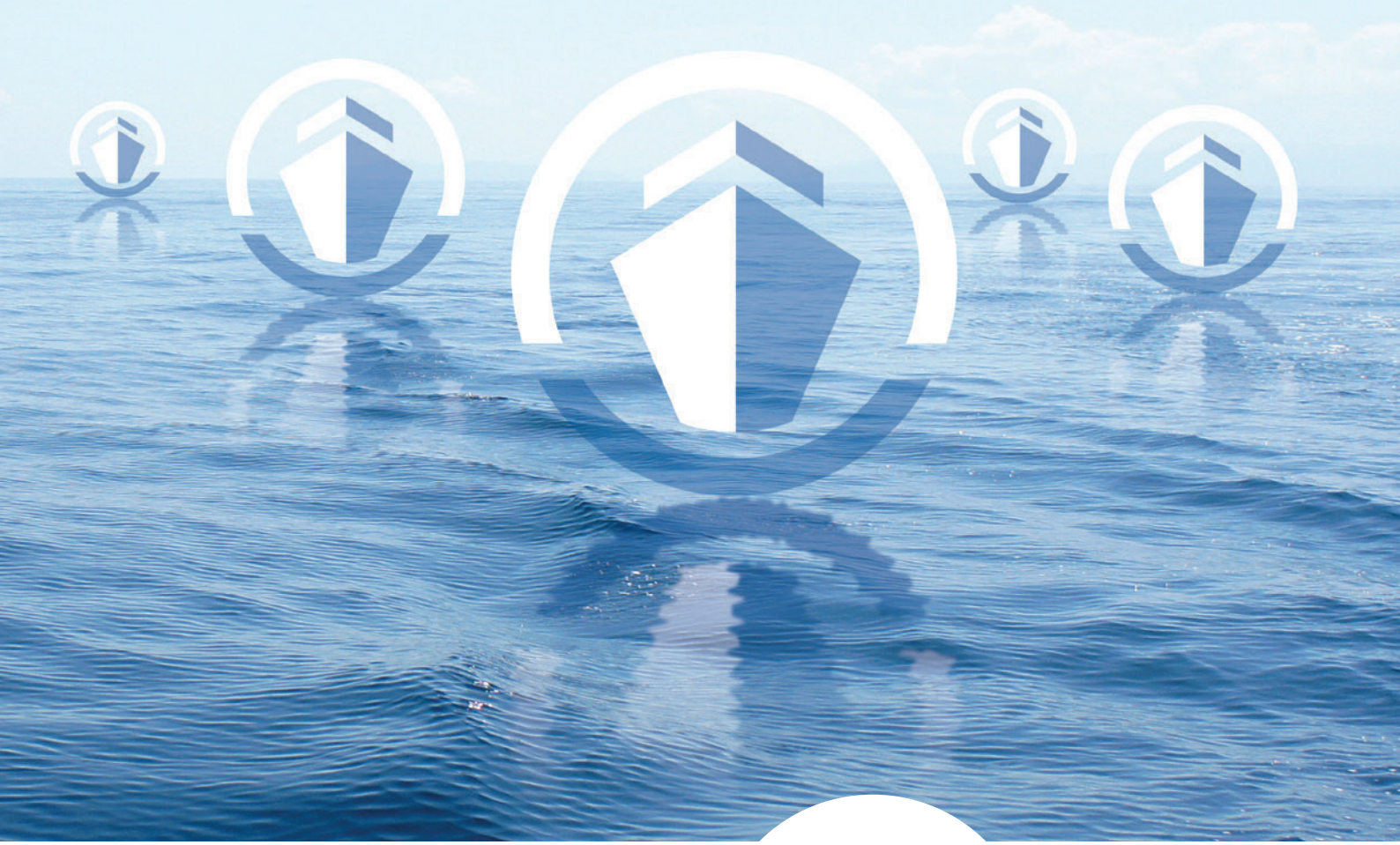
LeanShips

aims to demonstrate the effectiveness and reliability of energy saving and emission reduction technologies at full scale.



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What is this European Innovation Project all about?

Target markets …

… are the small to midsized ships for intra-European waterborne transport, vessels for offshore operations and the leisure and cruise market.

