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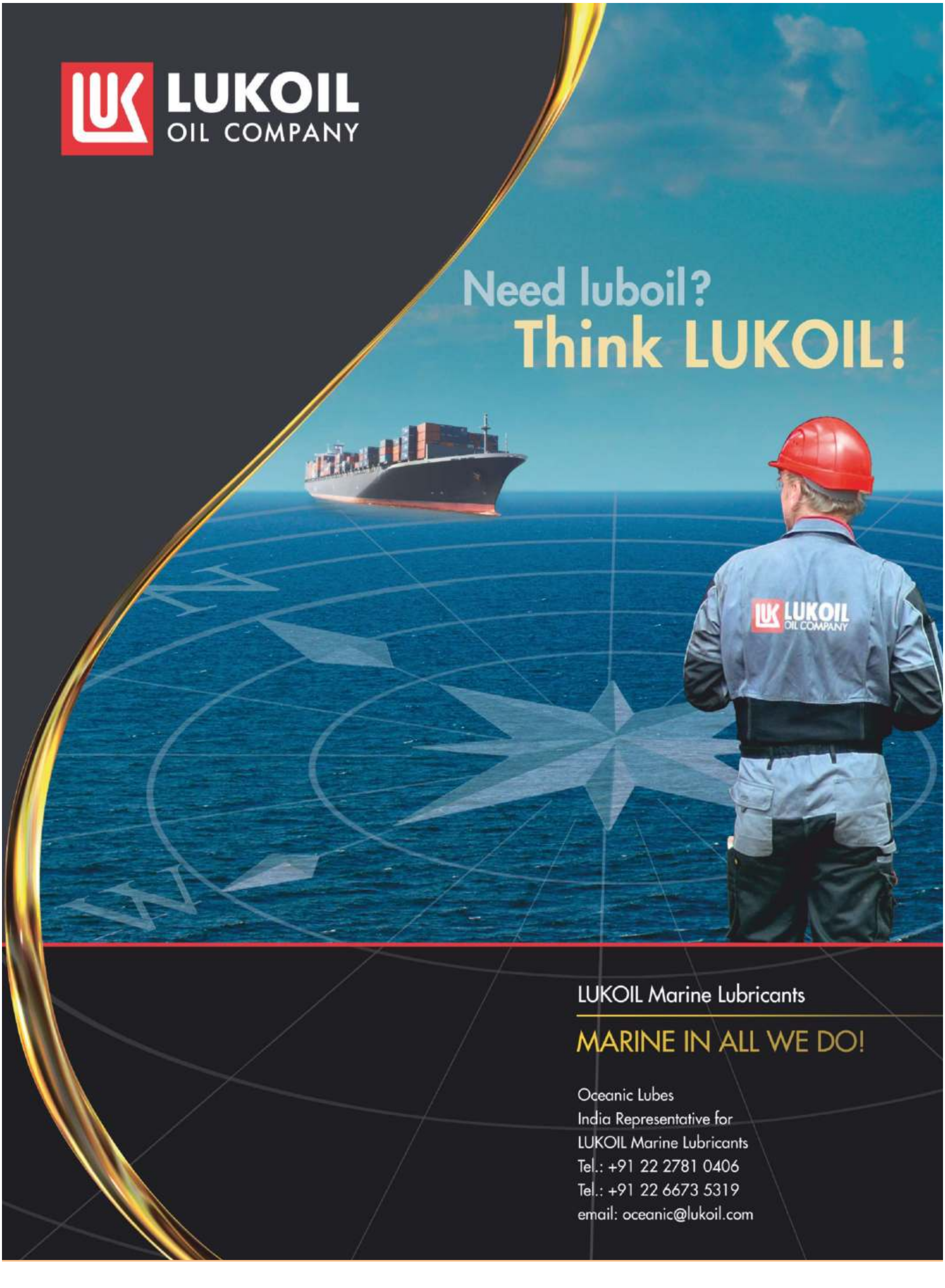

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EDITORIAL

Hope is a thing with feathers that perches in the soul.
– Emily Dickinson

We seem to perform better when we are physically challenged than when we are challenged physically. Our haul was nineteen in the Paralympics as compared to the single digit 7 in the Olympics.

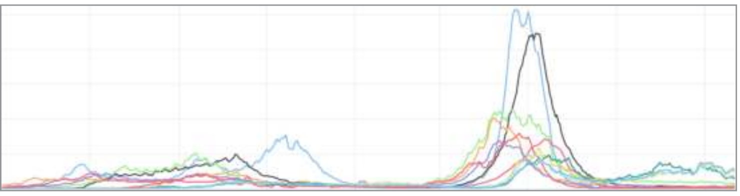
We could have got out of the teens to twenty plus… that was one hope.

On to another hovering hope…

What we see below could be a set of exemplar draw cards from an Indicator diagrams folder, but no.

These are the daily new Covid infected cases in various Indian States, the trends tracked from End-April 2020 to End-September 2021. The peaks had occurred in May 2021 (the peaks resembling dribbling injector indications are actually debilitated immunity breaches).

Do we not have our hearts fluttering with hope to have these wavy scrawls settle at a steady zero?



Source: MOHFW(India) & John Hopkins; ToI

In this issue…

Propulsion with combination systems have been in vogue and now adding a new dimension, battery powered tankers are expected to join the trade in 2022. The production costs for batteries are also steadily dropping due to the increasing usage. Driven by decarbonisation and fuel efficiencies, there are intense studies on flow batteries, hazards, configuration, life cycle and related issues apart from studies on pressure on ports' infrastructure (for shore-side charging needs) etc.

Electrical propulsion with battery back-up is one model gaining traction. The option to harvest power and store in batteries, which can be used when in need would mean good economics. Dr. Rajasekhar *et al.*, present a study of an Ocean Research Vessel for such a model. The power requirements and the harvesting range are optimised and paves way for settling on the architecture. The study and the calculations are kept at basic levels and are easily comprehensible by an interested reader.

We follow this with a free fall. Andrya Sara Roy and Dr. Sheeja present an interesting approach to the design of a free-fall life boat. Using CFD techniques, the loads are ascertained while the bow slams the water, enters the water and emerges. The modelling of the hull and the grid generation are discussed in a simple manner. The factors considered in designing such crafts and the scientific approaches to determine the scantlings etc., are discussed in a fluent fashion. This would be of interest to research students and the interested engineers.

And Dr. Vedachalam and Dr. Ramadass conclude the 3-part series on AUVs. The featured Part C highlights the requirements for future developments of such vehicles, especially on few crucial technologies. The intervention abilities, sub-sea homing and docking etc., are few that are highlighted with pictures. This places the essay at an easier reach for those who have been following the Parts (A & B) featured in the earlier issues. The most interesting takeaway is the discussion on bio-inspired vehicle designs. The turning speeds of few of the aquatic beings is sure to spin our minds into imagination. The explanation on the mechanism of propelling with the fins is good food for thought for the engineering minds.

VRV is back in the Competency Corner, explaining the power aspects of the engines. We plan to elevate these discussions to bring clarity on understanding layout envelopes, load diagrams and engine selection and operation etc.

Under Lube Matters, Sanjiv talks on measuring the cleanliness of the lube oils.

We are back to featuring students' essays and I hope to have contributions to the Students' Section becoming regular.

In the Heritage Hourglass, Dennard D'Souza goes down-South discussing the glory of Chola Navigation and paying tribute to scholar, B. Arunachalam.

IME(I) scales new heights…

The launch of the JMS and the flipbook have been received with good cheer and we hope to build on this. The guidelines for accessing the JMS/flipbook will be shared soon.

We hope these digital doings will make access and submissions easier.

Meanwhile, savour this October Issue.

Dr Rajoo Balaji
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Administration Office
IMEI House
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Navi Mumbai 400 706.
Tel. : +91 22 2770 16 64
Fax : +91 22 2771 16 63
E-mail : editormer@imare.in
Website : www.imare.in

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Cover Photo: **ORV Sagar Nidhi in Antarctic Waters**
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  - 2 Wire and 4 Wire 4 – 20 mA Loops
  - Loop calibration in simulate and source mode
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  - HMI programming and its usefulness in a PLC system
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  - Battery replacement
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  - Identifying and complete failure and channel failure
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- SCADA & DCS
  - Understanding a SCADA System
  - Understanding of a DCS System
- Theory of A/D and D/A conversion of these standard signals
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- Theory of Process control (P, P+I and P+I+D)
  - Understanding of a Process and its reaction rate
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  - How to identify between µC & PLC
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VIABILITY ANALYSIS ON INTEROPERABILITY OF HYBRID BATTERY SOLUTION FOR A SHIP

Dr. D. Rajasekhar, D. Narendrakumar, Ananthakrishna, P.S. Deepaksankar

ABSTRACT: A hybrid system improves ship performance, reduces fuel consumption and minimises harmful emissions. Environmentally friendly ships are designed to meet more stringent international regulations. In the present study, the oceanographic research ship Sagar Nidhi was used for the optimisation of energy management. Design optimised battery was used for storage of electrical/chemical energy along with conventional diesel-electric propulsion. Experimental data was used for model optimisation and to determine fuel efficiency. Power consumption during propulsion (economy and power), Dynamic Positioning, Port stay and standby conditions are considered for the present evaluation. Multiple tests at different electrical loading conditions are used to obtain the fuel economy of the hybrid system. Present investigations reveal about 10-15% fuel saving, around 20% reduction of harmful pollutants and a considerable improvement on the performance of DP system.

Keywords: Specific fuel consumption [SFC], Hybrid battery, Harmful pollutants, Diesel-electric propulsion, Research Ship.

1. Introduction

Research ships play a vital role in scientific studies relating to ocean/atmosphere/technology,etc. It is important to prepare ships which are suitable for numerous scientific activities, giving priority to safety. 'Sagar Nidhi' is India's pride and a state-of-the-art, ice-class research vessel of the sub-continent. It is built with Dynamic Positioning System [DP-II] of 5m accuracy, with an overall length of 103.6m and draft of 4.2m. She can accommodate 30 scientists with an endurance of 45 days. Sagar Nidhi is the 'first Indian flagged research ship which reached the 66°S latitude, facing 11 storms and 73 nm/hr wind speed, witnessing nature's harshest conditions and awesome breath-taking sceneries.'

The ship has twin screw diesel-electric propulsion system along with dynamic positioning capability (DP-2). 'Sagar Nidhi' is catering to the ongoing and new technology demonstration and ocean exploration programmes of Ministry of Earth Sciences (MoES) such as deployment/recovery/operations of Remotely Operable Vehicle [ROV], Autonomous Coring System [ACS], Autonomous Underwater Vehicle [AUV], Ocean Observation Systems [OOS] [viz., Tsunami buoys, OMNI buoys, Met Ocean buoys, RAMA moorings, ARGO floats], scientific expeditions to the Indian Sector of the Southern Ocean and various other research and technology development activities planned by the, MoES Govt. of India (**Figure 1**).

Figure 1: Sagar Nidhi

1.1 Advantages of Diesel-Electric Propulsion

Following are the major advantages of Diesel-Electric propulsion

a. Reduced fuel consumption and Improved efficiency

b. Vibration and noise reduction

c. Low maintenance

d. Better propulsion control

Schematic representation of diesel-electric propulsion is shown in **Figure 2**. In diesel-electric propulsion, electric power is generated and supplied to AC motor which drives the thruster (Azimuth and Bow thrusters). The specification of diesel-electric propulsion system on-board Sagar Nidhi is shown in **Table 1**.

Sagar Nidhi has four diesel generators, each with a power output of 1710 KVA (1368 kW) which caters entire power requirement of the ship. Two generators can cater to energy demand during transit. In DP mode, depending on external loading, the generator may start automatically. The present research investigates power optimisation at varying load conditions. The power optimisation is depending on the specific fuel consumption (SFC) of an engine. The SFC at varying load conditions is calculated experimentally. **Table 2** shows the experimentally determined SFC of Sagar Nidhi. The formula for calculating the SFC is: **SFC = FC/P**

SFC: Specific fuel consumption (g/kWh), FC: Fuel consumption (g/h), P: Power (kW)

In order to optimise fuel consumption; modelling of SFC is of great importance. The classical method of optimisation techniques includes direct search method and gradient search method which needs high number of iterations and unsuitable for non-differential functions.

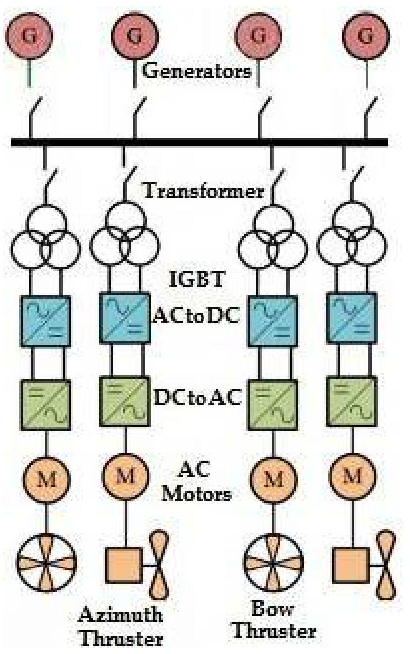

Figure 2: Diesel-Electric Propulsion

2. Hybrid Solution

Photovoltaic cell, Wind turbine, Sails, Kites etc., minimises fuel consumption and emission. It is also possible to improve overall efficiency using hybrid solutions. One such hybrid solution consists of a **diesel generator and battery** which is discussed here in detail.

Engine efficiencies can also be improved by operating at a minimum value of SFC. The engine will operate at higher or lower RPM depending on loading conditions. This will result in higher fuel consumption. The plot of the SFC of Sagar Nidhi for varying loading conditions is shown in **Figure 3**.

In a hybrid system, the Engine/Generator is operated at a minimum SFC to achieve higher efficiency. During lower load demand, the battery will be charged. The battery supplies energy during higher/peak energy demand.

2.1 Design & Development of a Model:

A theoretical model was designed and developed based on available energy data. The design model is primarily based on following factors.

System component	Specifications
Power Generation	4 x 1710 KVA
Power Distribution	690 V MSB
Azimuth Thruster Motor	3 phase, 1600 kW
Bow Thruster Motor	3 phase, 800 kW

Table 1: Specifications of Propulsion system

Engine Load	Fuel Consumption(Kg/h)	SFC(g/kWh)
100% Load	263	192
85% Load	220	189
75% Load	195	190
50% Load	141	206

Table 2: Fuel consumption at varying load conditions

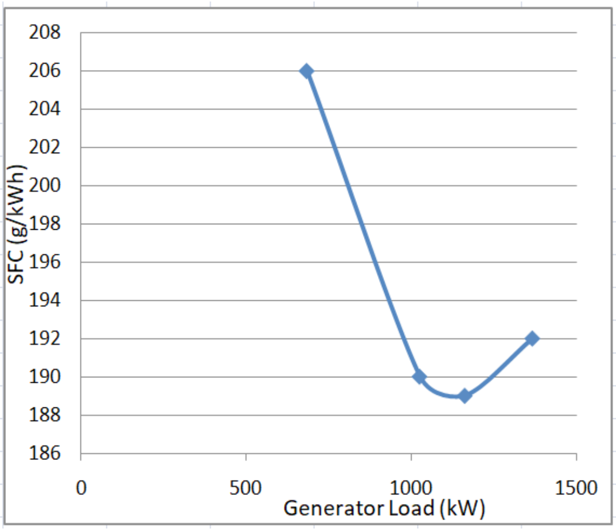

Figure 3: SFC of Generator at different load

- Vessel operations: Transit, DP, Manoeuvring, Harbour
- Load profile: Normal and Peak load
- Performance curve of an Engine/Generator
- Cost per unit time

$$P_R = [(P_{W1} + P_{W2} + P_{W3})/\eta].\ [1+FOS] + P_A$$

P_R: Actual Power required, P_{W1}: Power required in still water, P_{W2}: Power required for waves, P_{W3}: Power required for winds, FOS: Factor of Safety, PA: Auxiliary power requirement, η: Propulsion efficiency.

The power demand and operational time during various ship operations viz., Transit, Dynamic positioning, Port stay and Standby etc., are shown in **Table 3**. The power demand depends on the loading/unloading of scientific materials, various deployment and retrieval operation, sea conditions during transit and the need for DP during scientific operation. **Figure 4** shows the annual operational profile of Sagar Nidhi. Transit contributes 54% of ship-time; DP operation represents 30% of ship-time.

Figure 5 represents the schematic representation of standard propulsion. The standard propulsion system consists of a diesel generator which supplies electrical energy to Azimuth and Bow thruster motor through main switch board (MSB). It also supplies electrical energy for various auxiliary requirements.

In-order to optimise fuel consumption, the engine is to be operated at minimum SFC. When batteries are connected to MSB, batteries will be charged during lower power demand. Batteries will store and supply energy during peak load. Figure 6 shows a schematic representation of a propulsion system with batteries.

2.2 Battery Design

Batteries act as an energy source and are designed to meet the total power requirement. The maximum power output of each generator of Sagar Nidhi is 1368 kW. The SFC plot shows SFC of 190 g/kWh at 75% of maximum load and 189 g/kWh at 85% of maximum load. For minimum fuel consumption, the power output from each generator will be 1163 kW. The power generation and distribution system are programmed to achieve power generation by each generator at this identified power of 1163 kW. Any surplus production will be used for the charging of the battery.

3. Experimental Results

Fuel consumption during Transit, DP, Standby and Port stay were calculated with and without battery combinations (**Figure 4**).

3.1 Fuel Consumption Calculations

Annual fuel consumption of Sagar Nidhi during various ship operations viz., Transit, DP, Standby and Port stay are calculated as shown below. Fuel consumption will be calculated based on the following factors.

- FC: Fuel consumption (MT)
- N: No. of Engines/Diesel generator operating
- SFC at particular load (g/kWh)
- P: Load on each Engines/Diesel generator (kW)
- H: Operation time (Hours)

$$\mathbf{FC = [N \times SFC \times P \times H]/ 10^6}$$

Operation	Hours	Power Demand
Transit at 12 knots	440	3000
Transit at 10 knots	3220	2100
Transit at 8 knots	1060	1600
DP Operations	2460	800
Standby	500	750
At Port	1080	400

Table 3: Ship time vs. Power demand

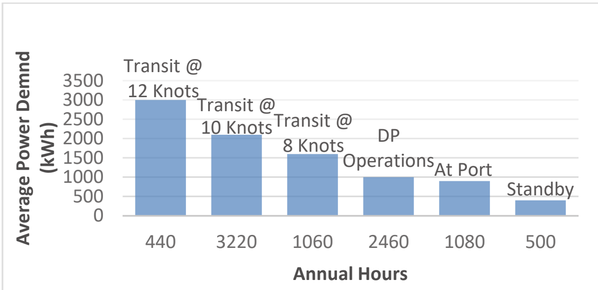

Figure 4: Annual operational profile of Sagar Nidhi

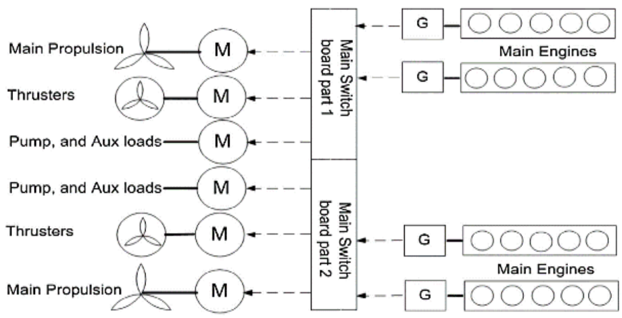

Figure 5: Standard Propulsion system

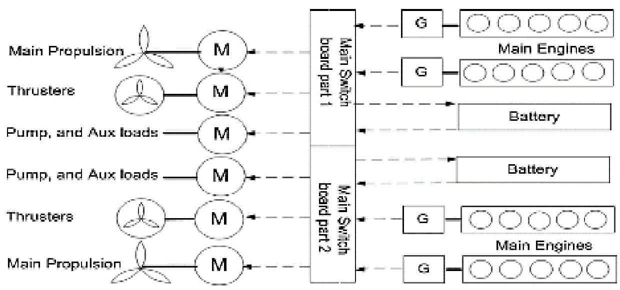

Figure 6: Propulsion system with Batteries

3.2 Calculation of Fuel consumption without Battery

Transit at 12 knots: An average power demand of 3000 kW will be supplied by 3 generators (1000 kW each). The total fuel consumption is 3 x 191 x 1000 x 440 = 2,52,120 kg (252.1MT).

Transit at 10 knots: An average power demand of 2100 kW will be supplied by 2 generators (1050 kW each). The total fuel consumption is 2 x 190 x 1050 x 3220 = 12,84,780 kg (1284.8MT).

Transit at 8 knots: An average power demand of 1600 kW will be supplied by 2 generators (800 kW each). The total fuel consumption is 2 x 200 x 800 x 1060 = 3,39,200 kg (339.2 MT).

DP Operation: An average power demand of 800 kW will be supplied by single generator. The total fuel consumption is 1 x 200 x 800 x 2460 = 3,93,600 kg (393.6 MT).

Standby: An average power demand of 750 kW will be supplied by single generator. The total fuel consumption is 1 x 202 x 750 x 500 = 75,750 kg (75.8 MT).

