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Breaking Probability of Wind Waves in Deep Water

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ABSTRACT

On the basis of the integral similarity among the three dissipation parametrizations most recently found by authors, it is hypothesized that the breaking possibility is dominated by Kuelegan number, and dependent on wave age somewhat. Kuelegan number is defined to be proportional to the cube of the wind friction velocity, and inversely proportional to the kinetic molecular viscosity and the gravitational acceleration, and could be interpreted as a kind of Reynolds number. This hypothesis is applied to analyze three datasets from both laboratory and field observations. It is shown that our hypothesis gives the better regression to the three datasets than other parametrizations, including friction velocity, wave age, wave steepness and wind-sea Reynolds number. It is demonstrated that wave breaking possibility is proportional to Kuelegan number, namely the cube of friction velocity, and wave age somewhat.

KEY WORDS: Wind-waves; energy dissipation; wave breaking possibility; Kuelegan number; wave age

INTRODUCTION

Breaking waves in deep water are believed to play an important role in the dynamics of the upper ocean and air-sea interaction, contributing to the energy dissipation of surface waves and enhancing the transfer of gas, heat, and mass across the ocean surface, while in coastal and offshore engineering the impulsive forcing and subsurface turbulent mixing due to large-scale breaking wave events are of central importance in structural loading and safety. Statistically the wave breaking is described in terms of wave breaking probability in time domain or in terms of whitecap coverage spatially. In principle, both these descriptions are equivalent to each other. So far most of models on breaking probability or whitecap coverage have been proposed as a function of wind speed on the basis of measurements. The results of these models indicate that there is a relatively large scatter of data in such relationships. This scatter can be attributed to the fact that the overall degree of wave breaking is determined by a combination of various conditions characterizing both wind and wave fields. Recently it is indicated that the parametrization of whitecap coverage can be improved by taking the state of wind wave development into account (Hanson and Phillips, 1999; Stramska and Petelski, 2003).

Wu (1979) proposed a cubic dependence of whitecap coverage on wind friction velocity from the consideration of energy dissipation due to wave breaking in the equilibrium state of wind sea. Most recently Guan and Sun (2004) found that there is an integral similarity among the three dissipation parametrizations, all of which are proportional to the cube of wind speed, the sixth power of wave steepness, and the cube of wave age, though they are significantly different both in mathematical form and in physical grounds. Banner et al. (2000) indicated that the breaking probability for dominant waves is strongly correlated with the wave steepness. In the present paper, it is hypothesized that the breaking possibility is dominated by Kuelegan number, which is proportional to the cube of wind friction velocity, and dependent upon the wind wave status as well. This hypothesis is applied to analyze the existing datasets, and it is found the observational data could be better fitted with Kuelegan number and wave age.

MODEL ANALYSIS FOR ENERGY DISSIPATION DUE TO WAVE BREAKING

The wave field is commonly described in terms of the 2D wave spectrum $F(\vec{k})$, where $\vec{k}$ is wave number vector. The evolution equation for the spectrum in deep water is