MARIN Maritime Research Institute Netherlands

Dynamic Positioning Committee
Marine Technology Society

Minimization of Thruster Dimensions for DP Systems

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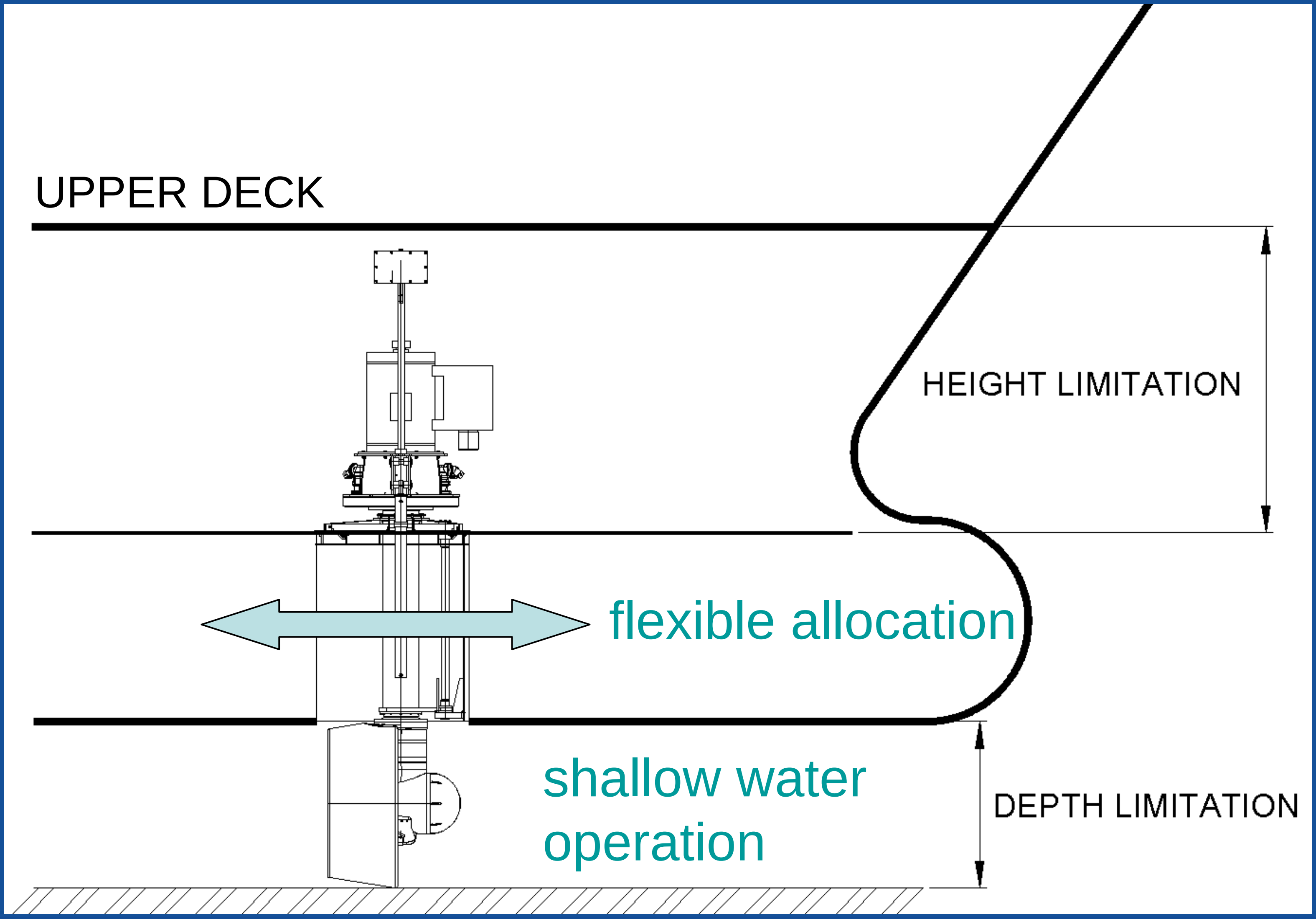
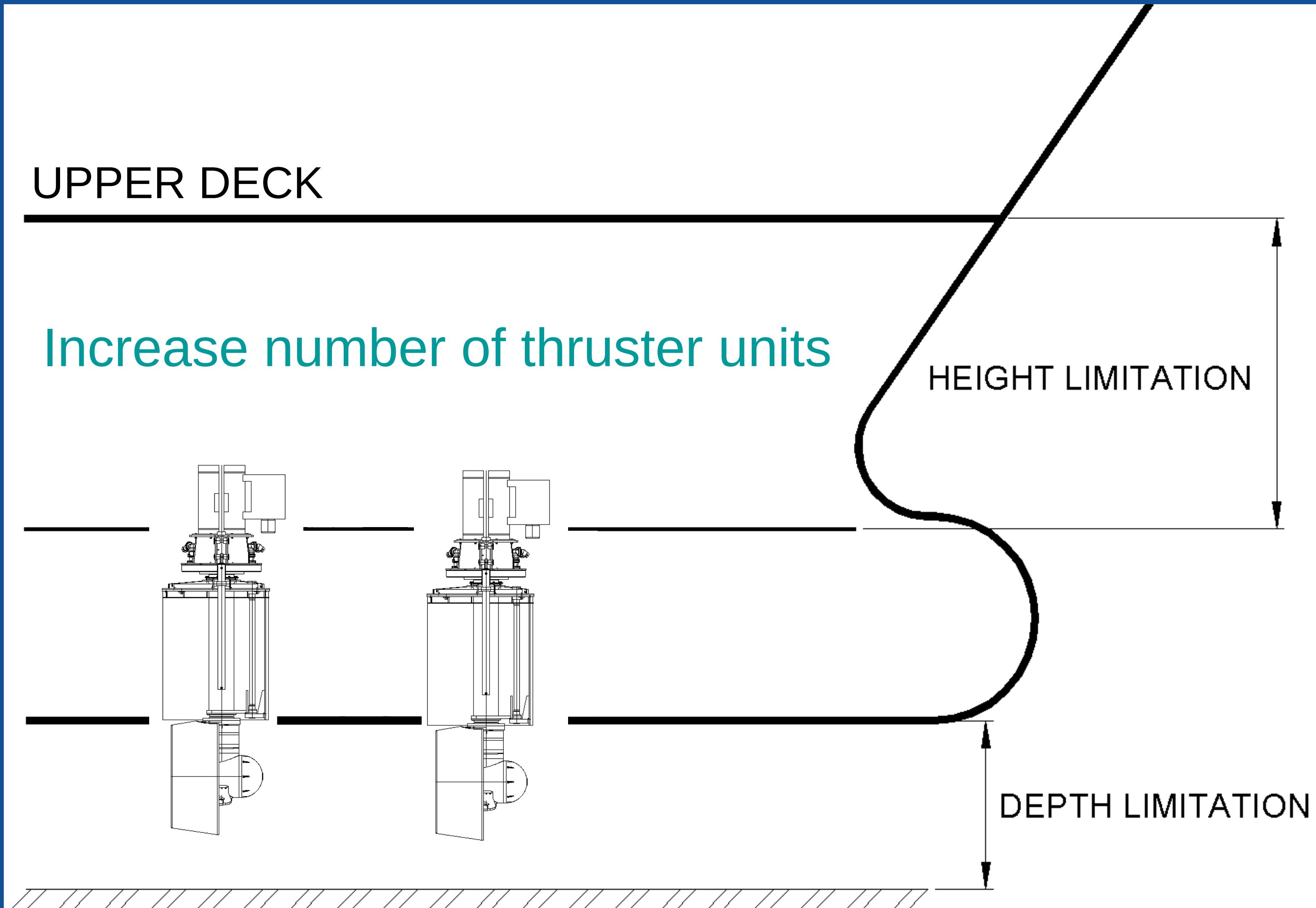
Why minimization?