Port Operation: An average power demand of 400 kW will be supplied by single generator. The total fuel consumption is 1 x 220 x 400 x 1080 = 95,040 kg (95MT).

> *"Sagar Nidhi is the 'first Indian flagged research ship which reached the 66°S latitude, facing 11 storms and 73 nm/hr wind speed, witnessing nature's harshest conditions and awesome breath-taking sceneries'"*

3.3 Calculation of Fuel consumption with Battery

Annual fuel consumption of Sagar Nidhi during various ship operations viz., Transit, DP, Standby and Port stay were calculated as shown below. Power generation is optimised for the minimum value of SFC. Power generation and distribution system are synchronised with battery or energy storage system **Table 5**.

Transit at 12 knots: An average power demand of 3000 kW will be supplied by the following two options

Operation	Hours	Power Demand (kW)	Load/ Generator	No. of Generator	Total fuel consumption (MT)
Transit at 12 knots	440	3000	1000	3	252.1
Transit at 10 knots	3220	2100	1050	2	1284.8
Transit at 8 knots	1060	1600	800	2	339.2
DP Operations	2460	800	800	1	393.6
Standby	500	750	750	1	75.8
At Port	1080	400	400	1	95.0
Total					**2440.5**

Table 4: Fuel consumption (Generator with equal load distribution)

Operation	Hours	Power Demand (kW)	Load/ Generator	No. of Generator	Total fuel consumption (MT)	Battery Status	Fuel consumption for required power
Transit at 12 knots	440	3000	1163	3	290.1	Charging	249
				2	193.4	Discharging	
Transit at 10 knots	3220	2100	1163	2	1415.6	Charging	1278
				1	707.8	Discharging	
Transit at 8 knots	1060	1600	1163	2	465.9	Charging	320
				1	232.9	Discharging	
DP Operations	2460	800	1163	1	540.7	Charging	372
Standby	500	750	1163	1	109.9	Charging	71
At Port	1080	400	1163	1	237.3	Charging	82
						Total	**2372**

Table 5: Fuel consumption (Generator and Battery combination)

i. 3 Generators (1163 kW each): The total fuel consumption is 3 x 189 x 1163 x 440 = 2,90,145 kg (290.1 MT). An additional power generated1,95,600 kWh will be used for the charging of battery.

ii. 2 Generators (1163 kW each): The total fuel consumption is 2 x 189 x 1163 x 440 = 1,93,430 kg (193.4 MT). Required additional power of 2,96,550 kWh will be supplied by the battery.

Transit at 10 knots: An average power demand of 2100 kW will be supplied by the following two options

i. 2 Generators (1163 kW each): The total fuel consumption is 2 x 189 x 1163 x 3220 = 14,15,557 kg (1415.6 MT). An additional power generated 7,27,720 kWh will be used for the charging of battery.

ii. 1 Generator (1163 kW): The total fuel consumption is 1 x 189 x 1163 x 3220 = 7,07,779 kg (707.8 MT). Required additional power of 30,17,140 kWh will be supplied by the battery.

Transit at 8 knots: An average power demand of 1600 kW will be supplied by the following two options

i. 2 Generators (1163 kW each): The total fuel consumption is 2 x 189 x 1163 x 1060 = 4,65,991 kg (465.9 MT). An additional power generated 7,69,560 kWh will be used for the charging of battery.

ii. 1 Generator (1163 kW): The total fuel consumption is 1 x 189 x 1163 x 1060 = 2,32,995 kg (232.9 MT). Required additional power of 4,63,220 kWh will be supplied by the battery.

DP Operation: An average power demand of 800 kW will be supplied by single generator. The total fuel consumption is 1 x 189 x 1163 x 2460 = 5,40,725 kg (540.7 MT). An additional power generated 8,92,980 kWh will be used for the charging of battery.

Standby: Average power demand of 750 kW will be supplied by single generator. The total fuel consumption is 1 x 189 x 1163 x 500 = 1,09,904 kg (109.9 MT). An additional power generated 2,06,500 kWh will be used for the charging of battery.

Port Operation: An average power demand of 400 kW will be supplied by single generator. The total fuel consumption is 1 x 189 x 1163 x 1080 = 2,37,392 kg (237.3 MT). An additional power generated 8,24,040 kWh will be used for the charging of battery.

4. Conclusion:

A feasibility study was made for the implementation of battery solutions on-board a Research Ship. Major vessel operations viz., Transit, DP, Port stay were considered for the present study. It has been observed that optimisation of fuel consumption will result in a considerable amount of fuel savings (approximately 70 MT). This was achieved through operating the Engine/Generator at minimum SFC. This can result in a considerable reduction of harmful ship-borne emission viz., SOx/NOx, CO, CO_2, PM etc., thereby ensuring an initiative towards green ship technology.

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About the Authors

Dr. D. Rajasekhar is an Eminent Scientist, presently working as **Scientist-G & Group Director** of Vessel Management Cell at National Institute of Ocean Technology, Chennai under the Ministry of Earth Sciences. He is a Fellow in Institute of Engineers (FIE-Marine), a Chartered Engineer C.Eng. (India), a Qualified ISO 9000 Lead Auditor, Marine Surveyor / NDT Expert. His area of expertise includes Operation and Maintenance of ships, Ship construction and Ship repairs. His past experience includes, Deputy Commandant (Engineer Officer) in the Indian Coast Guard and then as the Chief Engineer in Merchant Navy. He is also a recipient of numerous prestigious National Awards viz., **National Design Award [Mechanical Engineering], 'National Maritime Award', 'National Maritime Search and Rescue Award', 'Green Technology Innovative Award', 'Adroit Researcher Award [Engineering & Technology]', 'Director General Indian Coast Guard Commendation Award', 'Distinguished Scientist Award', 'Outstanding Researcher Award'** & **'Excellence and Innovation Award'** in recognition of exceptional contribution in his fields of expertise.

Email: rajasekhar@niot.res.in

D. Narendrakumar is a Scientist in Vessel Management Cell at National Institute of Ocean Technology, Chennai under the Ministry of Earth Sciences. His area of expertise are Strategic planning and management, Synthesis and characterisation of nanoparticles, AFM, STM, UV excited photoluminescence study, Particle sizing by spectrophotometer, Nano Electro Mechanical Systems (NEMS). He has published numerous technical papers with recent technological advancements using nanotechnology based marine applications. He is a Technical Expert Member of Marine Engineering and Safety Aids Sectional Committee TED 19 under Bureau of Indian Standards [BIS]. He is a recipient of **'National Maritime Award'** from the 'Ministry of Shipping', **'Young Engineer Award'** from The Institution of Engineers, India **'Young Scientist Award'** from 'Centre for Advanced Research and Design' for contribution and accomplishments in the area of Mechanical & Marine Engineering respectively.

Anantha Krishna Rao is a Scientist in Vessel Management Cell at NIOT, Chennai. He obtained his Master's degree in Material Science and Technology from N.I.T Calicut. He has hands on experience in Design Engineering, Material Inspection, Quality Control Techniques, Casting and Stamping Simulation. He has numerous technical papers published with recent technological advancements in materials technology. He is a recipient of **'National Maritime Award'** from the 'Ministry of Shipping'.

P.S. Deepak Sankar is a Scientist in Vessel Management Cell at NIOT, Chennai. He is a Marine engineer with his bachelor's degree in Mechanical engineering. His areas of expertise include hands on experience on marine engines, maintenance experience on various purifiers and boiler maintenance and bunkering. He has published many research papers with recent technological advancements in Marine Engineering. He is a recipient of **'Green Thinkerz Outstanding Engineer Award'** for his contributions towards Green Ship technology solutions.

STRUCTURAL RESPONSE OF FREE – FALL LIFEBOATS DURING EMERGENCIES

Andrya Sara Roy,
Dr. Sheeja Janardhanan

ABSTRACT: A lifeboat is a small floating structure released from ships during an emergency for the rescue of people on-board. This task is accomplished by dropping the structure from a predetermined height (drop height) and inclination (fall angle). The structure is now a freely falling body under the influence of gravity with the bow pointed down. The beginning of the lifeboat's trajectory includes an initial flight in air followed by its diving in water and then emerging out of water under the buoyancy effects. During sudden impact on the surface of water, large slamming loads act on the structure, especially at the bow. Slamming is of great concern as it results in severe structural damage of the bow as well as its supporting frames and scantlings. The study of slamming involves an interaction between the structural components of the lifeboat and the fluid load on the hull. Bow impact is a salient feature since high accelerations are exerted upon the lifeboat when it first hits the water surface during its water entry phase. In the present study, an approach for the design of a typical life boat is presented. Fluid pressure on the bow has been estimated using a computational fluid dynamics (CFD) approach coupled with a six degree of freedom (6DOF) solver. A user defined function (UDF) has been written in C language and has been complied within the solver for accomplishing the body motions. Geometric modelling and meshing have been carried out using ANSYS ICEM CFD and FLUENT has been used as the solver. The impact peak pressure has been applied at the bow and a 3D structural analysis has been performed initially at the bow region of the bare hull without scantlings and later with scantlings. The results seem to provide guidance for the design modifications in terms of scantling dimensions.

Keywords*:* Lifeboat, slamming, bow impact, buoyancy, scantlings, hull

1. Introduction

The most common understanding of a lifeboat is a small or infallible raft structure used for emergency evacuation. Free-fall lifeboats represent an evident improvement in safety over conventional type lifeboat systems. Conventional lifeboats are the one which are lowered with the help of ropes, pulleys or other means of lowering systems.

When conventional lifeboats are lowered into the sea, it is sometimes difficult for the lifeboats to move away from the parent vessel or from the distressed vessel because high sea current and wind continually returns the lifeboat back to the parent vessel. The return of lifeboat back to its parent vessel can also be due to the malfunctioning in the propulsion system. During its launch, the lifeboat may impact the sides of the distressed vessel, become severely damaged, and the occupants may fall into the sea suffering injury and even death. This situation is even more dangerous during a fire. The free-fall provides kinetic energy used to propel the lifeboat away from the distressed vessel during and after water entry. The heights of free fall range from approximately six meters on smaller ships to over 30 meters on drilling platform. **Figure 1** shows a life-boat about to be launched.

Figure 1 Free-fall lifeboat placed on its launching rail

Calculation of realistic design loads is challenging in the case of free – fall lifeboat. Experimental calculations are time consuming and expensive. CFD (Computational fluid dynamics) provides a platform for performing simulations in all stages, where the impact pressures are clearly depicted so that portion incapable of overcoming these impact pressures especially bow region and the hull are studied in detail. Lifeboat undergoes various phases in air as well as in its diving in water. Free – fall phase, water entry phase, re - emergence phase are most crucial phases since the structure undergoes large slamming forces. Slamming forces are of great concern because pressures act continuously on the lifeboat when it passes through various phases of its trajectory. Transient CFD simulations have been carried out for studying the impact pressure on the body. After getting the deformations from the impact pressure, scantlings of suitable thickness have to be designed and provided so as to resist the pressure which causes hull damage and collapse. Deformations on a bare hull are studied with these impact pressures and then scantlings of suitable thickness are provided.

2. Slamming Phenomenon

The lifeboats stern (aft) portion and the bow portion may emerge from a wave and re – enter the wave with a very high impact. This will develop very high successive hydrodynamic loads on the structure. Very high-pressure peaks are experienced by the hull of the ship due to this impact i.e., the impact between the hull of the boat and the water surface (slamming phenomenon). The effect of hull slamming on water surface is shown in **Figure 2.**

There are many types of slamming loads such as bow flare slamming, bottom slamming, stern slamming, green water and bow impact loads. These loads have transient behaviour and hence cause severe structural damages. Relatively high velocity occurs between the free surface of incompressible fluid and the hull portion and because of this the magnitude, rise time, duration of theses loads changes widely. The dynamic response of the hull structure is affected strongly because these transient impact loads are highly non – linear. Thus, for a structural design purpose the magnitude of these impact loads and pressure is important. The following factors should be taken into consideration.

1. Intensity and duration of impact pressure.
2. Spatial distribution and duration of impact.
3. For strength assessment equivalent static pressure is needed.
4. Determination of scantlings.
5. Geometry of bow and stern.

In cases where the lifeboat is subjected to bow flare slamming loads, the side plating of the bow is subjected to a great impact as it is rapidly immersed into water. As a result of this, a large fluid pressure covers comparatively larger impact area. There are two types of bow flare impact pressure.

a) Non impulsive pressure

b) Impulsive pressure. The magnitude of non-impulsive pressure is directly to the submergence whereas the magnitude of impulsive pressure rises rapidly and decays with time.

3. Phases of Lifeboat Fall and its Physics

The full journey of free - fall life boat is divided into different phases. The body interacts with different fluids, enters the water with high velocity, submerges and then re- emergence overcoming the buoyant forces. The entire trajectory is divided into several phases known as free–falling phase, water entry phase, submerged phase, re- emergence phase, and ascending phase. Main studies are concentrated on the water entry phase, submergence, and re- emergence phase and ascending phase. Various phases in the lifeboat fall is shown in **Figure 3.**

a) Launching Phase: Before lifeboat is launched it rests on a launching skid of the parent vessel. Several launching mechanisms are available. Among them releasing hook is the most common one. When the hook releases the lifeboat, it slides along the rail or the launching skid driven by the gravitational and frictional forces. When it moves on the rails and comes in contact with the end of the skid, the major part of the body will be freely falling while the aft portion of the lifeboat will be in contact with the skid. This will generate a rotation known as the rotation phase which will affect the water entry phase of the lifeboat. If the velocity with which the lifeboat slides down is greater,

Figure 2 Slamming effect of free-fall lifeboat

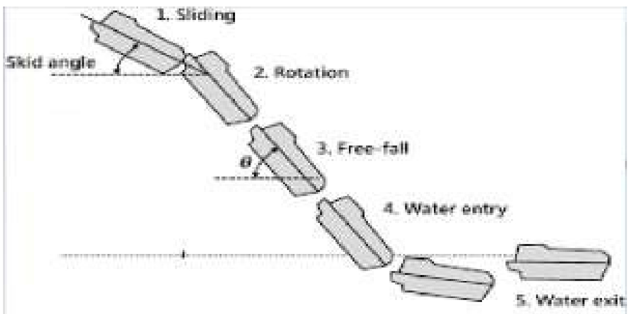


Figure 3 Various phases of free-fall lifeboat

There are many types of slamming loads such as bow flare slamming, bottom slamming, stern slamming, green water and bow impact loads.

then the rotation will be smaller. If the velocity is smaller than the rotation will be greater.

b) Rotation Phase: Rotation phase starts when the lifeboat is at the end of the launching skid. Gravity force, frictional force parallel to the launch rail and a force normal to the rail are the main forces governing this phase. The reactive force on the launch rail and the weight of the boat together forms a couple. This couple creates a tendency which will make the lifeboat to rotate as it slides off the skid.

c) Free - Falling Phase: Free – falling phase starts when the lifeboat is no longer in contact with the skid. Here the normal reaction force = 0. Main factors which affect the free – falling phases are the initial velocity from the skid, rotation, air resistance, skid plane angle, wind loads and also, the launching height. The only forces acting are the gravity and wind force. Air drag is considered in cases of large drop height. When the lifeboat is moving slowly and when it is at the end of the skid, there will be large variation in the angle of release. This angle has got great influence in the water entry phase of the lifeboat.

d) Water–Entry Phase: Hydrostatic and hydrodynamic forces are the force which acts upon the lifeboat during the water – entry phase. It is very interesting to know that two types of impact take place during this phase. The first one known as the bow impact arises when the lifeboat first hits the water surfaces. High accelerations are experienced by the bow of the boat. And the moment produced at the rotation phase gets reversed by the couple produced by the combination of weight of the lifeboat and the fluid forces. This reversed momentum reaches the stern (backside) portion of the lifeboat causing another impact called the stern impact.

e) Water – Exit Phase: The phase in which the lifeboat leaves the water. It overcomes its buoyant forces and will proceed to its positive headway.

4. Numerical Method

Modelling involved a 2D creation of lifeboat. The lifeboat is developed from the lines plan of Hyundai Company. And the surrounding fluid domain is also created. The fluid domain implies the water surface around the body. The domain is 10L from the outlet and 10L from the inlet. The total length of lifeboat is 17.7m and has a width of 4.151m is used in the numerical simulation. The body is assumed to be placed at 35 m from the sea level and it is modelled at an angle of 45^0. Each of the sides was named as inlet, outlet, top, bottom and these sides assigned for estimation purpose. The partial differential equations that govern fluid flow and heat transfer are not usually amenable to analytical solutions except for every simple case. Here for the analyses of fluid flow generated, the fluid domains must be sub divided into smaller and smaller domains. The governing equations are then discretised and solved inside each of these sub domains. The sub domains are so called elements or cells, and the collection of all elements or cells is called a mesh or grid. The process of obtaining or collecting proper grid is called grid generation or mesh generation. The most basic form of mesh classification is based upon the connectivity of the mesh whether it is structured or unstructured. The moving fluid zone including rectangular body is allowed to rotate by moment of hydrodynamic force acting on the body whereas the stationary fluid zone is fixed. The lifeboat has got a mass of 15000 kg. The boat is tilted at an angle of 45^0 and minimum mesh of 50 mm and a maximum mesh of 550mm is used. The

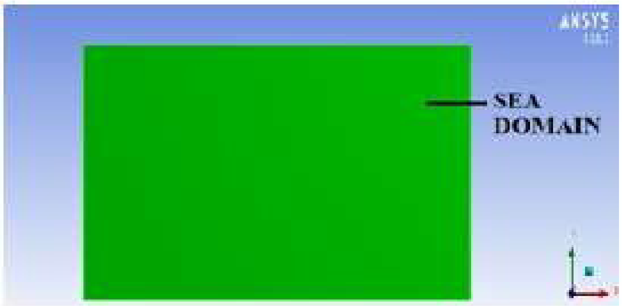


Figure 4 Modelled Sea Domain

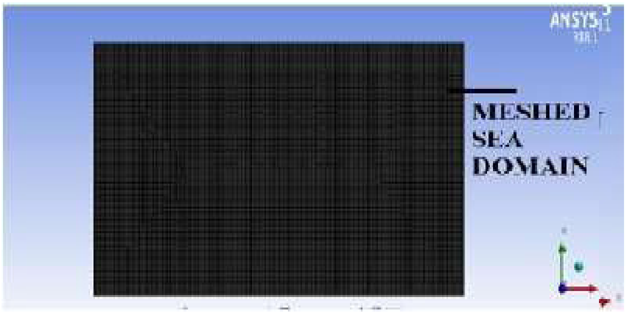


Figure 5 Meshed Sea Domain

Boundary conditions	Type
Inlet	Velocity inlet
Outlet	Pressure outlet
Top	Pressure outlet
Bottom	Symmetry
Lifeboat	Wall
Overset	Overset

Table 1 Boundary conditions

model and the mesh of the domain are shown in **Figure 4** and **Figure 5**.

Structured mesh is characterised by regular connectivity that can be expressed as two or three dimensional array. This restricts the element choices to quadrilateral in 2D or hexahedra in 3D. The regularity of the connectivity allows us to conserve space since neighbourhood relationships are defined by the storage arrangement.

An unstructured mesh is characterised by irregular connectivity which cannot be readily expressed as a two or three dimensional array in computer memory. This allows for any possible element that a solver might be able to use. Compared to structured meshes, the storage requirements for an unstructured mesh are so large that neighbourhood connectivity must be explicitly stored. Six degrees of freedom UDF file was compiled so as to capture the motion of the body in each and every second when penetrated into the water that's to understand the fluid-structure interaction.

Necessity of overset grid

Overset grid also known as chimera grid or overlapping grid. This type of meshing is useful in cases where large relative motion occurs between components. It eliminates re-meshing and smoothing. Mainly used for different bodies with the domain of interest. Overset meshing is a new method that allows to create a mesh set on the top of another one. The result will be calculated by the transfer of data at the boundaries of the overlapping mesh sets. An overset is provided around the lifeboat. A circular overset of diameter 25m is provided.

