A new curriculum on Numerical Methods in Mechanics and Design. Is it shipbuilding-like enough?

ABSTRACT

The paper describes a new curriculum for teaching computing methods in mechanics and design developed at Faculty of Ocean Engineering and Ship Technology, Gdańsk University of Technology, which has been introduced beginning from summer semester 2005. The new specialization covers the last 5 semesters (6 - 10) of the unified M.Sc. course in Ocean Technology. All courses of the new specialization are given in English. The objective of the new curriculum is to educate engineers skilful in applying modern modelling technologies for practical solving problems of structure and fluid mechanics, heat transfer and automatic control in the area of marine industry. The curriculum has been endorsed by General Electric (GE) as unique, novel and advanced one – moreover the company took patronage over the specialization. Similar encouragement has been obtained from PRS, LR, ABB and UGS when the idea of the course was presented on a special seminar.

The Faculty of Ocean Engineering and Ship Technology of Gdańsk University of Technology educates specialists in Naval Architecture and Marine Engineering. The 10-semester integrated M.Sc. course is divided into 2 parts: the first part (of 5 semesters) gives the student basic, fundamental knowledge in mechanical engineering, naval architecture and marine engineering, while the second part (of 5 semesters) is focused on the specialization and development of M.Sc. thesis.

For a long time the Faculty authority has observed that there is a growing demand for specialists well prepared and flexible in applying modern technologies for modelling and solving problems of structural mechanics, fluid dynamics, heat exchange and control in the fields of marine engineering and naval architecture. There is also growing practice for design testing at early design stages, product improvement analyses, estimation of product reliability by determining probable failure modes. All these activities demand to use computational methods because of costs and time of experiments, if such experiments are possible at all. Specialists skilful in such areas are needed by design computational centres, consulting companies, classification societies and maritime industry companies.

The maritime industry as well as mechanical engineering field requires „hard skills" in modelling and computing, since more and more prototyping tasks is being moved into computer virtual field. For graduates the possessing of such skills means employment security and independence. They have to be flexible, ready to look for jobs and to develop themselves into new areas. If modelling principles, theories, practical skills, capabilities to judge the obtained numerical results, and knowledge of experimental methods are mastered by graduates then it is easy for them to adapt to new challenges in new industries.

Advanced maritime industries like in South Korea do utilise knowledge and the highest skills (in that country 25% of employees of ship design offices hold Ph.D. degree, and 55% – – M.Sc. degree). What counts today is the capability to model phenomena for design, operational and managerial purposes. This capability is leveraged by using advanced CAD/CAE techniques in the design, manufacturing and product maintenance processes. The modern researcher and engineer is capable of rapid adoption of new technologies, which means continuous learning, system approach and the ability to implement new tools for his tasks. Young engineers have to possess capabilities to manage projects of various scale, including international projects (and the latter requires that they are fluent in English in managerial and technical tasks).

The Faculty's M.Sc. standard courses on Ocean Engineering (OE) – similarly to standard courses at mechanical engineering departments – give only partial training in the mentioned expertise areas, mainly because such studies are mainly aimed at educating broadly prepared designers. The present syllabus does cover many important subjects related to modelling and computing technologies, but the time devoted to the subjects is rather limited and most of work is done by students themselves during extra curriculum courses and thesis preparation. The semesters 1 ÷ 5 of the M.Sc. course provide broad basis, general engineering education, present basic problems in Naval Architecture (NA) and Marine Engineering (ME). The semesters 6 ÷ 9 serve for broadening the knowledge either in NA or ME, and the semester 10 is for diploma specialization (research and thesis preparation). There do exist „computational courses" like those on structural mechanics, CFD, modelling of strength of structures. However, the imperfections of the present model in the „computational" aspect are the following:

- lack of large course blocks devoted to the problems of modelling
- small number of projects which usually do not require advanced modelling
- large number of specialization courses which limit the scope of knowledge to be presented to students, and finally
- the specialization in computational methods usually takes place during research on thesis and it is based on individual studies on problems and supporting software (necessarily in somehow limited scope and not structured to serve for future development).

The Faculty's authority has observed that there is a need for a structured programme aimed at the development of mathematical modelling techniques, for furnishing students with solid fundamentals in computational methods used for modelling and problem solving in the mentioned expertise areas, for teaching practical problem solving techniques with the use of modern software and for the development of capabilities of organising and managing the project work.

