Applied Ocean Research 69 (2017) 100–115

Contents lists available at ScienceDirect

Applied Ocean Research

journal homepage: www.elsevier.com/locate/apor

Interceptor design for optimum trim control and minimum resistance of planing boats

M. Mansoori [a,*], A.C. Fernandes [b], H. Ghassemi [c]

[a] Khorramshahr University of Marine Science and Technology, IR, Iran
[b] Department of Naval and Ocean Engineering, Federal University of Rio de Janeiro, RJ, Brazil
[c] Marine Technology Department, Amirkabir University of Technology (Tehran Polytechnic), Iran

ARTICLE INFO

Article history:
Received 16 November 2016
Received in revised form
15 September 2017
Accepted 18 October 2017

Keywords:
Planing boat
Interceptor
Trim control
Finite volume
CFD
GCI

ABSTRACT

Interceptors are vertical blades installed symmetrically aft of the craft. This article aims to investigate the main geometrical (height and span length) parameters in interceptors. Different Models with and without interceptors at different heights and spans have been analyzed based on the finite volume method and SIMPLE algorithm using dynamic mesh. In order to validate CFD results, the grid convergence index (GCI method) has been used to estimate the uncertainties caused by grid-spacing and time-step. Although it has been proved that the interceptors are very useful in trim control and resistance reduction, choosing wrong size interceptors could not only destroy their effectiveness, but also endanger the planing boat due to the creation of a strong moment leading to negative trim. The results of this study show that among all effective variables, the boundary layer thickness (h) at the stern (where the interceptor is installed), is far more important than, some other particular parameter, on interceptor performance and should be taken into account in estimating the interceptor height (d) and span (s). Generally, the interceptor height should not be higher than 60 percent of boundary layer thickness at transom. For optimum efficiency, when the interceptor height equals 60 percent of the boundary layer, the interceptor span length should be seven times as much as the interceptor height. At the end, based on Reynolds number the paper presents three figures, setting the basis for optimal interceptor sizes for its use in planing boats.

1. Introduction

Trim variations are a great concern in planing boat design. These variations may lead to an increase in planing vessel resistance, thus creating instabilities such as the porpoising instability in high-speed vessels [1,2]. Therefore, it is necessary that the trim be controlled on high-speed crafts. The vertical blades, stern flap plates and wedge-shaped components, which are planted aft of the vessel, are the trim control appendages of planing vessels. The most well-known trim control device in high-speed planing crafts is the trim tab. In recent years, in order to control altitude, the interceptors have been successfully used in airplane wings, missiles and boats by creating lift forces [3–7]. Interceptors are vertical blades installed symmetrically aft of the craft. In Naval Architecture, they have been considered as an alternative to wedges and stern flaps and there is considerable evidence in literature about their high effectiveness [8]. Fig. 1 shows the outline of an interceptor implementation aft of a planing craft.

For the first time, MDI Company [9] suggested a series of model tests to determine and compare the roles of interceptor and trim tab. They considered interceptors with different heights but the same span size. The tests proved the hydrodynamic advantages of interceptors over trim tabs at different heights. Moline & Brizzolara [10] introduced a potential flow model to predict pressure and lift force in front of the interceptors. Brizzolara [11] used an interceptor at the maximum height of 200 mm on the steering interceptor of STENA HSS-1500 vessel with127 m overall length and 40 knot speed. On the other hand, Tsai and Hawing [12] examined the effects of trim mechanisms on resistance decrease. The outcomes of the experiment showed that the resistance of the planing craft and the running trim can be reduced by a well-designed trim mechanism. Krylov Shipbuilding Research Institute also performed several tank tests on catamaran and mono-hull models to explore the effectiveness of interceptors on resistance reduction, as well as the motion control of high-speed crafts [13,14]. Moreover, a new formulation was developed by Dawson and Blount as a basis to predict the equivalent lift of interceptors [15]. The effects of hydrodynamic interceptors on fast crafts were also investigated by Ghassemi and Mansoori based on a numerical method [16]. Their results showed that the interceptor exerts an intense

---

* Corresponding author.
E-mail address: mkerend2004@yahoo.com (M. Mansoori).

https://doi.org/10.1016/j.apor.2017.10.006
0141-1187/

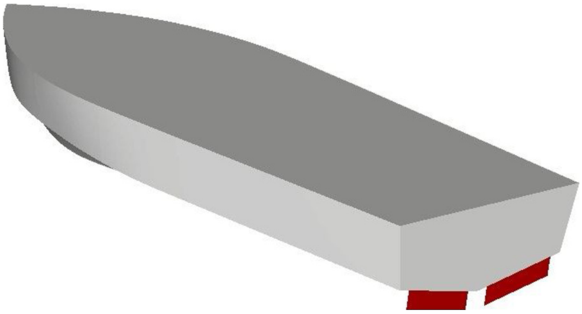

Fig. 1. The implementation of an interceptor aft of a planing craft.

