

Sustainable Maritime Solution: The Impact of K-Sail Wind-Assisted Propulsion and Propeller Choice

Åsa Windfäll Ph.D. – Solution Owner Ocean Going Vessels, Kongsberg Maritime

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Maritime

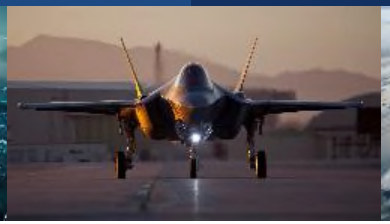
Defence

Digital

Discovery








The KONGSBERG Group

From deep sea to outer-space

14 629 employees

40 countries

48,8 BNOK revenue

Official numbers from the KONGSBERG Q4 2024 Report

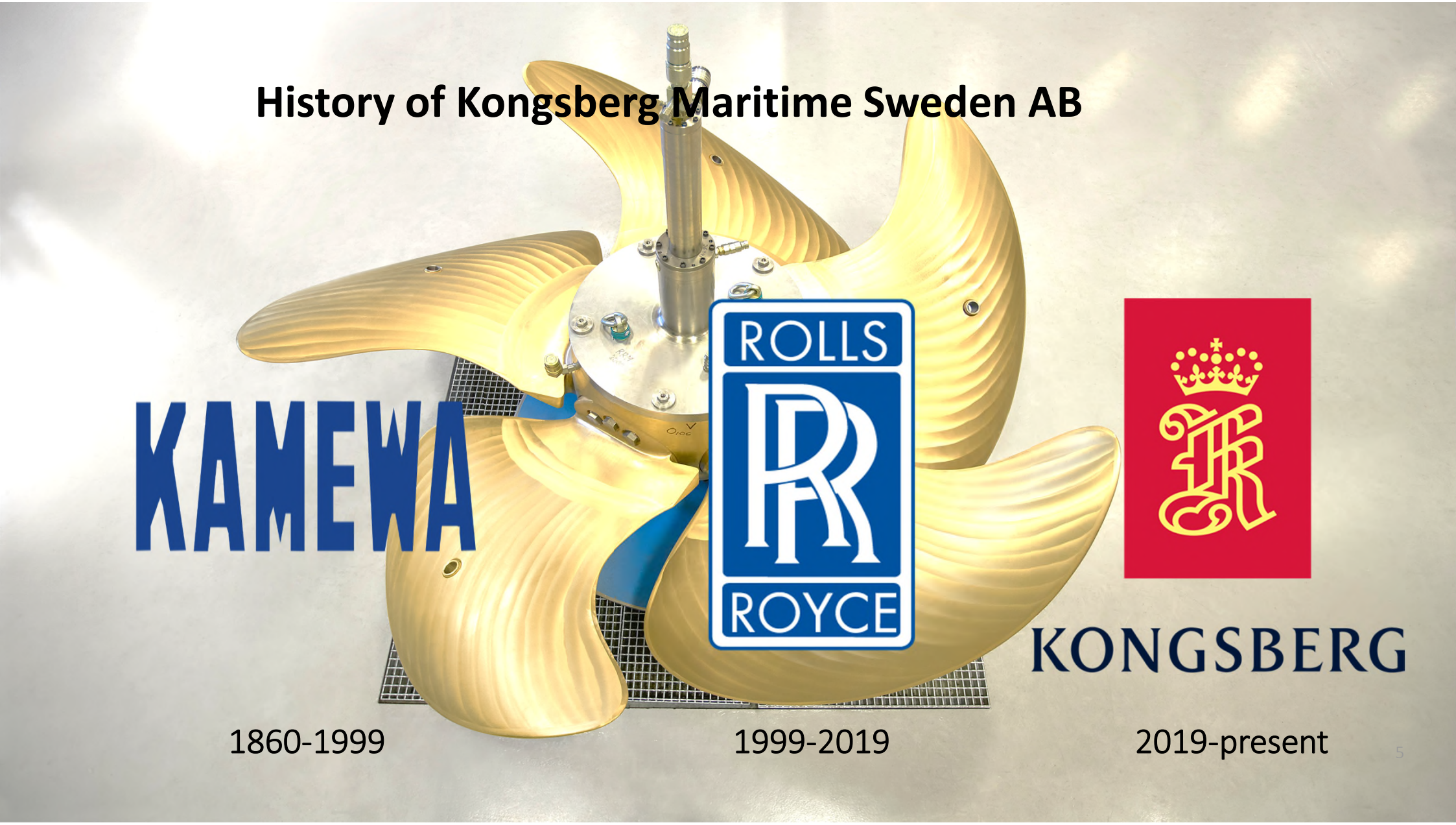
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Global reach,
local impact



Global reach, local impact

History of Kongsberg Maritime Sweden AB



KAMEWA

1860-1999

ROLLS ROYCE

1999-2019

KONGSBERG

2019-present

Kongsberg Hydrodynamic Research Center

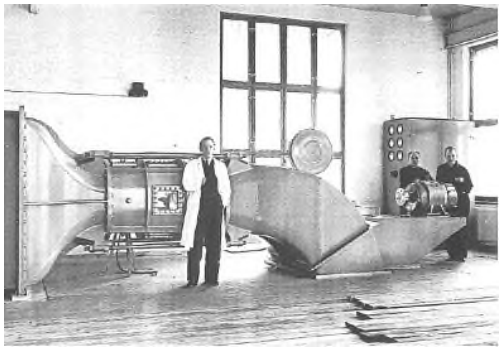
More than 100 years of experience



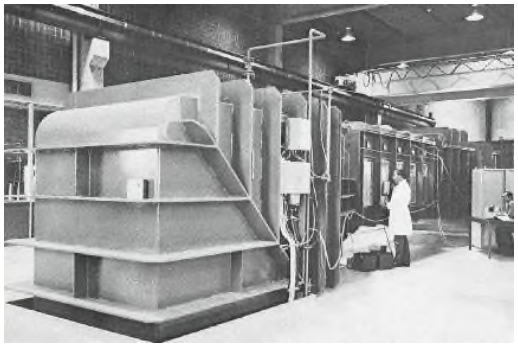
The first turbine test station at Björklundsgården



Interior from the first test station with it's chief engineer



Hans Edstrand in front of the first cavitation tunnel, 1942



The "new" KMW Marine laboratory taken into operation 1971



Kongsberg Hydrodynamic Research Centre today

1906	Outdoor turbine test station
1914	Indoor turbine laboratory
1923	Cavitation laboratory for turbines
1942	Cavitation tunnel for propellers
1971	The "new" KMW Marine Laboratory

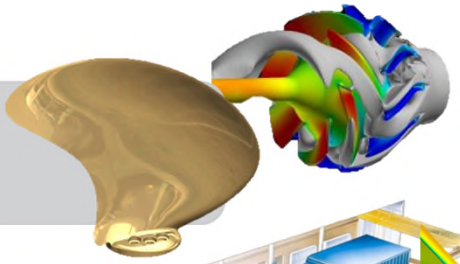


KONGSBERG
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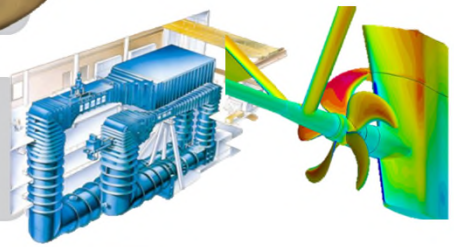
Kongsberg Hydrodynamic Research Centre

Kristinehamn, Sweden

Hydrodynamic Design
- Efficiency
- Vibration & Noise



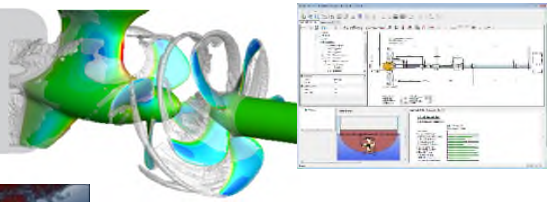
Hydrodynamic Analysis
- Numerical simulations (CFD)
- Model & Full-scale testing



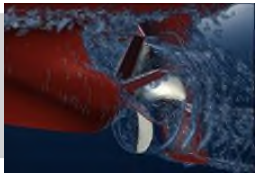
Sales & Customer support
- Customer presentations
- Support to sales engineers



Product & Methods development
- Product & Hydrodynamic R&D
- Sales & Design methods



Hydrodynamic research
- System performance
- Cavitation & Noise



Challanges in the maritime sector

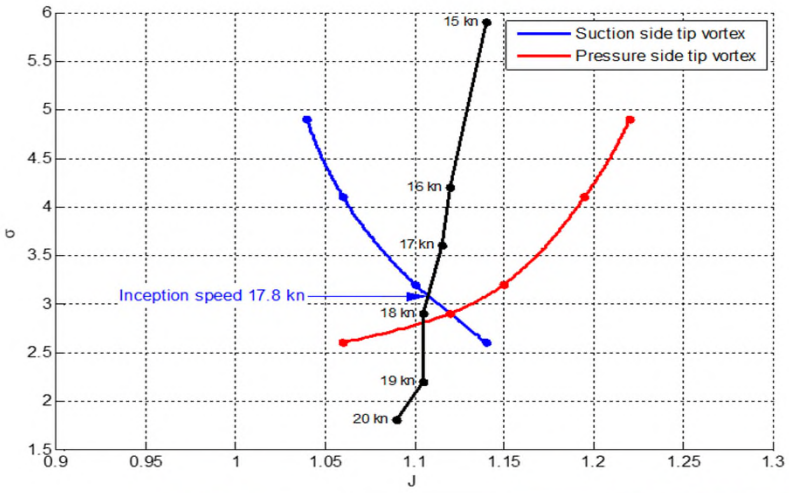
- Climate change mitigation, energy efficiency, reduce fuel consumption
- Reduce underwater radiated noise (URN)
- Maneuvering and course-keeping in rough seas

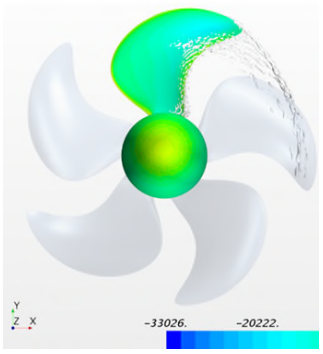
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Underwater Radiated Noise (URN)

History

- Historically the demand for limited Underwater Radiated Noise has been exclusively requested by the naval segment
- In an operating condition where the propeller cavitates, this is the dominating noise source for the ship.
- For surface ships a propeller without cavitation is considered silent
- Silent propellers has been designed analysing Cavitation Inception Speed (CIS)
- Once delivered and tested the feedback from navies regarding detailed full scale URN is limited due to national security.







