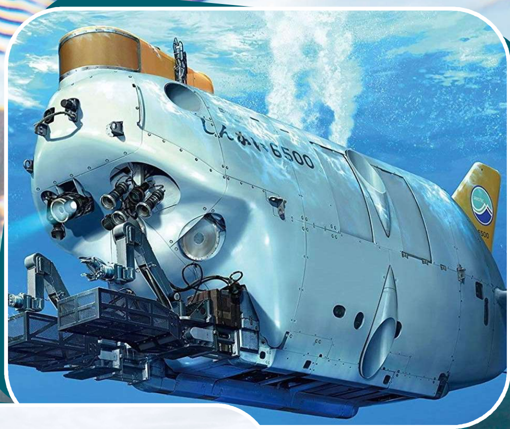
VOLUME 15 | July 2021
ISSUE 8 | 90/-

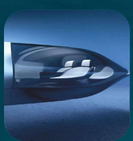
ISSN 2250 - 1967

MARINE ENGINEERS REVIEW (INDIA)

JOURNAL OF THE INSTITUTE OF MARINE ENGINEERS (INDIA)

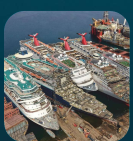
DIVE DEEP and DIVINE with AUVs





9
Technologies for Next Generation Scientific Autonomous Underwater Vehicles

15
In-Line and Cross-Flow Response Interactions during Vortex Induced Vibration of Marine Risers



21
Ship Recycling, Market Imperfections and the Relevance of a Consortium of Ship Recycling Nations in the Indian Subcontinent

The Institute of Marine Engineers (India)

IMEI HOUSE, Plot No.94, Sector-19, Nerul, Navi Mumbai – 400 706
Email: training@imare.in. Website: www.imare.in

REGISTRATION OPEN FOR Following DGS APPROVED COURSES (Online)
• MEO Cl. I (FG) 2 months course commencing on 1st July 2021 /1st Sep.2021/1st November 2021(followed by Simulator course)
• MEO CLASS III (NCV_CEO) UPTO 3000kW – STCW 2010- 2months course – 1st July 2021/1st November 2021/1st March 2022
• MEO Cl. III (NCV_SEO) Part-A - STCW 2010 -2months course –1st July. 2021 / 2nd Jan.2022
• MEO Cl. III (NCV_SEO) Part-B - STCW 2010 -4months course – 1st Sep. 2021 / 1st March 2022
• MEO Cl. IV (NCV) -STCW 2010 -4 months course – 1st October 2021/ 1st April 2022
• MEO CL. II (FG) – 4 months Course commencing on 1st July 2021/ 1st August 2021/1st Sep.2021/ 1st Oct.2021/1st Nov.2021/1st Dec.2021
• Refresher Updating Training (RUT) Course for revalidation of COC for all Engineers – 8th July 2021/ 15th July 2021/ 29th July 2021
• ENGINE ROOM SIMULATOR MANAGEMENT LEVEL (3DAYS) COURSE FOR MEO CLASS I : 1st July 2021 / 5th July 2021
• " ENGINE ROOM SIMULATOR MANAGEMENT LEVEL (5DAYS) COURSE FOR MEO CLASS II : 12th July 2021
• ENGINE ROOM SIMULATOR OPERATIONAL LEVEL (3 DAYS) COURSE – On request
• MEO Cl. IV(FG) non mandatory course (2months duration) – On request
• 2 weeks Induction course for Naval candidates – On request

Note: Payment can be done through the ICICI Bank (IFSC Code: - ICIC0000151) on A/C No.015101031872 in the name of

"The Institute of Marine Engineers (India)"

only after confirming the availability of seats.

Please make the payment from saving bank account only

not from NRI / NRE account

For Payment: Visit www.imare.in - Use the option "Buy Online" to pay the course fee

For enquiries contact on training@imare.in

For Registration of Competency Courses: https://forms.gle/DBvLuEarFpbk3aqX9

For uploading the documents – Mail your documents on documents@imare.in

after putting all documents in one pdf file

For Registration of Modular (RUT/ERS) Courses: https://forms.gle/DSmcvmMJkZAvLDvo9

Features: Experienced Faculty, Individual Attention


LUKOIL
OIL COMPANY
Need luboil?
Think LUKOIL!
LUKOIL
OIL COMPANY
LUKOIL Marine Lubricants
MARINE IN ALL WE DO!
Oceanic Lubes
India Representative for
LUKOIL Marine Lubricants
Tel.: +91 22 2781 0406
Tel.: +91 22 6673 5319
email: oceanic@lukoil.com

EDITORIAL

*Post hoc, ergo propter hoc: **After this, therefore because of this**.*

*(Referred to as **Post hoc fallacy**).*

The pundits are predicting a third wave... the political stakeholders cautiously paint the 'all-under-control-but-beware' poster. The Delta variant from the stock virus stable is finding takers. The bright side is that the infections and departures are diminishing and the vaccinations are finding favour. The mutations and trends indicate one thing with certainty: Comfort levels are still further away.

