moment generated by platform twist.
- Transverse bulkheads stiffen the arm in torsion by reducing the size of the panels, which increases the impact strength of the bottom of the fairing.

Design criteria

These criteria can be assessed by means of a finite-element analysis or a semi-analytical approach based on experiments. These design criterias are illustrated in Figure 12.

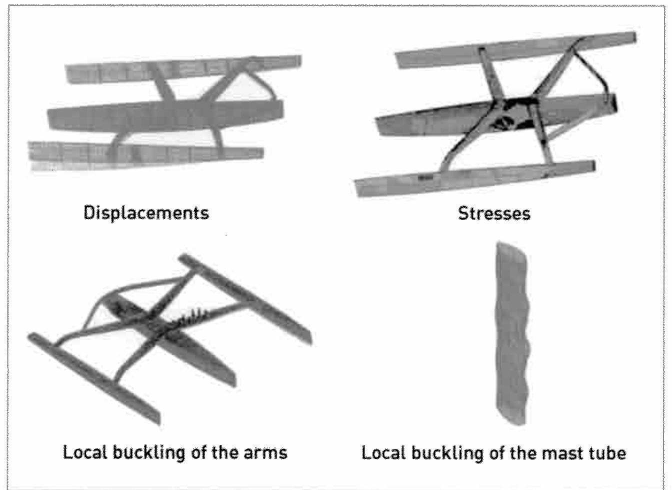

Fig.12: Typical design criteria for a racing multihull

An ORMA trimaran, like any other yacht, is designed to meet the following three criteria:
- Strength: The boat should not undergo structural damage while racing. At the design stage, a safety coefficient of 2 is commonly applied between the maximum dynamic calculated stress and the material failure stress. Several mechanical tests on coupons or structures are also carried out by laboratories in order to characterize the plies' behaviour in a realistic stacking sequence representative of those encountered in the structures under consideration.
- Stiffness: For a given trimaran platform architecture, stiffness can be tuned by modifying two significant parameters: the cross section geometry of the cross beams, central hull or floats, and the choice of a more or less stiff carbon fibre (from 235 to 450 GPa). High stiffness will increase the boat speed during transient events. The elastic energy will not be lost while the platform is deforming. However, high stiffness increases dynamic loads.
  A compromise is generally found as a function of the yacht's requirements (race around the world, across the Atlantic, alone or crewed, etc.).
- Stability: A set of buckling stability levels must be considered for composite materials. Local buckling results from the instability of panels such as mast walls, planking or deck walls, or cross beam fairing. Wrinkling is the instability of a sandwich panel skin which collapses locally under compression load.

Appendages & hydrofoils

The appendages of a sailing yacht are immersed hydrodynamic profiles that generate lift via several forces:
- Load preventing drift by using a keel spar and/or a daggerboard, which balance the transverse load caused by the sail lift.
- Lateral force applied to the boat by the rudder, generally located at the rear to ensure steering.
- Vertical force created by a hydrofoil, capable of lifting the floats partially or totally out of the water.

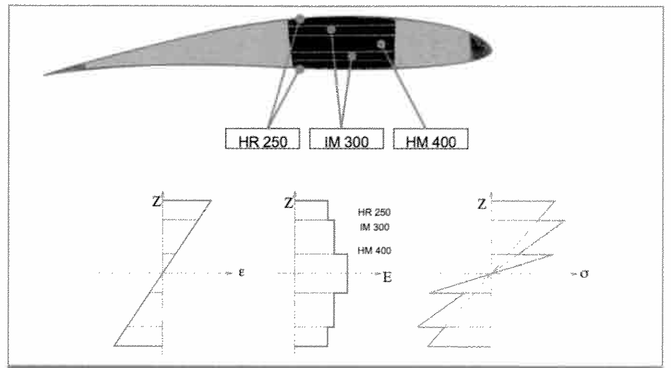

Fig.13: Typical design criteria for a racing multihull

To work properly, these appendages must withstand the loads applied, be very stiff to avoid parasitical motions, and be as thin as possible to prevent cavitation at high speed. For recent appendages capable of withstanding twice the weight of the boat, a specific design was provided, as shown in Figure 13. The primary structure is a massive monolithic beam made of three different types of carbon fibre chosen by stiffness and strength criteria. The stiffness of carbon fibre increases when it is closer to the centre of the beam. If a linear displacement field is assumed across the width, stiffness increases by 15% while strength grows by 25% compared to a stacking sequence using a single type of high-strength carbon fibre.

Conclusion

Some recent examples of monohull and multihull racing yachts have been described in this paper. In both cases, the design stage leads to weight savings in the hull structure. The use of finite-element modelling significantly improves the boat design. Mechanical models currently use composite shell elements and are sometimes run with non-linear hypotheses like large displacements. This approach leads to the design of extremely light structures which take advantage of composite materials such as unidirectional carbon prepreg and honeycomb core. Contrary to airframe structures, which require quasi-isotropic stacking sequences, boat hulls or appendages can use various stacking sequences without limiting guidelines.
This complicates the initial material's design and requires the designers to develop specific know-how.

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