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Scaling of Conventional and Unconventional Propellers

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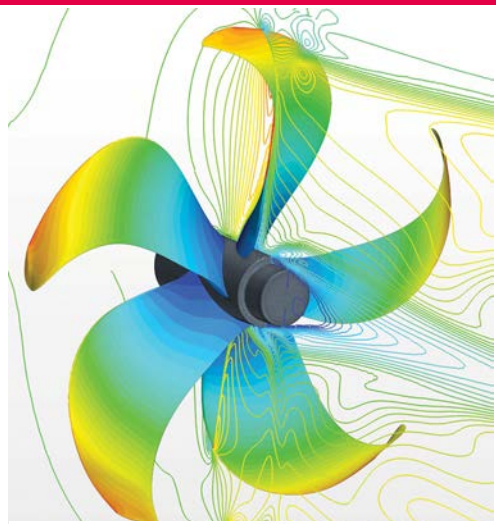
MAN Alpha

Agenda

MAN Alpha Kappel Propellers

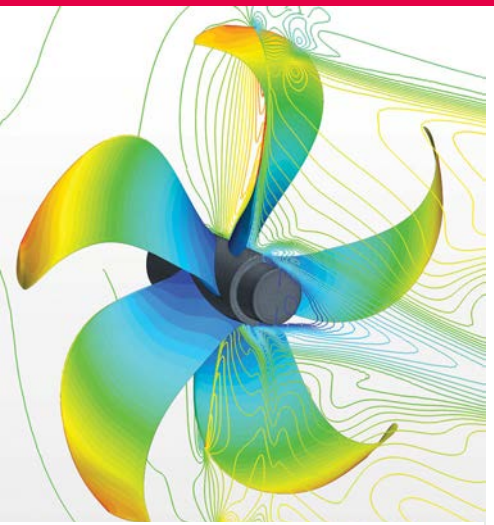
Experience implementing Kappel propellers

- MDT/Kappel cooperation agreement entered into in 2003
- Takeover of all rights of Kappel Propellers including design and future integration into MDT's propulsion portfolio in 2012
- Applicable to both FPP and CPP
- Increased propeller efficiency of 3-5% compared to conventional propeller design
- The improvement is only related to the propeller blade design and does not require any coordination with other suppliers
- Can be combined with most other Efficiency Improving Devices to achieve even higher efficiencies
- Reduced noise and vibrations



Kappel Design Procedure

Experience implementing Kappel propellers



Kasper
Propeller optimisation

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CLASS
Classification scantlings

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BEM
Cavitation evaluation

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CFD
Efficiency optimisation

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FEM
Strength analysis

Kappel Propeller References

- **Total number of propellers: 44**
- **Type of vessels**
  - Container
  - Bulk carrier
  - Tanker
  - Car carrier
  - Ro-Ro
  - Submarine
- **Applications**
  - FPP
  - CPP
  - New building projects
  - Retrofit projects

Scaling from model to full scale

Current ITTC rules

In order to predict the performance in full scale, the test values in model scales needs to be addressed with regards to

- **Scaling of the wake** - accounted for in ITTC 1978 rules and based on conventional propellers
- **Scaling of propeller** - accounted for in ITTC 1978 rules and based on conventional propellers

Wake Scaling methods

- ITTC 1978
- ITTC 1999
- Yazaki
- FORCE Technology

Wake scaling of Kappel propellers

The Kappel propeller generally experience a higher effective wake fraction (W_{TM}) in model scale. However, the scaling of the effective wake according to the ITTC 1978 and Yazaki methods leads to higher reduction in full scale effective wake fraction (W_{TS}) and consequently hull efficiency (η_H) when compared to conventional propellers. The reduction is only partly recovered by an improvement in open water efficiency η_H as a result of a higher advance ratio.

Wake Scaling according to ITTC 1978

ITTC 1978 wake scaling

$$w_{TS} = (t + w_R) + (w_{TM} - t - w_R)\frac{(1+k)C_{FS} + \Delta C_F}{(1+k)C_{FM}}$$

Potential wake component

Frictional wake component

- **t** : Thrust deduction factor
- **W_R** : Effect of rudder on the wake fraction
- **W_{TM}** : Model wake fraction
- **k** : Form factor determined from resistance test
- **C_{FS}** : Frictional resistance coefficient of the ship
- **C_{FM}** : Frictional resistance coefficient of the model
- **ΔC_F** : Roughness allowance

Wake Scaling according to ITTC 1999

ITTC 1999 wake scaling

Proposed by The Specialist Commitee on Unconventional Propulsors (ITTC1999)

$$w_{TS} = (t + w_R) + (w_{TM} - t - w_R)\frac{(1+k)C_{FS} + \Delta C_F}{(1+k)C_{FM}} + (w_{ms} - w_{m0})$$

