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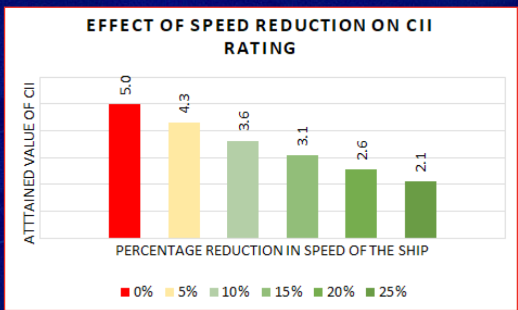
Criteria related to the speed of the vessel	Year 2023	Year 2024	Year 2025	Year 2026
CII Rating at the design speed	D	D	E	E
CII Rating with 5% reduction in the design speed	C	C	C	C
CII Rating with 10% reduction in the design speed	A	A	B	B
CII Rating with 15% reduction in the design speed	A	A	A	A



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Challenges in Locating Objects Lost in the Ocean

The Institute of Marine Engineers (India)

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EDITORIAL

Fear is the non-acceptance of uncertainty, if we accept it, it becomes an adventure.

- Rumi

The post-pandemic (are we really past the pandemic?) times have been turbulent and at many fronts, uncertain. India's economy scorecard is an example. Let us home in on shipping ...

India has over 1400 vessels and about 90-95% of India's trade is through the Indian Ports; 80% of ship recycling happens in and around the Indian sub-continent; India is amongst the top 5 largest seafarer-supplying Nations.

Given all these, we seem to have missed the boat in terms of tonnage, shipbuilding etc. The inertia is attributed to high tax/duty regimes, aging vessels (average age of Indian vessels >20 years) and insufficient infrastructure etc. Looking at the canvas, a major reason could be that the vision has been eluding.

We can consider a few pointed indicators from the progress made in the last decade: >190 Projects completed under Sagarmala; average Container turnaround down to 27 hrs; Cargo movement in national waterways >100 MT. With the Sagarmala progress and the thrust into our inland waterways, the tangible targets in MIV 2030 (e.g., 200 million MT by inland waterways) including ports modernisation, skills development etc., could be realised.

Further, the Financial Assistance Policy is supposed to fire up the shipyards and the Atmanirbhar Bharat Abhiyan (around ₹1600 Cr.) assistance is expected to make our shipping companies globally competitive. We hope that these adventures attain fruition.

Considering the current turbulent times, there is another acceptance we may find wanting...

Rumi defines anger as something born out of non-acceptance of things which are not under our control. With the acceptance, it turns into tolerance.

It would be worth ruminating on these words by Rumi.

In this issue...

The recently concluded MEPC 78 meet discussed the finalisation of technical guidelines for EEXI etc. In step, we present a study on the EEOI and CII estimations. Dr. Sindagi and Venkat Krishna have analysed the estimates considering a Bulk Carrier with varying load conditions and vessel speeds. The interesting study presents few good pointers as to how the EEOI may be maintained lower. The other takeaways are the proposed method for EEOI estimation in ports and the discussion on how operating parameters affect the CII. Sailing marine engineers will certainly find this interesting and comprehensible too.

We follow this with an immersing, long discussion on an ocean-related topic. The mystery of the missing planes and vessels in the deep waters have drawn our attention only from the merit of being sad news. The mechanism and the scientific approach towards searching for the missing things must be of interest to any engineering mind. Dr. Veda provides the information and discusses few well known disappearances.

The posterior probability mapping using historical data effectively, the Underwater Locating Beacon, locating debris with sonar imaging are interesting takeaways. The Multi Beam Sonar and the generation of the swath is explained in a simple manner and so is the discussion on the Synthetic Aperture Sonar. The explanation of the SOFAR idea keeps the discussion absorbing. The concluding sections summarise the understanding. Even missing all the mathematics, one would still grasp these deep water detection discussions.

A note to the readers: Hoping that interest would sustain as also that the topic needs an unbroken thread, we are hosting the article in one go (instead of in Parts). Would welcome your views.

Following the missing objects, we have a discussion on scrubbers Vijayakumar and Gautamgopinath highlighting the often-talked merits making them a preferable emission solution. Under Technical Notes, the Lube Matters deal with Polymer Additives and have one more write-up on auto berthing mechanism. And we continue our archive adventure with extracts from MER July 1982 issue.

As we flip through this July issue, let us hope that the ticking numbers are temporary and the infections would slide down, as also that the other jitters (national and global) would settle. Yet again, we may reflect on Rumi's wisdom.

Dr Rajoo Balaji
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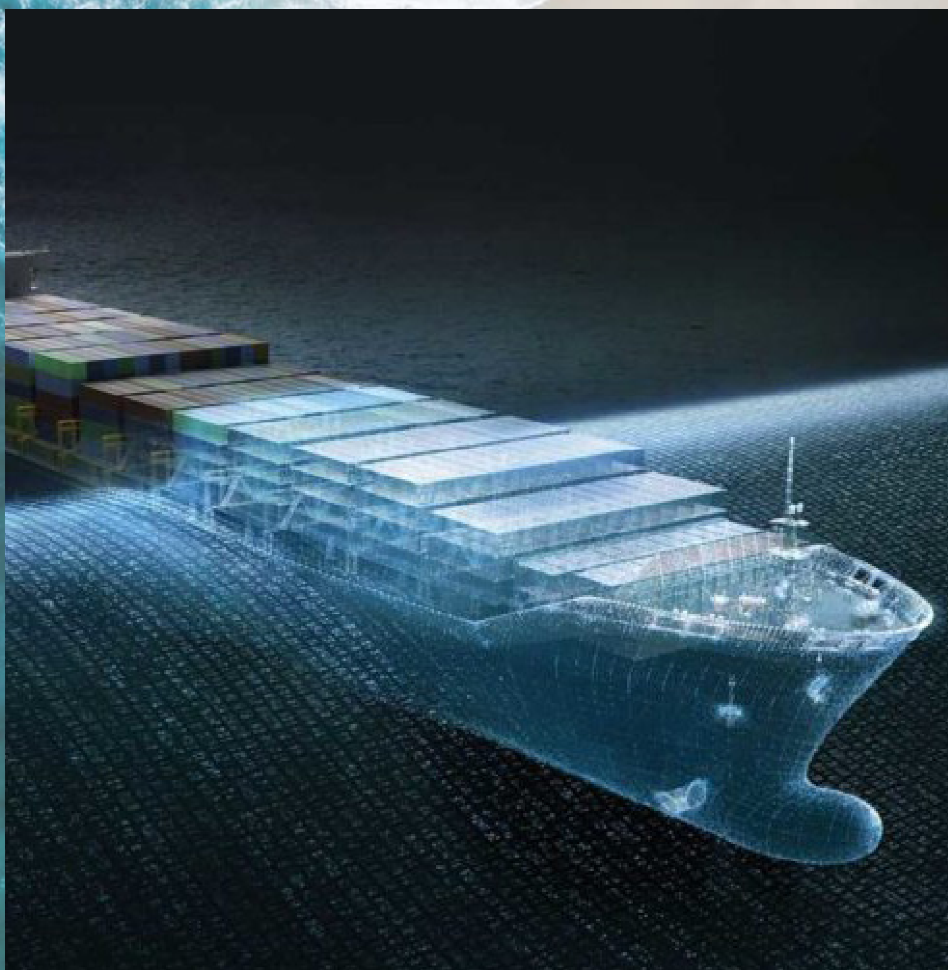

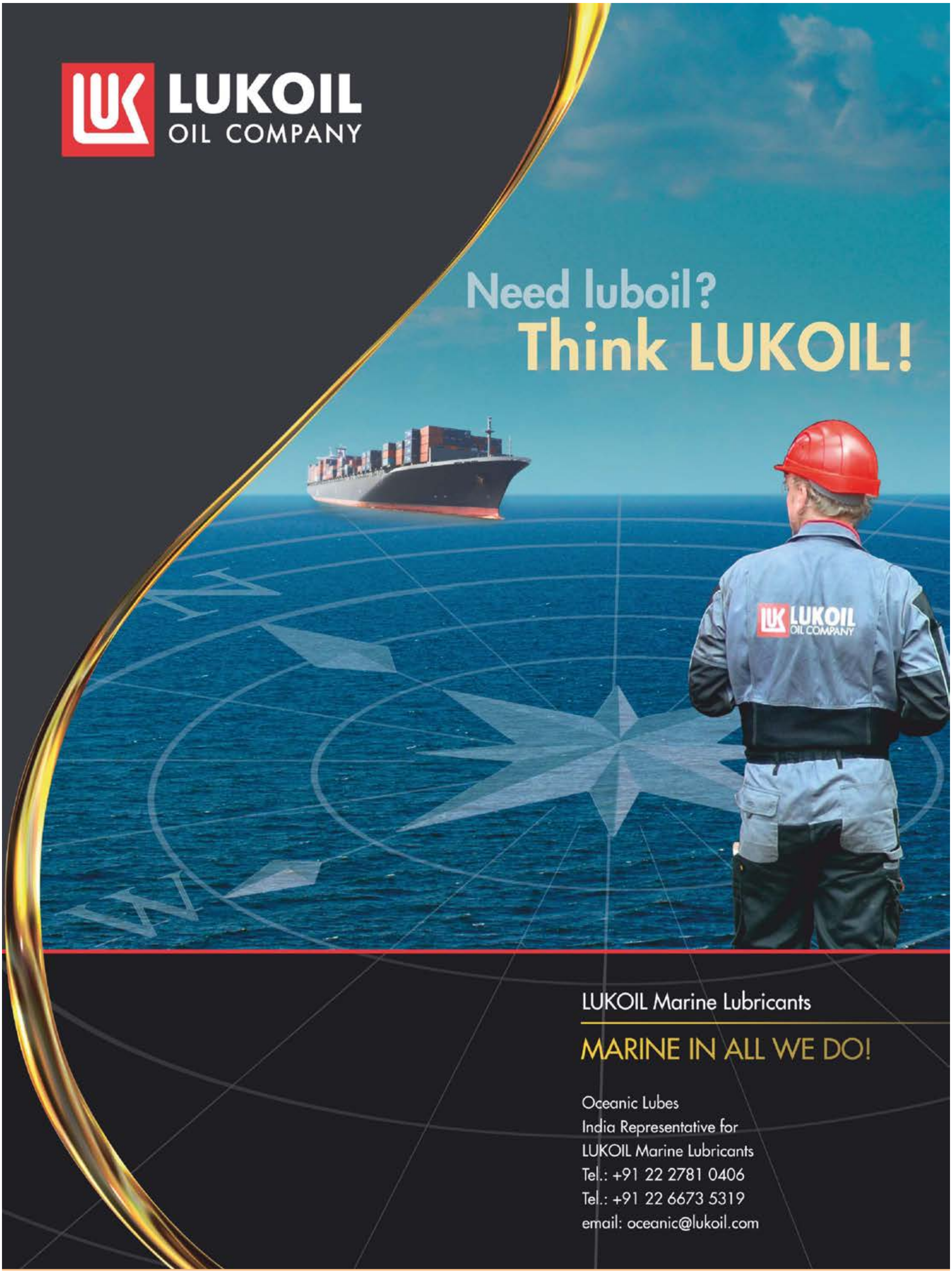
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INVESTIGATION OF THE ENERGY EFFICIENCY OPERATING INDEX (EEOI) AND CARBON INTENSITY INDICATOR (CII): A CASE STUDY FOR THE BULK CARRIER

Sudhir Sindagi
S. Venkat Krishna

ABSTRACT

IMO has adopted mandatory measures to reduce emissions of greenhouse gases from international shipping. The initial GHG strategy envisages, a reduction in carbon intensity of international shipping. To achieve the target set, IMO proposed the use of EEDI, EEXI, EEOI and CII as the measures to control and reduce emissions and circulated the guidelines for the same. These Guidelines can be used in the evaluation of the ship with regard to CO_2 emissions. As the amount of CO_2 emitted from a ship is directly related to the consumption of bunker fuel oil, the EEOI and CII can also provide useful information on a ship's performance with regard to fuel efficiency. In this paper, investigations on EEOI and CII for the Bulk carrier have been carried out for various loading conditions and the speeds of operation of the ship. This investigation has been carried out by reducing the speed of the ship, by increasing the energy efficiency of the vessel, by increasing the cargo carrying capacity of the vessel, and by changing the type of the fuel used with lowest value of conversion factor. The investigation will have the great importance for the ship owners, ship operators and the parties concerned to know the effect of various operating parameters on CII rating of the vessel. The paper also includes the methodology proposed to estimate the EEOI values during the port operations.

1. INTRODUCTION

IMO continues to contribute to the global fight against climate change, in support of the UN Sustainable Development Goal, to take urgent action to combat climate change and its impacts. IMO has adopted mandatory measures to reduce emissions of greenhouse gases from international shipping, under IMO's pollution prevention treaty (MARPOL) - the Energy Efficiency Design Index (EEDI) mandatory for new ships, and the Ship Energy Efficiency Management Plan (SEEMP). In 2018, IMO adopted an initial strategy on the reduction of GHG emissions from ships, setting out a vision which confirms IMO's commitment to reducing GHG emissions from international shipping and to phasing them out as soon as possible. The details of which are placed in the **Figure 1**. The Initial Strategy identifies levels of ambition for the international shipping sector noting that technological innovation and the global introduction of alternative fuels and/or energy sources for international shipping will be integral to achieve the overall ambition[1], [2]. Levels of ambition directing the Initial Strategy are as follows:

a. Carbon intensity of the ship to decline through implementation of the Energy Efficiency Design Index (EEDI) for new ships and the Energy Efficiency existing ship Index (EEXI) for old ships and Carbon Intensity Indicator (CII) for all the vessels;

b. Carbon intensity of international shipping to decline to reduce CO_2 emissions per transport work, as an average across international shipping, by at least 40% by 2030, pursuing efforts towards 70% by 2050, compared to 2008;

c. To reduce the total annual GHG emissions by at least 50% by 2050 compared to 2008.

The energy-efficiency requirements were adopted as amendments to MARPOL Annex VI in 2011 and they entered into force on 1 January 2013. The regulations make mandatory the Energy Efficiency Design Index (EEDI) mandatory for new ships, and the Ship Energy Efficiency

Management Plan (SEEMP) is made a requirement for all ships. In this paper, an investigation on EEOI and CII for the Bulk carrier has been carried out for various loading conditions and the speeds of operation of the ship. The paper has the following major sections:

A. Methodology used for the investigation

B. Results and discussion

   i. Energy Efficiency Operational Indicator (EEOI)

   ii. Carbon Intensity Indicator (CII)

   iii. Proposed methodology to estimate the EEOI values during the port operations

C. Effect of various operating parameters on CII rating of the vessel

   i. Effect of speed reduction

   ii. Effect of enhancing the energy efficiency

   iii. Effect of Deadweight capacity

   iv. Effect of type of fuel oil used for the propulsion

2. METHODOLOGY USED FOR THE INVESTIGATION

In its most simple form, the Energy Efficiency Operational Indicator is defined as the ratio of mass of CO_2 emitted per unit of transport work.

$$EEOI = \frac{\text{Mass } CO_2 \text{ emmitted}}{\text{transport work}}$$

$$EEOI = \frac{\text{Fuel Consumed} * C_F \text{ of the fuel}}{\text{Mass of Cargo transported} * \text{Distance Sailed}}$$

C_F of the fuel is a non-dimensional conversion factor between fuel consumption measured in grams and CO_2 emission. The value of C_F for different types of fuel are shown in **Table 1**.

The average of the EEOI for a period or for a number of voyages is obtained as shown below:

$$\text{Average EEOI} = \frac{\sum_i \sum_j (FC_{ij} \ X \ C_{Fj})}{\sum_i (m_{cargo,i} \ X \ D_i)}$$

In the Initial IMO Strategy on reduction of GHG Emissions from Ships (Resolution MEPC.304(72)) [1], [11]–[15], the level of ambition on carbon intensity of international shipping is quantified by the CO_2 emissions per transport work, as an average across international shipping. These Guidelines address the calculation methods and the applicability of the operational carbon intensity indicator (CII) for individual ships to which chapter 4 of MARPOL Annex VI, as amended, applies. For the calculation of Carbon Intensity Indicator (CII), the following guidelines have been adopted.

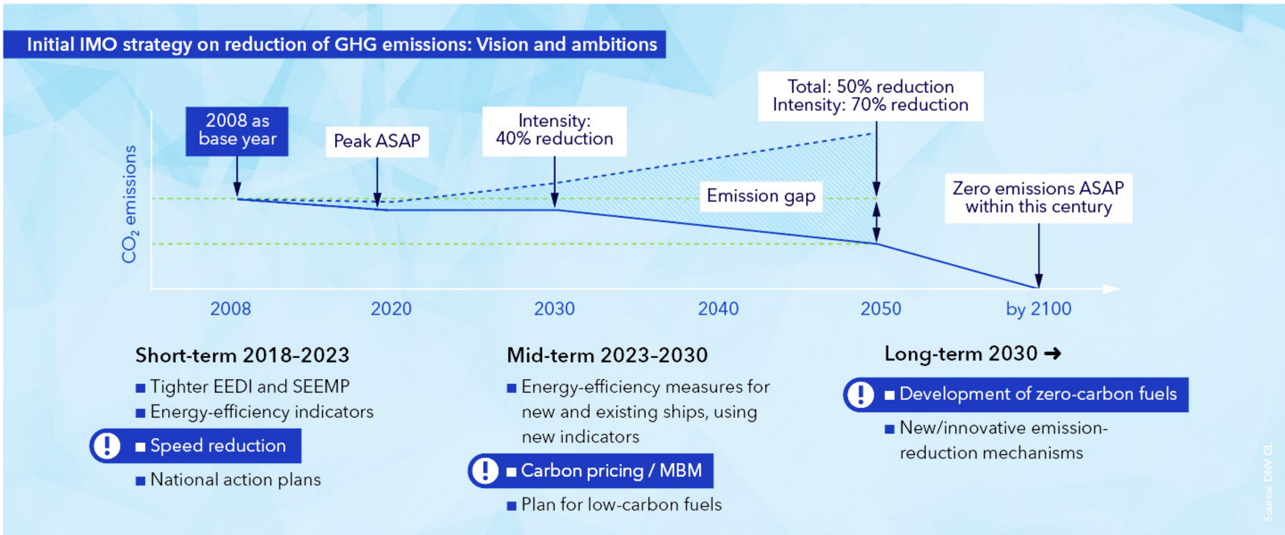

Figure 1: The initial IMO strategy on reduction of GHG emissions

Table 1: Type of fuel used along with respective conversion factors

Type of fuel	Reference	Carbon content	C_F (t-CO_2/t-Fuel)
1. Diesel/Gas Oil	ISO 8217 Grades DMX through DMC	0.875	3.206
2. Light Fuel Oil (LFO)	ISO 8217 Grades RMA through RMD	0.86	3.15104
3. Heavy Fuel Oil (HFO)	ISO 8217 Grades RME through RMK	0.85	3.1144
4. Liquified Petroleum Gas (LPG)	Propane	0.819	3
	Butane	0.827	3.03
5. Liquified Natural Gas (LNG)		0.75	2.75

a. Guidelines on operational carbon intensity indicators and the calculation methods (CII guidelines, G1)

b. Guidelines on the reference lines for use with operational carbon intensity indicators (CII Reference line guidelines, G2)

c. Guidelines on the operational carbon intensity reduction factors relative to reference lines (CII Reduction factor guidelines, G3)

d. Guidelines on the operational carbon intensity rating of ships (CII Rating Guidelines, G4)

Rating of each vessel by CII from 2023 consumption data (CII Guideline, G1) "A" – "E" rating has been calculated in accordance with Reference Line guideline (G2), Reduction Factor guideline (G3) and Rating guideline (G4).

In its most simple form, the Carbon Intensity Indicator (CII) is defined as the ratio of mass of CO_2 emitted per unit of transport work.

$$\text{Attained CII} = \frac{\text{Mass } CO_2 \text{ emmitted}}{\text{transport work}} = \frac{\text{Fuel Consumed} * C_F \text{ of the fuel}}{\text{Deadweight} * \text{Distance Sailed}}$$

Deadweight is proposed to use for the vessels like Bulk carriers, Tankers, Container ships, Gas carriers, LNG carriers, Ro-ro cargo ships, General cargo ships, Refrigerated cargo carrier and Combination carriers. For the vessels like cruise passenger ships, Ro-ro cargo ships, (vehicle carriers), Ro-Ro passenger ships, Gross Tonnage is proposed in place of Deadweight tonnage.

As shown in the **Figure 2,** the Reference value of CII (CII ref) is calculated using the formula

$$\text{CII Ref} = a \text{ Capacity}^{-c}$$

The values of constant a & c depend on the type of the ship and their deadweight capacity. Required CII values for the years 2023, 2024, 2025 & 2026 are calculated using reduction factors (Z) using the formula

$$\text{Required CII} = \frac{100 - Z}{100} * \text{CII ref}$$

Reduction factor (Z%) for the CII relative to the 2019 reference line are taken as per the declared values for the years 2023, 2024, 2025 & 2026. Z factors for the years of 2027 to 2030 are to be further strengthened and developed taking into account the review of the short-term measure. The rating of a ship would be determined by the attained CII and the predetermined rating boundaries, rather than the attained CII of other ships.

As illustrated in the **Figure 3**, the boundaries can be determined by the required annual operational CII in conjunction with the vectors, indicating the direction and distance they deviate from the required value (denoted as dd vectors for easy reference). The dd vectors for determining the rating boundaries of ship types depend on the type of the ship and their deadweight capacity. As shown in the **Figure 3** and as per the guideline, Low rated vessels ("E" or "D" on 3 consecutive years) should develop a plan of corrective actions and the plan should be approved by the Administration or RO.

Table 2 provides the details of the principal particulars of the hull selected for the investigation for which the Noon data was available for the entire year between Nov 2020 to Nov 2021. The data inputs were for the 303 days covering 20 voyages of which 11 were with laden condition and remaining 9 were with ballast condition. The deadweight and the mass of cargo was calculated based on the displacement in the fully loaded condition and lightweight of the ship. Displacement in the fully loaded condition was obtained from the hydrostatic table at the corresponding mean draft and trim of the vessel.

