Velocity and Pressure Field of Spilling Breakers

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1 INTRODUCTION

Very few experimental studies of the water motion of waves breaking on a beach are concerned with the anatomy of the breaking waves. Moreover, it is remarkable that experimental studies of the energy dissipation in the surfzone are literally "on the surface". Generally, measurements are restricted to characteristics of the surface elevation. Measurement of the internal velocity and pressure field would allow for a more detailed study of the anatomy of breaking waves and enable a direct estimate of momentum and energy flux, which makes a more fundamental study of the process of energy dissipation possible. For these reasons the feasibility of laser-Doppler velocity measurements in waves breaking on a beach was investigated. The investigation also included the measurement of pressures over the waterdepth.

2 EXPERIMENTS

The experiments were conducted in a 1 m wide by 50 m long glass-sided wave flume with a still water depth of 70 cm in the horizontal section of the flume. The generated waves were deprived of their free second harmonics and broke (spillingtype) on a plane, concrete beach with a 1:40 slope.

The preparatory nature of the investigation restricted the experiments to two incoming wave conditions and the following measurements:

- horizontal and vertical component of velocity, u and w , over the waterdepth with a laser-Doppler velocimeter in 2 stations in the horizontal section and 11 stations in and near the surfzone, simultaneously with the surface elevation and the input signal of the wave generator (because of the air-entrainment in the wave crest measurements were possible only up to

mean water level).

- pressure, p , over the waterdepth with differential pressure transducers (0,8 cm diameter) mounted in a transparent dummy-wall in 2 stations in the horizontal section and 4 stations in the surfzone, simultaneously with the surface elevation and the input signal of the wave generator.
- surface elevation, η , with resistance-type wave gauges in 38 stations (1 m interval) over the whole flume.

3 RESULTS

Using the command signal of the wave generator and the surface elevation as reference signals, it is possible to couple the non-simultaneous measurements of velocity and pressure in one vertical. For the description and analysis of each of the components u , w and p these components are considered as the sum of a deterministic, purely periodical component ($\tilde{u}$, $\tilde{w}$, $\tilde{p}$) induced by the wave motion and a non-periodical residual component (u' , w' , p'). The periodical component is obtained by ensemble-averaging. The major part of the residual component is formed by the turbulent fluctuations (frequency $10-50 T^{-1}$) induced by the breaking process. Electronic filtering shows that these fluctuations are non-stationary in time. Because of their time scale we may consider a time recording over, say, n waves as n independent recordings of the turbulent process. From this ensemble we can obtain an estimate of the statistical properties, e.g. r.m.s.-value, at a fixed time.

To quantify and analyse the integral properties, viz. momentum and energy flux, also the ensemble-averaged values of u^2 , w^2 , u^3 , uw^2 and pu are determined and integrated over time and depth. The component pu required for the energy flux is approximated by $\tilde{p} \tilde{u}$, thus neglecting the turbulent pu

interaction and the joint contribution of waves and turbulence. Since the measurements were only possible up to mean water level, extrapolations have to be made to the water surface.

At the time of preparation of this abstract analysis of the obtained results for the velocity and pressure field and the fluxes of momentum and energy was still in progress. An example of the obtained results is given by the following evaluation of the momentum flux.

For a number of stations in the surfzone the excess flux of momentum due to the presence of waves or radiation stress, S_{xx} , was determined from $S_{xx} = -h \int_{-h}^{\eta} (p + \rho u^2) dz - \frac{1}{2} \rho g (h + \bar{\eta})^2$ using the measured u , p and η . Gradients in the radiation stress induce a variation of mean water level, $\bar{\eta}$, as follows from the mean momentum balance (Longuet-Higgins and Stewart, 1962):

$$\frac{dS_{xx}}{dx} + \rho g (h + \bar{\eta}) \frac{d\bar{\eta}}{dx} = 0$$

The measured mean water level is compared (fig.1) with

- the mean water level calculated from the measured $S_{xx} = -h \int_{-h}^{\eta} (p + \rho u^2) dz - \frac{1}{2} \rho g (h + \bar{\eta})^2$ using the equation above and
- the mean water level calculated from the measured wave height, H_{rms} , using the linear approximation of $S_{xx} = (2\pi - \frac{1}{2})E$ and the equation above.

Figure 1 Comparison of measured and calculated mean water level