Underwater Radiated Noise (URN)

Today

- The number of commercial vessels built each year with a notation related to URN is increasing
- Some of the most strict classification URN requirements demands ”navy type” design philosopy
- Commercial projects gives Kongsberg the possibility to obtain full scale data



Vessel name	**MS MARJATA**
IMO	9648659
Design	LMG; Research & Explor.
Yard	STX OSV Langsten, H.777
Owner	FLO – Norway
Delivery	2013
Type	Twin Screw Promas
Propeller	CPP
Material Hub	NiAl Bronze
Material Blade	NiAl Bronze
Notation	Silent R
Service Speed	18.0 Knots



Vessel name	**REV OCEAN**
IMO	9840037
Design	Vard 6 16, Research exploration
Yard	Vard Brattvaag, H.884
Owner	Rev Ocean
Delivery	2019/20
Type	Twin screw Promas
Propeller	5 bladed CPP 102A, Dia 3.8 m
Material Hub	NiAl Bronze
Material Blade	NiAl Bronze
Notation	Silent R
Service Speed	17.0 Knots



Vessel name	**BELGICA**
IMO	9871294
Design	UT 844 WP, Oceanographic
Yard	Freire Shipyard, H.723
Owner	Government of Belgium
Delivery	2019/20
Type	Twin screw Promas
Propeller	5 bladed FPP, Dia 3.3 m
Material Hub	NiAl Bronze
Material Blade	NiAl Bronze
Notation	Silent R
Service Speed	14.0 Knots



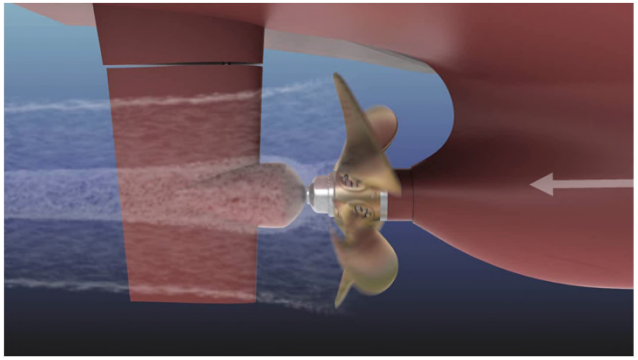
Vessel name	**SIR DAVID ATTENBOROUGH**
IMO	9798222
Design	UT 851, Research
Yard	Cammell Laird, H.1390
Owner	NERC
Delivery	2017
Type	Twin Screw Promas
Propeller	5 bladed CPP 157A, Dia 4.5 m
Material Hub	NiAl Bronze
Material Blade	Stainless Steel
Notation	Silent R
Service Speed	13 Knots

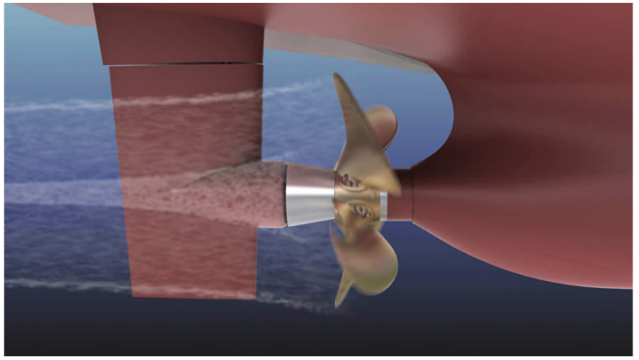


Vessel name	-
IMO	-
Design	
Yard	Damen Schelde Naval Shipb
Owner	Australian Antarctic, environm
Delivery	
Type	Twin Screw
Propeller	4 bladed CPP 194A, Dia 5.65 m
Material Hub	NiAl Bronze
Material Blade	Stainless Steel
Notation	Silent R
Service Speed	16 Knots

Imporoved Energy Efficiency and Manoeuverability

PROMAS - Integrated design of Propeller & Rudder





Typically 3-6% improved efficiency

Reduced pressure pulses (25%)
Improved Manoeuvrability
One single supplier & designer

Rolls-Royce data-strictly private

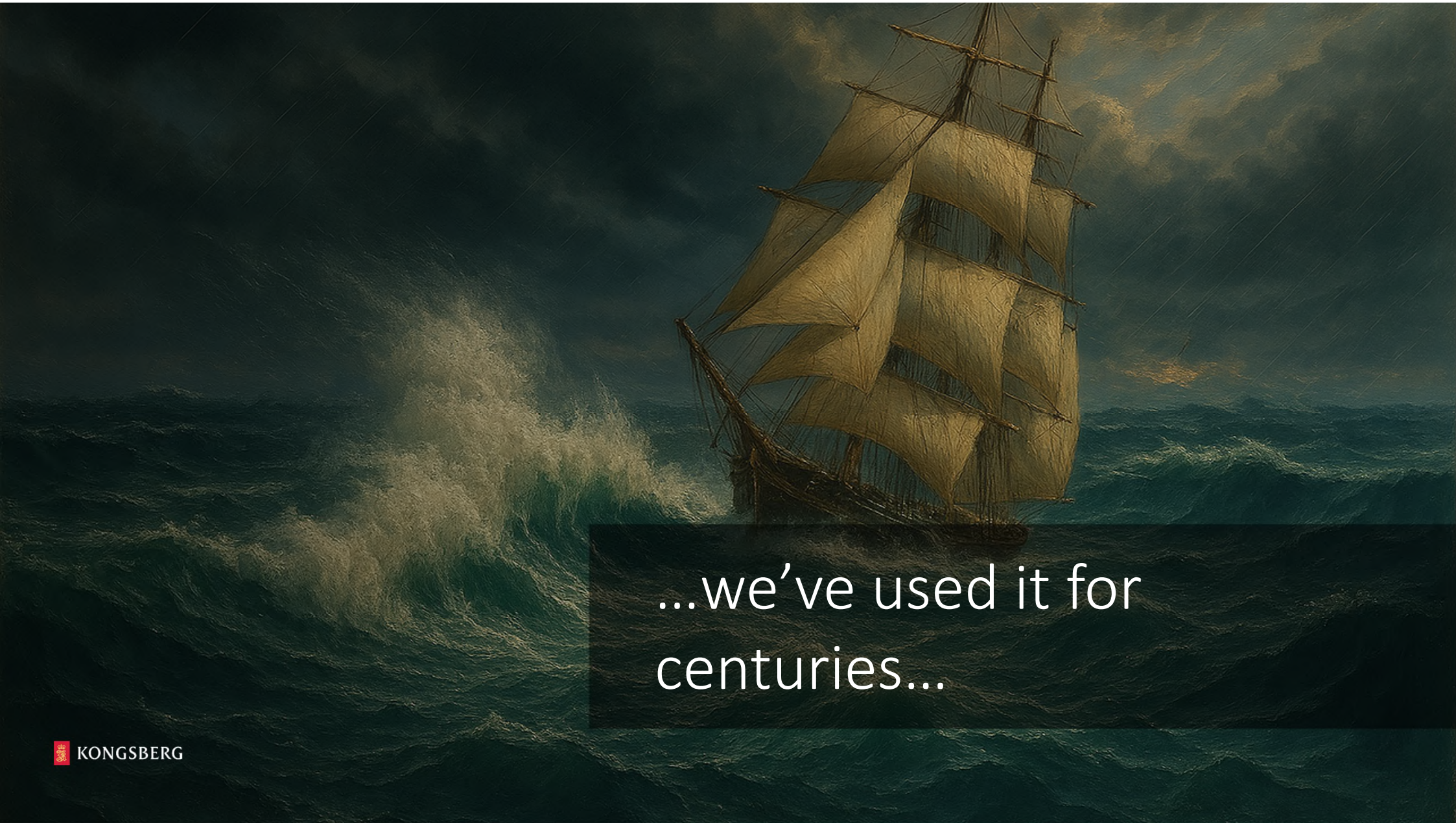
What can be done?

- The IMO has established regulations to reduce CO_2 emissions from ships.
- The IMO has also developed guidelines to help shipbuilders and operators reduce URN.
- Slower ship speeds and optimized propeller design can reduce CO_2 emissions and URN.
- Wind-assisted propulsion offer dual benefits: lower emissions and less noise.

