Experimental Optimization of Transient Waves in Extreme Seas

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ABSTRACT

The extreme wave climate - especially rogue waves of exceptional height or of abnormal shape - endangers offshore structures and ships. Such waves are transient phenomena, and neither the occurrence nor their physical structure is well understood.

This paper describes an experimental technique to optimize transient waves in extreme seas in a physical wave tank with flap-type wave generator. The design wave trains with predetermined individual waves or wave groups are initially synthesized with a sequential quadratic programming (SQP) method which is based on linear wave theory (Claus and Steinhagen (2000)). To account for nonlinear free surface effects and wave breaking this linear initial guess is further improved by experimental optimization of the wave train in a tank using the subplex method developed by Rowan (1990). The wave registration at the target location is compared to the target wave train. Based on deviations the subplex method generates a new set of wavetlet coefficients from which the improved control signal is derived. This loop is repeated until the termination tolerance is reached. Note that extreme wave steepness or even wave breaking during propagation is taken into account during this fully automatic experimental wave generation process.

Sea State and Target Wave Characteristics

The target wave train is defined in terms of integral parameters, i.e. significant wave height and peak period, and local characteristics of the wave field regarding wave and crest height of a particular wave sequence. The design variance spectrum is chosen to be the finite depth TMA spectrum. Embedded in random sea the transient target wave is characterized by three parameters:

- zero-crossing wave height \( H_{\text{max}} = 2 H_s \),
- maximum crest height \( \zeta_{\text{crest}} = 0.6 H_{\text{max}} \),
- target time \( t_{\text{crest}} = 42.85 T_p \).

Optimization Procedure

For a given design variance spectrum, the SQP method yields an optimized phase spectrum which corresponds to the desired wave characteristics. Note that this first solution is entirely based on linear wave theory. The wave generator control signal is determined by transforming the wave train at target location in terms of the complex Fourier transform to the location of the wave generator at \( x = 0 \), and applying the complex hydrodynamic transfer function.

The nonlinear physical target wave train is generated with the subplex method which uses the SQP results as input. The basic idea is that the subplex method optimizes a small number of wavetlet coefficients of the control signal in the time frame at the lowest scale which contain most of the signal energy. Hence, the number of free variables is reduced significantly and the computational efficiency is increased.

Results

The computer controlled, fully automatized wave generation and registration system with an integrated optimization process, has been tested in a physical wave tank at a water depth of 0.4 m. Fig. 1 presents preliminary results, i.e. the target wave train with the tailored rogue wave sequence as well as the SQP - start configuration of the optimization process and the final registration which has been accepted as satisfactory. Comparing the registrations and associated key results in the Table it can be stated that the basic linear SQP - start configuration is significantly modified. The finally achieved optimized random sea with the integrated tailored rogue wave sequence corresponds quite well with the objective function. Consequently, this new technique allows the generation of controlled rogue waves for the investigation of ships or ocean structures under design conditions.

REFERENCES


<table>
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<tr>
<th></th>
<th>( H_{\text{max}}/H_s )</th>
<th>( \zeta_{\text{crest}}/H_{\text{max}} )</th>
<th>( t_{\text{crest}}/T_p )</th>
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<tr>
<td>Target</td>
<td>2.00</td>
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<td>SQP</td>
<td>1.26</td>
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<td>Subplex</td>
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![FIG. 1: Transient wave in extreme sea: Comparison of target wave train with SQP - start configuration and subplex optimization result](image-url)

1  G.F. Claus, U. Steinhagen and Cs. Pákozdi