Energy and Environment in Ship Manufacturing Processes

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Abstract

The main issues of energy and environment in ship manufacturing processes in shipyards are presented. The direct and indirect demands of energy in the shipbuilding industry are clarified. The Life Cycle Analysis (LCA) of ships is addressed. The holistic approach of LCA is briefly outlined. Particular emphasis is placed on the methods commonly used to reduce energy consumption and control/reduce the relevant environmental impacts. The modern approach of Design for Environment in the shipbuilding industry is highlighted. The rationalization of materials used in shipbuilding and ship scrapping is briefly considered. The main types and consequences of hazard categories are given. The paper is concluded by stressing the importance of introducing the relevant energy and environment courses into the educational programs of Naval Architecture and Marine Engineering departments.

Key words: Shipbuilding, environmental impacts, energy, pollution, risk assessment, life cycle analysis, design for environment

I- Introduction

Awareness about environmental problems has increased significantly during recent years. There is now widespread appreciation of the serious health risks, degradation of natural resources, climate change and need for means of environmental protection. Energy consumption has adverse economic and environmental implications.

The shipbuilding and ship repair industries consume various types of energy for ship production and ship repair and therefore produce environmental problems. Identification of the size, scope and consequences of the harmful environmental impacts should receive some consideration. Consumption of energy in the shipbuilding and ship repair industries should be controlled and rationalized in order to protect the environment and improve the economics. Solving pollution problems of both industries should be directed to pollution prevention, reduction and control. This philosophy should be reflected in the teaching curricula of the Faculties of Engineering. Future engineers should be properly equipped with adequate knowledge on energy and environment so as to understand and contribute to resolving the local, regional and global environmental challenges.

II- ***Total Shipbuilding System***

The total shipbuilding system is composed of several activities involving prefabrication processes, fabrication processes, post fabrication processes, ship delivery and post delivery operations as well as handling and transportation of raw, fabricated sections and blocks. The main elements of these activities involving negative environmental impacts are materials used, energy consumed in the various operations and processes of prefabrication, fabrication, post-fabrication, handling and transport, assembly and construction, testing, maintenance and repair, etc.

III- ***Energy Used in the Shipbuilding Industry***

The energy demands for the shipbuilding industry could be divided into *direct* and *indirect* energies, see Fig. (1). The indirect energy used in the shipbuilding industry is required for the manufacture and production of the main & auxiliary engines, propellers, etc., production of shipbuilding steel (steel plates, sections and pipes, see manufacture of equipment and fittings, production of welding coils and electrodes, production of paints, etc.

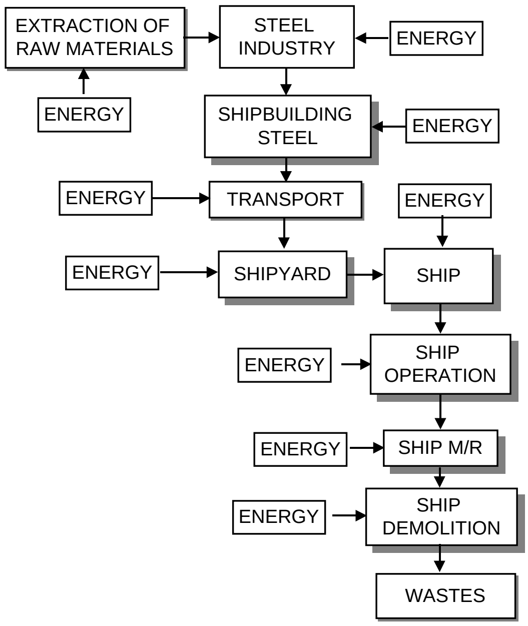

Fig. (1). Total Energy demand

The direct energy required for ship construction is used for the following processes: handling and transport of raw and fabricated materials, fabrication processes: cutting, forming of plates and sections, welding, assembly of steel plates and sections, construction of 2D and 3D blocks, assembly of blocks on berth or in dock, outfitting operations, tests and trials.

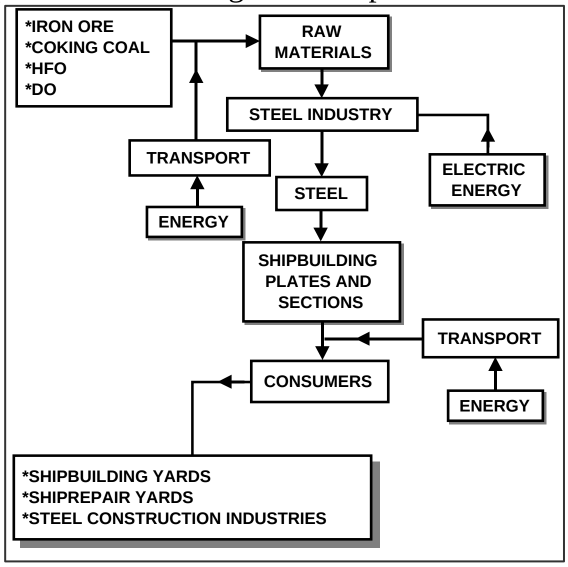

Fig. (2). Indirect Energy used in Shipbuilding

Figs. (3,4) show the energy demands for ship plate forming and for panel welding, (EE = Electric Energy, GE = Gas Energy).

