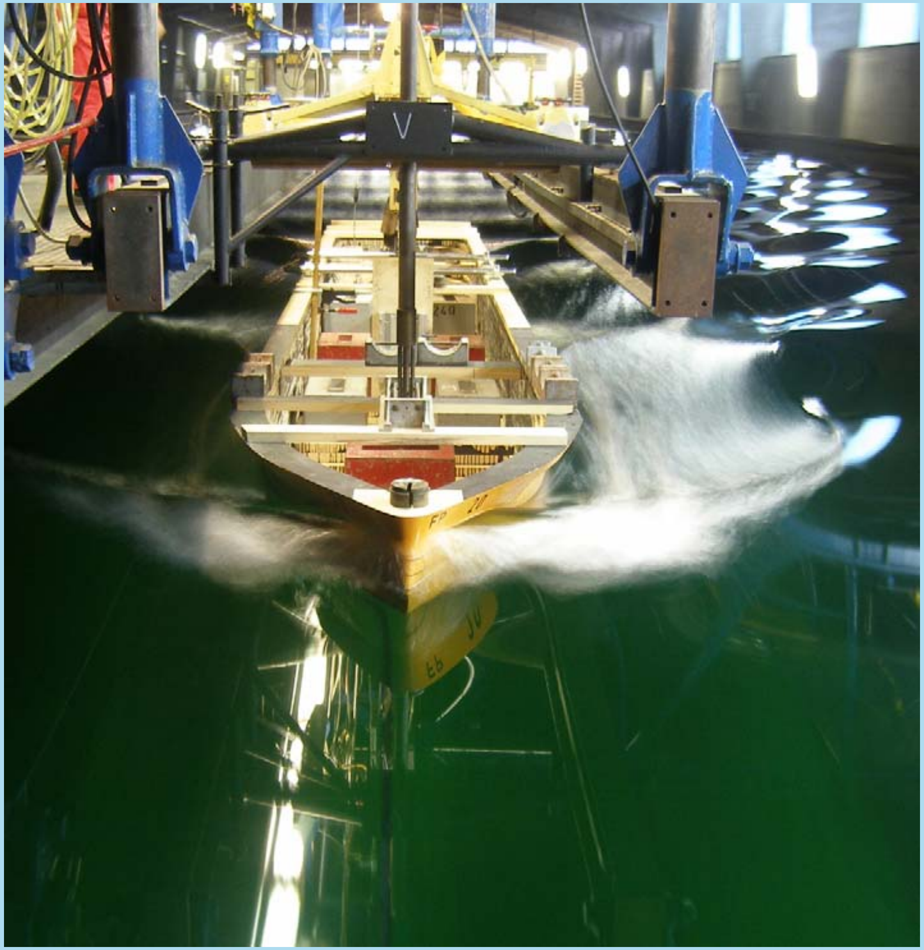


Hydrodynamic Optimization of Ships

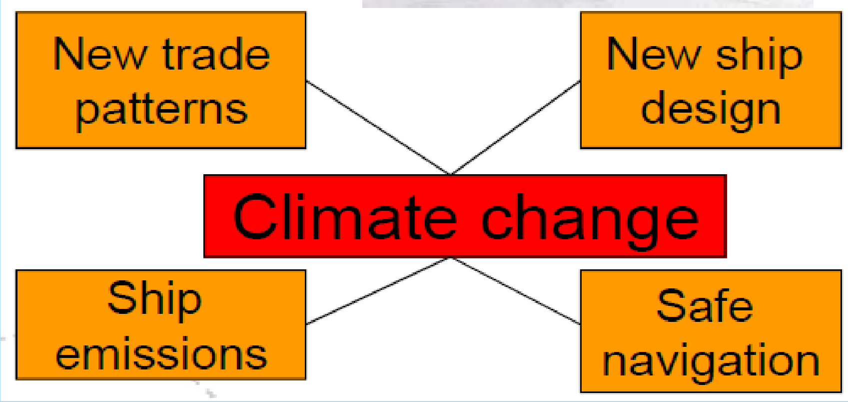
J. Friesch

Hamburg Ship Model Basin

Hamburgische Schiffbau-Versuchsanstalt GmbH · Bramfelder Str. 164 · D-22305 Hamburg · Tel.+49-40-69 203-0 (Fax -345) · info @ hsva.de

Hydrodynamic Optimization– What can be gained?

1. Introduction
2. Optimal main dimensions
3. Optimised hull form
4. Hull surface resistance
5. Propeller – rudder interaction
6. Optimisation for service conditions
7. Conclusions



- The World Sea Trade
  - The impact of the economic crisis
  - The environmental impact
  - New Requirements / Regulations
- Slow Steaming
  - Why slow steaming?
  - The optimum level of "slow"
  - Consequences for the propeller design
- Energy Efficiency Indices
  - EEDI / EEOI
  - Propeller polishing/coating
  - Operational Profiles
- Silent Steaming
  - Propeller induced underwater noise
  - Influences on underwater noise
  - Prediction of underwater noise

Hamburgische Schiffbau-Versuchsanstalt GmbH · Bramfelder Str. 164 · D-22305 Hamburg · Tel.+49-40-69 203-0 (Fax -345) · info @ hsva.de

Hydrodynamic Optimization– What can be gained?

IMO emission legislation – the big challenge for international shipping

SO_x: Regulation adopted

NO_x: Regulation adopted**

PM: Regulation under discussion

ECAs: Being expanded

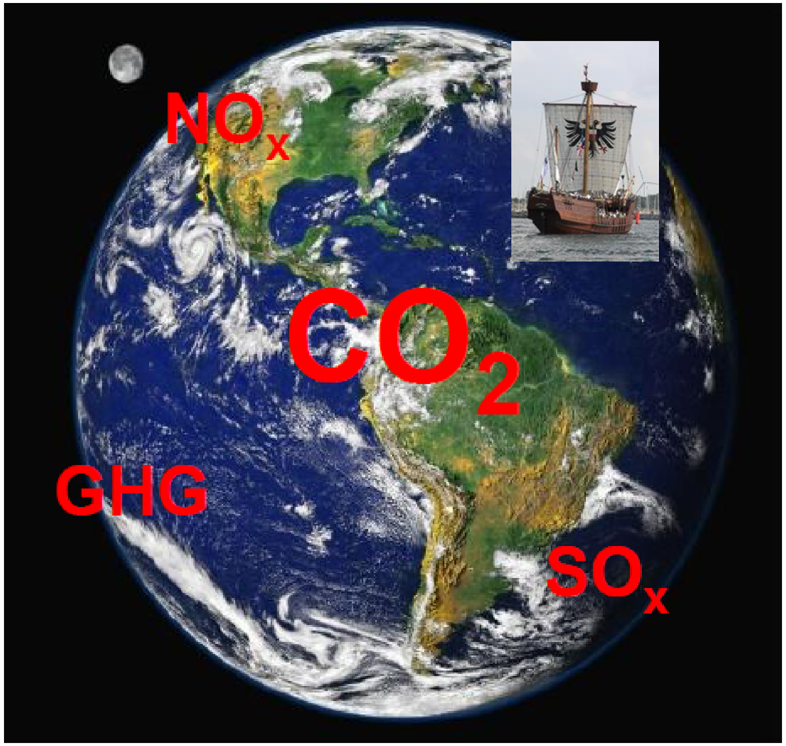
CO_2: Items discussed

CO_2: **Design index EEDI**

CO_2: **Operational Index EEOI**

Market-based instruments:

- Global bunker **levy** (tax)
- **CO_2 credits**



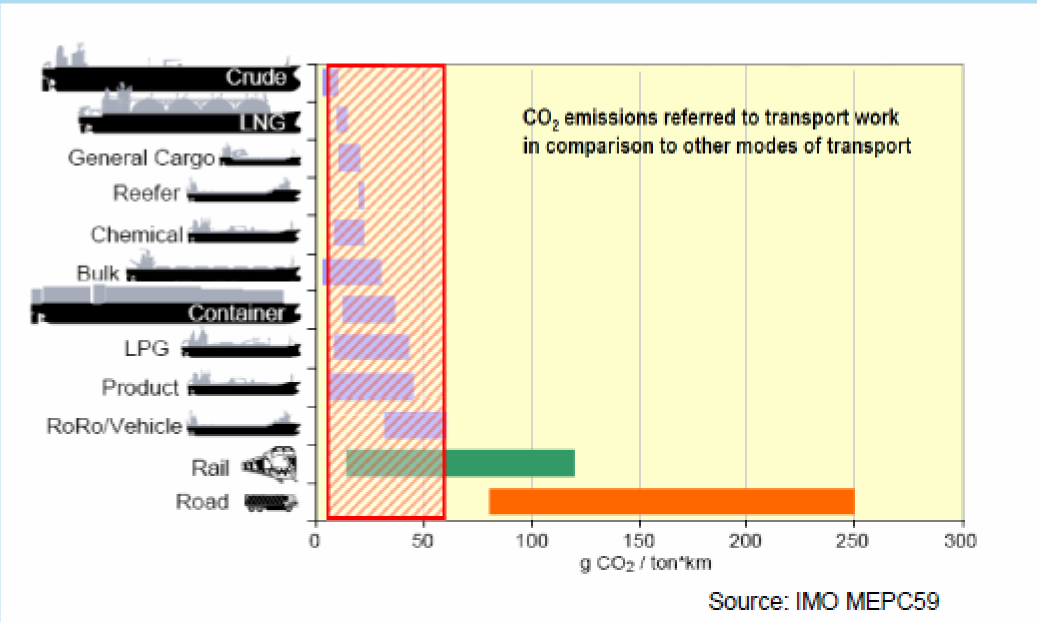
Hamburgische Schiffbau-Versuchsanstalt GmbH · Bramfelder Str. 164 · D-22305 Hamburg · Tel.+49-40-69 203-0 (Fax -345) · info @ hsva.de

Hydrodynamic Optimization– What can be gained?

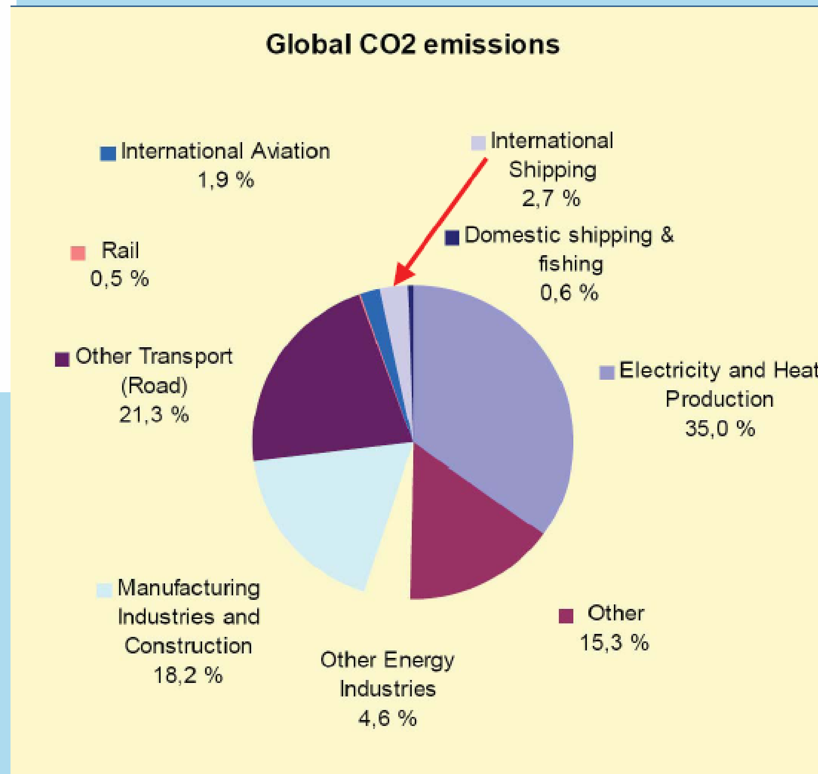
- **Over 95% of World Trade is carried in ships**
- **The vast majority of these ships are propelled by slow speed diesel engines – e.g. container ships and oil tankers**
- **The efficiency of these shipping operations means that CO2 emissions per tonne/km are very low**
- **NOx and SOx emissions are legislated by MARPOL Annex VI and Flag States (e.g. EU)**

Hamburgische Schiffbau-Versuchsanstalt GmbH · Bramfelder Str. 164 · D-22305 Hamburg · Tel.+49-40-69 203-0 (Fax -345) · info @ hsva.de

Hydrodynamic Optimization– What can be gained?

