

Elektroboot Eins: Tip-Rake Propeller Design for an Ultra-Light Electric Boat



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FRIENDSHIP SYSTEMS AG

CAESES User Conference 2024



FRIENDSHIP SYSTEMS

Introduction

Project Overview

- Designing a high-efficiency propeller for the ultra-light Elektroboot Eins
- Enhance efficiency and (top) speed
- Important: Match Propeller, Motor and Hull

Torqueedo

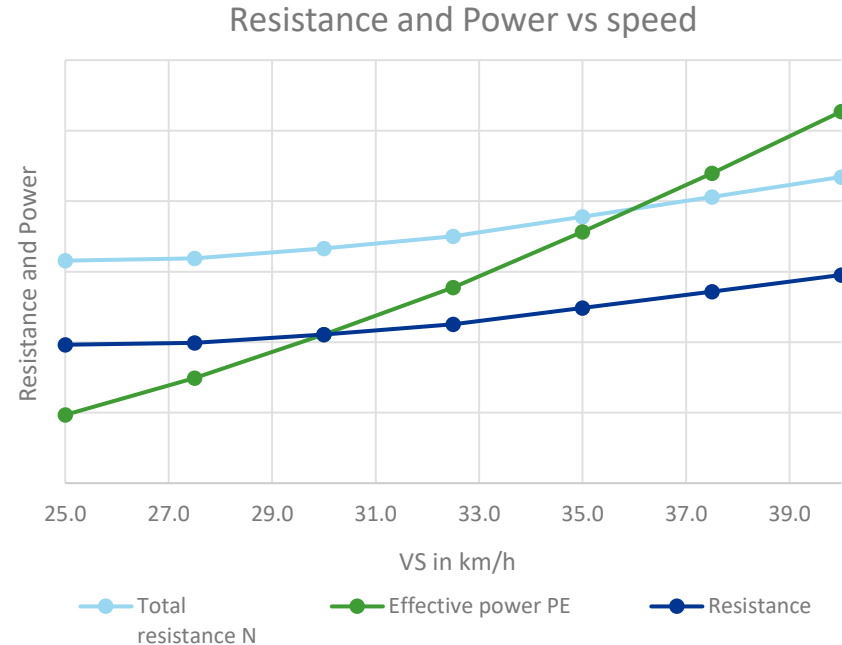
- Manufacturer of advanced electric outboards

KAEBON

- Innovator in lightweight electric boats

FRIENDSHIP SYSTEMS

- CAD modeling and CFD simulation



ELEKTROBOOT EINS

Lightweight

- 89 kg empty hull
- 370 kg in trials

Size

- Length 5.25 m
- Beam 1.7 m

Power

- Max 20 kw outboard
- 100% electric
- 45' @ full throttle

TARGET: 30 km/h



Cruise 12.0

Specs

- >12 kW
- 60 kg + battery
- 2 very good propellers
- Rev and Torque limiter
- Gearbox
- Anti ventilation plate + Fin

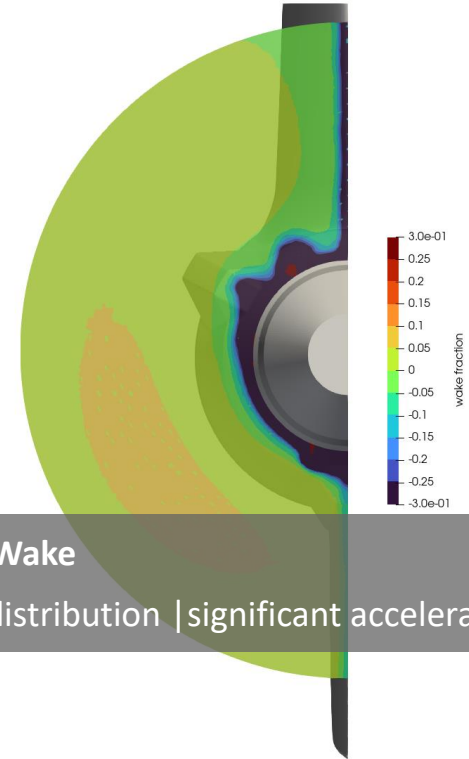
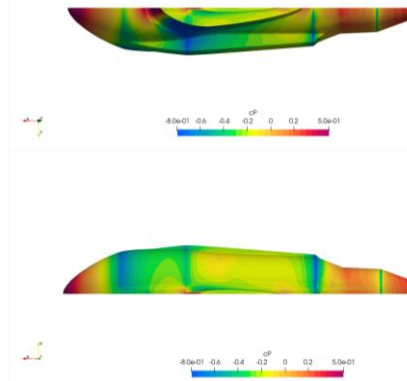
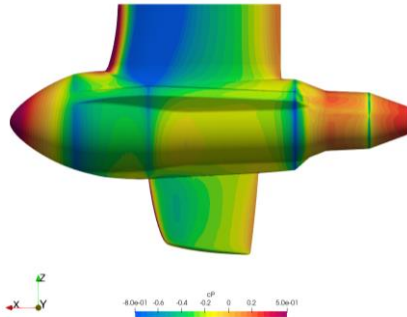
Reference speed (EB Eins): 27.4 km/h



