# ON THE BREAKING OF GENERATED WAVES RUNNING IN STILL WATER

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**Abstract.** This research is motivated by the requirement of hydrodynamics laboratories to generate extreme waves for testing ships in steep, large amplitude wave fields. For this purpose, finding criteria that determine if wave breaking will occur is important. Different from initial value problems, in this contribution we will consider the signaling problem: a time signal is prescribed to a wave maker in a wave tank that produces propagating waves running in initially still water. The aim is to observe the resulting nonlinear effects on the waves and to study in which cases the waves will or will not break. This also leads to a threshold value for generated waves, and, moreover, to the location in the tank where wave breaking may occur. To study this, we consider Bichromatic waves and Benjamin Feir-waves, and investigate the evolution by using a numerical simulation code HUBRIS developed by Westhuis; the validity of this code has been tested against laboratory experiments. The result of our investigations is that for both classes the parameters of wave breaking are more extreme in the signaling case than in the case of initial value problem.

**Keywords**: breaking criteria, signaling problem, Bichromatic waves, Benjamin Feir-

waves

## 1. INTRODUCTION

Extreme wave or often called freak wave occurred in the open ocean has become an interesting event to be investigated due to its destructive effects on ocean floating object and offshore structure. It becomes an important issue due to its difficulty to be predicted and to be reproduced. It is noted in [5] that a wave could be recognized as a freak wave if its height $H$ exceeds the significant wave height $H_s$ by factor 2.2 of measured wave trains. Of particular interest are extreme waves in the form of wave group structures; these are discussed in several papers, among which insightful investigations are presented in [13], [17], and [7]. The dynamics of such waves is often described as a non-linear self focusing phenomenon resulting in very steep waves of high amplitude arising intermittently within the wave group structures; see e.g. [10] and [8]. These self-focusing effects are often attributed to the modulation instability of Benjamin – Feir (BF) when the modulation

length of a monochromatic wave lies within the region of BF instability [4]. Related to the steepness of the waves, breaking may occur during extreme wave evolution. [9] associates wave breaking with wave steepness in the absence of wind. In [7], [11], [16] among others, investigations are presented on extreme waves and linked to wave breaking for wave group structures. Investigation on the generation of freak waves in a random ocean wave train using a so called time-like NLS equations is presented in [15]. This generation is characterized by JONSWAP power spectrum

Different from the investigation in [15], this research deals with *deterministic* extreme wave generation and will be linked to wave breaking. The study is motivated by the requirement of hydrodynamic laboratories to generate extreme waves for testing ships in extreme situations. For this purpose, finding criteria that determine if wave breaking will occur is important. In a specialized study on wave breaking, Song and Banner in [19] investigate the evolution of a quantity referred as the maximum of the squared steepness. A parameter of breaking is then defined as the mean convergence rate of this squared steepness. They considered the evolution of three types of initial wave groups, among which a monochromatic wave perturbed by a small symmetric sideband, referred here as the Benjamin-Feir instability case, and one case of bichromatic waves. For these cases they used a simulation model to calculate the evolution of ocean waves that have given initial profile; the profile contains various parameters to investigate dependence of the results on initial wave height, steepness etc. They found a threshold value for the quantity that marks the breaking of waves.

Different from Song and Banner's initial value problems, we consider the signaling problem for the same cases of periodic wave groups. Data for this investigation are generated by using a numerical wave tank HUBRIS developed by Westhuis, explained more detail in [21]; the validity of this code has been tested against laboratory experiments at Marine Research Institute, Wageningen, The Netherlands. The aim here is to investigate the resulting non-linear effects in the propagation of generated signals and to study in which cases the signal will or will not break. Further, in the case of breaking, we are interested in the location within the wave tank where the signal starts to break. To achieve our aims we adjust the quantity of Song and Banner, and define it at every position as the maximum of the product of energy and squared wave number, which is akin to the squared steepness, over time. It is shown in [2], that the maximum steepness can be well approximated by evaluating it at the largest wave. As a consequence, allowing its investigation only at the maximum elevation this quantity and the spatial variation of it can be calculated more efficiently.

The organization of this paper is as follows. In the next section, firstly, previous work on the onset of wave breaking as in [19] will be resumed as a base of our work. Then the modification on the parameter used in the previous work is presented, followed by explanation of the generation of data with HUBRIS for signaling problems. In section 3 the tabular and graphical results are presented up to the calculation of squared *maximal temporal steepness*. In section 4, concluding remarks are drawn.