All the observations led us to the development of the new specialization named : ***Numerical Methods in Mechanics and Design***.

➢ The fundamental thinking during development of the specialization curriculum was as follows.

The objective was to provide good, broad, professional preparation of students. They would master the skill of fast and independent learning. The course in question was aimed at providing deep – both theoretical and practical – knowledge about modelling techniques used in structural mechanics, fluid flow and heat exchange, and in control. We aimed at providing an experience in practical solving computational problems with the use of industry-applicable software systems. At the same time we would like to instil a critical attitude toward employed models through pointing the need of model verification and correlation with experiments. We aimed at developing project managerial skills by requiring to plan, perform and manage many various design projects.

➢ The assumptions for development of the specialization courses are as follows :

- ⇨ we would focus on theories and practice important for the mathematical modelling problems and related computational methods applicable in ocean engineering (naval architecture, power plants, deck equipment)
- ⇨ we would expand the knowledge and to give the students the opportunity for practical application of the knowledge – presenting them a large set of design projects from the field of ocean engineering and requiring them to study, analyse and model the designs and to draw engineering conclusions
- ⇨ we would support and develop their professional education by set of courses on ship structures, turbines, hydrodynamics, machine design, advanced material sciences (including basis of nanotechnology)
- ⇨ we would support the core courses by the topics important for modelling techniques and team-work: topology, project management and advanced CAD/CAE systems
- ⇨ the specialization courses would be given in English, because the graduates will work in international environment (at present, we have a 120 - hour intensive English language course during 2nd and 3rd semester).

The specialization programme is designed for a small group of students (15 ÷ 18 persons). It allows for flexibility in lecturing, namely for easy illustration of lectures by laboratory work and demonstrations. The division of courses is shown in Tab.1. and the detailed study plan in Tab.2, while Fig.1 shows the interdependence between basic courses, advanced courses and design projects during the studies.

Tab. 1. *Layout of courses during semesters for specialization in Numerical Methods in Mechanics and Design .*

10	Research and thesis	
9		**Designs**
8	Core courses	**Designs**
7	Core and auxiliary courses	
6	Core and auxiliary courses	
1 – 5	*Basic standard OE courses*	

Generally, the specialization requires total of about 1530 hours of classes in the semesters 6 ÷ 9. The core and auxiliary courses are assigned to the semesters 6, 7, and 8, while the design projects to the semesters 8 and 9. The thesis are planned for the semester 10 (students may start the research earlier). We also provide practical professional training : after 6th semester (6 weeks) and after 8th semester (4 weeks).

The design project, a very important phase in the curriculum, takes 45 hours in a semester. About 15 hours are planned for studying the problem and specific methods for its modelling. The remaining hours are planned for the modelling, analysis and conclusions.

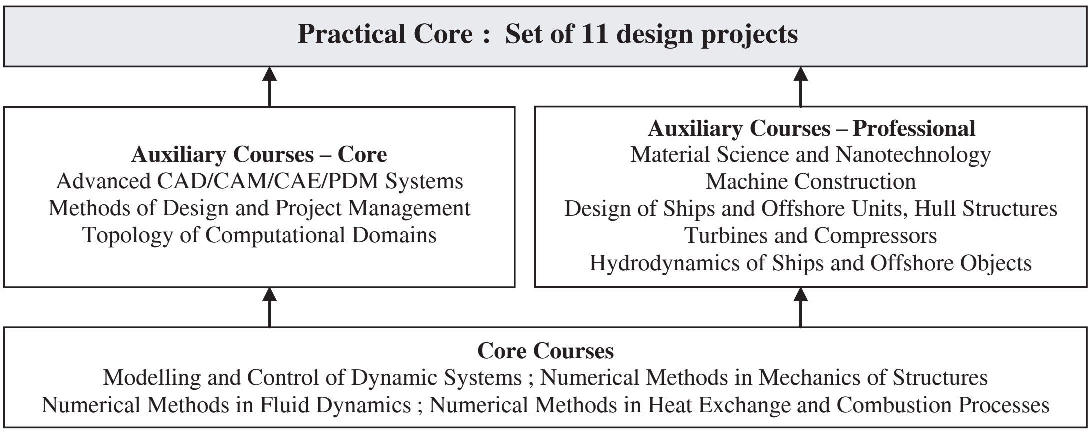

Fig. 1. *Progress and classification of courses for specialization in Numerical Methods in Mechanics and Design .*

Tab. 2 contains the plan of studies which shows the specific courses and their arrangement for the specialization in *Numerical Methods in Mechanics and Design*.

