



GUIDANCE NOTES ON

SELECTING DESIGN WAVE BY LONG TERM STOCHASTIC METHOD

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Foreword

The purpose of these Guidance Notes is to supplement the determination of design wave by long term stochastic approach for the *ABS Rules for Building and Classing Mobile Offshore Drilling Units (MODU Rules)*. These Guidance Notes provide users with step-by-step procedures for selecting design wave using long term stochastic method for non-ship type offshore structures. This methodology has been implemented in the ABS Eagle Offshore Structural Assessment Program (OSAP).

These Guidance Notes become effective on the first day of the month of publication.

Users are advised to check periodically on the ABS website www.eagle.org to verify that this version of these Guidance Notes is the most current.

We welcome your feedback. Comments or suggestions can be sent electronically by email to rsd@eagle.org.



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SECTION 1 Introduction

1 General

The design wave calculation by the short term stochastic method is provided in the *ABS Rules for Building and Classing Mobile Offshore Drilling Units (MODU Rules)*. The *ABS Rules for Building and Classing Floating Production Installations (FPI Rules)* require the installation's hull strength and fatigue assessment in the site-specific environmental conditions, considering both 100-year return period environmental events and wave scatter diagram data of wave height/period joint occurrence distributions. As a supplement to select the design wave from the site specific environmental conditions, these Guidance Notes provide the detailed procedures to determine the design wave by the long term stochastic method for non-ship type offshore structures.

3 Features

Information related to the long term stochastic method includes: loading conditions, load cases, dominant load parameters, response RAOs, waves, wave spectra, sea state, wave scatter diagram, design wave, etc.

The primary features of these Guidance Notes include:

- Wave spectrum and wave characteristics for site specific environment
- Wave data for long term design wave analysis
- Methodology for determining long term design wave

5 Application

These Guidance Notes describe procedures to select the design waves based on the long term stochastic approach. The procedures can be used for

- Response analysis – selecting design waves for non-ship type offshore structures.
- Assistance in non-ship type offshore structure design.

These Guidance Notes should be used in association with ABS Rules and Guides for non-ship type offshore structure analysis, such as the *MODU Rules* and *FPI Rules*.



SECTION 2 Waves

1 General

For offshore structures, the most dominant source of dynamic loads is waves. During the service life of an offshore unit, it will experience a large number of cyclic loads due to waves, from very small wavelets to possibly giant waves. A practical way to describe these unceasingly changing waves is to divide them into various categories (sea states), and use short term wave statistics to depict each sea state and long term wave statistics, usually in the form of a wave scatter diagram and wave direction rosette, to delineate the rate at which a sea state occurs.

In a similar way, there are two levels in the description of wave directionality (i.e., wave directional spectrum or wave spreading for short-term, and wave rosette for long term, respectively).

There are numerous texts that present information on ocean waves and the statistically based parameters that are used to define sea states. The key concepts resulting from the application of these theoretical developments are the characterization of a sea state as spectra comprised of numerous individual wave components, and the use of spectra moments to establish sea state defining parameters such as significant wave height and peak or zero crossing periods. For more details on this subject, refer to [5].

3 Wave Spectra (Short-term Wave Statistics)

3.1 Unidirectional Spectra

A wave spectrum describes the energy distribution among wave components of different frequencies of a sea state. Wave spectra can be obtained directly from measured data. However, various mathematical formulae of wave spectra have been available based on analysis of measured data, such as ISSC Wave Spectrum, Bretschneider Spectrum (or Pierson-Moskowitz (P-M) spectrum), JONSWAP spectrum and Ochi's six-parameter spectrum, etc. These spectrum formulae are suitable for different sea states.

A fully-developed sea is a sea state that will not change if wind duration or fetch is further increased (for a fixed wind speed). The Bretschneider spectrum is applicable to fully-developed seas. For most of the ships and offshore structures in ABS's classification, either the Bretschneider spectrum for open ocean areas with fully-developed seas, or the JONSWAP spectrum for fetch-limited regions is used, respectively. For example, the Bretschneider wave spectrum is usually employed to describe tropical storm waves, such as those generated by hurricanes in the Gulf of Mexico or typhoons in the South China Sea. The JONSWAP wave spectrum is used to describe winter storm waves of the North Sea. In some cases, it can also be adjusted to represent waves in Offshore Eastern Canada and swells, such as those in West Africa and Offshore Brazil. A suitable wave spectrum should be chosen based on a partially or fully developed sea state for selecting design waves. In general, the Bretschneider spectrum has a greater frequency bandwidth than the JONSWAP spectrum. Therefore, the selection of a spectrum should be based on the frequency characteristics of the wave environment.

The above-described two spectra are single-modal spectra, which are usually used to represent pure wind waves or swell-only cases. When wind waves co-exist with swells (i.e., there are multi-modes in the spectrum), no single-modal spectrum can match the spectral shape very well. In this case, recourse can be made to the use of the Ochi-Hubble 6-Parameter Spectrum or other wave spectrum.

3.3 Directional Spectra (Wave Spreading)

3.3.1 Long-crested Waves

This is a simple case where the observed wave pattern at a fixed point neglects different directions of wave components. It is equivalent to assuming that all wave components travel in the same direction. These waves are called 'long-crested' since the wave motion is two-dimensional and the wave crests are parallel. Waves produced by swell are almost long-crested in many situations since the crests of the wave become nearly parallel as the observation point recedes from the storm area which produced the waves.

