INTERNATIONAL JOURNAL OF INNOVATIVE RESEARCH & DEVELOPMENT

*ISSN 2278 – 0211 (Online)*

# Energy Consumption and Conservation in Shipbuilding

**Ch. Rajeswar Harish**
Scientist – B (NA), SMDR, Indian Maritime University, Visakhapatnam campus, Visakhapatnam, India
**Soumya K. Sunil**
Scientist – B (ELE), SMDR, Indian Maritime University, Visakhapatnam campus, Visakhapatnam, India

***Abstract:***
*Transportation of goods and people across water is a necessary engineering activity for the economic growth of individuals and society. But does this growth affect sustainable development through environmental degradation? A ship's life cycle consists of mainly the following stages: concept exploration, design, production, operation and maintenance and dismantling. Among them, the major energy consuming stages can be identified as (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 and indirect or overhead energy consumed in the shipyard which cannot be billed to a ship.*
*A shipyard is erected to build ship. Therefore 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 numbers of years (day, N) of productive life of a shipyard and knowing the CGT (Compensated Gross Tonnage) built per year (CGTy), one can calculate the energy to be accounted for in that ship's account.*
*The energy consumed in the shipbuilding process can be grouped under three heads.*
- *a) Direct Materials (energy contained in the materials of a ship and their transportation).*
- *b) Direct (energy consumed in construction of the particular ships such as electricity consumed due to welding, cutting , use of cranes, transportation of block etc).*
- *c) Indirect or overhead (energy consumed in the shipyard which cannot be billed to a particular ship, such as electricity and fuel consumed in administration, design, planning, transportation of personnel etc.).*

*For reduction of energy consumption in shipbuilding, the measures to be considered are Optimal design and procurement, Use of alternative materials which are biodegradable or re-usable, use of improved and modernised machinery, Elimination of re-work, Indirect energy consumption by optimal ship production or maximising CGTy and Use of alternative / renewable energy sources.*
*A fraction of the energy consumed in building a ship can be recovered by recycling. Ideally, for recycling to be effective, recycling yards should require minimum investment.*

***Keywords:*** *Sustainable development, Ship life cycle, Direct and process energy, Energy conservation*

## 1. Introduction

Our shipbuilding practices have not kept pace with global industry standards which have already graduated to a 'womb-to-tomb' concept called Concept, Assessment, Demonstration, Manufacture, In-Service, Disposal or CADMID in short.
The challenge of maintaining high product quality while simultaneously reducing production costs can often be met through investments in energy efficiency, which can include the purchase of energy efficient technologies and the implementation of process-wise energy efficiency practices. Energy efficient technologies can often offer additional benefits, such as quality improvement, increased production, and increased process efficiency, all of which can lead to productivity gains. Energy efficiency is also an important component of a company's overall environmental strategy, because energy efficiency improvements can lead to reductions in emissions of greenhouse gases and other important air pollutants.
A study has been undertaken in order to observe the energy consumption pattern in the Indian ship building yards and dismantling facilities. The energy consumption pattern for a single ship construction and dismantling was also tried to calculate.

**2. Indian Shipbuilding Industry Structure & Characteristics**

Shipbuilding industries are located in India along the coastline. Apart from the government shipyards like Cochin shipyard, Mazagon dock, GRSE, Hindustan Shipyard limited etc, there are above fifteen major shipyards in the private sector.

We, in our study, have tried to include shipyards from all sectors.

The study, consisting of two phases, was carried out as follows:

Phase 1: Establishment energy- Estimating the energy spent in establishment of a shipyard.

Phase 2: Specific energy - Estimating the energy, in all possible forms, that was actually spent in constructing a specific vessel.

*2.1. Phase 1: Establishment Energy*

For sustainability, a Greenfield shipyard must be 'greener' than an established yard. Therefore, one can consider alternative shipyard designs for energy reduction by horizontal transfer of ships such as end or side launching or use of ship lift systems without the use of a drydock.