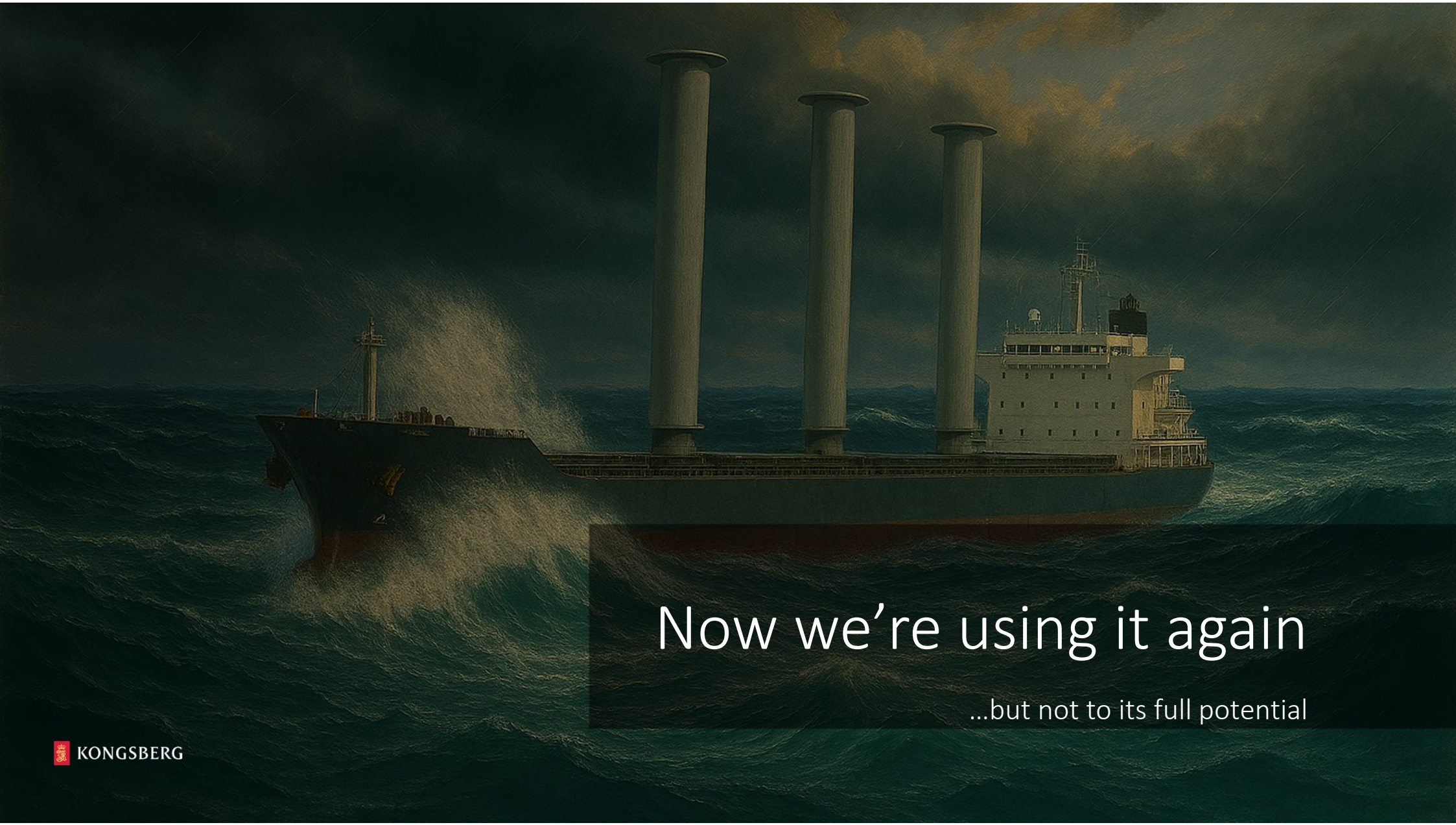
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…we’ve used it for centuries…
KONGSBERG


...until we stopped.
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Now we’re using it again
…but not to its full potential
KONGSBERG

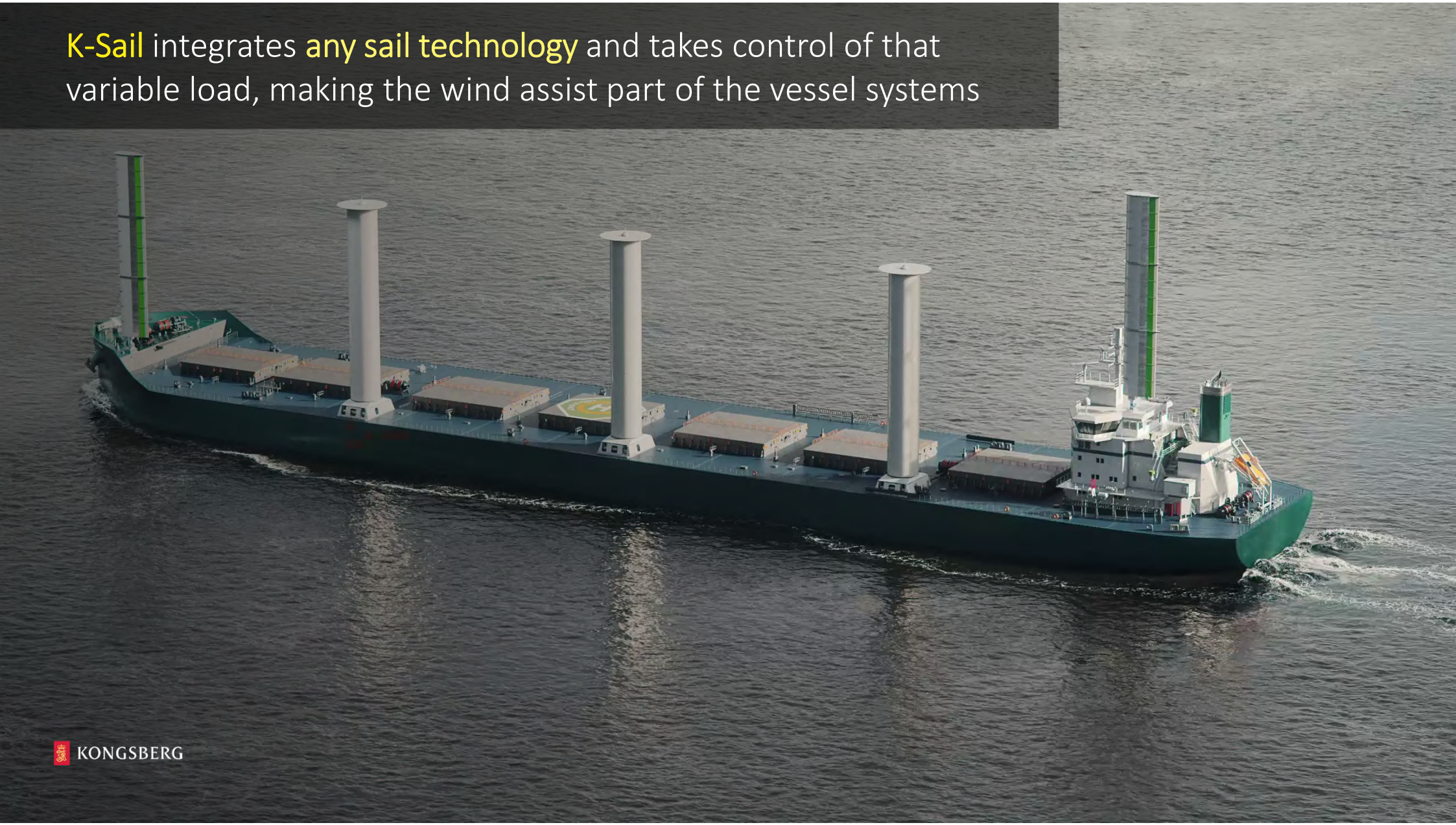

K-Sail
Integrated wind assist technology

Adding wind assist to a vessel means adding additional thrusters with variable load



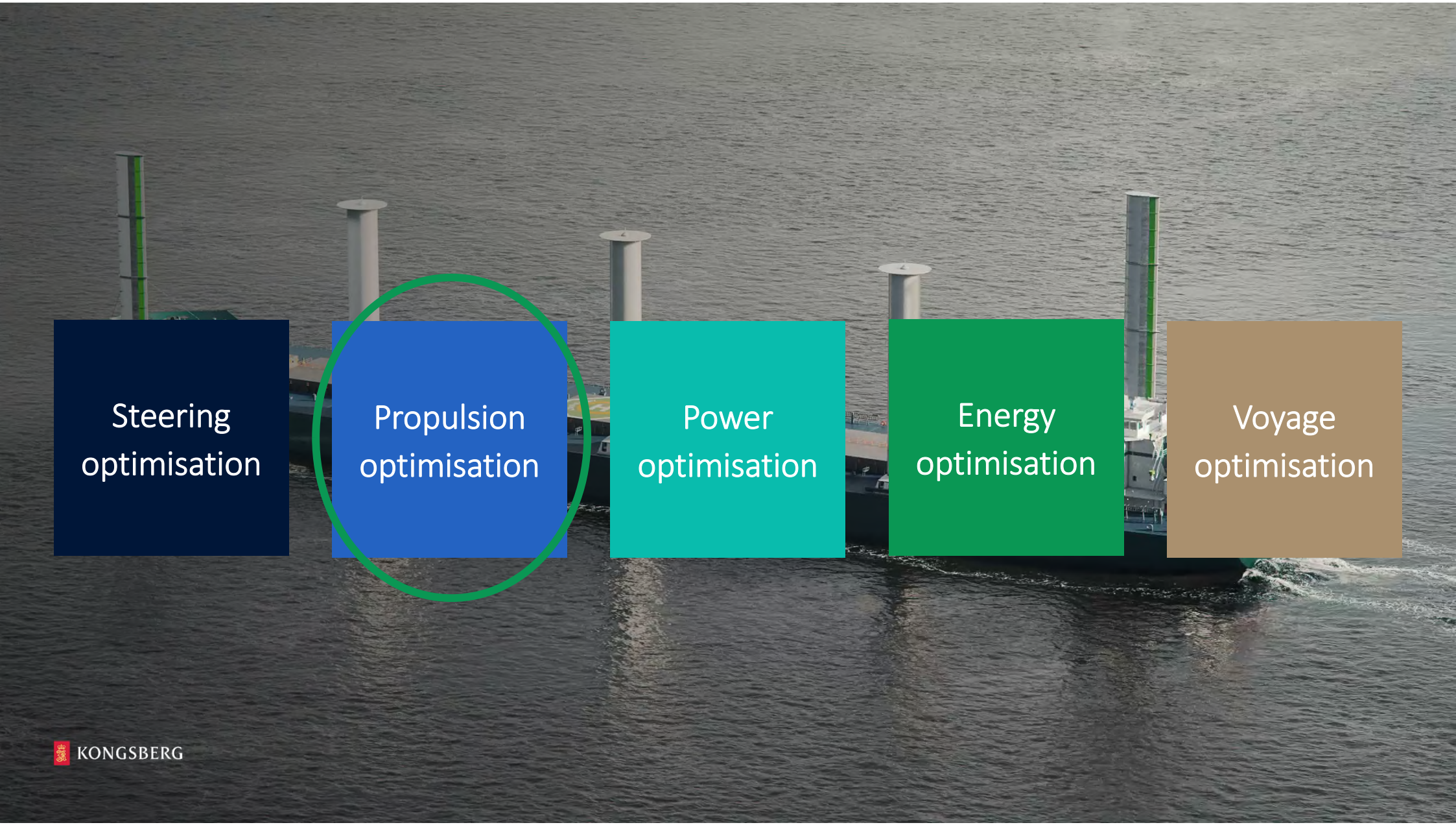
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K-Sail integrates any sail technology and takes control of that variable load, making the wind assist part of the vessel systems



