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Extended Lifting Line Theory Applied to two Interacting Yacht Sails
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a comparison between theoretical calculations and pressure measurements

Abstract

This thesis applies extended lifting line theory (Weissinger's ¾ chord method) to two interacting yacht sails.
The theory therefore is based on modelling the sails by vortex lines on their ¼ chord lines. The wakes of the sails is modelled as semi-infinite vortex sheets and the sea surface is modelled by using the usual method of 'image sails'. According to Weissinger's method the kinematic boundary condition is fulfilled at the ¾-chord line of each of the sails. This leads to two coupled integro-differential equations. They were converted into a linear system of equations by expressing the circulation distribution as a Fourier series. A MATLAB code was developed to solve this system and to obtain the spanwise load distribution for the two interacting lifting surfaces.
To validate the theory thin pressure-tapped sails in fibre glass sandwich construction were designed, built and used in wind tunnel experiments to obtain pressure distributions over two interacting yacht sails. The experimental results were first used to analyse the effects of sail trim and to show the influence of the assumptions made in the extended lifting line code. Finally the experimental results were used to validate the developed code and it is shown that predicted and measured spanwise circulation distributions typically agree to within 10 %. Moreover it was revealed, that the load distribution for two interacting sails obtained from an extended lifting line analysis is very similar to the one computed with a panel code.
The extended lifting line code was then used to theoretically analyse the influence of various parameters on the spanwise load distribution of two lifting surfaces. Using the example of two interacting flat plates the effect of taper ratio and of chordwise separation between the plates was studied. An investigation on the influence of different trims on the loading of two interacting sails revealed a number of basic phenomena that were similarly found in the wind tunnel experiments.
Finally it was shown how the extended lifting line code can be 'inverted' to be included in a sail optimization routine, which can produce the desired, optimized sail-shape for a given boat in given sailing conditions.