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Guidelines for Offshore Floating Wind Turbine Structures

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Introduction

Recently, potency of wind power generation is recognized as one of the leading renewable energy sources, and the number of wind turbines is increasing.

In Europe, introduction of the wind turbines are very progressive, and many turbines have been already installed in the most of proper locations on shore. Therefore, a big project to install wind turbines on the ocean is going on, and on the North Sea coast, which is shallow to a considerable distance from the shore, many wind farms driven by offshore fixed wind turbines are being constructed. Also, floating wing turbines are tested in the field now, and we believe that they will be used as a commercial machine in the near future.

In Japan, although introduction of the wind turbines are not so progressive like in Europe, more and more people recognize the importance of the wind turbines. However, since the size of the turbines gets bigger, and places for the wind turbines get fewer, a cost to build a wind turbine on land is going up. As a result, offshore wind turbines come under the spotlight in recent years.

Unlike the European seas, Japanese seas do not have many shallow areas, which are suitable for installation of the offshore fixed wind turbines. In Japan, many discussions on the floating wind turbines are continuing, and a project to operate a field test of the several floating wind turbines is now going on.

In case of offshore floating wind turbines, wind turbine is installed on a moored floating structure. In this case, the floating wind turbine must be treated as not only a simple wind turbine, but also as an offshore structure which has the wind turbine.

Nippon Kaiji Kyokai has prepared this “Guidelines for Offshore Floating Wind Turbine Structures,” in the expectation that it will be used as a safety guideline for design of the floating structures for the offshore wind turbines.

We hope this guideline provides you with useful information for safe and reasonable design of the floating structures for the offshore wind turbines, and contribute to parties concerned.

Guidelines for Offshore Floating Wind Turbine Structures

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Guidelines for Offshore Floating Wind Turbine Structures

Chapter 1 General

1.1 General

1.1.1 Application

-1. This guideline defines requirements of the materials, welding, stability, construction, equipment, machinery installations, electrical installations, mooring, and draft lines of the floating structures for the offshore wind turbines which are positioned at an offshore wind turbine site permanently or for long periods of time (hereinafter referred to as "Floating Structures"), and also of the materials, welding, and construction of the towers installed on the Floating Structures.

-2. This guideline is applied to the offshore wind turbines unattended except at the time of maintenance or inspection in principle.

-3. This guideline is for the Floating Structures located in the sea areas of which depth is not affected by the seabed. If a floating structure is installed in the sea area of which depth may be affected by the seabed, the shallow water effect is to be considered appropriately.

-4. Attention is to be paid to complying with the National Regulations of the coastal state in which the structure is located.

1.1.2 Equivalency

Floating Structures and towers which do not comply with some of the requirements given in this Guideline may be accepted provided that they are deemed by the Society to be equivalent to those specified in this Guideline.

1.1.3 Floating Structures with novel design features

With respect to Floating Structures of different types or with different systems from those specified in this Guideline, the required construction, equipment, and installation are to be specified respectively based upon the fundamental concepts found in the requirements given in this Guideline.

1.1.4 Design life

The design life of the Floating Structures and towers is to be the period of use defined in the design specification of the offshore wind turbines to be installed or 20 years, which is greater.

1.1.5 Wind turbine generator system

The wind turbine generator systems installed on the Floating Structures is to be at the discretion of the Society.

1.1.6 Machinery installations and electrical installations loaded on Floating Structures

The machinery installations and electrical installations related to safety of the Floating Structures are to be in accordance with the **Rules for the Survey and Construction of Steel Ships: Part D** and **Part H**.

1.1.7 Fire extinguishing systems

Corresponding to the machinery installations and electrical installations to be installed on the Floating Structures, proper fire extinguishing systems are to be prepared.

1.2 Definitions

1.2.1 Terms and definitions

The definitions and the terms given in this Guideline are as specified below:

1.2.1.1 Co-directional (wind and waves)

Acting in the same direction

1.2.1.2 Current

Flow of water past a fixed location usually described in terms of a current speed and direction

1.2.1.3 Design wave

Deterministic wave with a defined height, period and direction, used for the design of a Floating Strucures and tower. A design wave may be accompanied by a requirement for the use of a particular periodic wave theory.

1.2.1.4 Designer

Party or parties responsible for the design of a Floating Structures and tower

1.2.1.5 Environmental conditions

Characteristics of the environment (wind, waves, sea currents, water level, sea ice, marine growth, scour and overall seabed movement, etc.) which may affect the offshore wind turbine behaviour

1.2.1.6 External conditions (Floating Structures and tower)
Factors affecting an offshore wind turbine, including the environmental conditions and other climatic factors (temperature, snow, ice, etc.)

1.2.1.7 Extreme significant wave height
Expected value of the significant wave height, extrapolated from the distribution of extreme values of significant wave height at the field, with an annual probability of exceedance of 1/N ("recurrence period": N years)

1.2.1.8 Extreme wave height
Expected value of the highest individual wave height (generally the zero up-crossing wave height) with an annual probability of exceedance of 1/N ("recurrence period": N years)

1.2.1.9 Fast ice cover
Rigid continuous cover of ice not in motion

1.2.1.10 Fetch
Distance over which the wind blows constantly over the sea with approximately constant wind speed and direction

1.2.1.11 Highest astronomical tide
Highest still water level that can be expected to occur under any combination of astronomical conditions and under average meteorological conditions. Surges, which are meteorologically generated and essentially irregular, are superimposed on the tidal variations, so that a total still water level above highest astronomical tide may occur.

1.2.1.12 Hub height (wind turbines)
Height of the centre of the swept area of the wind turbine rotor above the mean sea level

1.2.1.13 Hummocked ice
Crushed ice and ice floes piled up into ridges when large ice floes meet with each other or with a rigid obstacle, for example a Floating Structure

1.2.1.14 Ice floe
Sheet of ice in size from metres to several kilometres, not rigidly frozen to a shore, still or in motion

1.2.1.15 Icing
Build-up of a cover of ice or frost on parts of an offshore wind turbine that can result in added loads and/or changed properties

1.2.1.16 Load effect
Effect of a single load or combination of loads on a structural component or system, for example internal force, stress, strain, motion, etc.

1.2.1.17 Lowest astronomical tide
Lowest still water level that can be expected to occur under any combination of astronomical conditions and under average meteorological conditions. Surges, which are meteorologically generated and essentially irregular, are superimposed on the tidal variations, so that a total still water level below lowest astronomical tide may occur.

1.2.1.18 Manufacturer
Party or parties responsible for the manufacture and construction of a Floating Structure and tower

1.2.1.19 Marine conditions
Sharacteristics of the marine environment (waves, sea currents, water level, sea ice, marine growth, seabed movement and scour, etc.) which may affect the wind turbine behaviour

1.2.1.20 Marine growth
Surface coating on structural components caused by plants, animals and bacteria

1.2.1.21 Metocean
Abbreviation of meteorological and oceanographic

1.2.1.22 Multi-directional (wind and/or wave)
Distribution of directions

1.2.1.23 Offshore wind turbine
Structure consisting of a wind turbine generator system, a tower, and a Floating Structure (including a mooring)

1.2.1.24 Offshore wind turbine site
The location or intended location of an individual offshore wind turbine either alone or within a wind farm

1.2.1.25 Reference period
Period during which stationarity is assumed for a given stochastic process, for example wind speed, sea elevation or response

1.2.1.26 Rotor – nacelle assembly
Part of a wind turbine generator system carried by the Floating structure and tower

1.2.1.27 Sea floor
Interface between the sea and the seabed

1.2.1.28 Sea floor slope
Local gradient of the sea floor, for example associated with a beach

1.2.1.29 Sea state

Condition of the sea in which its statistics remain stationary

1.2.1.30 Seabed

Materials below the sea floor

1.2.1.31 Seabed movement

Movement of the seabed due to natural geological processes

1.2.1.32 Scour

Removal of seabed soils by currents and waves or caused by structural elements interrupting the natural flow regime above the sea floor

1.2.1.33 Significant wave height

Statistical measure of the height of waves in a sea state, defined as the mean height of the highest third of the zero up-crossing waves, or as 4 $\sigma\eta$ where $\sigma\eta$ is the standard deviation of the sea surface elevation. To discriminate them, the former value is called statistically significant wave height, and the latter value is called spectrum significant wave height.

Note: Generally, the former height is expressed with H1/3, and the latter height is expressed with Hs or Hm0. In deep seas, the value is H1/3 = 0.95 Hs on the average, regardless of the wave spectrum.

1.2.1.34 Splash zone

External region of Floating Structures that is frequently wetted due to waves and tidal variations. This is to be defined as the zone between the highest still water level with a recurrence period of 1 year increased by the crest height of a wave with height equal to the significant wave height with a return period of 1 year, and the lowest still water level with a recurrence period of 1 year reduced by the trough depth of a wave with height equal to the significant wave height with a return period of 1 year. If a Floating Structure has fixed draft even when a water level changes, a splash zone can be an area 5m upward and 4m downward from the still water level.

1.2.1.35 Still water level

Abstract water level calculated by including the effects of tides and storm surge but excluding variations due to waves. Still water level can be above, at, or below mean sea level.

1.2.1.36 Storm surge

Irregular movement of the sea brought about by wind and atmospheric pressure variations

1.2.1.37 Floating Structure

Floating structure loading a wind turbine generator system and a tower, including a mooring for the floating structure

1.2.1.38 Tidal current

Current resulting from tides

1.2.1.39 Tides

Regular and predictable movements of the sea generated by astronomical forces

1.2.1.40 Tower

Part between a Floating Structure and a rotor-nacelle assembly

1.2.1.41 Tsunami

Long period sea waves caused by rapid vertical movements of the sea floor

1.2.1.42 Uni-directional (wind and/or waves)

Acting in a single direction

1.2.1.43 Water depth

Vertical distance between the sea floor and the still water level. As there are several options for the still water level (see **1.2.1.35**), there can be several water depth values.

1.2.1.44 Wave crest elevation

Vertical distance between the crest of a wave and the still water level

1.2.1.45 Wave direction

Mean direction from which the wave is traveling

1.2.1.46 Wave height

Vertical distance between the highest and lowest points on the water surface of an individual zero up-crossing wave

1.2.1.47 Wave period

Time interval between the two zero up-crossings which bound a zero up-crossing wave

1.2.1.48 Wave spectrum

Frequency domain description of the sea surface elevation in a sea state

1.2.1.49 Wind profile – wind shear law

Mathematical expression for assumed wind speed variation with height above still water level. Commonly used profiles are the logarithmic **(1)** and the power law **(2)**.

$$V(z) = V(z_r) \times \frac{\ln(z/z_o)}{\ln(z_r/z_o)} \quad (1)$$

$$V(z) = V(z_r) \times \left(\frac{z}{z_r}\right)^{\alpha} \quad (2)$$

Where, V(z) is the wind speed at height z;
z is the height above the still water level;
zr is a reference height above the still water level used for fitting the profile;
z0 is the roughness length;
α is the wind shear (or power law) exponent.

1.2.1.50 Zero up-crossing wave

Portion of a time history of wave elevation between zero up-crossings. A zero up-crossing occurs when the sea surface rises (rather than falls) through the still water level.

1.2.1.51 Type of Floating Structures

-1. Column-stabilized type

Column-stabilized type is the Floating Structure consisting of decks with wind turbine generator system, surface piercing columns, submerged lower hulls (footings), bracings, etc., which are semi-submerged to a predetermined drought.

-2. Barge type

Barge type is the Floating Structure in the shape of an ordinary barge having a displacement hull.

-3. Spar-type

Spar-type is the Floating Structure where the most part of the floating body is submerged by extending the floating body vertically to make the waterplane smaller.

-4. Tension leg platform (TLP) type

Tension leg platform type is the Floating Structure forcedly semi-submerged. The Floating Structure and the seabed are connected with a tension mooring line, and the structure is moored by tonicity generated by forced buoyancy.

-5. Others

Other type is the Floating Structure not specified in **-1** and **-4** above.

1.2.1.52 Mooring

-1. Equipment to maintain the Floating Structure permanently or for long periods of time at the predetermined position in the installation sea area. The mooring systems are categorized in to the following groups from **-2.** to **-4.**

-2. Spread Mooring System (SPM)

Spread mooring systems consist of mooring lines connected to piles, sinkers, etc., which are firmly embedded into the seabed, the other end of which is individually connected to winches, or stoppers which are installed on Floating Structures. The definitions of each category being as given in **(1)** to **(3)** below:

(1) Catenary Mooring (CM)

CM is defined as mooring forces obtained mainly from the net weight of catenary mooring lines (in the case of those provided with intermediate buoys or intermediate sinkers, their net weight or buoyancy). Here, the term “mooring line” means an integration of chains, wire ropes, fibre ropes or their combination, connecting means such as shackles, or intermediate buoys or intermediate sinkers, except periphery facilities for positioning such as piles, sinkers, etc. which are laid onto the seabeds.

(2) Taut Mooring (TM)

TM is defined as mooring lines arranged straight and adjusted by high initial mooring forces, and the mooring forces obtained from the elastic elongation of these lines. The term “mooring line” is defined in the previous section **(1)**.

(3) Tension Mooring System (TMS)

TMS is defined as those comprising supporting members such as piles and sinkers laid to the seabed, tension lines arranged upright direction, and connecting means to fix the tension mooring lines to the Floating Structures, and confining the Floating Structure’s heaves, rolls and pitches by the increased buoyancy created by pulling the Floating Structure downward and the tension in the mooring line. Here, tension mooring lines include steel pipes, chains, steel wire ropes and fibre ropes, and they are arranged straight in a high tensile force which is mainly obtained from elastic elongation of these lines.

-3. Single Point Mooring (SPM)

SPM is a system that allows Floating Structures to weathervane so that the Floating Structure changes its heading corresponding to wind and wave directions. Typical SPM systems are as shown below:

(1) CALM (Catenary Anchor Leg Mooring)

CALM consists of a large buoy connected to mooring points at the seabed by catenary mooring lines. The Floating Structure is moored to the buoy by mooring lines or a rigid yoke structure.

(2) SALM (Single Anchor Leg Mooring)

SALM consists of the mooring structure with buoyancy which is positioned at or near the water surface, and is connected to the seabed. The Floating Structure is moored to the buoy by mooring lines or a rigid yoke structure.

(3) Turret Mooring

The Floating Structure itself is fitted with a turret which allows only its angular movement relative to the turret so that it may be weathervane. The turret may be fitted internally within the Floating Structure, or externally at the stern/bow of the Floating Structure. The turret is generally connected to the seabed using a spread mooring system.

-4. Other Type of mooring system

Mooring systems other than those specified in **-2** and **-3** above.

1.2.1.53 Periphery facility for positioning

Periphery facilities for positioning are independent separate floating structures connected to the mooring installations of Floating Structure, and consist of large buoys for CALM, the mooring structures for SALM, fixed structures (dolphins, jackets, etc.) and sinkers/piles laid onto the seabed.

1.2.1.54 Weathertight

Weathertight means that in any sea conditions water will not penetrate into the Floating Structure and tower.

1.2.1.55 Watertight

Watertight means that the capability of preventing the passage of water through the structure in any direction under a head of water for which the surrounding structure is designed

1.2.1.56 Downflooding

Downflooding means any flooding of the interior of any part of the buoyant structure of a Floating Structure through openings which cannot be closed watertight or weathertight, as appropriate, or which are required to be left open for operational reasons.

1.2.1.57 Ascensor

Elevator, and other ascensors

1.2.1.58 Elevator

Cage shaped ascensor moving up and down on rails

1.2.2 Abbreviations

1.2.2.1 General

Abbreviations used in this Guideline are as follows:

1.2.2.2 Abbreviations

COD Co-directional
DLC Design load case
ECD Extreme coherent gust with direction change
ECM Extreme current model
EDC Extreme direction change
EOG Extreme operating gust
ESS Extreme sea state
ETM Extreme turbulence model
EWLR Extreme water level range
EWM Extreme wind speed model
EWS Extreme wind shear
HAT Highest astronomical tide
LAT Lowest astronomical tide
MIC Microbiologically influenced corrosion
MIS Misaligned
MSL Mean sea level
MUL Multi-directional
NCM Normal current model
NSS Normal sea state
NTM Normal turbulence model
NWH Normal wave height
NWLR Normal water level range
NWP Normal wind profile model
SSS Severe sea state

SWL Still water level
UNI Uni-directional

1.3 Quality assurance

1.3.1 General

It is recommended that the quality system complies with the requirements of **ISO 9001**.

1.4 Installation

1.4.1 General

-1. The manufacturer of a Floating Structure is to provide an installation manual clearly describing installation requirements for the Floating Structure.

-2. Installation procedures are to be such that if necessary, work can be broken off without causing danger to workers or unacceptable loads on the construction.

-3. When a Floating Structure is to be installed in a congestion sea area or deployed on a large scale, a risk assessment is to be conducted.

1.4.2 Documentation

The manufacturer of a Floating Structure and tower is to provide drawings, specifications and instructions for installation and erection of the Floating Structure and tower. The manufacturer is to provide details of all loads, weights, safe handling, and special tools and procedures necessary for installation of the Floating Structure and tower.

1.5 Maintenance and inspection

1.5.1 General

A Floating Structure and tower are to have access system for maintenance and inspection. The access system is to comply with relevant local, national and international regulations.

1.5.2 Design requirements for inspection and maintenance

-1. Any walkway or platform mounted on a Floating Structure is to be located above the splash zone at the time of maintenance and inspection. For safety, removal of marine growth should be considered. If there is a risk of icing, the limitation of accessibility to ladders and platforms under icing conditions is to be considered. Consideration is also to be given to the risk of damage to structures from falling ice.

-2. The design is to incorporate adequate clearance between a rotating blade tip and any walkway or platform.

-3. All aspects of a takeoff and landing facility for helicopters relevant to the structural safety of landing platforms, clearance, fire protection, marking, etc. is to comply with relevant national and international regulations and codes.

-4. Obstacle lighting and marking for marine navigation and aviation are to comply with relevant national and international regulations and codes.

-5. An ascensor to be installed in the Floating Structure and tower is to comply with the requirements defined in **5.10**.

-6. Food, water, emergency kit, and protection against cold for a stay of 1 week are to be prepared in a Floating Structure.

1.5.3 Maintenance manual

-1. A maintenance manual that complies with the section **1.5.3** in this Guidance is to be prepared and provided to workers.

-2. Each procedure of maintenance and inspection described in the maintenance manual is to be prepared based on the safety of workers.

-3. The maintenance manual is to require safety provisions for workers entering any enclosed working space that ensures any dangerous situation will be known by standby personnel to immediately initiate rescue procedures, if necessary.

