



**CCS Rule Change Notice For:**

**GUIDELINES FOR SHIPBOARD  
VIBRATION CONTROL**

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**Beijing**

### **Brief Introduction**

According to the issue of RULES FOR GREEN ECO-SHIPS(2020), 1.2 of Chapter 1, 15.5 and 15.6 of Chapter 15 are to be deleted.

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## Chapter 1 GENERAL

### 1.1 Introduction

#### 1.1.1 Purpose

Different vibration levels will be caused as ships navigate at sea, where the natural frequency of vibration system is consistent or approach to exciting frequency, resonance phenomenon may be induced. Although some units are not in resonance state, severe vibration may be arisen due to the increase of excitation. In addition to the adverse effects on the personnel, excessive vibration may bring fatigue damage to the local structural members or fault to the machinery equipment, even to influence the ship's normal operation.

Classification societies carry out the research working constantly to control the ship's vibration, however due to its complexity, except the shafting vibration, the ship's vibration has not been included as a class condition in their rules. With the increase of ship's dimension and speed, adverse vibration occurs to endanger the ship's safety and personnel's health severely. Therefore, classification societies have developed the class notations of habitability (for vibration), comfort (for vibration), comfort (for noise), structural vibration, mechanical vibration and noise as the criteria for shipowners to select.

ISO has also rewritten and issued ISO 6954-2000 Mechanical Vibration – Guidelines for the Measurement, Reporting and Evaluation of Vibration with regard to Habitability on Passenger and Merchant Ships, etc.

To improve the accommodation and working conditions for crew onboard ships, ILO has made provisions to “prevent the risk of exposure to hazardous levels of noise and vibration” and “taking the due consideration for the relevant international standards, review on an ongoing basis the problem of noise onboard ships with the objective of improving the protection of seafarers, in so far as practicable, from the adverse effects of exposure to noise” respectively in Standard A3.1 – Accommodation and recreational facilities, Guideline B3.1.12 – Prevention of noise and vibration and Guideline B4.3 – Health and safety protection and accident prevention of Maritime Labour Convention, 2006.

Therefore, to effectively control shipboard vibration is the essential measures for ensuring the habitability, safety and functionality onboard ships.

In order to effectively control the effects of adverse shipboard vibration and make the ship to meet the relevant requirements of vibration criteria, the Guidelines for Shipboard Vibration Control (hereinafter referred to as the Guidelines) has been developed by CCS.

#### 1.1.2 Application

(1) The Guidelines applies to all the vibration controls for all sea-going ships, high-speed craft, light-type ships and surface naval ships.

(2) Unless otherwise specified, ships applying for CCS class notations of vibration are to comply with the related requirements in the Guidelines.

#### 1.1.3 References

CCS Guidelines for Shipboard Vibration Control, 2000.

The Guidelines is developed on the basis of CCS experience and research results, including the requirements of the updated related international standards.

The Guidelines includes the related contents of CCS Rules for Classification of Sea-going Steel Ships and the related standards, and attention is to be given to the updated edition of the related

rules and standards in application.

The Guidelines is mainly referred to the following international standards and GBs:

- ISO 6954-1984 Mechanical Vibration and Shock – Guidelines for the General Assessment of Vibration on Merchant Ships;
- ISO 6954-2000 Mechanical Vibration – Guidelines for the Measurement, Reporting and Evaluation of Vibration with regard to Habitability on Passenger and Merchant Ships;
- ISO 20283-2-2008 Mechanical vibration – Measurement of Vibration on ships Part 2: Measurement of Structural Vibration;
- ISO 20283-3-2008 Mechanical Vibration – Measurement of Vibration on Ships Part 3: Measurement of Pre-installation Vibration for Shipboard Equipment;
- GB/T 7452-2007/ISO 6954:2000 Criteria for the Measurement, Reporting and Evaluation of Vibration with regard to Habitability on Passenger and Merchant Ships.

#### 1.1.4 Adverse vibration

(1) During the ship's operation, common vibrations are as follows:

- vibration of hull girders, superstructures and stern;
- vibration of panels, grillages, masts and structures in engine room;
- vibration of propulsion shafting;
- vibration of engine frame and machinery equipment.

(2) Adverse vibrations occur with the following phenomenon:

- fatigue damage of hull structure and mechanical parts;
- effects on the normal operation of machinery and equipment;
- effects on the normal working and life for the personnel onboard ships.

#### 1.1.5 Vibration control

(1) In order to predict ship's vibration at various stages, the Guidelines provides a set of flow to minimize the vibration, which is for the purpose of prediction or elimination of shipboard adverse vibration at design and construction stages through statistic data, empirical formula or estimation of computer program and assessment of vibration characteristics.

For the vibration onboard in-service ships, necessary calculation analysis and full-scale ship measurement may be carried out in accordance with the existing drawings and information, where the level of vibration exceeds the allowable values, vibration damping measures are to be taken as appropriate to improve the ship's vibration characteristics.

(2) Means for vibration control are:

- to minimize the excitation force and its transmission;
- to carry out frequency modulation so as to change the natural or exciting frequency of vibration system and preventing the resonance;
- to increase damping so as to deplete vibration energy and achieve the purpose of amplitude decrease;
- to increase structural strength so as to raise the anti-vibration ability;
- to install dampers for main equipment.

(3) The elements of vibration control are:

Within the maximum running speed range of main engine (85% to 100%), to control:

- main exciting force not exceeding the allowable values;
- the ratio between main exciting frequency and main frequency of vibrating body meeting the requirements of design criteria.

## 1.2—CCS Class Notations Related to Vibration

1.2.1 The class notations related to vibration and descriptions in Table of Environmental Protection Notations in Appendix 1 List of Class Notations for Sea-going Ships of Chapter 2, PART ONE of CCS Rules for Classification of Sea-going Steel Ships are shown in Table 1.2.1 as follows:

**Class Notations Related to Vibration and Descriptions** **Table 1.2.1**

Class notation	Description		Technical requirements to be complied with
COMF (VIB-N)	Comfort (vibration-N)	This notation may be assigned if the vibration levels in related spaces of the ship meet the Rule requirements for comfort of crew and passengers, with N=1 or 2 or 3 indicating different comfort levels, where 1 represents the highest comfort level	Chapter 16, PART EIGHT of CCS Rules for Classification of Sea-going Steel Ships
HAB (VIB)	Habitability (vibration)	This notation may be assigned if the vibration levels in related spaces of the ship meet the habitability requirements regarding crew and passengers in ISO 6954	Chapters 14 and 15 of CCS Guidelines for Shipboard Vibration Control
VIB (S)	Structural vibration	This notation may be assigned if related structures of the ship meet the structural vibration requirements in the Guidelines and no damage will be caused due to structural fatigue	Chapters 14 and 15 of CCS Guidelines for Shipboard Vibration Control
VIB (M)	Mechanical vibration	This notation may be assigned if related machineries of the ship meet the mechanical vibration requirements in the Guidelines and no damage due to mechanical fatigue or accelerated wear of moving parts will be caused	Chapters 14 and 15 of CCS Guidelines for Shipboard Vibration Control
VIB	Vibration	This notation may be assigned if the ship meets the requirements for both structural vibration VIB(S) and mechanical vibration VIB(M)	Chapters 14 and 15 of CCS Guidelines for Shipboard Vibration Control

1.2.2 The following corresponding class notations may be assigned to ships which the shipowners or shipyards apply voluntarily, subject to examination of vibration design and measurement results by CCS and after it is confirmed that the related measured vibration parameters meet the requirements of the Guidelines:

- (1) HAB (VIB): Class Notation of Habitability (for Vibration);
- (2) VIB (S): Class Notation of Structural Vibration;
- (3) VIB (M): Class Notation of Mechanical Vibration;
- (4) VIB: Class Notation of Vibration.

1.2.3 The final assignment of class notations of vibration is based on the design review and full-scale ship measurement. In order to make the measurement results meet the requirements, various elements influencing the vibration are to be controlled effectively.

