International Standard ISO 4867

INTERNATIONAL ORGANIZATION FOR STANDARDIZATION●МЕЖДУНАРОДНАЯ ОРГАНИЗАЦИЯ ПО СТАНДАРТИЗАЦИИ●ORGANISATION INTERNATIONALE DE NORMALISATION

Code for the measurement and reporting of shipboard vibration data

Code pour l'exécution des mesurages de vibrations à bord des navires et présentation des résultats

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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.

Draft International Standards adopted by the technical committees are circulated to the member bodies for approval before their acceptance as International Standards by the ISO Council. They are approved in accordance with ISO procedures requiring at least 75 % approval by the member bodies voting.

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Code for the measurement and reporting of shipboard vibration data

0 Introduction

The need for comparative data on ship vibration requires uniform test conditions. In general, comparative data can best be obtained during ship trials with known ballast loading. The relatively uniform vibration resulting from propulsion machinery excitation (turbine or diesel drive) can be masked or distorted by transient vibrations due to wave impact or slamming. Changes in wake distribution due to rudder angle and yaw can produce large increases in exciting forces. Operation in shallow water also has a significant effect on hull vibration. Propeller emergence, whether continuous or periodic, causes large increases in exciting forces. The effect of lateral vibration of the aft part of line shafting on hull and superstructure vibration should also be considered.

The aft part of the line shaft may have a lateral resonant frequency within the speed range of the ship which can be excited to strong vibrations by either unbalance or propeller forces.

Alternating thrust forces may cause dangerous vibration of the thrust bearing or machinery as a result of a longitudinal resonance in the propulsion system.

Diesel engines may vibrate about the three rotational axes and three translational axes and generate large forces which in turn may cause large ship vibrations.

The principal response of a ship hull is usually similar to that of a free-free beam in its lower modes. At higher frequencies, the response of the hull girder is equivalent to a forced response with ill-defined resonances and maximum response in the stern area. The stern area is an antinode for all bending and torsional modes excited by the propulsion system and is an appropriate reference point for the measurement of beam-like vibration and forced response. The response of superstructures and local structures may be evaluated in terms of the ratio of their vibratory amplitude to the amplitude of hull girder vibration at that location.

In this International Standard, the term "vibration severity" is used to describe the vibration conditions in the ship and, based on long-established practice in the industry, the peak value of vibration velocity has been chosen as the primary quantity of measurement; since, however, much data have been accumulated in terms of vibration acceleration and vibration displacement, a plotting sheet has been adopted on which data may easily be plotted using any of these quantities of measurement.

1 Scope and field of application

This International Standard establishes uniform procedures for gathering and presenting data:

a) on hull vibration in single or multiple-shaft sea-going merchant ships;

b) for vibration of propulsion-shaft systems as it affects hull vibration.

Such data are necessary to establish uniformly the vibration characteristics of hull and propulsion-shaft systems and to provide a basis for design predictions, improvements and comparison against vibration reference levels.

The procedures, where applicable, can also be used for inland ships and tug boats. In special cases, where objectionable vibration is found to exist, specific investigative studies may be required.

This International Standard is concerned with:

a) vibration of the main hull girder and superstructure excited by the propulsion system

— at shaft rotational frequency,

— at propeller blade rate, harmonics of blade rate and

— at frequencies associated with the major components of machinery;

b) excitation of the propulsion shaft and main machinery system.

It does not deal with other aspects of ship vibration at this time. Local vibration is dealt with in ISO 4868.

Anchor drop-and-snub tests in calm water may be an effective means of obtaining the first few vertical hull modes of vibration and their damping constants (see warning in 4.5.5).

Detailed design information on the ship is required to assist in developing empirical constants useful in evaluating the vibration of hull and machinery vibratory characteristics.

This International Standard gives general principles of vibration measurement on board ships to improve vibration engineering. Therefore, in individual cases, items to be measured may be selected or added to meet the aims of the vibration measurement of each ship.

