PROPAN
- Propeller Panel Code -

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PROPAN

Outline

- Theoretical Formulation
- Current Features
- IT Aspects
- Pre/Post-Processing
- Verification Studies
- Applications
- Main Publications

PROPAN

Introduction:

- PROPAN: Propeller Panel Code
- Started to be developed at IST in 1996
- Originally for potential flow calculations on marine propellers
- `www.researchgate.net/project/PROPAN-potential-flow-code-for-foils-and-rotors`

Theoretical Formulation:

- Assume incompressible, ideal (inviscid) fluid and irrotational flow
- Fredholm integral equation for Morino formulation:

$$2\pi\phi(p,t) = \iint_{S_B} \left[G(p,q) \frac{\partial \phi}{\partial n_q} - \phi(q,t) \frac{\partial G}{\partial n_q} \right] dS - \iint_{S_W} \Delta\phi(q,t) \frac{\partial G}{\partial n_q} dS$$

  where $G(p,q) = -1/R(p,q)$

- Surface discretisation: structured grid with quadrilateral panels
- Integral equation solved by collocation method
- Constant source and dipole distributions
- Iterative pressure Kutta condition

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Current Features:

- wings and rotors (open or inside a shroud)
- conventional and quasi-orthogonal grids
- steady and unsteady flows
- empirical rigid wake model and wake alignment model
- wetted flow, sheet partial (both face and back sides) and super-cavitation (one side only) on the blades
- leading-edge flow separation
- post-processing 2d viscous corrections

PROPAN

IT Aspects:

- input/output in ASCII format
- no GUI
- visualisation with Tecplot
- not parallelised
- routines in Fortran90
- Windows/Linux
- no code version (svn/git)
- no website, bug tracking system, forum, etc.

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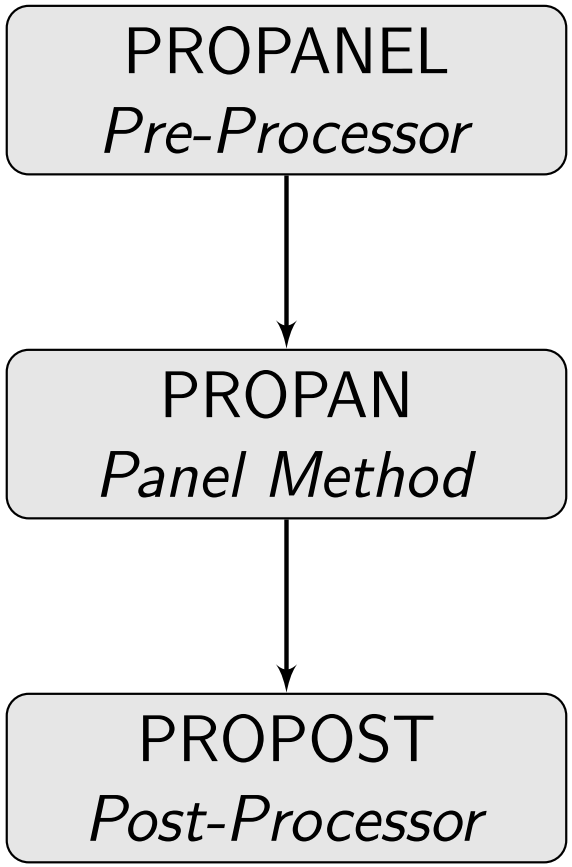
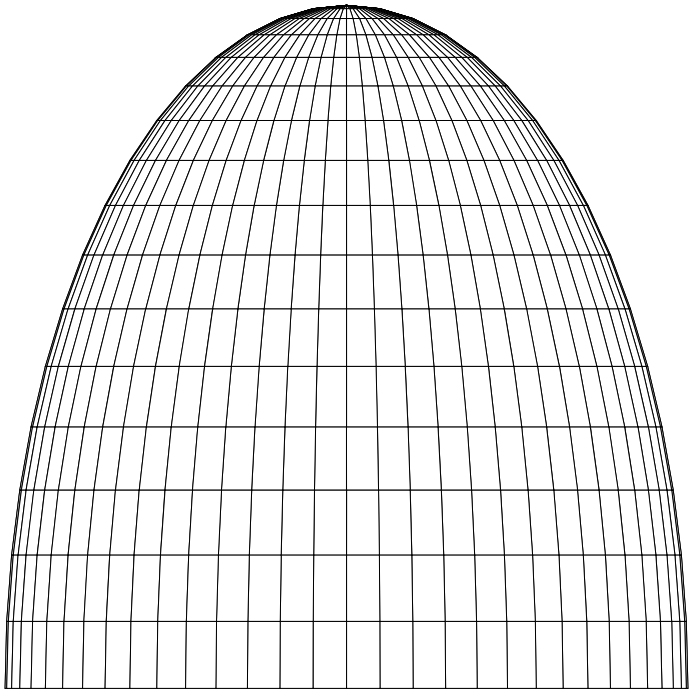
Pre/Post-Processing:

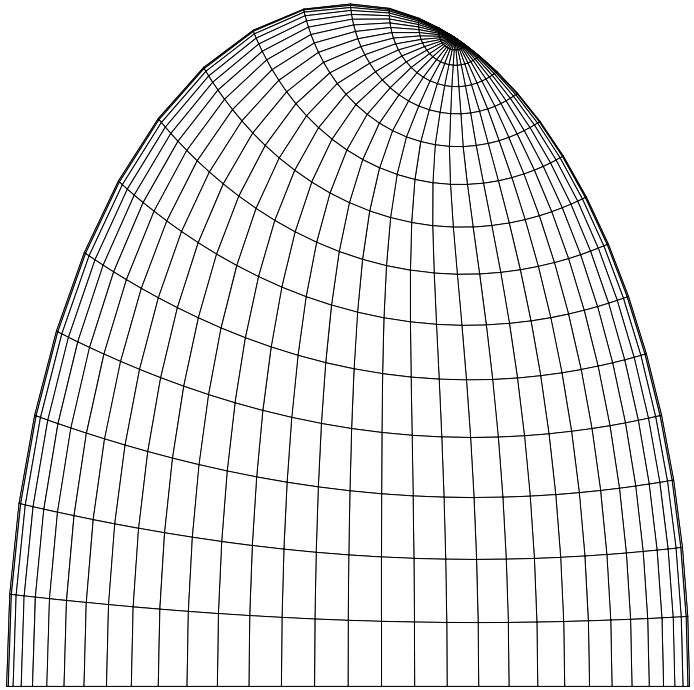
Codes written in Fortran90



Pre-Processing: PROPANEL

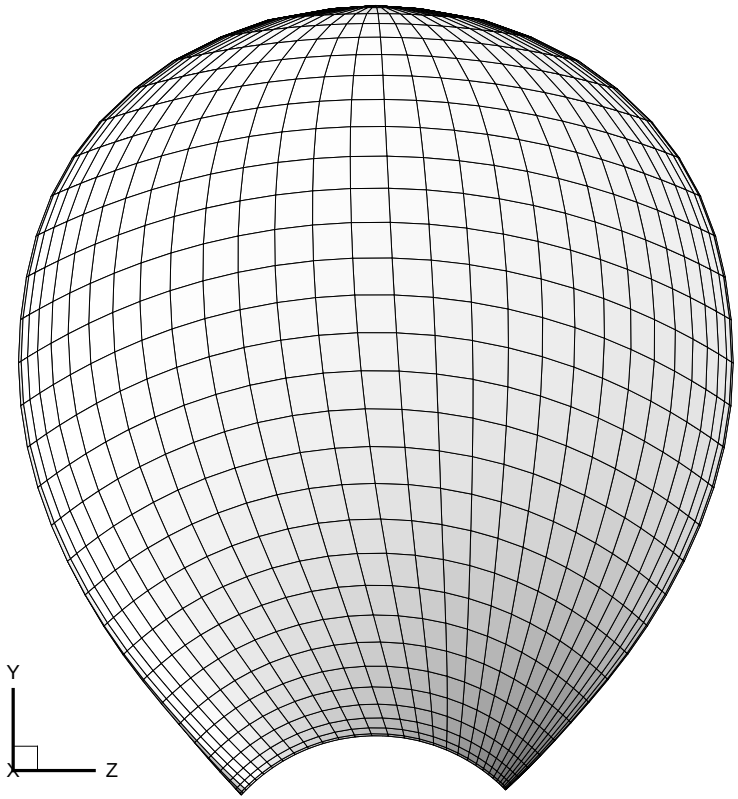
conventional and quasi-orthogonal grids: wings

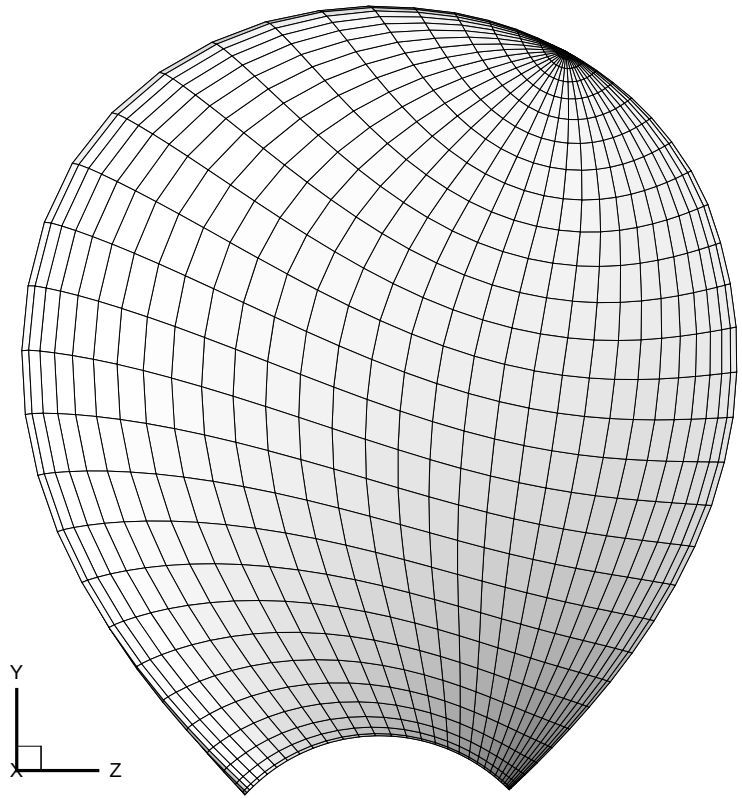




Pre-Processing: PROPANEL

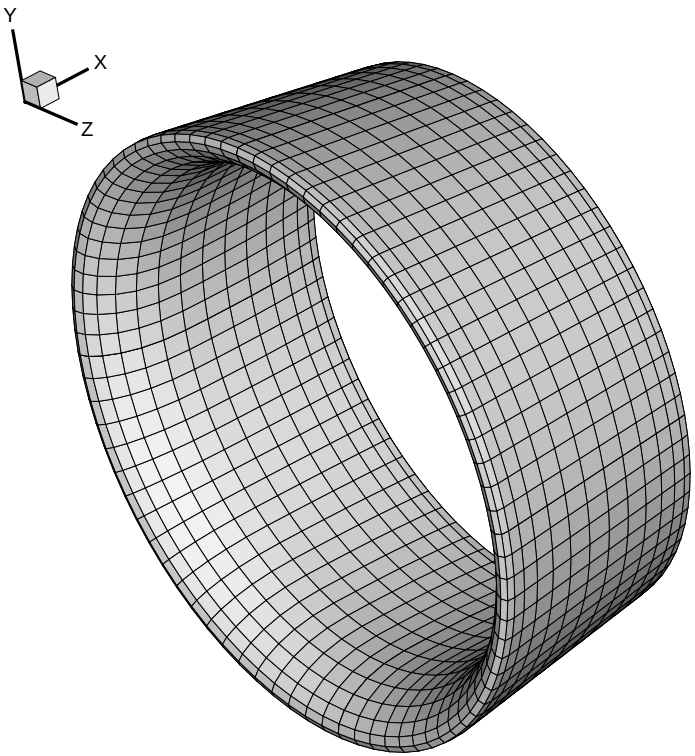
conventional and quasi-orthogonal grids: propeller blades