1.2.4 Where CCS is authorized to issue maritime labour certificates to the ships, the vibration is to be in compliance with the relevant requirements of ISO 6954:2000 Mechanical Vibration—Guidelines for the Measurement, Reporting and Evaluation of Vibration with regard to Habitability on Passenger and Merchant Ships and Chapter 14 of the Guidelines; while the noise is to be in compliance with the relevant requirements of IMO Code on Noise Levels On Board Ships and Chapter 16, PART EIGHT of CCS Rules for Classification of Sea-going Steel Ships or is to be in accordance with the related noise provisions of the flag States.

### **1.32 Effective Means for Controlling Shipboard Vibration to Achieve the Anticipated Habitability**

1.32.1 The habitability of shipboard vibration (or comfort of vibration) is the general assessment of vibration conditions, the vibration phenomenon likely occurred is to be controlled case by case, to achieve the expected habitability vibration criteria,. Hence, the flow of vibration control in the Guidelines, including the control methods provided in each Chapter are the effective means to achieve the anticipated habitability of vibration.

1.32.2 The habitability of shipboard noise (or comfort of vibration) is the general assessment of noise conditions, the noise phenomenon likely occurred is to be controlled case by case, to achieve the expected habitability vibration criteria. Ship's noise includes mechanical noise, hydrodynamic noise and electromagnetic noise. Generally, ship's noise occurs accompanied with vibration. Hull and local structural vibrations induced by excitation of main, auxiliary engines and propellers are transmitted from foundations, hull structures to compartment periphery structures in an elastic wave mode and could radiate the secondary airborne noise. Hence, the flow of vibration control in the Guidelines, including the control methods provided in each Chapter are one of the effective means to achieve the anticipated habitability of noise.

### **1.43 Meaning of Vibration Criteria**

1.43.1 In addition to the definite requirements in CCS Rules for Classification of Sea-going Steel Ships, the related parts of the Guidelines provide the corresponding vibration criteria.

1.43.2 The ship's vibration criteria are the standards to evaluate the vibration in locations where the personnel normally work and accommodate onboard, other than those to accept or inspect the machinery equipment.

1.43.3 Vibration criteria in the Guidelines mean the following respectively:

- (1) Structure vibration criteria: related to structural fatigue cracks;
- (2) Mechanical vibration criteria: related to fatigue damage or acceleration wear-down of moving parts;
- (3) Habitability vibration criteria in accommodation and working spaces: related to acceptable vibration levels by crew and passengers;
- (4) Comfort vibration criteria in accommodation and working spaces: related to comfortable environment levels of related spaces as specified by classification societies;
- (5) Restriction of forces and moments: related to the induced excitation or response.

### **1.54 Relationship Between Shipboard Vibration and Excitation**

1.54.1 Due to the fact that a ship itself is a complex elastic system, vibration response of a certain local structure or equipment induced by excitation may be a secondary excitation of the other local structure or equipment and coupling relationship may exist between different kinds of vibrations. Therefore, the vibration relationship of each part onboard is also complicated, which should be noted by the designers at the very beginning.

1.54.2 The excitation sources of ship vibration include primary and secondary ones, which may cause the local or global vibration. For ships, both the vibrations caused by primary excitation source and the vibrations caused by secondary excitation source are required to be acceptable.

(1) The primary excitation mainly includes:

- excitation of unbalanced moment for main engine;

- excitation of poor shafting alignment;
- excitation of auxiliary engine;
- excitation of pump;
- excitation of motor;
- excitation of propeller (fluctuation pressure and bearing force);
- excitation of rudder;
- excitation of turbulence.

(2) The secondary excitation mainly includes:

- shafting longitudinal vibration;
- shafting torsional vibration;
- shafting whirling vibration;
- transverse vibration of diesel engine frame;
- longitudinal vibration of diesel engine frame.

(3) Wave is also a primary exciting force, the ship's vibration caused by wave may lead to adverse vibration, however, it may be minimized by the change of ship's speed and course. With the increase of ship's size, for ships of more than 300 m in length, the natural frequency of vertical vibration for hull girders will be decreased with the minimum one of 0.5 Hz, then wave may lead to hull vertical vibration - wave induced vibration. Therefore, the effects of wave induced vibration on hull strength are to be taken into consideration in ship's design.

(4) The exciting frequency of various excitation sources may see the relevant Chapters in the Guidelines.

1.54.3 In order to be beneficial to analyse, judge and prevent the adverse shipboard vibration, the basic concepts of relationship between main excitation sources and vibration bodies are to be established.

The relationship between excitation source and vibration for main diesel engine onboard ships is shown in Figure 1.54.3-1 and the relationship between excitation source and vibration for turbine engine or main electric propulsion engine onboard ships is shown in Figure 1.54.3-2.

