Made in Germany: The Route to Real Competitive Advantage
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1 Abstract

In order to maintain its position as one of the leading shipyards in the RoRo- sector, the Flensburger Schiffbau-Gesellschaft (FSG) makes use of design tools based on FIRST PRINCIPLES, complemented by an efficient research network. How do these factors combine to confer competitive advantage on the yards customers?

2 Introduction

As the market nowadays is completely dominated by the customer’s demands for efficient ships, the life cycles of ship designs are reduced significantly. In the past, shipyards could survive by producing standard series of ships, selling them to different customers, but now the series ship is replaced by the tailor made design.

Consequently, a shipyard has to focus on shortening the product development phase to be able to cope with increased production efficiency and with individual designs. In addition, German shipyards will survive in a global competition only if they apply every possibility to optimize the product. And for product optimization, the early design stage is most important.

Fig. 1 shows the development of costs versus time for FSG’s series of Ro/Ro- vessels for UND. It can clearly be seen that nearly 70% of the total costs are fixed during the first four weeks of the project. During this phase, a negligable amount of costs is produced only. As the series length will be decreased further, the total project time will decrease, too, and the cost gradient during the initial design phase will become even more important.

![Figure 1: Comparison between actual costs and cost level fixed by the design for one ship and all 6 ships of the series](image)

Obviously, increasing the efficiency of the early design phase will hold the greatest potential for the future. This task is the most important strategic demand for the shipbuilding industry. Means to make this phase more efficient are sophisticated first principle based design tools on one hand and increased knowledge of the designers on the other. Understanding and interpretation of physical phenomena related to a specific design will become more important skills of a designer than empirical design experience.

From the above arguments, the following demands on competitive design strategies arise:
• Acceleration and improvement of the initial design phase.
• First principle design in all relevant technical points.
• Optimized product without unnecessary margins already for the first offer that is clearly superior to the competitor offers.
• Designing for customers needs together with the customer, giving him the possibility to influence the design process as well as the product.

The application of these design strategies requires **innovative design tools** and **revised design processes**. First principle based design tools have to replace empirical or knowledge-based approaches. Those design tools are not available in the software market, they have to be developed individually by the yards and their partners (universities, model basins, classification societies, etc.). If once the importance of the initial design phase is obvious, it is clear that a yard can not design better ships than a competitor if they both use the same software tools. Consequently, FSG has established a powerful R & D - group with the focus on first principle based software tool development especially for the Basic Design. Furthermore, a research network has been established that include major researchers.

The benefit in product development will be demonstrated by some examples from the daily business at FSG.

### 3 Hydrodynamics

#### 3.1 Hull form design for minimum Resistance

Today, numerical tools are available to predict the flow around ships. If the peripheral processes such as grid generation, post processing, hullform changes etc. are automated according to the design process, a complete calculation cycle takes not more than a few minutes. During a typical project development, more than 100 different hullforms can easily be examined in two weeks before the first model test is performed. The CFD-results allow to do optimizations that can not be performed with model tests alone. Using these tools in a consequent way, remarkable improvements are achieved.

This is demonstrated by fig. 2. There, four Ro/Ro-Designs are presented in a chronological way, from left to right. Far left, the design against which FSG had to benchmark their designs, is presented. The wave elevation shows good interference along the hull, but a remarkable amount of stern generated waves is left in the wake, which are hard to evaluate by model tests alone. Consequently, this design has high power demand at service speed of approx. 21.1 knots.

![Figure 2: Hull Performance of four Ro/Ro-Designs in deep water](image-url)
The avoidance the transom generated waves was a main task of FSG’s design for Turkish owner UND (left, Hull No. 713) using a thoroughly optimized trim wedge. It can clearly be seen that the wave pattern is more favourable over all and consequently, the power was significantly reduced. The next generation of RoRo-Vessels, the single screw driven top-deck vessels built for DFDS show that a clever hull concept can also be developed for single screw solutions (right, hull No. 721). The wave elevations show that also this vessel has a low resistance and the service speed could be increased further. The vessel far right demonstrates that CFD is most beneficial the higher the power demand: The innovative hull concept of FSG’s RoPax 2000 requires 26100 kW main engine power at 26 knots service speed. To achieve this, more than 250 hull form versions have been tested in the numerical towing tank and even the smallest details have been thoroughly optimized.