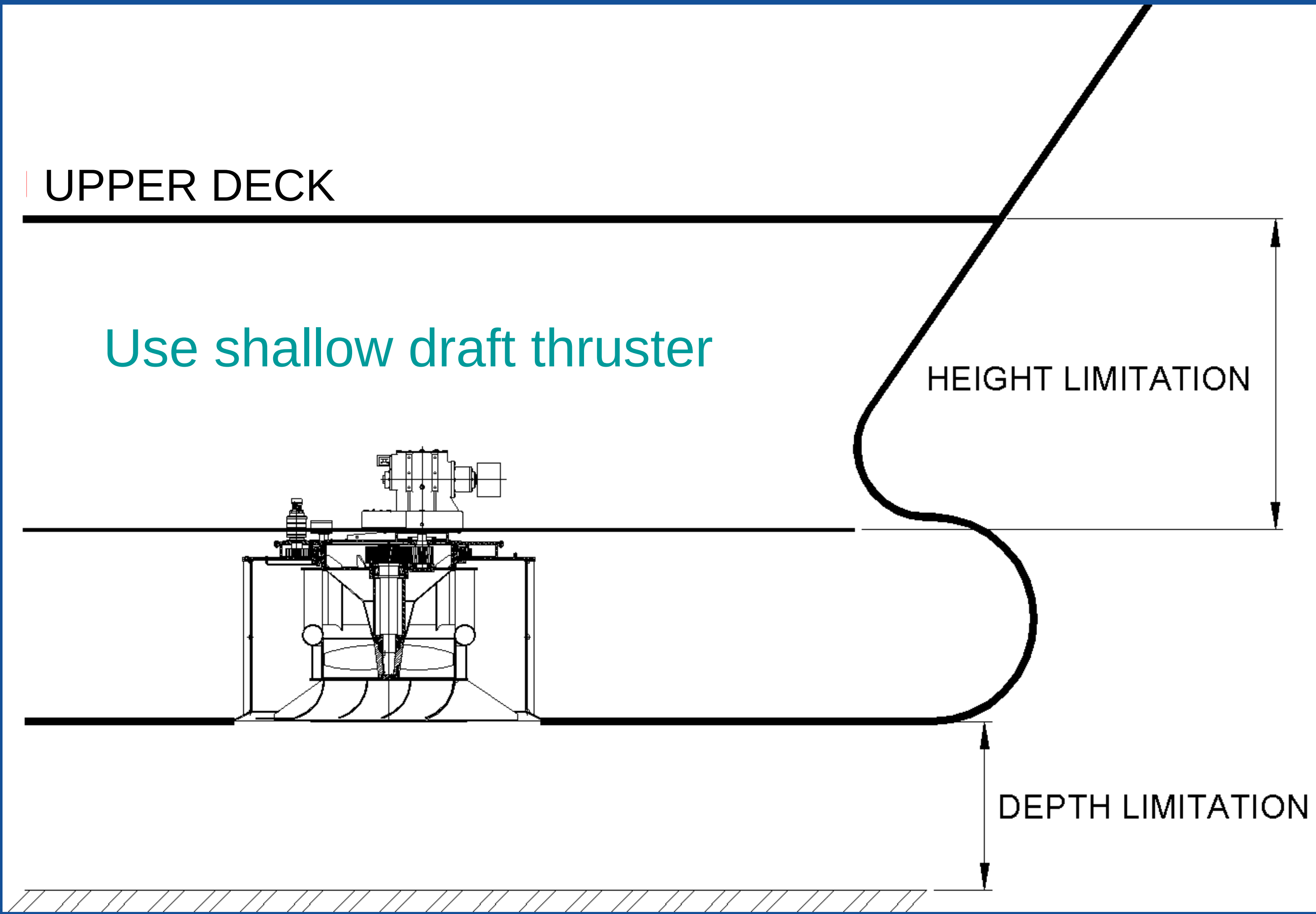
Solution 1

Increase number of thruster units



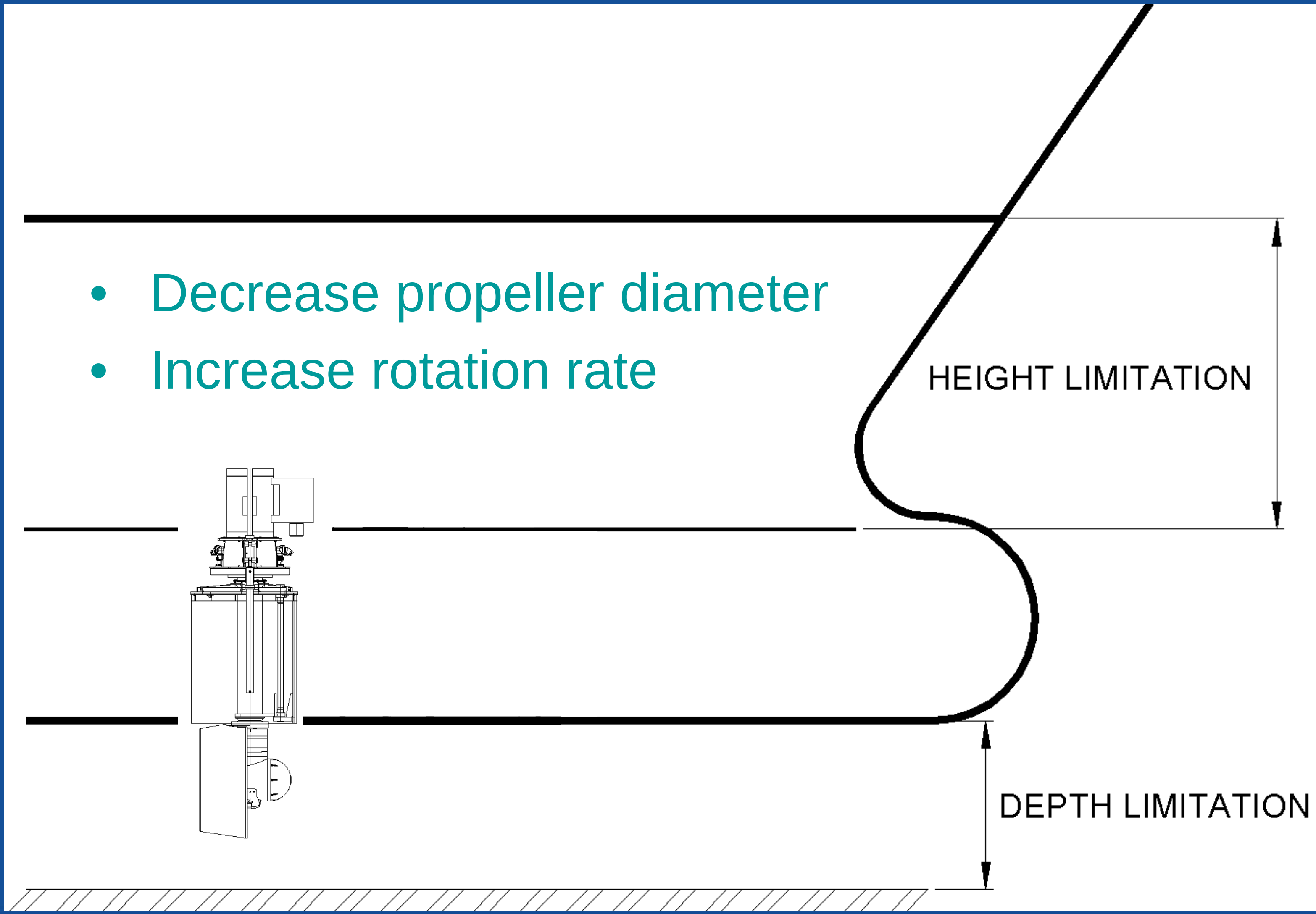
Solution 2

Use shallow draft thruster



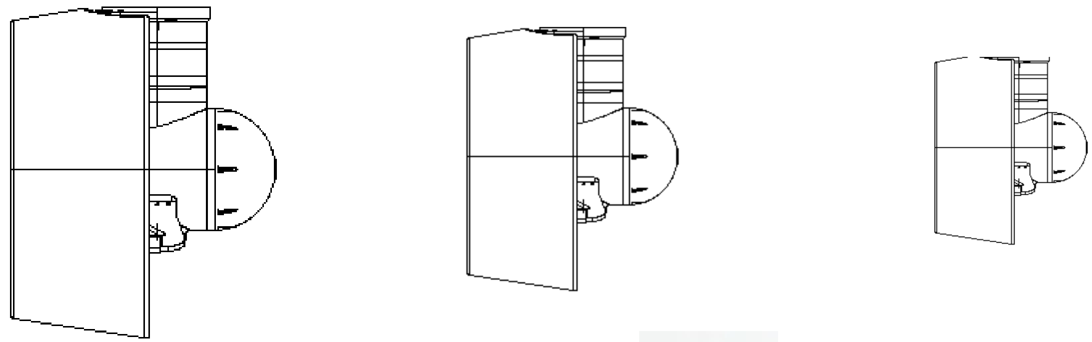
Solution 3

- Decrease propeller diameter
- Increase rotation rate

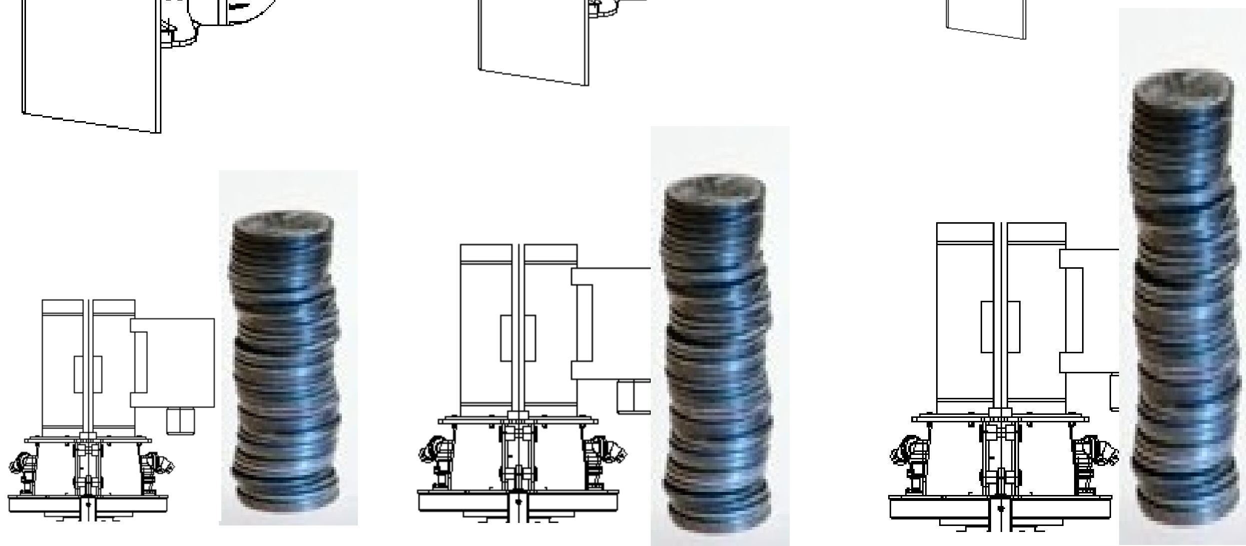


However ...