Wake scaling according to ITTC1978

W_{m0} = Model wake for conventional propeller without stator

W_{ms} = Model wake for unconventional propeller with stator

The ITTC 1999 method is found acceptable by the committee when applied to special propulsion devices that do not alter the flow around the hull

Other wake scaling methods

Wake scaling according to Yazaki (1969)

The Yazaki's method determines the wake scaling for ballast and loaded draft as function of

- Ship breath B
- Draft aft T_A
- Length between perpendiculars L_{pp}
- Model wake W_{TM}

No general public formula exist as the original paper only published curves for interpolation of the full scale wake – one for ballast and one for loaded.

The method is only applicable for single screw vessels

Other wake scaling methods

Wake scaling according to FORCE Technology (1967)

The FORCE Technology formula is based on an internal paper

The method is based on a calculation of the boundary layer thickness at the propeller plane and consider the parameters

- Length of ship upstream of propeller
- Ship speed Vs
- Propeller diameter
- Distance propeller centre to hull surface
- Hub diameter
- Scale ratio

The method is independent of the propeller type and measured W_{TM}

The method is applicable to both single and twin screw vessels

Scaling from model to full scale

Effect of using different scaling methods

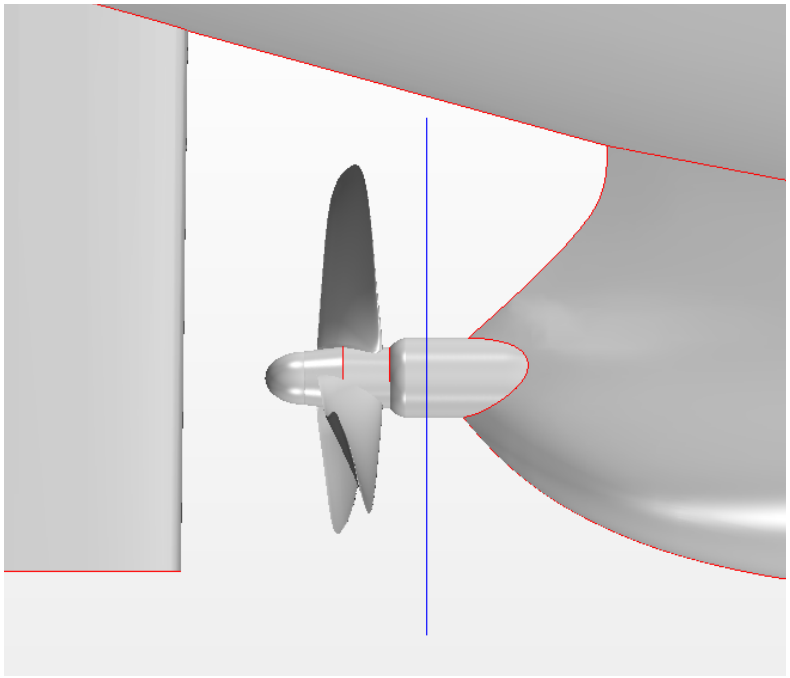
Propeller type	Prediction method	Thrust deduction	Wake fraction		Hull efficiency	Open-water efficiency	Relative rotative efficiency	Total efficiency	Kappel Improve-ment
			Model	Full					
		tm	wtm	wts	etah	etao	etar	etad	Δetad
Kappel	ITTC57	0.162	0.314		1.223	0.705	0.986	0.851	3.3%
	ITTC78	0.162		0.263	1.138	0.748	0.986	0.840	1.3%
	ITTC99	0.162		0.287	1.175	0.742	0.986	0.859	3.6%
Conventional	ITTC57	0.165	0.265		1.136	0.705	1.030	0.824	
	ITTC78	0.165		0.238	1.095	0.735	1.030	0.829	

