Prabu Duplex

4rd EMship cycle: October 2013 – February 2015

Novel application of large area propeller to optimize Energy Efficiency Design Index (EEDI) of ships

Nantes, February 2015

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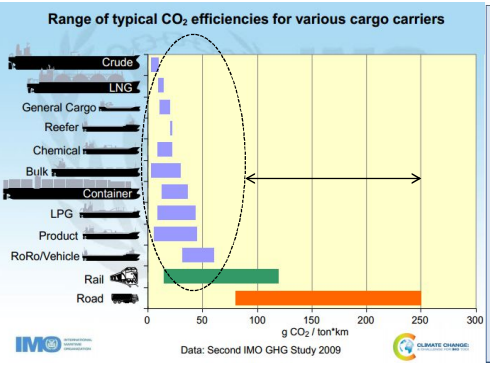
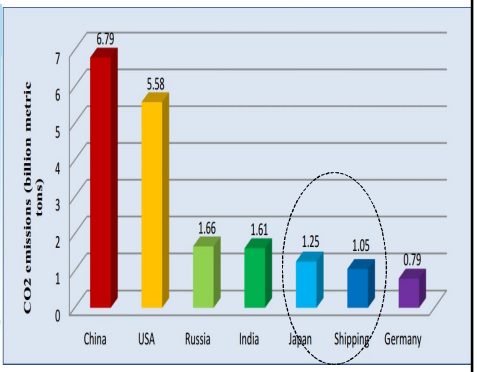
1. Introduction

Globalization → Increased transport → CO_2 Emissions → Climate change/ Global warming

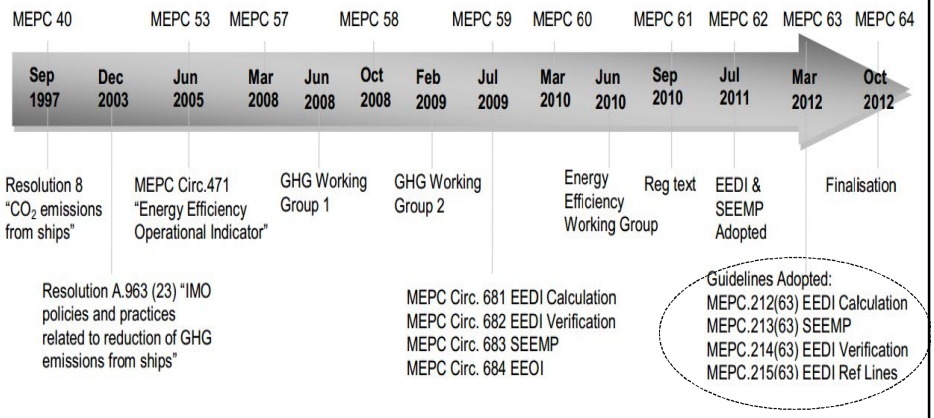
Shipping contribution 3%= Some major economies





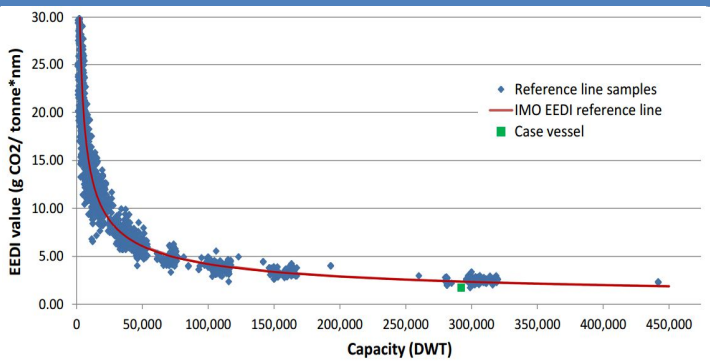
Source IMO

2. CO_2 Emission regulation by IMO



- **1st January 2013**
- **EEDI (Mandatory) New ships**
- **SEEMP (Mandatory) All ships**
- **EEOI (Voluntary) All ships**