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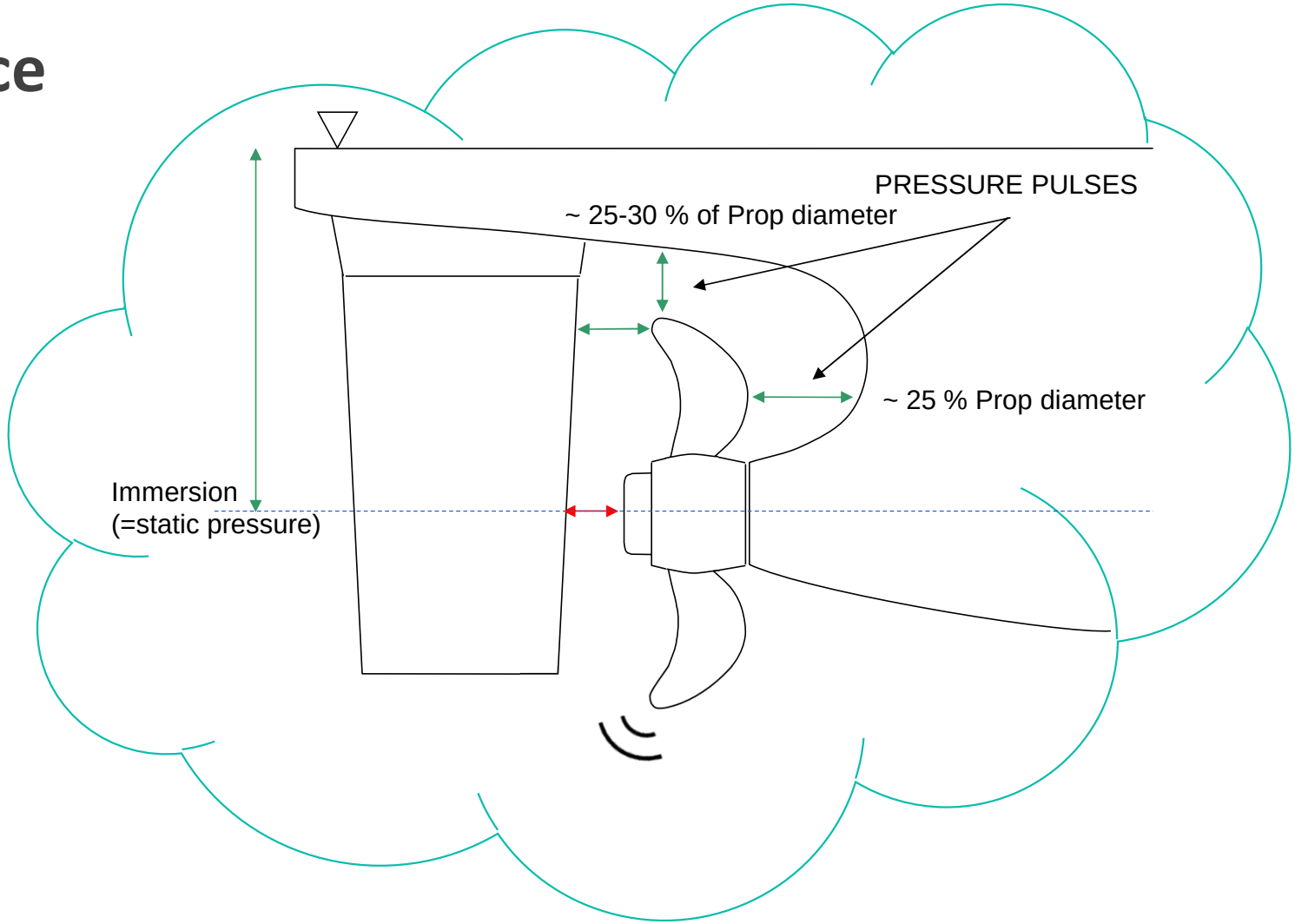

Sails can add significant amount of thrust forward
But they also change the vessel operation and power balance
⇒ Vessel arrive too early to port
⇒ Re-calculate voyage energy plan
⇒ Sails try to turn ship
⇒ Sail control balances sails so that sails and rudder act as one system
⇒ Compensating rudder angle adds more drag
⇒ Allocate power back to propulsion, vessel increase speed
⇒ Batteries are full
⇒ Too much hotel power
⇒ Energy management allocates energy to batteries
⇒ Power management allocates power to shaft generator
⇒ Engine runs with too low load
⇒ Propeller is running too lightly
⇒ Adaptive CPP increase propeller efficiency
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Steering optimisation
Propulsion optimisation
Power optimisation
Energy optimisation
Voyage optimisation
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Propeller Main Particulars

The Design Space

- Open or ducted propeller
- Fixed or Controllable pitch
- D - Diameter of the propeller
- Z – number of blades
  - FP: Z = 2 - 7
  - CP: Z = 3 - 5

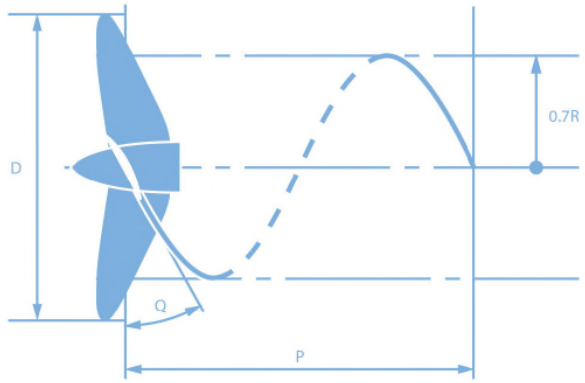


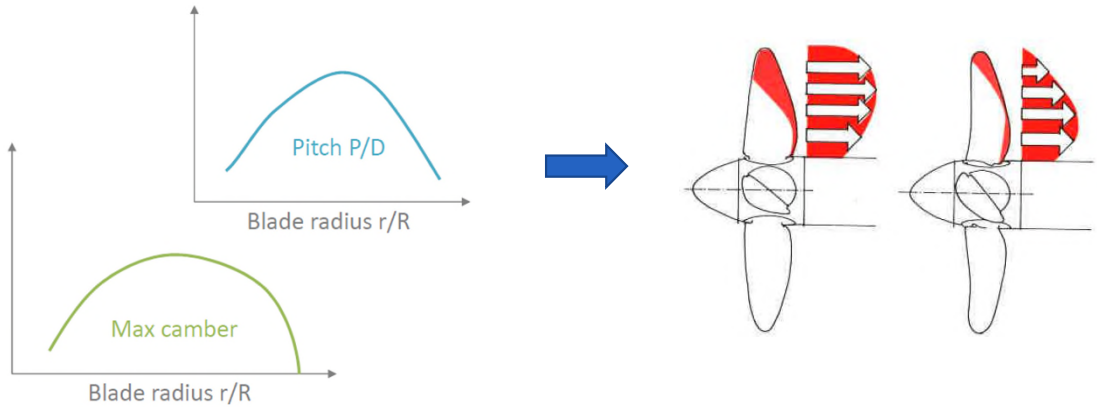
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Propeller Pitch and Load Distribution

- ”The axial distance the propeller would move forward during one revolution in a high-viscosity fluid” – P
- $P/D_{0.7R}$ normally referred to as the propeller pitch
- Not constant across the blade span, varies radially

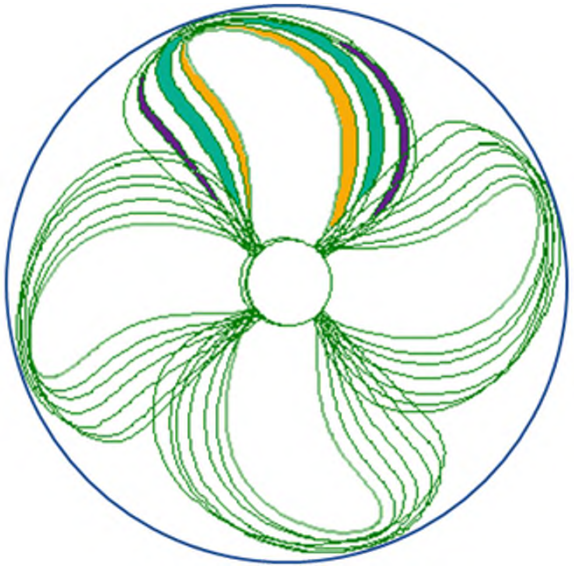
- Camber is the curvature of a propeller blade from its leading edge to its trailing edge. It helps generate lift and affects thrust and cavitation performance.
- We can distribute the loading by varying the pitch and camber of the radial sections.