Wake scaling – CFD analysis

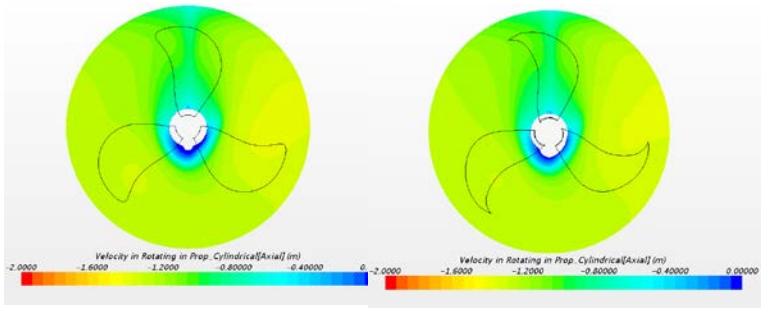
Wake field analysis in self propulsion

CFD self propulsion simulations

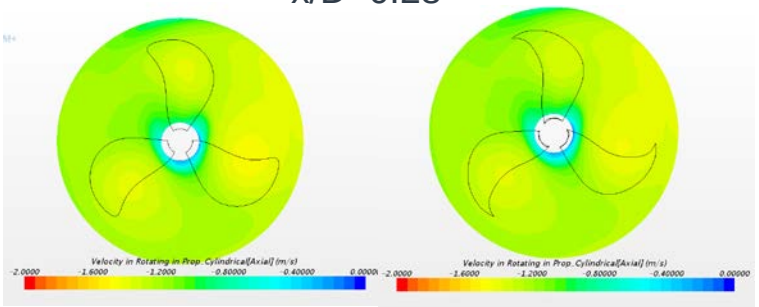
- Evaluate the inflow velocities to the propeller disc
- Compare the flow of conventional and Kappel propellers at different longitudinal positions