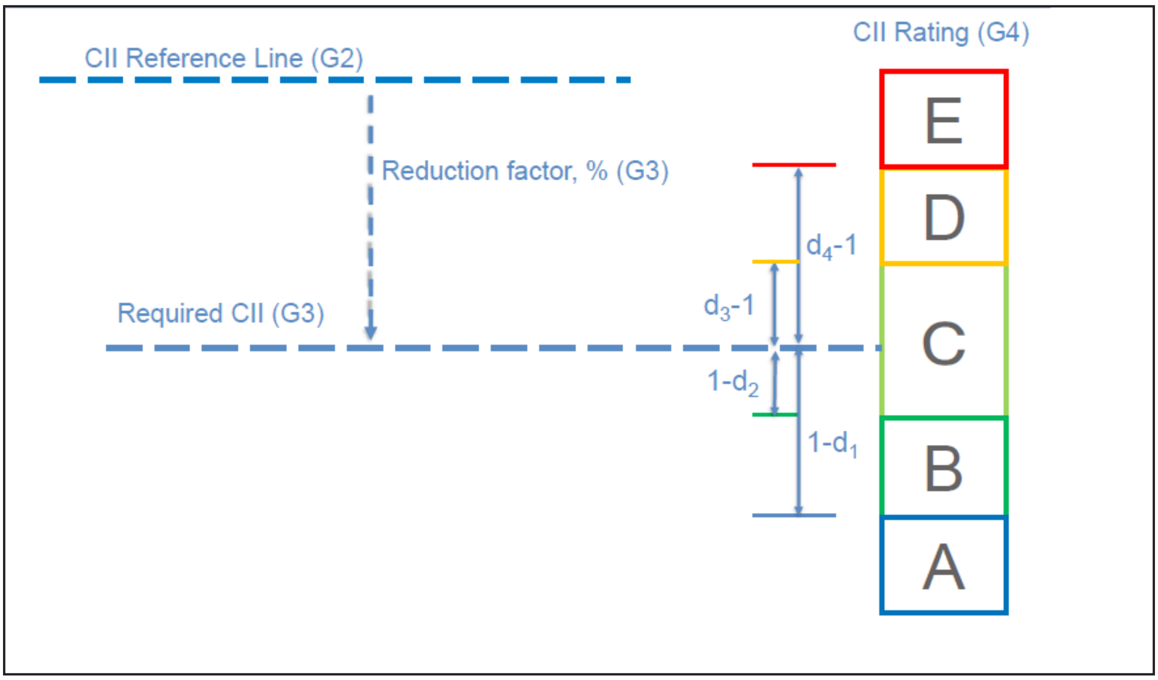

Figure 2: Image showing calculation of rating based on CII reference line and Reduction Factor

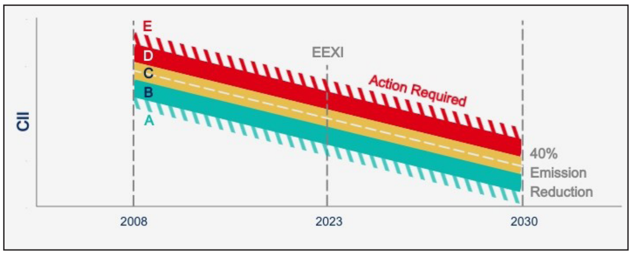

Figure 3: Different ratings of the vessel as per CII value and action needed for D & E graded vessels.

Table 2: Principal particulars of the vessel selected for the investigation

Sr. No	Principal Parameter	Value
1	Length	215m
2	Breadth	37m
3	Draft	12.0m a design condition
4	Speed	13.72 knots at the design draught

3. RESULTS AND DISCUSSION

Results obtained from the investigation have been discussed in the following subsection.

a. Energy Efficiency Operational Indicator (EEOI)

b. Carbon Intensity Indicator (CII)

c. Proposed methodology to estimate the EEOI values during the port operations

a Energy Efficiency Operational Indicator (EEOI)

EEOI values obtained from the investigation are analysed according to the following aspects.

i. EEOI Values as per the days of journey

ii. EEOI Values as per the voyages

iii. EEOI Values as per the voyages in Laden Conditions

iv. EEOI Values as per the voyages in Laden Conditions, showing distance for which ship moved

v. EEOI Values as per the voyages in Laden Conditions, showing mass cargo transported by the ship

vi. EEOI Values as per the voyages in Laden conditions, amount of fuel oil consumed, distance travelled and the mass cargo transported by the ship

Analysis using above approach will help enhance the energy efficiency of the ship for the future voyages/ journeys.

i. EEOI Values as per the days of journeys:

Figure 4 shows the graph of Existing EEOI values, Benchmark EEOI values for the year 2020 & 2021 for different journeys (days) of the ship.

As seen in the **Figure 4** graph, for most of the journeys, the existing EEOI values are well below the limiting values for the year 2020 & 2021. However, for few journeys, existing EEOI values are above the limiting values. In general, lower values of EEOI occur for the journeys with either higher values of cargo being transported or for the cases with the cargo transported for the larger distance by the ship, yielding higher values of transport work done by the ship. Moreover, lower values of EEOI can also occur for the journeys with lower value of fuel oil being consumed or the fuel with lower value of conversion factor (C_F) has been consumed, yielding lower values of CO_2 emitted by the ship. To understand and to take preventive action in avoiding higher values of EEOI, further in-depth analysis of EEOI values is necessary.

ii. EEOI Values as per the voyages:

Figure 5 shows the graph of existing EEOI values, Benchmark EEOI values for the year 2020 & 2021 for different voyages of the ship. One complete voyage may consist of different journeys of the ship (days) and in this case, EEOI values for one voyage has been calculated by taking rolling average EEOI for different journeys of the ship.

As seen in the **Figure 5** graph, for most of the voyages, the Existing EEOI values are well below the limiting values for the year 2020 & 2021. However, for one voyage, existing EEOI value is above the limiting value. Voyages with higher values of EEOI must be avoided and to do that, ship must move in such a way that it will emit less CO_2 or it transports large cargo for longer distance.

iii. EEOI Values as per the voyages in Laden Conditions:

Figure 6 shows the graph of existing EEOI values, Benchmark EEOI values for the year 2020 & 2021 for different voyages in laden condition. Laden condition means the ship is loaded with cargo, may or may not be

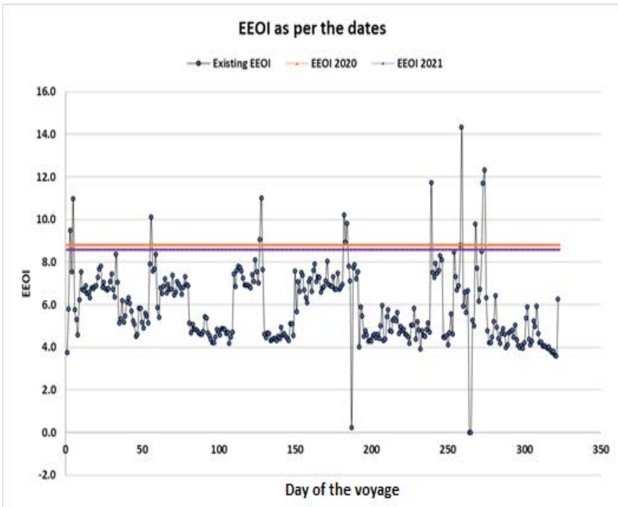

Figure 4: Graph of existing EEOI values, Benchmark EEOI values for the year 2020 & 2021 against different journeys (days)

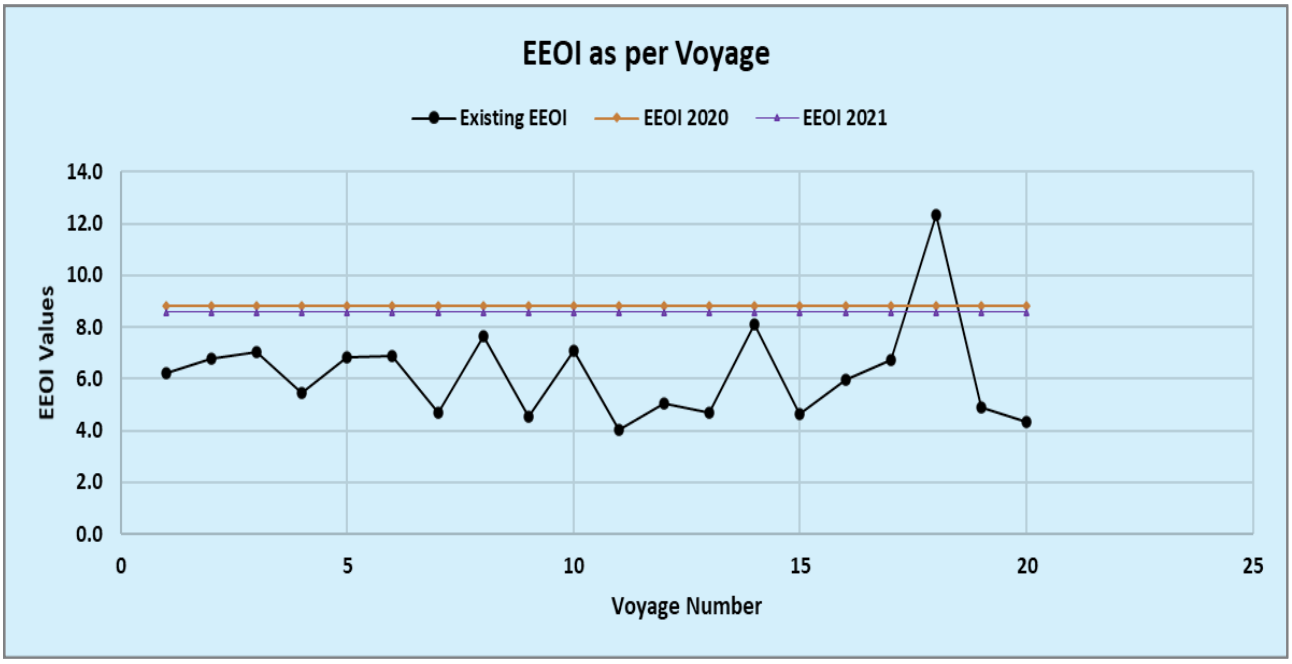

Figure 5: Graph of existing EEOI values, Benchmark EEOI values for the year 2020 & 2021 for different voyages

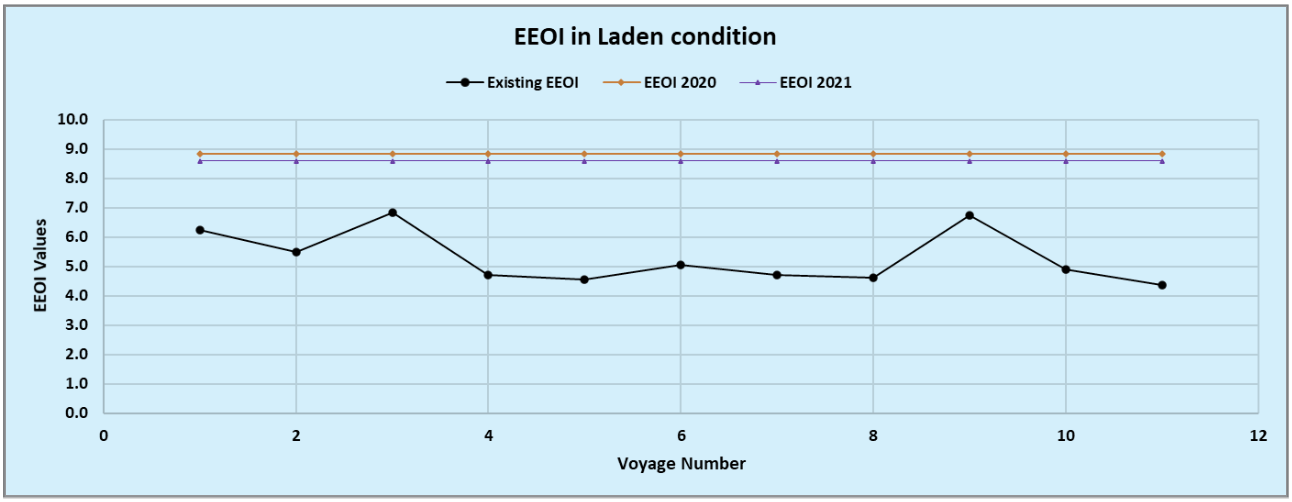

Figure 6: Graph of existing EEOI values, Benchmark EEOI values for the year 2020 & 2021 for different voyages in laden conditions

in its full capacity. Generally, laden condition of the ship yields lower values of EEOI, well below the limiting values.

As seen in **Figure 6** graph and as mentioned earlier, for all the voyages in laden condition of the ship, the Existing EEOI values are well below the limiting values. The major reason for the same is the larger quantity of cargo transported by the ship. The other reason could be the cargo has been transported for the larger distance. However, that needs separate study.

iv. EEOI Values as per the voyages in Laden Conditions, showing distance for which ship moved:

Figure 7 shows the graph of existing EEOI values, Benchmark EEOI values for the year 2021 and distance travelled for different voyages.

As seen in **Figure 7** graph and as mentioned earlier, for most of the voyages of the ship, the Existing EEOI values are below the limiting values. It can also be concluded from the graph that, larger distance travelled by the ship results in lower values of the EEOI. However, that conclusion is not correct for all the voyages, as, for a particular voyage, the mass of cargo transported could be lesser, resulting in higher values of the EEOI.

v. EEOI Values as per the voyages in Laden Conditions, showing mass cargo transported by the ship:

Figure 8 shows the graph of existing EEOI values, Benchmark EEOI values for the year 2021 and mass of cargo transported by the ship.

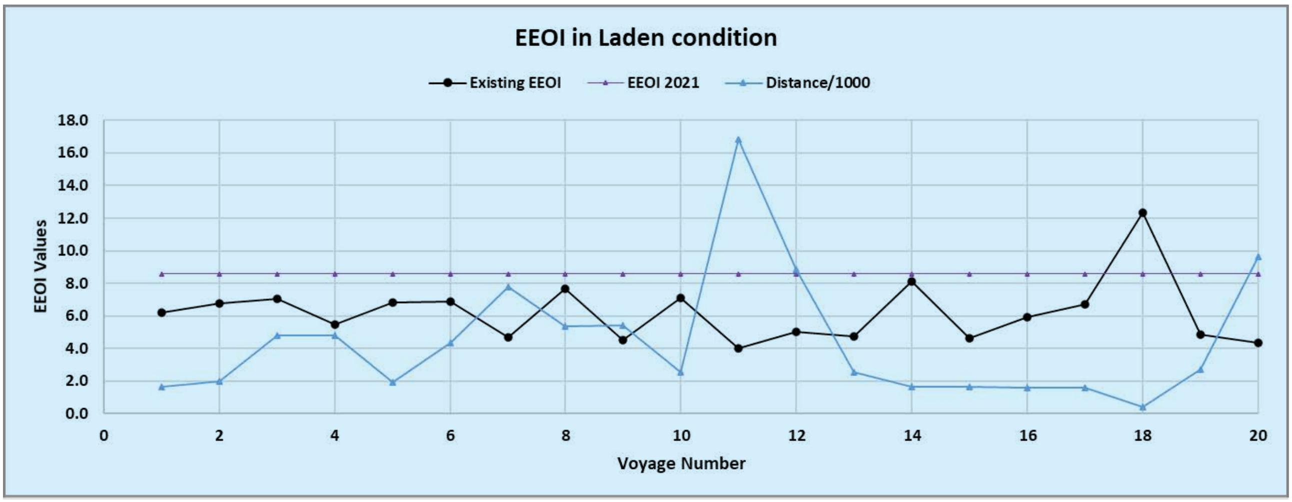

Figure 7: Graph of existing EEOI values, Benchmark EEOI values for the year 2021 and distance travelled for different voyages

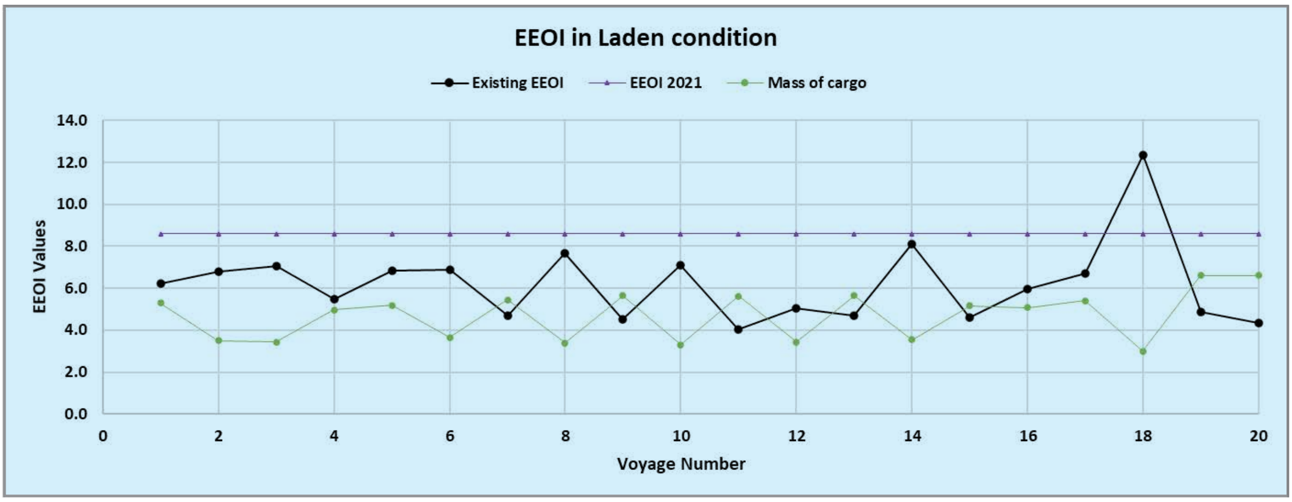

Figure 8: Graph of existing EEOI values, Benchmark EEOI values for the year 2021 and mass cargo transported by the ship

As seen in **Figure 8** graph, it can also be concluded that, larger mass of cargo transported by the ship results in lower values of EEOI.

vi. EEOI Values as per the voyages in Laden Conditions, amount of fuel oil consumed by the ship:

Figure 9 shows the graph of existing EEOI values, Benchmark EEOI values for the year 2021 and amount of fuel oil consumed by the ship.

As seen in **Figure 9** graph, it is expected that, higher quantity of the fuel consumed must result in the higher values of EEOI. However, that conclusion is not correct for few of the voyages, as, for a particular voyage, larger distance moved by the ship can also result in higher value of the fuel being consumed. Moreover, mass of the cargo transported can also be a deciding factor.

EEOI Values as per the voyages in Laden Conditions, amount of fuel oil consumed, distance travelled and the mass cargo transported by the ship:

Figure 10 shows the graph of existing EEOI values, Benchmark EEOI values for the year 2021, amount of fuel oil consumed, distance travelled and the mass cargo transported by the ship.

As shown in the **Figure 10**, such a combined data can be utilised for the final conclusion on EEOI values, reasons for the outcome and actions to be taken to avoid higher values of EEOI.

b. CARBON INTENSITY INDICATOR (CII)

Based on the guidelines provided, the CII values were calculated and the corresponding rating of the vessel were obtained. The values obtained from the investigation are given in **Table 3** and **Figure 11**.

As shown in **Table 3** and **Figure 11**, in the present condition of the vessel, it will achieve either D or E rating for the years 2023, 2024, 2025 & 2026, which is unacceptable and vessel needs to operate more efficiently and take necessary actions in improving the same.

c. PROPOSED METHODOLOGY TO ESTIMATE THE EEOI VALUES DURING THE PORT OPERATIONS

There is a methodology to calculate EEOI during laden voyages, but there is none to evaluate emissions during

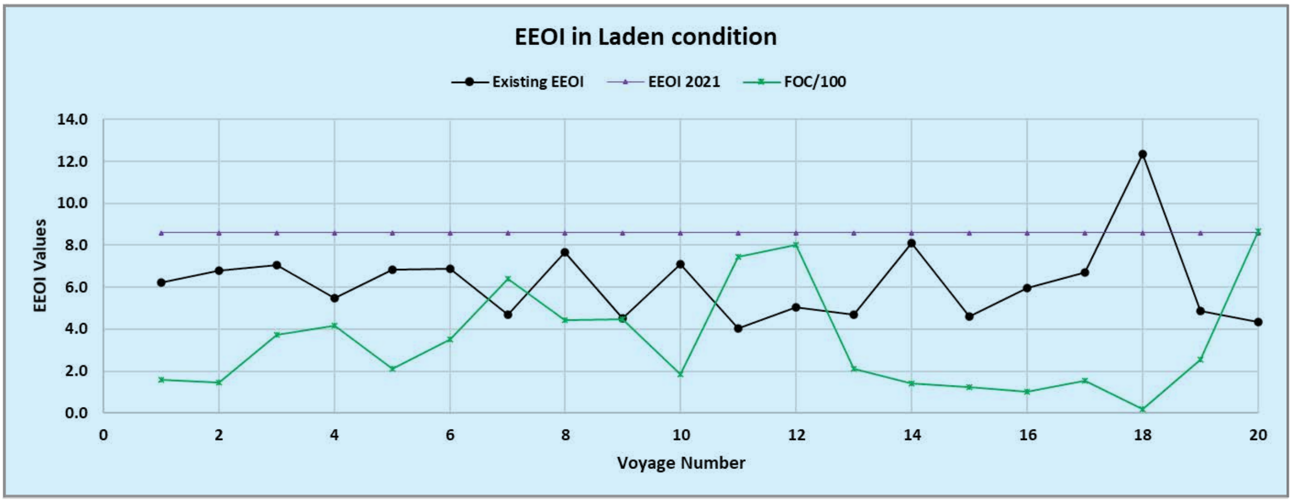

Figure 9: Graph of existing EEOI values, Benchmark EEOI values for the year 2021 and amount of fuel oil consumed by the ship

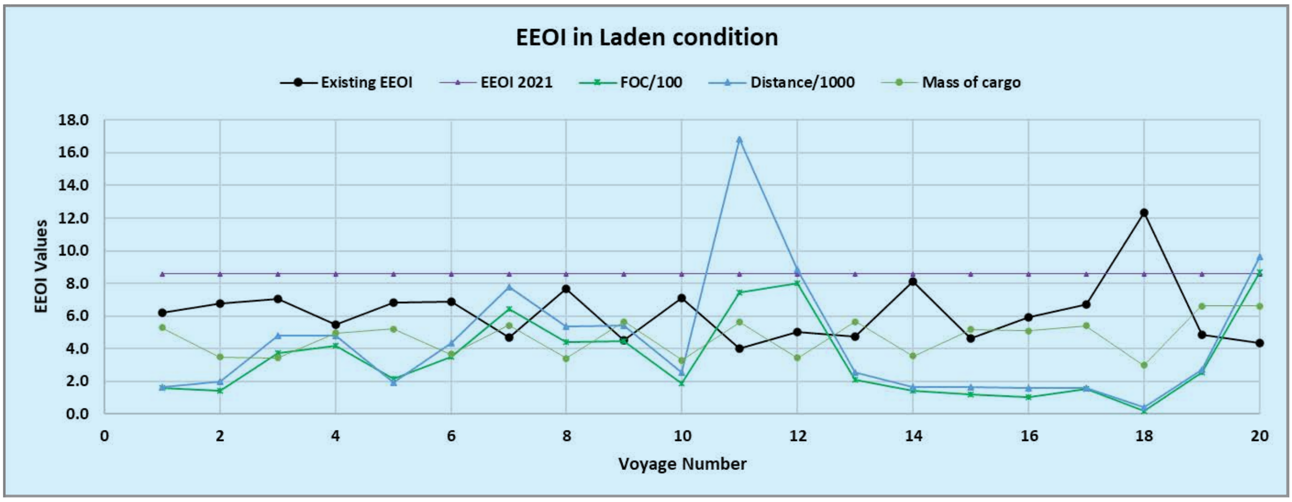

Figure 10: Graph of existing EEOI values, Benchmark EEOI values for the year 2021, amount of fuel oil consumed, distance travelled and the mass cargo transported by the ship

Table 3: Calculated CII values and the corresponding rating of the vessel

	Attained CII	Required CII for 2023	Rating 2023	Rating 2024	Rating 2025	Rating 2026
Annual CII (Voyage wise)	5.00	4.38	D	D	E	E
Annual CII (Ballast)	5.50	4.38	E	E	E	E
Annual CII (Laden)	4.75	4.38	D	D	D	D

port operations. It is important to evaluate emissions that occur in ports during cargo operations as some significant amount of fuel & energy is being consumed to perform work while transferring cargo from and to the vessel. Unfortunately, as vessel is stationary during cargo operations, one cannot evaluate emissions using the same criteria that is employed for a laden voyage. The term 'Transport work' is an amalgamation of mass of cargo transported and distance for which it is transported using ship. Hence, the criteria for evaluating EEOI for port operations must weigh in 'Transfer work' rather than 'Transport work'. A methodology to evaluate such emissions for port operations is proposed. Further, EEOI calculated in ports for transfer work, can be equated to equivalent Transport work EEOI (tonne-mile) to draw comparisons. The formula proposed is:

i. For cargo loading operations:

$$\text{EEOI(Loading)} = \frac{\text{Fuel consumed (MT fuel) x } C_F \text{ of fuel}}{\text{Total cargo loaded (MT cargo) x Effective Loading time (hours)}}$$

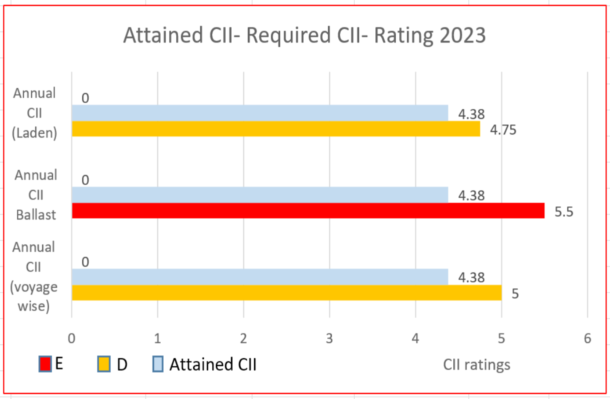

Figure 11: Attained CII values and rating of the vessel for the year 2023

Example: Bulk carrier: Cargo loaded = 50,000 MT Bauxite, effective cargo loading time: 36 hours.

