INTERNATIONAL JOURNAL OF INNOVATIVE RESEARCH & DEVELOPMENT

ISSN 2278 – 0211 (Online)

# Emerging Demand for Energy Efficiency – Role and Capability of Indian Register of Shipping

**A. R. Kar**
Indian Register, Department of Shipping, India
**S. S. Dhavalikar**
Indian Register, Department of Shipping, India
**D. R. Sonawane**
Indian Register, Department of Shipping, India
**P. Patil**
Indian Register, Department of Shipping, India
**D. B Prasada Naidu**
Indian Register, Department of Shipping, India
**D. B. Poojari**
Indian Register, Department of Shipping, India

***Abstract:***
*With increased awareness regarding efficient utilization of energy and decreasing emissions, maritime industry is striving to move towards integrated optimization. This paper highlights methodologies to achieve the same. Trim and Speed optimization studies with due consideration to minimum power in adverse condition is explained. EEDI assessor has been developed by Indian Register of shipping to calculate the ship's energy efficiency design index. Risk based approach is applied for alternative fuel i.e. LNG. Current development work is being carried out within IRS are brought out in this paper.*

***Keywords:*** *Trim/Speed Optimization, Maneuverability, Energy Efficiency, EEDI, LNG, Risk Assessment*

## 1. Introduction

International Maritime Organization (IMO) is working vigorously and consistently towards developing a comprehensive regulatory regime aimed at effectively protecting and preserving both the marine and atmospheric environment from pollution by ships. The objective of IMO is to further improve energy efficiency and reduce GHG emissions from international shipping through development of effective reduction measures.

In line with and in support to the IMO's objectives, Indian Register of Shipping is also working towards protecting and preserving the environment.

This paper details the work carried out by Indian Register of Shipping in the following areas:

- Energy Efficiency Design Index
- Safety aspects of Ship
- Minimum power requirements with due consideration to maneuverability in adverse conditions
- Trim and Speed Optimization using CFD
- LNG as an alternative
- Joint Industry Projects
- Sea Trial Analysis (STA)
- Design for Sea (DeFoS)

## 2. Energy Efficiency Design Index Calculator

Indian Register of Shipping IRS has come out with an EEDI calculator which is the implementation of the calculation guideline contained in IMO circular MEPC 1./Circ.681 and as amended. This accounts gram of CO2 exhausted per ton, per knot of cargo travel. Lesser EEDI value indicates more energy efficient ship.

