Refinement strategies for ship wave-resistance estimations using IGABEM solvers

Konstatinos V. Kostas*, **Panagiotis D. Kaklis**† **and Constantinos G. Politis**‡

* Mechanical & Aerospace Engineering, Nazarbayev University, Kazakhstan
email: konstantinos.kostas@nu.edu.kz, web page: https://seng.nu.edu.kz/

† Naval Architecture, Ocean and Marine Engineering, University of Strathclyde, UK email:
panagiotis.kaklis@strath.ac.uk, web page: https://www.strath.ac.uk/

‡ Naval Architecture, University of West Attica, Greece
email: cpolitis@uniwa.gr, web page: http://www.na.uniwa.gr/en/

ABSTRACT

The assessment of ship hull forms with respect to their hydrodynamic performance is a key aspect in hull-shape optimization and a prerequisite for "green" shipbuilding. Isogeometric analysis (IGA) has been successfully applied to the solution of the boundary integral equation associated with the Neumann–Kelvin problem and the calculation of the wave resistance of ships using both NURBS and T-splines ship-hull representations and a corresponding in-house developed isogeometric boundary element method (IGABEM) solvers; see [1] and [2]. Furthermore, we have also demonstrated the application of this approach in ship-hull shape optimization, exploiting appropriate ship-hull parametric models (in the context of NURBS or T-splines) and the corresponding IGABEM solver; see [3] and [4]. Specifically, following the isogeometric analysis approach, we approximate the field quantities (dependent variables) of the boundary-value problem in question using the very same basis that has been used for representing the geometry of the body, i.e., NURBS or T-splines, respectively. The unknown field quantities are then calculated by solving the linear system obtained by appropriately collocating the resulting boundary integral equations. The number of collocation points in this approach is directly linked to the number of coefficients used in body-surface representations, which can give rise to the following issues: a) body-surface representations with a low number of control points that require refinement to achieve a satisfactory accuracy in the approximation of the unknown field quantities and b) body-surface representations with a large number of control points, many of which can be superfluous and/or inappropriately distributed.

In this work, we are focusing on tackling the two issues mentioned above, by investigating and proposing adaptive refinement strategies which will enable a cost-efficient achievement of required accuracy in field quantities and the subsequent calculation of ship wave resistance. Specifically, for the case of surface representations with few control points (and consequently collocation points) an adaptive refinement approach based on the acquired field quantity estimates and local shape characteristics is examined and demonstrated for both simple body-shapes, with available analytical solutions, and standard ship hull forms. For the second case, i.e., surface representations with a large number of control points, we focus on common ship-hull surface representations, used in shipbuilding industry, that are not "analysis suitable". These geometries commonly employ unnecessary large numbers of control points, they have many and unevenly sized surface patches, and they can even exhibit discontinuities, e.g. multi-patch NURBS representations with gaps between surface-patch edges. For this case, we reconstruct the input hull geometry by employing the NURBS- or T-splines-based ship-hull parametric models, developed in our previous works, which guarantee analysis-suitable representations with low numbers of control points, and apply the same refinement strategies mentioned above.

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