which is necessary to hold down one or more components within alignment

3.5.4
testbed
support structure normally consisting of a massive and reinforced concrete structure to which the entire assembly of equipment, mounts and support structures is attached

3.6
test frequency range
range of one-third-octave band mid-frequencies between 10 Hz and 10 kHz

NOTE Depending on the equipment being tested, it may be reasonable to modify the frequency range, as agreed on by the purchaser and supplier.

3.7
structure-borne sound
mechanical vibration in solid structures, generated within the test frequency range by a vibratory source

NOTE 1 Main engines, auxiliary machinery can be structure-borne sound sources.

NOTE 2 In the frequency range above 16 Hz, structure-borne sound can be audible.

3.8
acceleration level
L_a
measure of vibration acceleration given by

$$L_a = 10 \lg \frac{a^2}{a_0^2} \text{ dB} \tag{1}$$

where

a is the r.m.s. value of the measured acceleration, m/s^2, and

a_0 is the acceleration reference value according to ISO 1683, where $a_0 = 10^{-6}$ m/s^2

NOTE When stating a level it is mandatory to always indicate the reference value, i.e. dB re 10^{-6} m/s^2.

3.9
velocity level
L_v
measure of vibration velocity given by

$$L_v = 10 \lg \frac{v^2}{v_0^2} \text{ dB} \tag{2}$$

where

v is the r.m.s. value of the measured velocity, in metres per second (m/s), and

v_0 is the velocity reference value according to ISO 1683, where $v_0 = 10^{-9}$ m/s

NOTE When stating a level it is mandatory to always indicate the reference value, i.e. dB re 10^{-9} m/s.

3.10
impedance
Z
complex ratio of the excitation force, F, to the velocity, v, taken at the same point in a mechanical system during simple harmonic motion

$$Z = F/v \tag{3}$$

NOTE 1 The unit of impedance is N·s/m. See ISO 2041 for more details on impedance.

NOTE 2 The knowledge of the impedance or **mobility** (3.11) of the foundation is necessary in the case of rigidly mounted equipment under test.

3.11
mobility
M
complex ratio of the velocity, v, to the excitation force taken at the same point in a mechanical system during simple harmonic motion

$$M = v/F \tag{4}$$

NOTE 1 The unit of mobility is m/(N·s). See ISO 2041 for more details on mobility.

NOTE 2 The knowledge of the mobility or **impedance** (3.10) of the foundation is necessary in the case of rigidly mounted equipment under test.

3.12
practically free condition
mounting configuration whereby the equipment throughout a large part of, or the entire, test frequency range can be considered to be freely suspended

NOTE 1 This is achieved by the use of very soft springs (resilient mounts) arranged between the attachment points of the equipment and the support structure. The loaded first vertical tuning frequency of the mounted equipment should not exceed about 10 Hz or be sufficiently below the lowest forcing frequency of the equipment. The loaded first vertical tuning frequency is the root of the ratio of the mount stiffness to the mass of the equipment and support structure above mounts, divided by 2π. For equipment with a mass of 100 kg or less, stiffer mounts may be used, provided the loaded first vertical tuning frequency does not exceed 15 Hz, and the local static stiffness of any foundation should be at least ten times higher than the dynamic stiffness of the mounts. The complete assembly, including equipment, support structure, resilient mounts and any foundation, should be supported on a rigid and massive testbed. Massive and rigid means that the test set-up is effectively isolated from disturbing vibration in the surroundings, i.e. above about 7 Hz.

NOTE 2 The purchaser and supplier might need to agree on alternative means and test requirements to prevent or account for interference due to limitations of the test site.

3.13
insertion loss
loss resulting from insertion of an element in a transmission system, being the ratio of the power delivered to that part of the system following the element, before the element's insertion, to the power delivered to the same part of the system after the element's insertion

4 Measurement requirements and procedures

4.1 General

The purchaser and supplier shall agree on the individual equipment to be tested; they may also agree on limits for equipment vibration or possible structure-borne sound (see Clause 5). It is necessary that both the purchaser and supplier agree on the scope of the tests (measuring positions, operating conditions, etc.) before conducting the tests to avoid misunderstanding. Unless the purchaser and supplier agree on other conditions, the measurements required by this part of ISO 20283 shall be vibration acceleration normally made during steady-state operating conditions of the equipment under test (see 4.8). For certain equipment, measurements during transient operating conditions and transient measurement techniques may be agreed on by the purchaser and supplier.

The vibration measurements on the attachment points of a machine or other equipment under practically free conditions are taken as a structure-borne sound source which the shipbuilder may then apply in conjunction with the impedances of the actual mounts (if mounts are being used in the installation) and the actual foundation aboard ship to predict the structure-borne sound from the equipment unit. The practically free condition for the test is achieved by the use of soft mounts below the attachment points (see Note in 3.2) which are instrumented for measurement. There may be occasion when the actual mounts and/or bedplate are delivered with the unit (see 4.2 and 4.7).

