The Society of Naval Architects
& Marine Engineers

# Improving the Propulsion Efficiency by means of Contracted and Loaded Tip (CLT) Propellers

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# SHORT RESUME

1997 - Graduated in Mechanical Engineering

1997 - 1998 MAN B&W, Augsburg

1999 - 2003 RINA HQ, Genoa

2003 - 2007 Independent consultant

2007 - Founder of SINM srl

Main fields of activity:

Failure investigation / Forensic Engineering

Ship Propulsion and Propeller Design

# PROPULSION EFFICIENCY

Stringent requirements on propulsion efficiency due to the current market trend, the rising cost of fuel, the concern for pollution and IMO EEDI and EEOI...

Historically much has been achieved in the reduction of the advance resistance of the hull, naked and appended.

In addition many propulsion improving devices (PID) have been invented, later abandoned and then reinvented and reintroduced in conjunction with energy crisis. Nowadays the PID portfolio spans over pre-swirlers, swirl recoverers, ducts, hull fins, rudder fins, bulbed or twisted rudders, hub caps... either alone or combined one with the other.

Very little innovation on convetional propellers: little is worth mentioning apart from the introduction of high skew and a continuous improvement of the annular profiles.

# UNCONVENTIONAL PROPS

At the same time two types of unconventional propellers have been developed: surface propellers, which bear little interest for commercial shipping, and tip propellers.

Tip Propellers:

Kappel Propellers (KAPPEL, Denmark, now MAN Diesel & Turbo)

about 10 installations

Up to 4 % gain over an equivalent conventional propeller

CLT Propellers (SISTEMAR, Spain, evolution of TVF Propellers)

more than 280 installations

About 5-8 % gain over an equivalent conventional propeller

# TIP PROPELLERS

KAPPEL

CLT

# CLT PROPELLERS

CLT propellers are characterized by the following:

- The tip chord is finite.
- An end plate is fitted at the blade tip, located on the pressure side.
- The blade tip bears a substantial load.
- The pitch increases from the root to the tip of the blades.
- Low to moderate skew.

Thanks to the end plates the pressure and suction side do not communicate, inhibiting the formation of tip vortexes and allowing the generation of thrust along the entire blade and the reduction of pitch.

# CLTP ADVANTAGES

Higher efficiency (between 5 - 8%)

- Fuel saving => Reduced emissions => Greater range
- Saving on MM/EE maintenance
- Higher top speed => greater operational flexibility

