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Ships and marine technology — Guidelines on vibration isolation design methods for shipboard auxiliary machinery

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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.

The procedures used to develop this document and those intended for its further maintenance are described in the ISO/IEC Directives, Part 1. In particular the different approval criteria needed for the different types of ISO documents should be noted. This document was drafted in accordance with the editorial rules of the ISO/IEC Directives, Part 2 (see www.iso.org/directives).

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For an explanation on the voluntary nature of standards, the meaning of ISO specific terms and expressions related to conformity assessment, as well as information about ISO's adherence to the World Trade Organization (WTO) principles in the Technical Barriers to Trade (TBT) see the following URL: www.iso.org/iso/foreword.html.

This document was prepared by Technical Committee ISO/TC 8, *Ships and marine technology*, Subcommittee SC 8, *Ship design*.

Introduction

This document has been developed in response to the demand, noted by the International Maritime Organization (IMO) and its Marine Environment Protection Committee (MEPC), for an International Standard on reduction of vibration and noise from machinery onboard ships, considering the negative effects of ship vibration and noise on the health of seafarers and the negative effects of underwater noise radiated from ships on marine life.

The reduction of ship vibration and noise may necessitate machinery vibration isolation measures. Although marine machinery vibration isolation design can be done by professional groups, such as consultant companies, with the development of modern shipbuilding technology, the integration of various technical fields for ship design is becoming a necessity.

The ship designers themselves should also understand the procedures, requirements and basic methodology of vibration isolation for shipboard machinery. The purpose of developing a basic methodology in this document is not limited to better vibration isolation measures, but to help ship designers take into account the need of machinery vibration isolation, planning for the space and weight for machinery vibration isolation in advance at the design stage and to consequently promote the application of vibration isolation design technology onboard.

Vibration isolation concerns the use of comparatively resilient elements called vibration isolators. Practical vibration isolators usually consist of springs, of elastomeric elements with damping or of a combination of these. The primary purpose of isolators is to attenuate the transmission of vibrations, whereas the main purpose of dampers is the dissipation of mechanical energy. Simple models based on systems with a single degree of freedom are useful for establishing some fundamental relations, such as single-stage isolation. Extensions of these models can account for the non-rigidity of supports and isolated items, as well as for reaction effects on vibration sources. More complex models apply to two-stage isolation that can provide greater attenuation than single-stage isolation systems. As common measures onboard a ship, single-stage and double-stage vibration isolation design methods are suggested in this document.

Ships and marine technology — Guidelines on vibration isolation design methods for shipboard auxiliary machinery

1 Scope

The purpose of this document is to provide general guidelines on the design of ship vibration isolation based on the basic methodology of vibration isolation for shipboard machinery, for example, auxiliary engine, compressor, fan, pump, etc. A well-designed vibration isolation system can significantly reduce the vibration transmission from shipboard machinery to ship structures lowering the noise level onboard the ship or the underwater noise radiated from the ship.

2 Normative reference

The following documents are referred to in the text in such a way that some or all of their content constitutes requirements 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 20283-3, *Mechanical vibration — Measurement of vibration on ships — Part 3: Pre-installation vibration measurement of shipboard equipment*

3 Terms and definitions

For the purposes of this document, the following terms and definitions apply.

ISO and IEC maintain terminological databases for use in standardization at the following addresses:

— IEC Electropedia: available at http://www.electropedia.org/

— ISO Online browsing platform: available at http://www.iso.org/obp

3.1
single-stage vibration isolation
vibration isolation where a single machinery or assembly is mounted on the ship foundation through a stage of elastic connection by a group of isolators

3.2
double-stage vibration isolation
vibration isolation where a single machinery or assembly is flexibly installed on an intermediate frame through a first stage isolator group, and an intermediate frame is mounted on the ship foundation through a second stage isolator group

3.3
displacement limiter
rigid element which is used in combination with the vibration isolator to avoid excessive displacement and consequent damages of the vibration isolation system

3.4
coast down test
test to determine the resonant frequencies of the machine isolation system for the machinery from a certain speed while it is shut down, simultaneously recording the vibration level until the machine stops

Note 1 to entry: Annex A gives information on the determination of the resonant frequencies of machine isolation system.

4 Basic requirements of vibration isolation system design

4.1 Vibration isolation performance

The design of vibration isolation should meet the requirements of vibration isolation performance and avoid resonance according to the structural dynamic characteristics of the ship structure including machinery foundation. The choice of vibration isolation type depends on the vibration levels difference between shipboard machinery and ship structure, as well as the limit of weight and space onboard the ship. The design requirements on the limit of the ship structure vibration response in ISO 20283-5 and relevant ship specifications can be referred to.

