AN ASPECT OF THERMODYNAMICS EDUCATION IN
CONSTANTA MARITIME UNIVERSITY:
EXERGOECONOMIC ANALYSIS OF INTERNAL COMBUSTION ENGINES

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ABSTRACT
Maritime Education and Training (MET) evolves along with the fast development of maritime industry. As a result any teaching syllabus content should derive from the exigencies and demands of the maritime industry.

Having in view that internal combustion engine are largely used in transportation sector, Thermodynamics education in Constanta Maritime University (CMU) includes the exergoeconomic analysis of these engines.

Thus, students in CMU are inured with the exergoeconomic (thermoeconomic) methodology, a method created in order to support a thermal and economical analysis for thermal systems. Considering objectives and professional competencies of students interested in obtaining a Bachelor’s degree in mechanical engineering. Thermodynamics curricula contains: the energetic analysis of internal combustion engines, the exergetic analysis of internal combustion engines, and the monetary analysis.

Keywords: EXERGOECONOMY, ENGINES, EDUCATION

1. INTRODUCTION
Maritime higher education has a tradition in Romania since 1972. In the effervescence due to the Romanian Revolution, the Merchant Marine Faculties split from the Navy and founded the Merchant Marine Institute of Constanta, in 1990. In 2000 the Institute turned into Constanta Maritime University (CMU) and at present is the only institution accredited to train students for the marine and shipping industry.

Education and training in C.M.U. aims at two careers: one at sea as a merchant marine officer and the other is an on – shore career in nautical economics or nautical technical environment. Applicants can choose between two faculties: Navigation and Naval Transport Faculty and Electromechanical Faculty.

Electromechanical Faculty includes four tracks:
- Marine Engineering (both full time and part time studies, 4 years of study) – graduates are awarded both Engineer Diploma (BSC) and Officer of the Watch (OWW) Engineer Certificate;
- Electrical Engineering (both full time and part time studies, 4 years of study) – graduates are awarded both Engineer Diploma (BSC) and Officer of the Watch (OWW) Electrical Certificate;
- Electronic Engineering and Telecommunication Systems (full time studies, 4 years of study) - its existence is explained by the rapid improvement of technology and navigational aids that have caused discussions at IMO level in order to have an electronist onboard;
- Environmental Engineering (full time studies, 4 years of study) – graduates will become specialists in the protection of environment.

Navigation and Naval Transport Faculty includes two tracks:
- Navigation and Naval Transport (both full time and part time studies, 4 years of study) – graduates are awarded both Engineer Diploma (BSC) and Officer of the Watch (OWW) Deck Certificate;
- Business and Engineering in Transports (full time studies, 4 years of study) – graduates are awarded Engineer Diploma (BSC) in engineering and economic field.
2. SKILLS AND COMPETENCIES NEEDED BY MERCHANT MARINE OFFICERS

Maritime Education and Training (MET) evolves along with the fast development of the maritime industry, having in view that technological developments go hand in hand with performant training. It is well known that developed countries introduce advanced technology and modern ships, while developing countries supply the seafarers. In the last years, in developed European countries is register a diminish in the number of seafarers. In the contrary, in Figure 1 is depicted student’s dynamic in C.M.U., based on the fact that seafaring is an attractive job for young Romanian generation due to its financial benefits and motivation.

![Figure 1: Student’s dynamics in C.M.U.](image)

The educational policy in CMU comprises the following main objectives [Spircu, Bancescu, 2008]:

- Moving to an educational system structured on three tiers: bachelor, master and doctoral (in C.M.U.: 7 Master of Science Degrees and 1 Ph.D. degree in Mechanical Engineering);
- Designing the university curriculum which has to comply with the competencies defined by domains or specializations, with focus on the outcomes of the educational process. In CMU, MET in not focusing only on STCW. Having in view that graduates are double certificated, as shown above, the development of C.M.U. curriculum, the particularization of courses, should be made also in agreement with the information acquired from the market research and within the limits established by ARACIS (ROMANIAN AGENCY FOR QUALITY ASSURANCE IN HIGHER EDUCATION), as shown in Figure 2.

