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Sustainable Development And Ship Life Cycle

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Abstract:

Transportation of goods and people across water is a necessary engineering activity for economic growth of individuals and society. But does this growth affect sustainable development through environmental degradation? A ship's life cycle consists of concept exploration, design, production, operation and maintenance and dismantling. Stages in the life cycle of a ship in which large energy is consumed can be said to be (i) shipbuilding (ii) ship operation and maintenance and (iii) ship dismantling. The energy consumed in building a ship can be grouped under major heads as establishment energy, direct energy in materials and its transportation, direct energy consumed in construction of the particular ship, indirect or overhead energy consumed in the shipyard which cannot be billed to a ship. The green ship concept is evolved to reduce energy consumption in shipbuilding, ship operation and maintenance. This can be achieved by optimised structural design for steel weight reduction and use of alternative materials, possible use of alternative and renewable fuels, propulsion systems and auxiliary systems, Innovative design development such as Ballast Free Ship(BFS) and proper system integration. Ship Design plays a crucial role for ensuring ship construction, operation and dismantling. It is therefore necessary to increase the scope of concept design by incorporating use of numerical analysis procedures at early stages of design, consideration of alternative fuels and propulsion systems, use of design for production and design for maintenance techniques. Standardisation and modularisation should be incorporated in ship design for improved production.

1.Introduction

The standard definition of sustainable development, suggested in 1987 and universally accepted is, development that meets the needs of the present without compromising the ability of future generations to meet their own needs. Avoidance of environmental degradation is a primary aspect of sustainable development. Environment includes atmosphere, the oceans and earth. In case of ships it means use of sustainable energy – renewable, alternative, green or low-carbon energy, reduction of pollution due to ship operation, accidents, construction and preservation of coastal zone.

Sustainability also includes safety of ship to reduce accidental pollution and socially acceptable norms of safety of life. Safety and environment are closely linked [Kuo 2012]. Also any development using sustainable energy must be economically acceptable.