Demonstrators will be carried out …

… combining technologies for improved efficiency and pollution reduction, in line with end-users' needs and requirements.

Main objectives …

CO_2 reduction of at least 25 %
Estimated fuel saving of up to 25 %
Expected decrease of SOx / NOx / PM air pollutants by up to 100 %

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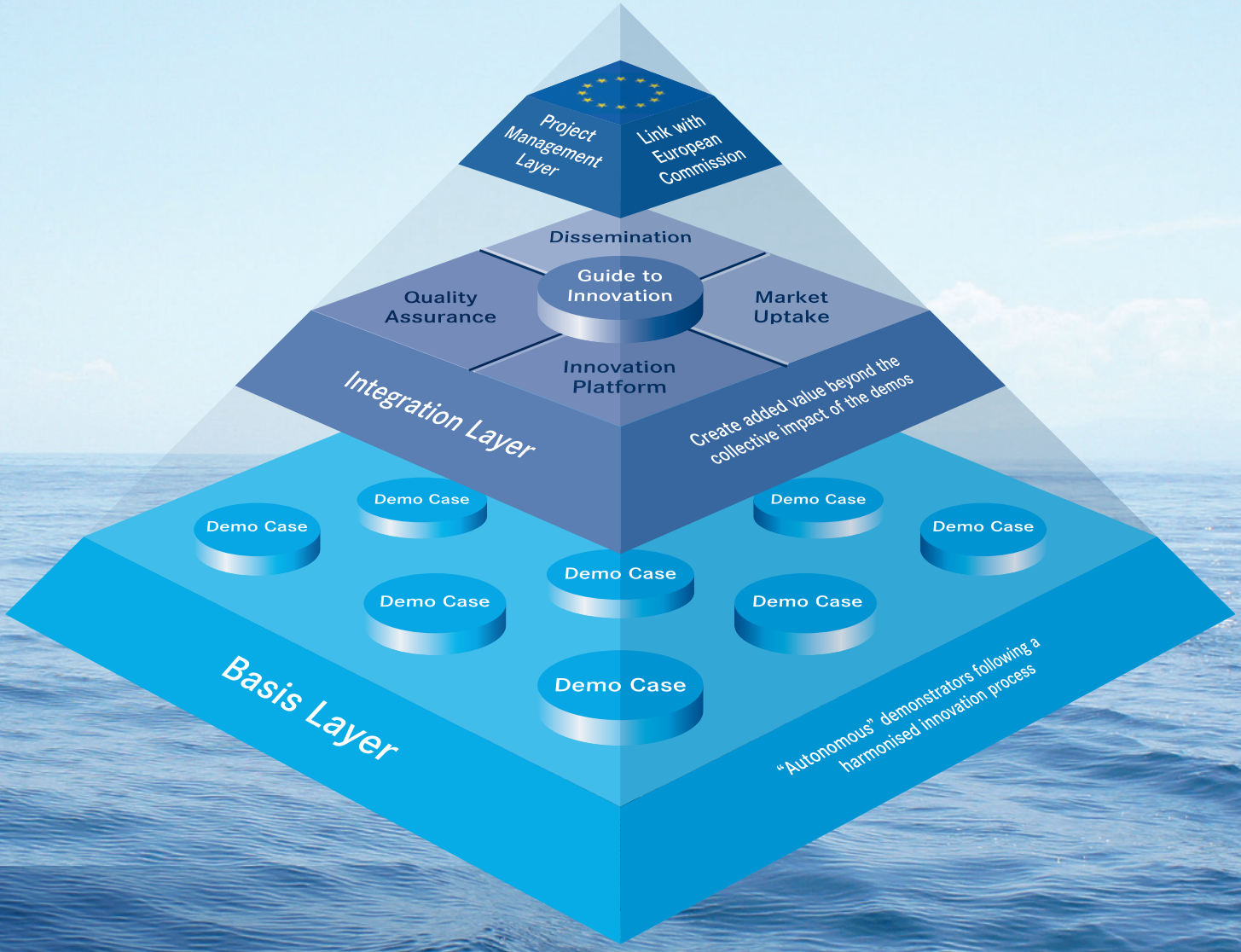

LeanShips

has a layered project structure and integrates
the experiences from the Demo Cases into a web-based "Guide to Innovation".