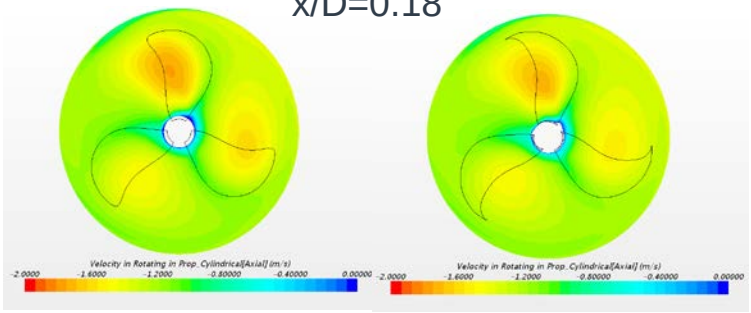
Conventional Kappel



x/D=0.28



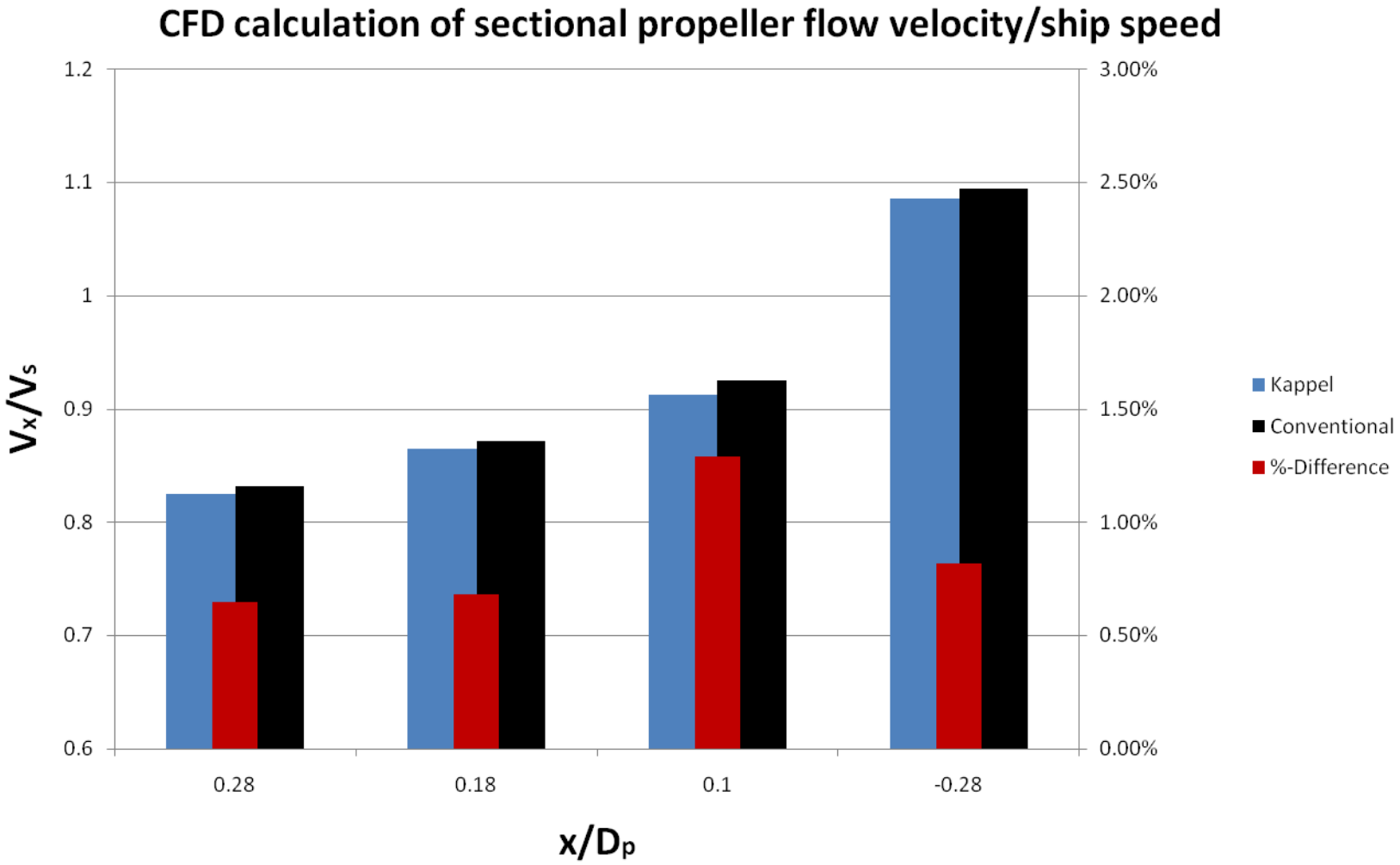
x/D=0.18



x/D=0.10

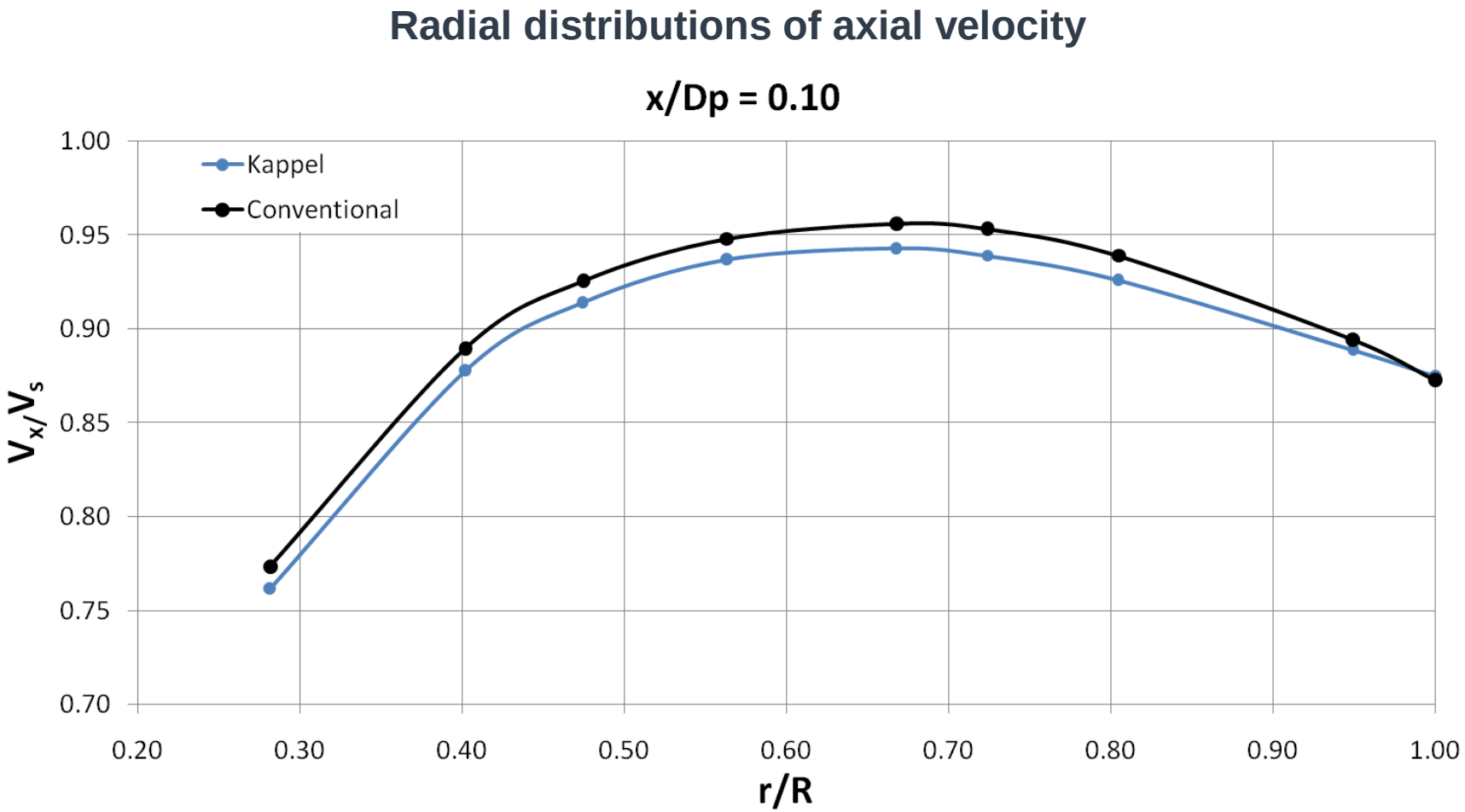
Wake scaling – CFD analysis

Wake field analysis in self propulsion



Wake scaling – CFD analysis

Wake field analysis in self propulsion



Wake scaling
Concluding remarks

With reference to the Kappel propeller

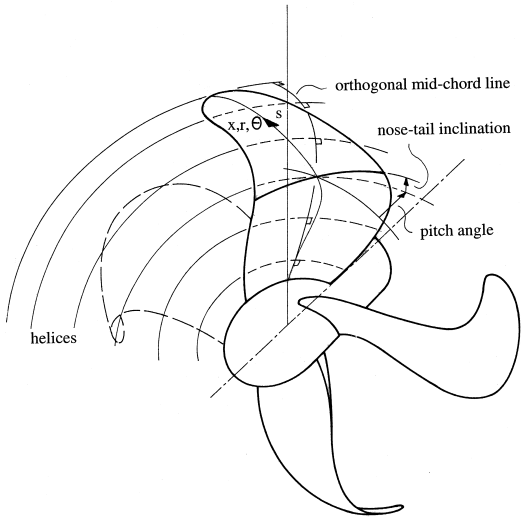
- The effective model wake is higher
- The hull efficiency is higher in model scale
- The velocities and accelerations are lower in front of the propeller and consequently the wake induced by the propeller is higher
- The alteration in flow is a result of a different radial velocity distribution – thus a change in the potential wake