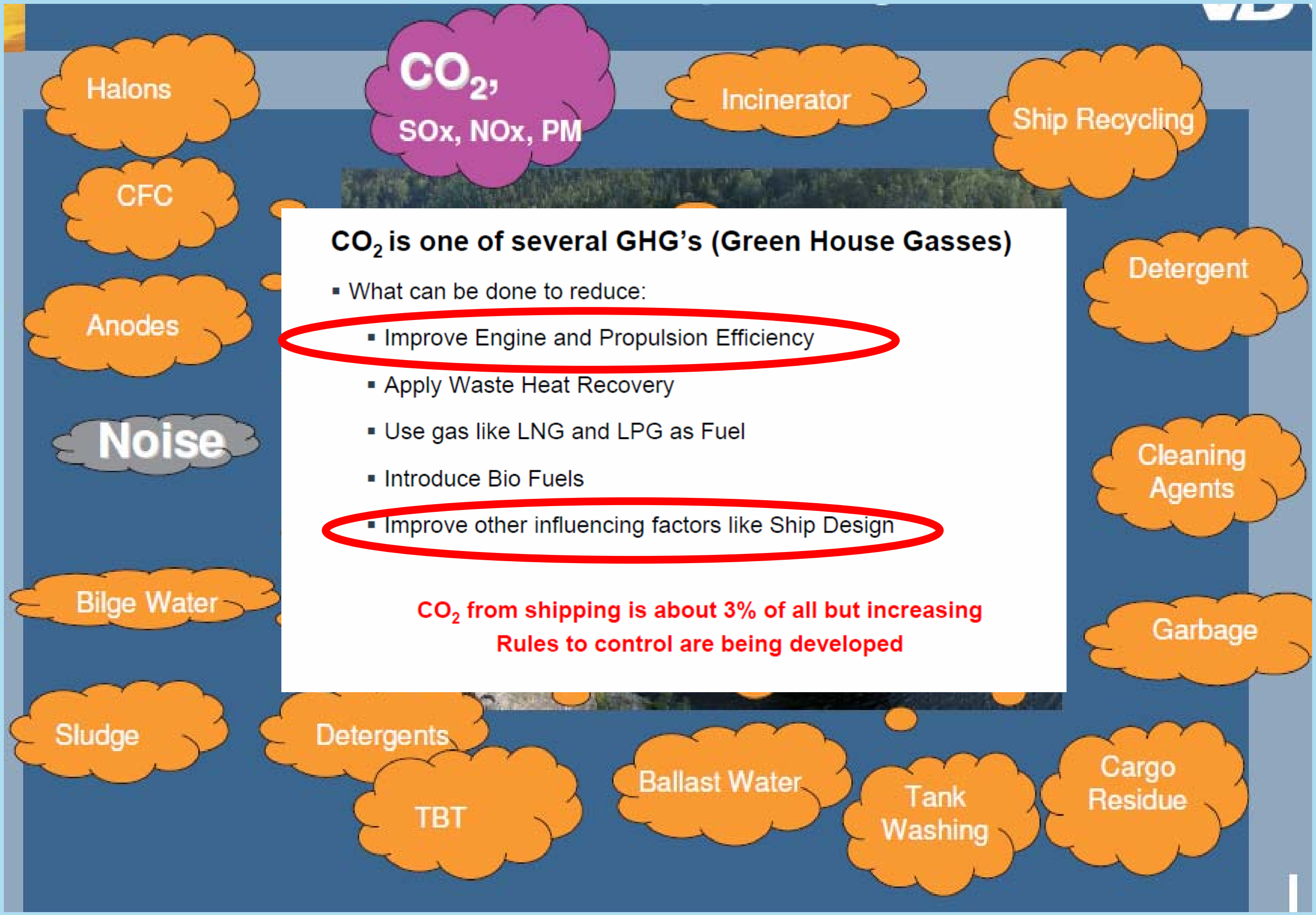


- How much CO_2 comes from shipping?
- Two recent studies:
  - 2007: 1100 mill. t
  - 2020: 1400 mill. t
- Shipping accounts for 3-4% of the total anthropogenic* CO_2 (**produced by human activities*)



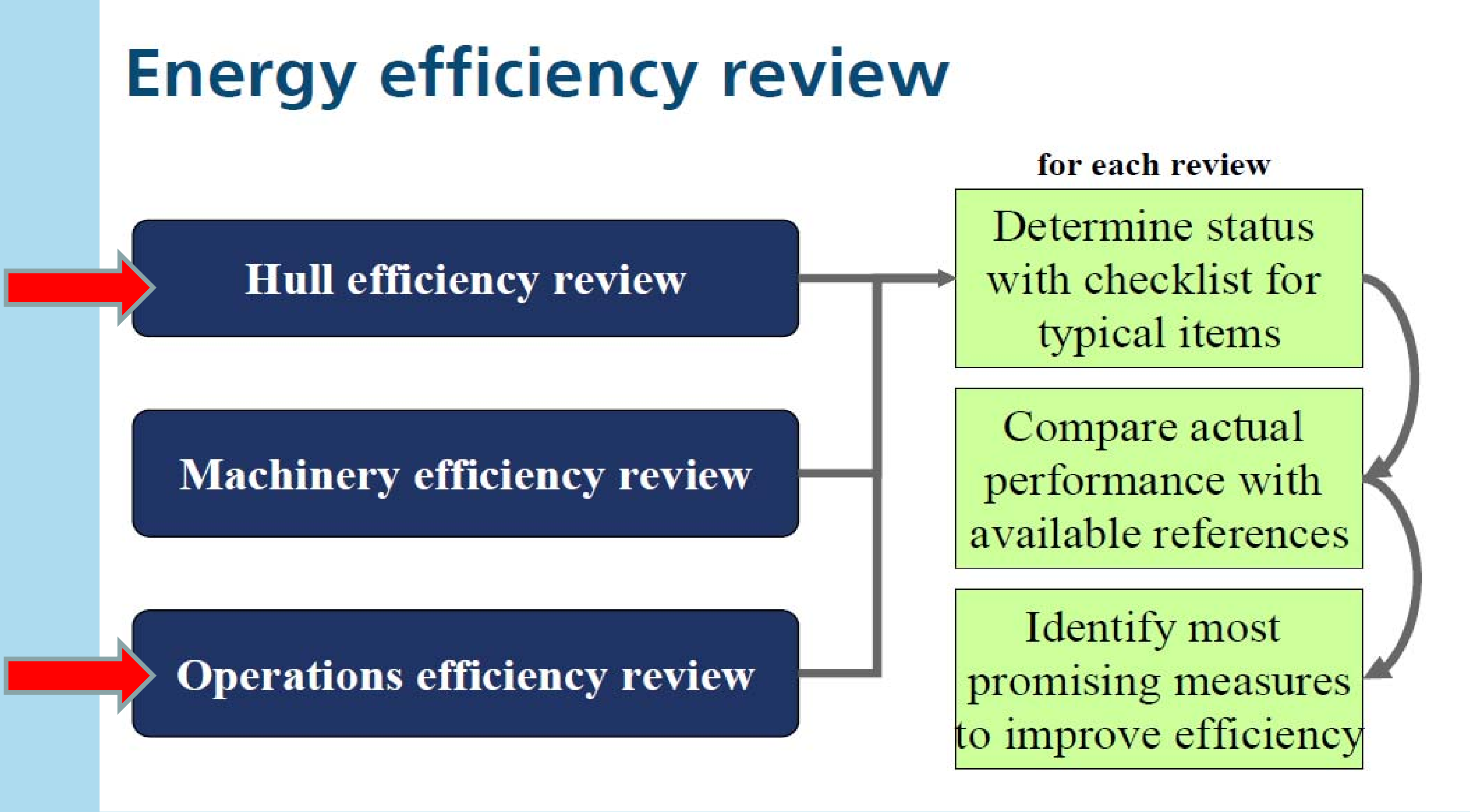
Hamburgische Schiffbau-Versuchsanstalt GmbH · Bramfelder Str. 164 · D-22305 Hamburg · Tel.+49-40-69 203-0 (Fax -345) · info @ hsva.de

Hydrodynamic Optimization– What can be gained?

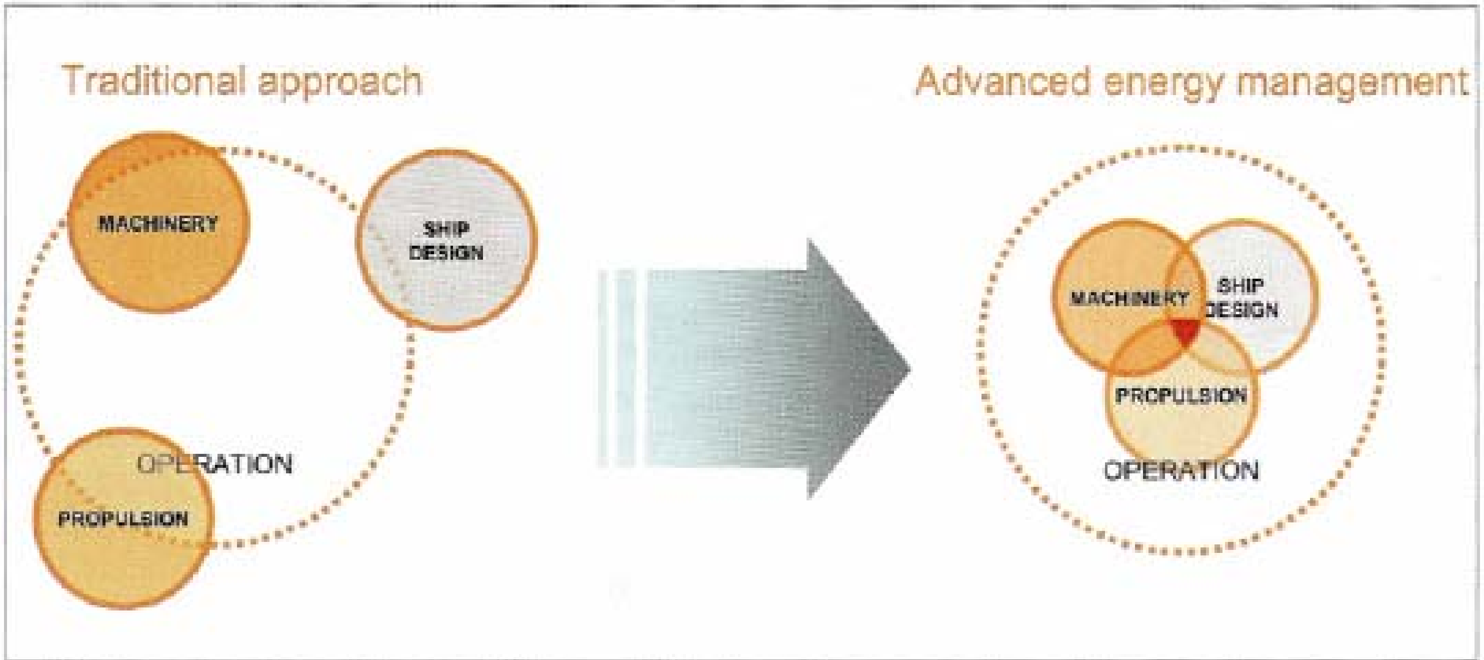


Hamburgische Schiffbau-Versuchsanstalt GmbH · Bramfelder Str. 164 · D-22305 Hamburg · Tel.+49-40-69 203-0 (Fax -345) · info @ hsva.de

Hydrodynamic Optimization– What can be gained?



Hydrodynamic Optimization– What can be gained?



Energy management calls for a better understanding of the entire ship's operations

Source: Wärtsilä SuH 2010

Hamburgische Schiffbau-Versuchsanstalt GmbH · Bramfelder Str. 164 · D-22305 Hamburg · Tel.+49-40-69 203-0 (Fax -345) · info@hsva.de

Hydrodynamic Optimization– What can be gained?

Ship Design Hull / Propulsor

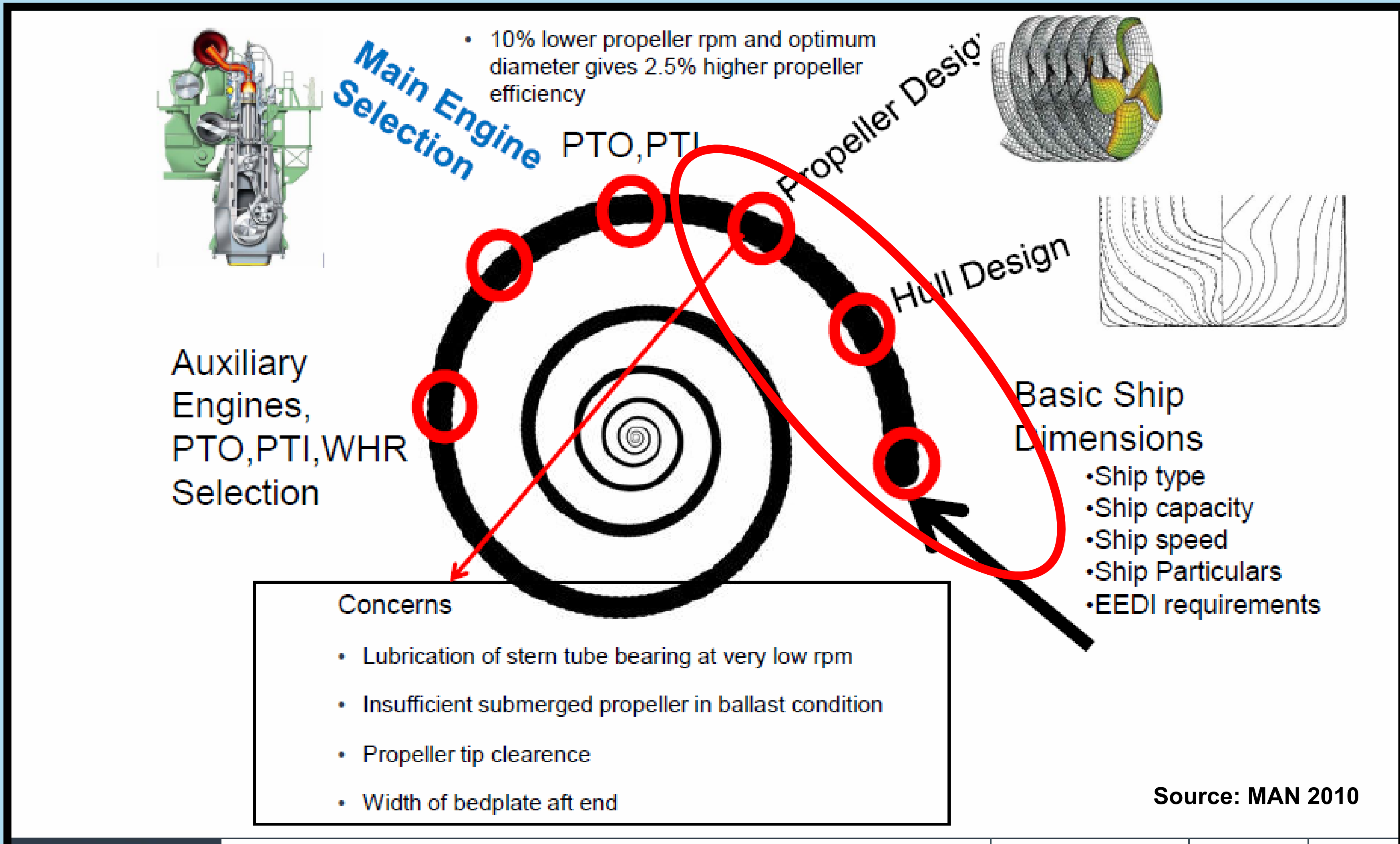
Ship Operation

- Main dimensions
- Ship lines
- detailed geometries
- Propulsor design point
- Appendages
- Optimize hull surface
- Energy saving devices
- Renewable energies
- Air cushion system

- Optimium trim
- Off Design conditions
- Added resistance
- Fleet speed optimisation
- Operating profile

Hamburgische Schiffbau-Versuchsanstalt GmbH · Bramfelder Str. 164 · D-22305 Hamburg · Tel.+49-40-69 203-0 (Fax -345) · info @ hsva.de

Hydrodynamic Optimization– What can be gained?