-4. The manual is to be available to workers in a language that can be read and understood by them.

-5. The manual is to include, but not be limited to:

(1) Maintenance and inspection procedures
(2) Maintenance and inspection periods
(3) Safe access procedures to Floating Structure
(4) Activity during bad weather
(5) Procedure for monitoring of marine growth
(6) Installation and construction drawings for Floating Structure and tower
(7) Emergency procedures based on **1.5.4**

-6. A maintenance and inspection record is to be attached to the maintenance manual. The maintenance and inspection record is to include, but not be limited to:

(1) Outline, and date and time of performed maintenance and inspection

(2) Outline of detected failure, and date and time of detection

(3) Measures against failure

(4) Date and time of amendment

1.5.4 Emergency procedures plan

-1. Probable emergency situations are to be identified in the maintenance manual and the required actions of the worker prescribed.

-2. The manual is to require that where there is a fire or apparent risk of damage to the components or structure of the offshore wind turbine, no one should approach the offshore wind turbine unless the risk is specifically evaluated.

Chapter 2 External conditions

2.1 General

2.1.1 General

-1. Floating Structures and towers are subjected to environmental conditions that may affect their loading, durability and operation. To ensure the appropriate level of safety and reliability, environmental and soil parameters are to be taken into account in the design and are to be explicitly stated in the design documentation. The environmental conditions are divided into wind conditions, marine conditions (waves, sea currents, water level, sea ice, and marine growth), earthquake and tsunami conditions, and other environmental conditions.

-2. Account is to be taken of the soil properties at the site, including their time variation due to seabed movement, scour and other elements of seabed instability, if they may be a problem.

-3. The external conditions are subdivided into normal and extreme categories. The normal external conditions generally concern recurrent structural loading conditions, while the extreme external conditions represent rare external design conditions. The design load cases are to consist of potentially critical combinations of these external conditions with wind turbine operational modes and other design situations.

-4. The manufacturer is to in the design documentation describe the values of essential design parameters.

2.2 Wind conditions

2.2.1 General

-1. A Floating Structure and tower are to be designed to safely withstand the wind conditions adopted as the basis of design. The wind regime is divided into the normal wind conditions which will occur more frequently than once per year, and the extreme wind conditions which are defined as having a 1-year or 50-year recurrence period.

-2. The design of a Floating Structure and tower is to be based on wind conditions which are representative of the sea area where the Floating Structure and tower are to be installed.

-3. A wind profile used for design of a Floating Structure and tower is to be as follows: If a wind profile that is peculiar to the sea area where the Floating Structure and tower are to be installed is severer than the one shown below, the wind profile that is peculiar to the sea area is to be used.

$$V(z) = V_{hub} (z/z_{hub})^{\alpha}$$

Where,
$V(z)$ is the wind speed at height z;
V_{hub} is the hub height operating wind speed;
z is the height above the still water level;
z_{hub} is the hub height above the still water level;
α is the standard value under normal wind conditions, 0.14;
α is the standard value under extreme wind condition, 0.11;

2.3 Marine conditions

2.3.1 General

-1. A Floating Structure and tower is to be designed to withstand safely the marine conditions adopted as the basis of design. The marine conditions are divided into the normal marine conditions which will occur more frequently than once per year, and the extreme marine conditions which are defined as having a 1-year or 50-year recurrence period. The normal range of water levels is, however, defined as the variation in water level with a recurrence period of 1 year. Refer to **2.3.4.1**.

-2. The design of a Floating Structure and tower is to be based on environmental conditions, including the marine conditions, which are representative of the offshore wind turbine site.

2.3.2 Waves

-1. Waves are irregular in shape, vary in height, length and speed of propagation, and may approach an offshore wind turbine from one or more directions simultaneously. The features of a real sea are best reflected by describing a sea state by means of a stochastic wave model. The stochastic wave model represents the sea state as the superposition of many small individual frequency components, each of which is a periodic wave with its own amplitude, frequency and direction of propagation; the components have random phase relationships to each other. A design sea state is to be described by a wave spectrum, S, together with the significant wave height, Hs, a peak spectral period, Tp, and a mean wave direction, θ wm. Where appropriate, the wave spectrum may be supplemented with a directional spreading function. Standard wave spectrum formulations are provided in **IEC61400-3 Annex B**.

-2. In some applications, periodic or regular waves can be used as an abstraction of a real sea for design purposes. A deterministic design wave is to be specified by its height, period and direction.

-3. The correlation of wind conditions and waves are to be taken into account for the design of an offshore wind turbine. This correlation is to be considered in terms of the long term joint probability distribution of the following parameters:

- mean wind speed V
- significant wave height Hs
- peak spectral period Tp

The joint probability distribution of these parameters is affected by local site conditions such as fetch, water depth, bathymetry, etc. The distribution is therefore to be determined from suitable long term measurements supported, where appropriate, by the use of numerical hindcasting techniques, refer to **IEC61400-3 12.4**.

-4. The correlation of normal wind conditions and waves may also include consideration of mean wind and wave directions. The distributions of wind and wave directions (multi-directional) may, in some cases, have an important influence on the loads acting on the Floating amplitude and tower. The importance of this influence will depend on the nature of the wind and wave directionality and the extent to which the Floating Structure and tower are axi-symmetric. The designer may, in some cases, demonstrate by appropriate analysis that it is conservative and therefore acceptable to assume that the wind and waves are aligned (co-directional) and acting from a single, worst case direction (uni-directional). In principle, the assumptions regarding wind and wave directions are considered for each design load case in **3.2**.

-5. When taking account of the wind and wave misalignment, particular care is to be taken to ensure that the directional data and wind turbine modeling techniques are reliable.

2.3.2.1 Normal sea state (NSS)

-1. The significant wave height, peak spectral period and direction for each normal sea state are to be selected, together with the associated mean wind speed, based on the long term joint probability distribution of metocean parameters appropriate to the anticipated site.

-2. For fatigue load calculations, the designer is to ensure that the number and resolution of the normal sea states considered are sufficient to account for the fatigue strength associated with the full long term distribution of metocean parameters.

-3. For ultimate load calculations, normal sea states are to, with the exception described in **3.2.2**, be those sea states characterised by the expected value of the significant wave height, Hs, conditioned on a given value of mean wind speed. The designer is to take account of the range of peak spectral period, Tp, appropriate to each significant wave height. Design calculations are to be based on values of peak spectral period which result in the highest loads acting on the offshore wind turbine.

2.3.2.2 Normal wave height (NWH)

-1. The height of the normal deterministic design wave, H_{NWH}, is to be assumed equal to the expected value of the significant wave height conditioned on a given value of the mean wind speed, $H_{s.NSS}$.

-2. Design calculations based on NWH is to be assumed values of wave period within the following range that result in the highest loads acting on the offshore wind turbine:

$$11.1\sqrt{H_{s.NSS}(V)/g} \leqq T \leqq 14.3\sqrt{H_{s.NSS}(V)/g}$$

2.3.2.3 Severe sea state (SSS)

-1. The severe stochastic sea state model is to be considered in combination with normal wind conditions for calculation of the ultimate loading of an offshore wind turbine during power production. The severe sea state model associates a severe sea state with each wind speed in the range corresponding to power production. The significant wave height, $H_{s.SSS}(V)$, for each severe sea state is ,in general, to be determined by extrapolation of appropriate site-specific metocean data such that the combination of the significant wave height and the wind speed has a recurrence period of 50 years. For all wind speeds, the unconditional extreme significant wave height, H_{s50}, with a recurrence period of 50 years may be used as a conservative value for $H_{s.SSS}(V)$.

-2. It is recommended that the extrapolation of metocean data be undertaken using the so-called Inverse First Order Reliability Method (IFORM). This method is described in **IEC61400-3 Annex G** which also gives guidance on how to determine $H_{s.SSS}(V)$ from site-specific environmental conditions.

-3. The designer is to take account of the range of peak spectral period, Tp, appropriate to each significant wave height. Within this range, design calculations are to be based on values of the peak spectral period that result in the highest loads acting on an offshore wind turbine.

2.3.2.4 Extreme sea state (ESS)

-1. The extreme stochastic sea state model is to be considered for both the extreme significant wave height, H_{s50}, with a recurrence period of 50 years and the extreme significant wave height, H_{s1}, with a recurrence period of 1 year.

-2. The values of H_{s50} and H_{s1} are to be determined from analysis of appropriate measurements and/or hindcast data for the offshore wind turbine site.

-3. The designer is to take account of the range of peak spectral period, Tp appropriate to H_{s50} and H_{s1} respectively.

-4. Design calculations are to be based on values of peak spectral period which result in the highest loads acting on an offshore wind turbine.

2.3.3 Sea currents

-1. Although sea currents may, in principle, vary in space and time, they are generally considered as a horizontally uniform flow field of constant velocity and direction, varying only as a function of depth. The following components of sea current velocity are to be taken into account:

- sub-surface currents generated by tides, storm surge and atmospheric pressure variations, etc.
- wind generated, near surface currents (wind currents);

-2. The total current velocity is the vector sum of these components. Wave induced water particle velocities and current velocities are to be added vectorially. The influence of sea currents on the relationship between wave length and wave period is generally small and may therefore be neglected.

-3. The influence of sea currents on the hydrodynamic fatigue loading of a Floating Structure and tower may be insignificant in cases where the total current velocity is small compared to the wave induced water particle velocity in the wave crest and where vibrations of the support structure are unlikely to occur due to vortex shedding or moving ice floes. The designer is to determine whether sea currents may be neglected for calculation of fatigue loads by means of an appropriate assessment of site-specific data.

-4. Definition of sub-surface currents and wind currents is to be based on **2.3.3.1** and **2.3.3.2**. However, when sub-surface currents and wind currents are considered simultaneously for analysis or experiment, this rule can be neglected.

2.3.3.1 Sub-surface currents

-1. The sub-surface current profile may be characterised by a simple power law over the water depth d, where the current velocity $U_{ss}(z)$ is defined as a function of height z above SWL:

$$U_{ss}(z)=U_{ss}(0)[(z+d)/d]^{1/7}$$

The 1-year and 50-year recurrence values of the sea surface velocity $U_{ss}(0)$ may be determined from analysis of appropriate measurements at the offshore wind turbine site.

-2. In general, it may be acceptable to assume that the sub-surface currents are aligned with the wave direction.

2.3.3.2 Wind generated, near surface currents (wind currents)

-1. The wind generated current may be characterised as a linear distribution of velocity $U_w(z)$ reducing from the surface velocity $U_w(0)$ to zero at a depth of 20 m below SWL:

$$U_w(z)=U_w(0)(1+z/20)$$

-2. The wind generated sea surface current velocity may be assumed to be aligned with the wind direction, and may be estimated from:

$$U_w(0)=0.01V_{1\text{-hour}}(z=10\text{ m})$$

where $V_{1\text{-hour}}(z=10\text{ m})$ is defined as the 1-hour mean value of wind speed at 10 m height above SWL

The 1-year and 50-year recurrence values of $V_{1\text{-hour}}(z=10\text{ m})$ may be determined from analysis of appropriate measurements at the offshore wind turbine site. These wind speeds may then be used with the equation **-1.** above to estimate the 1-year and 50-year recurrence values of wind generated sea surface current velocity.

2.3.3.3 Normal current model (NCM)

-1. The normal current model is defined as wind generated currents associated with normal wave conditions. The normal current model excludes tide and storm-generated sub-surface currents.

-2. The normal current model is to be assumed for those ultimate load cases involving normal and severe wave conditions (NSS, NWH, SSS), and for each load case, the velocity of the wind generated currents may be estimated from the relevant mean wind speed. Refer to **2.3.3.2**.

2.3.3.4 Extreme current model (ECM)

-1. The extreme current model is defined as the appropriate site-specific combination of subsurface currents and wind generated currents with recurrence periods of 1 and 50 years.

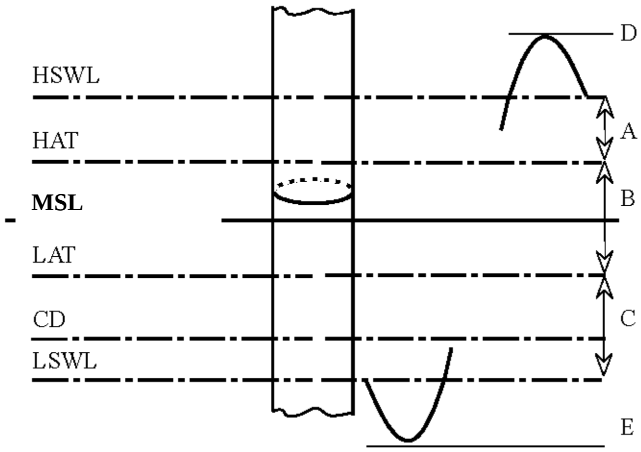
-2. The extreme current model is to be assumed for those ultimate load cases involving extreme wave conditions (ESS). Sea currents with the same recurrence period as the waves are to be assumed for these load cases.

2.3.4 Water level

For the calculation of the hydrodynamic loading of a Floating Structure, the variation in water level (if significant) at the site is to be taken into account. A constant water level equal to the mean sea level (MSL) may, however, be assumed for ultimate load cases involving normal wave conditions (NSS, NWH) with the exception stated in **2.3.4.1** below.

See **Fig. 2.1** for definition of water level:

Fig. 2.1 Definition of water levels



HSWL	Highest still water level
HAT	Highest astronomical tide
MSL	Mean sea level
LAT	Lowest astronomical tide
CD	Chart datum (often equal to LAT)
LSWL	Lowest still water level
A	Positive storm surge
B	Tidal range
C	Negative storm surge
D	Maximum crest elevation
E	Minimum trough elevation

2.3.4.1 Normal water level range (NWLR)

-1. The normal water level range is to be assumed equal to the variation in water level with a recurrence period of 1 year. In the absence of site-specific data to characterise the long term probability distribution of water levels, the normal water level range may be assumed to be equal to the variation between highest astronomical tide (HAT) and lowest astronomical tide (LAT).

-2. The NWLR is to be assumed for those fatigue and ultimate load cases involving the normal sea state model (NSS) based on the joint probability distribution of sea state conditions and wind speed (Hs, Tp, Vhub). The NWLR range is also to be assumed for ultimate load cases associated with:

· severe sea state (SSS) model
· wave conditions with a recurrence period of 1 year

-3. Ultimate load calculations are to be undertaken based on either the water level within the NWLR that results in the highest loads, or by appropriate consideration of the probability distribution of water levels within the NWLR.

-4. For the calculation of the hydrodynamic fatigue loads, the designer may in some cases demonstrate by means of an appropriate analysis that the influence of water level variation on fatigue loads is negligible or can be accounted for in a conservative manner by assuming a constant water level greater than or equal to the mean sea level.

2.3.4.2 Extreme water level range (EWLR)

-1. The extreme water level range is to be assumed for ultimate load cases associated with wave conditions with a recurrence period of 50 years. Load calculations are to be undertaken based on the water levels which result in the highest loads acting on a Floating Structure.

-2. The relevant design driving water levels are to be determined for calculation of the hydrodynamic loading, ice loading and buoyancy of a Floating Structure.

-3. In the absence of the long term joint probability distribution of metocean parameters including water level, the designer is ,at least, to undertake calculations based on the following water levels:

· highest still water level with a recurrence period of 50 years, based on an appropriate combination of highest astronomical tide and positive storm surge;

· lowest still water level with a recurrence period of 50 years, based on an appropriate combination of lowest astronomical tide and negative storm surge;

2.3.5 Sea ice

-1. At some locations, loading due to sea ice can be critical. The ice loads may be associated with static loading from a fast ice cover, or dynamic loading caused by wind and current induced motion of ice floes. Moving ice floes impacting a Floating Structure over a considerable period of time may result in significant fatigue loading.

-2. **IEC61400-3 Annex E** provides guidance with regard to ice load calculations.

2.3.6 Marine growth

-1. Marine growth influences the mass, the geometry, and the surface texture of a Floating Structure. Consequently, marine growth may influence hydrodynamic loads, dynamic response, accessibility and corrosion rate of the Floating Structure.

-2. Marine growth may be considerable at some locations and is to be taken into account in the design of a Floating Structure.

-3. Marine growth is broadly divided into “hard” (generally animal such as mussels and barnacles) and “soft” (seaweeds and kelps), where hard growth is generally thinner but rougher than soft growth. Marine organisms generally colonize a structure soon after installation but the growth rate tapers off after a few years.

-4. The nature and thickness of marine growth depends on the structural member’s position relative to the sea level, orientation relative to dominant current, age and maintenance strategy; but also on other site conditions such as salinity, oxygen content, pH value, current, and temperature.

-5. The corrosion environment is normally modified by marine growth in the upper submerged zone and the lower part of the splash zone of a Floating Structure. Depending on the type of marine growth and other local conditions, the net effect may be either to enhance or retard corrosion attack. Enhancement of corrosion processes by marine growth (e.g. through corrosive metabolites) is commonly referred to as Microbiologically Influenced Corrosion (MIC). Marine growth may further interfere with systems for corrosion control, including coatings/linings and cathodic protection.

2.4 Earthquake and tsunami

2.4.1 General

-1. Influence of earthquakes is to be properly taken into account. Force due to earthquakes is to be estimated by using maximum earthquake waves that have occurred in the past in the sea area where the floating structure is to be installed.

-2. Influence of tsunamis is to be properly taken into account. Tsunamis are to be taken into account as the maximum tsunami that have occurred in the past in the sea area where the floating structure is to be installed. However, in cases where water depth is deep enough, the effect of tsunamis may be deemed as changes of tidal level and current.

-3. In cases where earthquakes and tsunamis are taken into consideration, the environmental load such as winds and waves may be deemed as those in normal state.

-4. Liquefaction of the soil caused by earthquake is to be taken into account.

2.5 Other environmental conditions

2.5.1 Snow load

Influence of snow on a Floating Structure and tower is to be properly taken into account, if it cannot be neglected.

2.5.2 Seabed movement and scour

Influence of seabed movement and scour on the mooring of a Floating Structure is to be properly taken into account, if it cannot be neglected.

Chapter 3 Load

3.1 General

3.1.1 General

-1. Loads described in **3.1.2**, through **3.1.7**, is to be considered for the design calculations, and at the same time, loads on a wind turbine generator system, Floating Structure, and tower are to be taken into account.

-2. A coupled analysis in a time domain for a Floating Structure and tower is to be performed. Sufficient simulation time for analysis is to be ensured to figure out the load correctly. The load can be calculated with a model test of which appropriateness is approved by the Society. In this case, documentation about the design load calculation is to be submitted to the Society.

