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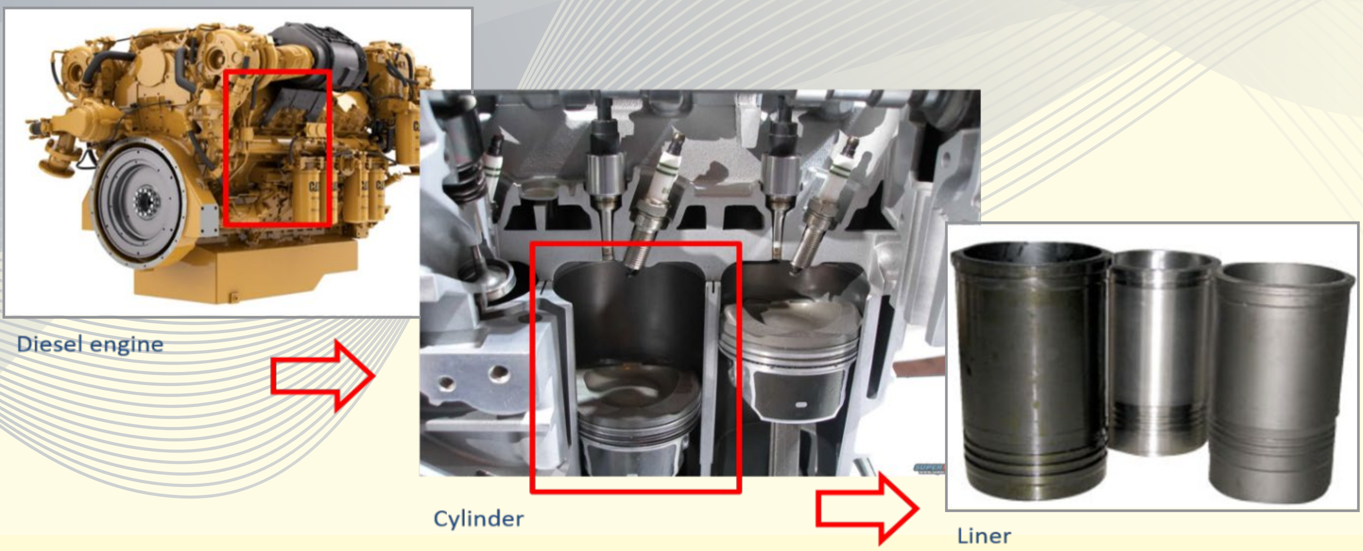
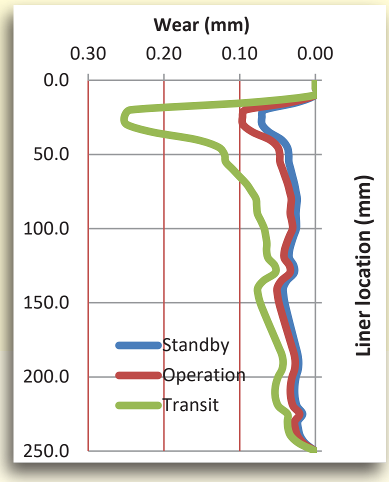
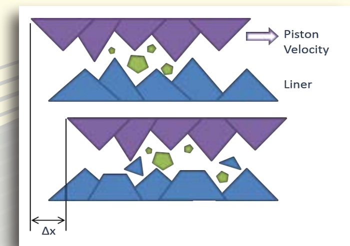
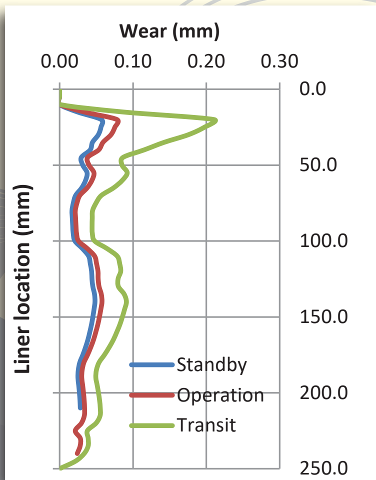




Condition Monitoring:

A Model to Predict Liner Wear





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EDITORIAL

Mostly it is loss which teaches us about the worth of things.

- Arthur Schopenhauer

We are in the 75th year of Independence. The Mahotsav of the Azadi started months back and as the moon is at its first quarter phase, we will celebrate the Independence Day to mark these celebrations. Independence did not mean development as shipping faced bad weather due to the discriminatory stance of the Colonials. Pre independence, coastal and overseas were monopolised by the British and Indian entrepreneurship was scuttled and sunk by the British. The struggle continued after independence also while facing the schadenfreude of the British and other ill-wishers.

Yet if one would count, we can see that Indian shipping has grown from around 0.19 million GT to over 13 million GT. The independence made this possible, although it may be argued that this growth could have been more copious had we not experimented with socialism and the licence raj (Is it really over?). However, the independence gave us the space, scope and spirit to do things the way we chose to do.

The flying and frontal symbol of this independence is our National Flag.

Humans being identity inclined, create symbols and feel different and superior. In that light, the Indian flag is symbolic of our union of diversities. The tricolour saw the works of Pengali Venkayya, Sister Nivedita and of course, the blessings of Mahatma Gandhi while being adopted. In the current celebratory mood, the 'Har Ghar Tiranga' campaign encourages unfurling the tricolour in our homes. And while we see the flag flutter, we may recall the independence and freedom we had lost to the invaders and the imperials. The worth of freedom and enterprise in the pursuit of happiness will then become evident.

In this issue...

The topic of diesel engines always brings in familiarity and fascination. Prabu Duplex, immersed in prediction research, takes us through a development of a wear prediction model for the diesel engine cylinder liner. The explanation of the major and minor thrust location, the resultant contact pressure distribution and the material adhesion effecting the surface wear are well explained. A thought provoking takeaway is the observation that with the operation profile and the type of propulsion system, the wear pattern varies. Landing with suggestions for progressing with experiments/case studies/ sensitivity analyses, Prabu leaves us at an interesting juncture. We can hope to have more wear discussions as his work progresses. Readers may recall his earlier essay on engine valve wear, more than a year back.

Sliding down the liner, we have Subhakar Dandapat expounding on the genesis of the East Coast Canal (ECC) system and how Odhisa's development has brought in ideations of connecting the ECC with the envisaged Eastern Waterways Grid and the NW5. Touching back with a historical note, the Author describes the evolution of the inland waterways. Marking the developments and deteriorations chronologically, Dandapat records the various activities and the non-productive neglect of the riverine systems. He captures the growth trail of Odhisa, the possible advantages of linking well with the NER of India, Bangladesh etc., and pitches for the ECC connectivity and the urgency for it. He signs off with an argument for green solutions while highlighting the need to exploit the inland waterways. This sure is an absorbing read.

Man mimics nature... always.

On that note we start another series. In this instance, Dr. Vedachalam educates on the bio-inspired engineering. Herein we discuss the science behind the migrations of birds and animals finding their spatial and orientation reference frame for navigation. Part A takes us underwater with the turtles and spinning lobsters which home in after being displaced to unfamiliar surroundings. Dr. Veda talks about Geo Magnetic Fields, chemical cues, species' abilities to find shortest possible routes and the studies with geo-tagging and tracking systems. This part concludes with the Bio-Inspiration talks and the current work on Autonomous Underwater Vehicles aided by Machine Learning algorithms implemented by NIOT. This three-part series promises to be quite interesting.

Sanjiv Wazir continues Lube Matters with additive talks.

And from the archives, we dig out the August 1982 issue and share a few glimpses.

This August issue carries three divergent discussions but all meaningful. We hope you enjoy this issue.

Dr Rajoo Balaji
Honorary Editor
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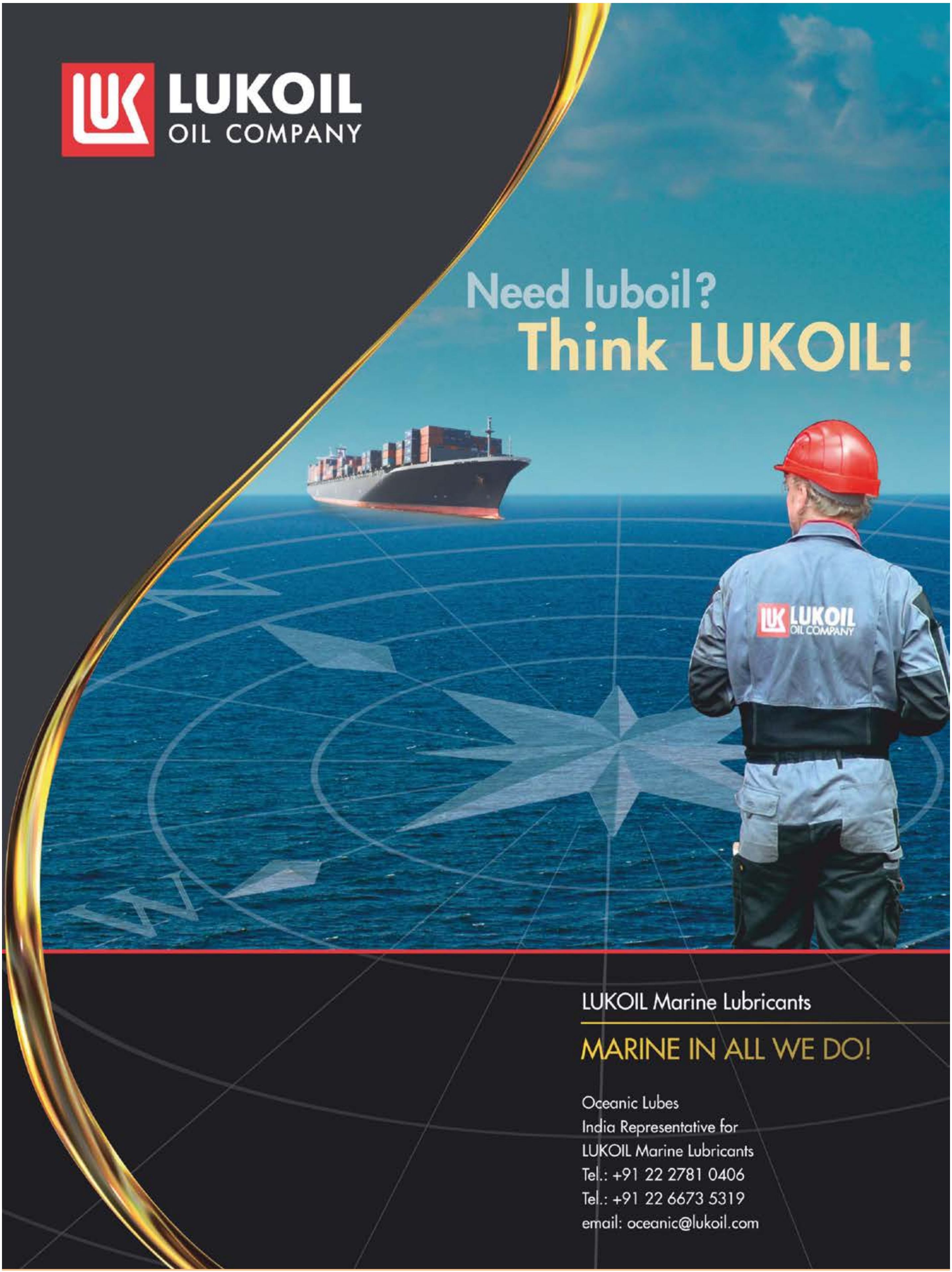
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CONDITION MONITORING MODEL FOR MARINE DIESEL ENGINE LINERS

Prabu Duplex

Abstract

The article is based on the academic exercises performed at the *University of Twente* for failure mechanisms and life prediction course. In this work, a wear prediction model for diesel engine cylinder liners is introduced in the beginning. Subsequently its application is demonstrated by means of a case study. The ways to make this model integrated into an industrial environment is then briefly discussed. In such a frame work, the time to failure of components, structures and systems under certain load conditions can be calculated, which enables one to develop preventive maintenance strategies or perform failure analysis during design or operation processes.

1 Introduction

The *internal combustion engine* is a heat engine that converts chemical energy of the fuel into mechanical energy; it is usually made available on a rotating crank shaft. The crankshaft in turn is connected to a transmission power train to drive a ship propeller in the case of ship or an alternator in the case of diesel generator. Marine diesel engines work under compression ignition (CI) process and such engines drive a variety of power and propulsion architectures which can be categorised as mechanical propulsion, electrical propulsion or a hybrid combination of both. These propulsion configurations are shown in **Figure 1**. One thing common in all these systems are diesel engines, which propel the ship or impart power to the propulsion systems.

These engines undergo frequent maintenance during which the vessel may be taken out of service or it requires an uninterrupted vessel operation scenario to plan such maintenance tasks [4, 5]. In reality, an appropriate operation window is hard to predict in advance. However, if one can estimate the condition without interfering with the engine operation, it will be easier to plan the maintenance activities. Among the engine clusters, cylinder liner is a significant maintenance driving component which is critical to the engine operation and also it is time consuming to do the relevant maintenance activities in it. Therefore, this work is aimed at demonstrating a liner condition prediction model. By developing such models, shipping companies can steer away from time/usage based to condition based maintenance activities.

2 Liner wear prediction model

The wear pattern along the cylinder wall is demonstrated by using the fundamental law of adhesive wear introduced by Archard, considering continuous sliding contact of two surfaces [9]. The law states that, in general, the amount of wear is directly proportional to the load and the sliding distance, but inversely to the hardness of the softer surface (cylinder liner) being worn. Expressed in the form of average wear depth worn off , and the apparent contact area of contact , it is shown as,

$$V_w = \frac{k_w L_w x_w}{3 h_w A_a} \qquad (1)$$

where L_w is the load, X_w is the sliding distance, h_w is the hardness of the surface, and k_w the dimensionless coefficient of wear dependent on the material in contact and the degree of cleanliness. The wear then becomes proportional to the accumulated sliding distance, or the number of reciprocating cycles, needed to reach that

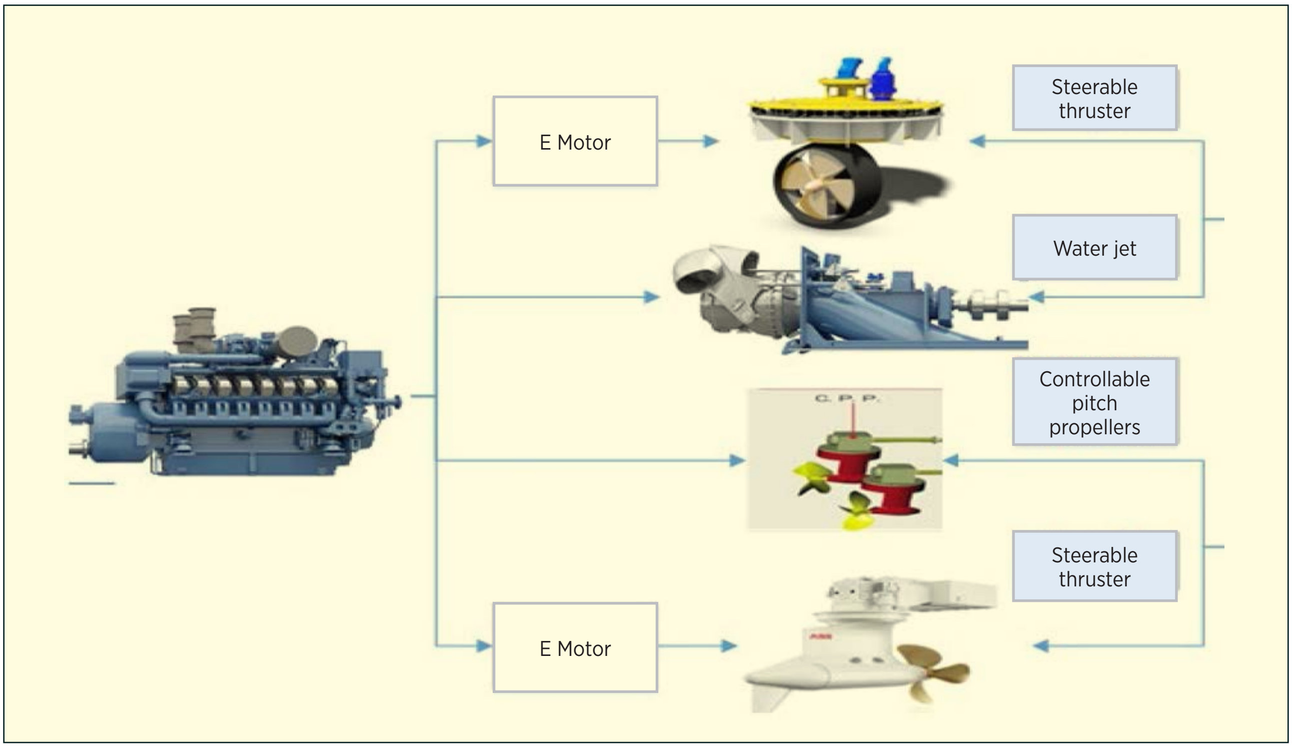

Figure 1. Overview of propulsion systems

distance. For reciprocating engine bore wear problem, considering wear only due to a single ring, equation can be rewritten as,

$$(V_w)_m = \left(\frac{k_w L_w (4sN)}{3h_w A_a}\right)_m = \left(\frac{4k_w s}{3h_w}\right) . (P_w)_m . N = k_w'(P_w)_m . N \quad (2)$$

where s is the stroke length, m is the number of rings, N is the number of power strokes, $(P_w)_m = \left(\frac{L_w}{A_a}\right)_m$ the m^th^ ring load pressure per cycle and $k_w' = \left(\frac{4k_w s}{3h_w}\right)$. The m^th^ ring load pressure per cycle is the summation of the load variations, when the film thickness is below LLFL on the cylinder wall in a four stroke cycle. Therefore, the wear depth distribution due to single ring is proportional to the summation of load distributions exerted on the cylinder wall by this ring corresponding to power, exhaust, induction and compression strokes.

$$(V_w)_m = k_w'[(P_w)_{Power} + (P_w)_{exh} + (P_w)_{ind} + (P_w)_{comp}]_m N \quad (3)$$

For the ring pack, the total wear will be sum of the wear depth distributions for all the rings, with consideration of the ring location on the piston. Mathematically the relation is

$$V_w(s) = [V_w(s)]_1 + [V_w(s - s_2)]_2 + [V_w(s - s_3)]_3 + \cdots (4)$$

where S_2, S_3 are ring locations of 2nd, 3rd rings etc., measured from the 1st ring location.

To calculate the amount of liner wear for a specific operating profile from equation (4), the following inputs are required: the constants k_w (wear coefficient), h_w (hardness) and s (stroke length), as well as the variable contact force P_w. The relation of the variable contact force P_w to the operating conditions is explained briefly in the following paragraph.

