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Sail and rig-plan design: be right first time

SMAR Azure Ltd explains to *Ship & Boat International* how its integrated sail design and analysis technology enables it to design optimal sail-rig plans

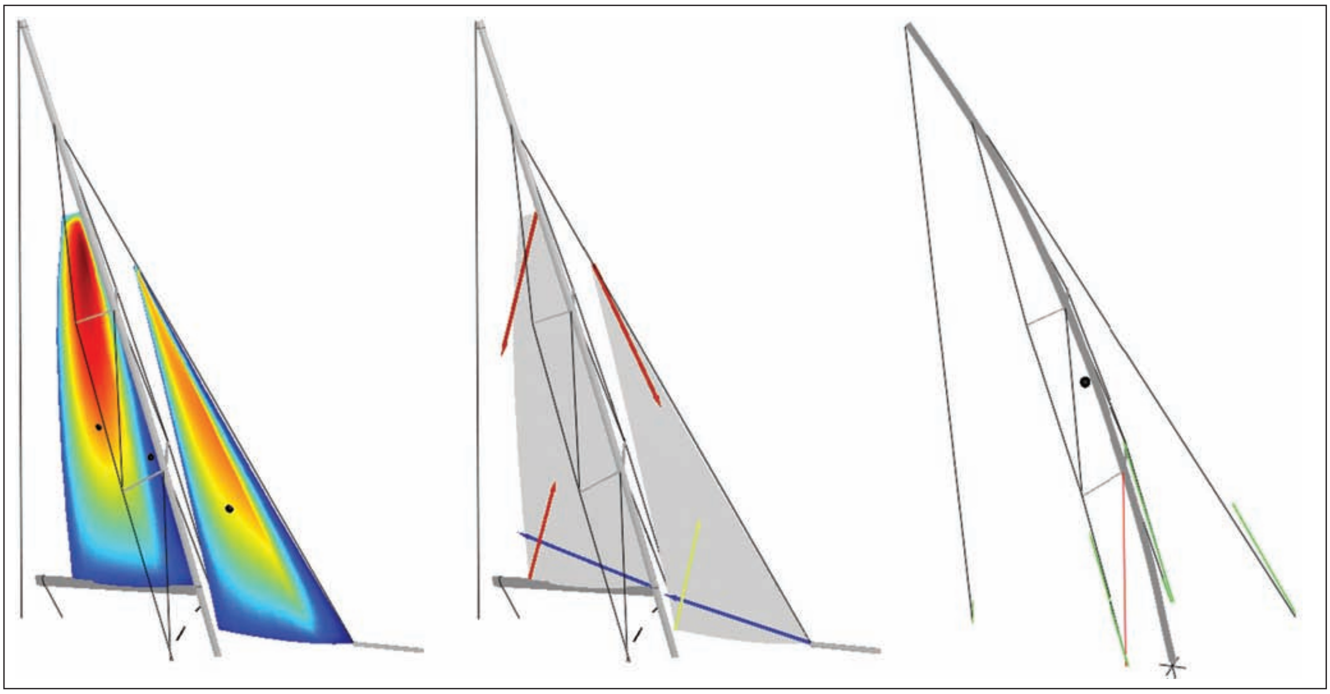


Figure 1 shows the impact of the loads developed by a reefed sail plan on the rig

Modern sailing boats are designed to attain high technical performance, while also maintaining high levels of comfort. Furthermore, increasing environmental concerns are pushing towards the refitting of existing yachts with advanced equipment. With this in mind, designing the optimal sail-rig plan poses a number of challenges.

Mast and rig design cover an important role in maximising the performance of sailing yachts. The design of optimal rigs should take into account realistic sail loads, whereas the design of optimal sail-plan should consider the particular rig configuration and its structural behaviour (mast bend, forestay sag). The challenge is to facilitate both.

Dr Sabrina Malpede, chief executive officer of UK-based SMAR Azure Ltd, observes that: “Our proprietary technology allows the yacht and rig designer to design optimal sail and rig plans by virtually simulating the structural behaviour of various rig configurations while sailing. With our integrated sail and rig technology – developed by the research and development [R&D] team at SMAR Azure – we can calculate the effect of the tuning loads on the rig and moreover calculating the sailing loads. We are able to perform the aeroelastic analysis of sails through the interaction of a structural non-linear Finite Element Model (FEM) with a vortex lattice aerodynamic model [1]. The final sail loads, evaluated in user-defined sailing conditions, and trim loads are applied to the various rig components”.