We can only keep our fingers (sanitised) crossed and hope that the oncoming waves are just small bumps and ripples. And wish we all live to observe that the predictions were just post hoc fallacies.

In this issue...

While above in the air, the drones and modern equipment are taking us to remote dimensions, the underwater equipment also is promising an exciting future in remote sensing and data acquisition. Dr. Vedachalam readily accepted my request for a 3-part educational essay series on AUVs. In the first (Part A) of the lot, Dr. Veda and Dr. Ramadass take us through the evolution and capabilities of underwater vehicles. I am sure this interesting series on autonomous underwater vehicles will take us deeper in understanding the underwater research and exploration.

From underwater, we come up to marine risers. Risers are the 'pipes' connected from the sea bed to the drill platform. These risers when connected to floating platforms are prone to vibrations as the fluid flows inside. The consequential frequencies and resonance situations are harmful to the structure. Dr. Vidya and Dr. Sheeja present a CFD study and analysis on the vibration aspect. This serious technical article would be of interest to research students.

And we have an easy read of a review paper by Dr. Emil Mathew on Ship Recycling. The status of recycling, the environmental harm, the labour issues, international regulations etc., are discussed. A simplistic solution by way of establishing a fund to support recycling is also proposed.

In regular columns, VRV continues with Part 3 of the Electricity/Magnetism discussions.

And we bring in another educational series of lubricating oils. In this starter, Sanjiv Wazir provides a short essay on used lube oil. This is sure to catch the attention of practising and preparing (for COC) engineers.

In the Heritage Hourglass section, Saba Purkar highlights the use of GIS and GPS as aids in underwater archaeological studies.

And while we are hoping to bring another dimension to MER soon, here is the July issue...

Dr Rajoo Balaji
Honorary Editor
editormer@imare.in

MARINE ENGINEERS REVIEW (INDIA)

JOURNAL OF THE INSTITUTE OF MARINE ENGINEERS (INDIA)

Administration Office
IMEI House
Plot No. 94, Sector - 19, Nerul,
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

Printed, Published and Edited by Dr Rajoo Balaji on behalf of The Institute of Marine Engineers (India). Published from 1012 Maker Chambers V, 221 Nariman Point, Mumbai - 400 021, an printed from Corporate Prints, Shop No.1, Three Star Co-op. Hsg. Society, V.P. Road, Pendse Nagar, Dombivli (E) - 421 201. District - Thane

Designed by : Mr Gaurav Kulkarni

In this Issue

Articles

09 Technologies for Next Generation Scientific Autonomous Underwater Vehicles
- N. Vedachalam, G. A. Ramadass

15 In-Line and Cross-Flow Response Interactions During Vortex Induced Vibration of Marine Risers
- Vidya Chandran, Sheeja Janardhanan

21 Ship Recycling, Market Imperfections and the Relevance of a Consortium of Ship Recycling Nations in the Indian Subcontinent
- Dr. Emil Mathew