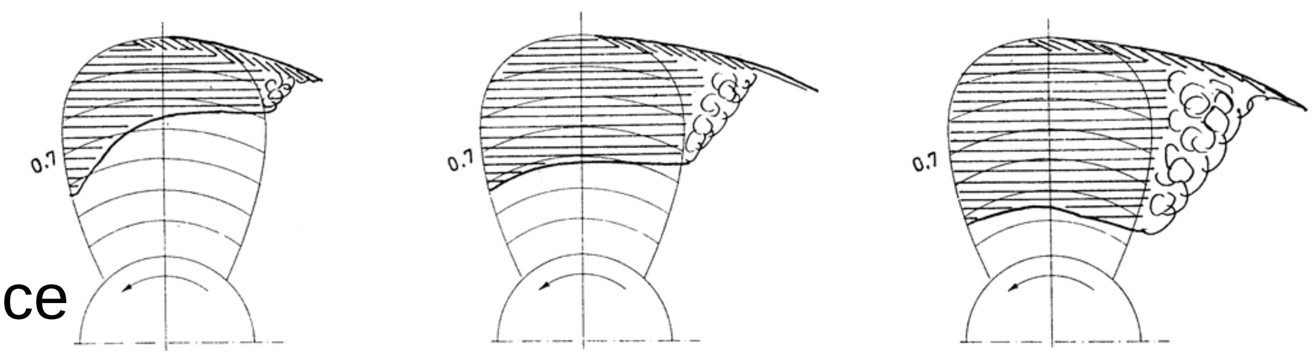
propeller
diameter



power and
cost



cavitation
→erosion
→vibration
→thrust influence



Objective

- What are the limits?
- How small can you make your thruster?
- Rules of thumb: Vtip & P/A rather fuzzy

Therefore:

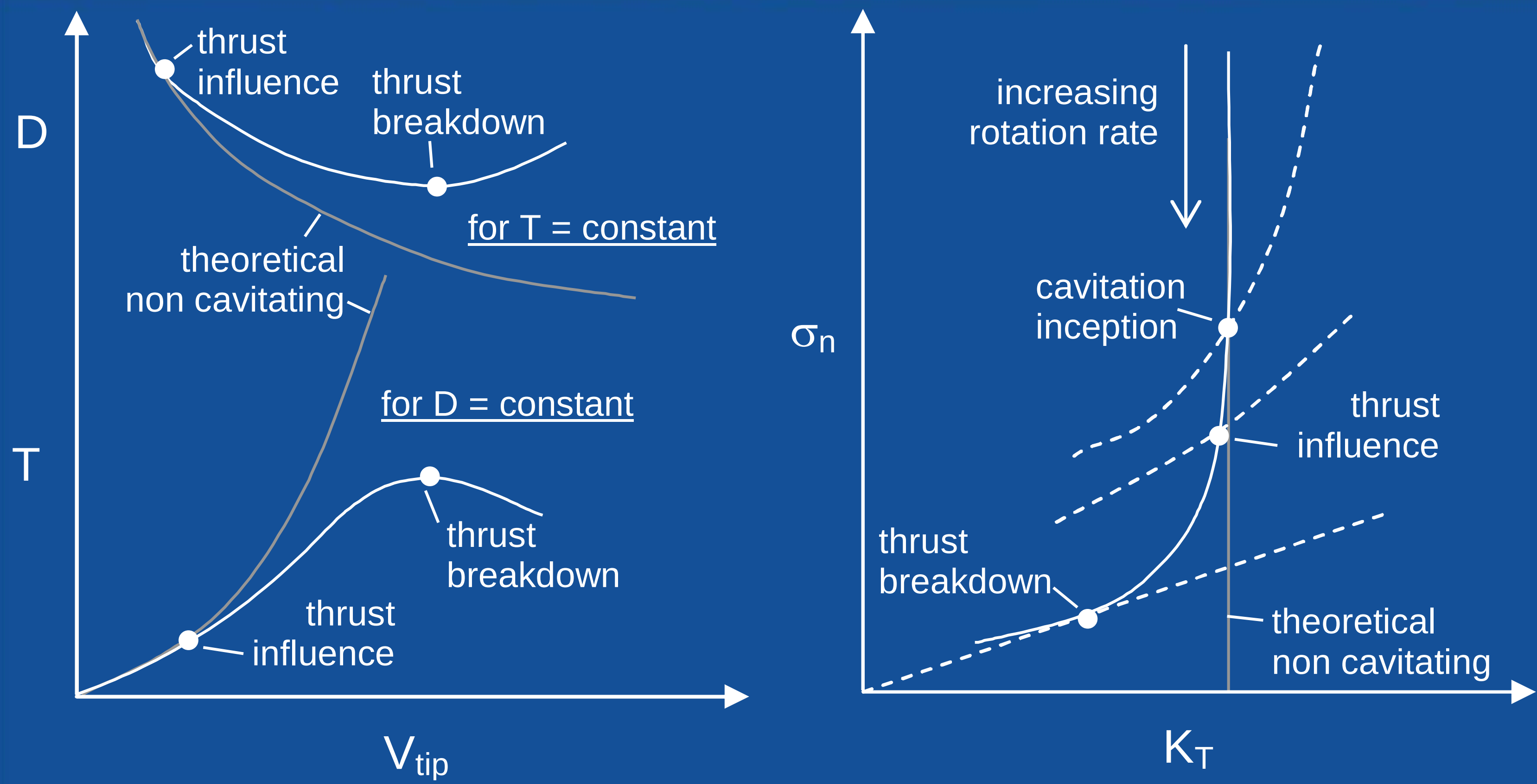
- Investigate by model tests:
  - How propeller design influences cavitation
  - How cavitation influences thrust and power
- Evaluate overall dimensions and costs

Focus on (near) bollard pull condition

Contents

- Maximum thrust density
- Propeller design space
- Thruster design
- Model tests
- Thruster size and cost
- Concluding remarks

Maximum thrust density

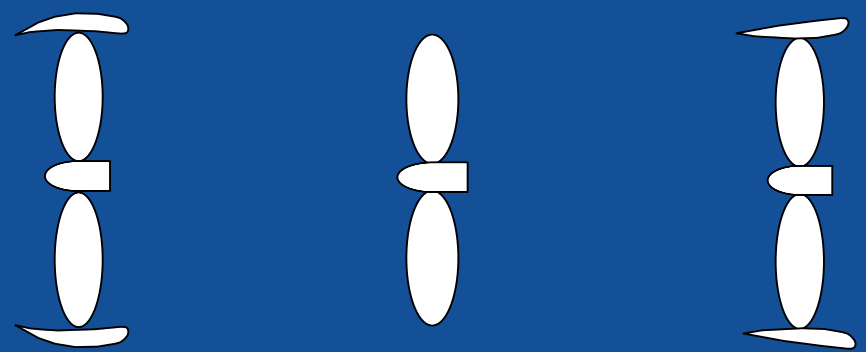


Thrust density: $$\frac{T}{A_0} = \frac{8 \cdot (P_0 + \rho g h - P_v)}{\pi} \cdot \frac{K_T}{\sigma_n}$$

Preliminary design study

Propeller concepts:

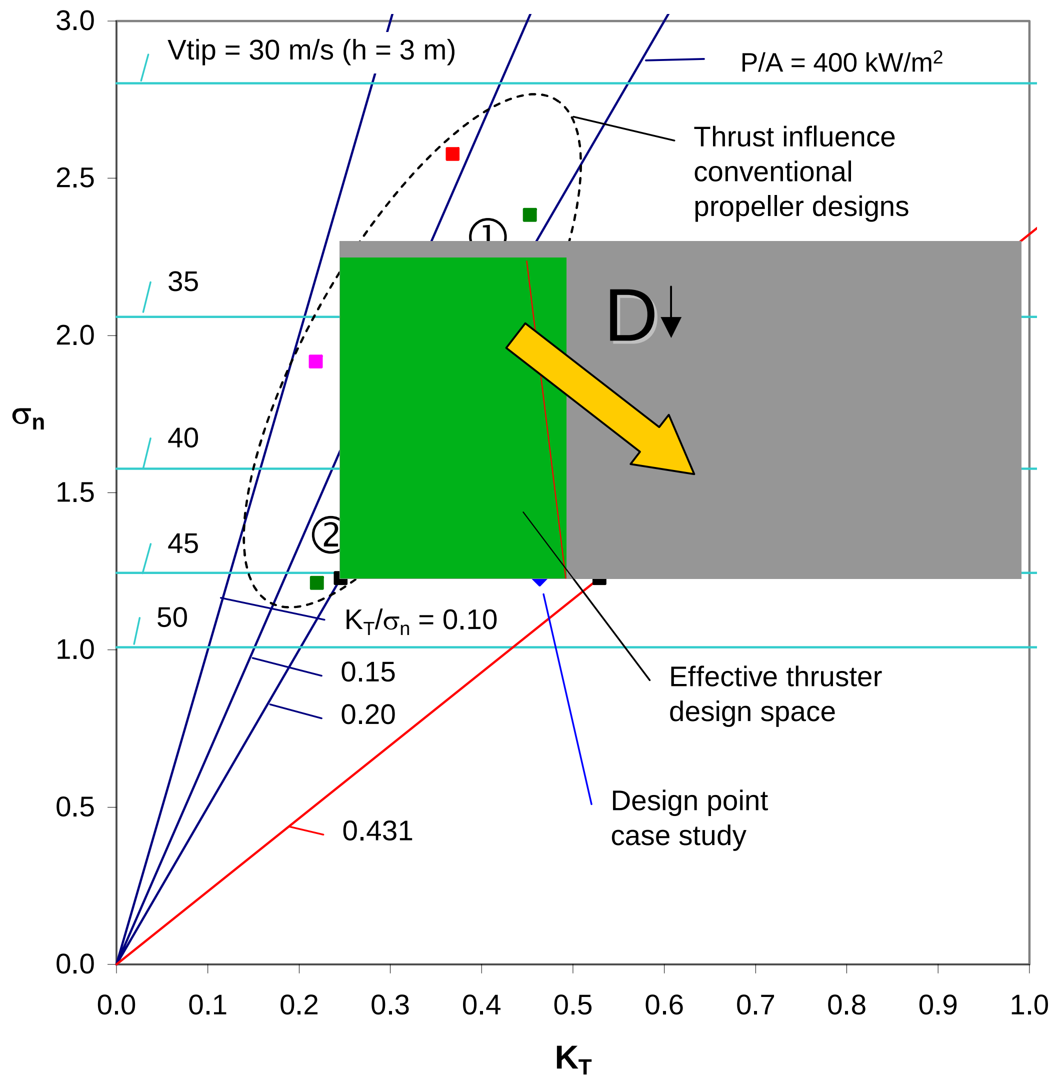
propeller in decelerating nozzle	open propeller	propeller in accelerating nozzle