For plate forming using line-heating method, acetylene is used for providing the required heat energy and CO_2 is the main polluting gas emitted. Assuming complete combustion of acetylene, the amount of emitted CO_2 could be estimated using the reaction equation for complete combustion as given by:

$$C_2H_2 + 2.5O_2 \Rightarrow 2CO_2 + H_2O$$

IV- ***Life Cycle Assessment in Shipbuilding Industry***

Life Cycle Assessment (LCA) adopts a holistic approach by analyzing the entire life cycle of a product starting with raw materials extraction and acquisition, materials processing and manufacture, material handling and transportation, product fabrication, product transportation, distribution, operation, consumption, product maintenance and repair and finally product disposal/scrapping. The solid waste management hierarchy involved in the product disposal/scrapping includes waste prevention, waste minimization at source, reuse, repair, recover, recycle, incineration (with or without energy recovery) and possibly landfill. Fig. (5) shows the input and output of any industrial process, including energy and environmental impacts.

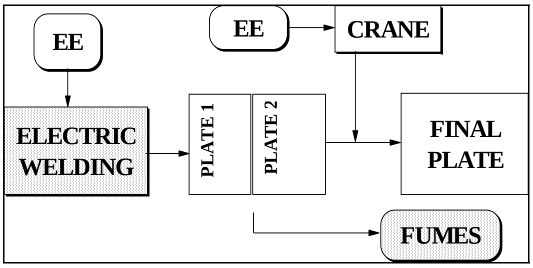

Fig.(4). Energy demands for welding

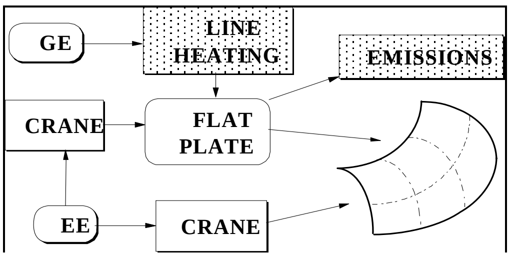

Fig. (3). Energy Demands for Plate Forming

The holistic approach of LCA of a product covers the energy consumption and associated environmental impacts over the entire life of the product. The main components of this holistic approach are:

- *Inventory analysis:* identification and quantification of energy and resources used and environmental releases to air water and land.
- *Impact analysis:* addresses the technical qualitative and quantitative characterization and assessment of the ecological and human health consequences and resource depletion.
- *Improvement analysis:* addresses the evaluation and implementation of opportunities to reduce environmental burdens.

LCA of ships should include not only environmental impacts but should also include rational use of construction and outfitting materials, rational use of energy in all stages and phases of ship design, construction, outfitting, operation, maintenance, repair and finally ship scrapping.

The main materials commonly used in ship production, which require rationalization, are: steel plates, sections and pipes, welding coils and rods, castings, forged parts, timber, paints, etc. The rational use of these materials should not only minimize energy consumption and the negative environmental impacts but should also have positive economic gains. The minimization of environmental impacts and wastes in ship construction could be achieved by the efficient use of steel plates, profiles, pipes and all other construction materials, efficient use of welding coils and rods, efficient use of paints, etc.

The main measures commonly taken to save energy consumed in ship fabrication and construction are: rationalization of inter-process transportation, reducing / improving bending and forming operations (2D and 3D forming), using press forming instead of line heating method, using large sizes of steel plates, particularly plate width, improving welding operations, improving accuracy of edge preparation, minimization of welding lengths, maximization of down-hand welding, minimization of cutting lengths of steel plates, widespread use of computer-aided marking and cutting, minimization of scrap by rationalization of plate nesting and minimization of rework.

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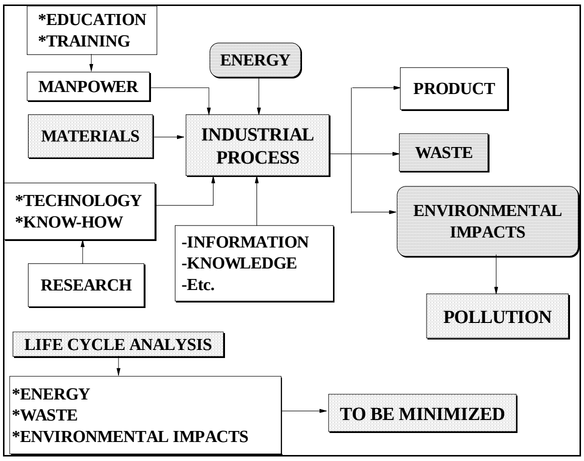

Fig. (5). Life Cycle Analysis

V- Educational aspects of energy and environment in shipbuilding

A brief statement of the main energy and environment courses relevant to the shipbuilding and ship repair industries is given below. These courses should improve University students awareness about energy consumption/saving and the relevant environmental impacts resulting from the manufacturing processes in the shipbuilding and ship repair industries.