Tab. 2. *Plan of studies for the specialization in Numerical Methods in Mechanics and Design .*

Sem.	Course name	Lecture	Lab.	Proj.	Seminar	Assess.	Type
6	Modelling and Control of Dynamic Systems	4	2			**Exam**	**Core**
6	Material Science and Nanotechnology	4	2			Credit	AuO
6	Advanced CAD/CAM/CAE/PDM Systems	1	5			Credit	**AuC**
6	Methods of Design and Project Management	4				Credit	**AuC**
6	Design of Ships and Offshore Units Hull Structures	4				Credit	AuO
6	Machine Construction	4				Credit	AuO
7	Numerical Methods in Mechanics of Structures	5	3			**Exam**	**Core**
7	Numerical Methods in Fluid Dynamics (Incompressible flow) – 1	2	2			**Exam**	**Core**
7	Topology of Computational Domains	3	3			Credit	AuC
7	Turbines and Compressors	4				Credit	AuO
7	Hydrodynamics of Ships and Offshore Objects	3	1			Credit	AuO
7	Control Design for Dynamic System			3		Credit	**Cdes**
8	Numerical Methods in Fluid Dynamics (Compressible flow) – 2	4	2			**Exam**	**Core**
8	Numerical Methods in Heat Exchange and Combustion Processes	4	2			**Exam**	**Core**
8	Free-Surface Flow around Ship's Hull			3		Credit	**Cdes**
8	Air Flow around Ship's Superstructure and Hull			3		Credit	**Cdes**
8	Stresses and Deformations of Machine Elements			3		Credit	**Cdes**
8	Vibrations of Machine Elements			3		Credit	**Cdes**
9	Strength and Vibrations of Ship Structure			3		Credit	**Cdes**
9	Project on Heat Exchangers			3		Credit	**Cdes**
9	Distribution of Temperature and Welding Stresses in Welded Joint			3		Credit	**Cdes**
9	Fuel Spraying and Combustion in Diesel Engine			3		Credit	**Cdes**
9	Flow Through a Turbine Stage			3		Credit	**Cdes**
9	Flow Within the Lubricating Film of Slide Bearing			3		Credit	**Cdes**
9	Physical training				2		
10	Diploma seminar				1	Credit	
10	Physical training				2		

Lecture	Lab.	Proj.	Seminar	Total hours	
46	22	33	5	1590	

Note : Classes are given in hours per week (15 weeks per semester).
Abbreviations : Lab. − laboratory, Proj. − project, Assess. – Assessment, AuO. – Auxiliary Ocean Technology, **AuC**. − Auxiliary Core, **Cdes**. – Core Design

The courses were prepared by the staff of the Faculty and the Institute of Fluid Flow Machinery of Polish Academy of Sciences. One may see that we have arranged the core and the auxiliary courses within the first 3 semesters, with the bulk courses concentrated on the first two of them. The first core courses are related to the automatic control (6th semester), structural mechanics and incompressible flow (7th semester), and they are followed by the remaining core courses on heat transfer and compressible flow (8th semester). It allows us to gradually introduce the design projects, starting from a single project on control system design (7th semester), followed by 4 projects divided into structural mechanics and CFD problems for incompressible media (8th semester), and concluded by 5 projects dealing with compressible flow, heat transfer, structural mechanics and lubricating flow (9th semester). Such layout of courses allows for gradual introduction of complex subjects, provides necessary tools at proper time, maintains student interest (since the core courses contain use of hardware laboratories as well as computer exercises), and allows the students for more self-study and more independence on design projects at the end of studies. It also gives some flexibility to less capable souls to made-up some credits they missed on earlier semesters. The students do their research and elaborate their thesis during the last semester. The thesis writing should be an experience on a high and interesting level for the students as they would probably have already handled and solved – with some guidance– – eleven diverse design projects.

We want to make clear to the students that the engineer – especially the computational expert working on phenomena modelling – works on models of reality. It demands of him a critical approach for the modelling results, consciousness that verification of the results is necessary, and that it is demanded of him not to hesitate to make experiments, accompanied by the knowledge how to conduct and evaluate the required experiments. For this we have provided the use of hardware laboratories – at the Faculty, at other faculties of the University and the Institute of Fluid Flow Machinery. The laboratories have to serve as lecture demonstrations, a place for selected experiments performed by students and a tool for professional training. We also provided a specialized (CAD/CAE orientated) computer laboratory fitted with modern equipment, connected to Faculty Intranet, equipped with professional software systems – to be used by future graduates in industry and continuously accessible for students.

