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THE NEW STERN DESIGN - A SOLUTION OF DRAG REDUCTION OF SHIPS

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Abstract: *The paper presents an original stern shape design. It leads to a better fluid flow, which reduces the drag. There are presented the direct and reverse problems and the numerical implementation. A current tube is taken into consideration. It contains the propeller, extends towards the prow and includes the entire stern section of a classic hull.*
The dynamics of a propeller depends on environment system. The fluid flow around a propeller working on a ship is different to that one tested in free water or in a cavitation tunnel. The fluid flow near the stern is a key factor for the ship design. The consequence is that a new stern design is a solution of drag reduction of ships.
Key words: *stern shape, propeller, wake, cavitation*

1. INTRODUCTION

The improvement of propulsion performances is an important goal in naval design. A good distribution of the ship wake from upstream plan, parallel to propeller, can lead to better propulsion ability and also to a reduced propeller cavitation (Ghose & Gokarn, 2004). The last mentioned effect has a positive consequence, decreasing vibrations and noise level of the stern.

Obtaining a good distribution of the ship wake is an objective in ship design. Usually a ship model contains the entire hull with smooth 3D surfaces (Tanasescu, 2001).

The global stability of the hull can be improved by using a particular stern architecture, with new fluid guiding surfaces – rib (corrugated) – like shaped.

The present-day tendency in the maritime transportation industry is represented by designing and building of bigger, faster, more energy-efficient and stable ships but simultaneously having stricter noise and vibration levels for stern hull structure. A modern ship hull lines are designed to minimize the forward resistance, to reduce the propeller cavitation, to improve the propulsion performance and to increase the global hydrodynamic stability. Since the apparition of the first ships, the naval architects tried to improve the existing hull forms. As a general recently accepted opinion, the ships of the future will be designed and built only on the basis of some new devised concepts. It is well known that the stern flow problem is very complex. The most recently known industrial achievements focused on flow improvement in the stern region which consists in symmetrically flattening of the stern lateral surfaces towards the central plane (Janson, & Larsson, 1996). This concept has resulted in a huge amount of inconveniences almost in all practical applications to real ships (unsuitable placing of equipments, lack of necessary spaces for inspections, repairs etc.). Always, but especially in the contemporary conditions of modern stern shapes appearance (more and more complex), the improvement of propulsion performances had represented and still represents a particularly important problem for the researchers from the naval hydrodynamics field and not only, mathematical model, uni-dimensional flow tube, which includes the new stern effects on the propeller.

Fig. 1. The new shape stern

Considering the theory of the current tube and the Bernoulli effect, we can appreciate that the 3D spectrum of the flow generated around and in the exterior of a classic hull stern having practiced cross corrugated sections can be substantially improved by architectural optimization in terms of unification (equalization) of the axle velocities in the anterior plan of the closest proximity of the propeller. The number of the corrugated teeth and their heights will be improved by direct numerical experiments. For every section, the size of the pace between teeth (the distance between two consecutive crests) decreases on the perimeter, from the diametric plan toward the borders. The maximum heights (amplitudes) of the corrugated teeth will be reached progressively, respectively longitudinally in front of the propeller and crosswise in the diametric plan. The directions of the longitudinal crests and teeth bases corrugated sections, which start immediately after the cylindrical zone, will be those of the stern natural current lines (which can be established by a flow test) in order to avoid the appearance of whirlpools and for obtaining a minimum resistance to motion.

2. THE MATHEMATICAL MODEL

2.1 Model of the stern shapes using the B-spline method

Usually, in the naval field, there are two methods used for defining 3D surfaces: Bezier method and B - spline method. The B-spline curves represent a generalization of the Bezier curves. The main difficulties of the Bezier method are:

- the numerical instability for a higher number of control points;
- the global change of the curve shape by the movement (moving) of a single control point.

For these reasons, in the present paper, as method for the numerical defining and manipulation of stern surfaces the B-spline technique will be used.

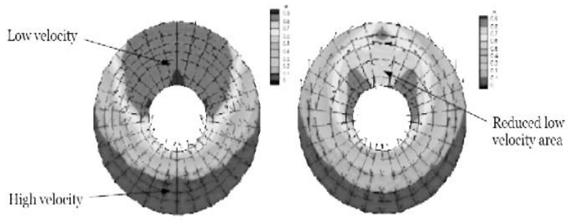

Fig. 2. Wake for initial stern and modified one

Fig. 3. Simulated nominal wake in the cavitation tunnel

The surface is generated by a grid of parametric curves. The method will be implemented on a computer with interactive graphic facilities for designing and smoothing (fairing) of the surface. Using a smaller number of fixed control points, the defining will be realized using the computer's screen interactively. An exact link between these fixed points (of control) and the surface defining is established by narrowing the longitudinal parametrical curves at water lines, thus making possible the manipulation of the surface in smooth projections on the screen. The surface defining by the B-spline method does not require any kind of specific geometric restrictions, the joint lines, the stern mirrors, discontinuities or propellers' hubs being modeling elements.

