UCL Mechanical Engineering

A View of UK Naval Engineering Education

Professor David Andrews FREng

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COTECMAR, Cartegena, Colombia
Overview:

- University College London at a glance
- UCL Department of Mechanical Engineering Overview
- Naval Architecture and Marine Engineering in the UK and at UCL
- Overview of UCL Marine Technology Teaching and Research
Some Facts about UCL

• Founded as University of London in 1826 (3rd English University)

• Non-conformist and liberal admissions tradition (in reaction to Church of England influence at Oxford and Cambridge)

• Tradition of teaching new, emerging and relevant disciplines
UCL at a Glance

• More than 25,000 Students:
  - 14,000 UG
  - 11,000 PG

• More than 8,000 Staff:
  - ~ 4,500 Academic & Research
  - ~ 4,000 Non Academic

• Turnover this year surpassing the £1B mark
  - Research Income ~50%

• A truly multidisciplinary environment

World Rankings:
UCL often features in the top 5 Universities worldwide; always in the top 20
• School of the Built Environment, Engineering and Mathematical and Physical Sciences (BEAMS); three Faculties.

• Faculty of Engineering Sciences; 10 Departments, several Institutes.

• **Department of Mechanical Engineering:**
  - 32 FTE Academic staff (expanding)
  - 17 FTE Administrative and Technical Support Staff
  - ~500 UG and PGT students
  - ~130 PGR & Postdoctoral Fellows

The first School of Engineering in England (founded in 1847).
Mechanical Engineering Teaching Programs

- 3- & 4-year Honours Degree Programmes (BEng & MEng) in:
  - Mechanical Engineering
  - Engineering with Business Finance

- 1-year MSc Degree Programmes in seven specialties:
  - Bio-Materials and Tissue Engineering
  - Engineering with Finance
  - Engineering with Innovation and Entrepreneurship
  - Marine Engineering
  - Mechanical Engineering
  - Naval Architecture
  - Power Systems Engineering
Mech Eng - Continuing Education and Short Courses

(both in Maritime sector)

- Marine Technology Educational Consortium
  (part time MSc in NA/MarEng)

- Submarine Design
  (one term post –MSc in NA)
Submarine Design Course

The Unique 3-months design course open to international participants.

**DESIGNED FOR ISR & SFs INSERTION**

**SHIP FEATURES**

| Submerged Displacement | 2932 te |
| Surfed Displacement    | 2618 te |
| Length of PH           | 47.2 m |
| Length (o.a)           | 65.6 m |
| Diameter of PH         | 8.0 m  |
| Reserve of Buoyancy    | 12.0 % |

**PROPULSION**

<table>
<thead>
<tr>
<th>Nuclear Plant</th>
<th>Boost Propulsion</th>
<th>Hotel Load/Back-up</th>
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</thead>
<tbody>
<tr>
<td>~3 MW (10MWt)</td>
<td>~4 MW/hr</td>
<td>~500 kW</td>
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<tr>
<td>PWR</td>
<td>Advanced Battery</td>
<td>PEM</td>
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**Cost:** £450 Million

100% AIP
UCL Marine Research Group Overview

12 Academic Staff
  – 9 Senior
  – 3 Junior

13 Research Staff
  – 4 Post Doc Researchers
  – 1 Research Fellow
  – 8 Research Assistants
  – and 40+ PhD Students
Naval Architecture and Marine Engineering Group

Design of Ships and Offshore Structures

- **Ship & Submarine Design**
  - Marine vehicles as nodes in the NEC battle-space
  - Low Carbon Shipping
  - Ship & Submarine Acquisition

- **Fluid Dynamics**
  - CFD for free-surfaces
  - Ship motions caused by waves

- **Hydrodynamics**
  - Energy Efficiency
  - Fluid/Structure Interaction
  - Ship Motions & Loads
  - Marine Renewable Energy

- **Structural Design**
  - Strength post Damage
  - Excessive OOC

- **Propulsion and Power**
  - Electric ships
  - Naval propulsion

- **Design Philosophy**
  - Engineering design
  - Building-block method (CAD)
  - Ship & Sub design

- **Design**
  - Design methods
  - Combat systems & UxVs.
  - Safety & emissions reduction

- **Marine Engineering**
  - Fuel cells on ships
  - Roll-damping
  - Ballast water

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- **Ship Design**
  - Ship Design
  - Ship Hydrodynamics
  - Renewables

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NA and Mar Eng in UK Naval Engineering

• Ships designed for Royal Navy in Royal Dockyards (Master Shipwrights)