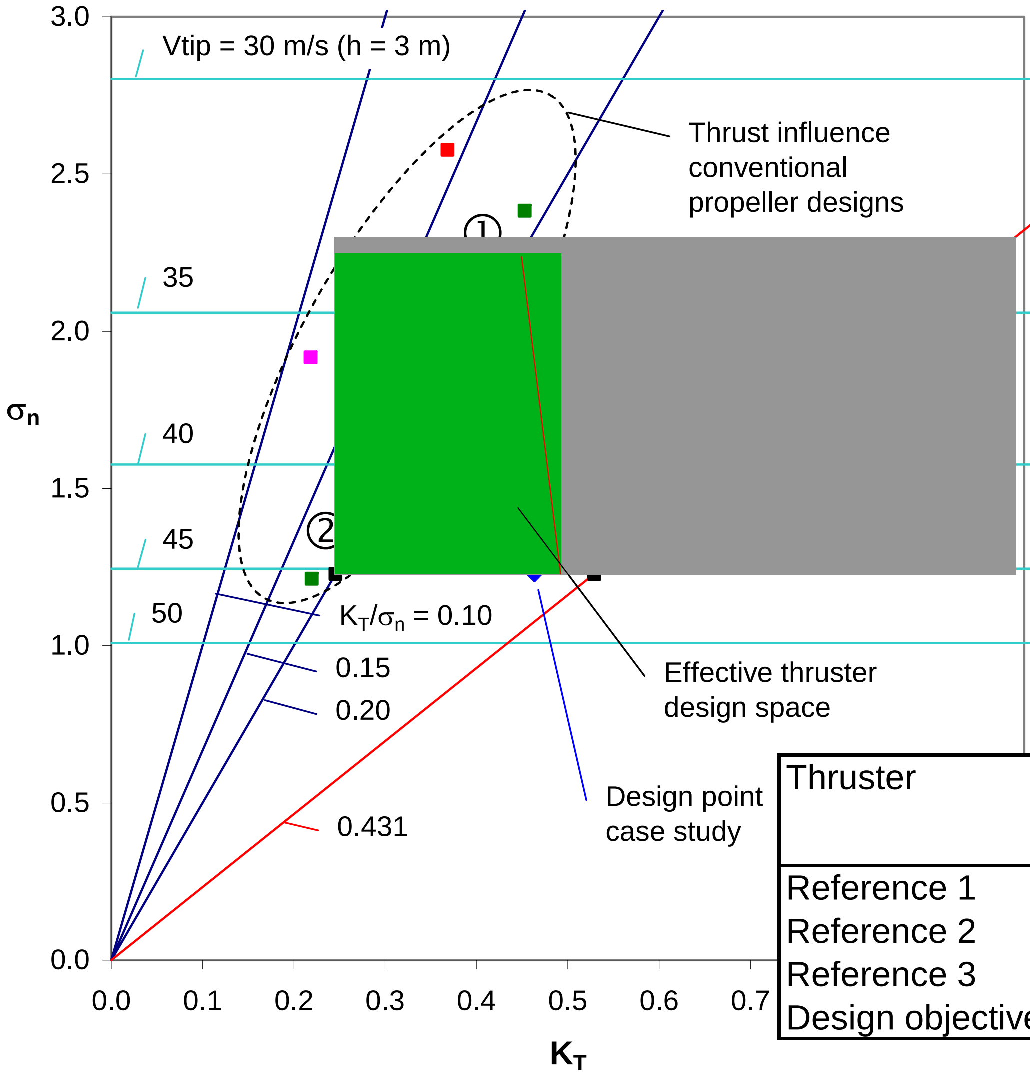
Highest thrust density:

Highest efficiency:

Propeller design space



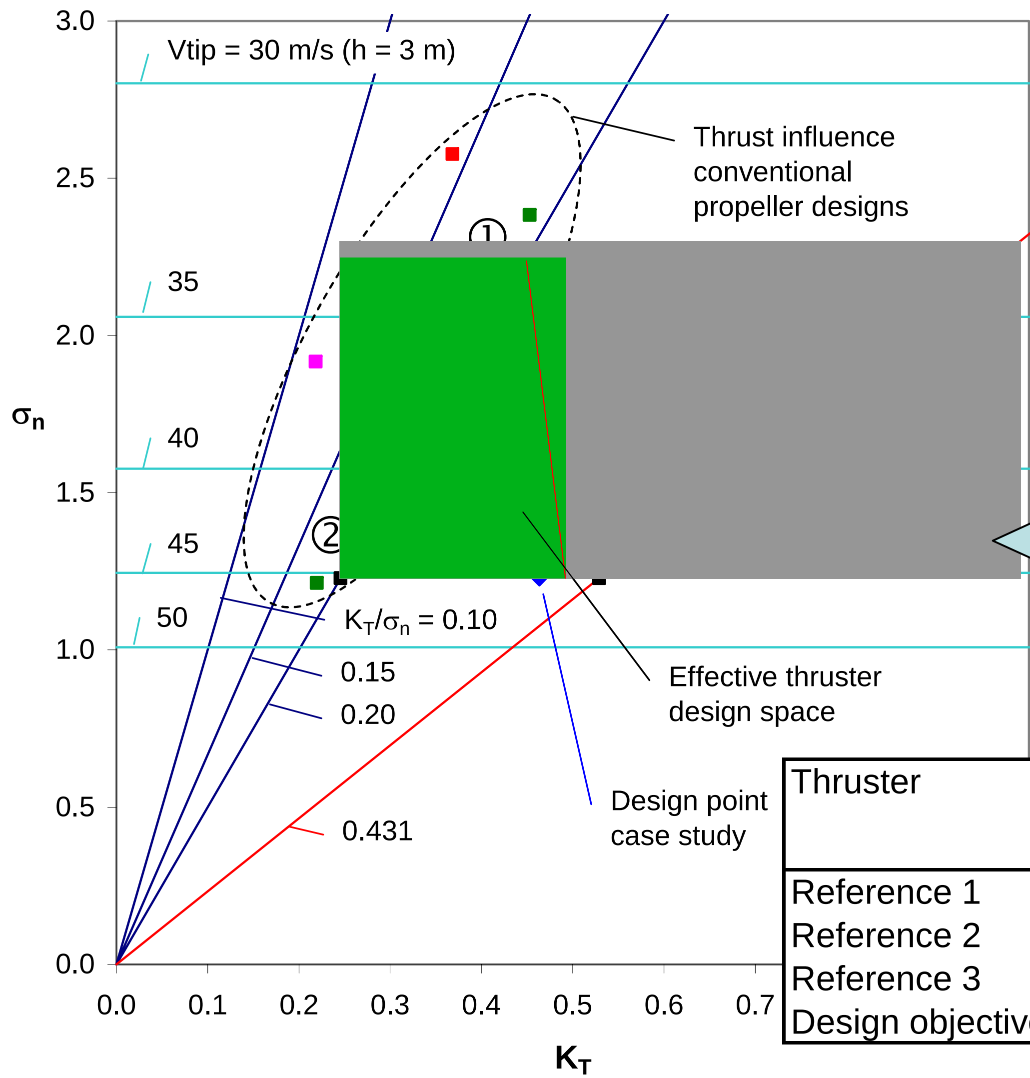
Propeller design space



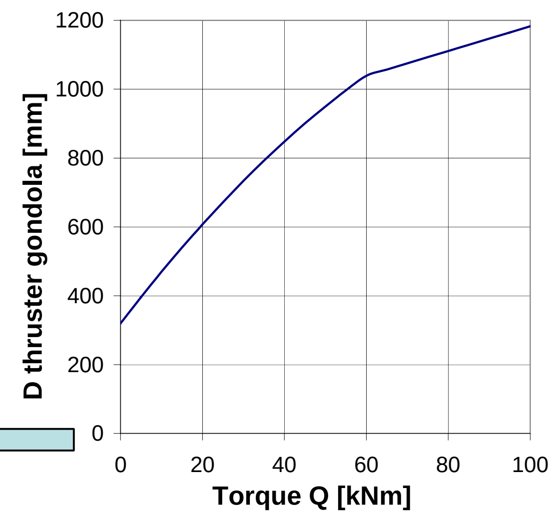
for T = 20 tons:

Thruster	D [m]	P [kW]	Vtip [m/s]	T/P [kg/hp]	T/A [kN/m^2]
Reference 1	1.94	1119	33.5	13.1	67
Reference 2	1.93	1245	45.3	11.8	67
Reference 3	1.32	1642	45.3	9.0	144
Design objective	1.41	1635	45.3	9.0	126