-3. In cases where motions of Floating Structures and towers are subjected to excitation by operation of the wind turbine, loads generated by excited motions are to be taken into account.

3.1.2 Gravitational and inertial loads

Gravitational and inertial loads are static and dynamic loads resulting from gravity, motion of a Floating Structure, vibration, and seismic activity.

3.1.3 Aerodynamic loads

-1. Aerodynamic loads are static and dynamic loads that are caused by the airflow and its interaction with the stationary and moving parts of wind turbines, Floating Structures and towers.

-2. The airflow is dependent upon the average wind speed and turbulence across the rotor plane, the rotational speed of the rotor, the density of the air, and the aerodynamic shapes of the wind turbine generator system components and their interactive effects, including aeroelastic effects.

3.1.4 Actuation loads

Actuation loads result from the operation and control of wind turbine generator systems.

3.1.5 Hydrodynamic loads

-1. Hydrodynamic loads are dynamic loads which are caused by the water flow and its interaction with a Floating Structure.

-2. The hydrodynamic loads are dependent on the kinematics of the water flow, the density of the water, the depth of the water, the shape of a Floating Structure and their interactive effects, including hydroelastic effects.

-3. Those parts of a Floating Structure which are not designed to be exposed to hydrodynamic loads are to be positioned at a height with a minimum clearance relative to the expected value of the highest crest elevation with a recurrence period of 50 years, accounting for the highest astronomical tide, positive storm surge, the crest height of the extreme wave, and motion of the Floating Structure. The minimum clearance, referred to as the air gap, is to be defined as 0.2* Hs50 but with a minimum value of 1 m.

Hydrodynamic loads arising from wave "run-up" should be considered, particularly for the design of Floating Structure appurtenances.

3.1.6 Sea ice loads

-1. Sea ice loads acting on a Floating Structure are both static and dynamic loads. Static loads have their origin either in temperature fluctuations or changes in water level in a fast ice cover. Dynamic loads are caused by wind and current induced motion of ice floes and their failure in contact with the Floating Structure.

-2. The relevance of ice loads design depends on the specific location and characteristics of the offshore wind turbine site (Refer to **IEC61400-3 Annex E**).

3.1.7 Other loads

-1. Other loads such as wake loads, impact loads, ice loads, etc., may occur and are to be included where appropriate.

-2. Hydrostatic loads acting on a Floating Structure because of internal and external pressures and resulting buoyancy are to be taken into account where appropriate.

-3. Vortex drag is to be considered if it generates vibration of the component and material of a Floating Structure (concerning impact on the mooring, see **ISO19901-7 7.4.7**).

-4. Lift force is to be calculated properly if it cannot be neglected.

-5. Frictional force due to currents is to be assessed properly if it cannot be neglected.

3.2 Design situations and load cases

3.2.1 General

-1. For design purposes, the life of a Floating Structure and tower can be represented by a set of design situations covering the most significant conditions that they may experience.

-2. The load cases are to be determined from the combination of operational modes or other design situations, such as specific assembly, erection or maintenance conditions, with the external conditions. All relevant load cases with a reasonable probability of occurrence are to be considered, together with the behaviour of the control and protection system. The design load cases used to verify the structural integrity of a Floating Structure and tower are to be calculated by combining:

- normal design situations and appropriate normal or extreme external conditions;
- fault design situations and appropriate external conditions;
- transportation, installation and maintenance design situations and appropriate external conditions.

If correlation exists between an extreme external condition and a fault situation, a realistic combination of the two are to be considered as a design load case.

-3. Within each design situation, several design load cases are to be considered. In principle, the design load cases in **Table 3.1** are to be considered. In that table, the design load cases are specified for each design situation by the description of the wind, marine, electrical and other external conditions. Additionally, if the offshore wind turbine is to be installed at a site where sea ice is expected to occur, the design load cases presented in **Table 3.2** are to be considered.

-4. For each design load case, the appropriate type of analysis is stated by "F" and "U" in **Table 3.1**. "F" refers to analysis of fatigue loads, to be used in the assessment of fatigue strength. "U" refers to the analysis of ultimate loads, with reference to material strength and structural stability.

-5. The design load cases indicated with "U", are classified as normal (N), abnormal (A), or transport and erection (T). Normal design load cases are expected to occur frequently within the lifetime of a Floating Structure and tower. A turbine is in a normal state or may have experienced minor faults or abnormalities. Abnormal design situations are less likely to occur. They usually correspond to design situations with severe faults that result in activation of system protection functions. The type of design situation, N, A, or T, determines the partial safety factor γ_f to be applied to the ultimate loads. These factors are given in **Table 5.1**.

Table 3.1Design load cases (DLC)

Design situation	DLC	Wind condition	Waves	Wind and wave directionality	Sea currents	Water level	Other conditions	Type of analysis	Partial safety factor
1) Power production	1.1	NTM $V_{in} < V_{hub} < V_{out}$	NSS $H_s = E[H_s \mid V_{hub}]$	COD, UNI	NCM	MSL	For extrapolation of extreme loads on the RNA	U	N (1.25)
	1.2	NTM $V_{in} < V_{hub} < V_{out}$	NSS Joint prob. distribution of H_s, T_p, V_{hub}	COD, MUL	No currents	NWLR or ≥MSL		F	—
	1.3	ETM $V_{in} < V_{hub} < V_{out}$	NSS $H_s = E[H_s \mid V_{hub}]$	COD, UNI	NCM	MSL		U	N
	1.4	ECD $V_{hub} = V_r - 2$ m/s, V_r, $V_r + 2$ m/s	NSS (or NWH) $H_s = E[H_s \mid V_{hub}]$	MIS, wind direction change	NCM	MSL		U	N
	1.5	EWS $V_{in} < V_{hub} < V_{out}$	NSS (or NWH) $H_s = E[H_s \mid V_{hub}]$	COD, UNI	NCM	MSL		U	N
	1.6	NTM $V_{in} < V_{hub} < V_{out}$	SSS $H_s = H_{s.SSS}$	COD, UNI	NCM	NWLR		U	N
2) Power production plus occurrence of fault	2.1	NTM $V_{in} < V_{hub} < V_{out}$	NSS $H_s = E[H_s \mid V_{hub}]$	COD, UNI	NCM	MSL	Control system fault or loss of electrical network	U	N
	2.2	NTM $V_{in} < V_{hub} < V_{out}$	NSS $H_s = E[H_s \mid V_{hub}]$	COD, UNI	NCM	MSL	Protection system or preceding internal electrical fault	U	A
	2.3	— EOG — $V_{hub} = V_r \pm 2$ m/s, V_{out}	NSS (or NWH) $H_s = E[H_s \mid V_{hub}]$	COD, UNI	NCM	MSL	External or internal electrical fault including loss of electrical network	U	A
	2.4	NTM $V_{in} < V_{hub} < V_{out}$	NSS $H_s = E[H_s \mid V_{hub}]$	COD, UNI	No currents	NWLR or ≥MSL	Control, protection or electrical system faults including loss of electrical network	F	—

Design situation	DLC	Wind condition	Waves	Wind and wave directionality	Sea currents	Water level	Other conditions	Type of analysis	Partial safety factor
3) Start up	3.1	NWP $V_{in} < V_{hub} < V_{out}$	NSS (or NWH) $H_s = E[H_s \vert V_{hub}]$	COD, UNI	No currents	NWLR or ≥MSL		F	－
	3.2	— EOG— $V_{hub} = V_{in}$, $V_r \pm 2$ m/s — , V_{out}	NSS (or NWH) $H_s = E[H_s \vert V_{hub}]$	COD, UNI	NCM	MSL		U	N
	3.3	EDC$_1$ $V_{hub} = V_{in}$, $V_r \pm 2$ m/s, V_{out}	NSS (or NWH) $H_s = E[H_s \vert V_{hub}]$	MIS, wind direction change	NCM	MSL		U	N
4) Normal shut down	4.1	NWP $V_{in} < V_{hub} < V_{out}$	NSS (or NWH) $H_s = E[H_s \vert V_{hub}]$	COD, UNI	No currents	NWLR or ≥MSL		F	－
	4.2	— EOG — $V_{hub} = V_r \pm 2$ m/s, V_{out}	NSS (or NWH) $H_s = E[H_s \vert V_{hub}]$	COD, UNI	NCM	MSL		U	N
5) Emergency shut down	5.1	NTM $V_{hub} = V_r \pm 2$ m/s, V_{out}	NSS $H_s = E[H_s \vert V_{hub}]$	COD, UNI	NCM	MSL		U	N
6) Parked (standing still or idling)	6.1	EWM Turbulent wind model $V_{hub} = k_1 V_{ref}$	ESS $H_s = k_2 H_{s50}$	MIS, MUL	ECM	EWLR		U	N
	6.2	EWM Turbulent wind model $V_{hub} = k_1 V_{ref}$	ESS $H_s = k_2 H_{s50}$	MIS, MUL	ECM	EWLR	Loss of electrical network	U	A
	6.3	EWM Turbulent wind model $V_{hub} = k_1 V_1$	ESS $H_s = k_2 H_{s1}$	MIS, MUL	ECM	NWLR	Extreme yaw misalignment	U	N
	6.4	NTM $V_{hub} < 0.7 V_{ref}$	NSS Joint prob. distribution of H_s, T_p, V_{hub}	COD, MUL	No currents	NWLR or ≥MSL		F	－
7) Parked and fault conditions	7.1	EWM Turbulent wind model $V_{hub} = k_1 V_1$	ESS $H_s = k_2 H_{s1}$	MIS, MUL	ECM	NWLR		U	A
	7.2	NTM $V_{hub} < 0.7 V_{ref}$	NSS Joint prob. distribution of H_s, T_p, V_{hub}	COD, MUL	No currents	NWLR or ≥MSL		F	－

Design situation	DLC	Wind condition	Waves	Wind and wave directionality	Sea currents	Water level	Other conditions	Type of analysis	Partial safety factor
8) Transport, assembly, maintenance and repair	8.1	To be stated by the manufacturer						U	T

(Remark)

(1) The abbreviations in **Table 3.1** are defined as follows:

COD co-directional (See **2.3.2**.)
ECD extreme coherent gust with direction change (**JIS C1400-1**)
EDC extreme direction change (**JIS C1400-1**)
ESS extreme sea state (See **2.3.2.4**.)
EWM extreme wind speed model (**JIS C1400-1**)
MIS misaligned (See **2.3.2**.)
MUL multi-directional (See **2.3.2**.)
NTM normal turbulence model (**JIS C1400-1**)
NWLR normal water level range (See **2.3.4.1**.)
NSS normal sea state (See **2.3.2.1**.)
SSS severe sea state (See **2.3.2.3**.)
UNI uni-directional (See **2.3.2**.)
F fatigue (See **5.6**.)
N normal
DLC design load case
ECM extreme current model (See **2.3.3.4**.)
EOG extreme operating gust (**JIS C1400-1**)
ETM extreme turbulence model
EWLR extreme water level range (See **2.3.4.2**.)
EWS extreme wind shear (**JIS C1400-1**)
MSL mean sea level (See **2.3.4**.)
NCM normal current model (See **2.3.3.3**.)
NWH normal wave height (See **2.3.2.2**.)
NWP normal wind profile model (**JIS C1400-1**)
$V_r \pm 2$ m/s Sensitivity to all wind speeds in the range is to be analyzed.
U ultimate load (See **5.4.2**.)
A abnormal
T transport and erection

(2) When a wind speed range is indicated in **Table 3.1**, wind speeds leading to the most adverse condition for Floating Structure and tower design are to be considered. The range of wind speeds may be represented by a set of discrete values, in which case the resolution is to be sufficient to assure accuracy of the calculation (in general, a resolution of 2 m/s is considered sufficient). In the definition of the design load cases, reference is made to the wind and marine conditions described in **Chapter 2**.

(3) In general, co-directionality of the wind and waves may be assumed for calculation of the loads acting on a Floating Structure and tower for all design load cases except those (DLC 1.4 and 3.3) involving a transient change in mean wind direction and those corresponding to the wind turbine in a parked (standing still or idling) design situation.

(4) The multi-directionality of the wind and waves may, in some cases, have an important influence on the loads acting on a Floating Structure and tower depending primarily on the extent to which the Floating Structure and tower are non-axisymmetric. For some design load cases as indicated in **Table 3.1**, the load calculations may be undertaken by assuming that the wind and waves are acting from a single, worst case direction (uni-directional). In these cases, however, the structural integrity is to be verified by application of the calculated worst case loads to relevant directional orientations of the Floating Structure and tower.

(5) The mean or extreme yaw misalignment to be considered for each design load case is to be as stated in **JIS C1400-1**. The yaw misalignment is defined as the horizontal deviation of the wind turbine rotor axis from the wind direction.

3.2.2 Power production (DLC 1.1 to 1.6)

-1. In this design situation, an offshore wind turbine is running and connected to the electric load. The assumed wind turbine configuration is to take into account rotor imbalance. The maximum mass and aerodynamic imbalances (e.g. blade pitch and twist deviations) specified for rotor manufacture are to be used in the design calculations.

-2. In addition, deviations from theoretical optimum operating situations such as yaw misalignment and control system tracking errors are to be taken into account in the analyses of operational loads.

-3. DLC 1.1 and 1.2 embody the requirements for loads resulting from atmospheric turbulence (NTM) and stochastic sea states (NSS) that occur during normal operation of an offshore wind turbine throughout its designed lifetime.

-4. For DLC 1.2 a single value of significant wave height may be considered for each relevant mean wind speed. The designer is, however, to ensure that the number and resolution of the normal sea states considered are sufficient to account for the fatigue damage associated with the full long term distribution of metocean parameters. The significant wave height, peak spectral period, wave direction and water level for each normal sea state are to be considered, together with the associated mean wind speed, based on the long term joint probability distribution of metocean parameters.

-5. For DLC 1.2, normal sea state (NSS) conditions are to be assumed. The significant wave height, peak spectral period and direction for each normal sea state are to be selected, together with the associated mean wind speed, based on the long term joint probability distribution of metocean parameters appropriate to the anticipated site. The designer is to ensure that the number and resolution of the normal sea states considered are sufficient to account for the fatigue damage associated with the full long term distribution of metocean parameters.

-6. DLC 1.3 embodies the requirements for ultimate loading resulting from extreme turbulence conditions. Normal sea state (NSS) conditions is to be assumed for this design load case and the significant wave height for each individual sea state is to be taken as the expected value of the significant wave height conditioned on the relevant mean wind speed.

-7. DLC 1.4 and 1.5 specify transient cases which have been selected as potentially critical events in the life of an offshore wind turbine. For these load cases, normal sea state (NSS) conditions are to be assumed and the significant wave height for each individual sea state is to be taken as the expected value of the significant wave height conditioned on the relevant mean wind speed. Alternatively, the simulations may be performed using a normal deterministic design wave (NWH), where the height is to be assumed equal to the expected value of the significant wave height conditioned on the relevant mean wind speed.

-8. For DLC 1.4, it may be assumed that the wind and waves are co-directional prior to the transient change in wind direction.

-9. DLC 1.6 embodies the requirements for ultimate loading resulting from normal turbulence (NTM) and severe sea state (SSS) conditions. The significant wave height for each individual sea state is to be computed from the conditional distribution of significant wave heights for the relevant mean wind speed, as described in **2.3.2.3**.

3.2.3 Power production plus occurrence of fault or loss of electrical network connection (DLC2.1 to 2.4)

-1. This design situation involves a transient event triggered by a fault or the loss of electrical network connection while the turbine is producing power. Any fault in the control and protection system, or internal fault in the electrical system, significant for wind turbine loading (such as generator short circuit) is to be considered.

-2. For DLC 2.1, the occurrence of faults relating to control functions or loss of electrical network connection is to be considered as normal events. For DLC 2.1, consideration should also be given to the design situation associated with ride-through of faults on the electrical network.

-3. For DLC 2.2, rare events, including faults relating to the protection functions or internal electrical systems is to be considered as abnormal.

-4. For DLC 2.3, the potentially significant wind event, EOG, is combined with an internal or external electrical system fault (including loss of electrical network connection) and considered as an abnormal event. In this case, the timing of these two events are to be chosen to achieve the worst loading. If a fault or loss of electrical network connection does not cause an immediate shutdown and the subsequent loading can lead to significant fatigue damage, the likely duration of this situation along with the resulting fatigue damage in normal turbulence conditions (NTM) is to be evaluated in DLC 2.4.

-5. For DLC 2.1, 2.2, 2.3 and 2.4, normal sea state (NSS) conditions are to be assumed and the significant wave height for each individual sea state is to be taken as the expected value of the significant wave height conditioned on the relevant mean wind speed. Alternatively, for DLC 2.3, the simulations may be performed using a normal deterministic design wave (NWH), where the height is to be assumed equal to the expected value of the significant wave height conditioned on the relevant mean wind speed.

3.2.4 Start up (DLC 3.1 to 3.3)

-1. This design situation includes all the events resulting in loads on an offshore wind turbine during the transients from any standstill or idling situation to power production. The number of occurrences is to be estimated based on the control system behaviour.

-2. For DLC 3.1 to 3.3, normal sea state (NSS) conditions are to be assumed and the significant wave height for each individual sea state is to be taken as the expected value of the significant wave height conditioned on the relevant mean wind speed. Alternatively, the simulations for these load cases may be performed using a normal deterministic design wave (NWH), where the height is to be assumed equal to the expected value of the conditional distribution of significant wave heights for the relevant mean wind speed.

-3. For DLC 3.3, it may be assumed that the wind and waves are co-directional prior to the transient change in wind direction.

3.2.5 Normal shut down (DLC 4.1 and 4.2)

-1. This design situation includes all the events resulting in loads on an offshore wind turbine during normal transient situations from a power production situation to a standstill or idling condition. The number of occurrences is to be estimated based on the control system behaviour.

-2. For DLC 4.1 and 4.2, normal sea state (NSS) conditions are to be assumed and the significant wave height for each individual sea state is to be taken as the expected value of the significant wave height conditioned on the relevant mean wind speed. Alternatively, the simulations may be performed using a normal deterministic design wave (NWH), where the height is to be assumed equal to the expected value of the significant wave height conditioned on the relevant mean wind speed.

3.2.6 Emergency shut down (DLC 5.1)

-1. Loads arising from emergency shut down are to be considered.

-2. For DLC 5.1, normal sea state (NSS) conditions are to be assumed and the significant wave height for each individual sea state is to be taken as the expected value of the significant wave height conditioned on the relevant mean wind speed.

3.2.7 Parked (standstill or idling) (DLC 6.1 to 6.4)

-1. In this design situation, the rotor of a parked wind turbine is either in a standstill or idling condition. DLC 6.1 to 6.3 are to be analyzed to determine ultimate loads for this condition, whereas DLC 6.4 is concerned with fatigue loading.