![Figure 2: Designing CMU curriculum.](image)

- Orienting educational process towards the students rather than towards the university staff, as currently. This objective is targeted to be achieved both in the teaching and in the examination processes.
- Decreasing the specialization degree in the first educational tier, and increasing the flexibility of the educational programs.
- Educational program to come in line with labor market requests and allowing fast integration of the graduating students in the labor market.

Trying to define the term of “competence”, we say that it is equivalent with the capacity, ability or skill of a person in performing a certain activity.

Competencies can be:

- **competencies created within the educational process** – are specific to the field of study (technical, economical, etc.); to create them it is needed:
a) to have knowledge in one or more fields from the curricula,
b) to be able to perform a scientific research work,
c) to be able to design new systems or technologies;

- **competencies related to the academic method used** – are not specifically connected to the field of study, being common to more domains; it is needed:
  a) to be able to approach a problem (to be used with appropriate theories, methods, technologies);
  b) to own mental abilities (to think, to make rational judgments, etc.);
  c) to be able to cooperate and communicate (to work in team, to assume responsibilities to lead, etc.);

- **competencies related to the understanding of the social context, with a time dimension** – are connected with having specific knowledge, with the ability of expressing them in different foreign languages, except the native language (maritime english – for seafarers), with knowing social aspects specific to other countries (an important issue in the framework of globalization and multi – cultural crew structure).

Implementing the Bologna Process in C.M.U. ment, firstly, the defining of competencies specific for the degrees offered, in order to ensure students mobility throughout Europe and the world.

**3. EXERCONOMICAL APPROACH**

**3.1. About exergoeconomics**

The energetic balance is the most common analysis tool of processes developed inside the termoenergetical systems. Its goal is to establish energy consumptions inside the surface of control of the studied processes and to point out these consumptions as useful components and loss.

So, the energetic balance represents a tool of quantitative analysis which needs to be completed with qualitative criteria in order to be able to optimize the thermoenergetic systems.

Exergoeconomic analysis of thermoenergetical systems represents a modern method of qualitative assessment of the performances of these systems due to the fact that considers all the internal factors of the processes and the connections with the ambient.

The method of the **exergoeconomic analysis** consists in the combination of the **exergetic analysis** with the **economic analysis** of the thermoenergetical systems. Exergy is the maximum work that a specified system (or state) could deliver, without breaking any of the laws of thermodynamics.

In the **exergetic analysis** are pointed out the imperfections of the processes by establishing exergy destruction and loss.

The combination of the **exergetic analysis** with the **economic analysis** allows calculation of the exergetic costs of each flow. This means that it is possible to work with the costs of the useful part of the energy.

Results that by the exergoeconomic analysis are settled direct relations between costs and irreversibility of the considered system. These relations have an economic aspect, but settle a direct connection between and technical/functional features of the considered systems.

For systems supplying several final products, the exergoeconomic analysis allows the establishment of the real costs of each product depending on his utility, measured by the exergy of the product.

**3.2. Exergoeconomic education in CMU**

Two dominant types of internal combustion engines are spark-ignition and diesel.

Due to the significant commercial importance of this equipment, future marine engineers should be inured to the exergoeconomic methodology, in order to ratify their technical and economical viability. These skills are gained though Thermodynamics curricula. This curricula was designed considering **competencies created within the educational process and competencies related to the academic method used**, needed for the specialization called **Marine Electromechanics**.
**Exergoeconomic analysis**

It consists in the following steps:

- make an exergetic balance in each component of the system;
- make an economic analysis of the subsystems;
- obtain the costs balance of exergy flows in each component;
- calculate the parameters that would allow the analysis of the processes associated to each component.

The exergoeconomic analysis can be applied to Otto and Diesel Standard Cycles to reveal which one is thermoeconomically more efficient.

**Energy cost**

Following propositions permit evaluation of the exergetic costs of the flows.

