

Tecnologie Marittime



ICAR CNR

ISTI Istituto di Scienza e Tecnologie dell'Informazione "A. Faedo"

INM/CNR Istituto di Ingegneria del Mare

IREA Istituto per il rilevamento elettromagnetico dell'ambiente

ITAE

IRC Istituto di Ricerche sulla Combustione

Rerum Causam Cognoscere - 1940 -

Scientific areas

Scientific areas

Green transportation
- Energy efficiency:
- Environmental friendly transportation

Safe, secure and smart operations
- Adapting to climate change
- Digital twin & Virtual laboratory
- Predictive maintenance
- Malfunctioning and damage detection:
- Integrated traffic control
- Emergency management

Advanced ship design, construction and performance improvement
- Innovative design
- Design approaches
- New and non-conventional vehicles
- EFD tools
- CFD-FEM-FSI tools
- Diagnostics and performance assessment
- New manufacturing process
- Advanced materials
- On board system

Automation and connectivity
- Unmanned systems:
- Remote sensing and self-diagnostics
- ICT & IOT
- Big data applications

Tecnologie marittime

Istitutes

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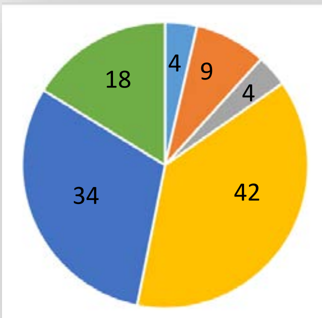
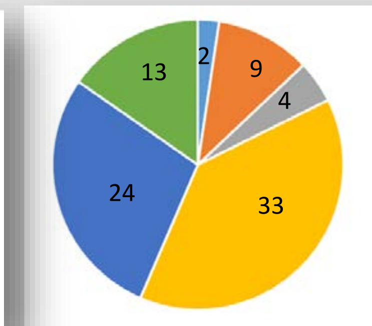
Efforts

Personnel (number)

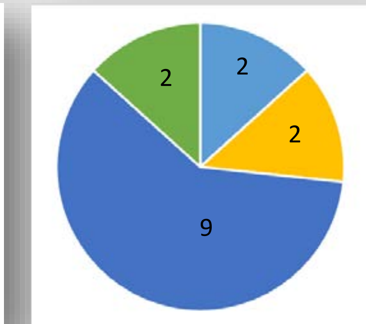
Total



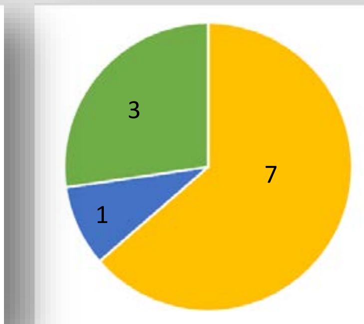
Research scientists and engineers



Senior research scientists and engineers

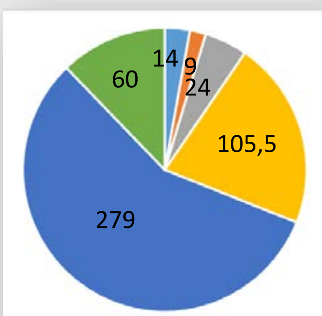


Research directors

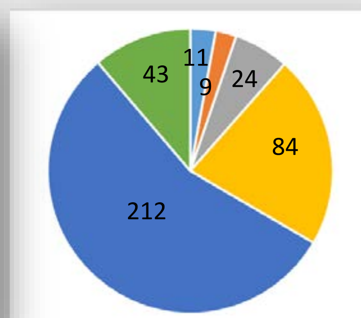


Person Months

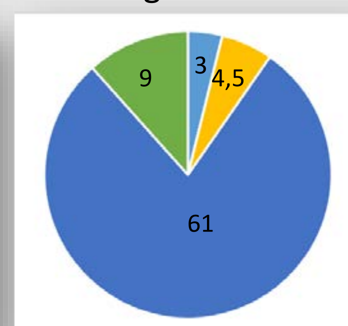
Total



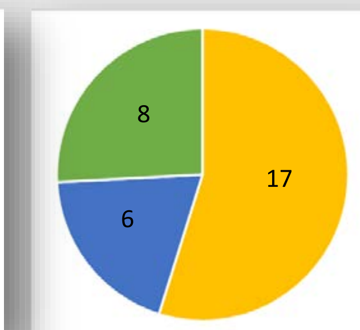
Research scientists and engineers



Senior research scientists and engineers



Research directors



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- ICAR CNR
- ITAE

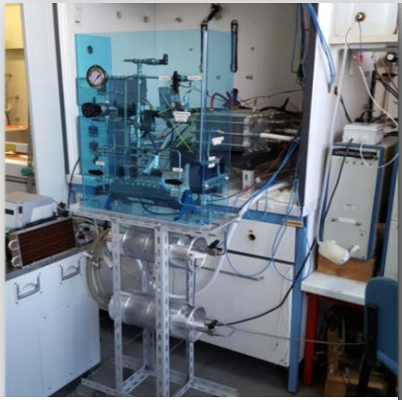
Energy efficiency

Polymer Electrolyte Fuel Cells

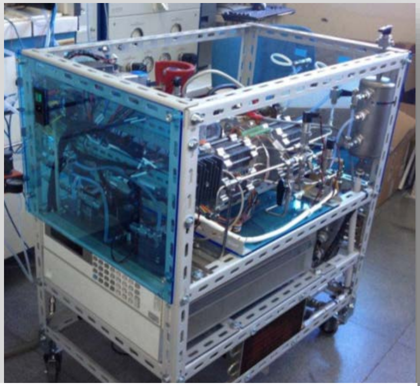
- PEFC power systems for on-board APU zero emission power generation
- PEFC/ICE hybrid propulsion for in-port low-emission and low power propulsion

o Unmanned systems:

- PEFC-powered Unmanned Underwater Vehicles (**UUV**) with enhanced performance and capabilities for hull inspection and maintenance
- PEFC systems for Unmanned Surface Vehicles (**USV**) for in-port environment monitoring
- PEFC systems for Underwater Smart Observatories (**USO**) for real-time environment monitoring
- New drone concepts for specific missions (Man-Over-Board Search and Rescue)



5kW PEFC system and integrated hydrogen storage for marine APU applications



1kW closed-Loop PEFC system for space/submarine AIP propulsion

Green transportation

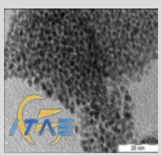
Energy efficiency

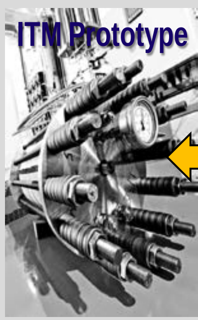
Polymer Electrolyte Membrane Water Electrolysers (PEMWE)

The activity is mainly related to the development of catalysts, membranes, electrodes, MEAs, stack components and their testing in single cell and stack.

ELECTROHYPEM (FP7-FCH JU) and HPEM2GAS (H2020-FCH JU) Achievements

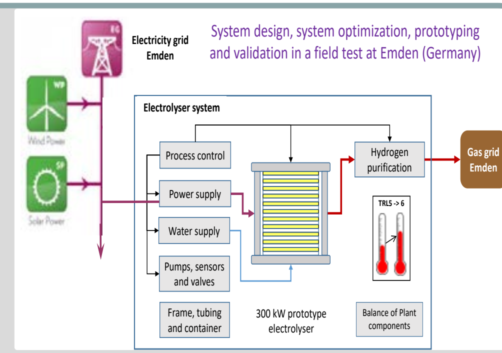
•Stable and compact PEM water electrolyser operating at high temperature (up to 140° C) with low catalyst loading (PGM <0.5 mg/cm^2 MEA) and new high efficient **Aquivion®** membrane
•Electricity consumption 45 KWh/kg H_2 for electrolysis
•Increased hydrogen output per stack by 50%
•Rapid response (< 2 s from min to max power)
•Long term stability (degradation lower than 5 µV/hr/cell)
•**European technology**: electrolysis system commercialised by an European SME, stack components (membrane, catalyst) commercialised by European Industry and SME





ELECTROHYPEM FP7

HPEM2GAS H2020



Stack Voltge	14-20 V
Current	60 A
Temperature	20-80°C
H_2 Production	250 Nl/h
O_2 Production	125 Nl/h
System Efficiency (HHV) at 40 °C	65%
Stack Efficiency (HHV) At 40 °C	85%
Power consumption [W]	1000

PEM Water electrolysis for Hydrogen as a clean and local fuel for transport

Next set of Actions

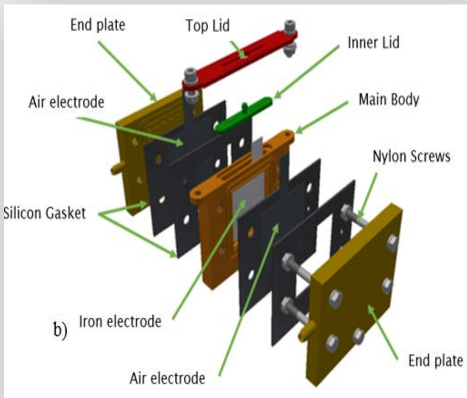
- Increased capacity (from 2 to 400 kg H_2/day)
- Continuous effort to reduce stack costs without lowering efficiency or durability
- Increased stack lifetime (> 100,000 hours)
- Deployment of industrial production line for membrane materials
- Deployment of combined packages: wind turbine and PEM water electrolyser

Green transportation

Energy efficiency

Batteries and fuel cells

Iron-air batteries



Activities

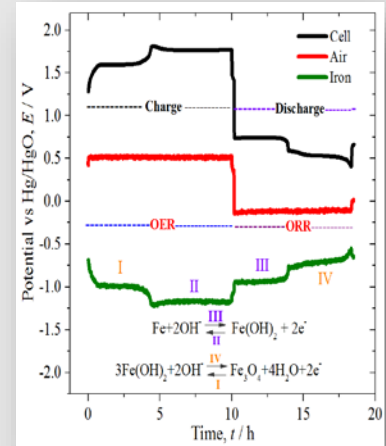
- Development of the materials for both electrodes of the battery:
- the negative electrode composed of an iron oxide-carbon composite.
- the air electrode, baed on noble metal catalysts supported on carbonaceous materials, perovskites, spinels, etc.
- Chemical-physical characterization of the materials.
- Electrochemical testing in half-cell and single cell of both the iron-based negative electrode and the air electrode.

Aim

Develop a new concept of battery based on a new metal/air technology that overcomes the energy density limitation of the Li-ion battery actually used.