Since most of the shipyards in India were constructed at an early date, the accurate data for the same was not available. The major raw materials in the shipyard construction, as in any other construction, were identified to be reinforced concrete cement(RCC), bricks and asphalt(roads).The methodology adopted here was to do a reverse estimation, starting with the data in hand, i.e.; with the available building dimensions, standard energy values and calculated quantities of raw materials, the total energy spent in the establishment of the shipyard was arrived. The dimensions of various shipyards being different, total energy of the shipyard has been categorised into 4 sections and per unit values were calculated in order to present an average energy from shipyards. Calculated section wise average energy are shown in table.1

| | |
|---|---|
| Energy in workshops and warehouses | 21GJ/$m^2$ (approx.) |
| Energy in buildings | 10 GJ/$m^2$ (approx.) |
| Energy in docks, slipways, berths and jetties | 3 GJ/$m^2$ (approx.) |
| Energy in roads | 33 MJ/m (approx.) |

*Table 1*

*2.2. Phase 2: Specific Energy*

a) Direct energy: The major consumables utilised in the construction of a ship were identified to be Steel, Electrodes, Paint, Oxygen and acetylene, electricity used in various ship building processes like cutting, moulding, welding etc.

b) Indirect energy: Electricity consumed in the common area like drawing office, warehouse, canteen etc and fuels used for transport of raw materials, which cannot be segregated vessel wise.

<u>2.2.1. Methodology Adopted</u>

i. From each shipyard, two or three specific vessels were selected, depending on the availability of data.
ii. Steel, paint and electrode consumption details were obtained from the warehouse.
iii. Electrical power consumption details were obtained from the concerned department.
iv. Oxygen/acetylene consumption data roughly was collected from warehouse.

| Consumable | Quantity | Energy | MJ |
|---|---|---|---|
| $O_2$ GAS | 100 Cu. Met. / 1 Ton net steel | 5.04 MJ/$M^3$ [i] | 504.00 |
| $CO_2$ GAS | 33 kgs. / 1 Ton net steel | 10204 MJ/TON [ii] | 336.73 |
| LPG | 10 kgs. / 1 Ton net steel | 45845 MJ/TON [iii] | 458.45 |
| PAINT | 7.9 kgs. / 1 Ton net steel | 514 MJ/TON [iv] | 514.00 |
| ELECTRODES | 625Nos. (or ) 34kgs / 1 Ton net steel | 34.3 GJ/TON | 566.37 |
| ELECTRICAL POWER | 96 KWH/ 1 Ton net Steel | 3.60 MJ/KWH | 345.60 |

*Table 2*

Consumables required for ship construction, as mentioned in table.2 can be known from approximated quantity calculated per 1tonne of net steel work. This data is used to calculate required respective quantities with known total ship net steel weight. This is then converted to energy terms using references of embodied energy for unit weight or volume. Graph 1 shows percentage contribution of each consumable per tonne net steel weight of ship construction.

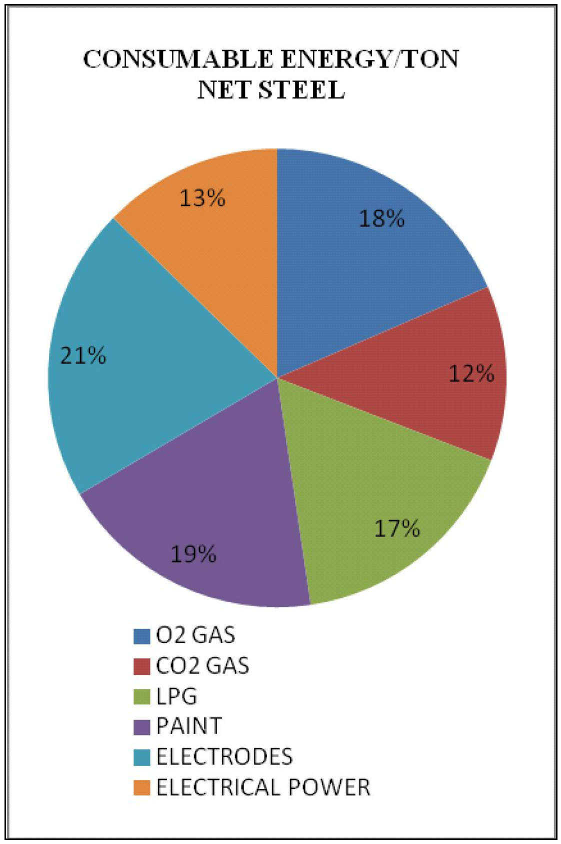


*Figure 1*

Total energy required from fabrication to hull berths for 1 Ton net ship steel work from above table 2 is *2.73 Gigajoules*.