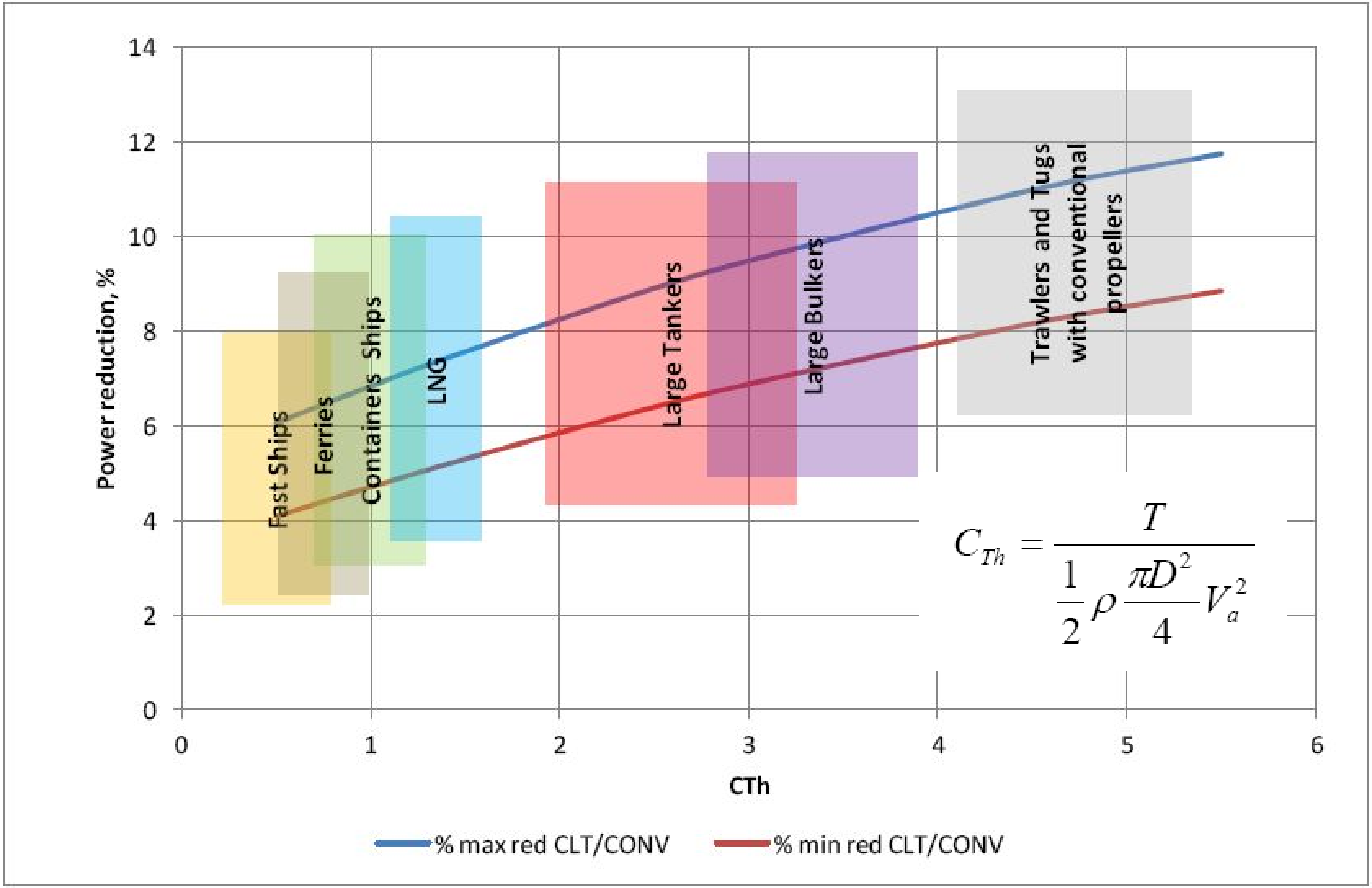
Inhibition of cavitation and of the tip vortex

- Less noise & vibrations
- Lower pressure pulses
- Lower area ratio

Greater thrust

- Smaller optimum propeller diameter
- Better maneuverability.

# CLTP ADVANTAGES




$$C_{Th} = \frac{T}{\frac{1}{2}\rho\frac{\pi D^2}{4}V_a^2}$$

# EQUIVALENT PROPELLERS

Equivalent CP propeller blades for a modern Ro-Pax:

For the same design point (ship speed, thrust, propeller rpm) the CLT propeller blade is shorter and has a lower area ratio.

The difference in geometry is striking!

# CLTP APPLICATIONS

The application range up to now:

- Up to 300,000 DWT
- Up to 22 MW per propeller
- Up to 36 knots.

Ship types:

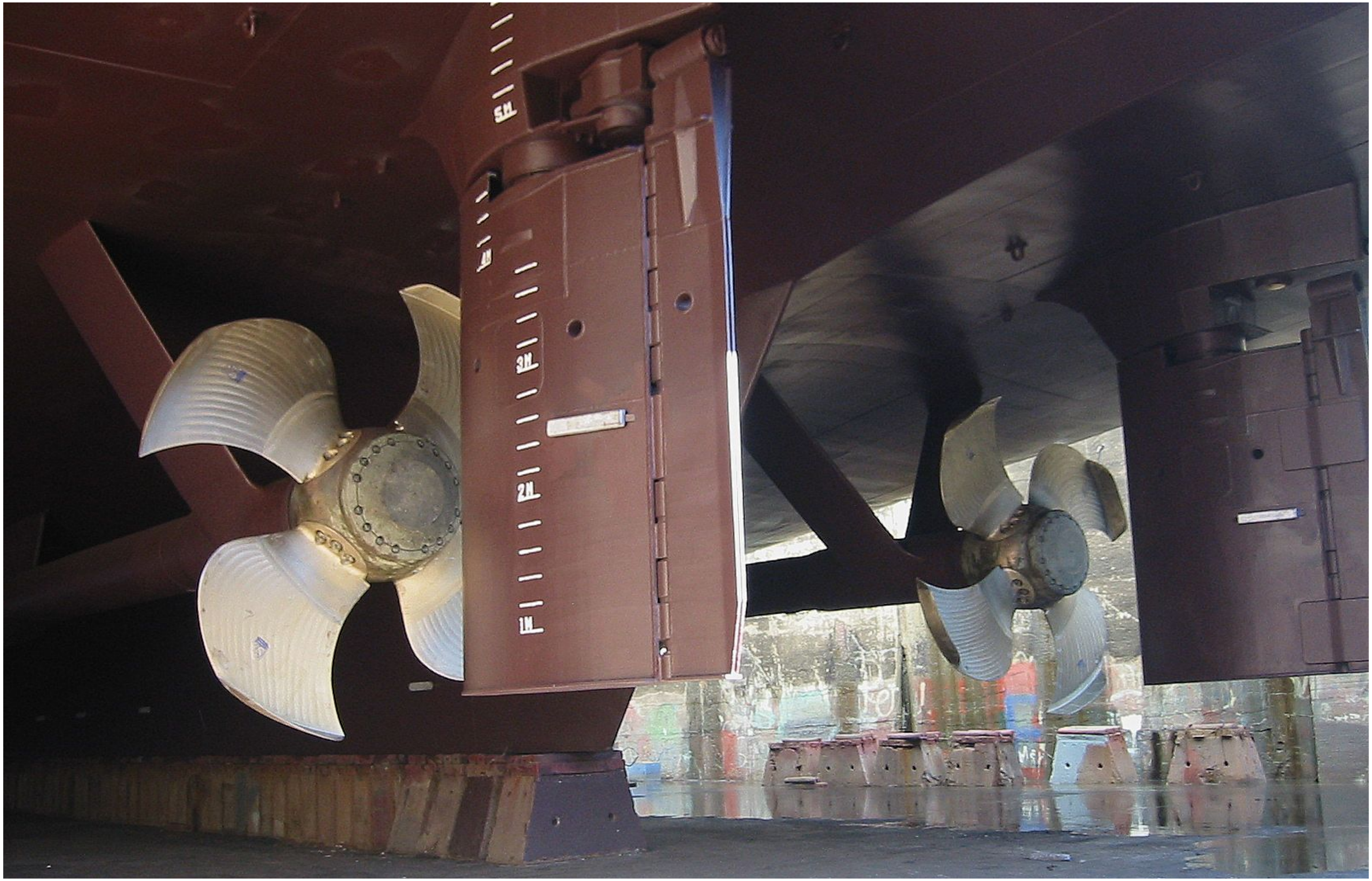
- Tankers
- Bulk Carriers
- General cargoes
- Container ships & Reefers
- Ro–Ro, Ro–Pax
- Fishing vessels & Trawlers
- Catamarans & Hydrofoils
- Patrol boat, Corvettes
- Landing crafts
- Oceanographic vessels
- Yachts