Propeller design space



$D_{gondola} = f(Q)$



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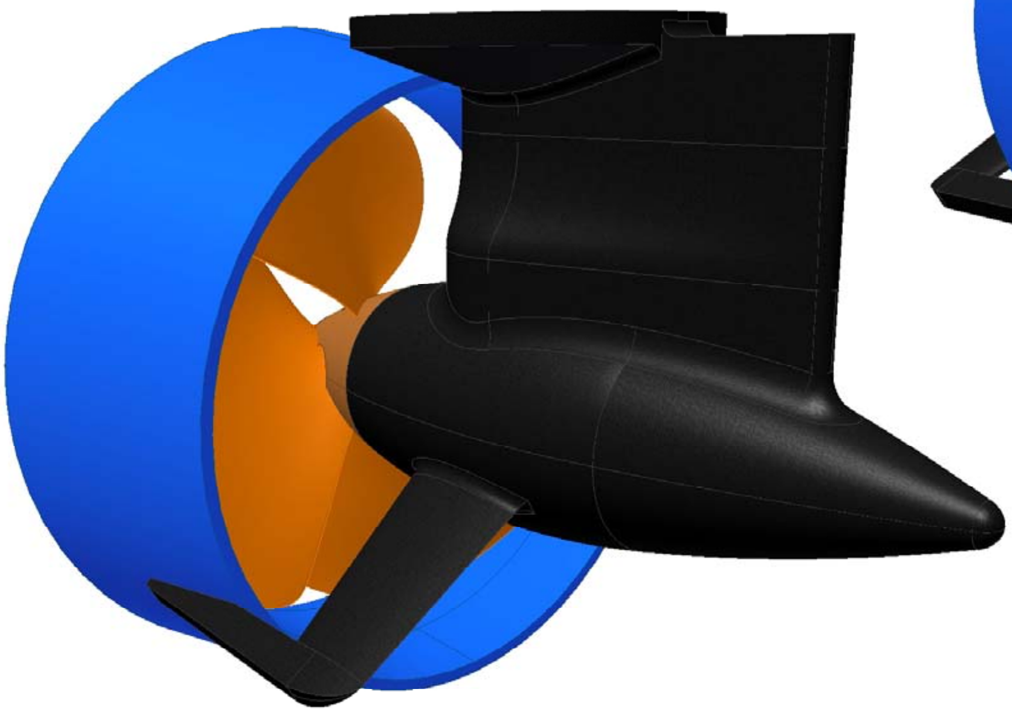
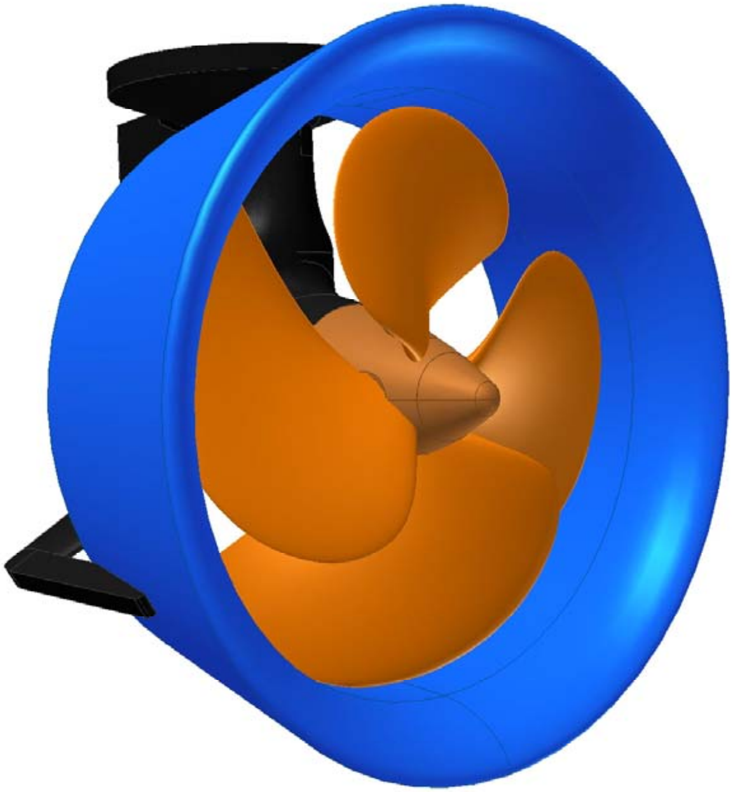
Thruster design

- Pulling propeller for minimum cavitation
- Streamlined housing



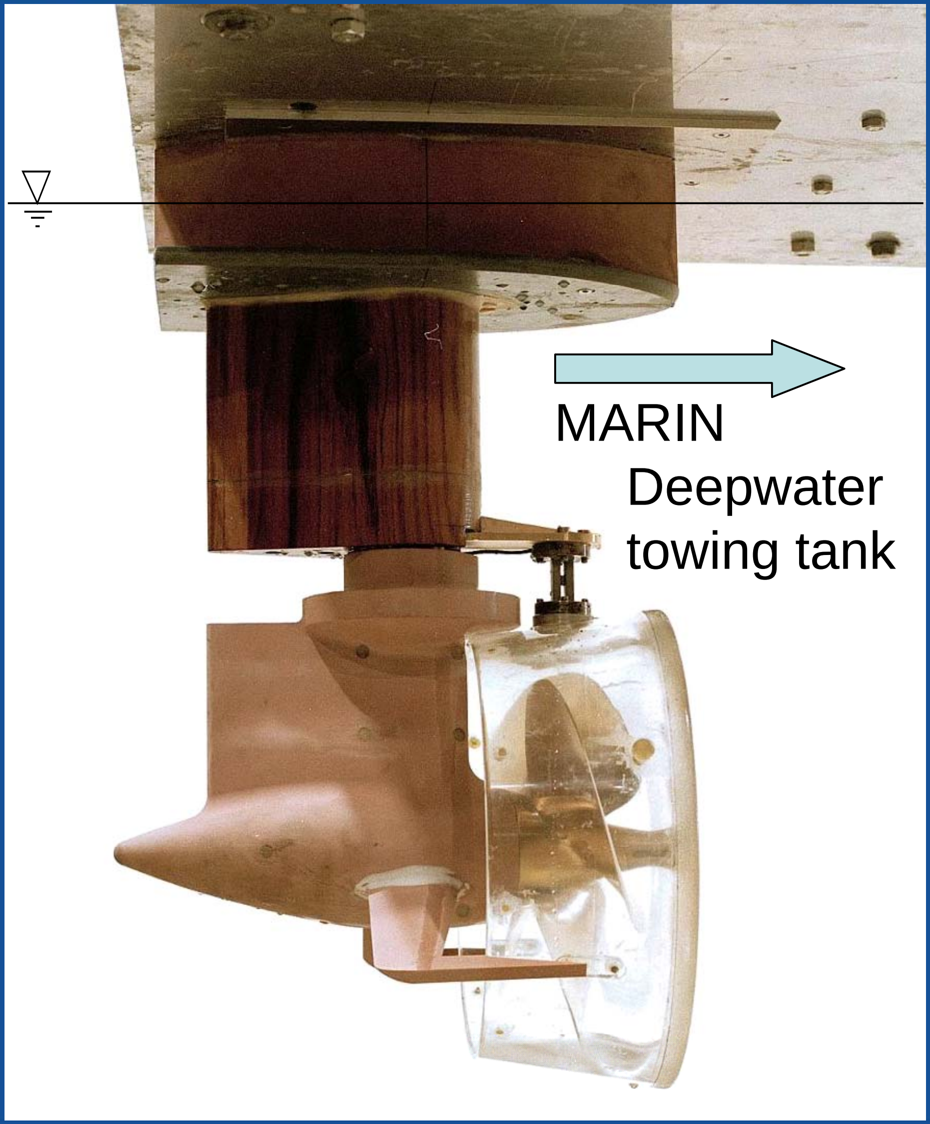


Bollard pull condition

Open water model tests

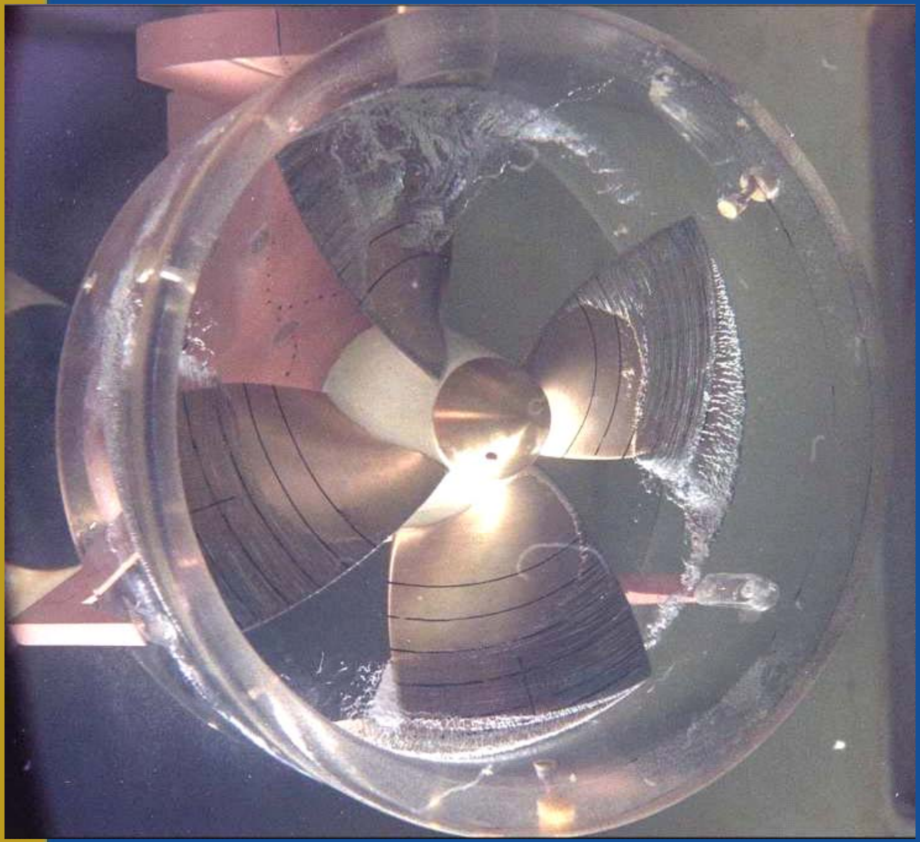
Bollard pull condition
at 20 tons
(without cavitation):