Results

- Aqueous iron-air battery with an energy density of 453 W h kg^{-1}_{Fe}.
- Discharge capacity of 854 mA h g^{-1}_{Fe} at 10 mA cm^{-2}



Direct Alcohol Fuel Cells

Activities

- Development of catalysts, electrodes and membranes
- Electrochemical characterization
- Stacks design and testing
  - o Passive mode operation monopolar mini-stack for portable applications
  - o Bipolar short stack for APU applications

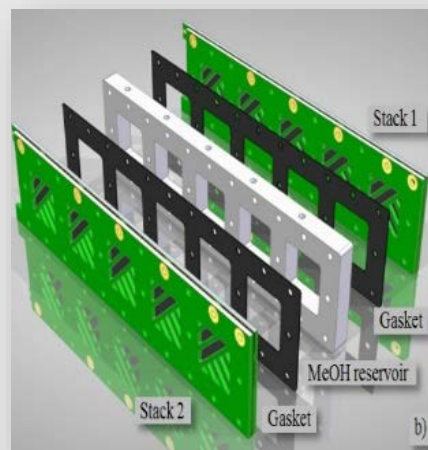
Results

- **PASSIVE MODE**

  Power density: 20-50 mW/cm^2
  Nominal Power ~ 1 W Single cell active area: 4 cm^2

- **BIPOLAR SHORT STACK**

  Power density: 100-250 mW/cm^2
  Single cell active area: 100 cm^2
  Operation temperature: 90-130 °C



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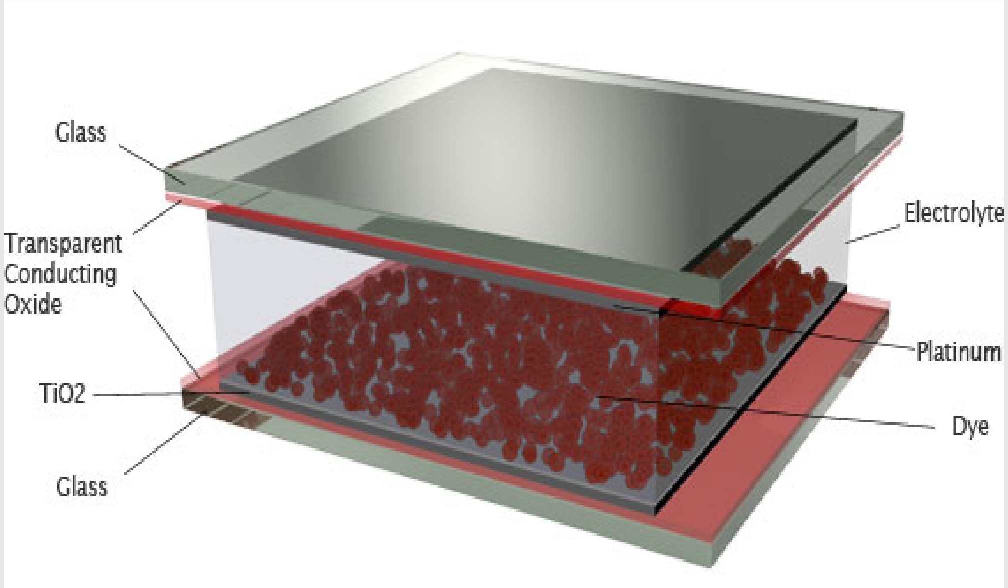
Energy efficiency

Nanomaterials for dye sensitized solar cells (DSSC) and Photo-electrolysis cells

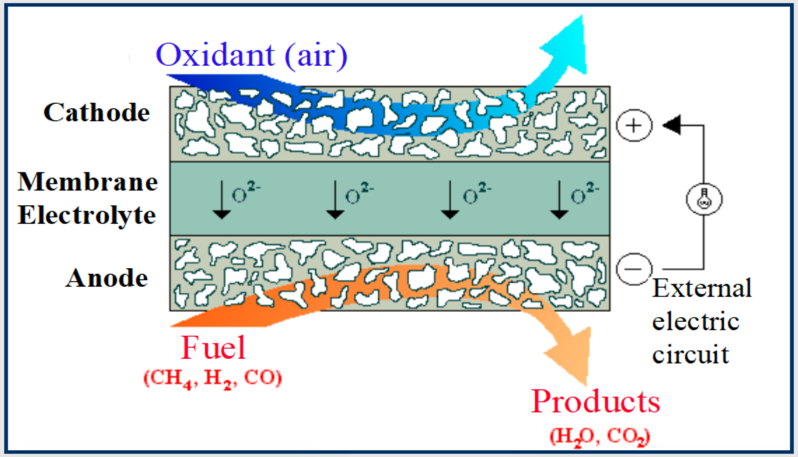
- **DSSC** consist of a iodide electrolyte **(dye)** sandwiched between a **photoelectrode** *(a conductive glass plate coated with porous TiO_2 that can adsorb photosensitive dye molecules)* and a catalytic-electrode (**counter electrode**).
- Light energy absorbed in the dye is converted to electricity via solar cell electrochemical properties.

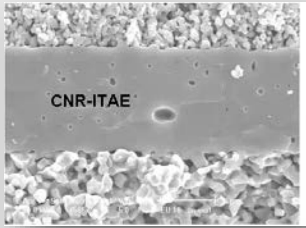
- Materials for the counter electrode:
  - Cost-effective materials (alternative to Pt): carbon blacks, carbon nanofibers, graphene, carbon xerogels
- Materials for the photo-electrode:
  - Fluoride-doped tin dioxide (SnO_2:F) + Ti-oxide (highly porous)

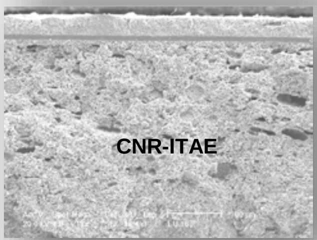


Energy efficiency

Solid oxide Fuel Cells (SOFCs)







Objectives

- **SOFCs** are based on *ceramic materials* and operate at high temperatures between 800 and 1000°C for conversion of fuels, including processed organic fuels, into electrical energy.
- Relevant applications are transportation, assisted power units, combined heat and power, etc..
- In the marine sector, the challenges are regarding the *reduction of the operation temperature* and the direct utilization of fuels appropriate for marine applications.

Approach

The approach is to develop ceramic electrolytes for intermediate temperature operation based on ceria and gallates, use a multifunctional electrocatalytic layer at the anode to favour internal fuel processing and tailor the composition of the perovskite cathodes to speed-up the oxygen reduction process

Scientific impact/results

The new materials and cell architectures have been validated for the direct utilization of reformed diesel for APU applications in the marine sector in systems up to 2 kW power

Energy efficiency

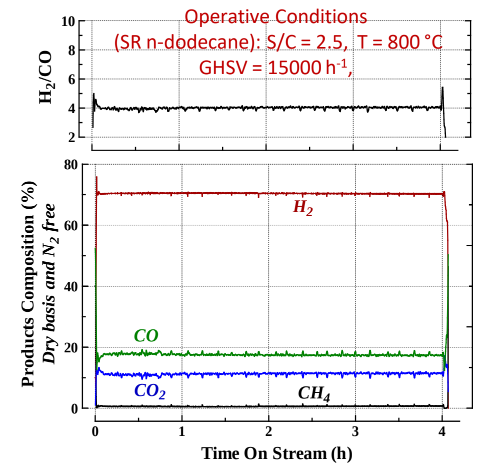
Advanced materials and nanotechnology

Design and development of structured catalysts and compact reactors with enhanced heat transport and surface to volume ratio properties for the conversion of the marine fuels into a hydrogen-rich mixture.

- The prepared structured catalysts show high porosity (about 79%), uniform coating with relatively low thickness (10 – 40 µm) and high mechanical strength (low weight loss under ultrasonic treatment about 1% by the loaded catalyst total weight)

Reactor	Catalyst Loading (g)	Volume/ Weight (cm^3/kg)	Rh Loaded (Wt %)	Size/weigth values	
				kWe^{H2}/L	kWe^{H2}/kg
Packed bed Commercial catalyst	220	200 / 1.5	2	5.2	1
Monolith	16	47 / 1	1	18.7	1.5

- Compared with pellet catalyst (packed bed reactor), the Rh/CeO_2 monolithic catalyst show higher activity (total fuel conversion) at high space velocity, with reactor volume and catalyst amount significantly reduced.



Future Perspective

Advanced structured catalysts are needed to realize compact, innovative and thermally integrated reactors for the conversion of Marine fuels into hydrogen-rich mixture for Fuel Cell based APU application. The utilization of compact and multifunctional reactors contribute to reduce the environmental emissions, minimizing capital and operating costs, increasing intrinsic safety and increasing production and efficiency of the processes.

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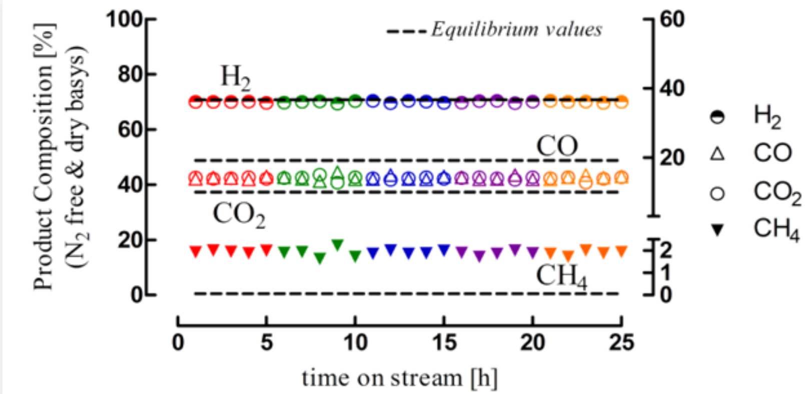
Green transportation

Energy efficiency

Advanced materials and nanotechnology

Design, realization and test of small-scale Fuel Processor Systems based on reforming processes of fossil and renewable fuels, finalized to syngas production and integration with Fuel Cell systems for mobile and stationary applications in the range of 1-30kW.

The prototype "DSR1" can produce hydrogen rich gas mixture for Solide Oxide Fuel Cells for auxiliary power units for naval applications from steam reforming of n-dodecane as surrogate of diesel.



Product composition after 5 daily cycles of 5 hours at T=800 °C, GHSV=3500 h^{-1}, S/C=2.5, compared with the related equilibrium values.

- H_2 content, dry basis and nitrogen free, in the products reaches a value of about 70% for a molar ratio S/C of 2.5;
- No evidences of carbon deposition phenomena and low concentration (CH_4=2%) of by-products formation were revealed.

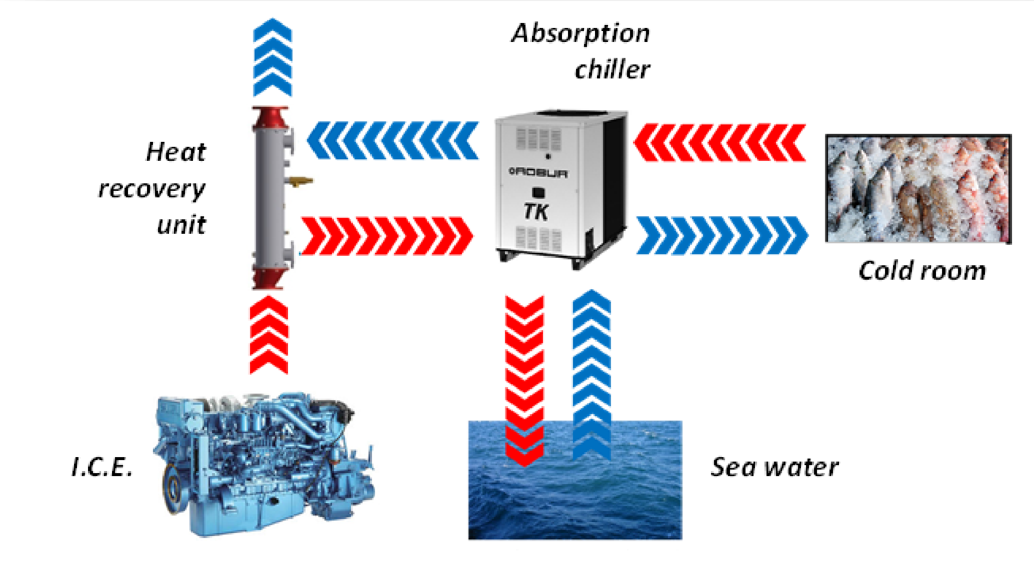
Future Perspective

New environmental friendly and competitive cost technological solutions for the utilization of marine fuels in fuel cell base APU for the generation of energy and heat on board.

The fuel cell technology provides high-efficiency energy conversion, with low pollutant emissions and silent operation. These features represent the main driving force behind fuel cell systems designed to be used as auxiliary power unit (APU) in mobile applications.