Optimal Main Dimensions and Hull Form

Hamburgische Schiffbau-Versuchsanstalt GmbH · Bramfelder Str. 164 · D-22305 Hamburg · Tel.+49-40-69 203-0 (Fax -345) · info @ hsva.de

Optimal Main Dimensions and Hull Form

Influence on Power Demand

New building, delivered 1994		Project (restricted Dimensions)	
Length between pp	135,70 m	Length between pp	118,50 m
Breadth moulded	19,60 m	Breadth moulded	21,50 m
Depth to main deck	10,65 m	Depth to main deck	11,00 m
Draught scantling	8,40 m	Draught scantling	8,50 m
Deadweight all told	13000 dwt	Deadweight all told	13000 dwt
Cargo tank volume	13600 m³	Cargo tank volume	13600 m³
Speed at same Pd	**14,9 kn**	Speed at same Pd	**14,1 kn**
Power at SS4, BF5			3300 kW
Service speed	14,5 kn	Service speed	14,5 kn
Power at SS4, BF5	**3000 kW**	Power at SS4, BF5	**3750 kW**

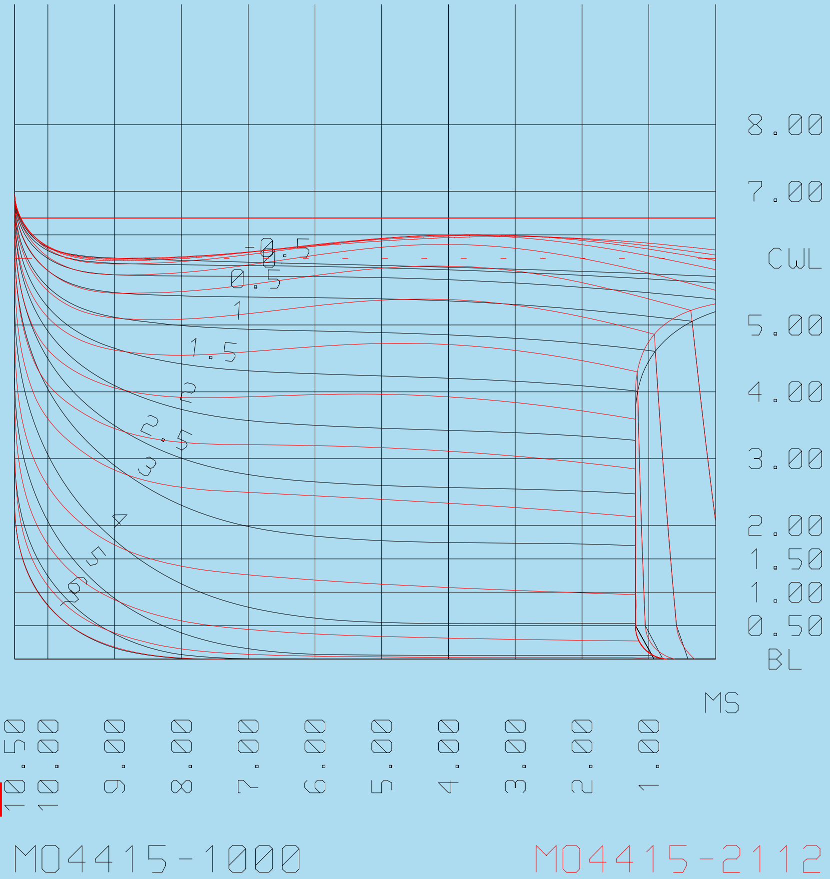
+25 % at 14.5 kn !

Hamburgische Schiffbau-Versuchsanstalt GmbH · Bramfelder Str. 164 · D-22305 Hamburg · Tel.+49-40-69 203-0 (Fax -345) · info @ hsva.de

Optimal Main Dimensions and Hull Form

Example: RoRo-Vessel

The Designer defined too strict hard points concerning arrangement of gear box and main engine
The resulting hullform (black lines) showed an unexpected high power demand in propulsion test
Smoothen the aft shoulder was possible by lifting up gear box, main engine and main deck!



Gain by smoothen the aft shoulder (red lines) : 17% at design speed

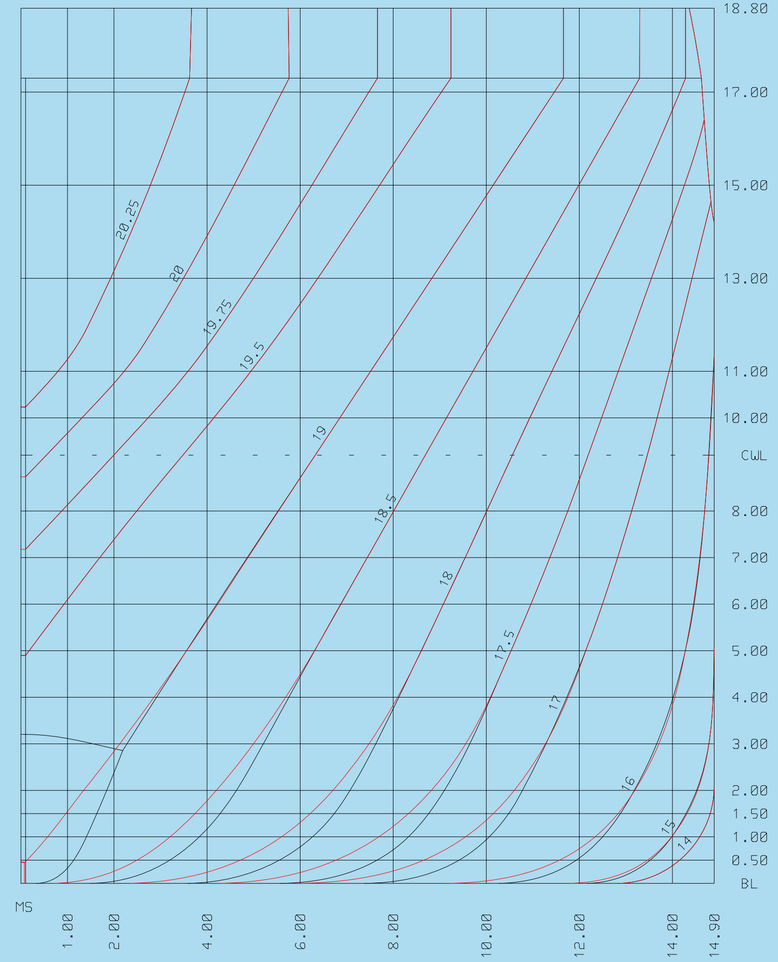
Hamburgische Schiffbau-Versuchsanstalt GmbH · Bramfelder Str. 164 · D-22305 Hamburg · Tel.+49-40-69 203-0 (Fax -345) · info @ hsva.de

Optimal Main Dimensions and Hull Form

<u>Example: Ice Class Tanker</u>

The designer tried to reduce fabrication costs by applying a too small bilge radius (black lines)
CFD calculations (potential flow) can not predict separations
In the paint flow tests separations in the bilge area became visible

Gain by rounding the bilge area in the fore body (red lines) : 8-10%



Hamburgische Schiffbau-Versuchsanstalt GmbH · Bramfelder Str. 164 · D-22305 Hamburg · Tel.+49-40-69 203-0 (Fax -345) · info @ hsva.de

Ship / Fleet Operation

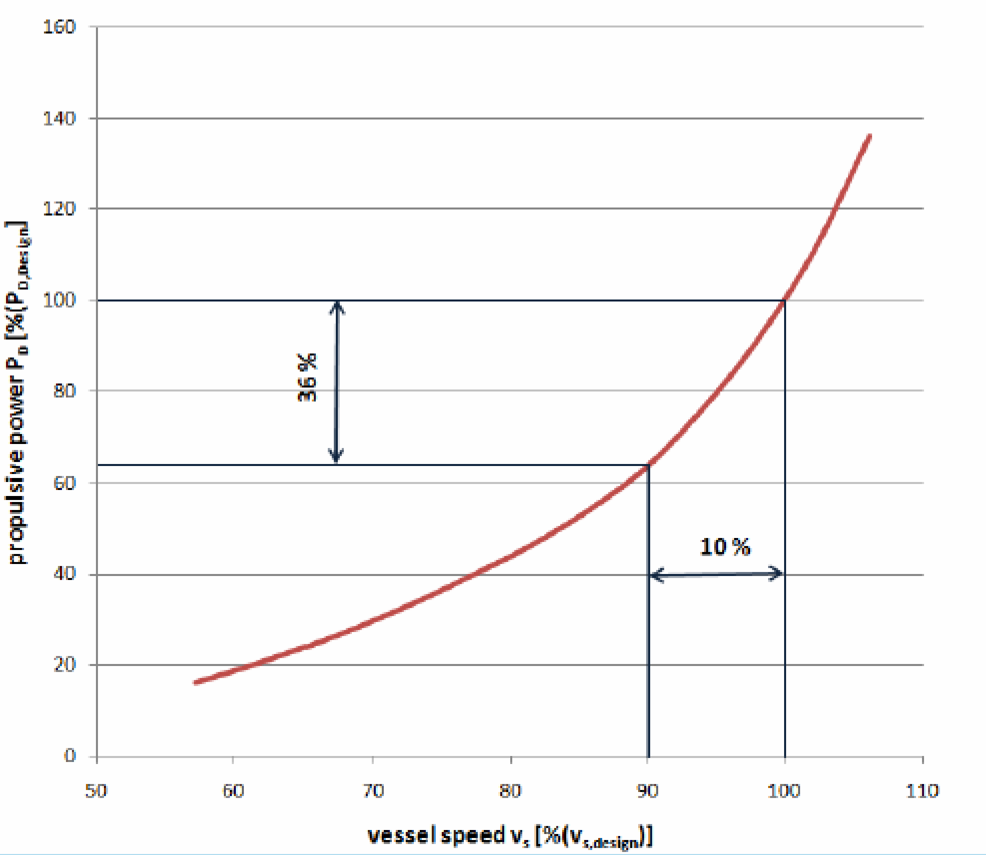
Hamburgische Schiffbau-Versuchsanstalt GmbH · Bramfelder Str. 164 · D-22305 Hamburg · Tel.+49-40-69 203-0 (Fax -345) · info @ hsva.de

Slow Steaming

Why Slow Steaming?

- Speed-power curve runs steep
- A small reduction in speed leads to significant power savings
- Increase of fuel oil costs
- Decrease of charter rates

There is a significant difference between vessel speed at optimal costs (15.3kts) and vessel speed at optimal profit (20.7kts).



Hamburgische Schiffbau-Versuchsanstalt GmbH · Bramfelder Str. 164 · D-22305 Hamburg · Tel.+49-40-69 203-0 (Fax -345) · info @ hsva.de

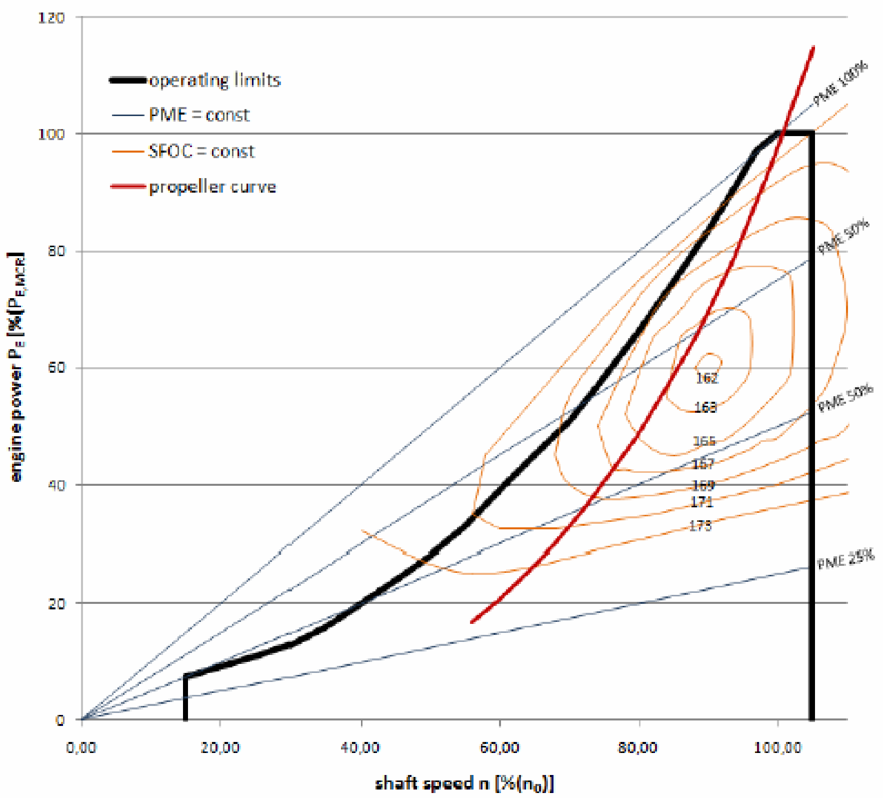
Slow Steaming

Constraints of Slow Steaming

- Time-critical freight
- Possible increase of wave resistant
- Lack of heat for auxiliary systems
- Increase of soot production