Shipping Matters

29 Class Action / Industry Moves

31 IME (I) Branch News

Education

32 Bol Bada Saab Bol

Columns

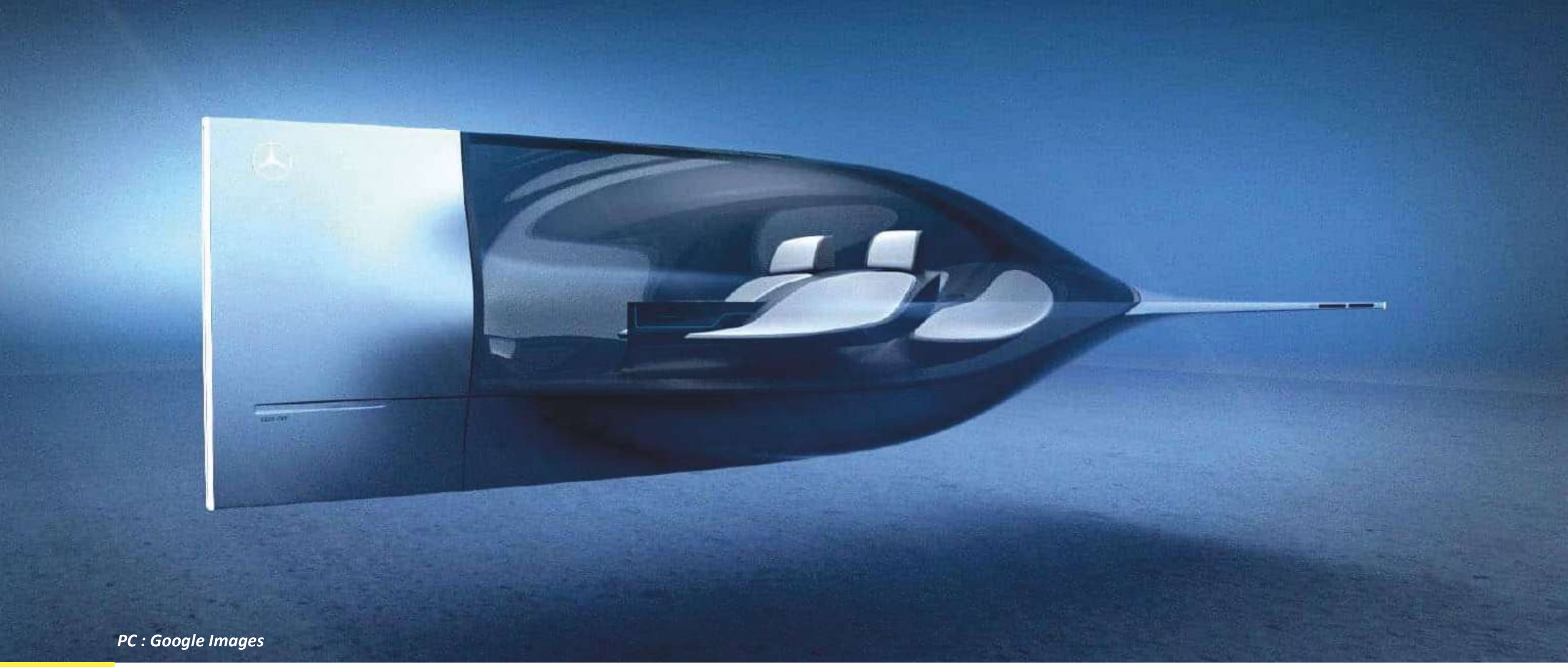
34 Technical Notes

36 Students' Corner

42 Competency Corner

45 Heritage Hourglass

49 In The Wake



PC : Google Images

Technologies for Next Generation Scientific Autonomous Underwater Vehicles

N. Vedachalam, G. A. Ramadass

National Institute of Ocean Technology, Ministry of Earth Sciences, Chennai, India

ABSTRACT

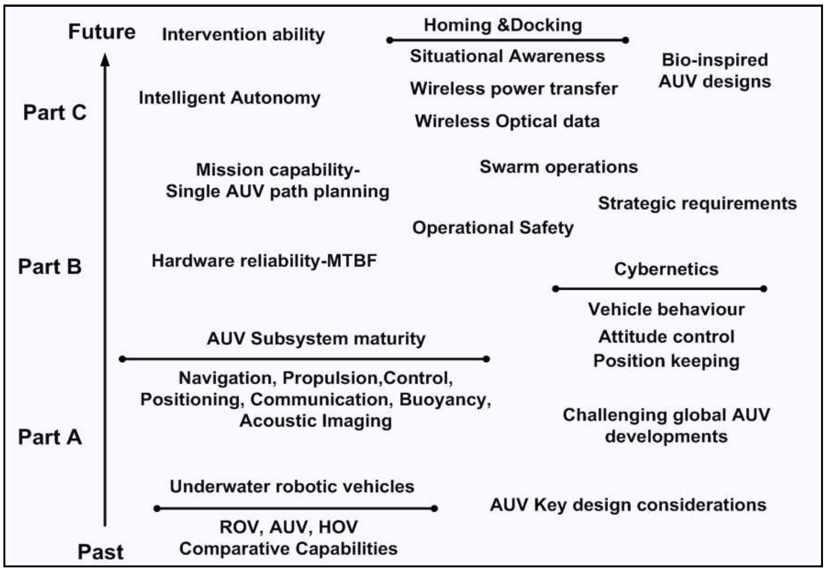
Autonomous Underwater Vehicles (AUV) are vital for exploring the vast marine resources, spatiotemporal monitoring of the tropical and polar oceans to understand the changes in climate patterns, monitoring marine pollution, engineering support, defence and identifying assets lost in the Oceans. The article comprising of three parts covering three issues gives an overview on the capabilities of underwater robotic vehicles, challenging AUV developments hitherto, subsystem maturity in terms of hardware reliability and vehicle performances, operational safety, cybernetics for position keeping and mission capabilities. The key technologies required for the next generation scientific AUVs, including, intelligent autonomy, swarm capability, intervention ability, subsea homing and docking for enabling long endurance missions and energy-efficient bio-inspired vehicle designs are detailed.

KEYWORDS: *AUV, bio-inspired, Homing, Intervention, Mission, Reliability, Swarm robotics*

INTRODUCTION

Oceans covering 72% of the Earth's surface houses immense living and non-living resources, plays a key role in regulating the Earth's climate. Considering the strategic importance of the oceans, the United Nations have proclaimed 2021-30 as the decade of ocean science for sustainable development. Policies are initiated across the globe for leveraging the growth of blue economy with appropriate vision, technology, integrated management, monitoring and time-bound regulatory reforms.

The world economic forum has highlighted the development of intelligent autonomous underwater vehicles for exploring oceans' resources and studying climate change, as one of the priority areas (**Table 1**).