**P₁:** The exergetic cost $B^*$ is a conservative property:

$$\sum_{\text{entrance}} B^*_i - \sum_{\text{exit}} B^*_j = 0$$  \hspace{1cm} (1)

**P₂:** For a system with more than one energetic resource, the exit unitary exergetic costs must be equal to the entrance.

$$\frac{B^*_1}{B^*_2} = \frac{B_1}{B_2}$$  \hspace{1cm} (2)

where: $B^*$ - exergetic cost flow [kW],
$B$ - exergy flow [kW].

**P₃:** If a system has more products (see above), the exergetic cost $\left(\frac{B^*}{B}\right)$ will be the same for each one of them:

$$\frac{B^*_3}{B_3} = \frac{B^*_4}{B_4}$$  \hspace{1cm} (3)

**P₄:** In the absence of value of an external loss flow, we shall admit a null exergetic cost.

So:

$$\frac{B^*_4}{B_5} = 0$$  \hspace{1cm} (4)

**P₅:** In the absence of external value, the exergetic cost of the entrance flows in the system is equal to its exergy:

$$B^*_1 = B_1$$  \hspace{1cm} (5)
For internal combustion engines, these propositions are applied as following (see Figure 3).

![Figure 3 Surface of control involving an internal combustion engine.](image)

From the energetic balance for internal combustion engines:

\[
B^*_{\text{fuel}} + B^*_{\text{air}} - B^*_{\text{power}} - B^*_{\text{heat}} - B^*_{\text{gases}} = 0
\]  

(6)

From P_3 results that unitary cost of heat is equal to the unitary cost of power:

\[
\frac{B^*_{\text{heat}}}{B_{\text{heat}}} = \frac{B^*_{\text{air}}}{B_{\text{air}}}
\]  

(7)

From P_4 we can say that exergetic costs for gas exhaustion flow and for the air flow are null:

\[
\frac{B^*_{\text{gases}}}{B_{\text{gases}}} = \frac{B^*_{\text{air}}}{B_{\text{air}}} = 0
\]  

(8)

From P_5, the entrance being the fuel, for him the exergetic cost is equal with the exergy itself:

\[
B^*_{\text{fuel}} = B_{\text{fuel}}
\]  

(9)

**Analysis of Monetary Parameters**

It is useful the cost balance for a subsystem shown in Figure 4.

![Figure 4: Balance of Monetary Costs](image)

\[
C_p B_p = C_F B_F + Z
\]  

(10)
where: $C$ – monetary cost per exergy unit, [€/kJ],

$Z$ – capital investment, [€/s].

The invested capital is determined by:

$$Z_i = \frac{3600 (A/P)}{t_{op}} \cdot F_i$$  \hspace{1cm} (11)

where: $A/P$ – capital recovering factor,

$t_{op}$ - the useful time life, [s],

$F_i$ - the investment for each equipment or subsystem, [€].

$$\frac{A}{P} = \frac{l(1+i)^N}{(1+i)^N - 1}$$  \hspace{1cm} (12)

where: $I$ – the interest rate,

$N$ – the reimbursement period, [year].

4. CONCLUSIONS
The large spreading of internal combustion engines, their penetration in maritime sector and their significant commercial importance led to the fact that future marine engineers should be inured to the method of exergoeconomic analysis. They should have competencies in make a qualitative assessment of the performances of these systems, but also in the economic analysis of them, through Thermodynamics education in C.M.U.

It is shown that exergoeconomic analysis considers the quality of energy (exergy) in allocating the production costs of process to different products it produces.

Thus, future specialists will have skills to analyze, evaluate and optimize energy systems.

This educational aspect agrees with the main goal of C.M.U.: to educate future marine engineers who can contribute to the development of maritime industry, being known that this industry needs engineers with adequate experience and also theoretical knowledge of both engineering and management.

By combining exergetic analysis with economic analysis, students are aware that Thermodynamics can be expressed as an interdisciplinary study.

5. REFERENCES