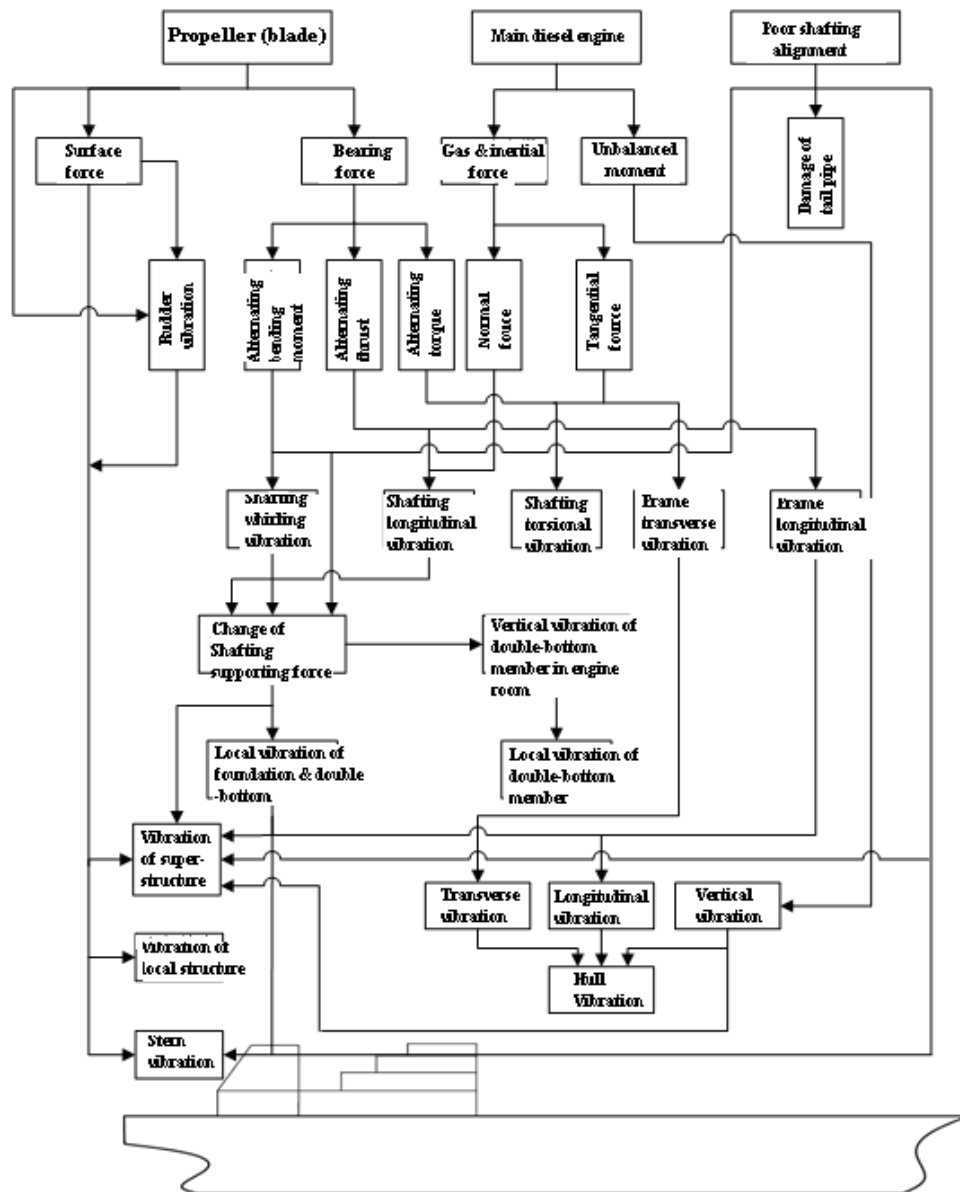
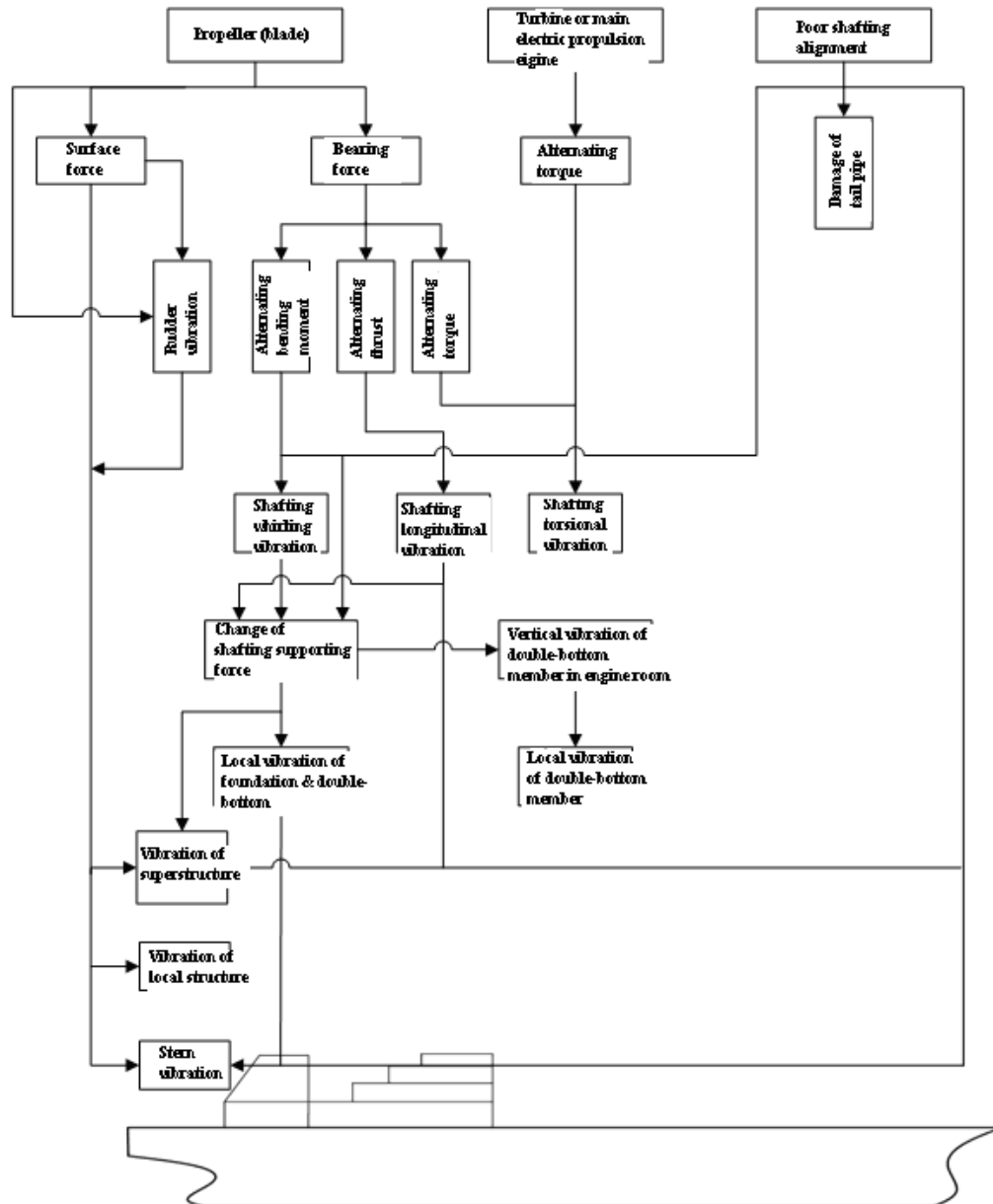


Figure 1.54.3-1 Relationship Between Excitation Source and Vibration for Main Diesel Engine



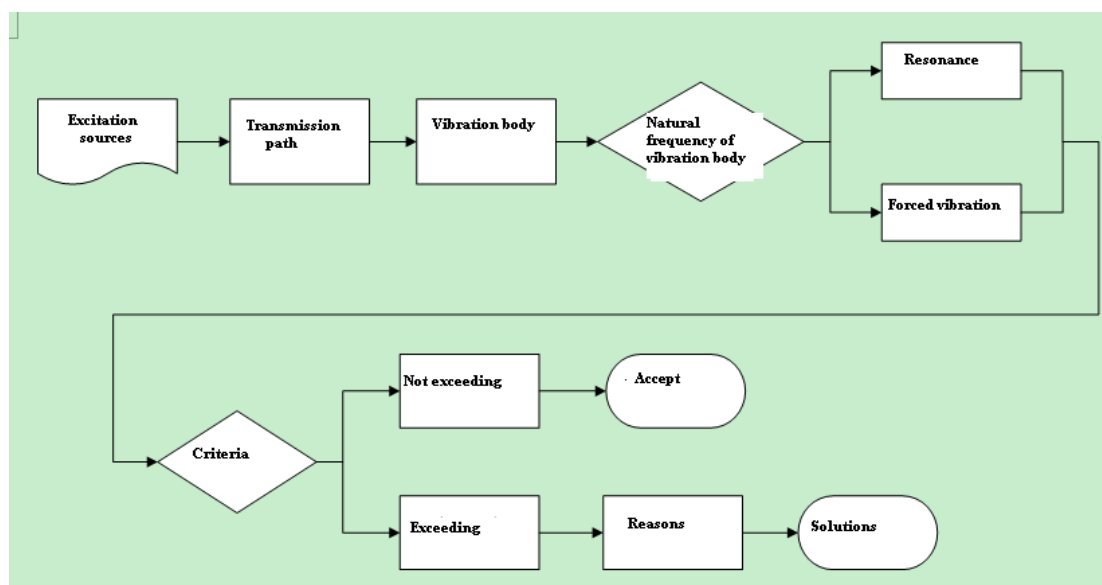
**Figure 1.54.3-2 Relationship Between Excitation Source and Vibration for Main Turbine Engine or Electric Propulsion**

### 1.65 Technical Routes to Research and Solve Shipboard Vibration

1.65.1 Where necessary vibration control is carried out in accordance with the requirements of the Guidelines, the adverse vibration may be prevented, and the anticipated vibration comfort of the ship may be achieved. However the shipboard vibration is to be researched and solved if adverse vibration is found by measurement or the anticipated vibration comfort is not achieved due to unexpected reasons.

1.65.2 The basic method to research and solve the shipboard vibration is first to analyse the primary and secondary excitation sources, then to study the transmission path of sources, and then to estimate the possibility of resonance together with the vibration body. For example, if resonance or forced vibration occurs, the criteria level is to be decided whether or not being exceeded, and if it exceeds the criteria, the reasons are to be investigated and the economical and effective

solutions are to be provided, as shown in Figure 1.65.2.



**Figure 1.65.2 Technical Routes to Solve Shipboard Vibration**

## 1.76 Basis of Vibration

### 1.76.1 Introduction

The actual vibration system is so complicated that full vibration analysis in accordance with its own conditions are not possible or necessary. For this purpose, a simplified mechanical model which represents an actual system is first to be established. Such model is to have the basic vibration characteristics of the original system and not so complicated. The simplification depends on the complexity, required analysis precision and calculation method of the original system.

Generally, the simplified model is divided into two categories, such as discrete system model and distribution system model, the discrete system model also includes lumped parameter model and finite element model.

The lumped parameter model consists of three basic elements, i.e. inertial element (concentrated mass), damping element (damper without mass) and elastic element (spring without mass) which are indicated as M, C and K respectively.