The law states that, in general, the amount of wear is directly proportional to the load and the sliding distance, but inversely to the hardness of the softer surface (cylinder liner) being worn

2.1 Contact force (P_w)

Based on the combustion chamber instantaneous pressure vs crank angle relation, and the masses of piston, connecting rod and their kinematic relationship, the net force applied on the piston, which is the result of gas and inertia forces, can be obtained and used for calculating piston side thrust load, as summarised below.

$$P_w = F_p + F_t \quad (5)$$

$$F_p = h \times p \quad (6)$$

$$P_w = [h \times p] = F_t \quad (7)$$

P_w is the contact force (peak load normal to the direction of sliding)

F_p is the force exerted by piston ring due to gas pressure

h is the piston ring height

P is the gas pressure

F_t is the piston side thrust assumed to be acting through piston ring.

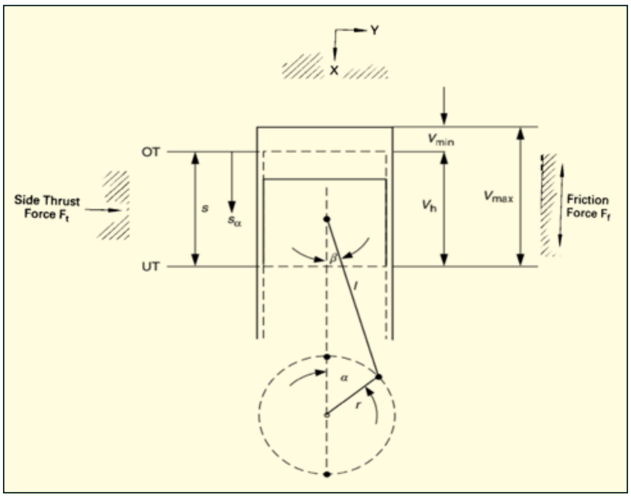

Figure 2. Force balance on a piston [16]

Piston side thrust (F_t)

The force balance of a piston is shown in **Figure 2**. The following terminologies are used for kinematic calculations and appropriate values are assumed for variables for demonstration purposes:

F_t	Side thrust force on the piston
m	Mass of the piston
P	Pressure in the combustion chamber
B	Bore
F_f	Friction force between the piston and cylinder walls
S_α	*Piston stroke*
r	Crank shaft radius
l	Connecting rod length
α	Crank offset
β	Connecting rod sweep angle

$\lambda_s = \frac{r}{l} =$ Connecting rod ratio

$\omega = 2.\,\Pi.\,n =$ Angular velocity

$$n = \frac{Number\ of\ crankshaft\ revolutions}{Time}$$

A force balance in the X direction gives the side thrust force on the piston as:

$$F_t = \left[-m\,\ddot{S}_\alpha + P\left(\frac{\pi}{4}\right)B^2 \pm F_f\right] \tan\beta \qquad (8)$$

The sign on the friction force term depends on the crank angle *negative* (–) for, $0^0 < \alpha < 180^0$, and positive (+) 180^0 for $< \alpha < 360^0$

Instantaneous piston stroke can be written as

$$\dot{S_\alpha} = \omega.r.\left[\sin\alpha + \frac{1}{2}.\lambda_s.\sin 2\,\alpha\right] \qquad (9)$$

Consequently, piston velocity becomes

$$\dot{S_\alpha} = \omega.r.\left[\sin\alpha + \frac{1}{2}.\lambda_s.\sin 2\,\alpha\right] \qquad (10)$$

Therefore, piston acceleration is

$$\ddot{S_\alpha} = r.\omega^2\,(\cos\alpha + \lambda_s.\cos\,2\,\alpha) \qquad (11)$$

A typical pattern of instantaneous piston position and acceleration; and connecting rod angle and thrust force is shown in **Figure 3**.

The side thrust force is the Y direction reaction to the force in the connecting rod, and lies in the plane of the connecting rod. From equation 8, it is seen that Ft is not a constant force, but changes with piston position (angle β, acceleration ($\ddot{S}_\alpha$), pressure (P), and friction force (Ft), all of which vary during the engine cycle). The high combustion pressure causes a strong reaction force resulting in large side thrust force. During the exhaust and compression strokes, the connecting rod is on the other side of the crankshaft and the resulting side thrust reaction force is on the other side of the cylinder. This is called the minor thrust side due to the lower pressures and forces involved and is again in the plane of the connecting rod. The side thrust forces are less in planes turned circumferentially away from the plane of the connecting rod, reaching a minimum in the plane at a right angle to the connecting rod plane. The side thrust force also varies with crank angular position as the piston moves back and forth in the cylinder. Thus, there is continuous variation both in the circumferential direction and along the length of the cylinder from TDC to BDC.

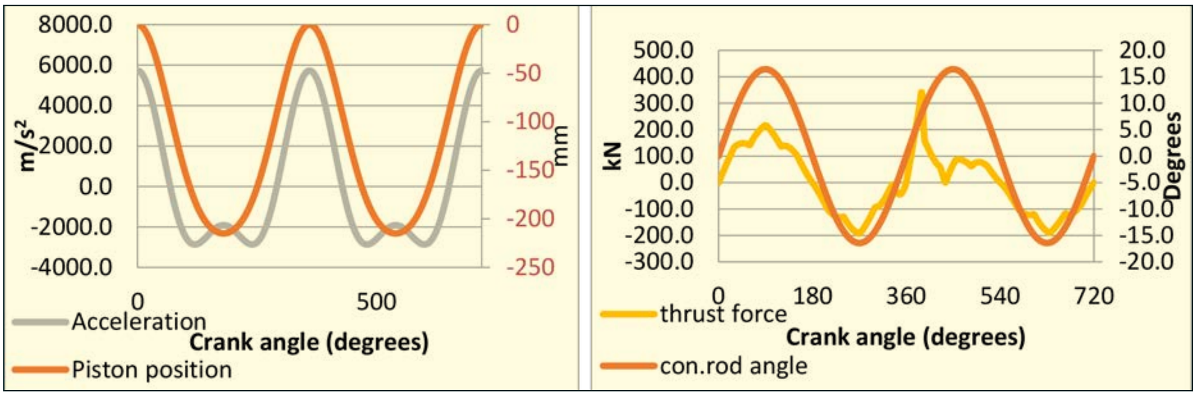

Figure 3. Instantaneous piston position & acceleration(L) Thrust force (R)

The side thrust load variations and the side of the cylinder against which the piston is sliding is shown in **Figure 4**. As shown, the load distribution on the side wall is then the superposition of load distributions due to each of the strokes, applied on the same side of the cylinder wall. Thus the total load distribution (P_w) which the piston will apply on the major thrust side per cycle is the superposition of load distribution I, III, V, VII, and on the minor thrust side, II, 1V, VI, VIII, as shown in **Figure 4.**

Based on this knowledge of load distribution and the dimensionless coefficient of wear, the wear then becomes proportional to the accumulated sliding distance during a reciprocating cycle. Therefore, it is capable of predicting wear near TDC during one engine cycle in both thrust and antithrust sides. The greatest wear occurs in the plane of the connecting rod on the major thrust side of the cylinder, as shown in **Figure 5**. Less wear will occur on the minor thrust side, although it is still significant. This wear will also vary along the length of the cylinder on both sides.

The wear algorithm can be summarised as follows:

- Obtain the combustion chamber pressure vs crank angle relations for the given engine operation condition (full load, half load, etc.).

The side thrust forces are less in planes turned circumferentially away from the plane of the connecting rod, reaching a minimum in the plane at a right angle to the connecting rod plane

- Based on assumed blow-by factor (3% is assumed) calculate the pressure distribution between the rings over the complete cycle.
- Determine the total contact pressure between the ring and bore along the cylinder wall for power, exhaust, induction and compression strokes for each of the rings.
- Compute the side thrust forces on the major and minor side walls and convert them in to ring bore contact load pressure.
- Sum the load pressure in steps 4 and 5 for two of the rings.

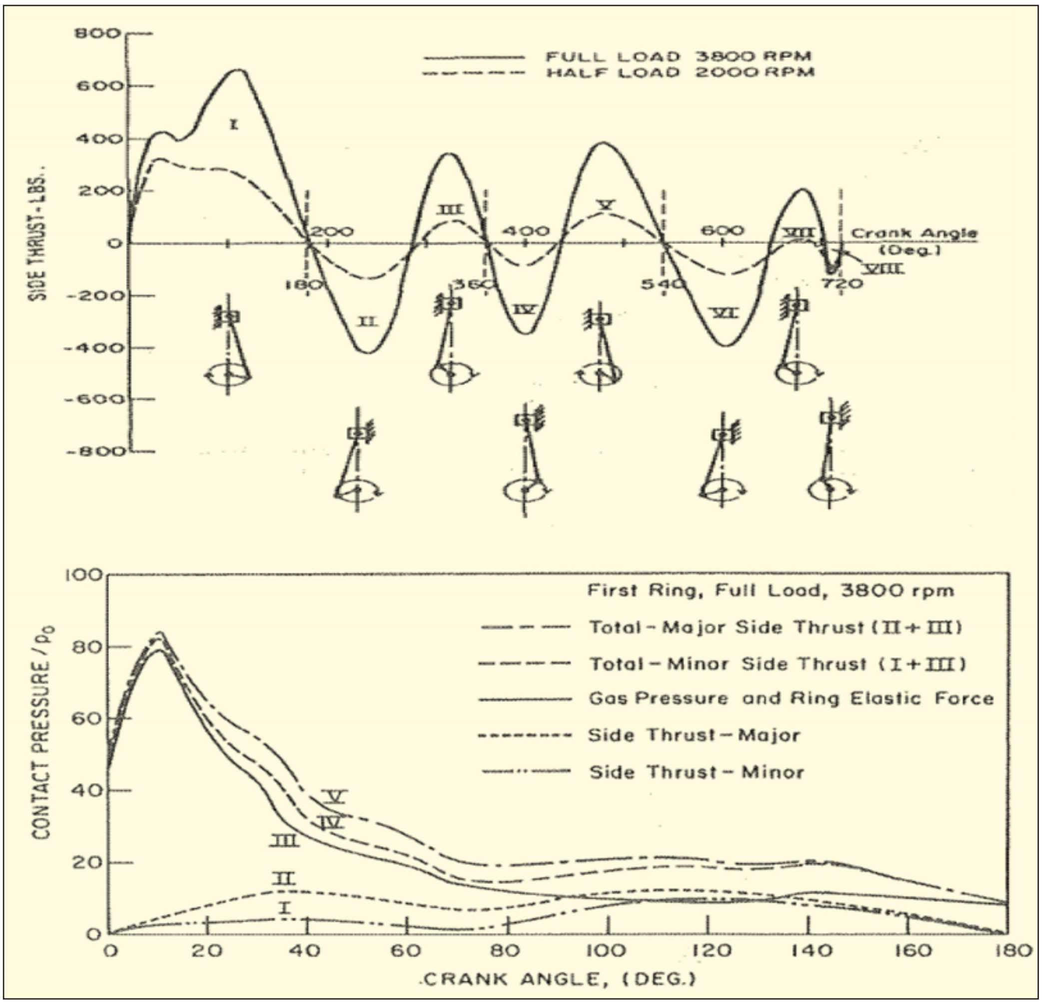

Figure 4. Piston side thrust load & the switch of ring bore contact sides (top), load distributions on major and minor side thrust cylinder side walls per cycle due to top piston ring (bottom) [9]

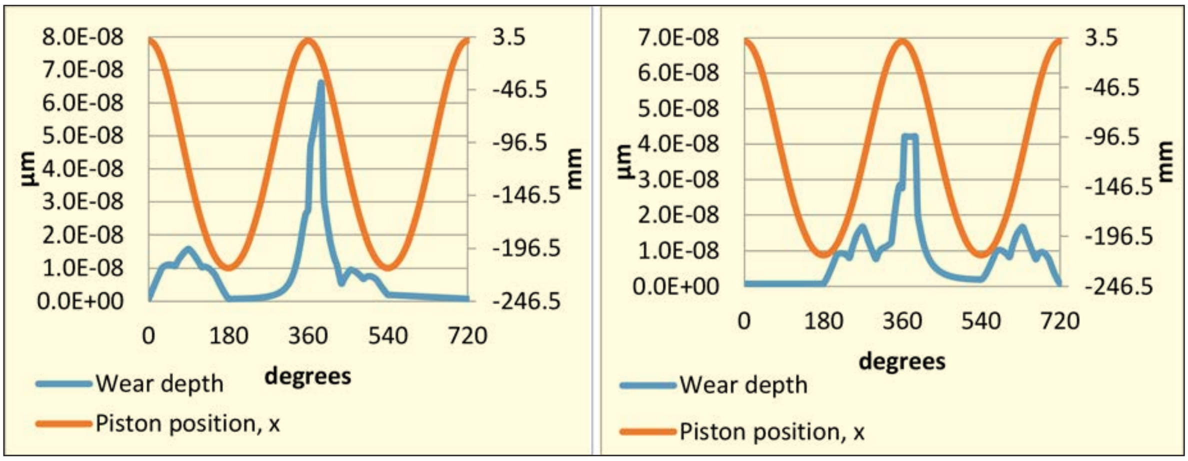

Figure 5. Wear depth per cycle in a scenario: Thrust side (a), Anti thrust side (b)

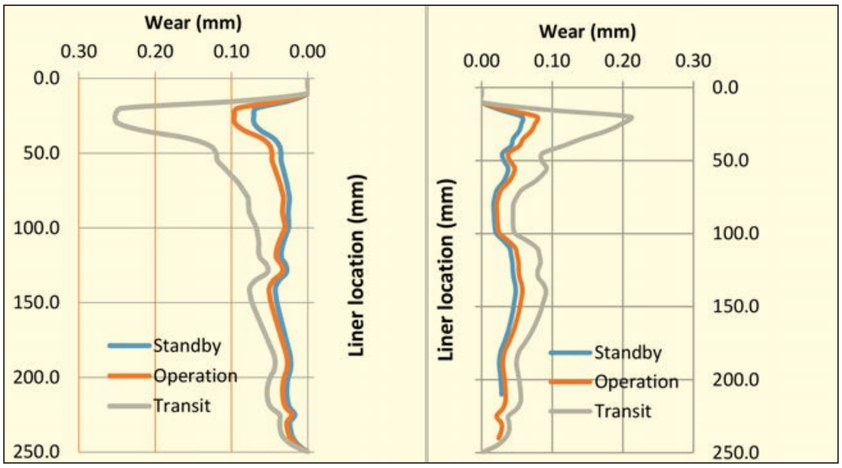

Figure 6. Wear pattern in various scenarios: Thrust side (a), Anti thrust side (b)

- The total contact pressure distribution will be the sum of the load pressure distributions of all rings with appropriate position shift according to the ring location design.
- Use Archard's formula to determine the wear pattern along the major and minor thrust sides and extrapolate for a given operation profile that includes the number of engine revolutions, load and operation hours.

3 Case study

It is generally observed in the maritime sector that, depending on the operation profile and propulsion system there is a wide discrepancy in the wear of liners among various propulsion systems. This phenomenon is demonstrated in this section. The following values are substituted in the equations in this model for preliminary calculations and other values are assumed as appropriate: Wear coefficient (K_w) is assumed to be 1x10^{-4}, and hardness (h_w) corresponds a value of 4.76x10^5 N/m^2. The specifications of engine geometry are obtained from an engine user guide and other relevant parameters are assumed. The engine combustion is assumed to follow dual cycle and the equations are given under Section 2.

For each set of RPM and load conditions (load is assumed to be a linear function of engine revolutions and fuel injected in a cycle is calculated based on it), as shown in **Table. 1**, wear analysis is carried out for 12,000 hours. Transit, standby and operation (say some cargo operation) modes are chosen for analysis. The results are shown in **Figure 6**; from which it is seen that maximum wear happens during transit operations. During this operation, both revolutions and load are much greater than in other modes, which results in excessive wear. Most importantly, a typical wear depth in thrust and antitrust sides for this scenario is shown in **Figure 6**. This is calculated from wear volume and by such analysis, change in internal diameter of the cylinder can be determined. One can then compare this value, with the engine operation manual to estimate the liner replacement interval or circularity restoration tasks.

Table 1. Scenario definition for critical scenario analysis

Operation mode	Engine RPM	Load (%)	Duration
Operation	1038	30	12,000
Transit	1530	85	12,000
Standby	876	20	12,000

Real Time Implementation

The demonstrated algorithm has tremendous capability to add value to the maintenance practices. More iteration needs to be done in order to make it work in a real context. The iterations will mainly take the form of experiments or observational case studies, which will be addressed in this section. Important design dependent parameters can be estimated by means of experiments or observational case studies. If this is not feasible, a sensitivity analysis can be carried out to eliminate the dependency of such parameters. The following lines summarises a tentative plan of experiments or case studies that can be performed to improve the model in the future.

- Influence of lubrication film on liner wear is neglected in this work that needs further investigation [7,9].
- For estimating the wear coefficient, the wear pattern of the used liners can be measured with micrometre and wear coefficient values can be determined. More study needs to be done to estimate wear as a function of gas pressure or load conditions.
- Hardness can be estimated with a hardness tester and the parameter (k_w) can be derived from it.
- Friction force needs to be neglected, assumed or to be calculated experimentally [11, 12].
- In the majority of the commercial high-speed diesel engines, there are no means of measuring combustion gas pressure and makers do not provide the pressure curves in the engine operation manual. Consequently, since the pressure measurement is important for determining the loads on the cylinder components and since it is not available, alternatives were sought. The transformation of the shaft speed variations to the in-cylinder pressures is possible; however, it is mostly applied on 4 to 6-cylinder engines. To model combustion, cycle conditions including the temperature and pressure can be estimated using the dual diesel cycle.

  Schulten and Stapersma [8, 13] use the six-point Seiliger cycle to model combustion. The dual cycle and Seileger cycle models are effective for calculating the gas pressure in the intermediate points as defined in this cycle. The zero-dimensional crank angle models determine the thermodynamic state of the air and combustion gas in the cylinder. This is done during crank angle rotation for the closed cylinder process, assuming a single homogenous ideal gas in the cylinder [15], which can be combined with a heat release model using Wiebe functions as proposed in [14]. CFD combustion models simulate the combustion process; however, developing such models demands a lot of computational power.

Acknowledgement

This is an academic work for a failure mechanisms and life prediction course. The exercises were performed during the first year of *Professional Doctorate in Engineering (PDEng)* program at the University of Twente. The course was coordinated by Prof. Tiedo Tinga who also headed Dynamics based maintenance (DBM) group during that period. I thank him for his valuable support. The idea to introduce this work in to maritime sector was first proposed by researcher Filippos Amoiralis [6] (based on extensive interviews with stake holders), who worked in DBM group in the year 2015. This wear model is under further development now.