pressure rate on its contact point. It also decreases the wet surface of the craft and drag forces coefficient, which finally lead to a better control of trim. The effects of boundary layer thickness on interceptor efficiency were investigated by Mansoori and Fernandes [17,18]. Their findings proved that to achieve good interceptor efficiency, many parameters should be taken into account besides interceptor height, but the most important factor is the ratio d/h, where d is the interceptor height and h is the boundary layer thickness at the transom. They also showed that the interceptor could control porpoising instability [19]. Furthermore, they proved that if an interceptor (while its height is 'd') is unfit, the first solution will decrease the interceptor height. Whereas, the height decrement results in lift force reduction. Another solution as confirmed in this paper is to use integrated interceptor (height = d/2) with trim tab (chord = d/2) instead of an unfit interceptor (height = d). By applying this, not only the lift is not decreased, but also the intense negative trim does not occur [20].

The present paper (a continuation of previous investigations by the authors) mainly aims to discover the relationship between interceptor height, chord length and boundary layer thickness at transom. Composed of many dynamic simulation results, the present paper shows the effects of interceptor sizes (height and span length) on pressure changes at the transom, trim, drag and wetted surface. Its main goal is to ease the design of the accurate interceptor scales in planing boats for the best efficiency and to avoid undesirable effects of the interceptor.

2. RANS solver and numerical scheme

In order to simulate the interceptor behind a planing hull model, a state-of-the-art RANSE solver with VOF (Volume of Fluid) method representing the free surface has been selected. The suitable simulation by finite volume method has the capability to solve the turbulent viscous flow around a body in stationary conditions, whereas the VOF method has the ability to predict the free surface around it. The VOF algorithm as developed by Hirt and Nichola [21] is used as basis for fluid advection. The method solves the incompressible Navier- Stokes equation with the free-surface condition on the free boundary. In the VOF method, a VOF function F (with values between 0 and 1) is used, indicating which part of the cell is filled with fluid. The VOF method reconstructs the free surface in each computational cell. This makes it suitable for the prediction of all phases in the local free surface problem. The incompressible Navier-Stokes equations describe the motions of a fluid in general terms. They are based on conservation of mass and momentum [22,23]. The discretization of the Navier-Stokes equations is done on a staggered grid, which means that the pressure is set at the cell centers and the velocity components at the middle of the cell faces between two cells. In the detailed work of Gerrits [25] other aspects of the numerical method applied in this study, are described in detail, such as:

- Discretization of R_C^n
- Discretization near the free-surface
- Inflow and outflow discretization
- Pressure Poisson equation
- Free surface reconstruction and displacement
- Use of the Courant-Friedrichs-Levy (CFL) number
- Calculation of forces and moments.
- Simple algorithm.
- k-ε turbulence model.

2.1. Mesh generation

The first step in grid generating within the finite volume method is to divide the domain into discrete control volumes. A number of nodal points are placed in the space between our geometrical margins. The boundaries (or faces) of control volumes are positioned mid-way between adjacent nodes. Thus, each node is surrounded by a control volume or cell. It is common practice to set up control volumes near the edge of the domain in such a way that the physical boundaries coincide with the control volume boundaries. Besides, the grid should be able to analyze the separations, stagnation point regions and boundary layers. The latter is critical in the present case [26]. Fig. 2 shows a sample of the generated grid around the model of the present paper.

To obtain a more accurate flow simulation, a better grid motion and an appropriate grid around the complex bodies, the area of flow

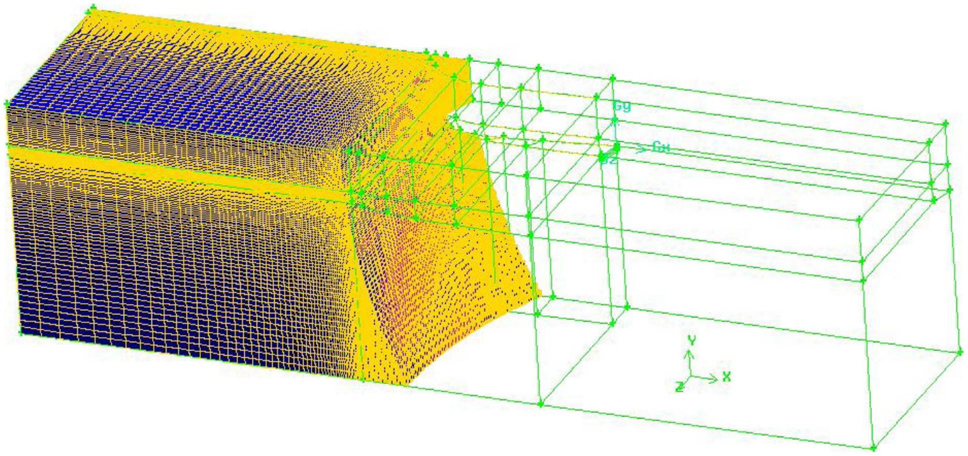

Fig. 2. A sample of the generated grid around the vessel.