The distribution system model consists of distribution parameter element, which is normally a continuous elastomer with the mass and stiffness distributed homogeneously or regularly.

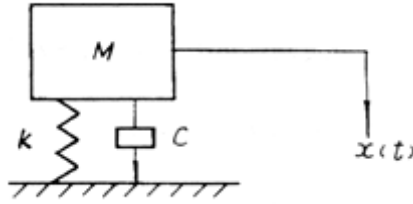
Obviously, for the same real system, various models according to the different needs may be simplified. In most circumstance, it may be multiple degree of freedom system which is similar to the discrete system, even may be simplified to single degree of freedom system.

In the vibration analysis, vibration of single degree of freedom system has the basic characteristics, by which may establish many basic concepts of vibration.

There are infinite natural frequencies for the distribution system theoretically, however only several lower-node/ lower-order natural frequencies and corresponding mode shape have practical significances.

### 1.76.2 Free vibration of single degree of freedom system

The single degree of freedom system is shown in Figure 1.76.2.1-1.



**Figure 1.76.2-1 Single Degree of Freedom System**

The equation of motion for single degree of freedom system is as follows:

$$M \ddot{x} + C \dot{x} + K x = 0 \quad (1.76.1)$$

where:  $M$  – mass, in kg;

$C$  – coefficient of viscous damping, in Ns/m;

$K$  – rigidity, in N/m,

$x$ 、 $\dot{x}$ 、 $\ddot{x}$  – displacement, in m, velocity, in m/s and acceleration, in  $\text{m/s}^2$  of mass  $M$  distanced from static balance location.

Where the damping of system is ignored, the vibration displacement  $x(t)$  with the time change may be shown as:

$$x(t) = A \sin(\omega_n t + \varphi_0) \quad (1.76.2)$$

where:  $A$  – amplitude of displacement, to be determined by the initial condition:

$\omega_n$  – natural circular frequency of system without damping:

$$\omega_n = \sqrt{\frac{K}{M}} \quad (1.76.3)$$

$\varphi_0$  – initial phase angle of free vibration without damping,  $\varphi_0 = \text{tg}^{-1} \frac{\omega_n x(0)}{\dot{x}(0)}$ .

where:  $x(0)$  — initial displacement as  $t = 0$ ;

$\dot{x}(0)$  — initial velocity as  $t = 0$ .

This is a harmonic vibration with the circular frequency  $\omega_n$ , depending on the mass and stiffness of the system, not related to the initial conditions. Where the damping is considered, the formula (1.76.1) is to be changed to:

$$\ddot{x} + 2\xi\omega_n \dot{x} + \omega_n^2 x = 0 \quad (1.76.4)$$

where:  $\xi$  – damping ratio, calculated as:

$$\xi = \frac{C}{2M\omega_n} = \frac{C}{2\sqrt{MK}} \quad (1.76.5)$$

In the most engineering issues, the damping ratio  $\xi$  is far less than 1, then the change of vibration displacement with the time may be shown as:

$$x(t) = A_1 e^{-\xi\omega_n t} \sin(\omega_d t + \varphi_1) \quad (1.76.6)$$

where:  $A_1$  — amplitude, calculated as:

$$A_1 = \sqrt{[x(0)]^2 + \frac{1}{\omega_d^2} [\dot{x}(0) + \xi \omega_n x(0)]^2}$$

$\omega_d$  — for system with natural circular frequency of damping:

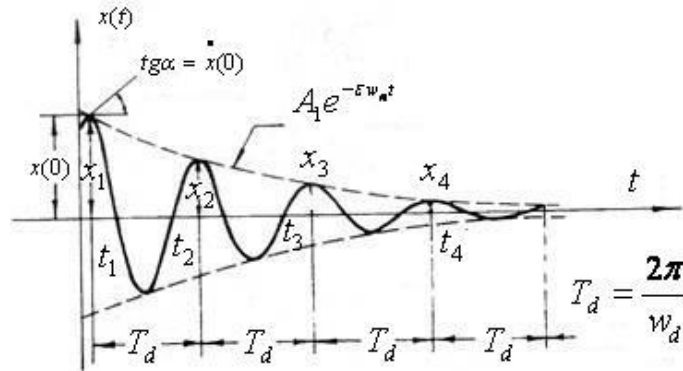
$$\omega_d = \omega_n \sqrt{1 - \xi^2} \quad (1.76.7)$$

$\phi_1$  — for system with initial phase angle of free vibration of damping, to be calculated by:

$$\phi_1 = \text{tg}^{-1} \left( \frac{\omega_d x(0)}{\dot{x}(0) + \xi \omega_n x(0)} \right)$$

Others are same as formula (1.76.2).

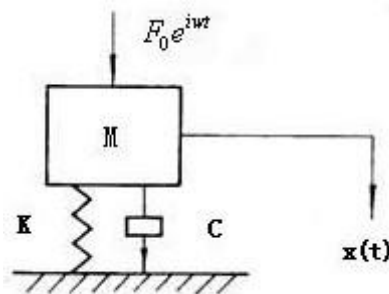
This is a vibration which the amplitude value decays with the time change based on the exponential rules, the time history is shown in Figure 1.76.2-2, circular frequency of vibration  $\omega_d$  is less than  $\omega_n$ . However, in practice, the minor difference may not be considered.



**Figure 1.76.2-2 Free Vibration with Damping**

### 1.76.3 Vibration response under harmonic excitation for single degree of freedom system

The single degree of freedom system with damping under the harmonic excitation is shown in Figure 1.7.3-1.



**Figure 1.76.3-1 Single Degree of Freedom System with Damping under Harmonic Excitation**

The equation of motion for single degree of freedom system under harmonic excitation is as follows:

$$M \ddot{x} + C \dot{x} + K x = F_0 e^{i\omega t} \quad (1.76.8)$$

where:  $F_0$  — amplitude value of excitation;

$\omega$  — circular frequency of excitation;

Others are same as formula (1.76.1).

The steady-state vibration response is as:

$$x(t) = A_2 e^{i(\omega t - \varphi_2)} \quad (1.76.9)$$

where:  $A_2$  — amplitude:

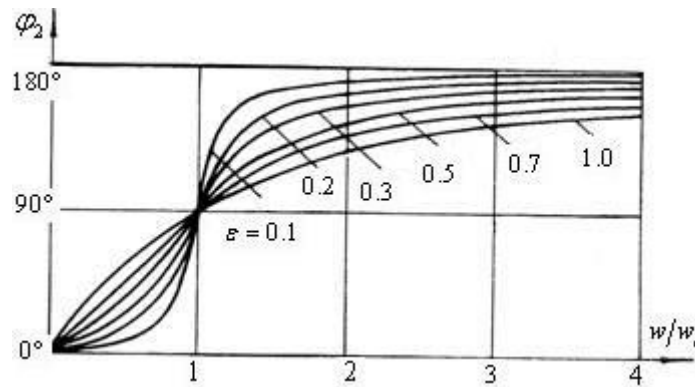
$$A_2 = \frac{A_{st}}{\sqrt{\left(1 - \frac{\omega^2}{\omega_n^2}\right)^2 + \left(2\xi \frac{\omega}{\omega_n}\right)^2}} \quad (1.76.10)$$

where:  $A_{st} = \frac{F_0}{K}$  — static displacement;

$\varphi_2$  — initial phase angle of forced vibration, to be calculated as:

$$\varphi_2 = \text{tg}^{-1} \left( \frac{2\xi (\omega/\omega_n)}{1 - (\omega/\omega_n)^2} \right) \quad (1.76.11)$$

The change of  $\varphi_2$  with frequency ratio is indicated by the curve of phase frequency characteristic, as shown in Figure 1.76.3-2.



**Figure 1.76.3-2 Curve of Phase Frequency Characteristic**

The vibration response of system is to be shown by dynamic amplification factor  $T_m$  :

$$T_m = \frac{A_2}{A_{st}} = \frac{1}{\sqrt{\left(1 - \frac{\omega^2}{\omega_n^2}\right)^2 + \left(2\xi \frac{\omega}{\omega_n}\right)^2}} \quad (1.76.12)$$

The change for  $T_m$  with ratio of  $\omega/\omega_n$  is indicated by the curve of amplitude frequency characteristic, as shown in Figure 1.76.3-3.