• Victory in 1805 - 100 years of “Pax Britannica”

• First School of NA (1811-32); 2nd School (1848-53); 3rd School (1873 – to date)

• 1883 Royal Corps of Naval Constructors (Civilian); Royal Navy Marine Engineers (Uniform)
  Merchant ship NA/MarE at several UK universities

• RCNC training (up to 1990s) now pared down to graduate engineering entry then UCL MSc + Sub Design + CEng
UK Naval Architecture and Marine Engineering for Naval Vessels

1864 - South Kensington, London

1873 - RNC, Greenwich, London

1967 - UCL, London

1967 - RNEC, Plymouth (ME)

UG -- Uni of Southampton
HMS SULTAN - Application Course

Grad -- UCL for MSc (1994)
MSc Course Structure

Oct
- Lectures
- Seminars
- Coursework

Feb
- Written Exams

Mar
- Ship Design Exercise

Apr
- Group Design Project

Jun
- Industrial and Ship Visits

Jul
- External Guests

Sep
- Research Project
- With Industry Support
UCL MSc Ship Design Exercise

MSC NAVAL ARCHITECTURE 2012
GROUP 1 - HIGH SPEED COASTAL SECURITY VESSEL

MSC NAVAL ARCHITECTURE 2012
GROUP 2 - FAST RO-RO FERRY

MSC NAVAL ARCHITECTURE 2012
GROUP 3 - HYDROGRAPHIC SURVEY SHIP

MSC NAVAL ARCHITECTURE 2012
GROUP 4 - ARCTIC EEZ PATROL VESSEL

MSC NAVAL ARCHITECTURE 2012
GROUP 5 - ARCTIC EEZ PATROL VESSEL

MSC NAVAL ARCHITECTURE 2012
GROUP 6 - FORCE MULTIPLIER CORVETTE

MSC NAVAL ARCHITECTURE 2012
GROUP 7 - SHORT-SEA FERRY
## MSc in NA – Engineering Science

### Topics

<table>
<thead>
<tr>
<th>Ship Hydro</th>
<th>Ship Dynamics</th>
<th>Ship Structures</th>
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<tbody>
<tr>
<td>• CFD</td>
<td>• Random Processes</td>
<td>• Ship Structural Design</td>
</tr>
<tr>
<td>• Basic R &amp; P Techniques</td>
<td>• Waves</td>
<td>• FEA</td>
</tr>
<tr>
<td>• Manoeuvring</td>
<td>• Structural Dynamics</td>
<td>• Grillage Synthesis</td>
</tr>
<tr>
<td></td>
<td>• Seakeeping</td>
<td>• S/M Structures</td>
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### General Engineering

- Numerical Methods
- Fatigue and Fracture Mechanics

*not examined and not part of M Eng 4th year*
At UCL Ship Design means both: Specific Elements and Overall Design

- Layout & Architecture
- Aesthetics
- Economics
- Structure
- Propulsion Power
- Hull Form Design
- Stability
- Seakeeping
- Safety
- Propellers
- Emissions
- Manoeuvrability
Recent Ship Designs

- Dual Mode Arctic OPV with Asymmetric Hull
- AAW Destroyer (Modular)
- Network enabled OPV
- Ocean-going Command Platform
- Energy Efficient Ultra Large Container Ship
- Offshore Wind Turbine & Marine Current Turbine Support Vessel
- “Slow Steaming” Cruise Liner with Sail Assist

- Ice Patrol Vessel
- Naval Replenishment /Support Ship
- Galapagos Luxury Cruise Yacht
- Oil Disaster Recovery Ship
- UXV Deployment Platform
- Affordable Frigate
- Aviation Ship
UCL Unique in Naval Engineering

- MSc emphasis on Ship Design
- Staff cycled through from MoD Naval Architects (Lecturers and Prof. NA) to provide Ship Design expertise
- Research in Ship Design
  - Advanced hulls – Trimaran – ONR ACCeSS
  - Computer Aided Preliminary Ship Design – since 1980
  - Low Carbon Shipping – UCL lead Newcastle, Strathclyde
Recent Ship Designs

Offshore Wind Farm Support Vessel
Recent Ship Designs - C3 SWATH
Recent Ship Designs

River Cruiser
The Marine Technology Education Consortium

is a collaboration of four UK universities:

- Newcastle upon Tyne
- Southampton
- Strathclyde
- University College London

Delivering long distance programs:

- MSc in Marine Technology
- PG Certificate in Marine Technology and
- Continuing Professional Development Programs (CPD)
UCL Mech Eng Facilities and Marine Tech
Examples of our Research

Environmental

The Everglades are sensitive to environmental changes, such as river speed and the presence of fertilizers in water. The exchange flow through emergent vegetation is driven by diurnal temperature variations and flow rate. On the right, we show results from a new study (with Paul Napier, MIT) on buoyancy-driven exchange flow through emergent vegetation which was studied using a laboratory analogue and CFD calculations. These new results assist our development of practical solutions for the future.