Energy efficiency

Waste heat recovery for refrigeration on fishing vessels



Testing station for absorption unit for refrigeration on fishing vessels

Prototype absorption unit for refrigeration on fishing vessels

Energy efficiency

Waste thermo-chemical conversion

- On site processing of dry organic waste through pyro-gasification treatment
- Reduction of the waste volume (on-board)
- Waste conversion into an energy carrier (syngas)

All organic waste

Gasification system

Bio-char

Water

Synthesis gas

Thermal energy

Energy efficiency

Energy Technology Managment

DeNOx : NH_3-SCR

- Celle a Combustibile ad elettrolita polimerico (PEFCs)
- Celle a Combustibile ad ossidi Solidi (SOFCs)
- Produzione di biodiesel
- Valutazione di sistemi di accumulo energetico (batterie e supercapacitori) presenti sul mercato
- Pretrattamento biogas liquefatto
- Sviluppo di catalizzatori innovativi per il cleaning di stream acquosi e gassosi
- Generatori di syngas da diesel

DeSOx + DeNOx :

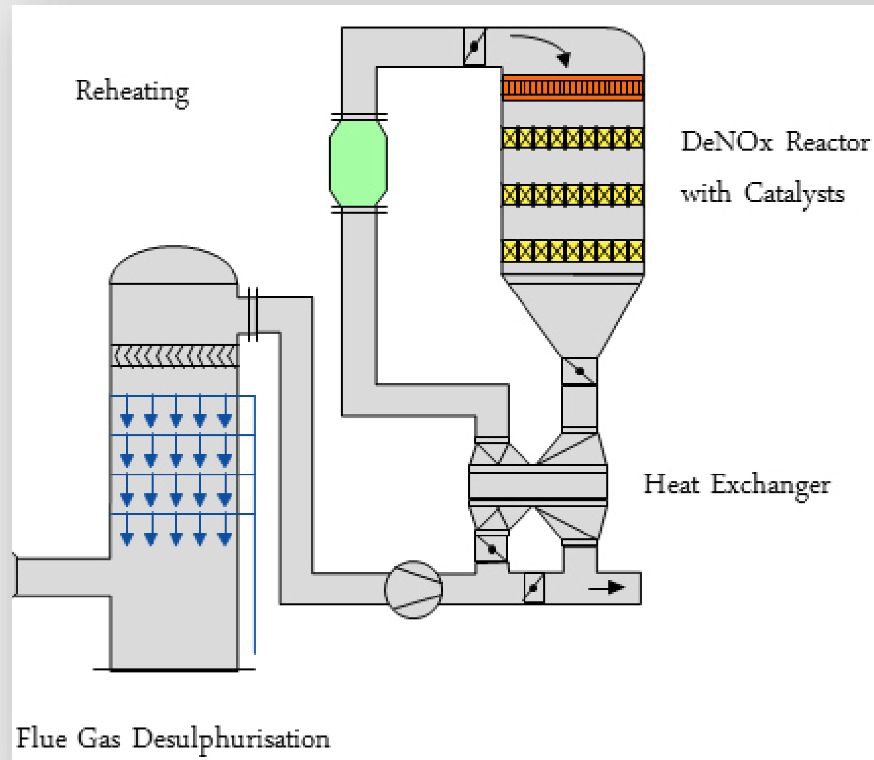
- Climatizzatore ad Adsorbimento per il condizionamento
- Predisposizione piano di costruzione impianti navali innovativi per pescherecci
- Macchine frigorifere ad adsorbimento per la conservazione del pescato
- Riqualificazione energetica ed ambientale ci cantieri ed aree portual
- Sviluppo Celle solari di terza generazione su supporto flessibile

Energy efficiency

Energy Technology Management

DeNOx : NH_3-SCR

DeSOx + DeNOx :



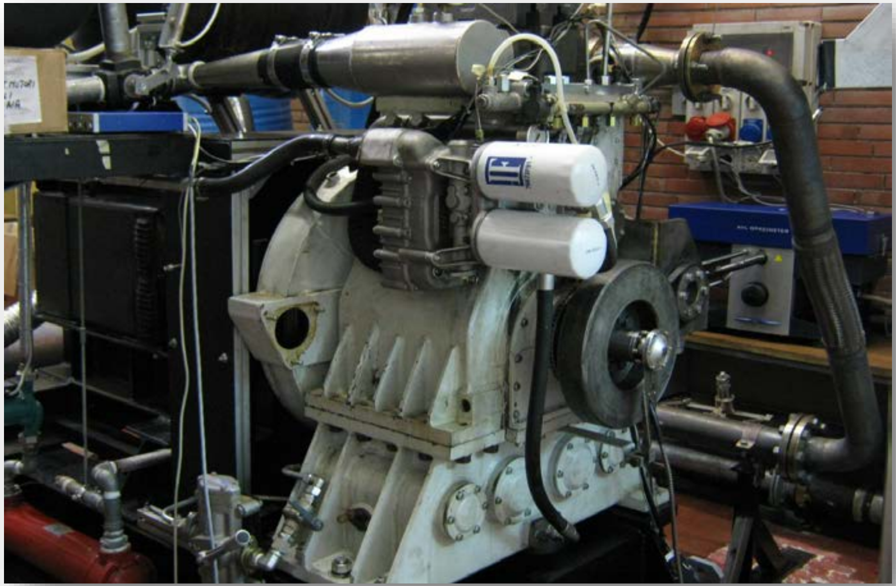
Sea Water Scrubber + Low Temp. NH_3-SCR

Energy efficiency

Engines for marine applications

Motore monocilindrico da ricerca dotato di sistema di iniezione common-rail ed elettro-iniettore per iniezioni multiple;

- Sviluppo ed ottimizzazione del sistema di combustione (geometria camera di combustione, strategie di iniezione per il controllo della combustione e delle emissioni inquinanti)
- Caratterizzazione degli spray di combustibile in ambiente a pressione e temperatura controllate per lo studio dell'atomizzazione e dell' evaporazione
- Sperimentazione di tecnologie dual-fuel con gas naturale nel collettore ed accensione pilota con combustibile diesel iniettato in camera di combustione
- Metodologie per il confort vibro-acustico a bordo nave

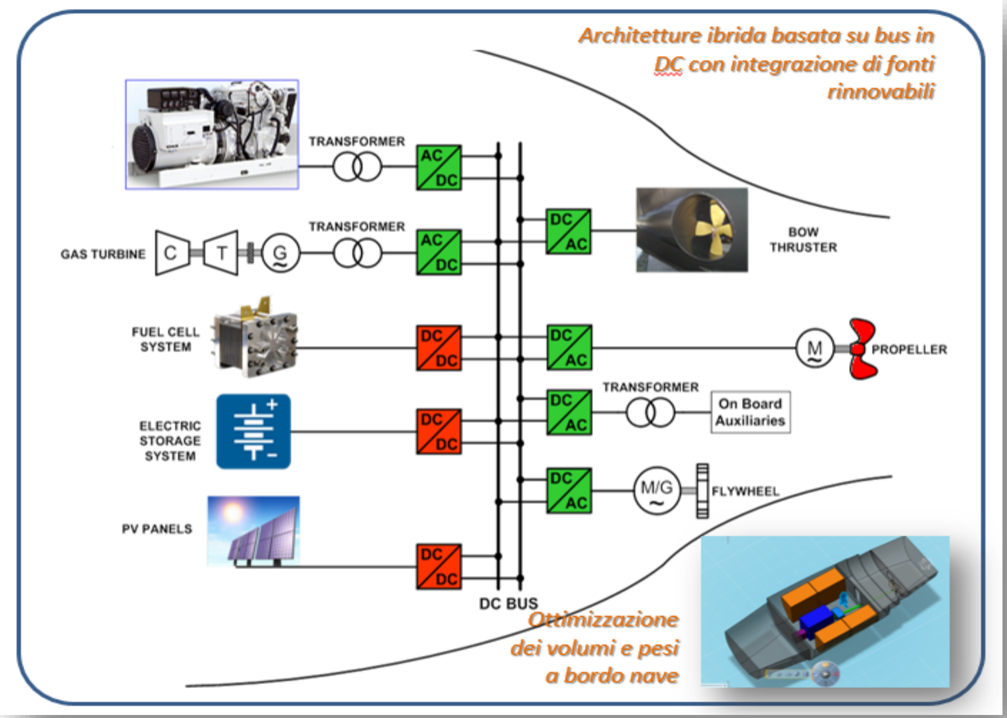


Dettagli motore		
Cilindrata	[cm^3]	4200
Alesaggio	[mm]	170
Corsa	[mm]	185
Rapporto di compressione		13.8:1
Potenza	[kW]	155
Coppia Massima	[Nm]	796
Velocità rotazione	[rpm]	1800

Energy efficiency

Hybrid engines for naval propulsion

Approccio
Analisi di architetture innovative di propulsione, con approcci di System Engineering ed attività sperimentali di laboratorio sui sistemi elettrici di conversione ed accumulo dell'energia.



Laboratorio dedicato allo studio sperimentale dei sistemi elettrici per la propulsione navale ibrida

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Energy efficiency

Drag reduction

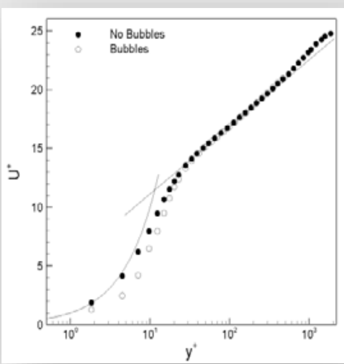
Objective:

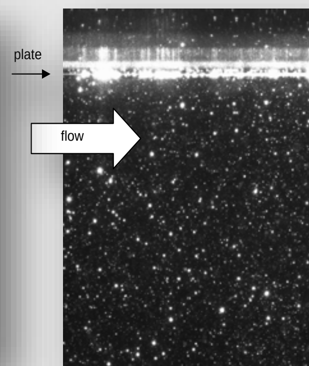
Assessment of super-hydrophobic, nano-structured coatings in:

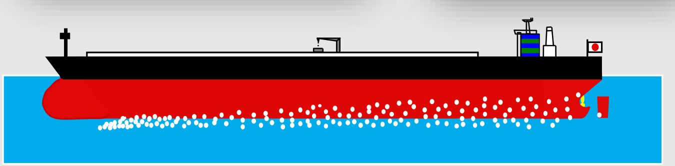
- drag reduction
- hydrodynamic noise reduction
- on board sensors disturbance reduction

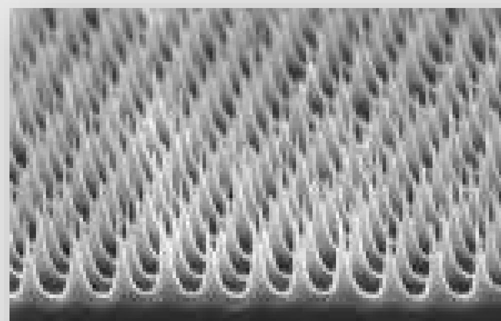
Approach:

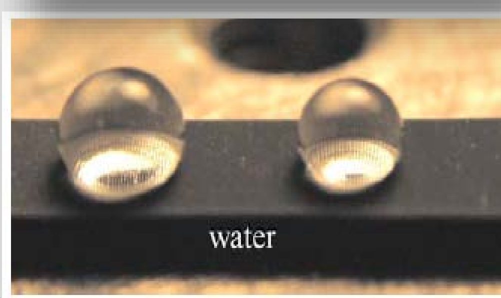
- Identification and characterization of the super hydrophobic coatings
- Boundary layer velocity field, pressure fluctuation at wall and vibro-acoustic measure.
- Theoretical model of wall shear-stress □w – pressure fluctuation spectra coupling
- Drag and vibro acoustic measures on a ship model.