Where  $\omega/\omega_n = 1$ , the formula (1.7.12) may be as follows:

$$T_m = \frac{1}{2\xi} = Q \quad (1.76.13)$$

where:  $Q$  — quality factor to describe the damping characteristic of system.

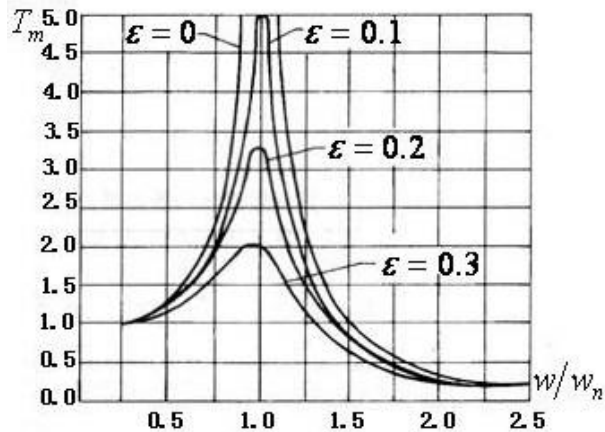


Figure 1.76.3-3 Curves of Amplitude Frequency Characteristic

### 1.87 Definitions and Vibration Parameters

1.87.1 For the purpose of the Guidelines, the following main terms are defined:

- (1) Displacement: means vector for distance change of targeted objects or particles relative to a certain referred position, in mm.
- (2) Velocity: means vector of targeted displacement relative to time coefficient, in m/s.
- (3) Acceleration: means vector of targeted velocity relative to time coefficient, in  $m/s^2$ .
- (4) System: means combination of the related parts to complete certain functions.
- (5) Vibration: means a phenomenon that the magnitude to describe the motion or position of mechanical system alternatively changes with the time relative to a certain average value either large or small.
- (6) Periodic vibration: means a period of the argument that reoccurs with the increase in a certain same time.
- (7) Vibration system: means any system either with or without damping and including mass and rigidity.
- (8) Steady-state vibration: means the continuous periodic vibration.
- (9) Harmonic vibration: means vibration changes with the time  $t$  in accordance with harmonic function rule.
- (10) Excitation: means external force or other inputs on the system.
- (11) Harmonic order or number of vibration: means number of harmonic waves for each speed of shafting or the value of vibration frequency divided by the speed of shafting.
- (12) Blade order: the harmonic order of exciting force caused by blades of propeller in uneven wake field is the integral multiple of number of blades may be called blade order, twice blade order, etc.
- (13) Blade order frequency: the frequency of exciting force caused by blades of propeller in uneven wake field is the blade order multiplying with revolution frequency of propeller.
- (14) Response: means the output of system which is effected by excitation.
- (15) Free vibration: means vibration occurs after the excitation or restraining is removed.
- (16) Forced vibration: means steady-state vibration caused by steady-state excitation.
- (17) Frequency: means number of vibration at time unit, in Hz for number of vibration at each second, in  $l/min$  for number of vibration at each minute.
- (18) Natural frequency: means vibration frequency determined by the mass and stiffness of system.

In general, n-degree of freedom system has n natural frequency and is arranged in the order from small to large, which is called 1st node/order natural frequency, 2nd node/order (node) natural frequency, n<sup>th</sup> node/order (node) natural frequency, etc.

(19) Vibration mode: means a targeted vibration characteristic, which is determined by characteristic value and the corresponding characteristic vector of the system.

(20) Amplitude of vibration: means the maximum value of harmonic vibration.

(21) Relative amplitude: means the ratio between amplitude at a certain point and that at a referred point.

(22) Mode shape: means a certain vibration mode, which is a graph to show the relative amplitude of each point.

(23) Node: means the position which the relative amplitude is zero for a certain mode shape of the system.

(24) Wave loop: means the position which the relative amplitude is the maximum for a certain mode shape of the system.

(25) Resonance: means vibration state which any minor change of exciting frequency will decrease the response of system during the forced vibration.

(26) Resonance frequency: means frequency as the resonance occurs.

(27) Resonance speed: means the speed at which the resonance is excited, is also called critical speed.

(28) Circular frequency: means number of vibration at each  $2\pi$  second, in rad/s or l/s, is also called circular frequency.

(29) Phase: means advanced cycle numerical of periodic function when measurement is taken as a certain value of argument is used as a basic one, in degree, is also called phase angle.

(30) Phase difference: means difference of phase angles with same frequency between two periodic functions, is called as phase angle difference.

### 1.8.7.2 Vibration parameters

#### (1) Main vibration parameter

In the Guidelines, ship's habitability (vibration) applies RMS velocity as the main parameter to evaluate the shipboard vibration.

Local structure and mechanical vibration apply displacement amplitude of vibration, amplitude of velocity or amplitude of acceleration as the main parameters to evaluate the shipboard vibration respectively. The displacement is applicable to the lower frequency, velocity is applicable to the higher frequency, and acceleration is applicable to even higher frequency.

The stress, torque, amplitude or frequency of vibration are applied as the main parameters to evaluate the shafting vibration.

#### (2) Relationship between vibration parameters

$$\text{Displacement: } x = A \sin \omega_n t$$

$$\text{Velocity: } v = \omega_n A \sin \left( \omega_n t + \frac{\pi}{2} \right)$$

$$\text{Acceleration: } a = \omega_n^2 A \sin(\omega_n t + \pi)$$

where:  $A$ — amplitude of vibration, in mm;

$\omega_n$ — vibration frequency, in rad/s;

$t$ — time, in s.

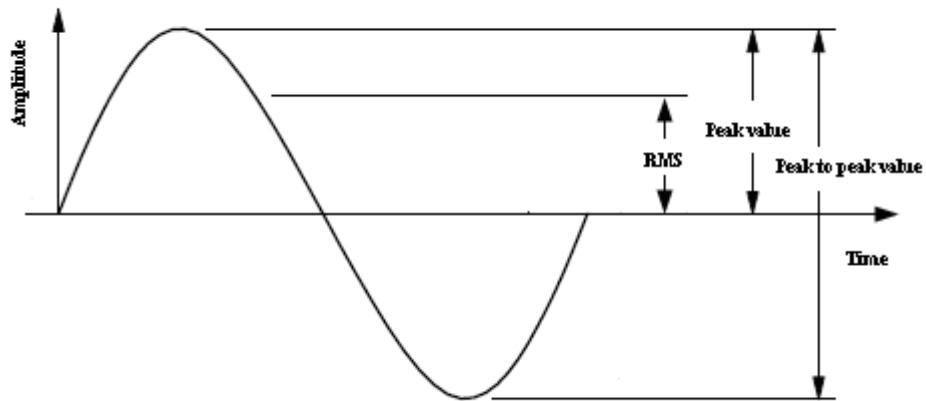
#### (3) Relationship among amplitude of vibration and RMS, etc.

For the sinusoidal curve, the relationship among amplitude of vibration (peak value), peak to peak value and RMS parameters is shown in Figure 1.87.2.

Peak to peak value =  $2A$  ;

Peak value or amplitude =  $\frac{1}{2}$  (peak to peak value) =  $\pm A$ ;

$\text{RMS} = \frac{1}{\sqrt{2}} A$ .



**Figure 1.87.2 Relationship among Amplitude of Vibration and RMS, etc.**

## Chapter 15 CLASS NOTATIONS CRITERIA OF VIBRATION

### 15.1 Introduction

15.1.1 For the purpose of improving the crew's accommodation condition and working condition onboard ships, ISO 6954-1984 Mechanical Vibration and Shock – Guidelines for the Overall evaluation of Vibration in Merchant Ships and ISO 6954-2000 Mechanical Vibration — Guidelines for the Measurement, Reporting and Evaluation of Vibration With Regard to Habitability on Passenger and Merchant Ships are the habitability criteria applicable to vibration acceptable to crew and passengers. From point of view of vibration influence on personnel, the habitability criteria may ensure the comfort and health for personnel, where the vibration limits are not exceeded, a health damage will normally not occur.