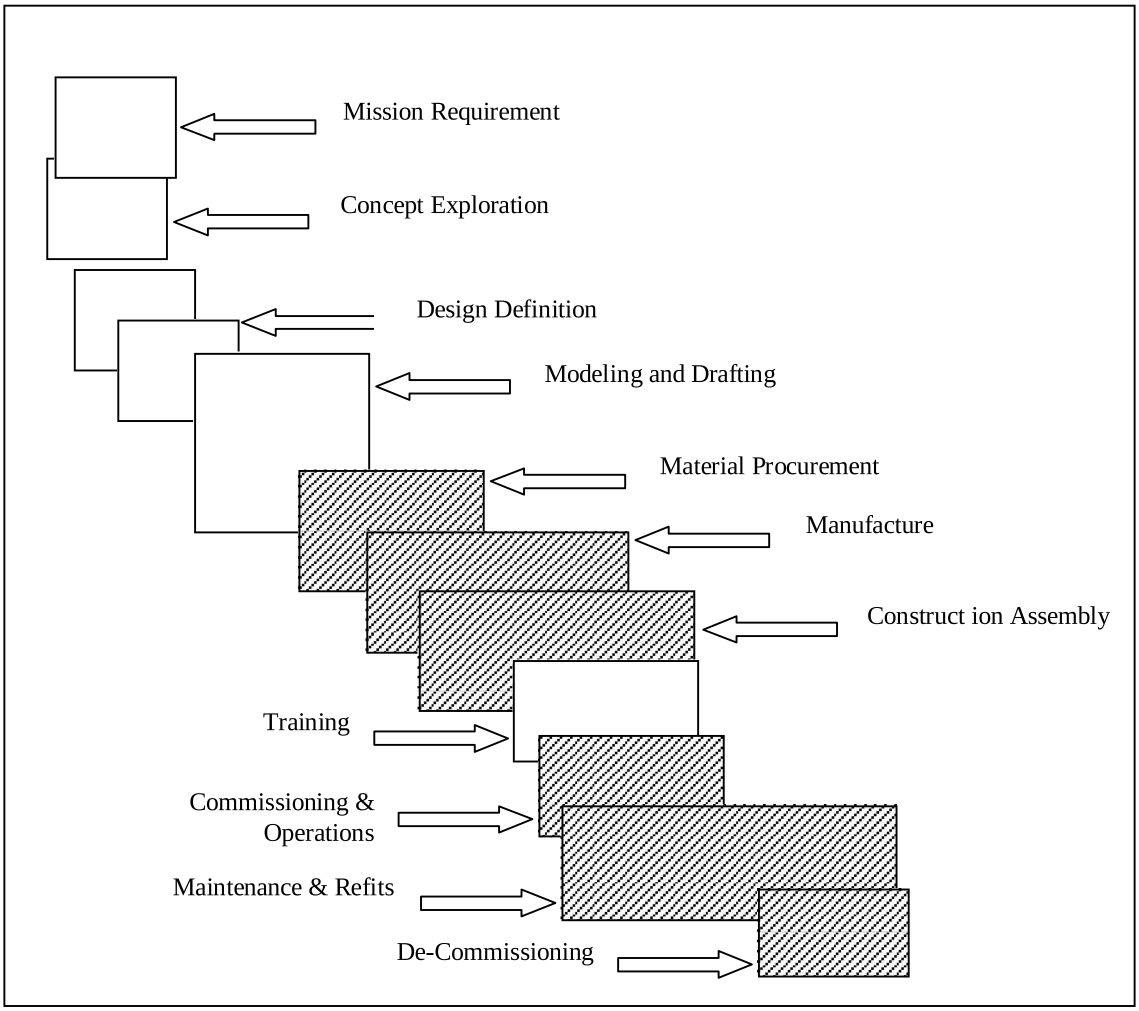

Figure 1: Different Stages Of Ship Lifecycle

Various stage of life cycle of a ship are shown in fig.1 starting from mission requirement, going through the process of ship acquisition (construction), ship operation and finally decommissioning. The hatched rectangles in the figure indicate the stages in which substantial energy is consumed. Basically these stages can be said to be (i) shipbuilding (ii) ship operation and maintenance and (iii) ship dismantling. This paper discusses the energy consumption and sustainability aspects of shipbuilding. The areas of ship operation and ship dismantling are briefly touched upon. The role of ship design in sustainable shipping is discussed in the last section.

2.Sustainable Shipbuilding

A shipyard is erected to build ship. Therefore the a portion of the energy spent in building a shipyard has to be billed to the ship's account built in that yard. One could assume a members of years (day, N) of productive life of a shipyard and knowing the CGT built per year (CGTy), one can calculate the energy to be accounted for in that ship's account or, the

$$\text{Estabilishment energy per ship} = \frac{\text{energy spent in building a shipyard}}{\text{N} \times \text{CGTy}} \times \text{CGT of ship}$$

Where CGT : Compensated Gross Tons defined as

$$CGT = A.\ GT^{B}$$

Where A & B are based on ship types given in referance.

After N Years, the establishment energy per ship vanishes. In other words, the energy spent under this head is nil for an old yead and has a value for new yards. This is equivalent to depreciation in financial accounting. Clackson research has introduced a catagorisation of 4 types of shipyards based on the stage of development of the yards as follows [Kennedy, 2008]

(i) Established

(ii) Newly established

(iii) Expansion yard

(iv) Greenfield shipyard

A shipyard has building docks / dry docks, shipways, roads, workshops, buildings, compound wall etc. which uses large amount of cement concrete and steel. As per data given by Portland cement, 1990 [*Wilson*] to produce 1 tonnes of steel, energy consumed is 5.792m BTU and one tonne of concrete, it is 1.7m BTU which includes transportation energy. Thus, for sustainability, a Greenfield shipyard must be 'greener' than an established yard. Therefore, one can consider alternative shipyard designs for energy reduction such as horizontal transfer of ships such as end or side launching or use of ship lift systems water without the use of a drydock.

The energy consumed in the shipbuilding process can be grouped under three heads.

(i) Direct Materials (energy contained in the materials of a ship and their transportation).

(ii) Direct (energy consumed in construction of the particular ships such as electricity consumed due to welding, farming, use of cranes, transportation of block etc).

(iii) Indirect or overhead (energy consumed in the shipyard which cannot be billed to a ship, such as electricity and fuel consumed in administration, design, planning, transportation of personnel etc.).

