

## Measured Wave Crest Distributions in Central and Southern North Sea Storms

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### ABSTRACT

Design criteria based on wave crest height are important for offshore engineering applications, including specification of platform deck elevation. This paper aims to assess how measured individual crest elevations fit each of three theoretical probability distributions.

The Rayleigh distribution has long been used to determine wave height in a narrow-banded sea. However, nonlinearities in real sea-states cause individual waves to become more peaked with increased crest amplitudes and decreased trough amplitudes which are inherently non-Rayleigh. Corrections to the Rayleigh distribution have been proposed by Jahns & Wheeler (1970) and Tung & Huang (1985).

Amoco have recorded wave profile data at platforms in the Southern and Central North Sea, amounting to a total data period of approximately eight years. The locations are Leman, 38 metres depth, and Lomond and North Everest, 90 metres depth. The wave sensors employed are a Thorn EMI infrared laser at Leman and Marex wave radars at Lomond and Everest.

The data were processed to reveal wave height, period and crest elevation of more than eleven million individual waves. Measured crest height distributions of this extensive data-set were compared with the two modified Rayleigh models. We conclude that, because the Tung and Huang distribution shows good consistency with the data and is based on sound theory, we recommend it for design applications.

**KEYWORDS:** Wave crest elevation, Rayleigh, Jahns & Wheeler, Tung & Huang.

### INTRODUCTION

In severe sea states, which are of interest to the design of offshore structures, it is known that nonlinearities will cause individual waves to become more peaked with increased crest amplitudes and decreased trough amplitudes. These nonlinearities do not appreciably affect the crest-to-trough excursions so that wave heights still seem to follow the Rayleigh distribution. However, the crest and trough envelope is no

longer symmetrical and the distributions of crest and trough amplitudes are therefore non-Rayleigh.

Although most offshore design criteria are based on wave height, there are several applications, including air gap selection, where the nonlinear increase in crest elevation is important. Therefore the use of the Rayleigh distribution in the derivation of those criteria which are based on crest elevation is inappropriate.

This paper aims to assess the applicability of two theoretical models, which provide corrections to the Rayleigh distribution, to the description of the inherently non-Rayleigh distribution of measured crest height. Analysis of an extensive database, consisting of more than eleven million individual waves, provides unique information regarding the nonlinear characteristics of measured data.

### THEORETICAL DISTRIBUTIONS OF CREST ELEVATION

From linear theory, the probability of wave crests exceeding a given amplitude is described by the Rayleigh distribution. Modifications to account for nonlinear effects, based on Stokes second-order wave theory for narrow-banded seas, have been proposed by Tung and Huang (1985) and Jahns and Wheeler (1970), the latter proposal being an empirical correction. Stokes nonlinearities require that crest amplitudes are generally greater than one-half the wave heights. This effect arises because small dynamic pressures associated with the water motion are ignored in linear theory.

#### The Rayleigh Distribution

The Rayleigh distribution provides a good description of crest statistics for moderate sea states:

$$F_R(\eta/H_{m0}) = 1 - \exp[-8(\eta/H_{m0})^2] \quad \text{Eq. 1}$$

where:

- $\eta$  = crest height,
- $H_{m0}$  = significant wave height of raw wave sample from which individual waves are obtained.