International Standard ISO 4868

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Code for the measurement and reporting of local vibration data of ship structures and equipment

Code pour l'exécution des mesurages des vibrations locales des structures et équipements de 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 local vibration data of ship structures and equipment

0 Introduction

The term "local vibration", as used in the shipbuilding industry, applies to the dynamic response of a structural element, an assembly of structural elements, machinery or equipment which vibrates at an amplitude significantly greater than that of the basic hull girder at the location. This vibration may occur at a frequency of the hull girder or of a machinery component. Typical examples include the vibration of parts of the superstructure, smokestack, mast, binnacle, turbine, pipe or deck plate. These local vibrations generally result from :

a) local flexibility of supporting structural elements; or,

b) the vibratory characteristics of the machinery concerned.

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 on vibrations of local structural elements or equipment in sea-going merchant ships. The procedures, where applicable, can also be used for inland ships and tug boats. Such data are necessary to establish uniformly the vibration characteristics present in various compartments on board ship and to provide a basis for design predictions, improvements and comparison against environmental vibration reference levels or criteria relative to reliability (of machines), safety (of structures) and habitability. The data are not intended to apply to the evaluation of the vibration of machines with respect to noise control or to the design of the machine or equipment under consideration. These latter cases will generally require specific diagnostic treatment and include a broader frequency range and more specialized instrumentation than is necessary for these general considerations.

This International Standard is concerned with local vibration measured on structural elements, superstructure, decks, bulkheads, masts, machines, foundations, equipment, etc., and only relates to the measurement and reporting of the local vibration of the structure or equipment mounted thereon. Concern over local vibration may be caused by :

a) the stresses due to the vibration, for example in the structure, in the equipment or attachments;

b) the necessity of maintaining trouble-free operation of a machine or other equipment which might be jeopardized by the malfunction or degradation of components;

c) the physical strain on man (habitability and performance);

d) the effects of the vibration on its environment, such as adjacent instruments, machines, equipment, etc.

The frequency range considered includes propulsion shaft rotational frequencies, rotational frequency of machines and other significant source frequencies, such as diesel firing, blade or vane passage, etc.

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 4867, *Code for the measurement and reporting of shipboard vibration data.*

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

3 Definitions

In addition to the 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 recording and 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

Measurement 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.

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.

Portable electronic and mechanical instruments capable of single-point measurements may be used.

4.2 Preferable test conditions

The preferable 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, with machinery running under normal conditions, unless otherwise specified;

NOTE — For exploratory purposes, tests may be carried out at the quayside if there is no reason to suppose that shallow water will influence the results.

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

c) the ship should be ballasted to a displacement 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);

e) individual machines may be run in isolation as required to investigate particular problems.

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

4.3 Transducer locations

4.3.1 Stern

Vertical, athwartship and longitudinal measurements as close as possible to the centreline and the stern, to establish the hull girder vibration characteristics. The location should be chosen so that the results are not influenced by local vibration effects.

4.3.2 Superstructure

Vertical, athwartship and longitudinal measurements on the superstructure front bulkhead, at a minimum of three different deck levels.

4.3.3 Local structures

Vertical, athwartship and longitudinal measurements at any local structure where evidence of local vibration occurs.

4.3.4 Local deck traverse

Vertical, athwartship and longitudinal measurements at a sufficient number of points in the area of local vibration to determine the relative vibration with respect to the hull girder.

4.3.5 Local machinery and equipment vibration

Vertical, athwartship and longitudinal vibration at the outside of machinery where there is evidence of large vibration amplitudes.

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 (Hz) or cycles per minute;

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

d) phase, where appropriate.

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. The calibration should be recorded.

4.5.2 Performance of measurements

Record data in the following conditions:

a) in free route, at 3 to 10 r/min increments from one-half to maximum speed. Additional runs at smaller increments are required in the vicinity of critical speeds and near service speed;

b) free route runs at the operation speeds;

c) special runs at speeds reported to cause local vibrations, as needed.

NOTE — 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.

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 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;

d) severity of local structural vibration at all measurement locations;

e) mode shape of local vibrations. Use hull girder vibration as reference for the mode shape;

f) severity of vibrations of local machinery or equipment at all measurement locations;

g) for additional optional measurements, if specified, see ISO 4867.

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, 3 and 4;

2) provide a sketch of the inboard profile of hull and superstructure.

b) a sketch showing locations of hull girder and local vibration transducers and their directions of measurement;

NOTE — For local vibration measurements, it is particularly important that the precise position of transducers should be noted since very small changes in position can lead to large changes in measured amplitude.

c) plots of displacement, velocity or acceleration amplitudes versus speed for shaft rotational frequency, blade rate or any harmonic thereof. Make use of forms of the kind shown in figure 1 using the rules given in table 6. Linear plots may also be used;

d) profiles of local deck vibration at each resonance from port to starboard and from the nearest aft to the nearest forward structural bulkhead;

e) tables of all significant vibration severities and their location and frequency. Include the shaft rotational frequency, for machinery-excited vibration;

f) hull girder natural frequencies identified from stern measurements and any unusual vibration condition encountered;

g) weather conditions during the measurements, including sea state and direction relative to the ship;

h) method of analysis of results;

j) type of instrument used.

6 Rules for presentation of vibration test results

a) Use one graph each (see figure 1) 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 (see figure 1) each for all measuring points and directions of measurement.

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)

⧖ Engine frequency (identify predominant orders)

Table 1 — Particulars of test ship

Particulars of ship			**Ship name**		
			Builder/year built		
Hull			Main engines		
Kind and type			Number, kind and type		
Class			Year built		
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 2. 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 speed 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 $t \cdot m^2$
2nd reduction gear			
1st reduction gear			
Flywheel			

Aft part of the shafting

Mass, t, and density, kg/m^3, of propeller	
Mass polar moment of inertia of propeller, $t \cdot m^2$	

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

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

Table 3 — Particulars of main diesel engines or turbine driven plants

Particulars of main engine						
Manufacturer				Natural frequency of shafting and crankshaft or gearing and turbines, c/min*		
Kind						
Type				Mode	Longitudinal	Torsional
		Maximum	Normal	1st		
Output, kW	Brake : Shaft :			2nd		
Rotational frequency, r/min				3rd		

Main diesel engine						
Number of cylinders		Mass and position in longitudinal and vertical direction of centre of gravity relative to crankshaft axis				
Cylinder bore						
Cylinder stroke						
Firing order	Indicate angle and cylinder number, propeller blade and event marker Forward running (looking forwards) 	Mass polar moment of inertia with respect to crankshaft axis				
		Stiffness values of thrust block, N/m				
			Order	Force N	Couple N·m	
		Free forces and couples due to unbalance	1st			
			2nd			
		Guide forces (H) and couples (X)				

Sketch of crankshaft or reduction gear system showing its major scantlings

* Give details of balancers, detuners, dampers, etc., which could influence vibration.