Available online at www.sciencedirect.com

ScienceDirect

Procedia Engineering 147 (2016) 336 – 341

Procedia Engineering

www.elsevier.com/locate/procedia

11th conference of the International Sports Engineering Association, ISEA 2016

Numerical prediction of the best heel and trim of a Laser dinghy

Mikka Pennanen[a,b], Rickard Lindstrand Levin[b], Lars Larsson[b], Christian Finnsgård[c,d,*]

[a]BlueWorks Inc., Veneentekijäntie 2, 00210 Helsinki, Finland
[b]Dept. of Shipping and Marine Technology, Div. of Marine Technology, Chalmers University of Technology, 412 96 Göteborg, Sweden
[c]Centre for Sports and technology, Chalmers University of Technology, 412 96 Göteborg, Sweden
[c]SSPA Sweden AB, Research, Box 24001, 400 22 Göteborg, Sweden

Abstract

As the Laser Olympic dinghy is one of the highest-level sail racing classes in the world, there is an interest in obtaining physical facts around the experience that already exist. For this reason, a numerical investigation has been carried out to find the best heel and trim angles in upwind sailing. Flat water is assumed. The core of the work is a newly developed Inverse Velocity Prediction Program (IVPP) that computes the required wind speed for a given boat speed. Input to the program is both available towing tank data and CFD results. By keeping speed constant interpolation is avoided in the very non-linear resistance-speed relation, reducing considerably the required number of CFD computations. Another reduction is obtained by a special technique for avoiding interpolation in leeway. Systematic CFD computations are carried out to find the optimum trim versus heel at the speeds 2, 3, 4, 5 knots. Using this relation the required wind speed at the four boat speeds can be expressed as a function of heel only. The heel angle corresponding to the smallest wind speed is the best. Knowing this, and the corresponding optimum trim, the position of the sailor is computed. It turns out that the predicted best positions correspond well with practical experience. However, the results highlight the benefit of a small heel in higher winds, which often is regarded as undesired by sailors.

Peer-review under responsibility of the organizing committee of ISEA 2016

Keywords: Sailing; VPP; CFD; Hydrodynamics; Laser; Dinghy

1. Introduction

Most research projects within sailing are aimed at improving the boat and the equipment, very few deal with the improvement of sailing skills. This is a project of the latter kind: the objective is to find the best position of the sailor in a Laser Dinghy. The Laser is one of the largest classes in the world and used in the Olympics. Among the top sailors the differences in speed are extremely small and the advantages of the correct position of the sailor can be decisive for a top position in a race.

Defining the best sailor position on a dinghy is not a trivial problem. Both trim and heel depends on the position, and this affects both aero- and hydrodynamics. For the Laser, the weight of the sailor is about the same as that of the boat so the sailor position has a profound influence on the location of the total centre of gravity. Moving the centre, the wetted surface area will change, which affects the frictional resistance. The shape of the underwater body as well as the waterline length will change, which affects the wave resistance. A variation in heel will change the effective draft and thereby the induced drag of the appendages. On the aerodynamic side the effective drive force varies with heel angle.

Within sailing yacht research and development Velocity Prediction Programs (VPP) are standard tools to evaluate the force balance and performance of the yacht. During the past two decades, Computational Fluid Dynamics (CFD) tools have also become available and now complement the VPP:s. Both tools are used in the present study, together with experimental data from a towing tank.

* Corresponding author. Tel.: +46 31 7729156; fax: +46 31 772 9124.
E-mail address: fch@chalmers.se

1877-7058
Peer-review under responsibility of the organizing committee of ISEA 2016
doi:10.1016/j.proeng.2016.06.304

CFD is used to compute a matrix of resistance and side forces to be imported in the VPP for the hydrodynamic modelling. As there are four main variables of the present problem, namely speed, trim, heel and leeway, the number of required CFD simulations could be excessive. Especially the speed is a challenge, since the resistance varies with speed in a very non-linear way. This problem is resolved through the development of an Inverse Velocity Prediction Program (IVPP), where the speed is given and the required wind speed computed. There are also some other techniques developed to keep the number of CFD simulations within reasonable limits.

In this project flat water is assumed and only upwind cases are addressed up to approximately eleven knots of true wind speed. This wind strength correlates to the maximum boat speed. Above this wind speed the boat speed does not increase at all or very little. However the rig aerodynamics would change significantly and waves would change the hull hydrodynamics.

2. The Laser Dinghy

The Laser was first designed and built in 1970 and officially unveiled at the New York Boat Show in 1971. Since 1996 it has Olympic status. It is a simple construction with a glass fibre hull, glass fibre appendages, an aluminum mast and a Dacron sail. It can easily be sailed even by a beginner. As the dinghy has no keel weight adding stability, the righting moment of the boat is mostly produced by the sailor hiking from the hiking straps. A body plan of the hull is shown in Figure 1.

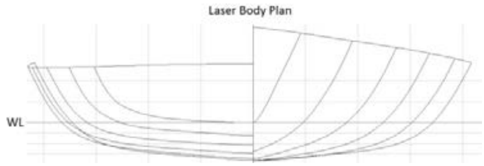

Fig. 1. Body plan of the Laser dinghy

3. Method

3.1. Procedure

The core of the work was the development of the IVPP. This was used twice. In the first round the resistance was taken from available tank tests of the Laser [1] without leeway and appendages. These were introduced in the IVPP by analytical formulae. The result was a good estimate of the equilibrium, and the leeway obtained was used in the subsequent CFD computations. This eliminated leeway as a variable in the systematic CFD computations, which were carried out for 2, 3, 4 and 5 knots. At each speed (except 2 knots) a matrix of heel and trim was computed. From this matrix the optimum trim for each heel could be obtained. By linking optimum trim to heel, the only remaining variable for each speed was heel. In the second IVPP round the resistance from CFD was used with a small correction for the effect of the error in leeway in these computations. The correction was based on the same empirical relations as in the IVPP. For each speed the required wind speed could then be computed as a function of heel only and the best heel angle was that where the required wind speed was the smallest. The best trim followed from the optimum trim/heel relation.

3.2. IVPP

Due to the space limitations only a brief description can here be made of the IVPP, for a full description see [2]. The logic of the program is similar to that of conventional VPPs (see [3]), the main difference being that the wind speed is guessed initially, rather than the boat speed and the result is wind speed rather than boat speed. The force and moment balances are

Aerodynamic Drive - Hydrodynamic Resistance
Aerodynamic Side Force - Hydrodynamic Side Force
Heeling moment - Righting moment

The advantage of the IVPP compared to a conventional VPP is the lack of interpolation between speeds. Since the speed-resistance relation is very non-linear, interpolation would be too inaccurate, unless a very large number of speeds were computed using the CFD method.

As explained above the hydrodynamic forces on the hull are taken either form the tank test results (first round) or CFD simulations (second round). To compute the forces on the appendages the ITTC-78 formula [4] is used for friction drag, and the Hoerner form factor for estimating viscous pressure drag [5]. The induced drag is calculated using formulae from lifting line theory (see e.g. [6]).