Underwater robotic vehicles used for seabed mineral exploration, oceanographic research, defence, offshore industries and subsea search activities are classified into unmanned and Human Occupied Vehicles (HOV). The unmanned robotic vehicles include Remotely Operated Vehicles (ROV), Autonomous Underwater Vehicles (AUV) and crawler-based sea bed mining vehicles. The significant deep water scientific ROV include ROPOS5000 of Canada, Jason 6500 of USA, UK's ISIS 6500, Japan's Kaiko 7000, Victor 6000 of France and India's ROSUB 6000. The significant HOV developments since 1960s are shown in **Table2**. With the objective of carrying scientific exploration in Indian Oceans, NIOT is developing a deep water HOV MATSYA 6000.

The deep-water ROV ROSUB 6000 developed by India's National Institute of Ocean Technology (NIOT), Shinkai 6500 HOV developed by Japan Agency for Marine-Earth Science and Technology (JAMSTEC) and AUV AUTOSUB 6000 developed by National Oceanography Centre (NOC), UK are shown in **Figure1**. The comparative capabilities and limitations of the underwater robotic vehicles are summarised in **Table 3**.

ROVs are powered and controlled from the ship-based control-console through the electro-optic umbilical and have unlimited operation time, but limited spatial and intervention capability. Even though deep water HOVs has excellent intervention capabilities with in situ human presence, their endurances are limited by the capacity of on-board batteries, which is normally up to 12h.

The AUVs are designed to operate autonomously, off a host deployment vessel, along with scientific pay loads, are effective in exploring remote and challenging environments, from the abyssal depths, hydrothermal vents to beneath the Polar ice shelves. The upcoming intervention AUV (I-AUV) equipped with manipulators will offer a cost-effective trade-off between the capabilities of the HOV and the ROV.

CHALLENGING AUV DEVELOPMENTS

The first deep water AUV L'Epaulard was deployed in 1980 for marine geosciences research at a depth of 5300m in the Pacific Ocean. Subsequently, a series of deep-water AUVs were developed (**Figure 2**) and are extensively used for collection of high resolution images at abyssal water depths, hydrothermal vent studies, monitoring chemosynthetic ecosystems, mapping benthic habitat, studying seafloor morphology, deep ocean search operations including aircrafts and assets lost at sea, exploring offshore hydrocarbon, construction support, and in the monitoring of the ocean environment. The details of the AUV involved in the geo-marine research are summarised in **Table 4**. In last decade, ~80 REMUS AUVs were used in the military and about 10 in the scientific research domains. These AUVs were designed to accommodate payloads including video or still cameras, sonar, magnetometers, fluoro-meters, dissolved oxygen sensors, conductivity, temperature, and depth sensors, pH sensors, and turbidity sensors.

Numerous Polar vehicles have been developed to understand the role of Polar Regions in climate change, ecosystem responses, strengthening the predictive models for environmental management and to enact appropriate policy reforms. The Unmanned Arctic Submersible (UARS) was the first to be deployed in the Beaufort Sea in 1972 for carrying out under ice elevation mapping. Subsequently, a number of specialised underwater vehicles were developed for various scientific investigations such as under ice morphology, under ice biological studies and to understand the extent of the continental shelves.

Priority areas
Technology, Climate change, Ocean Resources, Biodiversity, Cyber Security, Industry & Corporate Governance, Geopolitical & Geo-economic Co-operation.
Emerging technologies
Artificial Intelligence (AI), Internet of Things (IoT), Advanced Materials, Smart Grids, **Autonomous Vehicles**, Drones, Big Data Analysis, Precision Medicine, Genomics.

Table 1 Global priority areas and technologies [1]

Year built	Submersible	Country	Depth rating /achieved
1964	Alvin	USA	4500
1972	Pisces	USA	2000
1985	Nautile	France	6500
1990	Shinkai	Japan	6500
1990	MIR	Russia	6000
2002	RUS	Russia	6000
2009	CONSUL	Russia	6000
2009	Jiaolong	China	7000
2012	Deep Sea Challenger	Australia	11000
2018	Deep Sea Warrior	China	4500
2019	Triton	USA	10925
2020	Fendouzhe	China	10909

Table 2 Significant HOV developments

Feature	ROV	AUV	HOV
Endurance	Unlimite d	Limited	Limited
Spatial capability	Limited	>10s kms	< 10s kms
Connectivit y	Tethered	Untethere d	Untethere d
Interventio n capability	Limited	Maturing	Well proven

Table 3 Comparative capabilities of underwater robotic vehicles

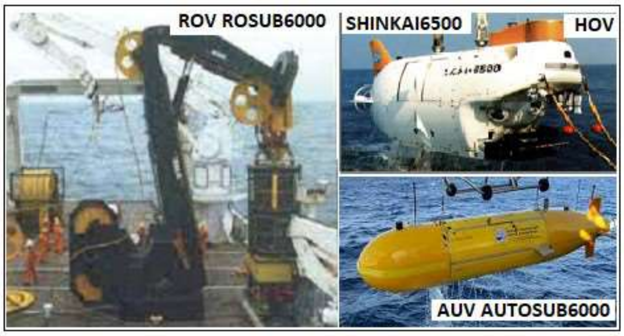


Figure 1 Deep-water unmanned and manned under water vehicles

In 1986, AUV Thesus laid the 175 km long optical fiber under the fast ice in the Canadian Arctic, from the North of Ellesmere Island to a scientific acoustic array in the Arctic Ocean. In 1988, REMUS was used for surface heat budget arctic ocean experiment programs in the Beaufort Sea. Autosub3 undertook six missions totalling about 510 km in 94 h beneath the Pine Island Glacier in the West Antarctica ice shelf. In 2007, as a part of the Arctic Gakkel vents expedition, AUVs PUMA and Jaguar were used for studying the hydrothermal vent sites up to 4000 m water depth, the deepest under ice AUV missions carried out till date.

