Improved hull design with potential-flow-based parametric computer experiments

Oscar F.A. van Straten*†, Egemen Celik†, Jouke H.S. de Baar*‡, Blanka Ascic‡ and Jochem S. de Jong‡

†Damen Schelde Naval Shipbuilding
De Willem Ruysstraat 99, Vlissingen, The Netherlands
e-mail: o.van.straten@damennaval.com, web page:
https://www.damen.com/companies/damen-schelde-naval-shipbuilding

‡Damen Shipyards Gorinchem
Avelingen West 20, Gorinchem, The Netherlands
e-mail: jouke.de.baar@damen.com, web page: https://www.damen.com/

ABSTRACT

There is a significant market pull and technology push to incorporate computational fluid dynamics (CFD) in the early vessel design phase. In this phase, one allows for large-impact changes in the hull geometry. The computational cost of CFD deployment in this early phase has two important drivers. Firstly, for an individual CFD simulation, accuracy is correlated with cost—both in man and CPU hours. Secondly, when we increase the number of shape parameters, we face the 'curse of dimensionality', an exponential increase of the number of individual simulations that are required to obtain a target accuracy [1]. We address these issues by using automated low-fidelity CFD and efficient sampling plans.

The general approach of the design and analysis of computer experiments (DACE) has been introduced by Sacks *et al* [2]. In the present case, it consists of the following steps: (1) parametrising the hull, by defining a baseline design and shape variations; (2) creating a design-of-experiments (DoE), with each experiment representing a hull variation; (3) running the potential flow solver, for different ship speeds, for each hull variation, to compute the performance; (4) creating a meta-model, which is a regression that maps the design parameters to the ship performance; and (5) exploiting the meta-model by means of the required analysis.

In this paper we present two applications. In the first application, we consider the hull lines optimisation of a naval supply vessel. We start by defining a parametric framework of the hull form generation, based on major design drivers. We then use a Latin hypercube sampling DoE, and run the performance prediction simulations in RAPID [3]. After that we create a meta-model, and use the results to plot a Pareto front, which allows the user to make an informed trade-off of the optimal design. In the second application, we consider the parametric analysis of an offshore patrol vessel (OPV). We use a space-filling DoE, and run the performance prediction simulations in ν-SHALLO [4]. We use kriging regression to create a meta-model, for further parametric analysis by the designer, allowing for optimisation and inverse design.

REFERENCES

[1] Bellman, R.E., *Dynamic programming*. Princeton University Press, (1957).

[2] Sacks, J., Welch, W.J., Mitchell, T.J. and Wynn, H.P., Design and analysis of computer experiments. *Statistical Science*, Vol. **4**, No. 4, pp. 409–423, (1998).

[3] Raven, H.C., *A solution method for the nonlinear ship wave resistance problem*. PhD Thesis, Delft University of Technology, (1996).

[4] Marzi, J. and Hafermann, D., *The ν-shallo user guide—release 1.8.6*. HSVA Report 1646/4.