In general, the effect of vibration reduction can reach more than 15 dB when the single-stage vibration isolation is adopted and reach 25 dB to 30 dB when the double-stage vibration isolation is adopted. Especially for the double-stage vibration isolation, transmissibility of the isolation system varies with different intermediate mass values. The heavier the intermediate mass block is, the better the vibration reduction effect is. Design of the weight of the intermediate mass block depends on the weight restriction and vibration reduction requirement. Meanwhile, the advantage of introducing the intermediate mass block is more obvious in the high-frequency range.

4.2 Vibration severity of machinery

The vibration response of mechanical machinery will be enhanced after elastic installation. When the value of the machinery vibration severity is large, it is easier to cause fatigue damage of machinery and to reduce the reliability of machinery operation. Therefore, machinery that is installed resiliently should meet the requirements of the vibration limits of machinery according to the product specification or ISO 10816.

4.3 Stability of machinery

Machinery installed resiliently should be ensured to work normally under conditions of machinery rocking by ship motion, such as yawing, rolling and pitching. Limiters can be mounted in combination with the vibration isolators to prevent the maximum displacement of any flexible joints isolating the system from exceeding the permissible value.

4.4 Environmental adaptability

Vibration isolation elements shall meet the requirements of marine products and be approved by the related administrator after inspection.

4.5 Ease of installation and maintenance

The vibration isolation system of shipboard machinery shall meet the requirements of space and weight for maintenance and machinery reinstallation of isolation elements. The specifications of vibration isolation elements should be universal for the convenience of maintenance.

5 Design procedure of single-stage vibration isolation

5.1 General

The design of single-stage vibration isolation depends on vibration characteristics, gravity centre, weight, size and form of machine mounting feet, etc., of ship machinery according to the general requirements. Through optimizing the parameters and layout of isolators, the vibration isolation analyses are then implemented to reach the desired vibration isolation.

5.2 Spectral analysis of disturbance

Test and plot (in accordance with ISO 20283-3) spectrum of disturbance from machinery can describe the excitation characteristics and analyse the main excitation frequencies.

5.3 Natural frequency

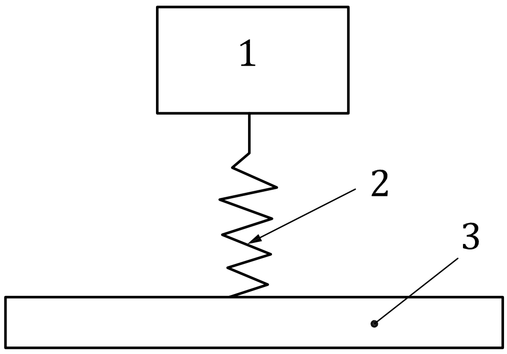
There are six degrees of freedom for the single-stage isolation system. The major exciting force can be projected to six directions of principal axes and there are corresponding major exciting frequencies. In the design of the vibration isolation system, the single-stage isolation system can be simplified as single-degree-of-freedom system for each direction of principal axes. For the considered directions, major exciting frequency, f, should be greater than $\sqrt{2}$ times of natural frequency of system, f_n, $f/f_n > \sqrt{2}$. The vibration transmissibility, T, from machinery to foundation of ship structure varies with the frequency ratio, f/f_n, and with the value of the loss factor, η, ($\eta = 2\xi(f/f_n)$, ξ is the damping ratio) as shown in Formula (1):

$$T = \sqrt{\frac{1+\eta^2}{[(f/f_n)^2 - 1]^2 + \eta^2}} \quad (1)$$

For frequency ratios of more than $\sqrt{2}$, T value is less than 1. This reflects that better isolation (smaller transmissibility) is obtained at higher frequency ratios. Thus, in order to obtain good isolation in the presence of a disturbance at a given excitation frequency f, the natural frequency, f_n, shall be designed as much lower than f as possible.

At such low-frequency ratios, the items with isolation system are subjected to greater motions than they would experience without any isolation. For auxiliary machinery onboard, design of an isolation system is restricted by revolution times and the number of resonant resolutions is difficult to be designed under the revolution times. Therefore, low-speed auxiliary machinery isolation systems generally should be carefully designed.

The natural frequency is the frequency of free vibration in which a system vibrates to dissipate its energy. The natural frequency, f_n, expressed in radian per second, is a function of its stiffness, K, and its mass, M, as shown in Formula (2). See Figure 1.



Key

1 mass, M

2 stiffness of spring, constant, K

3 foundation

Figure 1 — Schematic diagram of single-stage vibration isolation