Thruster	P [kW]	Vtip [m/s]	T/P [kg/hp]
Design objective	1635	45.3	9.0
Model test result	1718	44.3	8.6

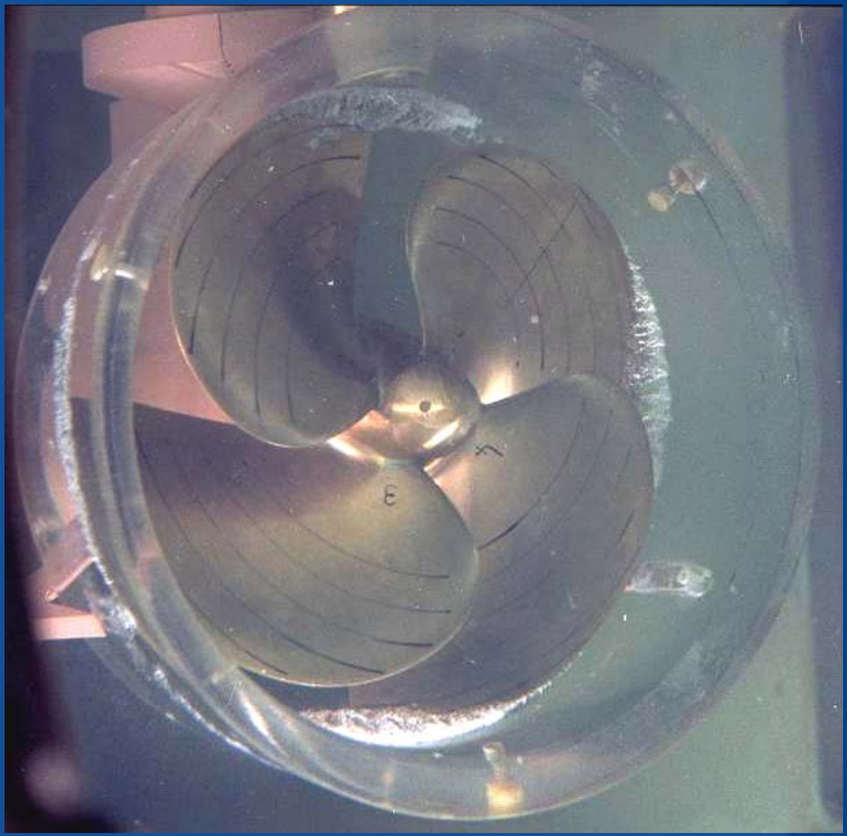


Cavitation observations in CT

at $J = 0.12$, $\sigma_n = 1.5$, $V_{tip} = 42$ m/s



Thruster with Ka 4-70 propeller
at T = 16.8 tons



Thruster with design propeller
at T = 14.8 tons

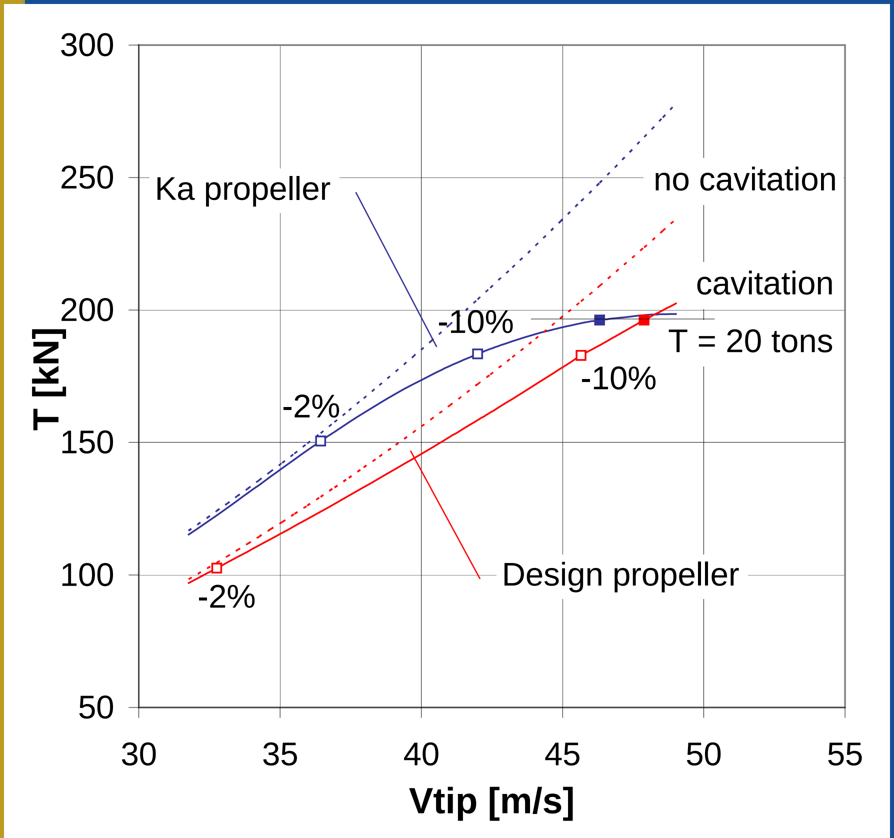
Cavitation observations

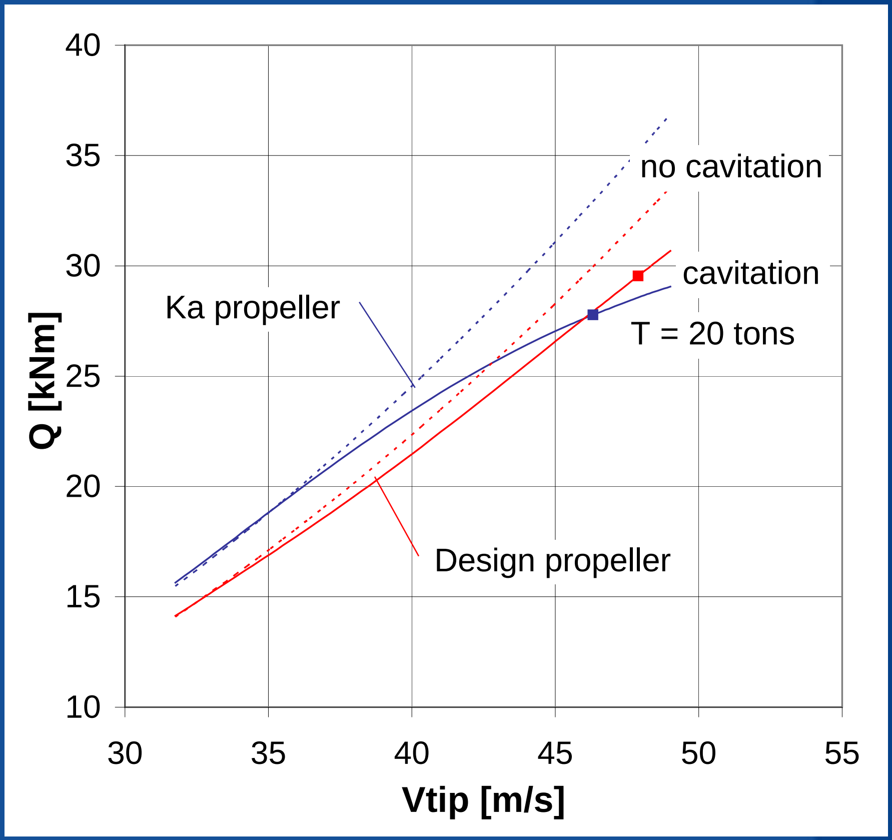
Thruster with Ka 4-70 propeller at T = 18.3 tons (V_{tip} = 47 m/s)

Thruster with design propeller at T = 17.5 tons (V_{tip} = 46 m/s)

