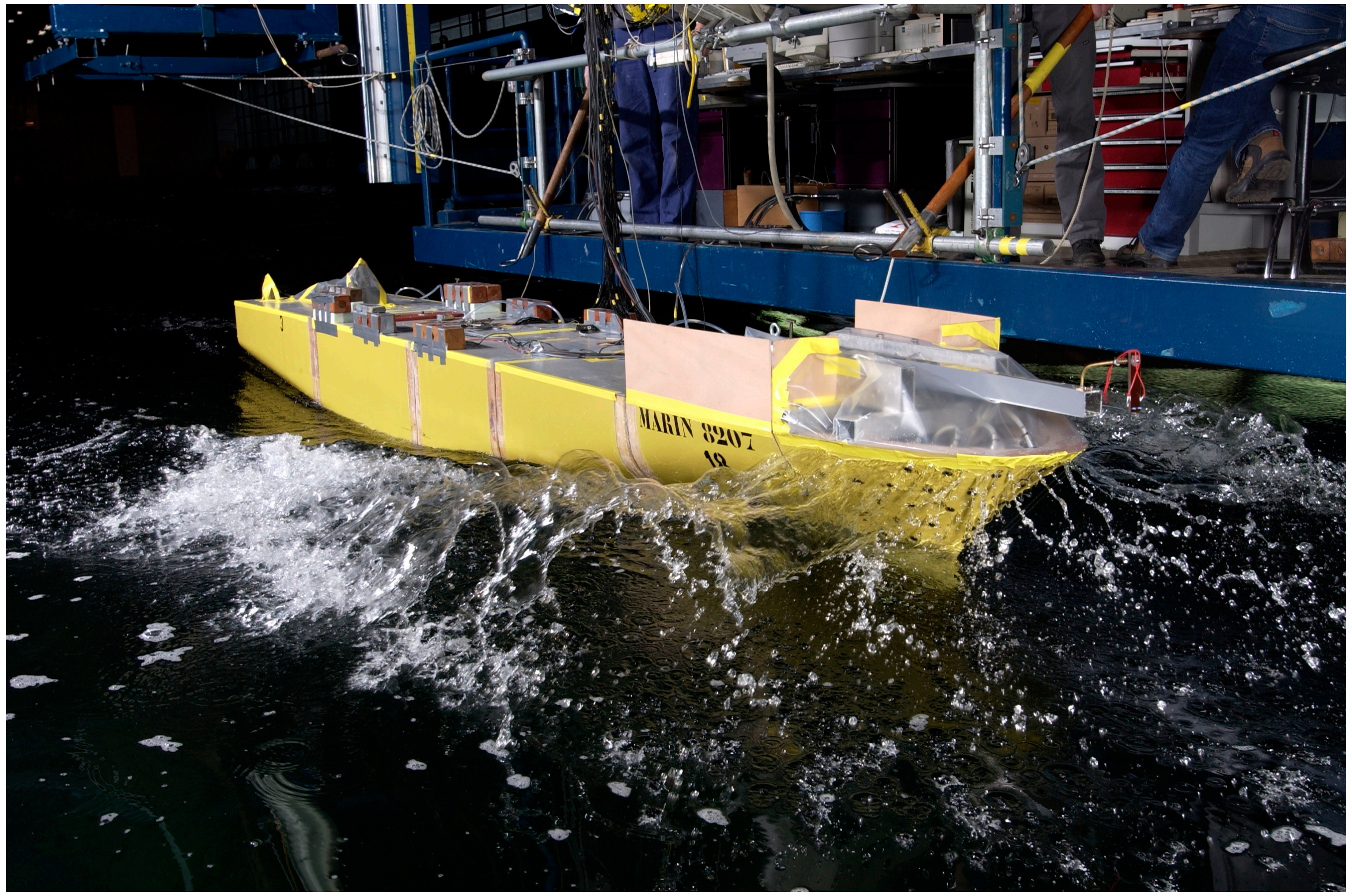

Segmented model with flexible beam (ELAST project)

Tackling the challenge of hydro-structural response

Evaluating the wave induced, structural response is of fundamental importance in the process of the design verification of a ship's structural integrity. CRS is performing state-of-the-art research in this field.