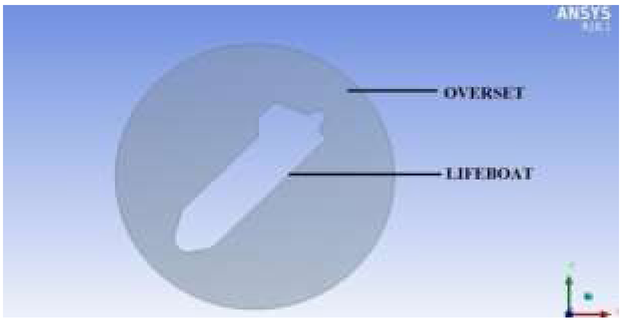


Figure 6 Meshed overset

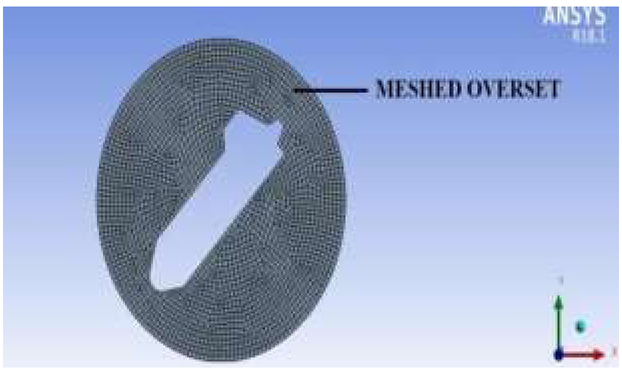


Figure 7 Overset provided around the lifeboat

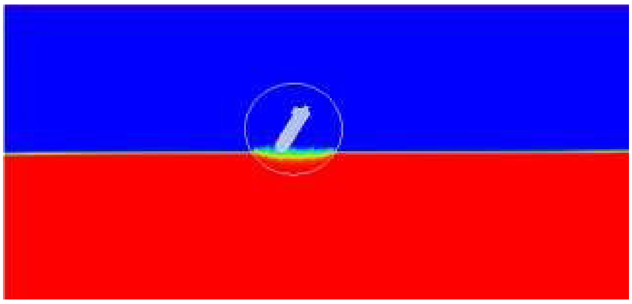


Figure 8 Simulations in fluent

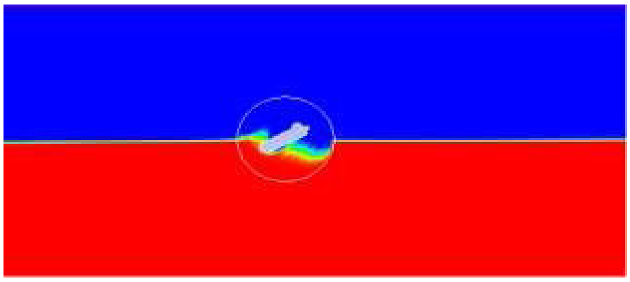


Figure 9 Simulations in fluent

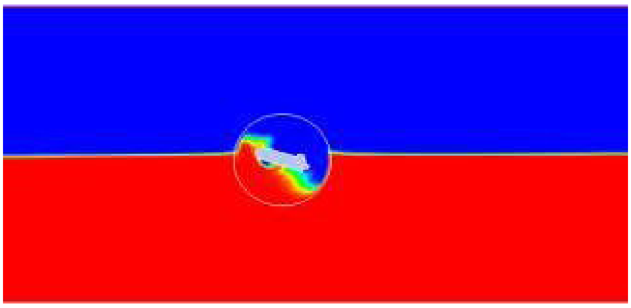


Figure 10 Simulations of lifeboat emerging out

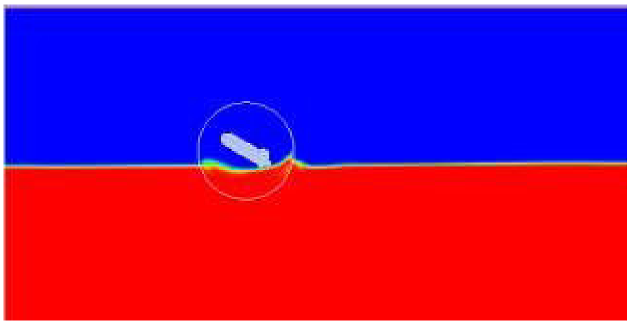


Figure 11 Simulations of lifeboat jumping in air

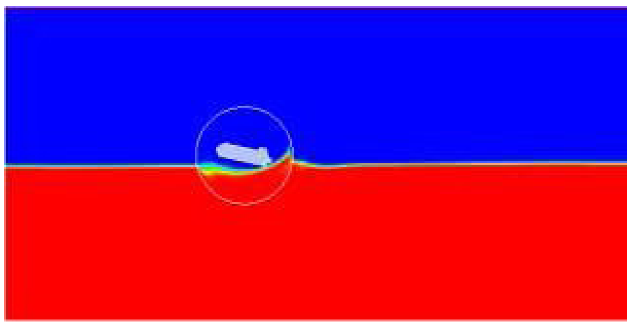


Figure 12 Simulations of lifeboat about to stabilize

> *The process of obtaining or collecting proper grid is called grid generation or mesh generation. The most basic form of mesh classification is based upon the connectivity of the mesh whether it is structured or unstructured*

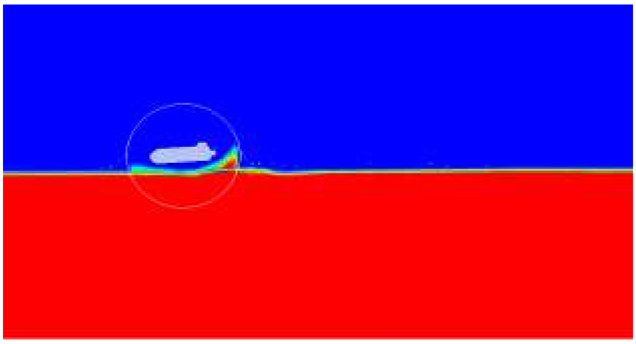


Figure 13 Simulations of lifeboat in its ascending phase

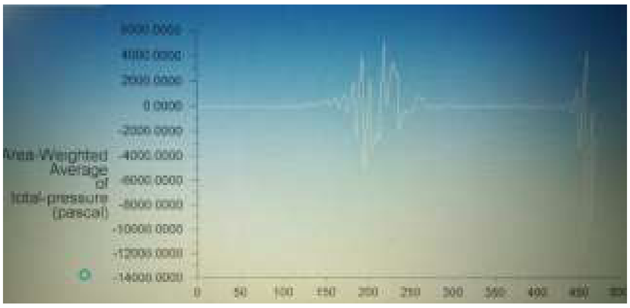


Figure 14 Graph showing pressure values

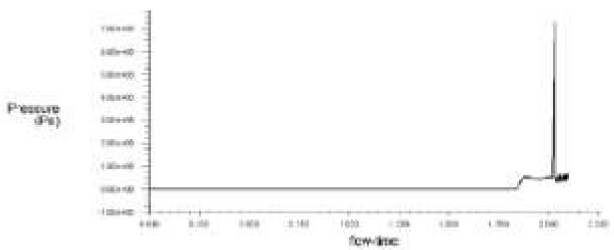


Figure 15 Graph showing maximum pressure values

5. Structural Analysis

Structural analysis helps in predicting the effect of loads in structures. Helps to develop a structure which will withstand all loads and deformations throughout its design life. Structural analysis forms basis of structural design. Finite element method is used for structural analysis. The hull is taken and developed for the analysis.

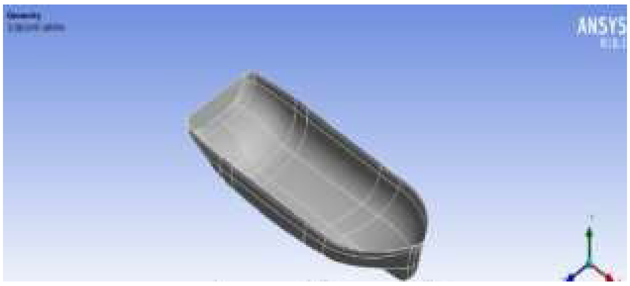


Figure 16 Modelled 3d lifeboat hull

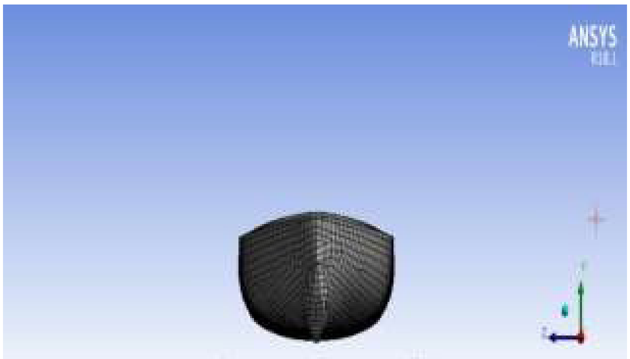


Figure 17 Meshed 3D Lifeboat hull

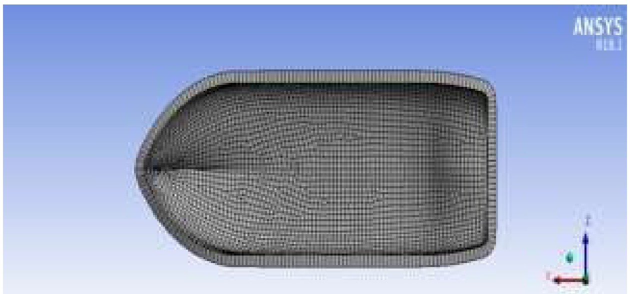


Figure 18 Meshed inner part of a 3D lifeboat hull

Transient structural analysis is carried out. Total deformation and corresponding stresses are analysed. Lifeboats hull is modelled in ANSYS Workbench. Material used is CFRP (Carbon fibre reinforced polymer). Carbon fibre reinforced polymer materials reduces the overall weight. Carbon fibre reinforced polymers are specially used for the construction of lifeboats. The model is meshed and has given fixed end support at one end. Deformations at the bow part is clearly depicted. Structural analysis is carried out in ANSYS Workbench. 3D model is modelled and is imported to ANSYS workbench for structural analysis.

Figure 19 Fixed condition given at the aft portion

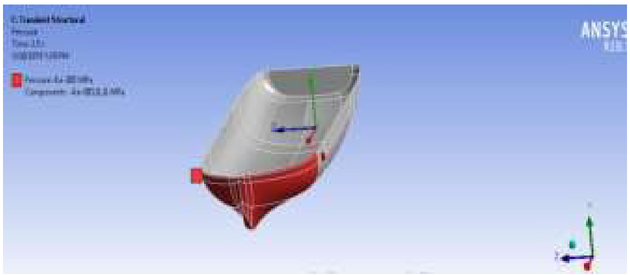


Figure 20 Pressure applied at the bow portion

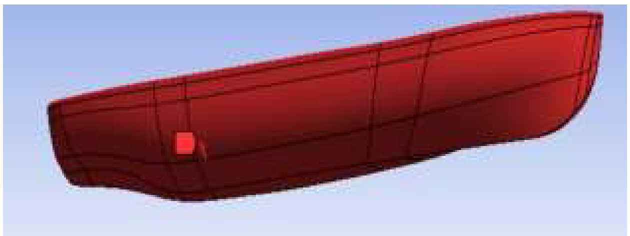


Figure 21 Pressure applied at the hull portion

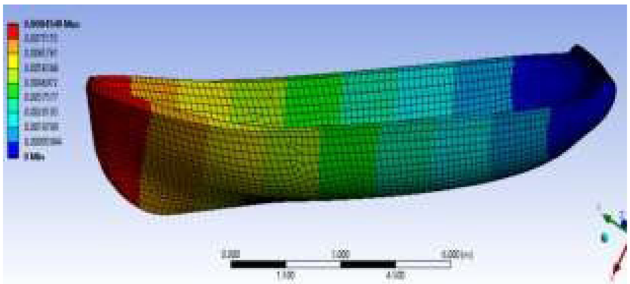


Figure 22 Total deformations at the bow and hull

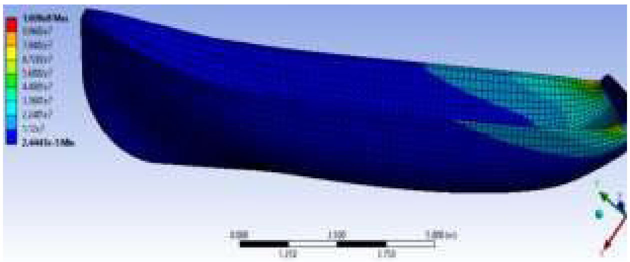


Figure 23 Equivalent stress at bow and hull

6. Conclusions

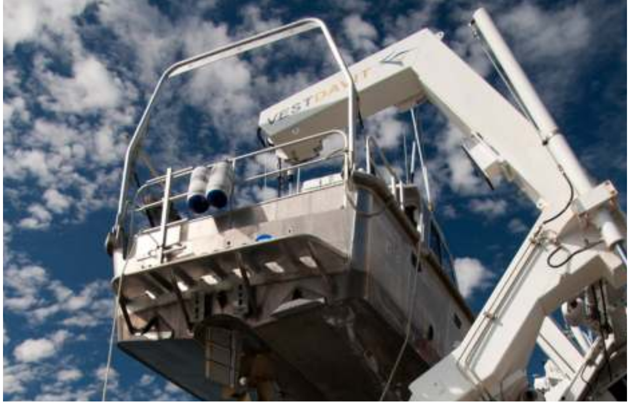
The sudden impact pressure of lifeboat during its water entry phase is obtained. Deformations in air water interface is captured and structural behaviour at the bow portion and that of hull of free fall lifeboat (FFLB) is clearly depicted.

Scope for Future Work

Design of scantlings has to be done to resist the maximum deformation. The work will be carried out with 3D CFD method for more accurate prediction of fluid pressures.

Acknowledgement

Our thanks go to our parents, Department of Mechanical and Civil staff, SSET for their collaborative support and for helping to make this work successful.



About the Authors

Andrya Sara Roy was a post graduate student in the Structural Division of Civil Engineering Department at SCMS School of Engineering and Technology. She is presently working in a structural engineering institution in Vancouver, Canada.

Dr. Sheeja Janardhanan is Associate Professor in the School of Naval Architecture and Ocean Engineering, Indian Maritime University, Vishakhapatnam. She has a PhD in Numerical Ship Hydrodynamics from the department of Ocean Engineering, Indian Institute of Technology Madras, India. Formerly she had served as a Surveyor in the Research and Rule Development Division of Indian Register of Shipping, Mumbai, India. She is also the principal investigator of the project, Hydro Vortex Power Generator (HVPG) partly funded by the Energy Management Centre, Govt. of Kerala, India.

Email: sheejaj@imu.ac.in

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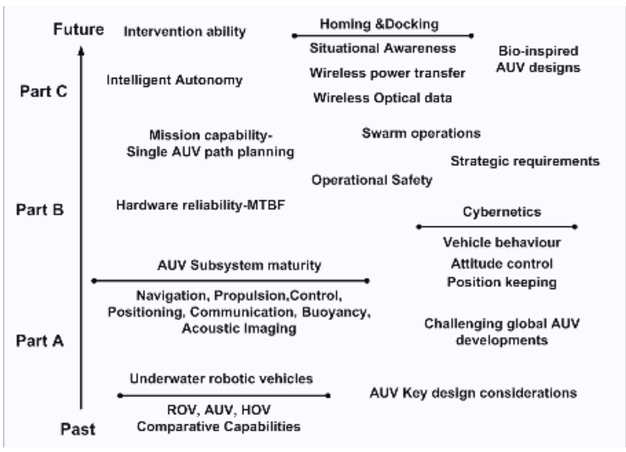
TECHNOLOGIES FOR NEXT GENERATION SCIENTIFIC AUTONOMOUS UNDERWATER VEHICLES (PART C)

Dr. N. Vedachalam,
Dr. G. A. Ramadass

Abstract: Autonomous Underwater Vehicles (AUV) are vital for exploring the vast marine resources, spatiotemporal monitoring of the tropical and polar oceans to understand the changes in climate patterns, monitoring marine pollution, defence and identifying assets lost in the Oceans. The first part of the article summarized the challenging AUV developments hitherto, the subsystem performances and mission capabilities. The second part detailed the hardware maturity, mission capabilities, strategic demands and the ongoing developments in achieving intelligent autonomy and swarm robotic systems essential for increasing the spatiotemporal capability. This issue discusses the requirements for realizing the key technologies for next generation scientific AUV, including, intervention ability, subsea homing and docking, and energy-efficient bio-inspired vehicle designs.

Index terms: AUV, bio-inspired, Homing, Intervention, Mission, Reliability, Swarm robotics.



Intervention ability

Intervention ability is the capability of the AUV to carry out successful subsea interventions using on-board manipulators. Successful accomplishment of a subsea task requires close coordination between the vehicle and the manipulator control systems, both having limited degrees of freedom. Various practical intervention scenarios undertaken by the subsea industry include docking, fixed base manipulation, learning by demonstration for free-floating manipulation and multi-purpose manipulation for object recovery. Till date, autonomous intervention capabilities have been demonstrated in ALIVE, SWIMMER, SAUVIM, GIRONA500, Trident, Triton and Pandora vehicles [1].

The first fully autonomous subsea intervention **(Figure 1)** was demonstrated during the ALIVE project, where a hovering capable AUV was able to home on to a subsea intervention panel using imaging sonar, and then docking into it using hydraulic grasps using visual feedbacks. Once docked to the panel, fixed manipulation strategy was used to open and close the valve. The most advanced demonstration is the wireless tele-operated

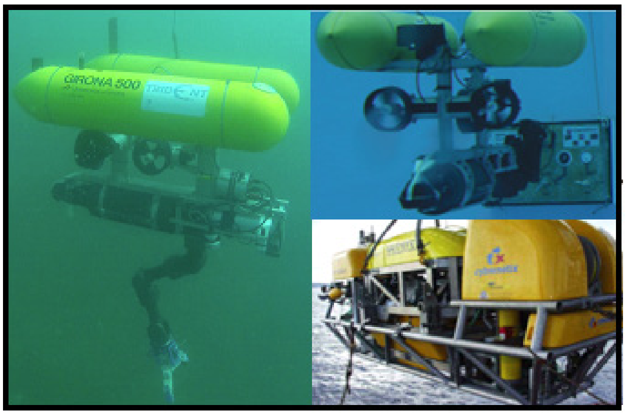


Figure 1. Autonomous intervention systems under development

intervention using light communication systems from the manned submersible to an underwater gateway connected to an umbilical. The interface framework indicating the requirements for an I-AUV is shown in **Figure 2.** A coordinated and tight real-time coupling between the manipulator and the vehicle increases the dexterity of the I-AUV operations. Closed form equations form the basis of the control design for the under-actuated I-AUV to perform underwater interventions tasks.

These promising I-AUV technologies requiring high level of decision making through deep and reinforced machine learning techniques and navigation autonomy are currently in level 3 out of 9 (9 being routinely used) of the development cycle necessary to adopt this technology in the offshore hydrocarbon industry, specifically in the deep water fields and long subsea tie-backs with no surface facilities, and data aggregation from the autonomous subsea observatories.

Homing and docking stations

Subsea homing and docking enables leveraging the submerged endurance capability of AUVs for long-term operations and reduces operation cost and hazards. Since 1997, the technology is being studied in various vehicles including REMUS, Odyssey, Dorodo, Explorer and NIOT-MagHomer (**Figure 5**), based on a combination of acoustics, optical and electromagnetic techniques (**Figure 3**) [2]. The electromagnetic homing guidance system demonstrated by NIOT-MagHomer is based on differential magnetometry [3] and vision-based docking using convolution neural networks is demonstrated by ISE (**Figure 5**) [4]. The homing and docking station (HDS), in addition to the homing and docking systems, have provisions to recharge the AUV on-board batteries upload the acquired mission data and download the next mission profile (**Figure 4**).

Situational Awareness

The HDS-AUV real-time Guidance Navigation and Control (GNC) system (**Figure 6**) should encompass a universal guidance framework that satisfies multiple requirements, including providing adequate degree of freedom (DoF)

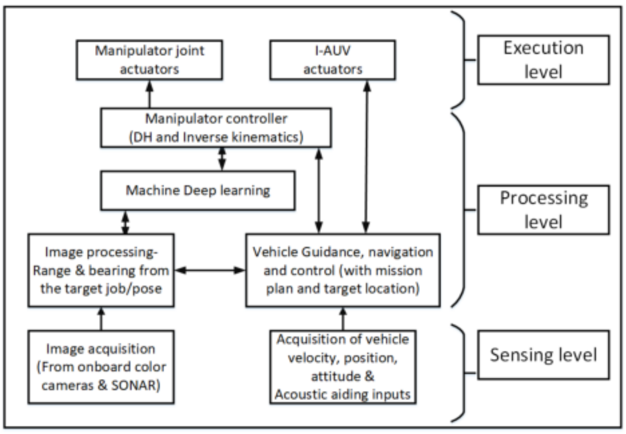


Figure 2. Propulsion-manipulation interface framework

Subsea homing and docking enables leveraging the submerged endurance capability of AUVs for long-term operations and reduces operation cost and hazards

to control the initial, midcourse, and final time-varying AUV and HDS pose, refinement of trajectory based on situational awareness, HDS geometry constraints when the AUV is closer to the dock, vehicle manoeuvrability limits in all DOF, on-board residual energy and the desired performance index, amidst operating environment constraints including water currents. The integrated HDS-AUV GNC system should offer long-range homing guidance using acoustic baseline positioning systems and short-range homing and pose correction using optical or electromagnetic methods. For realizing HDS, the key requirements include algorithms and systems for improving the situational awareness, high data rate communication between the approaching vehicle, preferably using under water optical communication and an articulated dock.