### 3.2 Propeller Design

Before a propeller design is analyzed in the towing tank and the HYKAT, numerical pre-optimizations are performed. Typically, one ore more propeller designers deliver their design via standard exchange format to FSG and there, the design is analyzed by numerical methods with respect to efficiency, cavitation and pressure pulses. Then, modifications are suggested, the design is altered and the next loop starts. Typically, FSG investigates three to five different blade designs per designer until the final decision is made. Besides excellent efficiency figures, much care has to be taken to minimize the pressure pulses, because they affect comfort of crew and passengers and are therefore also important safety issues. FSG uses a VLM code developed by HSVA to predict 1st and 2nd order pressure pulses.

![Pressure Pulse Grids](image)

**Figure 3:** Panel Grid and calculated pressure pulses at different time steps, DFDS-vessels, 15700 kW at propeller, propeller Design No. 7

Fig. 3 shows the results of pressure pulse calculation for the DFDS-ships at Trial Design condition. The pictures show the pressure pulse that is induced at the hull when a blade is passing, including cavitating and non cavitating part. To go the limit of what is technical possible, seven propeller designs have been analyzed in detail in HSVA’s large cavitation tunnel and for each design, 2-3 pre-designs have been analyzed in the computer. The benefit is shown in the following diagram (ref. Fig. 4): Here, the pressure pulses at blade rate and 2nd order are plotted for each individual propeller design chronologically. Starting with some 4 kPa at first order and 2.7 kPa second order, the final values at design no. 7 have decreased to 2 kPa and 1.1 kPa, respectively. Further improvements are possible, so the final values will be abt. 1.3 / 0.3 kPa, respectively. For the customer, these excellent values are of high economical interest: As the vessels have to operate under shallow water conditions, the speed can be kept at high values without having comfort problems.
3.3 Course-Keeping performance

According to author’s opinion, the most important manoeuvering criterion to be achieved is excellent course keeping ability also in coupling with the rolling/yawing motion in a seastate. Course keeping ability is mainly achieved by an efficient hull form, and efficient rudders that have quick turning ability. We design rudders as full spade types with highly efficient profiles, adopted to the slipstream, using a direct panel method for rudders in the propeller slipstream. This method - together with the propeller VLM-codes - is then used to determine all the necessary steering forces. If these are known, direct manoeuvering simulations for all types of manoeuvres are performed to judge upon the manoeuvring capability of the vessel. Together with the customer, it is decided whether the design is further to be improved, because the vessel can be operated easily in the computer.

Fig. 5 shows the results of the numerical optimization: The overshoot-angles calculated by the simulation have been reached during trial trip with an accuracy of approx 0.5 Degree. Compared to the IMO-manoeuvering recommendations, the overshoot angles are drastically smaller. The rudder action required for course keeping was found to be approx. 0.5 degree rudder action per minute, as performed by the
autopilot during the trial trip. In heavy weather, the course keeping ability can be judged from the resulting drift and rudder angles at yawing and swaying equilibrium (Fig. 5, top right) which can also be derived from numerical simulations. At 40 knots transverse wind speed, ship speed 21.5 knots, the resulting drift angle is less than 2.5 Degree and less than 3.5 degree rudder angle are required for course keeping. These low values, leading to a low additional resistance, have been achieved by systematically optimizing hull form and maneuvering devices for good course keeping ability.

3.4 Seakeeping performance

When designing the hull form, special care must be taken to achieve good seakeeping behaviour. This may be expressed by the achievable speeds against head seas on the one hand and by the judgement of accelerations on the other. To determine additional resistance in seaways, FSG uses a Rankine-source based linear strip theory combined with Faltinsen’s method for additional resistance. The theory includes detailed determination of mass moments of inertia as well as damping (especially for the rolling degree of freedom). Based on these evaluations, the power demand in a seastate and the achieveable speeds can be judged upon.

Especially for RoPax-Vessels, passenger comfort is a governing criterion. This is most important for the arrangement and location of public space areas. As design criterion for these public spaces we use the ISO-seasickness criterion. Fig. 6 shows the results of the ISO criterion for seasickness for a 25 knot, 200m RoPax-ferry which was designed for good seakeeping behaviour within a EU-funded research project.