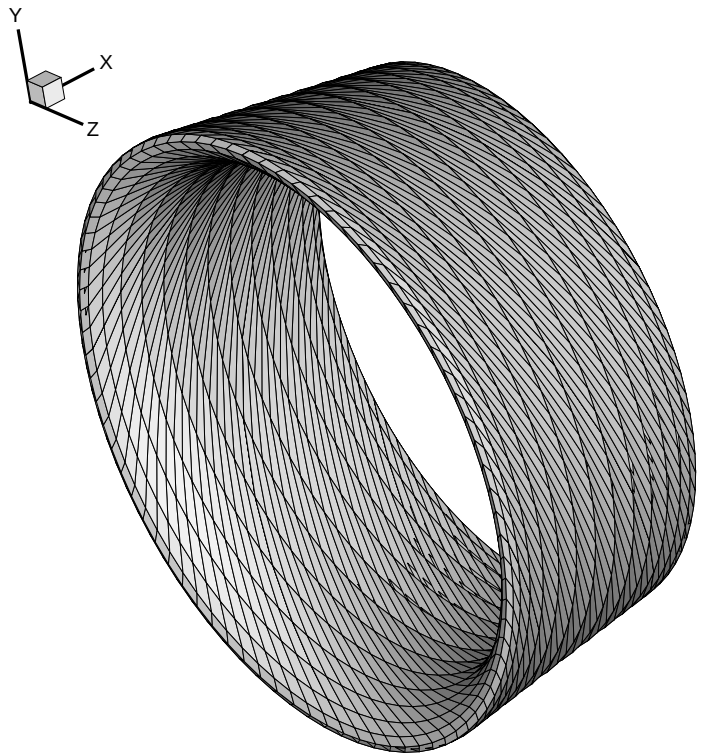




Pre-Processing: PROPANEL

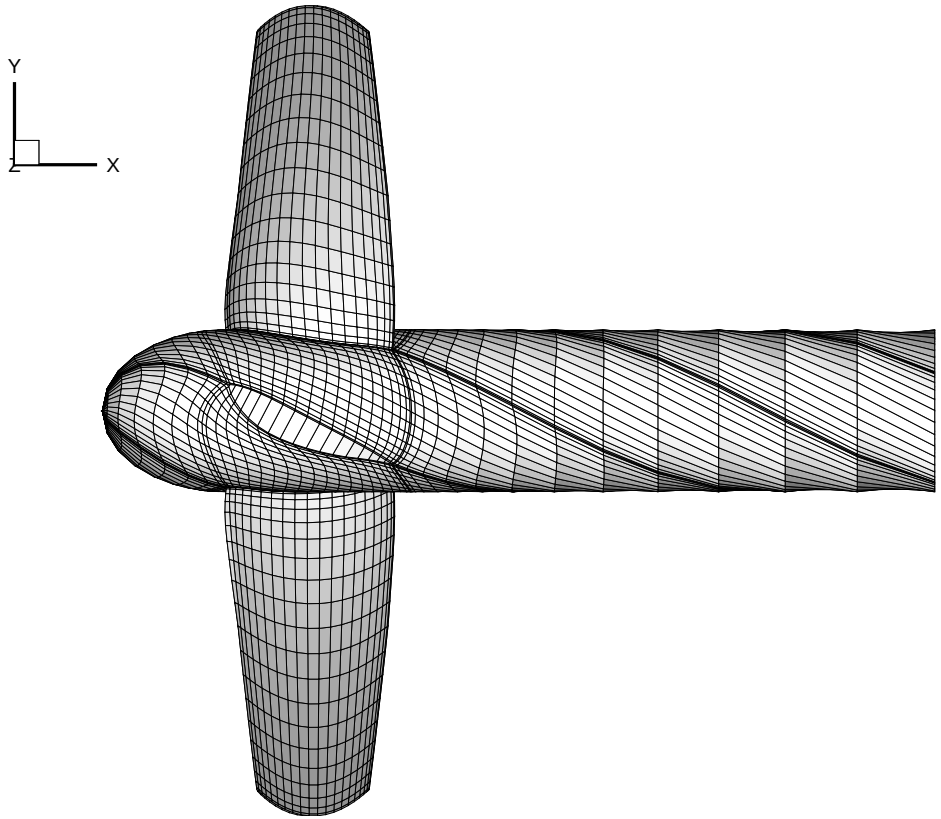
cylindrical and helical grids: ducts





Pre-Processing: PROPANEL

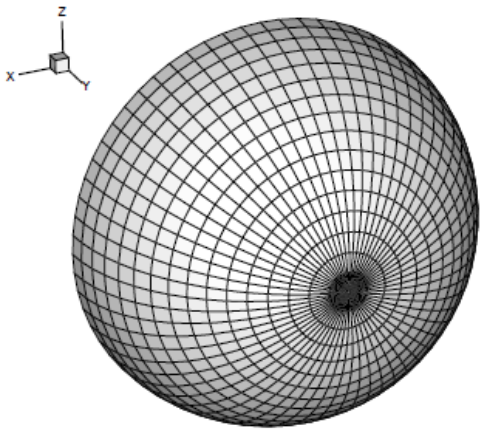
hub grids



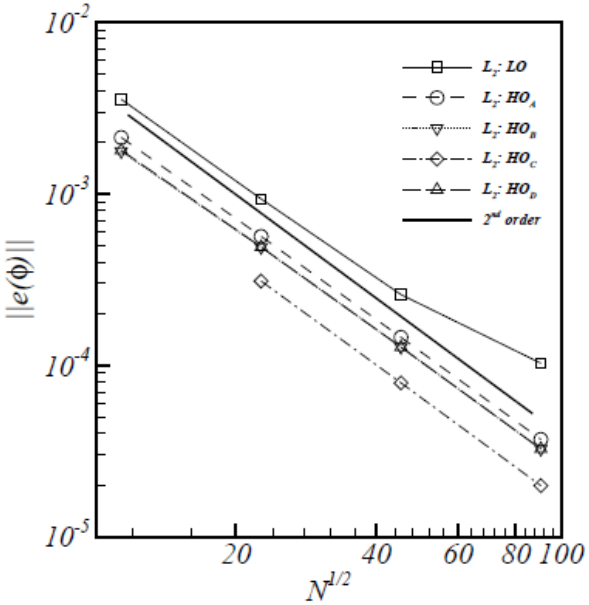
Verification Studies: sphere

grid convergence of velocity potential (Baltazar, 2005)

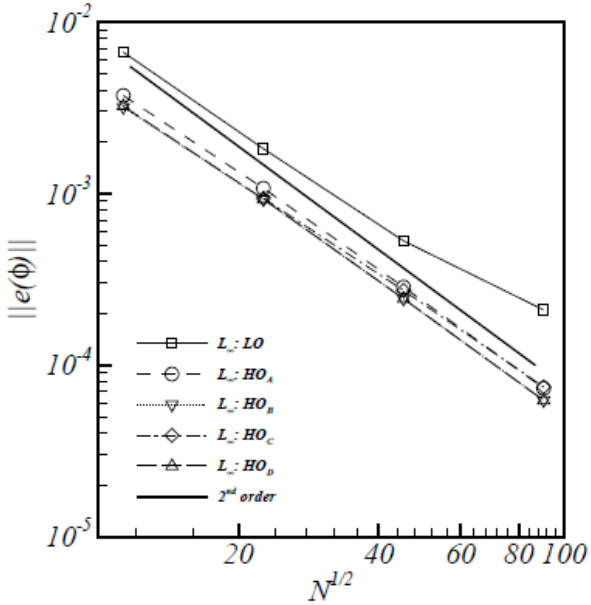
Sphere Grid



L_2 Error Norm



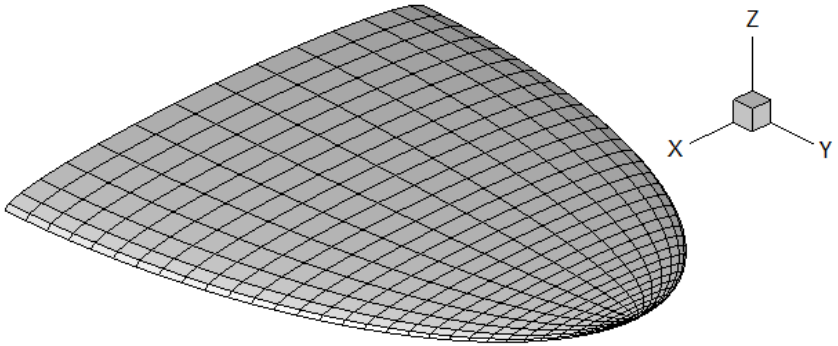
L_∞ Error Norm



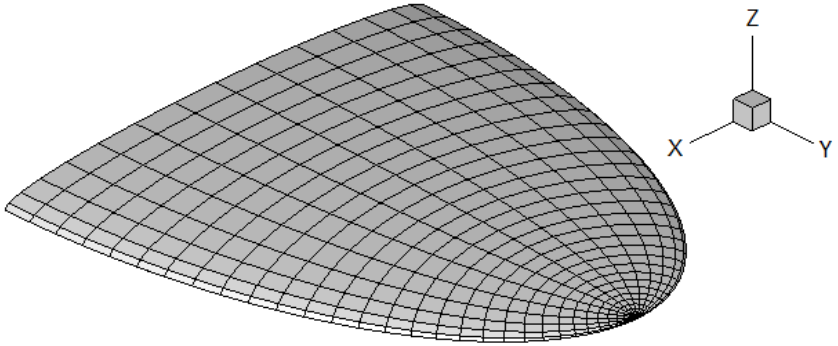
Verification Studies: ellipsoids

Computers & Fluids, 35 (2006)

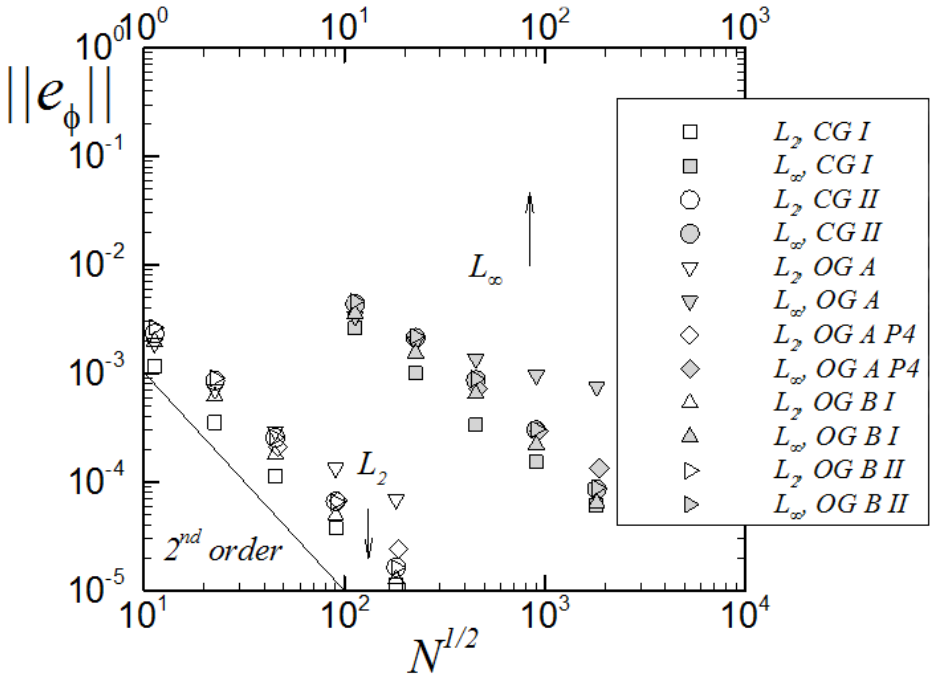
Conventional Grid (CG)



Orthogonal Grid (OG)



Grid Convergence of Velocity Potential

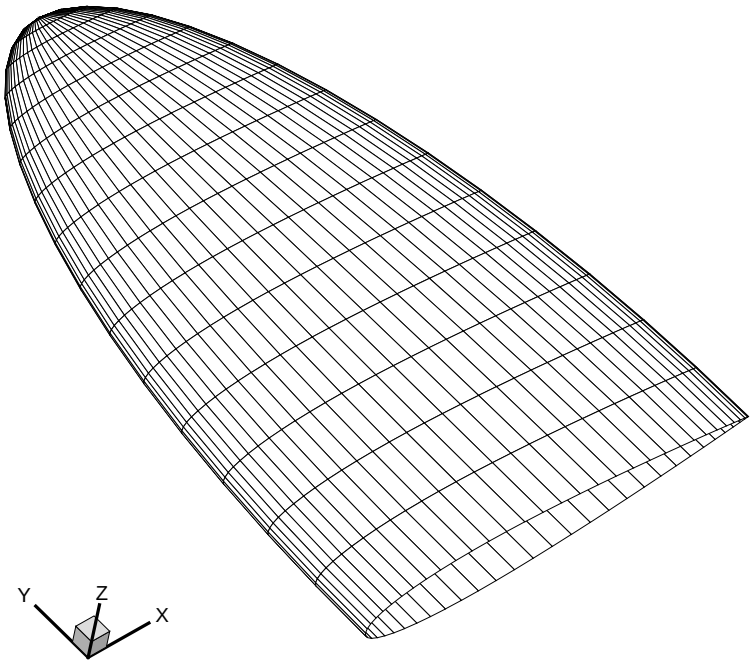


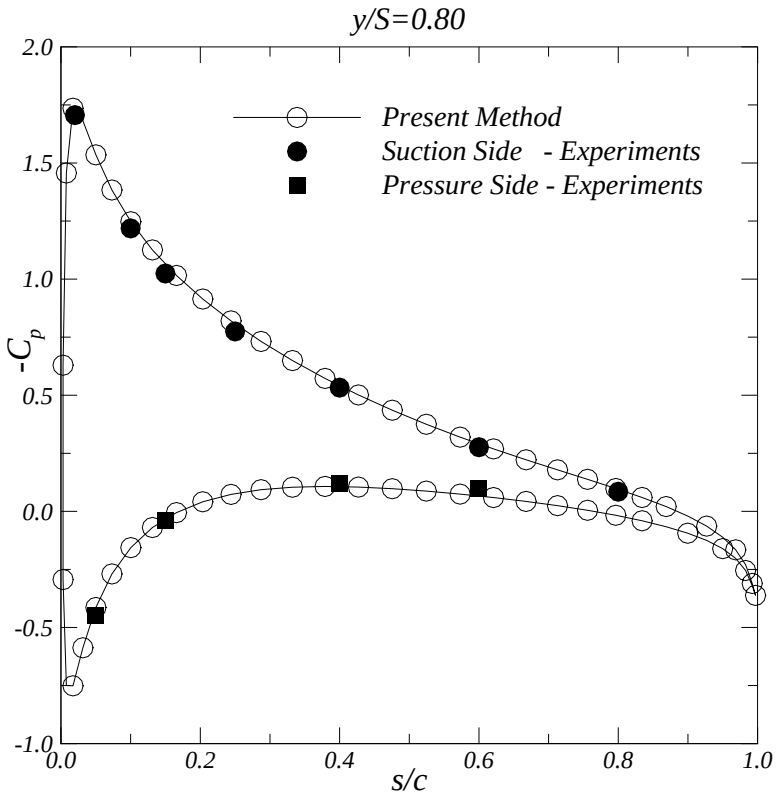
Applications:

