Experimental Validation of an Analytic Approach to Optimization of a Tidal Turbine Fence

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Introduction
Within the efforts of energy transition various technologies for harnessing of tidal energy sources are under investigation. One type of machine for the extraction of energy from tidal currents is the hydrokinetic turbine. To gather as much energy as possible, these machines are planned to be installed in tidal turbine arrays. The results to be presented contain an analytical method for the optimization of such turbine arrays by means of energy yield. The presented method is validated in a Froude scaled experiment. Results of the analytic approach and the validation are presented and discussed.

Discussion
In the case of wind turbine Albert Betz established an analytic optimization based on conservation of mass and momentum. Various studies have shown [1], that Betz theory is not feasible for hydrokinetic turbines in free surface flows. I.e. in case of shallow water and high blockage ($h_1 \sim d, b \sim d$, see **Figure 1**) the Betz limit is exceeded. This is not a falsification of Betz' theory but it indicates, that for the case of a shallow tidal currents or any comparable flow, free surface effects have to be taken into account. An analytical description of the optimization problem is established in [2]. For free surface flows, the coefficient of performance is shown to be a function of the blockage ratio σ, the turbine head $\bar{H}_T$, and the downstream Froude number $Fr_{\_}$. Figure 1 shows the coefficient of performance for a fixed value of blockage ratio $\sigma = 0.5$. The contour lines represent values of $\bar{C}_P$ calculated analytically by use of conservation of energy, mass and momentum equations. The markers represent values of $\bar{C}_P$ measured in the small scale test rig. The limit of $\bar{C}_P$ as defined by Pelz [3] is $\bar{C}_{P,opt} = 0.5$ for blockage ratio $\sigma = 1$.

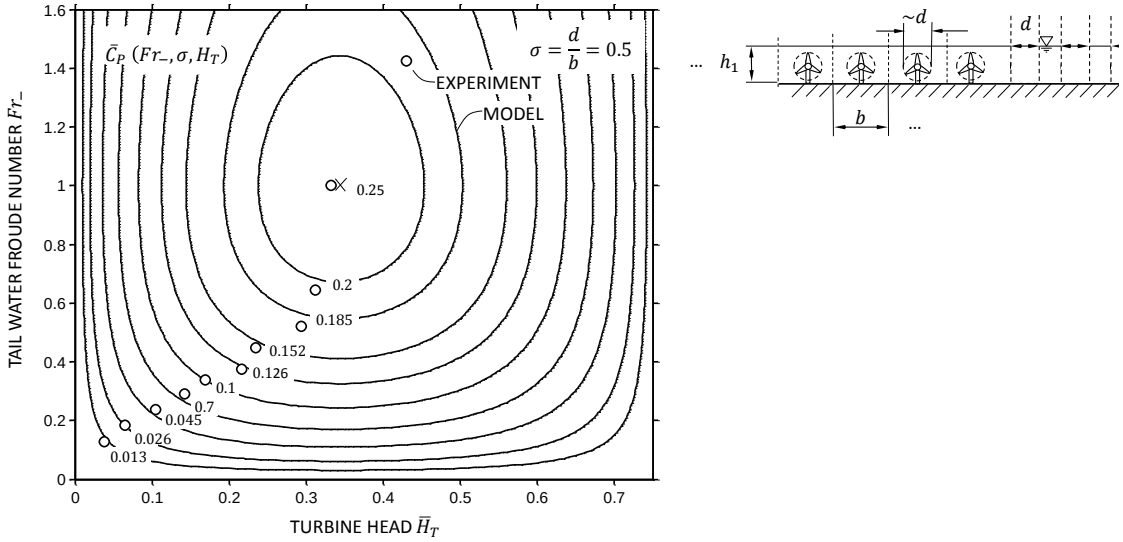

Figure 1: Coefficient of performance for a tidal turbine fence

Conclusions and/or Outlook
The distance in between each marker and the adjacent contour line can be interpreted as gap between calculated and measured values of $\bar{C}_P$. For subcritical Froude numbers $0 < Fr_{\_} < 1$ calculation and measurement are in good accordance. For supercritical Froude numbers $Fr_{\_} > 1$ there is a gap between measurement and calculations, which is intended to be closed for the final conference contribution's data by enhancement of measurement systems.

References:
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[3] Pelz, P: Upper Limit for Hydropower in an Open-Channel Flow, Journal of Hydraulic Engineering; ASCE / November (2011); DOI: 10.1061/(ASCE)HY.1943-7900.0000393