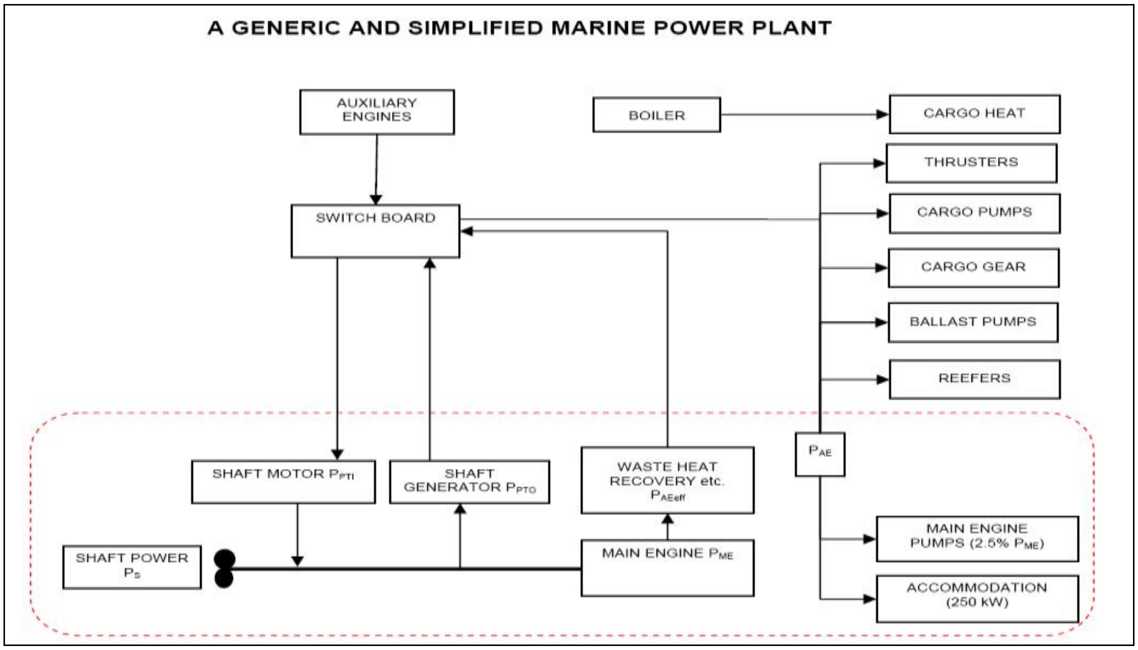



*Figure 1: Components affecting Attained EEDI*

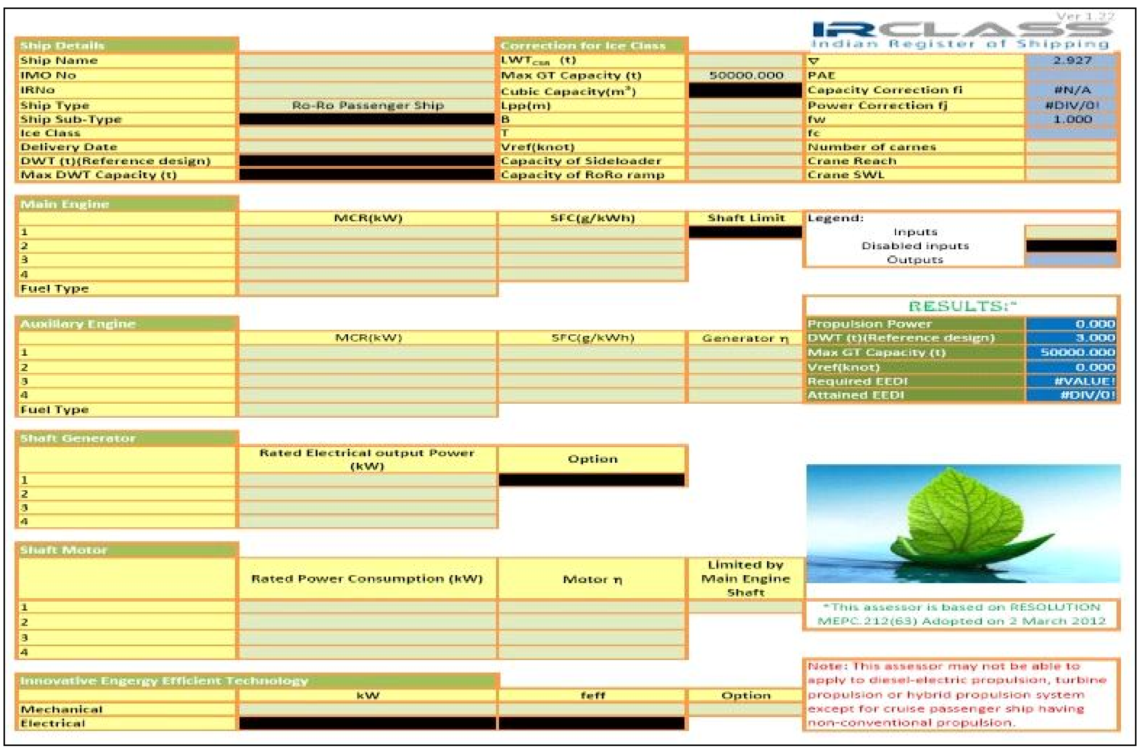
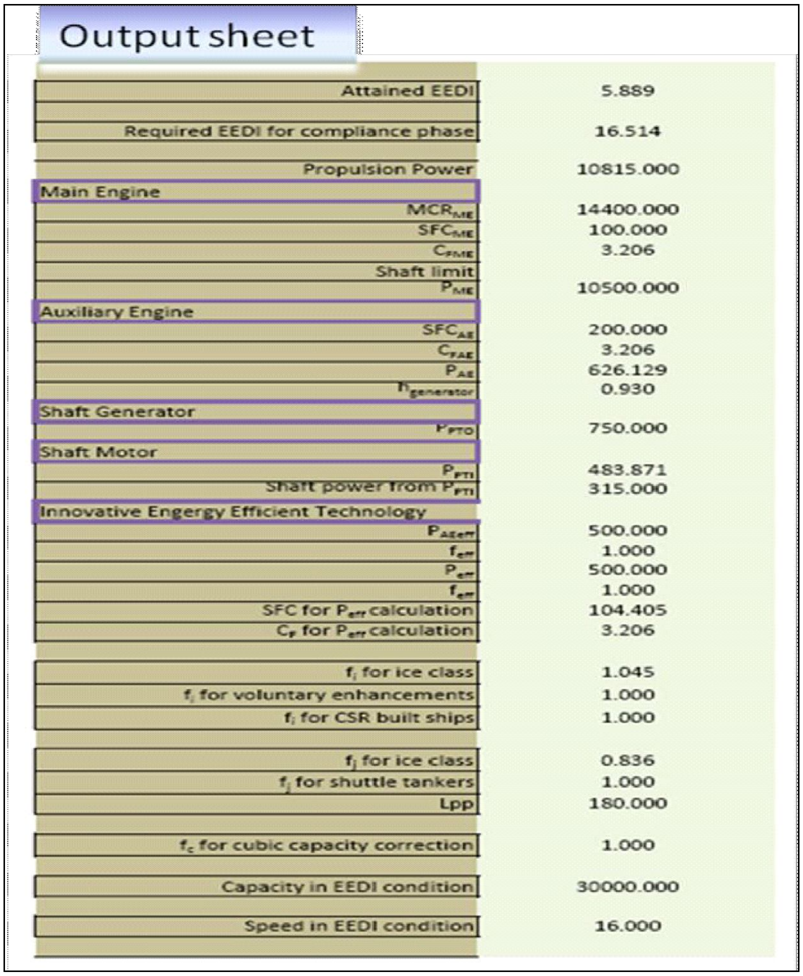



*Figure 2: IRS EEDI Calculator*

It calculates ship's attained as well as required EEDI, as applicable. It applies to bulk carriers, gas carriers, tankers, container ships, general cargo ships, refrigerated cargo carriers, combination carriers, LNG carrier, RO-RO cargo ship, Ro-Ro cargo ship (Vehicle carrier), Cruise Passenger Ship having non- propulsion and Ro-Ro passenger ship.