- wings
- marine propellers
- marine current turbines
- wind turbines

Applications: wings

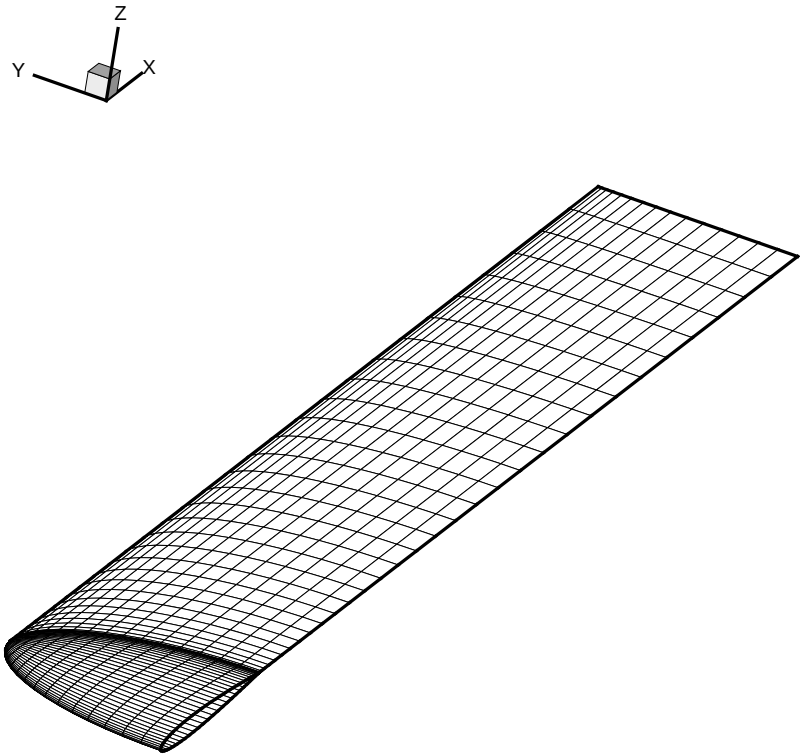
elliptical wing, NACA0015, $\alpha = 8°$

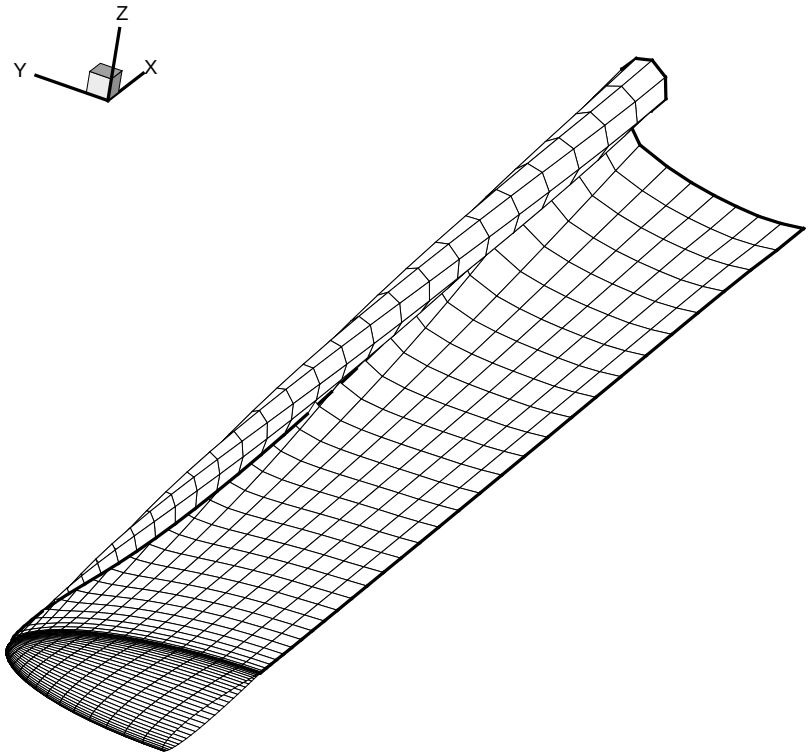




Applications: wings

rigid and aligned wakes





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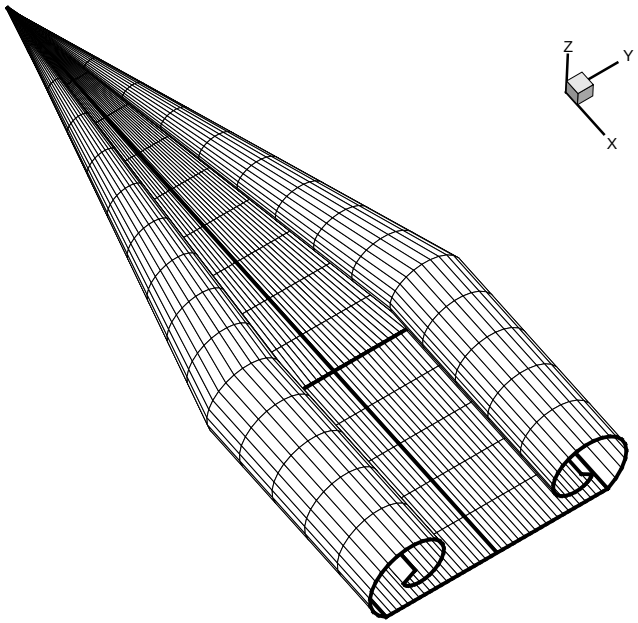
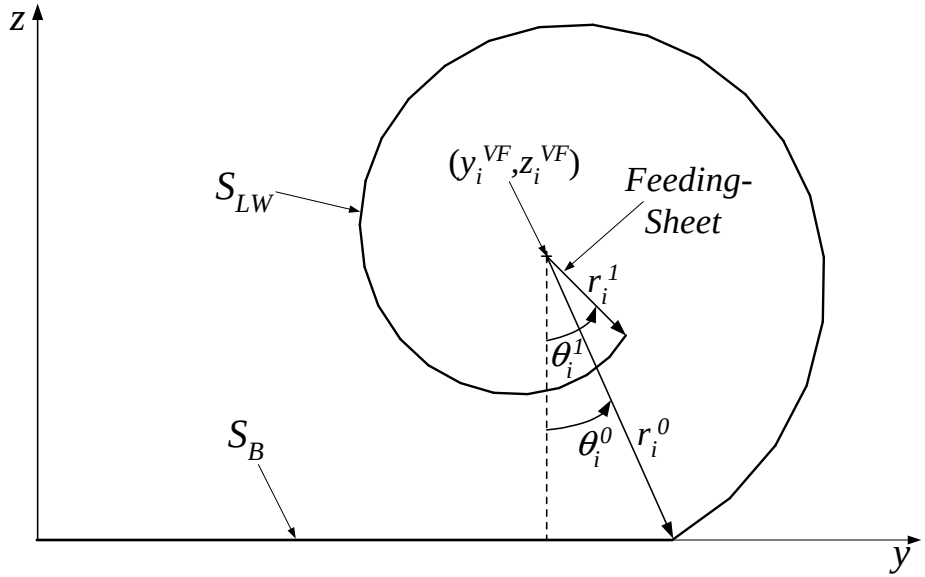
Applications: wings

