



## **Kinematics of modulated wave trains in presence of wave breaking events**

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In open sea, modulational instability is responsible for the generation of rather steep waves, even starting from moderate sea states. From theoretical estimates, the maximum wave amplitude can be as large as three times the initial amplitude. Such events expose ships to a severe environment with important consequences in terms of ship safety due to both stability and structural issues. Depending on the initial steepness, the maximum elevation at the focusing point may exceed some threshold value thus leading to breaking events which may be even more dangerous for ships or offshore structures, with large bodies of water possibly impacting on the structures.

The nonlinear evolution of modulated wave systems was investigated by Tulin and Waseda (1999) who analyzed the effects of sideband components on the solution by varying both the initial steepness and the normalized sideband frequencies. In this way, they arrived to a diagram which distinguishes the conditions where breaking and nonbreaking solutions exist. Those results were confirmed by fully nonlinear computations given in Landrini et al. (1998). Although the fully nonlinear computations in Landrini et al. (1998) enabled the identification of the breaking occurrence, the model adopted didn't allow to go beyond the breaking onset.

In this work the problem is studied by a two-fluid numerical model, which is capable of continuing the analysis even after the breaking onset and thus to investigate the air-water flow taking place during the breaking process. Such models, although providing a detailed description of the complicated flow, are highly expensive from the computational standpoint. Hence, a procedure has been developed which allows to use the results from potential flow methods to generate the input data file needed for the two-fluid solver. With such a coupling strategy, the evolution of modulated wave trains is simulated in time by fully nonlinear potential flow methods up to the time when the instabilities develop and the potential flow method stops. Then, the potential flow solution obtained a few instants before it stops is used to initialize the two-fluid solver and the simulation is restarted and continued beyond the breaking.

The solution procedure is applied to study the development of instability in modulated wave trains with different initial steepnesses, leading to either regular or breaking solutions. Results are presented in terms of free surface profiles with an analysis of the evolution of steepness and spectrum. Detailed descriptions of the flow in the breaking regions are provided as well.

[1] M.P. Tulin and T. Waseda (1999) Laboratory observation of wave group evolution, including breaking effects, *J. Fluid Mech.*, Vol. 378.

[2] M. Landrini, O. Oshri, T. Waseda and M.P. Tulin (1998) Long time evolution of gravity wave systems, *13th Int. Water Waves and Floating Bodies*, [www.iwwwfb.org](http://www.iwwwfb.org)