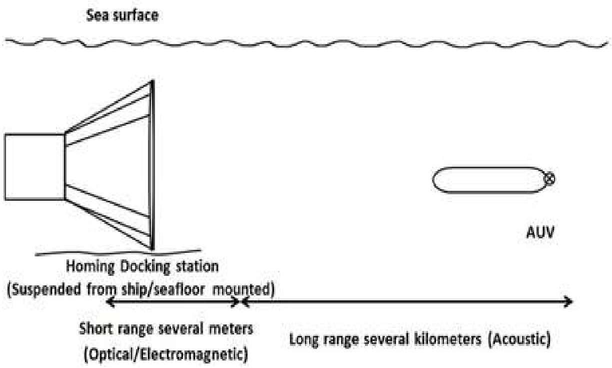


Figure 3. Concept of AUV homing [13]

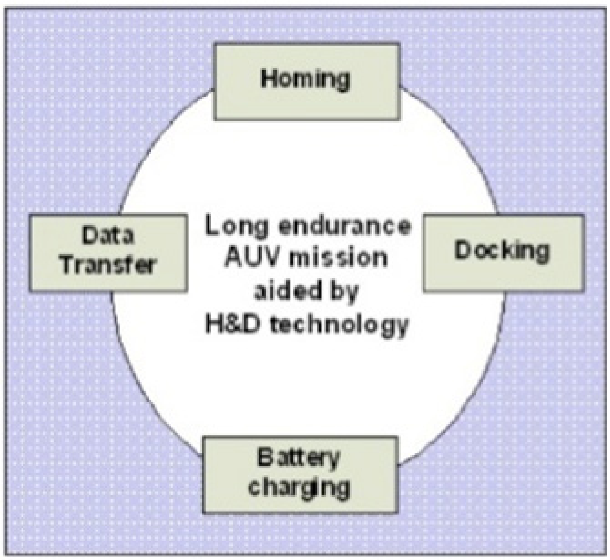


Figure 4. Requirements for subsea AUV HDS

Figure 5. Homing techniques demonstrated by NIOT, ISE, REMUS and Dorado [2][3][4]

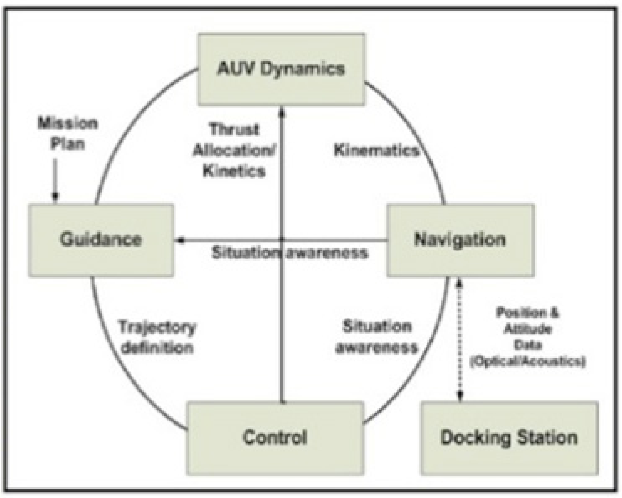


Figure 6. Configuration of the HDS GNC

Subsea inductive wireless power transfer

In HDS, the AUV batteries are to be charged by direct electrical power transfer using wet mate connectors or by subsea inductive power transfer (SIPT). In the case of SIPT involving the operation of the insulated transmitter and receiver coils in sea water, the power losses are mainly due to the eddy current losses produced in the electrically conductive saline medium, which is proportional to the electrical frequency and the magnitude of the current. Coreless planar coil configurations do not have the core loss component, which helps in having a comparatively increased efficiency over cored designs. But determining the value of mutual inductance in a saline water environment is crucial for coreless planar spiral windings, as it interacts with the capacitance to determine the resonant frequency, and its ratio to the resistance determines the quality.

With the availability of efficient electromagnetic finite element analysis (FEA) design tools, it is possible to calculate accurately the mutual inductance for any practical coil geometry and the seawater medium in which it is operating, with the highest possible accuracy. The power loss PL is based on the following relationship,

$$P_L = \frac{\oiiint_V |J_E|^2 dV}{\sigma_2}$$

where J_E is the eddy current density in sea water, σ2 is the sea water conductivity and V is the studied sea water volume. The eddy current losses in an N turn winding are expressed, using cylindrical coordinates (r-z) as

$$P_L = \frac{2\pi N}{\sigma_2} \int_0^{\infty} \int_0^{D} |\sigma_2 E(r,z)|^2 dr dz$$

where E (r, z) denotes the electrical field intensity in sea water.

Based on the numerical modelling and validated by experiments, a planar-coiled SIPT system operating at 75–125 kHz could have power transfer efficiency up to 70% for 50-mmwater gaps (**Figure 7**). The power transfer efficiency drops to 30% at 200m vertical gap and 300mm

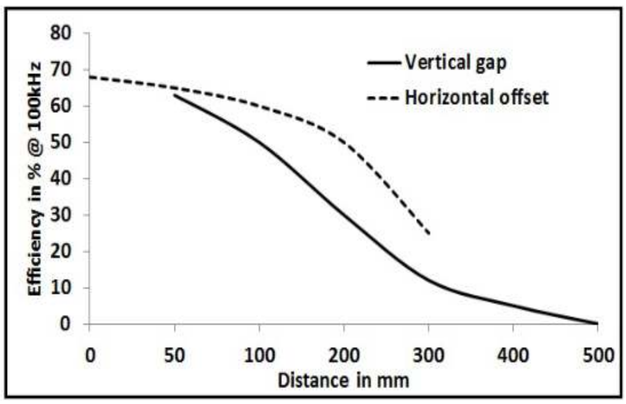


Figure 7. SIPT between planar coils operating at 100kHz

horizontal offsets, which indicates the need for precision alignment while charging inside the HDS (**Figure 8**) [5].

Wireless data transfer –Acoustic and Optical

Optical wireless communication (OWC) can provide higher data rates over relatively short distances compared to hydro-acoustic communications. Recent potential applications of OWC include collection of scientific data from spatially distributed stand-alone subsea observatories by means of systems extended from the mothership (**Figure 9a**) or by AUV (**Figure 9b**) and homing guidance for the deep-water AUV into the docking stations for charging the batteries and data exchange so as to increase subsea operational endurance (**Figure 9c**). Ongoing efforts toward the realisation of an OWC between the aircraft and the submarine (**Figure 9d**) show growing interest for the OWCin classified defence applications [6].

Effective communication between the HDS and the approaching AUV is essential for a successful dock. A subsea OWC system comprises an optical transmitter, the sea water medium, and an optical receiver. The effective communication range and the data rate is a trade-off between the apparent system design parameters including the transmitter power, type, beam width and orientation geometry of the optical transmitter, the sensitivity of the optical receiver and electronics induced noise; the inherent optical attenuation property of the operating sea water medium; and the ambient solar irradiance in the operating location [7]. The relationship representing the data transfer rate, channel bandwidth, inherent channel parameters and the apparent system parameters are shown in **Figure 10**.

Optical wireless communication (OWC) can provide higher data rates over relatively short distances compared to hydro-acoustic communications

In the signal to noise ratio (SNR) equation described in **Figure 7**, PT is the transmitted optical power in W, θ is the divergence angle of the transmitted beam in degrees, z is the optical link distance/range in meters, noise equivalent power (NEP) is the noise equivalent power for the operating bandwidth, c is the attenuation coefficient of the underwater channel in m^{-1}, D is the receiver aperture area in m^2 , / is the beam angle from the line of sight in degrees, BW is the band width in MHz and BR is the bit rate in bits/sec [8].

The attenuation of the optical signals in the sea water channel is due to the process of absorption and scattering. The absorption of the light due to the presence of dissolved salts, fumic and fulvic acids is the minimum for 470 nm wavelength, in the blue-green region of the visible spectrum. The scattering process deflects the light from the desired path attenuates the optical signal and reduces the signal to noise ratio thereby degrading the quality of communication. Based on Jerlov classifications, the optical attenuation coefficient is 0.151, 0.298 and 2.17 m^{-1} for clear, coastal and turbid harbour waters.

The choice of the optical transmitter depends on the required data rate, beam divergence, size of the receiver aperture and the underwater misalignment window. While LASER diodes are preferred for point to point

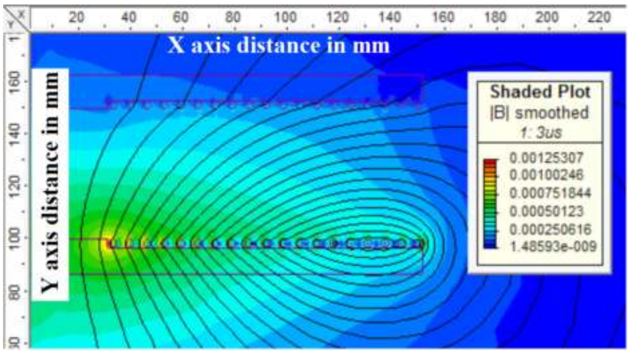


Figure 8. Flux distribution between the planar coils in sea water medium

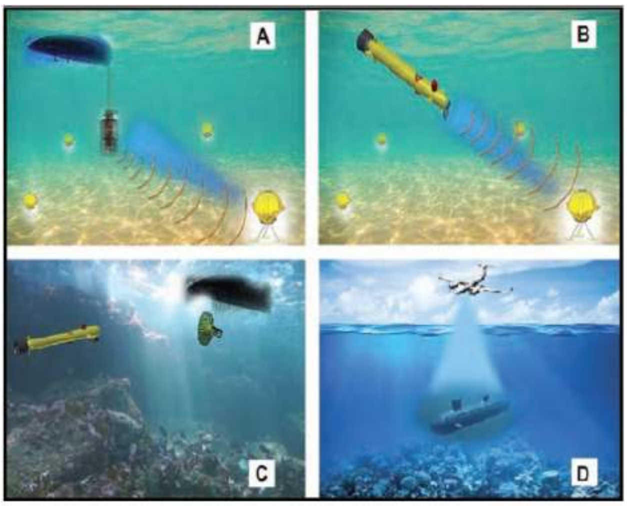


Figure 9. Rendering of the potential applications of OWC systems

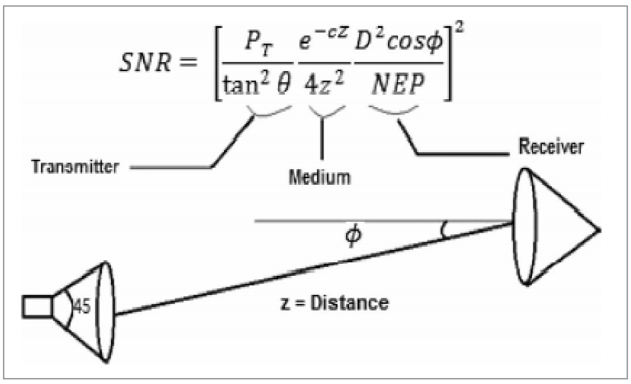


Figure 10. Design parameters for subsea OWC

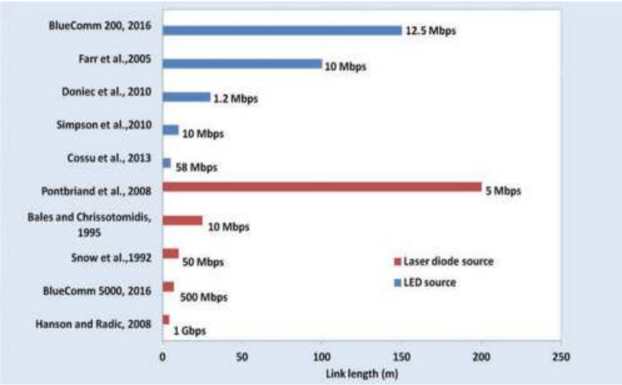


Figure 11. Recently reported OWC systems [8]

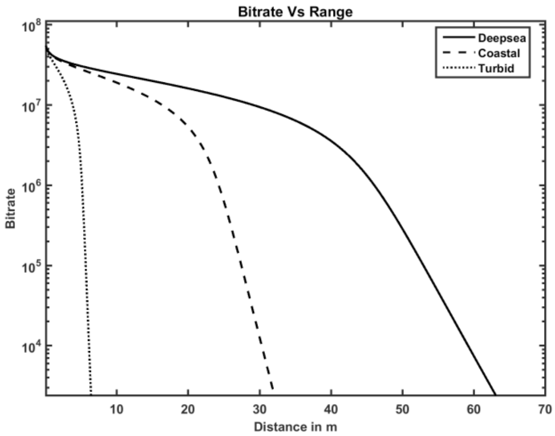


Figure 12. Possible OWC data rates in the Arabian Sea [9]

communication involving high data rates, light emitting diode (LED) based optical transmitters are best suited for fly-by data exchange between two subsea systems in a hydrodynamic marine environment.

The choice of the optical receiver depends on its sensitivity. Based on the aperture area, a typical photo diode has the capability to detect optical intensities <1mW/m^2. The avalanche photo diodes with multistage amplification systems are capable of detecting optical intensities in the range of several microwatts and the recently developed photo multiplier tubes and silicon photo multiplier systems could detect intensities up to a few pico-watts.

The performance of the reported subsea OWC systems based on LASE and LED technologies is depicted in **Figure 11**. The recently commercialized subsea OWC systems based on the LED transmitter operates with a data transfer rate of 12.5 Mbps with a range of 150m. Based on modeling and simulations based on field data collected by NIOT-developed 500m depth rated PROVe, the data rate Vs distance for a LED-based OWC when operated in different water depths in the Arabian Sea are shown in **Figure 12** [9].

Bio-inspired vehicle designs

Understanding the versatility of nature's creations and increased synergy between engineering and biology creates avenues for innovative vehicle designs based on bio-mimetic concepts. With ~ 500 million years of evolution, fish and aquatic animals are endowed with a variety of morphological and structural features that enable stability, manoeuvrability and efficient swimming performance (**Table 1**). Thus the goal of bio-inspired design is to use the biological inspiration to innovative vehicle designs that emulate the performance of animals, particularly in instances where animal performance exceeds current technology associated with AUV propulsion, sensing, control and navigation. This could help in realising autonomous underwater vehicles with efficient propulsion systems with vectored thrust mechanisms, oscillatory propulsors and fusiform body design with polymer composite materials for improved agility.

Table 1. Bio-inspired features for AUV design

Feature	Bio-inspiration
Sensing	Echolocation, electroreception
Pressure management	Buoyancy control
Energy optimisation	Fusi-form body design, schooling, burst swimming and gliding
Stability	Paired and median fins
Manoeuvrability	Flexible bodies, vectored thrust.
Speed	High aspect ratio oscillatory propulsors, jet propulsion
Compliant materials	Collagen, protein rubbers, mucous

Table 2. Fish classification based on swimming styles [10]

Swimming mode	Undulation	Oscillation
BCF	Anguilli	Subcarangi, Carangi, Ostracii, Thrunni
MPF	Raji, Diodonti, Gymnoti, Amii, Balisti	Labri, Tetradonti, Ostracii

Fish swimming is categorised into Body/Caudal Fin (BCF) propulsion and Median Paired Fin (MPF) propulsion. **The BCF is based on tail flapping propulsion and exhibits rapid swimming and turning capabilities.** Most agile fishes like Tuna and Sail fish are BCF types. **The MPF uses pectoral, dorsal and anal fin for propulsion.** Although this swimming mode is slower, it excels in greater manoeuvrability with higher degrees of freedom (DoF), enhanced controllability, and high efficiency. About 85% of the fish species produce thrust using BCF and the rest 15% with MPF propulsion. The BCF type and MPF type propulsion are further categorized into two modes, such as undulation motion (sine mode) and oscillation motion (C mode). **Sine mode involves transit of full-wave**

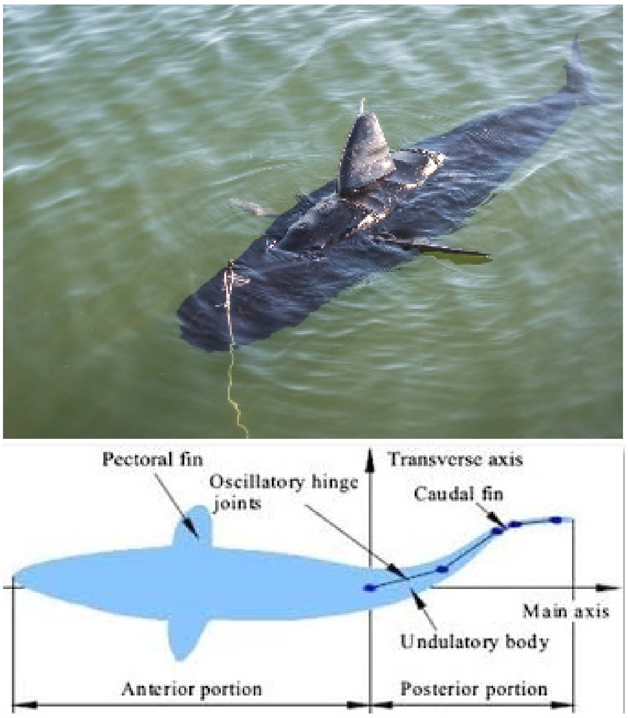


Figure 13. View of fish dynamics and Ghost swimmer

along the body axis, whereas C mode involves oscillation of body or fins without exhibiting a wave formation [10]. The classification of fish families based on various swimming styles is shown in **Table 2**.

Subsequent to the first robotic fish, Robo Tuna, developed in 1994 at the Massachusetts Institute of Technology, multiple models including Ghost Swimmer, SPLINE, RAZOR, BAUV, Ghostbot, Cephalobot and iSplash-II were reported (**Figure 13**). The Ghost Swimmer, built based on tuna oscillatory tail finis atactical, bio-inspired, autonomous AUV that employs the mechanics and dynamics of biological systems to create efficient sensing, swimming and high manoeuvrability catering to the needs of current riverine and littoral missions.

Based on the 23 robo fish designs reported in the past two decades, there still exist significant challenges to be addressed. The maximum swimming speed of sword fish is 27 ms^{-1}, whereas maximum speed of only 3.7 ms^{-1} has been achieved in robo-fish. Similarly, the maximum turning speed of archerfish is 4500°/s, whereas a robot fish achieves 670°/s. Moreover, real fish exhibits special behaviours such as a maximum quick start (wake dynamics) of 249 ms^{-2} in pike fish, escape manoeuvring, braking, and hovering. Achieving these special behaviours in robot fish needs integration of BCF and MPF styles, which could encounter synchronisation problems and design complexity that needs to be addressed by the researchers [11]. Machine learning and artificial intelligence tools show outstanding progress in modelling the non-linear dynamics, development of muscle-like actuators, exploration of special sensors of aquatic animals and group behaviours. These could accelerate the developments.

With ~ 500 million years of evolution, fish and aquatic animals are endowed with a variety of morphological and structural features that enable stability, manoeuvrability and efficient swimming performance

Understanding biophysical sensors such as magnetite and light-sensitive retina cryptochromes proteins, transducing mechanisms and the associated neural processing aiding the directional and true navigation capabilities in sea animals and migrating birds based on magnetic, olfactory, visual and inertial clues to trace back their way home, when displaced several kilometres helps in improving navigational capabilities of underwater vehicles. Examples include the valuable lessons learnt from the tag and recapture experiments done to establish the homing capability of spinning lobsters after being displaced several kilometres from a capture site; the capability of the juvenile loggerhead sea turtles to return to their feeding grounds based on the principles of bi-coordinate magnetic map after performing long spectacular marine migrations lasting for several years, despite the secular variations in the earth magnetic field during the intermediate migration period; the precision natal homing of salmons from the vast featureless oceans back to the originated river tributary based on the imprinted magnetic, chemical and olfactory clues; the usage of diurnal variation in the geomagnetic field in maintaining the circadian rhythm in animals living in the abyssal water depths where there is no clue of light [12-17]; shall aid in the biomimetic-based design of the strategic grade autonomous underwater vehicles.

Conclusions

The technological advancements in the high energy density battery storage, underwater navigation sensors, processing electronics, underwater navigation algorithms, high density buoyancy packs and lighter high-strength pressure casings supported by modern numerical modeling tools have enabled development of novel autonomous underwater vehicles capable of carrying out scientific exploration in impractical hostile environments. The strategic demand in the oceanography, glaciology, marine research, defence, engineering construction domains require further energy-efficient, agile and intelligent autonomous underwater vehicles with increased spatio-temporal capability capable of navigating thousands of kilometres in the deep oceans and Polar Regions.

The last two issues focused on the developments in unmanned and manned underwater vehicle technologies, potential applications of AUVs in the offshore sector and the performances of the state-of-the-art AUV subsystems, hardware maturity, operational safety, mission capabilities, strategic requirements, ongoing developments towards achieving intelligent autonomy in navigation, energy management and mission planning and the upcoming swarm robotic systems. In this issue the futuristic requirements including the need for increased synergy in realizing intervention abilities, subsea homing and docking with wireless power and optical data transfer features, and energy-efficient bio-inspired vehicle designs for strategic-grade autonomous underwater vehicles are detailed.

Acknowledgements

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About the authors

Dr. N. Vedachalam is currently a Senior Scientist with NIOT, Chennai. His 26 years of experience includes industrial power, process, offshore, and subsea domains at Aditya Birla Group and GE Power Conversion & Alstom Converteam in France. His technical exposure includes development of multi-megawatt power and control systems for deep-water enhanced hydrocarbon recovery systems of Ormen Lange subsea compression pilot with GE; Ocean renewable energy systems including ocean thermal energy conversion, wave energy systems & remotely operated vehicles with NIOT; subsea grids for tidal energy farms for Paimpol Brehat, France and industrial power generation, utilization and boiler control systems in process industries. He has about 85 publications in indexed journals, holds an international and two national patents in subsea robotics and subsea process. He is a recipient of the National Meritorious Invention Award in 2019 for the development and usage of underwater robotic vehicles. He is presently a Member of Bureau of Indian Standards and was the Secretary of IEEE Ocean Engineering Society- India Chapter and Executive Member of Marine Technology Society-India Section. He is a regular contributor to MER.