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Project Management Team
Damen Shipyards Gorinchem, Netherlands Maritime Technology,
Center of Maritime Technologies e.V., CETENA S.p.A.

Demo Case

New ship handling tug & CNG powered tug

This demo case provides two demonstrators. The first demonstrator is the harbour tug RSD (Reverse Stern Drive) 2513. This tug is of an entirely new type with improved hydrodynamic characteristics and TwinFin technology. These innovations increase the efficiency by allowing a smaller tug to do the same job in a safe way. To optimise the hydrodynamic behaviour, comprehensive computational fluid dynamics (CFD) calculations and model scale tests have been carried out. The new design also allows the use of a smaller crew (three instead of four to five), which contributes to a decrease in operational costs. The first tug has been built and just completed its trials successfully.

The second demonstrator is the ASD (Azimuth Stern Drive) 3212 CNG-E, which operates with compressed natural gas (CNG) as a fuel and has an additional hybrid (E) propulsion as well. At the project beginning there were four tugs operational with liquefied natural gas (LNG) as a fuel worldwide. These tugs use medium speed engines, which are voluminous, heavy and high on OPEX and CAPEX. This tug will use high speed engines, provided by MTU, to directly drive the thrusters. The use of these high speed natural gas engines offers a high power density, combined with cost-efficiency, compared to the medium speed engines that are used in the existing LNG fuelled tugs. This tug is currently in Engineering phase.

Damen Shipyards Gorinchem is responsible for the overall project coordination, including the coordination of the consortium as well as communication with the Project Officer in Brussels. Within LeanShips, Damen, the world leader in the development of workboats, will develop a novel shiphandling tug type. This RSD Tug will be fuelled by natural gas, which is stored on board under compressed form. The advantage of storing the natural gas under compressed form instead of liquefied, as it is the trend in shipbuilding, is that there is no boil-off. This leads to a safer and more environmentally friendly ship.

Pieter Huyskens, Research Manager

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New ship handling tug & CNG powered tug

Demonstrator I: RSD (Reverse Stern Drive) 2513

- entirely new type with improved hydrodynamic characteristics and TwinFin technology
- increased efficiency by allowing a smaller tug to do multiple heavy jobs in a safe way

Demonstrator II: ASD (Azimuth Stern Drive) 3212 CNG-E

- operates with compressed natural gas (CNG)
- MTU marine gas engines have competitive performance when compared with diesel
- additional hybrid (E) propulsion

Comprehensive computational fluid dynamics (CFD) calculations and model scale tests (demonstrator I)

- optimized hydrodynamic behaviour
- allows the use of a smaller crew (three instead of four to five)
- decrease in operational costs
- seven tugs have been built and all completed their sea trials successfully

Conclusion after test benches (demonstrator II)

The propulsion gas engine has been fully validated within the scope of the project's demo case and is available and ready-to-use for a variety of marine applications.

Compared to the medium speed engines that are used in the existing LNG fuelled tugs, the use of these high speed natural gas engines offers a high-power density, combined with cost-efficiency.

Results and exploitation

Application of **inherently gas-safe engine room** i.c.w. CNG resulting in a compact design solution of CNG propulsion.

Concept of **TwinFin technology** for a RSD Tug enables very compact tugs to perform operations faster, safer and more energy efficient.

Market uptake of natural gas propulsion train to a compact high performance harbour tug is taking place: First NG engines sold to customers.

Application of gas propulsion engine including adapted gas train: Ready to be exploited in a large variety of gas fuelled ships.

Creation of an adapted **safety concept for gas fuelled engines** for marine applications and criteria for approval of authorities for gas applications in ships.

Project partners involved

DAMEN · DAMEN SHIPYARDS GALATI · MARINE ENGINEERING · mtu · SVITZER

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Demo Case

The potential of methanol as alternative fuel

A major challenge that is faced by the shipping industry is the reduction of harmful emissions like soot, nitrogen oxides (NOx) and sulfur oxides (SOx). A possible solution is the introduction of methanol in the marine fuel pool. As one of the most widely shipped chemicals in the world, methanol is already present in most terminals. It is also biodegradable and more environmentally friendly than oil-based fuels. Being liquid at atmospheric conditions is a major advantage in handling, distributing and storing methanol. Also, methanol burns cleaner and emits less pollutants than diesel.