3. Energy Efficiency Design Index (EEDI)



- Ships to meet a level of energy efficiency .
- An early stage measure for ships efficiency.
- Based on its emissions, capacity and speed.
- EEDI= $\frac{CO2\ Emission}{Transport\ work}$

4. APPLICATION

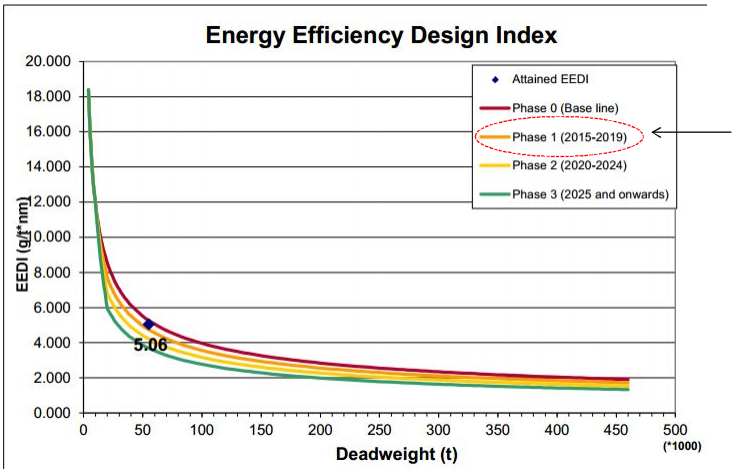
- Ships >= 400GRT
- Building contract on or after 1st Jan 2013
- Major conversion of existing ships.

✓ Bulk carrier
✓ Gas tanker
✓ Tanker
✓ Container
✓ General cargo
✓ Refrigerated cargo
✓ Combination carrier
✓ LNG

Recent addition

✓Ro- Ro
✓Passenger vessels

Attained EEDI < Margin value



$$EEDI = \frac{\Pi f_j \left(\sum P_{ME} * C_{FME} * SFC_{ME}\right) + \left(P_{AE} * C_{FAE} * SFC_{AE}\right) + \left(\Pi f_j * \sum P_{PTI} - \sum f_{eff} * P_{AEeff}\right) * C_{FAE} * SFC_{AE} - \sum f_{eff} * P_{eff} * C_{FME} * SFC_{ME}}{f_i * Capacity * V_{ref} * f_w}$$

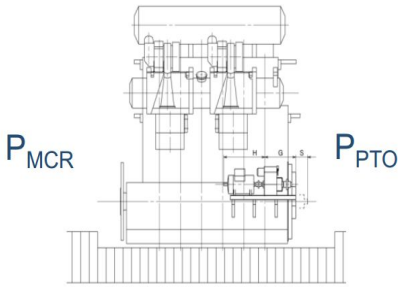
CO_2 emission Main engine - PTO
Ref: 75% $*(P_{SMCR} - P_{PTO})$

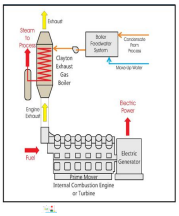
CO_2 emission Auxillary engine
Ref: 2.5% x P_{MCR} + 250 kW

CO_2 emission Power Take In
Ref: 75% PTI

CO_2 reduction WHR or similar
Electrical

CO_2 reduction Wind, Solar …
Mechanical



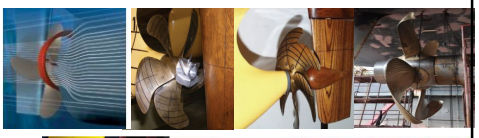


7. Energy efficiency

Energy saving methods

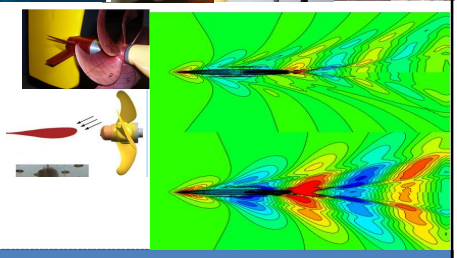
- Propulsion improving / Energy recovery devices
- Structural weight optimization
- Machinery technology
- Fuel efficiency of ships in service

Role of hydrodynamics



Separation in the aft body
•Nozzle , Wake equaling ducts.