Email: veda1973@gmail.com

Dr. G. A. Ramadass is currently the Director of NIOT, Chennai. His research areas include deep-sea technology, underwater acoustics, and marine instruments. He has handled multiple technology development programs leading to products and patents. He led the NIOT team during the 34th Indian Scientific Expedition to Antarctica in February-March 2015 with NIOT's indigenously developed Polar Remotely Operated Vehicle and carried out exploration in the lake and shelf area of Antarctica. He has been the Chief Scientist of 15 cruises and scientific explorations onboard various research vessels. His recent work includes publications in the international journals, international conferences and four international patents. He is a recipient of the 2010 Indian National Geoscience award under the exploration of oil and natural gas category and the National Meritorious Invention Award in 2019. He is member of various national committees, founding secretary of IEEE-OES India Chapter and Life member of the Ocean Society of India.

WAYS AND MEANS FOR QUANTUM JUMP IN SHARE OF COASTAL SHIPPING IN OVERALL FREIGHT MARKET IN INDIA

Mohammed Farhan Aqdus

Maritime powers in the Indian subcontinent have possessed navies for many centuries. Indian dynasties such as the Cholas used naval power to extend their influence overseas, particularly to Southeast Asia. The Marakkar Navy under Zamorins during the 15th century and the Maratha Navy of the 17th and 18th centuries fought with rival Indian powers and European trading companies. Such was the might of the Indian-origin vessels that the entire water region surrounding the vast coastline was named 'the Indian ocean', the only water body to be named after a country to date. Today, India has an extensive network of rivers, lakes, and canals, with approximately 14500kms of navigable waterways, out of which only 5685km is currently navigable, which forms a very diminutive part of this vastly untapped mode of transport. The spread of globalisation, the advent of railways, and the extension of the rail networks affected inland water transport in India. The rapid growth of roads coupled with inadequate development of the inland water transport sector, over the years gave a decisive setback, this transformation left the inland waterways as a neglected sector.

As shown in **Figure 1,** waterways are the cheapest mode of transportation amounting to only 1.19 INR per kilogram of cargo transported, as compared to roadways (1.41 INR) and railways (2.28 INR), yet this sector is the most underdeveloped. The secret to the development of any country is its intricate network of transports, and waterways being the cheapest mode of transportation massively helps in transit of bulky goods at a meagre cost. **Figure 2** shows the comparison of the percentage of waterways developed and used at a regular commercial basis amongst the developed regions.

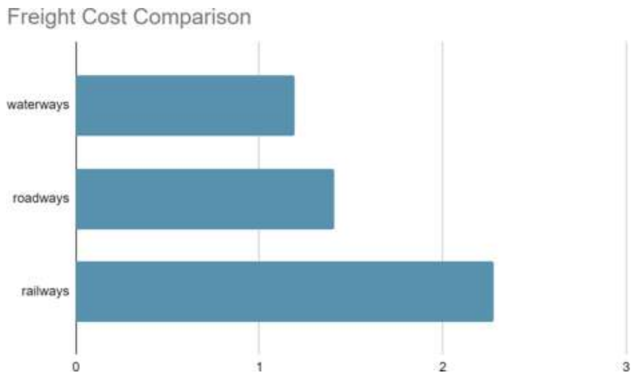

Figure 1: Freight Cost Comparison

On one hand, we have US, China and the EU which utilise the potential of over 65% of their inland waterway capacity, whereas India has tapped only 5% of its full potential. No wonder, India is taking quantum leaps in all the sectors, but with a more efficiently developed waterways network, the progress would be easier and faster.

So, if development of waterways can prove to be a Midas touch for the country's development, what's delaying the process? The following points broadly summarise the obstacles that hinder the growth of this intricate network.

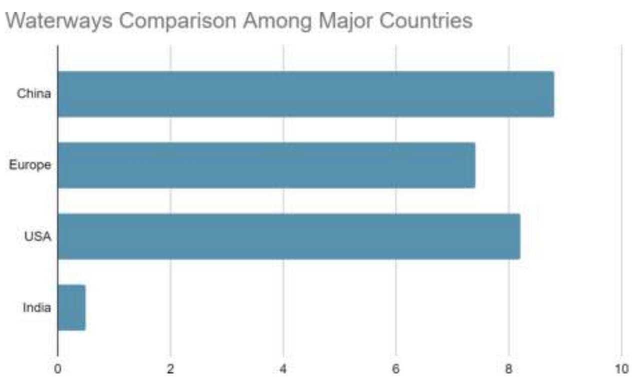

Figure 2: Waterways Comparison among Major Countries

1. TECHNICAL CHALLENGES

a) Inadequate Depth

Large part of Indian waterways has inadequate depth for commercial movement of cargo. Indian rivers especially in northern plains face severe problems of siltation round the year, the river bed rises impending the movement of cargo during non-monsoon months.

REASON FOR EXCESSIVE SILTATION

Figure 3 shows the water use distribution for a commercial hotspot in northern India. As can be seen 78% of the water used, is diverted towards agricultural activities, and with alluvial soil, getting excessively drenched, causes the siltation to form in river beds, thereby reducing their navigable depth.

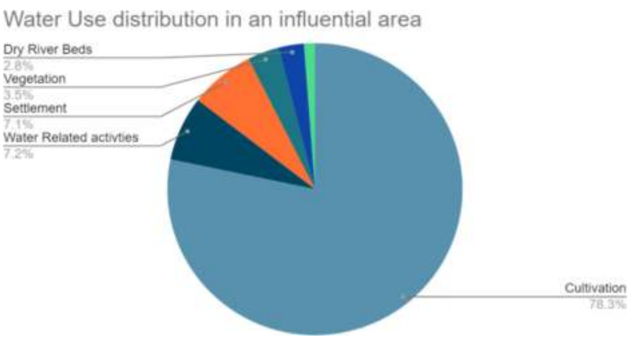

Figure 3: Water Use Distribution in an Influential Area

b) Shortage of IWT Vessels

Vessel building is highly capital intensive and faces difficulties in obtaining project finance from bank and financial institutions. As a result of which, the existing vessels are in a deplorable condition, and seeing the lack of incentives there is less interest amongst the business persons to start a venture.

c) Lack of 2Terminals

Barring the important ports and the ones identified by the government, there is a lack of development of other potential terminals. Without the terminals, there will be lack of connectivity which will inhibit the transport network.

d) Lack of night navigation infrastructure

Unlike the roadways, which is illuminated at night, the provision of such, is nearly impossible. Lack of night navigation facilities such as DGPS and RIS. Non-availability of waterway channel round the year coupled with lack of night navigational facilities, is a major challenge.

2. REGULATORY CHALLENGES

a) Policy Parity

The government needs to establish a level playing field between various transport means which will make inland water transport more cost competitive with other transport modes.

b) Legal and Administrative Hindrances

Since the navigable inland waterways invariably run through more than one state, it is important to have uniformity in the realm of various operational aspects of inland water transports throughout the country.

3. GEOPOLITICAL CHALLENGES

a) Cross Structures

Construction of dams/ barrages to increase the depth of navigational channels faces challenges of economic and environmental viability.

b) Interlinking of Rivers

The inland water transport has the strategic importance for connectivity of north eastern regions which do not have very efficient connectivity due to its geographical position and rail/road transport passing through the **'Chicken Neck'**.

4. FINANCIAL CHALLENGES

a) Government Investment

The government investment compared to rail infrastructure and development of road in successive five year plans, the inland water transport sector has been neglected consequently. The public investment in inland water transport modes have been far below the levels attained by other modes.

b) Capacity Building

There is a huge demand for trained manpower for vessel operations as well as for development and management of inland water transport infrastructure.

Amidst all these hurdles, the last half a decade has proved to be a boon for the river transport development, its importance is being realised and significant resources tapping has begun. One innovative solution in this regard is as follows.

INTEGRATED DEVELOPMENT APPROACH

This incorporates all the shortcomings in a given supply chain and tries to minimise it in one single comprehensive attempt. The following sectors which needs innovative approach has been identified-

a) Long term cargo commitment

Government contracts or through public-private partnerships may identify long term cargo commitment for economic stability of sustainable operations in the waterways

b) Viability gap funding

The stakeholder agencies may identify some cargo for specific composite project and develop them jointly with shippers and other stakeholders, the government should be willing to provide viability gap fund.

c) Model shift incentive

Even in the countries where inland water transport sector is developed, though active actions are being taken by the government to promote waterways. Since they have strengths which are beneficial to the economy as well as environment.

As of now we will delve deep into the current scenario of inland shipping, it is imperative to first identify the huge potential advantages that it presents if properly developed.

ADVANTAGES OF INLAND SHIPPING

1. As the acquisition of land for national and state highways becomes scarce and the cost of construction of roads, flyovers and bridges goes up, the government is now exploring using water as a means of public transportation
2. Water transport is not only environment friendly but also cheaper than other modes of transport.
3. It takes lesser time to transport cargo by waterways in some areas and the chances of congestion and accidents on highways are eliminated.
4. There is a huge potential for domestic cargo transportation as well as for cruise, tourism and passenger traffic.
5. There is huge potential for public-private partnership (PPP) led investments in dredging, construction, operation and maintenance of barges, terminals, storage facilities, and navigation, as well as tourism.
6. It will help in the generation of millions of job opportunities.
7. It will boost the maritime trade of the states and augment their economies.

ANALYSIS OF MAJOR INLAND CHANNELS IN INDIA

India has identified over 100 major navigable water channels, out of which 4 are the most important, these are otherwise called as the national waterways. Here is an analysis of all the major national waterways, their potential, problems and some innovative ideas for its further development.

NATIONAL WATERWAY 1

- Runs from Prayagraj to Haldia primarily running in the Ganges
- Spans a total of 1620 Kms
- Opened in 1986 but major work started in 2014
- It has a total of 21 terminals and will be having 3 MULTI MODEL TERMINALS by 2023
- Potentially the largest waterway network in India, connecting all the major economic hubs in the northern plains
- Due to excessive siltation and construction of barrages which has affected the rivers adversely, the potential is far from being reached

NATIONAL WATERWAY 2

- Runs from Sadiya to Dhubri
- It has a total length of 891 km
- Was opened to public in 1988
- Has 11 terminals with special floating terminals
- This waterway is of extreme political importance as it can connect the north east with the rest of the country (**'Chicken neck'** reference, earlier in the article!)
- Proper implementation and development of regional cooperation inland waterway transporting, which will ensure the optimum use of the potential
- Extensive investment in promoting this waterway as an alternative way for bulk route

NATIONAL WATERWAY 3

- It is primarily the inland navigational route located in Kerala.
- It runs 168 km
- It was opened to public in 1993
- This part is extensively used for transport of coir, spices and coffee
- Promoting this area as a tourist destination and encouraging cruise ships in the area will boost the economy to a greater extent

NATIONAL WATERWAY 4

- It is 1095 km long connecting the states of Telangana, Andhra Pradesh, Pondicherry and Tamil Nadu
- It was identified in 2008 and developmental works started in 2013
- Proper use of Revenue Model as in Goa and policy implementation for water transportation as in Bangladesh should be adopted for further development of this area

The government has taken some major steps to improve the conditions of the inland waterway transport, the major being the implementation of Namami Ganges project for extensive cleaning of river ganga. However, there are a lot of schemes which were announced, and with their proper implementation, can accelerate the speed of development, some of them are listed below.

STRATERGIES AND MEASURES TO ASSIST QUANTUM JUMP IN COASTAL SHIPPING

1. Proper implementation of Ports Regulatory Authority Bill 2011, which focuses on uniform platform for handling both government and state controlled ports.

2. In order to encourage opportunities in port sector, the government is offering a special tax incentive.
3. Foreign capital inflow has been permitted by the government through 100% FDI.
4. Maritime Agenda has been introduced under which 352 ports will be turned to major ports by 2020.
5. Some prospects of inland water transportation such as trade and commerce, industrial growth, revenue generation, public exposure etc. can be identified if adequate attention could be paid by government and other stakeholders in development of the area.

This report would be incomplete without the mention of one of the most revolutionary steps taken by the government which may transform the face of inland shipping for the better.

India has identified over 100 major navigable water channels, out of which 4 are the most important

THE SAGARMALA PROJECT

The **Sagarmala Programme** is an initiative by the government of India to enhance the performance of the country's logistics sector. The programme envisages unlocking the potential of waterways and the coastline to minimise infrastructural investments required to meet these targets.

It entails investing Rs. 8.5 trillion (2018) to set up new mega ports, modernising India's existing ports, developing of 14 Coastal Economic Zones (CEZs) and Coastal Economic Units, enhancing port connectivity via road, rail, multi-modal logistics parks, pipelines & waterways and promoting coastal community development, with the aim of boosting merchandise exports by US$110 billion and generating around 10,000,000 direct and indirect jobs.

The Sagarmala Programme is the flagship programme of the Ministry of Shipping to promote port-led development in the country by exploiting India's 7,517 km long coastline, 14,500 km of potentially navigable waterways and its strategic location on key international maritime trade routes. Sagarmala aims to modernise India's Ports, so that port-led development can be augmented and coastlines can be developed to contribute to India's growth. It also aims at "transforming the existing Ports into modern world-class Ports and integrate the development of the Ports, the Industrial clusters and hinterland and efficient evacuation systems through road, rail, inland and coastal waterways resulting in Ports becoming the drivers of economic activity in coastal areas.

Last but not the least, I have enlisted some of the innovative solutions to this complex issue, whilst keeping in view the current development. The following ideas are personal views on the issue at hand.

IDEAS TO IMPROVE THE COASTAL SHIPPING SCENARIO

1. Integration of coastal shipping with inland water transport.
2. Actively developing economic alliance in inland water transport.
3. Allowing private participation in maintenance of waterways. This will ease the economic and logistic burden on the government.
4. Reviving subsidy plans to attract private players. Incentivising could be the most important aspect of flourishing a new plan, through effective strategies, this can lead to a great boom in the participation of private enterprises.
5. Indigenous and non-indigenous businesses residing within the river transit area should form themselves into small scale cooperative ventures in order to attract government interest, as this will enhance their community potentials, resources to government, thereby bringing investors to invest in the area.
6. It is imperative that tax regimes need to be simplified and reduced to a one-window/one-time levy across regions so that administrative processes do not hinder physical free flow of movement.
7. Encouraging local traders to produce and send their indigenous products through coastal shipping to the world.
8. Either invest or privatise underdeveloped areas of ports for optimum utilisation.
9. Auctioning of all scrape and pig metals and other waste goods and utilised the funds gained in a better way.
10. Women should be encouraged to take up stevedore jobs and other port maintenance jobs which will improve employment.
11. Promotion of electric boats among the local fisherman and vendors to reduce the adverse impact of environment, and also put a halt to the regular maintenance costs.

In a nutshell, inland waterways in India has a huge potential, arguably the best in the world. All it needs is a bit of cooperation from us and the attention from the government, and rest assured when you will plan your next holiday, you will do it via a ferry!

About the Author

Mohammed Farhan Aqdus is a third year student of B. Tech Marine Engineering at IMU, Kolkata Campus.

Email: farhanaqdus1803@gmail.com

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CLASS ACTION/ INDUSTRY MOVES

Compilation : **Rashmi Tiwari**

NAVIGATOR GAS AWARDED DNV AIP FOR NEW AMMONIA FUELLED GAS CARRIER DESIGN

Navigator Gas has been awarded a new Approval in Principle (AiP) for an ammonia fuelled gas carrier design from classification society DNV. An industrywide consortium, including MAN Energy solutions, Babcock International, and the Norwegian Maritime Authority (NMA), has collaborated with Navigator Gas to achieve the Approval in Principle (AiP) from DNV. The awarding of the AiP was announced as part of London International Shipping week 2021.

For more information, please visit: www.dnv.com/maritime

METHANOL – FULL AHEAD ON THE VOYAGE TO ZERO

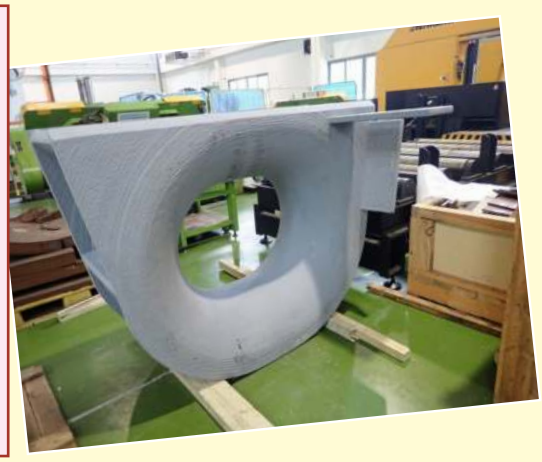
IMarEST and Sea Commerce (America) organised a commercial and technical seminar on the topic "Methanol as Marine Fuel" on 9th Sep 2021 in Dubai. The webinar discussed about adopting low and zero-carbon fuels and suggested to agree on using METHANOL as the best fuel option for ships. 100 in person and 168 online participants had the opportunity to interact with top industry experts from leading organisations including Methanex, Methanol Institute, Marinvest, DagMar Navigation, Proman, MAN and Anglo Belgium Corp, in an event which offered a unique opportunity to connect and network with fellow professionals.

For more information, please visit: https://www.imarest.org/

KEPPEL RECEIVES DNV VERIFICATION CERTIFICATE FOR THE WORLD'S LARGEST 3D PRINTED SHIPBOARD FITTING

Keppel Technology & Innovation (KTI) has received a verification certificate for a 3D printed deck mounted type Panama Chock (SWL150Ton) from DNV, the independent energy expert and assurance provider's Global Additive Manufacturing Technology Centre of Excellence in Singapore. The component, which is intended for non-class maritime applications, is the world's largest 3D-printed shipboard fitting. his component was manufactured by KTI's partner AML3D (ASX:AL3) using their patented Wire Additive Manufacturing (WAM®) process which used medium strength structural steel grade ER70S-6 wire feedstock.

For more information, please visit: www.dnv.com



INDIAN REGISTER OF SHIPPING (IRCLASS) DELIVERS EMERGENCY RESPONSE PLAN AND OIL SPILL RESPONSE RELATED SERVICES TO QATARI PORTS

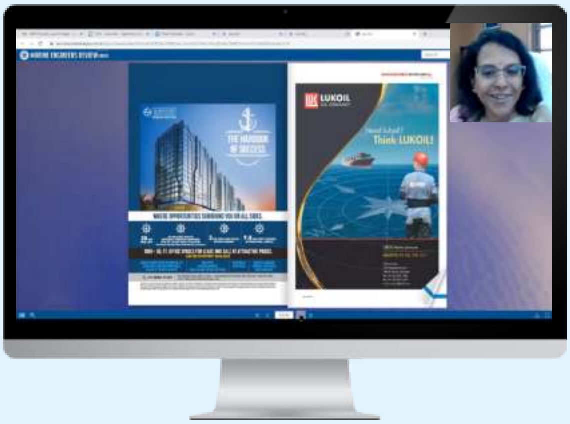
Indian Register of Shipping (IRClass) has delivered a set of detailed Emergency Response Plans (ERP) and Oil Spill Contingency Plans (OSCP) for Hamad and Al Ruwais ports. The two ports fall under the authority of Mwani Qatar. The plans meet both national and international guidelines and provide assurance that the ports will be able to respond effectively to any emergency, as well as cope with large and small-scale oil spills. The two busy ports handle a wide range of vessels including container, general cargo, ro-ro, livestock & offshore support and play a key role in Qatar's economic diversification and competitiveness strategy.

For more information, please visit: http://www.irclass.org

BRANCH NEWS

IME(I) SCALES NEW HEIGHTS

ESTABLISHMENT OF A MARINE ENGINEERING CHAIR IN IMU & MER FLIPBOOK LAUNCH



Adding another feather in the cap, IME(I) established a **Chair at the IMU** and launched **Marine Engineers Review (India) Flipbook and Journal Management System** on Tuesday, **7th September 2021** through online Zoom platform. The Chief Guest for the event was **Dr. Malini Shankar, IAS (Retd.), Vice Chancellor, Indian Maritime University and Chairperson, National Shipping Board.**

Mr. Uday Purohit, President, IME(I) welcomed the Chief Guest, past presidents, GC members, members of the institute and the marine fraternity who had joined the meet. He thanked Dr. Shankar for the establishment of the Chair. He further congratulated the publication sub-committee for the initiative of digitalising MER and also highlighted other engagements of IME(I) with Anglo Eastern Maritime Training Centre, MASSA, etc. He congratulated the first passing out batch, which had undergone the course in Ship Management & Logistics (NMIS-IME(I) collaboration).

Dr. Malini Shankar, thanked IME(I) for inviting her as the Chief Guest. She expressed delight in rejuvenating the partnership between the University and the alumni of erstwhile institutions, which are part of IMU now. The association with IME(I) would facilitate identification of research projects based on industry needs and can be undertaken by IMU, she observed. She highlighted that working on such projects would provide an opportunity to future mariners, and most importantly building the capacity of the University.

"I would like to see IMU to be the go-to institution for all problem solving related to the sector. And I would like IME(I) to be a partner in this voyage. It is a pleasure working with IME(I) and I look forward to continued association for mutual benefits to all," said Dr. Shankar.

Dr. Shankar then launched the MER Flipbook and the Journal Management System.