Total fuel (LFO) consumed (AE + Boiler etc.) for cargo operations: 10.5 MT.

Carbon conversion factor for LFO: 3.151040

EEOI= 1.838×10^{-5} t-CO2/MT_{cargo} -hours = 18.38 g-CO_2/MT_{cargo}-hours

Design speed of the vessel at design draught: 15 knots (conversion based on vessel capability & design). Considering 1hour loading time to be equivalent to corresponding design speed of 15 knots, the EEOI value during loading of the cargo will be:

EEOI(Loading) = 18.38/15 = 1.225 g-CO_2/tonne-mile

ii. For Cargo discharge operation:

A similar formula proposed above can be used.

$$\text{EEOI(Discharge)} = \frac{\text{Fuel consumed (MT fuel) x } C_F \text{ of fuel}}{\text{Total cargo discharged (MT cargo) x Effective discharging time (hours)}}$$

Example: Crude Oil tanker**:** cargo discharged 150,000 MT crude oil, effective cargo discharging time 42 hours. Total fuel consumed (LFO) for cargo discharging: 80 MT (for AE, Boiler, IG, cargo heating etc.,). Carbon conversion factor for LFO: 3.151040

EEOI = 4.00×10^{-5} t-CO2/MT_{cargo} -hours = 40.01 g-CO_2/MT_{cargo}-hours

Design speed of the vessel at design draught: 15 knots (conversion based on vessel capability & design). Considering 1hour discharging time to be equivalent to corresponding design speed of 15 knots, the EEOI value during discharge of the cargo will be:

$EEOI_{(Discharging)}$ = 40.01/15 = 2.667 g-CO_2/ tonne-mile

EEOI for port operations present a reasonable picture of the loading or discharging rates involved in it. Lower rates of loading or discharge coupled with higher consumptions will increase emissions, hence, the significance of cargo handling rates becomes important. This can generate valuable KPI regarding the activities during loading and discharging operations. It could be also used for comparisons between vessels or fleet or pool of vessels to evaluate efficiency during port activities. Delays during cargo operations could also result in additional emissions, which can be identified and optimised. Ports and terminals could also stand to benefit from these optimisations which can result in faster turnaround of vessels, lesser congestions leading to additional commercial benefits overall. Similar methodology could be adopted for containers, Ro-Ro vessels, gas carriers, passenger ships and other vessels.

4. EFFECT OF VARIOUS OPERATING PARAMETERS ON CII RATING OF THE VESSEL

It would be of great importance for the marine fraternity to know the effect of various operating parameters on CII rating of the vessel. This investigation has been carried out by reducing the speed of the ship, by increasing the energy efficiency of the vessel, by increasing the cargo carrying capacity of the vessel, and by changing the type of the fuel used with lowest value of conversion factor.

a. Effect of speed reduction on CII rating of the vessel

Investigation has been carried out on the by reducing the speed of the vessel. Five different cases of reducing the speed of the vessel were considered viz. 5%, 10%, 15%, 20%, and 25% reduction in the speed of the ship. Results obtained from the investigation are illustrated in **Table 4** and **Figure 12**.

As shown in the **Table 4** and **Figure 12**, with 15% reduction of speed of the vessel will make it to operate in the A rating which is the most desirable rating as per the MEPC guideline.

b. Effect of use of energy efficiency enhancing technique on CII rating of the vessel

Investigation has been carried out on the above vessel by enhancing the Energy Efficiency of the vessel. Five different cases of increasing energy efficiency of the vessel were considered viz. 5%, 10%, 15%, 20%, and 25% improvement in the energy efficiency of the ship. Results obtained from the investigation are illustrated **Table 5**.

As shown in the **Table 5** and **Figure 13**, with 25% improvement in the energy efficiency of the ship will make the vessel to operate in the A rating.

Lower rates of loading or discharge coupled with higher consumptions will increase emissions, hence, the significance of cargo handling rates becomes important

Table 4: Rating of the vessel as per the reduction in the speed of the vessel

Criteria related to the speed of the vessel	Rating for the year 2023	Rating for the year 2024	Rating for the year 2025	Rating for the year 2026
Annual CII (Voyage wise) at the design speed	D	D	E	E
Annual CII (Voyage wise) with 5% reduction in the design speed	C	C	C	C
Annual CII (Voyage wise) with 10% reduction in the design speed	A	A	B	B
Annual CII (Voyage wise) with 15% reduction in the design speed	A	A	A	A

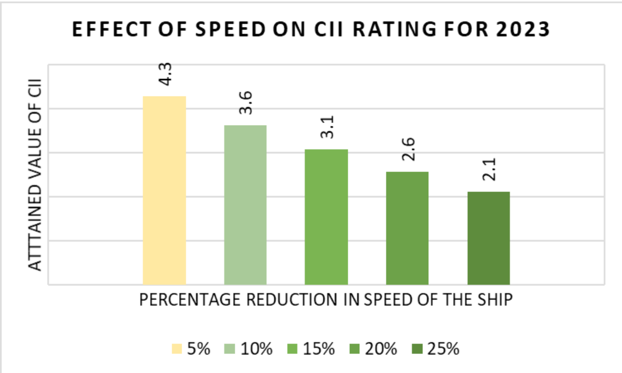

Figure 12: Image showing CII rating of the vessel for the year 2023 for different speeds

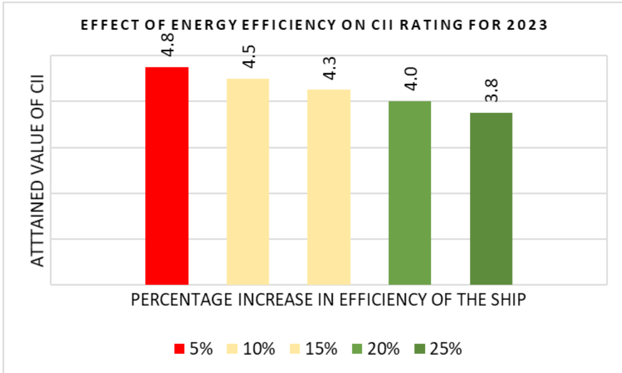

Figure 13: Image showing CII rating of the vessel for the year 2023 by enhancing Energy Efficiency

Table 5: Rating of the vessel by enhancing Energy Efficiency of the vessel

Criteria related to the speed of the vessel	Rating for the year 2023	Rating for the year 2024	Rating for the year 2025	Rating for the year 2026
Annual CII (Voyage wise) at the design speed	D	D	E	E
Annual CII (Voyage wise) with 5% improvement in Energy efficiency	D	D	D	D
Annual CII (Voyage wise) with 10% improvement in Energy efficiency	C	C	C	C
Annual CII (Voyage wise) with 15% improvement in Energy efficiency	C	C	C	C
Annual CII (Voyage wise) with 20% improvement in Energy efficiency	B	B	B	B
Annual CII (Voyage wise) with 25% improvement in Energy efficiency	A	A	A	A

c. Effect of Deadweight capacity on CII rating of the vessel

Investigation has been carried out on the above vessel by increasing the cargo carrying capacity (Deadweight) of the vessel. Five different cases of increasing the cargo carrying capacity of the vessel were considered viz. 5%, 10%, 15%, 20%, and 25% increase in the cargo carrying capacity of the ship. Results obtained from the investigation are illustrated in **Table 6**.

As shown in **Table 6** and **Figure 14**, even with 25% increase in the cargo carrying capacity of the ship, it will not make the vessel to operate in the A rating. Although, it is really difficult to convert the vessel to increase its capacity of the vessel even by 5%.

d. Effect of type of fuel oil on CII rating of the vessel

Investigation also has been carried out by changing the type of fuel used. It would be of great interest to the marine community to know the effect by using Liquefied Natural Gas (LNG) having lowest value of conversion factor. Results obtained from the investigation are given in **Table 7**.

Table 6: Rating of the vessel as per the increase in the cargo carrying capacity of the ship

Criteria related to the deadweight of the vessel	Rating for the year 2023	Rating for the year 2024	Rating for the year 2025	Rating for the year 2026
Annual CII (Voyage wise) at the design cargo carrying capacity	D	D	E	E
Annual CII (Voyage wise) with 5% increase in the deadweight	D	D	D	D
Annual CII (Voyage wise) with 10% increase in the deadweight	D	D	D	D
Annual CII (Voyage wise) with 15% increase in the deadweight	C	C	C	C
Annual CII (Voyage wise) with 20% increase in the deadweight	C	C	C	C
Annual CII (Voyage wise) with 25% increase in the deadweight	B	B	B	B

Table 7: Rating of the vessel by using Liquified Natural Gas (LNG) as fuel

Criteria related to the type of fuel consumed by the vessel	Rating for the year 2023	Rating for the year 2024	Rating for the year 2025	Rating for the year 2026
Annual CII (Voyage wise) using Heavy Fuel Oil (HFO)	D	D	E	E
Annual CII (Voyage wise) using LNG	C	C	C	D

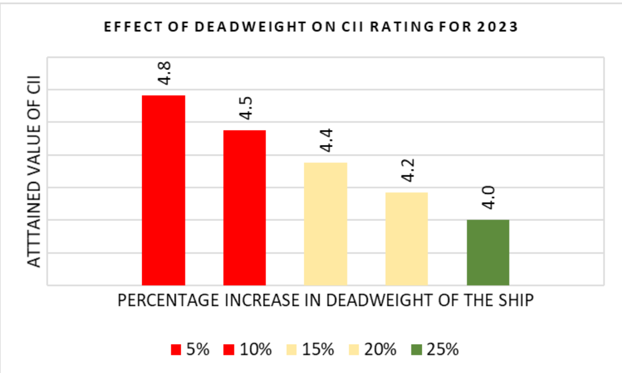

Figure 14: Image showing CII rating of the vessel for the year 2023 based on deadweight

As shown in **Table 7**, it is proposed to change the fuel type from Heavy Fuel Oil (HFO) to Liquefied Natural Gas (LNG) as fuel used has the considerable impact on the CII rating of the vessel.

e. Effect of distance sailed during a voyage

Another suggested way of reducing attained CII lies in maximising distance sailed by vessel during laden voyages in a year. As per the formula for CII emissions, the distance sailed is in the denominator. Hence, if the vessel manages to increase its business potential by travelling more distance during laden voyages in a year or "rather optimising the ratio of fuel consumed/ distance travelled in every laden voyage", there could be a significant impact on CII ratings. For this to happen, the operations department, charterers, cargo managers, terminals & ports, weather & route optimising agencies etc., have to plan well to ensure vessels arrive just in time, vessels turn around faster, lesser congestion in ports, optimise vessel loading and discharge rates for quicker operations etc. Reducing duration of ballast voyages by efficient sourcing of cargoes, such that vessel maximises its business potential (deadweight is another key deciding parameter that impacts emission ratings) can further improve CII rating of the vessel. Ideally vessel should plan to achieve maximum number of laden voyages during the year and reduce number of ballast voyages. The emission ratings thus achieved can also be compared with fleet of vessels of similar capacities or in the same vessel pool for understanding the impact of this aspect. Efficient planning with proper coordination between vested parties can make it happen.

5. CONCLUSION

IMO has adopted mandatory measures to reduce emissions of greenhouse gases from international shipping. To achieve the target set by the MEPC, IMO proposed the use of EEDI, EEXI, EEOI and CII as the measures to control and reduce emissions. In this paper, investigations on EEOI and CII for the Bulk carrier have been carried out for various loading conditions and the speeds of operation of the ship. The following inferences can be made based on the investigation carried out:

- Lower values of EEOI occur for the journeys with either higher values of cargo being transported or for the cases with the cargo transported for the larger distance by the ship, yielding higher values of transport work done by the ship. Moreover, lower values of EEOI can also occur for the journeys with lower value of fuel oil being consumed or the fuel with lower value of conversion factor (C_F) has been consumed, yielding lower values of CO_2 emitted by the ship.

- A combined graph showing existing EEOI values, Benchmark EEOI values, amount of fuel oil consumed, distance travelled and the mass cargo transported by the ship can be utilised for the final conclusion on EEOI values, reasons for the outcome and actions to be taken to avoid higher values of EEOI.
- It is important to evaluate emissions that occur in ports during cargo operations as some significant amount of fuel and energy is being consumed to perform work while transferring cargo from and to the vessel. A methodology to estimate the EEOI values during port operations has been proposed in this paper.
- Effective way to enhance the CII rating of the vessel is by reducing the speed of the operation of the ship. Another way is to utilise the energy efficiency enhancing techniques.

> **Hence, if the vessel manages to increase its business potential by travelling more distance during laden voyages in a year or "rather optimising the ratio of fuel consumed/distance travelled in every laden voyage", there could be a significant impact on CII ratings**

6. ACKNOWLEDGEMENTS

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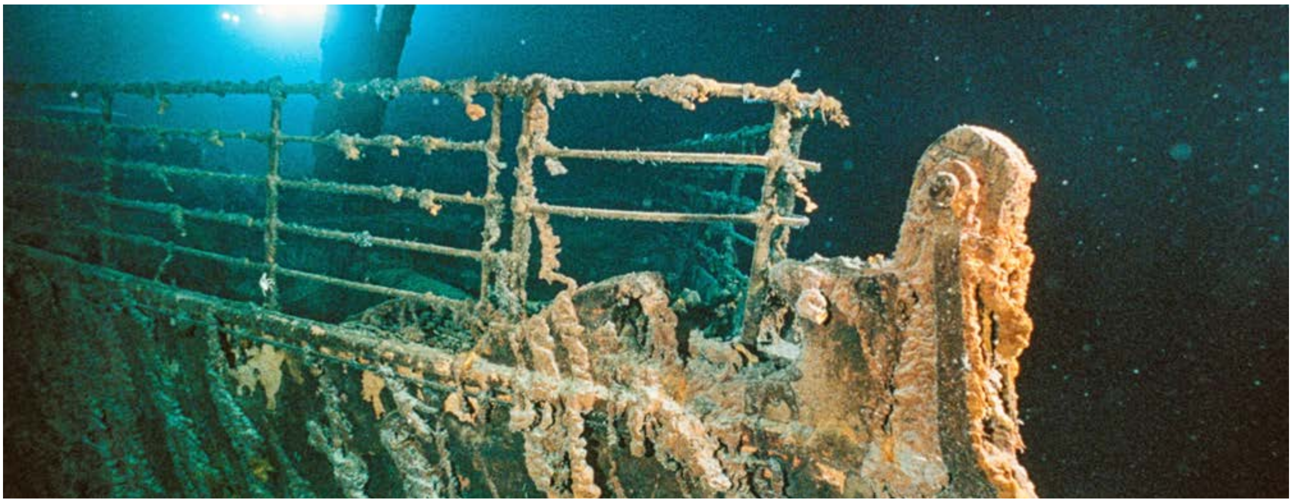
CHALLENGES IN LOCATING OBJECTS LOST IN THE OCEAN



N. Vedachalam

Abstract

Successful recovery of aircraft flight data recorder and ship voyage data recorder from the seafloor wreckage is essential to understand the causes of accidents and improving the operational safety. This article describes the recent efforts made in locating the wreckage of aircrafts lost in the ocean, methodologies adopted to generate posterior probability maps for narrowing down the ocean search area, ocean subsurface search for locating the underwater locator beacon and sonar-based search. The advances in high-resolution sonar imaging technologies, detectability of debris in deep waters and the importance of location-specific sound velocity profile in precisely locating the debris are detailed.

Introduction

Locating the wreckage of assets lost in the ocean, such as aircrafts, ships and submarines, and recovering on-board Flight / Voyage Data Recorders (FDR/VDR) provide valuable information for accident investigations and for improving operational safety. Till date, > 2 trillion commercial passenger-kilometres were flown over the major oceans.

During the past three decades, about 26 crashes involving commercial aircraft have ended in ocean crashes in water depths up to 5000m. They include Air France AF447 over the Atlantic Ocean in 2001, Asiana cargo flight 991 in the Korean strait in 2011, Malaysia Airlines flight MH370 over the southern Indian Ocean in 2014, Air Asia flight 8501 over the Java sea in 2015, Egypt Air flight 804 in the Mediterranean Sea in 2016.

The global fleet of > 94,171 ships categorised into passenger vessels, container ships, tankers, gas carriers, bulkers, dry and cargo carriers, with a consolidated dead weight tonnage (DWT) of ~2 billion Tons contribute to ~90% of the global trade. Dozens of maritime accidents occur every year resulting in sunken vessels.

The most prominent being the Titanic in 1912 in the Atlantic Ocean, MV Derbyshire in 1980 in the South China Sea, Herald of free enterprise in 1987, off-Belgium, MS Estonia in 1994 in the Baltic Sea, Sun Vista in 1997, Star Princess in 2006 off-Japan, Costa Concordia in 2012 off-Italy, etc. These accidents brought out significant changes in the marine safety legislation including in SOLAS Ch.6, MARPOL Double hull amendments, STCW, ISM and HNS protocol.

The nuclear and diesel-electric powered submarines that sunk in water depths ranging from 100 to 3000m include the USS Squalus, USS Scorpion, USS Thresher, USS Greenville, Soviet K-129, Soviet Kursk, Russian K159, Israeli Dakar, French Minerve, UC3 Nautilus and the Indonesian Nangalla has led to the significant developments in submarine rescue capabilities.

Locating recent ocean-lost aircrafts

Locating a missing asset in the vast ocean without precise information on the lost location is similar to "*searching a needle in a haystack*" and so timeliness of accident detection is important to narrow down/reduce the search area. A visual search is initiated when the exact location of an aircraft/ship that is subjected to abnormal operations is not known. Visual surface search is primarily conducted using aircraft and satellite images, and, if applicable, surface vessels to find the survivors and (if over water) floating debris.

The size of the search area is highly dependent on the information available about the last position, mainly for aircraft, as they move with high speeds. Locating an aircraft that has impacted on land is less challenging than one in water. The wreckage doesn't sink or drift and impact usually leaves ground marks and smoke from a

> *These accidents brought out significant changes in the marine safety legislation including in SOLAS Ch.6, MARPOL Double hull amendments, STCW, ISM and HNS protocol*

post-impact fire. Accidents over water pose a different set of challenges.

Aircraft usually breaks upon impact with water and most of it sinks to the seafloor. Floating debris immediately begin to disperse with the local wind and waves, and their spatial distribution becomes wider over time. From the BEA statistics [1] of major ocean-lost aircraft FDR recoveries (**Figure.1**), it is evident that the time to locate increases with the water depth, and still worsened if the last known position is inaccurate.

Air France AF 447

In 2001, the French aircraft AF447 with 228 passengers and crew on-board disappeared over the South Atlantic Ocean. Investigations revealed that the aircraft encountered an aerodynamic stall at an altitude of ~11.6 km before plunging into the ocean. The pitot tubes that track the flight speed were frozen and malfunctioned, setting off a series of events.

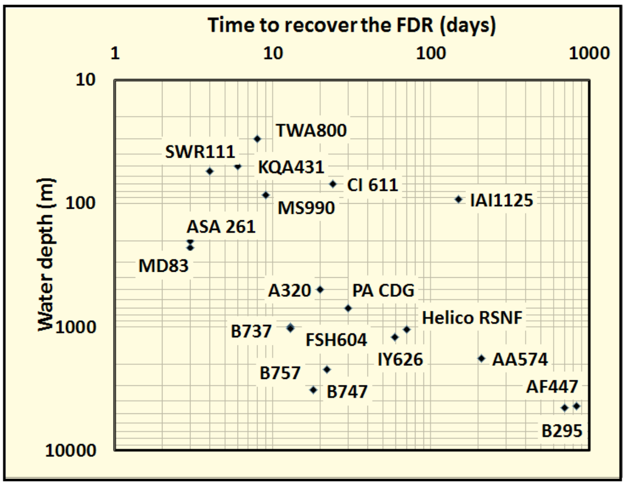


Figure.1. Statistics of ocean-lost aircraft FDR recovery [1]

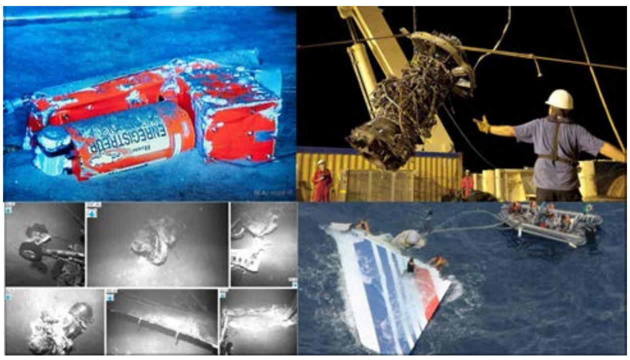


Figure.2. Salvage of AF447 wreckage from the Atlantic Ocean [2]

During its flight, the aircraft was programmed to transmit its position information every 10 minutes through the Aircraft Communications Addressing and Reporting System (ACARS). The aircraft also sent an unscheduled, triggered report during the event sequence.

The search team therefore had an indication that impact with water would have been within 4 minutes and almost certainly within 10 minutes from the last known position (LKP). Floating debris was located on the 6th day of the sea surface search (done over 17000 km^2) at a location 70 km from the aircraft's LKP. Based on these evidences, a passive acoustic search for locating the aircraft's underwater locator beacon (ULB) was carried out.

As locating the wreckage using ULB was unsuccessful, subsurface searches were carried out for locating the wreckage by scanning the ocean bottom using side scan MBS with the aid of posterior probability maps (PPM). After two years, with the revived PPM, AF447 wreck comprising of 1000 pieces, was located in a high probability area at a water depth of 3980 m (**Figure.2**).

The operation that involved French submarines, French research ship porquoi-pas, REMUS Autonomous Underwater Vehicles (AUV), towed sonar array ORION of the US Navy, Curv21 ROV, Remora ROV and Triton ROV of Norway. Typical systems are shown in **Figure.3**.

As a part of the subsurface search, ORION surveyed 1900 km^2 and three AUVs covered 4375 km^2 from an altitude of 600-700m. The under search trajectories (with the LKP marked in the centre) are plotted in **Figure.4**. Even though the aircraft's location was known within few minutes of flying time with additional information available to prioritise the search area, the ULB search was unsuccessful, which led to a sonar search that took four months over nearly two calendar years. The cost of search and rescue of the debris was 80 million Euro, spent by French and Brazilian armed forces [2].