Cavitation influence

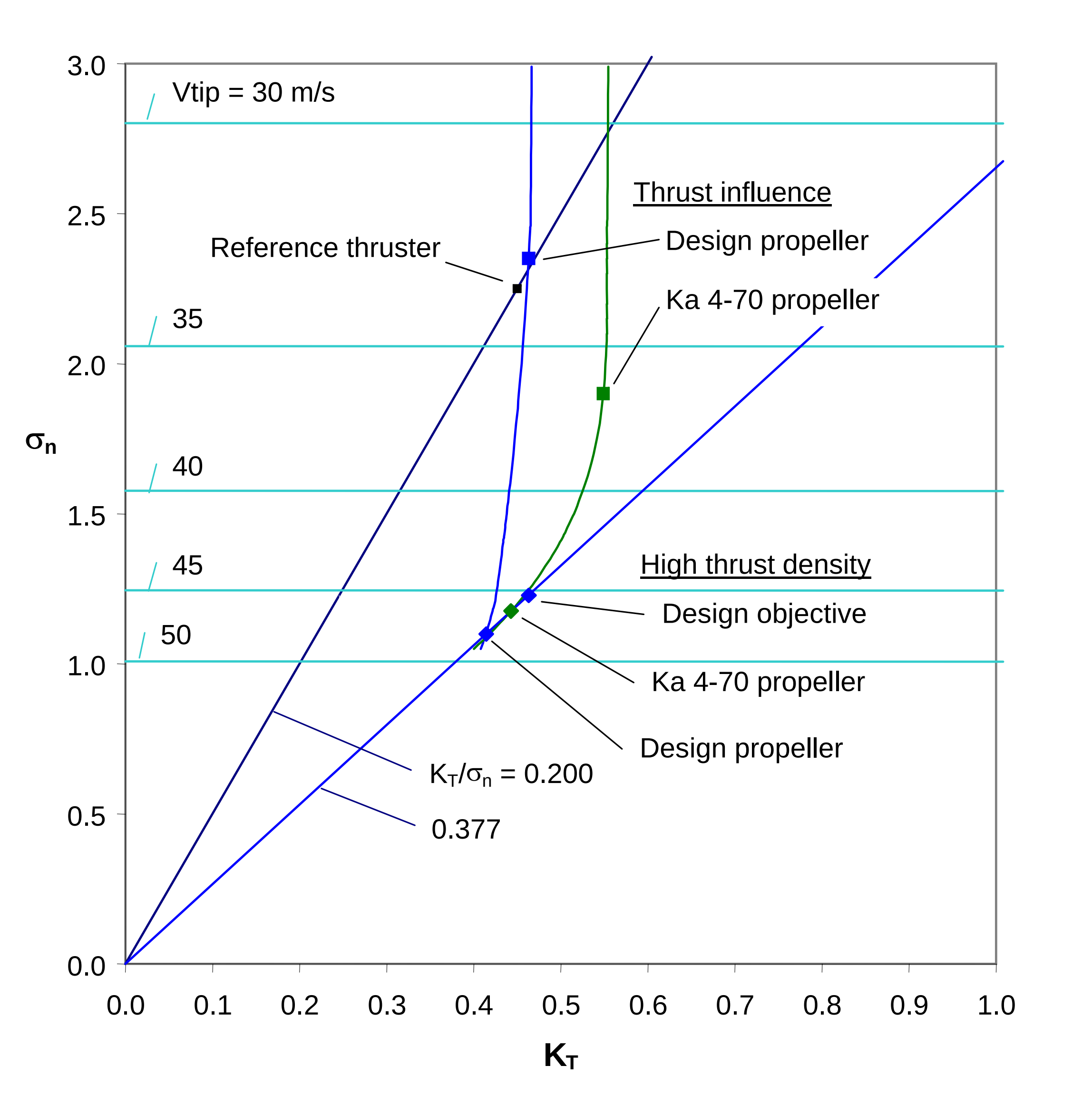
on thrust and torque in bollard pull condition for D = 1.41 m



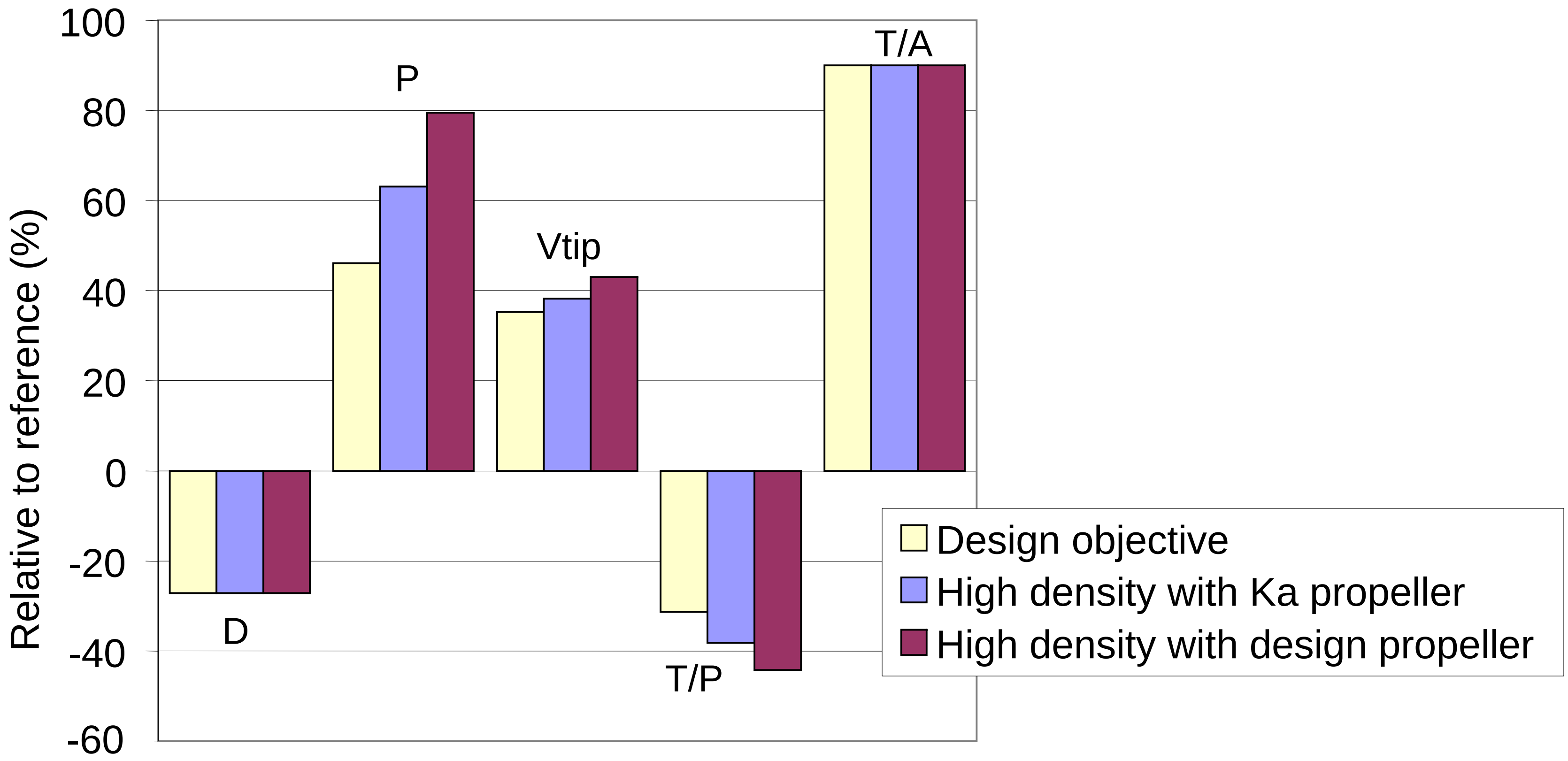


Design propeller is less influenced by cavitation

Comparison in design space

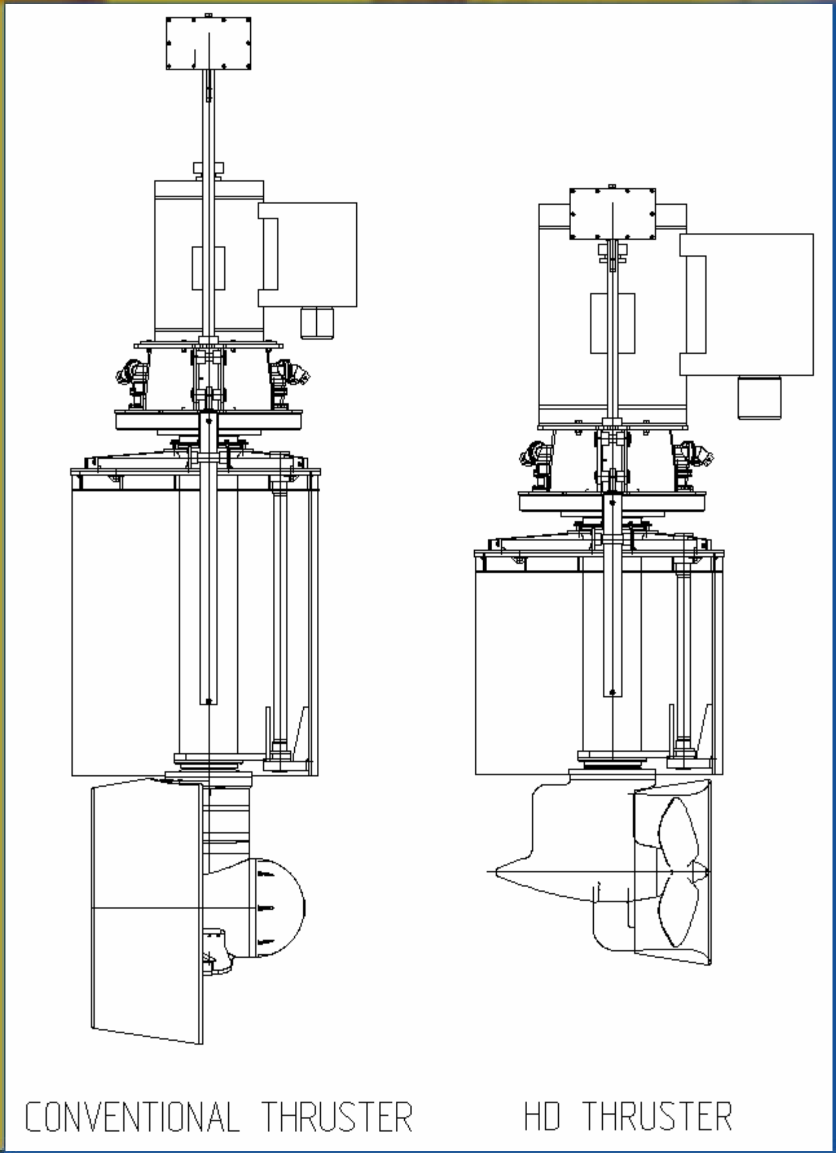


Comparison with reference thruster



Thruster with T = 20 tons	D [m]	P [kW]	Vtip [m/s]	T/P [kg/hp]	T/A [kN/m^2]
Reference	1.94	1119	33.5	13.1	67
Design objective	1.41	1635	45.3	9.0	126
Model tested with Ka propeller	1.41	1825	46.3	8.1	126
Model tested with design propeller	1.41	2009	47.9	7.3	126