Giving a brief detail about the JMS and Flipbook and IME(I) Chair at IMU, Dr. Rajoo Balaji, Editor, MER and Director, IMU Chennai campus said, "The flipbook is an evolution for a journal like MER. The digital technology enables us to reach out and disseminate knowledge. In coming years, MER will become a platform where researchers can publish their work. The establishment of chair at IMU is again an evolution which will benefit the entire marine fraternity. The vision we will see at the end of the decade in 2030, will have a narrative. The narrative will still have the marine engineer, IMU and IME(I) with a purpose for the nation and the planet."

A detailed walkthrough of the Journal Management System and Flipbook was given by Ms. Rashmi Tiwari, Sub-editor, MER.

The last section of the event was the tie-up and prize distribution ceremony. The speakers were Mr. Sunil Kumar, Fellow member of IME (I) and member Training Sub-committee, IME(I) Mumbai Branch; Mr. Francis Akkara, Assistant Director & Vice Principal, AEMTC; Mr. Mohan Singh Pal, Director, Maritime Education & Training, IME(I); Capt. M.P. Bhasin, Chairman, MASSA and Managing Director, MSC Crewing Services Pvt. Ltd.; Dr. B.K. Saxena, Chairman, NMIS and Mr. V. K Jain, Chairman, IME(I) Mumbai Branch. Mr. Purohit proposed the Vote of thanks.

IME(I) Branch News Visakhapatnam

Institute of Marine Engineers (India) Visakhapatnam branch organised an online Expert Talk on **24.09.2021** at 1800 hrs through Google meet. The topic of the talk was "Stability analysis of multi-purpose cargo vessel using MAXSURF software tool." The speaker of the session was Mr. **Dauson Nyoni** (from Tanzania), Marine Engineer currently pursuing M.Tech at Andhra University, Visakhapatnam.

With the growth of maritime transportation activity across the world, arises the operational requirements of Multi-purpose Cargo Vessel (MPCV) to facilitate the functions of shipment activities. The design of merchant ships must meet the requirement of International Safety standard from IMO**,** IRCLASS and other recognised regulatory bodies.

The hull strength and stability of the vessel must be good and capable to carry out the navigation operations through different sea environment behavior of waves and winds. The proposed multi-purpose cargo vessel was designed for transporting different kinds of commodities from one port to another or from one continent to another with vast amount of cargo tons e.g., Visakhapatnam Port Trust (India) to Dar-es-Salaam Port (Tanzania). This lecture dwells upon the use of stability calculations for the multipurpose cargo vessel.

At the outset Chairman, Mr. V. Lakshmipati Rao welcomed the members and briefed about the activities of the branch. Hon. Secretary Dr. V.V.S. Prasad introduced the speaker to the members. Meeting was concluded with the vote of thanks by Chairman, Mr. Amara Vijayananda Kumar.

IME(I) Kolkata Branch AGM

The Annual General Meeting of the Kolkata Branch for the FY ending 31st March, 2021 was held on 12 September, 2021 virtually / online.

In his opening speech, the Chairman of Kolkata Branch, Mr Amit Bhatnagar, welcomed all present. He informed that owing to Covid-19, the Branch operations and activities had been greatly hampered, and EC members were working in very difficult circumstances. He also stated that, after the closure of the Facilitation Centre, the Branch was facing financial difficulties. This had been overcome to a certain extent by conducting few workshops. However, even the workshops had to be discontinued due to the pandemic.

He recounted that the International Shipping Conference – ISCO 2020 was hosted successfully jointly with the Kolkata Chapter of the Company of Master Mariners of India, on 26, 27 and 28 November 2020 in virtual mode.

Mr. Bhatnagar further recalled that Kolkata branch had also conducted a first ever sailing seminar, on the theme, 'Natural Gas as Fuel Onboard Inland Vessels in New Normal', on 31 March 2021, as part of National Maritime Week Celebrations, in collaboration with GAIL (India) Ltd, onboard vessel 'Rivera'. 5 papers were presented during the Seminar.

Minutes of the previous AGM held on 27 October, 2020 were confirmed by a show of hands. The Branch Activity Report for the year 2020-21 was read out by Hon. Secretary, Mr. Gautam Sen. Balance Sheet and Audited Accounts for the year 2020-21, which had been posted earlier to the members, were accepted without any amendments. The auditors were reappointed for the financial year 2021-22. Under 'Any Other Matters', suggestions by the members who were present were taken note of. The Hon. Secretary then proposed a formal vote of thanks.

In a First - IMO Mock Session Competition By IMU-IMEI-DMET Alumni

The Mumbai Branch in association with DMET–MERI Alumni under the aegis of the Indian Maritime University (IMU) successfully conducted the first ever IMO Mock Session Competition. The Competition was in virtual mode for the students and scholars of IMU. This maiden edition was conducted in parallel for two topics viz., HTW: Ensuring Quality of On-board Training, MARPOL: Tackling Vessel based Marine Plastic Litter.

Inaugurated by Dr. (Mrs) Malini V. Shankar IAS (Retd.), Vice Chancellor, IMU on 31 July 2021, the competition was specially curated by Mr. Rajeev Nayyer, an industry veteran who has represented India at the IMO on numerous occasions. The panel of judges comprised Dr. B.K. Saxena, Ca. Ashok Mahapatra, and Mr. Dilip Mehrotra for the HTW, and Mr. M.V. Ramamurthy, Ca. M.M. Saggi and Mr. Achintya B. Dutta for MARPOL.

44 teams (HTW) and 79 teams (MARPOL) battled for victory over a three grueling rounds viz. Elimination, Intra Campus and Inter Campus after being mentored and guided by industry experts: Mr. Mohan Singh Pal, Ca. K.N. Deboo, Mr. V.K. Chandrasekharan, Mr. Sanjeev Ogale, Mr. David Birwadkar and Ca. M.C. Yadav for HTW and Mr.T.S. Girish, Mr. C.R. Dash, Ca. Gajanan Karanjikar, Mr. T.K. Sahu, Mr. Ajoy Chatterjee, and Mr. Ritesh Kaushik for MARPOL.

The competition, which is planned to be held on an annual basis, is the stepping stone to ensure future leaders of Maritime India are exposed to the art, philosophy and science of regulations development work at the International Maritime Organization (IMO). It envisages students to be able to grasp and appreciate the regulatory framework they will be exposed to, once in the Shipping Industry.

After elimination rounds, the 44 HTW and 79 MARPOL teams whittled down to 8 and 10 teams. The Inter Campus (Final) Round was held on 14 August in the presence of Mr. S. Barik, Chief Surveyor to the GoI. The Grand Finale and Prize distribution was held on 15 August, where Mr. Amitabh Kumar IRS, DG Shipping, was the Chief Guest, and the Guests of Honor were Mr. Arne Jan FLØLO, Consul General Norway and Dr. Sujata Naik, President, INSA.

Dr. Malini Shankar during her address mentioned that 'the end result exceeded our own expectations'. She recalled how an innocuous remark by a cadet about the challenges of absorbing and understanding dry topics like the working of the IMO etc., sowed the seeds for this Competition.

In his address, Mr. Amitabh Kumar appreciated IMU for the concept of Mock IMO Sessions, and choosing topical and critical subjects for the competition. He averred that such innovative steps would enable India to progress from a Reactor role to a leadership role at IMO one day. Dr. Sujata Naik, President INSA, Guest of Honor stated that platforms like this were the need of the hour for grooming future leaders. Mr. Andre Jan, Consul General, in his message, pointed out that both countries, though far away, were united by the ocean and there were numerous opportunities for collaboration in the maritime sector.

The Awards: The team led by Cdt. Anirban Bhattacharya from the Kolkata Campus (Guide: Mr. V.K. Chandrasekharan) won in the HTW segment and team led by Cdt. Naman Singh from the Vizag Campus (Guide: Mr. T.K. Sahu) won in the MARPOL segment. The IMEI - Mumbai Rolling Shield was presented by Chairman Mr. V.K. Jain and the DMET-MERI Alumni Rolling Shield was presented by the President of the DMET-MERI Ex-Cadets Association, Mr Anil Rao. In addition, cash prizes worth Rupees One Lakh sponsored by DMET-MERI Alumni and the Mumbai Branch were also distributed.

COMPETENCY CORNER

SHIP PROPULSION: PROPELLER CURVES AND ENGINE LOAD DIAGRAMS

(This column is for the Competency examination and related topics. The Knowledge Guru for this month is VRV from HIMT, Chennai).

V. R. Venkatesan

Ship propulsion is a complex topic. The ship's hull is propelled by the propeller, which is driven by the main engine. There are 3 "players" in this activity. The relation between the 3 should be well understood by marine engineers, especially those who are operating vessels.

The hull and propeller part is covered in text books on Naval Architecture including perhaps the most well-known Introduction to Naval Architecture, by Eric Tupper. Marine diesel engines are dealt with in various well-known books. However simple explanations linking all three are somewhat lacking.

This write up is aimed at providing a simple and easy understanding of the relation between the three.

To move the ship's hull, a linear force is required. This linear force comes from the thrust generated by the propeller. As for as the hull is concerned, only "thrust" matters. The power to propel the vessel comes from the main engine. As far as the main engine is concerned, its output power is "rotary" in nature.

The formula for the power at the propeller shaft is ($2\pi N/60$) X Torque. Thus "torque" is the factor for engine, and "thrust" for hull. It is the propeller which "connects" both. Propeller takes torque from the engine and turns it to thrust. As the "middle man" the propeller has to be matched to the hull and also to the engine.

The ship's propeller is a remarkable piece of equipment. The largest ship propellers weigh more than 150 tonnes and are more than 11 m in dia. These can handle engine output power of even 80,000 kw. All this in a single piece of metal which remains beyond our sight, underwater.

This write-up focusses on certain features of the fixed pitch propeller. Key factors related to the selection of a propeller, for a ship are covered. In particular, the selection of diameter, pitch and rpm are discussed. For a particular hull and propeller combination, how is a particular prime mover selected is also discussed.

For the marine engineer on-board, understanding the factors influencing the operation of the engine is very important. Implications of the engine selection for operational safety of the vessel have to be understood. An underpowered vessel is vulnerable in many ways.

When the prime mover is diesel engine, there are more issues. In a steam turbine, the energy produced (propulsive power) is stored in the steam and in the boiler. To produce the required power, steam at the correct rate has to be delivered to the turbine. However, in a diesel engine with combustion, (where the force is directly applied on the mechanism of piston-connecting rod etc.), the energy output is cyclic. Producing the required power is not a simple matter of pumping more fuel into the engine. The fuel has to be burnt in a short time available, keeping mechanical and thermal stresses under limits.

We will attempt to integrate these ideas meaningfully in **3 parts**.

Part 1 will cover matters relating to the hull.

Part 2 will focus on propeller characteristics and will seek to explain in simple terms, the reasons for selecting propellers of certain dimensions. For example, why is that usually the largest possible diameter is chosen for a propeller but the pitch has to be just right; not too less and not too much etc. **Part 3** will focus on matching the propeller with the right engine.

Resistance experienced by the hull is the most important variable in the operation of the vessel. It is also the single most external factor affecting fuel consumption, greenhouse gas emission etc., and needs to be understood well.

To put in perspective, all shipboard engineers are aware that increasing the rpm of the main engine results in increased power output. However only a few are aware that the relation between rpm and power is not linear. Engine power is in fact proportional to cube (or even more) of the rpm.

Engineers also need to understand that many changes within the engine such as type of fuel used, condition of engine parts such as fuel pump, injector, piston ring and liner largely **do not** affect the power output of the engine. **The power is influenced only by the RPM and conditions external to the engine**.

We will go into Part 1: Components of resistance faced by the hull and matters related to it

When a ship's hull is propelled through water, it experiences 4 types of resistances.

1. Frictional Resistance
2. Wave making resistance

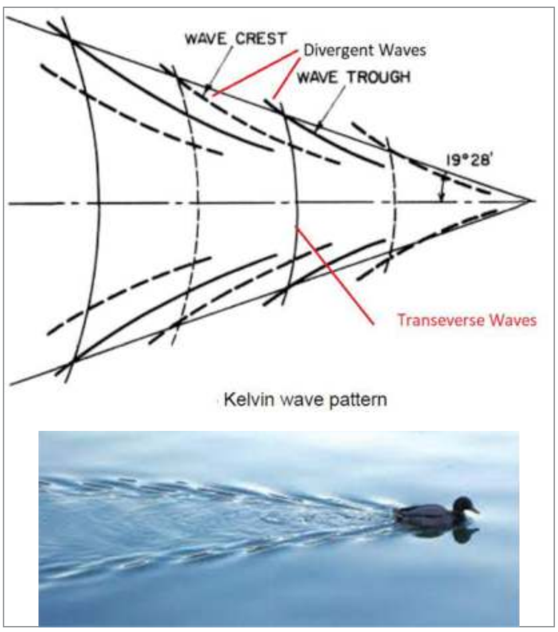


Figure 1: Wave Patterns

Resistance experienced by the hull is the most important variable in the operation of the vessel. It is also the single most external factor affecting fuel consumption, greenhouse gas emission etc., and needs to be understood well

3. Eddy resistance
4. Air/wind resistance.

The focus will be on the two main components, frictional and wave making.

Frictional resistance:

As a ship moves through the water, the friction of the water acting over the entire wetted surface of the hull causes a net force opposing the ship's motion. This frictional resistance is a function of the hull's wetted surface area, surface roughness, water viscosity and most importantly the speed of the ship. Frictional resistance is proportional to the wetted surface area and proportional to ship speed raised to an index close to 2. Unlike dry friction which ***does not change*** with area of contact or sliding speed, fluid friction is influenced both by area of contact and velocity. This is applicable both to fluids passing through pipelines, and also to ship's hull moving through water. Through various experiments conducted by William Froude, Osborne Reynolds and many others, the calculation of frictional resistance have been developed and refined.

Wave making

When a ship moves through water it makes waves. In any wave, water is lifted above the surface. To lift the water against gravity, work has to be done. The energy for this comes from the vessel. When the water lifted in the wave comes back down, the energy ***cannot be transferred back to the hull*** and remains in the water to be dissipated in the surrounding. This wave making is a "drain" on the kinetic energy of the vessel.

Wave patterns

Waves generated by a ship's hull exhibit a particular pattern of divergent and transverse waves. Interaction between the waves results in ***non-uniform change*** in wave making resistance at increasing ships speeds s as shown by the **Figure 1**. Even ducks make a similar wave pattern!!

Froude number

The proportion of different forms of resistance for vessels of different lengths and velocity can be seen on the basis of Froude number. Naval architects, as well as all engineers and scientists, use dimensionless coefficients to describe the performance of a system or to compare

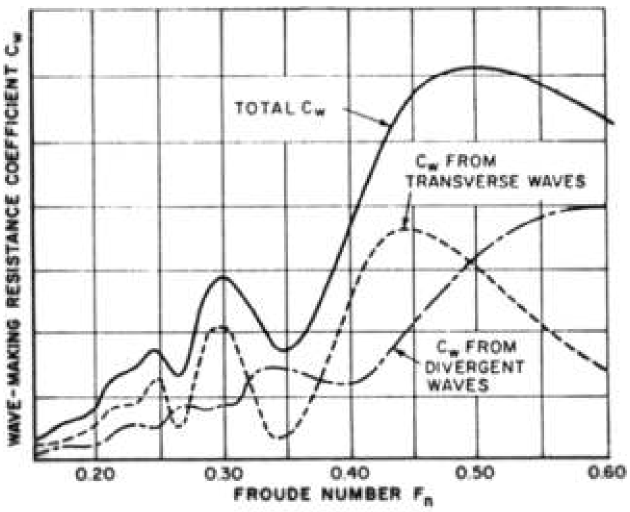


Figure 2 Froude Number to Wave-making Resistance

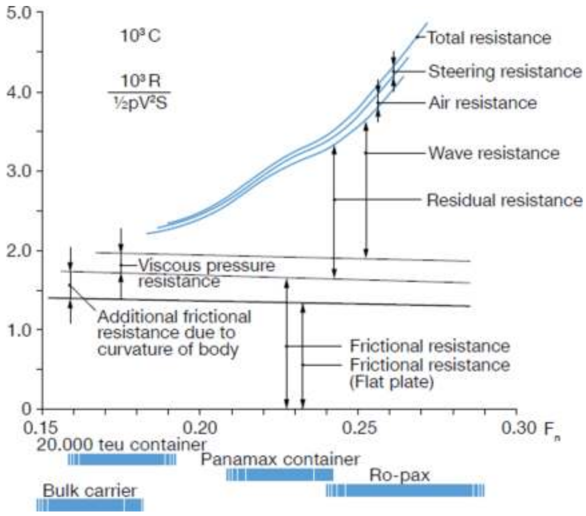


Figure 4 Resistance Comparison of typical vessels

different systems to each other. Froude number is a dimensionless number used to compare resistance.

Froude number is given by

$$Fn = \frac{V}{\sqrt{g \times L_{WL}}}$$

As can be seen in the **Figure 2**, wave making resistance increases with increase in Froude number. For a ship of given length, increase in speed results in an increase of Froude number.

As can be seen in **Figure 3**, for low ship speeds, frictional resistance dominates. At increasing speeds, the wave making resistance contributes significantly. Wave making resistance does not increase uniformly. Due to interaction between wave patterns created by different parts of the vessel, the rate of rise in wave making resistance is ***not uniform***.

The equation for total resistance in terms of dimensionless coefficients is,

$C_T = C_V + C_W$

Where: C_T = coefficient of total hull resistance

C_V = coefficient of viscous resistance

C_W = coefficient of wave making resistance

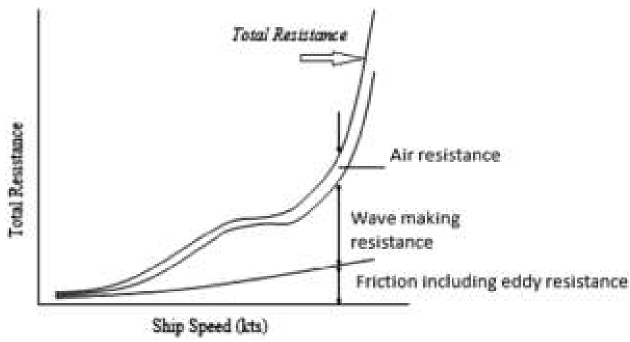


Figure 3 Ship's Speed to Resistance

$$C_T = \frac{R_T}{\frac{1}{2}\rho \cdot S \cdot V^2}$$

Where: R_T = total hull resistance; ρ = water density; S = wetted surface area of the underwater hull.

V = velocity

$$R_T = \frac{1}{2} \cdot C_T \cdot \rho \cdot S \cdot V^2$$

To illustrate the above calculations and the graphs, take the example of a vessel with the following details.

Ship type: Bulk Carrier

LBP: 199 m; Speed 14.5 knots; DWT 53000; Draft T: 13.1 m

For a bulk carrier L_{wl} = 1.02 LBP

This will result in a Froude number value of 0.167

This will result in a Ct value of 2.1/1000 from the graph (**Figure 4**).

Wetted surface area can be calculated from the approx. formula as below

$$S = 0.99 \cdot \left(\frac{\nabla}{T} + 1.9 \cdot L_{Wl} \cdot T \right)$$

From above values the WSA will be 9534.5 m².

The total resistance will be equal to about 571 KN.

This resistance value is for clean hull and calm weather.

From this value, the thrust to be developed by the propeller will be calculated. However other factors will come into effect once the propeller is introduced. These will be covered in **Part 2**.

About the Author

Chief Engineer **V. R. Venkatesan** is the Director (Academics) with Hindustan Institute of Maritime Training, Chennai.

Email: vrv@himtmarine.com

ENSURING DRINKING WATER QUALITY ON BOARD

Water safety and quality are fundamental to crew members and passengers on-board. Considering that water storage and distribution systems on ships are complex and could provide conditions for bacterial contamination, potable water on ships must be obtained only from those water sources and water supplies that provide potable water and are approved by the health administration or health authority.

In this respect, the ship's master or the officer who is responsible for the loading of water must ascertain whether or not the source of water is safe for use.

Health Risks

Associated with storage and distribution system of potable water on ships, the following should be taken into consideration:

1. Limited space on ships means that potable water systems are likely to be close to hazardous substances such as sewage or waste streams, and sources of heat.
2. Evidence from disease outbreaks indicates that contamination from sewage is one of the most common causes of waterborne outbreaks on ships.
3. Water production on board through Desalination, Reverse Osmosis or Evaporation can be associated with its own potential health problems.
4. Corrosion in plumbing may lead to metals leaching into water. Desalinated water produced on board may be corrosive while saline atmospheres may also have additional corrosive effects.

As per WHO requirements, water to be used for potable water purposes aboard ships must be provided with sanitary safeguards from the shore source, through the shore water distribution system, including connections to the ship system, and through the potable water system at each outlet in order to prevent contamination or pollution of the water during ship operation.

1. **Physicochemical:** Such parameters are easy to be noticed as they include, appearance, colour, taste which are easy to be checked. Additional parameters as PH, Conductivity, Salinity, chlorine, metals and hardness are laboratory checked and marked by all water providers on delivery notes.
2. **Microbial parameters:** These parameters are not easy to be monitored as they cannot be identified at first sight. These parameters include quantity of coliforms, Escherichia coli (E. coli), Intestinal enterococci, Heterotrophic plate count (HPC) etc. There are minimum industrial standards and limits for drinking water contamination by above parameters and they are subject to laboratory analysis after sampling.