15.1.2 Comfort vibration criteria for passenger's and crew's accommodation spaces and working spaces are the description of different grades of comfort environment as required in classification societies' rules based on the habitability criteria.

15.1.3 The vibration habitability and vibration comfort criteria do not reflect the issue of fatigue crack induced by hull structural vibration or the issue of fatigue damage or accelerated wear of movable component caused by mechanical vibration. Therefore, the issues for hull structure vibration criteria and mechanical vibration criteria are put forward.

### 15.2 Habitability Vibration Criteria

15.2.1 Habitability criteria for crew and passengers by ISO 6954-1984:

ISO 6954-1984 may be used for evaluation of the vibration of normal working and accommodation spaces of hull and superstructures for personnel, as shown in Table 15.2.1-1 and Figure 15.2.1, which, however, is not regarded as the standards for acceptance or survey of machinery and equipment. ISO 6954-1984 takes the peak values of displacement, speed or acceleration of each measuring point within the frequency range of 1 Hz~100 Hz as the evaluation indexes, regardless of vertical, longitudinal or transverse vibration, and the evaluation may be conducted by means of curves.

In the curve, the upper and lower margin lines are the constant acceleration line when  $\leq 5$  Hz, it is, or being the constant velocity line when  $\geq 5$  Hz. The measured vibration response under the lower margin line is the minor vibration and indicates that the ship's vibration characteristics are in good state; the measured vibration response above the upper margin line is the vibration unacceptable and unsatisfactory; the banded zone between the two margin lines is the vibration which may be generally felt but still acceptable.

Such criteria evaluate the shipboard vibration based on maximum repetitive value, where the measured value is *rms*, it is to be converted to the equivalent maximum repetitive value in accordance with the following formula, as to compare with the curve:

$$\text{The maximum repetitive value} = (C_F \sqrt{2}) \times rms \quad (15.2.1)$$

where:  $C_F \sqrt{2}$  — equivalent to crest factor ( $C_F = 1.0$  means pure steady sinusoidal vibration).

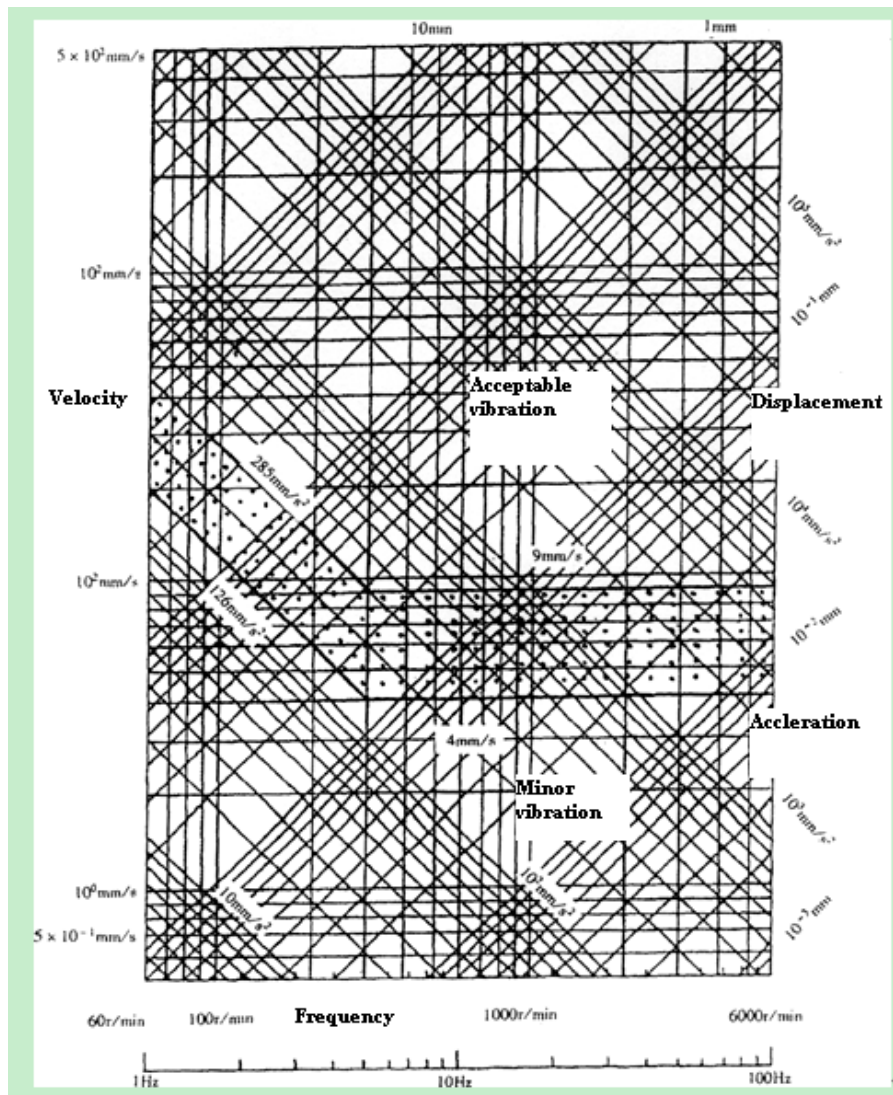
The corresponding conversion coefficient  $C_F$  is to be determined by measurement or assuming  $C_F = 1.8$ .

The evaluation process is different from ISO 2631-2, hence, causing ISO 6954 to be revised.

**Habitability Criteria Required by ISO 6954-1984**

**Table 15.2.1-1**

Curve	Frequency range	
	1 Hz~5 Hz	5 Hz~100 Hz
Upper margin	Peak acceleration = 285 mm/s <sup>2</sup>	Peak acceleration = 9 mm/s
Lower margin	Peak acceleration = 126 mm/s <sup>2</sup>	Peak acceleration = 4 mm/s



**Figure 15.2.1 Vibration Evaluation Criteria Required by ISO 6954-1984**

15.2.2 Habitability criteria for crew and passenger required by ISO 6954-2000:

(1) Application

ISO 6954-2000 reflects new research results on the vibration sensitivity of human beings, which is applicable to criteria of vibration evaluation related to habitability onboard passenger ships and merchant ships. The evaluation of motion sickness caused by low frequency motion may be referred to the other international standards.

(2) Habitability vibration criteria

The vibration levels in ISO 6954-2000 mean the root-mean-square of vibration frequency weighted acceleration or the root-mean-square of velocity within the frequency range of 1 Hz to 80 Hz, which are called full frequency weighted RMS acceleration or velocity. The full frequency

weighted RMS value is no longer a peak one.

Three different zones onboard, such as Zone A (passenger space), Zone B (crew space) and Zone C (working space) are divided by ISO 6954-2000, with the habitability vibration criteria of frequency weighted RMS in different zones shown in Table 15.2.2-1.

