OptiSWATH – A new way towards optimum SWATH Design

The research and development project OptiSWATH has been initiated to develop a fully automated software system for the hydrodynamic optimization of Small Waterplane Area Twin Hull (SWATH) designs. CAD and CFD tools for parametric modeling, calm water hydrodynamics and seakeeping analysis are integrated into a powerful optimization framework so as to further enhance each individual partner's competence in design and consultancy of high-performance SWATH vessels.

Since the late nineties an increasing number of new building orders for SWATH ships has been observed. The applications cover commercial as well as military projects like research vessels, offshore patrol vessels (OPVs), pilot tenders, yachts, and supply vessels for the offshore industry. The request for these special purpose ships opened up niche markets where only experienced designers and technology leaders are able to compete and satisfy the customer needs.

SWATH vessels feature two submerged, torpedo-like hulls connected by very slender struts to the platform deck well above the waterline. Due to the small waterplane area the ship motions are nearly decoupled from the wave excitation yielding outstanding seakeeping behavior. Typically, SWATH customers impose stringent requirements on the seakeeping performance but also expect low power consumption even when traveling at higher speeds. Therefore, it is mandatory to have tools at hand during the whole design process which allow the assessment of the key hydrodynamic properties for different hull variants. Consequently, these tools should flexibly support the designers in finding the best solution for a given task.

The Emden-based shipyard Nordseewerke GmbH (NSWE), a company of Thyssen-Krupp Marine Systems, gained experience on SWATH development during design, construction and delivery of the research vessel FS751 »Planet« for the German Navy. The vessel with a displacement of about 3,500 t and a speed of 15 kts is in service since 2005 and successfully fulfils its mission. The demand for an advanced optimization tool especially in SWATH design was recognized early by NSWE. For the joint research project OptiSWATH a network of competence was established among Friendship Systems GmbH (FSys), the Hamburg Ship Model Basin (HSVA) and MTG Marinetechnik GmbH (MTG) under the leadership and management of NSWE. The jointly developed software system combines state-of-the-art methods for the hydrodynamic optimization of complex hull forms in order to serve the challenging needs of SWATH customers.

Fig. 1 Nordseewerke-built SWATH research vessel »Planet« for the German Navy

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The optimization process starts with the definition of the hull form with specified parameter sets, followed by the analysis of calm water performance and seakeeping behavior. The results of the hydrodynamic computations are transferred to the optimization algorithm which varies the hull parameters in an optimization loop. This article sets focus on the developed OptiSWATH system and its

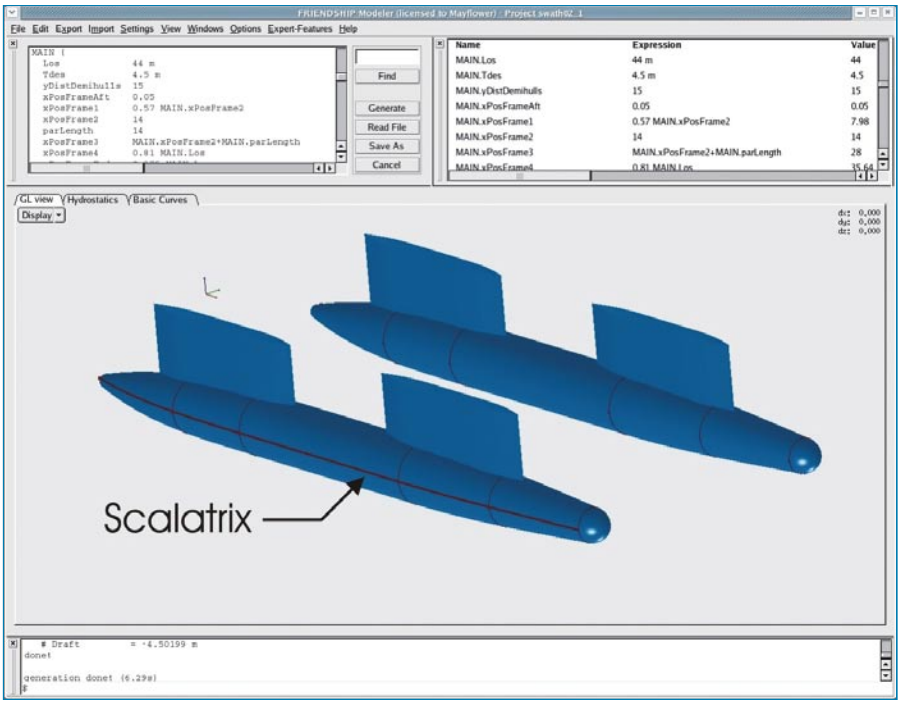

Fig. 2: Basic curve »Scalatrix« and the corresponding SWATH geometry

integrated analysis and optimization tools.