2 References

ISO 2041, *Vibration and shock — Vocabulary.*

ISO 4868, *Code for the measurement and reporting of local vibration data of ship structures and equipment.*

ISO 6954, *Mechanical vibration and shock — Guidelines for the overall evaluation of vibration in merchant ships.*

3 Definitions

In addition to those terms defined in ISO 2041, the following definitions are applicable.

3.1 free route : That condition achieved when the ship is proceeding at a constant speed and course with minimum throttle or helm adjustment.

3.2 hull girder : The primary hull structure such as the shell plating and continuous strength decks contributing to flexural rigidity of the hull and the static and dynamic behaviour of which can be described by a free-free non-uniform beam approximation.

3.3 hull girder vibration : That component of vibration which exists at any particular transverse plane of the hull so that there is little or no relative motion between elements intersected by the plane.

3.4 local vibration : The dynamic response of a structural element, deck, bulkhead or piece of equipment which is significantly greater than that of the hull girder at that location.

3.5 severity of vibration : The peak value of vibration (velocity, acceleration or displacement) during periods of steady-state vibration, representative of maximum repetitive behaviour, under the conditions defined in 4.2.

When using autographic records, suitable lengths of record may easily be recognized.

When using electronic methods of analysis, care shall be taken to use lengths of record, time constants and averaging times so that a good approximation to the steady-state amplitude is obtained.

4 Measurement of data

4.1 Instrumentation

Measurements should preferably be made with an electronic system which produces a permanent record. The transducers may generate signals proportional to acceleration, velocity or displacement. Recording can be made either on magnetic tape, paper oscillographs, or a combination of both. Use of paper oscillographs during the tests means that the vibration traces can be inspected directly and is very helpful in evaluating existing vibration problems. When displacement rather than either velocity or acceleration is recorded, the desired low-frequency signals associated with significant vibratory motion are the major components of a recorded trace. Thus, they are readily evaluated since they overshadow possible higher frequency signals with low displacement amplitudes.

Provision should be made for suitable attenuation control to enable the system to accommodate a wide range of amplitudes.

An event marker should be provided on the propeller shaft. Its position with respect to top dead centre of cylinder number 1 and a propeller blade should be noted. Cylinder numbering should be shown in figure 2.

The complete measuring system should be calibrated in the laboratory prior to the test and it is desirable to check the calibration of each recording channel before each stage of the test.

4.2 Preferable test conditions

The preferable test conditions shall be as follows:

a) the test should be conducted in a depth of water not less than five times the draught of the ship, unless otherwise specified;

b) the test should be conducted in a quiet sea (sea state 3 or less);

c) the ship should be ballasted to displacements as close as possible to the operating conditions within the ordinary ballasting capacity of the vessel. The draught aft should ensure full immersion of the propeller;

d) during the free-route portion of the test, the rudder angle should be restricted to about two degrees port or starboard (minimum rudder action is desired).

Any divergence from these conditions should be clearly stated in table 4.

4.3 Transducer locations

Vibration measurements should be taken at the following locations; measurements should preferably be taken simultaneously in order to determine vibration modes.

4.3.1 Stern

Vertical, athwartship and longitudinal measurements of the hull girder as close as possible to the centreline and the stern. These measurements should be used for reference purposes. When a torsional response of the hull shall be determined, a pair of deck-edge transducers for vertical vibration should also be employed. It should be ensured that the vibration of the hull girder is measured, excluding local effects.

4.3.2 Superstructure

Vertical, athwartship and longitudinal measurements at the following locations to determine the overall vibration of the superstructure:

a) wheelhouse, centreline at front of bridge;

b) main deck, centreline at front of deck house;

c) a pair of transducers to measure torsional motions of an aft deckhouse, when torsional vibration shall be determined.

Measurements should be made in the range of at least 90 to 100 % normal service shaft rotational frequency.