Hub vortex losses
•Efficiency rudders, Divergent propeller cap.



Frictional losses
•Reducing the propeller area to minimum

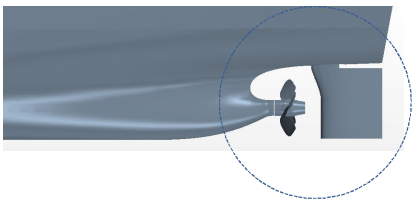
Rotational losses
•Rudder fins, pre swirl fins.

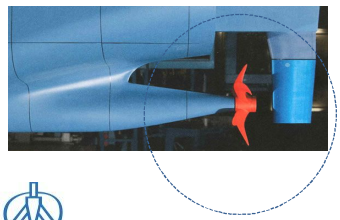
8. Thesis work

Relocated large area propeller

•Concept suggested by EU project Streamline to MS Nawigator XXI.

•Study the benefits applicable to EEDI with justification.

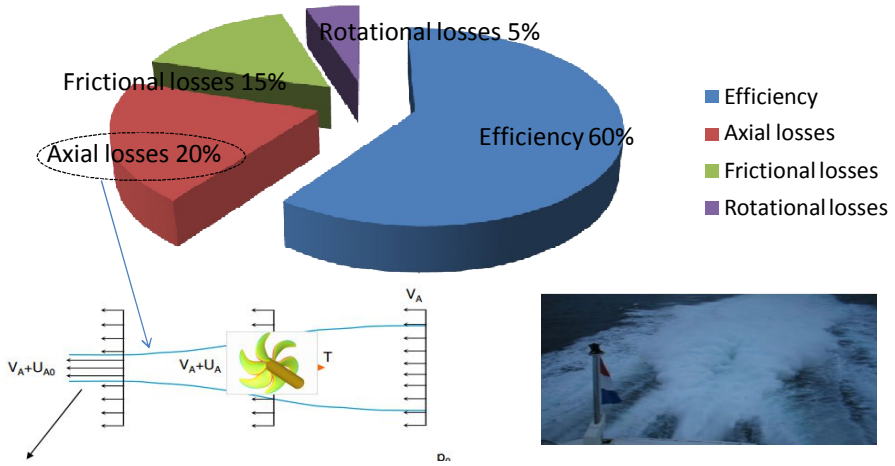




SEVENTH FRAMEWORK PROGRAMME

CTO S.A.

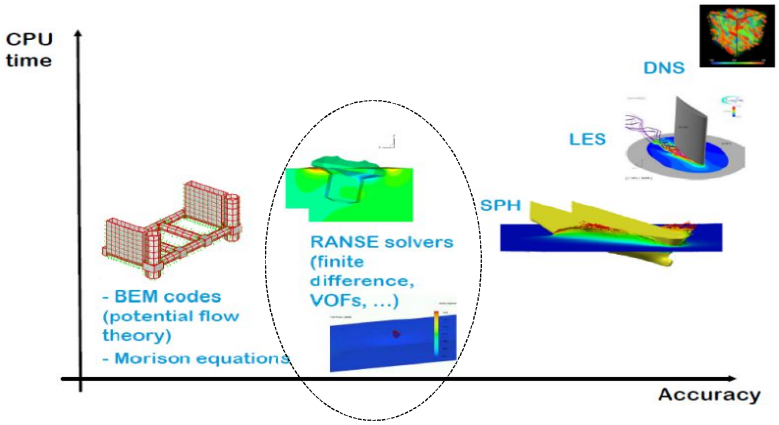
9. Propeller efficiency



- The propeller accelerates the incoming mass flow
- The flow must contract to conserve the mass.
- Speed difference → turbulence → energy losses
- Large diameter low RPM → Reduce axial losses

10. Numerical configuration

- **Memory** **:16GB RAM**
- **Processor** **:Intel® Core i5-4570 CPU @3.2 GHZ (4core)**
- **Software** **: Star-CCM+ (Version 9.04.009)**
- **Turbulence model** **: Realizable K-ϵ**
- **Mesh** **: Trimmer, Polyhedral**



11. Methodology

Validation of resistant coefficients with resistance test.