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IMPORTANCE OF EAST COAST CANAL SYSTEM INTEGRATED WITH NW5 WITH CONNECTIVITY TO THE EASTERN WATERWAYS GRID FOR A SUSTAINABLE AND VIBRANT INLAND NAVIGATION SYSTEM IN SOUTH ASIA

S. Dandapat

ABSTRACT

The East Coast Canal (ECC) System, an artificial canal developed and operated towards the end of the nineteenth century by the British colonial administration, was primarily for inland navigation, connecting Calcutta Port to Cuttack, the principal trade center of Odisha. The ECC system, with the delta rivers and the irrigation cum navigation canal system also developed in the British era, was the first surface transport mode and the lifeline of Odisha, which played a decisive role in the transportation system for freight and passengers between Bengal and Odisha provinces in the pre-independence era. The importance of the ECC system lasted for a short period, and it declined with subsequent abandonment towards the second decades of the twentieth century with the advent of rail and road modes. Since then, the canal system has remained neglected and without any steps for its restoration even after the declaration of NW5 (National Waterways No-5) with the river stretches of Brahmani, Mahanadi, and various delta river systems integrated with the ECC system in 2008 for developing and restoring the IWT system in the state. The recent industrialisation, mining exploration, etc., and the ambitious port policy of transforming the state into the hub of marine activities and the eastern gateway, have enhanced the potential of the canal system, with the river stretches of NW5 becoming the vibrant and viable links for integration to the proposed grid of the waterways systems, named the Eastern Waterways Grid, in the northern, eastern and NER (North Eastern Region) of the country and Bangladesh through the Indo-Bangladesh protocol routes as per the existing protocol.

Key words: Inland navigation system, navigation lock system, traditional and steamer boats, waterways grid, multy-modal transport system.

1.0 Introduction

The colonial-era East Coast Canal (ECC) System, developed during the nineteenth century, was primarily for inland navigation, connecting Kolkata Port to Cuttack, the principal trade center, and other trade centers of Odisha to commence inland water transport. And thus, the ECC system facilitated the first surface transport mode to connect beyond the state, termed the lifeline. The canal system played a decisive role in the transportation system for freight and passengers between Kolkata and Cuttack and various other trade centers of the state through the network of delta irrigation cum navigation canal systems, and riverine routes.

The ECC system also played an essential role in transporting freight and passengers from the coastal ports having services from Madras, Ceylon, Burma, Indonesia, etc., through coastal shipping

The ECC system also played an essential role in transporting freight and passengers from the coastal ports having services from Madras, Ceylon, Burma, Indonesia, etc., through coastal shipping. However, the importance of the ECC canal system lasted for a short period. It declined with subsequent abandonment towards the second decades of the twentieth century with the advent of rail and road modes without further repair and maintenance.

The declaration of the river systems of Brahmani and Mahanadi as NW5 (National Waterways No. 5) integrated with the ECC system in 2008 for developing and restoring the IWT system in Odisha, with further connectivity to the neighboring states, through major inland waterways systems in the Northern, Eastern, and NER of the country, and Bangladesh through a well-developed Waterways Grid, the potential of the ECC system for contributing its share to the multi-modal transportation network of the state and also the nation has improved substantially. It is primarily because of the rapid industrialisation in Odisha and the ambitious port policy to transform the state into the hub of marine activities and the eastern gateway. **Thus, today, the abandoned ECC system has assumed high potential as the vibrant and viable link for integrating the riverine portion NW5 with the proposed Eastern Waterways Grid, facilitating further connectivity to Southeast Asia.**

2.0 The History of developing ECC systems

Sir Cotton Arthur, the eminent British army hydraulic engineer, was the principal architect with his recommendation in 1856 for developing the delta rivers and canal system from the series of weirs and anicuts on the river Mahanadi for irrigation and navigation purposes, with an emphasis on providing connectivity to Calcutta Port from Cuttack through a separate coastal canal system. The British Administration did not accept the recommendation for implementation immediately. Subsequently, the development of the ECC and delta irrigation canal system for navigation, along with the development of the navigation lock system, was attributed to the devastating famine in the colonial history of Odisha during 1865-66, popularly known as the *"No Anka famine."*

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The famine was in the **9th** regnal year of **King Divya Singh Deva, the Gajapati king of Puri, Orissa,** with a colossal loss of life because of the complete failure in the transportation and distribution of food grain from Calcutta, Madras, and nearby towns in the absence of any mode of the transport system such as rail, road, or inland water transport. The existing trade between Calcutta and Odisha through sea routes touching the coastal and riverine ports on the coast did not have the adequate infrastructure to function as all-weather ports without convenient connectivity to the hinterlands. The landmark decision in the colonial history of Odisha with the setting up of the commission under the chairmanship of Colonel George Campbell in the year 1867 was instrumental for the inland navigation system through ECC and the delta irrigation canal system.

3.0 Brief Description of ECC system

The ECC system, for a total length of 217 km, comprises the Hijli (Hidgelee) Tidal Canal (HTC) for 93 km from Goenkhali to Rasulpur in W. Bengal and the Odisha Coast Canal (OCC) for 124 km from the border of W. Bengal to Charbatia, connecting the river Matai in Odisha. The development of the Hijlii tidal canal stretch was commenced in 1869 and completed during 1872-73. The OCC stretch was constructed from 1881 to 1888 under four ranges. The entire ECC system was operational, facilitating IWT between Calcutta port, Cuttack, and other trade centres during October 1888. **(Figure. 1).**

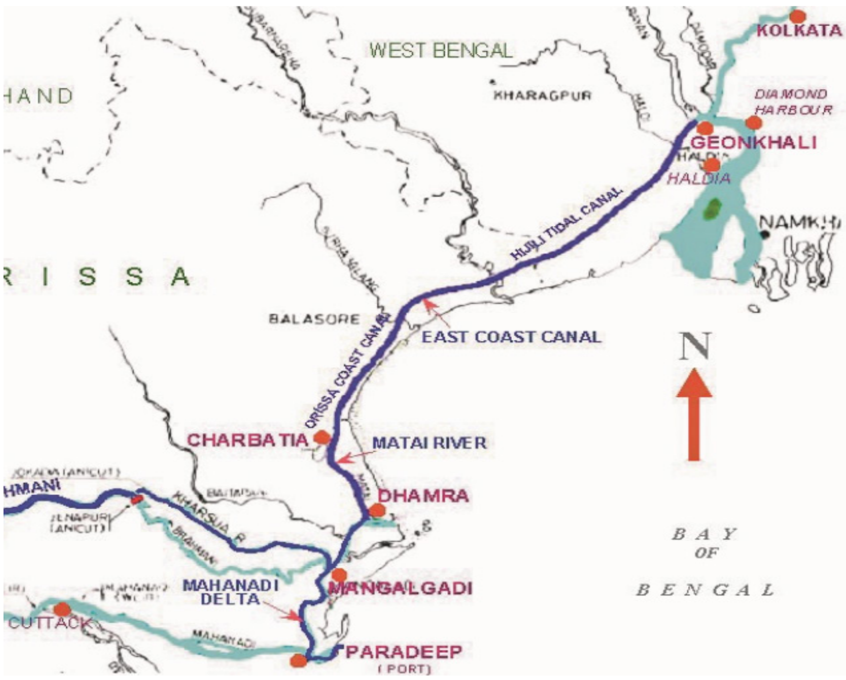

Figure 1. The NW5 and East Coast Canal System comprising of Odisha canal and Hidgelee Tidal canal system,
Source: IWAI

Most of the rivers in Odisha and a few in West Bengal flow in the eastern direction and merge with the Bay of Bengal. Therefore, the canal system traverses parallel to the sea-coast within a distance of 5km to 30km from the sea coast and crosses several rivers, such as **Haldi, Rasulpur, Subarnarekha, Panchpara, Bura-Balang, and** finally connects to the Matai River at Charbatia, through 12 navigation locks installed on the rivers as in **Figure.2.**

The connectivity of the ECC beyond Charbatia to Paradeep and subsequently to Cuttack and other trade centers is through the delta river systems like Mahanadi, Brahmani, Baitarani, and the irrigation-canal system constructed during 1858–1869 from the anicuts (barrages) built over on the river Mahanadi at Jobra and the Birupa at Jagatpur (near Cuttack). Inland water transportation was also established through the riverine navigation to all the four undivided coastal districts and even beyond the present-day Hirakud dam on the Mahanadi at Burla, reaching up to Durg and Raipur in Chhattisgarh.

The freight and passenger movement were under direct operation between Kolkata and Cuttack and also from riverine & coastal ports facilities at Balasore, Chandbali, Dhamra, Mangoljodi, False Point port, and Hukitola on the estuary of the river Mahanadi near Paradeep, having services from Madras, Burma, Ceylon, Malaysia, and Indonesia, etc., by the different sizes and capacities of traditional and steamer boats. M/s India General Steam Navigation Company and M/s Mac Neilod Company Ltd were stated as the major operators with a host of private freight and passenger services with a fleet strength of over 4000. **The annual traffic was over 11,98,028 maunds (or mann) as export and 2,32,353 maunds as import commodities during peak of the navigation, where one maund is equivalent to 37.324 Kg. The annual passenger traffic on an average was over 1.46 lakh pax on the Odisha Coast Canal system alone.**

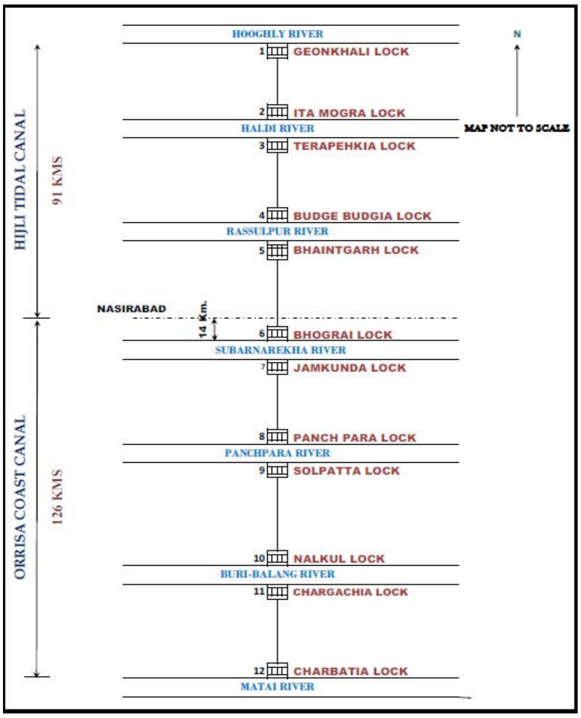

Figure 2. Schematic drawings of ECC showing the navigation locks passing through different rivers and navigation lock systems.
Source: IWAI

4.0 Causes for downfall and abandoning of the canal system

The importance of inland navigation through the ECC system started declining after the construction and operation of the Cuttack-Howrah Railway (present East Coast Railway) in 1902. The navigation was partially discontinued in 1905 for the stretch from Matai to the Subarnarekha River and ultimately abandoned in 1928 on the recommendation of the Odisha Flood Protection Committee with no further O & M measures. The navigation between Subarnarekha and the Hooghly River stretch continued sporadically up to 1960.

The effort of the flood advisory committee set up during 1927-28 to convert the canal system to a flood drainage canal system and protect it from cyclones in Odisha and Bengal after a detailed study was also not found to be techno-economically feasible. With the discontinuance of inland navigation and the complete absence of the O&M, the canal system deteriorated with encroachment for cultivation and aquaculture (**Figure. 3)** even after its declaration as part of NW5 (National Waterways No.5 for 588 km stretch from Talcher to Paradeep, Dhamra, and Goenkhali) in the year 2008 under the provision of the

Figure 3. Damaged & abandoned canal system, Source: Google website

National Waterways Act for development by the Inland Waterways Authority of India, the statutory body of the Ministry of Port, Shipping and Waterways.

5.0 Importance of ECC system in the present day integrated with NW5 and Eastern Waterways Grid

5.1 ECC system, a vital link providing a potential and vibrant waterways system

The ECC system has assumed significant importance because of its potential to provide a dynamic and viable inland navigation system in the efforts of the Odisha government to promote rapid industrialisation and turn the state into a hub of ports and harbour infrastructure. The ECC is a vital link between the river stretch of NW5 and the Eastern Waterways Grid, conceptualised originally by RITES Ltd., and subsequently further promoted by the World Bank for providing connectivity to Southeast Asia and the BBIN (Bangladesh, Bhutan, India, and Nepal) corridors, in the North Eastern Region and South Asia **(Figure.6 & Figure.7).**

The river stretches, including the creeks, for approx. 323 km of NW5 since its declaration has received the government's attention for development, considering its economic viability because of the connectivity of Talcher mineral belts with the industrial hubs at Kaling Nagar and important ports at Paradeep & Dhamra. Accordingly, the priority for the development of NW5 has been in three phases, as in **Figure.4**. Various studies and initiatives have already been taken for the first two stretches for development, and action has been initiated to develop the first stretch as a modern waterway. But to date, the 3rd stretch has not received any attention.

5.2 The economic growth and increased hinterlands

During the last few decades, Odisha has had a phenomenal economic growth because of the rapid industrialisation, mineral exploration, agricultural activities, fisheries development, etc. The strategic location of waterways, its proximity to the majority of existing and upcoming ports, and the vast hinterlands for the movement of the minerals, the raw materials, end products, etc. from the mines to industries and ports, and also ports to industries and other destinations within and beyond the state for domestic consumption and export. Following is a brief on the same.

- The notable **mineral belts in the vicinity** of NW-5 are the Talcher coal belts with MCL (Mahanadi Coal Ltd) and ECL (Eastern Coal Ltd), the mining belts in Daitary, Kiriburu, for iron ore, chromite, manganese, dolomites, etc.
- Mineral exploration and mining activities have led to **mineral-based industrialisation** for export and domestic consumption in the state, with an installed capacity of steel production of 33 MMT in 2021-22, which is projected to increase to 100 MMT per annum by 2030 with the installation of over 47 steel plants of different types and capacities.
- The twin **industrial hubs** at Kalingnagar and Vyasnagar alone have over 12 steel plants with a 47 MMTPA production capacity. The hubs have also accommodated the industries for chromite, manganese, etc.
- Besides, two more mega steel plants (export-oriented), by JSW (Jindal Steel Works) with an approved capacity of 47 MMTPA near Paradeep (Jatadhari), and another by Arcelor-Mittal & Nippon steel plant at

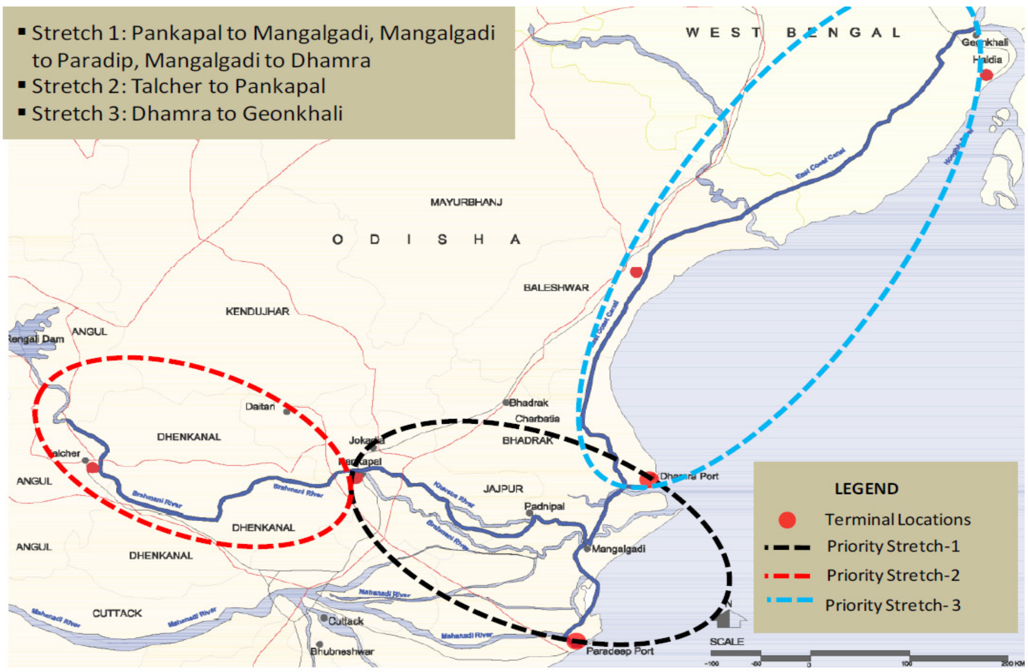

Figure 4. Priority stretches for development of ECC

The ECC is a vital link between the river stretch of NW5 and the Eastern Waterways Grid, conceptualised originally by RITES Ltd., and subsequently further promoted by the World Bank for providing connectivity to Southeast Asia and the BBIN (Bangladesh, Bhutan, India, and Nepal) corridors, in the North Eastern Region and South Asia

Kendrapara with an annual capacity of 24 MMTPA will be set up with their captive port facilities.

- PPL (Paradeep Phosphate Ltd), IFFCO (Indian Fertilizers Federation Cooperative Organization) Co, and the JSW (Jindal Steel Work) steel rolling plants are also located in the vicinity of Paradeep port.
- The IOC (Indian Oil Corporation) refinery plant at Paradeep, operationalised in 2019, is one of the major plants in eastern India, promising the growth of different petroleum-based industries. Similarly, the LNG and LPG hub at Dhamra is essential.
- The Concept Development Plan (CDP) of OEC (Odisha Economic Corridor), as part of ECIC (East Coast Industrial Corridor) prepared by the Asian Development Bank (ADB), will have 11 industrial clusters spanning approximately 600 km along National Highway- 16, with a total project area of 11366 acres. Two zones, namely, Zone-1 GBK (4748 acres): Gopalpur-Bhubaneswar-Kalinganagar; Zone-2 PKDS (6618 Acres): Paradip-Kendrapada-Dhamra-Subernarekha have been identified with the commencement of the project development activities. The existing industrial corridors at Balasore in Odisha and Haldia in West Bengal are also near the waterways, enjoying immense benefits.

5.3 Hub of Marine activities and Eastern gateway

The Odisha government has identified 14 potential sites on its 480 km long coast **(Figure.5)** for developing the port and harbor infrastructure. A few are already developed, a few are in progress, and others are in the project stage. Three existing ports at Paradeep, Dhamra, and Gopalpur, having a total capacity of 150 MMT per annum, are upgraded to 470 MMTPA in the next few years. Paradeep is supposed to be a world-class port with enhanced facilities, increasing its capacity to 750 MMTPA in the country's centennial.

Figure 5. Locations for developing port & harbor facilities on the coast of Odisha
Source: Website of Odisha IWT Directorate & Port

In implementing these projects, Odisha expects to become the vital exit point for the state and other land-locked states like Chhattisgarh, Jharkhand, Bihar, and Madhya Pradesh

Three new ports, i.e., Subarnarekha Port Pvt Ltd, at Kirtania with the investment of Tata Steel with an initial capacity of 10 MMTPA and a subsequent phase of 40 MMTPA, and Jatadhari Port Pvt Ltd, near Paradeep, a captive port of JSW with a total capacity of 23 MMTPA during phase-I and 70 MMTPA in phase-II, are under development. Besides, three more ports are under project clearance. These are Mahanadi Riverine Port at Mahakalpada with an annual capacity of 18 MMTPA in phase-I and 40 MMT PA in phase II, Kendrapara Port, a captive port for Mittal & Accelor steel plant, and one at Astaranga with 25 MMTPA. The project proposals for four more new ports at Inchudi, Chudamani, Chandipur, and Bhahabalpur are under study.