**Habitability Vibration Criteria of Frequency Weighted RMS within the Range of 1 Hz to 80 Hz in Different Zones** **Table 15.2.2-1**

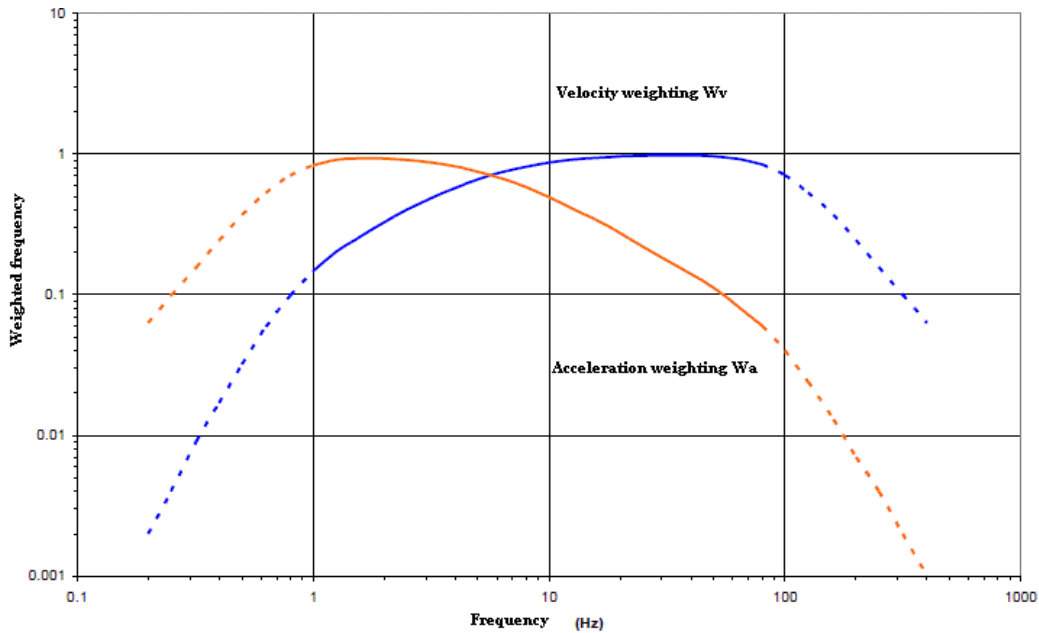
Parameter Evaluation	Category of zone					
	A (passenger space)		B (crew space)		C (working space)	
	Acceleration (mm/s <sup>2</sup> )	Velocity (mm/s)	Acceleration (mm/s <sup>2</sup> )	velocity(m/s)	Acceleration(mm/s <sup>2</sup> )	Velocity (mm/s)
A problem if greater than the value	143.0	4.0	214.0	6.0	286.0	8.0
No problem if less than the value	71.5	2.0	107.0	3.0	143.0	4.0

(3) Weighting function

The synthetic weighting curve in ISO 2631-2 is to be used for weighting function, as shown in Table 15.2.2-2 or Figure 15.2.2, the weighting function applies to all directions.

**Frequency Weighting within 1/3 Times Frequency Range of 1 Hz to 80 Hz** **Table 15.2.2-2**

Band Hz	Velocity weighting Wv	Acceleration weighting Wa	Band Hz	Velocity weighting Wv	Acceleration weighting Wa
0.20	0.00221	0.0629	10.00	0.869	0.494
0.25	0.00439	0.0994	12.50	0.911	0.411
0.32	0.00870	0.156	16.00	0.941	0.337
0.40	0.0170	0.243	20.00	0.961	0.274
0.50	0.0325	0.368	25.00	0.973	0.220
0.63	0.0589	0.530	31.50	0.979	0.176
0.80	0.0979	0.700	40.00	0.978	0.140
1.00	0.147	0.833	50.00	0.964	0.109
1.25	0.201	0.907	63.00	0.925	0.0834
1.60	0.260	0.934	80.00	0.844	0.0604
2.00	0.327	0.932	100.00	0.706	0.0401
2.50	0.402	0.910	125.00	0.533	0.0241
3.15	0.485	0.872	160.00	0.370	0.0133
4.00	0.573	0.818	200.00	0.244	0.00694
5.00	0.661	0.750	250.00	0.156	0.00354
6.30	0.743	0.669	315.00	0.0995	0.00179
8.00	0.813	0.582	400.00	0.0630	0.00899



**Figure 15-2-2 Weighted Function Curve Required by ISO 6954-2000**

(4) Full frequency weighted value

The full frequency weighted value is to be determined by:

$$a_w = \sqrt{\sum_i a_{wi}^2}$$

where:  $a_w$  — acceleration or velocity of frequency weighting;

$a_{wi}$  — acceleration or velocity of  $i$  times weighting within 1/3 times frequency range.

15.2.3 The general range of above-mentioned zones is as follows:

- (1) Passenger space: means the spaces provided for passengers, including public spaces (e.g. mess room, clinic, living room, reading and game room, fitness room, corridor, shop) and leisure zone on weather deck.
- (2) Crew space: means the spaces provided for crew, including accommodation space (e.g. cabin, radio room, clinic, office, laundry, mess room, leisure room) and bridge space (including navigation bridge, radar room, monitoring position, bridge wings).
- (3) Working space: means the spaces provided for crew to work, including workshop, engine room control cabin.

15.2.4 ISO 6954-2000 may also be applicable to other ships as requested by shipowners.

15.2.5 In application of the habitability criteria of ISO 6954-2000 for crew and passengers, the frequency weighted accelerated velocity RMS is used within the scope of 1 Hz to 5 Hz, and the frequency weighted velocity RMS is used within the scope of 5 Hz to 80 Hz.

### 15.3 Structural Vibration Criteria

15.3.1 Notwithstanding the compliance with shipboard habitability criteria, the adverse vibration in other zones not covered by the criteria are likely to occur, such as tank structure, or other structural members in stern and engine room, etc., For the purpose of avoiding occurrence of excessive vibration to reduce the risk of structure damage, structural vibration criteria has been provided. The consideration of prevention of structural fatigue cracks induced by vibration is

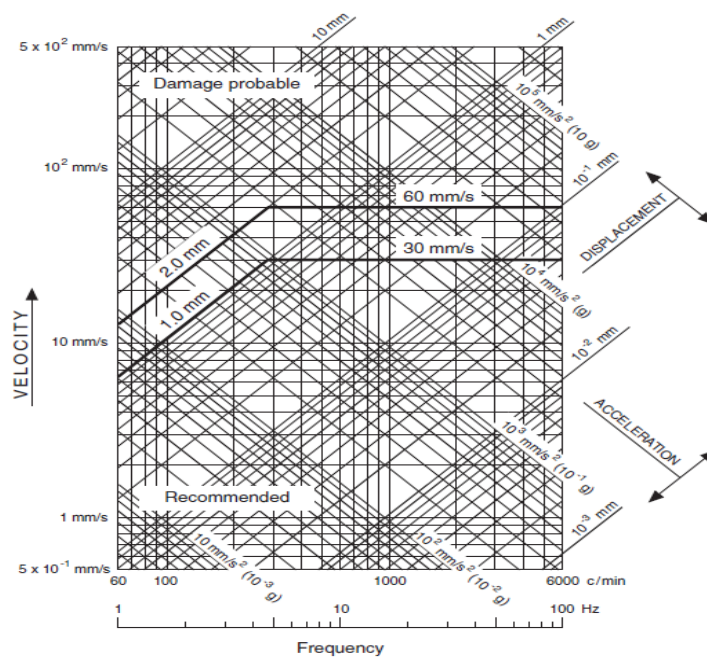
mainly given in structural vibration criteria, while the primary factors affecting the structural fatigue strength are:

- (1) vibration mode;
- (2) structural details (stress concentration);
- (3) material;
- (4) welding procedure;
- (5) manufacturing processing;
- (6) environment (corrosion medium).

15.3.2 The structural vibration parameters apply displacement, velocity or acceleration amplitude (peak values) as characteristics. Displacement or acceleration amplitude is used for vibration frequency within the range of 1 Hz to 5 Hz; velocity amplitude is used for vibration frequency within the range of 5 Hz to 100 Hz.

15.3.3 Unless otherwise agreed, the vertical, transverse or longitudinal vibration displacement or velocity amplitude of each point for the values of hull structural vibration criteria is to be generally controlled within the following range, as shown in Figure 15.3.3:

- (1) within the frequency range of 1 Hz to 5 Hz: less than 1.0 mm to be recommended; damage may occur when more than 2.0 mm;
- (2) within the frequency range of 5 Hz to 100 Hz: less than 30 mm/s to be recommended; damage may occur when more than 60 mm/s.



**Figure 15.3.3 Structural Vibration Evaluation Benchmark**

15.3.4 Unless otherwise agreed, the vertical, transverse or longitudinal vibration parameters of each point for the values of hull structural vibration criteria of high-speed craft, light ships and surface naval ships of more than 35 m in length are to be generally controlled within the range as shown in Table 15.3.4.

