International Journal of Offshore and Polar Engineering
Vol. 10, No. 4, December 2000 (ISSN 1053-5381)

Experimental Study of Breaking Wave Flow Field Past a Submerged Hydrofoil by LDV

P. De Blasi and G. P. Romano
Department of Mechanics and Aeronautics, University of Rome, Rome, Italy

F. Di Felice
INSEAN, Italian Ship Model Basin, Rome, Italy

F. Lalli*
ANPA, Italian Agency for Environmental Protection, Rome, Italy

ABSTRACT

In the present work the free surface flow past a submerged hydrofoil was studied by experimental techniques. The purpose of this experiment, carried out in a water circulating channel, was to investigate the flow field concerned with the steady 2-D breaking wave. Free surface profiles were measured by a conventional wave probe, while the velocity field was obtained by LDV, both in nonbreaking and breaking conditions. Present observations confirm that steady breakers are characterized by the onset of shear flow features, while buoyancy forces related to air entrainment also seem to play a significant role. The interaction of the breaker with the main flow gives rise to a turbulent wake, in which 3-D vorticity structures are visualized by the presence of rising bubbles. Experimental data are discussed in comparison with numerical solutions as well as some results available in the literature.

INTRODUCTION

Breaking waves play a very important role in marine hydrodynamics, both for ocean physics and engineering; in fact, breaking is the dominant sink in surface waves' energy budget. In the naval hydrodynamics context, as known, the wave resistance of a body near the free surface can be split in 2 components, the former related to the waves radiated far behind the body, the latter associated with the wave energy dissipated by breaking. In particular, it has been shown that ~15% of a ship model resistance can be concerned with breaking waves (Baba, 1969). In spite of that, the understanding of wave breaking and estimates of energy dissipation are still inadequate. In fact, 2-phase turbulent flows are not easily described or modeled by theoretical and numerical approaches, neither do they allow to simply perform accurate measurements.

Longuet-Higgins and Turner (1974) proposed an unsteady model for spilling breakers, based on a turbulent, aerated gravity current emanating from the crest, riding down the upstream face of the main wave body.

Peregrine and Svendsen (1978) suggested modeling the flow past a steady breaker as a turbulent mixing layer; in this context the role of the riding roller is basically to trigger the turbulence.

Battjes and Sakai (1981) performed an experimental investigation on the steady spilling breaker generated by a hydrofoil submerged in a stream generated in a water circulating channel, obtaining local velocity field by LDV. They observed the downstream flow behaving as a self-similar turbulent wake.

Duncan (1983) carried out the same experiment in a tank, providing a set of measurements relating to breaker and wave heights. He also surveyed the turbulent wake behind the breaking region and determined the breaking resistance. As a result, a large part of the pressure drag on the hydrofoil appears as momentum loss in the free surface turbulent wake.

Cointe and Tulin (1994) started from the open problems resulting from Duncan's work: What is the relation between the hydrofoil resistance, the breaker and the amplitude of the following wave train? And how much does the breaker suppress the trailing waves? They proposed a model for the steady breaker, assumed to be a stagnant eddy held in place by shear stresses acting on the separating streamline. Under some hypotheses (constant total head and shear stress along the dividing streamline) they obtained a relation between the breaker and the following wave train heights, in a good agreement with Duncan's experimental data. Moreover, they specified the breaking resistance generation mechanism.

Finally, Hyun and Shin (1997) studied the steady breaking waves generated by a bluff body, analyzing the mutual correlation between the wakes generated by the body and the breaker.

In the present work the free surface flow past a submerged hydrofoil was investigated by experimental techniques, both in nonbreaking and breaking conditions. In particular, the same experiment proposed by Duncan (1983) was carried out (but in a circulating water channel and at a larger scale). Free surface profiles were obtained by a resistive probe, and velocity measurements were performed by LDV; the free surface flow features in nonbreaking as well as in breaking conditions were carefully outlined. Detailed flow measurements could be important, for instance, to implement reliable closure turbulence models; successful implementations of Large Wave Simulation methods (Miller et al., 1998) in free surface flow computations require careful experimental investigations on energy dissipation and scattering due to breaking-induced turbulence.

---

*ISOPE Member.

Received September 11, 1999; revised manuscript received by the editors May 9, 2000. The original version was presented at the Ninth International Offshore and Polar Engineering Conference (ISOPE-99), Brest, France, May 30-June 4, 1999.

KEY WORDS: 2D free surface flow, breaking wave, LDV.