New challenges in the education of Naval Architects in TEI of Athens
K.A BELIBASSAKIS, G.K. HATZIKONSTADIS, G. THEOTOKATOS
Ch.N. STEFANAKOS, S. SARANTOPOULOS, Th. GEROSTATHIS, Y.G. GEORGIOU
Department of Shipbuilding, School of Technological Applications
TEI of Athens
Ag. Spyridonos, 12210, GREECE
kbel@teiath.gr   http://www.teiath.gr

Abstract: - In this work we describe recent advances in the curriculum offered and in the research conducted by the Department of Shipbuilding, School of Technological Applications at the Technological Educational Institute of Athens. The developments include the amendment of the curriculum by new specialized courses of the Naval Architecture and Marine Engineering discipline, as well as current research projects carried out by members of the Department, all funded in the framework of Operational Programme for Education and Initial Vocational Training (EPEAEK), coordinated by the Greek Ministry of Education and the European Union.

Key-Words: - Education & research, Naval Architecture & Marine Engineering

1 Introduction
The objectives of the Department of Shipbuilding (SD), School of Technological Applications at the Technological Educational Institute of Athens (TEI-A) are mainly focused on:
(i) the education of the students, following the current technological developments, in two major disciplines: Naval Architecture and Marine Engineering,
(ii) the advancement of the scientific/technological knowledge and its techno-economical exploitation by means of engineering applications through research work in areas of interest for the Naval Architect and/or the Marine Engineer, and finally
(iii) the diffusion of the newly acquired knowledge and technological research results in the educational process aiming to further upgrade the level of the offered studies.

Recent reformation of the course structure and the curriculum, including introduction of new courses and restructuring of the academic/educational program offered by the SD/TEI-A, aims at the improvement of the quality of the education up to the standards of a Bachelor’s Degree in Engineering.

One direction of current research in the discipline of Shipbuilding Technology includes:
(a) the development and enhancement of mathematical models for predicting the wave and current characteristics in the nearshore and coastal environment,
(b) its application to the prediction of oil pollutants transport,
(c) the exploitation of the above for the design of an optimized vessel for effective combat of marine pollution from oil-spills, based on the use of magnetic absorbing materials and efficient pollutant collection techniques.

Another direction of research, in the discipline of Marine Engineering, is focused on: (a) the development of mathematical models for predicting the marine engine’s performance and emissions, as well as the engine subsystems behavior, (b) the simulation of the complete ship system (engine-shafting system-propeller-hull), (c) the design of controllers for use in marine Diesel engines based on advanced control techniques, and (d) the testing of various engine design parameters.

Both research directions are supported by research groups consisting of members of the academic staff of SD/TEI-A as well as external research collaborators and last-year students. Collaboration with researchers from other Universities has also been accomplished, enabling interdisciplinary confrontation of the specific technological research problems and establishing collaboration links within the academia.

The above activities have been financially supported through funding in the framework of Operational Programme for Education and Initial Vocational Training (EPEAEK), coordinated by the Greek Ministry of Education and the European Union (EU).
2 Education in SD/TEI-A

The Department of Shipbuilding (www.teiath.gr/stef/shipbuilding_technology/) of the School of Technological Applications of the Technological Educational Institute of Athens (SD/TEI-A) have been recently proceed to the restructuring and reformation of their curriculum and studies program in order to conform with the requirements of the Batchelor degree level (5A according ISCED-UNESCO). The duration of studies with the new course program is 4 years/8 semesters, and the last semester been devoted to the Degree thesis and the practical training course, which are prerequisites for the completion of studies. The course contents have been amended by the introduction of new and important specialised courses, such as ‘Ship Design & Outfitting’, ‘Small Craft Technology’, ‘Local Ship Strength’, ‘Inspection Repair and Maintenance of Ship Structures, ‘Offshore Structures’, ‘Shipping Economics’, ‘Computer Aided Ship Design’ and others. In particular, within the course on Computer Aided Ship Design, the students gain basic knowledge and training on CAD systems and software, as, e.g., AUTOCAD®, AUTOSHIP®, (see Fig.1), and MAXSURF® packages.