Operating limits of main engine

- Limits of permanent power reduction:
  - abt. 40% MCR without engine kit
  - abt. 90% MCR with engine kit
- Engine upgrade kit:
  - Additional savings abt. 5%

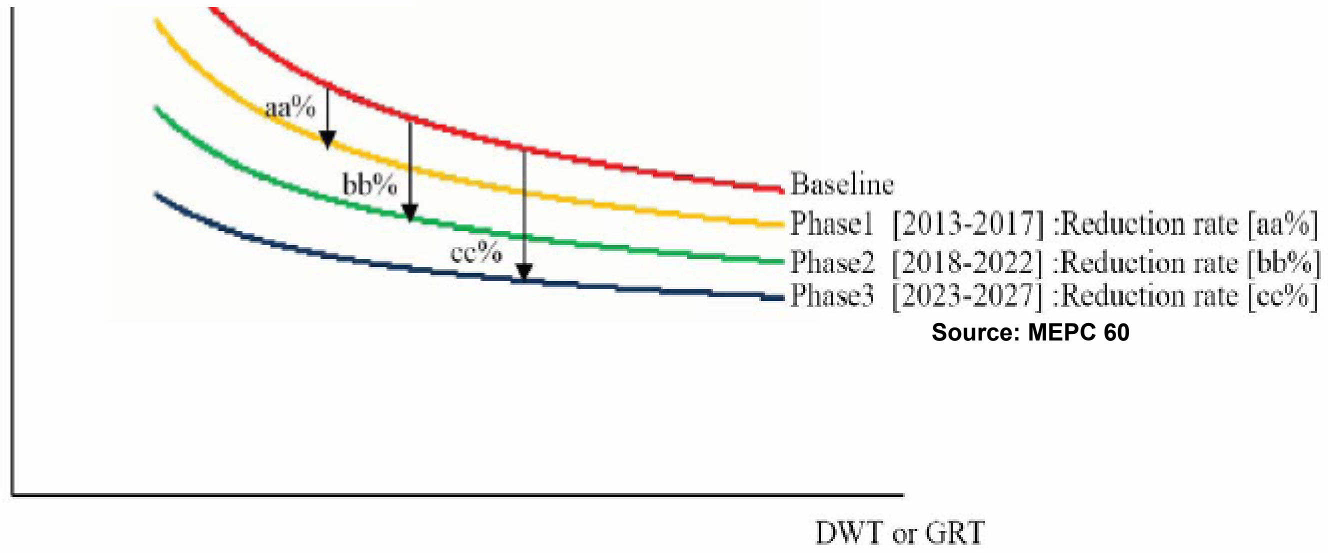


EEDI

EEDI: Energy Efficient Design Index

$$EEDI = \frac{CO_2 \text{ emission}}{\text{Benefit of ship}}$$

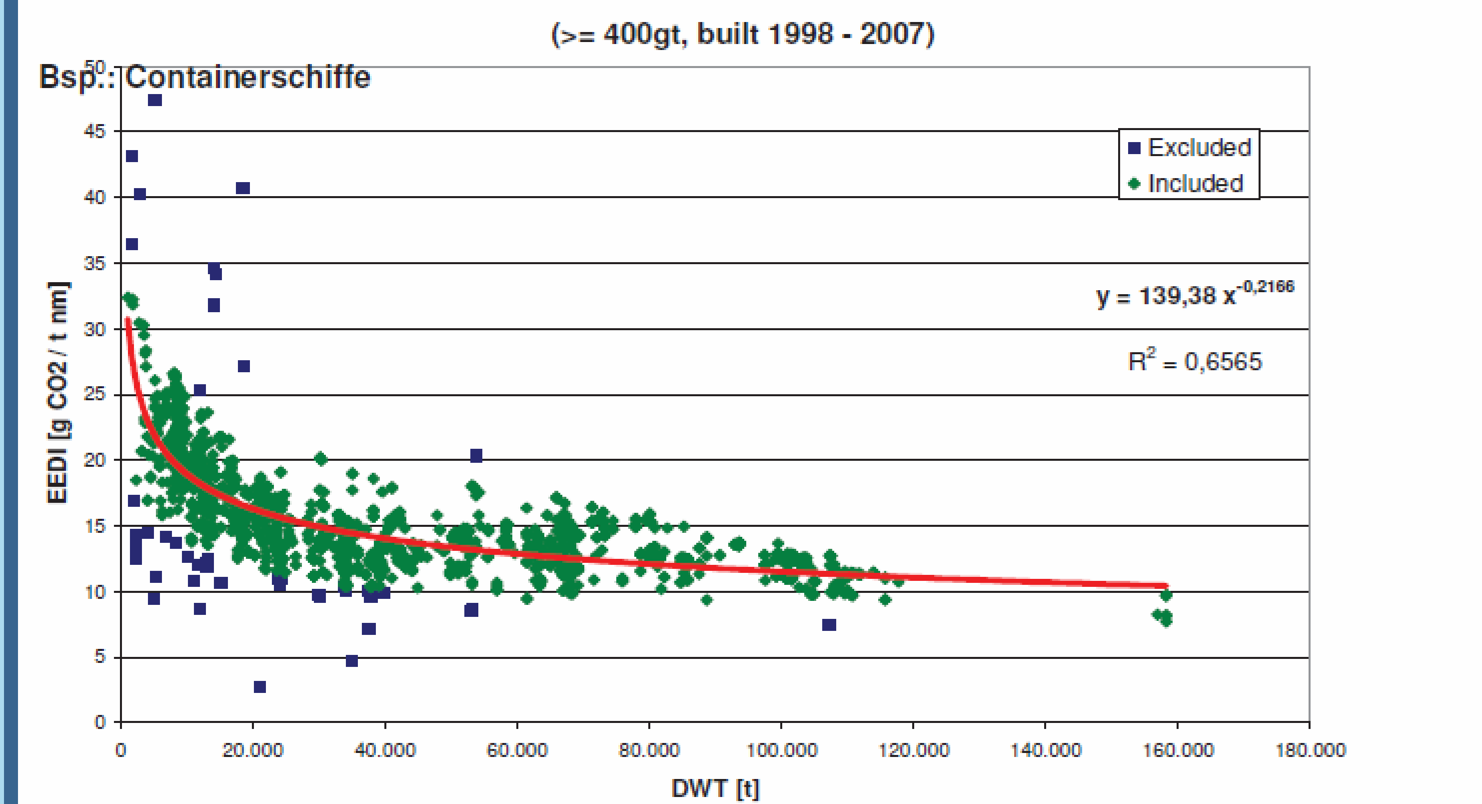
- CO_2 emission and accommodation — CO_2 emission from propulsion
- Benefit — Transported cargo x speed
- Unit — Gram CO_2 / Ton / Nautical Mile



Source: MEPC 60

Hamburgische Schiffbau-Versuchsanstalt GmbH · Bramfelder Str. 164 · D-22305 Hamburg · Tel.+49-40-69 203-0 (Fax -345) · info @ hsva.de

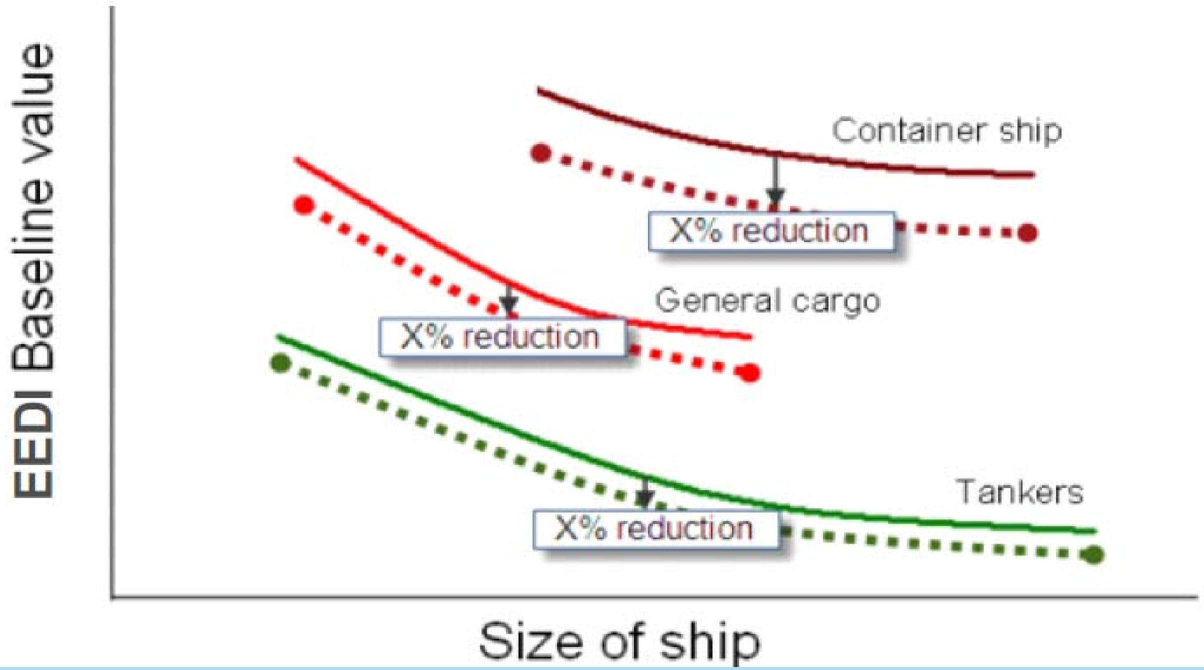
EEDI



Source: Krapp GL 2009

EEDI

- Application to **new ships**
- **Required EEDI** is obtained as X% reduction from the **baseline**, equally applied for all ship types
- Baseline is based on a regression analysis of historical data

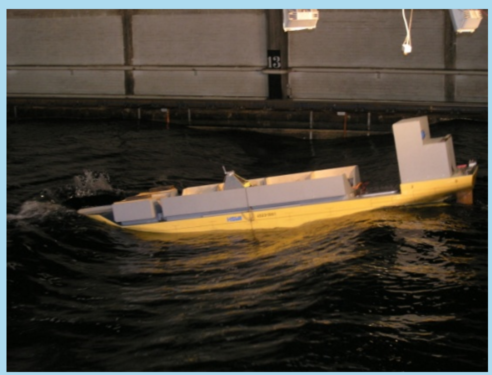


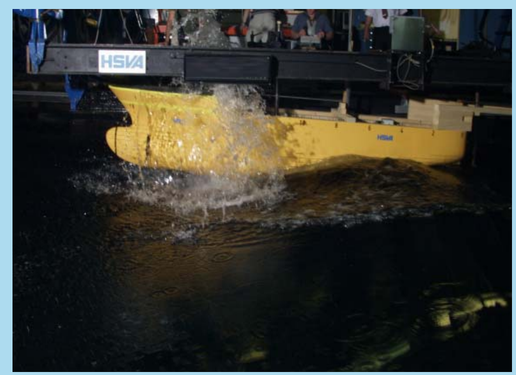
Hamburgische Schiffbau-Versuchsanstalt GmbH · Bramfelder Str. 164 · D-22305 Hamburg · Tel.+49-40-69 203-0 (Fax -345) · info @ hsva.de

Minimizing Hull Resistance

Frictional drag is the largest drag component of a ship.

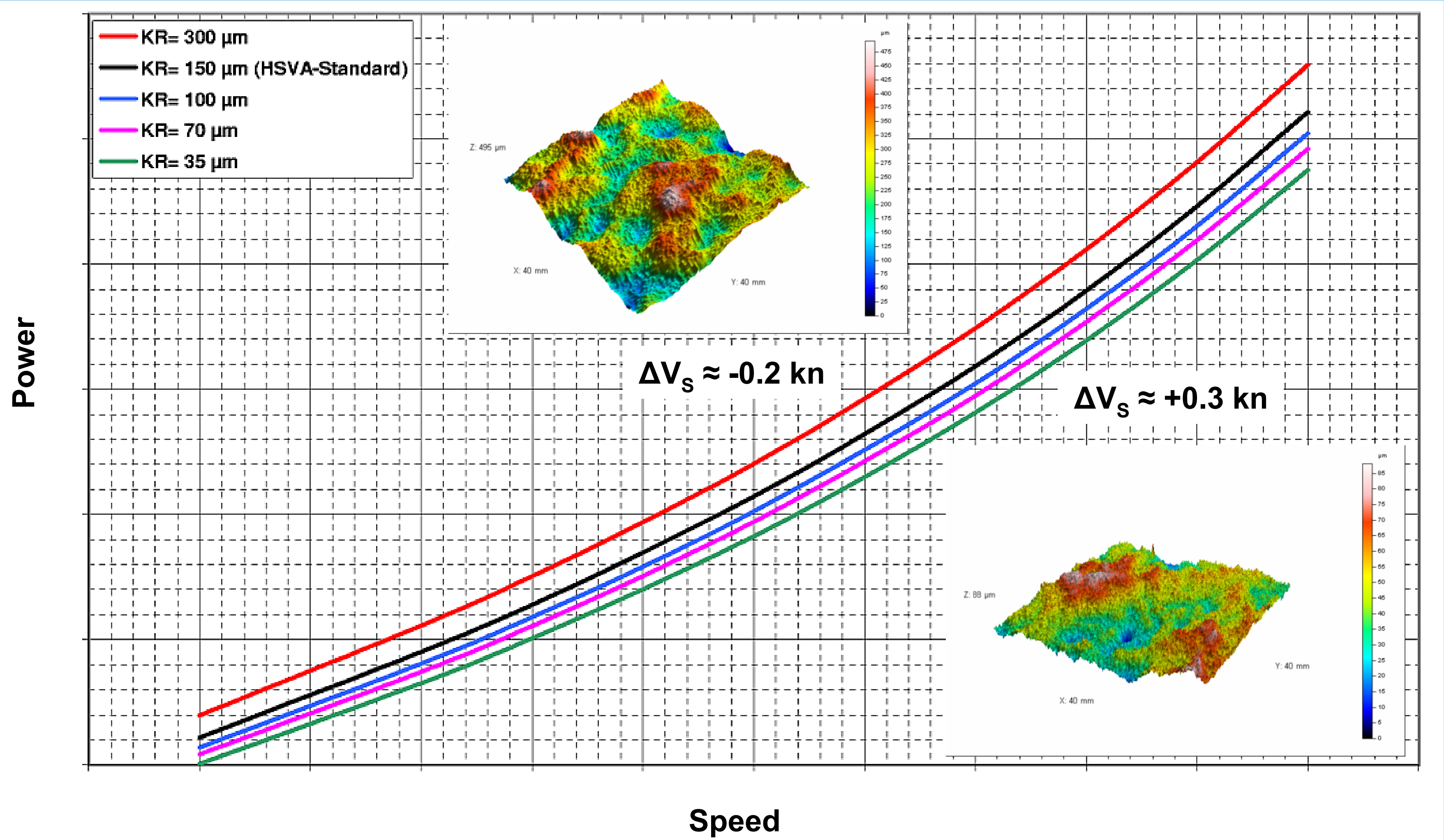
				Tanker	Container ship
Total drag	Fluid drag	Viscous drag	Frictional drag	75%	50%
			Viscous pressure drag	10%	10%
		Wave drag		10%	30%
	Wind drag			5%	10%