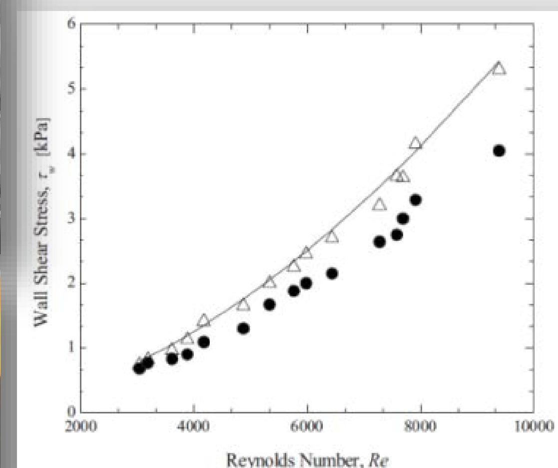












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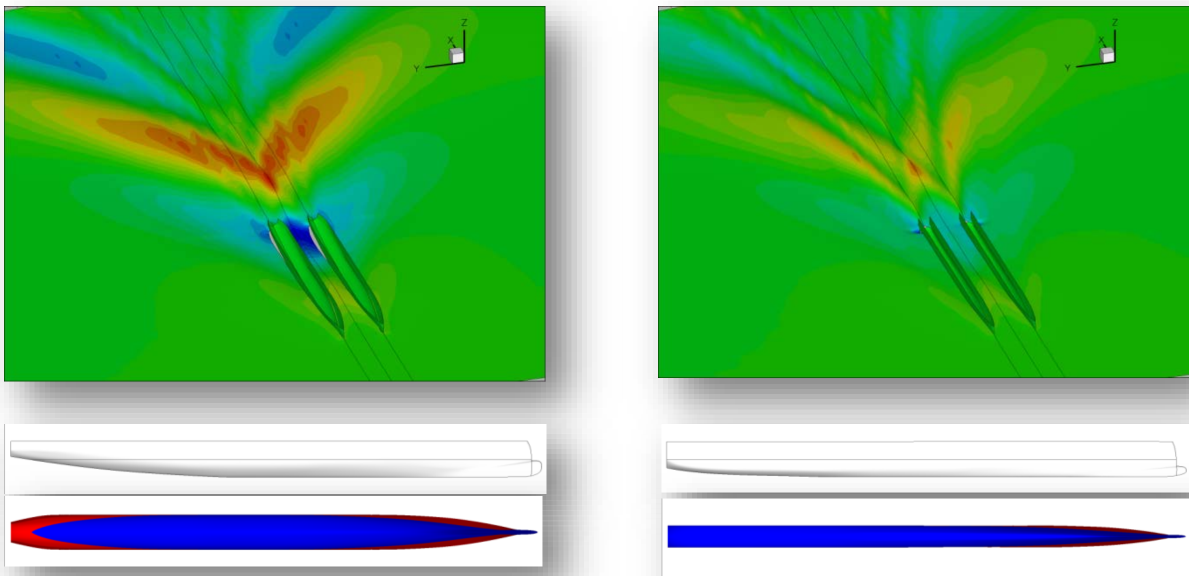
Environmental friendly transp.

Wave wash

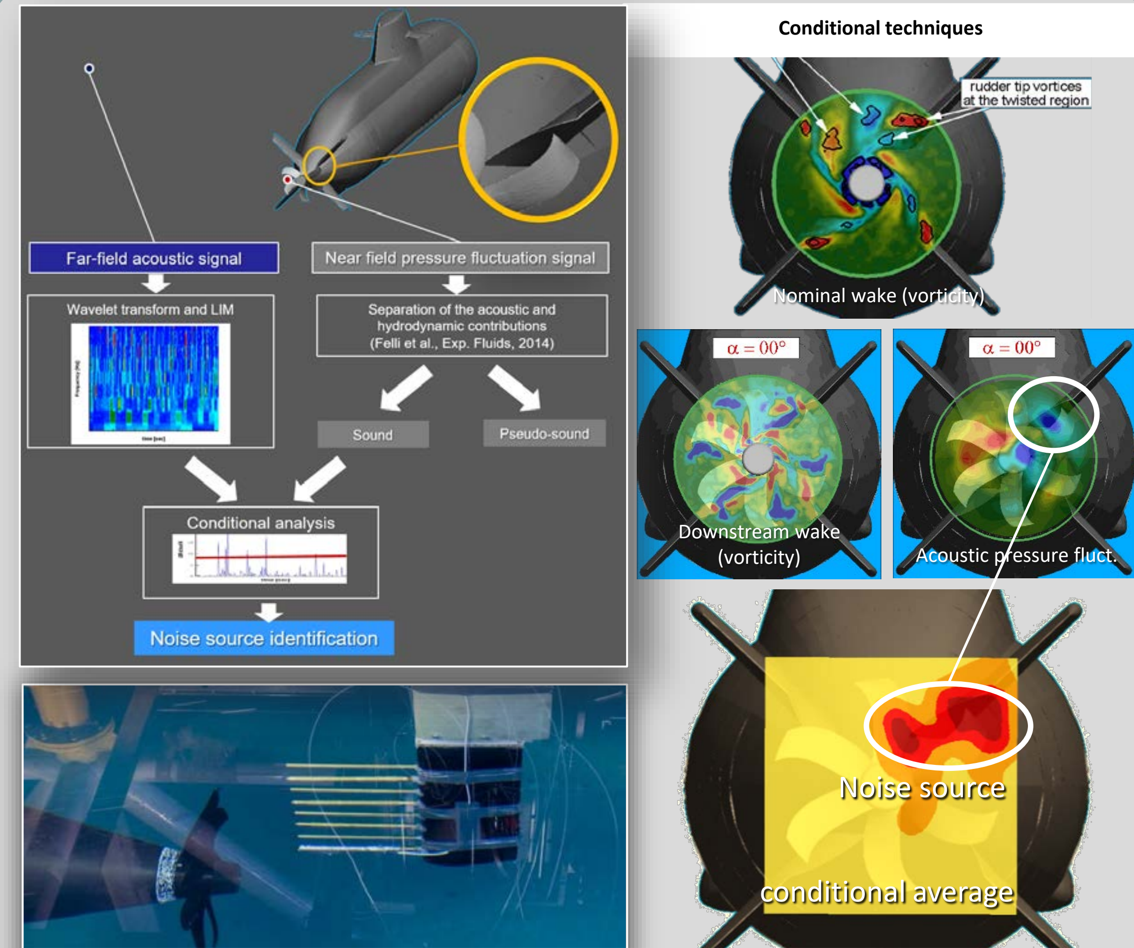


Approach

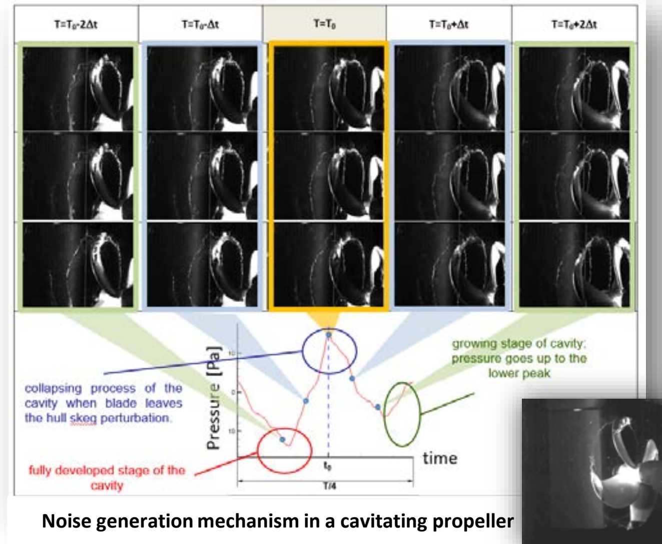
CFD, BEM, Wave propagation models, Numerical optimization of the hull, Near-field and far field wave measurements

Environmental friendly transp.

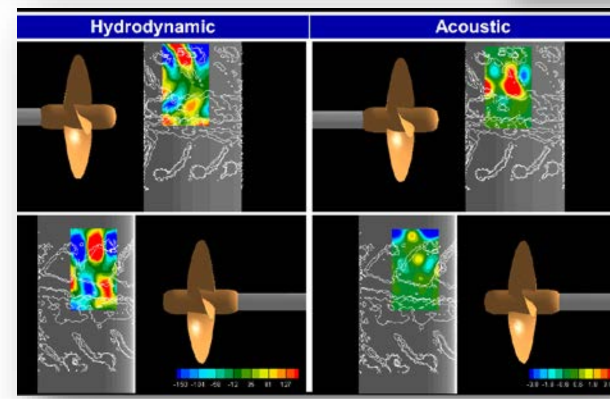
Naval Hydroacoustics: unconventional experim. methods for acoustic diagnostics



Noise source identification in a submarine



Noise generation mechanism in a cavitating propeller



Experimental methodologies to separate out sound and pseudo sound contributions from near field pressure measurements

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Environmental friendly transp.

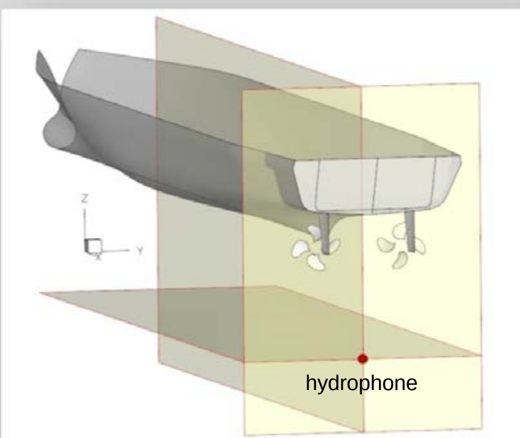
Underwater noise investigation via Ffowcs Williams-Hawkings (FWH) equations

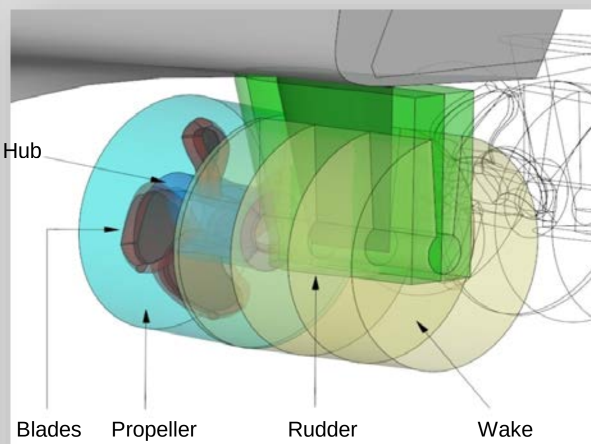
$$\Box^2 p' = \frac{\bar{\partial}}{\partial t}[\rho_0 v_n \delta(f)] - \frac{\bar{\partial}}{\partial x_i}[p\hat{n}_i \delta(f)] + \frac{\bar{\partial}^2}{\partial x_i \partial x_j}[pT_{ij}H(f)]$$

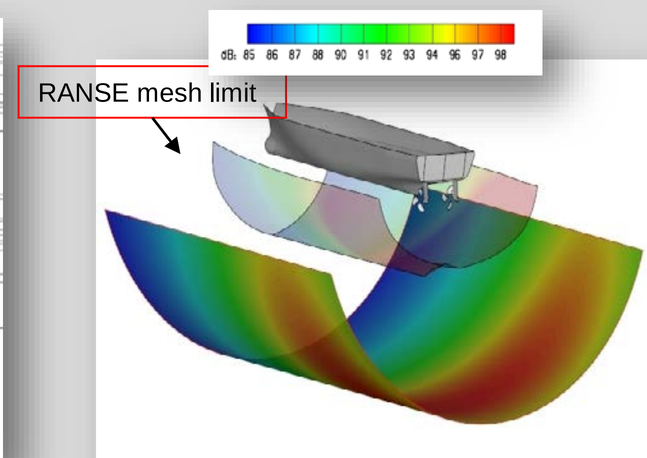
Noise | body shape | hydrodynamic loads | non-linear effects

The Ffowcs Williams - Hawkings equation (1969) directly arises from the fundamental conservation laws of mass and momentum and governs the sound generated by a body moving in a fluid flow.

1) Characterize the sources through the knowledge of the body shape, of the pressure distributions on the hull and, of the pressure and velocity fields in the bulk of the fluid around of the ship
2) Then use the FWH equation to propagate the noise in the far field.