Blade Area Ratio – EAR

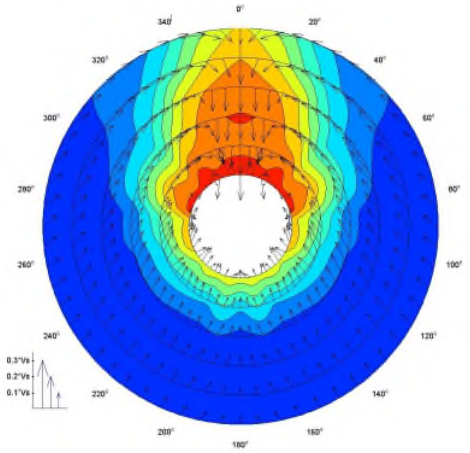
- Defined as $A_E/A_{0,}$ EAR- Expanded Area Ratio
- Small area, higher loading per unit surface area
  - Good for maximising efficiency
- Large area, lower loading per unit surface area
  - Good for minimising cavitation and impulsive forces.



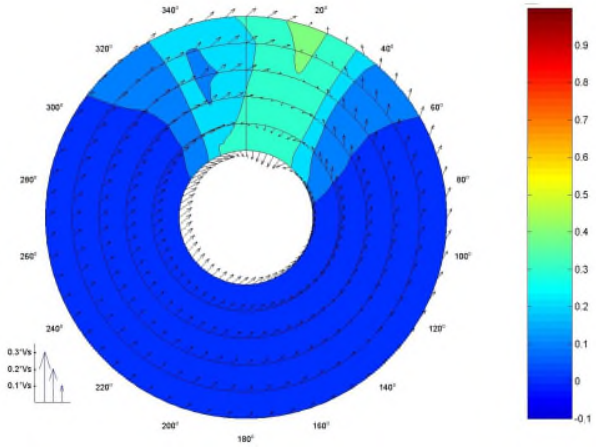
Propeller & Hull Interaction

Wake

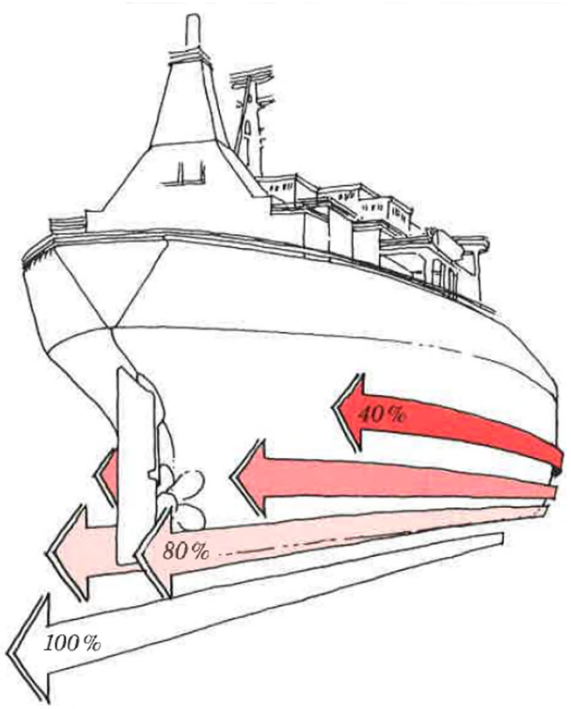
- Induces velocities in the water where the propeller will work



Single screw ship

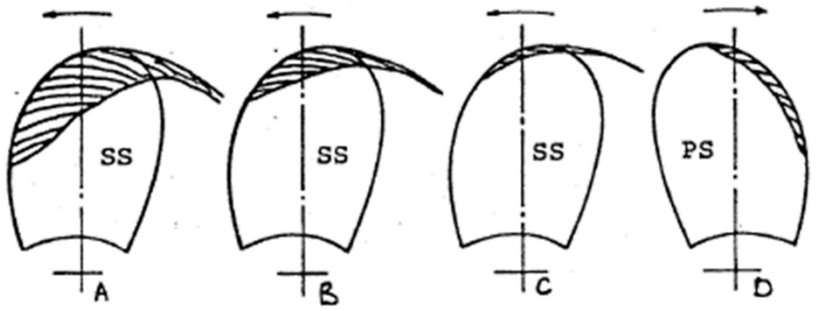


Twin screw ship

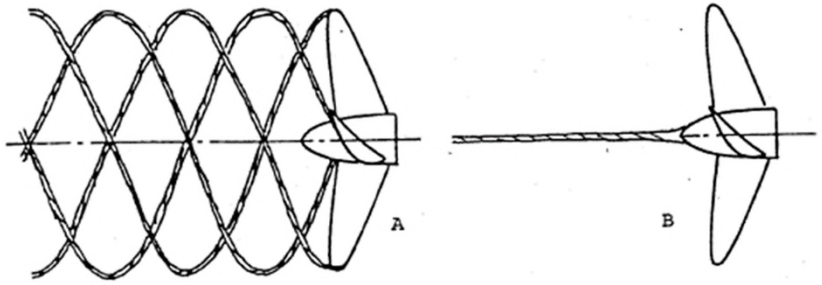


Cavitation in propellers

- A major propeller design constraint
  - Limits the maximum power density
- If cavitation ”free” → poor efficiency
- Design Considerations
  - Risk of erosion, pressure pulses & noise
  - Design margins; blade weight, efficiency
  - Wake can cause problematic cavitation



Sheet / Cloud Cavitation



Tip Vortex

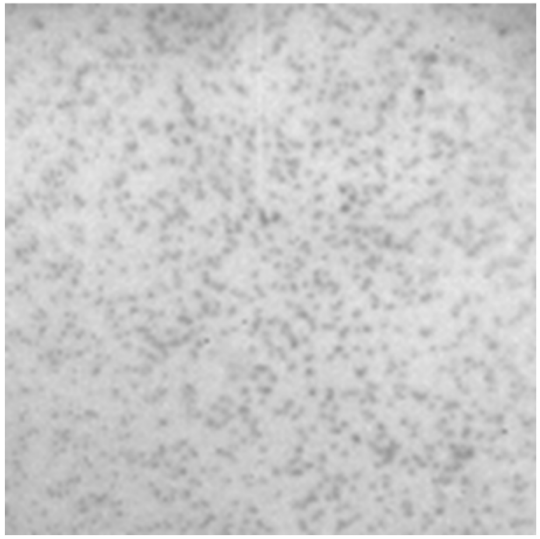
Hub Vortex

Cavitation

- Low pressure decreases boiling point to water temperature
- The water boils and a steam bubble is formed
- The steam condensates and the bubble implodes
- Implosion sends a shock wave through the water, i.e. pressure pulses, noise and vibrations

- If the implosion is close to a surface a small jet stream forms against the surface, leads to …