4.3.3 Machinery and thrust-bearing housing

a) For geared drives:

Vertical, athwartships and longitudinal measurements on top of thrust bearing housing (see figure 1). Recording should also be taken on one supplementary point on the thrust block foundation, in the longitudinal direction. Measurements at other locations indicated in figure 1 may be executed as optional at constant speed (contractual speed for instance). Other types of measurement to achieve the same results are permissible.

b) For direct diesel drives:

Recordings should be taken at the following locations, shown in figure 2:

1) on top of and on the foundations of the thrust bearing [similar to 4.3.3 a)];

2) on the top forward end of the main engine, in the longitudinal direction;

3) on the top forward and aft ends of the main engine, in the vertical and athwartships directions.

It is recommended that the following measurements should also be made:

4) on the forward end of the crankshaft (longitudinal only);

5) on the forward and aft ends of the engine foundations (vertical and athwartships only).

For the other measuring points, as shown in figure 2, optional recordings may be taken at constant shaft rotational frequency.

Measurements should be made throughout the normal operational range of the ship.

4.3.4 Lateral shaft vibrations (optional)

a) Vertical and athwartships vibration measurements should be made on the shaft relative to the stern tube (see figure 3). Other optional measurement points, as indicated in figure 3, may also be taken. Other types of measurement to achieve the same results are permissible.

Measurements should be made throughout the normal operational range of the ship.

Data concerning the characteristics of the aft part of the line shafting should be inserted in table 2.

b) In order to eliminate possible error, shaft run-out should be checked by rotating the shaft by the turning gear, and recording the first-order signal. This signal should be phased and the shaft vibration measurement corrected accordingly.

4.3.5 Torsional shaft vibration

To confirm the torsional vibration characteristics, torsional vibration measurements should be made either at the free end of the propulsion machinery, using a suitable torsional vibration transducer, and/or on the main shafting, using strain-gauges. Alternatively, depending on the system characteristics, a mechanical torsiograph, driven from a suitable position along the shafting or free end, may be used for this purpose. Torsional vibration measurements are considered mandatory for propulsion machinery, unless the design calculations approved by the Classification Society show that excitation of significant vibration in the operating speed range cannot reasonably be expected.

4.3.6 Local structures (optional)

When evidence of severe local vibration occurs, measurements should be made to form a basis for determining the need for corrective measures (see ISO 4868).

4.3.7 Deck traverse (optional)

Measure at the deck edge vertical and athwartships bending vibration at a sufficient number of points to permit determining the mode shapes at the lower frequencies, avoiding local resonances. Such measurements may be made by use of a reference transducer at the stern together with a portable transducer. Torsional modes require phased deck-edge measurements.

4.3.8 Hull pressure transducers (optional)

To obtain an indication of the magnitude of propeller-induced forces acting on the hull surface, the measurement of hull surface pressures may be carried out as an optional item. The minimum number of pressure transducers (three) should be located as shown in figure 4. Two transducers should be approximately in the propeller plane and one approximately 0,1 D forward of the propeller plane. To minimize the effect of plate vibration, all transducers in the hull plating should be located as close as possible to adjacent frames or partial bulkheads.

For research purposes, or for full integration of actual forces, a higher number of pressure transducers would be required, positioned over a large area above, aft and particularly forward of the propeller plane.

4.4 Quantities to be measured

The quantities to be measured are as follows:

a) displacement, velocity, acceleration, pressure or strain;

b) frequencies in cycles per second (hertz) or cycles per minute;

c) shaft rotational frequency (speed) in revolutions per minute or revolutions per second;

d) phase identification [see 5.1 d)].

4.5 Test procedure

4.5.1 Calibration of recording equipment

Each channel should be checked after completion of installation to ensure proper working condition, desired amplification setting and phasing. Checks should be made at regular intervals and for each setting of signal attenuation. The calibration should be recorded.