3 Research in SD/TEI-A

Besides the principal education activity, research is also a main objective of the Technological Educational Institutes (TEI). Externally funded research projects advance the scientific knowledge, offering in parallel the ability of developing collaborations between the academic staff and external researchers, with experience in specialized issues related to the specific scientific interests.

Recently, the Shipbuilding Department of TEI of Athens has been funded in the framework of EPEAEK II program for the upgrading of the courses and the acquisition of up-to-date equipment (scientific instruments, computers and other) with the amount of 174k€. Moreover, since last year, the Shipbuilding Department of TEI of Athens has also been funded in the framework of ARCHIMEDES program with the amount of 56 k€, for research in the direction related to optimization of shipbuilding technology aiming at the protection of marine environment against the oil pollution. Also, in the last call “ARCHIMIDES II” of the EPEAEK II program, SD/TEI-A has secured financial support with the amount of 51 k€ for the development of robust control systems of marine diesel power units (project proposal entitled: “Investigation Of Marine Diesel Engine Robust Control For Augmented Disturbance Rejection”). The required work will be accomplished by the research group of the Shipbuilding Department of TEI Athens in collaboration with research group from the School of Naval Architecture and Marine Engineering of NTUA.

4 New technologies for the protection of the Marine Environment from Oil Pollution

As it is known, the oil pollution of the sea represents a major environmental and economic problem worldwide. The oil spills, from which the sea environment is threatened, cause ecological disasters, usually followed by large negative economic impacts, especially as concerns the economic activities of the coastal areas. A sad example of this kind is the recent accident of the tanker PRESTIGE, in December 2002, in the Atlantic Ocean near the coasts of Spain and NW France.

According to recent international sources [1, 3] the average oil pollution of the sea amounts to 1.2-1.5 million tons annually. Nowadays significant funds are invested to develop technologies for the protection of marine environment against oil pollution. Although the combat of marine oil pollution has led to the development of various cleaning methods, none of these has been proved up to now to be fully efficient. The magnetic oil-absorbing materials are new technology against oil spills. This new technology has been tested successfully in recent pilot [1,2,4] experiments against oil spills. The method has been proposed by Nicolaides et al [1,2] and has shown its
effectiveness in laboratory and in situ experiments. This new technology is based on the method of magnetic separation, in combination with the use of a new oil-absorbing magnetic material. More specifically, it is based on the use of a floating oil-absorbing magnetic material, which absorbs the pollutant almost instantly, when dispersed at the surface of the oil spill. Due to its magnetic properties, the cleaning material can be collected using magnetic means (electromagnets, other systems of magnets) in relatively short time, and, according to the experimental measurements, it is able to absorb almost the whole amount of oil from the sea surface, see Refs [3,4]. The preparation in the laboratory of the new oil absorbing cleaner, called CleanMag® (as an acronym of Cleaning Magnetically), is obtained by mixing polymer with surfactants and magnetic material, (Nicolaides 1996; Patent GR1002782/96-OBI, see also in the WEB: http://www.teipir.gr/cleanmag).

In order to apply the proposed new technology in a large scale, a prototype vessel has been designed and built; for details see Ref [5]. The prototype ship with a total capacity of 47 register tons has been equipped with all machinery required for the CleanMag® technology. The specific vessel, CLEANMAG I – NANCY has the following characteristics:
- Length over all 18.50 m
- Breadth 4.56 m
- Depth 2.10 m
- Propulsion Engines 2 VOLVO PENTA 430 BHP
- Diesel-Electric generator 13.2 KW
- Hydraulic unit supporting the magnetic conveyor
- System for CleanMag material launching and 15 m³ tank for its storage
- Discharge Pump for the used material
- Voyage category: Areas Α1 and Α2 (and telecommunication equipment)