Output sheet

| | |
|---|---|
| Attained EEDI | 5.889 |
| Required EEDI for compliance phase | 16.514 |
| Propulsion Power | 10815.000 |
| **Main Engine** | |
| $MCR_{ME}$ | 14400.000 |
| $SFC_{ME}$ | 100.000 |
| $C_{FME}$ | 3.206 |
| Shaft limit | |
| $P_{ME}$ | 10500.000 |
| **Auxiliary Engine** | |
| $SFC_{AE}$ | 200.000 |
| $C_{FAE}$ | 3.206 |
| $P_{AE}$ | 626.129 |
| $\eta_{generator}$ | 0.930 |
| **Shaft Generator** | |
| $P_{PTO}$ | 750.000 |
| **Shaft Motor** | |
| $P_{PTI}$ | 483.871 |
| Shaft power from $P_{PTI}$ | 315.000 |
| **Innovative Engergy Efficient Technology** | |
| $P_{AEeff}$ | 500.000 |
| $f_{eff}$ | 1.000 |
| $P_{eff}$ | 500.000 |
| $f_{eff}$ | 1.000 |
| SFC for $P_{eff}$ calculation | 104.405 |
| $C_F$ for $P_{eff}$ calculation | 3.206 |
| $f_i$ for ice class | 1.045 |
| $f_i$ for voluntary enhancements | 1.000 |
| $f_i$ for CSR built ships | 1.000 |
| $f_j$ for ice class | 0.836 |
| $f_j$ for shuttle tankers | 1.000 |
| Lpp | 180.000 |
| $f_c$ for cubic capacity correction | 1.000 |
| Capacity in EEDI condition | 30000.000 |
| Speed in EEDI condition | 16.000 |

*Figure 3: IRS EEDI Calculator Output*

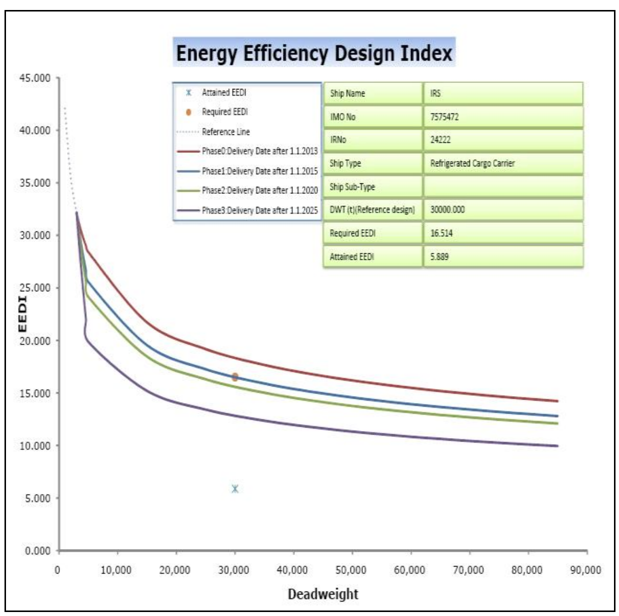



*Figure 4: EEDI Attained vs Required*

The calculator gives visual representation by plotting required and attained EEDI against the ship type reference line and associated phase limits for required EEDI. It also helps in calculating the propulsion power and deadweight capacity for the index condition.

This calculator will provide an easy way to optimize ship design parameters.

**3. Safety Aspects of Ship**

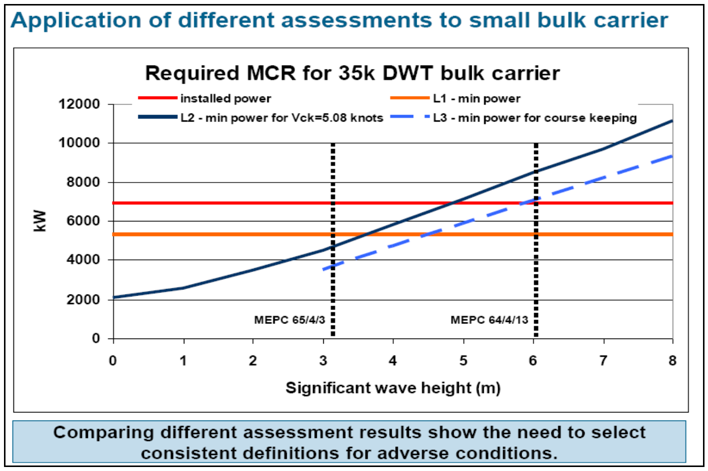



*Figure 5: Required MCR*

There has been a concern raised in the maritime industry and IMO that in course of considering Energy Efficiency of a ship there exist potential danger of compromising the safety aspects, primarily in the context of controllability of the ship in rough sea condition. As there probably be tendency to optimize hull form and powering of the ship in view of meeting energy efficiency regulatory requirements. In this respect course keeping and maneuverability properties of the ship are considered important parameters to reduce risk in the sea way. A safer ship should have adequate properties to ensure course keeping, turning and stopping abilities as well as safe maneuvering in shallow waters and in adverse conditions like wind, wave and currents. The basic maneuvering aspects are depended on the ship's hull and machinery and hence these require to be consciously investigated.

Adverse Condition is defined as mentioned in the Table 1.

| | Return period | Sig. wave height (m) | Wave period (s) | Wind (Bft.) |
|---|---|---|---|---|
| MEPC 62/5/19 | One week | 7.5 | 7.5 to 14.5 | 9 |
| | One month | 9.8 | 8.5 to 13.5 | 10 |
| MEPC 64/4/13 | Two days | 6.0 | 8.0 to 15.0 | 8 |
| *MEPC 65/4/3* | | *3.0 to 5.5* | | *7* |

*Table 1: Adverse Condition*

We are working on the maneuverability characteristics of the vessel so as to assess and ensure that the vessel complies and provides safe sailing. Different vessel types are chosen for the analysis. CFD analysis done on the vessel provides us with forces and moments acting on the vessel in calm sea, the hydrodynamic derivatives of the vessel are determined from them and then the vessels trajectory is determined which provides us with fair idea of its maneuverability characteristics and hence its safety in the sea way.

