Chair of Structural Analysis
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CFD Shape Optimization for Offshore Structures Subjected to Wave and Current Loading

The enormous energy potential of the world's oceans has been recognized as a promising source of renewable energy. The search to find efficient ways to harvest the oceans' energy has led to a particularly promising new technology: tidal stream generators. Developed prototypes have shown that tidal stream generators can contribute significantly to the world's power supply. Currently, efforts are being made to further optimize the structures. Innovative solutions for the foundations of tidal turbines are being developed, which take into account the unique environmental conditions at offshore sites suitable for harvesting tidal energy. Using modern computational methods, it is possible to exploit the full optimization potential of the foundation. The challenge lies in finding new and creative solutions for the complex problems associated with offshore engineering, flow simulations, and shape optimization.

Tidal Turbines

A gravity base foundation prototype for a tidal turbine was successfully installed near Jindo Island (South Korea) in Feb. 2010 by Ed. Züblin AG. Since June 2010, TUM has been investigating the structure in order to push forward the technology for large scale commercial use. The work addresses lack of research regarding the optimal foundation shape under wave-current loading.

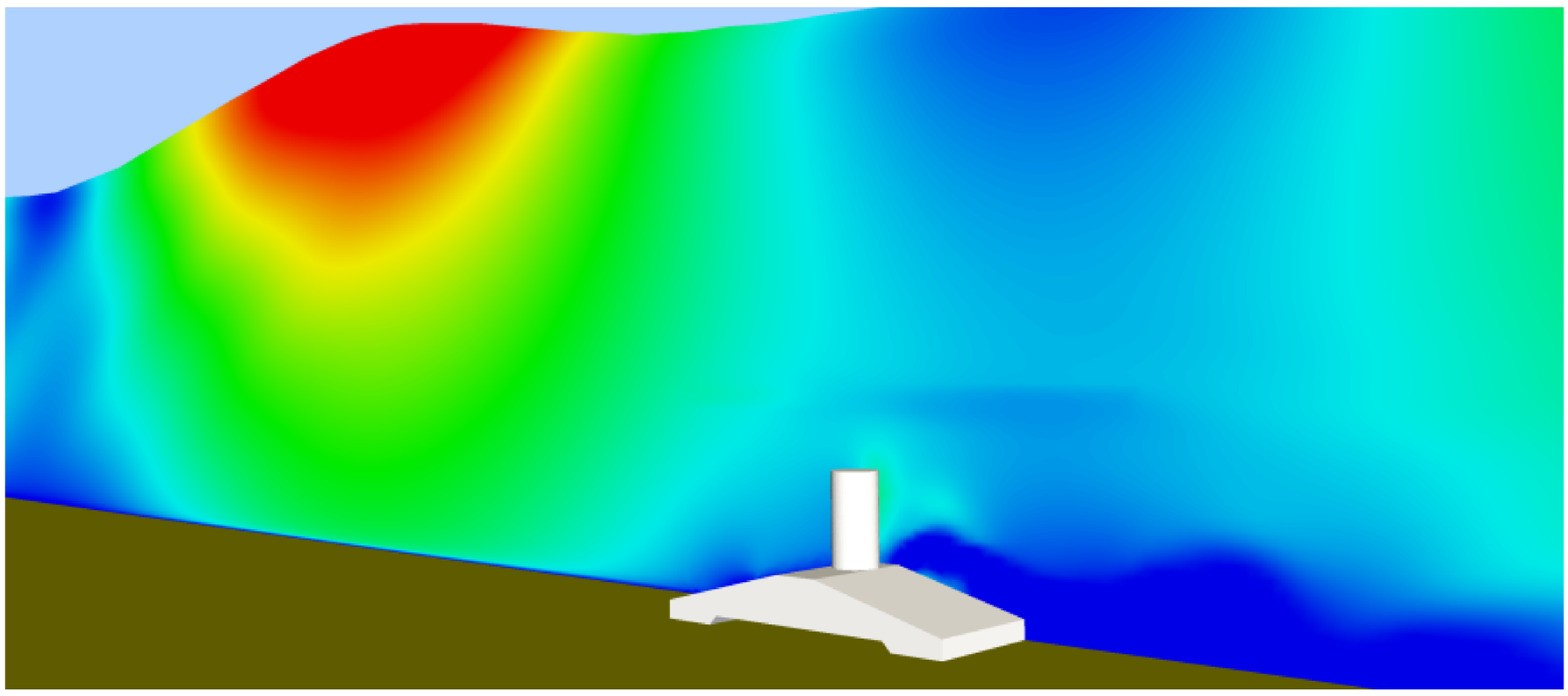
Tidal turbine prototype
[RENETEC & VOITH]

Gravity base foundation prototype
[RENETEC & Ed. Züblin AG]

Foundation installation at the project site
[RENETEC & Ed. Züblin AG]

