IT Trends in Shipbuilding

An overview of the recent COMPIT conference covering computer applications for ship design, by Volker Bertram, of the Department of Mechanical Engineering, University of Stellenbosch, South Africa, and Germanischer Lloyd, Hamburg, and Patrick Couser, of Sunnypowers.

Some of the latest developments in computer applications for ship design were presented at the recent International Conference on Computer and Information Technology Applications in the Maritime Industries (COMPIT).

This year, the seventh COMPIT was held in Liege, Belgium. From the earliest phases, modern ship design methods use CAD (computer aided design) models with up to several tens of thousands of elements to define the vessel. Generic CAD tools and those developed for other sectors (industrial design, automotive, aviation, etc.) are often unsuitable due to the very specific requirements of the marine sector:

- Custom or one-off design, normally without prototyping;
- very large number of parts;
- rapid design cycle;
- and especially the complex geometrical shapes of hullforms and associated free-form parts.

Over the last two decades 3D design methods have evolved in the shipbuilding industry. Initially 3D design was used only in the detailed design phase but, increasingly, shipyards have exploited the advantages of using 3D CAD descriptions of the vessels in earlier phases of the design. Three-dimensional design, as such, has no great intrinsic value: it is possible to design ships in 2D and even without CAD at all. However, the situation is changed when the 3D design data is used to create a product data model (PDM). The PDM ideally contains all the information required for the ship: hullform definition; performance analysis; general arrangement; detailed arrangement; ship systems specifications; planning and scheduling; purchasing requirements and bills of materials; etc. In this situation the 3D ship model then plays a central role in the design process.

A major part of a ship design project

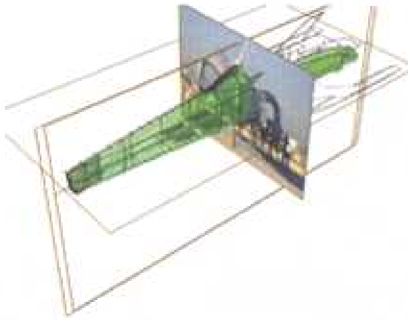


Figure 1: Paramarine allows recreation of CAD descriptions from photos, source: GRC.

deals with areas, volumes, weights, centres of gravity, etc. These can be evaluated quickly and reliably in 3D CAD systems. However, modern CAD systems now offer much more. The trend is generally towards simulation-based decisions guiding the design process (first-principles design). A 3D ship model is a prerequisite for most of these simulations. It generates, largely automatically, the detailed geometric input data required by these simulations: e.g. structural finite-element analysis (FEA), hydrostatic and CFD (computational fluid dynamics) analysis meshes. In some cases simulations are integrated within the CAD software, but the trend seems to be towards a selection of separate software applications with streamlined data transfer interfaces between them and often a central 'Manager' application or database to control the complete system.

Integrating and interfacing

In principle, there are two basic strategies that can be adopted to cope with the increasing diversity of available simulation programs:

1. integration of simulation programs into the CAD design tool, or
2. transparent data transfer between individual simulation programs which are independent of the CAD design tool through the use of (more or less) standard interfaces.

Integrated design tools, following the first strategy, are frequently limited to the design of certain types of ship, resulting in a loss of flexibility; and in many cases the focus is frequently towards integration rather than use of the best simulation tools.

Increasingly it is the second approach that is being used. This approach closely resembles corporate management: a top-level shell handles the user interface and farms out the work to individual simulation programs. For the user, the system appears as a single CAD system, but the modular structure offers greater flexibility for extending the system to include new and improved simulation applications. These systems often integrate the most frequently used simulation applications, such as hydrostatics and power prediction, but offer the flexibility to provide simulation tools with different scope and sophistication levels depending on the phase of the design and the level of detail required. Good business practice is to improve existing software, focussing the development on data transfer and user interface so that it may easily be incorporated into such a system.