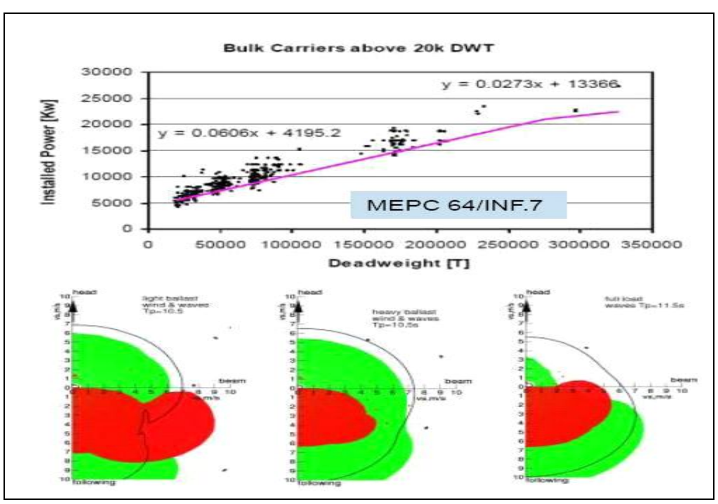
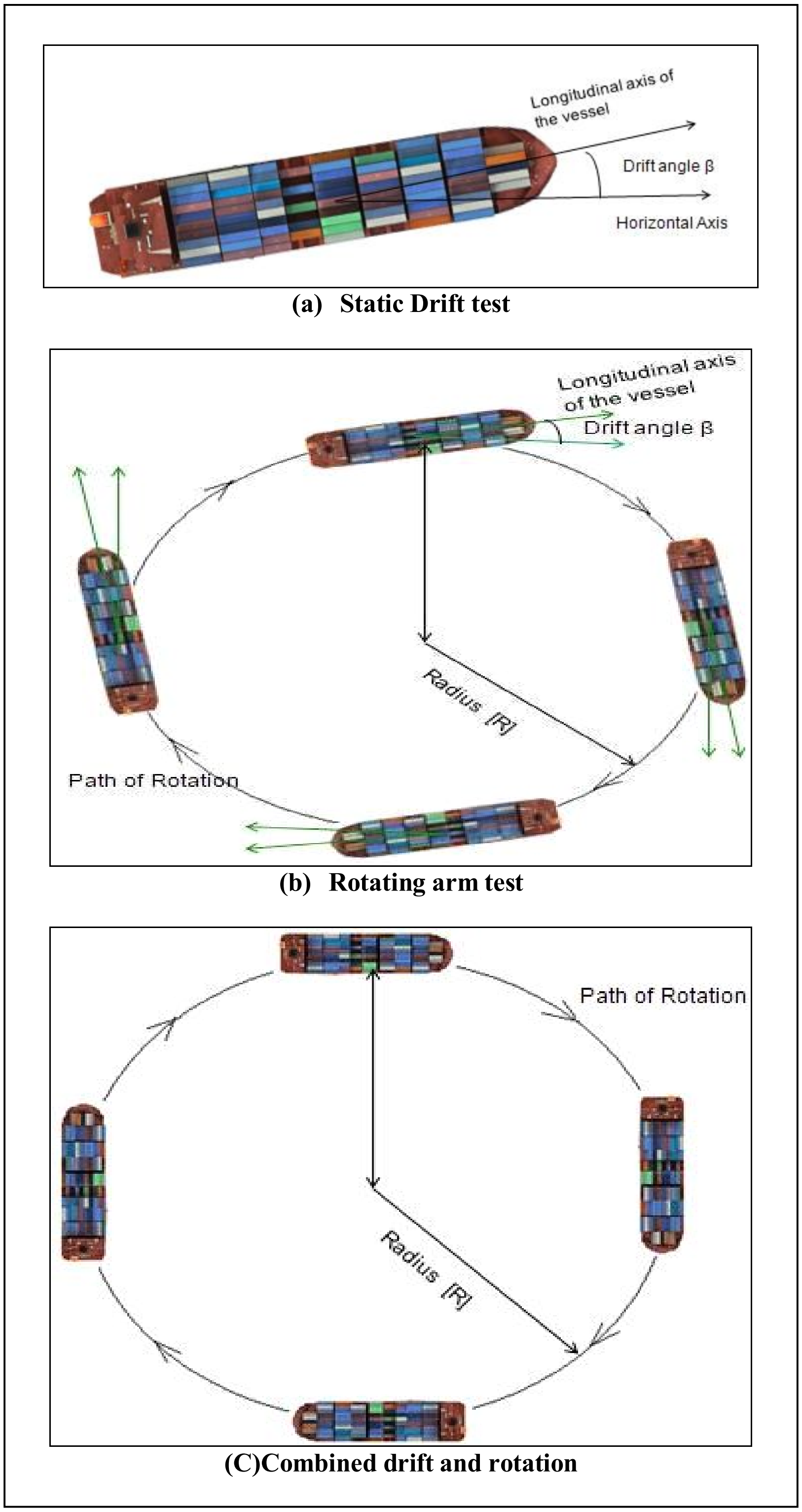



*Figure 6: Adverse conditions 3 approaches, wind and wave conditions*

Also, the effect of adverse conditions on the maneuverability is being researched by us.




**(a) Static Drift test**

**(b) Rotating arm test**

**(C)Combined drift and rotation**

*Figure 7: Tests Carried out Numerically*

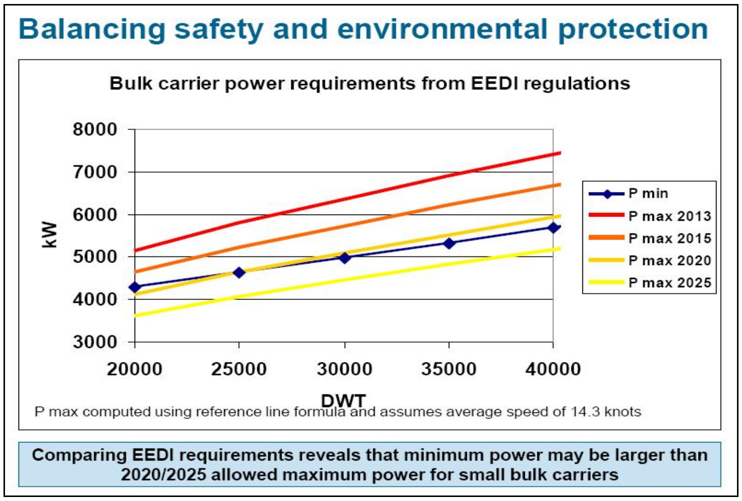



*Figure 8*

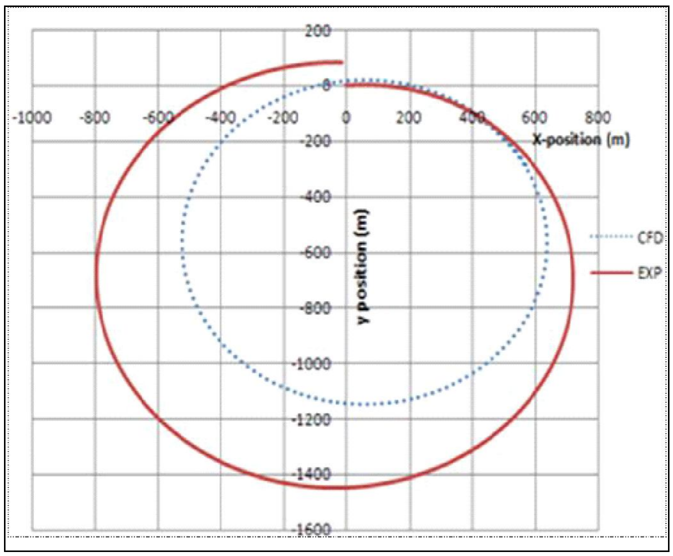



*Figure 9: Turning Circle*

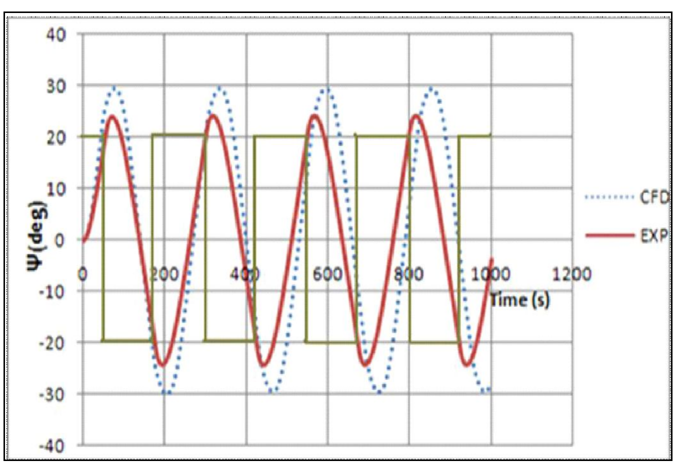



*Figure 10: Zig-Zag*

In this area EU has constituted a funded research project named EU-SHOPERA of which IRS is a member of its advisory committee. The main focus of this project is to develop a standard for requirements to ensure safe maneuvering of energy efficient ship. The objective of this work is to draw a right balance between the ships efficiency and safety.

**4. Trim and Speed Optimization**

Increasing fuel prices and environmental awareness is putting more pressure on the designers to minimize the fuel consumption. The fuel efficiency of ships is becoming more important as maintaining Ship Energy Efficiency Management Plan (SEEMP) is made mandatory by International Maritime Organisation.

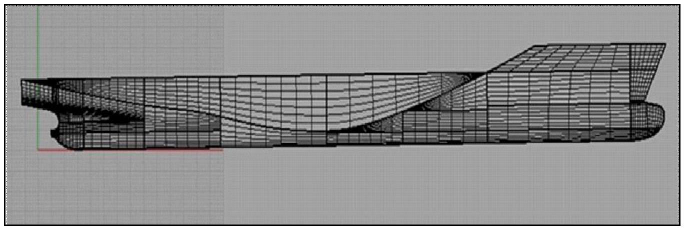


*Figure 11: Snapshot of Profile view at 0.6 degree trim.*

Designs of majority of ships are optimized for only one set of displacement, speed and trim (Designed values). It is realized that the trim affects the hydrodynamic factors of a vessel. Effect of trim on vessel performance in different conditions is therefore an essential step towards improving the operational efficiency and reducing the fuel consumption and corresponding emissions to air.