4.2 Measurement point locations

Measurements shall be made on the feet for both simply and compound-mounted equipment which include feet, or at the base of the equipment unit. Measurements shall be made above all mounts and isolators, i.e. on the feet or base of the unit under test, for both simply and compound-mounted equipment.

Measurement points on valves shall be on all the outlet flanges or nozzles and any other structural connections, except the inlets.

The purchaser and supplier shall agree on measurement locations for equipment which does not have well defined points of attachment (see also 4.7.1).

NOTE The purchaser and supplier could agree to refer to ISO 9611 for more detailed description of transducer locations. However, ISO 9611 contains requirements more suited for laboratory investigations, including measurements of rotational vibration, which are not considered in this part of ISO 20283 to be substantial contributors to structure-borne sound.

4.3 Transducer orientation and mounting

Measurements shall be made at the specified locations agreed on by the purchaser and supplier (see 4.2) in three orthogonal directions, one of which shall be vertical. For valves, measurements in two directions are required, perpendicular and parallel to the flow on all outlet flanges or nozzles.

NOTE The supplier's experience could be sufficient justification for reducing the number of measurements considerably, e.g. limiting to only vertical vibration. However, this needs to have the purchaser's concurrence.

Transducers shall be mounted in accordance with ISO 5348 or with the accelerometer manufacturer's instructions, preferably by screwing to an adaptor plate cemented to the equipment unit. Because the method of mounting strongly limits the upper frequency of measurement, magnetic, beeswax, adhesive tape or hand-held mounting methods shall not be used, except in instances where otherwise inaccessible or in the need of efficiency.

4.4 Measurement frequency resolution

4.4.1 General

One-third-octave band measurements in accordance with 4.4.2 shall be made at the locations specified in 4.2. Narrow-band measurements in accordance with 4.4.3 may be made, if agreed on by the purchaser and supplier, for purposes of diagnostics.

4.4.2 One-third-octave band measurements

One-third-octave band acceleration levels L_a (or velocity levels L_v depending on the agreement between the supplier and purchaser) shall be measured for the ambient (non-operating) conditions and the conditions specified in 4.8 over the test frequency range with centre frequencies of 10 Hz to 10 kHz or a range agreed on between the supplier and purchaser.

4.4.3 Narrow-band measurements

Narrow-band acceleration levels L_a may be measured with a constant-absolute or a constant-relative bandwidth analyser. The frequency range and analysis bandwidth should be selected according to the vibratory behaviour of the equipment (resonances, main working frequencies and their harmonics) and agreed on by the purchaser and supplier. The constant-absolute bandwidth should not be greater than Δf = 2,5 Hz, the constant-relative bandwidth should not be greater than 1/24 octave.

4.5 Calibration

4.5.1 Laboratory calibration

Calibration of vibration transducers may be performed by any appropriate method specified in ISO 5347 or ISO 16063 within 2 years before each use. Unless otherwise agreed on by the purchaser and supplier, calibration of each channel of the entire vibration measurement system shall be made at a minimum of two frequencies: one at the low end of the frequency range (e.g. 160 Hz); the other at the high end of the frequency range (e.g. 6,3 kHz). Calibration shall be made at voltages equal to those of the transducer output, corresponding e.g. to 90 dB, 110 dB, 130 dB and 150 dB (re 10^{-6} m/s^2) for accelerometers, to verify amplitude linearity.

4.5.2 Field check

The entire vibration measurement system, including the transducer(s), shall be checked at a minimum of one frequency point, using an accelerometer calibrator, at the beginning of each day and at the end of the equipment measurements. Field checks should be accurate within 2 dB.

4.6 Ambient vibration and its influence

Ambient vibration levels should be 10 dB below the vibration levels with the equipment operating, unless otherwise agreed on by the purchaser and supplier. Corrective measures may be taken to reduce the effect of ambient vibration on the equipment vibration to be measured. Measured levels of equipment vibration shall not be adjusted to account for the effects of ambient vibration.

If ambient vibration cannot be excluded, e.g. the vibration is generated by the test system or by the schedule of measurements (out of working time), a narrow-band analysis of the ambient vibration and the vibration of the equipment in operation might allow a separation of ambient vibration from equipment vibration. In these cases, the vibration level shall be corrected.

4.7 Test system

4.7.1 Mounting of equipment

Equipment is installed aboard ships in a variety of ways, the most common of which are

a) rigidly mounted to foundation,

b) rigidly mounted to a bedplate, which in turn is mounted

   — rigidly to foundation, or

   — resiliently to foundation,

c) resiliently mounted to foundation, and

d) resiliently mounted to a bedplate, which in turn is mounted

   — rigidly to foundation, or

   — resiliently to foundation.