Andrews et al. (2008) outline the Design Building Block approach as implemented in the PARAMARINE SURFCON software. The software is typical of more recent CAD systems, featuring "unusual" design and simulation options such as internal layout design and personnel movement and evacuation analysis at a conceptual design stage. This approach encourages a more holistic approach to the development of the ship design solution. The system brings together several buildings blocks which were developed by different partners with high competency in their respective fields. Graphics Research Corporation Ltd supplied the SURFCON component, an object-oriented naval architectural design package based on the ParaSolid modeller. This module covers not only the graphical description of the free-form hull surfaces, but also several traditional analysis utilities including: resistance and propulsion, stability, manoeuvring and radar cross-section assessment. The design system has recently been coupled with marineEXODUS; software developed at Greenwich University, Deere et al. (2008), to support discrete event simulation (DES) of personnel movement and evacuation. Importantly, the approach and toolsets developed are flexible and extensible, enabling the software to grow in response to evolving customer demands.

Hekkenberg (2008) describes an integrated design system for rapid conceptual design of inland ships under development at TU Delft. This work is a good example of a CAD system aimed at a specific niche market: the design tool is dedicated to a specific ship type (in this case inland ships) and a specific design phase (in this case conceptual design). This specific application of an integrated design system is representative of the state of the art:

"The key to speeding up a (relatively simple) conceptual ship design process lies in reducing the amount of manual labour: human input should be limited to making the important decisions as much as possible, without bothering about the tedious work of generating the drawings and doing the calculations that visualise the consequences of these decisions. For the design model under discussion, the solution to this was found in combining a CAD package (Rhinoceros 3D) with basic software able to perform non-geometry related calculations (MS-Excel) and a database of pre-defined scaleable ship elements (engines, propellers, hullforms, ...). These are linked through a number of command scripts (Visual Basic & Rhinoscript) that automatically draw 3D general arrangements in Rhinoceros, but can also feed geometric data (surface areas, centres of gravity) from Rhinoceros back into Excel for further calculations (weights, loads, strength requirements, stability, ...)."

Hekkenberg (2008)

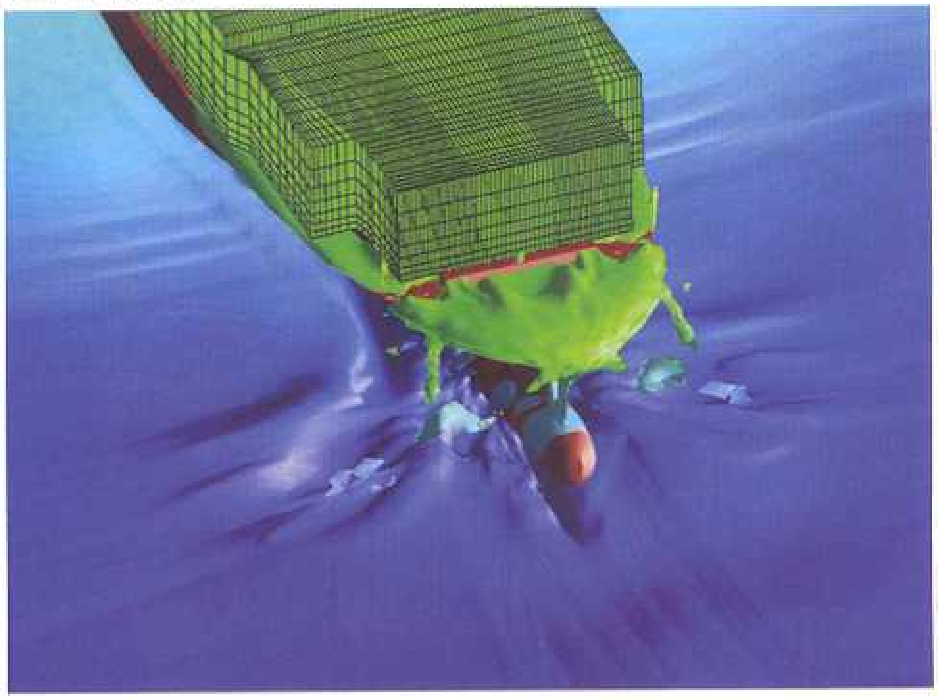
Optimisation may be seen as a special case of CAD system and design simulation integration. Optimisation requires the automatic generation (within the CAD system) and evaluation (by the simulation programs) of the design solutions. Optimisation has been a topic in ship design for at least four decades, but only the last decade has brought broader application and industrial maturity of these tools. The progress is due to three factors: better optimisation algorithms; more complex (and realistic) optimisation models; and more accurate design simulations and evaluation. Evolutionary algorithms (for example genetic algorithms) are now widely employed in naval architecture optimisations. Swarm algorithms appear on the horizon as a robust and efficient technique for optimisation. These algorithms copy the strategies of insect swarms to achieve a goal; the individual behaviour is simple and the power of these algorithms comes from massive parallel computations. While such modern evolutionary algorithms are advocated by research groups, tried and tested classical optimisation algorithms are still the preferred choice in industry. The European project IMPROVE (Rigo et al. 2008) may serve as an example: the project has developed a decision support system as a methodological assessment of ship designs. Using formal structural optimisation software, new ship types, namely a 220000m^3 LNG carrier, a large Ropax ferry and a chemical tanker have been developed.

