# Coupling an inviscid IGA–BEM solver with X-Foil's boundary layer model for 2D flows

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## ABSTRACT

In this work we couple an IGA-BEM[1] solver for 2D lifting flows with the viscous model in X-Foil [1], a vintage but still widely used software tool for the design and analysis of subsonic airfoils, towards deeper integration of the isogeometric concept in 2D flow models that incorporate boundary-layer corrections.

The formulation of the exterior potential-flow problem reduces to a Boundary Integral Equation (BIE) for the associated velocity potential. Adopting the approach presented in [3], the resulting BIE is handled by an IGA-BEM method, combining:

(i) A generic B-splines parametric modeler for generating hydrofoil shapes, using a set of 8 design-oriented parameters;
(ii) The very same basis of the geometric representation for representing the velocity potential, and
(iii) Collocation at the Greville abscissas of the knot vector of the hydrofoil's B-splines representation, appropriately enhanced to accommodate the null-pressure jump Kutta condition at the trailing edge.

For the viscous part of the solution, the two-equation model of X-Foil [2] is employed. X-Foil's inviscid solver is "circumvented" and inviscid isogeometric parameters are sent to its viscous component, namely the integral momentum and kinetic energy shape parameter equations presented in [2]. The derived coupled system is tested for NACA4412 and NACA0012 airfoils and the output lift and drag coefficients for different angle of attacks are compared to experimental data, uncoupled X-Foil results and one-way coupling results obtained [4] via the software tool PABLO [5].

The so-resulting coupled system can be used in airfoil/hydrofoil shape optimisation algorithms with a variety of optimisation criteria such as maximum lift coefficient, maximum lift-over-drag-ratio, minimum deviation of the airfoil/hydrofoil area from a reference area, etc.

## REFERENCES

[1] Drela, M. (1989) "XFOIL: An analysis and design system for low Reynolds number airfoils", MIT, Massachusetts, USA.

[2] Drela, M., Giles, M. (1987) "Viscous – inviscid analysis of transonic and low Reynolds number airfoils", *AIAA Journal*, vol. 25(10), pp. 1347 – 1355.

[3] Kostas, K.V., Ginnis, A.I., Politis, C.G., Kaklis, P.D. (2017) "Shape-optimization of 2D hydrofoils using an Isogeometric BEM solver", *Computer Aided Design*, vol. 82, pp. 79-87.

[4] Kostas, K.V., Ginnis, A.-A.I, Politis, C.G., Kaklis P.D. (2017) "Shape-optimization of 2D hydrofoils using one-way coupling of an IGA-BEM solver with a boundary-layer model", Coupled Problems 2017, VII International Conference on Coupled Problems in Science and Engineering, June 12-14, 2017, Rhodes (GR).

[1] BEM: Boundary Element Methods

[5] Wauquiez, C. (2000) "Shape Optimization of Low Speed Airfoils using MATLAB and Automatic Differentiation" Stockholm: Licentiate's Thesis - Royal Institute of Technology - Department of Numerical Analysis and Computing Science.

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