In implementing these projects, Odisha expects to become the vital exit point for the state and other land-locked states like Chhattisgarh, Jharkhand, Bihar, and Madhya Pradesh. Availing of the facilities and incentives extended under the Maritime Vision-2030 and Sagarmala flagship projects, Odisha may attract private investment to develop all-weather, deep-water, and multi-user ports of international standards and the associated infrastructure, becoming the gateway to eastern India with a clear vision, mission, and policies.

5.4 Need for sustainable multi-modal transportation (MMT) network with IWT

The vast hinterland connectivity for generating cargo traffic to and from the NER, central India, eastern India, and within the state, along with the potential for setting up port-based industries, CFS (container Freight Stations), and storage areas for handling containers and also other palletized cargo, will necessitate a sustainable and effective multi-modal transportation system with rail, road, and IWT. For various factors and reasons, the existing expressways, national highways, state highways, and railway systems (East Coast Railway) have constraints for further expansion.

The strategical locations of the majority of the mining belts and industrial corridors and the port and harbor infrastructures' proximity to the NW-5 and other waterways on the perennial delta river system in the coastal region, along with the ECC system, are ideal for adapting to the current development trend and technology in the port and shipping sector, making it economically viable to be an integral part of the MMT (Multi-Modal Transport) system, along with the proposed coastal highways of 450-km connecting Gopalpur to Digha in W. Bengal under the Centre's *"Bharatmala Pari yojana."* Accordingly, the holistic development of the waterways system needs to be planned and integrated with other modes of transportation, making them a robust MMT (Multi-Modal Transportation) system.

5.5 Integration of ECC system with Eastern Waterways Grid

Indeed, with rail and road mode, the existing transportation system in the state is presently congested and saturated, with little scope for further expansion. It may depend on the IWT mode, particularly NW-5 integrated with the ECC system in catering to the demand for future cargo traffic within the state and beyond, which has the potential to ease the burden by connecting to the ENWTG **(Eastern National Waterways Transportation Grids), as shown in Figure.6.** ENWTG was conceived and studied by RITES Ltd during 2013–14 to facilitate seamless movement of the divertible traffic projected for IWT from Odisha to different parts of the country and vice-versa, i.e., northern, eastern, and NER. ENWTG may further provide connectivity to the BBIN corridors, mainly countries like Bangladesh, Nepal, and Bhutan, through Indo-Bangladesh protocol routes as per the existing provision of PIWT & T (Protocol on Inland Water Transit & Trade) between India & Bangladesh, motor vehicle agreements, etc.

The **"Eastern Waterways GRID" (EEG),** conceived by the World Bank in 2020-21 without the NW5, in the

Figure 6. The Eastern National Waterways Transportation Grids conceived & studied by RITES with NW5 during 2013-14, source: RITES Report

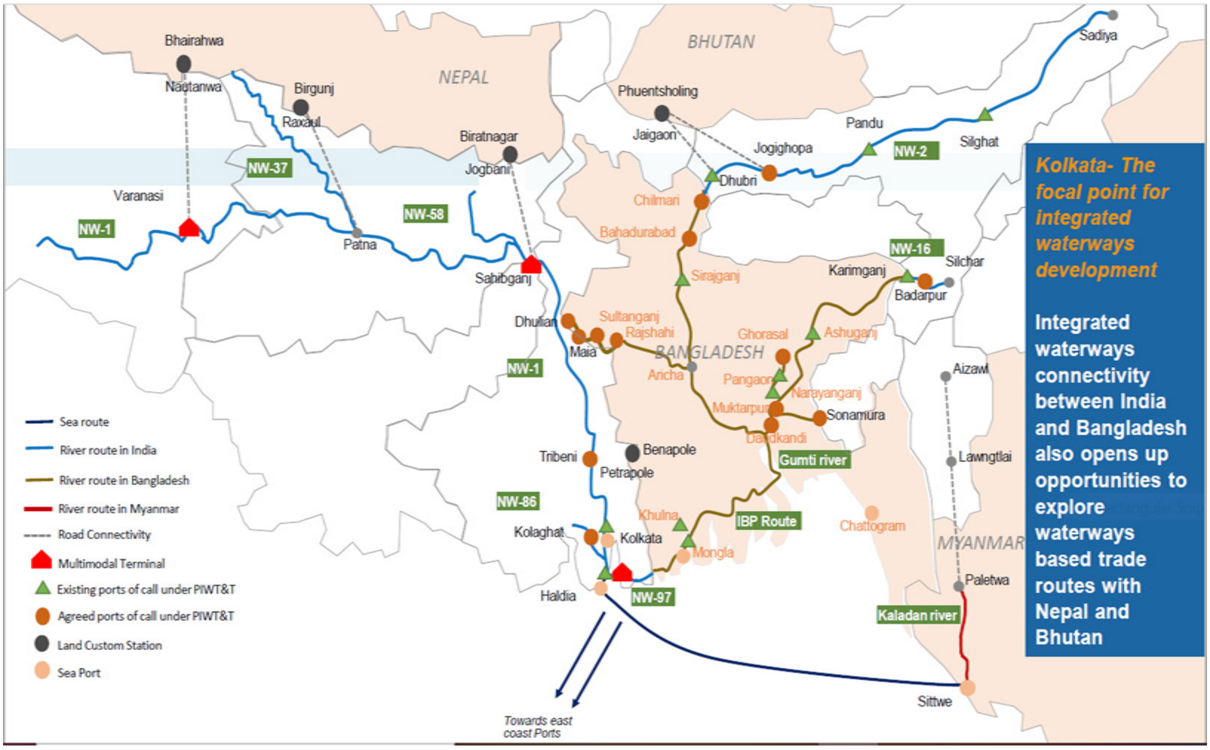

Figure 7. The proposed Eastern Waterways Grid without NW5, but with KMMT&T
Source: PPT of World Bank

absence of its development and further linking KMMT & T (Kaladan Multi-Modal Transport & Transit) to facilitate access to Southeast Asian countries like Myanmar and beyond **(Figure.7), is considered to be the extended form of ENWTG conceptualised by RITES.** Since NW-5 with the ECC system was supposed to be a vital component of the GRID in the original and the revised plans for a sustainable and viable inland navigation system, the development of the ECC system is crucial in linking to the proposed EEG. Besides having access to a host of neighbouring countries, the grid within India will provide connectivity to over 11 states with a network of over 5000 km of the inland navigation system.

6.0 Future Development Strategies

6.1 Issues on developing a sustainable and viable navigation system

The unique features of the canal system, traversing parallel to the seacoast and crossing several rivers with different sizes and types of navigation locks, bridges, and other cross-structures, encroachment, and damage already inflicted on many of these may pose difficulties for developing the canal system into a sustainable and economically viable inland navigation system with modern inland navigation technology.

The land acquisition for increasing the capacity of the waterways, enabling the navigation of cargo fleets of higher tonnage for SPV (self-propelled Vessels) and TBF (Tug Barge Flotilla) for effective integration with the riverine stretch of NW-5 and the Eastern Waterways Grid on Pan India and international standards, may also be a severe issue. The socio-economic and political issues, including R & R (Rehabilitation and Resettlement) due to land acquisition and the project execution, need to be studied in detail to address the same by adopting suitable measures. The idea of a multipurpose project for extending facilities like fishing, entertainment, and local transportation, as advocated by the experts, may make it a viable proposition.

6.2 New concept on the canal system for seamless operation

Construction and operation of the series of navigation lock systems having an average locking period of international standards for at least double navigation lanes may reduce the capacity of the waterway system along with high capital investment and recurring O & M expenditures. Therefore, the canal system's planning, layout, and design need to be studied and analysed to find the most technologically and economically feasible solutions through the modern waterway engineering

> ***The socio-economic and political issues, including R & R (Rehabilitation and Resettlement) due to land acquisition and the project execution, need to be studied in detail to address the same by adopting suitable measures***

Figure 8. Magdelburg Water bridge (Aqueduct) in Germany,
source: Google website

benchmark without or with minimum lock systems. The concept of a navigable aqueduct (water bridge) built and under operation on some waterways of Europe may provide the solution for crossing the rivers, creeks, roads, etc. on the ECC system, increasing the efficiency by eliminating the loss of time on account of the lockage on each lock system **(Figure. 8 & Figure.9)** ensuring seamless operation.

The modern navigation lock system with an efficient mechanism in their O & M and suitable measures for maintaining the fairway may also provide a viable waterway system with a fair degree of automation. Hence, because of the unique characteristics of the ECC system crossing the rivers in the densely populated and cultivated areas, the development of ECC needs special attention for its sustainability and economic viability. Adopting the latest technology to develop the canals for efficient and effective navigation and execution through experienced consultants and infrastructure developers of international repute requires the requisite expertise and exposure to modern inland navigation and infrastructure.

The TEF (Techno-Economic Feasibility) study, similar to any other project, will be necessary to prepare the DPR, the feed design, and engineering drawings for final implementation and find the sources of investment for execution and subsequent O & M. The final appraisal must be based on the socio-economic framework with various operational models. The assessment may also consider the external cost **benefits** such as the savings in energy consumption, the reduction of air pollution, i.e., the emission of GHG (Green House Gases) towards decarbonisation and earning carbon credits; the removal of congestion and accidents; the reduction of noise; surface occupation; less development; O & M costs compared to other modes of transport; etc., besides the benefits of the modal shift**.**

7.0 Conclusion

The ECC system as a standalone is not an economical stretch. But it is a vital link between the riverine economic bit of NW-5 and the proposed Eastern Waterways Grid, with a high potential to provide a vibrant and viable waterway in the country. Hence, the overall development of the ECC system with river stretches of NW-5 on priority without further delay has ample justification. Further, there has been renewed interest globally in adopting the IWT mode of transport in the total transportation system, mainly because of it being energy efficient, the cheapest, and environmentally friendly, with the characteristic of being eligible for the greenest mode of

Figure 9. The road passing under the Veluwemeer aqueduct in the Netherlands,
source: Google website

transport, reducing emissions and providing the solution to climate change, global warming, etc. The effort of the advanced countries to transform it into a greener mode of transport has already been praiseworthy.

India is also an active member of the United Nations Climate Change Campaign by attending the COP-15 held in Paris in 2015; COP26 held in Glasgow in November 2021, and pledging to reduce global warming to 1.5 degrees Celsius from 2 degrees; emission reduction to 40% by 2030; and 1 degree Celsius with zero-emission by 2070. India, accordingly, has adopted a host of policies and regulatory frameworks for this development. Therefore, the country must explore and utilise the high potential of the inland navigation system through systematic development in this direction. The rapid economic growth of Odisha and the development of the port and harbor infrastructure, making it the gateway to eastern India, will also require an efficient and vibrant multi-modal transport infrastructure with IWT. Therefore, the campaign for the early development of the ECC system receives proper attention.

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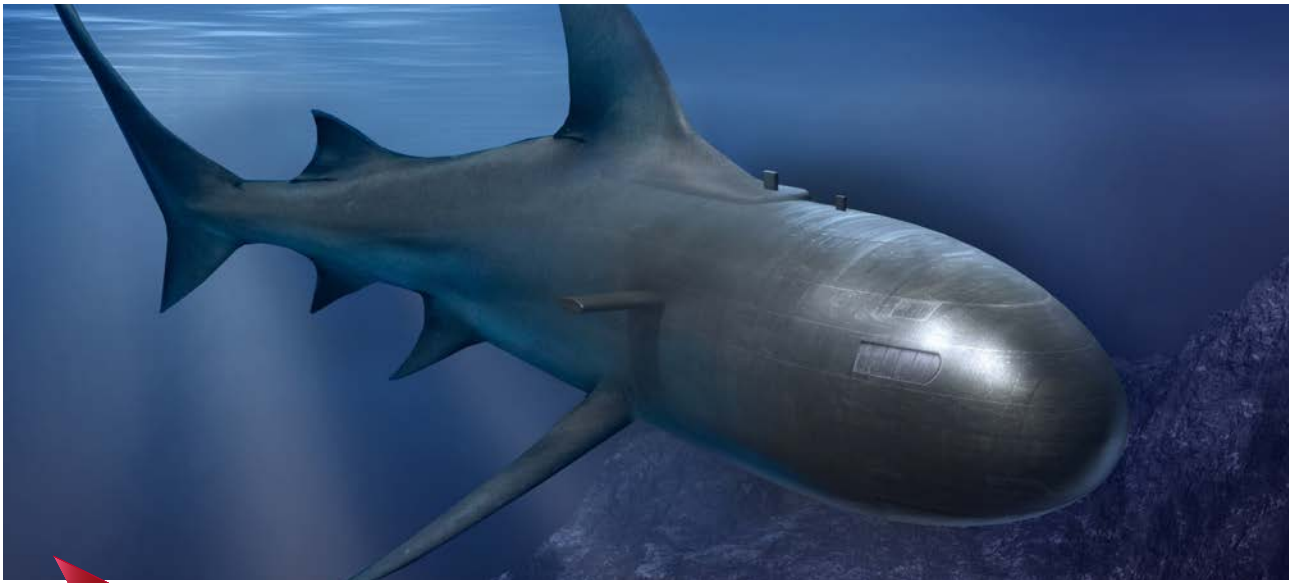
Subhakar Dandapat, with a B. Tech (Hons) degree (1979) on Naval Architecture from I.I.T Kharagpur and M.Sc. degree on Ship Production Technology from Strathclyde University, Glasgow U.K., worked at Hindustan Shipyard Ltd, a Government of India enterprise, Visakhapatnam, Inland Water Transport Directorate & Development Advisor (Shipbuilding & Ship repair) in the Ministry of Shipping, and finally joined Inland waterways Authority of India (IWAI), a statutory body under the administrative control of Ministry of shipping for development, regulation of National Waterways for shipping & promotion of IWT in the country. He worked in IWAI in various capacities and responsibilities and superannuated in May 2016 as Chief Engineer (Project & Marine).

As the post retirement assignment, Mr. Dandapat has been associated with M/s. Adani Port & SEZ Pvt Ltd., and its consultancy firm M/s. Howe Engineering Project (India) Pvt Ltd since September 2016. Currently he is engaged as "Local Technical Expert for India" to the USAID (United States Agency for International Development) sponsored project on "Upgrading and Greening of Inland vessels Fleet" of Bangladesh and North and NER of India.

INSPIRATIONS FROM NATURE IN ENGINEERING BIO-INSPIRED AUTONOMOUS UNDERWATER VEHICLES-PART A



N. Vedachalam

Abstract

Intelligent and efficient autonomous underwater vehicles (AUV) are vital for exploring the vast marine resources, spatiotemporal monitoring of the oceans to understand climate change patterns, monitoring marine pollution, defense purposes and identification of assets lost in the oceans. The article is published in three parts.

This (first) part reviews the trends in bio-inspired engineering, maturity of underwater navigation, understanding the abilities of sea animals including turtles, lobsters, salmon, whales and trans-ocean birds in long-range true-navigation with large-scale spatial cognition abilities that establishes idiosyncratic routes and the developments in bio-inspired magnetic homing guidance systems for AUV.

The second part discusses on the present maturity of AUV locomotion, energy-efficient locomotion of aquatic animals and the recent developments in bio-inspired continuum and soft robotics.

The third part brings out the need for swarm operations, fish flocking/shoaling abilities with intra-swarm intelligence supported by precise optomotor mechanisms, distributed perception, quorum decision process during predation and extreme low light vision capabilities in deep sea fishes. The observations could help in developing strategic bio-inspired agile AUV with improved propulsion, sensing, vision, control, navigation, machine-learning driven artificial intelligence and swarm capabilities.

	Inspiration from sea animals and trans-ocean birds
N	Geomagnetic imprinting, Secular variation, Spatial cognition, Buefin tuna, Olfactory clues, Magneto-reception, Geo-tagging, Beer-headed geese, White shark, Lobster, Salmon, Idiosyncratic routes, Godwit, Arctic tern, Pigeon, Honeybees, Albatross, Max shearwater, Herring gulls, Sea turtles
S	Schools, Distributed perception, Trafalgar effect, Synchro-kinesis, Shoals, Dunlin, Flock dynamics, Predator response, JLS decision, Optomotor response, Goldiflocks principle, V, J, Echelon, Honeybees, Quela, Fire-head tetras, Zebra fish, Quorum decision, Canada geese, Pigeon
L	Vortex wake, Rainbow trout, Roach, Pink-footed geese, Sail fish, ECBOI, COT, CE, AMR, Drag reducing adaptation, Carp, Pike fish, Sword fish, TBA, Archer fish, TBF
V	Bathypelagic zone, Winteria, Photophores, Opsin protiens, Bioluminescence, Dragon fish, Camouflage, Silver spring fish, Photon-level vision
	N: Long-range true-navigation S: Swarm capability L: Locomotion V: Vision

Introduction

The technological advancements in high energy density battery storage, underwater navigation sensors, processing electronics, underwater navigation algorithms, low-light cameras, high density buoyancy packs and lighter high-strength pressure casings supported by modern numerical modeling tools have enabled development of autonomous underwater vehicles (AUV) capable of carrying out exploration in remote, hostile and challenging environments, from the world's deepest hydrothermal vents to beneath the Polar ice shelves. The technological maturity of present deep water AUV is summarized in **Table 1**.

The strategic demand of deep water AUV in oceanography, glaciology, marine research, defense, engineering construction domains require further intelligent, energy-efficient and agile AUV with increased spatiotemporal capability capable of navigating thousands of kilometres in the deep-oceans and Polar Regions with swarm participation capabilities [1].

Table 1. Technological maturity of present AUV [1]

Feature	Technological maturity
Navigation	0.01% of distance travelled with a CEP50, heading accuracy of 0.01° sec Lat
Positioning	Ultrashort base line (USBL) accuracy with 0.2% of slant range with CEP50
Acoustic telemetry	Data rates of 62kbps in shallow waters at 10W; 9 kbps at 6km range at 55W
Propulsion	~7kms/kWh for a 6m long, 1m diameter, 2T AUV at 3 knots speed.

The behaviour of sea animals including turtles, lobsters, salmons, whales and trans-ocean birds such as Albatrosses, Manx Shearwater, Herring gulls and Arctic tern have fascinated scientists for long. They are curious in analysing their precise navigation over long distances; highly coordinated collective movements performed involving hundreds of individuals producing complex patterns and behaviours beyond their individual capabilities with speed, accuracy, cohesion and efficiency, their foraging and predation capabilities. Hence, understanding their self-organisation, collective motion, navigation, decision-making, construction, synchronisation and the spontaneous emergence of leader-follower relationships (**Figure.1**) shall bring out innovative bio-inspired AUV and intelligent swarm robotic systems.

The term 'biomimetics' first appeared in 1974 in Webster's dictionary, defined as the study of the formation, structure, or function of biological materials, mechanisms and processes, to synthesize artificial products that mimic natural ones

Trends in nature-inspired technologies

Understanding the maturity of nature's evolution has led to the development of more than 150 different nature-inspired algorithms that are being used for system engineering and optimisation. Nature-inspired algorithms are classified based on biology and natural phenomena.