V1-*The Environmental Engineering System*

The course on Environmental Engineering System should include design, construction, operation, maintenance and repair (M/R),scrapping. Design is one of the main courses given in Faculties of Engineering that has a close connection with the relevant issues of energy and environment. The environmental dimension in ship design should be an integral part of the holistic approach to ship design. The main objective of this holistic approach is to make safety, economy, and environmental protection an integral part of ship design, manufacture, operation, maintenance, repair and scrapping. Unfortunately, design for safety is appreciated only after serious accidents have occurred. Design for safety, therefore, should include risk to human life and risk to environment. Risk management should, therefore, be an integral part of the holistic design approach. In the maritime sector, tragic accidents causing environmental disasters have focused world opinion on ship safety and environmental protection through the introduction of the International Safety Management code (ISM).

The Factor of Safety commonly used in Engineering Design should, therefore, include not only safety of the structure but also risk to human life and risk to environment, as follows:

$$\gamma = \gamma_X . \gamma_Y . \gamma_Z$$

γ = Total Factor of Safety

γ_X = factor taking account of the safety of the system

γ_Y = factor taking account of the risk to human life

γ_Z = factor taking account of the risk to Ecology

The higher the magnitude of the total Factor of Safety, the less the probability of failure, the less the cost of failure, the less the risk to ecology but the higher the initial cost and the likely the irrational use of materials and resources. This indicates clearly that the magnitude of the Factor of Safety should be rationally selected so as to satisfy the requirements of safety, ecology, economy and environmental protection.

V2- *Risk Management*

Risk Management covers hazard assessment, risk analysis and methods used to reduce or prevent hazards, risk and failure. Risk management consists of formal scientific techniques that integrate knowledge about a contemplated action and its possible effects, account for uncertainty associated with that knowledge, express results from a probability standpoint to account for both knowledge and uncertainty. Risk assessment is, therefore, the process of assigning

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magnitudes and probabilities to adverse effects resulting from human activities. The course on Risk Management should cover assessment of hazards, development of accidental scenarios that could potentially lead to fatalities, injuries, etc, development of methods and actions to reduce risk, calculation of risk taking into account the likelihood of the scenario and the probable negative consequences.

Risk could be assessed by using the probability density functions of both Demand and Capability. In this case the options to reduce risk are: increase capability (sometimes very costly), decrease demand (sometimes not feasible), decrease variability and uncertainty of capability (possible), decrease uncertainty of demand (not always feasible). The methods used for risk reduction include: changes in the design of the physical system, changes in the design of the control systems, changes in the process variables, such as temperature, pressure, stress, etc., changes in the materials used, changes in the test and inspection methods and procedures of key components, using proper monitoring system.

V3- *Energy and Environment*

The course on Energy and Environment should clearly indicate the importance of using methods for energy conservation, raising energy efficiency in the various ship production processes, adopting energy saving techniques, controlling the environmental problems resulting from energy consumption, minimization of total energy consumption, minimization of wasted energy, using safer, cleaner and more efficient technologies and systems for ship production.

V4- Environmental Problems

The course on Environmental Problems should cover air pollution and emissions, water pollution, (rivers, coastal water, seawater, ground water, lake water), noise pollution, climate change, ozone depletion, etc. The course should briefly cover the main types, causes, scope, consequences, prevention, reduction and control of the negative environmental impacts.

V5- Industrial Pollution

The course on Industrial Pollution should clearly indicate the impact of industry on the main environmental problems such as climate change due to the increase of greenhouse gases, the consequences of irrational use of materials and resources, etc. the course should also cover the environmental and economic benefits resulting from introducing methods of increasing efficiency of production processes, cost-effective methods of handling unwanted effluents and methods of waste reduction.

V6- Waste Management

The course on Waste Management may include the environmental and economic benefits from ship life extension, waste prevention, minimization at source, re-use, recycle, recover, repair/upgrade, incineration, (with/without energy recovery) and landfill.

Ship scrapping is becoming an important industry in several countries. The outcome of ship scrapping includes usable materials, engines, equipment, fittings, etc. The outcome of ship scrapping should be rationalized so as to protect our natural resources, save energy consumption, minimize negative environmental impacts, minimize waste, etc. Waste management in ship scrapping should not only have significant economic opportunities but should also have positive impact on environmental protection.

V7- *Conclusions:*

The main conclusions drawn up from this paper are:

- Energy conservation and negative environmental impacts in the shipbuilding and ship repair industries require serious evaluation and quantification.
- LCA of ships could be used to assist shipbuilding companies to identify and quantify opportunities to minimize/control energy consumption and its impact to the environment and to realize cost savings by making more effective use of available resources.
- The teaching of Ship Design courses should be more comprehensive than that normally given in our Faculties of Engineering and should cover the main issues outlined above. The environmental dimension in ship design should be an integral part of the holistic approach of ship design
- The rational use of shipbuilding materials should not only reduce the negative environmental impacts and energy consumption but should also have positive economic gains.
- Waste management in ship scrapping should not only have
- significant economic opportunities but should also have positive impact on environmental protection.

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