More specifically, the conveyor has a breadth of 1.00 m, and at its fore-end exist (i) the magnetic drum and (ii) the buoys that stabilize it and make it follow any wave during operation in the sea surface. The magnetic drum has a 40 cm diameter and the magnetic field is created by means of permanent magnet of Nd-Fe-B type. The intensity of the magnetic field at a distance 10 mm from the surface of the drum is 0.5 Tesla (cylindrical magnetic multipole and radial magnetization direction). In Figure 2 a schematic view of the conveyor and magnetic drum is shown. Also, in Figure 3 a photo of the fore part of CLEANMAG I – NANCY is presented, in which the fore-end of conveyor and the magnetic drum are clearly exposed.

The prototype ship operation has been found satisfactory. However, since the particular type of vessel is clearly not the only one optimally implementing the CleanMag® technology, further improvements have been considered. After thorough investigation, it has been found that an optimized design can be achieved, especially concerning the ship operability and the cost-to-benefit ratio, by examining other ship hull forms such as the double hull vessel of catamaran type, see Fig. 4.

In this connection, the corresponding research project, in the SD/TEI-A focuses on:
(a) The development and enhancement of mathematical models for the forecasting of sea wave characteristics in the sea and the coastal area, and their impact focused on subjects concerning extreme events in coastal zones and events of pollution from oil spills.

(b) The development and enhancement of mathematical models for the propagation of pollutants in conjunction with wave models.

(c) The exploitation of the above in the development and optimization of a shipbuilding technology in order to solve problems related to oil pollution in the coastal environment.

The following breakdown in Work Packages has been done (WP):

WP.1 Development and enhancement of sea-coastal wave models.
WP.2 Development and enhancement of models for the transport of pollutants in the coastal zone.
WP.3 Optimization of shipbuilding technology for solving problems of oil pollution by using oil-absorbing material.
WP.4 Applications in areas of the Greek Seas – coastal zones.
WP.5 Evaluation and assessment of the results. Publicity actions.

Each of the above WPs is further broken down in a number of activities for ensuring the accomplishment of the prescribed tasks. The last stage of the project calls for an evaluation phase of the final results, including exploitation plans and the viability of further collaborations between the members of the scientific group.

5 Marine Diesel Engine Control

The marine Diesel engine is today the predominant prime mover used for ship propulsion. There are three major reasons for this fact: a) the superior thermal efficiency of Diesel engines, b) their ability to use heavy fuel oil, and c) slow-speed Diesel engines can be directly connected to the propeller without the need of gearbox and/or clutch.

The typical marine propulsion plant of modern merchant ships includes a single, long-stroke, slow-speed turbocharged, two-stroke Diesel engine, directly coupled to the vessel’s single, large diameter, fixed-pitch propeller. This configuration can provide large power outputs (up to 100 MW from a single unit) and yet is characterized by operational robustness due to its conceptual simplicity. At the same time, the crew number of the ship is reduced, resulting in greater need for ship automatic control. However, the usage of advance techniques in the design stage of propulsion engine controllers has not been fully adopted yet, mainly due to the inherent stability of the propulsion system (engine-propeller).

In the ship's powerplant specification stage, it is standard practice to include performance margins, the so called "sea" and "engine" margins (typically 15-30%), to account for the increases in power demand due to hull and propeller fouling, further increases in resistance due to sea severity, as well as to provide some leeway for engine running near the limits of its operating envelope. The above has as a consequence, apart from the increased cost and the required machinery space of the propulsion plant installation, and the subsequent reduction of the cargo spaces, reduced operating efficiency of the propulsion plant, and thus, increased operating ship cost. This is due to the fact that the tuning of a two-stroke slow-speed Diesel engine, which includes the engine turbocharger matching and the determination of the injection timing, as well as the exhaust valve opening, is optimized for a specific engine operating point, close to the engine maximum continuous rating (MCR) point. Thus, for a fixed geometry turbocharging system, operating the engine far from its optimization point, adversely affects the engine fuel consumption and up to an extent, the engine exhaust emissions, resulting in increased engine operating cost.