# CLTP TANKER ROY MAERSK

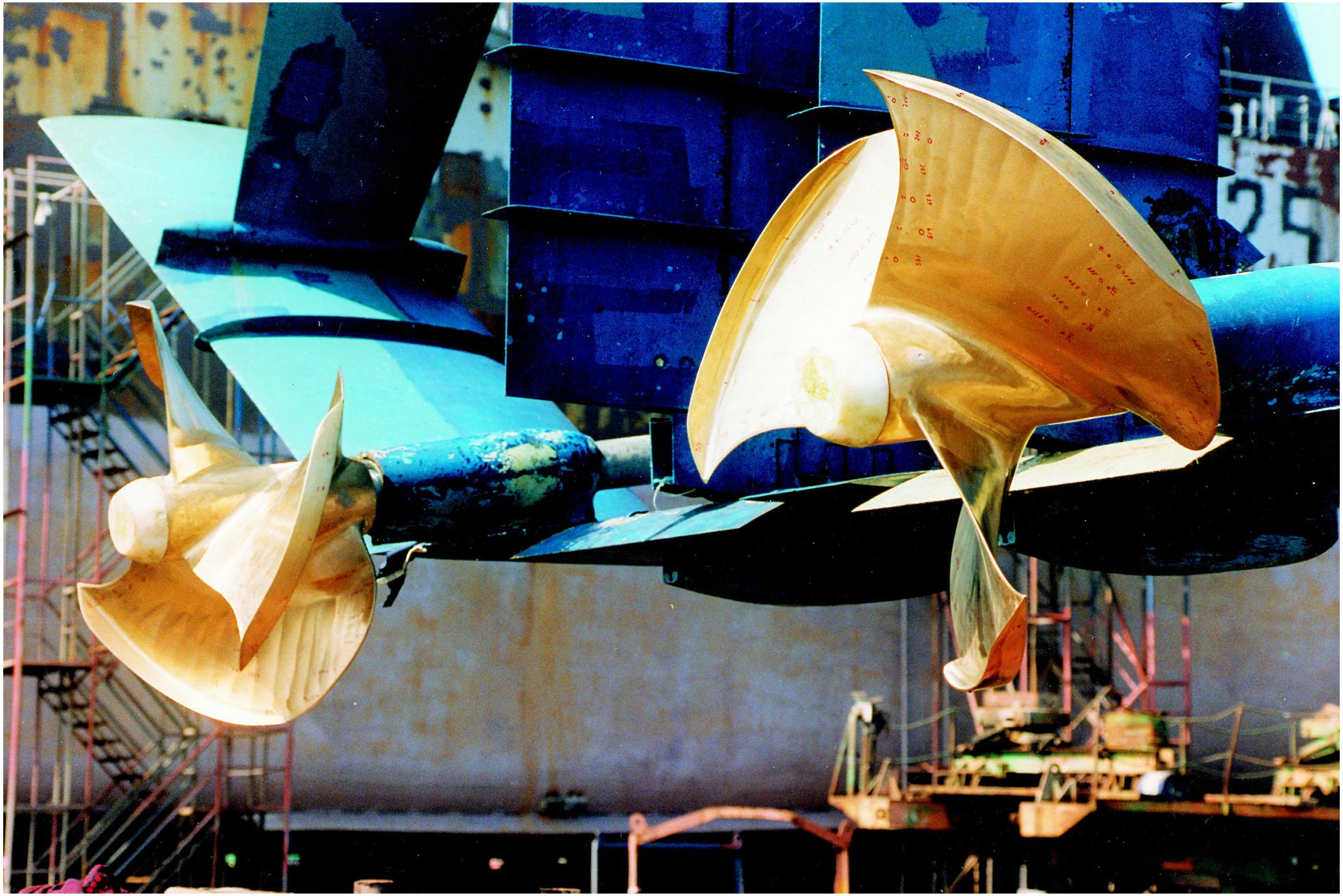
# CLTP BULKER

# CLTP CONTAINER VESSEL

# CLTP RO-PAX



# CLTP HYDROFOIL



# PAST R&D

Main Goal:

To have the same confidence on CLT propeller design and model test as for conventional propellers.

1997 – 2000 “Optimization of ship propulsion by means of innovative solutions including tip plate propellers.”