delta wing

76 deg. Delta Wing

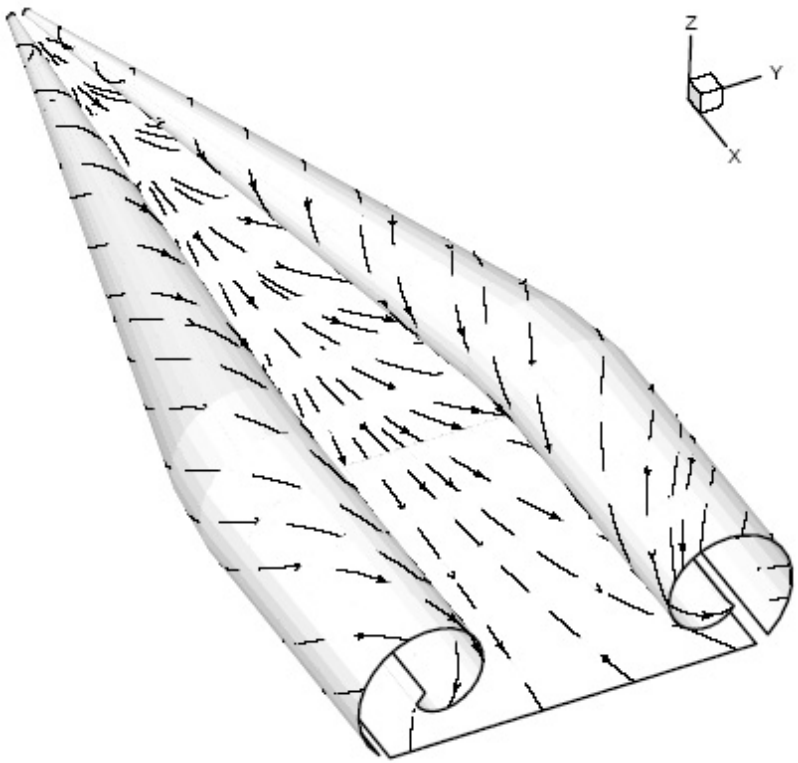


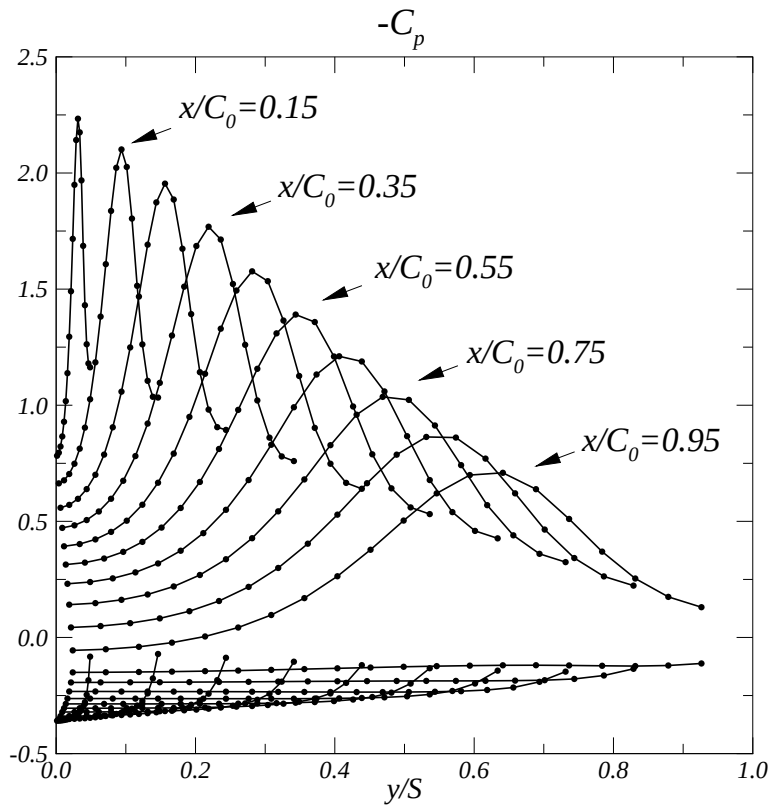
Empirical Wake Geometry



Applications: wings

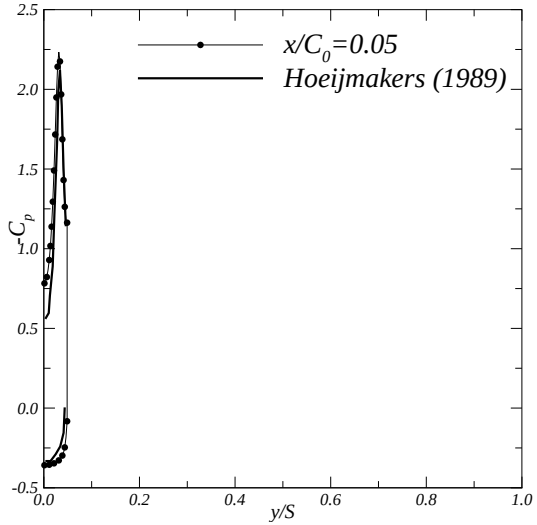
76 deg. delta wing at 20 deg. incidence

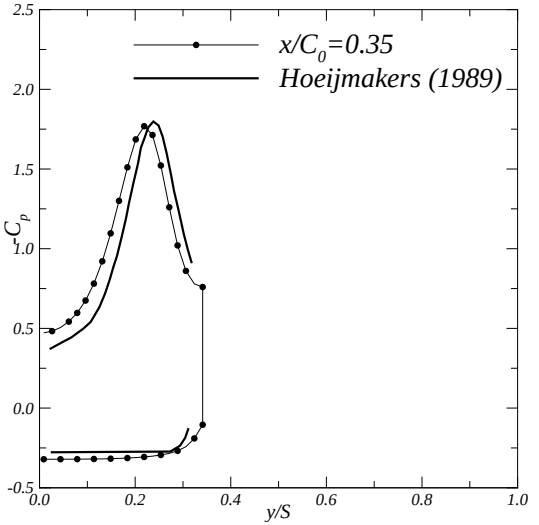


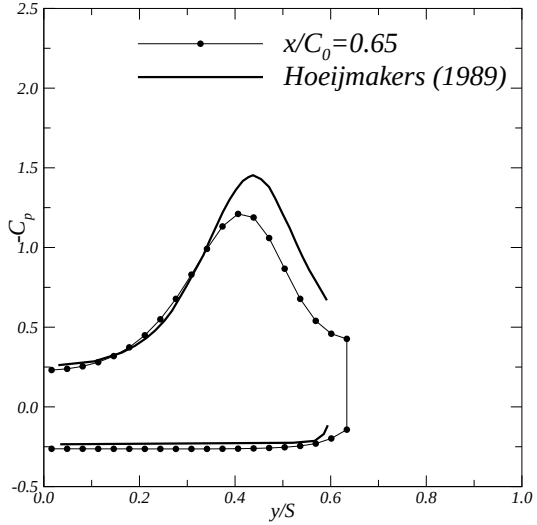


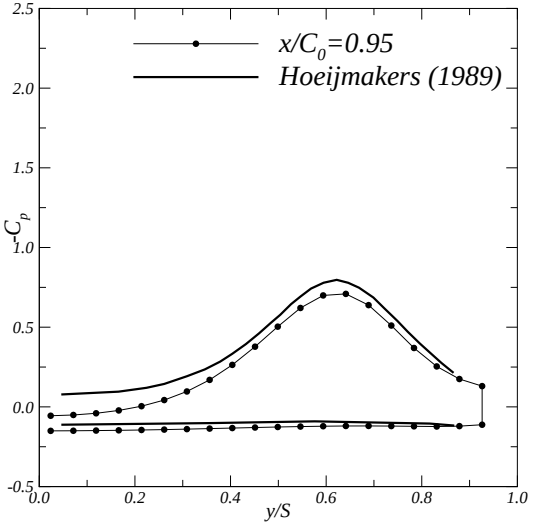
Applications: wings

76 deg. delta wing at 20 deg. incidence - pressure distribution



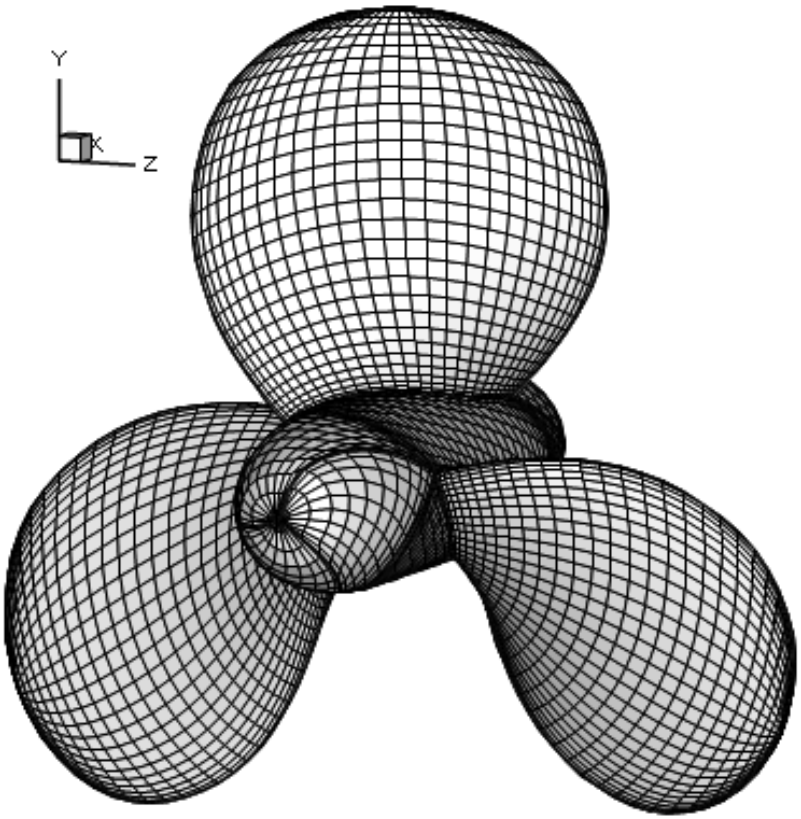


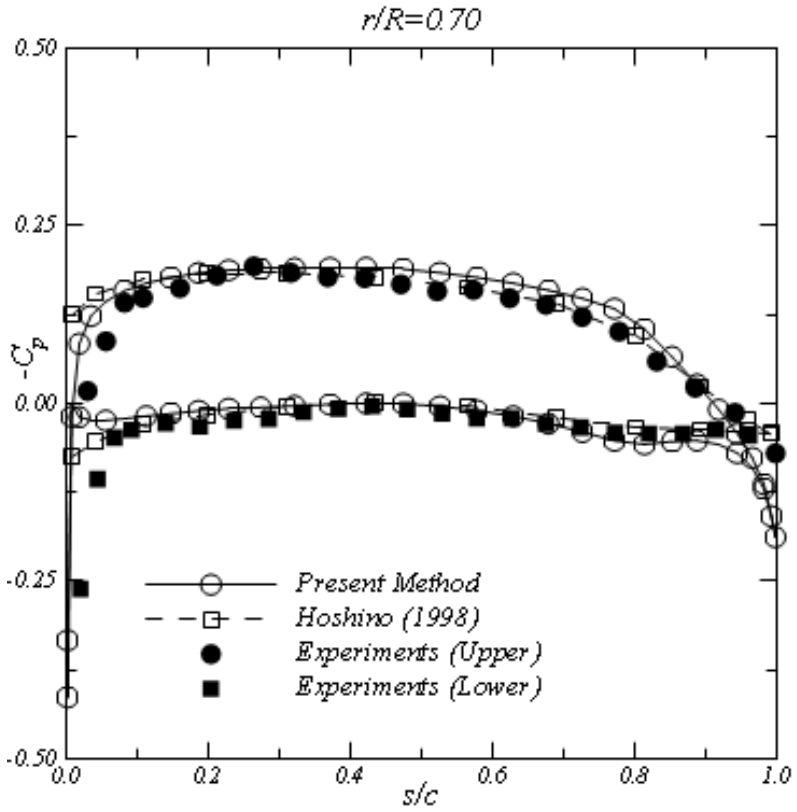




Applications: marine propellers

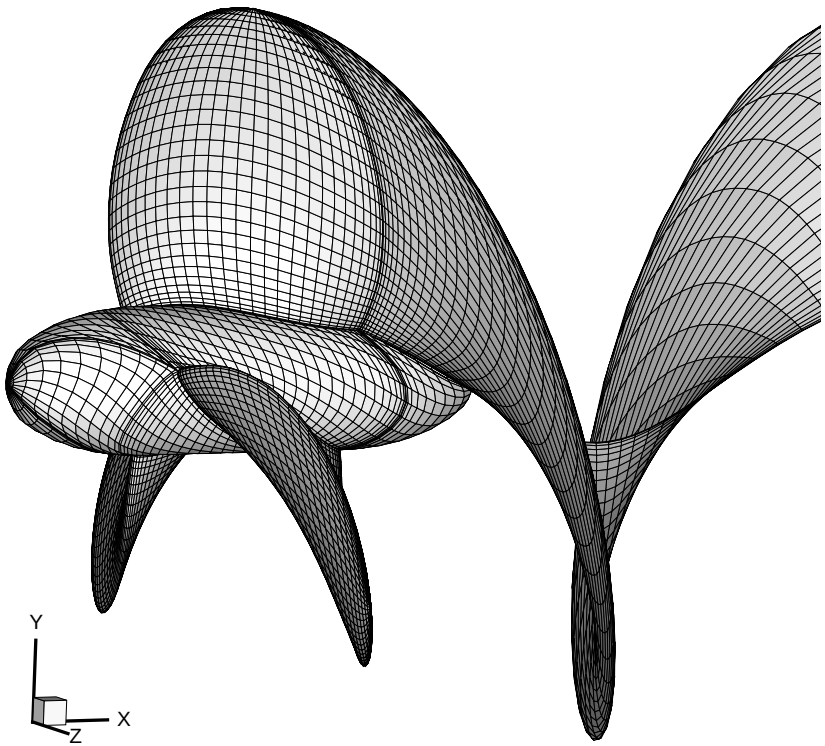
open propellers

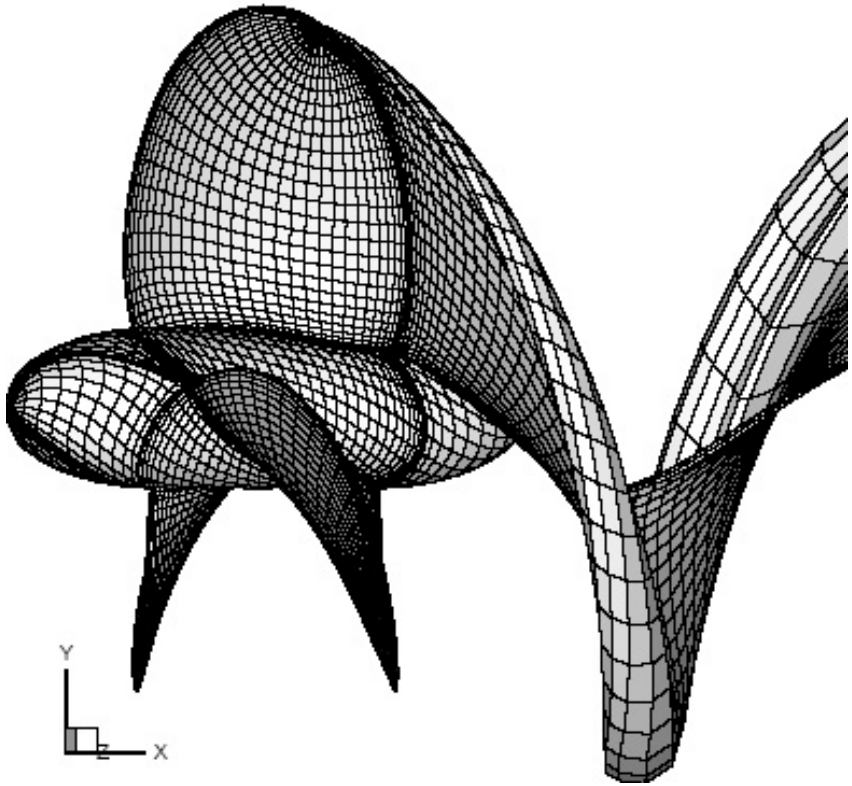