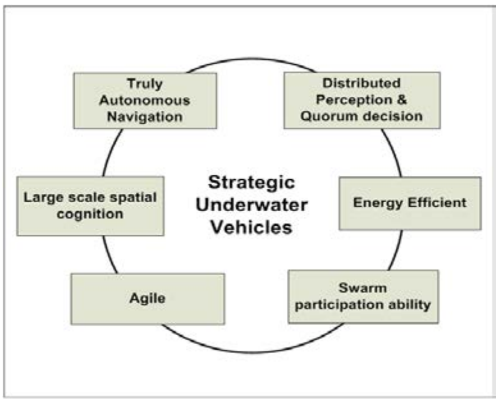


Figure 1. Lessons from nature for developing bio-inspired AUV

The biology-based algorithms are further classified based on the evolution and swarm behaviour. **The evolutionary algorithms include genetic algorithms, differential evolution, cultural evolution, evolutionary strategies and genetic programming. Algorithms are also based on physical laws, such as simulated annealing, gravitational search and big-bang big-crunch**.

In 1957, American engineer and physicist Otto Herbert Schmitt coined the term "biomimetic" as a biological approach to engineering. The term 'biomimetics' first appeared in 1974 in Webster's dictionary, defined as the study of the formation, structure, or function of biological materials, mechanisms and processes, to synthesize artificial products that mimic natural ones. Numerous bio-inspired algorithms have evolved after the introduction of the genetic algorithm (GA) by John Holland in 1975 (**Figure.2**).

In 1995, inspired by the social behaviour of bird flocking and fish schooling, Eberhart and Kennedy proposed the Particle Swarm Optimisation (PSO) algorithm, a population-based stochastic optimisation technique in which the birds and fishes are viewed as particles. The PSO that shares many similarities with the evolutionary GA is initialised with random population solutions and searches for optima by updating generations. However, unlike GA, the PSO has no evolution operators, such as crossover and mutation. Instead, the parameters of social and individual behaviours are used in PSO, including velocity and position of the particles.

The PSO is extensively used for approaches that are applicable to several optimisation problems. Subsequent to PSO, algorithms based on the behaviour of ant colony, artificial bees, termites, bats, cats, glow worms, frog, dolphin, grasshopper, bacterial foraging, cuckoo search, firefly, corona virus, Chimp, Mayfly and horse-herd algorithm evolved [2].

In 2014, experts published the Verein Deutscher Ingenieure (VDI) guideline in which biomimetics combines the disciplines of biology and technology with the goal of solving technical problems through the abstraction, transfer, and application of knowledge gained from biological models. Biological models based on this definition are biological processes, materials, structures, functions, organisms, and principles of success, as well as the process of evolution itself.

Since 2015, ISO standards provide several definitions in which biomimetics is defined as an interdisciplinary cooperation of biology and technology or other fields of innovation with the goal of solving practical problems through the function analysis of biological systems, *Bionics is described as a technical discipline that replicates, increases, or replaces biological functions by their electronic and/or mechanical equivalents*

their abstraction into models, and the transfer into and application of these models to the solution.

Bionics is described as a technical discipline that replicates, increases, or replaces biological functions by their electronic and/or mechanical equivalents. **The terms biomicry and biomimetics are both defined as a philosophy and an interdisciplinary design approach taking nature as a model to meet the challenges of sustainable development.** Hence a systematic approach of knowledge transfer from biological concept generators to technical applications has received increasing attention towards bio-derived sustainable developments.

Long range navigation

Present maturity of AUV navigation system and strategic requirements

The matured AUV integrated navigation system comprises inertial sensors (gyroscopes and accelerometers) aided by 3-axis velocity inputs from Doppler Velocity Log (and also derived from the accelerometers), depth sensor and real time position inputs from the Acoustic Positioning Systems (APoS). The phenomenal development in the navigation aiding sensors/systems has resulted in a highly precise Integrated Navigation System (**Figure.3**). The ring laser/fibre-optic gyroscopes have bias stability of 10^{-5} º/hr, angular random walk of < 0.003°/√h and scale factor accuracy of 1 ppm.

The accelerometers have a resolution of < 1µg, stability of < 160 µg/year and a scale factor of 300ppm. The Doppler Velocity Log 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 depth sensor that measures the hydrostatic pressure based on vibrating quartz crystal technology has a measurement sensitivity better than 2×10^{-7}, which translates to < 1 mm in 6000m water column.

The matured APoS Ultra Short Base Line (USBL) having an operating range of 10km at 10-15kHz frequencies has a positioning accuracy of ~0.2% of the slant range with 50% Circular Error Probability (CEP50). The integrated navigation with sensor fusion and Kalman prediction-correction algorithm gives a position accuracy of 99.9% of the total distance travelled. The acoustic telemetry modems with hemispherical beam patterns and optimized vertical and slant channels operating in 4-14 kHz range offer adoptive communication data rates of ~6 kbps up to 12km.

Long-range truly-autonomous underwater vehicles capable of navigating thousands of kilometres in deep-oceans and Polar Regions without the aid of dedicated ships is currently receiving significant interest among the oceanographers, glaciologists and marine scientists. The recent demands for long-range AUV include the Polar challenge, Seabed2030, oil spill mapping and time-bound missing aircraft search operations.

Navigation autonomy reduces the vehicle dependence on the surface vessel for the acoustic positional aid and the frequency of global positioning system (GPS) surface fixes. Navigation autonomy includes obtaining precision vehicle 3-axis velocities, heading pitch and roll from multiple sensors which is vital for position estimation and processing using Kalman predictor-corrector algorithms in dead-reckon mode, obstacle avoidance for AUV safety with the information processed from the sonar and on-board cameras, way point guidance based on pre-programmed targets, and an efficient mission plan

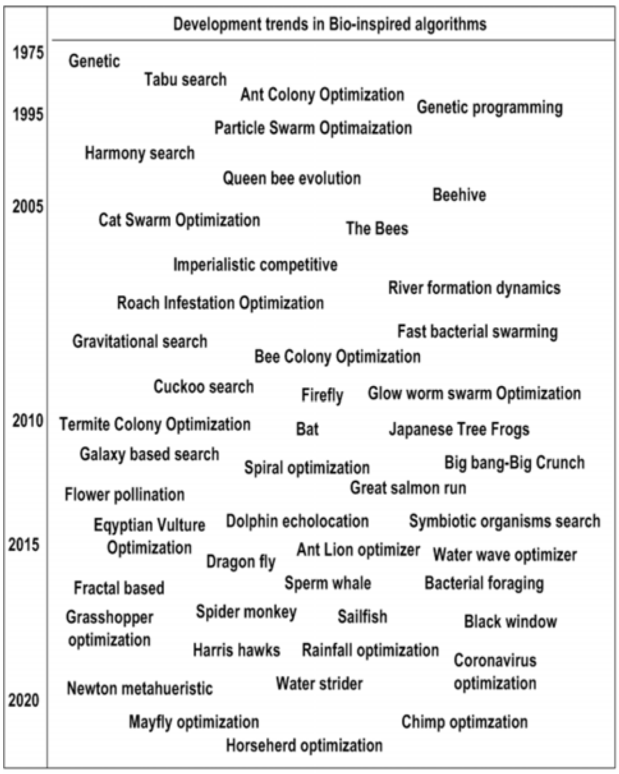


Figure 2. Evolution of bio-inspired algorithms [2]

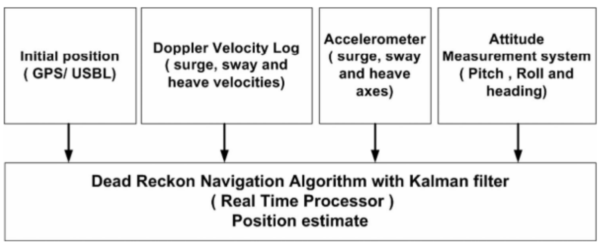


Figure 3. Vehicle position estimation dead reckon algorithm [3]

factoring-in the vehicle prognostics information, such as the battery status and health of the other vehicle subsystems[3].

Observations from nature

Migratory movements of trans-ocean birds and animals tend to be extremely accurate towards geographic locations such as oceanic islands or offshore reproductive areas. For many species, migratory routes are not learned, but are innate, which requires them to possess internal orientation mechanisms enabling autonomous navigation to specific targets.

For many species, migratory routes are not learned, but are innate, which requires them to possess internal orientation mechanisms enabling autonomous navigation to specific targets

They use magnetic, visual, olfactory and inertial clues to trace their way back home, when displaced several kilometres. The idea that terrestrial magneto-reception (MR) could be used as a compass by animals dates back more than a century. MR is the capacity to perceive the geo-magnetic field (GMF) that is pervasive across animal kingdoms including magneto-tactic bacteria to nematodes, crustaceans (spiny lobster), fishes (salmon), birds (pigeon), mammals (whales, mole-rat) and reptiles (sea turtle) (**Figure.4**).

The entire Earth is polarised with magnetic field converging near the poles, a phenomenon driven by the motion of the Earth's liquid core. While the GMF are rather regular, anomalies exist because of movement of the upper crust. Those changes, however, are small compared to the regular GMF. Therefore, the GMF is a reliable source of navigational information, especially, in the open ocean.

The GMF systematically varies across the surface of the earth in polarity (direction), inclination (angle between the magnetic field lines and the earth surface) (**Figure.5**) and the intensity, offering spatial and directional reference frame for orientation and navigation [4].

For animals that can perceive the direction of true geographic north (for example, by perceiving the area of the northern hemisphere night sky that appears to remain stationary as the Earth rotates), additional magnetic parameters such as declination (the difference between true north and magnetic north) might also potentially be used.

This directional or compass information enables sea animals and birds to maintain a consistent heading in a particular direction such as the north or east. The positional or map information helps an animal to assess its geographic position and move in the appropriate direction along a migratory route or towards a specific destination, such as its home.

Homing pigeons have long served as model animals to study large-scale spatial cognition that establishes idiosyncratic routes back to their home from distances >1000km based on olfactory clues that they recapitulate when flying solo. They easily determine map location at least at an order of magnitude better than the 2 km, which are estimated from the returns of visually impaired pigeons**.**

When flying as a flock, the collective route emerges as a compromise between the individual preferred paths through self-organized process leading to better overall routes. Keeton and Walcott were the first to reliably demonstrate that homing pigeons possess a magnetic compass sense that enables them to orientate quickly and depart in homeward direction, even when released in an unfamiliar site. When released they fly in circles to imprint the regional GMF and to get themselves oriented. The magnetic wires around the heads predictably distorted their departure bearings [5].

Honeybees have compass effect and the experiments imply that bees can detect slightest diurnal variation of ~50nT in the GMF against the 50,000nT background,

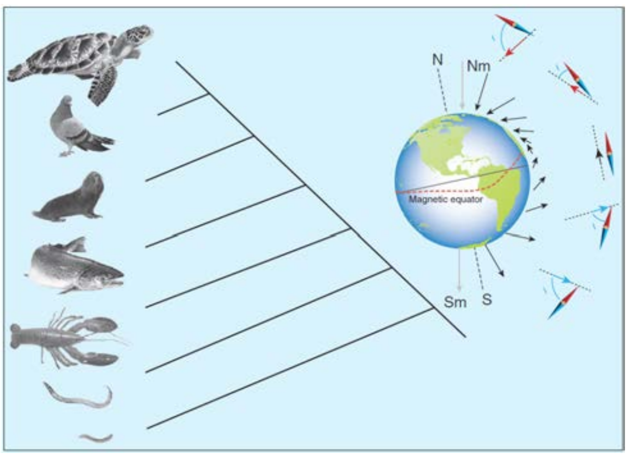


Figure 4. Animals utilising GMF for navigation

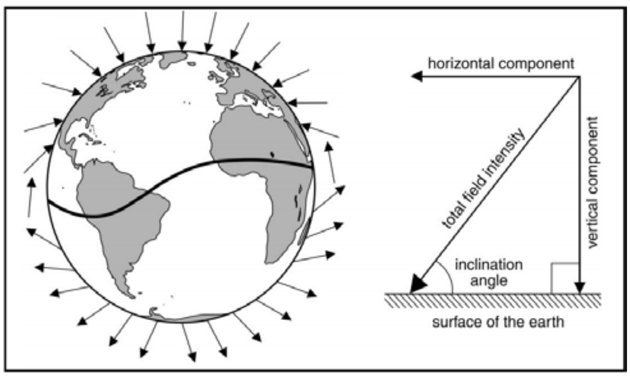


Figure 5. Components of the geomagnetic field [4].

which is similar to the case of pigeons and migratory birds. Small magnetic fluctuations affected their homing departure bearings , which is 0.13º/nT for pigeons and 2.5nT for gulls. The GMF does change a bit due to the solar radiation that is warming the earth ionosphere, creating the circadian rhythm, which could be detected by honey bees and animals living in absolute darkness, such as in the boreholes and deep oceans.

Several ocean animals have evolved to acquire the ability to derive useful directional and/or positional information from the GMF. The young loggerhead sea turtles perform one of the longest and most spectacular marine migrations, which evidently remain for at least several years (~25 years) in the gyre system in the Saragossa sea.

During this time, they cross to the eastern side of the Atlantic Ocean before returning as large juveniles to the North American coast, where they take up residence in coastal feeding grounds (**Figure.6**). Tagged experiments have revealed that hatching turtles can distinguish between different inclination angles and intensities corresponding to those that they encounter in different locations along their migratory route, and hence capable of long distance navigation [6].

The juvenile green turtles captured in the feeding grounds along the east coast of Florida were tethered to a tracking system inside a pool of water on land and exposed to the magnetic fields that exist at locations ~340 km north or south of the capture site. The turtles that were exposed to the GMF from the northern area swarm south, whereas those exposed to the GMF from the southern location swarm north, indicating the turtle's capability to acquire a magnetic map and the skills needed to navigate toward specific coastal areas.

Crystals of magnetite function as receptors for the magnetic sense in Salmon and other closely related fish. Green turtles nesting at Ascension Island migrate between this island and foraging areas located along the Brazilian coast, swimming in the open ocean for >2200km.

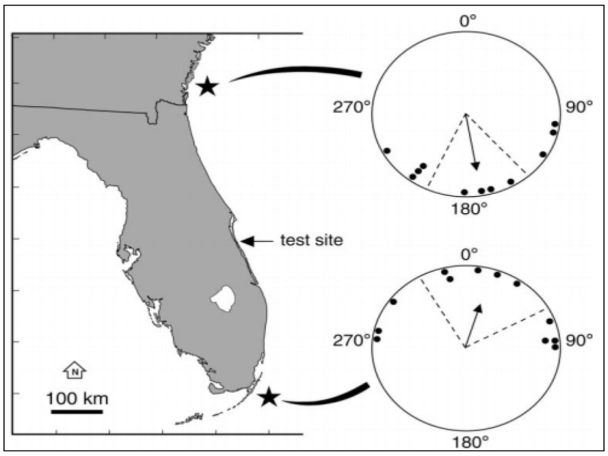


Figure 7. Spinning lobsters test site [7].

In the case of the spinning lobsters, tag and recapture studies (**Figure.7**) have shown that they are capable of homing after being displaced several kilometers from a capture site, where they have never been so far, which shows their true navigational capabilities. Thus spinning lobsters and sea turtles are capable of determining their position relative to a goal, without relying on familiar surroundings, cues that emanate from destination, or information collected during the outward journey [7].

The inclination and the intensity of the GMF that change gradually over time are termed as secular variation. The GMF intensity decreases in the western hemisphere and increases in the eastern hemisphere. Secular variations are calculated as a difference between the GMF intensity in the final and initial moments of the examined period, divided by the number of years in the period.

The changing secular variations are termed as excursions. Excursion takes place only in earth's liquid outer core, but not in the solid inner core. Based on the geological records, magnetic patterns found in volcanic rocks, especially those recovered from the ocean floor, show that the GMF has undergone numerous reversals of polarity. There have been 183 magnetic pole reversals (flip)

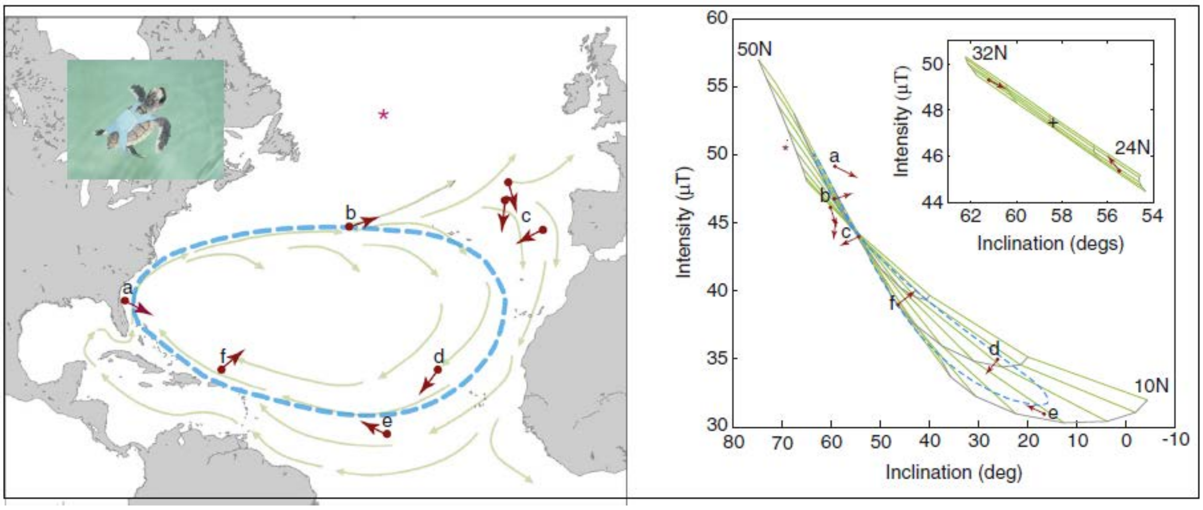


Figure 6. Sea turtles' migration in the Atlantic Ocean [6]

Salmons use chemical clues to navigate precisely back to their natal areas, often to a particular river branch, from the featureless ocean after an absence ranging from a few years to a decade

over the last 83 million years, average of once in 450,000 years. Subsequent to a flip, North Pole is transformed into a south pole and the South Pole becomes a North Pole.

The regional homing of juvenile turtles raises the interesting possibility that such animals may diminish the effects of secular variation on natal homing accuracy by updating their knowledge of the GMF in their natal region long before their first reproductive migration. This secular variation poses a potential complication for the GMF imprinting hypothesis because of the field changes that occur at the natal site during an animal's absence, which might cause navigational errors during return migrations.

The turtles in the Florida take ~20 years to mature. Given the rates of the secular variation during the past century (**Figure.8**), these turtles could hypothetically return a mean distance of ~134 km from their natal site, if they imprinted on inclination angle or ~262 km from it, if they used intensity.

Salmons use chemical clues to navigate precisely back to their natal areas, often to a particular river branch, from the featureless ocean after an absence ranging from a few years to a decade. The salmon imprint on the chemical cues of their natal rivers and streams has been demonstrated through experiments in which young fishes were exposed to specific chemicals during a critical growth period and subsequently released to undergo their normal migrations.