Explorer AUV was deployed in the Canada high Arctic for under-ice bathymetric survey near the Borden Island to establish the outer limits of its continental shelf under the UN convention on the law of the sea. It is capable of executing 80 missions covering 450 km with its unique variable ballast system enabling it to park on the sea floor or hold itself on the underside of the ice and capability of being charged under ice by using small portable remotely operated vehicles. Nereid under-ice hybrid vehicle capable of providing real-time human telepresence in the ice covered waters up to 40 kms lateral distances from the deployment vessel was developed for enabling under ice morphology and under ice biological studies.

In 2010, Sentry AUV was used to track and localise the subsea hydrocarbon plume at a depth of approximately 1100 m in the Gulf of Mexico during the deep water horizon oil spill and to see its impacts on the benthic fauna and habitats. During 2011, three REMUS 6000 AUV identified the debris of the lost Air France aircraft AF447 close to the mid-Atlantic ridge near 2°N in 3220 m water depth. In 2014, AUV Hugin 4500 was deployed for searching the lost Malaysian airliner MH370 in the southern Indian Ocean.

The first I-AUV, SWIMMER, comprising a shuttle AUV transporting an intervention ROV for enabling operations over deep-water hydrocarbon production facilities was developed in 2000. Subsequently, a host of I-AUV such as ALIVE, GIRONA are demonstrated. The AUVs developed over the past two decades for carrying out research in the Polar, deep waters and intervention applications are shown in **Figure 1**, which includes AUTOSUB 6000 (3a), Autonomous Benthic Explorer ABE (3b), Theseus (3c&d), Neried (3e) and GIRONA (3f) (**Figure3**).

PRESENT TECHNOLOGICAL CAPABILITIES

AUV are designed considering the mission objective, environmental conditions for the operative depth, payloads, communications, navigation, power source, buoyancy mechanisms and mission planning capability. The various environmental factors considered for the design of the AUV are mapped in **Figure 4**.

Subsystem performances

The subsystems of the AUV include navigation, propulsion, control, positioning, telemetry and the buoyancy management. The navigation system comprises inertial sensors (gyroscopes and accelerometers) aided by 3-axis velocity inputs from Doppler Velocity Log (DVL) and derived from the accelerometers, depth sensor and position inputs from the Acoustic Positioning Systems (APOS). The

AUV	Area operated
ABE	Juan de Fuca ridge off North-West USA & Lost City hydrothermal vent field in mid-Atlantic
Sentry	Galapagos rift hydrothermal vents in the Pacific , southern explorer ridge in the north east Pacific
Autosub	Cayman trough's Beebe and Von Damm active hydrothermal vent fields
Seal	Menez Gwen hydrothermal vents & Kerch seep area
Urashima	Iheya-North hydrothermal field off-Okiwana & in the Pika hydrothermal vent site in Mariana Trough
Allan	Santa Monica basin, offshore California
Sentry	Blake ridge diaper off-South Carolina in the eastern USA

Table 4 AUV and the location of scientific exploration [3][4]

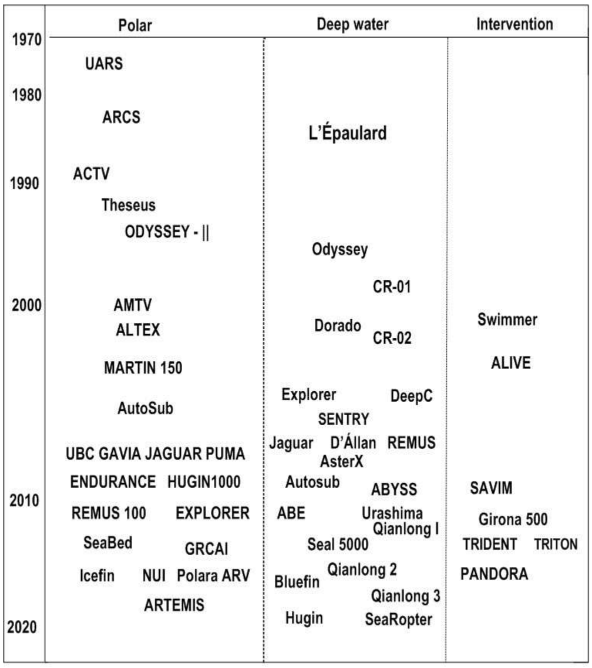


Figure 2 Trend in the AUV developments over four decades [2]

In 2010, Sentry AUV was used to track and localise the subsea hydrocarbon plume at a depth of approximately 1100 m in the Gulf of Mexico during the deep water horizon oil spill and to see its impacts on the benthic fauna and habitats

phenomenal trend in the performance of the navigation aiding sensors/systems over the past few decades has resulted in a highly precise Integrated Navigation System (INS).