In this Demo Case a Volvo Penta D7C-B TA (265 hp) has been converted to Dual Fuel operation in which the engine runs on both methanol and diesel. This operation mode allows to replace a substantial part of the original diesel consumption with methanol and as such reduces harmful emissions. To lower the threshold of adopting this technology, the converted engine has maintained 100 % diesel capability.

Bench tests have been performed on the engine to map the engine's efficiency, emissions and optimal control strategy. The recorded engine performance data are furthermore used in a life cycle emissions and cost calculations for two case study vessels. These case study results will be used to promote market uptake of the high speed methanol/diesel engine.

Ghent University has been working on methanol as an engine fuel since 2009. As of 2015, this has resulted in 2 successfully defended PhDs and 9 master theses, as well as 15 peer-reviewed publications. Ghent University is leading the demo case, converting a high speed marine diesel engine to dual fuel operation on methanol. The engine will be optimised for efficiency and emissions, with measurement results feeding into LCA calculations to show methanol's potential as a fuel for two case study vessels. These will serve to support the market uptake of this promising green fuel.

Prof. Sebastian Verhelst, Associate Professor of Internal Combustion Engines

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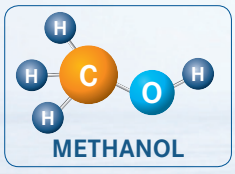
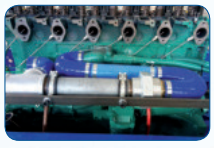
The potential of methanol as alternative fuel

Criteria for alternative fuels: scalable, storable, sustainable



- Biodegradable
- Liquid and thus easy to handle
- Enables neutral CO_2 emissions
- Acceptable energy density
- Great engine performance

Test engine



Volvo Penta D7C TA

6 in-line cylinders
7.15 l
195 kW @ 2300 rpm

A high speed diesel engine used for smaller vessels, has been converted with a methanol retrofit solution to dual-fuel operation in which the engine runs on both methanol and diesel.

Tests on retrofitted engine in Q3 2018

- Speeds between 1000 and 2000 rpm
- 28 load points

Results on dual-fuel methanol/diesel

- **Brake thermal efficiency:**
  a maximum relative increase of 12%
- **Methanol energy fraction:**
  obtained maximum 70%
- **Emissions:**
  NO and soot emissions of respectively 60% and 77%

Results and exploitation

Data from the **life cycle analyses** on life cycle total cost, fuel cost, emissions.

Measurement results on the engine efficiency, emissions and power output in dual fuel operation; retrofit solution for small engines.

Based on the **optimal control strategy** better “real life” sailing efficiencies and emissions are estimated.

Business plan on dual-fuel engines gives a market overview and insight in the financials and current obstacles.

Follow-up project with 2 industrial partners on the feasibility of a vessel conversion, a next step in bringing the technology to the market.

Project partners involved

DAMEN · GHENT UNIVERSITY · ABEKING & RASMUSSEN · Dredging International Marine & Waterway Contractor · methanex the power of agility · VOLVO PENTA

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Demo Case
SECA Refit Strategy

As per January 1, 2015, sulphur emissions by ships in Sulphur Emission Control Areas (SECA) has been limited substantially, requiring vessels to either switch over to a more expensive low Sulphur fuel or install abatement technologies in order to clean the exhaust gases before they are emitted into the open. Depending on several factors, like overall fuel consumption, investment costs and time spent in these areas, a choice has to be made on the method of compliance to these regulations for each and every individual ship. Technology choices for retrofitting existing ships are further limited by technical and economic factors, since these ships were designed to a different set of constraints. Wagenborg Shipping owns and operates a large fleet of about 185 mostly general cargo vessels which operate partly in these SECA areas. Due to the nature of the trade the operational profile, even of sister vessels, varies enormously and a prediction of any future operational profile for an individual ship is very unreliable. This makes it impossible to warrant any investment in abatement technologies by traditional calculation methods.