Hamburgische Schiffbau-Versuchsanstalt GmbH · Bramfelder Str. 164 · D-22305 Hamburg · Tel.+49-40-69 203-0 (Fax -345) · info @ hsva.de

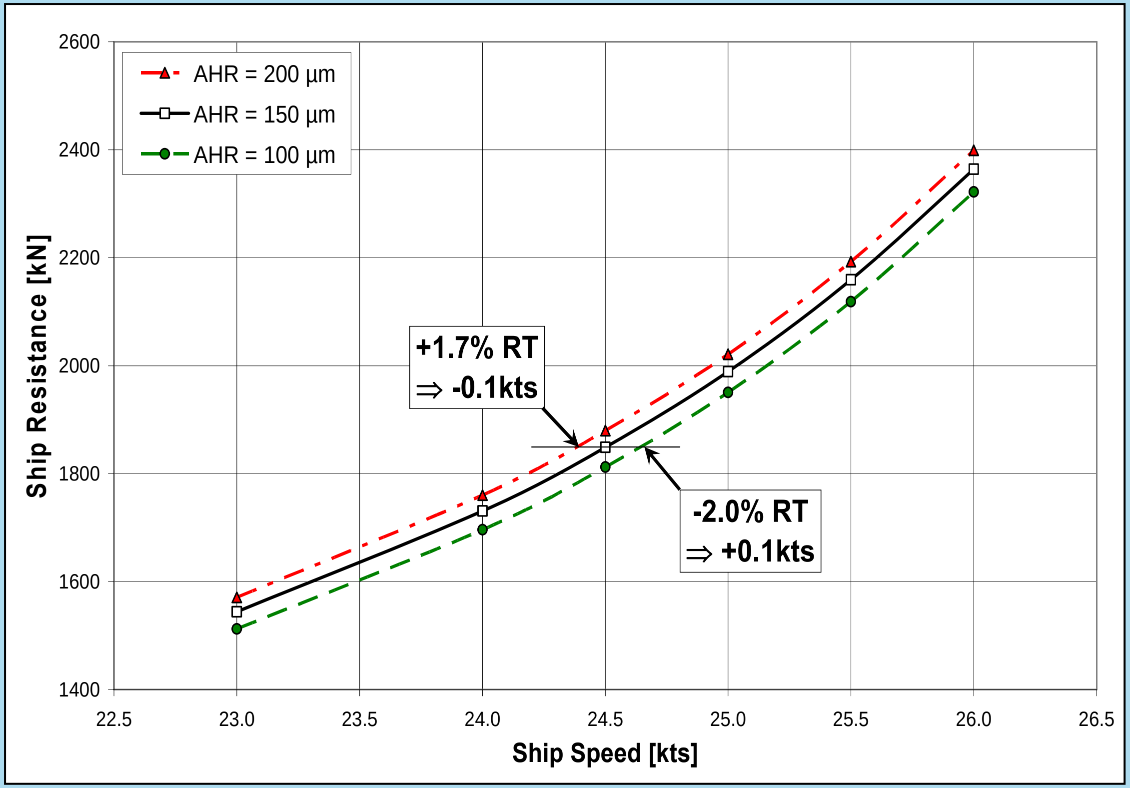
Minimizing Hull Resistance



Hamburgische Schiffbau-Versuchsanstalt GmbH · Bramfelder Str. 164 · D-22305 Hamburg · Tel.+49-40-69 203-0 (Fax -345) · info @ hsva.de

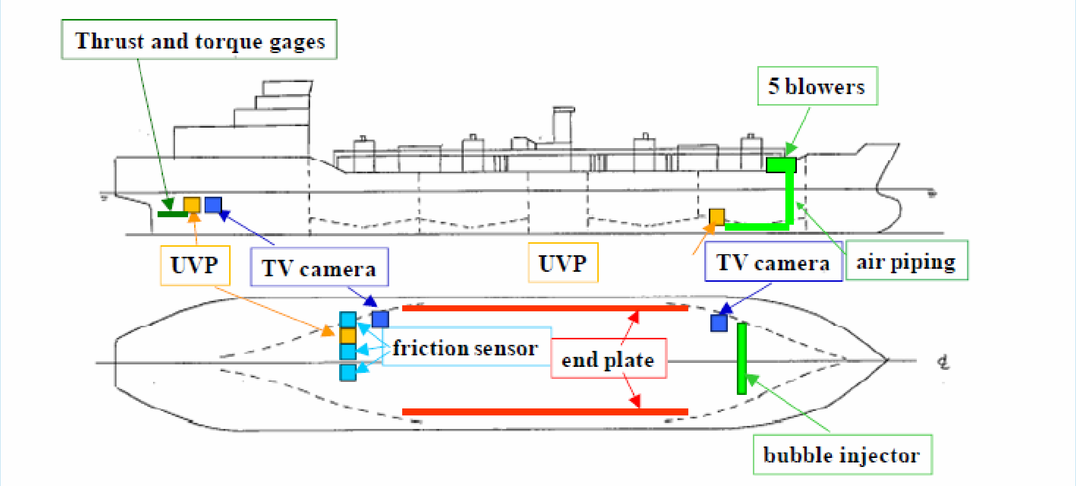
Minimizing Hull Resistance

The quality of the type of paint (anti-fouling) may influence the fuel oil consumption significantly, application of air cushions is also a possibility



Hamburgische Schiffbau-Versuchsanstalt GmbH · Bramfelder Str. 164 · D-22305 Hamburg · Tel.+49-40-69 203-0 (Fax -345) · info @ hsva.de

Minimizing Hull Resistance



The propeller thrust reduces by 12% maximum with air injection.

⇩

The ship's drag reduces by 12% or slightly more.

Friction drag at hull bottom=30% of total drag

⇩

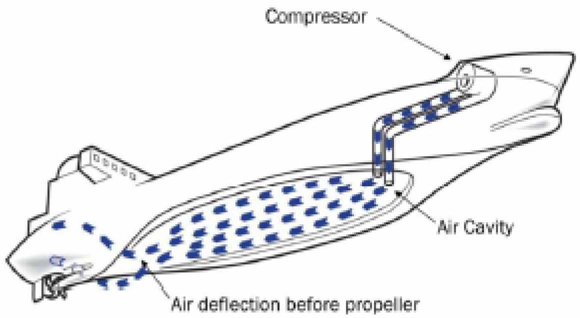
Friction drag at the hull bottom reduces by 40%.

Hamburgische Schiffbau-Versuchsanstalt GmbH · Bramfelder Str. 164 · D-22305 Hamburg · Tel.+49-40-69 203-0 (Fax -345) · info @ hsva.de

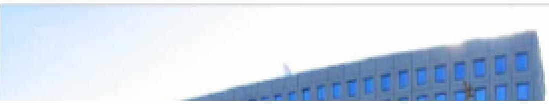
Minimizing Hull Resistance

ACS (Air Cavity System) (running)

Air cavities to keep injected air.
Full scale test in September 2008.

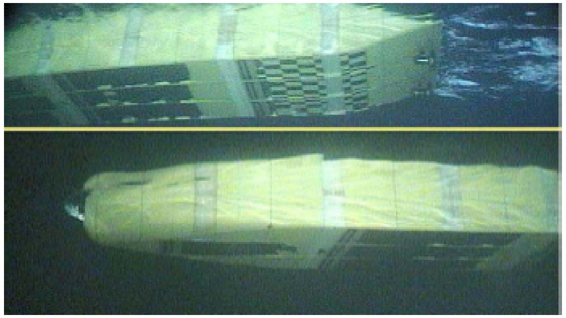


ACS concept



PELS(Project Energy-saving air-Lubricated Ships)(2001-2004, the Netherlands)

6m and 11.51m geo-sim model ship tests (resistance, self-propulsion, maneuvrability, seakeeping) were conducted aiming at application to 120m ship.
Pod propulsors were assumed, in order to avoid propeller operation in bubbly flow.

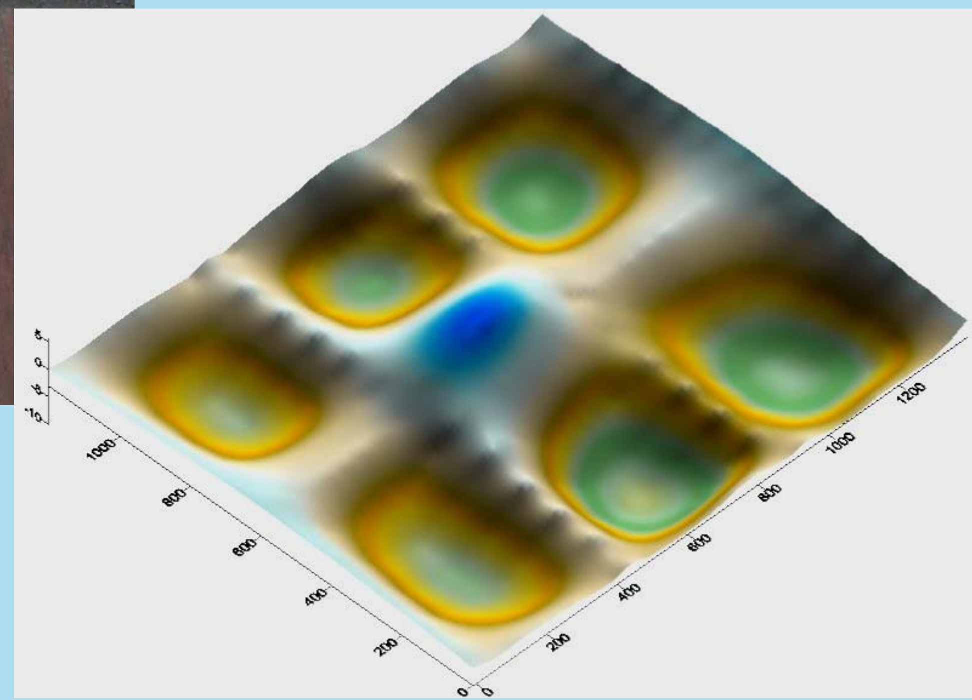


Free running

Thill, C. et al., 2nd Int. Symp. on Seawater Drag Reduction (2005)

Minimizing Hull Resistance

Imperfect Surfaces



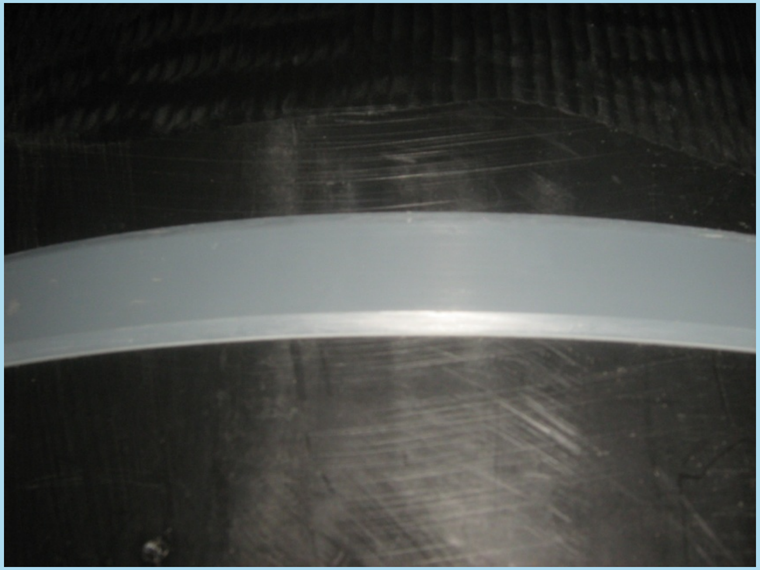
by bumps and welding seams

Minimizing Hull Resistance

Tests with different bodies:

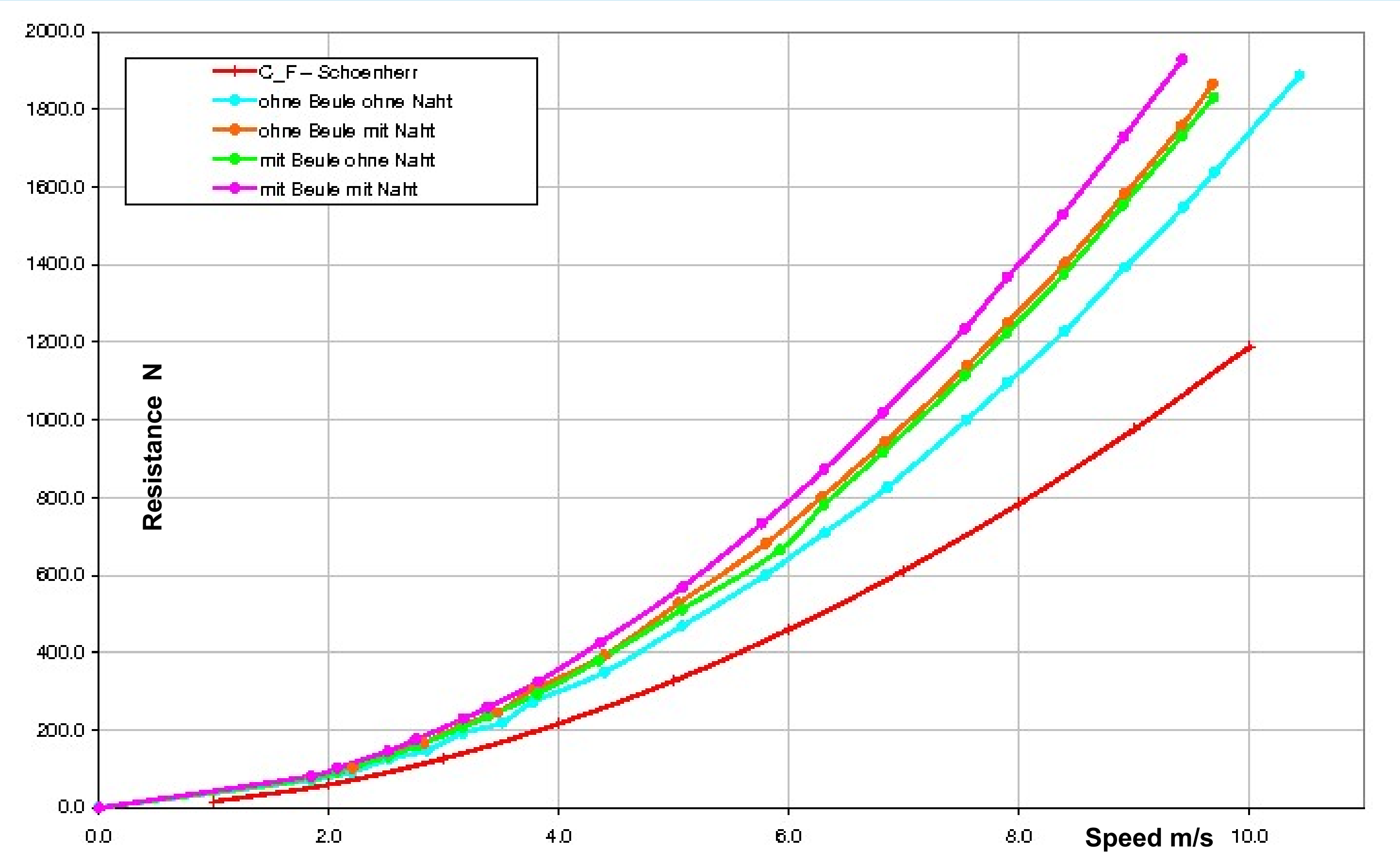
Full optimised shape,

with bumps, with welding seams, with bumps and welding seams



Hamburgische Schiffbau-Versuchsanstalt GmbH · Bramfelder Str. 164 · D-22305 Hamburg · Tel.+49-40-69 203-0 (Fax -345) · info @ hsva.de

Minimizing Hull Resistance



Hamburgische Schiffbau-Versuchsanstalt GmbH · Bramfelder Str. 164 · D-22305 Hamburg · Tel.+49-40-69 203-0 (Fax -345) · info @ hsva.de

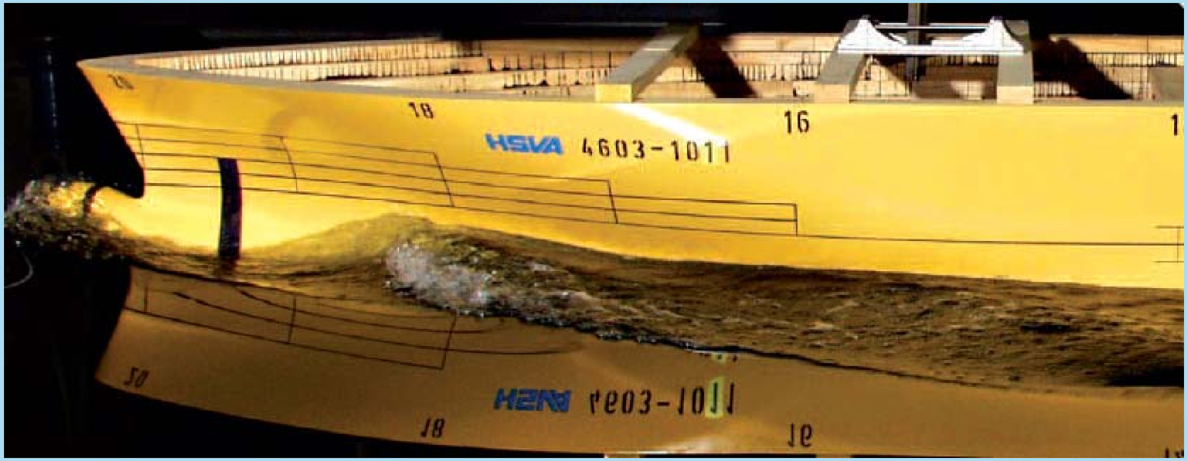
Minimizing Hull Resistance

1. Air lubrication is a powerful technique to reduce skin friction, the largest drag component of a ship.
2. Air lubrication has been validated by a full scale experiment using a ship exceeding 100m in length as a useful drag reduction technique.
3. Practical application of air lubrication methods should be promoted, in order to contribute to the prevention of global warming.

4. **Improve the hull surface by using improved, less rough paints**
5. **Polish welding seams**
6. **Avoid bumps and large deformations of the shell plates**

Hamburgische Schiffbau-Versuchsanstalt GmbH · Bramfelder Str. 164 · D-22305 Hamburg · Tel.+49-40-69 203-0 (Fax -345) · info @ hsva.de

How to operate a ship hydrodynamical efficient !



The reduction in required power between these two forms is about 16% !

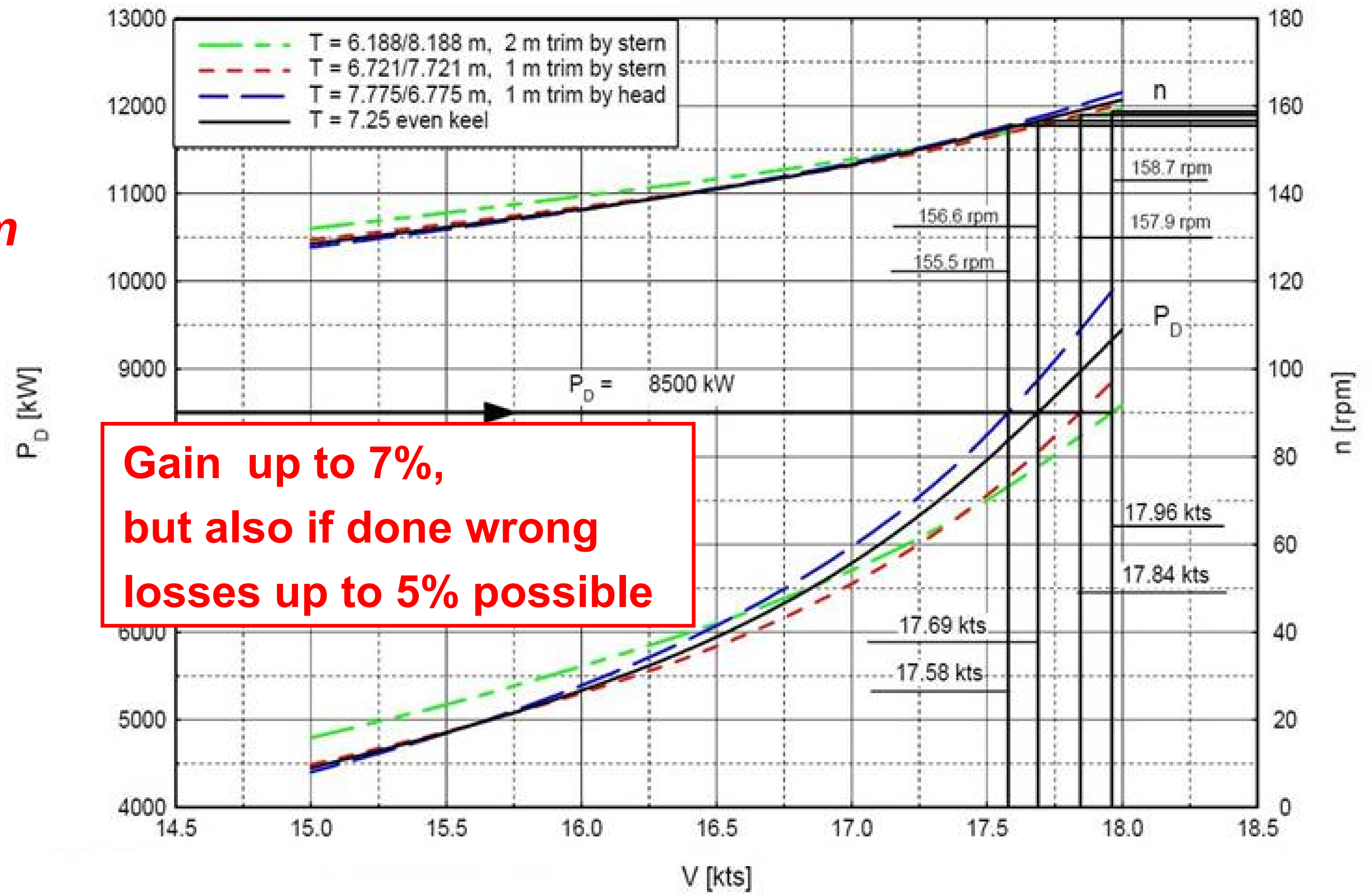
Look for Off-design conditions

Wave pattern at reduced draught and reduced speed

Hamburgische Schiffbau-Versuchsanstalt GmbH · Bramfelder Str. 164 · D-22305 Hamburg · Tel.+49-40-69 203-0 (Fax -345) · info @ hsva.de

How to operate a ship hydrodynamical efficient !

Look for
Optimum Trim
conditions



Gain up to 7%,
but also if done wrong
losses up to 5% possible

Hamburgische Schiffbau-Versuchsanstalt GmbH · Bramfelder Str. 164 · D-22305 Hamburg · Tel.+49-40-69 203-0 (Fax -345) · info @ hsva.de

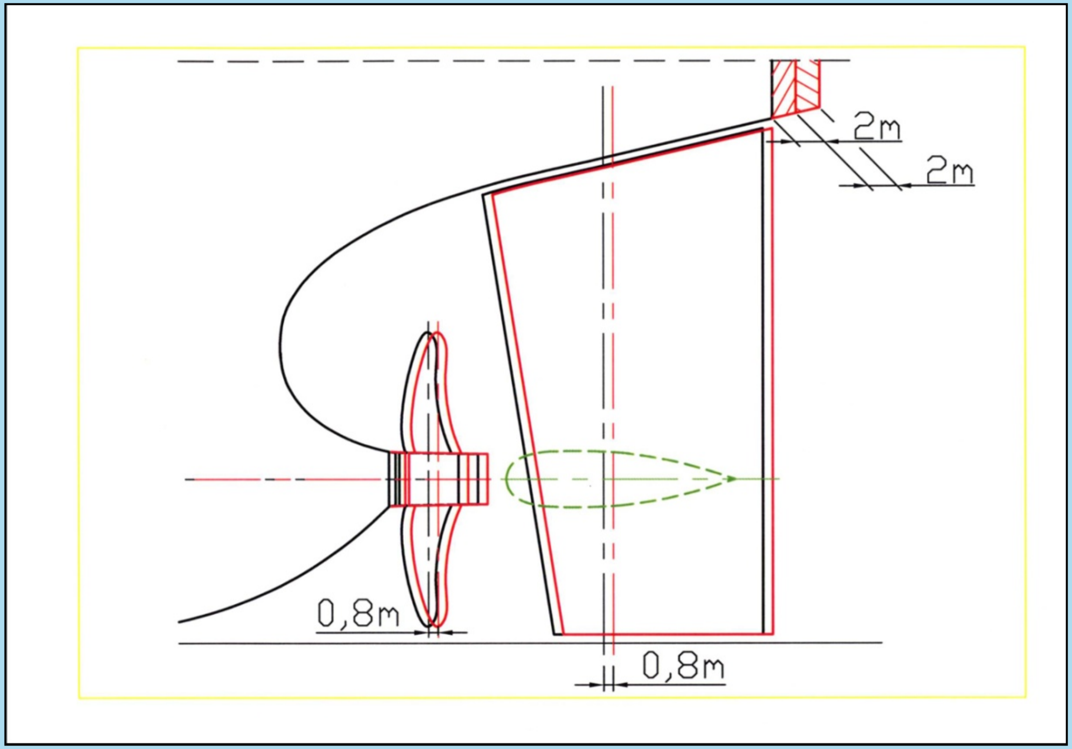
Optimise the Arrangement of Hull, Rudder, Propeller

Hull designer, rudder designer and propeller designer have to work in close co-operation

