

Joint Distribution for Wind and Waves in the Northern North Sea

Kenneth Johannessen, Trond Stokka Meling and Sverre Haver
 Statoil, Stavanger, Norway

ABSTRACT

This paper presents a joint probabilistic model of mean wind speed, significant wave height and spectral peak period. Simultaneous wind and wave measurements from the Northern North Sea covering the years 1973–99 are used as a database. The joint model is used to establish a contour surface, giving combinations of the weather parameters for which the exceedance corresponds to a return period of 100 years.

INTRODUCTION

For design purposes, it has been common to estimate the 100-year response by exposing the structure to the simultaneous action of 100-year wind, 100-year wave and 10-year current. Present design codes (e.g. NORSOK N-003) recommend a less conservative approach by stating that the targeted response extremes can be predicted by accounting for the actual correlation between the environmental processes. This requires a joint probabilistic model for the weather parameters of interest for the problem under consideration. This work was carried out in connection with modifications on the Veslefrikk installation in the Northern North Sea. Because the parameters of concern were mainly wind speed, significant wave height and spectral peak period, combinations of wind, waves and currents have not been looked at. Bitner-Gregersen and Haver (1991) and Johannessen et al. (2000) provide relevant information regarding joint distributions of meteorological and oceanographically parameters.

DEVELOPMENT OF JOINT PROBABILITY

The weather is described by the following 3 parameters:

- 1-h mean wind, W
- significant wave height H_{m0}
- spectral peak period, T_p

We seek a joint density distribution of the characteristic parameters, W , H_{m0} and T_p . This work has been connected to response analyses where the response most probably would be dominated by the variability of the wind. Thus, W is chosen as the primary parameter. Based on this the following joint density function seems reasonable:

$$f_{WH_{m0}T_p}(w, h, t) = f_W(w) \cdot f_{H_{m0}|W}(h | w) \cdot f_{T_p|H_{m0}W}(t | h, w) \quad (1)$$

MARGINAL DISTRIBUTION FOR WIND, W

We will assume that the marginal distribution of the 1-h mean wind speed at 10 m can be described by the 2-parameter Weibull

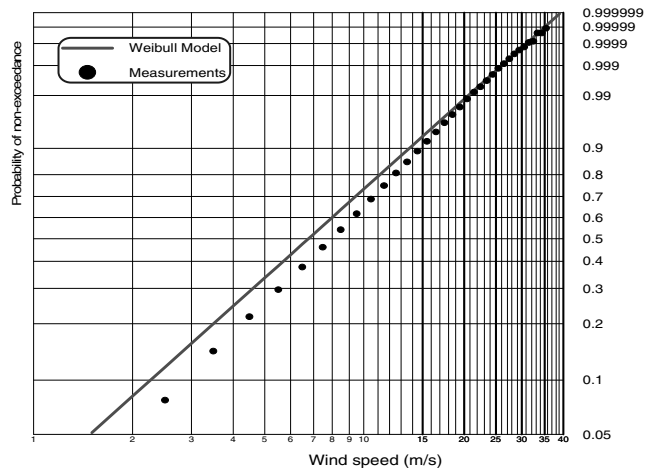


Fig. 1 Cumulative frequency distribution of 1-h mean wind speed for Northern North Sea

distribution:

$$F(W) = 1 - \exp\left[-\left(\frac{W}{\beta}\right)^\alpha\right] \quad (2)$$

where α and β are the shape and scale parameters, respectively.

Based on measurements from the Northern North Sea in the 1973–99 period, and the method of moments, the values $\alpha = 1.708$ and $\beta = 8.426$ were determined for these parameters. These parameters seem to give a reasonable description of the wind speed distribution and correspond to a 100-year extreme wind of 39.0 m/s. The distribution based on the measurements is plotted together with the fitted Weibull distribution in Fig. 1.

The data basis from the Northern North Sea consists of composite measurements from the Brent, Troll, Statfjord, Gullfaks fields and the weather ship *Stevenson*. For periods where measured data are missing, model data from the Norwegian hindcast archive (WINCH, gridpoint 1415) have been filled in; thus, a 20-year-long continuous time-series has been used.

CONDITIONAL DISTRIBUTION OF H_{m0} FOR GIVEN W

The 2-parameter Weibull distribution was suggested as the conditional distribution of significant wave height for given wind speed. Based on the measurements from the Northern North Sea,

Received September 6, 2001; revised manuscript received by the editors January 31, 2002. The original version (prior to the final revised manuscript) was presented at the 11th International Offshore and Polar Engineering Conference (ISOPE-2001), Stavanger, Norway, June 17–22, 2001.

KEY WORDS: Waves, wind, joint probabilities, contour plots.