The main objectives were to identify which methods of compliance are realistic for the fleet of Wagenborg, taking boundary conditions like available space and economic aspects into account. Additionally, a mathematical model was produced to assess an optimal refit strategy not only for an individual ship, but also for the entire fleet as a group. The economical, ecological, operational and technical effectiveness of each retrofit option was studied for each of five selected base line vessels.

The Horizon 2020/LeanShips programme gives Wagenborg Shipping the opportunity to develop a strategy for retrofitting our fleet of General Cargo vessels to meet challenging upcoming environmental regulations in our sailing area; reducing the environmental footprint of our vessels while simultaneously improving their commercial capabilities. All companies in our consortium are experts in their respective fields, and together we can take on this ambitious project which hopefully results in one or more real scale 'demo case retrofits' which will be used to validate the developed strategy.

Theo Klimp, Fleet Director

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SECA Refit Strategy

Assessment tool

- Monte Carlo simulation for highly varying operational profiles
- Compare scrubber, LNG and methanol retrofit options to benchmark of HFO+MGO
- Easy to extend with other retrofit options
- Easy to modify to use for new designs
- Extensive validation program with Wagenborg fleet

Wärtsilä hybrid type scrubber installed on board Balticborg/Bothniaborg

- Scrubber selected for the Wagenborg's B-borg series
- Scrubber enables Wagenborg to meet strict environmental regulations
- Valuable operational experience gained during the project

Desktop research: methanol as a fuel for the B-borg vessels.

- Functional design resulting in a General Arrangement
- Statutory compliance checked
- Gained knowledge and experience to implement Methanol in future designs

Using HAZID procedure for technical aspects

- Proven method to compare solutions on technical grounds

Results and exploitation

Analysis of operational data are used in fleet development for optimization of the utilization of the existing fleet and composition of the future fleet.

The **Monte Carlo simulation method** has proven to be a suitable method for an assessment tool when there is a high level of uncertainty/variations in the input variables.

The **assessment tool** supports decision making of the way (LNG, scrubber, methanol, mgo) to meet sulphur emission regulations and will be used to advise shipowners outside LeanShips.

Application of a scrubber on board of B-borg series of vessels to reduce sulphur emission; other shipowners may follow.

The **HAZID-methodology** was successfully used to assess practical aspects of a retrofit, in order to support decision making and will be used in the future.

Project partners involved

BOLIER · CONOSHIP · cryonorm · ENGIE · Lloyd's Register · NIESTERN // SANDER · WÄRTSILÄ · ROYAL WAGENBORG

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Demo Case

Expanding the application of ESDs to ships with CPP

In FP7 project GRIP, MARIN and Wärtsilä with partners worked on designing and optimising Energy Saving Devices (ESDs) for ships fitted with a Fixed Pitch Propeller (FPP). This resulted in the full scale demonstration of nearly 7% reduction in required propulsion power on a bulk carrier. To increase the total impact of ESDs on shipping energy consumption in additional markets, the next step was to investigate the energy saving potential of ESDs for ships with a Controllable Pitch Propeller (CPP). Most effective ESDs modify the swirl in the inflow (pre-swirl) or outflow (post-swirl) of the propeller. The amount of swirl strongly depends on the pitch of the propeller. As this is variable in a CPP, an additional optimisation challenge was added for ESDs for CPP.

This was done by designing, simulating and testing an ESD design for a Grimaldi vessel. Wärtsilä and MARIN were responsible for the ESD design and simulations, after model scale testing. Wärtsilä produced the ESD which was installed on the Grimaldi vessel for dedicated demonstration trials. ESDs under consideration are pre-swirl stators, pre-swirl ducts and post swirl propeller hub cap fins.

Ever since the founding of MARIN in 1929, our focus has been on the improvement of ship performance. As independent research institute we support the innovation and developments from the market supporting them with numerical simulations and model testing. In LeanShips MARIN leads this Demo Case in which they collaborate with Wärtsilä and Grimaldi to design an ESD for a ship with CPP. This builds on the experience and results of FP7 project GRIP coordinated by MARIN.