Hull shape generation by parametric modeling

In parametric modeling the hull form generation is based on a ship type specific definition of the desired geometrical characteristics, controlled by a set of design parameters. Besides a common range of main particulars, like length and beam of a ship's hull, more complex variations can be achieved using form parameters, like tangent angles or area coefficients, to define basic curves which describe special properties of the hull form.

From a set of longitudinal basic curves parameters are identified at considered x-positions to construct frames which provide the substructure for the hull surface. The hull shape is computed automatically by fulfilling the parametric requirements and by optimizing the underlying B-Spline curves with respect to mathematical fairness criteria [1]. Thus, hull forms can be generated very efficiently and systematic parameter variation are utilized to find the optimum shape for a specified objective and a given set of constraints.

The CAD tool Friendship-Modeler by Friendship Systems – capable of generating 3D-surfaces based on parametric descriptions – has long been successfully employed in monohull design. Obviously, the description of different hull types, e. g. of a yacht compared with a container vessel, requires distinct sets of form parameters. Hence, for the generation of SWATH forms new parametric models with specific parameter sets had to be developed and were plugged into the Friendship-Modeler. Within the parametric descriptions the demi-hulls are split into independent parts, namely the submerged floating bodies and the surface-piercing struts.

For example, the floating bodies of a simple SWATH model are defined by the midship section shape and the variation of its contour in longitudinal direction controlled by the so-called »Scalatrix«, see Figure 2. This parametric curve is used to scale the dimensions of the cross sections in relation to the midship section. Examples of typical midship sections available within OptiSWATH are illustrated in Figure 3.

Analysis of the calm water performance

The twin-hull arrangement of SWATH ships requires a thorough consideration of the calm water resistance. On the one hand the wetted surface area of SWATH vessels amounts approximately twice the area of comparable monohulls and therefore leading to a significant increase of viscous drag. On the other hand complex waves systems are generated by the interaction of the demi-hulls. As frictional parts can mostly be influenced via a change in surface area only, the wave resistance contribution is the principal part currently addressed in hull form optimization.

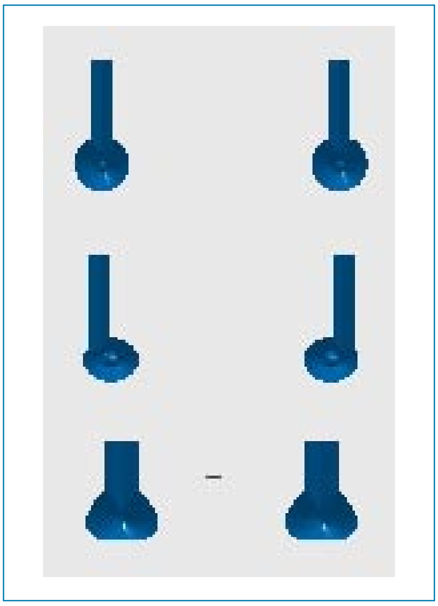

Fig. 3: Examples of possible SWATH midship sections within the current parametric descriptions

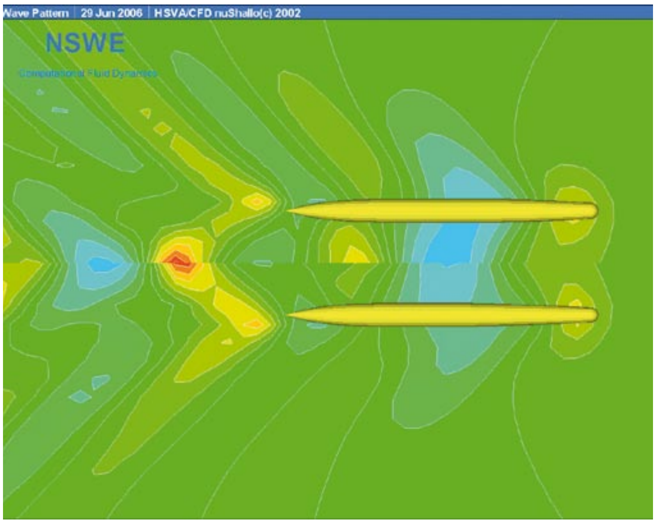

Fig. 4: Comparing the wave patterns of a baseline design (upper half) and an improved design (lower half)

In the context of OptiSWATH, wave resistance analyses are based on the potential flow code, ν-Shallo-SWATH, an extension to the standard ν-Shallo wave resistance code by HSVA which solves the fully nonlinear free surface wave resistance problem (by means of a Rankine panel method) [2]. Inherently, the potential flow method does not account for viscous effects. These effects are considered in an integral way using similar approaches as those applied in model testing.

Although potential flow methods cannot be expected to attain the same accuracy level as model tests, past exercises have shown [3] that they are well suited to compare hull design variants. Due to their unrivaled computational efficiency they lend themselves as ideal candidates for automated optimization procedures.