Malaysian Airlines MH370

The search of the Malaysian aircraft MH370 that went missing with 227 passengers and 12 crew lasted for 1046

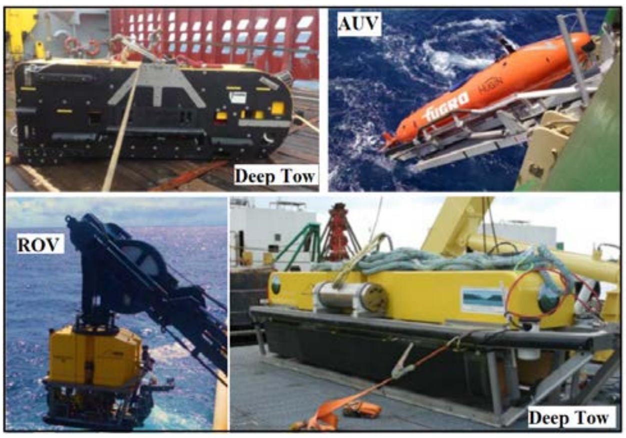


**Figure.3. Systems used for subsurface search [2]
(note: These typical systems were used for MH370)**

The subsurface search mapped 710,000 km² of the Indian Ocean seafloor (with 72 % of the area >3500m water depth) including 120000 km² of high resolution bathymetry

days. It is the largest search in the aviation history with mammoth effort involving US$ 0.2 billion. No data was received from the aircraft through the ACARS after the first 38 minutes of flight. Combing the clues obtained from the drifted debris collected on the shores of the Indian Ocean islands and the east African coastline, satellite communication data and the results of the surface and underwater search led to the identification of a specific area of the Indian Ocean, which was more likely to be where the aircraft ended the flight. Its last position was fixed at the northern tip of Sumatra by the surveillance systems operating that night, six hours before it ended the flight in the southern Indian Ocean.

The investigations for locating the aircraft were done using Inmarsat communication data. After contact with

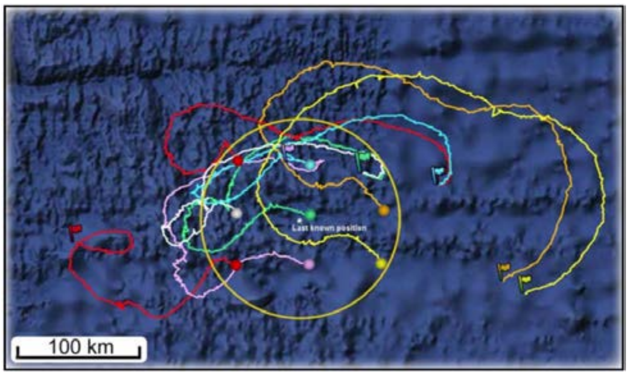


Figure.4. Subsea survey tracks for AF447 [2]

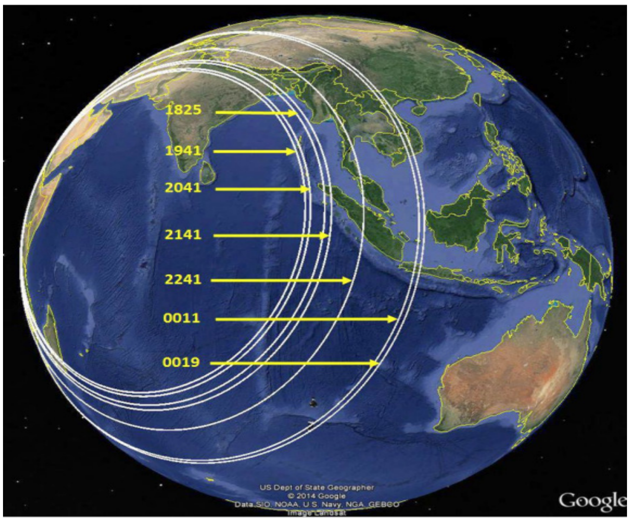


Figure.5. BTO ring solutions for tracing MH370 [3][4]

MH370 was lost, Inmarsat terminal continued to exchange signalling messages with the Ground Earth station (GES). The Burst Timing Offset (BTO) and Burst Frequency Offset (BFO) messages were analysed to determine the likely location of the aircraft [2].

The BTO is essentially the delay between when the transmission was expected (given a nominal position of the aircraft) and when it actually arrived, and is a measure of twice the distance of the aircraft from the satellite. The BFO is the recorded value of the difference between the received signal frequency and the nominal frequency at the GES. It is determined by several factors including the aircraft's location and ground velocity.

A series of seven rings, joining points on the earth's surface equidistant from the satellite, shows the range of possible locations of the aircraft at the time of each handshake (**Figure.5**). Considering the maximum speed of the aircraft into account, the BTO derived rings were reduced in length to arcs [3].

An alternate technique was developed by Inmarsat, which considered the relative velocity of the satellite to the aircraft, to determine if the aircraft flew the northern or southern route. This technique is based on the difference in frequency of the pulse sent and received by the GES, which was defined as the Offset Burst frequency (OBF).

The OBF results from the position and movement of the satellite relative to the aircraft (**Figure.6**) in which the aircraft attempts to compensate for the Doppler generated during its movement and the GES for the movement of the satellite. Based on these two described approaches, and the residual fuel available on-board aircraft, an area of ~ 25000 km² was identified (referred as 7th arc area) to have the highest likelihood of the MH370 wreckage. The 7th Arc in the Southern Indian Ocean is one of the most remote locations in the world where the seabed conditions varied from abyssal plain to complex bathymetric features (in depths 4000-6000m) such as the broken ridge seamounts [4].

During 2014, the 90-day US$ 93 million challenge was undertaken by the US-based seabed exploration firm Ocean Infinity in locating the MH370 debris in the most probable location in southern Indian Ocean using eight AUVs at 5600 m water depths with a target covering 1200 km² of seabed/day. During the search, Ocean Infinity covered 125,000 km² of seabed in 138 days [5].

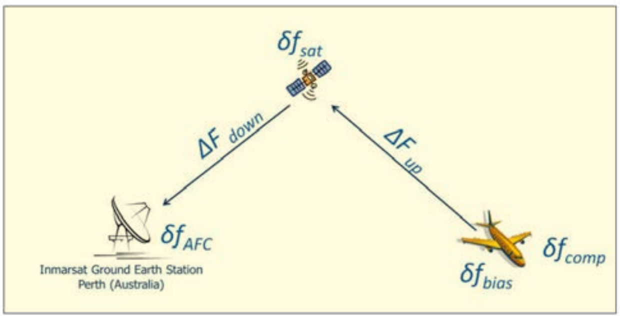


Figure.6. Bias of frequency calculation [3]

The sinkage time and velocity depends on the mass, added mass (amount of water that has flooded inside dry compartments of ship/aircraft), hydrodynamic shape (that determines the drag forces in six degrees of freedom), water current velocity profile and the direction

During the entire search operations, the surface search involving aircraft and vessels covered an area of several million km^2. The subsurface search mapped 710,000 km^2 of the Indian Ocean seafloor (with 72 % of the area >3500m water depth) including 120000 km^2 of high resolution bathymetry. Since there was very little information available about the aircraft's position (which partly led to the subsequent ULB search being unsuccessful) the sonar search area had to be several times greater than that for AF447.

Need for systematic approach

Based on the reported experiences, the systematic approach for ocean search is summarised in **Figure.7**. The first phase of the search involves locating the aircraft/ship's sea contact zone based on the LKP aided by PPM. The second phase involves search using ships and aircraft by visual means and with the aid of satellites images and radars. The third phase is the subsurface search, initially for locating the ULB, followed by ship/tow-body/AUV mounted SONAR for localising the wreck.

Factors determining sinkage kinetics and kinematics

Aircrafts usually break upon impact with water, sink and finally settles on the seafloor. The factors determining the sinkage velocity, sinkage time and the probable seabed landing location are shown in **Figure.8**.

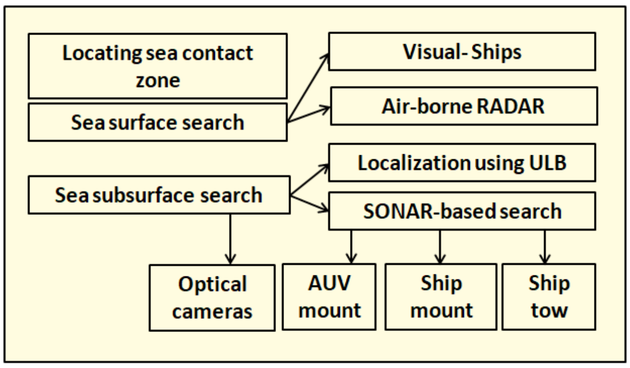


Figure.7. Methods for searching ocean-lost objects

The sinkage time and velocity depends on the mass, added mass (amount of water that has flooded inside dry compartments of ship/aircraft), hydrodynamic shape (that determines the drag forces in six degrees of freedom), water current velocity profile and the direction.

The water current velocity and direction determine the landing location on the sea floor. As an example, **Figure.8** also shows the water current and direction profile in the central Indian Ocean logged during May 2020 [5]. The velocity of the water continuously varies with depth, including in the X and Y directions. The profile is also dependent on the season.

Generating posterior probability maps

Based on the experiences of the Bureau of Enquiry and Analysis (BEA) for Civil Aviation Safety, when the aircraft position could be determined 1 minute prior to the accident, the probability of locating the wreckage within a radius of 4 and 6 nautical miles (NM) are 85% and 95%, respectively. When the aircraft position could be determined 10 minutes prior to accident, the wreckage

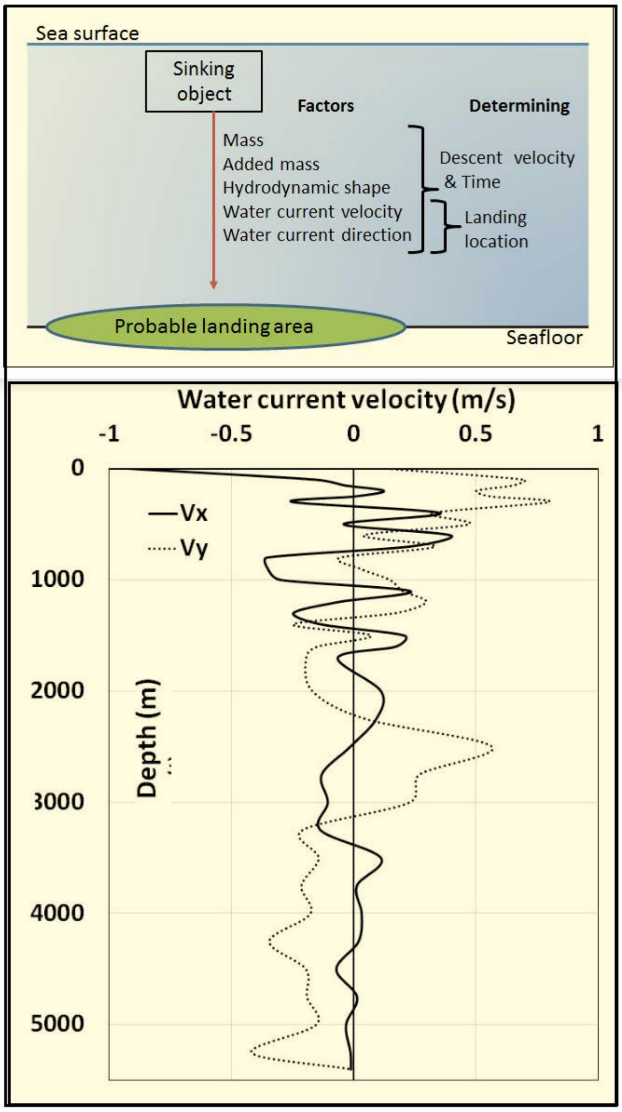


Figure.8. Factors determining the kinetics of sinkage [6]

will be at distance within 20 NM. This indicates that a 10-min interval between position reports would result in a potential ocean surface and subsurface search area of ~5000 km^2.

The computation of a priori distribution of target location based on the LKP using PPM was highly successful both as a predictor of location and to estimate of the search effort required. During the search for the lost submarine Scorpion in 1968, a priori target location probability distribution obtained by monte-carlo (MC) procedures helped to locate the submarine within 300m of the search grid cell that had the largest probability.

In the MC-based methodology, the sum of local effectiveness probabilities (LEP) weighted by the a priori target location probabilities are called search effectiveness probability (SEP), which defines the overall effectiveness of the search operation (defined in equations 1 and 2).

The methodology of SEP and LEPs were used previously in the Mediterranean hydrogen bomb search during 1966, when a B-52G bomber of US Air Force strategic air command collided with a KC-135 tanker during mid-air refuelling at an altitude of ~9.5 km over the Mediterranean Sea, off the coast of Spain.

In equation 1 and 2, Lj represents the a priori probability that target object was in rectangle j and Ej is the probability that the object would have been found and identified by the search effort.

$$SEP = \sum_{j=1}^{N} \mathrm{L_j E_j} SEP = \sum_{j=1}^{N} \mathrm{L_j E_j} \quad \text{............. (1)}$$

$$L_j' = \frac{L_j(1-E_j)}{1-SEP} \quad \text{...(2)}$$

The incremental maximisation of the SEP is the criterion used for search procedures. This criterion usually resulted in the recommendation that broad area search to be conducted in the search cells having the largest values of L_j'. The computation of LEP and SEP requires knowledge of the sensor capabilities and the navigational uncertainties of the search system.

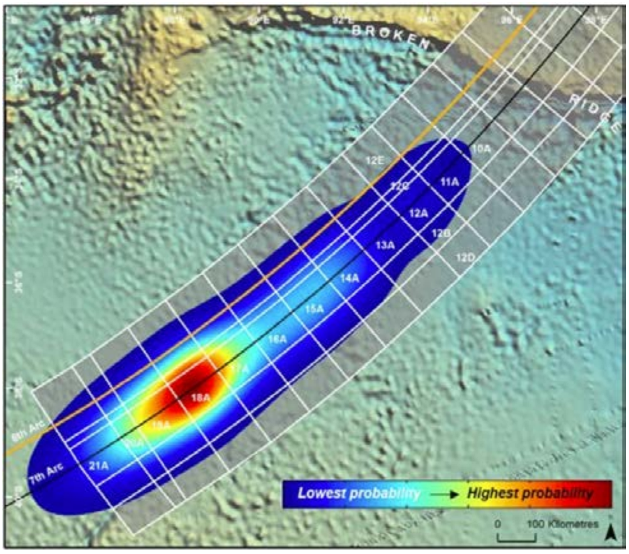


Figure.9. Results of Bayesian approach for MH370 end-of-flight [3]

Bayesian approach is described as a recursive method that calculates the posterior state distribution at each measurement (time) from a distribution at the previous measurement (time). It requires knowledge of three probability density functions namely, the prior distribution of the state at initialisation, p (x (0)); the state evolution p (xk |xk−1), and the measurement likelihood p (zk |xk).

During the MH370 debris search, Bayesian approach was used to calculate the probability distribution of the final location of the debris from the position data of the Inmarsat communication system, aircraft state vector and model of aircraft dynamics. The model of how the measured data relate to the aircraft location and velocity is expressed in equation 3.

$$p(x/z) = \frac{p(x,z)}{p(z)} p(x/z) = \frac{p(x,z)}{p(z)} = \frac{p(z/x)\,p(x)}{p(z)} \; \frac{p(z/x)\,p(x)}{p(z)}$$

$$= \frac{p(z/x)\;\, p(x)}{\int p(z/x')\,p(x')dx'} = \frac{p(z/x)\;\, p(x)}{\int p(z/x')\,p(x')dx'} \quad \text{.... (3)}$$

where x is the random variable or the state, which is the position of aircraft/ship, z is the measurement information (like positional data, sensor characteristics, aircraft dynamic behaviour sensor characteristics, aircraft dynamic behaviour and environmental conditions and constraints.

In the equation p(x) is the prior pdf of the state based on historical data, p(z|x) is the pdf of the measurement conditioned on the state and p(x|z) is the conditional pdf of interest (the posterior pdf), describing the distribution of state (e.g., aircraft location) considering the observed measurement.

As an example, the PPM results of the Australian Transport Safety Bureau (ATSB) for the MH370 end-of-flight scenario is shown in **Figure.9**. The colours in the area represent probabilities from lowest (blue) to highest (red).

Numerical software for ocean search and rescue (SAR) are maturing. They include SAROPS, BMT-SARIS, SARMAP, OCEAN-SAR, SAR Plan, TRANSAS and INCOIS-SARIT. These software generate the PPM over the radius centered at the LKP. These software tools allow a search planner to define scenarios, obtain the winds and currents necessary to compute drift trajectories, estimate effective sweep widths for search sonars, develop PPM for search object location and find near-optimal search plans given the amount of search infrastructure available.

SAROPS is a MC-based tool that uses thousands of simulated particles generated by the user inputs in a GUI wizard. It can handle multiple scenarios and search object types, model pre-distress motion and hazards, and account for the effects of previous searches. It accepts manual inputs of winds and currents for maximum probability of success. It considers flight altitude, speed, aircraft type, met conditions, visibility and sea state for the analysis.

Aircraft FDR and ship VDR are electronic recording devices placed in the aircraft/ship to facilitate aviation/ marine accident investigations

Subsurface search

Localisation of debris using ULB

Aircraft FDR and ship VDR are electronic recording devices placed in the aircraft/ ship to facilitate aviation/marine accident investigations. The FDR that captures and records the data are tested for extreme conditions so that it can withstand impact while crashing onto concrete walls at 750 kmph, withstand 2.25t of static load for 5 minutes stay intact at 1200ºC and withstand hydrostatic pressures up to 600bar.

When the FDR/ VDR comes in contact with seawater, the ULB (that is co-located) starts a continuous emission of acoustic signals (pings) for a defined period. The main components of the ULB are metal envelope including the end caps and a switch. The pulse generation electronic circuit which is embedded in a urethane cylinder drives the piezoelectric ceramic that transforms the electric pulses into pulses of acoustic pressure.

A primary lithium battery serves as a power source for the ULB. The output of the ULB (**Figure.10**) includes a 10ms pulse signal once per second at 37.5 kHz, which is detectable at distances up to 2 km, based on the ocean state and seafloor bathymetry.

ULBs are designed based on the International Maritime Organization (IMO) guidelines MSC.333(90) and MSC.163(78) with a depth-rating of 6000m and omni-directional acoustic source power of 160 db (1060 dynes/cm^2 rms at 1m). They weigh ~200gms and designed for operation of 90 days after activation. From Jan 1 2018, all aircrafts with a take-off weight > 27t and flying over sea >180 NM from the shore must also have a low frequency (8.8 kHz) ULB installed in their fuselage.

The ULBs are mandatory for passenger vessels with GRT > 3000t. Depth-rated directional towed pinger locators (TPL) are used for detecting the pulses transmitted by the ULB. They are designed for mounting on remotely operated vehicles (ROV), AUV and towed bodies. The TPL used during MH370 search operations is shown in **Figure.11**.

The effectiveness of the TPL (range) depends on the ULB transmitter power (Source Level/SL), Transmission Loss (TL) during the propagation in ocean (that depends on geophysical boundaries including bathymetry and physical properties of the ocean water such as temperature, pressure and salinity, ambient Noise Level (NL) and the sensitivity of the TPL. The relationship for calculating the TL and NL are shown in equations 4 to 6 [7][8].

$$TL = 20lgr + \alpha r \times 10^{-3} \quad (4)$$

$$NL = 101g\, f^{-1.7} + 6S + 55 \quad (5)$$

$$\alpha = \frac{0.109\, f^2}{1 + f^2} + \frac{40.7\, f^2}{4100 + f^2} + 3.01 \times 10^{-4} f^2 \quad (6)$$

where α is the absorption coefficient in db/km, r is the range in m, A equals 10 for shallow waters and 20 for deep waters. In the case of deep waters, the signal propagation paths between the ULB transmitter and the TPL include ocean surface reflection, surface duct, bottom bounce, convergent zone, deep sound channel and reliable acoustic paths.

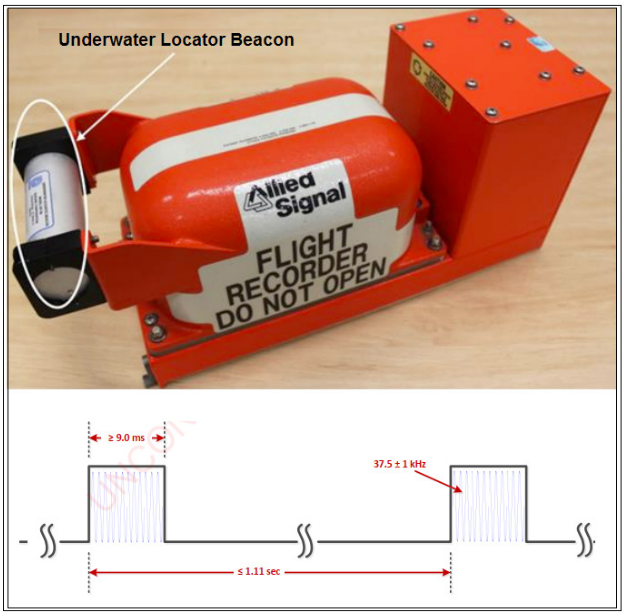


Figure.10. ULB with FDR and output signal format

Figure.11. ULB detector used for MH370 search operations [2]

The importance of SL, TL and NL in the successful detection of the ULB signal from a seafloor wreck is shown in the rendering (**Figure.12**). The rendering represents an ULB search with detector based on ship and AUV/Tow body. For the fixed SL and geo-boundaries, detection capability is better for an AUV/Tow body based receiver, as the signals experiences lower TL and subsea is characterised by lower ambient noise.

In case of ship-based receiver, signals experience higher TL and the sea surface is characterised by higher ambient noise.

Ambient noise includes contributions from many natural and anthropogenic sources. Ambient noise includes acoustic spectrum from below 1 Hz, to well over 100 kHz. It includes three constituents including wide-band continuous noise, tonal and impulsive noise. These combine to give the continuum of noise against which all acoustic receivers detect as the target signals. Impulsive noise is transient in nature and is generally of wide bandwidth and short duration.

The ULBs are mandatory for passenger vessels with GRT > 3000t. Depth-rated directional towed pinger locators (TPL) are used for detecting the pulses transmitted by the ULB

It shows peak amplitude and repetition rate. Continuous wideband noise is normally characterised as a spectrum level, which is the level in a 1 Hz bandwidth. This level is usually given as intensity in decibels (dB) relative to a reference level of 1 micro Pascal (μPa). Tonals are very narrowband signals and are usually characterised as amplitude in dB re 1μPa. The ambient noise level is variable and is dependent on the location and the environmental conditions. The component of ambient noise, which represents the NL is shown in **Figure.13**. It depicts the frequency and noise levels caused by heavy precipitation, near and distant shipping, wind (5 to 30 knots), shrimp and fish choruses.

