1. GENERAL

Extreme wave conditions in a 100-years design storm arise from the most unfavourable superposition of component waves of the related severe sea spectrum. When generating irregular seas at model scale this crucial condition related to the most critical storm spectra eventually may occur if the random phase shift of all superimposing waves happens to be zero at a certain position — a coincidence which requires a test duration of around 50 hours/√model scale.

As an alternative the component wave of a project oriented design spectrum can be tentatively generated in such a sequence that all waves superimpose without phase shift at a given position. This technique requires

- precise prognosis of the nonlinear hydrodynamics of wave group propagation,
- a sophisticated electro-hydraulic wave generator, and
- sufficient computer capacity for online control and data acquisition.

In addition it may be necessary

- to control the carriage and the track of the self-propelled vessel to ensure model/wave interaction at predefined positions and conditions;
- to provide tank side wall wave absorbers to prevent side wall reflections of diffracting or radiating wave systems generated by the model.

2. TRANSIENT WAVE TECHNIQUE FOR SEAKEEPING TESTS

The proposed technique is based on a fully automatic, computer controlled procedure which governs

- the generation of a short, specifically tailored, wave train with a "design" spectrum represented by the superposition of thousands of wave frequencies;
- the control of the speed of the carriage and of the model course.

As a result, the model meets the wave train within a predetermined section of the tank which is equipped with vertical side wall wave absorbers for simulating an infinite tank width (Clauss and Kühlmann, 1995). The duration of a typical seakeeping test is only a few minutes with a relevant time window of 10-30 seconds (Clauss and Kühlein, 1995a). As the wave train is exactly defined in space and time it is easy to transpose the registration to any position along the tank or on the moving vessel. Of course, wave trains are exactly repeatable. Thus, the wave/model interaction of towed or self-propelled vessels can be investigated at different speeds and at different positions in the tank.

As short and high wave groups with strong nonlinear characteristics evolve from long and low wave groups, the nonlinear characteristics can be developed from linear principles. During its metamorphosis the total energy of the transient wave is invariant, if breaking phenomena are excluded. Nonlinear surface elevations and particle motions as well as velocities and accelerations are calculated from an expanded velocity potential by solving the mutually dependent particle motion equations in time domain (Clauss and Kühlein, 1996). Fig. 1 shows the calculated nonlinear water particle motions of a wave packet at different positions (x=10m, 25m, 39.1m, and 45m (concentration point)). If wave spilling or breaking is prevented the nonlinear wave trains converge and — after passing the concentration point without energy dissipation — diverge and fade away as long, low, and linear wave groups. Consequently the extremely high "freak" wave has a linear past and a linear future.

Using this technology, a 3.2m wave (probably the highest wave in a tank so far) has been generated in the GWK (Large Wave Tank) in Hannover, Germany. The genesis of this transient wave is predictable, i.e. its kinematics and dynamics can be calculated at any position as a function of time and at any instant as a function of space.

Thus, the transient wave technique which was introduced by Davis and Zurnick (1964), and further improved by Takezawa and Hirayama (1976) has been developed from a battle-axe to a scalpel. It is adaptable to arbitrary model test requirements for investigating marine vessels or coastal engineering projects — in long wave trains or in short "freak" waves.

For seakeeping tests it is recommended to select the location of model/wave interaction shortly before the concentration point. This allows a perfect analysis of the wave-structure interaction within a few seconds and the model starts and stops under still water conditions. The wave steepness of the wave profile can be controlled at any position and time, to ensure that breaking phenomena are excluded. The check of the wave steepness can also be used as an input for modifying the shape of the Fourier spectrum.
3. ANALYSIS OF MODEL TESTS

For linear systems, the model response is expressed by transfer functions. If a model is investigated in a transient wave train its response (force, motion, etc.) can be transformed to the complex Fourier transforms. As the wave train and the model response are of limited length, this integration is performed within a selected time window. Thus no statistical scatter occurs, and the integration yields smooth spectra. The time window of the analysis is chosen interactively to avoid errors caused by wave reflections from beach and wave board. The transfer function (RAO) is calculated from the ratio of the respective Fourier transforms of the model response and of the incident wave group. The complex division directly yields the frequency dependent transfer function by magnitude and phase, if both Fourier transforms are related to the same point (Clauss and Bergmann, 1986). As in model tests with self-propelled models it is not possible to measure the wave profile at the model position, therefore the wave train which is measured at the wave probe attached to the carriage has to be transformed from this position to the model position. If the distance between both points is constant, the above transformation can be performed in the frequency domain. In model tests with self-propelled models, however, a constant distance is not being expected. This requires a transformation procedure in time domain (Clauss and Kühnlein, 1995b).

For nonlinear systems, transfer functions are useless. Therefore new tools for analysing model tests and presenting results are required. Nonlinear loads and response can be thoroughly investigated as any test is exactly repeatable. For investigating structures in a specified design storm the most unfavourable wave train or freak wave can be designed, and the interaction between structure and wave is evaluated under predictable test conditions. Even if the wave train is breaking, it may be the possibly worst condition for a given wave spectrum. The spectrum of this worst case model response is a useful tool to describe the wave/model interaction for a given sea spectra.

4. CONCLUSIONS

In summary, the application of the transient wave technique can be adapted to figure out and generate the worst conditions for the investigation of ships and marine structures. This new technique facilitates efficient and reliable investigations of their hydrodynamic characteristics. The transient wave train at the concentration point (breaking or non breaking) is the highest possible wave impulse of a given spectrum (freak wave). For the analysis of experimental tests with nonlinear model response new evaluation techniques are required.

5. REFERENCES


Fig. 1: Calculated water particle motions of a wave packet at z=10m, 25m, 39.1m, and 45m, d=1.5m