Marine

A major theme of the work in the laboratory is studying the flow around and forces acting on ships and submarines moving in the marine environment. On the right, the fluid particle trajectories around a generic-shaped submarnine, calculated numerically, are shown. This forms part of our ongoing study into improving the design of submarines and their detection, sponsored by QinetiQ.

Industrial

Mining and transport in multiphase flows is important in many process engineering problems. On the left, a false colour image shows a bubble rising through a inertial surface, illustrating the dominant modes of transport (diffusion, wake transport and turbulence). By drawing on the classic result from Darwin’s Travels, we have been able to develop a richer and more precise estimate of these physical processes. This work formed part of the Royal Society Sirimex “Data, bubbles and Marocations” in 1999.

Hurricanes in the northern hemisphere move northeast because of the action of a beta-plane (caused by variations in the Coriolis parameter with latitude). Their dynamics can be studied using a physical analogue realisable in the laboratory. On the right we show the initial dynamics of a banded mass of dental fluid which moves northeast on a topographic beta-plane. The images were taken on the world’s largest rotating tank in Grenoble (from joint work with Paul Napier). One of the important results was to understand how the direction hurricanes move depends critically on their initial internal structure. The new rotating platform facility developed in our laboratory will enable new insights into their complex dynamics.

Turbulent particle or droplet-laden flows occur in many different areas of engineering, such as combustion in engines, sediment transport in rivers, and gas particles dispersed by these studies. Spatially homogeneous flows remain a formidable problem to understand. Our theoretical and experimental research is reaching a number of these issues. On the right we see the development of vortex rings, which are being used to understand how dense particles interact with coherent structures in turbulence.

Dust in the atmosphere has an important effect on our health, but the manner in which it is lifted from soil, a process called resuspension, is unclear. Our recent research has shown that if the flow around sediment grains is turbulent, then the grain will be resuspended. The left-hand side of the figure shows a sphere resuspended by a flow of air. These images were taken in a APS Gallery of Fluid Motion award.

Improvements in propulsion systems, such as marine waterjets, are increasingly being used for powering fast ferries and naval vessels such as frigates, illustrated on the right-hand side. The development of new computational techniques to optimize their function becomes ever more important for a substantial part of the work of Prof. Zangwill, who is leading these developments in the UK.

The unsteady Kelvin wake generated by an accelerated body moving beneath a free surface is shown on the left, with the body moving left-to-right. The new towing tank facility which will be commissioned shortly will enable theoretical predictions such as these to be tested, and ship/submarine detection methods to be improved.

Gravity currents, which consist of fluid of contrasting density from the ambient fluid, flow over slopes due to horizontal variation in the hydraulic profile. A major study in this laboratory is involved in understanding the influence of an external ambient flow on their dynamics. Possible applications include the dispersal of biocides in streets. On the left, we show the steady flow of a density current in the presence of a layerwise inertial current, realisable in the laboratory, using a Hele-Shaw cell. The analysis of these flows requires conformal mapping techniques which while simple at the ambient level, form an exciting area of research internationally. Excellent agreement is obtained between these results and analytical calculations.

Multiphase flows, such as fluidization, is a core activity in this laboratory. Gasification refers to the vertical channeling of air through a bed of particles (gas sand) at sufficiently high flow rates that the sand becomes molten and exhibits similar properties to a fluid. When there are misty particles, they segregate. On the right, we show that the mode of segregation changes significantly with the fraction of large particles — on the top figure vertical bands of large particles are observed, while on the lower figure, the larger particles form the lower layer. This work was completed with Dr Gilbertson (Bristol University).
Design Research at UCL
Prof David Andrews & Dr Rachel Pawling

- Development of tools, procedures and processes
- Design studies, focussed research projects and longer term collaborative projects
- Collaborative, multi-disciplinary nature of the UCL MRG allows DRC research to contribute to many areas

Design for Production

- Producability studies on a Platform Support Vessel (PSV)

Offshore Infrastructure

- Offshore port study for EC
- UCL wind farm support vessel
Innovative Hullforms

▼ DRC research in the MRG has encompassed TriSWACH and Pentamaran forms for naval and civil applications

Unmanned Vehicles

▲▼ The DRC has investigated the use of unmanned vehicles at sea, including aerial, underwater and surface vehicles and their mother ships
Path Planning of Multi-USVs formation

Formation path planning:
- USV formation cooperative cooperation
- Path planning based on fast marching method
- Leader-follower control structure
- On-line real time path planning
Embedded Data Acquisition and Fusion System for Unmanned Surface Vehicle (USV) Navigation

**Aim:** continuously provide accurate navigational data and generate a synthetic map with USV’s trajectory and surrounding information.