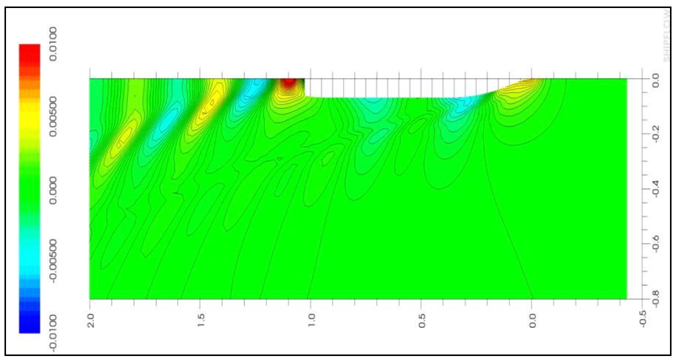



*Figure 12: Freesurface for 0.2 degree trim for full displacement at 11.40 m/s forward speed.*

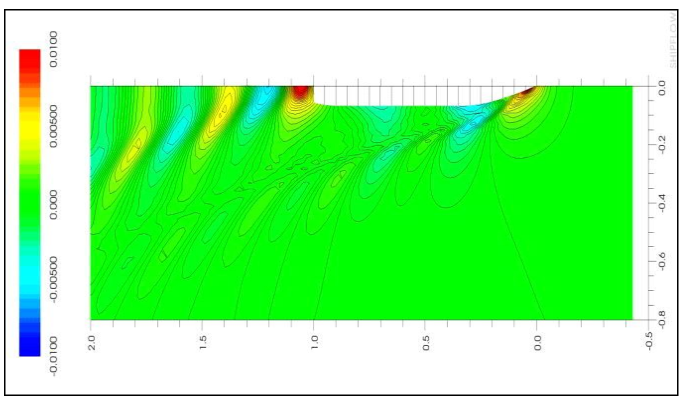



*Figure 13: Freesurface for -0.8 degree trim for full displacement at 11.40 m/s forward speed.*

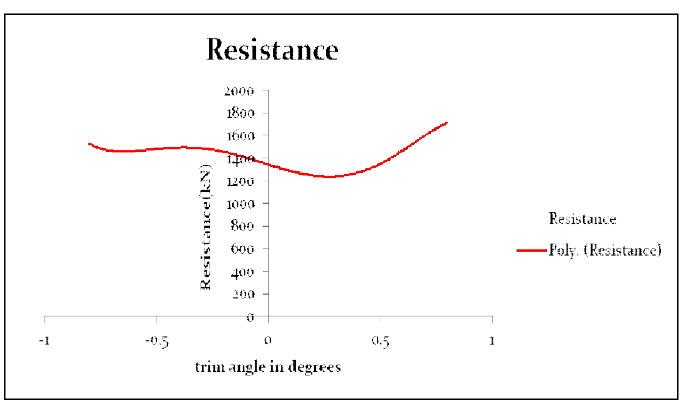



*Figure 14: Resistance versus trim angles for full displacement at 11.40 m/s forward speed*

The goal of this work is to numerically simulate and analyze the vessel's resistance in calm water for different combinations of trim, displacement and speed to obtain optimum trim and speed for respective displacements. The resistance values obtained from numerical code are validated with the model test results.

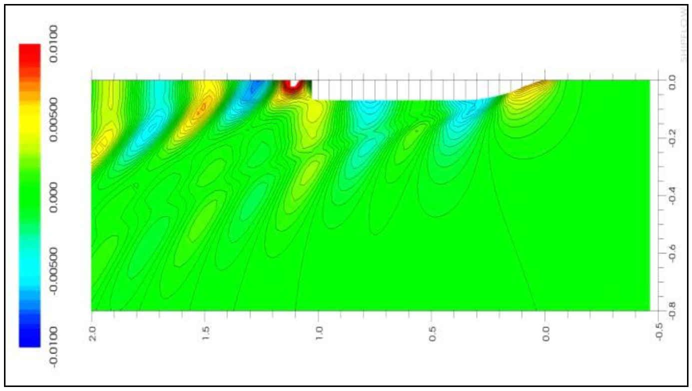


*Figure 15: Freesurface for 0.4 degree trim for full displacement at 12.35 m/s forward speed.*

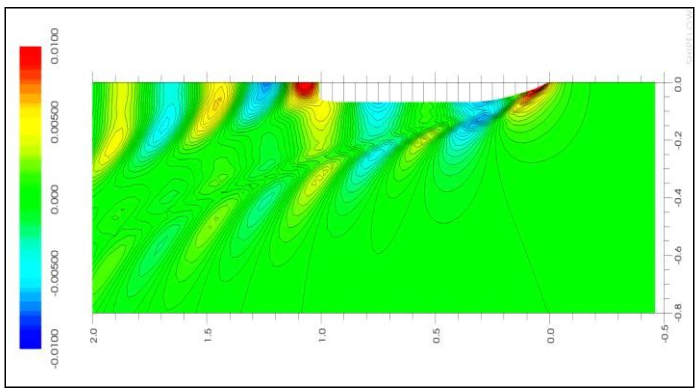


*Figure 16: Freesurface for -0.8 degree trim for full displacement at 12.35 m.s forward speed.*

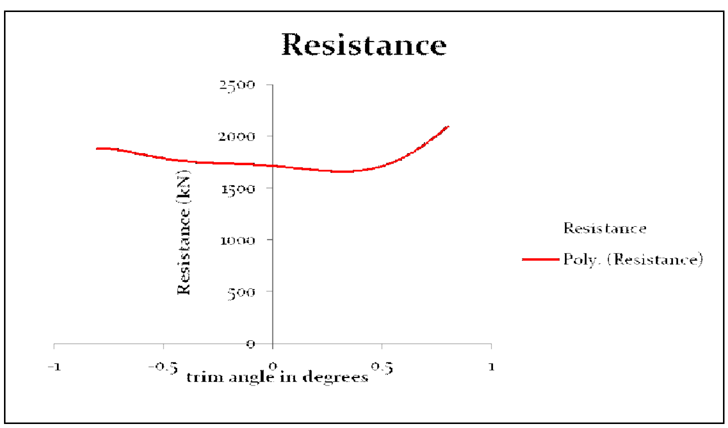



*Figure 17: Resistance versus trim angles for full displacement at 12.35 m/s forward speed.*

The KRISO container ship hull form has been taken for the trim optimization exercise. A series of resistance computation are made for different configurations. Graphs of Resistance versus Trim have been generated to provide optimum trim value for a given displacement and speed.