These artificially imprinted salmon returned as adults to breed in streams that had been scented with the same chemical. Thus salmons could imprint on both the inclination and intensity of the GMF, and use both elements as redundant markers of the natal area during their return [8].

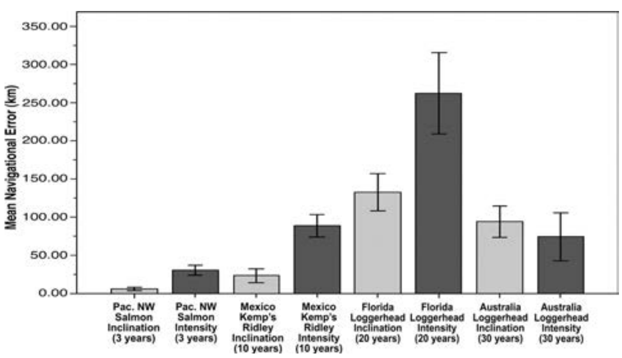


Figure 8. Secular variations in GMF

The advancements in the geo-tagging and tracking systems have helped to track spectacular trans-ocean fish migrations. **Figure.9a** shows the multi-year tracking of the salmon shark (green square indicating tagging site) shuttling between Alaskan coastal waters and a specific offshore foraging area. Each track represents the migratory journey undertaken in a different year.

The spectacular migrations of six satellite-tracked leatherback turtles nesting at Grenada Island (green dot) spanning over the entire Northern Atlantic Ocean is shown in **Figure.9b**. Most turtles wandered over large oceanic areas, but some (green and red track) migrated directly towards specific sites along the North American continental shelf.

Figure.9c shows the inter-hemispheric migratory journeys of two sooty shearwaters moving from their New Zealand breeding colony (green dot) first to oceanic areas in the Southern Pacific Ocean and then to wintering foraging grounds in the North Pacific. The figure of-eight route pattern is typical of trans-equatorial bird migrations [9].

Figure.9d shows the homing trips of eight green sea turtles that were displaced from their breeding sites at the Glorieuses Islands in the Eastern Indian Ocean (green dot) to an open-sea release site (yellow diamond), about 150 km away. The red tracks show the routes of turtles that were disturbed in the perception of the GMF through the application of a magnet on their head. Green tracks refer to undisturbed control turtles. Two turtles failed to return to the home island and moved to Comoros Island or towards Madagascar, while the others homed to Glorieuses, although following very circuitous paths.

Tagged experiments show that Atlantic blue fin tuna undertakes transatlantic migrations starting from the western Atlantic Ocean covering the Gulf of Mexico to the eastern Atlantic or the Mediterranean Sea. The female white shark tagged in the Western South Africa completed a transoceanic migration circuit between Africa and Western Australia extending more than 20000

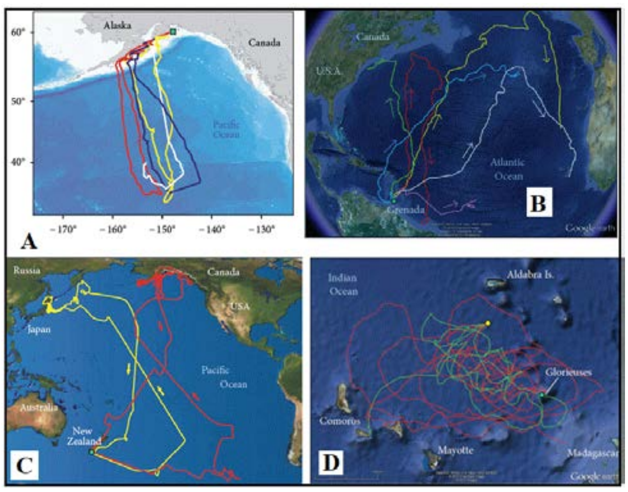


Figure 9. Spectacular trans-ocean fish journeys [9]

Based on path reconstruction, Falkland birds and New Zealand birds cover between 30000 and 60000 km following a distinctive figure eight pattern

km. During the migration to Australia, the shark was found to follow a remarkably straight course.

The fidelity of navigation of multi-decadal humpback whale migrating route despite oceanographic and GMF changes can be understood from the historic whaling records and 15 years of satellite-derived data. They show that humpback whale migrations including utilization of migrating corridor, pathways, direction, timing and velocity has not changed due to changes in the oceanographic conditions and GMF.

Figure.10 shows the satellite telemetry data that documented the spatio-temporal locations of 20 humpback whales as they migrated through a < 350 km wide and >3000 km long south-south eastern (SSE) corridor in the southern Atlantic Ocean between 2003 and 2018. The figure shows the GMF inclination angles at the northern and southern sides of the SSE migrating corridor.

The GMF significantly changed (~13%) due to secular variation at the humpback whales wintering grounds on Abrollhos bank between 2003 and 2017. The inclination angles equivalent to those present at the Abrollhos bank in 2003 were located >340 km to north-west and >130 km inland of Brazil coast in 2017. The secular variation of the GMF in the migration corridor was more severe at the southern end of SSE, where equivalent inland shifted > 400 km to west between 2003 and 2017.

The spatio-temporal fidelity of the hump whale movements, despite contemporaneous oceanographic and GMF changes, suggests that their movement decisions include clues from GMF and solar orientation. The Cetaceans, the animal family which whale belongs have bio-magnetite in the retinas of their eyes, which help GMF support navigation during the migrations.

Historically, Laysan Albatrosses, Manx Shearwater and Herring gulls were the species to be systematically tracked, as they cover enormous distances for foraging, being able to fly up to 15000 km in a single trip over wide oceanic areas. Based on path reconstruction, Falkland birds and New Zealand birds cover between 30000 and 60000 km following a distinctive figure eight pattern.

At present, light-weight trackers (few grams) help to follow even the smallest birds on their spectacular journeys. Tracking studies on ecological and behavioural patterns of birds showed that migrating birds fly almost 8000 km across the north Pacific, from Canada to Japan and China (**Figure.11C**) [[10].

The astonishing flights were the longest non-stop journey by bar-tailed godwit, which covered 11500kms over the Pacific Ocean in just 8 days. The longest (with stops) was by the Arctic tern, which covered about 96000kms in just less than a year, while the highest flyer was the individual beer-headed goose, which reached 7.3kms above the sea level when crossing the Tibetan plateau including the Himalayas (**Figure.11B**).

Tracking data also reveal that these birds take hefty diversions to find favourable winds, allowing them

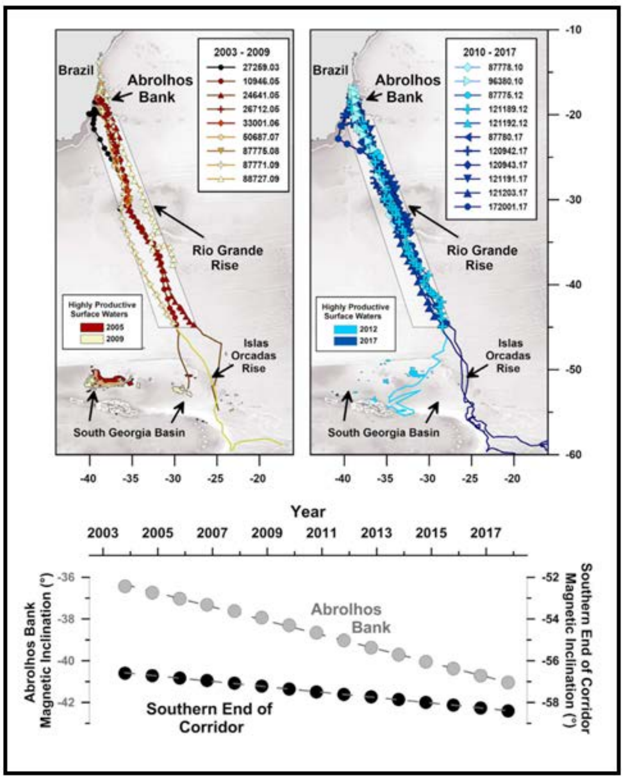


Figure 10. Spectacular humpback whale migrations [9]

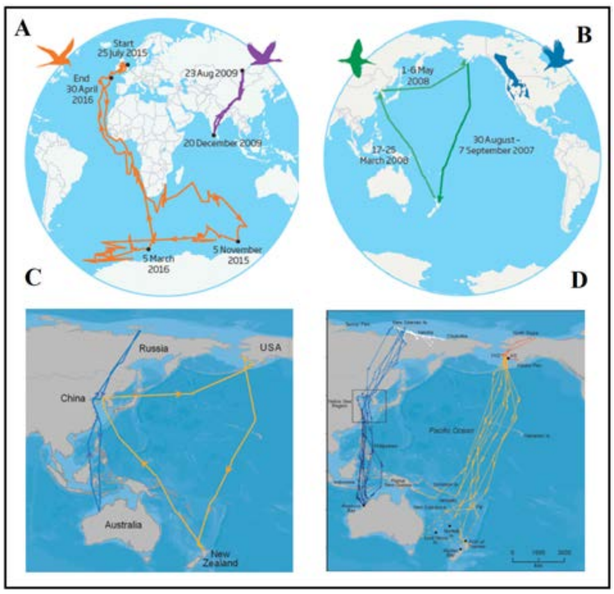


Figure 11. Spectacular trans-ocean bird journeys [10]

to drift when it is more energy-efficient than heading straight. The round-trip migrations of individual bar-tailed godwit were tracked (orange track) for 29280 km including three main migratory flights between New Zealand, China and Alaska. **Figure.11D** shows the tracks of satellite-tagged bar-tailed godwits during southward migration. Small thickened sections (circled markers) along track lines represent positions calculated from Argos data.

> **The astonishing flights were the longest non-stop journey by bar-tailed godwit, which covered 11500kms over the Pacific Ocean in just 8 days**

A total of eight birds transmitting during the southward migration period departed Alaska (30 Aug- 7 Oct) and headed south across the Pacific Ocean through a corridor ~ 1500 km wide. The estimated total flight distance for them, assuming no detours for the remainder of their routes was 11820 km [11].

Bio-inspiration

The navigational accuracy of the sea animals and trans-ocean birds and their unerring ability to travel between any two points by the shortest possible route, or the ability to home to a target area from anywhere provides evidence to support the usage of GMF as the key parameter for navigation and positioning of long range AUV.

An important caveat is that the fine-scale or local patterns of GMF contours are more complex than the general regional patterns because concentrations of magnetic minerals in the Earth's crust often generate local field anomalies. Although these variations are typically less than 1% of the total field, their gradients (i.e. variation per distance) can be significantly greater than the gradients due to the main dipole field, and variation in directions.

However, the complexity of local magnetic contours suggests that any navigational strategies that exploit magnetic topography over these smaller spatial scales are likely to be site-specific, difficult to generalize, and learned rather than inherited, which opens up new avenues in AUV navigation with machine-learning capabilities.

Unravelling the mystery of the organization of magnetic maps, and the exploitation of magnetic positional information by animals to guide their movements could offer new insight into GMF-based navigation. Long range GMF-based AUV navigation could be based on how animals treat a bi-coordinate map as two separate magnetic gradients.

If an animal knows the magnetic inclination and intensity that exist in a target area and if the isolines of these two magnetic parameters are not parallel in the geographic region, then the problem of arriving at the target could be solved if the animal uses first one gradient and then the other in alternating succession to approach the goal. Such a strategy might produce a more meandering path than computing a straight-line course, but no mental image (large scale cognition) and no unusual computational skills would be required.

Although determining the longitude is still challenging for the humans, the means by which the sea animals and birds determine the longitude and derive true navigation map using geomagnetic and olfactory cues and their internal clock requires further detailed research.

Subsea homing and docking (H&D) systems, used for increasing the spatio-temporal capabilities of AUV, should have provisions for offering reliable guidance for the AUV to return to, and manoeuvre into the dock, considering the vehicle attitude and dynamic response characteristics of the vehicle.

Inspired by sea animals and trans-ocean bird navigation, machine learning (ML) algorithms are implemented (by National Institute of Ocean Technology) for determining the range and heading correction in real-time for a MagHomer AUV approaching the H&D station [13]. The range was imprinted by supervisory ML (regression algorithm) of the magnetic field intensity and the unsupervised ML technique was used to identify the bearing angle by differential magnetometry (**Figure.12**).

Magneto-inductive sensors (with one in forward and another in aft) with a range of ±50µT and sensitivity and repeatability of few µT are used in the MagHomer. The 50W-20Hz electromagnetic homing guidance system (EMHGS) with AI-enabled NIOT MagHomer is demonstrated for autonomous intelligent homing over a range of 7m (**Figure.13**).

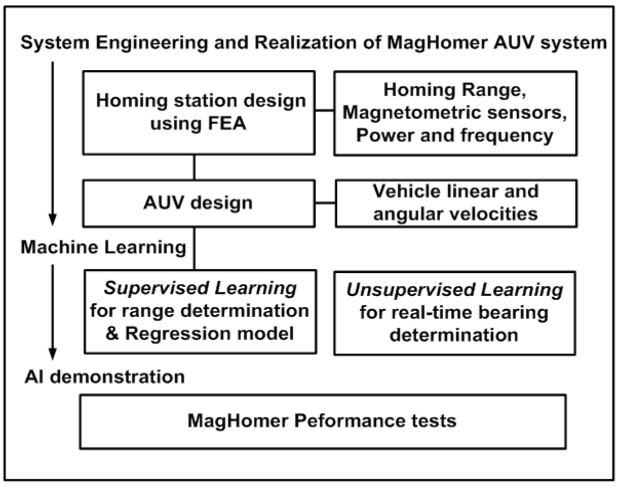


Figure 12. Realization of AI-enabled EMHGS with MagHomer

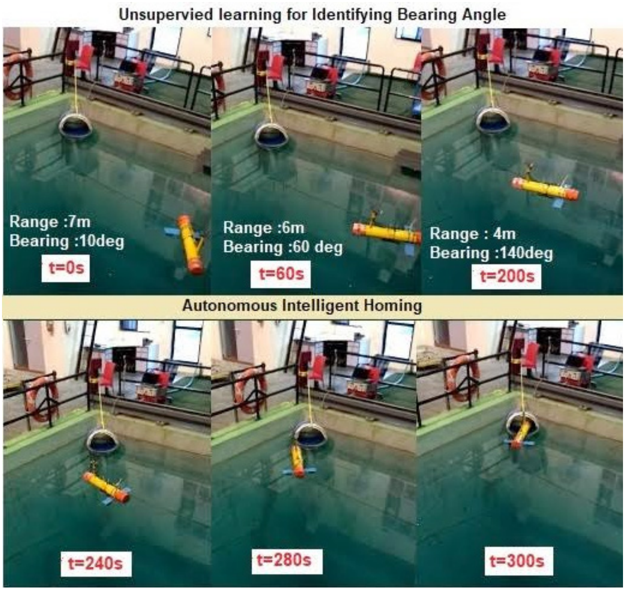


Figure 13. MagHomer Autonomous homing sequence

The sequences involved in the unsupervised bearing angle identification phase, orientation correction (up to 60s) and heading to the dock (till 300s) is shown in **Figure.13.** Further developments in sensing the olfactory clues and cameras as inputs using sensor fusion algorithms capable of large scale cognition shall aid in future developments of bio-inspired AUVs.

The second part of the article beings out details on the maturity of AUV locomotion, efficiency of fish locomotion and the developments in bio-inspired soft robotics. The third part explains the opto-motor response mechanisms, intra-swarm communication in fish shoal and bird flocks that help them in achieving synchrony with neighbour's kinematics, construction, synchronisation, distributed perception, quorum decision and the spontaneous emergence of leader-follower relationship, predation and foraging capabilities that helps in participating in a swarm. The photonic-level vision capability of fishes inhabiting in deep seas that could help in improving the capabilities of deep-ocean imaging systems shall also be discussed.

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Dr. N. Vedachalam is currently Scientist G in Deep Sea Technologies division of National Institute of Ocean Technology (NIOT), Ministry of Earth Sciences, India. He is the technical lead for India's first indigenously-developed deep-water manned scientific submarine MATSYA 6000. He holds a Bachelor's degree in Electrical and Electronics engineering from Coimbatore Institute of Technology (1995) and PhD in Techno-economics of marine gas hydrates from College of Engineering - Anna University, India. His 27 years of experience include industrial power, process, offshore and subsea domains at Aditya Birla group, General Electric & Alstom Power Conversion in France. Technical exposure includes development of multi-megawatt subsea power and control systems for Ormen Lange subsea compression pilot; Ocean Thermal Energy Conversion and wave energy systems; subsea renewable power grids; unmanned and manned underwater vehicles; ocean observation technologies and industrial systems. His research interests include energy, subsea robotics and reliability. He has more than 100 publications in indexed journals, holds an international and two national patents in subsea robotics and subsea processing. He is a recipient of the national meritorious invention award in 2019 for the development and usage of underwater robotic vehicles. He is a member of Indian Naval Research Board, member of Bureau of Indian Standards and was the Secretary of IEEE OES - India Chapter. He is a regular contributor to MER.

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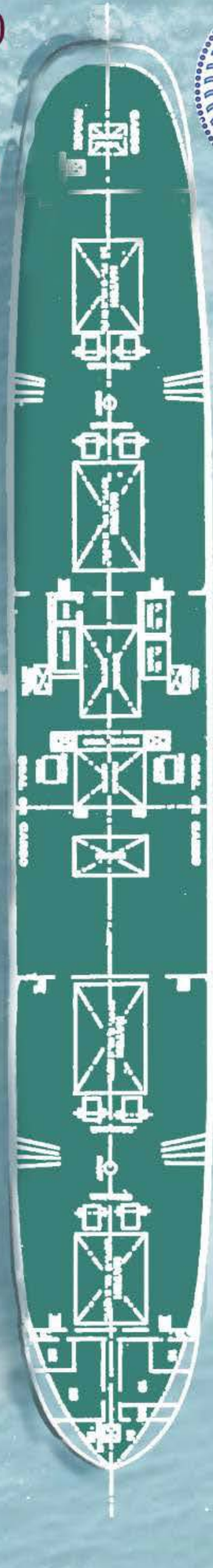

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THE INSTITUTE OF MARINE ENGINEERS. (INDIA)
MUMBAI BRANCH AND ITS NAVI MUMBAI & GUJARAT CHAPTERS

TECHNICAL NOTES

LUBE MATTERS # 14

OTHER ADDITIVES

Sanjiv Wazir

Introduction

During normal operation, lubricants used in internal combustion engines and other machinery are subject to intense thermal and mechanical stresses. Lubricants also must deal with various contaminants and combustion by-products. Hence lubricants have to be fortified with a variety if additives such as dispersants, detergents, etc. These surfactants and other additives like VII can have a stabilising effect on foams and emulsions that may form during normal operations. Foams and emulsions can impair effective lubrication. Hence several other additives, such as anti-foam agents, demulsifiers, emulsifiers, sea-swell agents, etc., are also used in many lubricants.

Antifoams

In most lubricating systems, oils get violently agitated in the presence of air. Foam forms due to entrainment of air (or gases) in the bulk fluid. Foam consists of a closely packed array of air bubbles, separated by thin liquid films. Gravitational liquid drainage in the films causing thinning of the oil film is the main mechanism of film rupture and foam dissipation. The viscosity and surface tension of the oil determine the extent of air entrainment and resultant foaming.

