

Preliminary Design of a Composite Wing-sail

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Abstract: An Abaqus/Standard FEA based study was carried out to develop a structural format for a wing sail used on a sailing boat, V-39 Albatross. As well as providing a novel structural solution to meet a challenging set of requirements, the study has given the necessary mass properties and stiffness data required to further progress the preliminary design phase of the overall boat.

The brief for the boat is to set a new world outright sailing speed record at Portland, UK. The choice of location influences the overall concept from the outset, since the conditions are closer to real world conditions when compared to currently favored locations for speed sailing. The boat is configured to add at least 10 knots to the current record by setting a speed above 60 knots (111 km/h). At speed the boat hulls will fly above the surface using a wing in ground effect. The pilot is able to sail on both port and starboard tack and can actively control the craft in roll and height as well as yaw.

The boat has two handed wing-sails to give both lift and power. Each wing-sail is split into an inner and outer plank. Each plank is free to rotate or 'weathercock' about its longitudinal axis into the local air stream. The degree of lift generated by a given plank is set by controlling the upward deflection of a full trailing edge flap. This approach brings an essential weight saving benefit when compared to the conventional approach of adopting a tail surface to provide stability and control; this would necessitate the addition of four booms, tail surfaces and additional counterweights, one for each plank. The overall CG position of the boat is paramount to its stability and control and would not allow this additional structure.

The 'tailless' aerodynamic approach adopted gives rise to a profound structural problem. A wing type structure would typically have a very different in-plane and perpendicular flexural stiffness. This causes the direction of deflection to differ from the direction of applied wing lift. This effect results in a shifting of the centre of lift and causes the outer plank to exert unwanted moments about the axis of rotation to the inner plank. This prevents satisfactory plank stability and control.

The structure developed includes a main tubular carbon fiber spar holding the bearing housings as well as carrying the wing-sail bending and shear loads. The surrounding structure including ribs, skin and secondary spars gives each plank its form and carries local aerodynamic loads into the main spar. However, this additional structure has been partially decoupled from the main spar to prevent it from increasing the flexural stiffness of the main spar in the plane of the plank. The resultant structure has near axisymmetric properties and therefore mimics a purely tubular structure.

Composite modeling techniques used are of a macroscopic nature, i.e. composite lay-ups are represented using thick conventional shells. Angular contact bearings are defined within the interaction module and their weight represented through a concentrated force at the control point. The plank Mylar skins are tensioned by applying a temperature predefined field and including an expansion (contraction) step.