Cruise 12.0 CFD

OpenFOAM

- Enclosure in open-water
- wake field
- Added resistance vs. speed data



Added Resistance and Wake

Non-uniform pressure distribution | significant acceleration

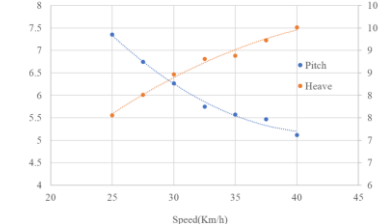
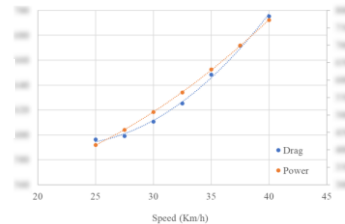
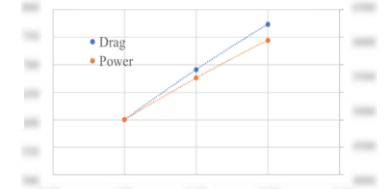
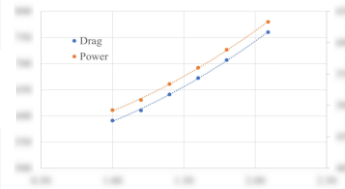
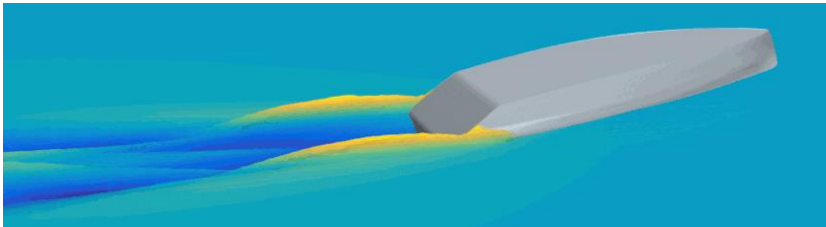


ELEKTROBOOT EINS CFD

STAR-CCM+

- Overset Grid
- AMR for Overset Grid and Free Surface
- Wall function ($y^+ 70$), Symmetric

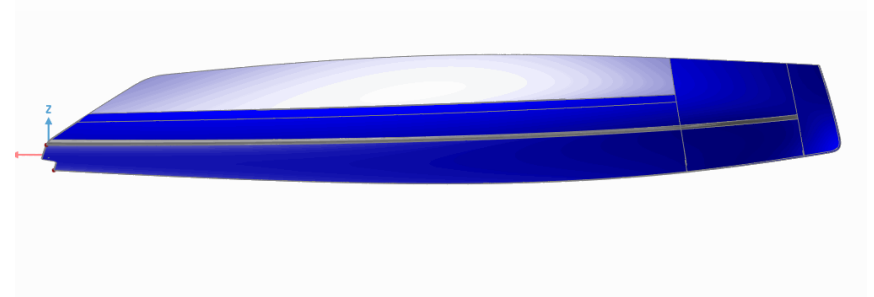
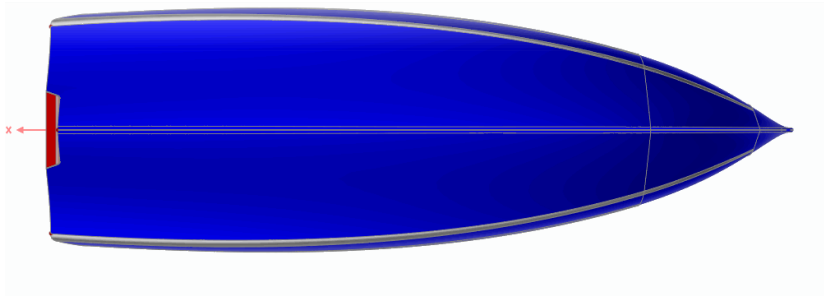
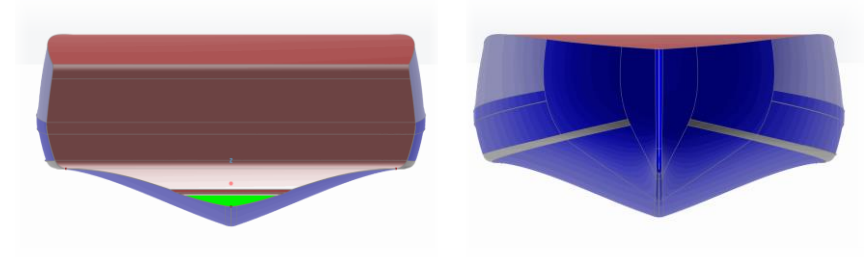
	Drag	Pitch	Heave	Power	LCG(from aft)	LCB-LCG	Static Trim Angle
	N	deg	cm	Watt	m	m	deg
Configuration 0							
Configuration 1							
Configuration 2							
Configuration 3							
Configuration 4							
Configuration 5							