Low viscosity fluids produce foams with large bubbles that tend to break down quickly. High viscosity fluids generate small bubbles that tend to form stable foams that are difficult to dissipate. Presence of surface-active materials, such as detergents, dispersants, emulsifiers, etc., increase the tendency for foaming. Particulate contamination can provide nucleation points for foam formation and increase foaming.

Excessive foaming can result in breakdown oil films under load, sluggish operation of hydraulic systems, increased oil oxidation and cavitation.

Antifoam oil additives work by altering the surface tension of the oil, reducing the film strength at the oil/air interface, resulting in rupturing of the air bubbles, causing them to break down and agglomerate. The larger bubbles rise more rapidly to the surface of the oil where they burst readily (**Figure. 1**).

Antifoam additives are low solubility surfactants that are added as very fine dispersions in the oil. The required dosage can be very low (3 – 150 ppm). Excessive dosage can result in more air entrainment, especially in stagnant systems. The most used foam inhibitors are polymeric compounds such as polysiloxanes, having very low surface tension (lower than that of hydrocarbons).

Hence several other additives, such as anti-foam agents, demulsifiers, emulsifiers, sea-swell agents, etc., are also used in many lubricants

Demulsifiers

Some lubricant formulations, especially those containing surface-active agents, tend to form strong emulsions when water is present. Emulsified oil can result in breakdown of hydrodynamic oil film and lead to wear. Presence of water in oil can also lead to loss of bearing life, corrosion, hydrogen embrittlement, increase foaming tendency, etc. In IC engines, Ingress of blow-by gases, or recycling of exhaust gases can result in the formation of a viscous emulsion sludge. Demulsifiers are added to enhance water separation, so the free water can be drained out of the system. Demulsifiers have limited solubility in the bulk phase and migrate to the interface of the droplets, where they dislodge the surfactants and reduce inter-droplet interaction. This allows droplets to come closer together and form larger and larger aggregates of droplets. Gradually distinct phases are formed, and the water can be physically removed (2).

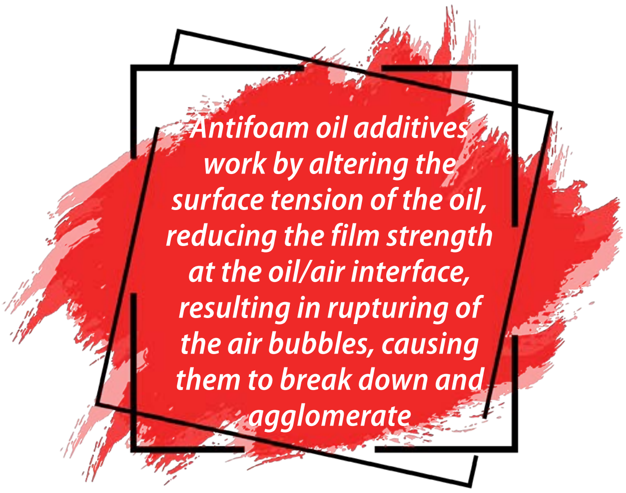
Emulsifiers

Emulsifiers are chemical compounds that enable two immiscible liquids to form a stable mixture. Certain marine stern tube oils are formulated to allow formation of stable water-in-oil emulsions with high (10-20%) concentration of water. Oil-in-water emulsions are primarily used as metal-working fluids, that are low cost and easy to dispose of. Certain hydraulic fluids requiring fire-retardant properties are formulated from O/W emulsions.

Common emulsifiers & demulsifiers are made from polymer compounds.

Seal-swell agents

Seals are widely used in lubrication systems. They are commonly made from polymeric elastomers such as nitrile rubber, polyacrylates, silicones and flouro-elastomers. Different lubricant formulations can cause shrinkage, brittleness, surface deterioration of seals. Different seal materials react differently with different base oils additives. Seal swell agents are used to maintain the integrity of the seals. They are commonly used in hydraulic and transmission fluids (3).



Multifunctional additives

Many additives perform more than one function. ZDDP known mainly for its anti-wear property also exhibits strong anti-oxidation & anti-corrosion action. Basic sulphonate detergents also have rust and corrosion inhibition properties. Polyacrylates and styrene-ester polymers can act as VII, dispersants, and pour point depressants (4).

Other additives

Biocides and Anti-misting agents are also used in some lubricants and metal-working fluids. Dyes are used to colour-code some oils and greases to ensure correct usage.

Lubricant formulation

Lubricant additives are usually supplied as packages, which are blended in mineral or synthetic base oils to make the finished product. Viscosity Index Improvers are supplied separately from the additive package, because the two are not always compatible. For applications needing VII, the VII elements are blended with the base oil along with the package. **Table 1** shows the main types of additives used to formulate major lubricant grades (4).

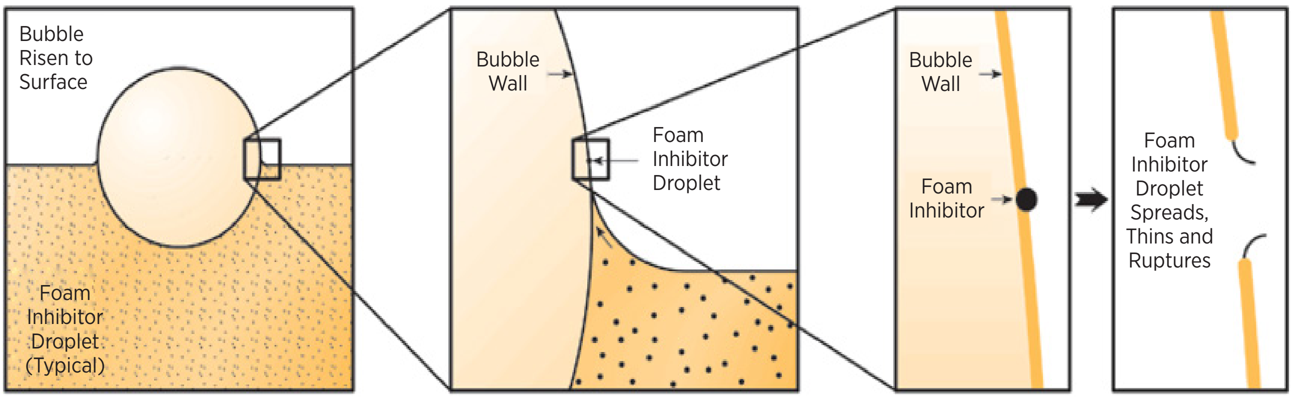


Figure 1. Mechanism of Antifoam additive (1)

Table 1. Common additive types used in different lubricants

ADDITIVE	Petrol Engine Oils	Diesel Engine Oils	AW Hydraulic Fluids	Industrial Gear Oil	General R & O Oil	Greases
Dispersant	✔	✔				
Detergent	✔	✔	✔			✔
AW/EP	✔	✔	✔	✔		✔
Oxidation Inhibitor	✔	✔	✔	✔	✔	✔
Corrosion Inhibitor	✔	✔	✔	✔	✔	✔
Friction Modifier	✔	✔		✔		
Pour Point Depressant	✔	✔	✔	✔	✔	
Foam Inhibitor	✔	✔	✔	✔	✔	
Viscosity Index Improver	✔	✔	Only HVI			
Others			✔			✔

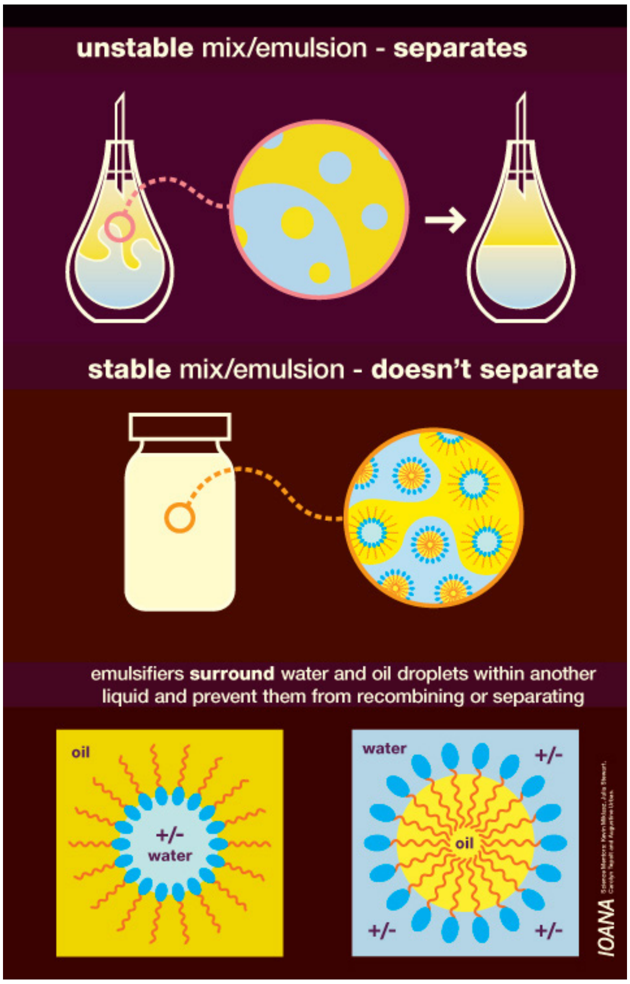


Figure 2. O/W & W/O emulsion structure (3)

Lubricant additives are usually supplied as packages, which are blended in mineral or synthetic base oils to make the finished product

Conclusions

Reliability of lubricants is a function of the quality of its base oil, additive package, and formulation. A wide variety of additives are used. New additives are being regularly developed to meet evolving needs. The additives, being reactive chemicals, can react with one another either synergistically or antagonistically. The lubricant formulators expertise lies in minimising the antagonistic effects and maximising the synergetic effects through careful balancing to deliver the intended performance (4).

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INDICATOR CARDS: A MARINE ENGINEER'S LAMENT

This forum is for reflections from readers.

Do mention your name, email, membership grade and number (if Member of IMEI) with your mails.

Abid Ansari
(sailing Marine Engineer)

With the advent of Autonomous ships and breakthrough technology applications on board ships, the conventional methods of monitoring machinery operations have undergone, please pardon the cliché, a 'sea change'! Suddenly all the stories one had heard in the last century, about marine engineers becoming jobless, may actually come true. The breed of the true-blue marine engineer may go the way of the Velociraptor - extinct!

Engineers and watch-keepers today are no longer what they were a few decades ago. As those 'Vintage Class' engineers who are still alive would concur, we were taught to be alert and to use all our senses while taking rounds of machinery and control spaces. The term 'senses' were meant to include the following:

1. Eyes - looking for visual indications, we had to have 20/20 vision. A colour blind engineer was unthinkable, being able to distinguish the Red from the Green was a basic requirement.
2. Ears - open for auditory cues, beats, thrums, whines and the usual noises that machines make or sometimes, don't make. This helped us identify unusual and abnormal sounds.
3. Nose - sniffing for odours, fumes, various hydrocarbons, the exhaust from the engines, flue gas from the boilers and all the mouth-watering smells emanating from the galley. A whiff of IG or Carbon monoxide from the cargo holds could also be the last dying function of this sense.
4. Skin - touching surfaces to gauge temperatures and vibrations. A die-hard engineer would also pet the machines under his purview coaxing them to give their best,
5. Tongue - not so much, though we could check salinity and textures. This sense was more employed on land during shore leave rather than on board.

   And lastly,

6. Common sense - the less said, the better. Engineers rely more on logic, intuition and routine. Differentiating a Right hand thread from a Left, recognising an uncommon, irregular nut among the M12s and M16s, etc.

(I am told that certain navigators possess this extraordinary sense when distinguishing between Port and Starboard, though I haven't been blessed with such shipmates.)

As automation slowly crept into a seafarer's life and machines surrendered to electronics, we found rudimentary checks being handled by the early automated systems.

"Pfff...so what? Let the automation have some fun", we said. Little did we know that we were letting the fabled camel into the tent.

For example: checking liquid levels in tanks - earlier we were proficient in the use of the sounding rods and tapes, slowly graduating to sight glasses and further advancing to pneumatic level gauges and so on. But now the system had fancy sensors of its own, thingamajigs designed to alert the engineer when alarming conditions were triggered. But that was it. The system could do no more, it was left to the engineer to take action upon getting the alert. We were, after all, the engineers!

Subsequent iterations of automation enabled the system to take action when alarming conditions were detected.

"Alright, go ahead", said the engineers grudgingly.

For example: A low level condition triggering the starting of a pump to raise the liquid level in a tank. This took away some of the engineer's scope of duties and allowed him to focus on other work. Of course, the option of overriding the system's response was provided to the engineer as a 'fail-safe' measure in case the system was to develop a fault. We still had an upper hand!

Later, computerisation came in and enabled multi-tasking. This was solid-state trouble from beyond the seas. The naive engineer was lured by the flashy display screens, monitors and HMIs. We didn't realise then that behind the clickety-clackety keyboard lurked a formidable adversary, one who would claim our profession and make us useless. It was a pre-cursor of evil tidings but the gullible engineer could not understand the foreboding signs of eventual doom. For any seaworthy engineer for whom converting psi to kgf/cm^2 to kN to bar took a fair deal of energy, heat generation and pressure build-up under their craniums, this was a usurper who had no qualms about stealing their jobs.

The damn system could monitor an infinite number of parameters all at once.

Of course this greatly relieved us from conducting routine inspections, but hey, we were losing touch with our machines. Now when the engineer did random inspections he began to doubt himself, because the system was already second guessing him, superseding him sometimes! The spanner and hammer had been replaced by a mouse.

Further advances in technology enabled the system with decision making abilities critical to the operations.

"Hold on! Hold on! Wait-a-minute. What do you mean by 'decision making abilities'?

For example: the system could now proactively take measures in order to prevent any alarm conditions from arising at all. That meant that the machinery spaces could be left on its own without any human intervention.

Unmanned machinery operations meant that the engineer was no longer required.

That was it then. We were just a notch away from being decommissioned. We were no more than the obsolete donkey-pumps that we had discarded, fit to be scrapped. In theory, that would have seemed to be the case, at least.

However, experience from practical installations showed that, in reality, the systems needed human intervention from time to time. The reasons were many:

bugs in the software; a non-routine condition being triggered; malfunctions of sensory devices; incorrect operating settings, and most commonly power issues.

All of the above gave us false hope and opened our relief valves. *"Heh, heh, replace the marine engineer, would you? We are indispensable",* we thought. Ignorance and the haughty pride of generations of marine engineers coursing through our body's pipelines kept our spirits up.

We hadn't the faintest clue that the whole world was scheming against us. The hapless marine engineer could not utter a word when the systems got upgraded to a newer version, the bugs were removed, all possible contingencies were considered, solid state instruments got a digital makeover and power - *poof, put in another back-up battery.*

The marine engineer was now not only dumbstruck but also proven dumb. The machinery control room was not his to control anymore. All the tricks of the trade that he had learnt slogging in the bilges were now just lines of code for the PLCs. In his earlier avatar, his knees would get scuffed and his overalls would be drenched. '*Blood, sweat and tears*', as some would have said. Now his decision making ability was limited to two things: how to eat eggs for breakfast, should it be an omelette, a bullseye, scrambled or plain hard boiled and which movie to watch in the evening!

Oh, how the mighty had fallen!

Circa post 2020:

Improved software systems have more or less eliminated a majority of the setbacks that early automation suffered from. Redundant power back-ups and enhanced algorithms have made the systems more reliable. Above all, the new millennium has seen a radical acceptance of IT enabled systems on board ships. Moreover, the shipping industry itself has shaken off its inertia and is now adopting greener technologies. All this has resulted in dramatic developments on ships, to name a few:

AI and ML enabled systems providing smarter solutions to sustain optimum Operations; Robust machinery with workhorse abilities to overcome the foulest of weather; Operational design with inherent fail-safe and redundant features to eliminate downtime; IOT interlinking the various systems within the ship creating a microcosm of small systems, and Enhanced broadband communications connecting the systems to remote control stations.

The Autonomous ships had arrived! Machines had taken control of humanity, er.... I mean, marine engineers. Autonomous ships - Ghost ships with nary a human presence. These ships were the equivalent of Thanos for us engineers. And had it been possible, they could have gotten away saying...... "*I am inevitable!"*.

The marine engineer today faces an existential crisis. He now sits on land, far away from the ship, wishing for the good old days, when he could call the shots. The ship meanwhile is making its trans-Atlantic voyage comfortably. She looks different from the ships that the engineer had sailed on. For starters, everything is electric! Electric, can you believe that? Electricity, the bugbear of most marine engineers. Propulsion and Steering are also electric enabled it seems, some fancy stuff going by the name of AZ iPod or something, hanging off the rump of the ship like an outboard motor. Whatever happened to the Stern Tube and Lignum Vitae?

Standing quietly to one side, the electrician - the one man on board who had the least say in the erstwhile affairs of the machinery - is smirking with an all- knowing attitude that reeks of condescension and a 'you-guys-deserve-it' kinda look. *"Didn't you always look down upon me?*", he seems to ask. *"Now, take that, you mechanical scallywags"*. *"Go play with your nuts and bolts on some rust bucket. Ha!"*

Now allow me to tell you about us marine engineers. We can fill volumes with our knowledge about Steam and its power, about residual fuels and internal combustion engines and about all things mechanical, big and small.

To a lesser extent we could even boast about various tools and instruments. Also we could tell you about naughty two-strokes and four-strokes. Different strokes for different folks, they say. That's how different we are. We could also tell you how the nomenclature of ships changed from S.S. to M.V.

That reminds me, *"Shall we now be addressing these autonomous ships as E.V."?*

I shall miss the days when I could tell the engine room staff, *"Boys, make sure you take rounds from the funnel to the tunnel"*. I shall also miss the cheeky reply from my fourth when he would say, *"Chief, the engine room is a rectangle, how can I take a round"?* Nowadays, it is a rare chance that you get a fourth on board. Heck, what am I talking about? They have already replaced me with some bots and here I am talking about the fourth engineer. I shall miss the days when I could hold my head against the main engine's crankcase doors and listen to her heartbeat. I wonder whether the E.V. shall have a heartbeat at all, heartless machine that she is. She took away our existence.

I shall miss the days when I had to fill Log books and use my grey cells to calculate distances, fudge fuel figures and flourish my signature. Now the system spits out impartial, realistic reports cocking a snook at my limited clerical abilities.

But we are not giving up. We didn't give up when there was a blackout at sea in the middle of Hurricane Katrina. We didn't give up when the dummkopff of an oiler mixed sludge in fuel service tank. We didn't give up when we had to use tissues to attend to nature's business because we had emptied the fresh water tanks and the evaporator was kaput.

Engineers, brothers-in-arms, I implore you, beseech you. Do not give in to the onslaught of the semiconductors and the algorithms. Do not be fuddled by self- learning computer programs. Do not play on the back-foot just because some PLC thinks it is smarter than you. After all they are only doing what we have done before, maybe a million times.