We have also access to the following hardware laboratories :

at our Faculty

★ a ship hydrodynamic laboratory (towing tank, cavitation tunnel, circulating water channel)
★ a mechanical engineering laboratory (slide bearing test stand, rotor dynamic test stand, and hydraulic equipment test stand)
★ a control system laboratory (various control devices at educational computer-controlled settings)
★ a structural mechanics laboratory (deformations of ship structures)
★ a material science laboratory,

at other scientific institutions

☆ nanotechnology laboratory at the Faculty of Chemistry, Gdańsk University of Technology (GUT)
☆ aerodynamic laboratory – at the Institute of Fluid Flow Machinery, Polish Academy of Sciences
☆ combustion and heat transfer laboratory – at the Institute of Fluid Flow Machinery, Polish Academy of Sciences.

The access to the facilities gives the students a chance to fully develop their capabilities without leaning just on the computational modelling techniques, by requiring them to do some experimental work, to understand the limitation of the numerical models and to pay attention both to the real physical processes and theories which describe them. The rich laboratory environment gives also a chance to do validation and verification studies during development of student thesis.

The example of such approach is shown in Fig.2 which displays the air test turbine and its numerical model prepared for computations by using FLUENT software.

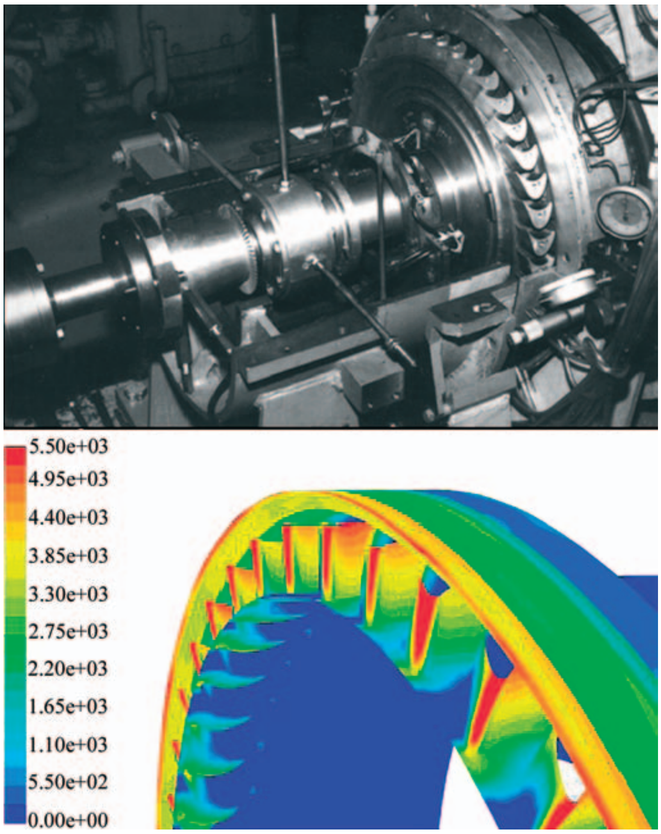

Fig. 2. *View of the model turbine rotor – laboratory and computational model (courtesy of mr. Robert Stępień, M.Sc.) .*

Tab.3 shows the computer software to be used in the laboratory. The software has so far consisted of the following basic packages.

Tab. 3. *Software packages used in the computer laboratory .*

Application Area	Software
CAD/CAM/CAE/PDM	UNIGRAPHICS/SOLID EDGE
Dynamic system modelling	MATLAB/SIMULINK, MATHEMATICA
Structural mechanics	ANSYS, NASTRAN
CFD and heat transfer	FLUENT, ANSYS, PHOENICS
General office	MS OFFICE, Open Office

The first graduates of the specialization will leave the university in the year 2007. We can see that there is a potential for foreign students to join the studies in that unique specialization. The specialization is open for the Polish students from other faculties of GUT who would like to study mathematical modelling of structures, flow or control. The specialization may be also easily converted into M.Sc. studies (second level). Some specially crafted post-graduate courses in selected fields of mathematical modelling may be also developed for the industry needs (for example, „*Computational methods in structural mechanics*", „*Computational methods in fluid mechanics and heat transfer*" or „*Computational methods in fluid mechanics*").