Ir. Maarten Flikkema, Senior Project Manager

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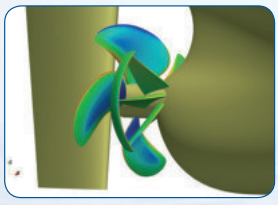
Expanding the application of ESDs to ships with CPP

ESD CFD



- Design competition aiming at best performing Energy Saving Devices (ESD) for this ship
- Design optimisation based on real operational profile of this ship
- Pre-Swirl device showed to be the best performing from numerical simulations

Model tests

- Verification of numerical simulations for speed – power performance
- Evaluation of forces of ESD in seaway
- Ballast and operational draught

Full scale demo

- ESD built by Wartsila, installed on M/V Portogallo
- Dedicated speed trials done at ballast draught before and after installation

Results

- **Gain in fuel efficiency:** 3.5% at operational draught and speed
- **Gain in fuel efficiency:** 1.1% at ballast draught
- **Overall positive business case with payback period:** 2.3 years

Results and exploitation

Experience with **Hydrodynamic design** of pre-swirl stator is ready to be applied to ships and ESDs and personnel to be trained.

Model test report proves only minor differences between numerical models and model test, which gives confidence to apply to design method to further commercial designs.

Installation of the ESD on board in February and March 2019 in Besiktas Dry Dock. With good results: All tolerance limits were respected.

Publishing of the results of sea trials in various technical papers and popular media to show the experience and inform potential clients for design optimisation of ESDs.

Commercialization of an ESD for a vessel with a CPP, also in combination with a redesigned propeller and other ESDs.

Project partners involved

MARIN

WÄRTSILÄ

GRIMALDI GROUP

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Demo Case

Large Diameter Propeller for General Cargo Vessel

Improving vessel propulsive efficiency is a fundamental aspect of reducing fuel burn and hence reducing CO2, and this in turn will result in corresponding reduction in SOx, NOx and PM. Computational Fluid Dynamics (CFD) assessment and scale model tests carried out in STREAMLINE, an EU Framework 7 project, demonstrated that a large propeller design has the potential to significantly improve the propulsive efficiency of a vessel.

In LeanShips the Large Diameter Propeller Demo Case takes this concept a step further leading to a commercially viable full scale vessel design. This Demo Case assesses the benefits of a new hull design incorporating a Large Diameter Propeller in a traditional position but with much reduced propeller/hull clearance. The main work will consist of developing a Large Diameter Propeller system and integrated aft-ship design for an ice-class general cargo ship, undertaking a CFD performance assessment at full scale simulating a 25,000TDW ice-class demo vessel, and validating this assessment using model testing. The final output of the Demo Case will be a full basic vessel design capable of being further matured into detailed full scale vessel design.

Rolls-Royce has world leading capability in propeller design and is leading the Large Diameter Propeller Demo Case in LeanShips. The successful outcome of this work will be achieved by harnessing the considerable and varied capabilities of the Demo Case partners: Wagenborg and Conoship providing ship design, Rolls-Royce delivering the propeller design, MARIN affording design, modelling and testing capability, Chalmers providing modelling design capability and Lloyd's Register supplying the Classification Society input.

David Bone, Marine R&T Programme Manager

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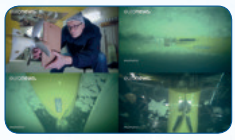
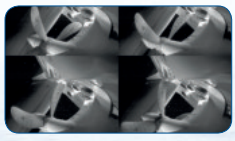
Large Diameter Propeller for General Cargo Vessel

Large Diameter propeller for a 25000TDW General Cargo ship

- Ultra large diameter propeller with optimised aft ship design
- High efficiency
- Slow revolution drive train
- Full basic vessel design

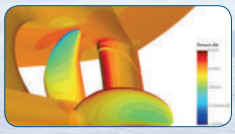
Scale model tests

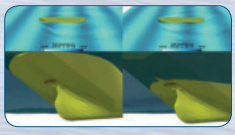




- Test performance in ice
- Investigate ventilation and cavitation characteristics
- Perform seakeeping and overall performance tests

CFD simulations





- Run pressure pulse simulations for small gap between hull and propeller
- Cavitation simulations
- Performance simulations in different sea states
- Comparison between models tests and CFD simulations

Conclusion

The rational radical Large Diameter Propeller has the potential to reduce required shaft power with 15-20 %, reducing fuel consumption and emissions significantly.

