Experiments with Non-Stationary Gravity Surface Wave Turbulence

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Evolving wave turbulence is the least studied and most poorly understand object. Here we report new experimental data on the non-stationary wave turbulence regimes preceding formation of the steady state and on the decaying wave turbulence occurred the wave generators are switched off. We will present several puzzling effects for which we suggest possible explanations and outline open problems. Clearly, most of work on identifying the mechanisms in the evolving wave turbulence still remains to be done.

One can identify two characteristic time scales in non-stationary wave turbulence. The dynamical characteristic time scale τ_D can be estimated from the nonlinear deterministic dynamical equations for the water waves. Taking into account that the leading process for surface gravity waves is four-wave interaction from dimensionality approach one can get an estimate $\tau_D \sim g^2 \omega^{-5} \eta^{-2}$ and then for the wave nonlinearity, γ, we obtain $\gamma = k\eta \sim (\tau_D \omega)^{-1/2}$, where η is the wave elevation RMS and k and ω are the wave number and frequency. An estimation for the kinetic time scale can be obtained from the kinetic equation [1] and dimensionality, $\tau_k \sim g^4 \omega^{-9} \eta^4 = \tau_D^2 \omega = \gamma^{-2} \tau_D$. For our typical flume experiment $\eta \sim$5cm, $\gamma \sim 0.2$, $\omega \sim$1Hz, $\tau_D \sim$4s and $\tau_k \sim$100s. When the forcing is switched off the kinetic time scale rapidly increases due to the strong dependence of τ_k on η. In terms of energy spectra in decaying regimes we expect Kolmogorov-Zakharov spectra in the inertial range whose overall amplitude is gradually decreasing. Because most of the wave turbulence energy resides at the largest scales near the forcing frequency ω_f, the wave energy density per unit area $E \sim E_\omega$.Thus for the energy dissipation rate $\dot{E} \sim \dot{E}_{\omega f}\, \omega_f$. Using Kolmogorov-Zakharov spectrum for gravity waves, one can obtain $E_{\omega f} \sim g^3 \omega_f^{-1/2} t^{-1/2}$. Thus prediction of the weak turbulence theory is that the peak energy spectrum, at ω_f, should decay as $t^{-1/2}$.

Our experimental data contradict some of these theoretical estimations. The experiments were conducted in a rectangular tank 12x6x1.5m filled with water up to the depth 0.9m. The gravity waves were excited by sectional piston-type wavemaker simultaneously at 2 frequencies modes 0.993 and 1.14 Hz with the angles between modes k-vectors 7. The measurements were done simultaneously in t and x domains using the techniques described in [2]. In the experiments with non-stationary wave turbulence the wavemaker was started at pre-set amplitude which kept constant during rising and stationary phase and then turned off to observe the decay. Fig 1a and 1b show examples of observations in rise and decay phases. Fig. 1a presents the time evolution of k-spectral amplitudes for the experiment with γ=0.35. Growth of phase looks completed after about 100s which corresponds to τ_k. One also can see breaking waves appeared at the end of rising phase. Fig 1b shows decay of ω-spectrum components filtered between 4 and 7 Hz. Oscillations of RMS amplitude corresponds to non-monotonic decay of spectral components, which somehow can be related to finite size effects (resonant mode clusters), though such resonances should be even more pronounced at lower frequencies. Presented experimental results show that the non-stationary processes are richer than can be expected from standard theory and further study is required.

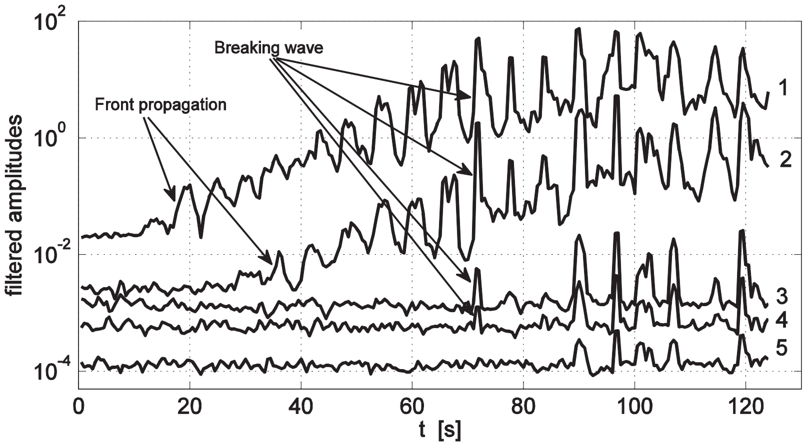

Fig. 1a

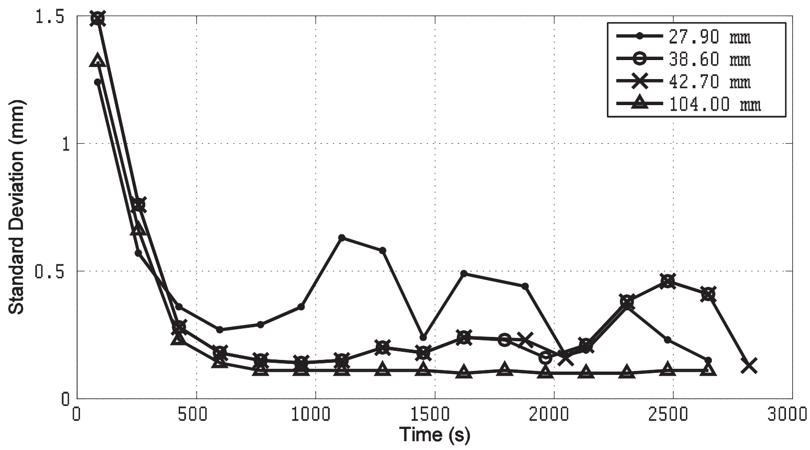

Fig. 1b

References

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