**3. Merits of Ship Dismantling**

The vessels after becoming decommissioned are taken to ship dismantling yards. Ship dismantling is the reverse process of ship building. Therefore, the components of energy consumption will be similar to shipbuilding except that the energy in materials will not be there since no new material is added.

The Indian subcontinent accounts more than 70 percent of the global demolition. The importance of this industry can be gauged from the fact that the ships steel continues up to 8.5 percent of annual steel production in India.

Hence, it is clear that the ship is not dismantled but it is recycled, as world life fund defines recycling as the processing of waste or rubbish back into raw materials so that it can be made into new items.

| Consumable | Quantity | Energy | MJ |
|---|---|---|---|
| LPG | 15kg/ton | 45.8 GJ/TON | 687.7 |
| Oxygen | 70m3/ton | 5.04 MJ/$M^3$ | 352.8 |
| Diesel | 3.5ltrs/ton | 37.4 MJ/LTR | 130.8 |
| Electricity | 0.3 kWh/ton | 3.6MJ/KWH | 0.9 |

*Table 3*

In life cycle of a ship, last stage is dismantling and energy consumed in extracting one tonne of steel from ship is *1.17 Gigajoules* (table 3).

**4. Energy Conservation Measures for construction of Shipyard**

Energy saving measures to be considered while constructing a shipyard is detailed under each section.

*4.1. Replacing Portland Cement by Ternary Cement[v]*

From results of adiabatic temperature rise tests, concrete mixture mixed with Type IV cement displays the higher rate of heat evolution generated from hydration than those of concrete mixtures of ternary cements; PSLB-352 [ordinary Portland cement (30%),

blast furnace slag (50%), and class C fly ash (20%) and PSLB-442 [ordinary Portland cement (40%), blast furnace slag (40%), and class C fly ash (20%).]
It indicates that the ternary cements can be used as an alternative of Type IV cement for massive members.
Ternary cements provide economical and environmental advantages by reducing Portland cement production and CO2 emission, since it makes use of a high percentage of slag.

*4.2. Development of Sustainable Construction Material Using Construction and Demolition Waste.* [vi]
A sustainable construction material (brick) using construction & demolition (C&D) waste is used as fine and coarse aggregates.
Recycling is a major productive area in which considerable quantity of waste can be utilized for manufacturing new building materials. Embodied energy is such bricks (also known as eco-bricks) are found to be minimum. Eco bricks are energy and resource efficient bricks made with waste materials and produced using cleaner production techniques. With improved quality, they result in reduced carbon footprints while also reducing the stress on virgin resources.

*4.3. Moisture Susceptibility of Warm Mix Asphalt*[vii]
In case of asphalt pavement construction especially with hot asphalt mix (HMA), a high mixing and compaction temperature is required throughout the construction process to maintain sufficient workability. This high mixing and compaction temperature is required throughout the construction process to maintain sufficient workability.
It has been found that warm mix asphalt (WMA) can be used to replace WMA because it is produced at 20-40 deg C lower temperature than HMA but provides the same level of workability.
WMA also provides other advantages such as:
Better working condition due to absence of harmful gases
Lower energy consumption in mix production.
Quicker turnover to traffic.
Longer hauling distances.
Extended paving season
Also, lower void content due to improved compaction make the pavement more durable.

**5. Energy Conservation Measures for Ship building processes**
Majority of the ship building processes like cutting, welding, lifting, bending, moulding, blow drying etc. make use of electricity.

*5.1. Energy Efficiency in Manufacturing Operations.* [viii]
Energy consumed by a CNC machine tool consists of two parts: a fixed part and a variable part; the fixed part attributed by start up and certain running operations, whereas variable part varies with machine loads.
Total power consumed can be calculated as a sum of the standby power, cutting power and additional power losses. By optimizing the cutting parameters (spindle speed, feed rate and cutting depth), balance of process efficiency and carbon emissions can be achieved.