- The ITTC 1999 wake scaling should be applicable

Open water scaling

The ITTC 1978 open water scaling is based on

- The profile characteristics at radius r/R=0.75
- A correction to K_{TM} and K_{QM} according to
  - $K_{TS}=K_{TM}-\Delta K_T$
  - $K_{QS}=K_{QM}-\Delta K_Q$

- For Kappel propellers the r/R=0.75 does not represent a characteristic radius

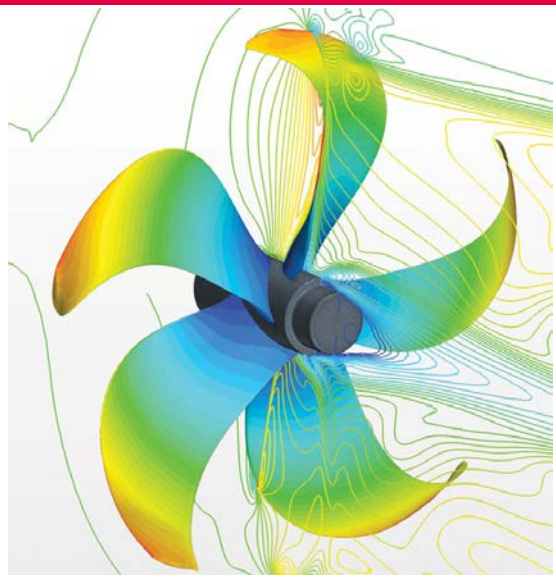


Scaling of Kappel propellers

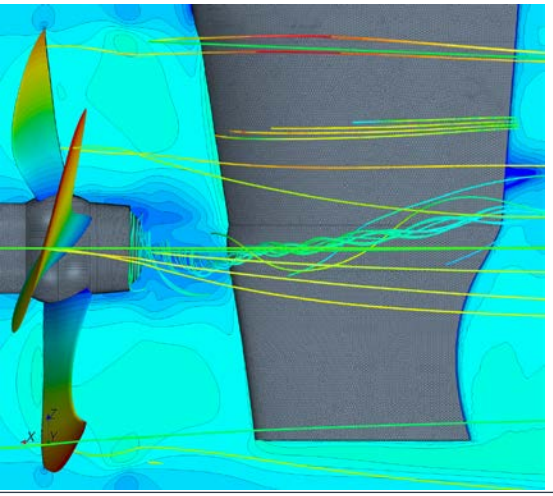
- Instead the strip methods developed by Prof. Poul Andersen is proposed
  - Strip wise calculations to account for the more outward curved part of the Kappel propeller
  - Applicable to conventional propeller as well
  - Essential that strip widths are calculated correctly – orthogonal to the adjacent helices