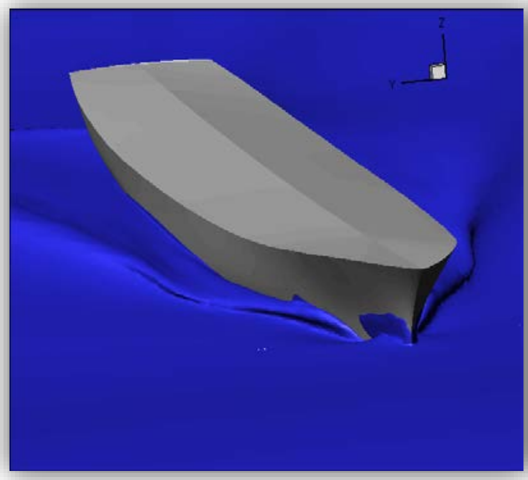


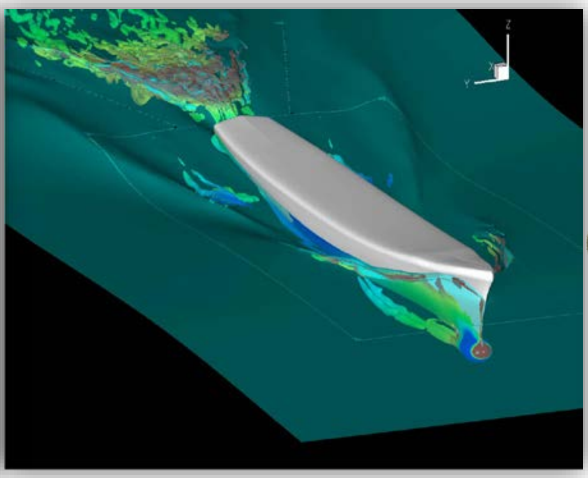


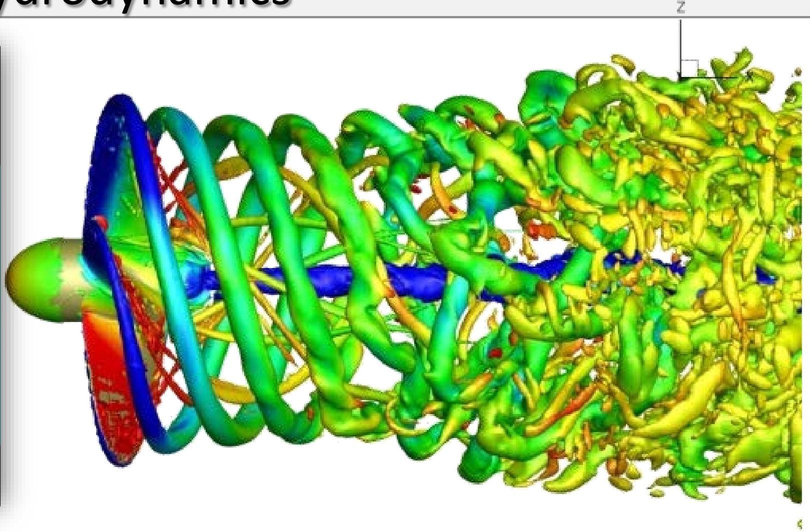


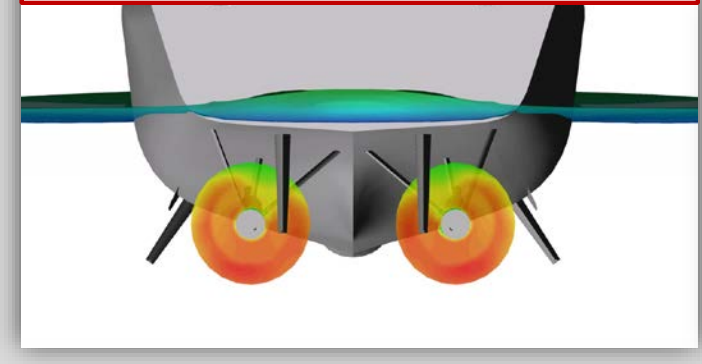
CFD-FEM-FSI methods

Numerical methods for hydrodynamics

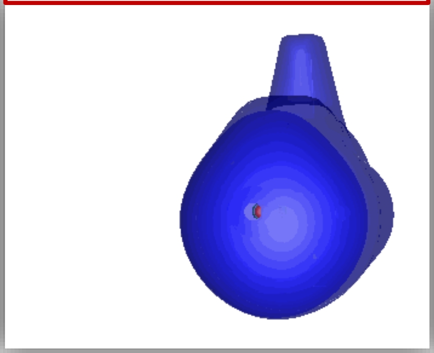




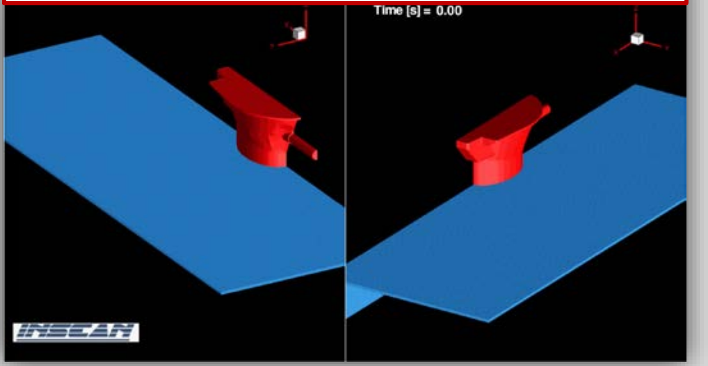




Propeller flow during a ship turning circle manoeuvre by RANSE



Torpedo dynamics in a launching operation

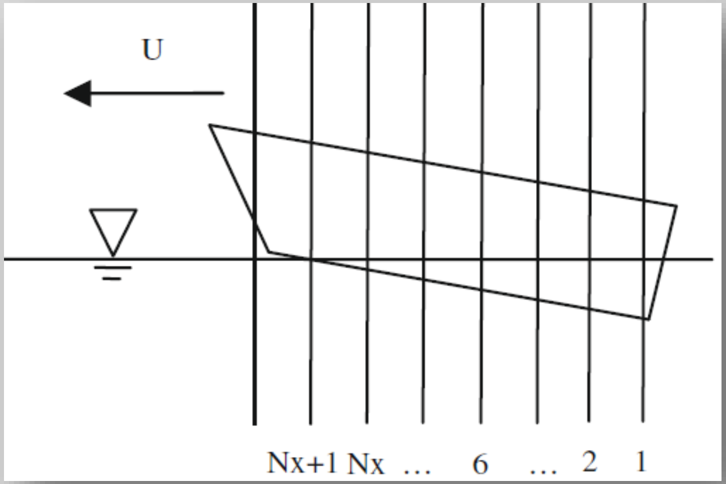


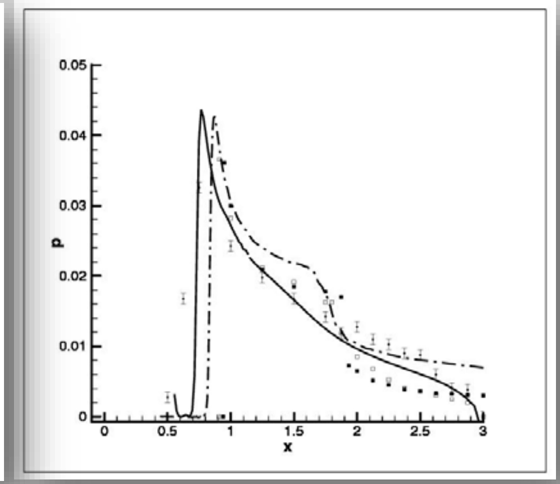
SPH simulation of the flow around a snorkel system

CFD-FEM-FSI methods

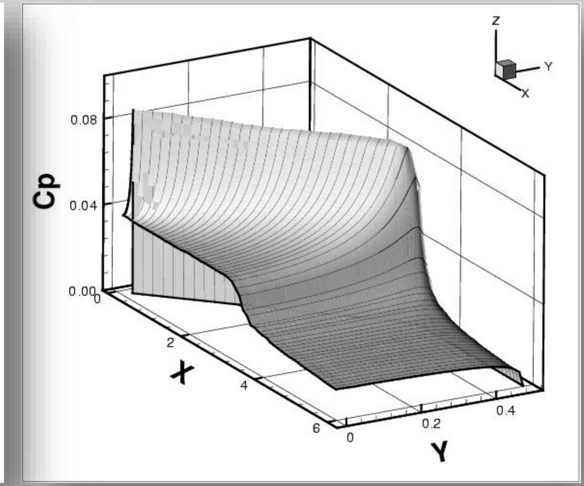
Numerical model for high-speed crafts hydrodynamics

- Simplified hydrodynamic model based on 2D potential flow
- 3D flow via 2D+t approximation
- Validated versus 3D RANS solver
- Developed for steady and unsteady flow
- Coupled with the ship motion and structural deformation
- Quite efficient for design process and stability analysis