Applications: marine propellers

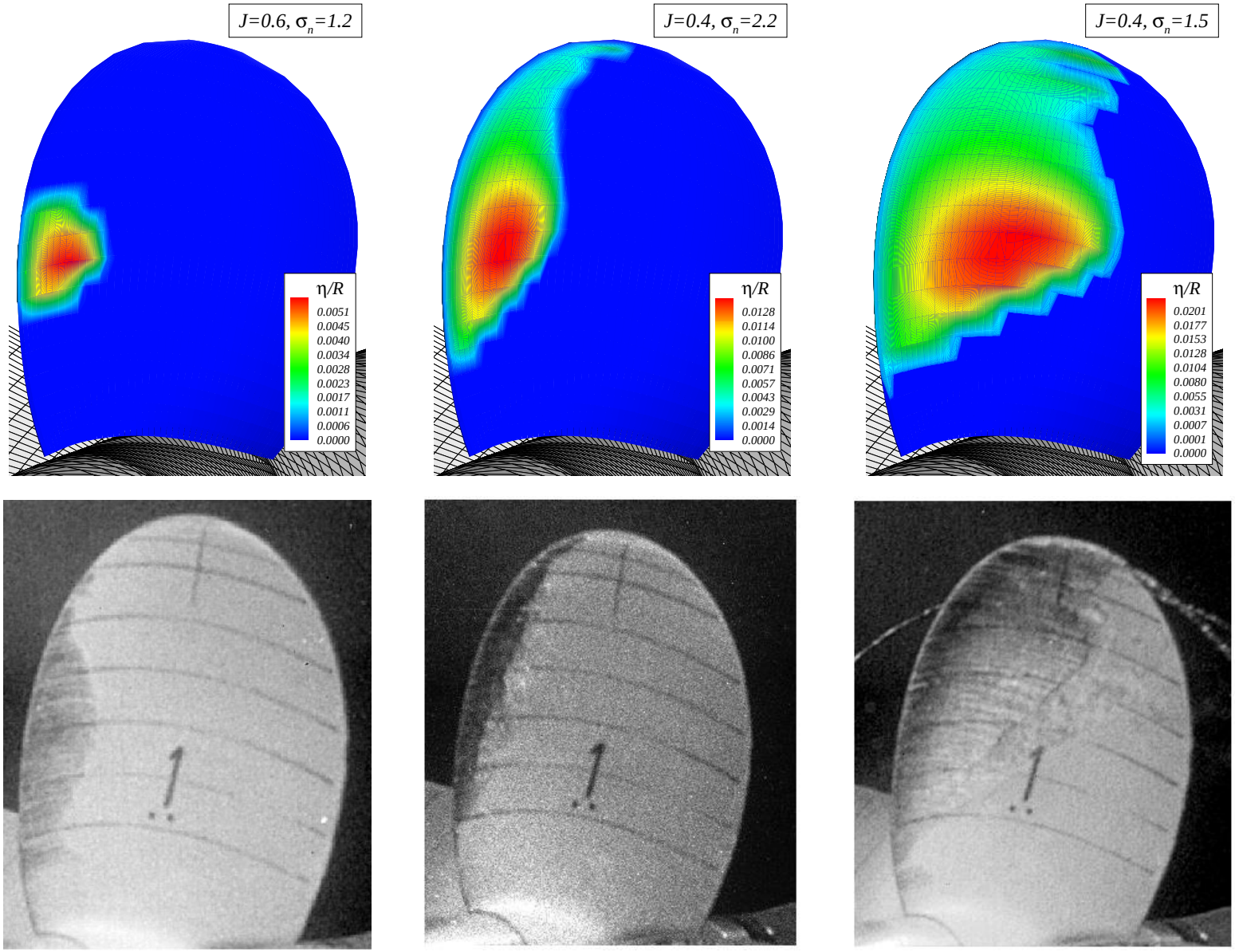
rigid and aligned wakes





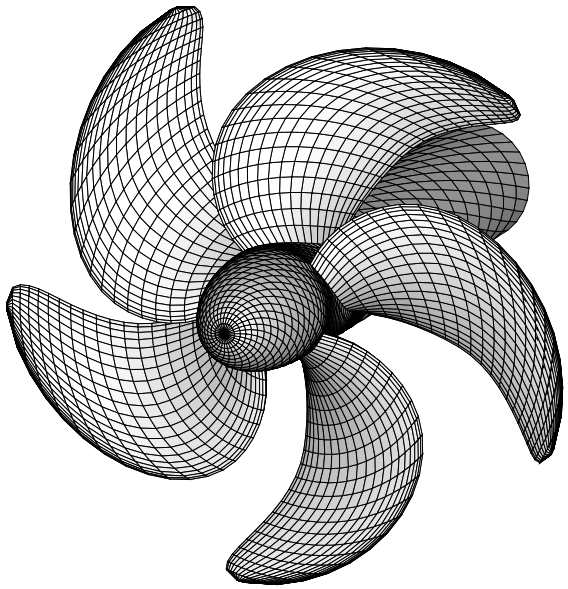
Applications: marine propellers

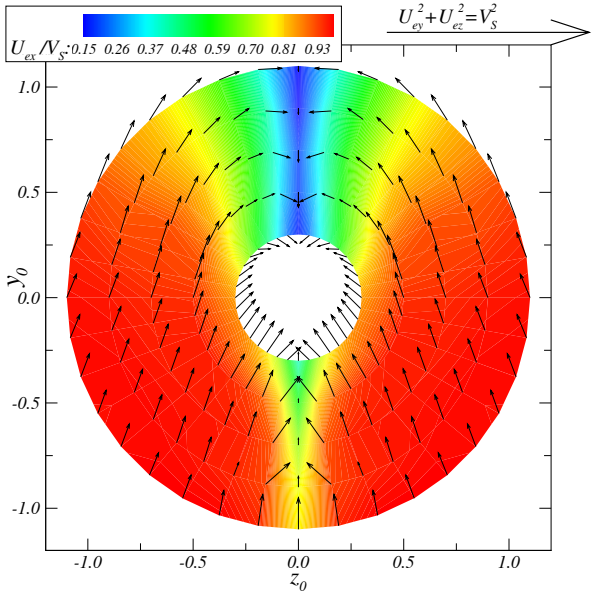
cavitation analysis

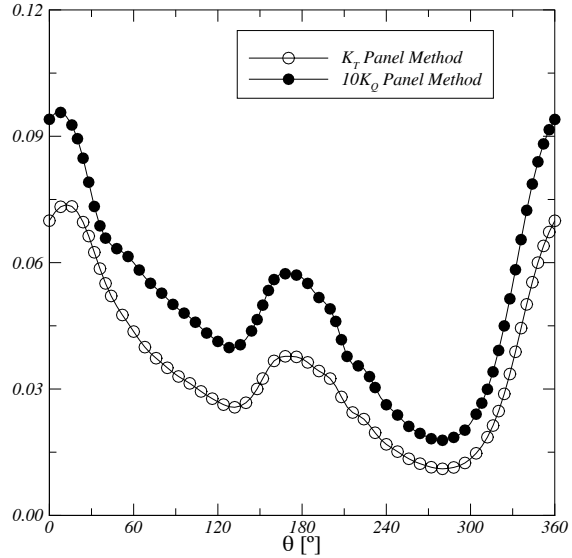


Applications: marine propellers

performance behind wake field

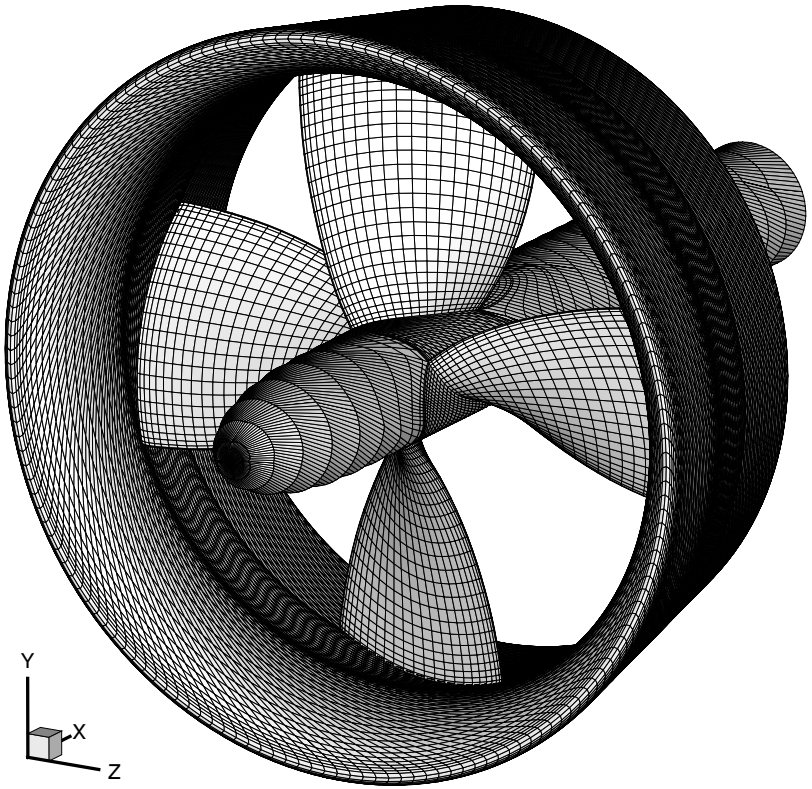


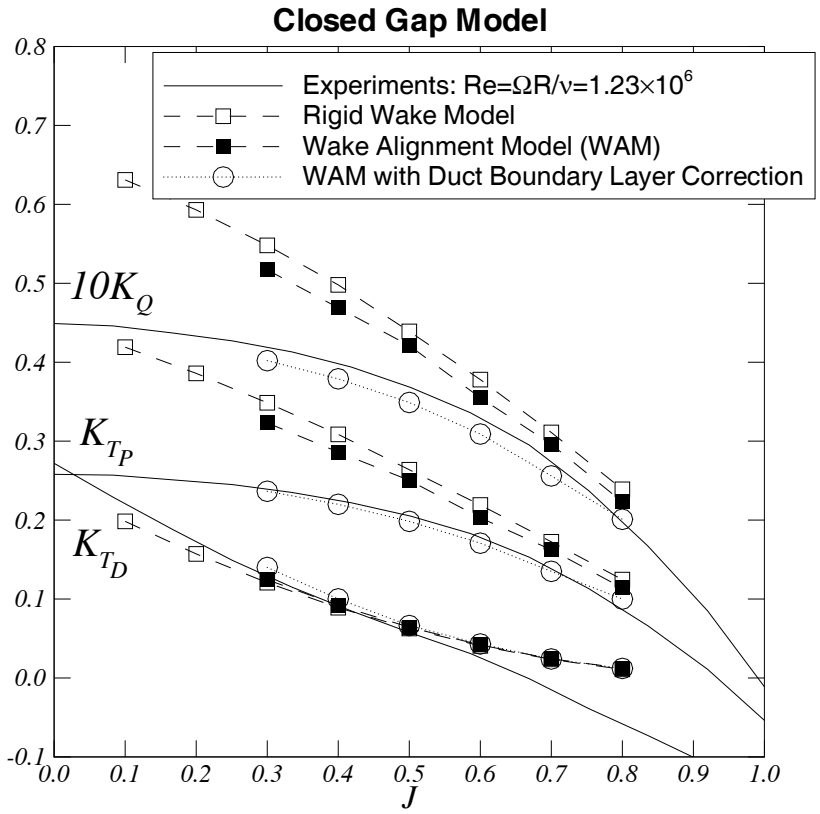




Applications: marine propellers

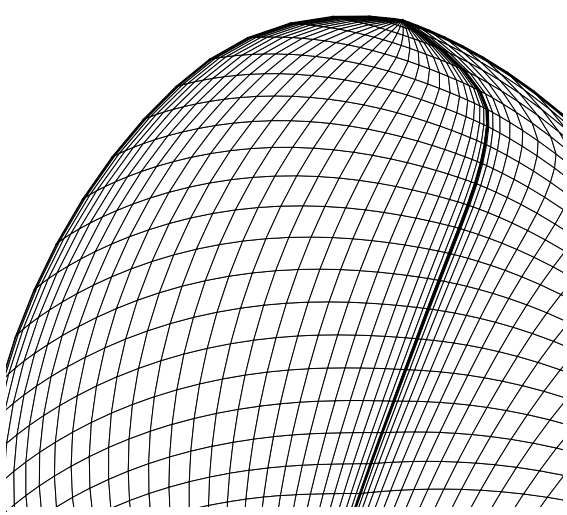
ducted propellers



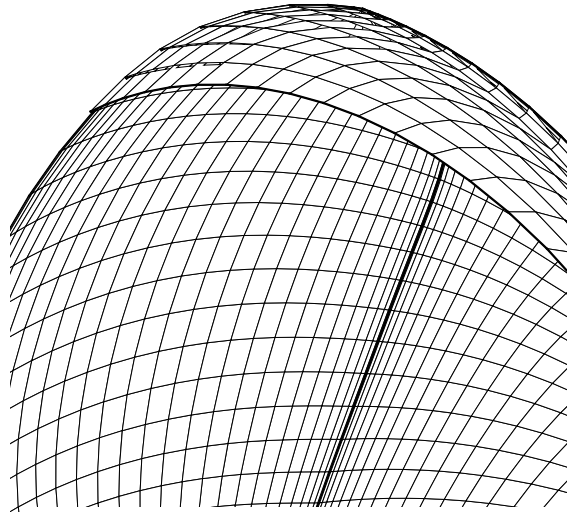


Applications: marine propellers

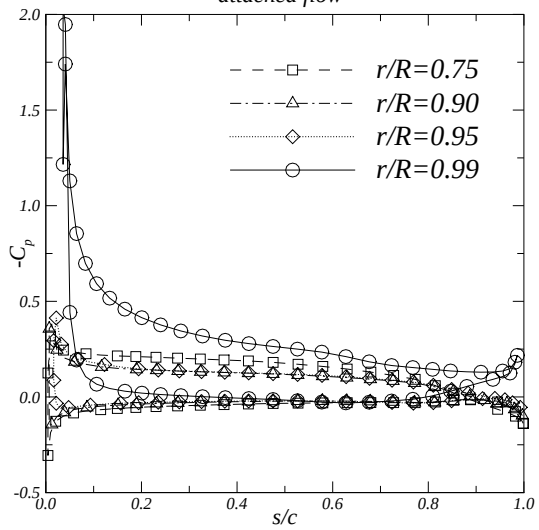
leading-edge vortex sheet separation modeling