High thrust density



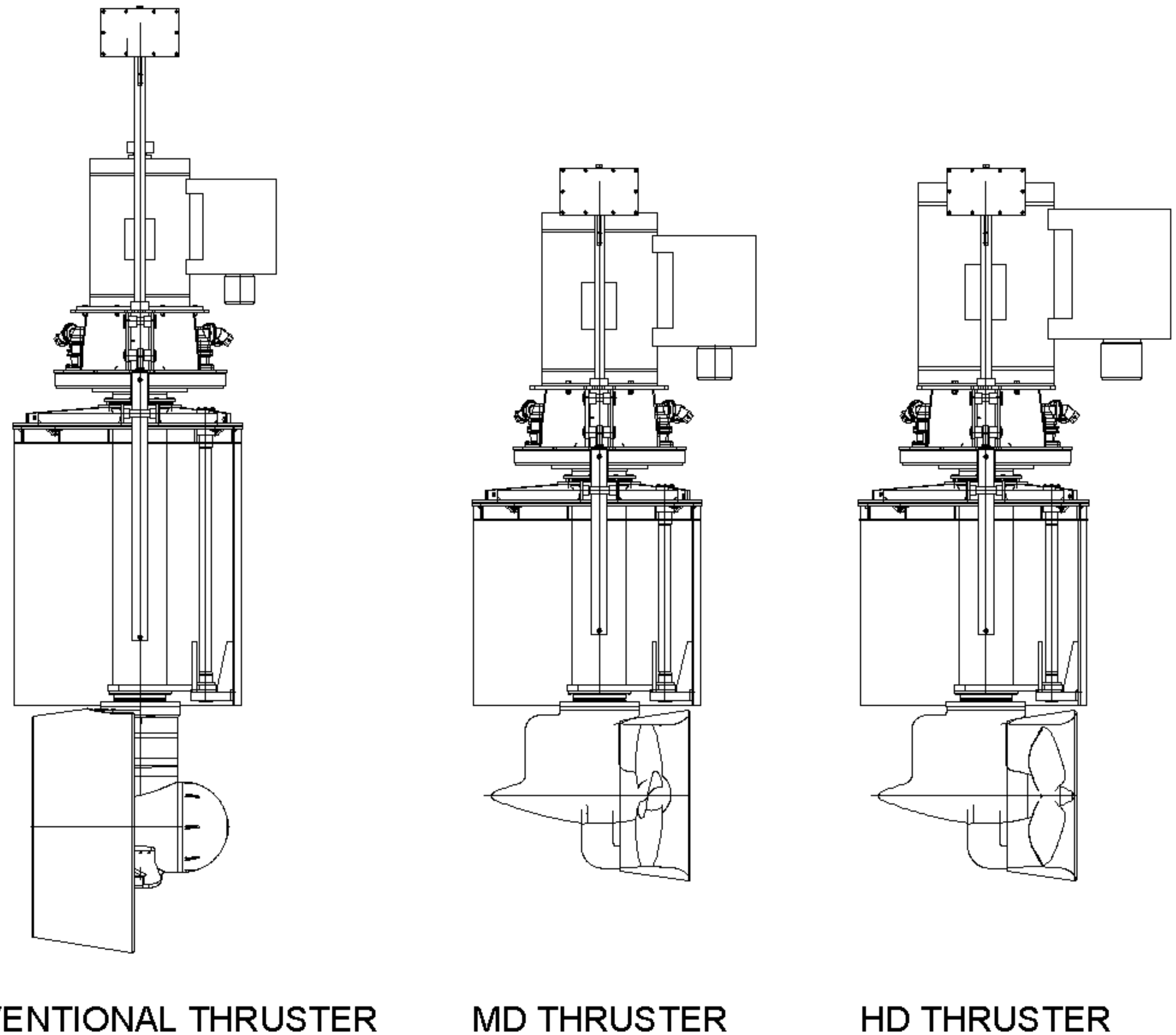
Size:

- only gain outside hull

Cost:

- acquisition 25% increase
- operational about 50% increase

Medium thrust density



Size:

- gain inside and outside hull

Cost:

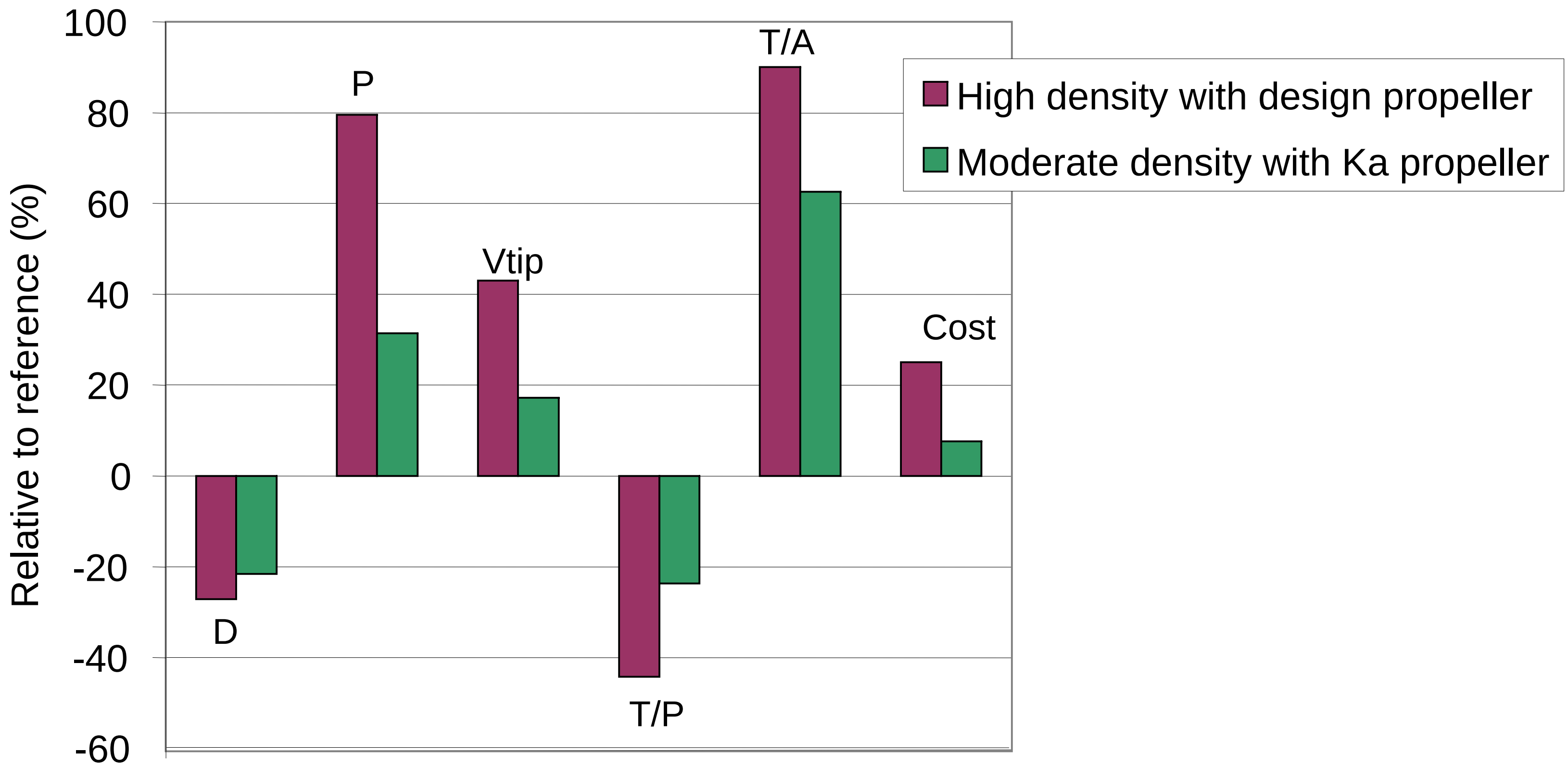
- acquisition 8% increase
- operational about 15% increase

Concluding remarks

- Significant reduction in propeller diameter is possible for thruster with pulling propeller. At cost of significant power increase
- Higher power limits decrease of overall dimensions because of size electric drive system
- Moderate reduction of D_{prop} is advised with inboard and outboard gain in dimensions and moderate extra cost
- Propeller designer may accept limited sheet cavitation as compromise between thrust influence and efficiency

Questions

Medium thrust density (2)



Thruster with T = 20 tons	D [m]	P [kW]	Vtip [m/s]	T/P [kg/hp]	T/A [kN/m^2]
Reference (conventional)	1.94	1119	33.5	13.1	67
MD Thruster with Ka propeller	1.52	1471	39.3	10.0	108
HD Thruster with design propeller	1.41	2009	47.9	7.3	126