

A Nonlinear Spectral Model for Directional Random Waves at Decreasing Depths

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ABSTRACT

A wave propagation spectral model to second order of approximation is suggested, which provides the actual directional spectrum at decreasing depths, starting from the corresponding one in deep water. The model implements the procedure already proposed for shoaling, refraction and saturation processes by adding bottom friction; utilizes deep-water directional spectra involving JONSWAP frequency spectra and frequency independent spreading functions; finally, it considers straight coastlines with slowly varying bathymetry, the extension to the usual three-dimensional bottom not involving special difficulties. The bottom friction process is formalized through a scheme which gives the relevant directional spectrum for the effective flow regime (laminar, rough turbulent, smooth turbulent, transitional) in the bottom boundary layer, depending on the wave field and Nikuradse roughness parameter. The model was tested by comparing it with field data from Maa, and the results are quite satisfactory.

INTRODUCTION

The deep-water wave climate being assigned, the mathematical models which quantify the modifications experienced by multidirectional random waves propagating in decreasing depths are generally based on directional spectra, and they differ from one another in the processes considered and in whether they are linear or nonlinear. Some of these spectral models are well summarized by Dalrymple (1992), also with reference to methods founded on the wave action.

Recently, Rebaudengo Landó et al. (1996) introduced a spectral model $[ADS]_2$ to second order of approximation in the description of the random wave fields, which takes into account the shoaling, refraction and saturation processes. The model needs the knowledge of the spectral model to first order $[ADS]_1$ deduced by Scarsi (1995) on the basis of both the $[LW]_1$ model suggested by Le Méhauté and Wang (1982) for the shoaling and refraction processes, and the $[TMAR]_1$ model proposed by Gentile et al. (1994) for the saturation process, and it utilizes the procedure formulated by Laing (1986) for the specification of the second order spectra starting from the corresponding first order ones. The models $[ADS]_1$ and $[ADS]_2$ adopt deep-water directional spectra constructed by mean JONSWAP frequency spectra and frequency-independent spreading functions. Nevertheless, they can be specified with different values for the spectral parameters, especially as regards the enhancement and peak width parameters, and with frequency-dependent spreading functions. In the following a brief description of the aforementioned models is given with reference to straight coastlines with slowly varying bathymetry, noting that the extension to a three-dimensional bottom does not involve special difficulties, unless the bathymetry is so complex that diffraction becomes important.

In the present paper, the linear $[ADS]_1$ and nonlinear $[ADS]_2$ models have been adapted to consider also energy dissipation due to bottom friction. This process is formalized by adjusting a pro-

cedure carried out by Rebaudengo Landó and Scarsi (1984) to evaluate the spectral bottom friction experienced by random waves. It takes into account the different flow regimes which may be present in the bottom boundary layer, that is, laminar, smooth turbulent, rough turbulent and transitional ones. The adjustment, performed by assuming some relationships given by Hasselmann and Collins (1968), Hasselmann et al. (1973) and Collins (1972) as a starting point, allows the spectral energy dissipation to be obtained by a proper spreading of the global energy dissipation on the actual frequencies and directions in a way similar to that developed by Madsen et al. (1988), and Graber and Madsen (1988). Thus, the $[ADS]_1$ and $[ADS]_2$ models are able to give the corresponding $[ADS^*]_1$ and $[ADS^*]_2$ models which consider the bottom friction process, jointly with the shoaling, refraction and saturation processes.

SPECTRAL WAVE PROPAGATION MODELS WITHOUT BOTTOM FRICTION

As mentioned above, the spectral models relevant to the shoaling, refraction and saturation processes refer here to a bottom with straight and parallel contours, and they are summarily described enough for practical use. The first order $[LW]_1$ model suggested by Le Méhauté and Wang (1982) provides the shoaling and refraction directional spectrum $[S_{SR}(f, \phi, \phi_m, h)]_1$ on finite depth, the relevant spectrum $[S_o(f, \phi_o, \phi_{mo})]_1$ on deep water being considered in the usual form:

$$[S_o(f, \phi_o, \phi_{mo})]_1 = [S_o(f)]_1 D_o(\phi_o, \phi_{mo}) \quad (1)$$

which involves the frequency spectrum $[S_o(f)]_1$ and the frequency independent directional spreading function $D_o(\phi_o, \phi_{mo})$. It turns out:

$$[S_{SR}(f, \phi, \phi_m, h)]_1 = [S_o(f, \phi_o, \phi_{mo})]_1 K_{SH}^2(f, h) \cdot K_{RE}^2(f, \phi_o, h) \partial \phi_o / \partial \phi \quad (2)$$

In the previous equations, the index o indicates deep water conditions; f is the frequency; h is the water depth; ϕ , ϕ_o and ϕ_m , ϕ_{mo} are the angles which identify the wave component directions and the overall mean wave direction referred to the normal n to the bathymetry, as shown in Fig. 1; and K_{SH} and K_{RE} are the shoaling and refraction coefficients. The angles ϕ , ϕ_o and ϕ_m , ϕ_{mo} are related to each other by the following inverse direction functions

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