The industry (shipyards, design offices, international product manufacturers) seems to be interested in the new course. In June 2005 we held a seminar with the industry to present our approach and proposal. The participants expressed appreciation of the programme, gave their comments and said „we are waiting for your graduates". There were also formal endorsements of the programme by companies like General Electric, ABB or Unigraphics Graphics Systems (UGS). They expressed their readiness to invite students for apprenticeships in Poland and abroad, as well as their wish to co-operate with the Faculty (special lectures for students) and to certificate the CAD course as „Advanced" (UGS).

There is also noticeable interest of foreign students to participate in the programme – we have already enrolled foreign students within ERASMUS exchange programme.

It is also worth noticing that the programme is challenging and interesting for the most promising students at the Faculty: we have asked the students of 4th semester to select their specialization, and about half of the group of excellent students (10 persons) have signed up to participate in the programme.

As for the initial question : *is it a shipbuilding-like specialization?* We think that it is the case :

- the core problems and applications come directly from the maritime industries
- the studies provide substantial basis that allow for development and work in the fields of ocean engineering
- the studies give good theoretical background and request individual studies and self-development from the students in order to be well prepared for the future jobs from the view point of independence, self-direction, and to be able to work as subcontractors
- it is a Hi-Tech specialization which supports development of the marine industry (since there are needs for new constructions, re-working and exploring new opportunities for design optimisation; therefore the graduates knowing the newest design aiding technologies are constantly sought - - after).

About the author

The author of this paper is **Wojciech. A. Misiąg**, D.Sc., who held, in the years 2002-2005, the post of Associate Dean for Education of the Faculty of Ocean Engineering and Ship Technology, Gdańsk University of Technology.

FOREIGN *conference*

ISCORMA – 3

On 19-23 September 2005
Cleveland, Ohio, USA, hosted :

The third International Symposium on Stability Control of Rotating Machinery

ISCORMA Conferences were initiated at South Lake Tahoe, California in the year 2001, and continued by Polish scientists of Gdańsk University of Technology who organized 2nd Conference of the kind in Gdańsk in 2003.

Program of ISCORMA-3 was divided into 27 sessions during which 67 papers were presented. Their authors represented universities, research centers and industries of 10 European countries, Australia, Brazil, China, Egypt, India, Japan, Korea, Mexico, Taiwan and USA.

The number of papers of US authors (21 papers) of course prevailed in the scope of the Conference program; the next in number were those of Polish authors (7) and Japanese ones (5).

Polish authors presented the following papers:

- *Application of statistical methods for the evaluation of the condition of marine gas turbine engines and predicting the time of their faultless operation* – by A. Adamkiewicz (Polish Naval University)
- *Effect of bearing clearance on the dynamic characteristics of cylindrical journal bearing* – by S. Strzelecki and T. Zieliński (Łódź University of Technology)
- *Dynamic characteristics of cylindrical journal bearings with variable axial profile* – by S. Strzelecki (Łódź University of Technology) and S. M. Ghoneam (Menoufia University, Egypt)
- *Non-linear interactions in large power machine with cracked rotor* – by J. Kiciński and S. Banaszek (The Szewalski Institute of Fluid-Flow Machinery, Polish Academy of Sciences, Gdańsk)
- *Dynamic characteristics of tilting 5-PAD journal bearing* by S. Strzelecki (Łódź University of Technology
- *Effect of design parameters on the dynamic characteristics of tilting - PAD journal bearings* – by S. Strzelecki and H. Kapusta (Łódź University of Technology)
- *Robust controllers for electrohydraulic actuators* by Z. Gosiewski (Białystok Technical University) and M. Henzel (Military University of Technology, Warsaw).

Besides, the group of Polish scientific workers, namely:

- W. Batko (AGH University of Science and Technology, Cracow)
- Z. Domachowski (Gdańsk University of Technology)
- Z. Gosiewski (Białystok Technical University)
- J. Kiciński (The Szewalski Institute of Fluid-Flow Machinery, Polish Academy of Sciences, Gdańsk)
- K. Kosowski (Gdańsk University of Technology)
- Z. Kozanecki (Łódź University of Technology)

took part in work of the International Scientific Committee consisted of 40 persons, and Z. Gosiewski acted as a member of 6-person Organizing Committee.