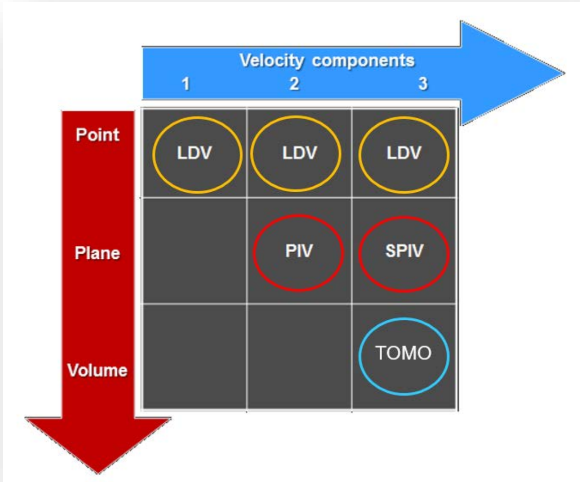
Longitudinal pressure profile

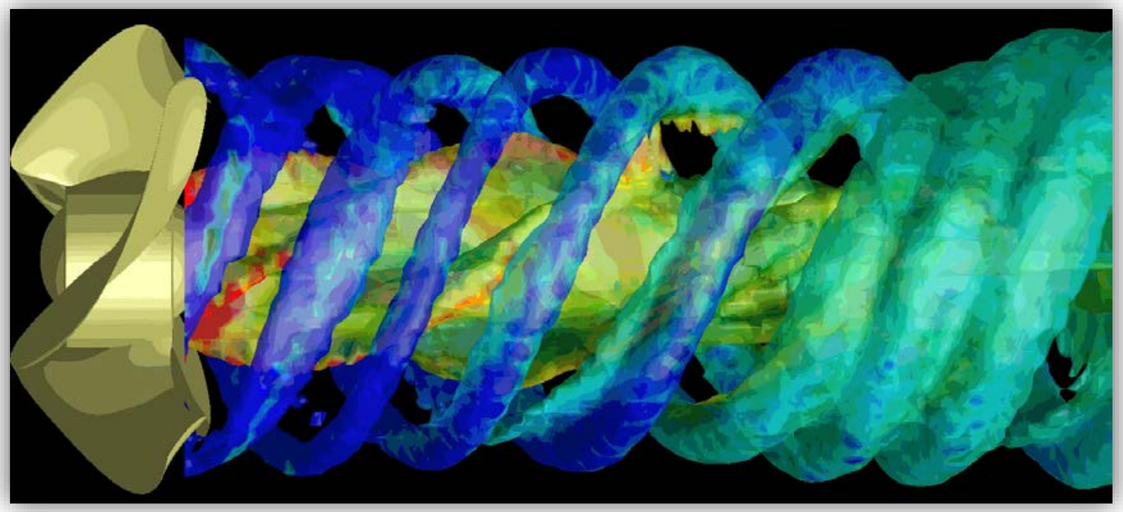


Pressure distribution on the demi-hull

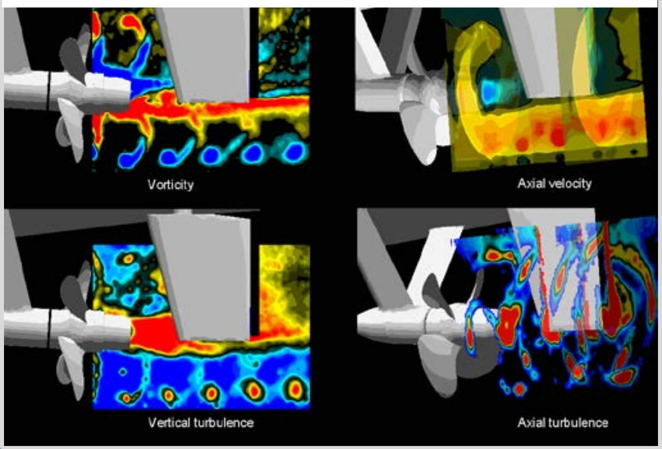
Experimental methods

Experimental methods for hydrodynamics

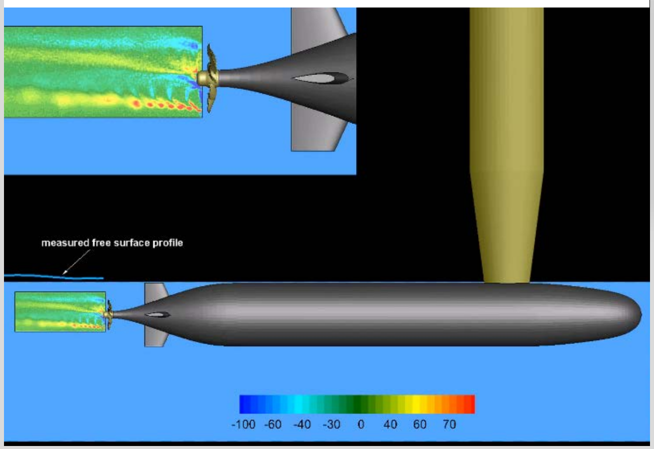




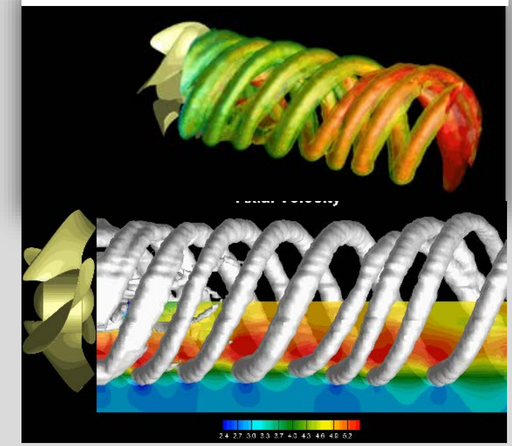
Laser Doppler Velocimetry



Particle Image Velocimetry



Tomography



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Experimental methods

Underwater Acoustic Calibration Standards

Motivations

- Absolute measurement of sound in the sea are driven by concerns about the environmental impact of human activities, which radiate most of their energy below 1 kHz.
- New standards are required for calibration of both hydrophones and autonomous noise recorders in the 63 Hz and 125 Hz third-octave frequency bands, as required by guidelines of the EU Marine Strategy Framework Directive.
- Long-term operation of capabilities is needed within EU, including regulatory support, research collaborations, quality schemes and accreditation.

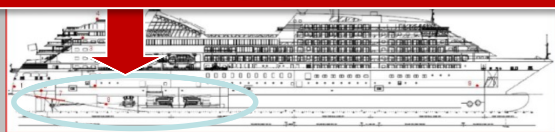
Aim

Develop scientific and technical research capabilities within Europe for the calibration of hydrophones and autonomous noise recorders. An improved metrology framework across EU Member States will underpin traceable measurement of underwater sound in support of regulations and EU Directives such as the Marine Strategy Framework Directive 2008/56/EC

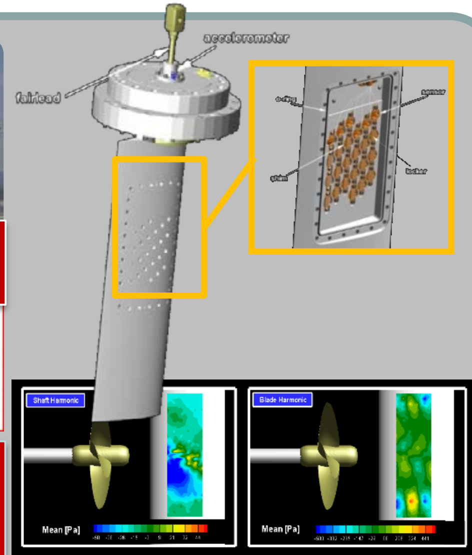
Diagnostics and performance assessment

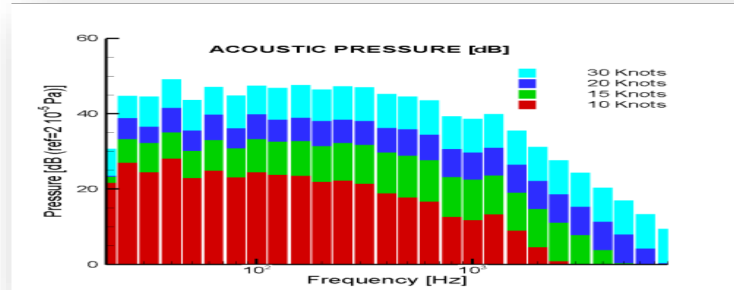
Ship Comfort: internal noise and vibration levels

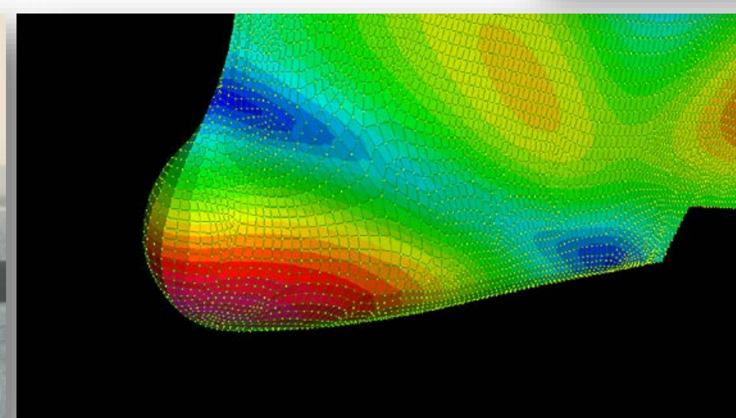
Cruise ships are often affected by comfort reduction on overhanging decks



Rudder vibrations and stern slamming may overcome engine and propeller as vibration sources in these zones







Diagnostics and performance assessment

Design of offshore structures

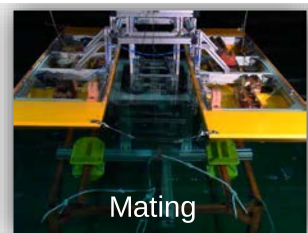
Topics

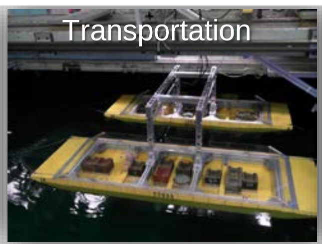
I. Hydrodynamic loads on offshore structures
II. Floating, moored and fixed configurations
III. Deployment of offshore structures
IV. Offshore wind structures

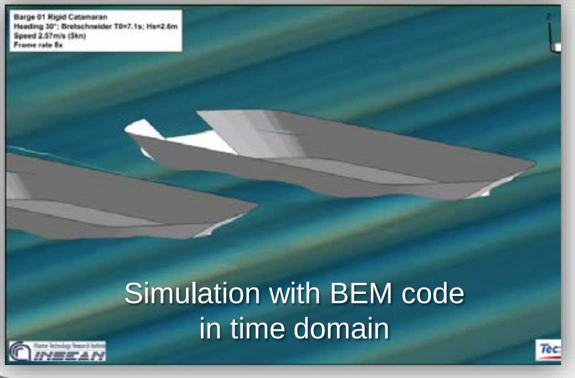
Approaches

I. BEM
II. Nonlinear FEM
III. Reduced-order models
IV. FSI coupling

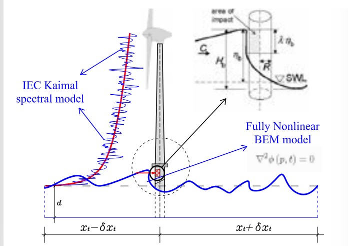
Analysis of transportation and mating of the topside of a jacket structure

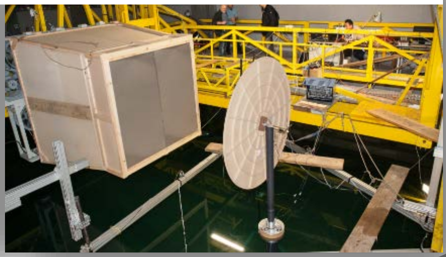






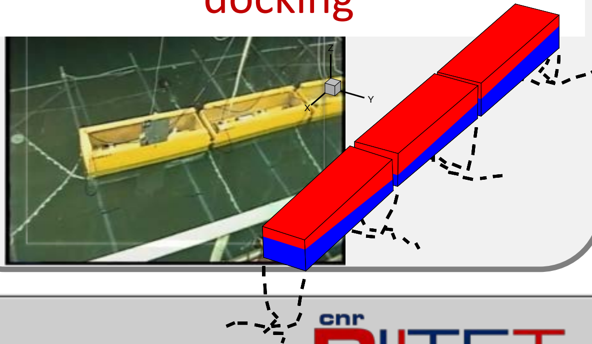
Offshore wind





Impact loads on jacket structures

Segmented pontoon for docking



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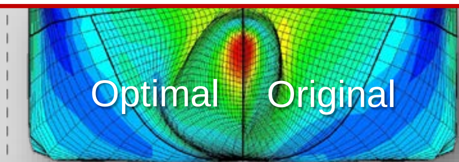
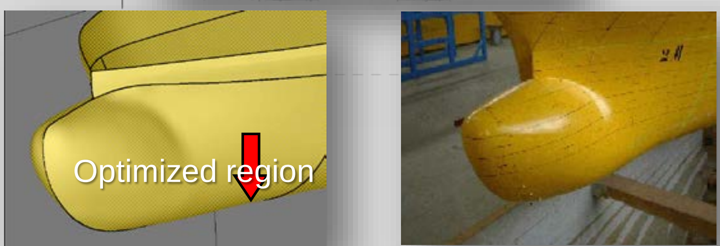
Innovative design

Design optimization

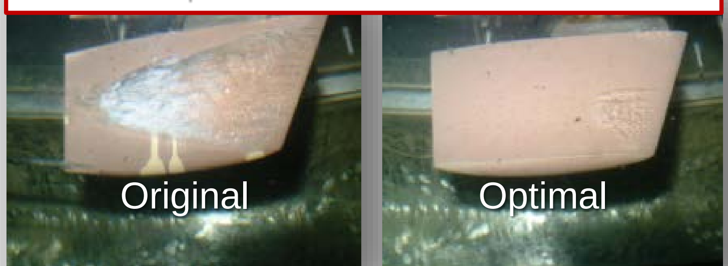
Applications: EEDI and fuel reduction, Hydrodynamic noise reduction, Ship stability (seakeeping), Wash wake reduction, material/structure optimization, multidisciplinary coupling between hydrodynamics and structures