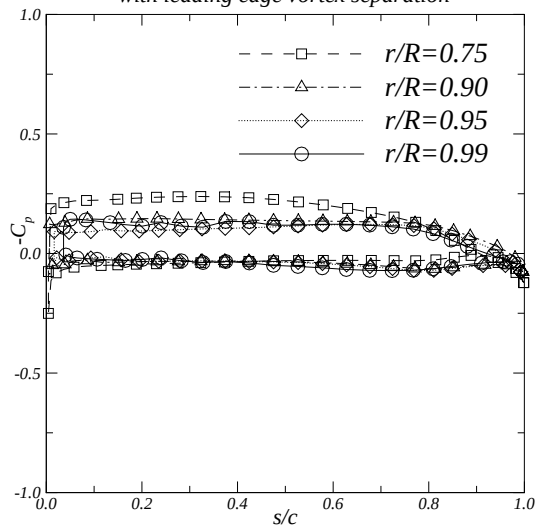


attached flow



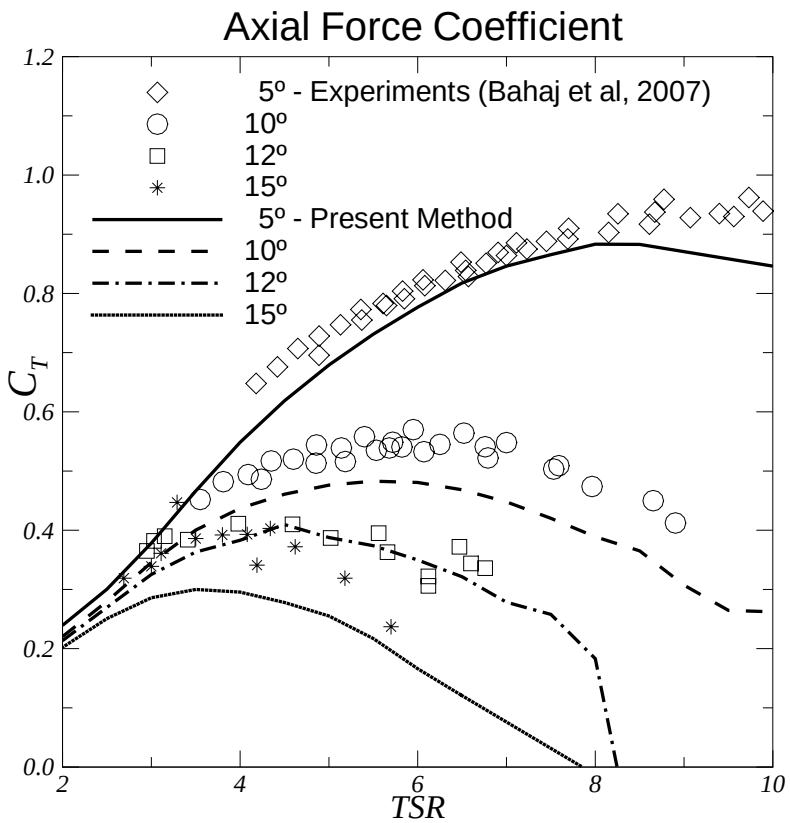
with leading edge vortex separation

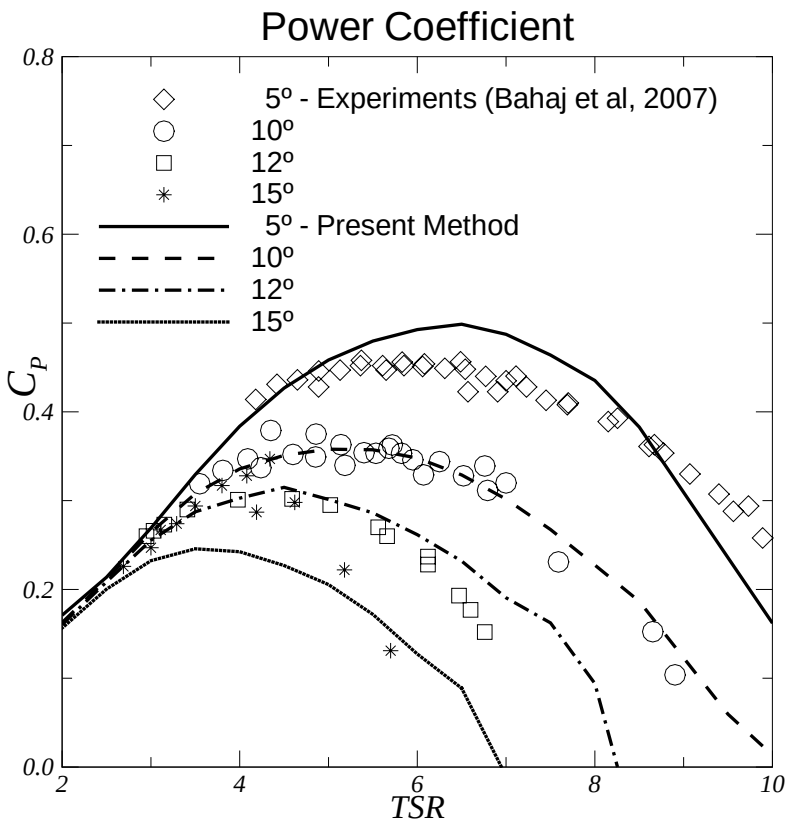




Applications: marine current turbines

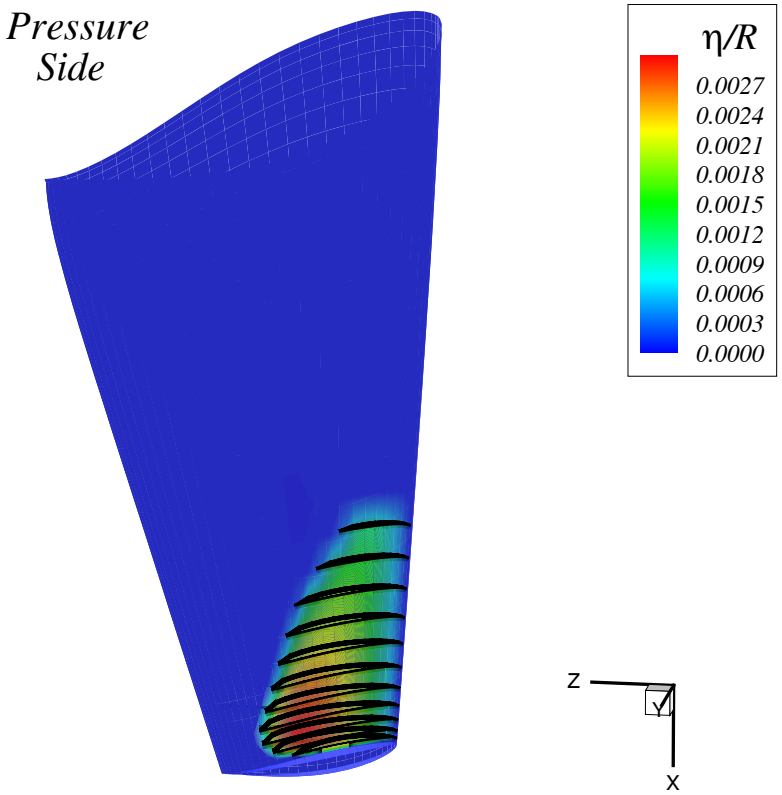
performance characteristics in uniform flow

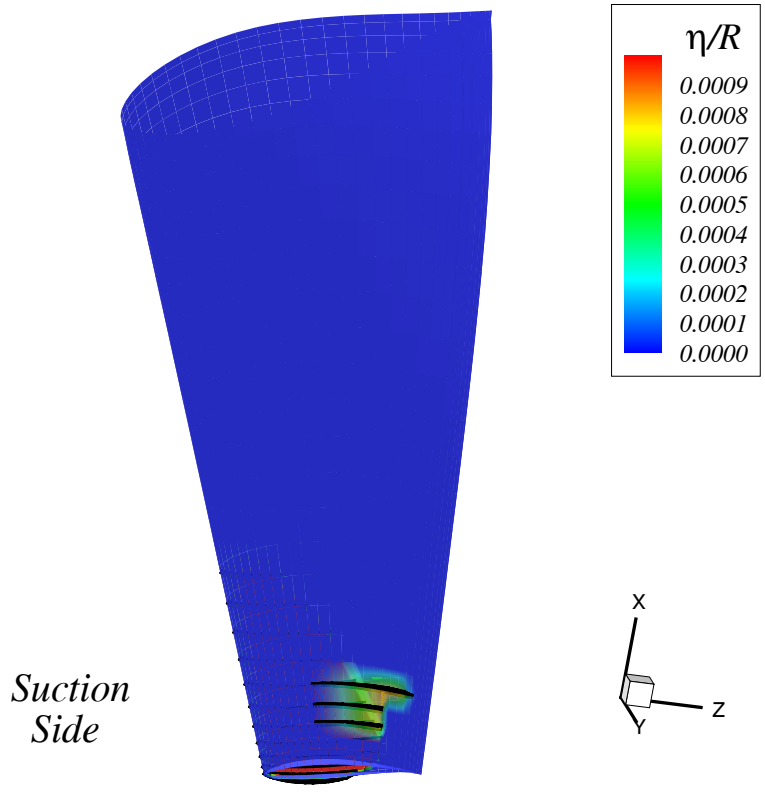




Applications: marine current turbines

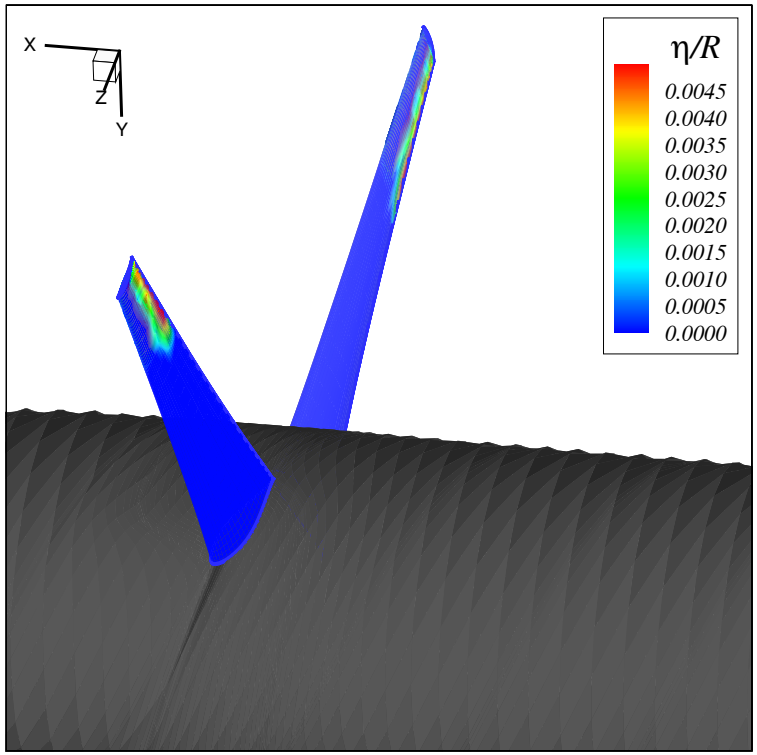
cavitation analysis

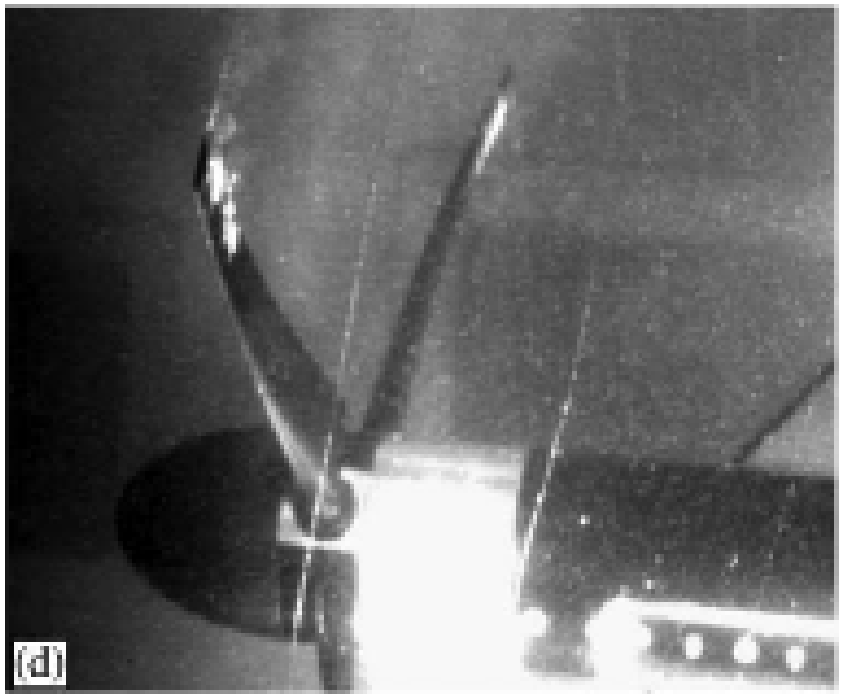




Applications: marine current turbines

cavitation analysis

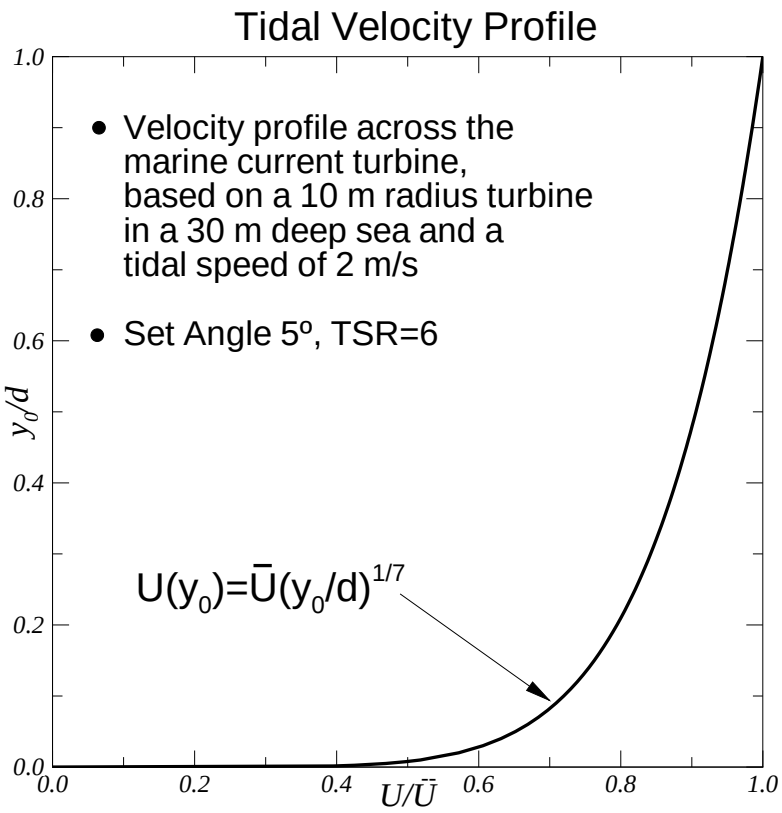


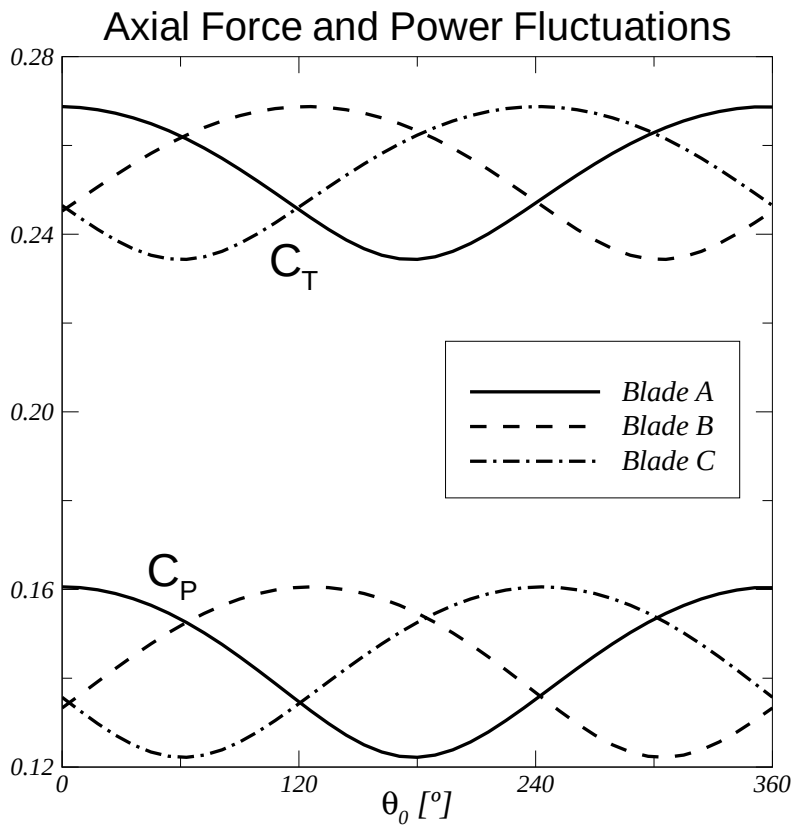


Taken from Bahaj et al. (2007).