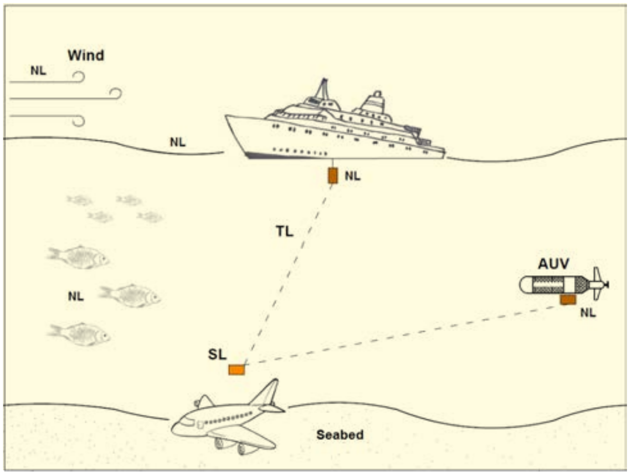


Figure.12. ULB localisation based on ship and AUV/tow body

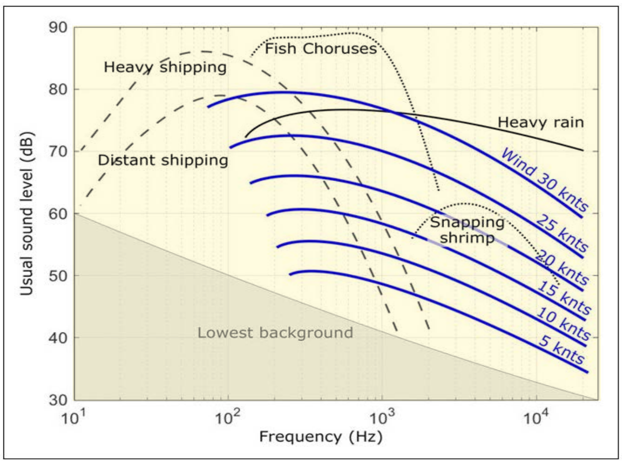


Figure.13. Sources of ambient noise in the ocean

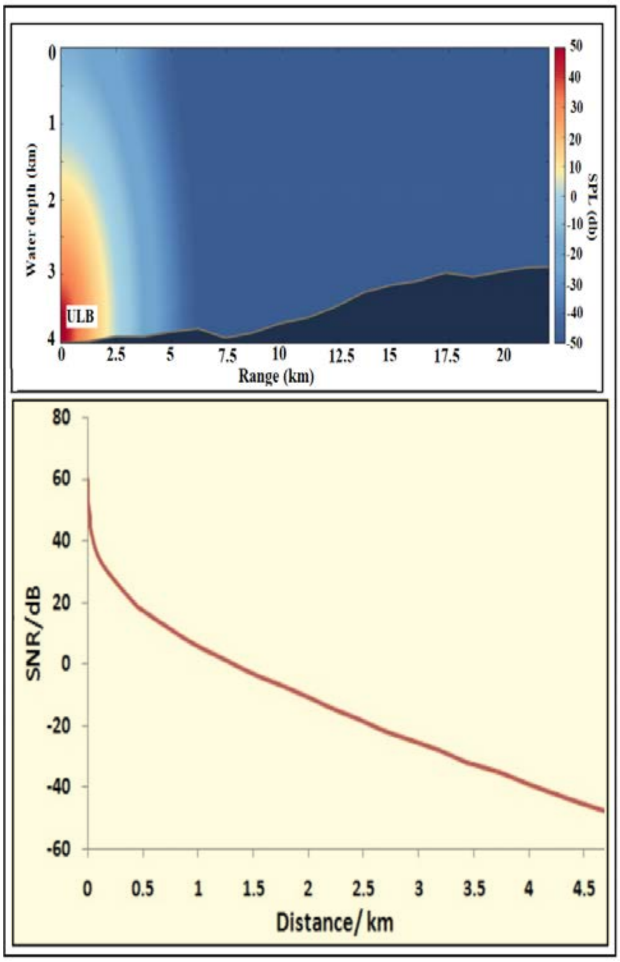


Figure.14. Bellhop simulation results for the range of 37.5 kHz ULB signal in tropical waters [9]

Modeling and simulation software are available for analysing the acoustic signal propagation in the ocean. They include Bellhop, DESERT, SUNSET and NS2. Bellhop is based on beam tracing approach for predicting the acoustic pressure fields in ocean environments. Beam tracing is done using geometric and physics-based spreading laws to determine the beam coordinates during the propagation.

Active sonar imaging is the construction of images in range and direction from the backscattered echoes from transmission pulses to estimate the acoustic reflectivity of the scene to the highest possible geometrical resolution

The inputs for the simulation tools include specifications of the directional pressure sources, sound velocity profile pertaining to the location and the geo-acoustic properties of the boundary zones. The simulation outputs include TL, Eigen rays, arrivals and received time-series.

The results of the Bellhop simulations for a 37.5 kHz ULB signal in tropical waters are shown in **Figure. 14**. It represents the signal to noise ratio (SNR) during sea state 5 and the noise bandwidth of 5 Hz [9]. Sensitive TPL detects the signals up to 3km based on the sea state.

The characteristics of commercial grade ULB and TPL are summarised in **Table.1**. The TPL measures the relative bearing angle to zero-in on the ULB. The relative bearing of an object is the clockwise angle from the heading of the TPL (onboard tow body/AUV) to a straight line drawn from the TPL to the ULB. The principle of determining the bearing angle is described in **Figure.15**, in which the phase difference of the incident wave front at the TPL receiver array (comprising of multiple transducers) is measured [6].

Table.1. Capability of commercially TPL

Parameter	Specification
Frequency Range	8-45 kHz
Bearing accuracy	5º
Bearing resolution	2º

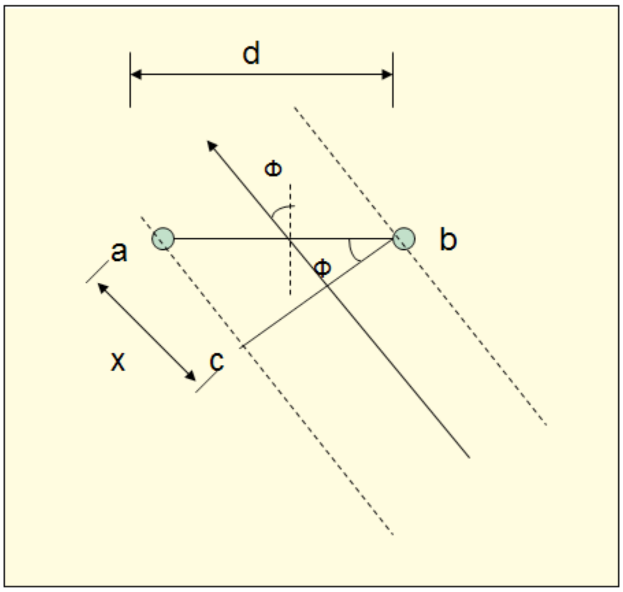


Figure.15. Zeroing on ULB based on bearing angle measurement

In the **figure d** is the distance between the TPL transducers, x is the extra distance travelled by the wave front to reach transducer "a" after reaching transducer "b". If α be the phase difference between wave front reaching a and b, λ is the wavelength, the bearing angle is calculated based on the time difference of arrival between the hydrophones separated by distance d.

$$\Phi = \sin^{-1}\left(\alpha * \left(\frac{\lambda}{2}\right) \pi * d\right) \quad \text{...(7)}$$

Once a ULB is detected, multiple search passes with a TPL are needed to adequately triangulate the location of the ULB. As indicated in **Figure.16**, the SNR at the TPL is an important factor that determines the accuracy of the range estimation. At higher noise levels, the range estimation inaccuracies could be up to 70% and at lower noise levels, the range accuracies could be much better, even better than 5%.

Locating the debris using sonar imaging

Active sonar imaging is the construction of images in range and direction from the backscattered echoes from transmission pulses to estimate the acoustic reflectivity of the scene to the highest possible geometrical resolution. Multi-beam sonars (MBS) are a type of active sonar system used to characterise the sea floor and detect objects in the water column or along the sea floor. MBS

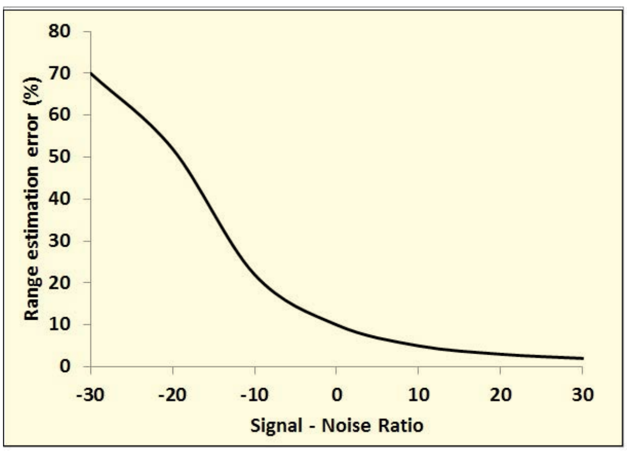


Figure.16. Range accuracy with SNR

are categorised into side scan, sector scan and synthetic aperture sonar (SAS).

Multiple physical sensors of the sonar called transducer array, sends and receives sound pulses to map the seafloor/objects. The sea floor depth or bathymetry is computed by measuring the time it takes for the sound to leave the array, hit the floor and return to the array. The functionality of the MBS is based on the sonar equation defined in equation 8,

SE = SL-2 TL+BS-NL ..... (8)

SE is signal excess, TL is transmission loss, BS is back scatter strength, NL is the noise at the location, all measured in decibels (db).

Operation at a higher frequency increases the ratio, but limits the achievable range of the sonar due to higher absorption in the saline sea water medium. These challenges are overcome using a Synthetic Aperture Sonar (SAS)

The dimension of the swath in the across track or athwart ship direction (perpendicular to the path of the ship) is called the swath width (**Figure.17**), and it can be measured either as a fixed angle or as a physical size that changes with depth. Seafloor scanning carried out using side scan sonar mounted on the ship, AUV and deep tow body is represented in **Figure. 18.** The figure shows the tow body at an altitude of 100-150m from the sea floor at a location where the water depth is 2500m.

MBS employ beam steering technique to convert the amplitude and phase information recorded by the hydrophone array into the amplitudes of echoes observed by the array at discrete angles. Beam steering technique is used to create a series of "virtual" hydrophone arrays, each sensitive to a different angle. The data from the hydrophones forms many steered beams that have beam widths in the athwart ship direction of ~2°, and spacing of ~ 1° between their axes.

Beam-forming is implemented using digital signal processing (DSP) by means of digitally delaying the channels in the array so that the array looking direction is steered to either side of the bore sight. The signal is then summed over the array for each range of interest (delay-and-sum). The beam steering angles that emerge from the Fast-Fourier-Transform (FFT) processing will be limited to a discrete set of angles which will depend on λ/d and on N, the number of hydrophones in the array.

Synthetic Aperture Sonar

The azimuth (along-track) resolution of the sonar is the ratio between the acoustic wavelength and the length of the array, example, 1:100 means a resolution of 1m at

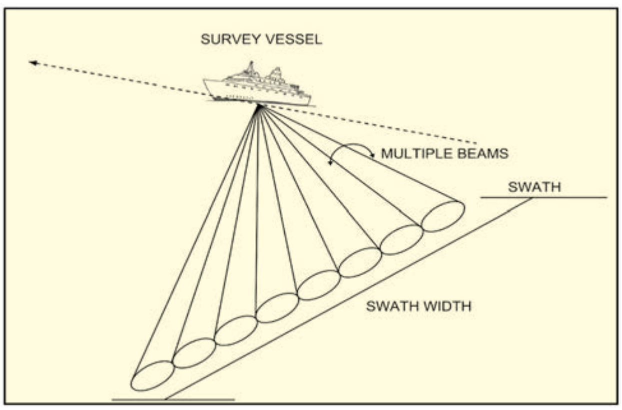


Figure.17. Rendering showing the beams and swath of a MBS

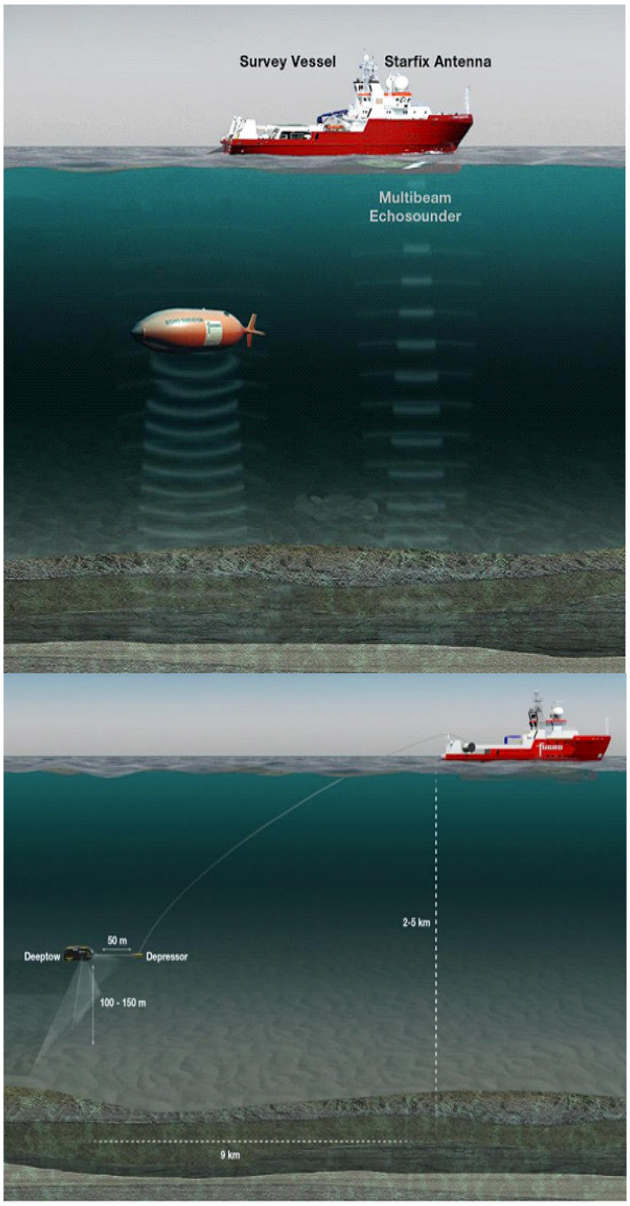


Figure.18. MBS scanning done using ship, AUV and TB [2]

100m range. A longer array will increase this ratio, but fitting such a long array in a ship/tow body/AUV is impractical. Operation at a higher frequency increases the ratio, but limits the achievable range of the sonar due to higher absorption in the saline sea water medium. These challenges are overcome using a Synthetic Aperture Sonar (SAS). The principle of imaging using SAS is based on the coherent coordination of data collected over multiple locations such that the along-track resolution is improved (**Figure.19**) [10] [11].

Sound velocity in the oceans varies between 1450 and 1570 m/s depending on the temperature, salinity and water depth

The maximum length of the synthetic aperture is given by the field-of-view (FoV) of the transmission and receiver elements. The image quality is a function of the range, as the signal to noise ratio (SNR) is range dependant. Thus, SAS is a space-time processing, where the data are collected by a moving platform in time and thereafter processed to produce an earth-fixed spatial image. Constant area coverage rate is a feature of the SAS processing i.e. as the speed increases, the range decreases proportionally (equation 9).

Speed x Range = Constant, for a given sonar design....(9)

Importance of precision attitude inputs for SAS

Interferometry in SAS processing works by co-registering two or more images by when the angle of coincidence to the target/seabed is slightly different. Then the phase difference is unwrapped to a time difference estimate and thereafter tuned into a digital elevation map estimate. SAS requires navigation fidelity of typically 1/16 of an acoustic wavelength to create high resolution seafloor images.

For a 120 kHz system, this amounts to knowing where the position of the array with an accuracy of better than 1mm. Hence the challenge is especially in acquiring the required vehicle stability and navigational accuracy for effective SAS processing with associated SAS system cost.

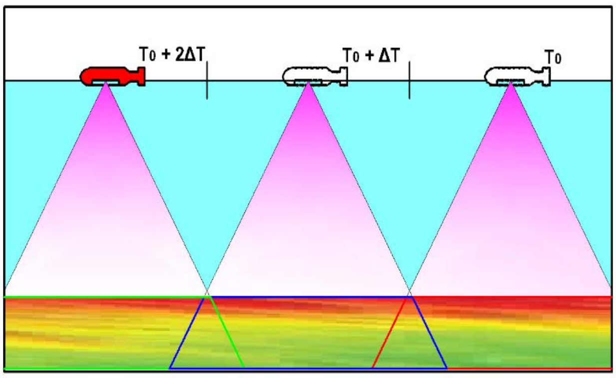


Figure.19. Principle of synthetic aperture sonar [11]

At present matured navigation systems based on fibre optic gyroscopes (FOG) or ring laser gyroscopes (RLG) have a heading, pitch and roll accuracy of 0.01º, random walk of better than 0.003°/√h and scale factor accuracy of 1 ppm. The accelerometers have a resolution of better than 1 μg, stability of better than 160μg/year and a scale factor of 300 ppm.

The recent Doppler velocity log (DVL) have an accuracy of ±0.1 cm/s and velocity resolution of 0.01mm/s in the bottom track mode (0.3-200m), and an accuracy of ±0.3 cm/s velocity resolution in the water tracking mode. The upcoming Correlation Velocity Log (CVL) operates at lower frequencies with better accuracies and higher range.

With the present technological maturity, with the SAS with inputs for precise attitude and heading reference system (AHRS), by covering a range of 200m on each side of the AUV cruising at 2 m/s, it is possible to have on-board high resolution of up to few centimetres and well as co-registered images, covering ~2 km^2/h. The specifications of commercial grade SAS are shown in **Table.2.**

Importance of vehicle speed

Due to the spatial sampling requirements the maximum platform velocity Vsas achievable for distortion-free imaging is a function of the physical aperture length (L) and ping repetition interval (PRI). Therefore, the condition to be satisfied is,

Vsas ≤ L/2 PRI .... (10)

With precise attitude inputs and with the recommended platform velocity, SAS offers a trade-off between sonar range and resolution. SAS provides over 25 times greater resolution at a range with 3 times increase in area that is covered compared to conventional side-scan MBS. Two distinct processing schemes convert the per-time-slice angles and amplitudes to a set of beam angles or direction of arrivals (DOAs) and time of arrivals (TOAs) of bottom echoes.

Table.2. Commercially available SAS

Operating frequency	Range	Array length and elements	Platform speed
60 kHz	1500m	4.3m, 32	1 m/s
100 kHz	300m	2m, 24	2.5m/s
100kHz	200m	1.2m, 32	2 m/s
17.5/150kHz	100m	0.6m, 24	2 m/s
300kHz	200m	1.2m, 32	2 m/s

Both of these processes employ ship motion (attitude) data to convert direction angles from the hydrophone-centered coordinate system (also called tow-body frame) in which they are transformed into the earth-centered coordinate system (earth frame). Ensuring the tracking system and accurate positioning of the deep-tow vehicle is critical to ensure complete sonar coverage.

Variations in the speed of sound causes sound waves to refract/ bend when they travel obliquely through layers of water that have different properties of salinity and temperature

The approach normally used to control the underwater towed systems are by controlling the attack angle of the wing and by deploying or retracting the tow cable to produce suitable external forces and moments. The coordinate systems representing towing ship, tow cable and the tow body is shown in **Figure.19.**

With reference to **Figure.20**, the relationship between towed-body frame and the earth-fixed frame is expressed in terms of Euler angles (equation 11).

$$[t\ n\ b] = [i_b, j, k_b]R^T(\phi,\theta,\psi)W(\alpha,\beta) \quad \ldots\ldots\ldots\ldots (11)$$

where c = cos c, s = sin and φ, θ, ψ are the roll, pitch and heading angle of the tow body, respectively. In equation 13, α represents the rotation angle about the k axis into the plane of t and n. The angle β represents the rotation angle about the b axis brings i and j into coincidence with t and n.

$$R(\phi,\theta,\psi) = \begin{bmatrix} c\psi c\theta & -s\psi c\theta + c\psi s\theta s\phi & s\psi s\phi + c\psi c\phi s\theta \\ s\psi c\theta & c\psi c\phi + s\phi s\theta s\psi & -c\psi s\phi + s\theta s\psi c\phi \\ -s\theta & c\theta s\phi & c\theta c\phi \end{bmatrix} \quad \ldots (12)$$

$$W(\alpha,\beta) = \begin{bmatrix} c\alpha c\beta & -s\beta c\alpha & s\alpha \\ -s\alpha c\beta & s\alpha s\beta & c\alpha \\ -s\beta & -c\beta & 0 \end{bmatrix} \quad \ldots\ldots\ldots\ldots (13)$$

With system parameters and the sea state as inputs, dynamic simulations can be performed using software such as Orcaflex. The real-time response of the cable tension and the towed underwater body under different munk moments could be achieved by changing the different Munk moment coefficients. The results could provide a theoretical basis for the optimal design of a tow cable and towed body.

However, under real ocean environments, the unsteady motion of a towing ship is transmitted down the cable to the towed body, resulting in perturbations both of attitude and position relative to the towing ship. Depending on the sea state and the response of a towing ship, these perturbations can be large enough to throw off the towed body beyond acceptable limits. The maintenance of the attitude of a towed body that is as stable as possible under different towing conditions is one of the major concerns of during tow-body survey [12].

Figure.21 shows a typical track plot of the tow ship and the deep-tow vehicle (reproduced from MH370 search) [2]. It represents how far the deep-tow vehicle and the mother vessel were relatively off the planned survey line. The steps in the red vessel track, these were from the vessel shifting position to help to steer the deep-tow vehicle down the planned survey line. This allowed the operators to manipulate the deep-tow vehicle position using the ship position.

Area coverage and detection sensitivity

When searching for wreckages, the altitude of the side-scan MBS depends on the dimension of the wreckage, depth of the ocean at the search location, image resolution requirements and the number of beams in the sonar. Depending on these factors, side scan surveys are carried out either from the ship or TB or AUV.

As described in the previous sections, survey is normally carried at a speeds limited to 5 knots, as higher speeds reduce the resolution. Computations are carried out for area that could be covered per hour using a side-scan MBS with beam swath of 150º when surveying at various altitudes and speeds, and the results are plotted

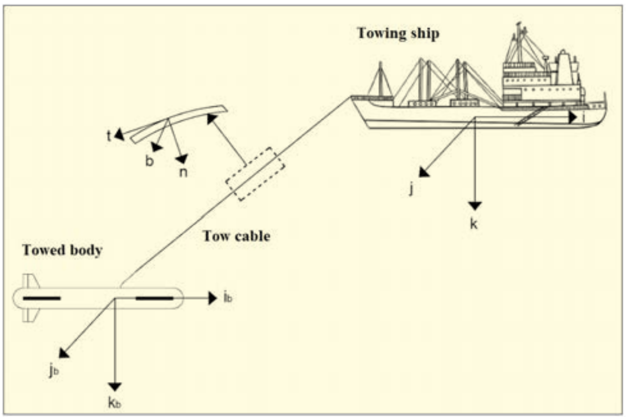


Figure.20. Coordinates of the TB, tow cable and ship [12]

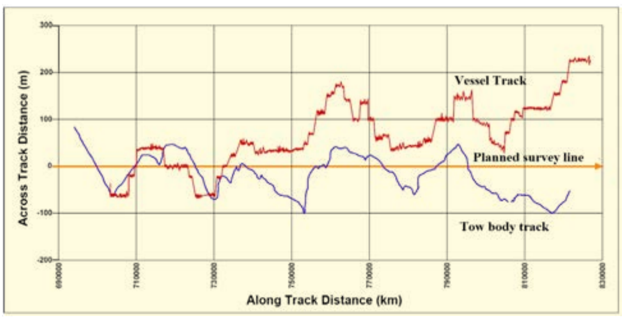


Figure.21. Challenge in line keeping during towed array survey [2]

in **Figure.22**. As an example, surveying using ship in water depths of 3000m at 3 knots, has a swath of ~22km and covers 230 km^2/h.