ELEKTROBOOT EINS CFD

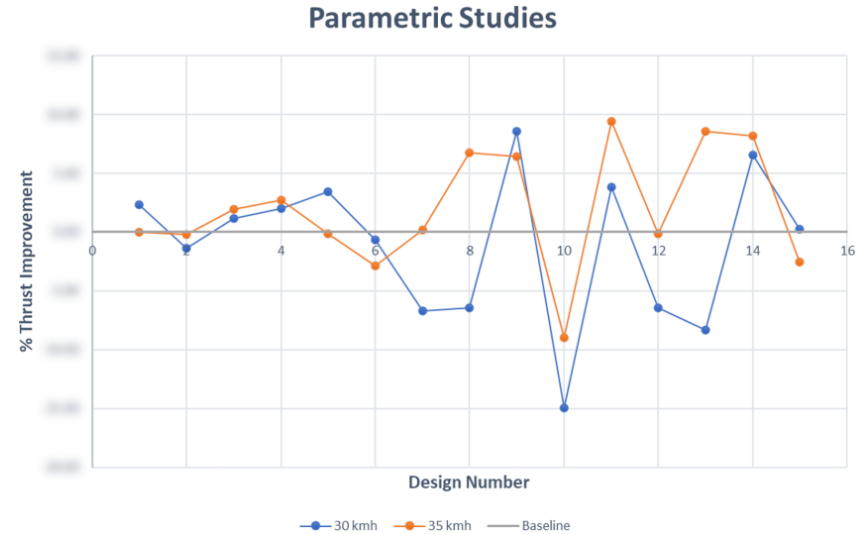
STAR-CCM+

- Overset Grid
- AMR for Overset Grid and Free Surface
- Wall function ($y^+ 70$), Symmetric
- Design of Experiments on Hull



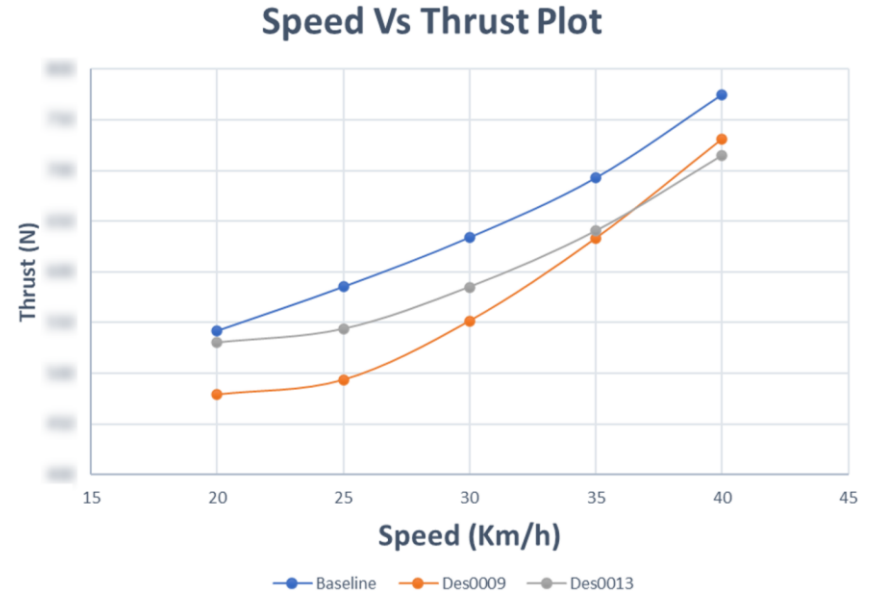
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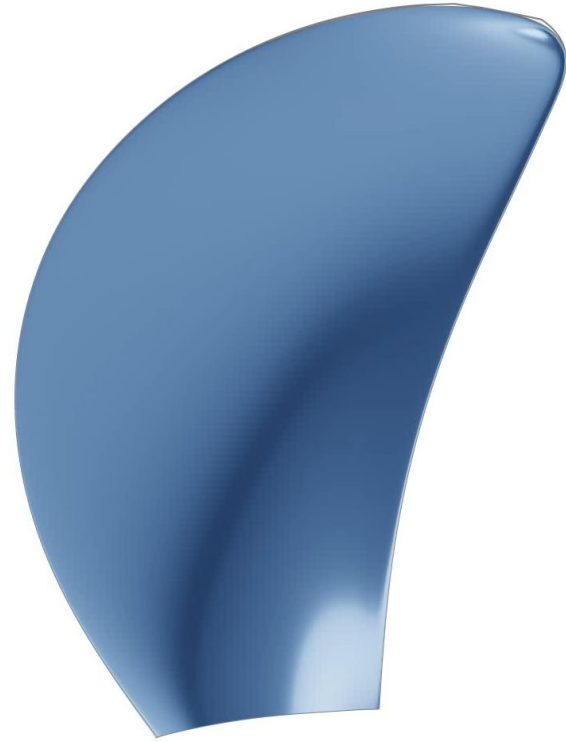
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Propeller Design