Evaluation of large area propeller with open water test.

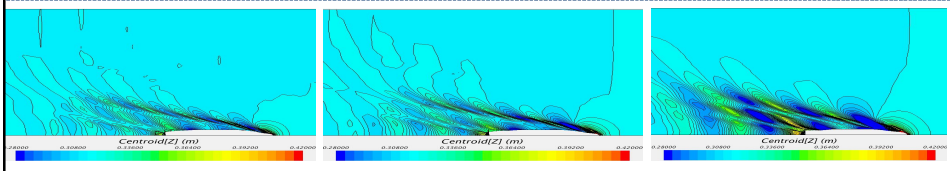
Friction correction force determination with self propulsion tests.

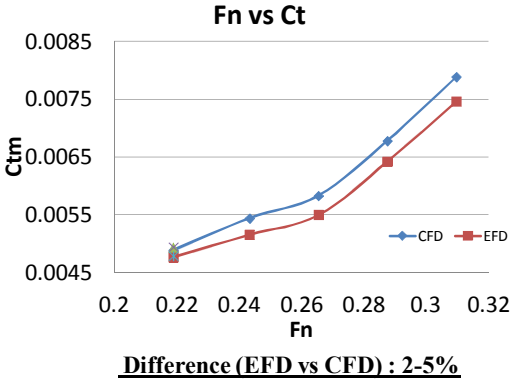
Propeller relocation

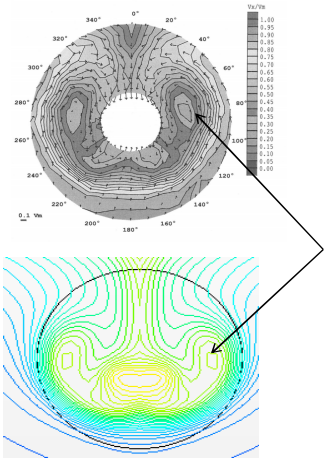
Performing a self propulsion test in each of the new locations .

Analysis of results.