Applying a ducktail (with trim wedge) may gain up to 2-3%

Optimum rudder and propeller position may gain up to 1-2%

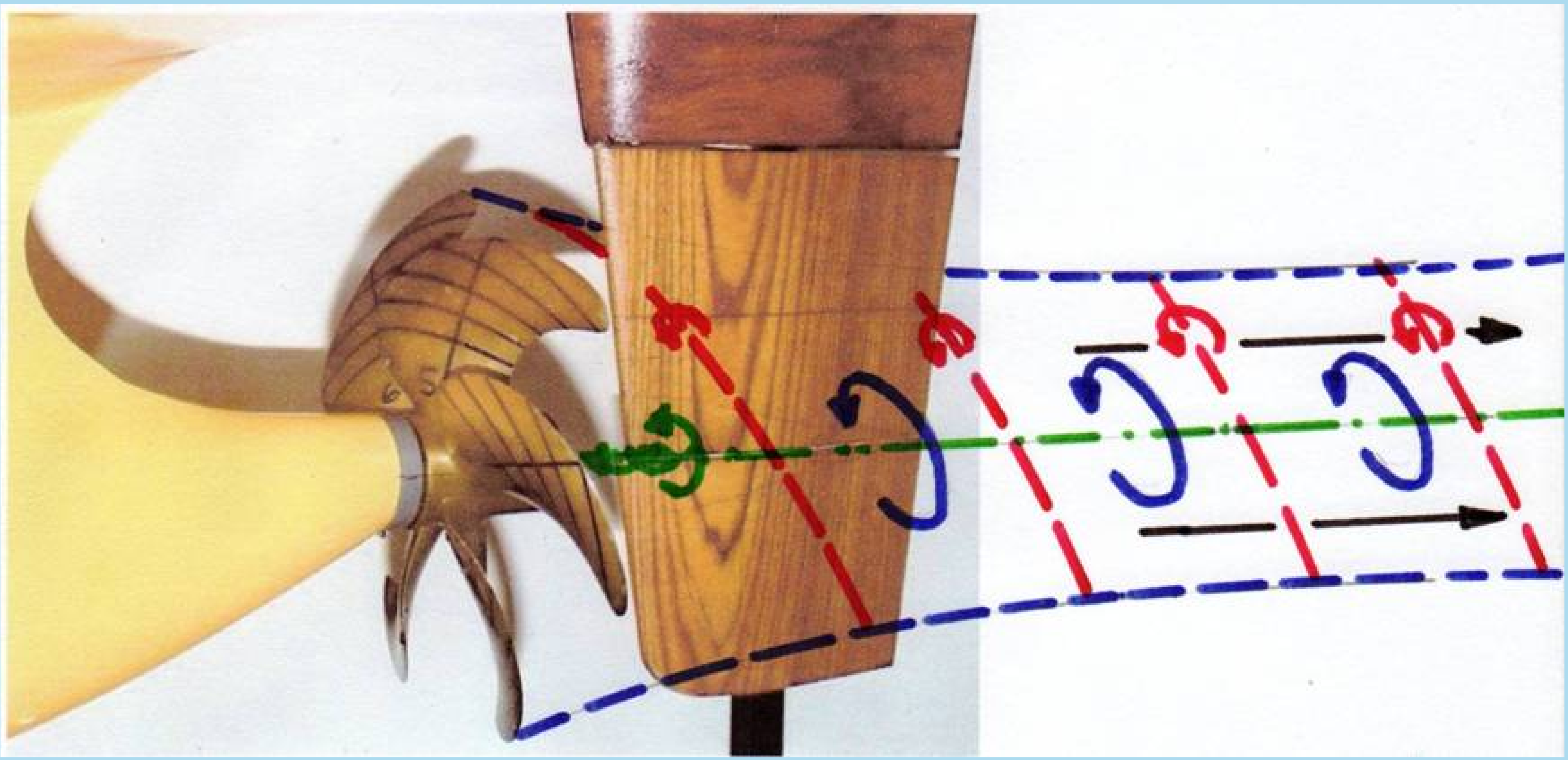
Applying a rudder bulb may gain additionally 1-2%



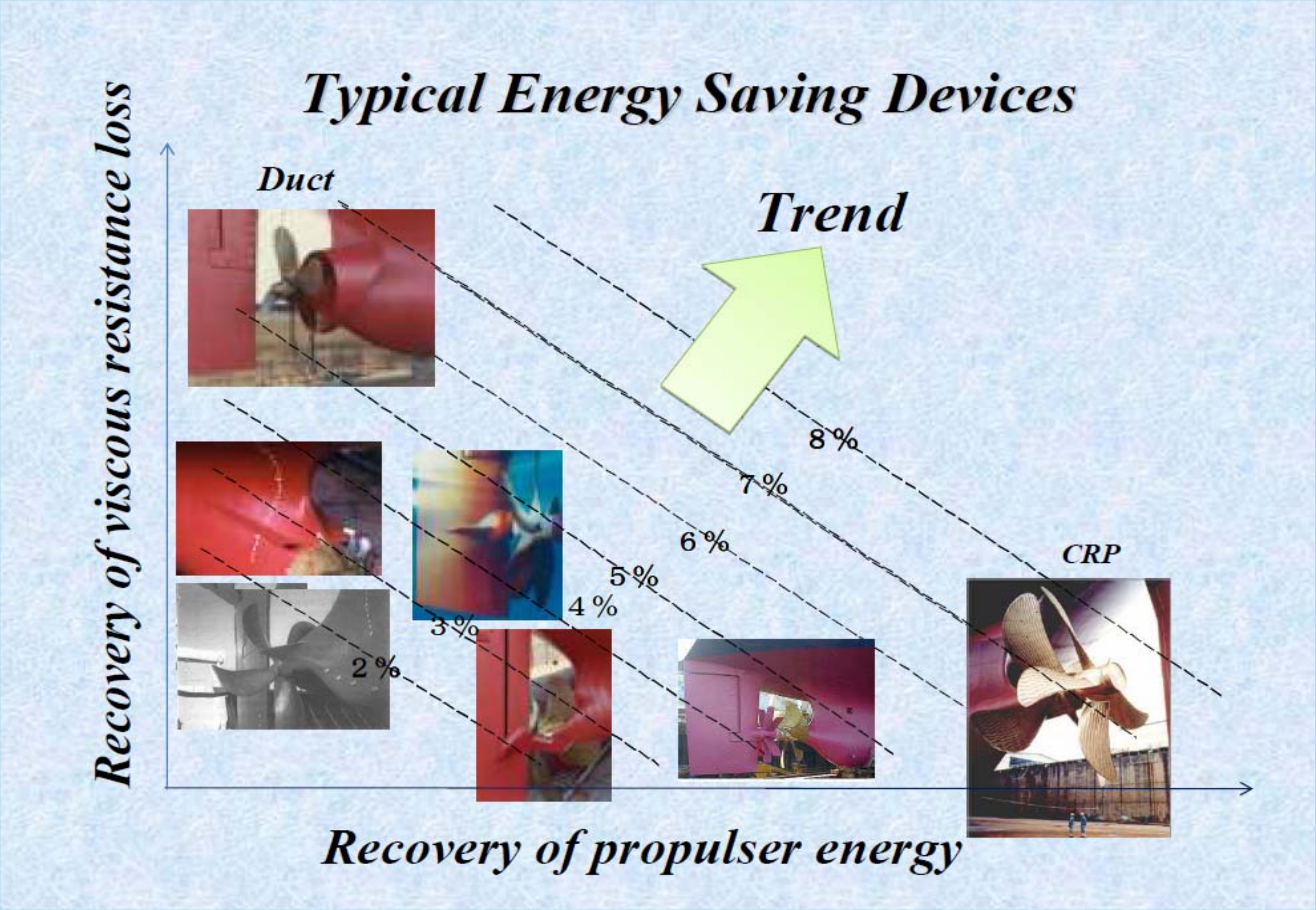
5% in Power are equal to a gain in speed of 0.26 knots for this Project

Hamburgische Schiffbau-Versuchsanstalt GmbH · Bramfelder Str. 164 · D-22305 Hamburg · Tel.+49-40-69 203-0 (Fax -345) · info @ hsva.de

Devices improving Propulsive Efficiency



Devices improving Propulsive Efficiency



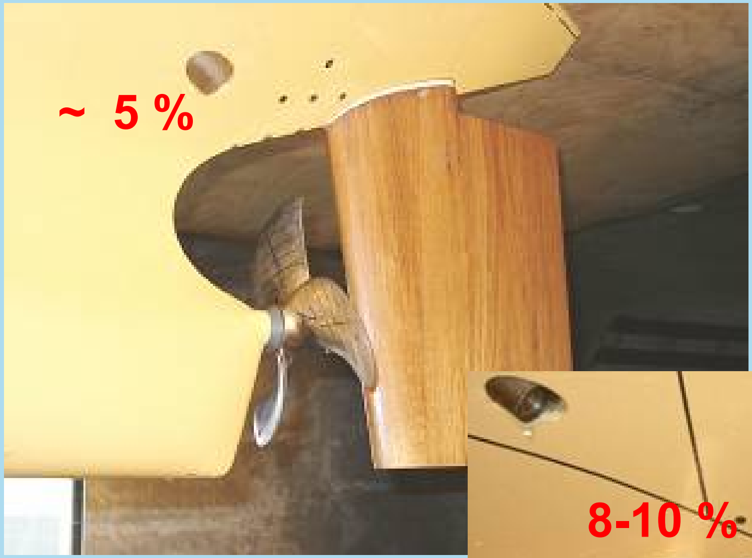
Hamburgische Schiffbau-Versuchsanstalt GmbH · Bramfelder Str. 164 · D-22305 Hamburg · Tel.+49-40-69 203-0 (Fax -345) · info @ hsva.de

Devices Improving Propulsive Efficiency

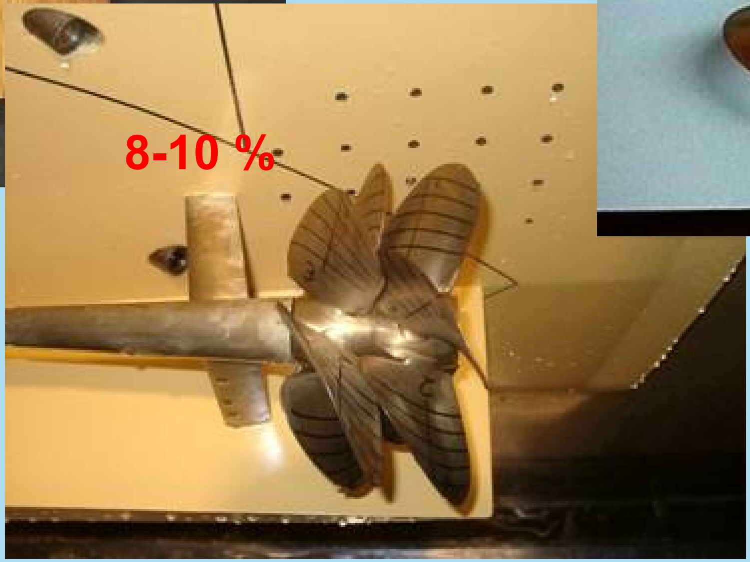
Pre Swirl Fin Systems	Designer DSME	gain up to **4%**
Rudder Fin Systems	Designer HHI	gain up to **4%**
Twisted Rudder with Costa Bulb	Designer BMS/HSVA	gain up to **4%**
Mewis Duct		up to **8%**

Hamburgische Schiffbau-Versuchsanstalt GmbH · Bramfelder Str. 164 · D-22305 Hamburg · Tel.+49-40-69 203-0 (Fax -345) · info @ hsva.de

High Efficiency Propellers



3-bladed Propeller for VLCC



Contra-rotating Propellers

Kappel-Propeller

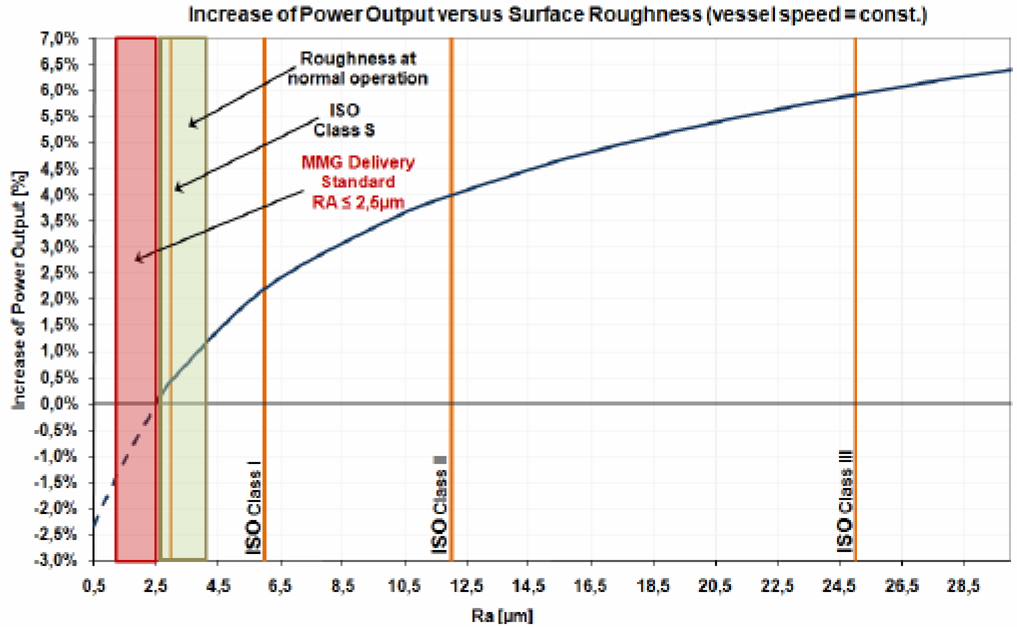
Hamburgische Schiffbau-Versuchsanstalt GmbH · Bramfelder Str. 164 · D-22305 Hamburg · Tel.+49-40-69 203-0 (Fax -345) · info @ hsva.de

High Efficiency Propellers

Improving Efficiency by Polishing / Coating?