2001-2003 “Research on the cavitation performance of CLT propellers, on the influence of new types of propeller blades annular sections and the potential application to POD’s”

2003 – 2005 “Research on the performance of high loaded propellers for high speed conventional ferries”

Result:

Development of ad hoc model test procedures and extrapolation.

# EXTRAPOLATION

Extrapolation procedures were presented at the 2005 Motor Ship Conference and are based on ITTC '78 plus special correction for the peculiar characteristics of CLT propellers.

Scale effects on:

viscous forces over the blades

lift forces over the blades

viscous forces over the end plates

# CLT & CFD

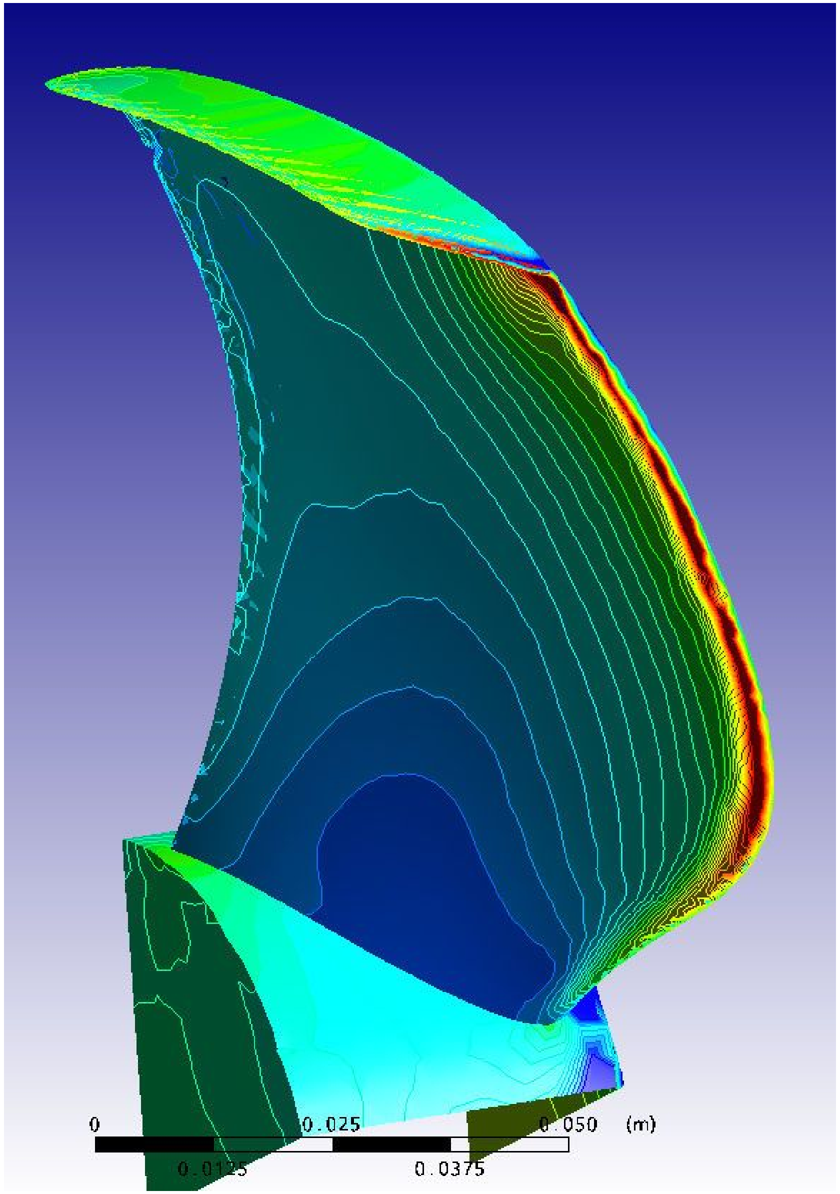
CFD for ship propulsion are a qualitative not a quantitative method due to fact that it is impossible to validate the results at full scale!