Fully Parametric CAESES model

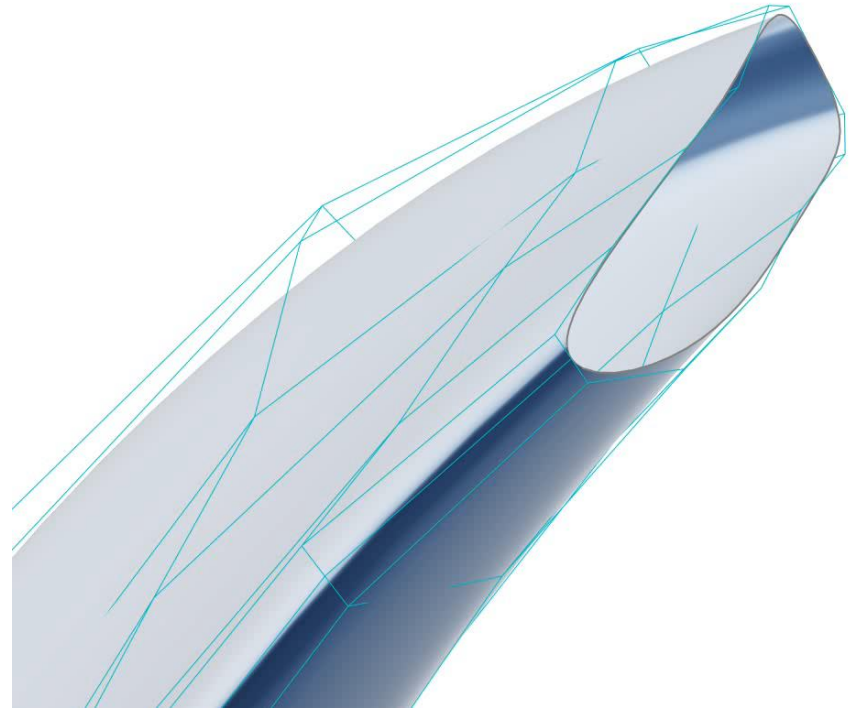
- Center surface modeling



Propeller Design

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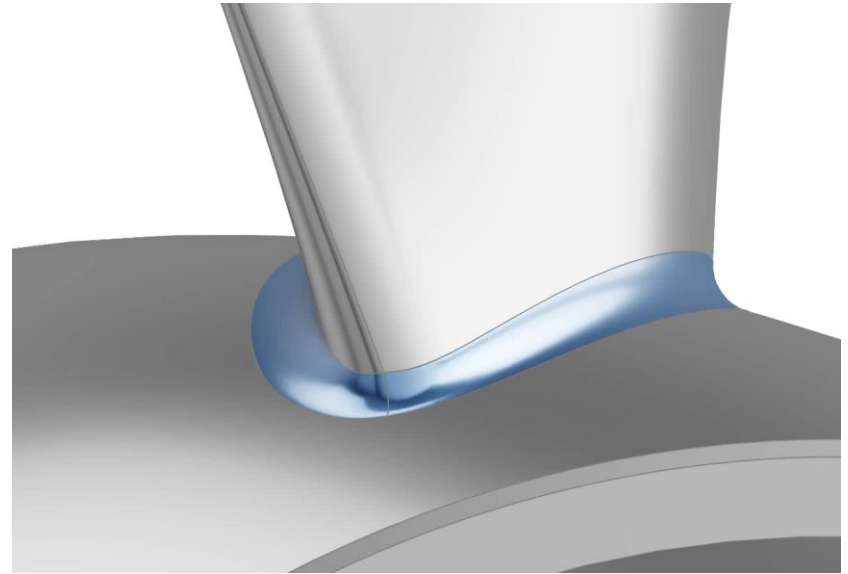
- Center surface modeling
- Tip closure