Applications: marine current turbine

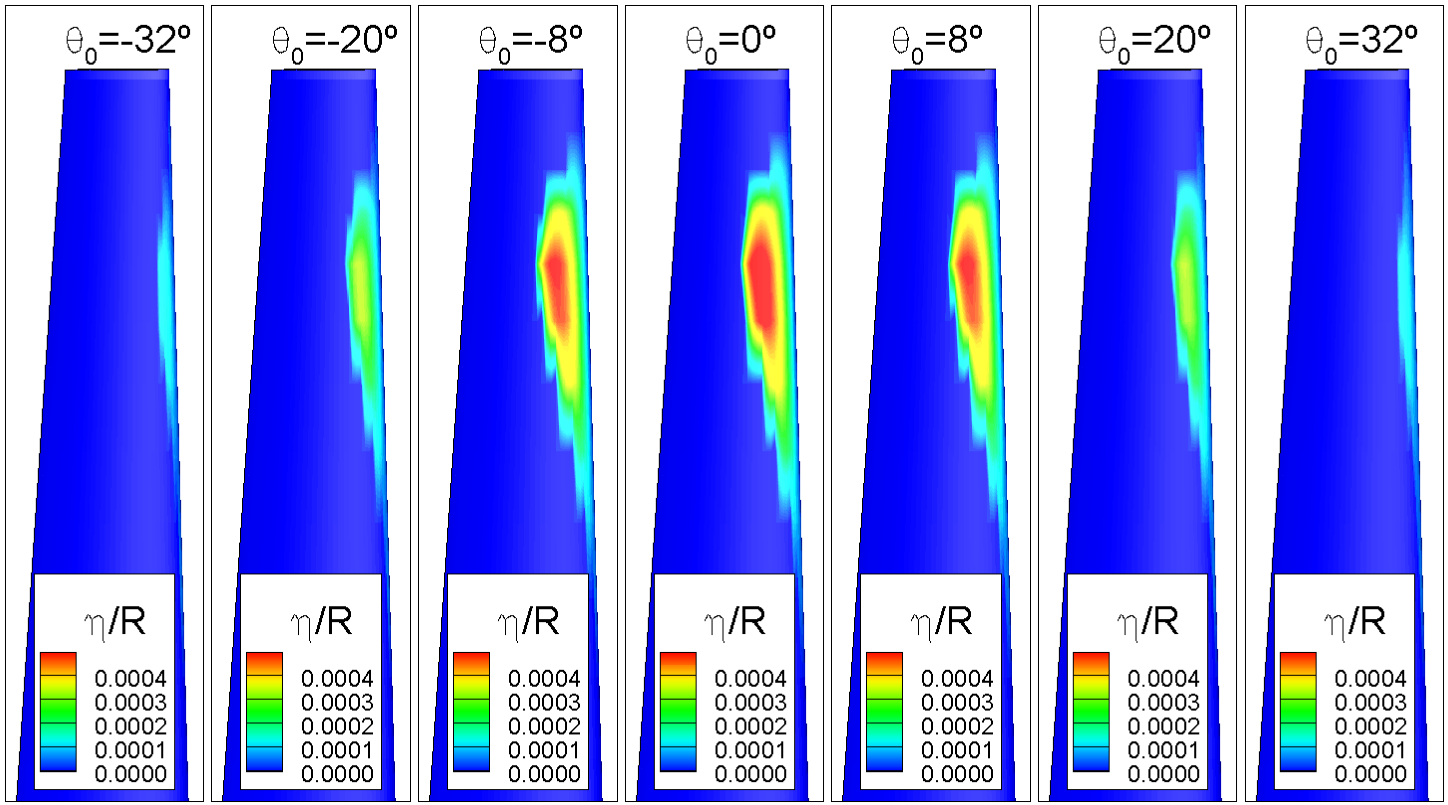
performance in tidal profile





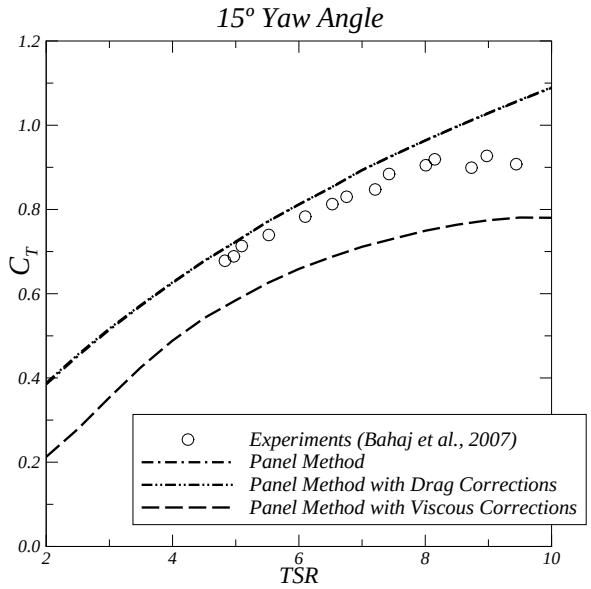
Applications: marine current turbines

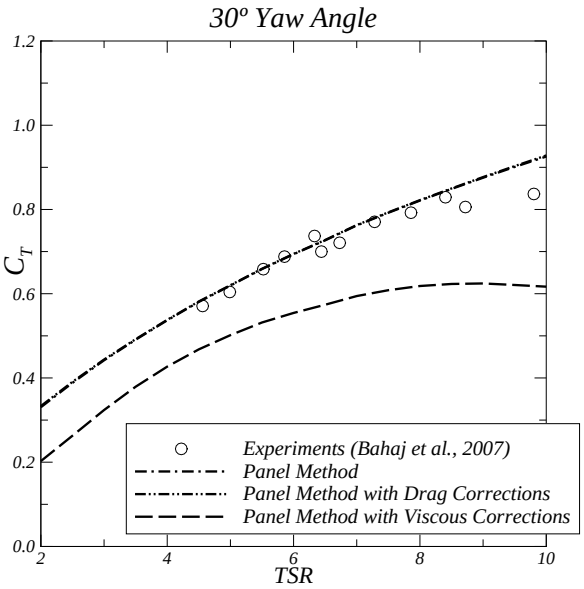
unsteady cavitation in tidal profile

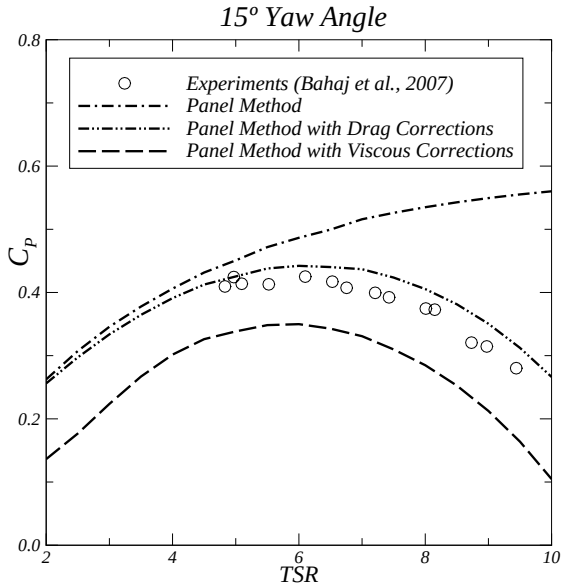


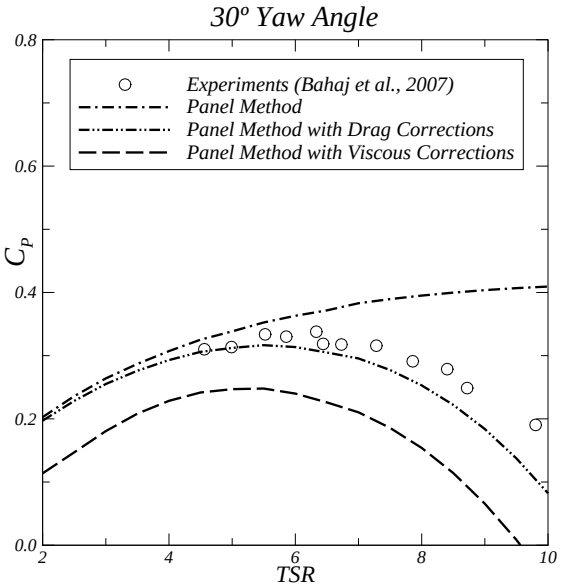
Applications: marine current turbines

yawed inflow conditions



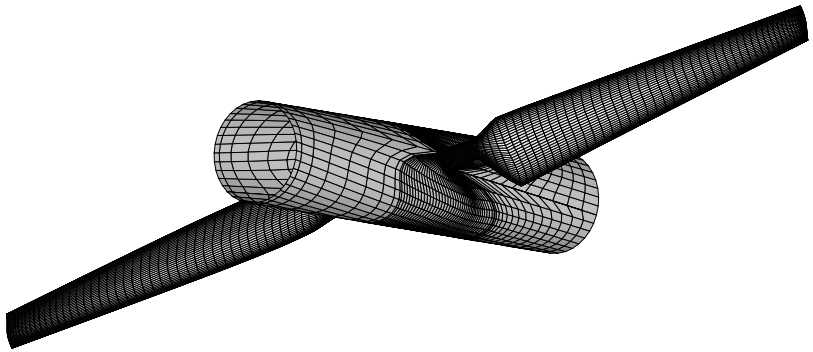






Applications: wind turbines

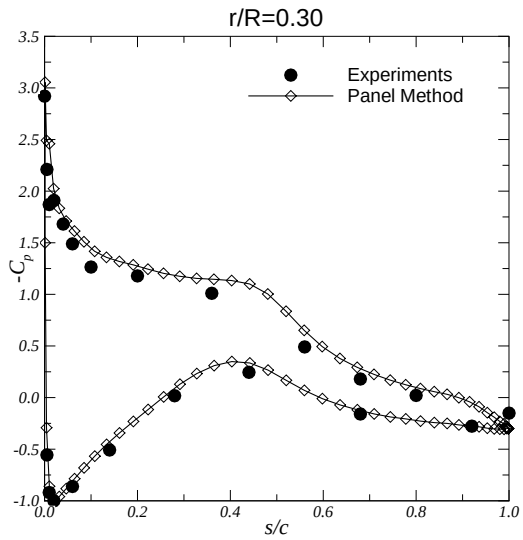
performance prediction

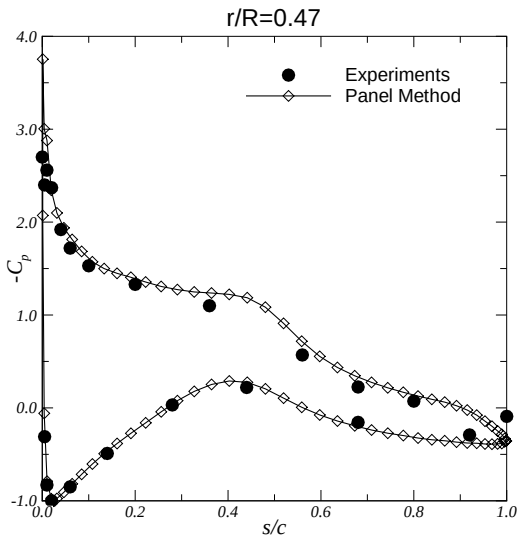


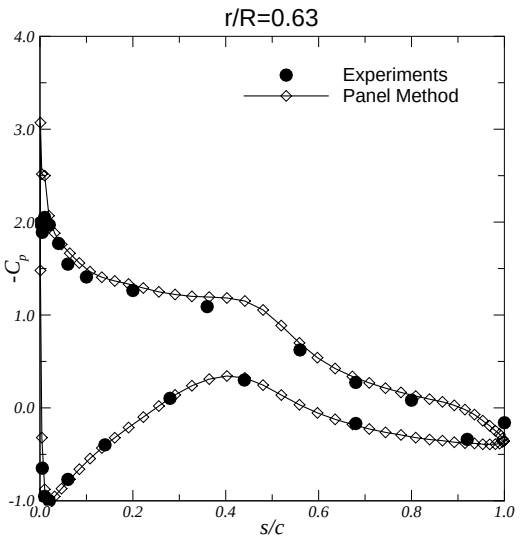
TSR=5.42; C_P=0.326 (Num.); C_P=0.358 (Exp.)