*5.2. Increasing Energy Efficiency for Welding* [ix]
Selecting and applying the right welding technology saves energy, material and manpower.
To be as energy-efficient as possible, welding processes must reduce spatter, achieve high weld speed, and significantly improve gap "bridge ability," while offering controllable heat input.
Three intelligent and practical solutions are— cold metal transfer (CMT), Laser Hybrid, and Delta Spot, the spot welding process — that improve efficiency and offer a quick return on investment.
Robotic welding may be cost-effective, but it must be a continuous, uninterrupted operation. Robots equipped with conventional metal active gas (MAG) welding systems must stop frequently in order to clean welding spatter from the nozzles. This offers plenty of scope for savings in time, energy and material.
Switching to the CMT process results not only in far less welding spatter, but in a considerably more stable metal transfer and a significant reduction in the tilt angle of the electrode. This alone reduces the stoppage time of the robot welding cells by more than 60%, and increases the efficiency of the electrical energy used.
If gap bridge ability is as high as possible, the time and costs required in preceding production stages is reduced and there is no need to fix the parts to be welded in position. Compared with conventional MIG or laser processes that use a cold wire feed, Laser Hybrid achieves three times the welding speed and, due to the lower energy input, consumes far less electrical energy while simultaneously reducing thermal distortion.
Conventional spot welding, especially of aluminium components, is characterized by high electrical consumption and high levels of electrode wear. The result is frequent stops while the electrodes are changed and high electrode costs.
The Delta Spot spot-welding system features a continuous process tape that runs between the electrodes and the sheets. This protects the electrodes, brings clean, fresh material to the contact points before each weld, and reduces total energy consumption. The flexible and totally controllable process permits continuous spot welding of a consistently high quality — regardless of the material to be welded. The demonstrable increase in product quality and system productivity, the reduced waste, and energy and material consumption savings all come together to provide a more efficient and stable production process.

*5.3. Aspects of Energy Efficiency in Machine Tools* [x]

Besides the use of energy-efficient motors in the auxiliary components, many possibilities for reducing the base load can be found in proper energy management. Measures to support the operator during setup also increase energy efficiency, because they shorten non-productive phases and reduce the influence of the base load. A requirement-oriented deactivation of auxiliary components therefore offers substantial potential energy savings. The CNC can be used as the central control unit for the energy management of a machine tool and its associated periphery.

*5.4. Reduction of Machine Idle Time through Optimal Support during Setup*

To reduce the energy requirement per part, non-cutting periods such as tool and set-up times should be kept as small as possible.

*5.5. Minimising the Scrap through Closed Loop Technology*

Analyses of metal-cutting processes show that the power consumption of a CNC control with feed-axis and spindle motors frequently comprise only 25 to 30 % of the total required power. On the other hand, the auxiliary components in the machine or its environment play a dominant role in the energy balance.

The selection of the position encoder can have a decisive effect on the efficiency of spindle motors and direct drives. Position encoders with high line counts are essential for the high efficiency of servo-controlled drives. It has been proven that linear encoders increase accuracy and therefore contribute to higher precision and reproducibility of machining results. This makes it possible to reduce waste in production and, as an immediate result, the energy requirement per good part.

*5.6. Energy Efficiency using Fibre Laser Cutting System* [xi]

Fibre laser technology has a series of advantages over $CO_2$ laser systems, in that it requires “virtually no maintenance,” is more energy efficient, and occupies less space on the shop floor. A laser power supply is smaller than a $CO_2$ supply; yet fibre delivery allows a laser beam to travel greater distances so larger cutting tables can be used.

**6. Measurement & Verification Process for Calculating and Reporting on Energy and Demand Performance** [xii]

The desired outcome of each of these project-specific M&V plans is to quantify the impact, or performance, to a stated degree of certainty, as a result of a particular Energy Efficiency & Demand Side Management EEDSM measure implemented.

In addition to the primary energy impacts (e.g. kWh consumption and kW demand during a certain period), an Energy Conservation Measure (ECM) often has secondary impacts such as extending equipment life cycles, increased worker productivity, increased quality control, etc.