Propeller Design

Fully Parametric CAESES model

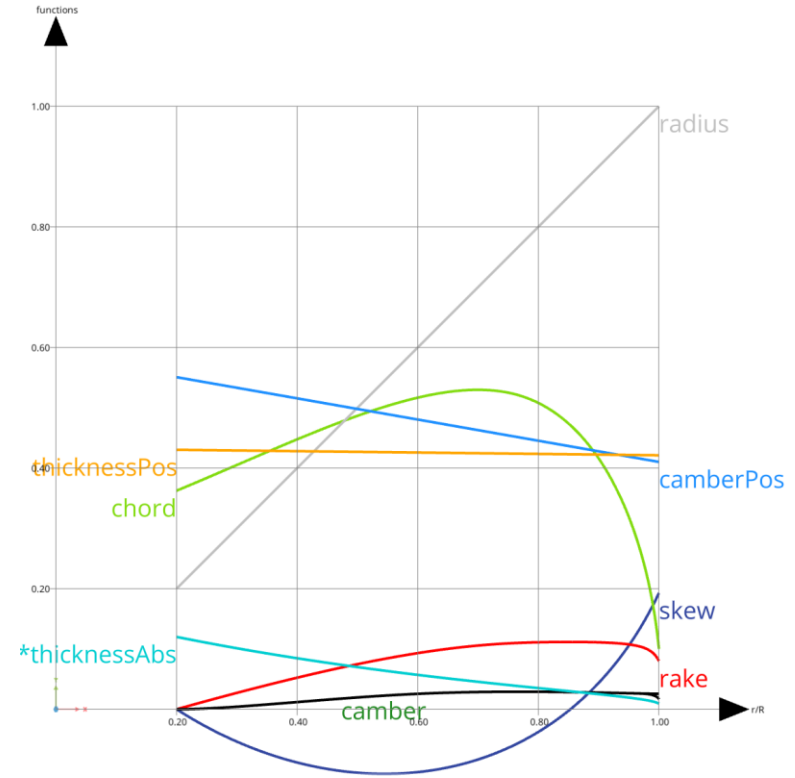
- Center surface modeling
- Tip closure
- Variable Radius Fillet



Propeller Design

Fully Parametric CAESES model

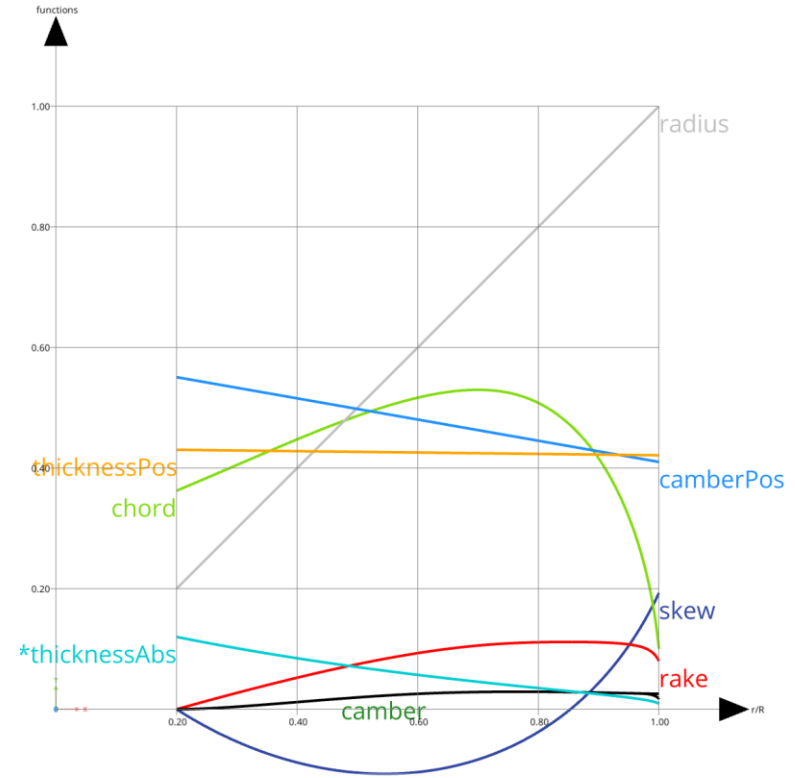
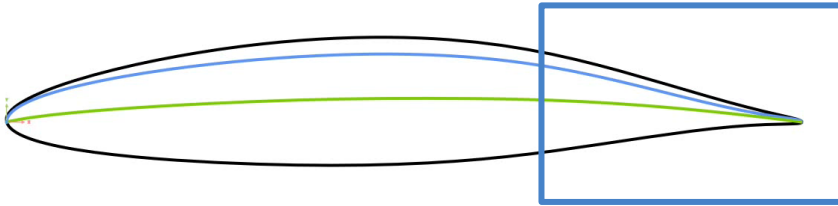
- Center surface modeling
- Tip closure
- Variable Radius Fillet
- Thickness according to ABS rules



