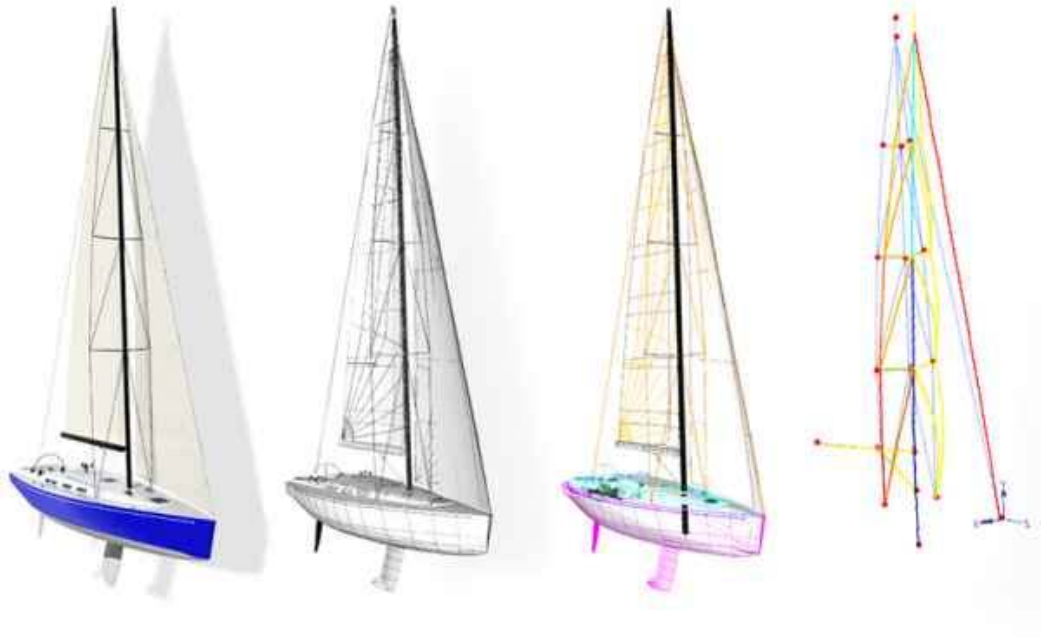
POLYTECHNIC OF TORINO
FACULTY OF ARCHITECTURE 1
Degree in Architecture
Honors theses

Structural analysis of a sailing rig. Case study design and optimisation
by Luca Roccati
Tutor: Vittorio Nascè
Co-tutor: R. A. Shenoi

This dissertation has been developed through a collaboration between the Politecnico of Turin (Department of Structural Engineering and Geotechnics) and the University of Southampton (Ship Science Department).
A discipline associated with architecture from the start, in recent years, "Naval Architecture" has specialised in the design of sports sailing boats through *Yacht Design* studies, where the attention is focused on the rig and the entire sails manoeuvring system.
This structural complex is an integral part of the "engine" of a sailing boat, transmitting to the hull the propulsive effect of the wind acting on the sails in a delicate balance of opposing forces.
This dissertation explores the possibility of improving the speed performance of a sailing yacht through the design and optimisation of the rig and the rigging.
This goal was pursued by considering a single, and yet decisive, element of the boat, leaving the hull and sails unaltered.
The design and optimisation process was applied to different rigs having specific requirements in terms:

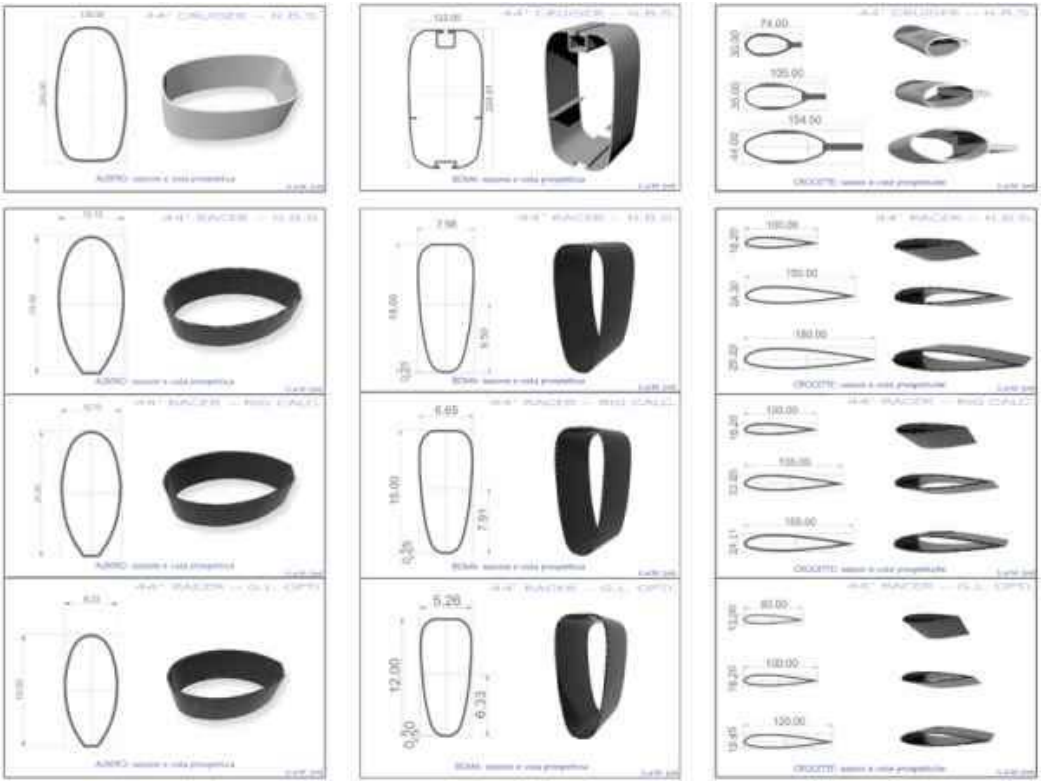
- navigation philosophy: cruise vs. regatta;
- technology of the materials employed: carbon fibres, aramid fibres and special metals;
- dimensioning methods employed.

The rigs examined are characterised by three orders of sweep back spreaders, for use in a 44 ft. long fast cruiser, which is the type of yacht used most widely, in that it combines the possibility of pleasure cruising with racing on the regatta fields.



Three-dimensional model of the boat studied, with static scheme of the rig

After defining state-of-the-art yacht design provisions and methods, a number of guide lines were identified for the design of a cruiser rig and the design of a regatta rig in several versions. The same dimensioning methods were used in connection with all the different design criteria to be able to evaluate the influence of the weight of the materials on the improvement of speed performances.



Cross-sections of the mast, the boom and the spreaders as a function of the different philosophies and dimensioning methods (cross-sectional and perspective views)

The deck plan of the 44 ft., with the relative running rigging needed for the control of the sail surfaces, was also changed to adapt it to the cruising and regatta configurations.
The first step consisted of identifying the parameters having the greatest influence on boat performances in the various optimisation methods:

- the total weight of the rig;
- the height of its centre of gravity;
- windage.

To improve the efficiency and structural performance of the rig, it was decided to use the technology of composite carbon fibre materials.
Resort to different design techniques made it possible to work out the optimal composition of the laminate (mixture design) and to determine the best orientation and sequence of the laminations stack.
After that, the results obtained according to the various guide lines were compared in order to assess the structural and sailing performance levels achieved with the different rigs.
This was done with the aid of specific yacht design computer codes, and namely:

- Composite Pro for mixture design and the determination of the mechanical properties of the laminates;
- XFoil for the aerodynamic study of the sections;

- Maxsurf and Rhinoceros for modelling the water lines of the hull;
- LPP (Line Processing Program) for the determination of hull hydrostatic data;
- VPP (Velocity Prediction Program) for the simulation of sailing performances in different types of regatta.

From the development of the dissertation, the following conclusions can be drawn:

- the hull being the same, replacing the cruising rig with regatta rigs generated appreciable differences in terms of speed and overall performance;
- the element having the greatest influence on final performance capabilities is the height of the overall centre of gravity of the boat, which is a function of the weight of each rig;
- a comparison between different regatta rigs revealed but minimal differences in terms of rig dimensioning and hence in terms of performance as a function of the design methods and design criteria employed.

Best Boat Speeds – the different speeds developed by the boat with the different rigs envisaged as a function of 20 knot true wind angles

The results obtained can be summarised in a single parameter: speed. For example, from a comparison between a boat with a regatta rig and a boat with a cruising rig, it has been determined that it takes the former, on average, 15 seconds less to cover a nautical mile over an Olympic route with a true wind of 20 knots.

For further information, e-mail:
Luca Roccati: luca.roccati@fastwebnet.it