Therefore, performing a trim study has potential for saving of fuel and reduction of emission significantly. It will provide adequate information to the ship operators to enable taking appropriate measures for saving of fuel and improving relevant regulatory compliance.

**5. LNG as an Alternative**

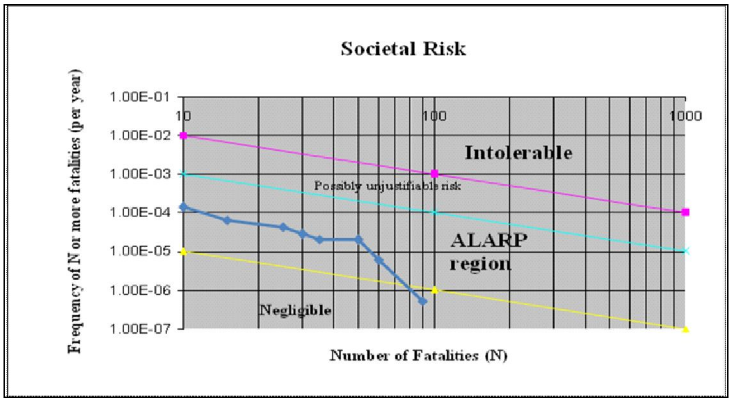



*Figure 18: F-N Curve*

IRS has developed capability to identify hazards by using techniques such as HazOp, What-if analysis, Hazard index – Dow's Fire & Explosion index method. The hazard identified can be used for detailed Quantitative Risk Assessment (QRA). HAZOP is a systematic review of the process plant design, to evaluate the effects of deviations from normal operating conditions. It is normally used to generate recommendations to improve the safety and operability of a design.

IRS has developed capability to carry out quantitative risk assessment of ports and terminals and based on risk identified to prepare an effective emergency action plan to reduce the consequence.

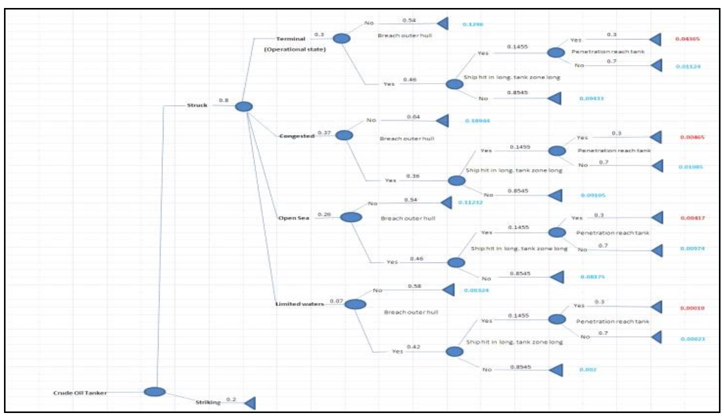


*Figure 19: Event Tree*

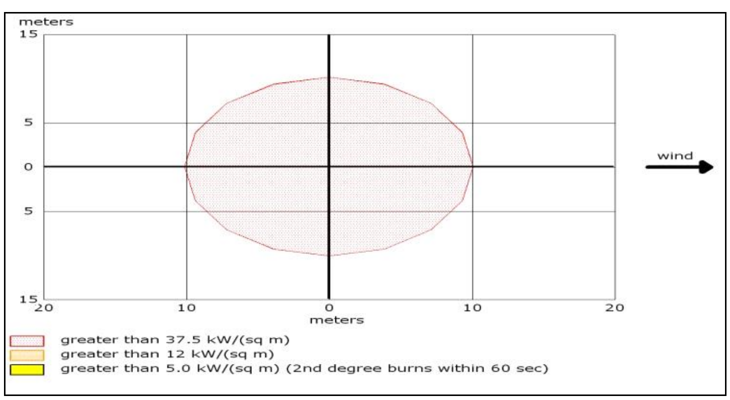



*Figure 20: LNG Jet Fire*

QRA involves four steps such as hazard identification, failure frequency estimation, consequence estimation and risk estimation. IRS has developed in house tools for evaluating thermal radiation levels of concern for fire (pool fire, jet fire, flash fires), overpressure levels of concern for explosion (Bleve, vapor cloud explosion), toxic levels of concern (Toxic hazards), which is used for consequence analysis.