Propeller torque demand fluctuations may occur, not only in bad weather, but also at moderate sea states under certain conditions, e.g. when a large
containership exhibits significant rolling due to beam sea encounter. This can impose prohibitive limitations to near-MCR propulsion plant operation (persistent engagement of fuel index limiter), and may require set point reduction, which may eventually lead to delays in the ships’ schedule. The conservative, but safe policy of providing engine margins leads invariably to a larger engine, which is underutilized in the lifetime of the vessel.

Propulsion system integration and control is a field of increasing importance, as digital electronics. In combination with mechatronics and advances in actuator and sensor technologies allow for sophisticated control, as well as advanced optimisation techniques, to be applied to marine propulsion. Such developments can provide “smooth” and reliable plant operation, avoidance of critical situations (such as overspeed, mechanical or thermal overloading etc.) and improved fuel economy. Furthermore, as the public interest focuses on the environmental acceptability of marine propulsion systems, the minimisation of pollutant emissions has to be considered too. The last years, the manufacturers of marine engines have produced engine models with electronic control based on microcontrollers and advanced control devices (actuators, sensors) in order to obtain more engine flexibility, smoother and more efficient engine operation, reduction of emissions and smaller sea/engine margins.

In order to advance the research in the direction of marine propulsion plant system control, the project entitled “Investigation Of Marine Diesel Engine Robust Control For Augmented Disturbance Rejection” was set up by the research group of the SD/TEI-A in collaboration with the School of Naval Architecture and Marine Engineering of NTUA. The project objectives are the theoretical analysis and investigation of a systematic method for the tuning of the PID (Proportional-Integral-Differential) speed regulator of marine Diesel engines. In addition, the uncertainties and disturbances observed during the operation of a ship propulsion plant system will be formally recorded. The latter is necessary for the development and testing of marine Diesel engines control system.

Such a method, which will be the outcome from the project, will allow for the design of engine controller that would achieve efficient, smoother, safer and environmentally adapted operation of the propulsion plant system of merchant ships, especially if these control systems are implemented for the control of the new generation marine engines. If this can be achieved, then smaller engine margins may be specified with associated cost advantages.

In addition, further understanding of the operation of the complete propulsion plant (engine and its subsystems, shafting system, and ship propeller) will be achieved during the project. This is due to the planned detailed modelling of the physical as well as thermochemical processes of the various components of the propulsion plant system. In parallel, simpler transfer function models will also be developed, which will be validated using the detailed engine model, and will allow for the engine PID controller analysis. Finally, the closed loop system stability, the propulsion plant system inherent dynamics, the robustness of the closed loop system against neglected dynamics and parametric uncertainty are specific tasks that it is expected to be thoroughly investigated during the project and fundamental directions for their solution will be proposed.

Recent developments in marine diesel propulsion and control systems by major manufacturers can be found in Refs. [6,7,8] and [9]. Survey of mean per cycle value semi-static thermodynamic models, which are used for development of controllers for marine internal combustion engines can be found in Refs. [10,11,12] and [14]. For a concise presentation of the concepts and methods for robust control see Refs [13,14] and [15]. Finally, the latest relevant works of members of the research group can be found in: Refs. [16,17,18,19,20] and [21].

6 Conclusion

In this work recent advances in the curriculum offered and in the research conducted by the Department of Shipbuilding, School of Technological Applications at the Technological Educational Institute of Athens are described. The developments include the amendment of the curriculum by new specialised courses of the Naval Architecture and Marine Engineering discipline, as well as current research projects carried out by members of the Department.

The present work has been financially supported by the EPEAEK- TEI of Athens program, funded in the framework of Operational Programme for Education and Initial Vocational Training (EPEAEK), coordinated by the Greek Ministry of Education and the European Union.
References:


