# Studies of the Interaction Between Surface Films and Water Waves -Part II

E. Schlicke[a], A.D. Arnott[a], J.M. Buick`[b], J. Pullen[a], N.H. Thomas[b], C.A. Greated[a]

In the ocean it is common for the water surface to be covered with a slick. A slick can occur when chemicals are discharged into the sea, for example, during an oil spill, or by natural means where they are produced by plankton and marine animals. As described by Schlicke et al. (2000), wave breaking and turbulent mixing is the prime factor in the dispersal of surface films on the water surface. However, the presence of the film damps the waves and thus inhibits the breaking process. To investigate this complex interaction, a theoretical and experimental study is being undertaken.

Understanding of nonlinear amplification of gravity waves prior to emergence of breaking and its inhibition by filming calls for attention to film damping of parasitic capillary waves riding on the fronts of gravity waves. This latter phenomenon was first observed by Cox (1958) and has since been studied by many authors.

Previous theoretical work on this aspect has emphasised clean surfaces, the theoretical clean surface being achieved through the dynamic boundary condition at the surface which equates the tangential surface stress to zero. The work has been couched typically in terms of energetic cascades from forced macroscale motion as gravity waves, via mesoscale transfer through the parasitic waves, to microscale viscous dissipation in subsurface boundary layers and can be viewed as an analogy to the energy cascade between eddies with different length scales in turbulence. The damping action of the slick is concentrated at the high wavenumber end of the spectrum, however, damping is also observed at lower wavenumbers due to enhanced energy transfer from the lower wavenumbers to the higher wavenumbers (Alpers & Hühnerfuss, 1989).

Because filming introduces a selective suppression of the parasitic mesoscales and so blocks internal escape of macroscale energy, a plausible postulate might be gravity wave amplification. Admittedly counterintuitive and undemonstrated as yet, this suggestion is phenomenologically equivalent to laminarised acceleration of wall turbulent boundary layer in response to polymeric additives whose principle action is elimination of inertial transfer by mesoscale motions. Theoretical analyses of this question are being explored, presently emphasising more obvious extensions of established approaches for clean surfaces but other ideas are also being considered, also implications of wider significance for biogenically filmed coupling of air-sea interactions on deep ocean.

Here we concern ourselves with one specific problem: parasitic capillary waves riding on the forward face of longer steep gravity waves. The capillary waves are referred to as parasitic since they are sustained by energy transferred from the `gravity wave on which they ride. Here we consider how the development of the capillary waves is influenced by the presence of a surface film and consider the change in the energy transfer between gravity and capillary waves is altered.

[a]Department of Physics and Astronomy, The University of Edinburgh, Edinburgh EH9 3JZ, Scotland, UK.
[b]CEAC, Aston University, Birmingham, B4 7ET, UK.

A theoretical description of parasitic capillary waves riding on gravity waves on a clean surface is given by Fedorov & Melville (1998) who derive a Bernoulli-type equation at the surface. They consider the solution for an inviscid fluid and obtain an approximation for viscous contributions in the boundary layer. An extension of this work to study similar waves in the presence of a surface film, the changes observed in the wave profile and the energy of the waves is considered.

The experimental work is concerned with the investigation` of the waveform of parasitic capillary waves riding on the fronts of gravity waves and the effect that surface films have on them. Building on the work of Pullen (1998), the films have been shown to significantly affect the motion of the surface layer of water molecules, see figure 1. Using the wave tank in figure 2, gravity waves are produced which have capillary waves riding on their fronts. Using shadowgraph and laser slopemeter techniques, the form of these capillary waves can be ascertained. The effects of 2 films are being investigated. One group of experiments uses Oleic acid as the filming material on top of, as it's filming properties are well understood. The other group of experiments will use initially ``clean'' distilled de-ionised water, but left over a period of time for a natural film to form. In this 2$^{nd}$ case, the experiments will be run periodically as the natural film forms, in order to try and extrapolate back to completely clean conditions.

Acknowledgements: the financial support of EPSRC UK is gratefully acknowledged.

References

Alpers W & Hühnerfuss H. The damping of ocean waves by surface films: a new look at an old problem. J. Geophys. Res., 94:6251-6265, 1989.

Cox CS. Measurement of slopes of high-frequency waves. J. Mar. Res., 16:199-225, 1958.

Fedorov AV & Melville WK. Nonlinear gravity-capillary waves with forcing and dissipation. J. Fluid Mech., 354:1-42, 1998.

Pullen J. Particle Image Velocimetry applied to waves with Surface Active Films. PhD Thesis, The University of Edinburgh, 1998.

Schlicke E, Arnott AD, Buick JM, Pullen J, Thomas NH & Greated CA. Studies of the I nteraction Between Surface Films and Water Waves - Part I. To be presented at EuroMech 416 colloquium, Genoca, Italy, 17-20 September 2000.