**Values of Hull Structural Vibration Criteria for High-Speed Craft, Light Ships and Surface Naval Ships**

**Table 15.3.4**

Zone		Frequency range of 1 Hz to 5 Hz		Frequency range of 5 Hz to 100 Hz
		Acceleration (mm/s <sup>2</sup> )	Displacement (mm)	Velocity (mm/s)
Main zone: deck which may be generally accessible by personnel and the structure installed with equipment		160	—	5
Stern zone: deck which may be generally accessible by personnel and the structure installed with equipment		220	—	7
Mast top zone		—	—	15
Other structures not influencing the comfort or skilled operation by personnel and not installing with essential equipment, such as hold/tank, void space, etc.	Steel	—	1.0	30
	Aluminium alloy	—	0.33	10

**15.4 Mechanical Vibration Criteria**

15.4.1 In order to avoid the fatigue damage of machineries or accelerated wear of moving parts, the mechanical vibration parameters are to be controlled.

15.4.2 The mechanical vibration parameters apply displacement amplitude, velocity amplitude or acceleration amplitude (peak values) as characteristics.

15.4.3 Unless otherwise agreed, the mechanical vibration is not to exceed the values of vibration criteria as shown in Table 15.4.3.

**Mechanical Vibration Criteria**

**Table 15.4.3**

Equipment	Frequency (Hz) and displacement (mm)	Frequency (Hz) and velocity (mm/s)	Remark
Low-speed diesel engine	1 Hz to 2.4 Hz 1.5 mm for vertical or longitudinal direction; 1.0 mm for transverse direction	2.4 Hz to 100 Hz 10 mm/s for vertical or longitudinal direction; 25 mm/s for transverse direction	See 5.5.3 of the Guidelines
Medium and high-speed diesel engine	—	4.8 Hz to 100 Hz 15 mm/s for fixedly installed; 25 mm/s for elastically installed	
Generator driven by diesel engine and motor for propulsion	—	4 Hz to 100 Hz 18 mm/s	Applying for fixedly and elastically installed
Generator driven by turbine	—	4 Hz to 1000 Hz 7 mm/s	Applying to fixedly installed and elastically installed
Supercharged engine	3 Hz to 4.8 Hz 1.0 mm	4.8 Hz to 26.5 Hz 30 mm/s	
Turbine	—	5 Hz to 1000 Hz 5 mm/s	Applying to fixedly installed and elastically installed
Main driving gear box	—	4 Hz to 1000 Hz 7 mm/s	
Shafting bearing	1 Hz to 2 Hz 0.4 mm	2 Hz to 100 Hz 5 mm/s	
Motor, separator, hydraulic driving motor, fan	—	4 Hz to 200 Hz 7 mm/s	
Screw type or centrifugal compressor	—	4 Hz to 200 Hz 7 mm/s for fixedly installed; 10 mm/s for elastically installed	
Reciprocating compressor	—	4 Hz to 200 Hz 30 mm/s	Applying to fixedly installed and elastically installed

15.4.4 Unless otherwise agreed, the mechanical vibration of high-speed craft, light ships and surface naval ships of more than 35 m in length is not to exceed the values of vibration criteria as shown in Table 15.4.4.

**Mechanical Vibration Criteria of High-Speed Craft, Light Ship and Surface Naval Ship**

**Table 15.4.4**

Equipment	Frequency and displacement	Frequency and velocity	Remark
Medium and high-speed diesel engine	1 Hz to 4.8 Hz 0.5 mm	4.8 Hz to 100 Hz 15 mm/s	
Generator driven by diesel engine	1 Hz to 3.2 Hz 0.5 mm	3.2 Hz to 100 Hz 10 mm/s	
Generator driven by turbine	1 Hz to 2 Hz 0.4 mm for rigidly installed; 0.8 mm for elastically installed	2 Hz to 100 Hz 5 mm/s for rigidly installed; 10 mm/s for elastically installed	
Supercharged engine	3 Hz to 4.8 Hz 1.0 mm	4.8 Hz to 26.5 Hz 30 mm/s	26.5 to 300 Hz 5g for acceleration
Turbine	—	5 Hz to 1000 Hz 5 mm/s	
Gear	—	5 Hz to 1000 Hz 5 mm/s	
Shafting bearing	1 Hz to 2 Hz 0.4 mm	2 Hz to 100 Hz 5 mm/s	
Motor, separator, hydraulic driving motor, fan	1 Hz to 2 Hz 0.4 mm	2 Hz to 100 Hz 5 mm/s	
Screw type or centrifugal compressor	—	4 Hz to 200 Hz 7 mm/s for fixedly installed; 10 mm/s for elastically installed	
Reciprocating compressor	1 Hz to 3.2 Hz 0.5 mm	3.2 Hz to 100 Hz 10 mm/s	

### **15.5 Assignment for Class Notations of Vibration**

15.5.1 ~~CCS class notations related to vibration and meanings are given in Table 1.2.1, Chapter 1 of the Guidelines.~~

15.5.2 ~~Upon the application by shipyard or shipowner and after the vibration design and measurement results haven been examined by CCS to confirm that the measured vibration parameters meet the relevant requirements of this Chapter, the following corresponding class notation may be assigned:~~

- ~~(1) HAB (VIB): class notation of habitability (vibration), meeting the requirements of 15.2 in this Chapter;~~
- ~~(2) VIB (S): class notation of structural vibration, meeting the requirements of 15.3 in this Chapter;~~
- ~~(3) VIB(M): class notation of mechanical vibration, meeting the requirements of 15.4 of this Chapter;~~
- ~~(4) VIB: class notation of vibration, meeting the requirements of 15.3 and 15.4 in this Chapter.~~

15.5.3 ~~When applying for class notation of vibration, the following information is to be provided to CCS for examination, the Analysis Report of Shipboard Vibration Calculation is to be submitted together with the drawings:~~

- ~~(1) Analysis Report of Shipboard Vibration Calculation (for information);~~
- ~~(2) Shipboard Vibration Measurement Program (for approval);~~
- ~~(3) Shipboard Vibration Measurement Report (for approval).~~

~~15.5.4 For ships applying for CCS class notation of vibration, the vibration measuring organization is to be recognized by CCS. The organization is to be capable of preparing the Shipboard Vibration Measurement Report required by Chapter 14 in the Guidelines.~~

~~15.5.5 The Shipboard Vibration Measurement Program is to be submitted to CCS for approval at least three months before the vibration measurement.~~

~~15.5.6 The shipyard is to submit the Shipboard Vibration Measurement Report and carry out the vibration state assessment, in conjunction with the Analysis Report of Shipboard Vibration Calculation. Where the requirements are not complied with, improvement measures are to be provided and to be confirmed by measurement.~~

~~15.5.7 Parties concerned are to confirm measurement conditions and measurement data, and to endorse on the corresponding records.~~

~~15.5.8 After confirmation by CCS that the shipboard vibration parameters comply with the relevant requirements of this Chapter, the corresponding class notation is to be affixed to the characters of classification.~~

#### **15.6 Maintenance for Class Notations of Vibration**

~~15.6.1 The information required in 15.5.3 is to be kept onboard ships for examination.~~

~~15.6.2 For ships assigned with class notation of vibration, if a ship has been converted or modified or repaired, including the renewal of essential machineries which may influence the vibration onboard ships, measurement is to be carried out. Depending on the vibration evaluation, CCS will arrange measuring points in the selected typical spaces and machineries to carry out vibration measurement in order to confirm whether it is still in compliance with the requirements of this Chapter.~~

~~15.6.3 In annual surveys, confirm that no conversion, modification or repair which may influence the vibration characteristics is to be made onboard the ship.~~

~~15.6.4 In renewal surveys, shipboard vibration is to be evaluated. Where any vibration phenomenon or alteration which may influence vibration level is found, a vibration measurement for related equipment is to be carried out.~~

~~15.6.5 In vibration measurement, measuring points are to be arranged in the selected typical spaces and machineries, as to confirm whether the vibration state is still in compliance with the requirements of this Chapter.~~