Results and exploitation

Model tests and CFD simulations show promising results for ventilation, cavitations and sea state performance.

Model tests indicate clear benefits by significantly reduced shaft power requirements.

Risk assessments and design guidelines enable the Large Diameter Propeller technology to be utilisied in new ship designs.

The Large Diameter Propeller is a step change technology in ship design with potential of significant reduction in fuel consumption and emissions.

Project partners involved

KONGSBERG · Lloyd's Register · MARIN · CHALMERS UNIVERSITY OF TECHNOLOGY · ROYAL WAGENBORG · CONOSHIP INTERNATIONAL

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Demo Case

Decision Support System for ship energy efficiency

The mission of this demonstrator has been to improve the overall energy efficiency of passenger ships, in order to reduce the emissions per each passenger and per each mile of navigation. A dedicated Decision Support System (DSS) has been developed combining different energetic models helping to manage the ship as much efficiently as possible. Thanks to the hydrodynamics, propulsion, electrical and thermal models, the actual energy status of the ship is known and optimized in real time. Thus, the captain has the possibility to make decisions in real time.

A specific ferry ship, Victoria I from Tallink, has been made available for installation of dedicated sensors, data acquisition and demonstrator tests. Moreover, several innovative technologies have been evaluated in order to assess cost effectiveness, compliance with the applicable regulatory framework and, obviously, their global impact on the overall efficiency of test case cruise ships. Several studies have been conducted to assess the on-board applicability of the newest technologies and structural solutions, taking into account their impact on layout and on-board architecture of passenger vessels.

The improvement of overall energy efficiency of passenger ships leads to a consequent reduction of emissions into the atmosphere in terms of emission / payload (number of passengers) / mile ratio.

The objective of AS Tallink Grupp by participating in and investing into LeanShips is to search for additional possibilities for further decreasing the negative environmental impact from its fleet's operations. The company looks into various innovative solutions, including software based ones like this, to cut the overall fuel consumption through smart sailing methods and by doing so also cut the emissions from the operations. The new alternatives in cooperation with the current ones should deliver noticeable results in diminishing the company's ecological footprint. Tallink is especially interested in green and smart solutions, which are applicable for both existing fleet and new buildings.

Aaro Arnus, Technical Superintendent

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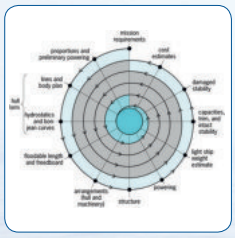
Decision Support System for ship energy efficiency

Goals



To improve the overall energy efficiency of leisure/passenger ships and reduce emissions / payload / mile ratio, in compliance with the applicable regulatory framework at competitive conditions through:

- An integrated efficiency approach with innovative ships lay-out and structures.
- A Decision Support System (DSS) for Energy Management, in line with EEOI and SEEMP requirements.

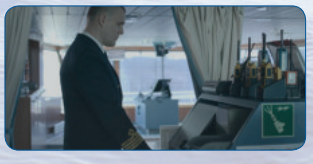
Main Activities

- Energetic analysis: energy quantitative and exergy qualitative analysis for performances evaluations.
- Propeller and hull optimisation: new solutions for numerical simulation of ship self-propulsion model test.
- Catalogue of Innovative solutions: evaluation of the most promising green technologies rising in the maritime market.
- Decision Support System: development of a system supporting captain and crew members managing the ship in the most efficient way.
- Innovative leisure /passenger ships concept: **new** structural and layout solutions enabling also the installation of new technologies

Relevant Markets

Target markets are the ships for intra-European waterborne transport, vessels for offshore operations and the leisure and cruise ships.

Onboard Test



DSS has been tested on board Victoria I, demonstrating the DSS ability to work together with existing equipment and newly installed equipment

Results and exploitation

- Review of most promising technological innovations and in principle on-board applicability evaluation.
- Development of a prototypal Decision Support System suitable for several marine applications.
- DSS tested on-board Victoria I ferry in real navigation conditions.
- Possibility to remotely monitor ships data thanks to a reliable ship to shore interface.
- The installation of new solutions evaluated in the project could lead up to 10 % energy saving.