The aim of measurement and verification (M&V) is to quantify the impact of implemented EEDSM projects. This impact is quantified by comparing the energy use before and after the intervention of EEDSM. The “before” case is referred to as the baseline; the “after” case is referred to as the post intervention or modified (actual) consumption.

*6.1*

a) Energy Regulations, Codes and Standards – The use of available energy regulations, codes, and standards is encouraged in order to provide a convenient, clearly defined, and consistent baseline energy use.
b) Common Practice – under certain circumstances, the use of “standard practice” or “market standard” may be more appropriate for baseline development. The key issue is to have the actual baseline development process well-documented and replicable.
c) Performance of similar systems (or buildings) without any of the proposed energy savings measures implemented – The use of standard technologies are often documented for use in similar systems or facilities and in similar economic sectors.
d) A benchmark determined by a national policy, regulation of administration and/or jurisdiction – This case is especially important when a grant for a new (Greenfield) project is introduced.

*6.2. Measurement and Verification (M&V) typically has the Following Stages*

a) Understanding of the planned Scope of Work
b) Development of the M&V Plan
c) Secure agreement for the M&V Plan
d) Pre-Implementation Measurements (in order to obtain the baseline)
e) Development of baseline according to the M&V Plan
f) Secure agreement for the Pre-Implementation (initial) baseline
g) Post Implementation Verification/Audit
h) Post Implementation Measurements
i) Adjustment of Baseline and Calculation of Performance
j) Produce and Submit M&V Performance Report
k) Repeat Cycle for Project or Contract Duration

*6.3. All EEDSM Projects Have the Following Three Standard Elements.*

a) Operating hours.
b) Load/Requirement.
c) System efficiencies

It is through changing any one, or any combination, of these three standard elements that savings are generated.

**7. Conclusions**

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.

The paper enlists energy consumption in shipbuilding in various sectors. However, there is need for further studies in order to validate the results. These results would stand as reference for any kind of energy estimation. Conservation methods have been discussed to preserve the non-renewable resources of energy.

**8. Practical Observations**

a) Due to ordering consumables on a refill basis for maintaining a minimum fixed stock in the warehouse, ship specific records regarding the ordering and utilization of consumables is not maintained by majority of the shipyards presently.
b) Most of the consumables are not issued ship-wise and procurement is done for a group of vessels.
c) A trivial amount of embodied energy is wasted as scrap, accurate value of which cannot be ascertained.
d) Entire shipyard has single energy meter, which reads the consumption of the electricity of the entire yard. This may include activities totally unrelated to shipbuilding (like ship repair activities carried out in the yard).

**8. Acknowledgement**

The authors would like to thank Ministry of Shipping for sanctioning the study on the Energy consumption in ship building and ship dismantling Industry and Director of Indian Maritime University, Visakhapatnam Campus, various shipyards and colleagues for their guidance, assistance and support for carrying out the study.

**9. References**

i. Energy Efficiency in Steel Industry and Clean development Mechanism, by Steel Authority of India Limited.
ii. Report by Climate Registry Default Emission Factors U.S. and EPA United States 2012.
iii. G.P. Hammond and C.I. Jones (2006) Embodied energy and carbon footprint database, Department of Mechanical Engineering, University of Bath, United Kingdom.
iv. Paint Energy by Hempel, Corporate Responsibility Report 2013.
v. Paper on Influence of cement type on heat of hydration and temperature rise of mass concrete, by MH Lee in Indian Journal of Engineering and material sciences.
vi. Paper on Development of sustainable construction material using construction and demolition waste, by V A Dakwale and R V Ralegaonkar in Indian Journal of Engineering and material sciences.
vii. Paper on Moistures susceptibility of warm mix asphalt, by Mehmet Bayazit in Indian Journal of Engineering and material sciences.
viii. Paper on Quantitative approach to analyse carbon emission of CNC based machining systems, by Ying Tang from Research Gate.
ix. Article from www.weldingdesign.com.
x. Article from www.heidenhain.us .
xi. Press release from www.hypertherm.com .
xii. Article from www.cleanenergyministerial.org