Additional functionality

As marine CAD systems mature, they provide additional functionality either by directly integrating new features or by offering new links to external simulation software.

After a more general discussion of CAD user requirements and how different surface description techniques match these requirements (highly recommended for further reading), Forrest (2008) describes new features that have added to the PARAMARINE design system. One feature of particular interest is a novel method for the reverse engineering of existing designs: a scaleable Bitmap object enables the electronic version of a drawing (such as a lines plan) to be imported into the PARAMARINE design and positioned in relation to the 3D datum. Alternatively,

Figure 2: Advanced CFD simulations for green water on deck and slamming, source: Germanischer Lloyd.



stations of offsets may be imported which, can be used to generate splines in order to improve the accuracy of model fit between stations.

A fundamental part of the vessel's general arrangement is the definition and management of all ship spaces as well as the preliminary layout of the main equipment (including weapons systems on naval vessels) and accommodation items in these spaces and on the main deck areas. Traditionally, most of the tasks related to compartment design and to the definition of the ship's general arrangement have been done using 2D drafting tools in combination with poorly integrated or stand-alone tools for calculation and analysis. Recent evolution of 3D design tools has led to a new approach for compartment design based on the generation of a 3D compartment model. Alonso et al. (2008) describe recent activities of SENER to include a tool for compartment design in FORAN. A mixed approach combines the advantages of both the 2D and the 3D approaches, but removes most of their restrictions and drawbacks. The new method combines a 3D general arrangement tool which provides all the functionality and techniques of the 3D approach, with 2D tools used when 3D information is unavailable for the equipment or accommodation items or when it is necessary to perform quick modifications of the compartment layout. Working on the deck plan, together with 2½D modelling and visualization techniques, these 2D tools efficiently define the compartment boundaries and accommodation areas and spaces.

Structural design applications have grown beyond mere drafting and parts management tools and now increasingly include structural rules and intelligent support to handle these rules. The new Common Structural Rules (CSR) for tankers and bulkers have triggered CAD developments to support the design process for these ship types which constitute two-thirds of the world's fleet in terms of tonnage. Napa Ltd and ABS have jointly developed such a software tool for assessing ship scantlings against CSR requirements, Holmberg (2008). During the process of evaluating the rules, a 3D model of the ship structure is created behind the graphical user interface. The calculations are then performed using information derived from the 3D model. An FE model can be automatically generated as a by-product of the rule assessment and creation of classification drawings can be automated on the basis of the 3D model. Costing related data can be derived and the model can be exported to detailed design packages.

