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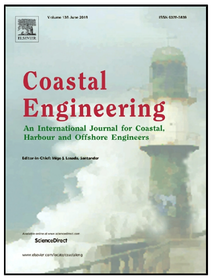

Wind generation of waves: Energy and momentum transfer - an overview with physical discussion

Rolf Deigaard, Peter Nielsen

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Wind generation of waves: energy and momentum transfer - an overview with physical discussion

Rolf Deigaard[a*], Peter Nielsen[b]

[a] DHI, Coastal and Estuarine Dynamics, Agern Allé 5, DK 2970 Hørsholm, Denmark
[b] School of Civil Engineering, The University of Queensland, Brisbane, 4072, Australia

Abstract

The study considers the generation of surface water waves by wind through pressure and shear stress acting on the surface. The situations of temporal growth of an infinitely long uniform wave train and of down-wind growth of a stationary non-uniform wave field are treated. The mechanisms of energy and momentum transfer between the wind and the waves are considered and it is explained how the 'wave Reynolds stress' and the wave set-down are contributing to a force balance over the water column. The role of the wind forcing for the wave drift and a mean current is shown. The analogy between energy dissipation by wave breaking and wave generation by a harmonic surface shear stress is discussed together with the transfer of momentum to the ocean currents by breaking waves.

Keywords: Wind generated waves, wave drift, radiation stress, fetch limitation, duration limitation, momentum transfer

1. Introduction

Generation of water waves by wind has been studied experimentally and theoretically for many decades. The investigations have focussed on different aspects, such as the details of the airflow over the waves and the interaction between the wave and the wind driven current or between long waves and shorter wind generated waves. A major challenge for gaining insight into the wave generating process has been to describe the details in the air flow over the propagating wave and the surface stresses exerted on the water surface from the wind. An early theoretical model was the intuitively attractive idea of Jeffreys (1924) and (1925), who described the forcing from the pressure distribution resulting from a sheltering effect, which creates a pressure reduction in the lee zone behind the wave crests. However, the model does not account for the wind velocity profile and does not give a realistic prediction of the rate of energy transfer. Phillips (1957) developed a description based on the variable stresses induced by the turbulent fluctuations in the wind, which can explain the initial formation of small three-dimensional 'cat paws' but not the later development of the wave into a real sea state. Miles (1957) developed a more realistic model for the air flow over waves based on a perturbation of a uniform wind with a realistic velocity profile. Two domains of secondary circulation cells are found below and above the critical height where the wind speed is equal to the wave celerity. The model gives the right order of magnitude of the rate of energy transfer and with a perturbation proportional to the wave height an exponential wave growth is predicted. The perturbation in Miles' model is described without considering viscous effects and later refinements, e.g. which with the application of turbulence models for description of an eddy viscosity have confirmed the soundness of the concept behind this model, at least for fast moving waves; similarly, detailed field investigations have found agreement with its predictions, Hristov et

* Corresponding author: rd@dhigroup.com