Optical gyroscopes based on Sagnac-Laue principle are used to measure the AUV attitude in three angular degrees of freedom (Yaw, pitch and roll), The ring laser gyroscopes (RLG) have attained full maturity overcoming the lock-in effect experienced at very low rotation rates. The residual limit of the fibre-optic gyroscopes (FOG) bias stability is the ambient temperature time transient, which when controlled could achieve a long bias stability of 10^{-5} degree/hr (**Figure 5A**). These strategic grades RLG/FOG have an angular random walk of < 0.003°/√h and scale factor accuracy of 1 ppm. The strategic grade accelerometers have a resolution of <1μg, stability of <160 μg/year and a scale factor of 300ppm.

The DVL transducers elements are fixed in a Janus array configuration with four beams oriented in a circle, separated by 90° azimuths and with a common angle with respect to vertical. The Doppler shift is measured in each beam by digitising the received waveform, correcting for speed of sound and frequency-drift errors, computing the Doppler shift and combining velocities in the beam pairs to generate fore–aft and starboard–port velocity components. The recent DVL (**Figure 5B**) have an accuracy of ±0.1 cm/s and velocity resolution of 0.01mm/s in the bottom track mode (0.3-200m), and an accuracy of ±0.3 cm/s velocity resolution in the water tracking mode. The upcoming Correlation Velocity Log (CVL) operates at lower frequencies with better accuracies and higher range. The INS performance, in addition to the precision and quality of the individual inertial sensors (especially the gyroscopes bias stability that determines the heading accuracy) also depend on their alignment when strapped down on-board the AUV. A misalignment of 2° could result in a navigation inaccuracy of up to 0.6% of the distance travelled, which is a significant error for long range AUV. The recently introduced integrated INS-DVL system reduces the misalignment errors. The depth sensor that measures the hydrostatic pressure based on vibrating quartz crystal technology is highly stable and has measurement sensitivity better than 2×10^{-7}, which translates to <1 mm in 6000m water column.

The matured APOS Ultra short base line (USBL) transducers (with range and bearing measurement principle shown in **Figure 5C**) having an operating range of 10km at 10-15kHz frequencies has a positioning accuracy of ~0.2% of the slant range with 50% Circular Error Probability (CEP50). The location-specific Sound Velocity Profile (SVP) is required as inputs to the APOS for achieving the indicated positioning accuracy. Without SVP inputs the position error could be up to 150m at 5500m water depths (2.7% of the range) in the Indian Ocean.

The quality of the hydro-acoustic communication defined based on bit error rate (BER) depends upon the underwater channel properties, operating frequency, distance between the acoustic transmitter and the receiver, transmitter power and the modulation techniques used in the communication protocols. The plot (**Figure 6**) shows the range of acoustic communication in various water depths and the acoustic

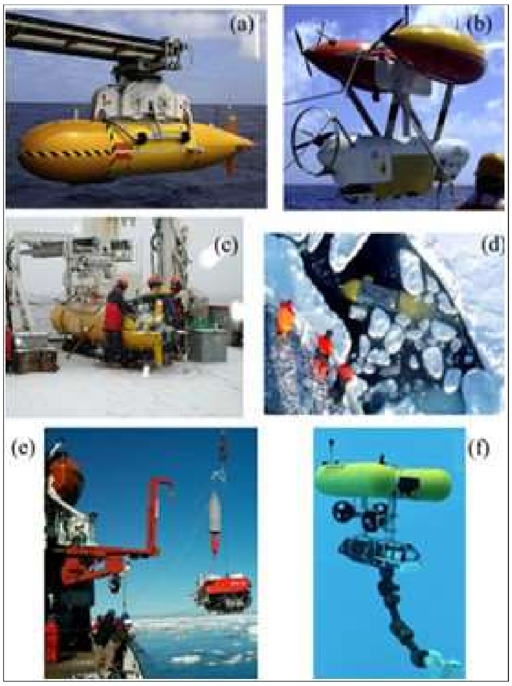


Figure 3 Challenging AUV developments [2]