Combination of Efficiency Improving Devices
Kappel Propeller and Rudder Bulb

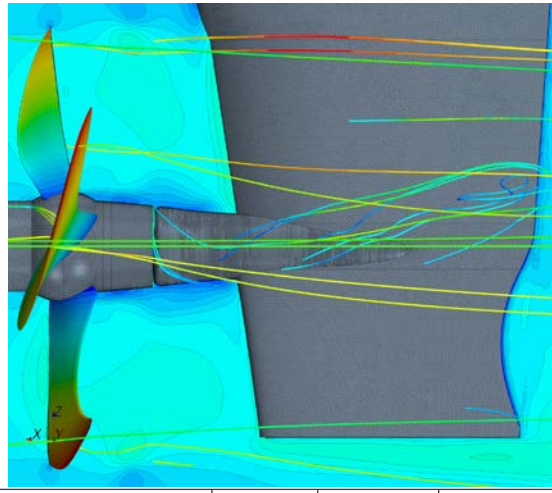
The Kappel propeller is characterised by having its propeller tips gently bended towards the suction/forward side in order to reduces the losses associated with the tip vortex flow



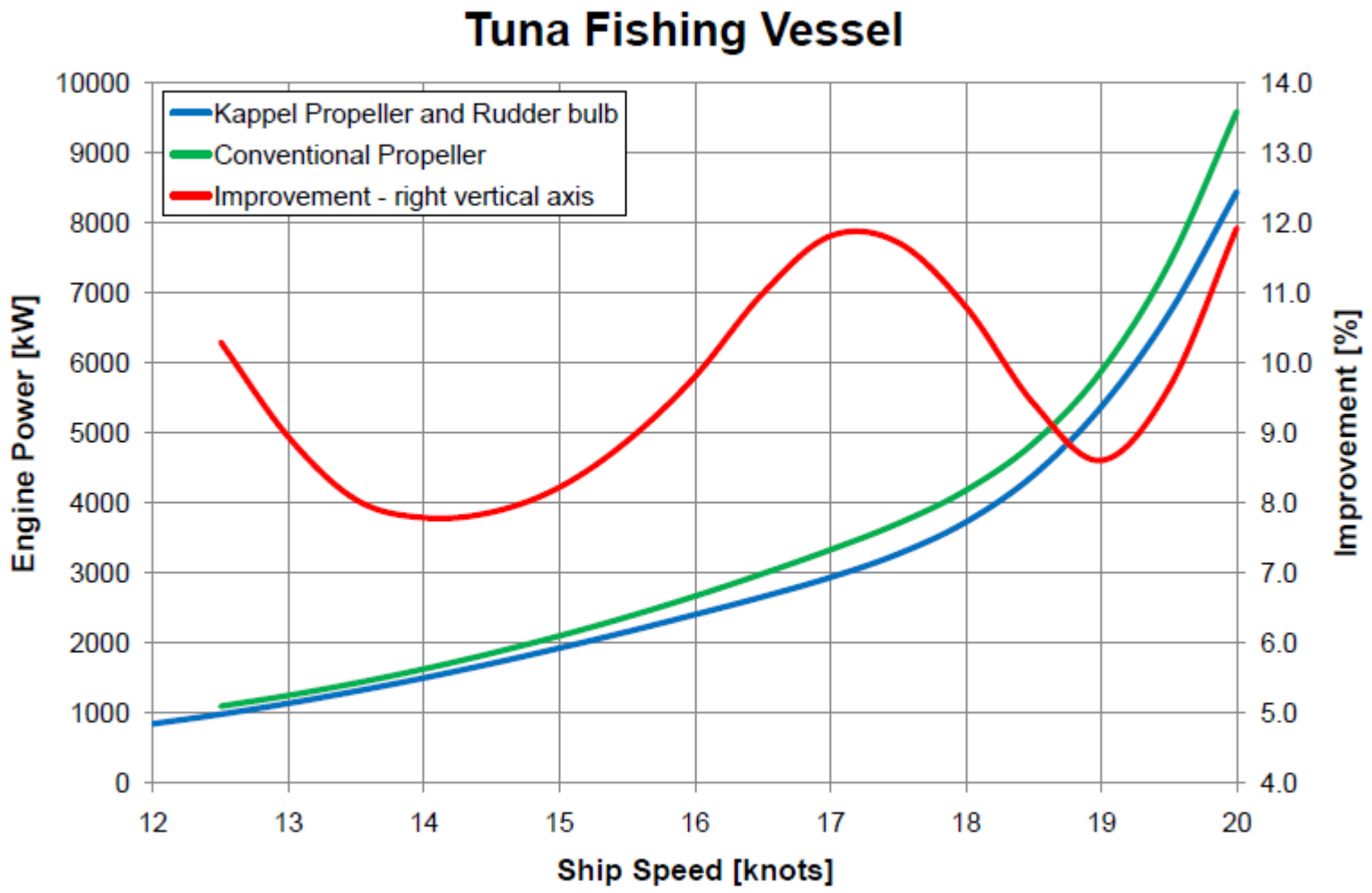
These two EID are to a large degree cumulative as they recapture the losses from two different flow fields – tip and hub flow