4.5.2 Performance of measurements

Record hull and machinery vibration data in the following conditions:

a) make a steady deceleration or acceleration run of, preferably, less than 5 r/min^2 to determine location of critical speeds;

b) in free route, run from half shaft rotational speed to maximum at increments of 3 to 10 r/min. Additional runs at smaller increments are required in the vicinity of critical speeds and near service speed (see 4.5.3);

c) hard turns to port and starboard at maximum speed (optional);

d) crashback from full power ahead to full power astern (optional);

e) anchor drop-and-snub (optional, see 4.5.5).

4.5.3 Free-route runs

For free-route runs, permit the ship to steady on constant speed. Hold the speed for a sufficient time to permit recording of maximum and minimum vibration values (about 1 min). In multiple shaft ships, all shafts should be run at, or as close as possible to, the same speed to determine total vibration levels. In certain instances it may be preferable to run with a single shaft for the determination of vibration modes.

4.5.4 Measurement during manoeuvres

The ship should be at maximum speed at the start of all manoeuvres.

For manoeuvres, start the recorder as the throttle or wheel is moved. Allow to run until maximum vibration has passed. This normally occurs when the ship is dead in the water during a crashback manoeuvre or when the ship is fully in a turn.

4.5.5 Anchor drop-and-snub test

For the anchor drop-and-snub test, the anchor shall fall freely and be snubbed quickly by use of the windlass brake, and shall not touch bottom. The ship shall be dead in the water for this test, with a minimum of rotating equipment in operation. Care shall be taken not to exceed the recommendations for free drop as indicated by the manufacturer of the anchor windlass. Data should be taken continuously from the moment the anchor is released until vibration can no longer be detected.

5 Analysis and reporting of data

5.1 Analysis

Analysis should provide the following information for all runs:

a) severity of vibration at the propeller shaft rotational frequency (first order) for hull girder transducers;

b) severity of vibration at blade rate frequencies for hull girder and machinery transducers;

c) severity of vibration of each detectable harmonic of shaft rotational frequency or blade rate for hull girder and machinery transducers as applicable. Also the severity of each detectable multiple of crankshaft rotational frequency in the case of geared diesel installations;

d) phase relation between various transducers at blade rate, as applicable, using a suitable reference datum, for example a hull girder or machinery transducer or event marker;

e) for diesel engines, phase relation should be provided between all transducers measuring in the longitudinal direction and for the transducers on top of the engine measuring torsional motions; therefore, each group should always be measured simultaneously;

f) severity of vibration at hull girder and machinery resonances.

NOTE — The presence of beating effects, if any, should be noted by recording maximum and minimum values of the amplitude and the frequency of the beat.

5.2 Reporting of data

Data reported should include the following:

a) the principal ship design characteristics:

1) complete tables 1, 2 and 3;

2) provide sketch of the inboard profile of hull and superstructure;

3) provide a lines plan of the stern configuration, for about one-fifth of the length of the ship.

b) a sketch showing locations of hull girder and machinery transducers and their directions of measurement. Transducer locations for local vibration measurements should be shown on a separate sketch;

c) the trial conditions, recorded using table 4;

d) plots of displacement, velocity or acceleration amplitudes versus speed for shaft rotational frequency, blade rate, or machinery excitation frequency or any harmonic thereof. Make use of forms of the kind shown in figure 5. Additional form sheets should be used according to table 5. Linear plots may also be used;

e) results of measurements at local areas reported using table 5 and figure 5;

f) results from manoeuvres tabulated as indicated in tables 6 and 7;

g) results of an anchor drop-and-snub test, including the identified hull natural frequencies and, from the decaying vibration traces, the derived damping coefficients. Presentation of oscillograph traces is desirable;

h) method of analysis of the results;

j) type of instrument used;

k) the report should note the hull natural frequencies and modes which have been identified. It should also mention any undesirable or unusual vibration condition encountered.

6 Rules for presentation of vibration test results

a) Use one graph each (see figure 5) for vertical, athwartship and longitudinal hull vibration at stern.