The first results not satisfactory, up to 6.5% error on KT and 16.5% error on KQ at model scale!

Need to develop ad hoc CFD / numerical codes for CLT propellers.

Collaboration with VTT, CEHIPAR, UNIGE.

Latest calculations show better agreement with model test results and scale effects of similar magnitude to the one measured in the field.



# ROY MAERSK

In 2006 A.P. Moeller Maersk who, at that time, was conducting an internal evaluation of energy saving devices, selected CLT propellers as the single most promising device and a joint R&D campaign was launched.

CLT propellers were designed for a 2,500 TEU container vessel, a 35,000 DWT product tanker and a VLCC and were tested at model scale at HSVA, Hamburg. The CLT propeller for the 35,000 DWT product tanker was also tested at CEHIPAR and it was retrofitted on the M/S Roy Maersk at the end of October 2009.

Results are in good agreement with model tests and design calculations.

| LPP | 162.0 | m |
|---|---|---|
| B | 27.40 | m |
| D | 17.30 | m |
| T | 9.75 | m |
| Δ | 35,300 | t |

| | Conventional | CLT | |
|---|---|---|---|
| D | 5.65 | 5.25 | m |
| z | 4 | 4 | - |
| AeAo | 0.563 | 0.490 | - |
| H@07R | 3.685 | 4.050 | m |

# SPANISH NAVY

BAM class corvettes, equipped with CP CLT propellers (twin screw, 4 blades, diameter 3.45 meter, MCR 2 x 4.5 MW).

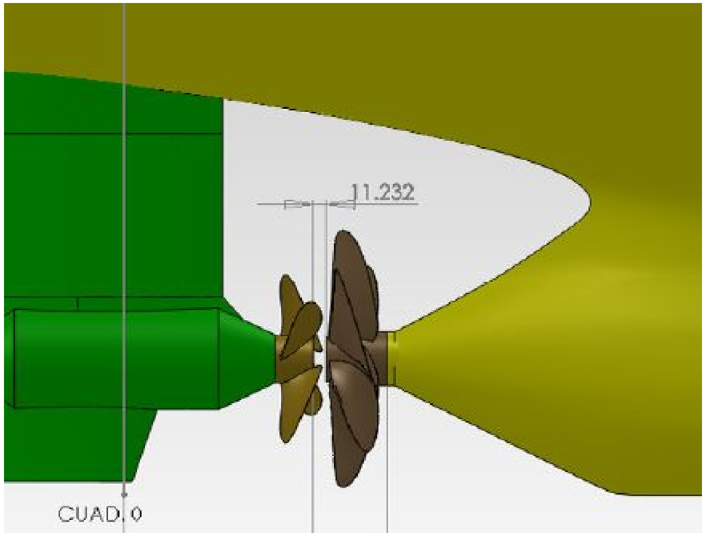
M/v Cantabria, logistic ship, equipped with the largest and most powerful CP CLT propeller manufactured to date (single screw, 5 blades, diameter 5.7 meter, MCR 21.8 MW).

# TRIPOD

TRIple Energy Saving by Use of CRP, CLT and PODded Propulsion" (TRIPOD) is a European FP7 project currently conducted by ABB and VTT, Finland, AP MOLLER MAERSK, Denmark, CEHIPAR, CINTRANAVAL-DEFCAR and SISTEMAR, Spain.

The main goal is the development and validation of a new propulsion concept for improved energy efficiency of ships through the advance combination of three existing propulsion technologies: podded propulsion (POD), CLT tip loaded end plate propellers and counter-rotating propeller (CRP) principle.

Different propulsion configurations of 8.500 TEU's container vessel "Gudrun Maersk" will be analysed: single screw ship with conventional propeller and CLT propeller, CRP arrangement with conventional and with CLT propellers.