Propeller Design

Fully Parametric CAESES model

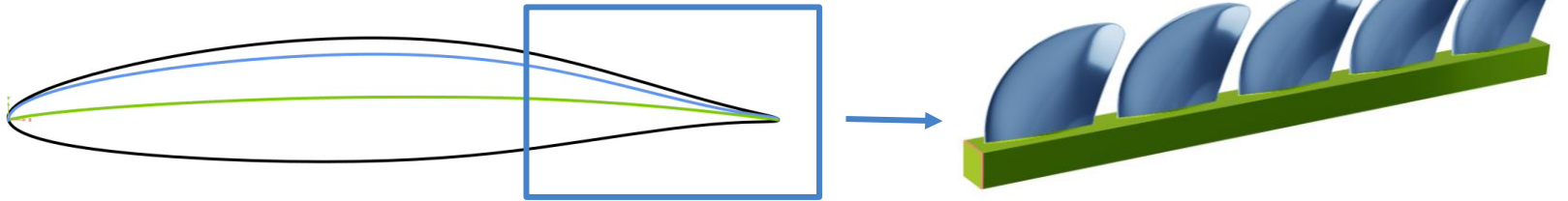
- Center surface modeling
- Tip closure
- Variable Radius Fillet
- Thickness according to ABS rules
- NACA66 modified based profile definition
- Minimum TE thickness adjustment



Propeller Design

Fully Parametric CAESES model

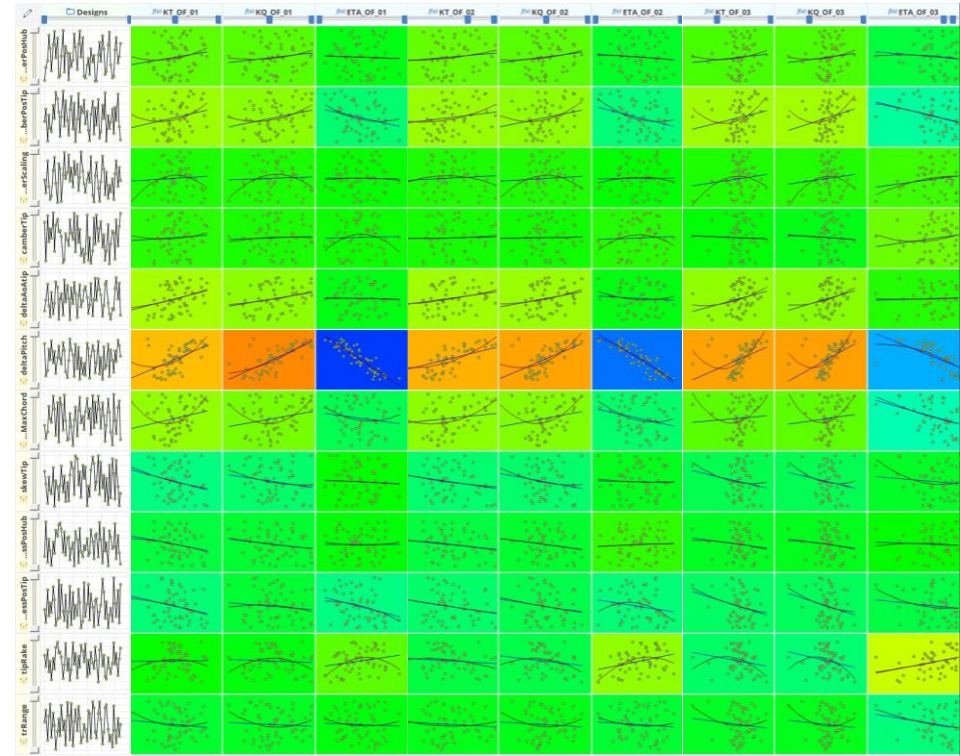
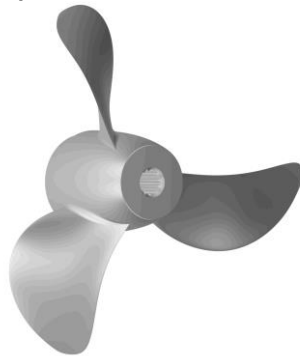
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Propeller Design

Fully Parametric CAESES model

- Center surface modeling
- Tip closure
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- Thickness according to ABS rules
- NACA66 modified based profile definition
- Minimum TE thickness :
- 12 Design Variables



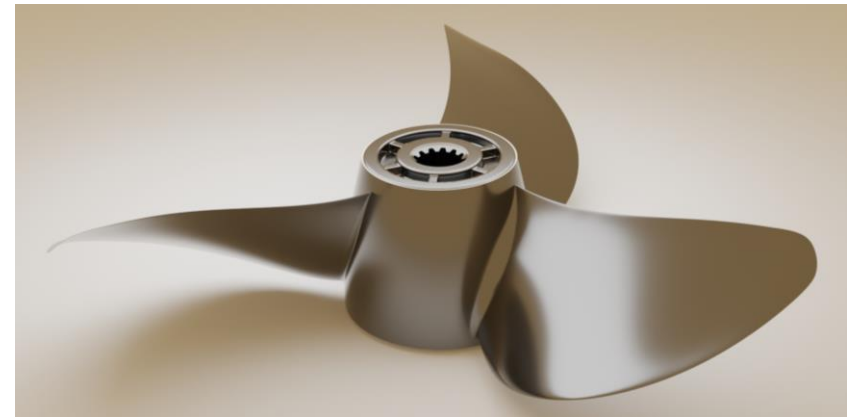
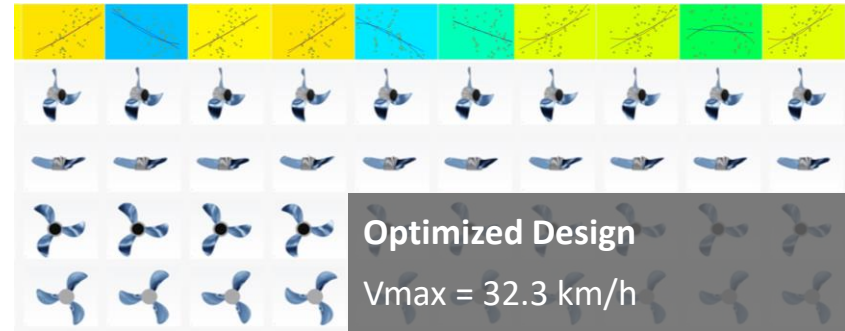
Optimization