-2. For DLC 6.1 and 6.2, the combination of extreme wind and wave conditions are to be such that the global extreme environmental action has a combined recurrence period of 50 years. In the absence of information defining the long term joint probability distribution of extreme wind and waves, it is to be assumed that the extreme 10-min mean wind speed with 50-year recurrence period occurs during the extreme sea state with 50-year recurrence period. For DLC 6.3 the same assumption is to be applied with regard to the combination of the extreme 10-min mean wind speed and the extreme sea state each with a 1-year recurrence period.

-3. DLC 6.1 to 6.3 may be analyzed using simulations of turbulent inflow and stochastic sea states. Subsidiary load cases of DLC 6.1 to 6.3 are defined in **Table 3.1**, based on this approach.

-4. In DLC 6.1, 6.2 and 6.3, misalignment of the wind and wave directions are to be considered for calculation of the loads acting on a Floating Structure and tower. Where appropriate site-specific measurements of wind and wave directions are available, these are to be used to derive the range of misalignment angles relevant to the combination of extreme wind and wave conditions associated with these design load cases. Load calculations are then to be based on values of misalignment within this range that result in the highest loads acting on the Floating Structure and tower.

In the absence of appropriate site-specific wind and wave directional data, the misalignment that results in the highest loads acting on the floating structure is to be considered. If this misalignment exceeds 30°, the extreme wave height may be reduced due to the decay in severity of the sea state over the period associated with the change in wind direction which causes the misalignment. The reduction of the extreme wave height is to be calculated taking account of the fetch and other relevant site-specific conditions.

-5. Concerning the requirements specified in **-4.**, the extreme wind and wave conditions may be assumed to be initially co-directional. As the storm passes over the site of the wind turbine, the wind direction may change causing a misalignment relative to the wave direction. During the time taken for a significant wind direction change, the severity of the wave conditions will have reduced.

-6. If slippage in the wind turbine yaw system can occur at the characteristic load, the largest possible unfavourable slippage is to be added to the mean yaw misalignment. If the wind turbine has a yaw system where yaw movement is expected in the extreme wind situations (e.g. free yaw, passive yaw or semi-free yaw), the turbulent wind model is to be used and the yaw misalignment will be governed by the turbulent wind direction changes and the turbine yaw dynamic response. Also, if the wind turbine is subject to large yaw movements or change of equilibrium during a wind speed increase from normal operation to the extreme situation, this behaviour is to be included in the analysis.

-7. In DLC 6.1, for an offshore wind turbine with active yaw system, a yaw misalignment of up to ± 15° using the steady extreme wind model or a mean yaw misalignment of ± 8° using the turbulent extreme wind model are to be imposed, provided that the absence of slippage in the yaw system can be assured.

-8. For DLC 6.1, the turbulent extreme wind model is to be taken together with the extreme sea state (ESS) conditions. The response is to be estimated using full dynamic simulation based on at least six 1-hour realizations for each combination of extreme wind speed and extreme sea state. In this case, the hub height mean wind speed, turbulence standard deviation and significant wave height are to be taken as 50-year recurrence values each referenced to a 1-hour simulation period.

The 1-hour value of the 50-year recurrence mean wind speed may be obtained from the 10-min average by use of the conversion stated in **Table 3.1**:

$$V_{50.1\text{-hour}} = k_1 V_{50.10\text{-min}} : k_1 = 0.95$$

The 1–hour value of the turbulence standard deviation may be obtained from the 10-min value as follows:

$$\sigma_{\text{i.1-hour}} = \sigma_{\text{i.10-min}} + b : b = 0.2\text{m/s}$$

The turbulence models given in **JIS C1400-1 Annex-B** may be used together with the 1-hour values of 50-year recurrence mean wind speed and turbulence standard deviation given by the two equations above.

The significant wave height for a 1-hour simulation period may be obtained from the value corresponding to a 3-hour reference period by the use of the conversion stated in **Table 3.1**. The value of k_2 is as follows:

$$k_2 = 1.09$$

Realizations shorter than 1 h may be assumed if the designer is able to demonstrate that this will not reduce the estimated extreme response. Constrained wave methods may be used for this purpose, refer to **IEC61400-3 Annex D**. In the case of a constrained wave analysis based on a simulation period of 10 min, the hub height mean wind speed is to be taken as the 10 min value with a 50-year recurrence, the significant wave height is to be taken as the 3 h value with a 50-year recurrence and the embedded regular wave is to have the magnitude of the extreme wave height with a 50-year recurrence, H_{50}.

-9. In DLC 6.2, a loss of the electrical power network at an early stage in the storm containing the extreme wind situation is to be assumed. Unless power back-up for the control and yaw system with a capacity of 6 h of wind turbine operation is provided, the effect of a wind direction change of up to ± 180° is to be analyzed.

-10. For DLC 6.2, the turbulent extreme wind model is to be taken together with the extreme sea state (ESS) conditions and the hub height mean wind speed and significant wave height is to be taken as 50-year recurrence values. The extreme response is to be estimated using the same methods as described above for DLC 6.1.

-11. In DLC 6.3, the extreme wind with a 1-year recurrence period is to be combined with an extreme yaw misalignment. An extreme yaw misalignment of up to ± 30° using the steady extreme wind model or a mean yaw misalignment of ± 20° using the turbulent wind model is to be assumed.

-12. For DLC 6.3, the turbulent extreme wind model is to be taken together with the extreme sea state (ESS) conditions and, in this case, the hub height means wind speed and significant wave height is to be taken as 1-year recurrence values. The extreme response is to be estimated using the same methods as described above for DLC 6.1.

-13. In DLC 6.4, the expected number of hours of non-power production time at a fluctuating load appropriate for each wind speed where significant fatigue damage can occur to any component (e.g. from weight of idling blades) is to be considered. Particular account is to be taken of the resonant loading of a Floating Structure and tower due to excitation by the waves and influence by the low aerodynamic damping available from the rotor in a standstill or idling condition. Normal sea state (NSS) conditions are to be assumed. The significant wave height, peak spectral period and direction for each normal sea state are to be selected, together with the associated mean wind speed, based on the long term joint probability distribution of metocean parameters appropriate to the anticipated site. The designer is to ensure that the number and resolution of the normal sea states considered are sufficient to account for the fatigue damage associated with the full long term distribution of metocean parameters.

3.2.8 Parked plus fault conditions (DLC 7.1 and 7.2)

-1. Deviations from the normal behaviour of a parked wind turbine, resulting from faults on the electrical network or in the wind turbine, are to require analysis. If any fault other than a loss of electrical power network produces deviations from the normal behaviour of the wind turbine in parked situations, the possible consequences are to be the subject of analysis.

-2. In case of a fault in the yaw system, yaw misalignment of ± 180º is to be considered. For any other fault, yaw misalignment is to be consistent with DLC 6.1.

-3. In DLC 7.1, the fault condition is to be combined with extreme wind and wave conditions, so that the global extreme environmental action has a combined recurrence period of 1 year. In the absence of information defining the long term joint probability distribution of extreme wind and waves, it is to be assumed that the extreme 10-min mean wind speed with 1-year recurrence period occurs during the extreme sea state with 1-year recurrence period.

-4. DLC 7.1 may be analyzed using simulations of turbulent inflow and stochastic sea states. Subsidiary load cases of DLC 7.1 are defined in **Table 3.1** based on this approach.

-5. In DLC 7.1, misalignment of the wind and wave directions is to be considered for calculation of the loads acting on a Floating Structure and tower. Where appropriate site-specific measurements of wind and wave directions are available, these are to be used to derive the range of misalignment angles relevant to the combination of extreme wind and wave conditions associated with this design load case. Load calculations are then to be based on values of misalignment within this range that result in the highest loads acting on the Floating Structure and tower.

In the absence of appropriate site-specific wind and wave directional data, the misalignment that results in the highest loads acting on the Floating Structure and tower is to be considered. If this misalignment exceeds 30º, the extreme wave height may be reduced due to the decay in severity of the sea state over the period associated with the change in wind direction which causes the misalignment. The reduction of the extreme wave height is to be calculated taking account of the water depth, fetch and other relevant site-specific conditions.

-6. If slippage in the yaw system can occur at the characteristic load found in DLC 7.1, the largest unfavourable slippage possible is to be considered.

-7. For DLC 7.1, the turbulent extreme wind model is to be taken together with the extreme sea state (ESS) conditions. The extreme response is to be estimated using the same methods as described above for DLC 6.1a.

-8. In DLC 7.2, the expected number of hours of non-power production time due to faults on the electrical network or in the wind turbine is to be considered for each wind speed and sea state where significant fatigue damage can occur to any components. Particular account is to be taken of the resonant loading of a Floating Structure and tower due to excitation by the waves and influenced by the low aerodynamic damping available from the rotor in a standstill or idling condition. Normal sea state (NSS) conditions are to be assumed. The significant wave height, peak spectral period and direction for each normal sea state are to be selected, together with the associated mean wind speed, based on the long term joint probability distribution of metocean parameters appropriate to the anticipated site. The designer is to ensure that the number and resolution of the normal sea states considered are sufficient to account for the fatigue damage associated with the full long term distribution of metocean parameters.

3.2.9 Transport, assembly, maintenance and repair (DLC 8.1)

-1. For DLC 8.1, the manufacturer is to state all the wind conditions, marine conditions and design situations assumed for transport, assembly on site, access, maintenance and repair of an offshore wind turbine. The maximum stated wind conditions and marine conditions are to be considered in the design if they can produce significant loading on the wind turbine. The manufacturer is to allow sufficient margin between the stated conditions and the wind and marine conditions considered in design to give an acceptable safety level.

-2. Loads occurring during transport, assembly, access, maintenance and repair of an offshore wind turbine are to be taken into account:

- weight of tools and mobile equipment;
- loads from operation of cranes;
- mooring and fendering loads from vessels serving the wind turbine;
- where relevant, loads associated with helicopter operations.

-3. An impact on the area of a Floating Structure, which contacts a service vessel coming alongside, is to be considered.

-4. The design situation, the maximum size of the service vessel and the limiting external conditions for approach of a Floating Structure by the vessel are to be stated by the designer. The designer is to consider an impact not less than that caused by the service vessel coming into contact with the Floating Structure at a speed of 0.5 m/s and considering an added mass coefficient of 1.4 for sideways collision and 1.1 for bow or stern collision. It is to be assumed, in this case, that all the kinetic energy associated with the impact is absorbed by the fendering installation. The loading associated with maximum wind and marine conditions allowed for service vessel access is to be combined with that due to the service vessel.

-5. The energy absorbed by a Floating Structure will depend on its stiffness in comparison to that of the impacting component of the vessel. Following a vessel impact, it is important to examine any damage to the Floating Structure caused by the impact force and determine any necessary repair work to be undertaken to ensure that the required load carrying capacity of the Floating Structure is preserved.

-6. If information about the service vessel is not known by the designer, the impact force can normally be accounted for by applying 5 MN distributed as a horizontal line load. This load is to be considered to include dynamic amplification. The vertical extent of the collision zone is to be assessed on the basis of the vessel draft, and the maximum wave and tidal elevations allowed for service vessel access. For local pressure calculation, a vertical extension of 2 m may be assumed.

-7. Loading of an offshore wind turbine due to helicopter operations is to be considered where relevant. The design situation, the maximum size of helicopter and the limiting external conditions for approach of an offshore wind turbine by the helicopter is to be stated by the owner or designer of a Floating Structure, and taken into account in the load calculations.

3.2.10 Sea ice design load cases

In addition to the load cases in **Table 3.1**, the load cases in **Table 3.2** is to be considered for the design of a Floating Structure for an offshore wind turbine that will be installed at a site where sea ice is expected to occur. The sea ice design load cases E1 to E7 are further described in **IEC61400-3 Annex E**.

Table 3.2 Design load cases for sea ice

Design situation	DLC	Ice condition	Wind condition	Water level	Type of analysis	Partial safety factor
Power production	E1	Horizontal load from temperature fluctuations	NTM $V_{hub}=V_r\pm 2$ m/s and V_{out} Wind speed resulting in maximum thrust	NWLR	U	N
	E2	Horizontal load from water fluctuations or arch effect	NTM $V_{hub}=V_r\pm 2$ m/s and V_{out} Wind speed resulting in maximum thrust	NWLR	U	N
	E3 For extrapolation of extreme events	Horizontal load from moving ice floe at relevant velocities $h=h_{50}$ in open sea $h=h_m$ for land-locked waters	NTM $V_{hub}=V_r\pm 2$ m/s and V_{out} Wind speed resulting in maximum thrust	NWLR	U	N
	E4	Horizontal load from moving ice floe at relevant velocities $h=h_{50}$ in open sea $h=h_m$ for land-locked waters	$V_{in}<V_{hub}<V_{out}$	NWLR	F	—
	E5	Vertical force from fast ice covers due to water level fluctuations	No wind load applied	NWLR	U	N
Parked	E6	Pressure from hummocked ice and ice ridges	EWM Turbulent wind model $V_{hub}=V_1$	NWLR	U	N
	E7	Horizontal load from moving ice floe at relevant velocities $h=h_{50}$ in open sea $h=h_m$ for land-locked waters	NTM $V_{hub}<0.7\ V_{ref}$	NWLR	F	—

(Remark)

The abbreviations used in **Table 3.2** are as follows:

DLC	design load case	EWM	extreme wind speed model (**JIS C1400-1**)
NTM	normal turbulence model (**JIS C1400-1**)	NWLR	normal water level range (See **2.3.4.1**.)
F	fatigue (See **5.6**.)	U	ultimate load (See **5.4.2**.)
N	normal		

3.3 Calculation of loads

Load calculations are to be performed using appropriate methods taking proper account of the combination of relevant external conditions.

3.3.1 Relevance of hydrodynamic loads

-1. The marine conditions at an offshore wind turbine site are to be considered properly.

-2. For load calculations associated with the design of a Floating Structure and tower, all loads as described in **3.1.2** through **3.1.7** are to be taken into account. The load calculations are to be based on external conditions that are representative of the offshore wind turbine site.

3.3.2 Calculation of aerodynamic loads

-1. Aerodynamic load calculations acting on a Floating Structure and tower are to be performed using appropriate methods. Design loads may be estimated through model tests as deemed appropriate by the Society. In such cases, data relative to the calculation of design loads is to be submitted to the Society.

-2. The wind velocity for the design environmental condition is to be based on the statistical measurement wind data for the specific installation site or the analysis and interpretation of wind measurement data for the specific installation site by weather consultants.

-3. Wind load acting on a Floating Structure may be calculated by the following **(1)** and **(2)**.

(1) Wind pressure P (N/m^2) is to be calculated as follows:

$$P = 0.611 C_s V(z)^2$$

$V(z)$: $V(z)$ is the wind speed at height zm.

C_s : Shape coefficient given in **Table 3.3**.

Table 3.3 Shape coefficient C_s

Structural members	C_s
Spherical structures	0.4
Cylindrical structures	0.5
Main Hulls	1.0
Deckhouses	1.0
Independent structural members (cranes, shapes, beams, etc.)	1.5
Under-deck parts (smooth surface)	1.0
Under-deck parts (exposed beams, girders, etc.)	1.3
Working towers (each surface)	1.25

(2) The wind force F_{wind} (N) exerted on each structural member is to be calculated as follows. The total wind force is to be obtained by summing up the wind forces exerted on each structural member.

$$F_{wind} = P_{wind} A_{wind}$$

A_{wind} : Projected area (m^2) of windage on a plane normal to the direction of the wind. In cases where the atmospheric projected area varies according to the changing of drafts, the area is to be on the minimum draft.

In cases where structural members may be affected by the shadow effect in which data and calculations are submitted to the Society and considered appropriate, wind forces may not conform to the above-mentioned formula.

3.3.3 Calculation of hydrodynamic loads

-1. The calculation of the hydrodynamic loads acting on a Floating Structure and tower are to be performed using appropriate methods. Design loads may be estimated through model tests as deemed appropriate by the Society.

-2. The wave and tidal current for the design environmental condition are to be based on the statistical measurement wave and tidal current data for the specific installation site or the analysis and interpretation of wave and tidal current measurement data for the specific installation site by weather consultants.

-3. Wave force acting on a Floating Structure and tower is to be as follows:

The dynamic response due to a wave is to be estimated, in principle, by using numerical simulation. The dynamic response estimation of a structure is to be done within the limits of the wave period that have effective energy in the wave spectrum by analysis programs that appropriately model the structures and their moorings. In particular, wave period proximity of which dynamic response is the maximum is to be calculated in detail.

-4. Current force on a Floating Structure is to be calculated by the typical equation shown below.

Current force $F_{current}$ (kN) on the submerged part of any structure is to be calculated by the following equation. In cases where analysis programs designed to simultaneously calculate the load due to waves and current force is adopted, it is to comply with provisions specified otherwise.

$$F_{current} = 1/2 \rho_{water} C_D A_{current} u_c |u_c|$$

ρ_{water} : Density of water＝1.025 （t/m^3）

C_D : Drag coefficient in steady flow based on data obtained from model tests or reliable coefficients

u_c : Current velocity vector (m/s) normal to the plane of the projected area. In cases where wave particle velocity is considered to be not negligible, the current velocity is to be added to the wave particle velocity.

$A_{current}$: Projected area (m^2) exposed to current. In cases where the underwater projected area varies according to the changing of the draft, the area is to be on the maximum draft. In the case of slender structures in which the influence of an increase of the projected area due to marine growth is considered to be not negligible, maximum marine growth for one year is to be taken into account.

-5. The effect of marine growth on the hydrodynamic loads on a Floating Structure is to be taken into account.

-6. If the marine growth thickness is such that certain assemblies of components are completely blocked, the effect is to be properly incorporated in the modeling of the hydrodynamic loads on a Floating Structure.

3.3.4 Calculation of sea ice loads

The calculation of the static and dynamic loads due to sea ice is to be performed using appropriate methods.

3.3.5 Calculation of loads

-1. Loads as described in **3.1.2** through **3.1.7** are to be taken into account for each design load case. Where relevant, the following is also to be taken into account:

- structural dynamics and the coupling of vibrational modes;
- the mass of the marine growth on the resonant frequencies and dynamic loading of a Floating Structure
- the dynamic response of the wind turbine to the combination of aerodynamic and hydrodynamic loads.

-2. The resolution of metocean parameters (significant wave height, peak spectral period and mean wind speed) used to define load cases for fatigue load calculations are to be sufficient to account for the fatigue damage associated with the full long term distribution of metocean parameters.