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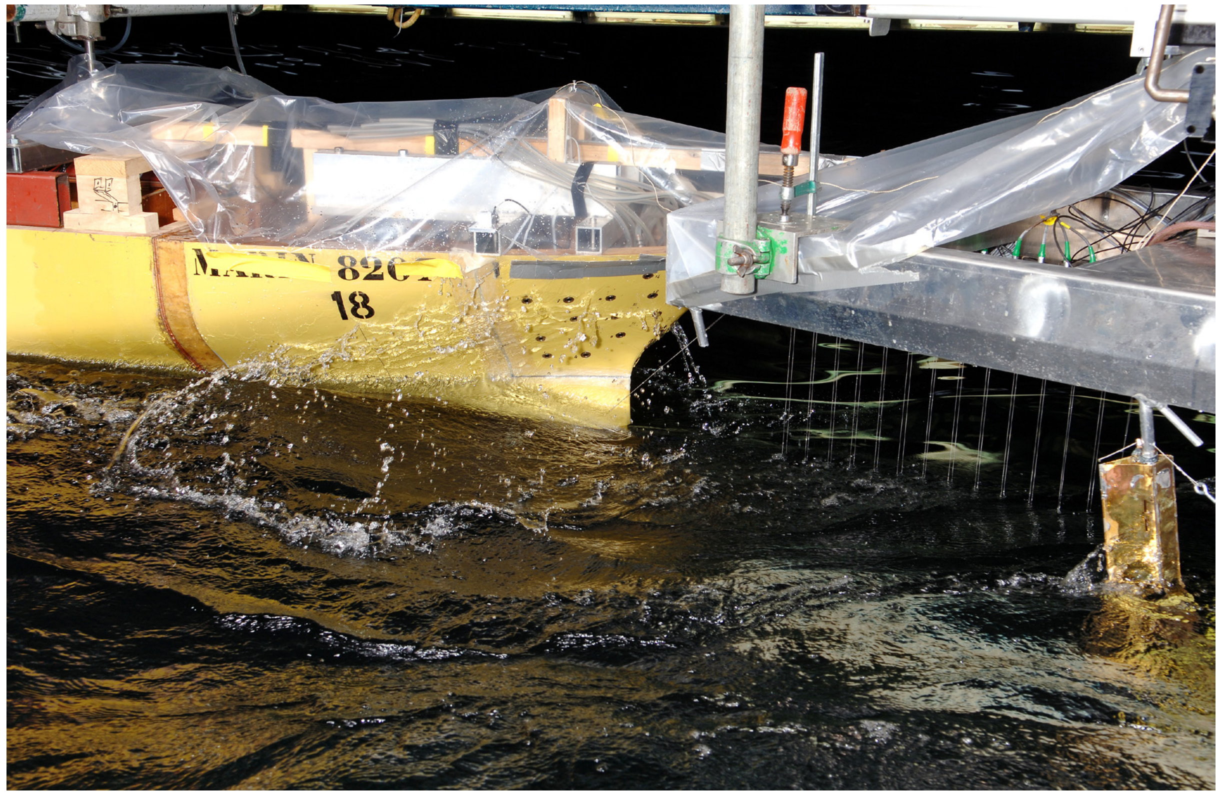
Hydro-structure interactions include a variety of complex physical phenomena which should be taken into account from both the quasi-static (low frequency wave loading), and fully dynamic (springing, whipping…) points of view. The most critical part of the problem is related to the efficient modelling of the seakeeping behaviour, which should include both the global (wave diffraction and radiation) and the local (slamming, sloshing, green water …) effects for a ship sailing with arbitrary speed in heavy seas. Due to the extreme complexity of the different phenomena involved, and in spite of all the past and recent developments, all the details of the hydro-structure interactions are still not fully mastered today.



Forced motion experiments (WHIP-1 project)

CRS's research efficiently combines numerical, experimental and full-scale monitoring activities, which are all used together in order to ensure the validity and reliability of the final numerical tools. Several working groups are taking care of the different aspects of hydro-structure interactions, using both the simpler but faster potential flow-based models, and the more complex but computationally expensive CFD models.