Best Practice

Each ship operator should provide managed vessels with guidance for drinking water supply, storage, distribution and use, in accordance with the following applicable guidelines:

1. International Health Regulations (IHR) of WHO
2. European Union (EU), Drinking-Water Directive (DWD) 98/83/EC
3. MLC 2006 (Standard A3.2-Food & Catering)
4. World Health Organization (WHO), (Guide to Ship Sanitation, 3rd Edition, 2011 & Guidelines for Drinking Water Quality, 2008)

A water safety plan (stand alone or part of catering safety plan) should be followed on board including procedures for purchasing, delivery, sampling, storage and distribution of drinking water on board.

Safety/security of water tanks to be considered for security or sabotage purposes also.

Labelling of water storage/draw points on board is vital in order that crew and passengers may be informed of the sources and also if the water is drinkable or not. Hoses and piping system should also be labelled for drinking water and procedures for testing to implemented.

As per MLC 2006, "frequent documented inspections" of drinking water supplies should be carried out. This ensures that ship-owners are acting responsibly with a clear trail for port state control officers to inspect. To ensure water quality stability it is recommended that examination be carried out at **least twice a year**.

The frequency of the tests will be determined based on the following criteria:

1. frequency of ship drinking water supply
2. refreshing of water through the desalination process
3. visual observation
4. Monitoring the treatment procedure (check & optimise the treatment system according to manufacturer's instructions, re-hardening system, UV sterilisation system, etc.).

Sampling should be performed from locations considered as highly hazardous. Specific sampling points should be taken into account, such as:

1. potable water supply lines
2. freshwater tank systems
3. toilets & showers
4. galley
5. crew or passengers' cabins
6. any other connection or tank that has been used for potable water

Furthermore, requirements regarding drinking water on board by the Flag Administrations need to be taken into consideration.

Collected from various topics of W.H.O.

NOTE: Recently, on-board a ship, the drinking water sterilizer was non-functional (no spares were available on-board). There was an inordinate delay and the sterilized water could not be provided. A crew member reported the matter to the PSC with photographic evidences, just before arrival in a Port. The ship was fined, vessel was detained and the Master was issued a warning.

About the Author

L.S. Ganapathy, Email: ganapathyls@gmail.com

This forum is for reflections from readers.
Do mention your name, email, membership grade and number (if Member of IMEI) with your mails.

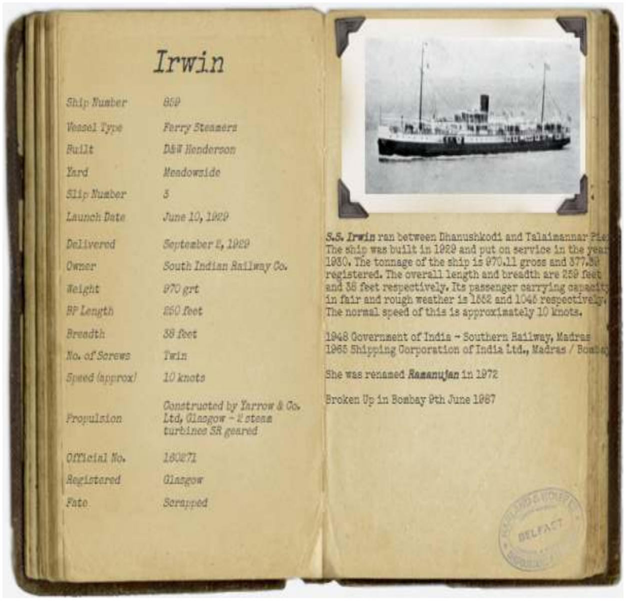
Travels down the time...

When I was kid of about 12 years old (*circa* 1969), during the school holidays we used to travel from Chennai to Colombo by train-ship-train to visit my father who was stationed at Colombo looking after his business interest.

The first part of the journey would be by Rameswaram mail or the Indo-Ceylon Express. It used to be called as Boat Mail also because it carried the post etc., (mail and the people who will board the boat) to be delivered to the steamer, which would carry it across the waters to Ceylon (Sri Lanka). And those were peaceful times also.

One has to board the Boat Mail from Madras Egmore station. The journey time lasted for around 24 hrs. The train usually left early morning around 7-8 am and reached the Railway station at Rameswaram (Dhanushkodi) Island, next day morning. On the same day afternoon, we used to take the ship S.S. Ramanujan.

The vessel S.S Ramanujan used to be in the anchorage. We used to take a big country boat from a small jetty to the anchorage. The country boats usually carried 20 to 30 people. There were no cabins for passengers in S.S Ramanujan. The vessel had a first class deck and a second class deck, sheltered on top. There were benches and chairs around where one can sit, relax and enjoy the sea ambience. The voyage lasted about three and a half hours covering a (ground) distance of around 30 km.



Irwin

Ship Number	859
Vessel Type	Ferry Steamers
Built	D&W Henderson
Yard	Meadowside
Slip Number	3
Launch Date	June 10, 1929
Delivered	September 2, 1929
Owner	South Indian Railway Co.
Weight	970 grt
BP Length	250 feet
Breadth	38 feet
No. of Screws	Twin
Speed (approx)	10 knots
Propulsion	Constructed by Yarrow & Co. Ltd, Glasgow - 2 steam turbines SR geared
Official No.	160271
Registered	Glasgow
Fate	Scrapped

S.S. Irwin ran between Dhanushkodi and Talaimannar Pier. The ship was built in 1929 and put on service in the year 1930. The tonnage of the ship is 970.11 gross and 377.39 registered. The overall length and breadth are 259 feet and 38 feet respectively. Its passenger carrying capacity in fair and rough weather is 1552 and 1045 respectively. The normal speed of this is approximately 10 knots.

1948 Government of India - Southern Railway, Madras
1965 Shipping Corporation of India Ltd., Madras / Bombay

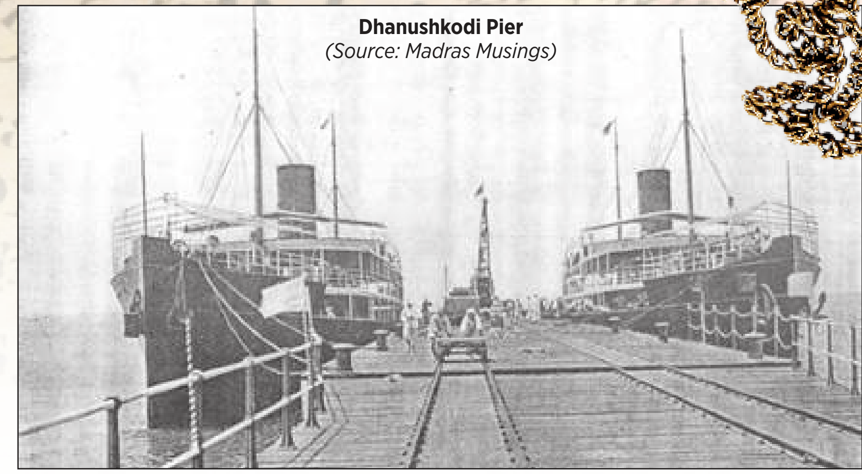
She was renamed **Ramanujan** in 1972

Broken Up in Bombay 9th June 1987

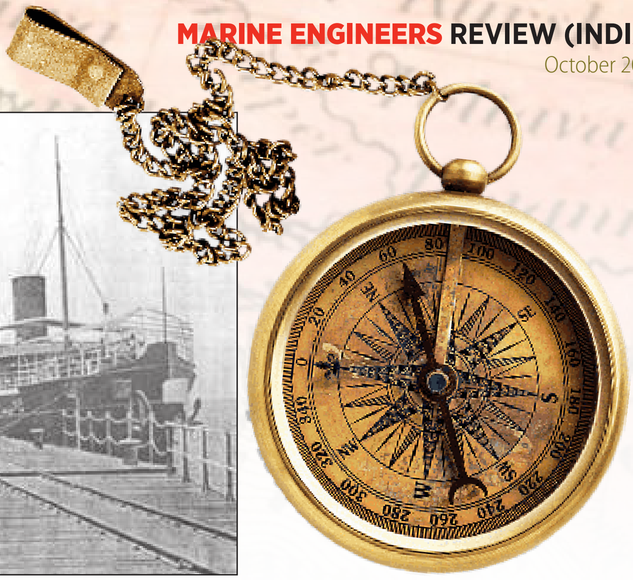
Details of S S Ramanjuan

On the ship, one can see the reciprocating steam engine from the top deck. The Engineers used to wear white boiler suits. I was fascinated with the machines and ship. That made me to think of joining the merchant navy as a Marine Engineer. On the other side (Ceylon) was a jetty at Talaimannar. From there, we used to take a train bound to Colombo. The whole journey (train/ship/train) from Egmore to Colombo took just over 2 days.

The ticket for the entire trip (train/boat/train) could be bought from Egmore station and costed around Rs. 30 for second-class and around Rs. 60 to 80 for first-class (the upper deck). The bosun of the ship was my school mate's uncle. We used to take 2nd class ticket for the journey and on reaching the ship, the bosun will let us sneak into 1st class deck and we used to enjoy ourselves. I met the same bosun after a couple of years at Singapore pier. I was a 4th engineer by then and my ship was tied up next to his vessel on the same pier. He was going ashore from M.V. Chidambaram (The passenger vessel which sailed between Chennai and Singapore). He could not recognise me and I introduced myself and recalled all the fun on board S S Ramanujan. He was indeed very happy and



Dhanushkodi Pier
(Source: Madras Musings)

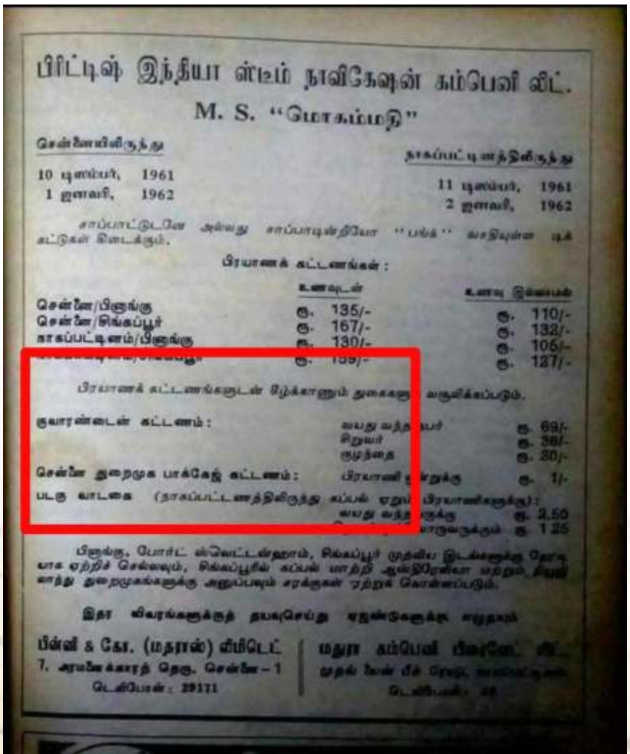


excited to see me as 4th engineer. Call it destiny that he played a small mentor's role in my life and my chosen profession of marine engineering.

Lot of foreigners and Sri Lankan seamen used travel by road from Europe to India and from India to Sri Lanka through this multi-modal facility. Cars (one car at a time) will be loaded onto the boat arrangement (With two country boats tied up together) by driving through. The boats will take the car to the ship and then the ship's cranes will place the car on deck. I must have travelled 5 to 6 times on the same ship whenever we got long school holidays. These are some memories of my sea travel on a steamer to Sri Lanka.

Some interesting facts about S.S. Ramanujan (Some additional info is attached taken from the Harland & Wolff pages while web hunting):

Typical Advertisement for the east bound ships of those days



Built 1929; First owner; South Indian Railway Co; Latter SCI took over 1965; Passenger carrying capacity 1552; Twin screw steam engines.

R. Muthusamy (F 3989). rsamy501@gmail.com

Reference:

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2. http://www.theyard.info/ships/ships 0

Mail to editor

Dear Editor,

First of all I want to congratulate you and the team for launching MER Journal Management System and Flipbook. The September Issue came out very nicely. I am able to see the hard work and effort the team is putting into. I personally liked Dr. Purnima Jalihal's article on Ocean Technology. It was very informative as well as catchy. You have taken the journal to a great height.

Best wishes for future!

Dr. Vedachalam

Dear Editor,

Thank you for publishing my review in full and for the page get up! Shared it with my contacts on social media including Mr Ranadive. I also wish to congratulate you and the MER team for launch of the digital version. Under your able leadership MER has evolved into a truly professional publication. I see a definite improvement in its content as well as presentation. Great job!

Mr. URP Sudhakar

LUBE MATTERS 4: MEASURING OIL CLEANLINESS

Sanjiv Wazir

Introduction

The primary function of a lubricant is to separate surfaces to reduce friction. Particulates in the lubricant can disrupt the hydrodynamic or elasto-hydrodynamic (EHD) lubrication film between the metal surfaces leading to premature wear of the metal surfaces. When metal-to-metal or particle-to-metal contact exists because of a loss or break in the lubricating film, adhesive and abrasive wear occurs. This generates more wear particles that further contaminates the oil.

Sources of particulates

Solid particulate contamination can come from wear debris, dirt (silica), seals, gasket materials and scale/ rust products in reservoirs and oil storage containers. Regardless of the solid contaminant type, when the size of the particulate is greater than the clearance between metal rubbing surfaces, abrasion of the metal surfaces occurs.

(Reader may refer to LUBRICATION ENEMY NO.1, MER 12/2014 by the author for more details on particulate contamination)

Typical Clearances in Hydraulic Components

All types of oil lubricated machinery components such as gears, vanes, casings, valves, rotors, hydraulic pumps and motors, compressors, bearings, etc., are made to various standard fits and clearances **(Figure 1)**. Precision rotating components such as rolling element bearings are manufactured to even closer clearances between contacting metal surfaces.

COMPONENT	CLEARANCE (μm)
GEAR PUMP	
Gear Pump	0.5 - 5
Side Plate	0.5 - 5
Gear Housing	0.5 - 5
VANE PUMP	
Vane tip	0.5 - 5
Vane Surface	5 - 13
PISTON PUMP	
Piston Bore	5 - 40
Valve Plate cylinder	1.5 - 10
SERVO VALVE	
Control Piston	18 - 63
Baffle Plate	2.5 - 8
CONTROL VALVE	
Control Piston	2.5 - 23
Cone Valve	13 - 40

Figure 1 Fitting Tolerances of some hydraulic Components (Ref. 1)

Quantifying the number of particles in the sample

To quantify the quantity and size of solid particulate contamination in oil, ISO has developed standard ISO 4406. This standard, (see **Figure 2**) provides the method for expressing oil cleanliness based on the solid particulate micron size and the quantity of that size particulate present in the oil. These cleanliness standards correlate to the identification of solid particulates measuring ≥ 4, ≥6 and ≥14 microns (represented as R4/R6/R14) according to the quantity of these solid particles found per ml of oil.

Acceptable limits to sizes & numbers of particulates

The clearances between rubbing surfaces for each equipment type determine the maximum particulate size that can be allowed in the oil before abrasion occurs. Besides clearances in larger components & assemblies like gears and rotors, the same lubricant may be lubricating the shaft bearings and seals that have much finer clearances. High pressure hydraulic system components, screw compressors have even tighter clearances. Rolling Element Bearing clearances are also exceptionally fine. Clearances in all the components of a system must be considered and cleanliness level that corresponds to the smallest clearance must be used

ISO 4406 SCALE NUMBERS		
NUMBERS OF PARTICLES PER ml		ISO SCALE NUMBER
MORE THAN	UPTO & INCLUDING	
80,000	1,60,000	24
40,000	80,000	23
20,000	40,000	22
10,000	20,000	21
5,000	10,000	20
2,500	5,000	19
1,300	2,500	18
640	1,300	17
320	640	16
160	320	15
80	160	14
40	80	13
20	40	12
10	20	11
5	10	10
2.5	5	9
1.3	2.5	8
0.64	1.3	7
0.32	0.64	6
0.16	0.32	5
0.08	0.16	4
0.04	0.08	3
0.02	0.04	2
0.01	0.02	1

Figure 2 ISO 4406 Cleanliness Code

when determining the oil cleanliness level required for a system (see **Figure 3**).

Measuring the Number and Sizes of Particles in the Sample

The two commonly used techniques for measuring the number of samples in the oil sample in the lab are microscopy & laser light blockage.

ISO CODE NUMBERS R4/R6/R14	TYPE OF SYSTEM	SENSITIVE COMPONENTS
23/21/17	Low Pressure Systems with large clearances	Ram Pump
xx/20/17	WinGD Engine oil (Other limits for particles > 20 micron)	
20/18/15	Typical cleanliness of fresh hydraulic oil from oil manufacturer. Low pressure heavy industrial system	Flow Control Valves. Cylinders
19/17/14	Med Pressure general machinery & mobile equipment	Gear Pumps & Motors
xx/19/16	MAN, Engine oil before engine	
18/16/13	High Quality Reliable Systems. Typical HSD cleanliness standard	High Pressure pumps & Motors. Directional & Pressure control valves
xx/16/13	MAN, Engine oil after servo filter (ME Engines)	
17/15/12	Hydrostatic transmissions & sophisticated control systems	Proportional Valves
16/14/11	High-Pressure Long-Life systems and Servo valves	Industrial servo valves
15/13/09	Overly critical systems requiring high reliability that are extremely sensitive to dirt	High Performance servo valves

Figure 3. Recommended Oil Cleanliness Levels (Ref. 1, 2)

Optical Microscopy (ISO 4407)

Figure 4 Optical Microscope

The original method for determining the level of particulate contamination in liquids used in hydraulic systems was by counting the number of particles deposited on the surface of a membrane filter using an optical microscope. Particle sizes ≥ 2 µm can be measured and counted by this method. While it is slow and expensive, it is the most accurate method of particle counting, unaffected by some of the limitations of automated methods. MAN recommends use of this method for particle count of Mn Eng. Hydraulic oil **(Figure 5)**.

Automatic Optical Particle Counting (ISO 11500)

The most widely used method for determining lubricant cleanliness is to use an automatic optical particle counter. In a laser-based APC instrument, due to the parallel nature of the laser beam, light scattering from the unimpeded laser beam is minimal, until a particle passes through the instrument. As the laser beam strikes the particle flowing with the sample through a capillary tube, light scatters and hits the photocell. There is a change in voltage across the photocell that is related to the size of the particle. Since the particles in the lube sample are not usually spherical, an algorithm generates an "equivalent spherical diameter" for the particle. Automatic particle counter does not work well with dark lubricant or one that is heavily contaminated with silt or soot or is emulsified.

To quantify the quantity and size of solid particulate contamination in oil, ISO has developed standard ISO 4406

Before the engine or the hydraulic filter:
The oil cleanliness should be in accordance with ISO 4406, acceptance criteria xx/19/15.

After the engine or the hydraulic filter:
The oil cleanliness should be in accordance with ISO 4406, acceptance criteria xx/16/13.

Cleanliness of hydraulic oil is normally examined by the laser method. However, this is not a suitable method for the system oil, as the system oil is black containing harmless soot, small water-droplets, air-bubbles, etc., which the laser method counts as particles. With the microscope method, the soot, etc., is removed and merely the number of actual particles are counted. MAN Diesel & Turbo therefore recommends using the microscope method (ISO 4407).

Figure 5 MAN, recommendations for main engine oil cleanliness and PC measurement (Ref.2)

Measurement of particles using an optical microscope as specified in ISO 4407 establishes the size of a particle as being equal to its longest dimension, whereas an optical particle counter derives the size of an equivalent spherical particle from its cross-sectional area, a value different in most cases from that determined with a microscope.

Expressing the PC results

The particle size/numbers measured by either by microscopy or laser method are then expressed by the ISO 4406 code number. See example below.

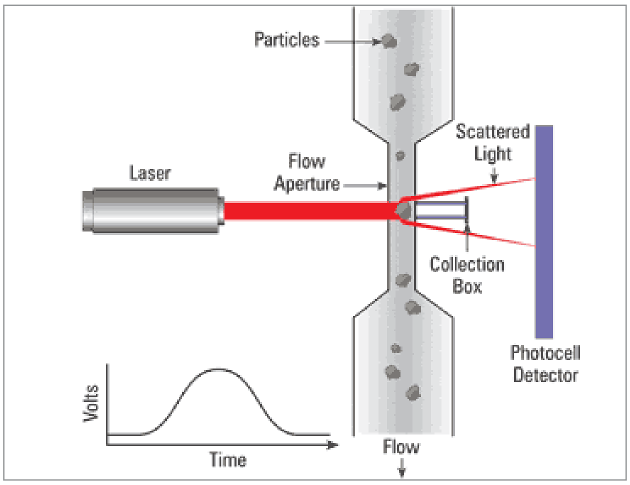

Figure 6 Light Scattering Particle Counter (Ref. 3)

Example Particle Count	
Size in Microns	Particle Count ≥ size, per ml
4	6205
6	1854
10	732
14	387
20	94
50	27
75	7
100	1

R4/R6/R14

ISO 20/18/16

ISO code number	Number of Particles per ml	
	More than	Up to and including
22	20000	40000
21	10000	20000
20	5000	10000
19	2500	5000
18	1300	2500
17	640	1300
16	320	640
15	160	320
14	80	160
13	40	80
12	20	40
11	10	20
10	5	10
9	2.5	5
8	1.3	2.5
7	0.64	1.3

Figure 7 Example of determination of ISO 4406 Particle code numbers from the measured particle counts of a sample

The clearances between rubbing surfaces for each equipment type determine the maximum particulate size that can be allowed in the oil before abrasion occurs

About the Author

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

Email: sanjiv@lukoil.com

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STELLAR NAVIGATION IN THE CHOLA ERA: A TRIBUTE TO B. ARUNACHALAM

Dennard H D'Souza

ABSTRACT: The Southern Peninsula of India has had an ancient tradition of navigation dating from the early centuries of the *Sangam* Era (300 B.C.E – 200 C.E). Texts like the *Akananuru, Purananuru, Pattinapalai* etc., which are great works in Tamil literature speak vividly of maritime activity on the coast of Southern India. Corroborating the ancient Tamil accounts are foreign travelogues, like the *Periplus of The Erythraean Sea,* which gives a detailed description of seafaring activities, geographical contours and merchandise traded in the southern Indian peninsula.