Recap

- Resistance Data from CFD analysis of hull
- Added resistance of outboard motor assembly + margin (gears, wind, waves, ...)
- CFD data of propeller in open-water

Procedure

- Simulate at multiple advance coefficients
 - Open-water diagram
 - Thrust and torque vs. speed @ max rpm
 - Match Thrust and Resistance
 - Constrain torque
 - Maximize speed



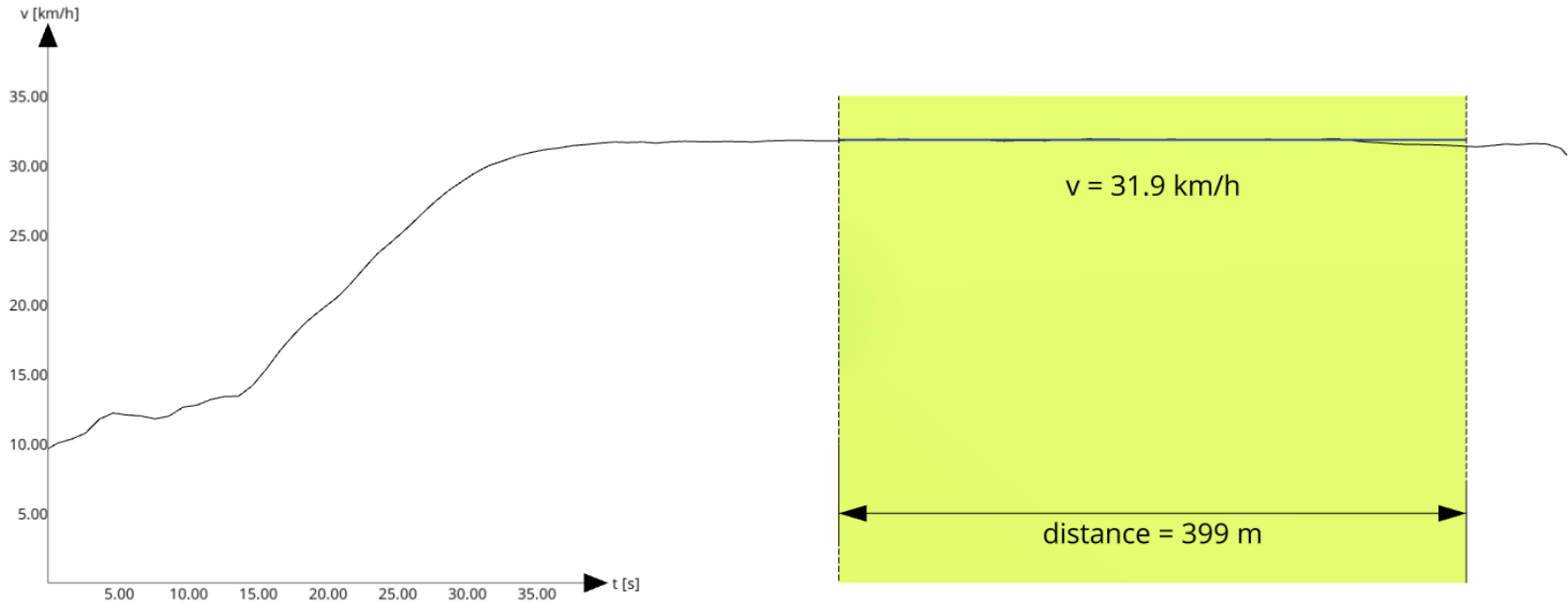
Field Test



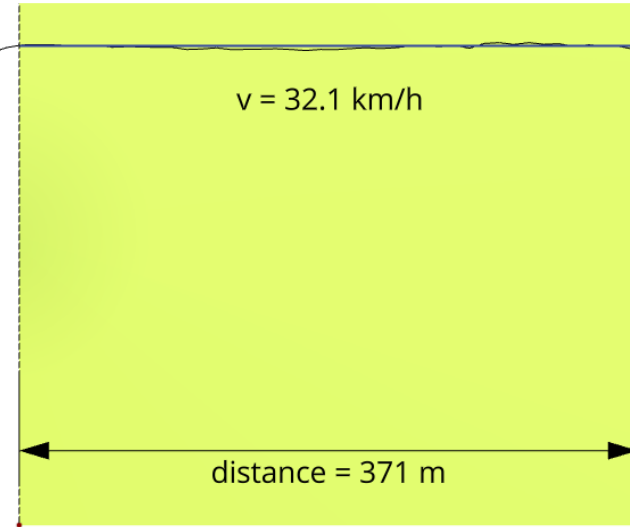
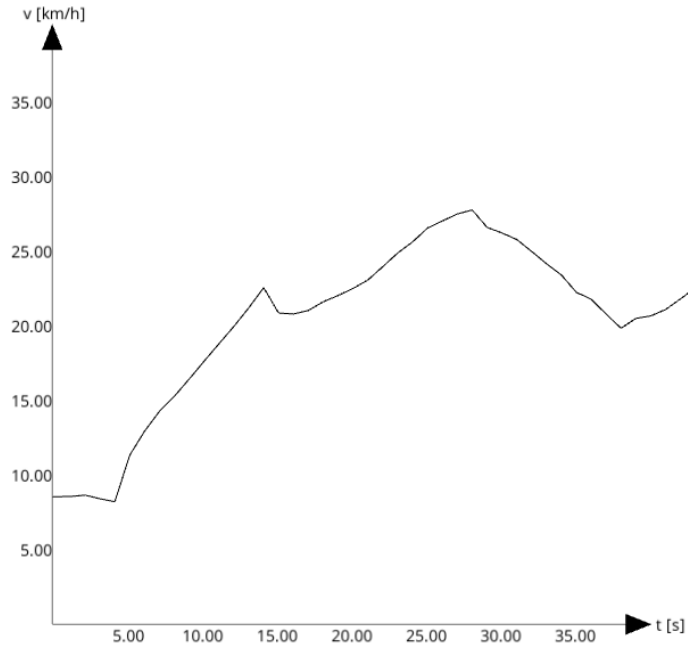
Chiemsee Bavaria, calm water, no wind



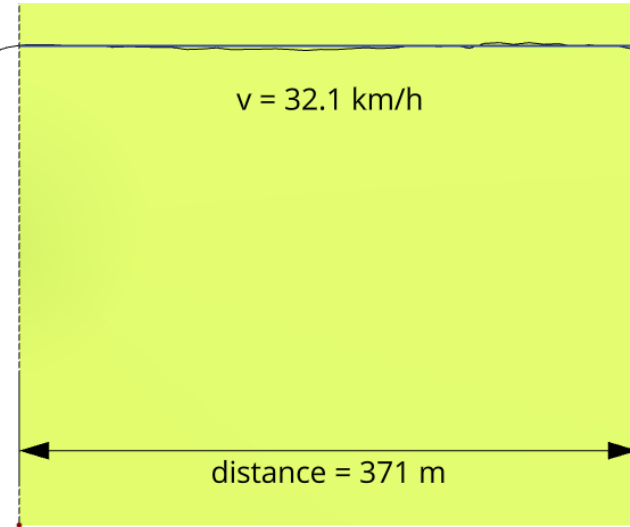
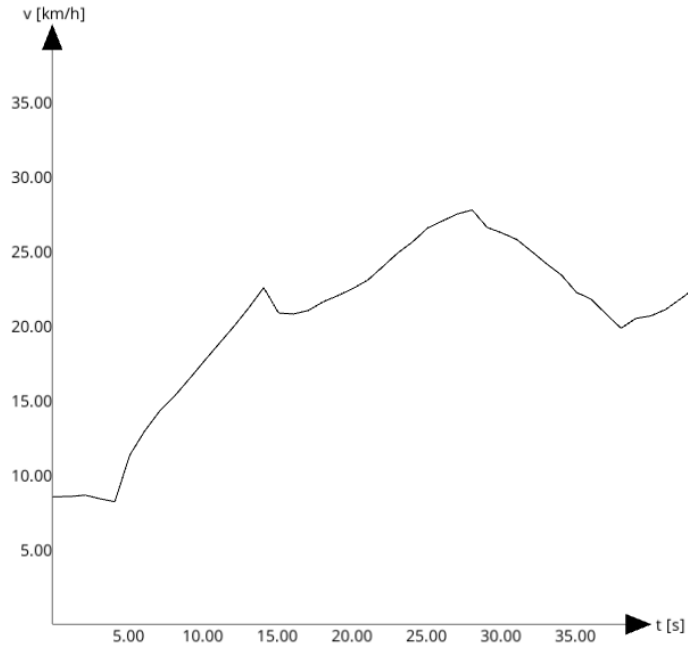
Field Test direction1



Field Test direction2



Field Test direction2







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