2.2 Reverse problem

In the reverse problem, the stern geometry is regarded as unknown and dominated by a number (by a set) of control points. The dimensionless axial component of velocity, U_{xi} on the propeller disk plan is calculated by interpolation of the RANS results (direct problem) in the circumferential directions (θ) and radial (r) so that it can be expressed as $U_x(r_i, \theta_i)$. If n represents the number of sample points from the propeller disk plan, we can make the notation: $U_x(r_i, \theta_i) = U_{xi}$, $i = 1, ..., n$.

The reverse problem of redesigning the geometry of stern shape can be formulated as follows: using the mentioned wanted axial ship wake coefficients, U_{xi} you redesign the new geometry of the stern.

2.3 Numerical method

Being given an initial arbitrary solution (pre-estimated) for the researched set of parameters – control points B (obtained by using the geometry of the stern shape and the approximation of the B-spline surface), the Marquardt numerical method (algorithm) consists in solving the direct problem in order to obtain the axial ship wake U_x (Marquardt, 1963).

3. NUMERICAL ANALYSIS

We have proposed, a new stern hydrodynamic concept of streamline tube type, (having quasi-cylindrical increasing sections), which starts from front propeller disk and stretches until hull cylindrical region – figure 1. In devising of this new design concept, the authors referred to two well known theories:

- the streamline tube theory (the water particles axial velocities distribution at entrance in the propeller disk can be configured favorably - homogenized-by comprising the radial corrugated stern sections in a stream tube that also comprises the propeller disk);

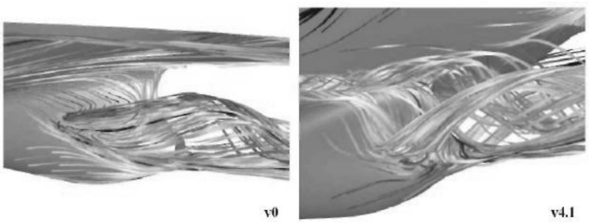

Fig. 4.Vortex initiation and separation

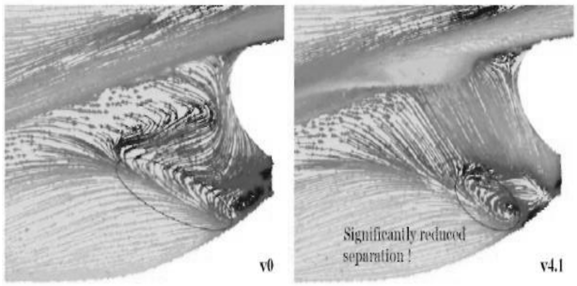

Fig. 5. Limit streamlines on stern surface

- the Bernoulli effect (increasing of water particles axial velocities in the regions within which the water pressure is decreased) (Batchelor, 1991).

Considering the streamline tube theory and the Bernoulli effect, we can estimate that the 3D spectrum of flow generated around and outside of a classical stern hull having practiced transversal corrugated stern sections can be substantially improved by an architectural optimization in the sense of axial velocities from a propulsion propeller immediate front plane uniformization – figure 2. In this figure observed comparison between experimental wakes obtained for the model with initial stern shape design (left) and for the model with modified stern shape in conformity with the new concept design (right).

The directions of the crenellated-corrugated sections teeth crests and troughs longitudinal curved lines will be those of the stern natural streamlines (which can be established experimentally in a flow visualization test) for vortices turning up avoiding and for a minimum forward resistance obtaining.

Finally, the most important, until now, proved result, is the reducing of propeller cavitation (working in the simulated nominal wake of the hull using the new stern hydrodynamic concept- it can be remarked lack of cavitation – figure 3).

Unfortunately, this cavitation decreasing (lack of cavitation) is associated with initiation and movement of some multiple increased vortices as seen in Figure 4 (left - the model with initial stern shape design, simple vortex; right- the model with modified stern shape in conformity with the new concept design, multiple vortices). Thus resulting the separation (although a low one) of the boundary layer as seen in figure 5 (left – the model with initial stern shape design; right – the model with modified stern shape inconformity with the new concept design).

4. CONCLUSIONS

The new concept of stern shape proposed as well as the reverse mathematical problem presented above for its optimization, based on the Levenberg – Marquardt algorithm reduce the drag of the ships.

The most important result is the reduction of propeller cavitation (working in the simulated nominal wake of the hull using the new shape stern).

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