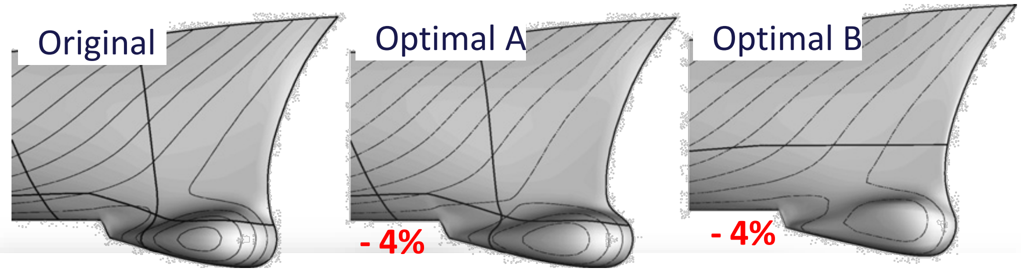
Bulb optimization



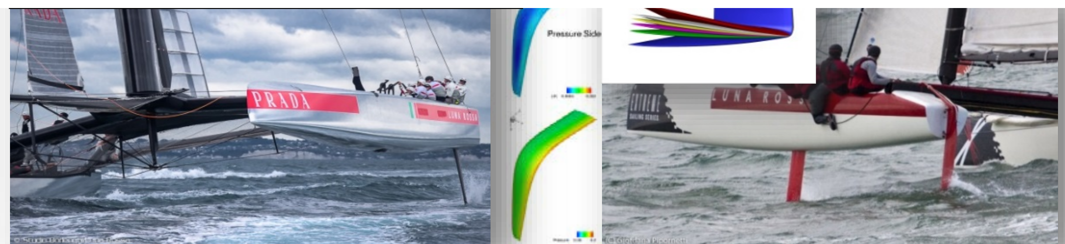


Anti-torpedo cavitation mechanism reduction





LUNA ROSSA



Italian frigate: optimization of the wave elevation

Innovative design

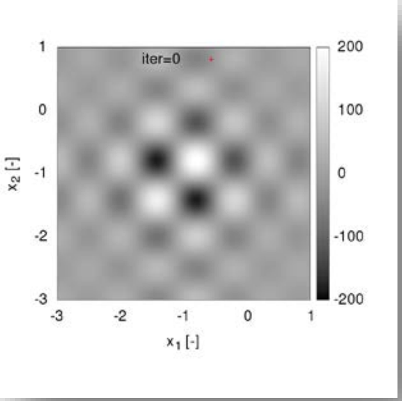
Multidisciplinary Analysis and Optimization Research

Numerical solvers

- CFD and CSD
- FSI
- Uncertainty quantification

Optimization algorithms

- Global and hybrid global/local
- Derivative-free
- Deterministic



Shape modification

- Free-form deformation
- Orthogonal patches
- Morphing

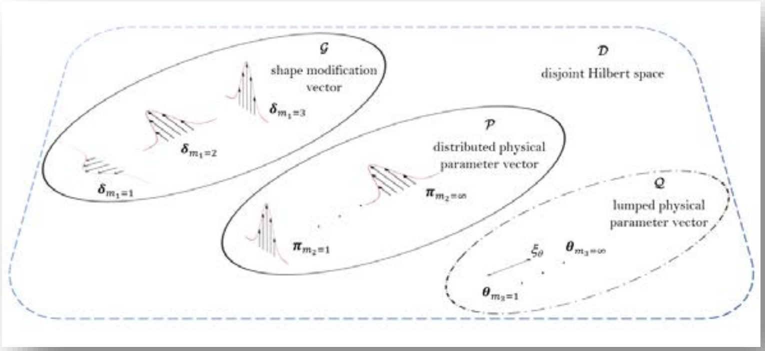
Metamodelling

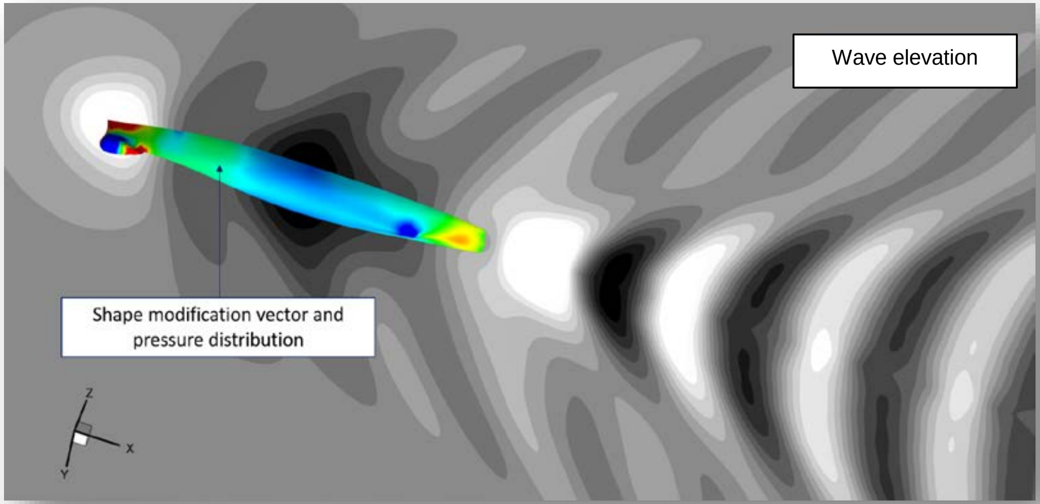
- Single- and multi-fidelity
- Adaptive sampling methods

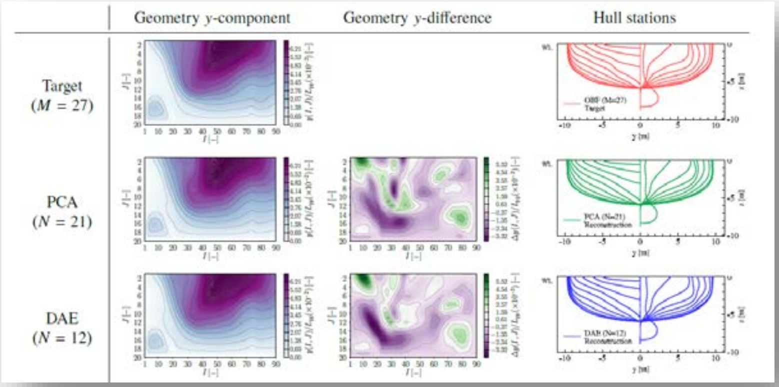
Innovative design

Dimensionality Reduction

- Linear and nonlinear methods
  - PCA, Local PCA, Kernel PCA, Deep Autoencoder
- Design-space dimensionality reduction in shape optimization by:
  - Geometry-based formulation (only)
  - Combined geometry- and physics-based formulation
- Physical data assessment







Predictive maintenance and damage detection

Ship safety: Load and response prediction

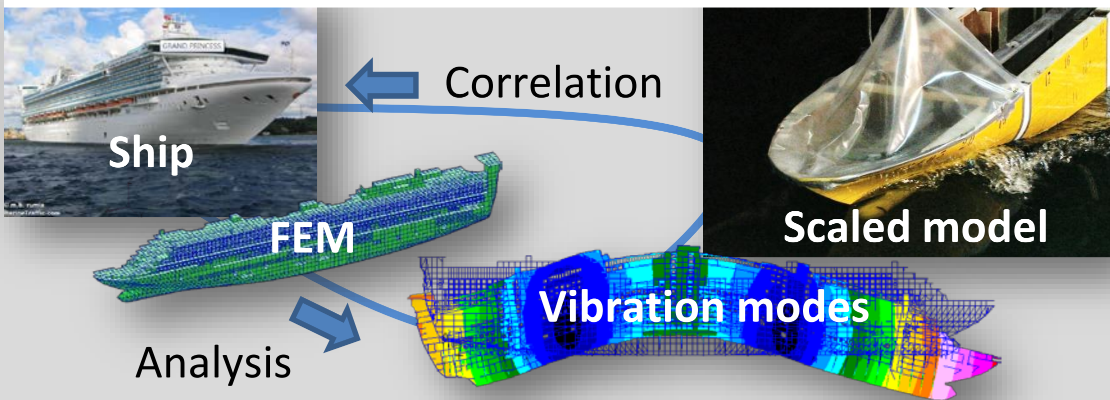
Topics

I. Prediction of large amplitude motion and elastic response of ships and catamarans
II. Slamming statistics, modelling and mitigation
III. Fatigue evaluation
IV. Design and assessment of physical models obeying similarity laws

Approaches

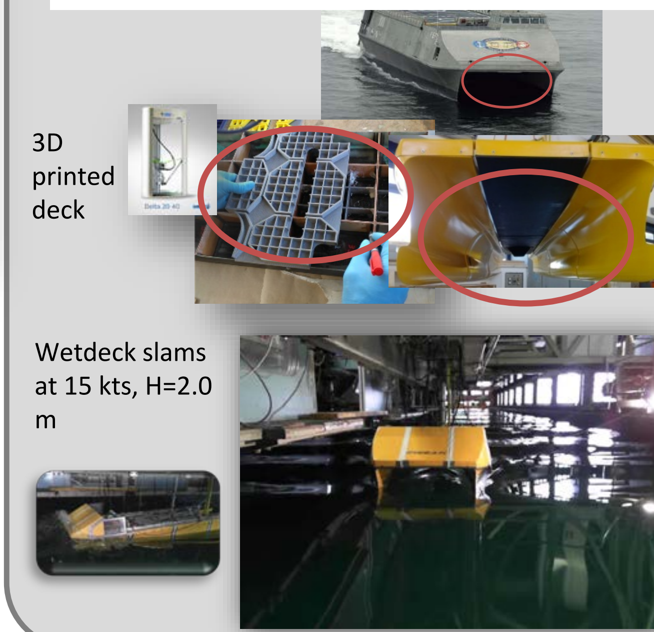
I. CFD (BEM, RANSE, SPH) & FEM
II. FSI (numerical & experimental)
III. Reduced-order models

Scaling & testing



Strength & Fatigue

Slamming impact



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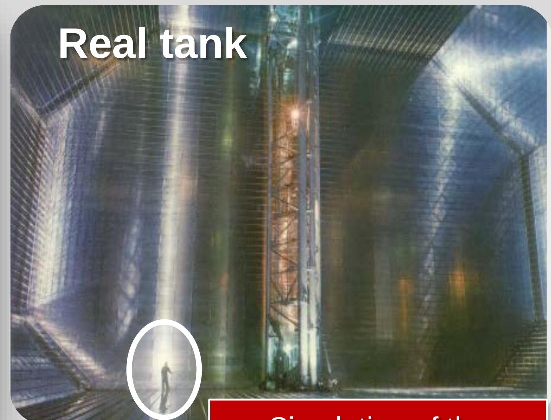
Safe, secure and smart operations

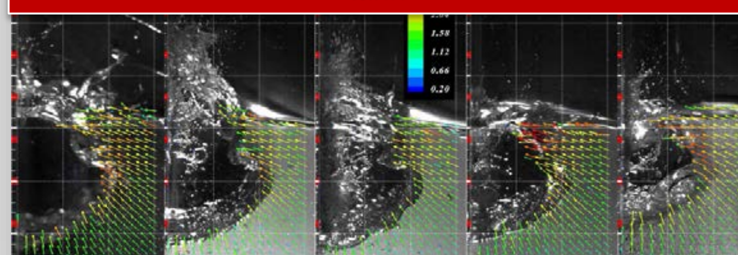
Predictive maintenance and damage detection

Ship safety: water on deck & sloshing in tanks

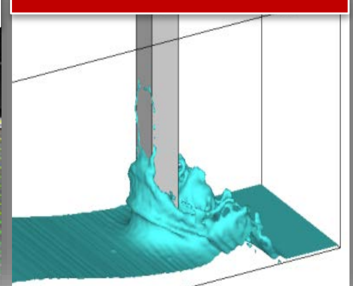
Wave impacts (water on deck, slamming) may damage infrastructures and load on board. Sloshing motion in tanks (movement of liquid-with a free surface-subject to external motion) can produce air compression with damage/risk of the infrastructure

