Chapter 4

Experimental insights into mechanisms of wave breaking

4.1 Introduction

In spite of many years of theoretical efforts to gain insight into the mechanics of breaking waves, a more complete understanding of wave breaking and its onset as well as energy dissipated during breaking is still lacking (Banner and Grimshaw, 1992).

Most of the information on wave breaking which has been collected in the past is a result of experimental observations in the field and in laboratory tanks. The visual recording of wave breaking occurrence is probably the most reliable method. Also other methods have been reported in the literature based on measurements of surface elevation, velocities and accelerations. Some of these techniques are often laborious and not sufficiently efficient to be applied in practice. Banner and Peregrine (1993) provide an overview of deep water breaking wave detection technology. Although it is generally recognized that an individual wave-breaking event usually starts when water particle velocity at the wave crest reaches the velocity of wave propagation, surface fluid velocity is difficult to measure in the field. Therefore, indirect methods have been developed to detect and quantify wave breaking. They are related to various surface geometry signatures including a jump in the slope of the water surface at the breaker, an optical contrast of the sea surface associated with breaking, void fraction, whitecap coverage, subsurface turbulence, underwater sound, infrared properties of the surface, microwave backscatter, radar reflectivity and others. Some of these techniques will be described in this chapter, but other methods, particularly optical methods, related to whitecapping will be left for discussion in Chapter 7.

In recent years some modern indirect methods of wave breaking detection, based on processing of the recorded sea surface oscillations, have been proposed. Among the most promising methods, such approaches as application of the wavelet transform (Liu, 1994; Liu and Mori, 2001; Massel, 2001b) and
76 4 Experimental insights into mechanisms of wave breaking

the phase-time method based on the Hilbert transform (Huang et al. 1999, Zimmermann and Seymour, 2002) are the most promising.

4.2 Definitions of parameters of steep and breaking waves

In general, the breaking process can be characterized by various measurable quantities such as (Hwang et al., 1989):

- onset of breaking
- time scale of breaking
- length scale of breaking
- intensity of breaking
- phase of breaking inception, and
- multiplicity of breaking.

Following Hwang et al. let us provide short definitions of the above quantities:

**Onset of breaking** – definition of the onset of breaking is twofold. In experimental studies it means that observed waves exceed some threshold behaviour, related to foam formation on the sea surface and high curvature of the wave crest. In numerical calculation, wave breaking onset is associated with a threshold linked for example to nonlinear wave group hydrodynamics.

**Probability of breaking occurrence** – defined as the ratio between the number of breaking waves and the total number of waves recorded (Longuet–Higgins and Smith, 1983; Ochi and Tsai, 1983; Hwang et al., 1989).

**Time scale of breaking** $\Delta t_b$ – the breaking duration, defined as the time interval during which the threshold variable exceeds the critical value.

**Vertical length scale of breaking** $\Delta \zeta_b$ – elevation jump defined as the difference in surface elevations during breaking.

**Horizontal length scale of breaking** $\Delta l_b$ – length of breaking wave usually derived from the measured breaking duration ($\Delta t_b$) and the period of the corresponding breaking wave ($T_b$). Using the fact that $C_b = \frac{g}{2\pi T_b}$ is the phase speed of the breaking wave, the quality $l_b = C_b \Delta t_b = \frac{g}{2\pi} T_b \Delta t_b$ is the horizontal length scale of a breaking patch (Phillips, 1985).

**Intensity of breaking** – quantity which determines the energy loss during breaking. It can be measured by two other measurable or calculable quantities, namely the elevation jump $\Delta \zeta_b$, being proportional to the potential energy loss, and $\Delta Q_b = u^2 + w^2$, representing the kinematic energy loss during breaking.