Project partners involved

FINCANTIERI · SIREHNA NAVAL GROUP · TALLINK · CETENA · MEC MARINE ENGINEERING · REVNETEK SYSTEMS IT MANAGEMENT · RINA · CHANTIERS DE L'ATLANTIQUE

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Demo Case

Adding environment and energy-efficiency to ships

The activities have contributed to enhance the environment and energy efficiency of ships with a consequent reduction of emissions into the atmosphere, addressing different ship functions.

Waste Treatment: Hydrothermal Oxidation treats all types of ship waste. It is air-emission free, fully automated and saves space on ship decks. Demonstrator was built and is now tested on a cruise ship.
Conditioning of Waste produces valuable and easy-handling resource from all types of ship waste. It is environmental-friendly. Demonstrator was built and is now tested onshore.

Waste Heat Recovery: Organic Rankine Cycle converts waste-heat into electrical power. This process was made compatible to marine conditions and integration onboard ships. Energy Storage System allows efficient storage & re-use of waste-heat to avoid using fuel boiler and for engine pre-heating. Demonstrator was built and is now tested onshore.

Emission Reduction System Solutions for Emission Reduction cleans the exhaust gases of large marine engines from PM and NOx. A PM Filter Demonstrator was built is now tested onshore. Solid Sail Technology is an efficient foldable wind propulsion for large ships through full-composite sail and free-standing 360° rotating rig. An onshore demonstrator is being built.

Heir to a long tradition of innovation, European shipbuilding industry settled programmes for Research & Development and participates to national and European co-funded R&D projects for decades. These R&D programmes aim at strengthening European shipbuilding's leadership for designing and building more environmental friendly ships, with a particular focus on energy, air emission and waste management. Therefore every partner of the demo case is fully prepared to contribute to improve the energy efficiency of leisure/passenger ships.

Pierre Berseneff, Research & Development Senior Project Manager

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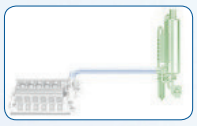
Adding environment and energy- efficiency to ships

Emission Reduction



Cleaning the exhaust gases of large marine engines from Particulate Matter and NOx

Hug Engineering, Fincantieri, Rina

Solid Sail Technology

Reliable, foldable & efficient wind propulsion system for large ships through full-composite sail & free-standing 360° rotating rig

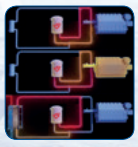
Chantiers de l'Atlantique

Hydrothermal Oxidation

Clean & automated onboard treatment of all shipboard waste through Hydrothermal Oxidation

Leroux & Lotz, Chantiers de l'Atlantique

Energy Storage System



Storage & re-use of waste-heat through Phase-Change Material to avoid using a fuel boiler and for engine pre-heating

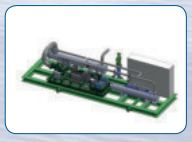
Hutchinson Paulstra, Chantiers de l'Atlantique

Conditioning of Waste

Valuable resource production from ship-generated waste by using different conditioning steps

Meyer Werft, HS Emden/Leer, Lloyds Register

Organic Rankine Cycle



Generation of electrical power from waste-heat recovery through a Marine Organic Rankine Cycle

Enertime, Chantiers de l'Atlantique

Results and exploitation

Hydrothermal Oxidation: demonstration on-going onboard a cruise ship.

Conditioning of Waste: land-based demonstration ongoing.

Organic Rankine Cycle: technology designed for marine use.

Energy Storage System: land-based scaled demonstration ongoing.

Emission Reduction: scaled demonstration on-going for PM filtration.

Solid Sail Technology: scaled demonstration on-going.

Project partners involved

CETENA · enertime · FINCANTIERI · CHANTIERS DE L'ATLANTIQUE · hugengineering. · RINA · HUTCHINSON PAULSTRA · Lloyd's Register · MEYER WERFT · LLT LEROUX & LOTZ TECHNOLOGIES · HOCHSCHULE EMDEN·LEER

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