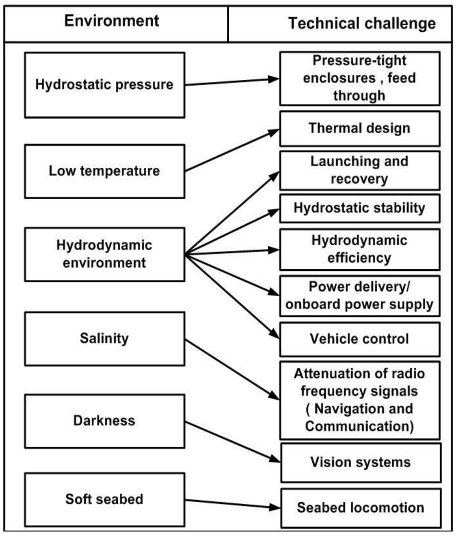


Figure 4 Ocean environment and technical challenges

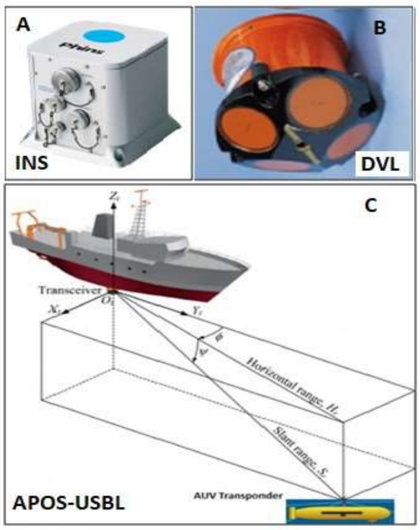


Figure 5 AUV navigation, positioning and imaging systems

transmitter power requirements determined with ray tracing simulation tool Bellhop.

The acoustic telemetry modems with hemispherical beam patterns and optimised for vertical and slant channels operating in 4-14 kHz range offer adoptive communication data rates of ~6 kbps up to 12km. The 11 km depth-rated Global Navigation Satellite System (GNSS) receiver with integrated antenna and electronics helps the AUV in surface navigation. The recently developed 11km depth-rated 2-way Iridium satellite communication with pressure-rated antenna enables satellite connectivity when the AUV is on the sea surface.

The forward looking imaging sonar can be tuned from 200kHz-1 MHz has an adjustable range from 1.5-200m with a corresponding resolution of 2mm and 10mm, respectively. The azimuth (along-track) resolution of a sonaris is the ratio between the acoustic wavelength and the length of the array (e.g., 1:100 means a resolution of 1m at 100m range). A longer array will increase this ratio, but fitting such a long array in an AUV is impractical. Operation at a higher frequency increases the ratio, but limits the achievable range due to higher absorption in the saline sea water medium. The recent high resolution interferometric synthetic aperture sonar (SAS) operating in 70-100 kHz range uses data from several consecutive pings of the same sonar to synthesise the size of a longer sonar array (**Figure 7**). With the SAS, by covering a range of 200m on each side of the AUV cruising at 2 m/s, it is possible to have on-board high resolution of up to few centimetres, as well as co-registered images, covering~2 km^2/h.

The propulsion system comprises batteries managed by battery management system (BMS) and brushless direct current (BLDC) motors operated by variable speed power electronic inverter. The matured Nickel-Manganese-Cobalt (NMC) cathode based Lithium-Ion batteries have energy density of 75-200Wh/kg, a specific density of 150-315 Wh/l, cycle stability, efficiency, reliability, low self-discharging rate and low memory effect. With 7% redundant cells, these batteries could have a near-zero failure rates. The BMS helps to continuously monitor the cell temperatures, state-of-charge and state-of-health which ensures safety and supports mission planning. The pressure-balanced oil-filled (PBOF) propulsion thrusters operated using direct-driven BLDC motor with rare earth magnets (having high magnetic flux density) and magnetically coupled propeller eliminates shaft seals and speed reduction gear boxes. These thrusters are very compact, weighing ~3 kg/kW in air and produce ~15kgf/kW at vehicle/water advance velocities of 5 knots.

The developments in the Titanium alloys, ceramics, copper-beryllium, duplex steel and composites have resulted in low weight, high strength and reliable pressure resistant housings used for housing the vehicle electronics. The syntactic foam that is used for making the vehicle near-neutrally buoyant are available with densities of ~600 kg/m^3 and low water absorbing characteristics offers effective buoyancy at full ocean depths. The precision buoyancy adjustment systems help in effective servoing at desired water depths with minimal usage of thrusters.

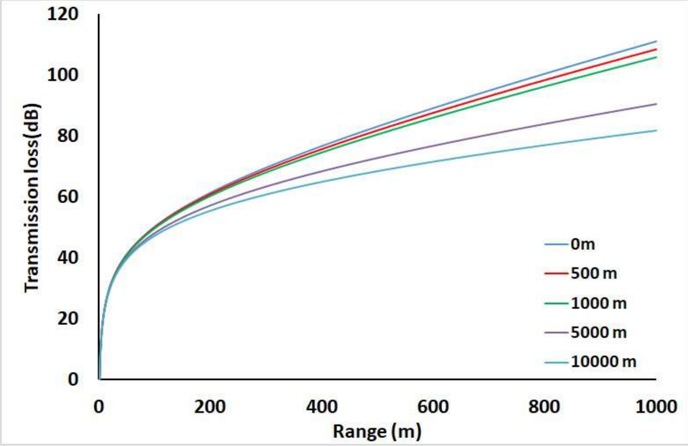


Figure 6 Acoustic transmission loss at various water depths

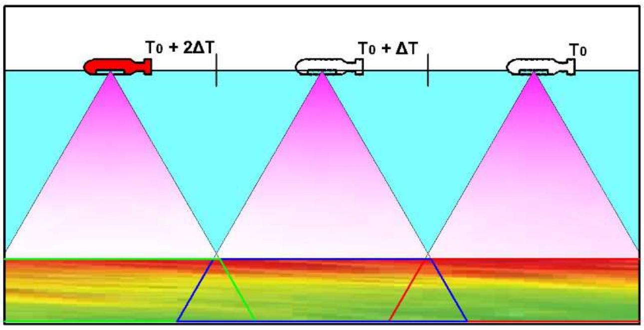


Figure 7 Principle of synthetic aperture sonar

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

Table 5 Technological maturity of present AUV [3][4]