The acoustic image of the AF447 wreckage (located ~2300kms south-west of Australia) captured during the 18^{th} mission of REMUS AUV sonified using 120kHz side scan-sonar from a range of 700m is shown in **Figure.23**. The wreckage comprising of 1000 pieces was at 3400m water depth spread over 600 x 200m area.

Computations are carried out to identify the minimum detectable size of the wreckage using side-scan sonar with 880 beams and swath angle of 150° at various water depths and the results are plotted in **Figure. 24**. At 4000m water depths, the minimum detectable sizes are 35m and 15m based on 1 and 2 pings, respectively, when surveyed from a surface ship. When one or two beams sonifies the wreckage, multiple transects could infirm the presence of the wreckage.

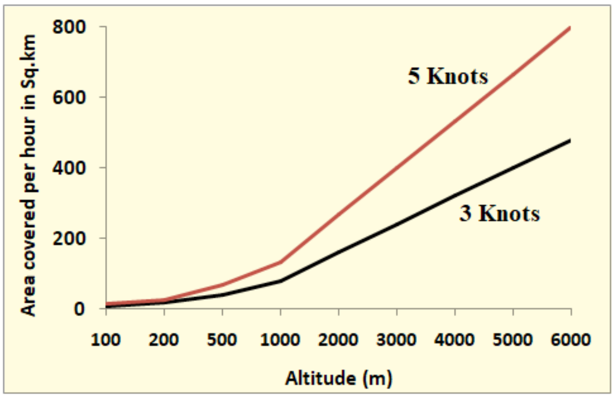


Figure.22. Survey area using side-scan sonar at various altitudes and speed

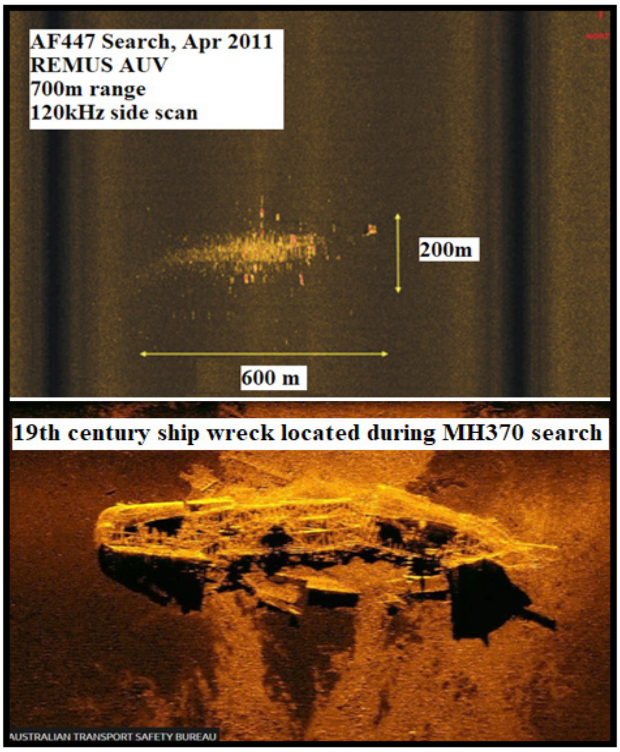


Figure.23. Debris of MH370 located by Hugin AUV and 19^{th} century ship wreck uncovered during MH370 search [1][2]

Sound velocity profile inputs for precise positioning

Sound velocity in the oceans varies between 1450 and 1570 m/s depending on the temperature, salinity and water depth. It increases at ~ 4.5 m/s/°C and ~ 1.3 m/s/psu (salinity) and ~1.7 m/s/100m. The sound velocity variation with depth is called sound velocity profile (SVP) (**Figure.25**). At depths >1000m pressure becomes the important factor.

It combines with temperature and salinity to produce a zone of minimum sound speed, and is called SOFAR (SOund Fixing And Ranging) channel. If a sound is generated by a source in the SOFAR zone, it becomes trapped by refraction. Dispersed horizontally rather than in three directions, the sound will travel for greater distances in the SOFAR conduit.

In practice, the existing systematic, accurate, and reliable measurements of sound velocity in ocean waters are based on Mackenzie, Coppens, Del Grosos NRL II, UNESCO equation (based on Chen and Millero) and the NPL equation (formulated by Leroy, Robinson and Goldsmith). The recent relationship proposed for the calculation of sound velocity in seawater as a function of temperature, salinity, depth and latitude in all oceans and open seas is,

$$\begin{aligned} C = {} & 1402.5 + 5T - 5.44 \times 10^{-2} T^2 + 2.1 \times 10^{-4} T^3 \\ & + 1.33S - 1.23 \times 10^{-2} ST + 8.7 \times 10^{-5} ST^2 \\ & + 1.56 \times 10^{-2} Z + 2.55 \times 10^{-7} Z^2 - 7.3 \times 10^{-12} Z^3 \\ & + 1.2 \times 10^{-6} Z (\Phi - 45) - 9.5 \times 10^{-13} T Z^3 \\ & + 3 \times 10^{-7} T^2 Z + 1.43 \times 10^{-5} SZ. \quad (14) \end{aligned}$$

Variations in the speed of sound causes sound waves to refract/bend when they travel obliquely through layers of water that have different properties of salinity and temperature. This creates inaccuracy in the position of the wreck during MBS imaging. Hence location-specific SVP is an important input required for precise localization of the sonar images.

Based on the SVP logged using Valeport mini SVS sensor (sonic instrument which measures the sound

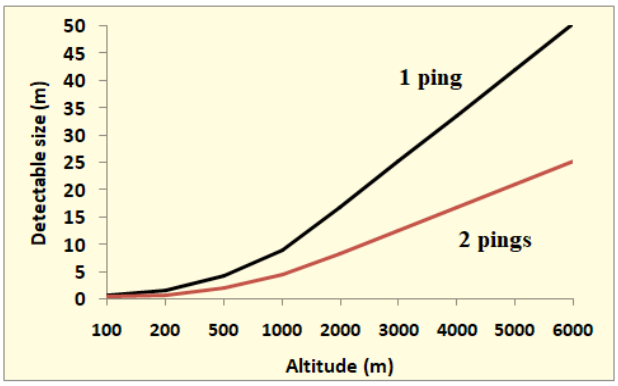


Figure.24. Wreckage detection based on sizes and survey altitude

velocity based on time of flight) in the Indian Ocean in April 2010, it is found that, without SVP inputs the positioning error of sonar images could be up to 150m at 5500m water depths in the Indian Ocean (**Figure.26**).

Discussion and conclusion

From the search, recovery and investigation of the aircrafts lost in deep oceans, including AF447 and MH370, it is clear that if the aircraft's last known position is inaccurate or there is a delay in responding, the floating debris will drift from the impact point and get dispersed, increasing the size required for a surface search. Debris drift modelling becomes less accurate over time and

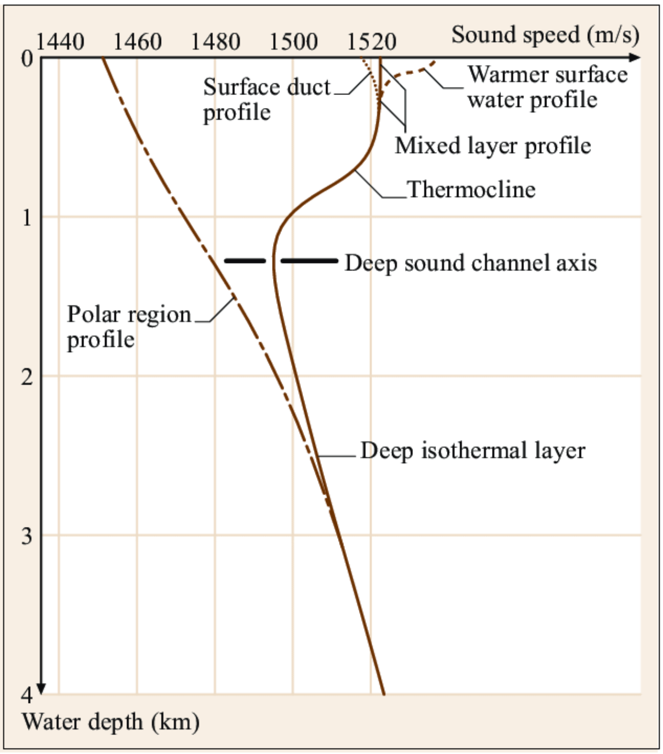


Figure.25. Sound velocity profile in the oceans

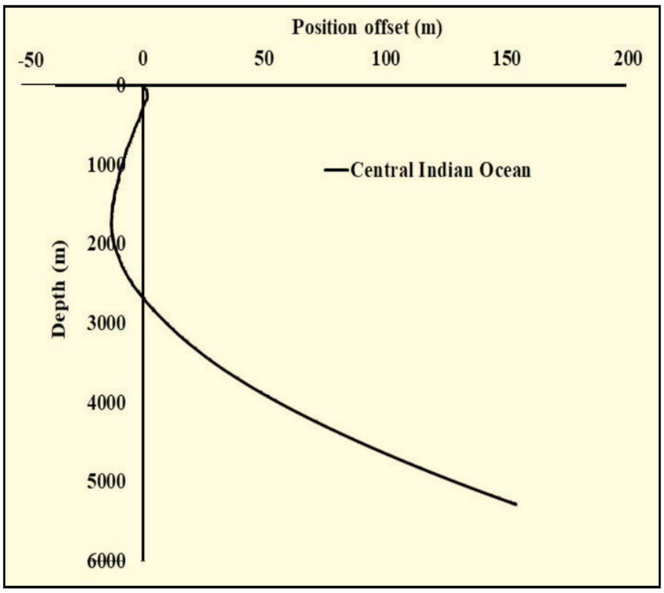


Figure.26. Offset in sonar image location without SVP inputs

the precisely locating the underwater locating beacon becomes more uncertain.

Under such circumstances, underwater locating beacon may not be detected before batteries are exhausted, resulting in a sonar search that needs to cover a wide area. Ultimately, every stage of the search becomes increasingly more difficult and costly. From the statistics of flight data recorder recoveries, the time to locate the ULB and the debris increases with the water depth, and still worsened if the last known position is inaccurate.

Hence it is clear that when appropriate monitoring and response mechanisms are in place to capitalise on each opportunity to narrow the search area, the total search effort becomes far more manageable with greater probability of success. It is therefore imperative to obtain the best possible information about the impact location and to deploy effective search assets to the area as soon as possible to minimise the search area and maximise the likelihood of finding survivors and floating debris.

Once the last known location is precisely known, factors including mass, added mass, hydrodynamic shape, water current velocity profile and the direction are required to determine the sinkage velocity and sinkage time, which are essential for generating posterior probability maps based on monte-carlo or Bayesian approaches for locating the seafloor wreckage with the highest probability.

Commercially available modeling and simulation tools enable to define scenarios, provide inputs including aircraft state vector, model of aircraft dynamics, winds and currents necessary to compute drift trajectories, estimate effective sweep widths for search sonars, develop PPM for search object location and find near-optimal search plans given the amount of search infrastructure available.

The recent decision to incorporate low frequency (8.8kHz) underwater location beacon increases the range of detection up to 5 kms and simulation tools help to precisely predict the acoustic pressure fields based on beam tracing approaches under different geo-physical boundary conditions. The advances in sonar imaging, specifically the synthetic aperture sonar, the need for high precision attitude inputs for precise image processing, importance of vehicle speed during imaging survey are explained in detail.

The area that could be covered at various surveying speed at different altitudes and the detection sensitivity and the importance of sound velocity profile in precise localisation is also discussed. In addition to the efficient monitoring technologies and rapid response mechanisms for locating the ocean-lost assets, the ongoing US$ 3 billion Seabed 2030 efforts to create a full global sea floor bathymetry map with a 100m resolution could be of help in early localisation of the sea floor wreckage [13].

ABBREVIATIONS

ACARS	Aircraft Communications Addressing & Reporting System
AHRS	Attitude Heading Reference system
ATSB	Australian Transport Safety Bureau
AUV	Autonomous Underwater Vehicle
BEA	Bureau of Enquiry and Analysis
BF	Body Frame
BFO	Burst Frequency Offset
BTO	Burst Timing Offset
CVL	Correlation Velocity Log
DOA	Direction of Arrival
DSP	Digital Signal processing
DVL	Doppler Velocity Log
DWT	Dead Weight Tonnage
EF	Earth Frame
FDR	Flight Data Recorder
FFT	Fast Fourier Transform
FOG	Fiber Optic Gyroscope
FOV	Field of View
GES	Ground Earth Station
GRT	Gross Registered Tonnage
GUI	Graphical User Interface
HNS	Hazardous and Noxious Substances
IMO	International Maritime Organization
INMARSAT	International Maritime Satellite
ISM	International Management Code for the Safe Operation of Ships and for Pollution Prevention
LEP	Local Effectiveness Probabilities
LKP	Last Known Position
MARPOL	Prevention of Pollution from Ships

MBS	Multibeam Sonar
MC	Monte Carlo
NL	Noise level
NM	Nautical miles
OBF	Offset Burst frequency
PPM	Posterior Probability Maps
PRI	Pulse Repetition Interval
REMUS	Remote Environmental Monitoring Units
RLG	Ring Laser Gyroscope
ROV	Remotely Operable Vehicle
SAS	Synthetic Aperture sonar
SE	Signal Excess
SEP	Search Effectiveness Probabilities
SL	Source Level
SNR	Signal to Noise Ratio
SOFAR	Sound Fixing And Ranging
SOLAS	Safety of Life at Sea
SONAR	Sound Navigation and Ranging
STCW	Standards of Training, Certification and Watch keeping for Seafarers
SVP	Sound Velocity Profile
SVS	Sound Velocity Sensor
TL	Transmission Loss
TOA	Time of Arrival
TPL	Towed Pinger locator
ULB	Underwater Locator Beacon
UNESCO	United Nations Educational, Scientific and Cultural Organization
VDR	Voyage Data Recorder

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SCRUBBERS ON HIGH SEAS TO RULE THIS DECADE

Manogaran Vijayakumar
Kappuvaveetil Gauthamgopinath

ABSTRACT

The aim of MARPOL convention is to prevent pollution of the marine environment. It seeks to control airborne emissions from the ships with some limitations. The convention prescribed the Sulphur content in fuel oils used on board ships not to exceed 0.5% m/m on and after 1 January 2020. These contemplate the shipping companies to switch over to use other compliant fuels or install Exhaust Gas Cleaning System (EGCS) / Scrubbers. EGCS/Scrubbers clean the exhaust gas released in order to discharge a minimum amount of So_x. To evaluate the selected EGCS/Scrubbers technology from ship owners and charterer's point of view, the proposed analysis in this paper indicates the success of scrubbers than 0.5% VLSFO, in which the amount that vessels with the EGCS/Scrubbers units installed can earn for a voyage. At the outset, fuel cost plays a vital role which is always an exponential function, in this part EGCS/Scrubbers take more attractive investment appraisals than other alternative compliant fuels throughout this decade.

Keywords: MARPOL convention; EGCS / Scrubbers; 0.5% VLSFO; 3.5% HSFO

INTRODUCTION

The IMO has efficiency requirements as part of Annex VI of MARPOL to reduce CO_2 emissions from the shipping industry, and they adopted the "IMO strategy on reduction of Green House Gas (GHG) emissions from ships" in 2018. The following objectives are agreed upon:

- Carbon intensity of international shipping is set to decline and action are to reduce CO_2 emissions per transport work, on average across international shipping, by at least 40% by 2030, with efforts to reach 70% by 2050, compared to 2008; and GHG emissions from international shipping to peak and decline, with total annual GHG emissions reduced by at least 50% by 2050, with efforts to phase them out, in line with the Parley for the Oceans (Knudsen, 2021).

In the year ahead, a strategy review will take place.

EU Regulations (All voyages to, from and between EU ports) in 2013, the Commission set out a strategy towards reducing GHG emissions from the shipping industry.

- Monitoring, Reporting, and Verification of CO_2 emissions from large ships using EU ports are the three steps in the strategy. This step has now been implemented and is known as the EU MRV
- Goals for reducing greenhouse gas emissions in the maritime transportation sector
- In the medium to long term, additional measures, including market-based measures. The European Union recently approved the inclusion of shipping in its emissions trading scheme

The requirements are similar to those of the International Maritime Organization (IMO), but the EU regulations include cargo information, and data submitted to them will be made public. 2018 was the first year of reporting.

According to the European Environment Agency's greenhouse gas emissions data, emissions account for 3.7 % of total EU CO_2 emissions. This annual report is based on data from 2018 emissions reported by companies until September 2019 under the EU Regulation on CO_2 emissions from maritime transport monitoring, reporting, and verification (MRV). The data and report are published each year to provide a better understanding of the monitored fleet's characteristics, CO_2 emissions, and energy efficiency.

EGCS / Scrubbers are used on some ships to reduce air pollution. Flag states accept this as an alternative method of meeting the Sulphur limit. Some ships reduce air pollution by incorporating EGCS / Scrubbers. As mentioned, Flag States accept this as an alternative method of meeting the Sulphur limit requirement. These scrubbers are intended to remove Sulphur oxides from the exhaust gases of the ship's engines and boilers. As a result, a ship equipped with a scrubber can use heavy fuel oil (3.5 %) because the Sulphur oxide emissions will be reduced to a level equivalent to the required fuel oil Sulphur limit (0.5 %).

As a result, the article discusses VLSFO's challenges, future fuel options, the edges taken over by the EGCS / Scrubbers.

SULPHUR CAP- 2020

Sulphur Oxides (Sox) are produced during the combustion of Sulphur-containing fuel. The main concern with Sox emissions is when they are emitted close to land, where they have a direct impact on human health and the environment; they cause lung and heart diseases, as well as acid rain, which has a significant impact on the health of forests, farmland, and freshwater. Shipping accounts for approximately 9% of global SO emissions. The International Maritime Organization (IMO) has imposed a Sulphur limit on marine fuel oils. The legislation also allows a vessel to burn high Sulphur fuels if Sox emissions are removed from the exhaust and result in the same concentration of Sox emissions as burning low Sulphur fuels, such as if a vessel installs an EGCS / Scrubbers. As of January 1st, 2020, the IMO adopted a global Sulphur cap limiting all vessel exhaust emissions to a maximum 0.5 % Sulphur content, requiring ships to either burn 0.5 % Sulphur fuel or use alternative technology to reduce emissions to an equivalent level. This requirement is in addition to the 0.1 % Sulphur limit in the North American, US Caribbean, North Sea, and Baltic Emission Control Areas (ECA), In addition to the IMO legislation, local limits are enforcing in Hong Kong, European Union Ports, China, South Korea, Malaysia and California. The Californian regulations differ slightly from ECA requirements, as they require vessels to use MDO/ MGO. The Sulphur cap in China's designated 'inland' ECA (navigable waters of the Yangtze River, and the Xijiang River main lines) was further tighten to 0.1%S on 1st January 2020 for sea-going vessels. We expect in time more ECAs will appear around the world – Mediterranean, Caribbean, Japan, and Norway are possible in the near future (Knudsen, 2021).

0.5% VLSFO AND ITS CHALLENGES

After started using 0.5%VLSFO continuously, the shipping fraternity faced the key issues which can damage the marine diesel engines due to cat fines, excessive sludging, compatibility issues, asphaltene, high wax appearance temperatures (cloud point) and fuel stability. 0.5%VLSFO is incompatible even with same type of fuel from same refiner but bunkered in different locations. The new low Sulphur fuel hasn't stopped the issues of fuel instability and contamination which are of primary concern for ship owners, ship managers and operators. The problem is that VLSFO does not really exist as one fuel. It is a range of chemicals that are so wide, variable and volatile that it is staggering that it is even labelled as one type of fuel (Mahajan, 2021).

UNSTABLE AND VOLATILE FUEL

0.5%VLSFO was discovered to be not just one fuel but new blends forming thousands of unique permutations. Various blends of 0.5%VLSFO have been found to be highly variable, easily contaminated and very unstable. These blends were also very volatile, changing critical properties within the space of days and weeks, rather than the usual months when the oil is stored.

METALLIC SAND IN THE ENGINE

0.5%VLSFO is the residual part left at the end of the refining process, and is produced using a chemical process called catalytic cracking. To make this cracking process more effective at lower temperatures, hard particles of Aluminium (Al) and Silicon (Si) are added to the oil. They resemble a metallic form of sand.

COMBUSTION QUALITY OF FUEL IN THE ENGINE

0.5%VLSFO poses a particular risk. It takes much longer between the time the fuel enters the chamber of an engine to when it ignites. This causes a massive shock wave (known as a 'diesel knock'). Swedish ship reinsurers, one of the thirteen big ship insurers in the world), highlighted that ignition problems occurred with 0.5%VLSFO when the CCAI was between 850 and 890.

WAX DEPOSITS

Solidifying 0.5%VLSFO in colder temperatures poses a major risk of engine failure in colder temperatures.

One of the most visible issues with 0.5%VLSFO is what the industry describes as 'wax deposits.' Chemicals known as Aromatic and Paraffinic compounds are mixed in different ways to make 0.5%VLSFO. This turns flowing ship oil into a sticky putty. This putty is unusable in ships and clogs up all aspects of a ship's pipelines and machinery.

THE VISCOSITY PROBLEM

Oil needs to maintain a certain viscosity to be safe given the way that ship engines have been designed.

Viscosity is measured as a centistoke (CST). Industry reports from March 2020 show viscosity plummeting to dangerously low levels (indicating a high degree of running fluids).

EXHAUST GAS CLEANING SYSTEMS / SCRUBBERS WITH 3.5% HSFO

The IMO guidance covers aspects of the fuel oil purchase all the way up to loading the purchased fuel oil on board. The requirements for fuels used in marine diesel engines and boilers are specified in an International Standardization Organization (ISO 8217). ISO has released a new standard: ISO/PAS 23263:2019 Petroleum products - Fuels (class F) - Considerations for fuel suppliers and users regarding marine fuel quality in light of the implementation of a Sulphur limit of 0.5 % in 2020 (Li et al., 2020).

To achieve the same level of emission reduction, Regulation 4 of MARPOL Annex VI allows Administrations (flag States) to approve "equivalents" - any fitting, material, appliance, or apparatus to be installed in a ship or other procedures, alternative fuel oils, or compliance methods used as an alternative to that required" - that enables the same emission control standards to be met Flag States have accepted and approved EGCS / Scrubbers**,** as meeting the requirements for Sulphur oxide reduction (Green book, 2021).

The same regulation on Equivalents contains an important requirement, which states in paragraph 4 that "the Administration of a Party that allows the use of an equivalent shall Endeavor not to impair or damage its environment, human health, property, or resources, or those of other States." The International Maritime Organization (IMO) has established stringent criteria for the discharge of wash water from any EGCS / Scrubbers residues produced by the EGCS/Scrubber unit, which is typically in a closed-loop configuration, should be delivered ashore to appropriate reception facilities. Such residues should not be discharged into the sea or burned on board.

Open- loop scrubbers add water to the exhaust gas which turns Sulphur oxides (Sox) to sulphates/sulphuric acid. Open-loop scrubbers return wash water to the sea. The wash water must meet strict criteria, so that discharge wash water should have a pH of no less than 6.5. There are also strict limits on discharge of Polycyclic Aromatic Hydrocarbons (PAHs) and nitrates (Lack & Corbett, 2012).

