# TURBULENT FEATURES BENEATH BREAKING WAVES

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## INTRODUCTION

The process of wave breaking is one of the most complex and difficult subjects in fluid mechanics and by far not been fully understood yet. Many results about laboratory investigations and numerical simulations concerning breaking waves have been presented in the past, e.g. Ting and Kirby (1996) or Lin and Liu (1998). However almost all of them concentrated on depth induced breaking when a wave approaches a beach. Harms and Schlurmann (2004) presented the results of PIV measurements under breaking transient wave packages. Due to the relatively coarse resolution of 1.598 x 1.598 mm per pixel, PIV data precluded the analysis of turbulence and only mass transport velocities have been investigated. To further complete the studies of breaking waves exceeding a critical steepness the current paper presents numerical simulations of the turbulent features beneath these waves using a 3D-Navier-Stokes solver and the Volume-of-Fluid (VOF) method to account for the free surface.

## NUMERICAL MODEL

Solving the Navier-Stokes equations with the Finite Volume Method, the advective terms are discritized with different schemes up to third order in space, while time discretization is only first order accurate. However, preliminary tests approved that higher order schemes are not necessary to further reduce the numerical error. The free surface is tracked by a VOF method with an enhanced algorithm to reconstruct the phase change between air and water more accurately, hence minimizing the numerical diffusion of the original VOF approach. Different models are used to account for turbulent effects on and due to wave breaking, starting with standard k-ε- and k-ω-models and ending with more sophisticated, yet more costly Reynolds-Stress-Models. Even the attempt to more or less directly resolve the turbulent features will be made, as the required high grid resolution can be concentrated locally with adaptive mesh refinements, e.g. based on velocity gradients.

Waves are generated by Dirichlet conditions, defining the velocities of water particle motions and the displacement of the free surface at one boundary. Given the time series of water surface elevation from measurements, the velocity field under irregular waves is reconstructed very accurately by means of a Local Fourier Approximation (Sobey, 1992). This allows for a very good reproduction of laboratory experiments in the numerical wave tank.

## RESULTS

Figure 1 on the left shows a video image of the breaking process together with the corresponding velocity field from PIV. The results from a numerical simulation using the standard k-ε-model for turbulence are displayed on the right. The vectors represent water particle velocities and are comparable to the PIV data. Additionally the numerical model provides information about turbulence quantities such as the ratio of turbulent viscosity to molecular viscosity shown as contours in this example. Note that turbulence is primarily generated at the front of the breaking wave and concentrated near the water surface.

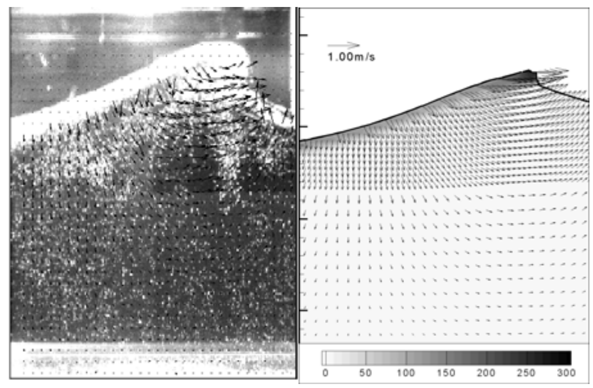


Figure 1 – PIV data (left) and results from numerical simulation (right)

In the full paper a more detailed analysis of turbulent features, like production, transport and dissipation of turbulent kinetic energy, vorticity and second order correlations is presented. Furthermore, a comparison between different turbulence models is made and the advantages and disadvantages of each approach in context with the simulation of breaking waves are worked out. Under the assumption of isotropy of Reynolds stresses two dimensional simulations provide reliable results in many situations. Whether this is true or not for the present case of breaking waves is finally shown by the difference between two and three dimensional simulations.

## REFERENCES

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