The time values state after which period of time 10% of the passengers suffer from sea-sickness. For these investigations, nonlinear treatment of the rolling motion is required to obtain realistic values for the vertical accelerations. Together with a probability distribution of the seastate parameters, probability that the public spaces can not be serviced can be determined, and these spaces can be arranged in such a way that this probability becomes a minimum.
3.5 Evaluation of parametric rolling

Due to the fact that RoRo- and RoPax-vessels do have a barge type aftbody and a semi-submerged transom, they lose much of their initial stability on the wave crest. Therefore, these vessels are vulnerable to parametric rolling, which should definitively be avoided. Using nonlinear seakeeping simulations, the hullform can be designed for a minimum risk of parametric rolling. FSG uses the Blume-Criterion to judge whether a ship is save in a certain sea state or not. As results, we get permissible wave heights as function of ship speed and encounter angle.

Fig. 7 gives an overview about the improvements that can be achieved using such design techniques: The left picture shows the results for the initial design of a 200 m, 25 knots RoPax - ferry. It can clearly be seen that in following seas and slow speeds, the vessel suffers from parametric rolling. It capsizes in waves of approx. 4m wave height if wave length equals LbP. With the help of the simulation, the phenomena that lead to capsizing can be accessed by the designer and without impeding speed power performance or other governing criteria, a hull form can be designed that is safe against the risk of capsizing, as fig. 7, right, demonstrates.
4 Concurrent engineering with first principle tools

4.1 General

If once fast and reliable design tools exist and if they can be applied during the initial design stage, this gives the possibility to couple different engineering disciplines early enough to optimize not only a part of the system, but the complete system itself. It is the multi-disciplinary, simultaneous engineering that makes a design competitive, as the following example will show. On the other hand, one has to be aware of the fact that new design tools do also have influence on the design process, which in some cases has to be reengineered itself.

4.2 Example for simultaneous engineering

Figure 8: Simultaneous engineering during the initial design stage
Fig. 8 gives an example of a typical situation during the development of our UND-vessels where simultaneous engineering principles are beneficial: The hull form designer wants to create a hull form for minimum resistance and uses CFD-techniques as already mentioned above. The flow analysis gives a hint where the hull form can be improved. In this case, it would be beneficial if the low pressure zone at the aftbody bottom could be improved, which would then mean that buttocks should be lifted. At this region, the engine foundation is located and it has to be checked whether this is physically possible. Typically, this region is sensitive to deflections, which might be harmful for the system propulsion train - gear box - main engine. In parallel to the CFD-optimizations, FEM calculations are performed with models automatically generated from the same data model. These calculations give a hint whether there is potential for improvements or whether the limit is reached.

In parallel, the engine room layout is determined. In this specific case, potential was identified by modifying the lube oil tank at the critical region, which gave potential for improving the hull form and at the same time designing the steel structure for minimum deflections. The benefit is obvious: The improvement was made by combining several technical disciplines, and a competitor can achieve the same improvement only by applying comparable design techniques. As a result, the UND ships have better speed performance than the competitor ships, and the light ship weight is 1800 t less.

To achieve these benefits, the design process has to be rearranged: The typical design spiral is replaced by the parallel applications of first principle based tools, which have to be tailored for design purposes.

5 Conclusions

The competition in the shipbuilding industry forces shipyards to increase the competitiveness of their products as well as their productivity. If European Shipyards want to compete against the Far East, this can only be done by intelligent products, which require intelligent engineering principles and powerful design tools. On the other hand, these new design processes require new engineering skills: The understanding of physical phenomena related to a specific design and the proper modelling of these phenomena by numerical algorithms and, of course, the adequate interpretation of the results. Within this respect, Europe has a clear advantage due to a very active and ongoing research and development infrastructure. Shipyards have to cooperate with the researchers and to establish research networks to exploit the research results. If this is done consequently, a shipyard will have significant competitive advantage in the market, and the products developed by such kind of shipyard will be superior to those competitor products that have been developed only by empirical knowledge. And that is exactly in author’s opinion the main route to real competitive advantage in the market.