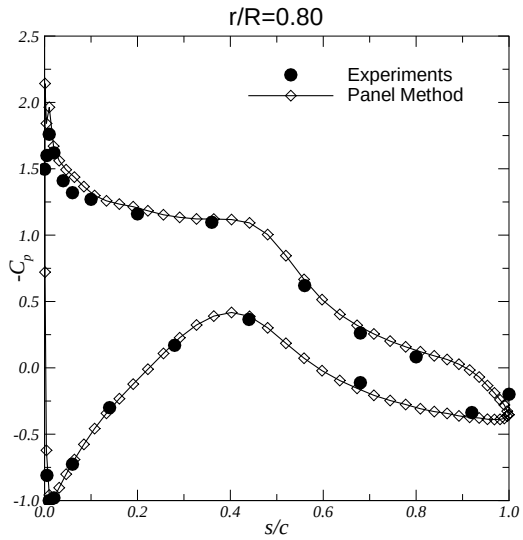
Applications: wind turbines

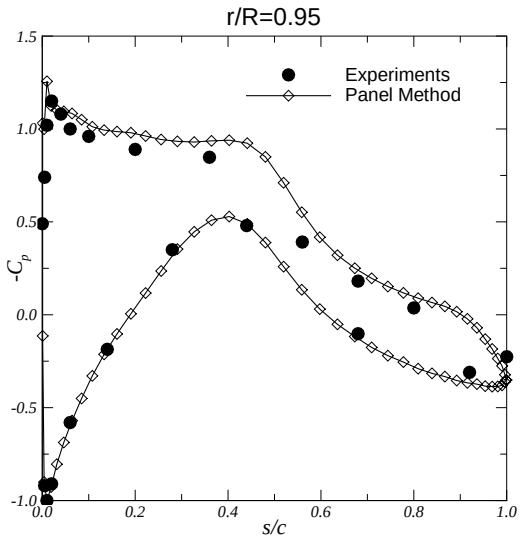
performance prediction





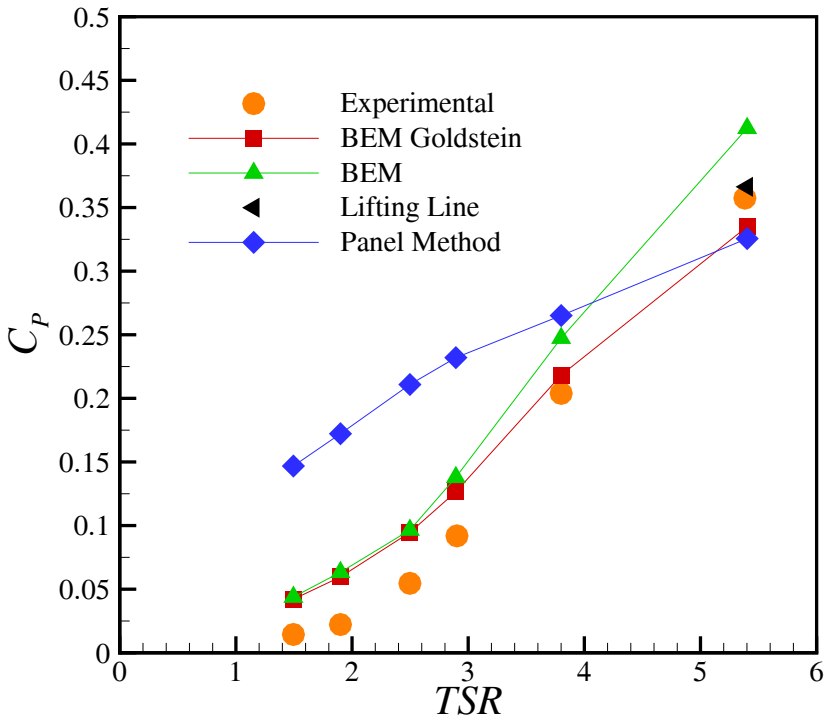


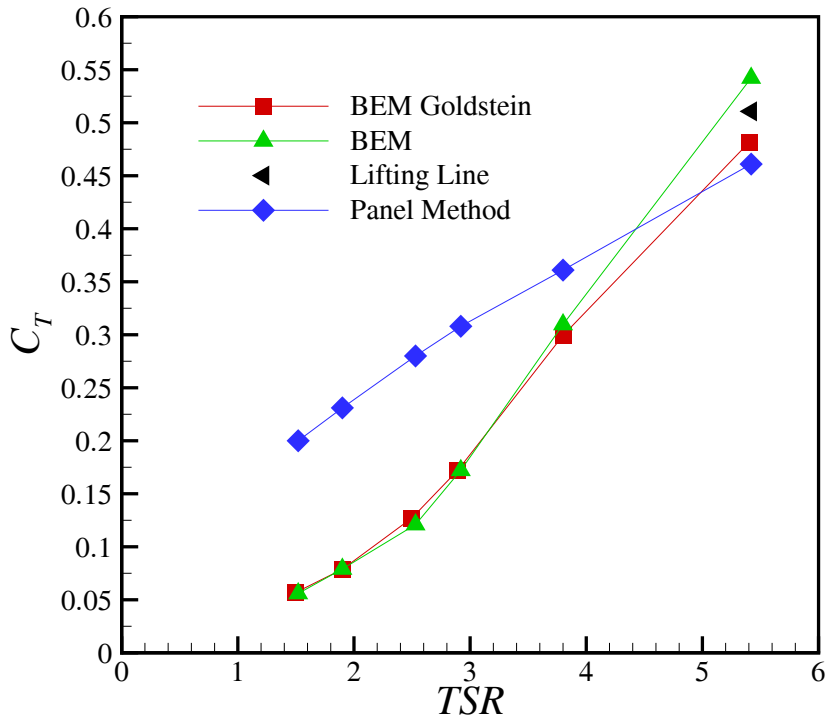




Applications: wind turbines

performance prediction





Main Publications:

- J. Baltazar. "Estudo Numérico do Escoamento Potencial na Extremidade de Asas Elípticas com um Método de Elementos de Fronteira." Master's Thesis, IST, May 2002. (in Portuguese)
- J. Baltazar. "A Higher Order Potential Based BEM for Three-Dimensional Flows." Technical Report POSI-SFRH/BD/14334/2003, April 2005.
- J. Baltazar. "On the Modelling of the Potential Flow About Wings and Marine Propellers Using a Boundary Element Method." Ph.D. Thesis, IST, September 2008.
- J. Baltazar. "Leading-Edge Vortex Flow Modelling Around Delta Wings Using a Boundary Element Method." In Proceedings of the III Conferência Nacional em Mecânica de Fluidos, Termodinâmica e Energia, September 2009.
- J. Baltazar, L. Eça. "Generación de Mallas Estructurada en Superficie." Información Tecnológica 17(3), 107-116, 2005. (in Spanish)
- J. Baltazar, L. Eça. "A Surface Grid Generation Technique for Practical Applications of Boundary Element Methods." In Proceedings of the Conferência Nacional de Métodos Numéricos em Mecânica dos Fluidos e Termodinâmica, June 2006.
- J. Baltazar, J.A.C. Falcão de Campos. "A Study on the Modeling of Marine Propeller Tip Flows Using BEM." In Proceedings of the Congreso de Métodos Numéricos en Ingeniería, July 2005.
- J. Baltazar, J.A.C. Falcão de Campos. "Unsteady Potential Flow Calculations of Marine Propellers Using BEM." In Proceedings of the Conferência Nacional de Métodos Numéricos em Mecânica dos Fluidos e Termodinâmica, 2006.
- J. Baltazar, J.A.C. Falcão de Campos. "Hydrodynamic Analysis of a Horizontal Axis Marine Current Turbine With a Boundary Element Method." In Proceedings of the 27th International Conference on Offshore Mechanics and Arctic Engineering, June 2008.
- J. Baltazar, J.A.C. Falcão de Campos. "A Boundary Element Method for the Unsteady Hydrodynamic Analysis of Marine Current Turbines." In Proceedings of the 2nd International Conference on Ocean Energy, October 2008.
- J. Baltazar, J.A.C. Falcão de Campos. "Unsteady Analysis of a Horizontal Axis Marine Current Turbine in Yawed Inflow Conditions With a Panel Method." In Proceedings of the 1st International Symposium on Marine Propulsors, 2009.
- J. Baltazar, J.A.C. Falcão de Campos. "On the Modelling of the Flow in Ducted Propellers With a Panel Method." In Proceedings of the 1st International Symposium on Marine Propulsors, June 2009.

PROPAN

Main Publications:

- J. Baltazar, J.A.C. Falcão de Campos. "A Numerical Study on the Iterative Techniques to Solve Partial Cavitation on Marine Propellers Using BEM." In Proceedings of the International Conference on Computational Methods in Marine Engineering, June 2009.
- J. Baltazar, J.A.C. Falcão de Campos. "An Iteratively Coupled Solution of the Cavitating Flow on Marine Propellers Using BEM." Journal of Hydrodynamics 22(5) supplement 1, 838-843, 2010.
- J. Baltazar, J.A.C. Falcão de Campos. "Hydrodynamic Analysis of a Horizontal Axis Marine Current Turbine With a Boundary Element Method." Journal of Offshore Mechanics and Arctic Engineering, Vol. 133, November 2011.
- J. Baltazar, J.A.C. Falcão de Campos. "Prediction of Sheet Cavitation on Marine Current Turbines With a Boundary Element Method." In Proceedings of the ASME 31st International Conference on Ocean, Offshore and Arctic Engineering, OMAE, 2012.
- J. Baltazar, J.A.C. Falcão de Campos. "An Iteratively Coupled Solution Method for Partial and Super-Cavitation Prediction on Marine Propellers Using BEM." In Proceedings of the 10th International Conference on Hydrodynamics, October 2012.
- J. Baltazar, J.A.C. Falcão de Campos. "Prediction of Unsteady Sheet Cavitation on Marine Current Turbines With a Boundary Element Method." In Proceedings of the 6th International Conference on Mechanics and Materials in Design, July 2015.
- J. Baltazar, J.A.C. Falcão de Campos. "A Comparison of Panel Method and RANS Calculations for a Horizontal Axis Marine Current Turbine." In book: CFD for Wind and Tidal Offshore Turbines. Publisher: Springer International Publishing. Editors: Esteban Ferrer, Adeline Montlaur, 117-128, 2015.
- J. Baltazar, J.A.C. Falcão de Campos. "An Iteratively Coupled Solution Method for Unsteady Sheet Cavitation Prediction on Marine Propellers Using BEM." In Proceedings of the 12th International Conference on Hydrodynamics, 2016.
- J. Baltazar, J.A.C. Falcão de Campos. "Potential Flow Modelling of Ducted Propellers With Blunt Trailing Edge Duct Using a Panel Method." In Proceedings of the 6th International Symposium on Marine Propulsors, May 2019.
- J. Baltazar, J.A.C. Falcão de Campos, J. Bosschers. "A Study on the Accuracy of Low and Higher Order BEM in Three-Dimensional Potential Flows Past Ellipsoids." In Proceedings of the 5th International Conference on Boundary Element Techniques, July 2004.

PROPAN

Main Publications:

- J. Baltazar, J.A.C. Falcão de Campos, J. Bosschers. "Open-Water Thrust and Torque Predictions of a Ducted Propeller System with a Panel Method." International Journal of Rotating Machinery, Article ID 474785, 2012.
- J. Baltazar, J.A.C. Falcão de Campos, J. Bosschers. "Potential Flow Modelling of Ducted Propellers With a Panel Method." In Proceedings of the 4th International Symposium on Marine Propulsors, June 2015.
- J. Baltazar, J.A.C. Falcão de Campos, J. Bosschers, D. Rijpkema. "Recent Developments in Computational Methods for the Analysis of Ducted Propellers in Open Water." Journal of Ship Research 63(4), 219-234, December 2019.
- J. Baltazar, D. Melo, D. Rijpkema. "Analysis of the Blade Boundary-Layer Flow of a Marine Propeller With RANSE." In Proceedings of the VIII International Conference on Computational Methods in Marine Engineering, 2019.
- J. Baltazar, D. Rijpkema, J.A.C. Falcão de Campos, J. Bosschers. "A Comparison of Panel Method and RANS Calculations for a Ducted Propeller System in Open-Water." In Proceedings of the 3rd International Symposium on Marine Propulsors, May 2013.
- J. Baltazar, D. Rijpkema, J.A.C. Falcão de Campos, J. Bosschers. "Prediction of the Open-Water Performance of Ducted Propellers With a Panel Method." In Proceedings of the 5th International Symposium on Marine Propulsors, June 2017.
- J. Baltazar, D. Rijpkema, J.A.C. Falcão de Campos, J. Bosschers. "Prediction of the Open-Water Performance of Ducted Propellers with a Panel Method. " Journal of Marine Science and Engineering 6(1), 2018.
- J.A.C. Falcão de Campos, P.J.A. Ferreira de Sousa, J. Bosschers. "A Verification Study on Low-Order Three-Dimensional Potential-Based Panel Codes." Computers & Fluids 35, 61-73, 2006.
- T. Clara, J.A.C. Falcão de Campos, J. Baltazar. "Added Mass Effects on the Natural Frequencies of Marine Current Turbine Blades." In Proceedings of the 6th International Conference on Mechanics and Materials in Design, July 2015.
- R. Duarte. "Estudos Sobre um Método de Elementos de Fronteira Para o Cálculo do Escoamento Potencial Estacionário em Hélices Propulsores Marítimos." Master's Thesis, IST, December 1997. (in Portuguese)
- F. Hogan. "Análise do Desempenho Aerodinâmico da Turbina Eólica NREL com um Método de Elementos de Fronteira." Master's Thesis, IST, October 2010. (in Portuguese)
- P. Ponte. "Effect of the Duct Trailing Edge Geometry on the Calculation of a Ducted Propeller With a Boundary Element Method." Master's Thesis, IST, November 2011.
- E. Quarona. "Design Loading Optimization of a Horizontal Axis Turbine with Lifting Line and Panel Method." Master's Thesis, IST, October 2019.

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