The influence of a yacht’s heeling stability on optimum sail design

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This paper presents fundamental results concerning the optimum design of yacht sails and masts. The aerodynamics of a high aspect ratio sail in uniform flow is analysed using lifting line theory to maximise thrust for a given sail area. The novel feature of this work is that thrust is optimised subject to the constraint that the aerodynamic heeling moment generated by the sail is balanced by the righting moment due to hull buoyancy (and the weight of the keel). Initially, the heel angle is therefore unknown, and determined as part of the solution process. Under the assumption of small heel angle, the problem reduces to minimising a quadratic form in the Fourier coefficients for the circulation distribution along the mast, and a simple analytic solution can be derived. It is found that if the mast is too high, the upper section is unused, and as a consequence there is a theoretically ideal mast height for a yacht of given heeling stability. Under the constraints of given sail area and heeling equilibrium it is found that no advantage is to be gained by allowing reverse circulation near the top of the mast. Various implications for yacht performance are discussed.

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