12. Resistance test

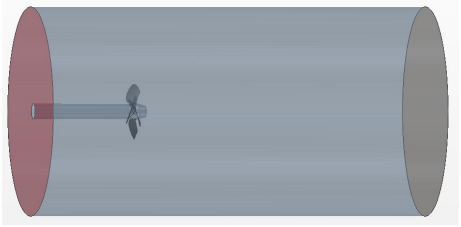


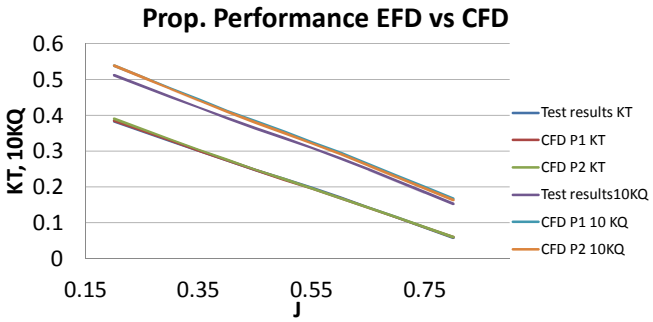




Difference (EFD vs CFD) : 2-5%

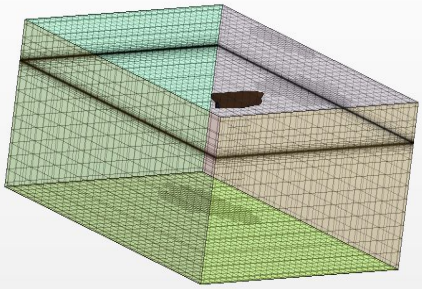
13. Open water test

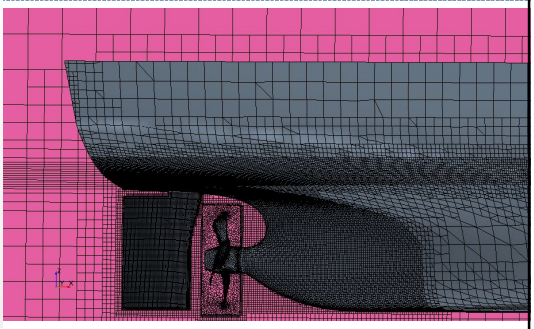




Difference (EFD vs CFD) : 1-6%

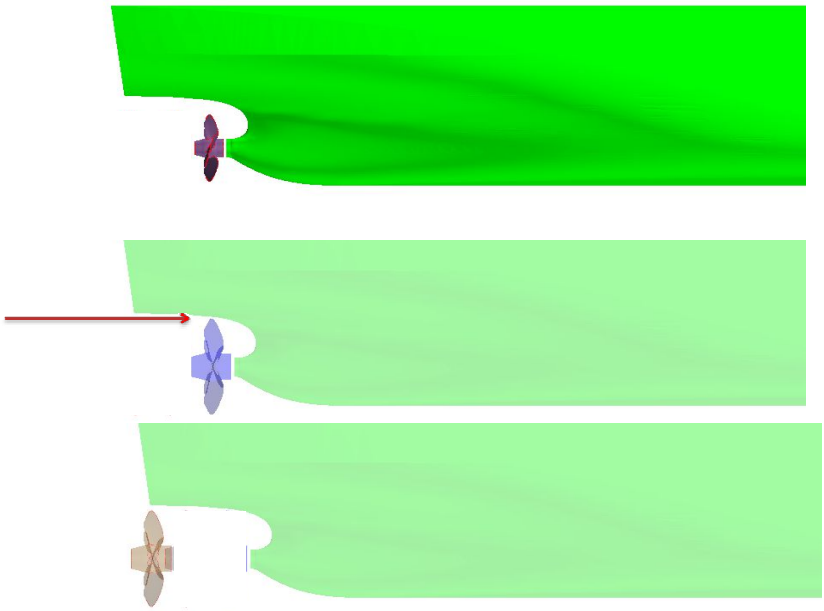
14. Self propulsion tests (Step 1)



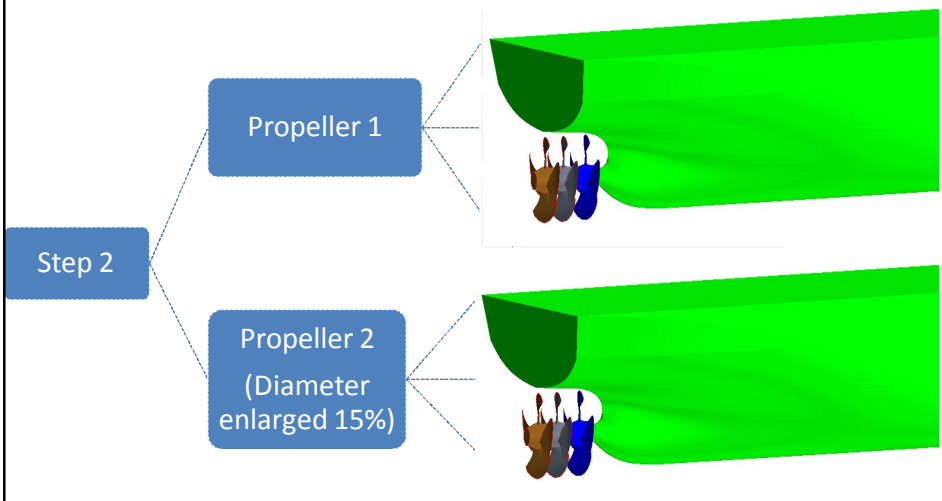


	Star CCM	Experiments	%Diff
Fr correction force (N)	3.5	3.81	8.14
Thrust (N)	42.50	50.67	16.12
Torque(N.m)	1.56	1.70	8.02
Kt	0.20	0.24	
Kq	0.032	0.04	
Del.Power(Watts)	88.10	95.78	