Fig. 2 gives the energy consumption break up for construction of a ship. Indian Maritime University, Visakhapatnam campus has been given a project by Ministry of Shipping to study energy consumption pattern in Indian Ship Yards.

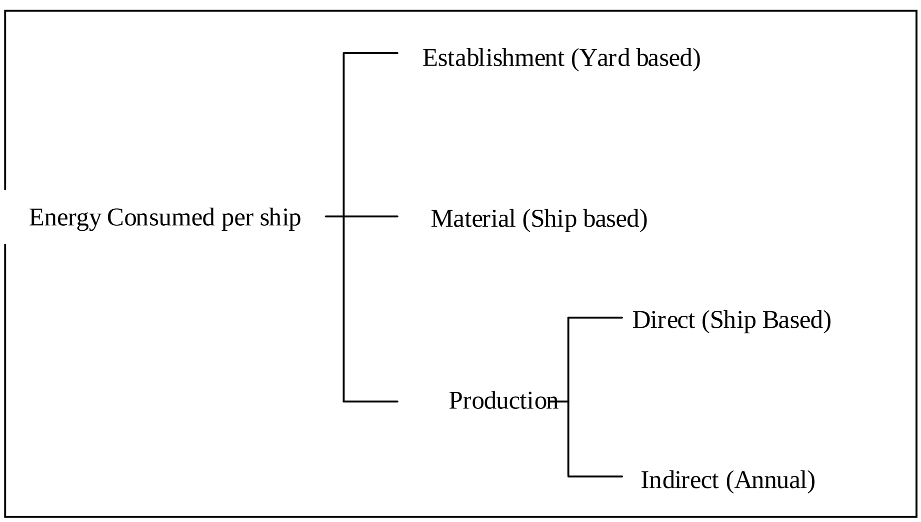

Figure 2:Energy Consumption breakup in Shipbuilding

A good account of green shipbuilding is given in reference [*He-ping, 2008*]

For reduction of energy consumption in shipbuilding, the following measures may be considered:

- Use of minimum quantity of steel and other energy consuming materials by optimal design and procurement of material through short distance transportation or through water which is the least energy consuming transportation system.
- Use of alternative materials which are biodegradable or can be recycled. Wood is a good candidate for use on board ship provided it is available without causing large scale deforestation.
- The direct energy consumption in shipbuilding can be reduced by use of improved / alternative energy consuming less electrical power than older machines, improved production techniques and processes and improved planning.
- Large direct energy saving can be achieved by elimination of re-work through quality assurance and quality management at every stage of production.
- Indirect energy consumption or overhead energy consumption per ship can be estimated on an average basis as equal to

$$\frac{Total\ overhead\ energy\ consumption\ in \bullet year}{CGTy} \times CGT\ of\ ship\ .$$

This can be reduced by optimal ship production or maximising CGTy to its optimal level. This can be achieved by ensuring efficient shipbuilding which in turn will depend on full orderbook position and timely delivery of ships.

- Use of alternative / renewable energy sources is the general prescription for reduction of energy consumption in shipbuilding.

3.Sustainable Ship Operation

Environmental impact due to ship operation can be due to

- Ship waste
- Bilge water
- Black waste water
- Grey waste water
- Oil discharge
- Ballast water movement
- Paint system
- Air emission
- Excess Ship Energy Consumption
- Safety

Most of these issues can be addressed during the ship design stage at the beginning of ship lifecycle as shown in fig. 1. Operational energy control is done through IMO recommended Ship Energy Efficiency Management Plan (SEEMP) and International Safety Management (ISM).

4.Sustainable Ship Dismantling

Ship dismantling is the reverse process of ship building. Therefore, the components of energy consumption will be similar to fig. 2 except that the energy an materials will not be there since no new material is added. Apart from energy issues, there are two other problems associated with dismantling:

- Occupational and safety issues which have been discussed in details in the last few years. In India, sufficient prescriptive (regulatory) action has been taken to reduce the occupational hazards and safety issues.
- Hazardous materials, if not handled carefully, can cause environmental and safety problems. These include handling of nuclear material, handling of loose asbestos inhalation of which cause asbestosis. IMO is aware of this problem and, in association with guidelines of classification societies, have been developed recommendations for issue of green passports to ships that carry a complete list of hazardous materials on board.