Numerical Wave Channel

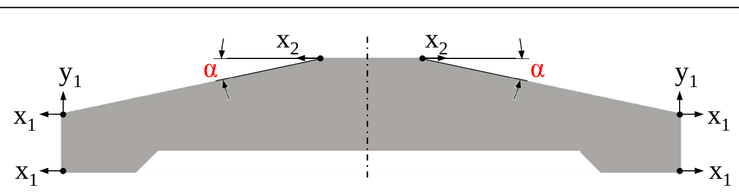
A numerical wave channel was implemented, capable of simulating realistic marine environments. The fundamental approach is to gain access to structural wave loads based on the numerical solution of the unsteady Reynolds-averaged Navier-Stokes (URANS) equations. A multiphase flow is incorporated into the simulation by utilizing the Volume of Fluid (VOF) method. The wave is calculated using the Fenton model and is introduced into the flow problem in the form of boundary conditions. A Computational Fluid Dynamics (CFD) approach to modelling wave-current interaction was developed and applied to investigate the prototype structure.



Simulation of the gravity base foundation in the numerical wave channel under combined wave-current loading

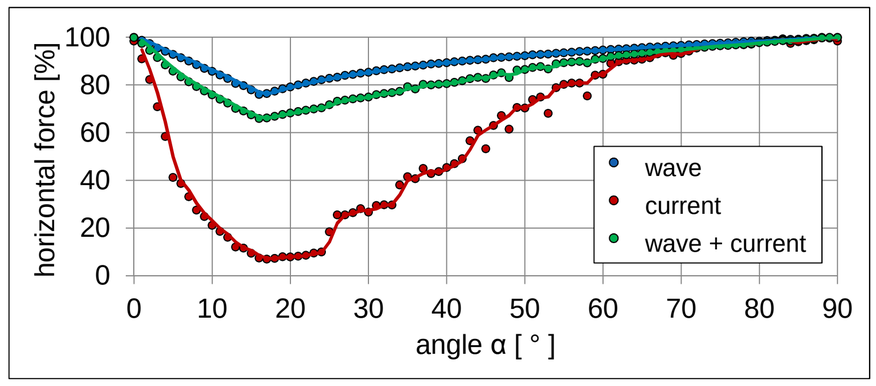
CFD Shape Optimization

New foundation geometries are developed that are optimized regarding the hydrodynamic loading. The analysis is carried out under consideration of pure wave, pure current, and combined wave-current loading. Automated optimization strategies are implemented in order to efficiently design structures based on site specific offshore data. The results are reduced structural loads allowing for a more economical foundation regarding material and installation costs. Exemplary, a single parameter optimization problem is shown on the right. The objective functions for the different load cases give insight into the optimal design of the structure. Optimization strategies are being developed in order to efficiently close in on the design optimum.

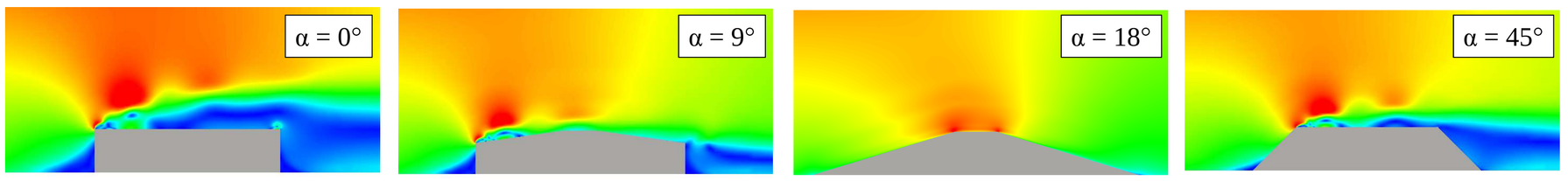


Objective function:	horizontal force
Design parameter:	angle α
Equality constraints:	structure height & volume

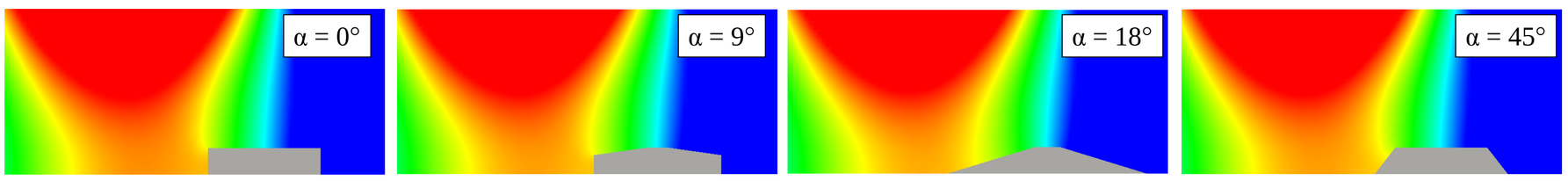
Problem definition for the optimization of the gravity base foundation



Resulting objective functions for wave and current loading



Velocity contour plots for combined wave-current loading on various shapes. Red and blue are regions of high and low velocity respectively



Pressure contour plots for pure wave loading on various shapes. Red and blue are regions of high and low pressure respectively