15. Constraints

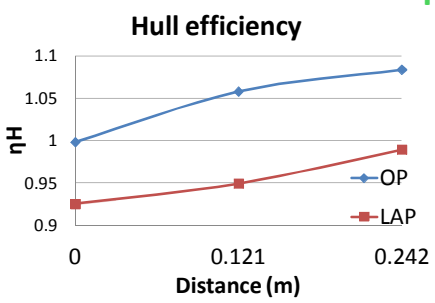


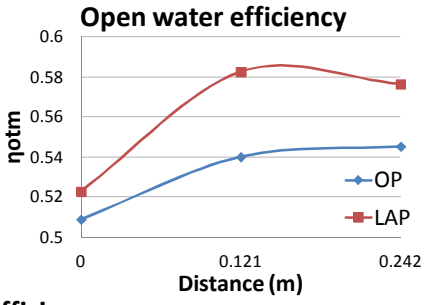
16. Methodology

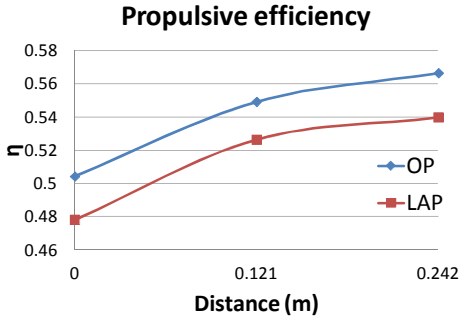


17. Result analysis

Pro

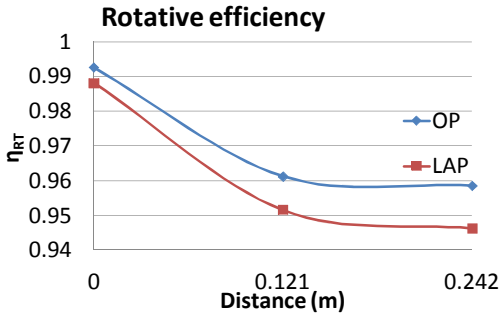




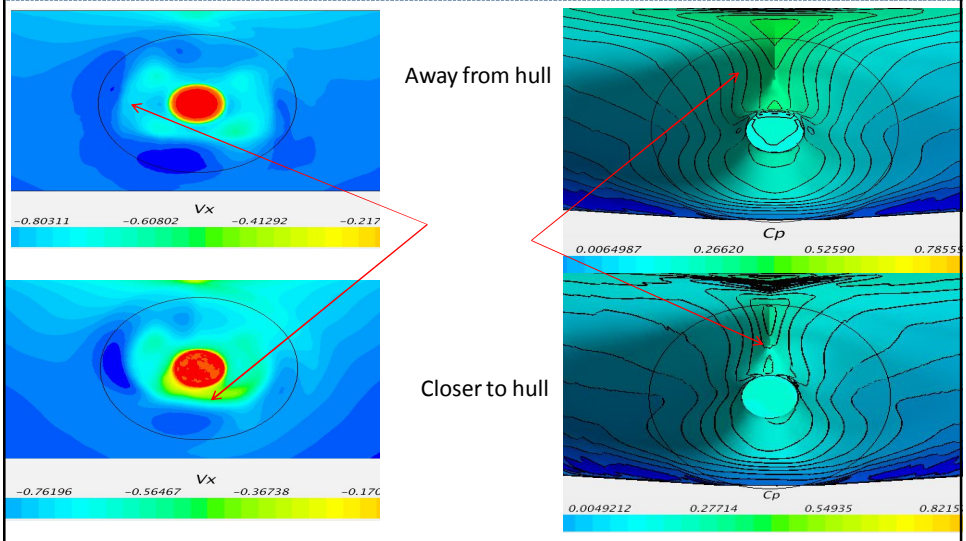


18. Result analysis

Cons



19. Hull efficiency and velocity profile

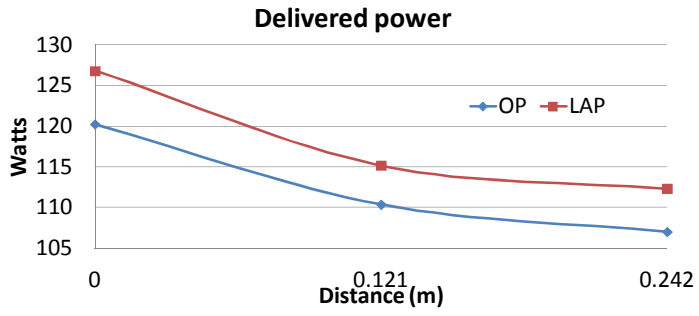


Velocity profile upstream of propeller plane

Pressure on the hull

20. Benefits

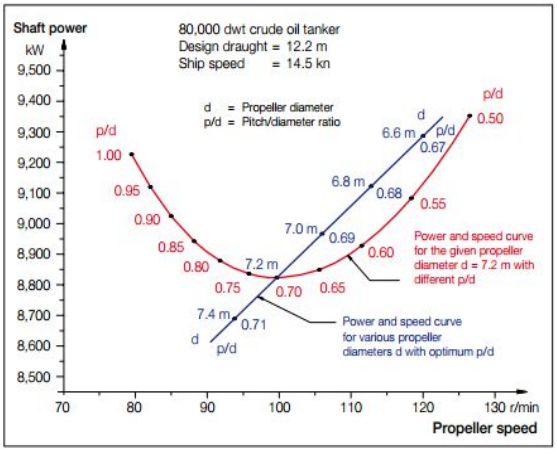
	Propeller1			Propeller2		
						
Propulsive efficiency	Ref	8.92	12.34	-5.18	4.41	7.07
Delivered Power (Watts)	Ref	-8.19	-10.98	5.5	4.22	-6.59



21. Influence of P/D ratio in propeller design

Influence of P/D ratio in propeller design (MAN B&W)

Large area propeller (LAP)	
Propeller diameter [mm]	270
Chord length $R_{0.75}$ [mm]	60
Number of blades Z	4
Max thickness $R_{0.75}$ [mm]	3.34
Pitch ratio at $R_{0.75}$ [-]	0.823
Scale-α [-]	1:20.909
Original propeller (OP)	
Propeller diameter [mm]	220
Chord length $R_{0.75}$ [mm]	89
Number of blades Z	4
Max thickness $R_{0.75}$ [mm]	3.4
Pitch ratio at $R_{0.75}$ [-]	0.866
Scale-α [-]	1:20.909



Important observation

→ **Large area propeller performed poorer**

Choose appropriate P/D ratio for good results

22. Application

Attained EEDI	Required EEDI (Phase 0)	Required EEDI (Phase 1)	Result