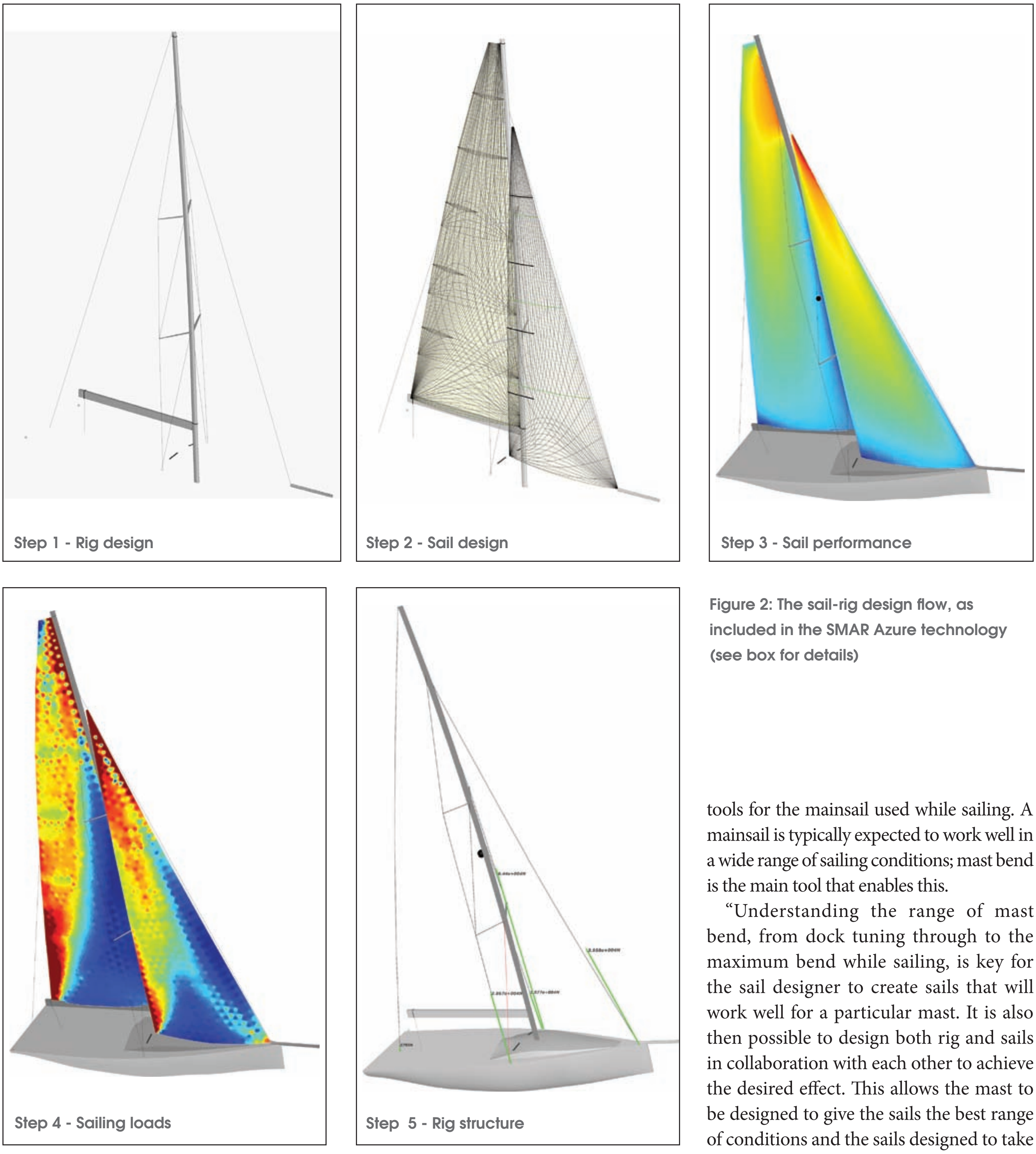
Malpede adds that: “Unlike existing structural analysis tools (FEM/FEA) for rigs, the SMAR Azure technology can directly take into account the fluid-structure interactions between sails and rig components [2], which will allow further improvements over current design methods.” The ability to calculate the effect of sailing loads, tuning and also inertial loads on rigs allow designers to optimise rig weight and stiffness for optimal sailing performance.

Sail-rig plan design flow

Using AzureProject, the proprietary technology for sail and rig design, SMAR Azure’s R&D team draws the initial geometry for the rig and sails and assigns the structural properties to each rig element and sails. The initial sail-rig plan is defined as ‘baseline’ (step 1 and 2 in Figure 2, p38).

Sail performance is evaluated by simulating the impact of variations in sail trim, sailing conditions and sail shape geometry. Optimal sail and rig plan are conjunctly developed via an automated evaluation of sail coefficients in a variety of sailing/trimming conditions and by varying the sail’s geometry. The outcome is an optimal sail-plan, in terms of sail dimensions and geometry (step 3).

Once the optimal sail-rig plan geometry is defined, the structural design of the sail



Step 1 - Rig design

Step 2 - Sail design

Step 3 - Sail performance

Step 4 - Sailing loads

Step 5 - Rig structure

Figure 2: The sail-rig design flow, as included in the SMAR Azure technology (see box for details)

and rig can start. The goal is to ensure that the structural properties of the sail and rig will perform as 'by design'. On the one hand, rig deformations, mast bend and forestay sag, are calculated under sailing and tuning loads; on the other hand, the calculated flying sail-shapes take into account the rig influence.