**Initial Results:**
- Provided smoother measurements
- Recovered the trajectory
- Matched the practical situation

Contact: Prof Bucknall
Roll Motion Investigation of TriSWACH Ships
Mr. Stojanovic, Ms. Muk-Pavic, Prof Bucknall

Background

1. Fast ships capable to operate in in range of ocean conditions are required in the littoral zones.
2. Up to date no detailed research was published investigating TriSWACH motion characteristics in detail.
3. It is essential for further development and optimization of the TriSWACH hullform, that a toolset for accurate motion and damping prediction is developed.
4. Office Of Naval Research (U.S. Navy) supports this research project as a means of exploring the characteristics of TriSWACH hullforms.

Main Achievements

- Different transversal positions of side-hulls were tested at Stevens Institute to determine the RAOs in head and beam seas.
- Capsizing of the model occurred in mid-inboard position of single displacement sidehulls allows to disregard that configuration from any further testing.
- Roll decay tests of different sidehull shapes at the same transversal position were obtained in to determine the differences in roll responses (U.S. Naval Academy).

Main findings: Coupling of roll and heave motions

1. During the roll decay tests, TriSWACH models without side-hull haunches had insignificant heave motion.
2. Heave motion, during the roll decay tests of TriSWACH models with side-hull haunches, decayed at double the roll natural frequency.
3. Roll decay of prismatic sidehulls is significantly affected by their cornered shape and larger wetted surface are comparing to conventional sidehulls.

Research Goals

1. Investigate coupling of roll and heave motions of TriSWACH in roll.
2. Develop an accurate CFD model.
3. Develop an accurate roll motion equation for accurate prediction of TriSWACH roll motion.
4. Develop semi-empirical method for accurate prediction of roll damping coefficients for different sidehull transversal positions.

Conventional Sidehulls

Planned Impact

1. Re-test the model experiments in CFD.
2. Increase the accuracy of CFD model.
3. Develop a semi-empirical model for roll damping coefficients prediction, to accurately fits the model and CFD data.
Offshore Windfarm Maintenance Strategies
Ms Muk-Pavic & Dr Pawling

• Recent research at UCL led to the production of a tool for modelling different Operation and Maintenance strategies for offshore wind farms.

• The model incorporated a range of input parameters such as array location, configuration and equipment reliability and developed a maintenance strategy utilising a choice of vessels.

• The model was validated by comparison with available data, with good correlation. Ongoing work is examining the use of the UCL developed Design Building Block approach to design Wind Farm Support vessels.
Turbulent Acidic from Ships (Contact: Prof Eames)

The dispersion of discharges is investigated experimentally, analytically and computationally. These tools are applied to describe the behaviour of acidic discharges from a moving ship.

The experimental near field analysis provides a basis on which a mathematical model is developed for the dispersion of acidic jets or plumes in an alkaline environment.

The mathematical model was extended to include the effects of the ambient flow on a tangential discharge from the ship. This analysis can be used to improve the accuracy of capturing empirical measurements from the discharge.

Computational analysis describes the mixing behaviour once the discharge has been swept into the wake of the ship.
Ship Safety Research: FAROS
Prof David Andrews & Dr Rachel Pawling

- EC FP7 funded, 3 year project
- Incorporating human factors into Risk-Based Design of ships.
- 12 member Consortium
- Using experimental data, simulations, parametric ship models and optimisation processes
- A key UCL contribution is the development of models for VLCC and Aframax tankers
- Project builds on previous research and development of RBD for ships which began with EC SAFEDOR
Ship Safety Research: FIREPROOF
Prof David Andrews & Dr Rachel Pawling

- Completed EC FP7 funded, 3 year project
- Incorporated fire safety into Risk-Based Design of ships
- 13 member Consortium
- Combination of historical data and simulations used to determine probability and consequences
- Key UCL contributions were:
  - Development of structure for fire risk metrics
  - Development of a ship product model (SPM) for fire safety analysis