“Optimisation and Design of Contra-Rotating Propellers”

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1. Introduction

Although single screw propellers represent nearly the totality of the propulsors used on existing conventional ships, multi stage propellers and in particular Contra Rotating Propellers have many theoretical advantages. One obvious reason is the possibility to cancel the moment and lateral force transmitted from the propulsor to the craft, a minor but interesting feature for applications such as torpedoes and small single engine boats (in particular having surface piercing propellers). From the hydrodynamic point of view CRP are attractive for their higher efficiency; over the past decades model testing and numerical simulation have shown an increase of efficiency, compared to single propellers, ranging from 5 to 15 percent. The reason of this increase of efficiency in mainly due to the near cancellation of the swirl of the forward propeller by the after propeller. Despite this theoretical advantages, there are limited application of CRP on ships, mainly due to the cost and mechanical complexity of the required epicyclic gearing, but also to the higher difficulty of the design.

One of the first method developed for the design of CRP was outlined by Lerbs [1], that extended the lifting line method for single propellers, including the mutual interference of the two propellers, to compute the optimum circulation distribution. A practical extension of the method was implemented by Morgan [2]. More recently Kerwin et all. [3] presented a more rigorous lifting line method for the design of optimum CRP. A more exhaustive list of reference can be found in Cox [4].

In the present method the optimisation and design of CRP is performed in several steps. Forward and after propellers are computed in chain, each time taking into account of the velocities induced on the mean propeller plane by the other screw and its vortical wake. Knowing the inflow at the propeller plane the optimum circulation, chord and thickness distribution is computed with a so called Genetic Algorithm (GA). The blade (or its best momentary guess) is represented as a grid of vortices (Vortex Lattice Method) and the hydrodynamic load (vorticity) is varied in a quasi-random way to compute the distribution that maximise the efficiency. At each iteration hydrodynamic and mechanical loads (bending moments and centrifugal forces) are computed at each section to obtain the best compromise between circulation, chord length and thickness that minimise viscous and potential flow losses, while satisfying the required blade strength.

A Design Panel Method (DPM) is then applied to compute the pitch and camber at each section able to develop the required load distribution (spanwise and chordwise). The effect of the hub is included, as well as the alignment and contraction of the trailing wake are performed.