Better and more simulations

Analysis of vessel hydrostatic stability was among the first applications of computers to the field of naval architecture. Today, the naval architect can perform stability analyses for intact and damaged conditions almost at the push of a button. Modern stability regulations and simulations are closely linked. Progress in simulation techniques now offer simulation-based stability assessment for dynamic conditions, whether it be stability in waves (parametric rolling) or progressive flooding of a damaged vessel. For example, NAPA has incorporated a CFD simulation method for progressive flooding developed at the Helsinki University of Technology, Metsä et al. (2008). The tool allows for a more realistic assessment of ship safety in the damage condition, capturing dynamic effects and intermediate flooding conditions, which are frequently the most critical.

In CFD today, advanced industrial applications include unsteady viscous flow simulations with complex two-phase flow simulations (complex wave formation and cavitation). The market has consolidated to a handful of vendors who offer FEA and CFD analysis tools with associated grid generation and post-processing applications. For example, Queutey et al. (2008) present a six-degrees-of-freedom seakeeping simulation using such a free-surface capturing viscous solver (the motions are not prescribed by an external inviscid solver but are calculated as part of the solution).

The examples above represent applications of continuum mechanics. As a new approach fundamentally distinct from continuum mechanics, discrete event simulation (DES) has evolved rapidly and has proven to be a versatile and powerful tool for many applications supporting ship design. DES is used in practice by several shipyards to support operational and strategic planning of the shipyard operation. Despite the relative simplicity of the underlying theory, simulations of complex systems are able to offer considerable benefits in terms of qualitative insight (e.g. identification of bottlenecks) and quantitative information (time taken to perform an assembly or to unload a ship; occupancy rates for workstation; etc.). Essentially the same technique is applied for modelling processes in ports and the loading and unloading of ships.

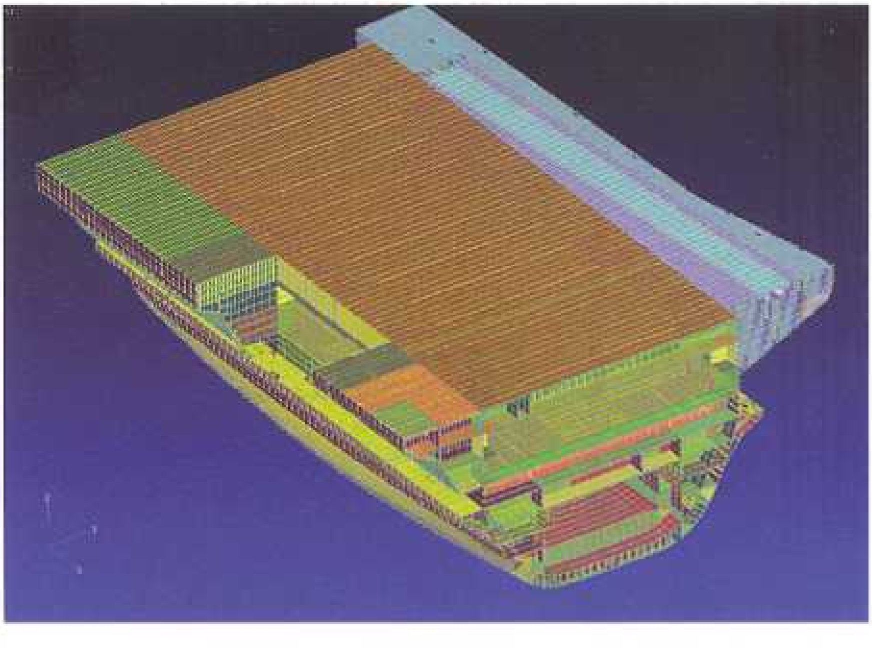


Figure 3: Rapid CAD modellers reduce model creation time to typically one week, source: Granitx.

The simulation of processes that involve humans requires elements that mimic human decision-making and intelligence. This is, for example, the case in ship evacuation simulation. The trend is to equip each simulated human with a certain perception and reasoning capability. Such multi-agent systems have drifted into practical applications and are likely to become increasingly important for a variety of simulations relevant to ship design. Deere et al. (2008) present recent work at Greenwich University, which is amongst the leading groups in this field. They have applied their code maritimeEXODUS to evaluate ship layouts from a human factors perspective, choosing a naval vessel to demonstrate the process.