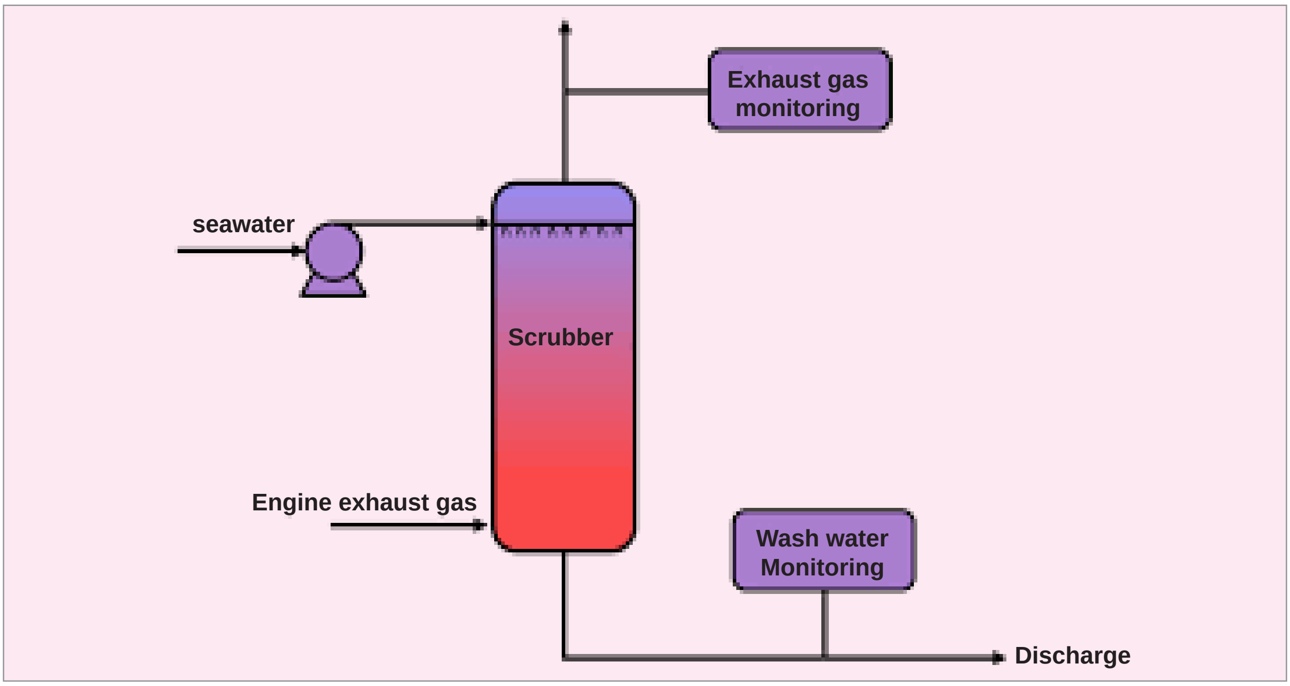
PRINCIPLE OF EGCS / SCRUBBERS SYSTEM

Exhaust gas streams pass through an alkaline scrubbing material inside the scrubber, which neutralises the acidic nature of the exhaust gases and removes any particulate matter.

The scrubbing material is then collected with the wash water, which can either be stored or disposed as effluent right away. The system's cleaned exhaust is discharged into the atmosphere. The scrubbing material is selected so that specific impurities such as Sox or NOx can be removed through chemical reactions.

Marine scrubbers use lime or caustic soda to desulphurise water, resulting in Sulphur-based salts that can be easily discharged because they do not pose a threat to the environment. Because of their alkaline nature, scrubbers can use sea water, fresh water with added calcium/sodium sorbents, or hydrated lime pellets as a scrubbing medium (Paulsrud, 2015).

Inside the scrubbers, packed beds of gas-pollutant removal reagents (such as limestone) are used to increase the contact time between the scrubbing material and the gas. The vertical flow of water inside the scrubbers is slowed by these packed beds, which intensifies the exhaust gas cooling and acidic water neutralisation process. Scrubbers are designed to maximise the involved reactions:



INVESTMENT WORTHY FOR EGCS / SCRUBBERS SYSTEM

- Total Engine Power --53,000KW
- Sulphur content -- 3.5%
- Fuel oil consumption per day ---35MT/day
- Estimated HFO per year --12,775 MT/annum
- Fuel price 3.5% HSFO (as on mid Nov 2021) --460USD/MT
- Fuel price 0.5% VLSFO (as on mid Nov 2021) ---630USD/MT
- EGCS / Scrubbers Component cost --3,500,000USD
- EGCS / Scrubbers Installation cost ---1,000,000USD
- EGCS / Scrubbers Total investment cost ---4,500,000USD
- Estimated 3.5% HSFO cost per year (as on mid Nov 2021) ---------------------------------------5,876,500USD
- Estimated 0.5%VLSFO cost per year (as on mid Nov 2021) --------------------------------------8,048,250USD
- Estimated rate spread between 3.5%HSFO and 0.5%VLSFO per year ---------------------------2,171,750USD

SO_2 (gas) + H_2O + ½O_2 → SO_4^{2-} + 2H+ (Sulphate ion + Hydrogen ion).

HCO_3^- + H^+ → CO_2 + H_2O (Carbon-di-oxide + Water).

Salient features of using EGCS / Scrubbers system includes;

- It has very few moving parts, the design is simple and easy to install on board.
- Apart from de-fouling and operational checks, the system requires very less maintenance
- This system does not require storage for waste materials

Estimated payback period for the EGCS considering the total investment on the System will be less than 2.1 years

This calculation is an approximate estimation. Various factors influencing the fuel consumption, fuel cost, load, current, routing etc., has to be taken into account for detailed estimation.

FUTURE FUEL AND ITS TRANSITION PERIOD

The work of classification and standardisation societies like DNV GL helps to ensure systems are brought up to scratch and held to a higher standard. It is with LNG, LPG, Methanol, ammonia, hydrogen, and lithium-ion battery. May be by 2050 we will have found a way to include decarbonised source of fuel within the maritime sector. That would be transformational (McKinnon, 2011).

CONCLUSION

By using exhaust gas cleaning system-scrubbers, ship operators, owners, managers, front liners ship staffs can operate marine diesel engines without worry about costly engine failures, lay-up or any off-hire caused by contamination, fuel instability and its associated problems with the low Sulphur fuel, also scarcity and availability of the future fuels. In far, future fuels like lithium-ion batteries, methanol, ammonia, hydrogen may be the complementary to EGCS /Scrubbers but still cannot be compensated in terms of monetary beneficial.

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TECHNICAL NOTES

LUBE MATTERS # 13 POLYMER ADDITIVES

Sanjiv Wazir

Introduction

Mineral oil-based lubricants tend to lose their hydrodynamic film forming ability at higher temperatures due to drop in their viscosity. In the early days of automotive lubrication this problem was resolved by changing from “Winter grades” (low viscosity oils) in winter to “Summer grades” (high viscosity oils) in summer. In the 1930s, scientists discovered that this deficiency could be overcome by the addition of certain synthetic polymers. Then it became possible to make “all-season” motor oils. This led to the rapid adoption of such “multi-Grade” oils from the 1950s.

Polymer additives such as viscosity index improvers (aka viscosity modifiers), pour point depressants, emulsifiers, demulsifiers, anti-foam agents, seal-swell agents, etc., are now key components in high performance lubricants. Some compounds with polymeric structures are also used as synthetic base oils.

Viscosity Index Improvers/Viscosity Modifiers

Viscosity index (VI) was normally used as a measure of the change in oil viscosity with temperature. VI is derived from the measured viscosities of the oil at 40° and 100°C. An oil having a large viscosity change in this temperature range is a Low VI grade whereas oil exhibiting less change in viscosity over this temperature range is termed High VI grade.

In modern lubrication systems this may no longer be useful, because many equipment now operate at extreme temperatures. At such temperatures the actual viscosities do not match those expected from the VI of the oil. Other measures of viscosity such as HTHS (High Temperature High Stress) viscosity (measured at 150°C) are used in such cases.

The main function of Viscosity Index Improvers (VII) is to minimise oil viscosity variations with temperatures. These additives are high molecular weight polymers, that change shape with temperature. They are added to low viscosity oils to moderate the decline in the oil viscosity at high temperatures **(Figure 1)**.

At low temperatures, the polymer molecules occupy a small volume, have little association with the bulk oil, and hence result in minimal change in oil viscosity. At high temperatures due to the addition of thermal energy, the polymer chains extend or expand. The resultant increase in surface area increases the association (solubility) of the polymer molecules with the bulk oil **(Figure 2)**. This effectively increases the oil viscosity.

The addition of VII to the oil results in a shallower slope of the VT line. Variable thickening of the oil by VII has

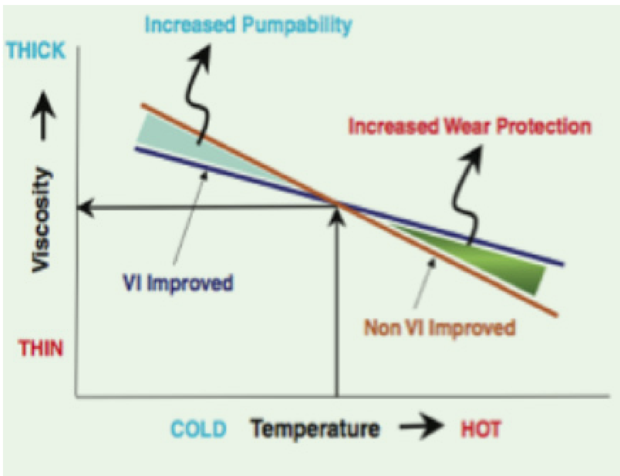

Figure 1: Effect of VII on viscosity-temperature (VT) properties of an oil (1)

enabled formulation of multi-grade oils. Multi-grade oils are mixtures of a small number of very large molecules (VII) in the small molecules of the base oil.

The size of the VII polymer (molecular weight) impacts the thickening efficiency and shear stability of the viscosity modified oils in contrasting ways.

Thickening efficiency is proportional to the length of the polymer backbone of the additive molecules. High molecular weight polymers provide higher viscosity.

Viscosity loss in a viscosity modified oil can result from shearing of the VII additives due to mechanical or thermal breakdown of the polymer. Shear related viscosity loss affects the larger (high molecular weight polymers) more than the smaller ones. Shear related viscosity loss is often observed in equipment where the oil is subjected to intense shearing e.g., gear and vane pumps, journal bearings, etc. The viscosity loss can be temporary (original viscosity is regained once shear is removed) caused by reversible deformation of the polymer molecules. Viscosity can be lost permanently (viscosity does not revert to the original once shear is removed), caused by polymer molecules break down. This is undesirable **(Figure 4)**.

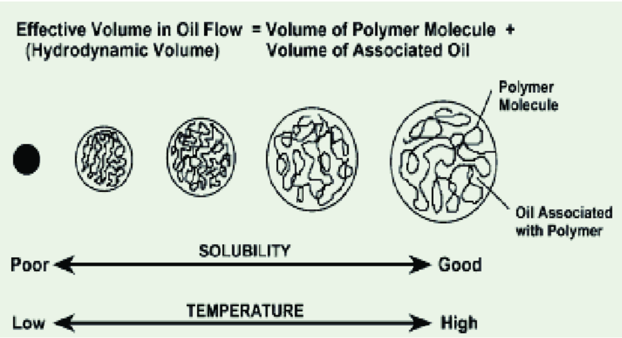

Figure 2: Mechanism of oil thickening by viscosity modifiers (2)

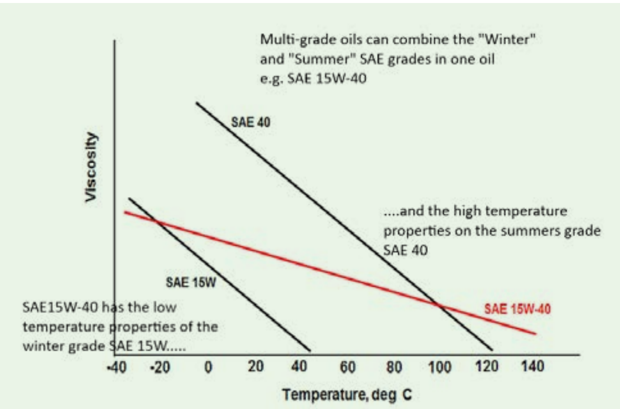

Figure 3: VT property of Multi-Grade Engine oil SAE 15W 40 (3)

Whether temporary or permanent, shear stability of the polymeric molecules is related to its size (molecular weight).

Engine lubrication is mostly hydrodynamic in nature and hence lubricant with lower shear stability is acceptable.

Gear lubrication is mainly boundary in nature and therefore lubricant with high shear stability is desired.

Additives are applied accordingly.

VII additives are mainly olefin-based polymers (e.g., polyisobutylene) or ester-based polymers (e.g., polymethacrylates).

In addition to its impact on VT properties, VIIs also affect pour point, fuel efficiency, and extreme wear performance. VIIs are widely used in multi-grade engine oils, some gear and hydraulic oils, transmission fluids, etc.

Pour Point Depressants

Fluidity of an oil is very important under all conditions. When starting an engine from cold, it is important that all moving parts receive good lubrication. At low temperatures lubricating oils can undergo (i) solidification, (ii) solidification with formation of a precipitate of macro-crystals of wax, (iii) solidification with microcrystals of wax forming a lattice type structure that can trap the remaining oil. Pour point is the temperature of the oil 3°C above the temperature at which oil shows no movement when the sample container is held horizontal for 5 seconds.

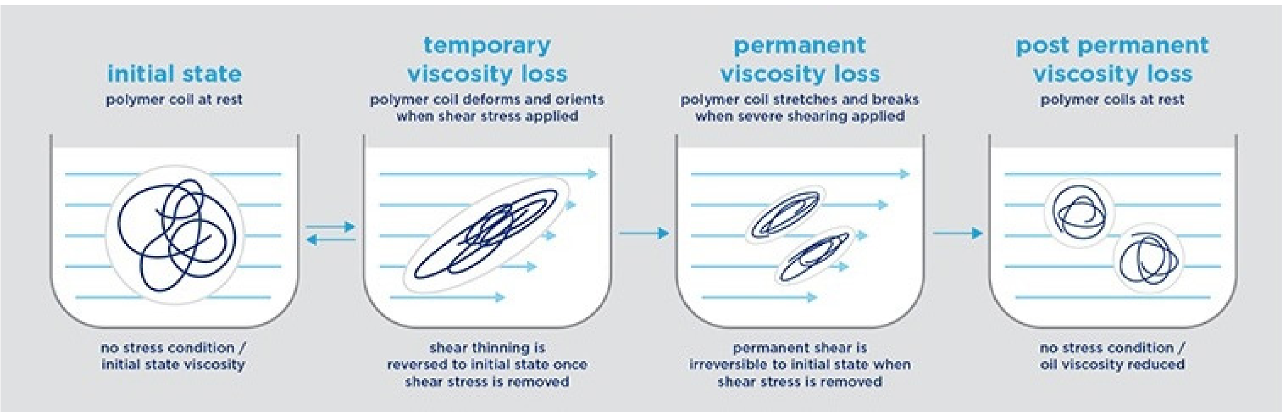

Figure 4: VII and Shear Stability (4)

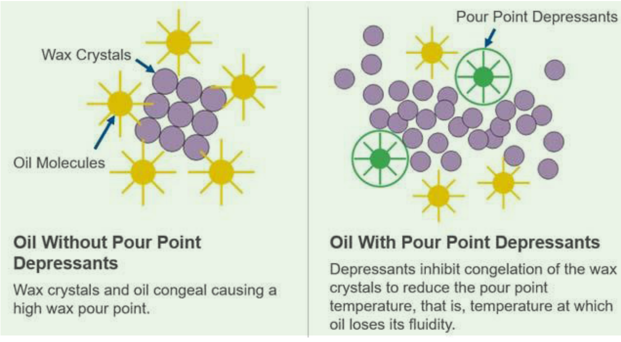

Figure 5: Action of pour point depressants (5)

While most base oil manufacturing processes remove wax to a large extent, complete dewaxing is impractical because of process limitations and costs. It is also to be noted that wax has high VI properties. Mild dewaxing in combination with the use of pour point depressant (PPD) is often favoured.

PPDs are usually organic polymers with a comb like structure (short backbone with long pendant groups) and found in a range of molecular weights.

PPDs have no effect on the temperature at which wax crystals start forming or the amount of wax that separates out. PPDs act as wax crystal modifiers and work by adsorbing onto the newly forming crystals. This inhibits lateral crystal growth, preventing oil entrapment in the crystal structure, and keeps the bulk oil fluid. Oil can move freely even if stray, solitary wax crystals are present.

Conclusions

Minimising and controlling the effects of temperature variation on oil viscosity and flow characteristics is key to operation of a large variety of machinery. Viscosity Index Improvers and Pour Point Depressants play a critical role in considerably extending the operating temperature range of mineral oil-based lubricants to meet this requirement.

Some more polymeric additives shall be discussed in Lube Matters #14, Other Additives.

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ABOUT THE AUTHOR

Sanjiv Wazir is a Technical Adviser with LUKOIL Marine Lubricants. He is a mechanical engineer from IIT-Bombay. He is a marine engineer and a member of the Institute of Marine Engineers. He is a Certified Lubrication Specialist from the Society of Tribologists & Lubrication Engineers (STLE), USA and is a member of the Tribological Society of India. He has contributed to MER on marine lubrication developments in the past, and on oil contamination issues under "Lube Matters," earlier.

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AUTONOMOUS DOCKING: SMART SHIPPING TECHNOLOGY FOR SMART PORTS

Balagopal Sunil

A disruptive smart ship technology will revolutionise ship design and marine vessel operations is the Autonomous docking and positioning for ships. In the present times, maritime companies are constantly reviewing technology innovations and new initiatives to drive sustainability and profitability by optimising vessel efficiency and performance of their fleets. For sure "Autonomous Technologies" are poised to transform the maritime industry.

Some of the talked about technologies include the Internet of Things (IoT), sophisticated remote sensing, data collection and analytics, data storage, data transfer, high resolution imaging, Cloud technology, tracking, advanced robotics, machine learning, artificial intelligence (AI) as well as virtual and augmented reality (VR and AR).

An Australian company, MAID (Marine Autonomous Intelligent Docking), has devoted more than a decade for developing and patenting intellectual property called "MAID IP" on systems and methods that enable fully autonomous docking and positioning of marine vessels (MAID Technology).

The patented MAID Technology has multiple applications for Commercial, Offshore Oil & Gas, Passenger, Defence and Public Security marine vessel sectors. It enables fully autonomous ship docking and marine positioning operations through the use of sensors and closed loop control of the propulsion systems.

The uniquely innovative design technology can identify where the vessel is within its surroundings while also recognising the desired docking location. MAID's technology autonomously validates and pre-determines the docking location to ascertain if it is big enough to accommodate the vessel's dimensions. It can also be used for maintaining a safe vessel-to-vessel position, whether it is static or moving.

MAID Technology incorporates dynamic obstacle handling and object recognition to track other vessels and objects in the ship operating harbour. It can autonomously stop or alter the path as required to maintain a collision-free approach to the docking position, controlling the vessel drive systems to manoeuver the vessel at a controlled direction and controlled speed clearing all navigational hazards. The vessel's speed is reduced on approach to the dock, and it stops and maintains the vessel at a default distance from the dock - all without any human intervention.

MAID Technology uses a single unique method to overcome all external variables that affect the vessel's motion such as wind, waves, swell, leeway, tides, set and drift, without the need to measure these variables. This minimises the number of components required and subsequent installed system cost, while maximising reliability, precision, and safety during docking.

This enhances operational efficiency by decreasing the time to dock a vessel, reducing fuel consumption and emissions. The technology also results in lower labour costs, with less crew required to dock a vessel.

MAID Technology and MAID IP can also be applied to enable 360° situational awareness, providing exact, reliable real-time data for detecting objects, vessels, and external structures such as docks and offshore infrastructure, as well as the position of the vessel, its velocity, and attitudinal information, relative to its surroundings.

The autonomous control technology has the potential to prevent accidents and injuries caused by human error and the subsequent cost of repairs, damages, and other associated losses. It has the added benefit of reducing the likelihood of vessels being out of service due to accidents or repairs. Autonomous vessel control decreases wear and tear on vessel propulsion system components resulting in reduced operating costs, increased efficiency, increased reliability, and reduced maintenance costs.

As the maritime sector moves towards autonomous shipping, such solutions will help in the safety, efficiency, cost reduction and environmental gains.

Globally, it is reported there are approximately 3,000 marine collisions each year. Studies show that three-quarters of collisions are due to human errors. With the introduction of autonomous shipping technologies, it is presumed that collisions will be dramatically reduced and potentially eliminated.

Autonomous technologies are now seen as a key contributor to reducing CO_2 emissions in the maritime sector by enabling faster positioning and more efficient control while optimising speed profiles that can lead to fuel savings and fewer emissions.

Additionally, maritime incidents like grounding, stranding, foundering and collisions can have a serious impact on the environment and are often attributed to insufficient situational awareness by crew. Autonomous technologies can help to prevent accidents, thereby protect the environment impact damages and maritime claims.

Autonomous shipping will need to overcome some initial challenges such as adhering to COLREGS, which outlines the 'rules of the road,' providing navigation instructions for ships to follow to prevent collisions at sea. Next is the question of Cyber security to ensure autonomous vessels are not prone to cyber-attacks and hijackers who could potentially take what is called 'virtual control of the vessel'.

Finally, because the UN Convention on the Law of the Sea 1982 requires (under Article 94) that each ship must have a Master who is always 'in charge'.

On May 25, 2021, Maritime Safety Committee (MSC) of IMO, at its 103rd session in May 2021, completed a regulatory scoping exercise to analyse relevant ship safety treaties, to assess how Maritime Autonomous Surface Ships (MASS) could be regulated.

The completion of the scoping exercise represents an all-important first step to ensure that regulation will keep pace with technological developments. Varying degrees of autonomy were considered:

1. **Crewed ship with automated processes and decision support (Degree One).**
2. **Remotely controlled ship with seafarers on board (Degree Two).**
3. **Remotely controlled ship without seafarers on board (Degree Three).**
4. **Fully autonomous ship – unmanned (Degree Four).**

The maritime industry is positively looking to automate smaller parts of a ship's operation to deliver immediate benefits such as enhanced safety and operational efficiency while ensuring ships have a simpler operation. The good example of Degree One autonomy is the autonomous docking/departure operation.

End result: Sooner autonomous docking will become widely adopted well before autonomous ships become common and MAID appears to be well placed to provide the vital IP and Autonomous Docking Technology for SMART PORTS.

Supporting regulations and training will follow in coming days.

[The write-up is based on inputs from MAID Technology and MAID IP]

GOING ASTERN INTO MER ARCHIVES

MER… Four decades back… The July 1982 Issue

This issue is geared up. The first article under 'Driveline', is on gearing: **Marine Propulsion Gearing-prevention is better than cure**. Predictably, many discussions on the line shafting alignment and gearing problems appear relevant for present installations also. A section of the article is reproduced. The second one is on '**Epicycle gears in merchant ships**' and another one is on using Medium speed engines with gears for slow speeds.

The following article is on '**Propeller Shafting and accessories**'. There are familiar discussions on shaft deflection, vibrations, seals etc. One interesting discussion the Author proposes. Axial clearance between the propeller and the ship, the lateral distortion of the aft section. The checks should be on the bearing contact and the shaft alignment. The corrections: Bearings have to be adjusted to the altered situation. There are mentions of slope boring, keyless shaft tapers etc.

There is one article on managing ship operations: **How to get your ship costs down**. A couple of caricatures from the article…

And theres is an interesting article on **Non destructive Testing of Heat exchangers** and another on **Shipboard operational studies with microelectronics**.