Chapter 4 Materials and welding

4.1 General

4.1.1 General

-1. Materials and welding work used for a Floating Structure are to comply with the following **(1)** to **(4)**:

(1) The materials used for important structural members are to be those that comply with the requirements specified in **Part K of the Rules for the Survey and Construction of Steel Ships**.

(2) The steel used for parts under major loads in the direction across the plate thickness are to be made of steel material designed for special features to support loads in the direction across the plate.

(3) The welding work of important structural members is to be in accordance with the requirements specified in **Part M of the Rules for the Survey and Construction of Steel Ships**.

(4) The mooring chains, chain parts, wire ropes, fiber ropes, and anchors are to be in accordance with the requirements specified in **Part L of the Rules for the Survey and Construction of Steel Ships**, or standards deemed appropriate by the Society.

-2. The materials and welding work used for a tower are to be at the discretion of the Society.

Chapter 5 Structural design

5.1 General

5.1.1 General

-1. The integrity of the load-carrying members of a Floating Structure and tower are to be verified and an acceptable safety level is to be ascertained.

-2. The strength of structural members is to be verified by calculations and/or tests to demonstrate the structural integrity of an offshore wind turbine with the appropriate safety level. The load level in any test for strength verification is to correspond with the safety factors appropriate for the characteristic loads according to **5.4**.

-3. Calculations are to be performed using appropriate methods. Descriptions of the calculation methods are to be provided in the design documentation. The descriptions are to include evidence of the validity of the calculation methods or references to suitable verification studies.

-4. To design a Floating Structure and tower, structural analysis for the load cases defined in this Guidelines is to be performed.

-5. Structural members are to have sufficient strength against buckling in consideration of their shapes, scantlings, boundary conditions, etc.

-6. Members subject to repeated stress are to have sufficient fatigue strength, taking the value and number of cycles of the repeated stress, the shape of members, etc. into consideration.

-7. The effect of local stress concentrations is to be considered for notches in members or discontinuous parts of structure.

-8. In obtaining respective local stresses of the members, all the stress components concerned are to be summed up. The scantlings are to be determined on the basis of criteria which combine, in a rational manner deemed appropriate by the Society, the individual stress components acting on the respective members.

-9. The categories of structural members and application of steel of a Floating Structure are to be in accordance with the requirements specified in **6.2, Part P of the Rules for the Survey and Construction of Steel Ships**.

-10. The designs of welded joints are to be in accordance with the requirements specified in **1.2, Part C of the Rules for the Survey and Construction of Steel Ships**. In cases where consideration is given to the welded joints of parts where the stresses may concentrate and the shapes of welded joints for fatigue strength design, data relative to them is to be submitted for Society approval.

-11. Floating Structures which are installed in icy sea areas are to comply with the requirements given in **Chapter 5, Part I of the Rules for the Survey and Construction of Steel Ships**.

-12. In cases where large openings such as moonpools, turret mooring systems, etc. are provided, Floating Structure are to be suitably reinforced and possess strength continuity.

-13. Towers are to comply with the requirements in this chapter, and also to be at the discretion of the Society.

-14. The strength of Floating Structures and towers during towing and installation is to be at the discretion of the Society.

-15. Floating Structures are not to collapse or drift at the time of earthquake or tsunami.

5.2 Structural arrangements

5.2.1 General

-1. Tank sizes are to be sufficient enough to avoid any motion due to resonance of liquid in the tanks with rolling and pitching of Floating Structures. In case where such motion is not avoidable, swash bulkheads are to be provided inside tanks. However, in cases where the structural member of tanks possess sufficient strength against loads caused by the motion of liquids in such tank, the above requirements need not apply.

-2. The other structural arrangements are to be at the discretion of the Society.

5.3 Design methodology

5.3.1 General

Model testing and prototype tests may also be used as a substitute for calculation to verify the structural design.

5.4 Overall strength analysis

5.4.1 Method

Those guidelines use the partial safety factor to account for the uncertainties and variability in loads and materials, the uncertainties in the analysis methods and the importance of structural components with respect to the consequences of failure.

5.4.1.1 Partial safety factor format

The safety level of a structure or a structural component is considered to be satisfactory when the design load effect S_d does not exceed the design resistance R_d:

$$S_d \leqq R_d$$

This is the design criterion. The design criterion is also known as the design inequality. The corresponding equation $S_d = R_d$ forms the design equation.

5.4.1.1.1 Design load effect

The following **(1)** or **(2)** are to be used to establish the design load effect S_{di}:

(1) The design load effect S_{di} is obtained by multiplication of the characteristic load effect S_{ki} by a partial safety factor γ_{fi}.:

$$S_{di} = \gamma_{fi} S_{ki}$$

Where, S_{ki}: Characteristic load effect

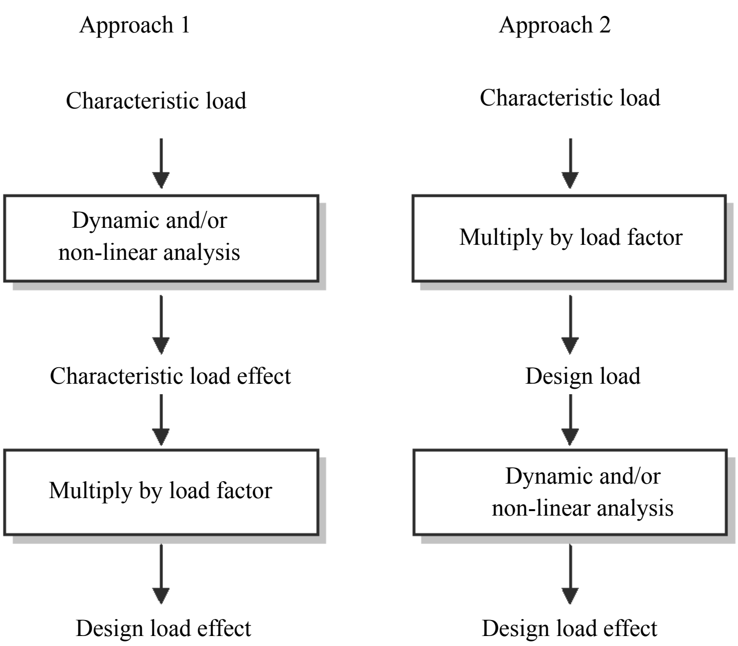
(2) The design load effect S_{di} is obtained from a structural analysis for the design load F_{di}, where the design load F_{di} is obtained by multiplication of the characteristic load F_{ki} by a partial safety factor γ_{fi}:

$$F_{di} = \gamma_{fi} F_{ki}$$

Where, F_{ki}: Characteristic load

The first approach is generally used to determine the design load effect when a proper representation of the dynamic response is the prime concern, whereas the second approach is generally used if a proper representation of non-linear material behaviour or geometrical nonlinearities or both are the prime concern.

Fig. 5.1 The two approaches to calculate the design load effect



5.4.1.1.2 Design resistance

The following **(1)** or **(2)** are to be used to establish the design resistance, R_d, of a particular structural component:

(1) The design resistance is determined from the characteristic material strength:

$$R_d = R\left(\frac{1}{\gamma_m} f_k\right)$$

Where, γ_m : Partial safety factor for material strength

f_k : Characteristic value for the material strength

(2) The design resistance is determined from the characteristic resistance of the particular structural component:

$$R_d = \frac{1}{\gamma_m} R_k$$

Where, γ_m : Partial safety factor for material strength

R_k : Characteristic value for the component resistance

5.4.2 Overall strength

-1. The ultimate load cases and associated load safety factors are to be used in the design of a Floating Structure and tower.

-2. In principle, for each load case in **Table 3.1** and **Table 3.2**, the design criterion in this section **5.4** is to be verified.

5.4.2.1 Partial safety factors for loads

Partial safety factors for loads are to be at least the values specified in the following table:

Table 5.1 Partial safety factors for loads (γ_f)

Unfavourable loads [a]			Favourable [b] loads
Type of design situation (See **Table 3.1** and **Table 3. 2**.)			All design situations
Normal (N)	Abnormal (A)	Transport, erection, and maintenance (T)	
1.35	1.1	1.5	0.9

Note

a) When a gravity load is "Unfavourable load," the partial safety factor of the gravity load is to be 1.0.

b) Pretension and gravity loads that significantly relieve the total load response are considered favourable loads.

5.4.2.2 Partial safety factors for resistances and materials

The design resistances of a Floating Structure and tower are to be determined according to the **ISO** offshore structural design standards or other recognized offshore design standards. For the characteristic values for material strengths of the Floating Structure and tower, specified yield strength of the materials is to be used. Alternatively, the design resistance of the tower may be determined according to **JIS C1400-1 7.6.2.2**.

5.4.3 Special partial safety factors

Lower partial safety factors for loads may be used where the magnitudes of loads have been established by measurement or by analysis confirmed by measurement to a higher than normal degree of confidence. The values of all partial safety factors used are to be stated in the design documentation.

5.5 Scantlings of structural members

5.5.1 General

-1. For the primary structural members of a Floating Structure and tower, which contribute to the overall strength, the scantlings are to be determined in accordance with the requirements in **5.4**. However, the requirements in **5.5.2** and **5.5.3** may be applied to the primary structural members of the Floating Structure.

-2. For a Floating Structure subjected to local loads, the requirements in **Part C** and **Part CS of the Rules for the Survey and Construction of Steel Ships**, or other requirements deemed appropriate by the Society may be applied.

5.5.2 Thickness of plating of Floating Structures

The thickness of plating of the primary structure of a Floating Structure such as shell plating which contributes to the overall strength, subjected to distributed loads, is not to be less than obtained from the following formulae, whichever is greater:

$$75.2S\sqrt{h_s / K_e} + C \quad (mm)$$

$$60.8S\sqrt{h_c / K_p} + C \quad (mm)$$

S : Spacing of transverse or longitudinal frames (m)

h_s : Head of water in static loading (m)

h_c : Head of water in combined loading (m). The combined loading is a condition in which the Floating Structure is loaded with combined loads of the static loads, dynamic loads such as wind loads, wave loads, operation loads, etc. which affect the overall strength and loads induced by the accelerated motion of the Floating Structure due to these loads and heeling.

K_e : As given by the following formulae, whichever is smaller:

$K_e = (235 - K\sigma_{s1}) / K$

$K_e = 1.45(235 - K\sigma_{s2}) / K$

K_p : To be obtained from the following formulae:

・Where $\sigma_{c1}\sigma_{c2} > 0$, the value given by the following formulae, whichever is smaller:

$K_p = \left(55225 - K^2\sigma_{c1}^2\right)/(235K)$

$K_p = 2\left(235 - K\left|\sigma_{c2}\right|\right)/K$

- Where $\sigma_{c1}\sigma_{c2} < 0$, the value given by the following formulae, whichever is smaller:

$K_p = \left(55225 - K^2\sigma_{c1}^2\right)/(235K)$

$K_p = 2\left(235 - K\left|\sigma_{c1}\right| - K\left|\sigma_{c2}\right|\right)/K$

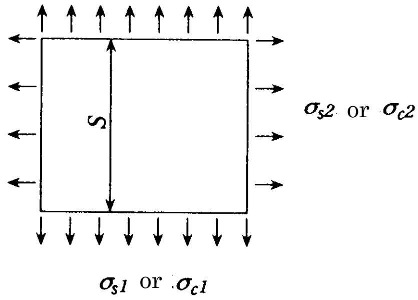
$\sigma_{s1}\sigma_{s2}$: Axial stresses acting on the panel in static loading (*N/mm*^{2}), see **Fig. 5.2**.

$\sigma_{c1}\sigma_{c2}$: Axial stresses acting on the panel in combined loading (*N/mm*^{2}), see **Fig. 5.2**.

K : Material factor given in **2.2, Part P of the Rules for the Survey and Construction of Steel Ships**

C : Corrosion allowance specified in **5.7.3** (*mm*)

Fig. 5.2 Axial Stresses $\sigma_{s1}, \sigma_{s2}, \sigma_{c1}$, and σ_{c2}



5.5.3 Section modulus of transverse or longitudinal frames of Floating Structures

The section modulus of transverse or longitudinal frames which support the panels prescribed in **5.5.2** is to be obtained from the following formula:

$$\frac{1079CKSh_c\ell^2}{235 - K\sigma_{c0}} \quad (cm^3)$$

C : Coefficient such as 1.0 for both ends fixed, and 1.5 for both ends supported

ℓ : Span of frames (*m*)

σ_{c0} : Axial stress in combined loading (*N/mm*^{2})

S, h_c and K: As specified in **5.5.2**.

5.5.4 Local buckling of cylindrical shells of Floating Structures

Unstiffened or ring-stiffened cylindrical shells subjected to axial compression, or compression due to bending, and having proportions which do not satisfy the following relationship, are to be checked for local buckling in addition to the overall buckling:

$t > 0.044D\sigma_Y\,(mm)$

t : Thickness of shell plating (*mm*)

D : Diameter of cylindrical shell (*m*)

σ_Y : Specified yield stress of materials (*N/mm*^{2})

5.6 Fatigue strength

5.6.1 General

-1. Structural members subject to repeated stress are to have sufficient fatigue strength, taking the value and number of cycles of the repeated stress, mean stress, the shape of members, etc. into consideration.

-2. Fatigue analysis is to be performed based on the environmental condition of the specific installation site considered in the design of the Floating Structure and tower.

-3. Design fatigue life is equal to the design service life of the Floating Structure and tower but not less than 20 years.

-4. For each load case in **Table 3.1** and **Table 3.2**, for which fatigue analysis is required, design standard is to be verified.

5.6.2 Fatigue strength evaluation

-1. Fatigue analyses are to be carried out on stress concentration areas which are possible to cause detrimental fatigue cracks, areas subject to reaction forces from mooring systems, and connection areas of plate materials, deemed necessary by the Society.

-2. In fatigue analyses, all kinds of repeated loads are, in principle to be considered.

-3 In fatigue analyses, the accessibility to the individual structural members for the purpose of inspection is to be considered.

-4. In fatigue strength evaluations, the cumulative fatigue damage ratio is to be calculated based on the assumption of linear cumulative damage. The results of any evaluation and information regarding methods used in such evaluation such as the method of stress analysis, applied S-N Diagram, the consideration of mean stress, etc. are to be submitted to the Society.

-5. Alternatively, the design resistance of the tower may be determined according to **JIS C1400-1 7.6.3.2**.

5.6.3 Recommended measures to improve fatigue strength

-1. For structural members exposed to corrosive environments where fatigue strength is considered critical, effective corrosion controls are to be done by electric protection or other equally effective means.

-2. For structural members where fatigue strength is considered critical, special attention is to be paid to weld defects during fabrication. In their welding, full penetration welding is recommended.

5.7 Corrosion control means and corrosion margins

5.7.1 General

Corrosion control means for Floating Structures and towers are to be provided taking their design service life, maintenance, corrosive environment, etc. into account.

5.7.2 Corrosion control means

The standard corrosion control means to be provided according to the corrosive environment to which structural members of Floating Structures and towers are exposed are specified in the following **Table 5.2**:

Table 5.2 Standard corrosion control means

<table>
<tr><th colspan="3">Structural members to be provided with corrosion control means</th><th>Means of corrosion control</th></tr>
<tr><td>Above the splash zone</td><td rowspan="3">External shell structural members</td><td>Upper deck, side-shell plating</td><td>Coating with rust-resistant and weather-resistant paint</td></tr>
<tr><td>Splash zone</td><td>Side-shell plating</td><td>Effective coating or lining
Consider that corrosive environment in the splash zone is severer than the other parts.</td></tr>
<tr><td>Below the splash zone</td><td>Side-shell plating, bottom shell plating</td><td>Coating with sea water corrosion resistant paint, installation of cathodic protection or use two means at the same time</td></tr>
<tr><td colspan="2">In ballast tank</td><td>Primary members such as bulkheads, floors, girders and Stiffeners such as longitudinals</td><td>Coating with sea water corrosion resistant paint or use coating and cathodic protection together</td></tr>
<tr><td colspan="3">Primary structural members and internal compartment materials other than those shown above</td><td>Coating with rust-resistant paint</td></tr>
</table>

5.7.3 Corrosion margin

-1. Corrosion margins according to the corrosive environment to which structural members are exposed are to be in accordance with the values given in **Table 5.3**. In cases where a corrosive environment is clearly severer than assumed, values that are bigger than the values given in **Table 5.3** or additional corrosion control means considered appropriate will be required. In cases where requirements in **Part C** and **Part CS of the Rules for the Survey and Construction of Steel Ships** are applied to the design of a Floating Structure, scantlings are to be larger than those defined in the requirements:

-2. When additional means of corrosion control deemed appropriate by the Society are given to a Floating Structure and tower, the corrosion margine defined in preseeding **-1**. may be reduced as deemed appropriate by the Society.

Table 5.3 One side corrosion margin for structural members

<table>
<tr><th colspan="2" rowspan="2">Corrosive environment</th><th colspan="2">One side corrosion margin (mm)</th></tr>
<tr><th>Period intended to operate: 20 years</th><th>Period intended to operate: 30 years</th></tr>
<tr><td rowspan="2">In ballast tank</td><td>Face of girder</td><td>1.0</td><td>1.3</td></tr>
<tr><td>Other than shown in above</td><td>0.8</td><td>1.0</td></tr>
<tr><td colspan="2">Exposed to air (above the splash zone)</td><td>1.0</td><td>1.1</td></tr>
<tr><td colspan="2">Splash zone</td><td>1.0</td><td>1.1</td></tr>
<tr><td colspan="2">Exposed to sea water (below the splash zone)</td><td>0.5</td><td>0.6</td></tr>
<tr><td colspan="2">Other than those shown above</td><td>0.5</td><td>0.6</td></tr>
</table>

Note)

In cases where the period intended to operate assumes an intermediate value of Table 5.3, the period intended to operate is to be determined by linear interpolation and rounded up to one decimal place. In cases where the period intended to operate exceeds 30 years, the period intended to operate is to be determined by linear extrapolation using the values equal to those in cases where the period intended to operate is 20 years and 30 years and rounded up to one decimal place.

5.8 Fenders, etc

5.8.1 General

-1. Suitable fenders which contact with other ships such as work-ships, service ships, etc. are to be provided to the contact area of a Floating Structure.

-2. Except for cases where the Society gives a special approval, appropriate access means used for operations are to be prepared.

-3. Ladders, steps, etc. are to be provided inside compartments for safety inspections as deemed appropriate by the Society.

5.9 Helicopter decks

5.9.1 General

The loads for helicopter decks are to comply with the requirements specified in **3.2.7, Part P of the Rules for the Survey and Construction of Steel Ships**.