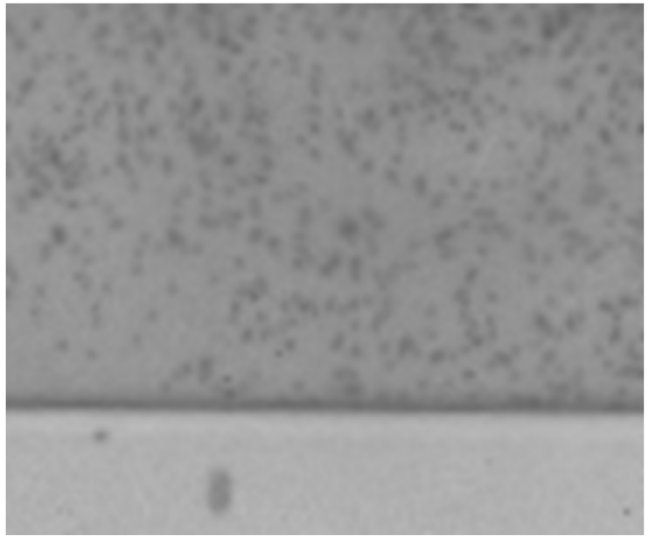
- Erosive caviation



In the fluid

Pressure pulses

Vibration

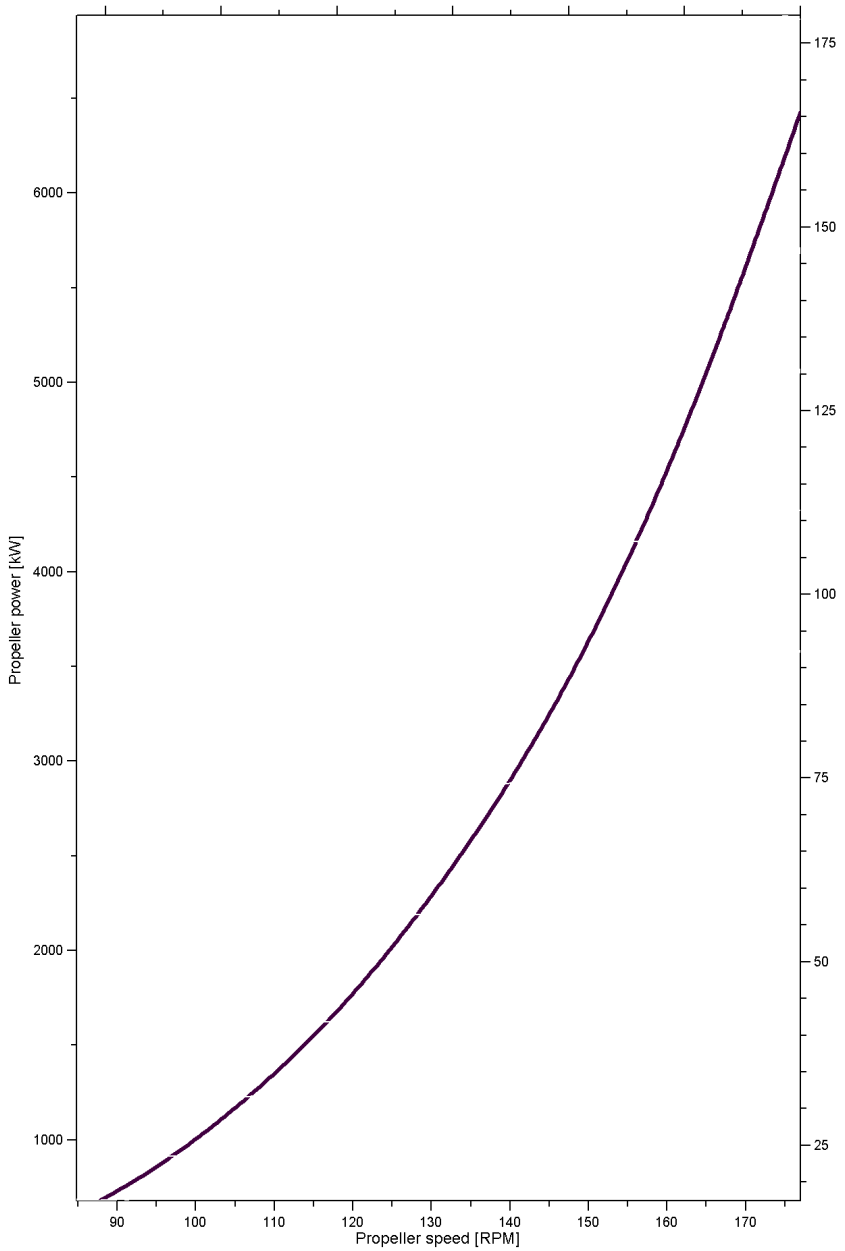


Near surface

Risk for erosion

Pdn-diagram

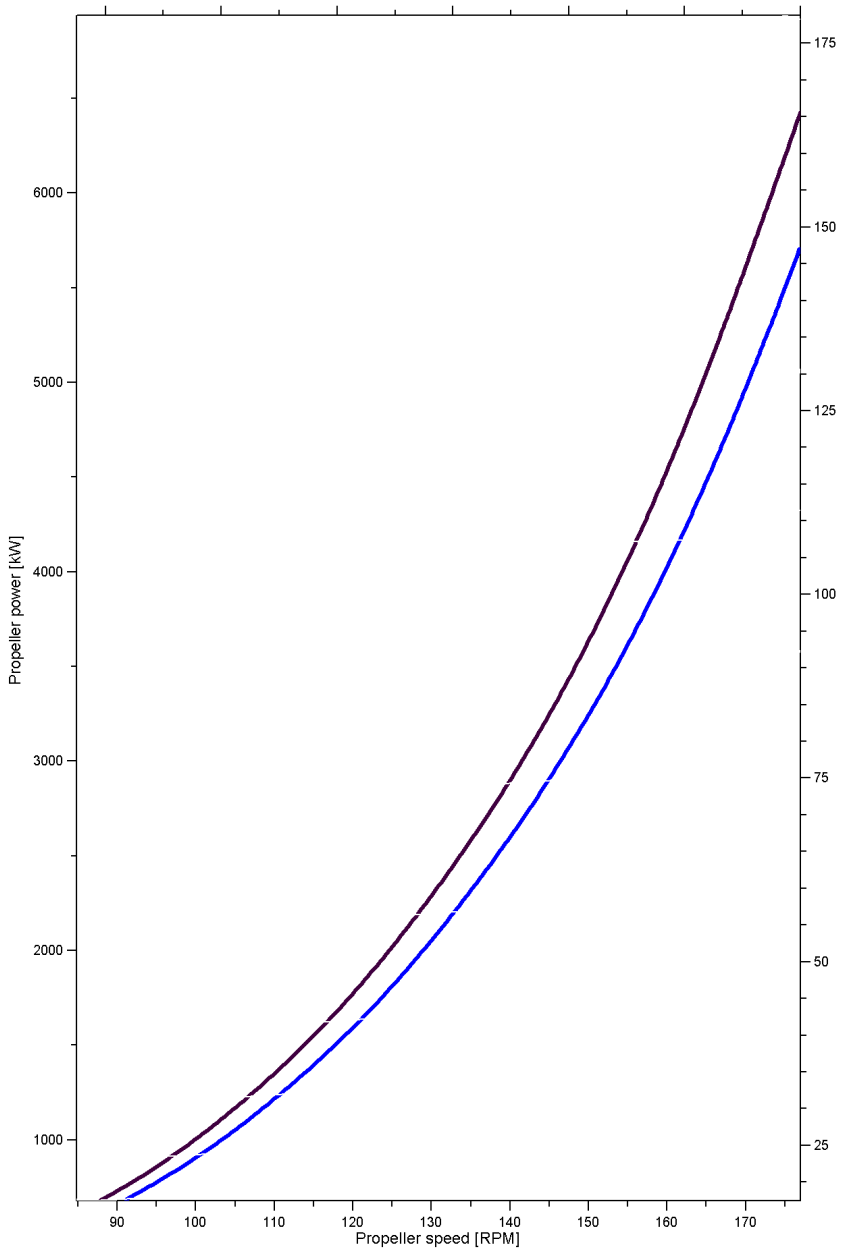
- Pd - delivered propeller power [kW]
- n – PRM
- Black line – propeller pitch



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Pdn-diagram

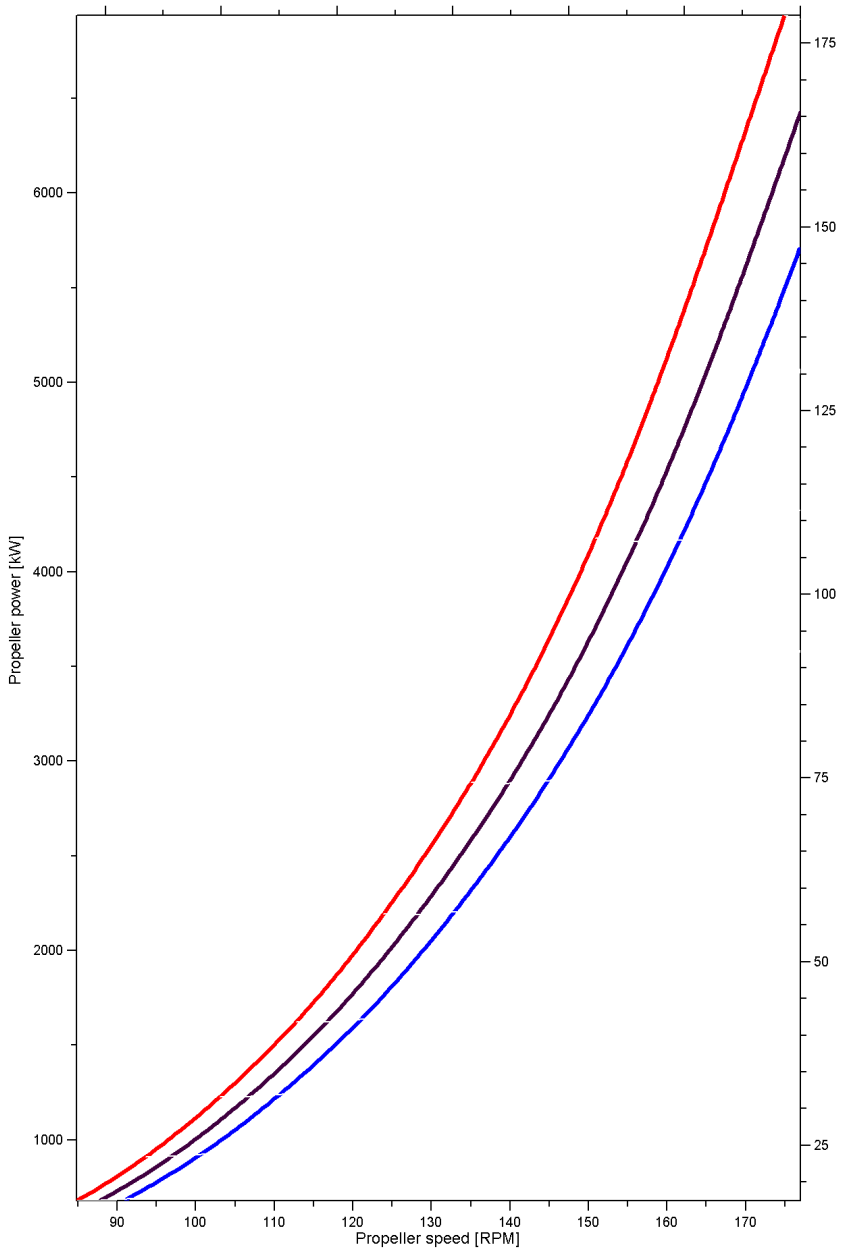
- Pd - delivered propeller power [kW]
- n – PRM
- Black line – propeller pitch
- Blue line – propeller pitch with light running margin