IRS has also developed capability to carry our risk analysis, flammable and toxic dispersion analysis and evacuation analysis for collision scenario of LNG fuelled vessel.

| What If | Causes | Consequences | Safeguards | Recommendations/ Comments |
|---|---|---|---|---|
| 1. What if there is an LNG leak from pump /piping/hoses during transfer? | - Corrosion/erosion<br>- External impact<br>- Fatigue<br>- Gasket failure<br>-Hose failure or Disconnection<br>-Improper hose Connection<br>-Improper Maintenance<br>-Material defect (e.g. weld)<br>-Piping not properly cooled down prior to transfer<br>-Use of inappropriate hoses (e.g. not LNG rated)<br>-Valve leaking<br>-Vibration<br>-Excessive movement of hose<br>-Supply truck drives away with hose connected<br>-Another vessel collides with the receiving vessel<br>-Cargo dropped onto pipeline/hose<br>-Fire aboard the receiving vessel<br>-Extreme sea State<br>-Earthquake | - Small release of LNG, may resulting in brittle fracture of ship deck;<br>- Fire/explosion/Cryogenic hazards to equipment in the immediate area;<br>- Fire/explosion/Cryogenic hazards to personnel in the immediate area | -Bunkering procedures<br>-Communication between person in charge<br>-Controls and/or prohibitions of simultaneous passenger and bunkering operations<br>-Drip tray<br>-ESD system<br>-Flammable material detectors<br>-Designed breakway coupling protects other equipments<br>-Equipment inspection/testing of equipment<br>-Maintenance procedures<br>-Supervision during transfer operation<br>-PPE<br>-Use of certified hose<br>-Vessel emergency response plan<br>-Port emergency response plan<br>-Appropriate electrical classification in bunkering area to limit ignition sources | |
| 2. What if there is an LNG leak from pump/ piping/hoses during transfer? | -Corrosion/erosion<br>-External impact<br>-Gasket/packing failure<br>-Improper maintenance | - Small release of LNG<br>- Small release of LNG, resulting in fire damage to Truck tank | -Bunkering procedures<br>-Controls and/or prohibitions of simultaneous passenger and bunkering operations | |

*Figure 21: What-if analysis*

Stringent international regulations on emissions are forcing the shipping industry to rethink its fuelling options. The IMO's Marine Environmental Protection Committee has introduced emission controls, which will increasingly affect international shipping over the next decade. The introduction of Emission Control Areas (ECA's) in European, U.S. and Canadian territorial waters means that ship owners must begin to consider alternatives to traditional heavy fuel oil. One solution is the switch to LNG as ship fuel. The use of Liquefied Natural Gas (LNG) as a ship fuel is one possible solution to reduce the atmospheric emissions from shipping to air. To ensure a competitive fuel supply, LNG bunkering must be possible for each type of gas-fuelled vessel under the same conditions as bunkering Heavy Fuel Oil (HFO). This includes the safe bunkering of LNG during cargo loading and unloading, as well as during passenger embarking and disembarking operations.

IRS has initiated work on operational risk analysis of LNG bunkering and installation to analyze the effects of LNG spills on structures and human beings in terms of Flammable and toxic dispersion analysis.

**6. Participation in Joint Industry Project**

IRS has joined the joint industry projects Sea Trial Analysis (STA) and Design for Sea (DeFoS) conducted by MARIN. STA has developed recommended practice and analysis for sea trials. Also software STAIMO is developed for onboard analysis and reporting of sea trials. This software is in accordance with ITTC guidelines for sea trials as adopted by MEPC 64. Powering calculations of a vessel are done for contract and EEDI conditions. Reference speed for EEDI is calculated within the software.

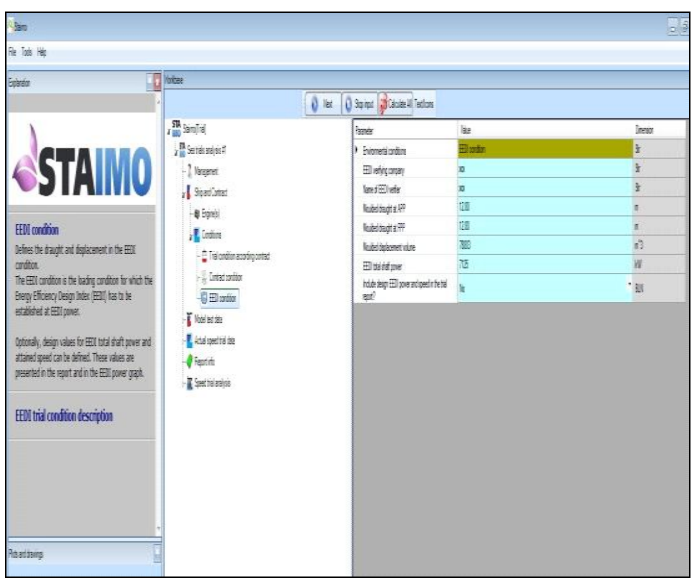



*Figure 22: STA Software*

Final powering calculations depend on sea margin calculations. Hence, DeFoS is aimed at accurate sea margin calculations. Operational profile of the vessel is taken into account for sea margin calculations. Software for these calculations is under development. Also weather dependent factor for EEDI is targeted in DeFoS.

**7. Conclusions**

Much work needs to be done in the areas mentioned above to have a look at the regulatory impact. Integrated approach is to be taken to assess the overall increase in energy efficiency when multiple strategies are employed to achieve improved EEDI.

**8. Acknowledgements**

The author's of this paper would like to thank the senior management of IRS for their continual support in encouraging state of the art research within IRS.

**9. References**

i. Deepti Poojari, Sheeja Janardhanan, A.R Kar, "Maneuverability Assessment of a container ship Using Steady RANS method," Proceedings of the Twenty-fourth (2014) International Ocean and Polar Engineering Conference, Busan, Korea, June 15-20, 2014
ii. Crane, CL, Eda, H and Landsburg, A (1989) "Controllability," Principles of Naval Architecture, Vol 3, pp 200-258.