5.10 Elevating equipment

5.10.1 Application

-1. In cases where elevating equipments do not comply with the requirements of this section due to the special reasons, those deemed appropriate by the Society considering structure and usage may be accepted.

-2. The Society is to check that equipments not defined in this section cause no trouble in operation of the relevant elevating equipment of a Floating Structure and tower, and approve the use of them.

5.10.2 Material, structure, and performance

-1. Materials used for elevating equipments are to be fireproof and corrosion proof materials, unless otherwise provided. In cases where deemed appropriate by the Society, this requirement may be dispensed with.

-2. Elevating equipments are to have structure causing no risk to operators in normal operation.

-3. Elevating equipments are to generate no trouble at the time of maintenance and inspection even when a Floating Structure and tower are heeling.

-4. Elevating equipments are to perform without any fault due to vibration of a Floating Structure and tower.

5.10.3 Installation

Elevating equipments are to be installed in areas allowing elevating without any risk.

5.10.4 Safety factor

-1. Elevating equipments are to have a safety factor to the braking strength for their important parts, which are equal or higher than those in **Table 5.4** when a load corresponding to the limit load is applied in the normal operation state.

-2. Elevating equipments are to have no fault even when a load 1.25 times or higher than the limit load is applied.

-3. Elevating equipments are to operate reliably even when a load 1.10 times or higher than the limit load is applied.

Table 5.4 Safety factor of ascensor

Class	Safety factor
Main rope or chain	10.0
Cage	7.5
Supporting beam	5.0
Other metal structures	5.0

5.10.5 Safety device

-1. Elevating equipments are to have safety devices to protect persons.

-2. Elevating equipments are to have devices of which main ropes wind around the hoisting device drums flatly.

-3. Three or more main ropes of elevating equipments are to be used. They are to have strength to prevent falling when one rope is cut down.

5.10.6 Special measures

Elevating equipments are to comply with additional requirements deemed necessary by the Society according to the structure and use conditions of the elevating equipments in addition to the requirements in this section.

5.10.7 Inspection record of elevating equipments

-1. An owner of a Floating Structure is to prepare an inspection record of elevating equipments in the Floating Structure.

-2. An owner of a Floating Structure is to attach the assignment of elevating equipment limit load, etc. defined in **8.3.3** to the inspection record of elevating equipments mentioned in **-1**.

-3. An owner of a Floating Structure is to record in the inspection record of elevating equipments when an inspection defined in **5.10.8** is performed in the inspection record of elevating equipments.

5.10.8 Inspection of elevating equipments

An owner of a Floating Structure is to give an inspection of elevating equipments for which limit load and maximum number of person are assigned based on the requirements in **8.3.3** to check any problem.

5.10.9 Indication of limit load

An owner of a Floating Structure is to prepare indications of the assigned limit load and maximum number of person in redily visible parts of elevating equipments.

Chapter 6 Mooring

6.1 General

6.1.1 General

-1. Floating Structures are to be provided with moorings complying with the requirements given in this Chapter or **ISO19901-7**.

-2. In the case of positioning systems which keep Floating Structures at a specific position by connecting moorings installed on the Floating Structure to any of the periphery facilities for mooring defined in **1.2.1.53**, construction of such periphery facilities for mooring and such moorings are to be as deemed appropriate by the Society.

6.1.2 Mooring

-1. Moorings are to be sufficiently capable of positioning Floating Structures at a specific location against all of the design conditions for operations as well as all of the safety conditions for systems embedded on the seabed.

-2. In the case of moorings of Floating Structures installed in sea areas where low temperature, freezing, ice formation, etc. are predicted, the effects of such things are to be taken into consideration or appropriate countermeasures are to be provided.

6.1.3 Conditions to be considered for mooring analysis

-1. With respect to the design of moorings, conditions including the following are to be considered: Concerning the condition **(3)**, except for cases where deemed necessary by the Society, consideration only when other Floating Structures, moorings, and others are near the relevant Floating Structure and moorings is acceptable.

(1) Intact condition

A condition where all structural components of the Floating Structure and mooring remain intact

(2) Damage case with one broken mooring line

A condition with any one mooring line broken at its design environmental condition which causes the maximum mooring line load for the entire system, where, however, the structure of the Floating Structure proper remains intact. It should be noted that the mooring line subjected to the maximum load in intact conditions when broken may not lead to the worst broken mooring line case. Designers are to determine the worst case by analyzing several cases of broken mooring lines including broken lead line and broken adjacent line cases.

(3) Transient condition with one broken mooring line

A condition with one mooring line broken (in principle, the lead line is to be considered as broken) in which the moored Floating Structure exhibits transient motion (overshooting) until it has settled at a new equilibrium position.

-2. The effects of increased line tension, etc. due to overshoot of Floating Structures are to be considered through the analysis of the transient conditions of one broken mooring line. The proper clearances between Floating Structures and any near-by structures are to also be verified.

-3. In the case of Single Anchor Leg Mooring (SALM), cases considering a loss of buoyancy due to damage of a compartment of the SALM structure should be analyzed for position mooring capability instead of cases with one broken mooring line.

-4. Mooring analysis in combination with the assistance of thrusters is to be as deemed appropriate by the Society.

6.2 Mooring analysis

6.2.1 General

-1. Mooring analysis is to be conducted based on the external conditions as specified in **Chapter 2**. Such analysis is to include the evaluations of the drift forces generated by the external conditions, the response of the Floating Structure, and the corresponding mooring line tension.

-2. Mooring analysis as deemed appropriate by the Society is to be carried out for the all prospective mooring conditions. The effects due to the draught changes of the Floating Structure are to be taken into consideration. In the case of Floating Structures mooring to individual periphery facilities, such as CALM, separate from the Floating Structure, mooring analysis for the total system, including any periphery facilities, is to be carried out.

-3. In case of moorings using mooring lines, analysis is to be carried out under the awareness that there is no excessive bend of any lines in way of the contact points between mooring lines and mooring equipment (fairleaders, etc.) fitted on Floating Structures.

-4. The moorings of Floating Structures and the seabed mooring points (anchors, sinkers, piles, etc.) of any periphery facilities for mooring are not to be slid, uplifted, overturned, etc. against any envisioned force from the mooring lines. In cases where scouring effects are not considered to be negligible, appropriate consideration is to be taken such as the modification of burial depth, protection against the flow around seabed mooring points, etc.

-5. Mooring analysis is to be made under the awareness that the mooring is subjected to steady forces of wind, current and mean wave drift force as well as wind and wave induced dynamic forces. Maximum line tension is to be calculated considering that wind, wave, and current come from unrestricted directions. However, in cases where the data for the specific positioning area of a Floating

Structure prove a restricted direction of wind, wave and current in that area, calculations under such specific directions may be accepted.

-6. The maximum offset of a Floating Structure and maximum tension of a mooring line is to be calculated. Depending on the analysis objectives, a quasi-static analytical method, or dynamic analytical method as deemed appropriate by the Society may be used for calculations.

6.2.2 Mean environmental forces

-1. The calculation of steady forces due to wind and current are to be in accordance with **Chapter 2** and **Chapter 3**. However, to calculate wind loads, the following **(1)** and **(2)** are to be satisfied:

(1) An average wind speed per one minute is to be used. When the average wind speed per one minute is not available, a proper spectrum is to be calculated according to the data, and converted to the average wind speed per one minute with statistical methods.

(2) The partial safety factor defined in **5.4.2.1** may not be considered.

-2. Mean and oscillatory low frequency drift forces may be determined by model tests or using hydrodynamic computer programs verified against model test results or other data. Mean drift forces may be determined using standards deemed appropriate by the Society.

-3. Load information is to be prepared based on appropriate analysis, model tests, etc., and such information is to be provided on board.

6.2.3 Maximum offset

-1. Maximum offset may be calculated as the sum of the offset due to steady components such as wind, current, and wave (steady drift), and dynamic motion offset due to the dynamic components of forces induced by waves (high and low frequency).

-2. The following formula is to be adopted as the standard for calculating maximum offset. In the following formula, mean offset and significant single amplitude or maximum amplitude of the maximum offset obtained from model tests or analysis methods deemed appropriate by the Society are used. However, when time history domain method is used, this requirement may be neglected.

$S_{max} = S_{mean} + S_{lf\,(max)} + S_{wf\,(sig)}$ or $S_{max} = S_{mean} + S_{lf\,(sig)} + S_{wf\,(max)}$, whichever is greater.

Where,

S_{mean} : Mean offset of the Floating Structure due to wind, current and mean drift

$S_{lf(sig)}$: Significant single amplitude low frequency motion

$S_{wf(sig)}$: Significant single amplitude wave frequency motion

The maximum values of low frequency motion $S_{lf\,(max)}$ and wave frequency motion $S_{wf\,(max)}$ may be calculated by multiplying their corresponding significant single amplitude values by the factor C, which is to be calculated as follows:

$$C = 1/2 \cdot \sqrt{2 \ln N}$$

$$N = \frac{T}{T_a}$$

T : Hypothetical storm duration (*seconds*), minimum 10,800 (i.e. 3 *hours*). In the case of areas with longer storm durations (monsoon areas), T needs to be a higher value.

T_a : Average response zero up-crossing period (*seconds*)

In the case of low frequency components, T_a may be taken as the natural period T_n of a Floating Structure with a mooring. T_n can be calculated as follows using the mass of the Floating Structure m (including added mass, etc.) and the stiffness of the mooring system k for horizontal motion (port-starboard, fwd-aft, rotation) at the Floating Structure's mean position and equilibrium heading as follows:

$$T_n = 2\pi\sqrt{\frac{m}{k}}$$

In such cases, information about the stiffness of moorings, damping forces, and other parameters which may affect the maximum values of low frequency motion are to be submitted to the Society for reference.

-3. In the case of single point moorings, the maximum offset for motion in waves is to be calculated using a non-linear time history domain method or model tests. In such cases, wave irregularities and wind variances are to be considered as well.

6.2.4 Calculation of mooring line tensions

-1. In order to calculate the maximum tension acting on the mooring lines, the severest combination of wind, waves and current is to be considered together with a sufficient number of angles of incidence. Although this severest condition generally corresponds to cases where all of the wind, wave and current directions are consistent, in the case of specific sea areas, the combination of wind, waves and current in different directions which are likely to create a higher tension are to be taken into account as needed.

-2. In calculating the tension acting on mooring lines, at least items **(1)** to **(3)** mentioned below are to be considered. Item **(4)** may be assessed as necessary. This analytical procedure can be called a quasi-static analytical procedure and is to be adopted as the standard for calculating the tensions acting on mooring lines. The calculated maximum tension of mooring lines has to have, in principle, a suitable safety factor specified in **Table 6.1** corresponding to specific breaking tension.

(1) Static tension of mooring lines due to net weight and buoyancy

(2) Steady tension of mooring lines due to a steady horizontal offset of Floating Structures induced by wind, waves and current

(3) Quasi-static varying tension of mooring lines due to Floating Structure motion induced by waves
(4) Tension of mooring lines in consideration of their elastic elongation in cases where they are used in a moderately taut condition (generally in shallow waters), or in cases where mooring lines with low rigidity such as fibre ropes are used

Table 6.1 Safety factors for mooring lines

Condition	Safety factor	
	Chains or wire ropes	Synthetic fibre ropes
Intact		
Dynamic analysis	1.67	2.50
Quasi-static analysis	2.00	3.00
One broken mooring line (at new equilibrium position)		
Dynamic analysis	1.25	1.88
Quasi-static analysis	1.43	2.15
One broken mooring line (transient condition)		
Dynamic analysis	1.05	1.58
Quasi-static analysis	1.18	1.77

-3. The maximum tension in a mooring line T_{max} is to be determined as follows, except for cases where time history domain method is used:

$$T_{max} = T_{mean} + T_{lf\,(max)} + T_{wf\,(sig)} \quad \text{or} \quad T_{max} = T_{mean} + T_{lf\,(sig)} + T_{wf\,(max)}$$, whichever is greater

T_{mean} : Mean mooring line tension due to wind, current and mean steady drift

$T_{lf\,(sig)}$: Significant single amplitude low frequency tension

$T_{wf\,(sig)}$: Significant single amplitude wave frequency tension

The maximum values of low frequency tension $T_{lf\,(max)}$ and wave frequency tension $T_{wf\,(max)}$ are to be calculated by the same procedure as that used for obtaining the motions at low frequency and wave frequency described in **6.2.3-2** above.

-4. Moorings are to be designed so that the failure of any one mooring line does not cause the progressive failure of the remaining mooring lines. The tension acting on the remaining mooring lines is to be calculated using the quasi-static analytical procedure. The safety factors for the tension of such mooring lines are, in principle, not to be less than those specified in **Table 6.1** corresponding to their respective specific breaking tension. The period of recurrence of environmental loads such as wind and wave loads, however, may be taken as one year.

-5. In the analysis of the one broken mooring line condition given in **-4** above, in the case of a Floating Structure which is moored in the proximity of other Floating Structures, the safety factors for any mooring lines arranged on the opposite side of the other Floating Structures are to be taken as 1.5 times of those indicated in **Table 6.1**.

-6. In cases where the following items **(1)** and **(2)** are taken into account in addition to **-2** above, the safety factors required in cases where quasi-static analytical procedures are adopted may be modified to values deemed appropriate by the Society.

(1) Dynamic tension in mooring lines due to damping forces and inertia forces acting on each mooring line in cases where they are generally used in deep water
(2) Quasi-static low-frequency varying tension of mooring lines due to the low-frequency motion of Floating Structures in irregular waves in cases where they are used in a sufficiently slack condition (in cases where the natural period of motion of a Floating Structure in a horizontal plane is sufficiently longer than the period of ordinary waves)

-7. In the case of taut mooring systems, the following are to be satisfied, in addition to **-1** to **-5** above:

(1) Such systems are to be designed so that no slack is caused in any mooring line due to changes in line tension.
(2) Changes in the tension of mooring lines due to tidal difference including astronomic tides and meteorological tides are to be considered.
(3) The effects of any changes in the weight and displacements of heavy items carried on board upon the tension of mooring lines are to be sufficiently taken into account.
(4) In cases where the effects of the non-linear behavior of mooring lines on their tension are not negligible, tension due to non-linear behavior is to be considered.

-8. In the case of tension mooring systems, the requirements specified in **10.4.2, Part P of the Rules for the Survey and Construction of Steel Ships** are to be complied with in addition to **-1** to **-5** above.

-9. In the case of single-point mooring systems, the requirements specified in **10.5.2, Part P of the Rules for the Survey and Construction of Steel Ships** are to be complied with in addition to **-1** to **-5** above.

6.2.5 Fatigue Analysis

-1. The fatigue life of mooring lines is to be assessed in consideration of the changing tension range, T and the number of cycles, n. The fatigue life of mooring lines is to be evaluated by estimating the fatigue damage ratio, D_i in accordance with Miner's law using a curve relating the changing tension range to the number of cycles to failure. (T-N curve):

$$D_i = \frac{n_i}{N_i}$$

n_i : Number of cycles within the tension range interval, i, for a given sea state

N_i : Number of cycles to failure at changing tension range, Ti

The cumulative fatigue damage, D for all expected number of sea states NN (identified in a wave scatter diagram) is to be calculated as follows:

$$D = \sum_{i=1}^{NN} D_i$$

The value of D multiplied by 3.0 is not to be greater than 1.

-2. The fatigue life of each mooring line component is to be considered. T-N curves for various line components are to be based on fatigue test data and regression analysis.

-3. Special consideration is to be given to the fatigue strength of the connections between the mooring lines and Floating Structures, and the connections between the mooring lines and seabed mooring points.

-4. When the Society approves the necessity, influence of vibration due to eddy resistance is to be considered.

6.2.6 Corrosion and wear

To protect chains from corrosion and wear, the link diameters is to be increased properly according to salinity in the installation sea areas. The standard extra rink diameters to protect chains from corrosion and wear are as follows:

Splash zone and contact area with hard sea bottom : 0.2mm to 0.4mm per year
Others : 0.1mm to 0.2mm per year

6.3 Design of mooring lines

6.3.1 Components of mooring lines and seabed mooring points

-1. Each component of moorings is to be designed using design methods by which the severest loading condition can be verified. The strength of connecting shackles, links, etc. used at the connecting points between the mooring lines and Floating Structures and between mooring lines and seabed mooring points are, in principle, to have safety factors against the breaking loads of such mooring lines or the ultimate strength of structures not less than those indicated in the **Table 6.2**.

Table 6.2 Safety factors

Safety factors	
Intact conditions	2.50
One broken mooring line	1.43

(Note)

* : In cases where a safety factor of 2.0 is ensured, even in the any one broken mooring line condition, a safety factor of 2.5 may be accepted.

-2. In the case of catenary mooring systems, mooring lines are to be sufficiently long so that no up-lifting forces act on the parts of the mooring line around the mooring point on the seabed under design conditions. In the case of soft clay conditions (like in the Gulf of Mexico), a small angle for the one broken mooring line condition may be considered in cases where deemed acceptable by the Society.

-3. Information verifying that the holding power of seabed mooring points is sufficient against the expected tension from the mooring lines in accordance with **6.2.4** is to be submitted to the Society for reference.

-4. In the case of seabed mooring points which rely on friction with the seabed surface, if the submerged unit weight of mooring lines is constant, the maximum load at the seabed mooring point F_{anchor} can be calculated as follows:

$$F_{anchor} = P_{line} - W_{sub} WD - F_{friction}$$

$$F_{friction} = f_{sl} L_{bed} W_{sub}$$

P_{line} : Maximum mooring line tension

WD : Water depth

f_{sl} : Friction coefficient of mooring line on seabed at sliding which is to be determined in consideration of soil conditions, the type of mooring line, etc. In the case of soft mud, sand, and clay, the values of f_{sl}, and the coefficient of friction at the start f_{st}, indicated in the **Table 6.3** may be used.

L_{bed} : Length of mooring line on seabed at design storm conditions, not to exceed 20% of the total length of a mooring line

W_{sub} : Submerged unit weight of mooring line

In cases where submerged mooring lines are not a single line, or those cases where using intermediate sinkers/buoys, the above equation is to be applied in consideration of such effects.

-5. The safety factors for the horizontal holding power capacity of the seabed mooring points of catenary mooring systems and taut mooring systems are, in principle, to be in accordance with **Table 6.4**. However, the above may not be complied with in cases where required ultimate holding capacity is to be determined based on mooring loads derived from dynamic analysis taking into account mooring line dynamics.

-6. The safety factors for the vertical holding power capacity of the seabed mooring points of taut mooring systems are, in principle, to be in accordance with **Table 6.5**. The safety factors for the tension mooring systems are to be determined by the Society.