The rudder bulb is characterised by a slim-lined fairing connecting the rotating propeller hub with the rudder with the purpose of regaining the axial and rotational losses in-between the two members



Kappel test results
Combined Kappel and Rudder Bulb



Kappel test results
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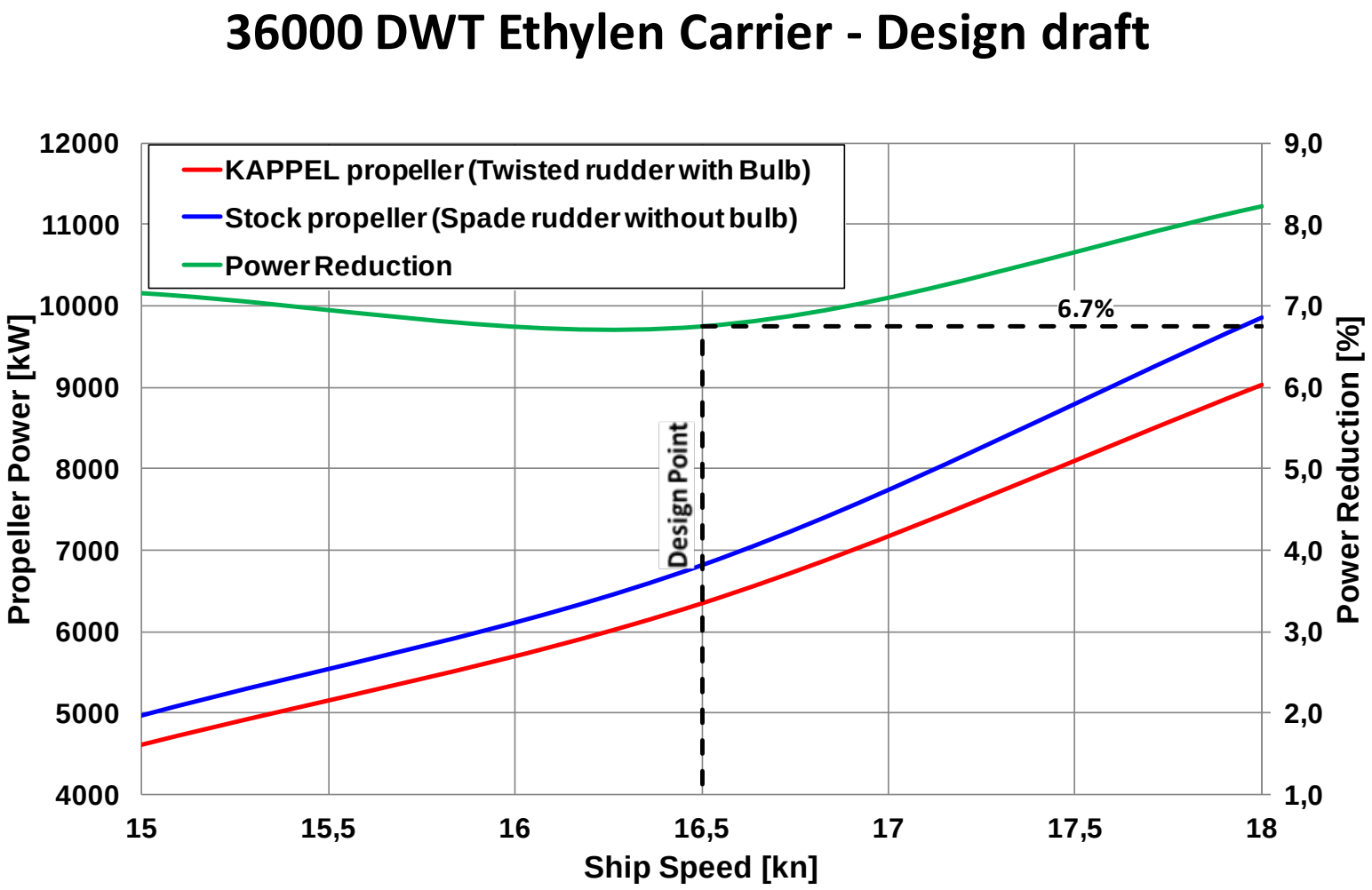
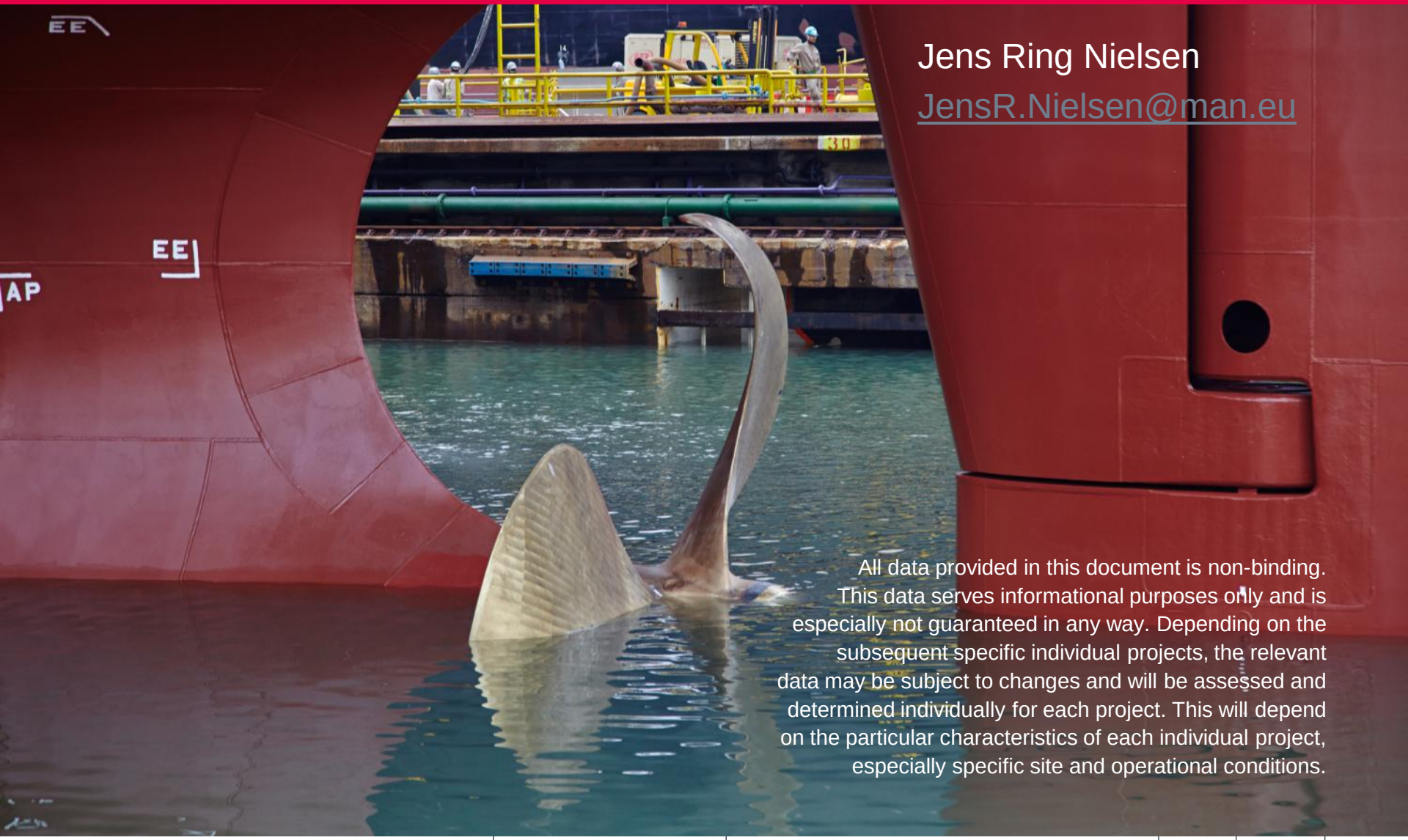


Summary and Conclusions

- The Kappel propeller exhibits a higher effective model wake (W_{TM}) than conventional types, but experience a larger reduction in full scale wake (W_{TS}) when using the ITTC 1978 and Yazaki method. This leads to lower hull (η_H) and total efficiency η_D.
- The open water scaling of Kappel propellers according to the ITTC 1978 method does not account for its more outward distribution of chords
- Recommendations for wake scaling of Kappel propellers
  - Apply the Force Technology method

    or
  - Apply to the Kappel propeller the same difference in model to full scale wake as measured for the conventional propeller. Identical to applying the ITTC 1999 wake scaling for special propulsion devices
- Recommendation for open water scaling of Kappel propellers
  - Apply a strip method i.e. Prof. Poul Andersen

Thank You for Your Attention!



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