An intruguing section was 'Public Research'. Herein short briefs on unpublished research is provided. What caught the imagination was that there was a box which

False economy

ALL BRITISH ships over 350 kW now have to carry at least one engineer officer. But, to avoid this, some owners are trying to register ships at 'optimistically low' propulsion powers. They think that the lower manning requirements for foreign ships gives their competitors an unfair advantage. However, large low-powered ships can present hazards which may well outweigh the savings made. So, regulations drafted with the best intentions could actually make ships more dangerous.

Variable and versatile

THE EPICYCLIC gear is a versatile unit. Its role in merchant ships has been invaluable insofar as steam-turbine plant is concerned. Without it, the modification of machinery to reduce fuel costs would have been impracticable. It could also play an important future role, if shipowners decide that their current slow-speed diesels are still not providing a propeller speed for optimal fuel efficiency.

One recent innovation incorporating such gears is the Vickers constant-speed generator drive. As yet unbuilt, this unit can provide a constant output speed from a variable input speed and is said to have a higher efficiency than any conventional systems. Variable-speed epicyclics, in this case, allow the gearbox to be more compact and lighter than alternative methods.

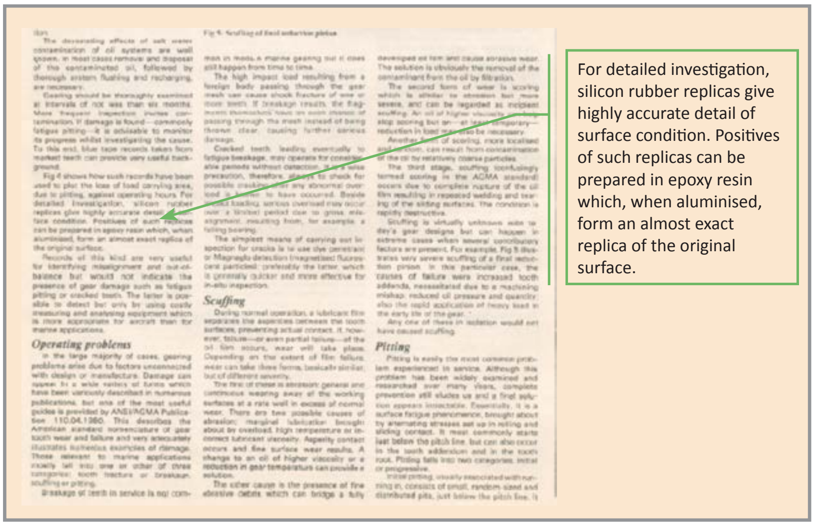
MAN/B&W considers this system to have great potential. The engine-builder evaluated various forms of shaft-driven generators and concluded that the Vickers system is highly competitive and particularly appropriate as an integral unit in its new L35MC/MCE engine.

But, regardless of whether or not a shaft generator is used, there are great advantages in having variable speed gears for manoeuvring so that the engine can continue to run at its optimum rating. This will become more and more important as more special purpose vessels are built—eg. with DP.

Whether the epicyclic will prove the best solution remains to be seen.

MER JULY 1982 35

... considerable expense in sending out vital parts by air.



For detailed investigation, silicon rubber replicas give highly accurate detail of surface condition. Positives of such replicas can be prepared in epoxy resin which, when aluminised, form an almost exact replica of the original surface.

... food must suit the religious and other requirements of the crew.

is on the locked-up stresses. Welding stresses (experience shows upward hull distortion) could be released possible during heavy weather can cause dimensional changes, particularly to the aft section. These need to be checked during the guarantee dry-docking after about one year, carried the address etc., of the public funded research and informing that those interested can get the full Reports for a price.

We would welcome such organisations for hosting their available works in MER.

We invite observations, discussion threads from readers, taking cues from these sepia-soaked MER pages – Hon.Ed.

CHENNAI BRANCH SEMINAR:

FUEL STABILITY & FUTURE FUELS AND OPEN HOUSE SESSION WITH PRESIDENT

On 24th May 2022, the, Chennai Branch of the Institute of Marine Engineers (India) held its first physical meeting since the Covid 19 pandemic had slowed down activities in 2020. The President of the Institute Shri. Vijendra Kumar Jain was the Chief Guest for this technical session. Shri. Idris Talib Technical Manager, APAC (Singapore) made a technical presentation at Hotel Savera. Around 80 members including student members from the 1st student chapter of HIMT College attended the technical session. The impressive turnout saw 3 Past Presidents along with 4 Past Chairmen of the Chennai Branch grace the occasion.

The Secretary, of the Chennai Branch Shri. S. Kannan, was the Master of Ceremonies along with the EC Member, Shri. S. Ramesh. and Shri. Sanjeev S Vakil, Chairman of the Branch welcomed everyone to the Technical Seminar and thanked everyone for turning out in large numbers.

In his address, Shri. Jain emphasised the need to broaden the Institutes' Objectives. He updated the gathering of the progress made in the formation of an International Chapter, digitisation of Library books, the commencement of new courses along with the progress of the various sub-committees in the period gone by. He also commended the opening of the first student chapter of IME(I) in HIMT College, Chennai, which had been inaugurated by Dr. Malini Shankar (Hon'ble Vice-Chancellor, Indian Maritime University) earlier in the day.

The stage was then taken over by Shri. Idris Talib who briefed all with a presentation on "Fuel Stability & Future Fuels".

In the presentation, he spoke about their two products "Aderco 2055G 4 in 1 Fuel Conditioner" and "Aderco L1050". He stated that "Aderco 2055G the latest in the generation of fuel treatment solutions, which is 100% vegetal-organic, ash-less and metal free and which has been successful in delivering the three fundamental priorities of today's shipping industry Efficiency, Economy and Environment protection.

He also briefed the gathering about how the product has been able to tackle some of the major concerns with respect to marine fuels like agglomerates and sludge precipitation, water

GOA BRANCH

TECHNICAL SESSION: UPCOMING REGULATIONS ON ENERGY EFFICIENCY & DECARBONISATION IN SHIPPING

The Goa Branch of the Institute of Marine Engineers (India) organised a Technical Session on 26th March 2022 at 1800 hrs IST on the topic "Upcoming Regulations on Energy Efficiency & Decarbonisation in Shipping".

Shri. Vaman Gaitonde, Chairman IME(I) Goa introduced the speaker Shri. Kunal Sharma, Surveyor, Indian Register of Shipping. He is actively involved in energy efficiency services at IRS. He has represented IACS as its spokesperson at IMO's inter-sessional working group on reduction of GHG emissions.

The session covered the background of the regulations like the UN Framework Convention on Climate Change, the IMO Strategy on reduction of GHG emissions and the sustainable development Goals. Emission Reduction Measures, Short Term Measures for Required EEDI, Concept of EEXI and its applicability and the regulations were actively discussed in the meet. Various short term measures and the path to compliance for EEXI, concepts of CII Short/Mid/ Long term measures for reduction of GHG were deliberated.

The session was joined by a good number people from the Marine fraternity of Goa. Shri. Raghu Ram Achanta, Secretary IME(I), Goa concluded the meet with a vote of thanks.

suspension in the fuel, microbial growth, purifier fouling, clogged filters and strainers, cat-fines, poor fuel atomization and ignition delays, fouled combustion chambers, fouled exhaust gas system, vanadium corrosion and particulate matter emissions.

After this introduction, he discussed about the action of “Aderco 2055G” on fuel in which the properties of the product like self-dispersion (which negates the need for any separate mixing or dosing equipment), its surfactant and detergent action (which keeps the fuel matrix of hydrocarbons); its ability to reduce wear and lower emissions; as well as the capability to prevent sludge formation and reduce existing sludge to molecular aromatic structures that can be burnt more efficiently. Finally he talked about various recognitions that the product has received. He stated that ADERCO 2055 G REACH compliant, BR attested and also EPA registered.

He spoke about the dosage required in storage tanks which varies from 2 litres per metric tons of fuel for initial dosage to 1ltr per 55 metric tonnes of fuel subsequently and nonhazardous classification that the product has been recognised along with no transportation restrictions (flash point>146 degree Celsius). He also gave a rough idea in regard to the cost that the owners would have to pay to make use of the technology, which he said would be around $1/ Tonne of fuel, which according to the company’s claim is going to be rather cost-effective for the ship owners as it would cut down their repair cost and other uncountable expenses those would incur otherwise due to bad quality fuel.

After the presentation Shri. Idris opened up the stage for doubts, discussions, and suggestions to the gathering, in which he addressed questions from the members, some of which were:

1. Impact on combustible properties of fuel due to its mixing
2. Any changes in the design configuration of the system or engine required
3. Time required for proper mixing of the product with the HFO
4. Shelf-life of the product while packed, and when opened or mixed with fuel
5. Cost-effectiveness of the product

The seminar was followed by a lively and interactive ‘Open House’ wherein the Chennai Branch Members inquired about the progress of the IME(I) and also gave their suggestions for its improvement to the President.

At the end, all the dignitaries, members, and cadets were invited for dinner, arranged by the Chennai Branch, where all had the chance for one-on-one interaction with each other after a long period of time. The evening was called to a close with the promise to keep working at the same pace to further enhance the Institute’s output towards ever-escalating targets and results.

KOCHI BRANCH

The Institute of Marine Engineers (India), Kochi Branch conducted an hour and half long session of YOGA LecDem for imparting awareness of Yoga on the occasion of the International Yoga Day, being celebrated all over the World on 21st June. (It was also as per the directives from DGS, Mumbai vide Circular no 20-19016/6/2021-TRG-DGS dated 27/04/2022, for students at the Institute). Sixteen students undergoing the Class I Preparatory course and their faculty were mainly the participants. It was indeed a moment of pride and honour for our Branch, as it was conceived and conducted by the Chairman of the Branch, Mr. S. Krishnankutty. It was a captivating hour and half of Lecture cum Demonstration. Mr. Krishnankutty is an ardent follower of Yoga and he has been practicing Yoga for more than 40 years.

The feedback from participants was quite positive.




MUMBAI BRANCH

SEMINAR ON "BUSINESS INTEGRITY & ANTI-CORRUPTION - IMPERATIVES & WAY FORWARD IN THE MARITIME INDUSTRY"

A hybrid seminar on "Business Integrity and Anti-Corruption-Imperatives and Way Forward in the Maritime Industry", was held on 17th June 2022 by IME(I) Mumbai Branch jointly with CMMI. The objective of the seminar was to apprise industry stakeholders about the Corruption & related practices in the maritime sector, how to deal with them and the working of Maritime Anti-Corruption Network (MACN).

Capt. K.V. Pradhan, Deputy Master, CMMI, extended warm welcome to all the attendees and briefed about the topic. Capt. Pradhan also expressed his gratitude to Mr. Vijay Arora, Managing Director, Indian Register of Shipping and Mr. V. K. Jain, President, IME(I) for marking their presence in the event. He mentioned that everyone from ship's Captain to Owner are exposed to the corruption as the primary problem has always been that the certain authorities indulge into corrupt practices that must be dealt with. Further, he emphasised on the fact that MACN has been in place that raises consciousness of the challenges that are being faced in implementing anti-corruption principles; sharing best practices; and requiring training tools for various seafarers. Later, he invited Mr. S. M. Rai, Senior fellow of IME(I) to take over as moderator and the event further.

Mr. Rai welcomed the key note speaker Mr. Deepak Shetty, who retired in the highest rank of Secretary to the Govt. of India and served the sector, as Director General of Shipping. He is the Senior Adviser (India) to the MACN, Copenhagen. Later, Mr. Rai introduced other speakers of the event, Capt. M.P. Bhasin, Chairman of Maritime Association of Shipowners Shipmanagers and Agents (MASSA); Mr. Anil Devli, CEO, Indian National Shipowners Association and Dr. Sanjay Bhavnani, Director and CEO, MMS Maritime India Pvt. Ltd. Mr. Rai then urged Mr. Deepak Shetty to share his views on the MACN and about corruption in Maritime Industry.

Mr. Shetty indicated about the United Nation's special development goals. To make the audience understand about the goals he presented an example, "For instance, if we look at goal number 16 and more explicitly, we are aware, there are 17 goals and about 162 targets under them cumulatively. But if we zero down on goal number 16 and get down specifically to target 16.5, it expressly emphasises that creating a welfare-oriented society across the globe is crucial, and that is the advocacy of no less than the United Nations, which has 193 member nations around the world. So, the pitch that the UN is making, courtesy of the 16.5 target of goal 16 of the STG, is that if the world ought to be and this is a normative objective, this is what it is in terms of moral faith. The UN is trying to bring persuasive value to this. So, it is advocating that we need to get there." Further speaking of MACN's new initiative - GPIP (Global Port Integrity Program), Mr. Shetty confirmed that a risk analysis of all the incidents arising out of reports coming in from masters and crew are taken into consideration by MACN. MACN have applied risk management tools and arrived at a matrix in terms of which 1189 ports globally in as many as 149 maritime nations have been ranked inter se in terms of an integrity index.

INSA CEO Mr. Anil Devli cited that it's been few years now since the journey of MACN commenced. The objective of this is to mutually get together and fight corruption. He also assured that INSA is working to confront all the concerns associated with corruption and agreed to the suggestions that matter be taken up at the National Shipping Board level.

Capt. M.P. Bhasin, the next speaker of the event said, "How many of you sitting here knew about MACN?" except for the companies that were the signatories. He said first take is that awareness is the main tool where we need such kind of seminar or webinar on a much larger scale, across all parts of India. He added that the second take is confidence building which needs to be spread across the Maritime spectrum by MACN by sharing case studies and/or some data of their success at various countries/ports. MACN is growing into a world-wide Maritime anti-corruption organisation. He said there is full support to MACN from MASSA as Many of MASSA member lines are already member of MACN. He emphasised that anti-corruption work needs to be seen by shipping companies, seafarers, port workers, government officials, donors, and members of the public in every working place. He appreciated the joint efforts of CMMI and IME(I) in bringing the seminar on MACN.

Lastly, Dr. Sanjay Bhavnani gave a power point presentation on corruption in Maritime Industry and mentioned that we are discussing about maritime corruption and all of us know that the shipping industry has been prone to widespread corruption over the years. Due to its isolated nature, it faces more corruption disputes than most other industries. He particularly highlighted the sailing staff and the trauma and embarrassment they face onboard while facing many corrupt practices and demands. He however was very positive that if handled well these practices can be corrected with the role and help of MACN.

Thereafter Mr. Rai & Mr. Sanjeev Mehra (Secretary, IME(I) Mumbai Branch) steered a Q&A session wherein the questions from audience were addressed.

At the end, as a token of appreciation all the speakers were presented with Mementoes by Mr. V. K. Jain and Capt. Pradhan.

The Seminar concluded with a vote of thanks by Mr. V. K. Jain, President, IME(I).

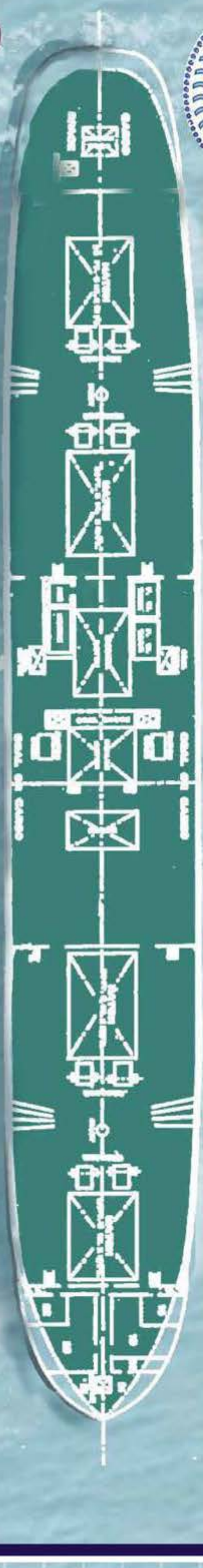
The Institute of Marine Engineers (India)
is pleased to announce

INMARCO 2022

Evolving Maritime World for Greener & Sustainable Future

QUADRENNIAL INTERNATIONAL MARITIME CONFERENCE & EXHIBITION

17th, 18th & 19th, NOVEMBER' 22
HOTEL SAHARA STAR, MUMBAI



ABOUT THE CONFERENCE:

Since its inception in 1982, INMARCO has always witnessed an overwhelming response from the Maritime sector which in turn has prompted the Institute to organise this conference and exhibition quadrennially.

Papers are invited from Engineers, Manufacturers, Designers, Shipbuilders, Operators, Students, Educators, Researchers, Recyclers, Adjudicators, Salvors and other Maritime related stakeholders

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THE INSTITUTE OF MARINE ENGINEERS (INDIA)
(MUMBAI BRANCH AND ITS NAVI MUMBAI & GUJARAT CHAPTERS)

IN THE WAKE

Rajoo Balaji

Corona Chronicles & Continuing Conflicts

I carry the uncertainty theme to the last column too…

The uncertainty continues… China has shuttered down Shanghai (partially though) to contain the Covid infections. China's Zero-Covid policy has telling effects on the global trade…

It looks like the existing product/raw material shortage will steepen and the supply chain will remain disrupted. And so will the inflation.

Shipping is dented by the conflict as well… Near to 100 vessels and about 2000 seafarers are affected (in Ukrainian Ports as an earlier count shows) but the numbers appear to be coming down slowly. IMO has been appealing to Ukrainian Charities, Governments…. The appeals are lost in the din of the gunfire.

And the Blue Corridor for safe passage and evacuation that IMO has been asking for…

Anyone has any news on that?

Shipping matters

However, there is news that shipping costs are coming down (almost >15%)… container crunch is cooling… (July-August is the season to watch and settle, perhaps).

And the digital developments are gaining pace… UK will be accepting electronic documents (eDoc?) for trade. A whole gamut of documentation is being considered to go the digital way: Bills (BL/Bills of Exchange etc.), Certificates (origin/insurance etc.), Receipts (Warehouse/shipboard etc.), transactions etc. Yet the Brexit bite appears not to be healing for UK as expected, especially with protocols on the Irish ports and border fronts.

Cruise liner chaos: Behold, the cruise industry is blossoming in India… but be ready to wait for hours to board and to carry your baggage to the ship and also for not being allowed in some ports…

A recent tale of cruise may give us lessons to learn from…

While Tamilnadu Tourism is pushing for the cruise liner calls and attract tourists, Chennai port is only partly ready (has a good passenger terminal but no car park and direct access) with the means and men. If you still manage to board the vessel, be prepared to be turned away from ports (Pondicherry did not allow a cruise liner to come in).

Well, that will be another story to be told under… 'It happens only in India'.

The recent MEPC 78 sitting has brought not much cheers for the R&D Fund proposal for decarbonisation efforts. A quick look at what was discussed: Guidelines for the EEXI, CII & SEEMP; GHG Strategy, technical and market-based measures; Amendments to MARPOL Annex I (IBC Code on watertight doors) & Annex II (Hazard Evaluation Procedure); New SECAs; ballast water experience.

Trust there will be more discussions on this MEPC, I guess.

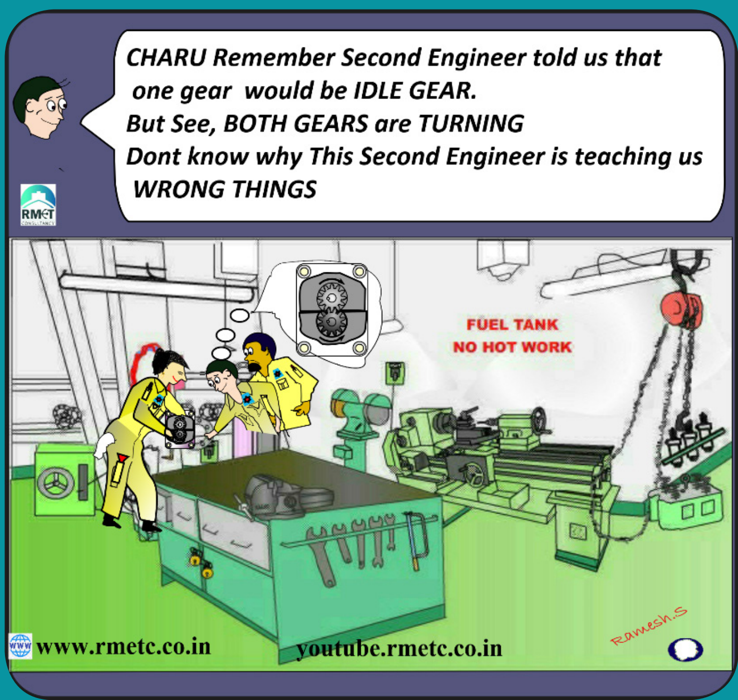
About July

6/7: World Zoonoses Day. Wish we see the end of the zoonotic disturbances this year.

7/7: World Chocolate Day: Wish we had such days for Indian sweets.

12/7: Paper Bag Day (India): Wish we find a way to change plastics to paper.

THE END VIEW

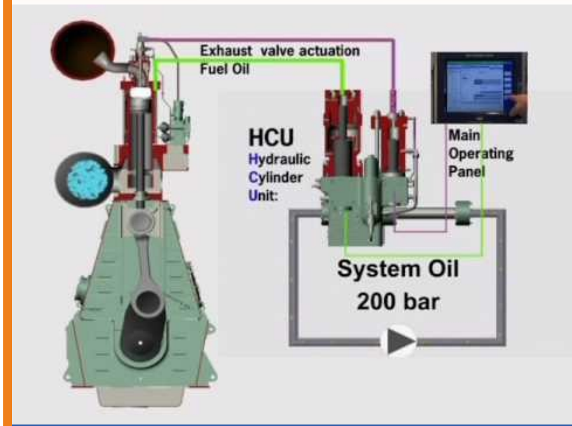


Idea, Words & Drawing: **Ramesh Subramanian**

MASSA Maritime Academy, Chennai

The Institute of Marine Engineers (India)

Electronic Engine Familiarisation Course (ME-Type Engine) Delivered online with Cloud access to ME Engine Simulator



This 3 days course is designed for all Ship's Engineer Officers and Electro Technical Officers responsible for the operation of ME Engine. This course consists of technical lessons and practical instructions on the design, principles, operating procedures and maintenance activities for the safe, efficient and optimal performance of the engine system.

Course Aims and Objectives:

The course aims to provide practical understanding of the principles, design, operation and maintenance of the ME Engine System, enabling participants to safely and efficiently operate the engine and perform fault-finding in the control system.

Coverage / Program Focus:

This course deals with the following training areas:

- **Introduction to ME Engine**
- **Hydraulic Power Supply (HPS)**
- **Hydraulic Cylinder Unit (HCU)**
- **Engine Control System (ECS)**
- **Main Operating Panel (MOP)**
- **Standard Operation**

Entry Requirement / Target Group:

Entry is open to all Ship's Engineers and Electro Technical Officers with basic knowledge of diesel engines.

DATE & TIMING : 19th to 21st **July'22**; 16th to 18th **Aug'22**; 20th to 22nd **Sep'22**
8:00 am - 4:00 pm IST

VENUE : Web Platform / Zoom**. APPLICATION LINK:** https://forms.gle/e4As7kCucR5xoJBm9

REGISTRATION & PAYMENT : Rs. 15,000/- /- per participant – inclusive of taxes.
For IME(I) Members 13,500/- per participant - inclusive of taxes.
Payment to be made to: https://imare.in/buy-online.aspx
(Under Category - Value added Courses) *10% discount available for IME(I) members*

FOR MORE INFORMATION : **@IME(I)** - **email:** training@imare.in, Ms. Anukampa
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@ MASSA Maritime Academy Chennai - **email:** mmachennai@massa.in.net
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After registration and payment, please email the details of the receipt to: ***training@imare.in***

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