TRANSFORMATION OF NONLINEAR WAVE GROUPS IN DEEP WATER

WEN-SON CHIANG [1], SHIH-CHUN HSIAO [2] and HWUNG-HWENG HWUNG [3]

[1] Ph. D. Candidate, Department of Ocean & Hydraulic Engineering,
National Cheng-Kung University, Tainan, 701, Taiwan
(Tel: +886-6-238-1937 ext 232, Fax: +886-6-6-384-0206,
e-mail: chws@mail.ncku.edu.tw)
[2] Postdoctoral Fellow, Department of Ocean & Hydraulic Engineering,
National Cheng-Kung University, Tainan, 701, Taiwan
(Tel: +886-6-6-238-1937 ext 322, Fax: +886-6-6-384-0206,
e-mail: schsiao@mail.ncku.edu.tw)
[3] Professor, Department of Ocean & Hydraulic Engineering,
National Cheng-Kung University, Tainan, 701, Taiwan
(Tel: +886-6-6-384-0207, Fax: +886-6-6-384-0206, e-mail: hhwung@mail.ncku.edu.tw)

Transformation of wave group in deep water is an important topic in ocean engineering and science due to its effect not only on the design and construction of offshore structure but also on the safety of ship motion. Some interesting phenomena such as disintegration of wave trains, recurrence of initial wave status and frequency downshift of wave spectrum have been reported in previous studies for different kind of wave groups. In which, the evolution of initially weak modulated wave trains has been most extensively investigated.

On the other hand, the investigation on wave groups compose of two component waves with equal amplitude but slightly different frequency is relatively limited. Lo and Mei (1985) simulated the evolution of bichromatic wave trains by solving numerically the extended nonlinear Schrödinger equation. Stansberg (1992) reported that bichromatic wave trains deform with propagation, by separating into smaller groups. The energy focusing induced to large wave and breaking was observed. Baldock et al. (2000) examined the surf beat induced by bichromatic wave groups breaking on a beach, in which they showed the surf beat generation in the experiments agrees well with theoretical prediction. Westhuis et al. (2001) performed experiments on the evolution of bichromatic wave groups in deep water. They demonstrated that the deformation of bichromatic wave trains in deep water depends on the wave steepness and frequency difference between the imposed wave components.

In this paper, the experimental data on the long fetch evolution of bichromatic wave trains in deep water were analyzed. Besides, the numerical simulation based on the nonlinear Schrödinger equation and multi-layer Boussinesq equations developed by Lynett & Liu (2004) were given, respectively. The results of experiment and numerical simulations were compared in detail. In particular, experimental data for one case of non-breaking wave groups and one case for breaking type wave groups propagating in the constant water depth are given and these data are compared to numerical results. Typical results of evolution of dimensionless amplitude for case B11 using NLS model is shown in Fig. 1. It is found that for non-breaking cases, the wave trains evolve modulation and demodulation periodically in the experimental data and this phenomenon can be better predicted by the nonlinear Schrödinger equation (NLS). However, for the free surface displacement, the multi-layer Boussinesq model gives better phase agreement with experimental data. For breaking case, the amplitude of lower sideband frequency is selectively amplified through the breaking process, which can be qualitatively simulated in the NLS model result by adding an additional proper damping function. The experimental data also show weak evolution of induced bounded long wave during the breaking process.

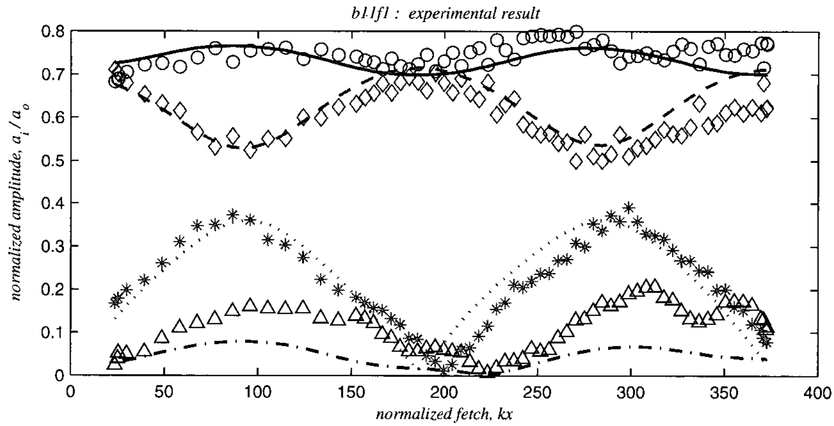

Fig. 1 The evolution of dimensionless amplitudes of NLS model results for Case B11; a1=a2=5 cm, T1=1.5sec and T2=1.7sec. Circle (solid line): ω_1; diamond (dashed line): ω_2 ; Triangle (dashed-dotted line): $2\omega_1-\omega_2$; Asterisk (dotted line): $2\omega_2-\omega_1$.

REFERENCES

Baldock et al. 2000. Breakpoint generated surf beat induced by bichromatic wave groups. Coastal Engineering, 39, pp. 213-242.

Kato, Y. & Oikawa, M. 1995, "Wave number downshift in modulated wavetrain through a nonlinear damping effect", J. of the Phys. Soc. of Japan, Vol. 64, No. 12, pp 4660-4669.

Lo, E. and Mei, C. C., 1985. A numerical study of water-wave modulation based on a higher-order nonlinear Schrödinger equation. J. Fluid Mech., 150, pp. 395-416.

Lynett, P. and Liu, P. L.-F., 2004. A multi-layer approach to wave modeling. Proc R. Soc. Lond. A. Vol. 460, pp 2637-2669

Stansberg, C. T., 1992. On spectral instabilities and development of non-linearities in propagating deep-water wave trains., Proc. 23th Int. Conf. Coastal Eng., Kobe, pp. 658-671.

Trulsen, K. and Stansberg, C. T., 2001. Spatial evolution of water surface waves: numerical simulation and experiment of bichromatic waves. Proc. of 11th ISOPE, pp. 71-77.

Westhuis et al., 2001. Experiments and numerics of bichromatic wave groups. J. Waterway, Port, Coast. and Ocean Engineering, 127(6), pp. 334-3342.