# NICOP

Studio di Ingegneria Navale e Meccanica

Within the framework of the National International Cooperative Opportunities in Science and Technology Program (NICOP) the OFFICE OF NAVAL RESEARCH of the U.S. NAVY (ONR) has contracted SISTEMAR for a two years R&D project called "Energy Efficient Contracted-Loaded Tip (CLT) Propellers for Naval Ships"

SISTEMAR will design a CLT propeller and NSWCCD will design and alternative Tip Loaded Propeller; both propeller models will be manufactured and tested by CEHIPAR. Computations will be made both by NSWCCD and SISTEMAR/CEHIPAR for the two propeller designs using RANS methods at model and full-scale Reynolds numbers.

This project will provide the US Navy with direct experience on energy efficient tip plate propellers.

# CARNIVAL - GRAND CLASS

CARNIVAL CORPORATION has recently launched decided to investigate CLT propellers by mens of a series of model tests, the goal is to compare a state-of-the-art conventional propeller with a CLT propeller on basis the Grand Class.

The propulsion system is composed by two 21 MW Siemens electric motors, each driving a FP propeller via conventional shafting.

Resistance and self-proulsion model tests with will be performed by CEHIPAR while cavitation tests and pressure pulses measurements will be performed by HSVA (Hamburg) in the HYKAT.

| | | |
|---|---|---|
| LPP | 289.9 | m |
| B | 35.97 | m |
| T | 7.92 | m |
| GT | 109,000 | - |
| Capacity | 4,314 | People |
| Built | 1998 | - |

# EEDI, EEOI, PROPS & PIDS

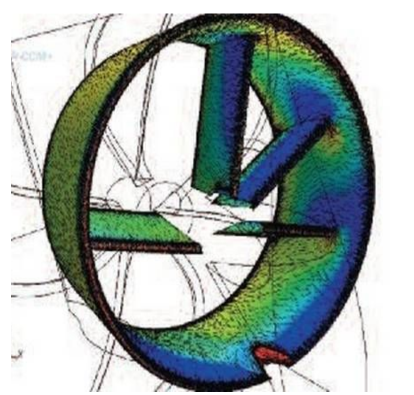
In principle the careful optimization of the hull (main dimensions, bow and stern shape), followed by the selection of a tip plate propeller and of a bulbed and twisted rudder will result in a high propulsion efficiency (hence low EEDI and EEOI).

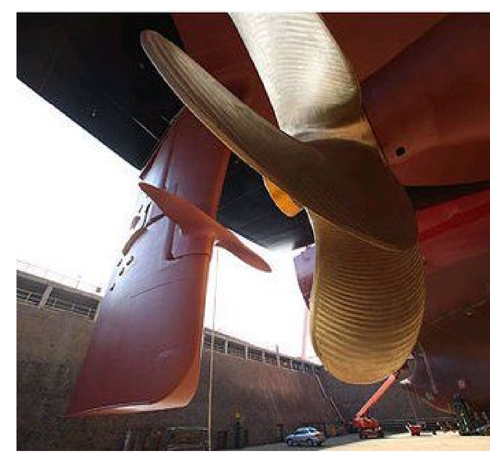
If the above is performed effectively, the use of further PIDS (e.g. pre or post stators) is likely to bring only marginal gains.

The exception are vessels with unfavourable main dimensions and non optimized hulls.

The design of the propeller and of the selected PID must be integrated.

To retrofit a PID without updating the propeller is substandard.





# CONCLUSIONS

Tip propellers in general and CLT propellers in particular are a a mature technology.

Their merits of have been proven in about 280 full scale applications on very different ship types.

The efficiency increase (and hence the achieved fuel saving ) is in the range of 5 – 8 %, being higher for slow vessels with high block coefficient.

The ROI for new buildings is very short (3 to 6 months), making CLT propellers a dominant choice for increasing the propulsion efficiency and lowering the EEDI and the EEOI.

In addition CLT propellers do not introduce any modification whatsoever to the vessel, therefore they can be introduced also as retrofits or for vessels the design of which has been already concluded.

Finally CLT propellers are compatible with most of the PID currently offered, thereby allowing even further efficiency gain.