3.3.2 Short-crested Waves

If the observation station is inside the storm area, different waves will come from different directions, and the combined wave system will be short-crested waves. The spreading of wave directions should be taken into account to describe the short-crested waves.

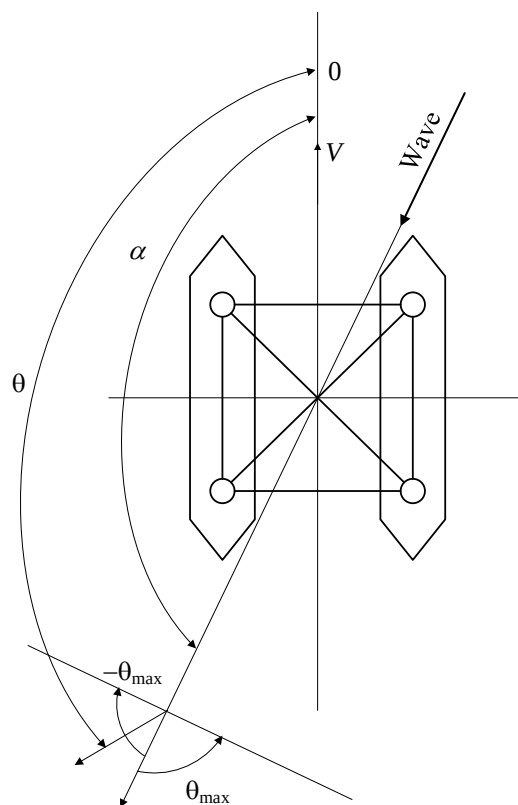
3.3.3 Wave Spreading

Considering the wave spreading, the wave energy spectrum can be obtained by integrating the spreading wave spectrum over the range of directions from $-\theta_{\max}$ to $+\theta_{\max}$ ($\theta_{\max}$ can be typically taken as 90°). The general expression for wave spreading is given by:

$$S_{\eta}(\omega) = \int_{-\theta_{\max}}^{\theta_{\max}} S_{\eta}(\omega, \theta) d(\theta - \alpha)$$

where α denotes the predominant wave direction and θ is the wave spreading angle, as shown in Section 2, Figure 1.

FIGURE 1
Definition of Spreading Angles



In general, directional short-crested wave spectra $S(\omega, \theta)$ may be expressed in terms of the uni-directional wave spectra:

$$S(\omega, \theta) = S(\omega)D(\omega, \theta) = S(\omega)D(\theta)$$

Where the latter equality represents a simplification often used in practice. $D(\omega, \theta)$ and $D(\theta)$ are spreading functions and fulfils the requirement:

$$\int_0^{2\pi} D(\omega, \theta) d\theta = 1$$

A common cosine spreading function used for the wave spectrum is:

$$D(\theta) = \frac{\Gamma(1 + n/2)}{\sqrt{\pi}\Gamma(1/2 + n/2)} \cos^n(\theta - \alpha)$$

where

Γ = Gamma function

$$|\theta - \alpha| \leq \frac{\pi}{2}$$

n = wave spreading parameter, which is a positive integer. Typical values for wind sea are $n = 2$ to $n = 4$. If used for swell waves, $n \geq 6$ is more appropriate.

3.5 Wave Spectral Formulation

The shape of a spectrum supplies useful information about the characteristics of the ocean wave system to which it corresponds. There exist many wave spectral formulations (e.g., Bretschneider spectrum, Pierson-Moskowitz spectrum, ISSC spectrum, ITTC spectrum, JONSWAP spectrum, Ochi-Hubble 6-parameter spectrum, etc.).

3.5.1 Bretschneider or Two-Parameter Pierson-Moskowitz Spectrum

The Bretschneider spectrum or two-parameter Pierson-Moskowitz spectrum, also known as ISSC spectrum (representing by significant wave height and mean period), or ITTC spectrum (representing by significant wave height and one of energy period, peak period, mean period and zero-crossing period) is the spectrum recommended for open-ocean wave conditions (e.g., the Atlantic Ocean).

$$S_{\eta}(\omega) = \frac{5}{16} \frac{H_s^2 \omega_p^4}{\omega^5} \exp \left[-\frac{5}{4} \left(\frac{\omega_p}{\omega} \right)^4 \right] \text{ in m}^2/(\text{rad/s}) \text{ (ft}^2/(\text{rad/s}))$$

or

$$S_{\eta}(\omega) = \frac{1}{4\pi} \frac{H_s^2}{\omega^5} \left(\frac{2\pi}{T_z} \right)^4 \exp \left[-\frac{1}{\pi} \left(\frac{2\pi}{T_z} \right)^4 \omega^{-4} \right] \text{ in m}^2/(\text{rad/s}) \text{ (ft}^2/(\text{rad/s}))$$

where

ω_p = $2\pi/T_p$ modal (peak) frequency corresponding to the highest peak of the spectrum, in rad/s

H_s = significant wave height, in m (ft)

ω = circular frequency of the wave, in rad/s

T_z = average zero up-crossing period of the wave, in seconds