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Pdn-diagram

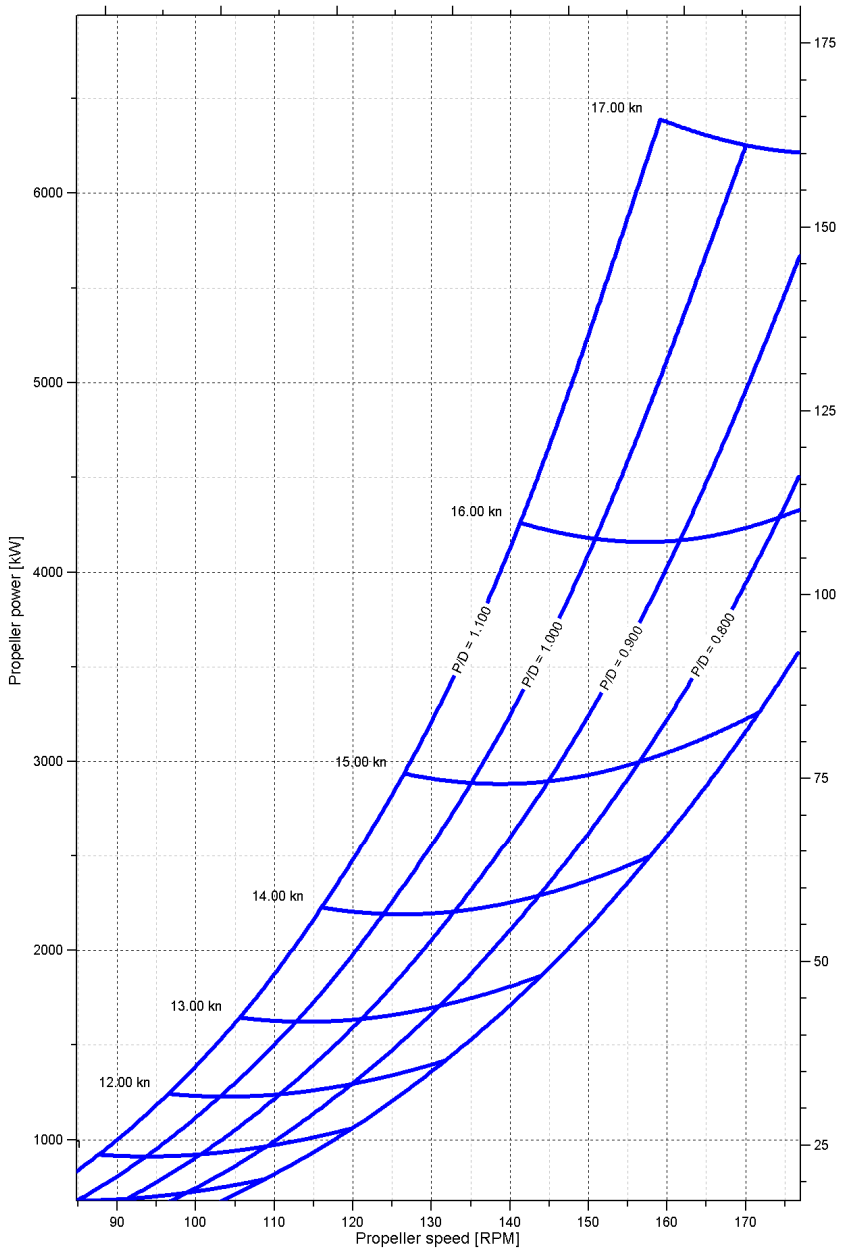
- Pd - delivered propeller power [kW]
- n – PRM
- Black line – propeller pitch
- Blue line – propeller pitch with light running margin
- Red line – propeller pitch with heavy running margin



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Pdn-diagram CPP

- Pd - delivered propeller power [kW]
- n – PRM
- Vertical blue lines – different propeller pitches
- Horizontal blue lines – ship speed



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Propeller Design Wind Assist - CPP

Traditional design

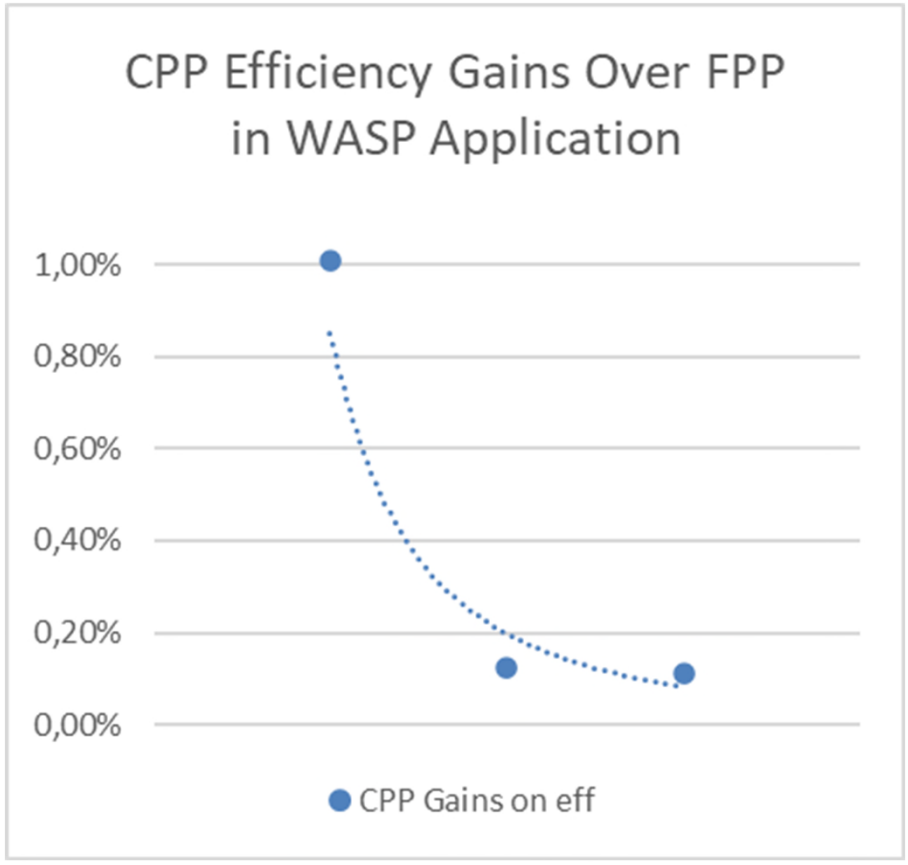
- Optimization is typically performed at a **single design point**, such as cruising speed.
- Focus is placed on maximizing efficiency or minimizing cavitation at that specific condition.

Design for Wind Assist

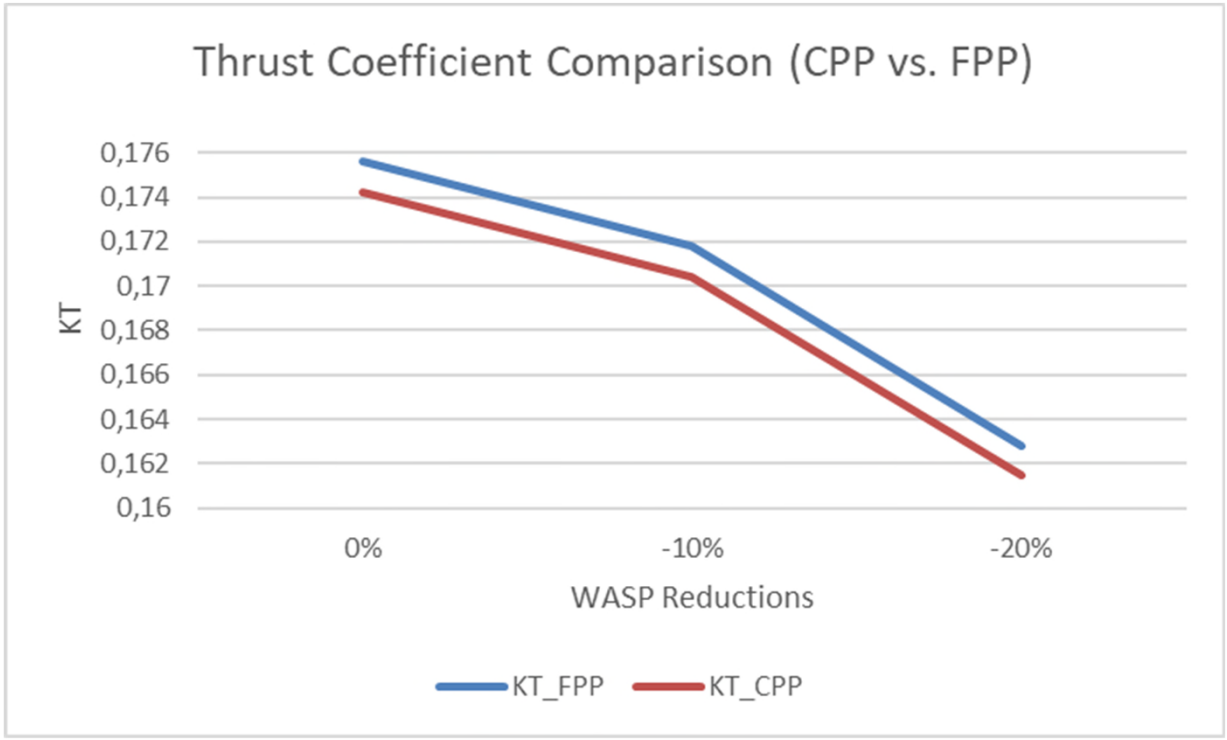
- Requires **multi-point optimization** due to varying operational conditions.
- Several design points are considered simultaneously (e.g., different speeds, wind angles, thrust demands).
- The goal is to **minimize overall cavitation** and **maximize average efficiency** across the full operating envelope.

Key Insight:
“Instead of optimizing for one ideal condition, wind-assisted propeller design seeks a balanced performance across many scenarios.”