5.06 g/t.nm	5.27 g/t.nm	4.74 g/t.nm (10% margin reduced)	Valid in phase 0 but for phase1
Delivered power gain of 8.2% resulted in 4.66 g/t.nm			Phase 1 requirement satisfied

23. Conclusion

- The method is a promising choice to optimize EEDI values.
- Interesting trends in propulsion factors observed.
- Short comings noted.
- The ability of the software is proved.
- With proper modeling reliability of model basin can be reduced.

24. Future work

- The work to be continued with rudder and modified hull.
- Choosing an appropriate large area propeller with optimum Pitch/ Diameter (P/D) ratio.
- Improving the numerical setup to offset the requirement of towing tank.
- Incorporating optimization methods for improving hydrodynamic performance.

25. References

1. Knutsson, Daniel, and Lars Larsson. "Large area propellers." *SMP'11 (Symposium on Marine Propulsors*. 2011
2. *Second IMO GHG Study 2009*, International Maritime Organization (IMO) London, UK, April 2009; Buhaug, Ø., Corbett, J.J., Endresen, Ø., Eyring, V., Faber, J., Hanayama, S., Lee, D.S., Lee, D., Lindstad, H.,Markowska, A.Z., Mjelde, A., Nelissen, D., Nilsen, J., Pålsson, C., Winebrake, J.J., Wu, W., Yoshida, K.
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6. Procedure for calculation and verification of theEnergy Efficiency Design Index (EEDI), International Association Of Classification Societies Ltd IACS Proc Req. 2013.