Propeller Roughness:

- ISO Class S (3 μm)
- MMG Standard (≤ 2.5 μm)



Propeller coating:

- Surface roughness abt. 0.8μm
- Costs abt. 20,000 US$
- rigid or flexible surfaces

Propeller polishing (due to fouling):

- Savings of abt. 30%
- Minimum service intervals depending on vessel and route

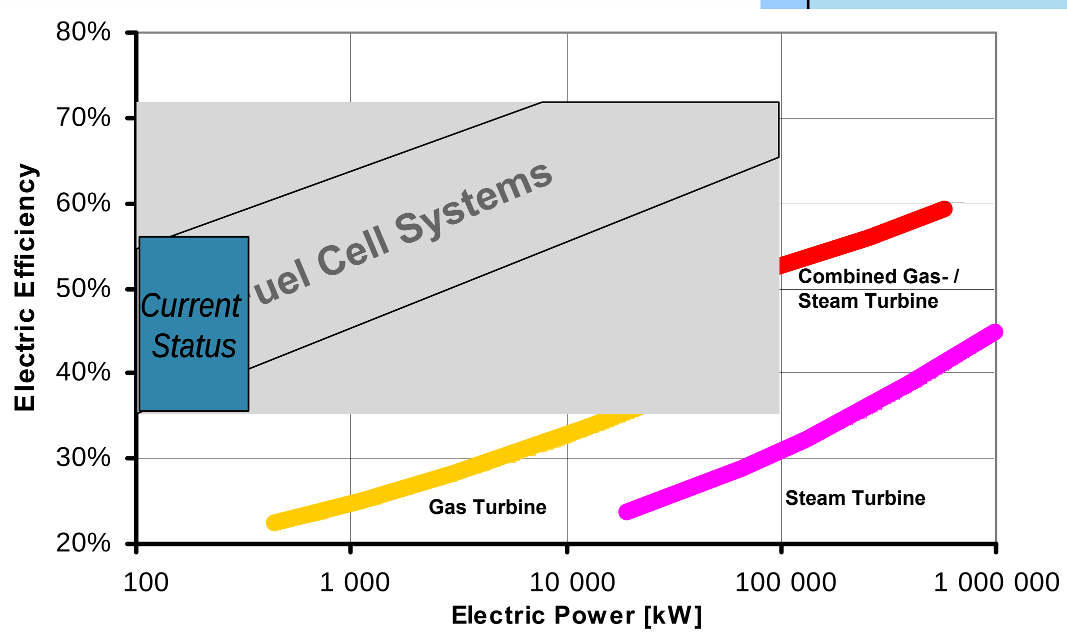
Source: MMG 2010

Hamburgische Schiffbau-Versuchsanstalt GmbH · Bramfelder Str. 164 · D-22305 Hamburg · Tel.+49-40-69 203-0 (Fax -345) · info @ hsva.de

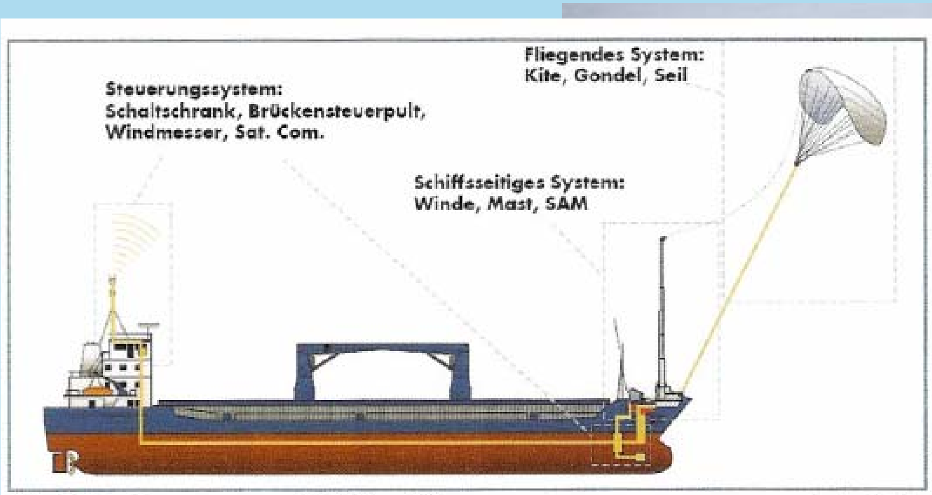
Alternative Ways to Go

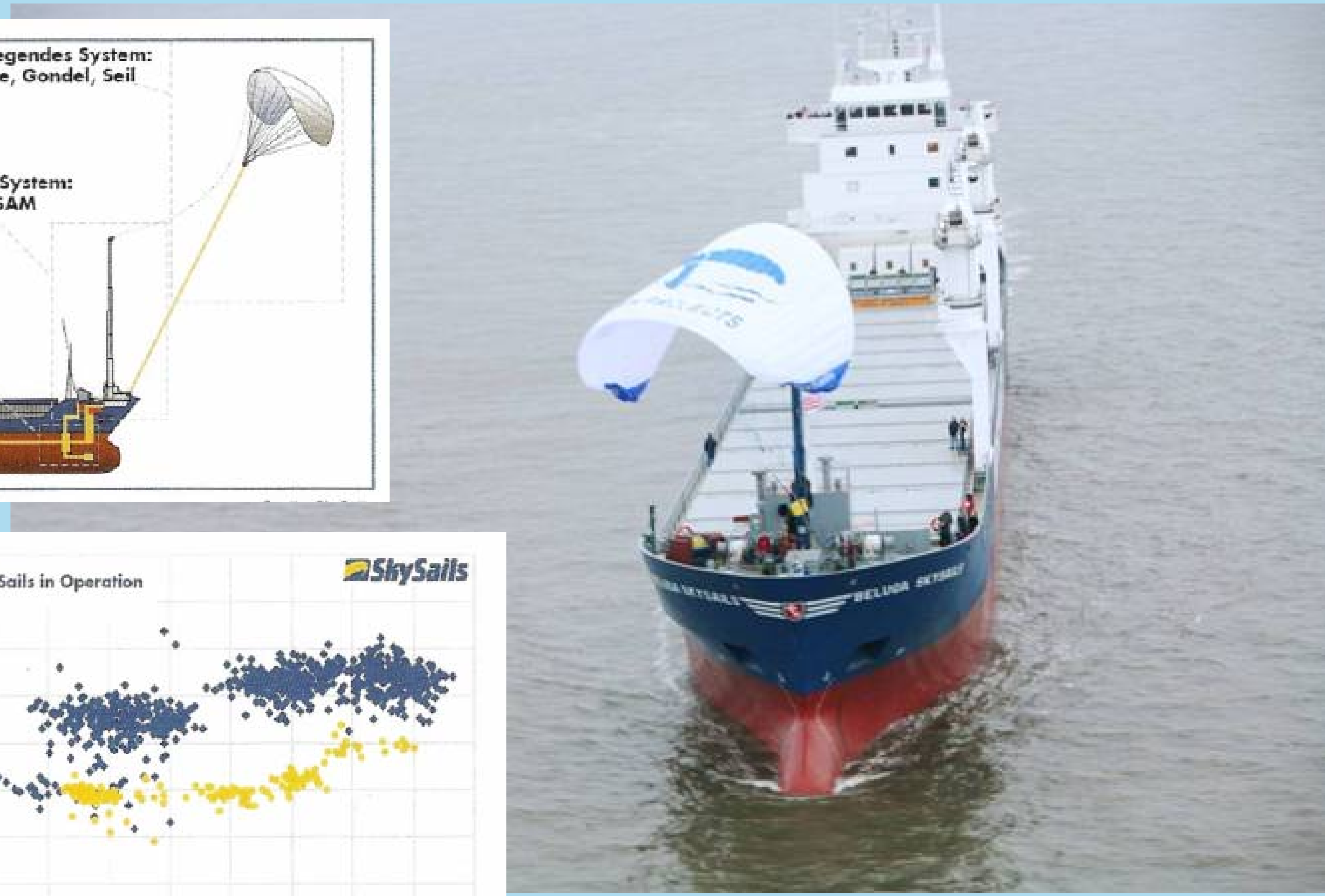
Alternative Ways

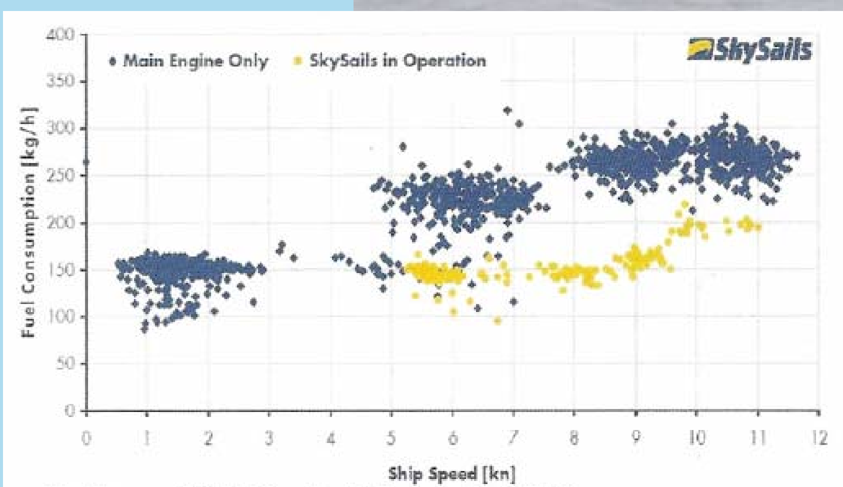
- Fuel cells N
  N
- Sun and wind N
- Nuclear power P



Wind Power

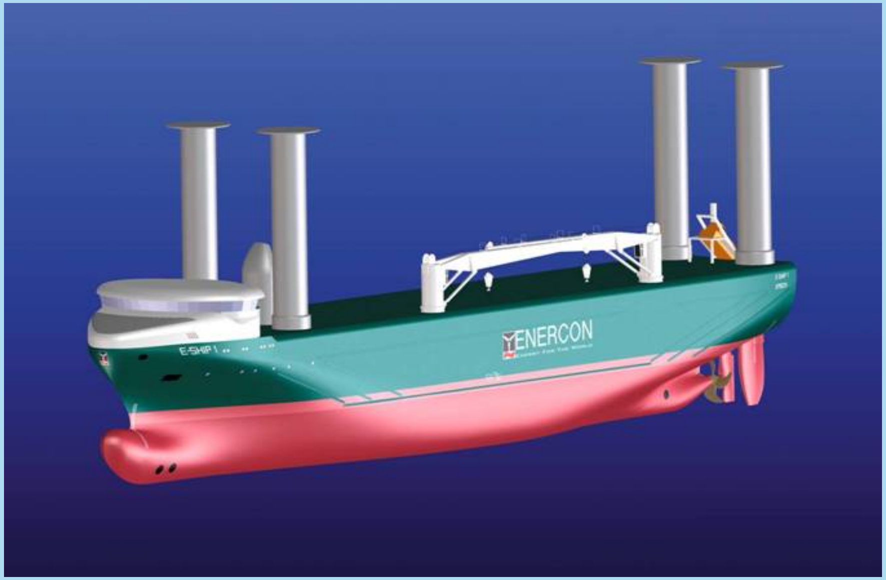


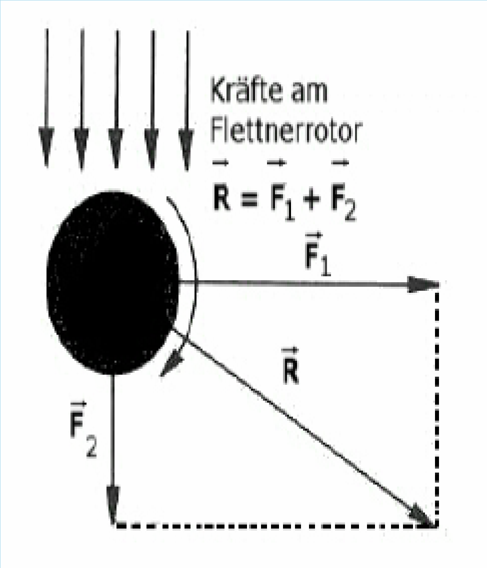


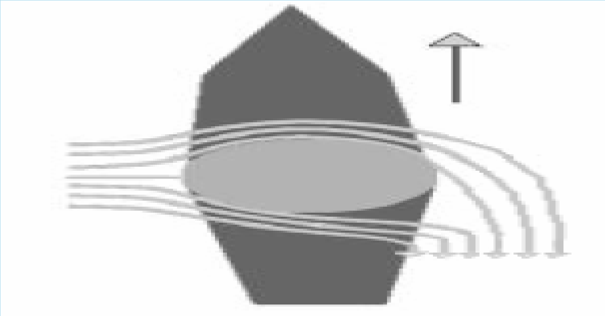


Verdrängung 4000t, CP Propeller, Wellengenerator: 150 kW

Wind Power







Hamburgische Schiffbau-Versuchsanstalt GmbH · Bramfelder Str. 164 · D-22305 Hamburg · Tel.+49-40-69 203-0 (Fax -345) · info @ hsva.de

Hydrodynamic Optimization– What can be gained?

Conclusions

Optimising **main dimensions** may gain	up to 25%
Avoiding too strict **hard points** may gain	up to 17%
Using an **experienced designer** may gain	up to 10%
Optimising the **hullform** may gain	up to 7%
Devices **improving propulsion efficiency** may gain	up to 8%
Optimising **arrangement of rudder and propeller** may gain	up to 3%
Optimising **hull surface** may gain	up to 10%

Further improvements can be achieved by optimising the whole ship for
real off-design conditions!

The gains are valid for the examples shown here. The benefits given above are not fully cumulative!

Hamburgische Schiffbau-Versuchsanstalt GmbH · Bramfelder Str. 164 · D-22305 Hamburg · Tel.+49-40-69 203-0 (Fax -345) · info @ hsva.de

The best possible way to avoid pollution from shipping ???

Thank you for your Attention

Hamburgische Schiffbau-Versuchsanstalt GmbH · Bramfelder Str. 164 · D-22305 Hamburg · Tel.+49-40-69 203-0 (Fax -345) · info @ hsva.de