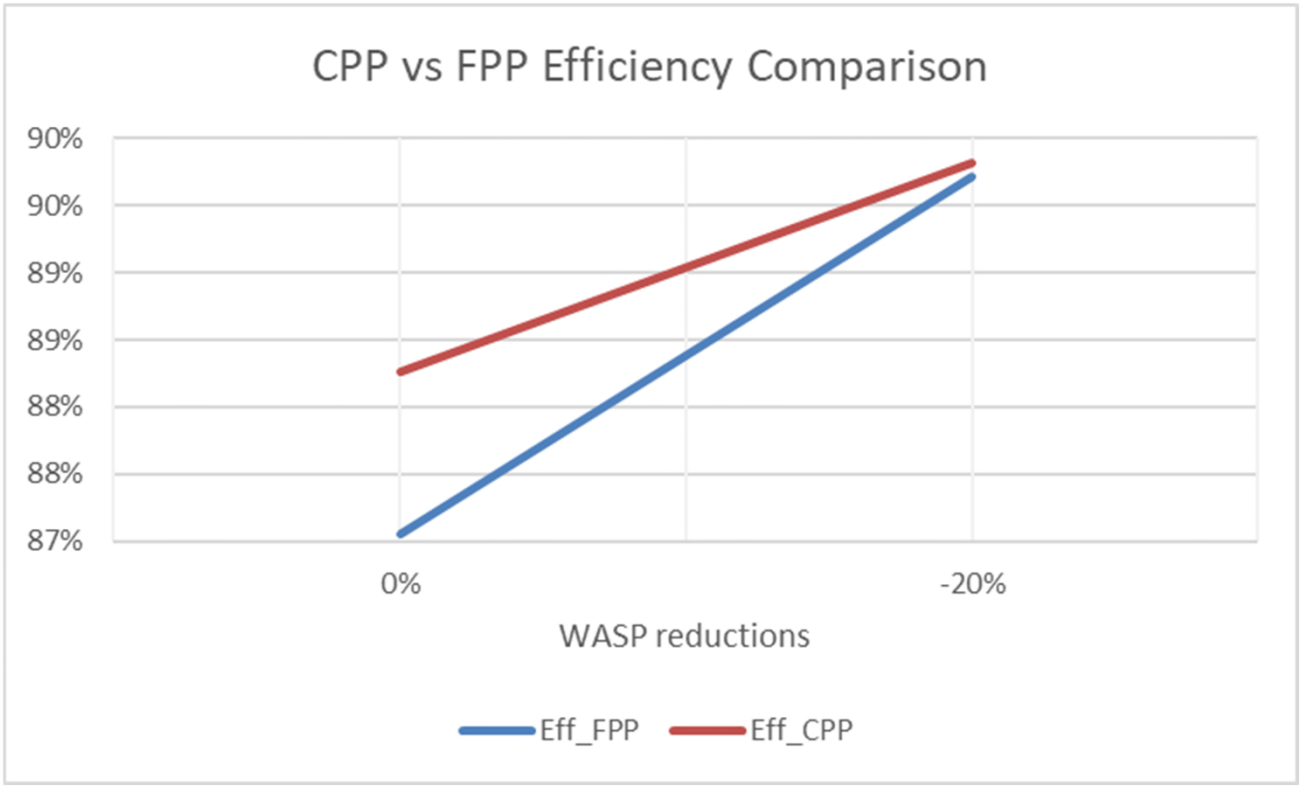
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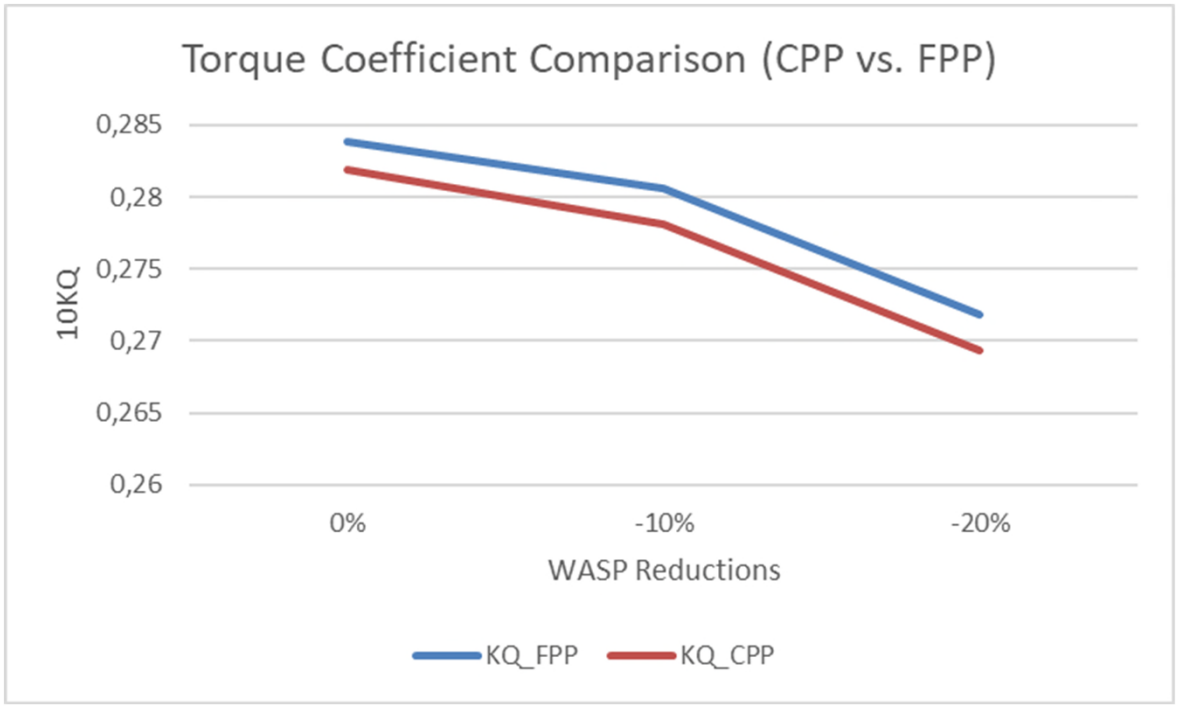
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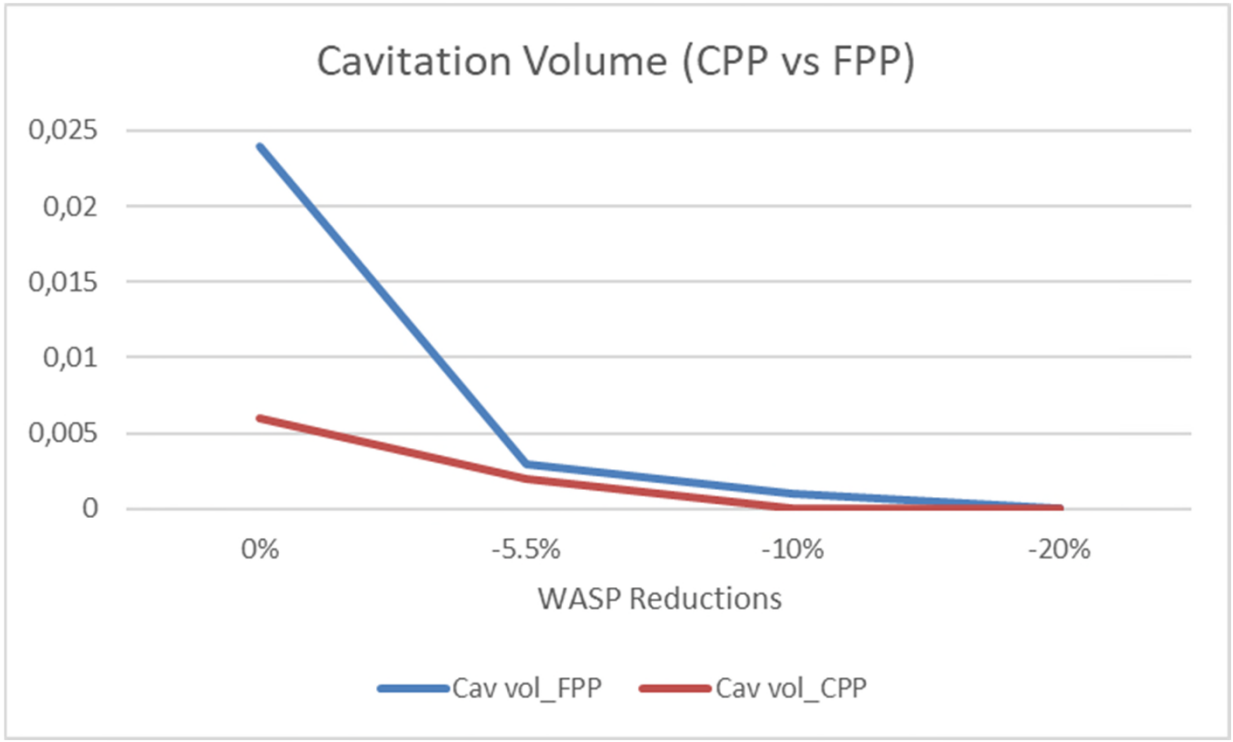
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Propeller choise - CPP

Pros

- Allows for variable pitch adjustment for optimal performance
- Better maneuverability and control
- Efficient fuel usage under varying load control
- Highly adaptable in dynamic operating environments
- Enables reversing without changning shaft rotation
- Enable constant engine RPM operation, allowing efficient use of shaft generators

Cons

- More complex and more expensive
- Requires regular maintenance
- Larger hud ratio compared to FPP

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Propeller choise - FPP

Pros

- Simple and robust design
- Lower const and easier to manufacture
- Minimal maintenance requirements
- High efficientcy during steady-state operation

Cons

- No flexibility in pitch adjustmen
- Less efficient under varying load conditions
- Limited maneuverability
- Requires reversing gear for reversed thrust

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Thank you!



asa.windfall@km.kongsberg.com

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