Hydro response Calculating loads on ships and, thereby, the motions in waves has been done since the sixties. At first this was done using a 2D approach (strip theory) and this was corrected for the effect of forward speed. In the late seventies and eighties 3D methods were developed, very often these methods also needed some tricks to include forward speed effects. An example of a development of the latter option is the CRS program PRECAL. The common approach in these methods was the assumption of small disturbances relative to the equilibrium position. This assumption resulted in a linear program.

A number of accidents (e.g. sinking of the Estonia in 1994) showed that extreme loads are clearly very important and also that these are outside the scope of programs based on a linear approach. These conclusions led to the development of the time domain program PRETTI, which uses the linear hydrodynamic results of PRECAL and adds nonlinear effects due to the actual immersion of the hull.

It was assumed that in deploying such a simplified approach - ignoring the nonlinear effects in the dynamics - the main components of the nonlinear loads were captured. Although this approach is still state-of-the-art for long duration simulations, it excludes slamming events. Therefore, a long-term research programme was started resulting in a string of CRS projects: SLAM, ELAST, WHIP-1,2 and WHAM. The work evolved from drop tests on 2D ship sections to several model test campaigns using 3D segmented models and flexible beams to model the structure of the ship. At the same time, a software development programme was started to include hull bending modes in both PRECAL and PRETTI. This evolved into a full restructuring of both codes – which was quite a project on its own.

15 years of slamming studies
The slamming problem was, and still is, a very hard nut to crack. Two approaches were developed, one 2D method based on a strip theory type approach and a 3D momentum method. Both methods give good results for head seas cases, but impacts in quartering waves appeared to be much harder to predict. In fact, it appeared that really extreme impacts were caused by relatively short and steep waves. It is not necessary that the complete bow emerges just before such an impact. This implies that approaching the slamming problem by a drop test simulation has its limitations. After studying the slamming problem for some 15 years, we had to conclude that the model of the incoming wave (linear Airy model) also needed to be improved to properly describe the velocity in the crest of steep waves.

SLAMFLOW The new approach to tackle the slamming problem is to make use of CFD calculations; this is done in the SLAMFLOW project. Today's large computers have no problems handling grids with a number of cells in the order of 10^7. Such grids can solve the local flow problem sufficiently accurately to have a good impression of impact pressure and duration.

However, extreme values cannot be determined by only CFD. Long-duration simulations with CFD are totally unrealistic. Therefore, approximate methods are required that are able to select the critical events that

Stresses in the frigate type hull structure obtained with the STRUC tool

Free running experiments with a model having 10 segments in the bow area (WHIP-2 project)

can then be evaluated using CFD. In this way the probability of the event is determined by the approximate method, while the magnitude of the impact (and its consequences) are determined by CFD results.

Structural response Once there was a tool available that could calculate pressures on the hull of a ship, the STRUC-1 working group was started up in 2001. The goal of this working group was to provide the link between the hydrodynamic calculations and the structural calculations. The approach taken was a one-way coupling. Unit panel pressure load cases were defined to be calculated by different finite element solvers. Combined with transfer functions of the calculated pressures, this results in transfer functions of stresses.

The developed tool STRUC takes care of the necessary interfacing between the two programs and determines the long-term fatigue damage and extreme load assessment. The basis for the structural CRS tool was ready. As nonlinearities in the loads have an important contribution to fatigue and ultimate load assessment, these were addressed as part of STRUC-2. This working group also changed the way the loads were translated from the unit pressure to the unit wave method. Once the number of hydrodynamic panels exceeds the number of load cases, the latter is a more efficient method.

SANE to SIINE The SANE working group that followed collaborated closely with the PRETTI-2 working group. As a result of PRETTI-2's activities, the hull bending modes were included in PRECAL. The STRUC software now served not only as a post-processor for PRECAL, but also as a pre-processor in which the global bending modes were determined. Additionally, the SANE working group carried out more extensive validation work of the tool and its robustness. The most recent group SIINE finished this work in 2018.

An important topic within the working groups was the user-friendliness of the tool. The operational profile used in the long-term assessment has a clear and significant effect on the analysis. Its definition is therefore very important. As such it should be clear to the user of the tools how this definition is properly done. Nonlinear work performed in STRUC-2 was revisited and is now an integral part of STRUC.
Finally, the testing and validation of these state-of-the-art tools and their capabilities was completed.