Table 6.3 Coefficient of Friction f

	Starting (f_{st})	Sliding (f_{sl})
Chain	1.00	0.70
Wire rope	0.60	0.25

Table 6.4 Safety factor for the horizontal holding capacity of the seabed mooring points of catenary mooring systems and taut mooring systems

Safety factor	
Intact	1.50
One broken mooring line extreme	1.00

Table 6.5 Safety factor for the vertical holding capacity of the seabed mooring points of taut mooring systems

Safety factor	
Intact	1.20
One broken mooring line extreme	1.00

6.4 Mooring equipment

6.4.1 General

Mooring equipments used for tension mooring systems are to meet the following requirements **(1)** and **(3)**:

(1) For laying tension mooring lines, the initial tension in all mooring lines is to be coordinated to achieve approximate uniformity. Power equipment capable of adjusting the tension mooring lines is to be provided as necessary.

(2) A tension monitoring system is to be provided for each tension mooring line.

(3) Plans and documents showing that the supporting members laid to the seabed are designed so that they cannot be pulled up under any design load condition are to be submitted to the Society for reference.

6.4.2 Chains and wire ropes

-1. Chains, wire ropes or fibre ropes used for moorings are to comply with the requirements given in **Chapter 3** and **Chapter 4, Part L of the Rules for the Survey and Construction of Steel Ships** or any standards deemed appropriate by the Society. In cases where the Grade *R*4 chains specified in **3.2, Part L of the Rules for the Survey and Construction of Steel Ships** or stronger chains are used, special care is to be taken because repairs by welding for any defects, loose studs and corrosion by welding is, in principle, prohibited for such chains.

-2. Intermediate sinkers, intermediate buoys and anchors, sinkers, piles, etc. for seabed mooring points are to be as deemed appropriate by the Society.

6.4.3 Chain stoppers

-1. Individual equipment of moorings such as a chain stopper is, in principle, to be approved by the Society.

-2. Chain stoppers used for moorings are to have sufficient strength against the maximum tension of the mooring line as deemed appropriate by the Society.

-3. In the case of laying taut mooring lines, the initial tension in all mooring lines is to be coordinated to achieve approximate uniformity. Power equipment capable of adjusting the tension of mooring lines is to be provided as necessary.

-4. A tension monitoring system is to be provided for each taut mooring line.

6.4.4 Fairleaders

-1. In cases where chains are used for mooring lines, the standard length of the part where the chain and fairleader make contact is to be not less than 7 times the chain diameter.

-2. In cases where wire ropes or fibre ropes are used for mooring lines, the standard length of the part where the wire rope and fairleader make contact is to be not less than 14 times the wire rope nominal diameter.

-3. In the case of arrangements that do not comply with the standards given in **-1** or **-2** above, detailed analysis in which the effects of bending loads acting on mooring lines is taken into account is to be carried out. Otherwise, mooring analysis is to be carried out modifying the values of the safety factors given in **Table PS4.2.1, Part P of the Rules for the Survey and Construction of Steel Ships** upto those values deemed appropriate by the Society.

6.5 Single point mooring systems

6.5.1 Design loads for structures

-1. The design of the structure and equipment of single point mooring systems is to consider the severest combination of various loads including at least the following. A detailed report about such designs is to be submitted to the Society for reference.

(1) Dead loads

(2) Dynamic loads due to motion (including rotating motion around turn tables)

(3) Mooring loads

(4) Fatigue loads

-2. In order to consider the design loads acting on turret systems, the loads from mooring lines due to gravity, buoyancy, inertia, and hydraulic forces, etc. are to be taken into account.

6.5.2 Structural components

-1. Structural components are, in principle, to be in compliance with the codes or standards deemed appropriate by the Society and structural strength is to be evaluated by suitable methods such as FEM, etc.

-2. When performing the analysis mentioned in **-1** above, the allowable stress for von Mises stress is to be 60% of the specified yield strength (not to exceed 72% of the specified tensile strength) of the material used for the part in concern. In the case of transient conditions in the broken mooring line condition, however, the value of allowable stress may be increased up to but not exceeding 80% of specified yield strength.

-3. Structural components are to have sufficient strength against buckling in consideration of their shape, size, surrounding conditions, etc.

-4. A fatigue life evaluation is to be carried out for those parts among essential components designated by the Society, such as turret systems, yokes, etc.

-5. The structures of the periphery facilities for mooring, the connections between such periphery facilities for mooring and moorings and the connections between such periphery facilities for mooring and seabed mooring points are to be those complying recognized standards/codes.

-6. The parts of Floating Structures which transmit and dissipate the loads from turrets and yokes (turret bearing parts, etc.) are to be capable of withstanding such loads and are to be suitably reinforced.

6.5.3 Mechanical components

-1. The mechanical components of single point mooring systems (turret bearings, driving mechanisms, various connecting attachments, etc.) are to be in accordance with standards/codes deemed appropriate by the Society in addition to relevant requirements given in **Chapter 7, Part PS of the Rules for the Survey and Construction of Steel Ships**.

-2. The bearings which carry the loads from rotation structures and mooring lines (turret bearings, etc.) are to be designed with a safety factor of not less than 2 against the destructive yielding of the bearing surface.

-3. Notwithstanding **-2** above, swivel bearings or others which do not carry loads may be designed in accordance with standards/codes deemed appropriate by the Society.

Chapter 7 Stability and draft line

7.1 General

7.1.1 Application

-1. Stability of Floating Structure is to be in accordance with the requirements given in this chapter.

-2. Attention is to be paid to the water-tightness of places where electrical cables penetrate into Floating Structures.

-3. Stability of Floating Structures of Tension-leg platform type is to be as deemed appropriate by the Society..

7.1.2 General

-1. All Floating Structures are to satisfy the stability requirements in this chapter under all applicable conditions.

-2. Floating Structures's motion is to be appropriately controlled so as to not have any detrimental effect on thetower or wind turbine.

-3. Stability calculations are to be based upon conditions where the mooring system affects the Floating Structure or where it does not, whichever is more severe.

-4. For the purpose of stability calculation, the free surface effects of liquids in tanks are to be taken account to.

-5. For the purpose of stability calculation, the loads effects of snow accumulation and icing on the Floating Structure, based upon data from the installation sea area, are to be taken into account as needed.

-6. Stability when Floating Structures are towed and installed is to be as deemed appropriate by the Society.

7.1.3 Stability information booklet

Stability information booklets are to be submitted to the Society for approval. Said booklets are to include the results of stability evaluations under representative operating conditions and, assumed damage condition as well as the damage conditions of mooring systems.

7.1.4 Wind heeling moment

-1. Wind loads are to be obtained in accordance with the requirements in **Chapter 2** and **3**. However, calculations for wind loads are to be in accordance with the following **(1)** and **(2)**:

(1) The average wind velocity per minute is to be used in stability calculations. If the wind velocity data does not provide an average wind velocity per minute, it may be necessary to use the data to determin a suitable spectrum and then use this spectrum to statistically calculate a wind velocity per minute.

(2) The partial safety factors defined in **5.4.2.1** do not need to be considered in stability calculations.

-2. Fordamage stability calculation, wind loads can be obtained from wind velocity of 25.8 *m/s* (at 10m above sea surface).

-3. Heeling force levers are to be taken vertically from the centre of lateral resistance or, if possible, the centre of hydrodynamic pressure of the under water body to the centre of pressure of the areas subject to wind loading.

-4. Wind heeling moments are to be calculated at several angles of inclination for each mode of operation.

-5. Where deemed appropriate by the Society, wind heeling moments may be assumed to vary as a cosine function of Floating Structure heel angle.

-6. Wind heeling moments derived from authoritative wind tunnel tests on representative models of the Floating Structure may be considered as alternatives to the method given in **-2** to **-4** above. Such heeling moment determination is to include lift effects at various applicable heel angles, as well as drag effects.

7.2 Intact stability

7.2.1 General

-1. All Floating Structures are to have positive stability at calm water equilibrium positions.

-2. All Floating Structures are to have sufficient stability to withstand the overturning effect of heeling moments induced by winds and motions induced by waves.

-3. Curves of righting moments and of wind heeling moments similar to **Fig. 7.1** are to be prepared.

-4. Righting moment curves and wind heeling moment curves are to be calculated in relation to the most critical axes and sufficient numbers of floating conditions.

-5. Righting moment curves are to be positive over the entire range from upright to θ_3 of the second intercept angle shown in **Fig. 7.1**. In addition, heeling angles are to be up to the angle in which the blades of wind turbines do not touch the sea surface.

7.2.2 Column-stabilized type

In **Fig. 7.1**, Floating Structures of this type are to meet the following stability criteria:

$$\text{Area } (A+B) \geq 1.3 \times \text{Area } (B+C)$$

However, the angle of heel is to be θ_2 .

7.2.3 Barge type

In **Fig. 7.1**, Floating Structures of this type are to meet the following stability criteria:

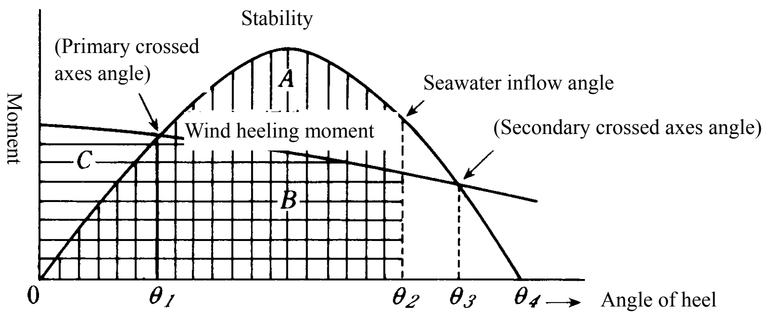
Area $(A+B) \geq 1.4\times$ Area $(B+C)$

However, the angle of heel is to be to θ_2 or θ_3 , whichever is smaller.

7.2.4 Spar type

Floating Structures of this type are to have a stability equivalent to column-stabilized type and barge type.

Fig. 7.1 Righting moments and wind heeling moment curves



7.3 Damage Stability

7.3.1 General

-1. All Floating Structures are to have sufficient freeboard and be subdivided by means of watertight decks and bulkheads to provide sufficient buoyancy and stability to withstand the flooding of any single compartment defined in **7.3.2** under any operating condition.

-2. All Floating Structures are to have sufficient stability to withstand the flooding any one compartment defined in **7.3.2,** heeling moments induced by winds based upon horizontal wind velocity superimposed from any direction and Floating Structures' motion due to waves.

-3. The final waterline after flooding is to be below the lower edge of any downflooding opening.

-4. For the purpose of damage stability calculations, decreases in heeling angles caused by pumping out damaged compartments, ballasting, filling other compartments, or mooring forces, etc. are not to be considered.

7.3.2 Flooding compartment

The following **(1)** to **(3)** compartments are to be considered flooded:

(1) Compartments adjucent to the external shell located between 5.0*m* above and 3.0*m* below the waterline.

(2) Compartments penetrated by electricalcables, etc. at places below the waterline.

(3) Compartments having places subject to mooring line reaction forces and compartments which may possibly flood.

7.4 Watertight compartments and closing appliances

7.4.1 Watertight compartments

-1. The arrangements and scantlings of watertight decks and bulkheads need to be effective to the point necessary to satisfy damage stability requirements.

-2. Where watertight boundaries are required for damage stability, they are to be made watertight. This includes the penetrations of all piping, ventilation devices, electricalequipment, etc.

7.4.2 Closing appliances

-1. The construction and closing appliances of openings through which the flooding of sea water is likely are to be in accordance with relevant requirements given in **Part C** or **Part CS of the Rules for the Survey and Construction of Steel Ships.**.

-2. Closing appliances which are not located within areas of calculated immersion and for which special considerations are given are to be as deemed appropriate by the Society.

7.5 Draft line

7.5.1 General

-1. The freeboard of a Floating Structure is to be determined based on the Floating Structure’s stability, water-tightness and structural strength.

-2. A draught scale, extending above and below the waterlines, is to be indicated.

Chapter 8 Surveys for Floating Structures

8.1 General

8.1.1 Application

-1. Class surveys of Floating Structures specified in this Guideline, are to be in accordance with the requirements of this **Chapter 8**.

-2. The Floating Structures are required to have monitoring systems (anemometers, wave height meters, etc.) that are capable of monitoring external environmental forces (mainly winds, waves, currents, etc.) acting on them. However, where environmental data on sea areas in the vicinity of the Floating Structures are available, the monitoring systems onboard the Floating Structures may be dispensed with.

-3. Periodical surveys such as annual surveys, intermediate surveys, special surveys for Floating Structure may be dispensed when sufficiently reliable information on safety of the Floating Structure can be acquired from other Floating Structures having same constructions and also the Society gives approval.

8.1.2 General requirements on surveys

-1. General requirements of the classification survey, class maintenance survey, and other relevant surveys are to follow the requirements specified in **Chapter 1, Part B of the Rules for the Survey and Construction of Steel Ships**. At classification surveys and class maintenance surveys, it is to be verified that the Floating Structures are in good conditions through examinations, tests and investigations carried out to the satisfaction of the surveyor.

-2. When conducting surveys, particular attention should be paid to the requirements of National Regulations of coastal states in addition to the requirements specified in this Chapter.

8.1.3 Terminology

Terms defined in this Chapter are as follows. Terms not defined in this Chapter are according to **1.2**.

(1) Inspection plans

These are documents specifying inspection times, the times when the surveyor is present, the objects and the methods of inspections for periodical surveys, which are approved by the Society.

(2) Documents on inspection procedures

These are documents specifying detailed inspection procedures (inspection procedures, etc.) and acceptance criteria for periodical surveys which are approved by the Society.

8.2 Equivalency

8.2.1 General

Notwithstanding the requirements in this Chapter, the Society may approve inspection plans, methods, procedures, etc. differing from those specified in this Chapter if they are considered to be able to attain equivalent results.

8.3 Classification survey during construction

8.3.1 General

-1. In the classification survey during construction, surveys are to be carried out on construction, equipment, machinery, electrical installations, stability, and draft lines in order to ascertain that they meet the relevant requirements of this Guideline.

-2. In the classification survey, surveys for materials, construction, equipment, machinery, etc. are to be carried out in accordance with the requirements specified in **8.3.2** to **8.3.8** in addition to the relevant requirements specified in **Chapter 2, Part B of the Rules for the Survey and Construction of Steel Ships**.

8.3.2 Submission of plans and documents

-1. Submission of plans and documents for approval

With respect to the classification survey during construction, the following plans and documents are to be submitted to the Society for approval before the work is commenced.

(1) General

(a) Inspection plans

(b) Documents on inspection procedures

(2) Floating Structure

(a) General arrangements

(b) Cross sections (showing the draft line and draft line during towing)
(c) Longitudinal sections
(d) Details of inspection facilities
(e) Supporting structures of tower
(f) Details of welding procedures
(g) Details of painting and corrosion control procedures
(h) Towing arrangements
(i) Arrangements and construction of moorings
(j) Stability information booklet (including the information regarding towing)
(k) For column-stabilized Floating Structure, construction of all columns, lower hull, footings, and bracing
(l) For machinery and electric installations relating to the safety of the Floating Structure: plans and documents specified in the relevant Chapters in **Part D** and **Part H of the Rules for the Survey and Construction of Steel Ships**
(m) Other plans and/or documents deemed necessary by the Society

(3) Tower
(a) General arrangements
(b) Detail drawings of primary structures
(c) Specification of bolts
(d) Details of painting and corrosion control procedures
(e) Transition pieces
(f) Drawings of anchor bolts
(g) Other plans and/or documents deemed necessary by the Society

(4) Elevating equipments (only for Floating Structures and towers equipped with elevating equipments)
(a) Arrangements of elevating equipments
(b) Construction drawing of elevating equipments
(c) Calculation sheets on strength of elevating equipments
(d) Document showing materials of elevating equipments
(e) Document showing how to use elevating equipments

-2. Submission of plans and documents for reference

With respect to the classification survey during construction, the following plans and documents are to be submitted for reference in addition to the plans and documents specified in **-1**.

(1) General
(a) Maintenance manual (including items related to maintenance for wind turbines)

(2) Floating Structure
(a) Method and calculation sheets of structural analysis
(b) Data or documents on environmental conditions used for determination of design loads and calculation methods of total external forces and moments due to wind, waves, tidal currents, mooring, and other loads
(c) Documents on the effects of icing or snow on loading, stability and projected area
(d) Calculation sheets on intact and damage stability in all conditions
(e) Calculation sheets for major loads acting on supporting structures from the wind turbines
(f) Documents relating to the requirements of **(b)** to **(e)**, where the loads and stability are determined using appropriate model tests or computing methods
(g) Cross curves of stability
(h) Curves of righting moment and wind heeling moment
(i) Capacity plans and sounding tables of tanks
(j) Plans indicating arrangement of watertight compartments, openings, their closing appliances, etc. necessary for calculation of stability
(k) For machinery and electric installations relating to the safety of the Floating Structure: plans and documents specified in the relevant Chapters in **Part D** and **Part H of the Rules for the Survey and Construction of Steel Ships**

(l) Document indicating outline of construction process
Plans and documents indicating the construction work to be completed, or equipment to be installed on Floating Structures at the building shipyard or engineering companies where the midway stage of construction work is made prior to the installation of Floating Structures
(m) Towing methods and strength calculation sheets during towing
(n) Procedures for testing (including testing before and during the installation of Floating Structures, etc.) and stability experiments
(o) Design calculation sheets on moorings
(p) Installation procedures of moorings and the installation work procedures of Floating Structures at their site of installation
(q) Other plans and/or documents deemed necessary by the Society

(3) Tower
(a) Method and calculation sheets of structural analysis
(b) Data or documents on environmental parameters used for determination of design loads and calculation methods of total external forces and moments due to wind, waves, and other loads
(c) Procedures for tightening of bolts
(d) Procedures for loading of towers
(e) Test procedures performed at the time of loading of wind turbines
(f) Other plans and/or documents deemed necessary by the Society

-3. The installation work procedures specified in **-2. (2)(p)** above are to include the following as applicable. The work process of each item is to include a method of confirming the adequacy of completed work as well as relevant judgment criteria.