SWATH vessels suffer from additional velocity and floating position dependent trimming moments. The so-called Munk Moment (induced by the asymmetric flow past the demi-hulls) and the small restoring moment due to the small waterplane area may lead to strong trim variations. The use of stabilizer fins on the bow and the aft end of the submerged floating bodies is common practice in SWATH design. Both fixed as well as controllable fins are engaged to maintain an upright floating condition over the speed range. An additional module to calculate the fin forces using lifting line theory as well as the computation of the additional trimming moments were implemented into ν-Shallo-SWATH. By virtue of these amendments realistic floating positions are obtained in the comparative predictions of pressure distribution, wave elevation and resistance. Figure 4 compares the results (wave pattern along the hull) for two alternative hull forms obtained for a single speed corresponding to Froude number 0.35.

Analysis of seakeeping behavior

Considering that one of the prime motivations for a SWATH design is its favorable behavior in moderate to heavy seas, the assessment of the seakeeping performance plays an essential role in the design process. In order to analyze the seaworthiness of a ship, significant amplitudes and frequencies of the ship's response at various sea states are evaluated. Therefore, MTG shared their expertise of seakeeping analysis within OptiSWATH by providing their program system SEDOS. This code is based on strip theory and accounts for the interaction between the demi-hulls by interfering the waves radiated from one demi-hull with the incident sea waves on the other demi-hull and vice versa [4].

SEDOS offers the possibility to investigate the motion behavior of SWATH ships in various sea states, characterized by e.g. JONSWAP or Pierson-Moskowitz spectra. In addition to the rigid body motions, significant acceleration amplitudes at specified motion prediction points as well as the probability of wet-deck slamming, deck-wetness, and propeller emergence can be computed.

A post-processor is employed to determine the Operability Performance Index (OPI) and the Seakeeping Performance Index (SPI). The OPI describes the percentage of the time a ship operates in a specified sea state without exceeding given limits of motion amplitudes, while the SPI defines the percentage of downtime of a ship in a sea territory characterized by a specific distribution of sea states. As an example, Figure 5 displays the OPI for the roll motion in a selected sea state. The red area indicates the angles of encounter and the speeds at which roll motions are expected to exceed a specified limit.

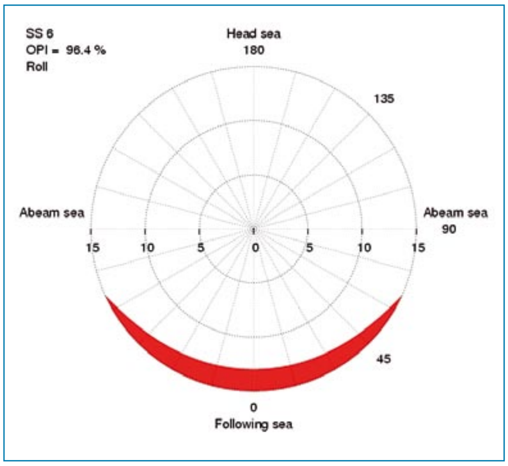

Fig. 5: Operability Performance Index for the roll motion of a SWATH vessel

Framework integration and optimization process

The FRIENDSHIP-Framework has been developed by FRIENDSHIP SYSTEMS as an integration platform for various design tasks, especially with respect to hydrodynamic optimization. The integration currently focuses on parametric CAD functionality, hydrodynamic analysis, and an optimization environment including advanced constraint management capabilities. The aim of the integrated approach to geometrical and physical modeling is the elimination of redundancies in the data models so as to reduce the risk of errors and to increase effectiveness for systematic investigations of the design space. Based on a common entity structure, information between different tools is exchanged by a set of predefined and customized entities, both geometric and non-geometric. Within OptiSWATH the FRIENDSHIP-Framework has been further developed and extended to support SWATH design. For example, the stabilizer fin entity supplies construction data for the geometric model and also provides information to the wave resistance and seakeeping simulations.

The FRIENDSHIP-Optimizer provides state-of-the-art optimization algorithms and variation techniques and – plugged into the framework – addresses all entities of the data model directly. The embedded FRIENDSHIP-Watchdog is a constraint management tool for statistical analysis supporting the designer and the optimization engine in decision making, see also [5].