In the period following the Sangam era, the *Pallavas* held sway over both land and sea. As per the Vayalur inscription, it can be inferred that the *Pallavas* maintained a naval fleet. Besides their militaristic prowess, the *Pallavas* were facilitators of sea trade especially with countries of the Far East. A Tamil-Brahmi inscription and a Pallava coin found in Takua Pa in Thailand point to this trade link.

Long after the *Pallavas* had lost power to the Mediaeval Cholas in the Tamil country, the Cholas like their predecessor the *Pallavas*, maintained a naval force which attacked Sri Lanka in the south and the kingdom of Sri *Vijaya* in the Far East. The *Chola* era was not only a watershed period in the history of southern Indian naval competency, but it is also a period of a burgeoning overseas trade. Trade corporations like the *Nanadesi* and the *Ainurruvar* had a wide network stretching as far as Arabia in the west to china in the east. All of this would not have been possible without a thorough knowledge of navigation and seafaring techniques. It is well known from Arab sources that the Cholas relied on stars for charting the sea. They also made use of instruments like the *Ra-p-palagai* for position fixing and the *Tappu Palagai* to measure speed at sea. Besides this, the early medieval Chola navigators were expert boat builders, producing crafts for long voyages. This paper analyses various nautical practices employed by the Cholas from diverse sources.

Keywords: Nautical Practices, Medieval South India, Cholas, Pallavas, Boat Building, Celestial Navigation.

Background

"The emerging Vankam (ship) plies across the rising waves of the open sea, driven by the wind force, without knowing the limit of the sea and unaware of the night or day-time; the captain of the vessel once he leaves the sandy coast and the guiding light, steers it well aided by nature."

- *Akananuru*

The above passage is from the Akananuru, an anthology of Tamil poems which was composed somewhere before the 2nd century of the Common Era. It tells us of wind propelled craft whose Captain is skilled enough to navigate the sea without the use of guiding lights. Thus, hinting to the presence of a robust nautical tradition as early as the second century C.E. The period succeeding the Sangam Era is marked by a brief hiatus called the *'Kalabhra'* interregnum. Viewed as an era of darkness, the *'Kalabhra'* period is conspicuous for the lack of historical data, so much so that archaeology does not throw up any substantive material findings. Even if there was maritime activity, the record remains incomplete. However, with the decimation of the *'Kalabhras'* in the 6th century, Tamilakam bounced back to its former glory with the ascension of the Pallavas and the Chola after them. Maritime activities peaked during this period.

Although in the Pallava Era, South India had regained its maritime prowess with the deployment of a naval expedition to Sri Lanka, it was actually the Cholas who traversed the threshold of Indian navigational history by launching naval attacks on the irate Sri Vijaya kingdom (Modern Day South East Asia). Convening a naval attack would be a demanding task. Knowledge of sea routes, climate, and asterisms for position fixing would have been of major importance. And this could have only been possible had the Tamils developed a sophisticated corpus of navigational knowledge. This they certainly did!

Ironically enough, nothing in this genre of literature survives from that period and what is available are excerpts from Arab accounts alluding to Chola navigational practices and later date redactions of navigational texts from Kerala and Lakshadweep, which preserve remnants of older material tracing from earlier periods, most likely from the Chola era[1]. Prof Arunachalam painstakingly compiled the data from disparate sources and collated into a well edited book called the Chola Navigational Package. This was a milestone in the study of early medieval Indian maritime history, never before an attempt was made by Indian academia to reconstruct the seafaring practices which evaded documentation in the copious literary production of Indian vintage.

The Arab Accounts of Chola Navigational Material

The early medieval Chola school of navigation was favourably received by Arab navigators like Ahmed Ibn Majid (circa 1432 – 1500), who is often cited as authority by later date Arab navigators. Ibn Majid in his book *Kitab Al Fawa'id Fi Usul Al Bahr Wa'l Qawa'id* often makes reference to Chola navigational practices so much so that the second half of the seventh *Fa'ida* may have been taken almost literally from a Chola pilot's sailing direction[2]. Surprisingly around the time of Ibn Majid, the Chola Empire had ceased to exist and South India was now under the grip of the Vijayanagara Empire but the navigational digest of the Cholas may have still been in circulation. Tibbet states that Ibn Majid inherited a long tradition of Arab navigation in the Indian Ocean[3] and it would go without a doubt that Arab navigators before Ibn Majid, whose tradition he inherited would have made contact with the Chola navigators of the day.

Stellar Navigation Chola Style

The Tamil seamen used a handful of stars for navigation. A set of 56 stars were used by navigators to chart their route out at sea. Most of these stars were moon culminating and close to the ecliptic with Canopus and the Great Bear being exceptions. Some of the stars used by the Tamil navigators were *'Margasiram', 'Tiruvadirai', 'Makham', 'Krutikka', 'Rohini', 'Poosom', 'Punarpoosam', 'Chitrai', 'Swati', 'Kettai', 'Tiruvonam', 'Revati'* to name a few[4]. However, these stars are seen in the lower latitudes of the northern hemisphere therefore susceptible to being poor visibility. Stars like *'Mukkona Velli', 'Saptarishi', and 'Kapila Nakshatra'* are visible in middle and higher latitude and were therefore reliable stars for navigation. The voyaging season would start in January with the sighting of the *'Ardra Nakshatra'*. This day was marked with the celebrations of *'Arudra Darisanam'*, in all Shiva temples across the Coromandel coast and more specifically in the Nataraja temple in Chidambaram which also happened to be the imperial temple of the Chola.

Seamen Names	Indian classical	Standard English
Ottrai Velli / Malaya Velli	Agastya	Canopus
Nalu Velli / Ciluvai Velli Sanku Velli / Crus Velli	Trisanku	Southern Cross
Ezhu Velli / Kappal Velli	Sapta Rshi	Ursa Major/Great Bear
Cemmeen (Red Star)	Ardra	Betelgeuse
Margaseeram	Mrigasirish	Bellatrix
Ulakkai Velli	Haran	Orion Belt
Araan Kottai / Kootu Velli	Kruttika / Kartik	Pleiades
Odakol / Iranai Velli	Punarpoosam, Poosam	Pollux-Castor, Procyon
Sottu Velli / Sothi	Swati	Arctrus
Sothi Velli	-	Capella
Tiruvonam	Sravan	Alpha Aquila
Mukkona Velli		Cassiopiea
Chittirai	Chitra	Spica Virginis
Makam	Magh	Regulus
Trasu Velli	-	Centauri (Alpha, Beta)
Vada-Meen, Vaadai Velli	Arundati	Al Cor

Figure 1: Navigation stars of Tamil coasts
(Source - Chola Navigation Package by B. Arunachalam pg. 55)

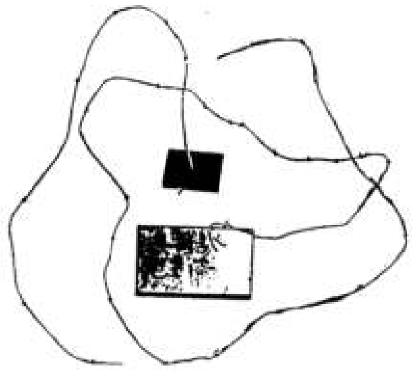
Figure 2: Thiruvonam
(Source: www.thoughtco.com)

The *'Ardra'* and *'Margasiram'* were used as pathfinders for sailing in the East-West direction. Another star related to the *'Ardra'* is the *'Thiruvonam'* which was alternatively used by Tamil sailor as a stellar rhumb especially in the evening for position fixing. Since the 'Ardra Nakshatra' is only visible at dawn in the East and can only be seen at dusk in the evening due west, Thiruvonam rises in the evening towards the east[5] thus making it useful rhumb indicator for mariners to set sail in the eastward direction especially in the evenings.

They were aware of the fact that the high tide shifted by 48 mins each day. The knowledge of 'tithi' (a day established after calculation from the new moon) and high tide duration and date from the period of *'Ekadasi'* to *'Chaturthi'* indirectly associating the location the moon and the sea. Rightly said, the Chola navy was termed as a blue water navy with its vast expanse of knowledge of the sea and a desire to interpret it for better.

[1]Arunachalam.B. Chola Navigational Package, Maritime History Society, 2004, P59

Figure 3: Ardra nakshatra
(Source - chidambaramhiddentreasures.com)



Ra-p-palagai, with two boards

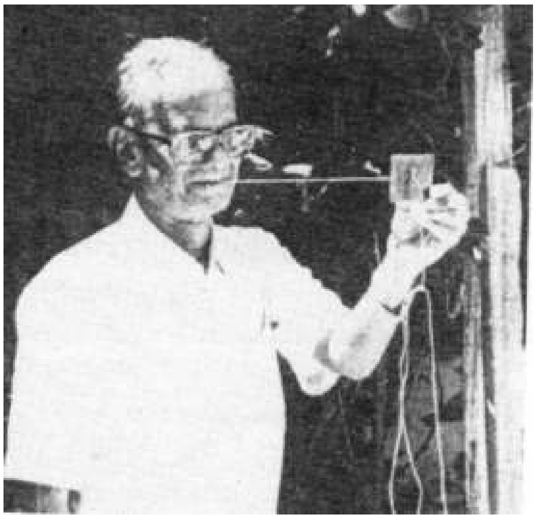


Figure 4: Ra-p-palagai instrument
(Source - Chola Navigation Package by B. Arunachalam pg.56)

Instruments used for navigation during the Chola Era

The Tamil seamen used instruments like the *'Kau Velli Palagai'* or *'Ra-p-palagai'* as it is known in Lakshadweep to determine the latitude. The *'Ra-p-palagai'* was made from a rectangular board measuring 3" x 2.4" i.e. 4 x 3 *virals* (A viral is a space between two knuckles of the middle finger) with a hole in the exact center through which runs a string knotted and fixed at the back of the board. The string has a number of knots where each knot position corresponds to specific ports of call. This is determined by repeated visits to the port with aid of a star. The *'Ra-p-palagai'* board is used by placing the string between the teeth and aligning the lower rim of the board with the horizon and the upper rim with the star. The specific knots help in identifying the position of the port of call[6]. However, the *'Ra-p-palagai Sastram'* maintains that the board can only be used in the northern hemisphere.

Conclusion

With a documented history of maritime activity comprising trade and naval expeditions, it is highly probable that the Tamils possessed the wherewithal including the much-needed nautical knowledge to traverse the sea. Sadly, these practices were either not penned down or if written, did not survive the ravages of time thus, leaving the record on this aspect of human endeavour incomplete.

Fortunately enough due to the efforts of Prof. B. Arunachalam who reconstruct some of the nautical practices from foreign accounts. For example, from the Arab Navigational digest like the Fa'waid and indigenous sailors' manuals, which contain elements from the early medieval nautical practices, we were able imagine how the Cholas would have sailed the ocean using method of stellar Navigation. What we learn from these sources is that the Cholas had a very sophisticated nautical package of its time. For example, Ahmed ibn Majid, the author of Fa'waid refers to the Chola mode of navigation even after the sun had set on the Chola Empire a few centuries ago. And seamen in the Malabar Coast and Lakshadweep Island had used redacted navigational manuals containing Chola nautical practices up to the modern times.

The Cholas used double mast boats like the Kolandia which were agile and easily manoeuvrable in the waters of the Indian Ocean. They preferred lateral sailing and used stars close to the equator for position fixing. The major star used as pathfinders were the *'Ardra Nakshatram'* and *'Thiruvonam'*. Instruments like the *'Ra-p-palagai'* came in handy to chart navigational paths while at sea, speed was measured using a lead fitted plank called the *'Tappu palagai'* and time was measured with the help of a perforated bowl called the *'Naligai Vattikal'*. Besides all this, the Cholas were experts on monsoon patterns. They harnessed the north easterlies to sail their boats in the Indian Ocean region.

Thus, with the available data, we can conclusively prove that the Chola were master navigators and they possessed a reservoir of nautical knowledge which was a sophisticated nautical package of its time and era.

About the Author

Dennard H Dsouza has a Master's degree in Ancient Indian Culture History and Archaeology from Saint Xavier's College, Mumbai. His major area of Interest is the study of ancient polities of the East and intermingling of Cultures, Religion and Art as a result of trans-regional movement. Currently, he works at the Maritime History Society as a Research Associate, where his work entails a vast range of subjects from Ancient Indian Nautical Practices to Maritime Community Heritage and Traditions.

Email: dennard.rac@mhsindia.org

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IN THE WAKE

Rajoo Balaji

Corona Chronicles

Covid has cast its shadows long from Crew woes to cadets' woes....

While unfinished training ashore is one end, incomplete sea time on board is on the other end of the trainees' Covid Times bandwidth.

What are the issues (amongst others of extended contracts; quarantine; work stress after joining)?

- Training periods disrupted both on board and ashore
- Joining/sign off problems (Visas; Covid Tests etc.)

Some solutions sighted:

1. Reduce the pre-sea training intake numbers (possible, I guess)
2. Increase ship berths (how?)
3. Place trainees on defined routes for ease of sign-on/sign-off (only small number may benefit; not helpful in the long run)
4. Approve simulator training (for required sea time) [India did it in lieu of part of the workshop training for cadets ready in last leg of training].
5. Recognise time on all type of vessels for the first CoC (possible? Yes)
6. Provide external funding to (berth) sponsoring Companies to make up some expenses due to extended time etc.

Any thoughts on this?

News you can Use (Pandemic Plans): The national focal point of contact for crew change and repatriation of seafarers (for many countries... as of now 45) can be found in the IMO's online Global Integrated Shipping Information System (GISIS).

Shipping Matters
But It still pays to be a Seafarer...

Guess good news pours for those under training and getting their CoCs...

BIMCO Report: Highlights a current shortfall of 26,240 STCW certified officers.

Where is the shortage ? Management Level, and in the tanker and offshore sectors. (Okay... I can hear murmurs that this is old news).

So what is new?

Officer turnover rates reduced from 8% to 6%. This is good and bad news mixed.

How? This means people will stay longer in the sea career and availability of empty slots for new entrants will take longer.

What else? Gender balance is getting better.... Now Female seafarers have reached 1.28% of the total workforce and increasing.

And repeat: It pays to be a seafarer (literally)....

The International Bargaining Forum (yes, there is one) settled a 4.5% wage rise for seafarers (3% in 2022 & 1.5% in 2023) under the ITF-Ship-owners' agreements.

Any catch? You have to be on vessels under Flags of Convenience. And there are about 9000+ of them, for a guess.

(Guess Indian seafarers got a similar pay rise deal sometime back ?!).

Allow no Automation

A new Luddite-like situation in sight.

The U.S. International Longshoremen Association (yes, there is one and it is powerful, I believe) will not cooperate with automated eco systems (ships and ports).

What are they particularly opposing?

Ships guided by satellites, on-board sensors, and AI. Any ship with no personnel on board is a no-go (and their gangs will not unload the vessels).

What is the argument?

"...greedy companies only interested in making money and eliminating workers who helped them build their success and companies." Sounds familiar?

ILA promises to "keep productivity levels above what automated equipment could produce," (excluding pandemic periods where the low levels are unavoidable).

Man vs Machine will go on from Sci-Fi to Sci-Fact!

Tech Talks:

'Digital' is the mantra to dig in the modern times. There are a lot of name droppings in conversations and we hear 'Digital Twins'. We could find some great use in twinning for operations. Industry public feel twinning will help reduce operational costs (which could be much more than design costs etc.).

A model for the vessel's life cycle: shipyard design, construction, sail out, sea trails, operation....

This will certainly benefit.

And who will be the best to handle the twins? The Ship-owners and the Operators.

Tail piece: And so we will have twins now separated at birth singing the same songs and wearing the same colours but the two shall never meet (A sad Bollywood ending there).

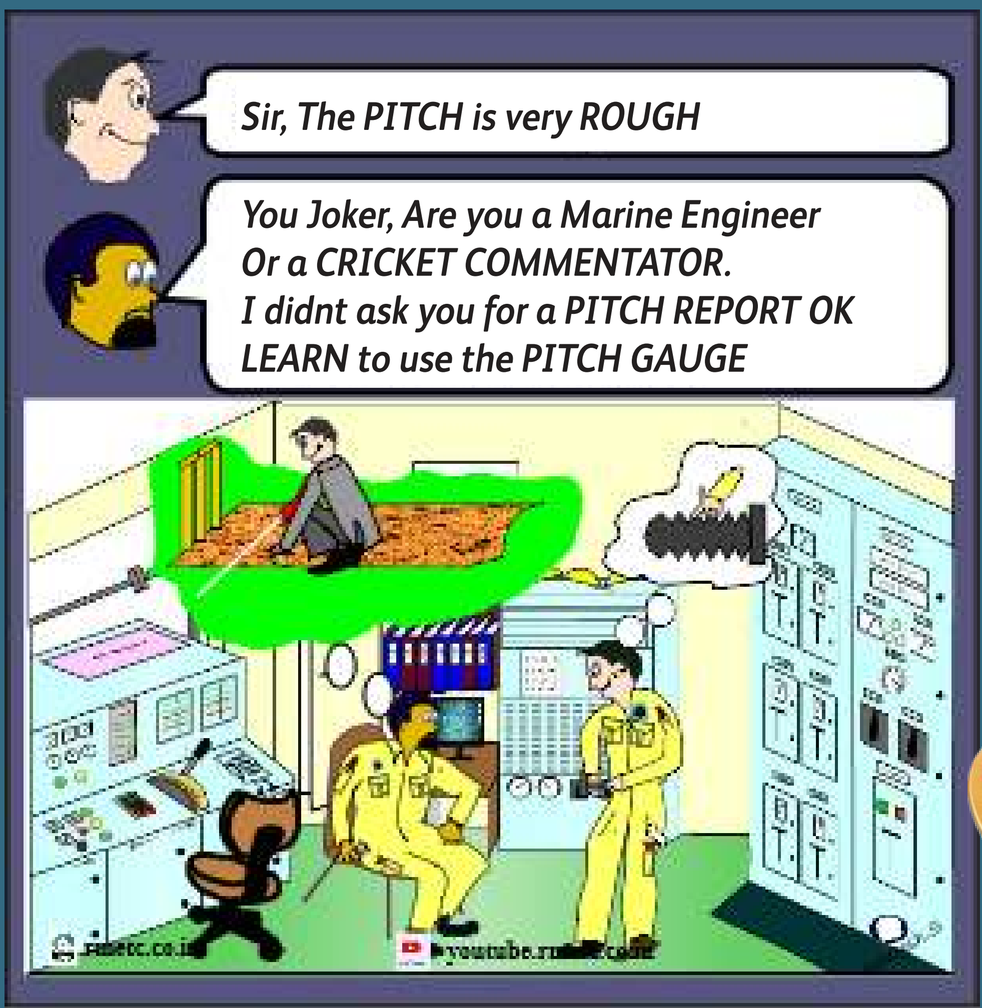
About October

Spaced about a month apart from India's Teachers' day (5/9), is the World Teachers' day [5/10].

If there be teachers, there must be students... World Students' day [15/10].

And there is a (Happy) Boss' day [16/10]. Will this work? Yes, Boss.

THE END VIEW

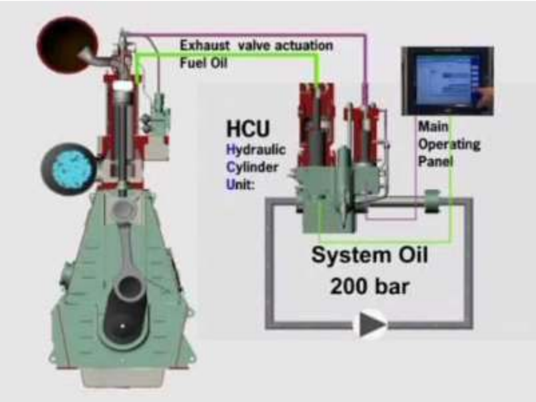


Idea, Words & Drawing: **Ramesh Subramanian**

MASSA Maritime Academy, Chennai

The Institute of Marine Engineers (India)

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



This 3 days course is designed for all Ships' Engineer Officers and Electro Technical Officers responsible for the operation of ME Engine. The course practically 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:

The course practically 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 : October 12th,13th and 14th 2021, 8:00 am to 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)
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