(1) A general outline of a Floating Structure and its periphery facilities, including moorings
(2) Document describing survey results on seabed conditions of installation areas
(3) The installation procedures of seabed mooring points including things such as anchors, sinkers, and piles and the procedures of connecting mooring lines to seabed mooring points including at least the following:
(a) Necessary preparations and processes for the installation of the Floating Structure (including information about anchors, riggings, work barges used, etc.)
(b) Procedures for positioning and orientation of seabed mooring points (including the criteria for allowable deviations in positioning and orientation)
(c) Item list to be confirmed before the completion of work and their criteria for acceptance (driven depth of the piles, sank depth of the sinker, etc.) corresponding to the type of seabed mooring points (anchors, sinkers, piles, etc.)
(d) Procedures for connecting mooring lines to seabed mooring points including precautions to prevent the twisting of mooring lines during installation
(4) Procedures for the tensioning tests of moorings
(a) Rigging arrangements for the tensioning tests of mooring lines and seabed mooring points
(b) Work ship (barge) set up to carry out such tests
(c) Detailed tensioning test procedures
(5) Procedures for hooking up mooring lines to periphery facilities for mooring on the sea
(a) Rigging and towing procedures of Floating Structures for hooking them up to periphery facilities for mooring
(b) Preferred ballast condition of Floating Structures prior to the hook up
(c) Procedures for the sequential hook up of mooring lines, the repositioning of Floating Structures, and the tensioning of the lines
(d) Method of determining the correct tension of mooring lines and acceptable design tolerances
(e) In the case of turret mooring, the method of securing turrets against movement and the safety precautions for the entire hook-up installation
(f) Procedures for tensioning by the ballasting of Floating Structures (if applicable in the case of tension moorings, etc.)

-4. Notwithstanding the requirements in **-1** and **-2**, part of the plans and documents specified in **-1** and **-2** may be omitted in accordance with provisions specified otherwise by the Society, in cases where the Floating Structure and tower are to be built at the same place of manufacture based on plans and documents which have already been approved.

8.3.3 Construction survey

-1. At classification surveys during construction, the presence of a surveyor is required at all stages of the work on construction, equipment, machinery, and electrical installations in cases where the tests or inspections specified in **2.1, Part B of the Rules for the Survey and Construction of Steel Ships** and **8.3.4** to **8.3.8** are carried out and in cases where the submitted plans and documents regarding tests or inspections specified in **8.3.2** are verified by the Society.

-2. The presence of a surveyor is required for elevating equipment and related construction works when:

(1) A load test of elevating equipment is performed, and

(2) An operation test of elevating equipment is performed.

-3. For elevating equipments surveyed by the Society and passed the survey (those initially tested in load testing only), the number of persons and limit load are to be specified and an assignment of elevating equipment limit load, etc. is to be delivered.

-4. The number of persons mentioned above is to be equal to the maximum integral number acquired by the limit load in the load testing divided by 75 kg.

-5. The requirements specified in **-1.** may be modified with regard to the actual status of facilities, technical abilities, and quality control at the place manufacture.

8.3.4 Hydrostatic test, watertight tests, and relevant tests

-1. Hydrostatic tests, watertight tests, and other relevant tests in the classification survey during construction are to be in accordance with the requirements in **2.1.5, Part B of the Rules for the Survey and Construction of Steel Ships**.

-2. Notwithstanding the requirements in **-1,** these tests may be altered as specified by the Society, in view of design conditions.

8.3.5 Survey during construction

-1. Surveys at shipbuilding yards, etc. where the structures of Floating Structures are constructed, are to be carried out in accordance with **Rules for the Survey and Construction of Steel Ships: Part B, Chapter 2** for those survey items that are considered to be in common with those of ordinary ships.

-2. When draft scales are installed, the presence of surveyor is required

-3. Surveys for wind turbine towers are to be conducted at the time specified by the Society during internal fabrication and assembly of the towers, and at the time of installation to Floating Structures. Surveys for the towers are defined in the following **(1)** to **(3)**:

(1) General examinations are to be carried out on towers including welded and bolted connections.

(2) Non-destructive tests are to be carried out on welded connections of primary structural members and other parts liable to bear high stress.

(3) It is to be confirmed that the tower is properly installed in its designed position and within the allowable design tolerance.

-4. Surveys necessary in order to tow the Floating Structures to their site of installation are to be carried out.

-5. In cases where moorings and wind turbines are installed on Floating Structures at works different from the shipbuilding yards where hull structures are constructed (including the sea areas of the site of installation), the surveys for the supporting structures of installations are to be carried out at suitable occasions before the final survey at the site of installation.

8.3.6 Surveys during the installation of Floating Structures

During the installation of moorings, the following items are to be verified and surveyed by the attending surveyor of the Society:

(1) The mooring components of Floating Structures are to be examined for abnormalities before installation.

(2) Test results are to be confirmed for those components which are required to be tested at manufacturer facilities.

(3) The area around the seabed mooring points is to be examined and reported on by divers or remotely operated vehicles (ROVs) before installation to ensure that there is no obstruction.

(4) During the installation of Floating Structures to their seabed mooring points, the following is to be verified:

  (a) Proper locking of all connecting shackles from mooring lines to seabed mooring points, and from mooring lines to mooring lines.

  (b) Sealing of all kenter shackle locking pins

  (c) Correct size and length of all the components of mooring lines

  (d) Whether seabed mooring points are installed in their designed positions and are orientated within allowable design tolerance

(5) Mooring lines are to be confirmed to be laid out as designed and in accordance with predetermined procedures

(6) After moorings are deployed at their site of installation, the following tensioning tests are required for each mooring line:

  (a) During tests, each mooring line is to be pulled to its maximum design load for the intact design condition and held at that load for 15 minutes. The integrity of the entire mooring line from the seabed mooring point to the connecting end at the structure of the Floating Structure as well as movement of the seabed mooring point is to be verified.

  (b) Notwithstanding **(a)** above, the test load for soft clay may be modified as deemed appropriate by the Society. Even in such cases, however, test loads cannot be reduced less than 80% of the maximum intact design loads.

  (c) Notwithstanding **(a)** and **(b)** above, the tensioning tests of mooring lines may be waived in cases where detailed investigation reports are submitted to the Society and deemed appropriate. In such cases, however, preloading each seabed mooring point to generate the maximum holding power is required. The load of this preloading is not to be less than the mean intact design tension, and such that the integrity and proper alignment of mooring lines can be verified.

(7) Mooring lines are to be verified for firm and adequate connections to chain stoppers.

(8) Catenary angles of mooring lines are to be measured and verified for compliance with design specifications and tolerances.

(9) Upon completion of installation, the connection of Floating Structures to their periphery facilities is to be verified for compliance with design specifications. Divers or ROVs are to be arranged as necessary for the survey of any underwater parts deemed necessary by surveyors.

(10) After installation of Floating Structures, monitoring is to be conducted and if influence of vortex drag is found, countermeasures are to be taken.

8.3.7 Onboard testing and stability experiments

-1. During the onboard testing of Floating Structures, the following items are to be verified and surveyed by the attending surveyor of the Society.

(1) Control systems of wind turbines
(2) Performance tests of such systems that are necessary for adjusting the draught, inclination, etc. of Floating Structures, like ballasting systems
(3) Running tests of machinery and electrical installations related to safety of Floating Structures (during their operation, no abnormalities in the condition of Floating Structures are found)
(4) According to the requirements **1.1.7**, running tests of fire fighting systems installed in Floating Structures, if available

However, if the items specified above are verified by simulating installed conditions at shipbuilding yards, such tests may be dispensed with after installation.

-2. The results of onboard tests are to be submitted to the Society as Onboard Testing Records.

-3. Equipment which cannot be verified due to special reasons that are related to such equipment only being capable of functioning after start-up and commissioning is to be identified for verification at the next annual survey.

-4. Stability experiments

(1) In the classification survey during construction, stability experiments are to be carried out after completion of the construction work. When it is difficult to conduct stability experiments on installed wind turbines, they are to be carried out before installation of the wind turbines, and the results of them with addition of the influence of the wind turbines may be accepted. A stability information booklet prepared on the basis of the stability particulars determined by the results of stability experiments is to be approved by the Society.
(2) When sufficiently reliable information on stability of Floating Structures, such as stability experiments results of the same type of Floating Structures, is available, and also when the Society gives approval, stability experiments for each Floating Structure may be dispensed with.

8.3.8 Documents to be maintained on board

-1. At the completion of a classification survey, the surveyor confirms that the finished versions of the following applicable drawings, plans, manuals, lists, etc., are on Floating Structures and towers:

(1) General arrangements of Floating Structures and towers
(2) Cross sections, longitudinal sections, scantling plans (construction profile), deck plans, and shell expansion of Floating Structures
(3) Details of primary structures of towers
(4) Ballast and bilge piping diagrams
(5) Fire extinguishing appliances arrangement
(6) Stability information booklet
(7) Mooring and towing arrangement plans
(8) Instructions for machineries related to safety of Floating Structures
(9) Inspection record of elevating equipments

8.3.9 Classification surveys of Floating Structures not built under survey

-1. The actual scantlings of the main parts of Floating Structures and towers are to be measured, in addition to the general examination of the structures, equipment, machinery, electric installations, elevating equipments, stability, and draft lines as required for the special survey corresponding to the Floating Structures' age in order to ascertain that they meet the relevant requirements in this Guidelins.

-2. In the case of those Floating Structures intended to be surveyed in accordance with **-1** above, the plans and documents as required by the requirements given in **8.3.2** are to be submitted for Society approval.

-3. Hydrostatic and watertight tests are to be carried out in accordance with the requirements given in **8.3.4**.

-4. Onboard testing and stability experiments are to be carried out in accordance with the requirements given in **8.3.7**. However, onboard testing and stability experiments may be dispensed with provided that sufficient information based on previous tests is available and neither alteration nor repair affecting onboard testing has been made after such previous tests.

-5. At the completion of a classification survey after construction, preparation of drawings and documents defined in **8.3.8** at Floating Structures and towers are to be confirmed.

8.4 Periodical surveys

8.4.1 General

-1. Periodical surveys on Floating Structures are to be conducted based on inspection plans and inspection procedures.

-2. The owners and designers of the Floating Structures are required to submit the inspection plans and inspection procedures to the Society for approval prior to the periodical surveys being carried out.

8.4.2 Preparation for periodical surveys

-1. Before surveys are commenced at each periodical survey, inspection plans and procedures, as well as survey records and maintenance reports until the last periodical survey which include photographs and records (test results, etc.) are to be presented to the surveyor.

-2. Records on the maximum environmental conditions experienced by the Floating Structure from the last periodical survey up until the date of application for inspection are to be presented to the surveyor.

-3. Calibration records of inspection tools are to be presented to the surveyor.

-4. Areas subject to inspection are to be made safe (by cleaning, etc.)

8.4.3 Annual surveys

At annual surveys, records specified in **(1)** and **(2)** are to be confirmed based on the inspection plans and inspection procedures. Where deemed necessary by the Society or surveyor or when an application has been made by the owner of Floating Structures, the surveys may be carried out in accordance with the requirements of the special survey.

(1) Maintenance and inspection records defined in **1.5.3-6**

(2) Records on the environmental conditions defined in **8.4.2-2**

8.4.4 Intermediate surveys

At intermediate surveys, surveys based on inspection plans and inspection procedures are to be conducted in addition to that at annual survey. Where deemed necessary by the Society or surveyor or when an application has been made by the owner, the surveys may be carried out in accordance with the requirements of the special survey. At intermediate surveys, inspections specified in **(1)** to **(5)** are to be conducted in principle:

(1) Intermediate survey for construction and equipments

At intermediate surveys, surveys defined below are to be conducted:

(a) General examinations of the following items as far as practicable:

i) Shell platings and exposed decks upper than draft line

ii) Ventilators and air pipes

iii) Watertight bulkhead

iv) Position of draft line

v) Drain pipes, suction pipes, exhaust pipes, and valves

vi) Structure of moorings and around moorings upper than draft line

vii) Structure around openings within areas that can be surveyed, upper then draft line

viii) Fire extingushing equipments

(b) General examination of openings such as doors, etc. that are required to have water-tightness and weather-tightness; inspection of their closing appliances and fittings

(c) For Floating Structures over 5 years of age, an internal examination of representative ballast tanks. However, when special measures against corrosion and fatigue strength deemed appropriate by the Society are taken, surveys may be dispensed with.

(d) Thickness measurements of the relevant ballast tank are to be carried out, if deemed necessary by the surveyor as a result of **(c)** above.

(e) During intermediate surveys for moorings, the following are to be carried out: However, when special measures against corrosion and fatigue strength deemed appropriate by the Society are taken, surveys may be dispensed with.

i) General examinations of structures of mooring line stoppers (including their foundations)

ii) General examinations of mooring line tensioning equipment

iii) Measurements of the catenary angles of mooring lines in order to confirm that tensions remain within their designed permissible limit. In cases where mooring wires are used, wire tensions are to be confirmed to be within designed permissible limits by using methods appropriate for such wires.

iv) Visual inspections of mooring lines above the water to confirm no wear/tear.

v) General examinations of turret mooring system bearings (including confirmation of the effectiveness of lubricating systems)

vi) General examinations of structures, equipment, etc. above water and so far as can be seen/accessible to confirm no harmful corrosion, wear, damage, etc.

vii) Confirmation of no abnormalities in the working condition of mooring system equipment (winches, windlasses, etc.).

(2) Intermediate surveys for machinery and electrical installations

At intermediate surveys for machinery and electrical installations loaded on Floating Structures, examinations specified in **4.3, Part B of the Rules for the Survey and Construction of Steel Ships** corresponding to the type of machinery and electrical installations are to be carried out.

(3) Intermediate surveys for wind turbines and towers

At intermediate surveys for wind turbines and towers, the items **(a)** to **(e)** below are to be carried out:

(a) General examinations of towers, tower supporting structures, and connection between towers and Floating Structures (including confirmation of paint conditions)

(b) Check of bolt tightening conditions to the extent possible

(c) In cases where welded connections are prepared, repaired parts of welds are to be subject to non-destructive tests.

(d) General examination of openings such as doors, etc. that are required to have water-tightness and weather-tightness; inspection of their closing appliances and fittings

(e) Check of control systems of wind turbines

(4) Elevating equipment

At intermediate surveys for elevating equipments, the items **(a)** and **(b)** below are to be carried out:

(a) General examinations of elevating equipments

(b) Running test for emergency stop devices of elevating equipments

(5) Others

It is to be verified that the documents and booklets to be maintained on borad according to the requirements in **8.3.8** are kept on Floating Structures and towers and readily available.

8.4.5 Special surveys

-1. Commencement and completion of the periodical surveys is to follow the requirements specified in **5.1.1, Part B of the Rules for the Survey and Construction of Steel Ships**.

-2. In-water surveys are to be conducted by a company approved by the Society. Divers skilled in operations of underwater cameras and underwater videos, or approved in-water survey robots are to be assigned.

-3. At special surveys, detailed surveys based on inspection plans and inspection procedures are to be carried out in addition to that at intermediate survey. At special surveys, surveys specified in **(1)** to **(5)** below are to be conducted in principle:

(1) Special surveys for construction and equipments

At intermediate surveys, the items below are to be carried out:

(a) Internal and external parts of Floating Structure, cofferdam, inside and outside of ballast water tanks. However, when special measures against corrosion and fatigue strength deemed appropriate by the Society are taken, surveys may be dispensed with.

(b) Measurement of potential difference to confirm that the corrosion control systems are effective within the design range. When the galvanic anode method is used, typical anode diminution is to be figured out.

(c) Thickness measurements for structural members of the parts mentioned in **i)** and **ii)** below are to be carried out, if deemed necessary by the surveyor as a result of **(a)** and **(b)** above. In that case, appropriate ultrasonic equipment or other approved means are to be used to obtain accurate readings, and the results are to be reported to the Society.

i) Structural members in locations considered by the surveyor to be prone to rapid wastage or showing excessive corrosion

ii) Representative parts of splash zones or related structures near the draught

(d) For moorings, the inspections mentioned in **i)** to **x)** below are to be carried out. However, when special measures against corrosion and fatigue strength deemed appropriate by the Society are taken, surveys may be dispensed with. Also, for mooring systems, the continuous survey system may be adopted.

i) Check of installation points of Floating Structure and seabed connecting parts

ii) General examinations of mooring lines (entire length including end attachments for connections)

iii) Close examinations and measurements of dimension reductions for the mooring lines in way of areas which are potential hazards for excessive corrosion and wear (areas subject to abrasion, i.e. seabed connecting parts, splash zones of mooring lines near the water surface, etc.)

iv) General examinations and non-destructive tests of chains and stoppers above sea level (to be cleaned up before surveys)

v) General examinations of turrets and their related equipment. Reductions of thickness due to corrosion are to be measured for structure members with heavy corrosion, and for Floating Structures in which 15 or more years have passed since being commissioned.

vi) General examinations for high stress level areas, or relatively short fatigue life areas (to be cleaned up before surveys)

vii) General examinations of the parts connecting mooring lines to seabeds (to be cleaned up before surveys)

viii) Measurement of cathodic potential readings at representative underwater locations of mooring systems to confirm the effectiveness of cathodic protection systems within a designed acceptable range

ix) General examination and operating test of equipment used for moorings

x) For tension moorings, a thorough examination and thickness measurements of pipes, where pipes are used for mooring lines

(e) Parts designated by the Society as having a concentration of stress may require non-destructive tests.

(2) Special surveys for machinery and electrical installations

At special surveys for machinery and electrical installations loaded on Floating Structures, examinations specified in **5.3, Part B of the Rules for the Survey and Construction of Steel Ships** corresponding to the type of machinery and electrical installations are to be carried out.

(3) Special surveys for wind turbines and towers

At special surveys for wind turbines and towers, surveys at the intermediate surveys are to be carried out.

(4) At special surveys of elevating equipments, surveys at the intermediate surveys are to be carried out, and additionally, surveys for main parts or driving parts in hoisting machines of elevating equipments are to be carried out. However, when maintenance records and other information are deemed appropriate by the surveyor, inspections by the attending surveyor may be dispensed with.

(5) Others

It is to be verified that the documents and booklets to be maintained on borad according to the requirements in **8.3.8** are kept on Floating Structures and towers and readily available.

8.4.6 Periodical review of the inspection plan and inspection procedure

-1. The structural members of Floating Structures to be inspected and the inspection level applicable thereto are to be reviewed at intervals periodically taking into consideration factors such as the results of periodical surveys and abnormal environmental conditions having occurred.

-2. When any changes or additions to the inspection plans and inspection procedures are made as a consequence of the review mentioned in **-1** above, the inspection plans and inspection procedures including the changes and additions are to be submitted to the Society for approval.

8.5 Occasional surveys

8.5.1 General

-1. When the Floating Structures encounter external forces which are beyond the environment conditions assumed at the design stage, the owner of the Floating Structures is to carry out an occasional inspection of structural members and report the results to the Society, or is to apply for an occasional survey to the Society.

-2. When essential parts of Floating Structures or important facilities surveyed by the Society are damaged, or to be repaired, changed, or remodeled, application for an occasional survey is to be submitted to the Society.

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