Malpede explains: "Rig deformations have a high impact on the sail shapes. Let's think about a mainsail. Understanding the dynamic interaction between the mast and mainsail is critical to achieving the best performance. The mutual interactions are complex as the sail forces influence the mast bend, which in turn influences the sail shape. Mast bend is one of the major trimming tools for the mainsail used while sailing. A mainsail is typically expected to work well in a wide range of sailing conditions; mast bend is the main tool that enables this.

"Understanding the range of mast bend, from dock tuning through to the maximum bend while sailing, is key for the sail designer to create sails that will work well for a particular mast. It is also then possible to design both rig and sails in collaboration with each other to achieve the desired effect. This allows the mast to be designed to give the sails the best range of conditions and the sails designed to take full advantage of the mast bend. A similar process is also involved when considering the forestay sag and the headsail shape."

Using AzureProject, the sail loads, as corner loads and stress, are calculated (step 4). Then, rig deformation under sailing and dock tuning loads is assessed (step 5) using RigEdge, SMAR Azure's latest rig design and analysis tool – which also allows alternative sail plan performance and trimming conditions to be compared. This enables SMAR Azure to properly define the initial dimensions of spars/rigging, and their structural properties. This process also entails the evaluation of the rig deformation and internal force in the worst case scenarios, as seen in the reefed sail-plan (see figure 1).

Malpede concludes: “The ability to carry out the fluid-structure interaction analysis of sail-rig plan is critical to the structural design of sails and rig. The ability to evaluate both realistic loads on rigs and the interaction between rig element and sails, leads not only to the optimisation of shape and weight to guarantee optimal performance, but moreover to a dramatic reduction in the cost of prototyping and manufacturing. ***SBI***

References

1. MALPEDE, S, BARALDI, A, ‘A fully integrated method for optimising fiber-membrane’, Proceedings of the 3rd High Performance Yacht Design Conference, 2008.

2. MALPEDE, S, NASATO, F, ‘A Fully Integrated Sail-Rig Analysis Method’, Trans RINA , Vol 153, Part B2, Int J Small Craft Tech, 2011.

Figure 2: The sail-rig design flow, as included in the SMAR Azure technology

Step 1 - Rig design
Geometric definition of:
- **Spars (mast/spreaders)**
- **Running/Standing rigging**

For each spar/cable element, the designer can set material properties

Step 2 - Sail design
Geometric definition of:
- **Mainsail**
- **Headsails**
- **Spinnakers**

For each sail it is possible to assign material properties by either selecting the sailcloth or by the definition of the fibre layouts

Step 3 - Sail performance
Inputs:
- **Sailing conditions: AWA/AWS or TWS/TWA/BS**
- **Trimming conditions**

Outputs:
- **Pressure force**
- **Sailing coefficients**

Step 4 - Sailing loads
Inputs:
- **Sailcloth or fibre-membrane design**
- **Constraints/external loads**

Outputs:
- **Flying sail shape**
- **Sailing loads**

Step 5 - Rig structure
For specified tuning loads and calculated sail loads the following are calculated:
- **Forestay and removable stays load and sag**
- **Vertical and diagonal shroud tension on both sides**
- **Mast bend and compression**
- **Collar forces**

Platform for success

Lee Archer and James Roy of BMT Nigel Gee Ltd examine the potential of applying a platform engineering approach to the design and build of super yachts of less than 500gt, or around 25-50m, in a paper presented at RINA’s Design and Construction of Super & Mega Yachts conference held in May

The paper, *Platform engineering for production and semi-custom yachts*, looks at the possible benefits of implementing a platform design approach and highlights some of the barriers that may exist within the current set up of a typical high volume production boatbuilder.

Archer and Roy, senior project manager and yacht design director, respectively, at BMT Nigel Gee Limited, note in their paper that the last two decades have seen many production boatbuilders move from their traditional focus on yachts of less than 24m to incrementally larger vessels in order to enter the super yacht market.

However, the production boatbuilding model, which relies on economies of scale and standardisation of design and engineering to reduce costs, does not fit with the super yacht market’s demands for customisation in every vessel. Many established super yacht builders, in the 30-40m range, use the semi-custom model which addresses some of these issues. However, a platform engineering model, say Archer and Roy, can offer higher degrees of flexibility for both the shipyard and client.

They outline three typical tried and established build methods; the chosen method of each yard normally dictates how the design and management aspects of building the yacht are completed. These methods are:

- Custom building – every aspect of the architecture, engineering and design is bespoke;
- Semi-custom – majority of the yacht is designed; minor items can be tailored to the individual customer (ie, interior furnishings, performance of the air-conditioning); and
- Production building – The customer is limited to a very small number of previously costed and tested items.

Archer and Roy argue that the nature of highly bespoke custom yachts means design and build time will subsequently be much longer. Where production build methods are employed, although little customisation is available, the design, build time and purchase costs are significantly reduced.

The middle ground, semi-custom building, is by far the largest category in the