Identify severity of vibration for evaluation of habitability. Use ● for objectionable, ◑ for questionable, and ○ for acceptable vibrations;

b) use one graph each for vertical, athwartship and longitudinal thrust bearing vibration;

c) use graphs as needed for machinery and lateral shaft vibration. Each graph should identify the transducer positions by referring to figures 1, 2 and 3.

NOTES

1 Additional graphs should be used to identify phasing relationships, etc.

2 The following marks should be used throughout the report for easy identification:

□ Propeller shaft frequency

○ Blade rate

△ Twice blade rate

◇ Three times blade rate

▽ Higher frequencies (identify)

X Engine frequency (identify predominant orders)

Table 1 — Particulars of test ship

Particulars of ship			**Ship name**		
			Builder/built year		
Hull			Main engines		
Kind and type			Number, kind and type		
Class			Built year		
Construction			Bore and stroke, mm		
			Number of cylinders		
Length L_{pp} between perpendiculars, m			Power, kW		
Breadth B moulded, m			Speed, r/min		
Depth D moulded, m			Location*		
Draught T (full load), m			Unbalance couple**, N·m	M_{v1}	
Displacement Δ (full load), t				M_{v2}	
Block coefficient c_B				M_h	
Deadweight, t			Propellers		
Lightweight, t					
2nd moment of area of midship section, m^4	I_v		Number and type		
	I_h		Number of blades		
Shear area of midship section, m^2	A_v		Pitch ratio		
	A_h		Expanded area ratio		
Sketch of midship section			Skew in degrees		
			Diameter D_p, m		
			Speed, r/min		
			Type and number of rudders		
			Sketch of screw aperture***		
Remarks :					

* For diesel engines, the distance from the aft perpendicular to centre of engine. For turbine, the approximate location, for example amidships, semi-aft or aft.

** In the case of an engine having unbalanced force and/or any other excitation necessary to describe the vibratory phenomenon, the value should be added in the "Remarks" column.

*** See example in figure 4 b). Substitute appropriate sketch in multiple screw or ducted propeller ship.

Table 2 — Particulars of propulsion-shaft system

Particulars of propulsion-shaft system

Number of shafts	
Maximum and normal speed, r/min	
Type of bushing material	
Shaft alignment (straight or rational)	

Rotating parts

		Diameter mm	Length mm
1	Tail shaft		
2	1st intermediate shaft		
3	2nd intermediate shaft		
4	3rd intermediate shaft		
5	4th intermediate shaft		
6	Thrust shaft		

	Diameter mm	Mass t	Mass polar moment of inertia t·m²
2nd reduction gear			
1st reduction gear			
Flywheel			

Aft part of the shafting

Mass, t, and density, kg/m³, of propeller	
Mass polar moment of inertia of propeller, t·m²	

	Stiffness N/m	Distance mm
Aft support of tail shaft		***
Forward support of tail shaft		****
Intermediate bearing		

Natural frequency, c/min	Lateral	Forward whirl	Counter whirl
Mode 1st			
Mode 2nd			

Stationary parts

		Diameter mm	C* mm	Support**
a	Stern tube aft bearing			
b	Stern tube forward bearing			
c	1st intermediate bearing			
d	2nd intermediate bearing			
e	3rd intermediate bearing			
f	4th intermediate bearing			
g	5th intermediate bearing			
h	6th intermediate bearing			
i	7th intermediate bearing			
j	8th intermediate bearing			
k	9th intermediate bearing			
l	Thrust block			
m	Bull gearing aft bearing			
n	Bull gearing forward bearing			

Sketch of thrust block and its foundation with major scantlings

Sketch of shaft system showing relative location of rotating and stationary parts. Indicate the length of aft bushing (L) and (L/D).

* Diametral clearance.

** For example, on double bottom, in propeller bossing.

*** Distance between the propeller centre of gravity and aft support of the tail shaft.

**** Distance between two tail shaft supports.