Let us swear by our Torque wrenches that we shall take control again. Let us not weep tears of 15W40 lubricant because electronic and software systems have overtaken the trusty mechanical ones. Let us face this new world as sure as the ball-peen hammer that we wield.

These automatons are not the Terminators we need to fear. We are the resistance. We shall learn their way. We shall infiltrate them, take advantage of their strengths and mould them to do our bidding.

And I promise you, as sure as the bump of a positive displacement machine, that we shall rule! Once again.

GOING ASTERN INTO MER ARCHIVES

MER... Four decades back... The August 1982 Issue

This issue has a lot of fuel: sludge handling; blended fuel issues...

An interesting article is on how a cargo ship can be converted into 'frigate' by installing launchers (and weapons of course) in containers, placed on the deck. The article on fouling of seawater cooling systems offers some good insights. There is more content (the Indian additions, we suppose) than what is listed in the CONTENTS page. A notable one is the article on Modern Trends in Thermal Power Generation.

The 'Problems' page features 3 interesting problems (Rudder stock failure; propeller shaft fracture and CO_2 system failure). Some extracts are reproduced to tickle your interest...

The Postbag has some interesting observations on shortage of engineer officers. Maybe these issues will remain perennial. An extracted part of the letter (with call out) is inserted.

CONTENTS

CO_2 system malfunction and filter damage

A difficult problem with maintaining some CO_2 fire-fighting systems is that they can only be checked to establish if they are operating correctly when an actual fire occurs onboard. If the system malfunctions, the consequences could be disastrous.

For example, in a case reported by the Swedish Club, a 10 000 dwt containership on voyage off the Portuguese coast suffered a fire in the engine room. It was caused by lubrication oil from a leaking filter spraying on the engine exhaust pipe.

The engine was immediately stopped and the CO_2 system was operated. Two engineers also fought the blaze with portable fire extinguishers. The two pilot bottles of CO_2 were released to operate, via valves, wires and wheels, the bottles in the engine room. However, none of this action prevented a great deal of damage, amounting to $400 000. It was subsequently found that the stanchion for the wire transfer system was broken and therefore, it was unable to break the seals of the bottles in the engine room. Only the two pilot bottles emptied.

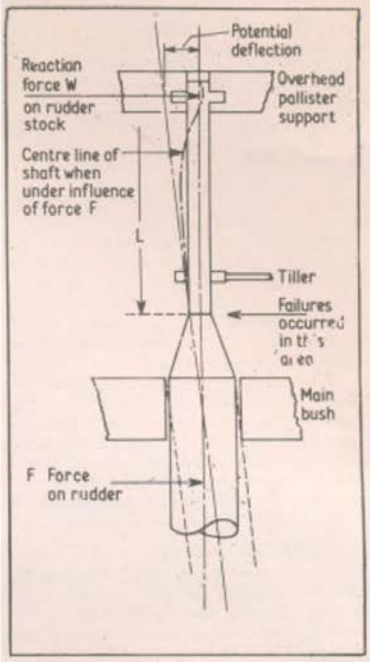
The weakness in the system had not been discovered earlier despite periodic inspections by classification society surveyors. The vessel had actually been sailing for eight years with a useless fire-fighting system.

● In another case, again involving filters, although not causing a fire, a significant amount of damage occurred to the engine bearings.

Engineers operating two 18-cylinder medium-speed engines noticed that there were no pressure drops over the duplex and automatic lube oil filters. The duplex filters were opened up and it was found that the 60 micron outer mesh was missing on most elements; some had large holes in them and some O-rings were missing. On opening up the automatic filters, about half the 25 micron cartridges were missing.

In view of these findings, the engine bearings were inspected and they showed heavy score marks. One crankpin was also damaged with score marks up to 0.8 mm deep.

The cause of the bearing damage was attributed to foreign particles in the lubricating oil caused by poorly maintained filters. The estimated cost of repair was $200 000, most of which could have been saved by regular inspection and replacement of filters.



Mr Fowler's interpretation of how a loose fit on the main bush allowed the rudder stocks to cant and consequently fail by double flexure.

...future merchant navy officer is able to think abstract and understand scientifically while he should be an expert doer and handy improviser.

...that many young merchant navy officers quit the sea after a few years' service. They have come on board with too much knowledge which could not be used in practice therefore they prefer to go ashore earnings ashore are also better.

Engineer officer shortage?

Sir,

Concerning your Opinion (March MER) 'The loneliness of the long distance sailor'. I am not very well informed about the present state of the education system in the UK, but the following account of a report in a Dutch newspaper explains what is happening in the Netherlands.

The report says that very few school leavers look for jobs as deck or engineer officers and quotes the Nedlloyd monthly magazine 'Parade' as saying that the cause is the non-functioning of the new HTS structure applied at schools.

According to the magazine, it is desired that the future merchant navy officer is able to think abstract and understand scientifically while he should be an expert doer and handy improviser. Thus, many students who thought they had chosen a lively profession are stuck in a heavily theoretical training programme.

During the 'Practical' year the apprentices are seldom allowed to leave the ship whilst in foreign ports, which very often means disillusionment.

Of the 453 boys and girls who started the new HTS structure in 1976, 225 passed their exams. Of these, only 132 applied for a job with a Dutch shipowner. Nedlloyd expects that, as from this year, the number of first year-students will drop considerably because MAVO school leavers will not be allowed to join the preparation-year for the HTS structure anymore.

According to Nedlloyd the picture becomes even more gloomy considering that many young merchant navy officers quit the sea after a few years' service. They have come on board with too much knowledge which could not be used in practice therefore they prefer to go ashore earnings ashore are also better.

The newspaper report concludes by claiming that the Royal Dutch Shipowners Association has calculated that the deep sea trade will, in about five years, have a shortage of about three hundred young deck officers and four hundred young engineer officers.

It seems a very difficult task to develop a system which delivers high-calibre professional people who like their job so much that they stick to it. It is a very disappointing experience to have chosen a profession which cannot fulfil ones expectations to such an extent that looking for a job ashore is the only way to change an unhappy working life.

A Baljet

Roosendaal, Netherlands

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

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IME(I) NEWSLETTER: ADVERTISEMENT FOR EDITOR

Over the years, the MER has become the most sought after Journal of the Indian maritime industry. MER has been the face of the Institute, hosting the happenings in the Branches, while maintaining the spirit as a Technical Journal. MER is poised to evolve as a preferred research Journal with the Journal Management System and other ongoing efforts.

Maintaining pace with this growth, a monthly Newsletter of the Institute is being planned for, which will complement the Journal as a platform to accommodate the Branch news, industry news and other happenings in the field. The Newsletter will also carry brief discussions on competency related questions, trivia on maritime history, heritage etc.

Assuredly, while giving the space and scope for this new Newsletter, the functional arrangement and focus of the MER will remain as before and as always.

Being so, this new entity being created by the Institute requires a focused attention and an able person at the helm. On that note, IME(I) invites application for the position of **Honorary Editor, IME(I) Newsletter** (name of the Newsletter is yet to be finalised).

The right candidate should have a flair for writing and a passion for connecting with the readers. Being a fresh initiative, it will be a challenging task for the Hon. Editor of the Newsletter to carry forward this idea successfully, whilst retaining the high quality of content. High standards meeting strict publishing deadlines and collating quality material month after month are expected to be maintained. The term of Editor of the newsletter shall be till **1st January 2024**. The Hon Editor will be assisted by an Editorial Board and a Sub-Editor. The Hon. Editor will be free to choose his/her Editorial Board team.

Interested Members may apply with a one page write up as to why they believe that they are the right candidate. They may also explain as to how they plan to make the newsletter more interesting.

Kindly apply in confidence to president@imare.in with a copy to accounts@imare.in before 10th August 2022.
The Newsletter is expected to hit the stands by first week of September 2022.

OBITUARY

S V S REDDY (F- 062)

11.01.1941 – 11.07.2022

C/E **Singham Venkata Subha Reddy** popularly known for spreading positivity in and around him was born on 11-01-1941 at Kadappa district, Andhra Pradesh. He was trained at DMET, a world class training institute to be marine engineer. Having served in various pioneering shipping companies for 10 years, he joined Chennai Port Trust from where he retired in 1993.

To put his experience in the service of marine fraternity, he chose to teach Marine Engineering and served in all frontline marine institutions. Recognising his contribution to the Maritime Industry, he was rightly awarded the Lifetime Achievement Award from National Maritime Day celebration Committee, Chennai at 46th National Celebration Day in 2009.

He is survived by his good lady Mrs. S. Sujani. He is remembered and spoken about for his positive and warm approach to one and all.

Mr. Reddy passed away on 11th July, 2022.

May his soul rest in peace.

CHENNAI BRANCH

STUDENT'S TECHNICAL LECTURE IN HIMT COLLEGE

On 24th May 2022, Chennai Branch of the Institute of Marine Engineers (India) held its Students Technical Lecture meeting in HIMT College Presea campus in Kalpakkam, off Chennai. The President of the Institute Shri. Vijendra Kumar Jain was the Chief Guest for this technical lecture session. Shri. Sanjeev Ogale, Chairman, IME(I), Pune Branch was the Guest of Honour.

Welcome address was given by Shri. Sanjeev S Vakil who informed that this was the first physical meeting after 2 years of COVID 19 pandemic and stressed more on the technical acumen required in the Engineering cadets and Junior Engineers who are expected to take on the legacy given by their predecessors in the field of Marine Engineering.

The session was taken forward by Shri S. Ramesh (EC Member, IMEI Chennai), who invited 2 BTech (4th Year) cadets to give their presentations.

Then, Cdt. Rahul Kumar Singh presented a paper on "Fuel cell as an alternative propulsion", where he stressed on the concept of using Fuel Cells as a solution to Green Shipping.

Cdt. Tamminaina Yagnesh discussed a paper on "Autonomous life boat" giving various options to control the direction of life boat with a remote app.

It was followed by an inspiring and motivating speech given by industry expert, Shri. Suresh Shenoy. (V-Ships Management), giving deep insight about the marine industry and the

need to comply with various regulations and also about how to beat stress, so that the seafarers may stay focused in the long run.

Shri. Ramesh Subramanian then moderated a Q & A session.

After an interesting Q & A session, the Guest of Honour Shri. Ogale spoke about how he came up in life and how he started his own company and about his future plans to teach the cadets about entrepreneurship in marine industry. He stressed on the saying, "Commitment and dedication is the key to success".

Chief Guest Shri. V. K. Jain spoke about the transition phase of maritime industry and important maritime regulations paving the way for the future trends. He also spoke on the future plans of IME(I).

Shri. S. Kannan, Hon. Secretary, IME(I) Chennai Branch then proposed the Vote of Thanks.

93rd GOVERNING COUNCIL MEETING – AN OVERVIEW

The **93rd GC Meeting** of the Institute was held on **16th and 17th July 2021** through hybrid mode. The meeting was attended by 12 Members in person at Visakhapatnam and 7 Members online.

The President, Mr. V. K. Jain, chaired the meeting and welcomed the GC members.

The Chairpersons of the various Subcommittees and Branches presented/ informed, for discussion, their activity report/s (including External Bodies), ATR (Action Taken Reports) and their financials (actual operational figures vis-à-vis that budgeted). A status update of issues closed and those pending were discussed.

The Agenda for the GC Meeting, which usually addresses matters of governance, also included discussions/ information / proposal and resolutions such as adoption of 92nd GCM / update on Benevolence fund, proposal on amendments to the objectives in the AoA & MoA, and changes to the time line of election procedure and adoption of e-Voting and the consequential changes to the ORP.

The GC also deliberated upon investment plan for funds held, procurement of a LNG Simulator for IGF Advance Course, expansion of training activities to other Branches (e.g. Kochi /Visakhapatnam), setting up of overseas chapters, expansion of Mentorship program for students in MTI, further streamlining of the MER and its digitalisation, redevelopment of IME(I) Website / i-Connect App etc., amongst others. An update on the quality audit by IRQS and CIP, and the opening of students chapter at HIMT was also presented.

The meeting ended with a vote of thanks by the Vice President, Mr. Amit Bhatnagar.

Port of Madras
(Circa 19th Century)

IN THE WAKE

Rajoo Balaji

Corona Chronicles & Continuing Conflicts

The seafarers' port entries and shore leaves are still curtailed. Indian ports are still under the restrictions, it appears. Even the 'on shore' and 'short hand' leaves are on hold.

Onshore leave for 4-6 hours is not possible in Indian ports complain the seafarers, even if the State Government has relaxed restrictions. The short hand leave for 10-15 days remains in the wish list.

The Seafarers' Unions have taken it up with the Home Ministry.

Woebegone seafarers! When will their woes be gone?

And they have become worse says the latest Seafarers Happiness Report.

It is the lowest in eight years, it observes.

(Obvious) Reasons: Covid; shore leave restrictions; UkRu war.

The fallout is the strained ambience on board... and there is the menace of bullying and harassment on board.

Results of a study in the Report: 50% of women got bullied; about 17% faced sexual harassment; 1% of all cadets have faced sexual assault.

The IMO's MSC have taken notice of this and looking at addressing these under the STCW Convention.

Maybe we will have another couple of modular courses...

Basic Bullying Course; Advanced Bullying & Harassment Course?

Shipping matters

The Agniveer aspirants get more options...

MoPSW paves avenues for the Agniveers transitioning into Merchant Navy [MN]:

IN Ratings to Certified MN Ratings;

IN Electrical Ratings to Certified Electro-Technical MN Ratings;

IN Ratings to Certified Class IV NCV CoC;

IN Electrical Ratings to Certified MN ETO;

IN Cook to Certified MN Cook;

Get a Diploma in Electrical/Mechanical; better prospects in MN. Of course, INDOS and CDC thrown in.

And so it will come to pass that the Agniveers shall become Jalveers.

About August

Though a few days are well known, let us pick a few not-so-well known days:

7/8, National Handloom Day. Request: Buy a handloom made National Flag for the I-Day.

Let 'Har Ghar Tiranga' happen with the handloom tricolour.

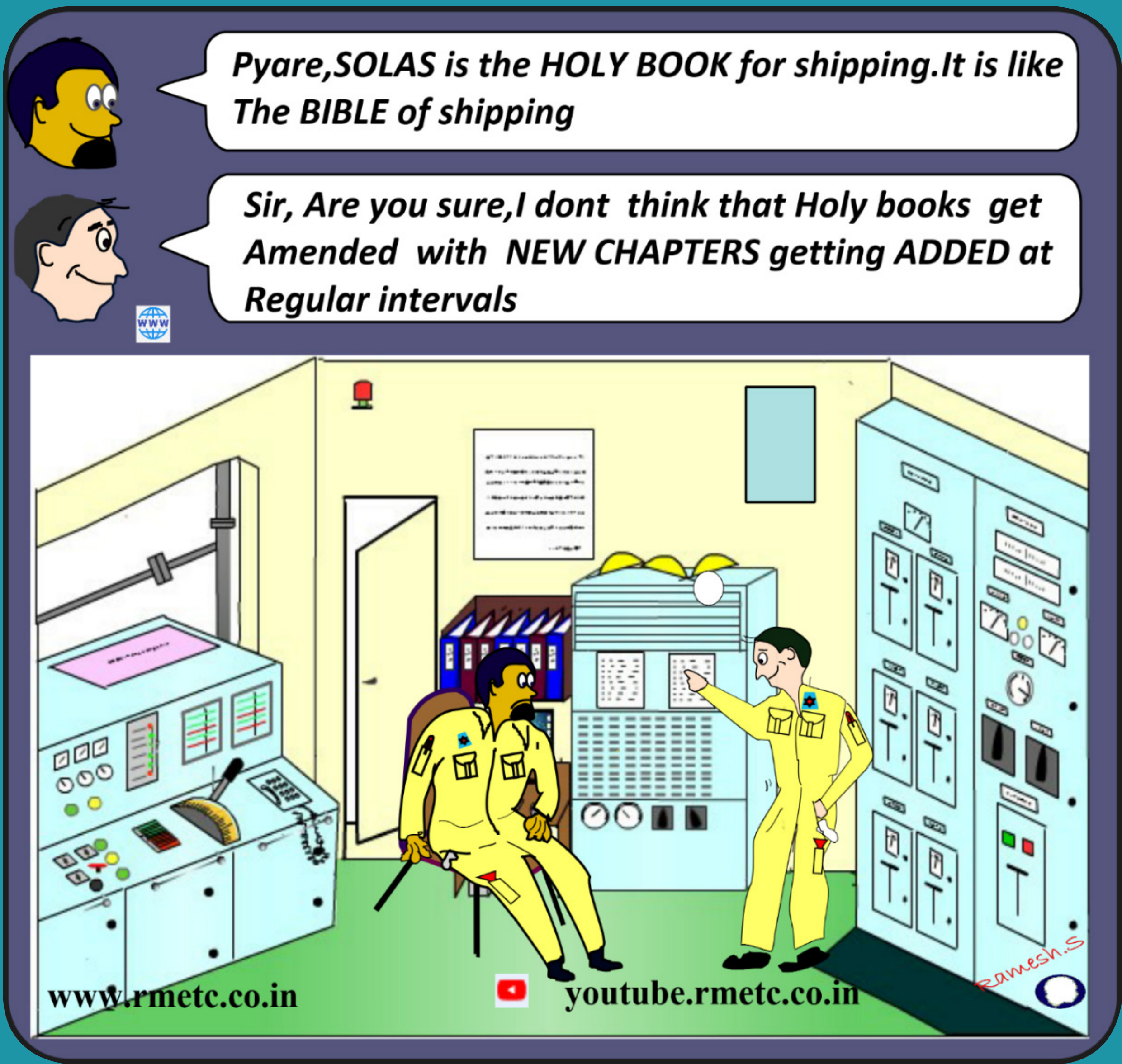
13/8, World Left handers' Day: Salute a spare a thought for Rafael Nadal (for bowing out of Wimbledon semis).

22/8, International Day for Victims of Acts of Violence based on Religion or Belief:

May we work towards the day when we might make this Day of Harmony!

●

THE END VIEW

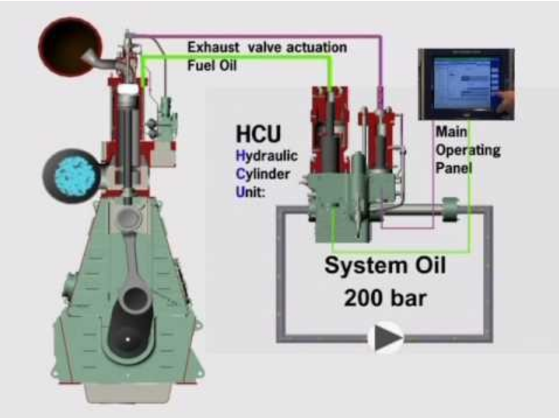


Idea, Words & Drawing: **Ramesh Subramanian**

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	:	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 **(M)**. 9819325273, **(T)** 022 27701664 / 27711663 / 2771 1664. **@ MASSA Maritime Academy Chennai** - **email:** mmachennai@massa.in.net Ms. Saraswathi, **(T)** 8807025336 / 7200055336 .

After registration and payment, please email the details of the receipt to: ***training@imare.in***

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