5.Ship Design And Sustainability

Can sustainability be one of the ship design objectives? A ship design evolved with this objective is called a 'green ship'. Many research and design groups have been working together to evolve a green ship design [Kim etal, 2011; ECORYS, 2012, "Green Ship of the Future",2012]. Such a design activity should include

- Optimal hydrodynamic design of hull shape, appendages and their location to reduce water resistance and estimate flow onto the propeller and improved seakeeping behavior. This involves extensive use of CFD techniques and packages at the concept design stage itself supported by required prototype / model testing.
- Improved design of propulsion device for increased propulsion efficiency. This also involves extensive analysis by CFD techniques and model testing.

- Innovative hull lubrication system to reduce corrosion, reduce fouling and perhaps reduce frictional drag. This includes paint systems which are non-poisonous and don't pollute the environment. IMU-V has been awarded a R&D project sponsored by Department of Science and Technology, New Delhi to investigate paint behavior due to flow and stress levels on the hull surface and use of naturally available material in paint systems.
- Optimised structural design to reduce hull (steel) weight and having high level of structural safety and reliability. This requires three dimensional structural analysis using FEM techniques at the concept design stage. Use of different materials, use of smart materials are also required to be studied for possible use to improve structural properties and reduction of structural degradation during ship's life.
- Possible use of alternative fuels (eg. LPG / LNG or Bio-Fuel) and alternative propulsion systems (LNG fired engines, electric propulsion etc.) ["NOAA Green Ship Initiative", 2011, Vissamsetty etal, 2011].
- Possible use of renewable energy sources for propulsion or as an auxiliary power source. The renewable energy source may include wind or solar energy or hydrogen fuel cells.
- Innovations in designs to develop pollution free ship such as no-ballast ship (NOBS). IMU-V and IIT kharagpur together have evolved a ballast free ship design [Gupta etal, 2008] by providing free flow pipes below the ship hull. Fig .3. shows such a ship model which has been numerically analysed and model tested for its hydrodynamic behavior. Studies on this concept are still continuing.

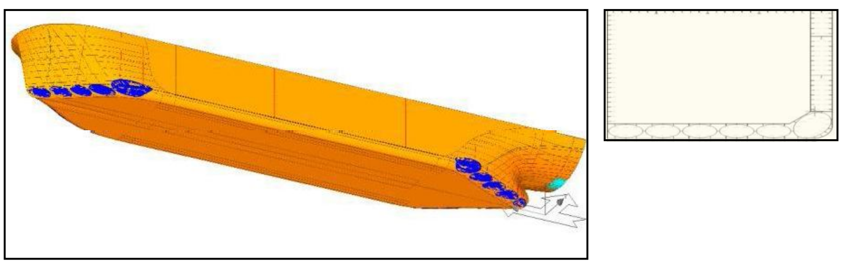

Figure 3: The Ballast-Free Ship Concept

- System integration of all the above into a single green ship including procedure for production and instruction for maintenance.

Conventional design activities include standard design practices at concept and basic design stages without giving particular attention to sustainability. If this is to change such that one includes sustainability as an objective consciously, the following steps must be taken

- Use of CFD and FEM based numerical studies at the early design stage
- Consideration of all alternatives of propulsion systems, fuels, renewable energy sources for (auxiliary) power and selection of installation.
- Use of design for production tools and techniques so that production is easy and shipbuilding can support sustainability. Standardisation and modularisation should be incorporated in ship design for improved production.
- Use of design for maintenance so that instruction for maintenance can be easily followed. This requires improved structural design and proper accessibility provision in layout of structural components and equipment.

IMU-V has proposed a national program of green ship design and development to Ministry of Shipping which will involve a large number of R&D institutions, academic institutions and the industry.

6.Conclusion

Sustainable shipping means environmental protection which includes less energy consumption and pollution free and safe ship operation over ship lifecycle. The energy consumption for building a ship has been discussed. It has been stated that energy consumption during shipbuilding can be reduced by improved production methods, techniques and processes and mostly by elimination of rework and having a full order book position. Design of a green ship means reduced energy consumption leading to sustainable environment. It has been stated that design of ship includes, as a matter of regular practice, use of numerical techniques such as CFD and FEM, development of ship machinery system for low energy consumption, reduction of CO_2 emission and use of design for easy and quick production and easy maintenance.

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