The design, analysis, and optimization tools employed in OptiSWATH are integrated in the FRIENDSHIP-Framework as displayed in Figure 6. The input data needed for ν-Shallo-SWATH and SEDOS are generated by the corresponding controllers. The framework executes the external tools, manages the output data and provides specified infor-

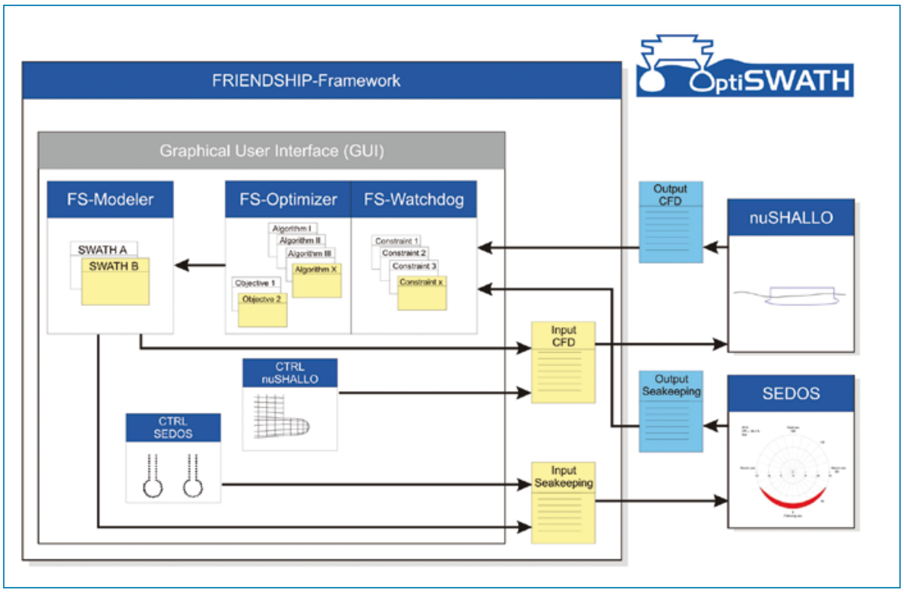

Fig. 6: Integration scheme of the OptiSWATH system

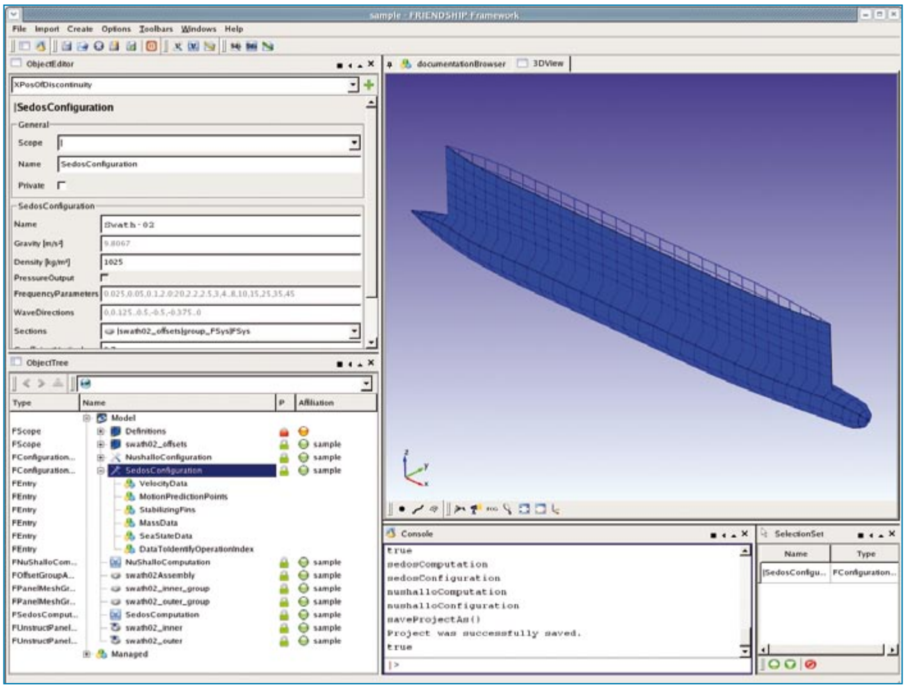

Fig. 7: Screenshot of OptiSWATH integration tool (Graphical User Interface)

mation to the optimizer. In the optimization process new parameter sets are generated leading to modified hull designs, which are subsequently evaluated by the hydrodynamics tools. This procedure is repeated until an optimum is found within the set of given constraints.

Perspectives

The design system OptiSWATH introduced in this article permits a significant speed-up of the complex SWATH design process. Within a few days hundreds of different designs are analyzed automatically, which- provides a solid basis for decision making to the naval architect.

Future work within the joint research project OptiSWATH will cover the development of further parametric models, motivated by the knowledge increase during the project. The validation of the analysis and optimization tools will continue. A next step towards a comprehensive hydrodynamic assessment of SWATH vessels is the implementation of a propulsion prognosis tool into the optimization chain.

The introduction of the OptiSWATH design system for current SWATH projects at Nordseewerke shows very promising results. By virtue of OptiSWATH conventional SWATH hull forms, as commonly used, with sometimes rather disappointing hydrodynamic characteristics will belong to the past.

Literature

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