Faster model generation

In an ideal world, a 3D CAD model is initiated at the early design phase and expanded as the design develops. This central 3D CAD model serves as the starting point for assorted simulations where the required input data and analysis meshes are generated, largely automatically, from the model by suitable interface/grid generation software. The reality in our industry is somewhat different: despite the widely documented and (in principle) accepted advantages of 3D models in the total process chain, most shipyards still often employ 2D CAD for basic structural design, because this is perceived to be cheaper than the creation of a 3D model. One argument for 2D drawings is that the software is cheaper and easier to use. Another argument is that 3D models for different applications have different levels of detail and also often different data structures. For many years, it was difficult or impossible to re-use data from a 3D CAD model developed during basic design later on in detailed (production) design. Such software is only now starting to emerge.

If a 3D model exists, the model is frequently not suitable for use in simulation software. Each simulation requires certain model characteristics tailored to balance computational effort and accuracy of results. Frequent practice is to create input models for simulations (and optimisation) manually. All major CAD vendors in our industry are working to improve the interfaces between 3D CAD models for basic design and simulation (particularly FEA) tools. Despite undeniable progress, fully automatic transfer does not yet appear in sight. However, semi-automatic generation of these data is feasible, e.g. Wilken et al. (2008). In this case, the geometry is imported from the CAD model and a pre-processor ensures suitable grid generation. The main problem lies in the necessary abstraction of a global model for FEA. In the FEA model, stiffeners are not modelled geometrically, but attributed to plate elements using a variety of possibilities (truss elements, beam elements, increased plate thickness, orthotropic material properties, etc.). Further, the detail of a suitable FEA model depends on the application to which it will be put and the results it will be required to produce. High-level (expert) domain knowledge is thus required to generate a suitable model and the same is true for CFD simulation models. We therefore expect grid generators to remain semi-automatic for some time to come.

Figure 4: Parametric design saves time and money. source: AVEVA.

Rapid model creation, modification and validation are key industry requirements and CAD developers have been able to accelerate this process by various techniques. Virtually all commercial CAD tools employ some sort of parametric modeller. Increasingly, simple functions such as automatic generation of repetitive parts are enhanced by knowledge-based support. An example of this is the automatic adjustment of scantlings or insertion of additional stiffeners if required by classification rules due changes of, for example, double-bottom heights, Dumez et al. (2008). Best practice is to create a 3D CAD model of a ship, typically in one week; subsequent FEA model generation for simple models is then largely automatic and grids can be generated within minutes.

Virtual prototyping

Simulation and virtual reality (VR) engines may be combined if ergonomics are important. VR may combine physical mock-ups (e.g. operating consoles) with virtual models of screens, larger environments within the vessel, etc. Human testers or virtual mannequins can then be studied performing ship-operation tasks at the design stage. Le Therisien and Mais (2008) give several examples of these simulations made by DCNS in France.

One application of virtual prototyping is the simulation of operations. DNCS simulated the flight-deck operations of a new aircraft carrier: catapult launching, landings, maintenance and fuelling. The simulation served not only to estimate the time required for individual tasks, but also to identify inconsistencies early in the design process. Another application concerned the set-up of operational premises: here the goal was to integrate the various components of a room and to check functional and ergonomic performance at full scale. The interactive examination of complex premises allows multi-disciplinary teams (architects, ergonomists, crew, etc) to evaluate the design. For example, the complex interaction of a team of sailors during berthing operations of a frigate identified problems of accessibility and mutual blocking of team members. As a final application, a workstation for the new FREMM frigates was evaluated. In an immersive space, the real armchair of the operator was placed in the virtual environment. The operator was then monitored performing several specific tasks. Since all objects of the workstation were movable in real time, the optimal placement of displays and controls was found relatively quickly, avoiding the necessity of producing several physical mock-ups. DCNS reported that in their experience, the savings from detecting design errors early in the design process outweigh the investment costs for the dedicated hardware and software required for the virtual prototyping. *NA*