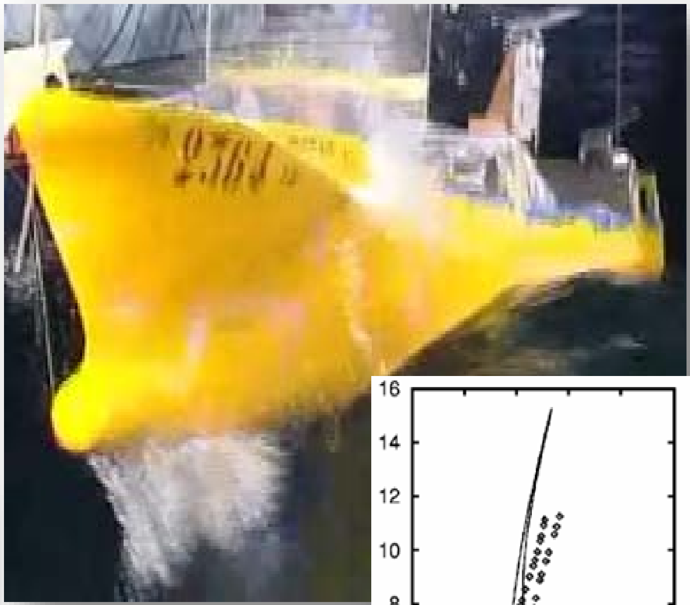


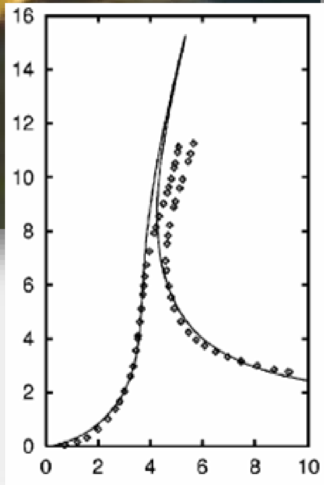
Two phases (air+water) pressure simulation in the tank



Simulation of the impact on an infrastructure







Comparison between numerical results (line) and experimental data (dots) of an impact into the water

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Safe, secure and smart operations

Damage detection

Structural Health Monitoring of ship structures

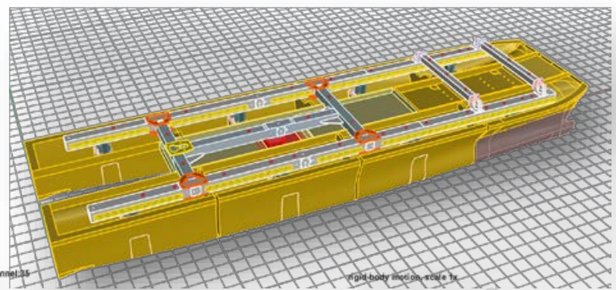
Topics

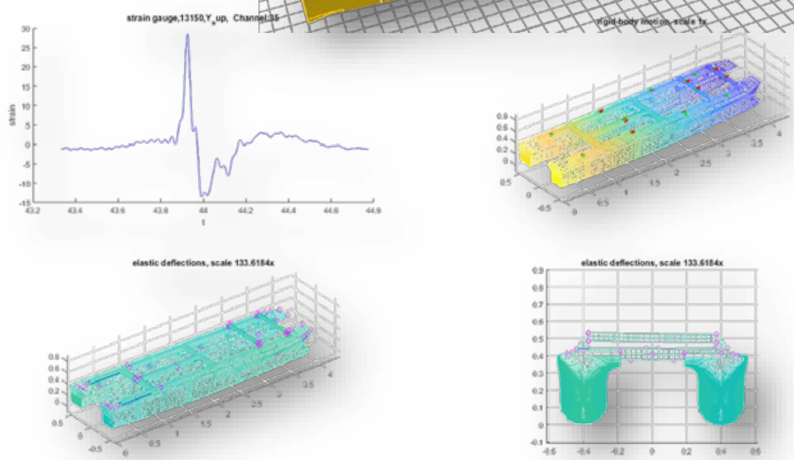
I. Load monitoring and reconstruction
II. Virtual sensors
III. Model updating (reduction of uncertainties, hydro-structural damping)
IV. Damage detection

Approaches

I. FEM & Advanced signal analysis
II. Laboratory experiments for validation

Reconstruction of the deformation field based on few sensor data, reduced FEM and state observers

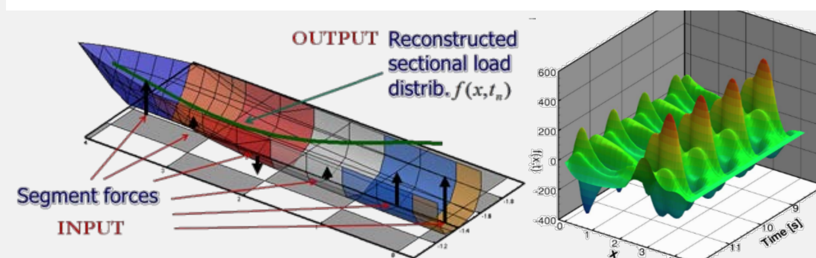




Damage detection

Use of damage indicators based on curvature analysis

Load reconstruction



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Integrated traffic control

Environmental monitoring, underwater surveillance, exploration and mapping

Approach

MIS, DSS for the analysis of heterogeneous data sources, Bayesian methods for oil spill risk prediction, Underwater vision & intelligence, Multimodal sensing, image annotation & data fusion, Onboard scene understanding & cooperative sensing, 3D immersive environment & virtual diving

- Oil-spill detection & monitoring and evolution forecasting
- Marine & Underwater areas surveillance
- Underwater monitoring, exploration and mapping for archaeology by means of Autonomous Underwater Vehicles (AUVs)
- Intruder detection & monitoring

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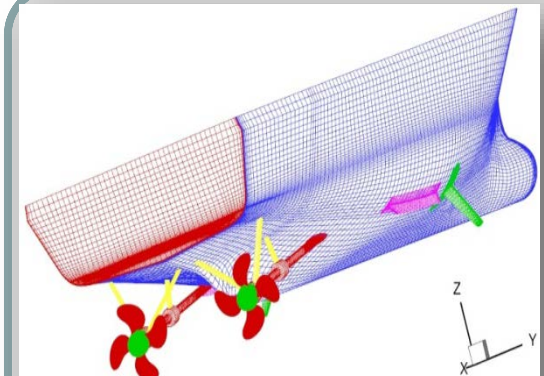
Safe operations

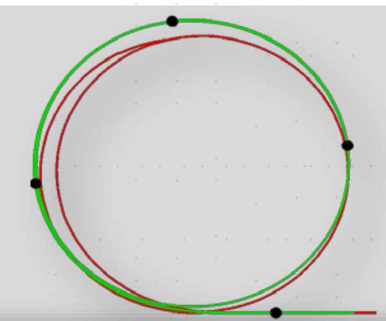
Ship safety: seakeeping & maneuvering

Wave impacts (water on deck, slamming) may damage infrastructures and load on board. Sloshing motion in tanks (movement of liquid-with a free surface-subject to external motion) can produce air compression with damage/risk of the infrastructure

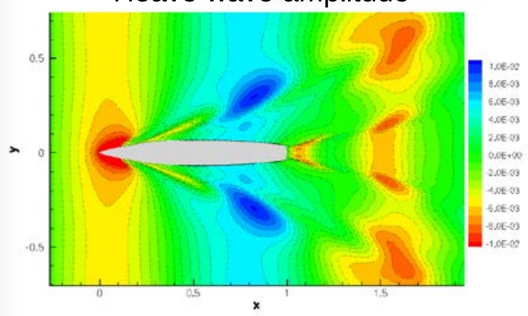


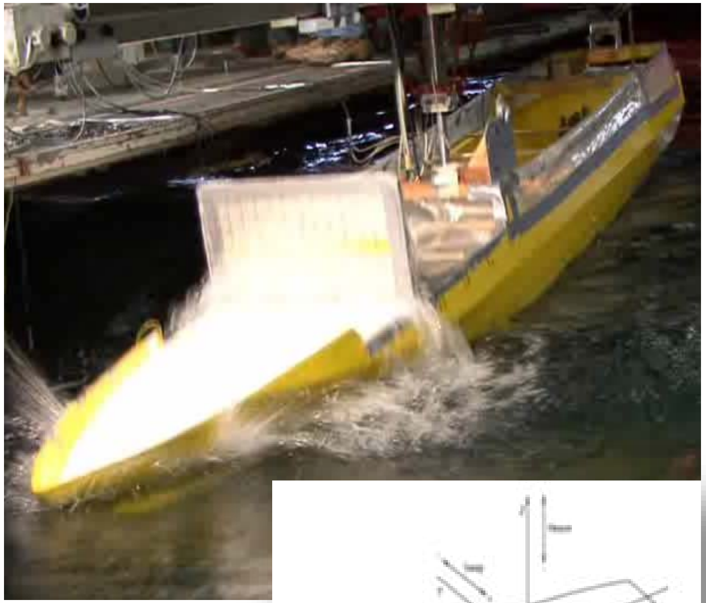
Realistic configuration at model scale with operating propeller

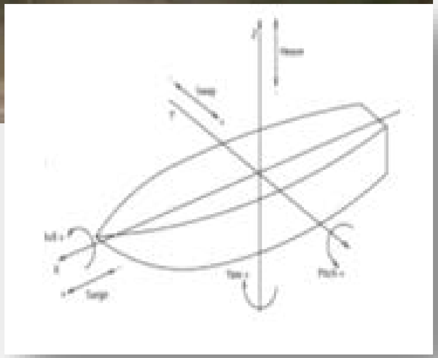
Trajectory:
Green: numerical solution
Red: experimental data



Heave wave amplitude





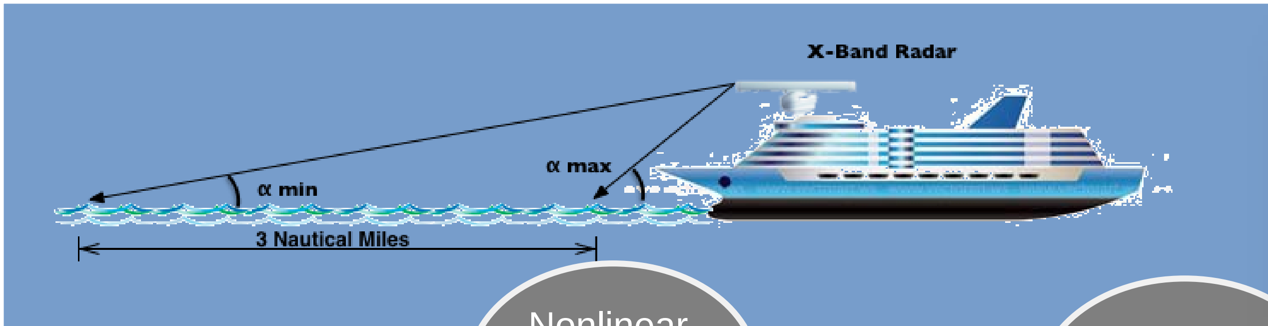


Safe operations

Ship safety: seakeeping & maneuvering

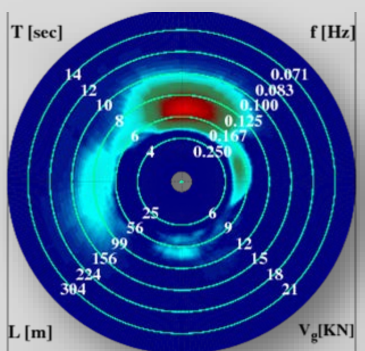
Approach

Intermediate and long term wave and ship motion prediction, wave radar measurements, numerical predictions

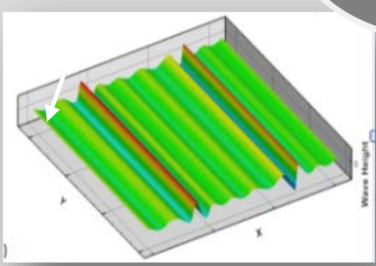


Nonlinear Wave propagation

Model of ship dynamics



X-Band Radar: wave and current measurement



Wave propagation

Ship motion prediction

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