The precision of vehicle attitude control depends on the accuracy of the hydrodynamic parameters of the AUV. Computational Fluid Dynamics (CFD) models based on the Navier-Stokes and continuity equations are used to determine the drag force and added mass coefficients in multiple DOF. Models such as k-ε standard, RNG k-ε model, SST k-ε model simulate the turbulence effect in the flow around the AUV hull. The accuracy of CFD calculation results depends on the quality of grid division, the choice of

The developments in the Titanium alloys, ceramics, copper-beryllium, duplex steel and composites have resulted in low weight, high strength and reliable pressure resistant housings used for housing the vehicle electronics calculation mode, the setting of parameters and the boundary conditions.

In the David-Taylor Model Basin (DTMB) approach, which is more suitable for variable configuration AUVs, is based on the force-response principle, in which the hydrodynamic parameters are determined by the vehicle actuators (propeller, rudder and fin) and the precision vehicle on-board INS and DVL. The drag force coefficients are identified from the thrust force required for moving the vehicle at a constant velocity. The added mass is identified by subjecting the vehicle to sinusoidal motion and measuring the thrust required for achieving the acceleration and matching the velocity profile.

Thus the developments till date have resulted in AUV with the excellent performances (**Table 5**) including higher vehicle endurance, precise navigation, reliable acoustic telemetry, high resolution bathymetry/ imagery, collision avoidance, path/trajectory planning capability and excellent system reliability.

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 modelling tools have enabled development of novel autonomous underwater vehicles capable of carrying out scientific exploration in hostile and challenging 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. These requirements clearly indicate the need for increased synergy in realising intelligent autonomy, swarm capability, intervention abilities, subsea homing and docking abilities with wireless power and optical data transfer features, and energy-efficient bio-inspired vehicle designs for futuristic autonomous underwater vehicles. The details shall be covered in the Part B and C which are scheduled to be published in the subsequent months.

ACKNOWLEDGEMENTS

The authors gratefully acknowledge the support extended by the Ministry of Earth Sciences, Government of India, in funding this research.

REFERENCES

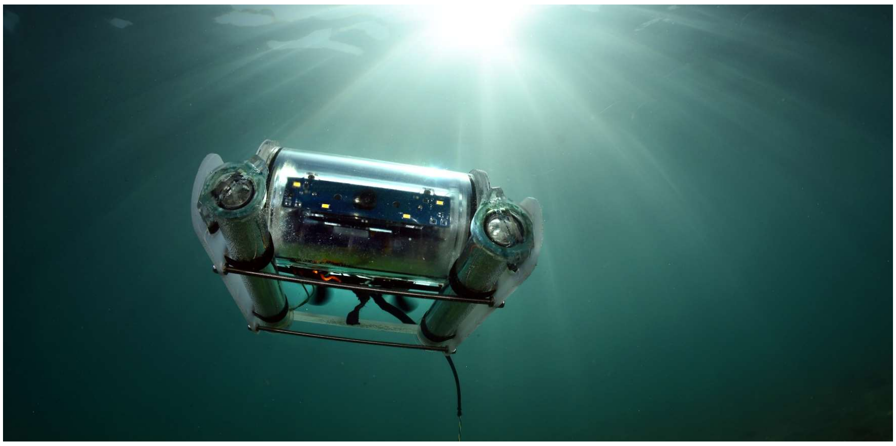
1. World economic forum, Annual Report 2019-20,https:// www.weforum.org /reports/annualreport-2019-2020.
2. N. Vedachalam, R. Ramesh, V. Bala Naga Jyothi, V. Doss Prakash, G. A. Ramadass, 2018, Autonomous Underwater Vehicles - Challenging developments and technological maturity towards strategic swarm robotics systems, Taylor & Francis Journal of Marine Georesources & Geotechnology, https://doi.org/10.1080/1064119X.2018 .1453567.
3. Gidugu Ananda Ramadass, Narayananswamy Vedachalam, Arunachalam Umapathy, Raju Ramesh, Vandavasi Balanagajyothi, 2017, Finite element analysis of the influence of ambient temperature variations on the performance of fiber optic gyroscope sensing coils, Marine Technology Society Journal, Vol.51, Number 1, Jan/Feb 2017, pp. 16-22(7).
4. N. Vedachalam, R. Ramesh, V. B. N Jyothi, V. Doss Prakash, G. A. Ramadass, M. A. Atmanand, Design considerations for strategic autonomous underwater swarm robotics systems, Mar 2020, Marine Technology Society Journal, Vol.55, pp:9-19.

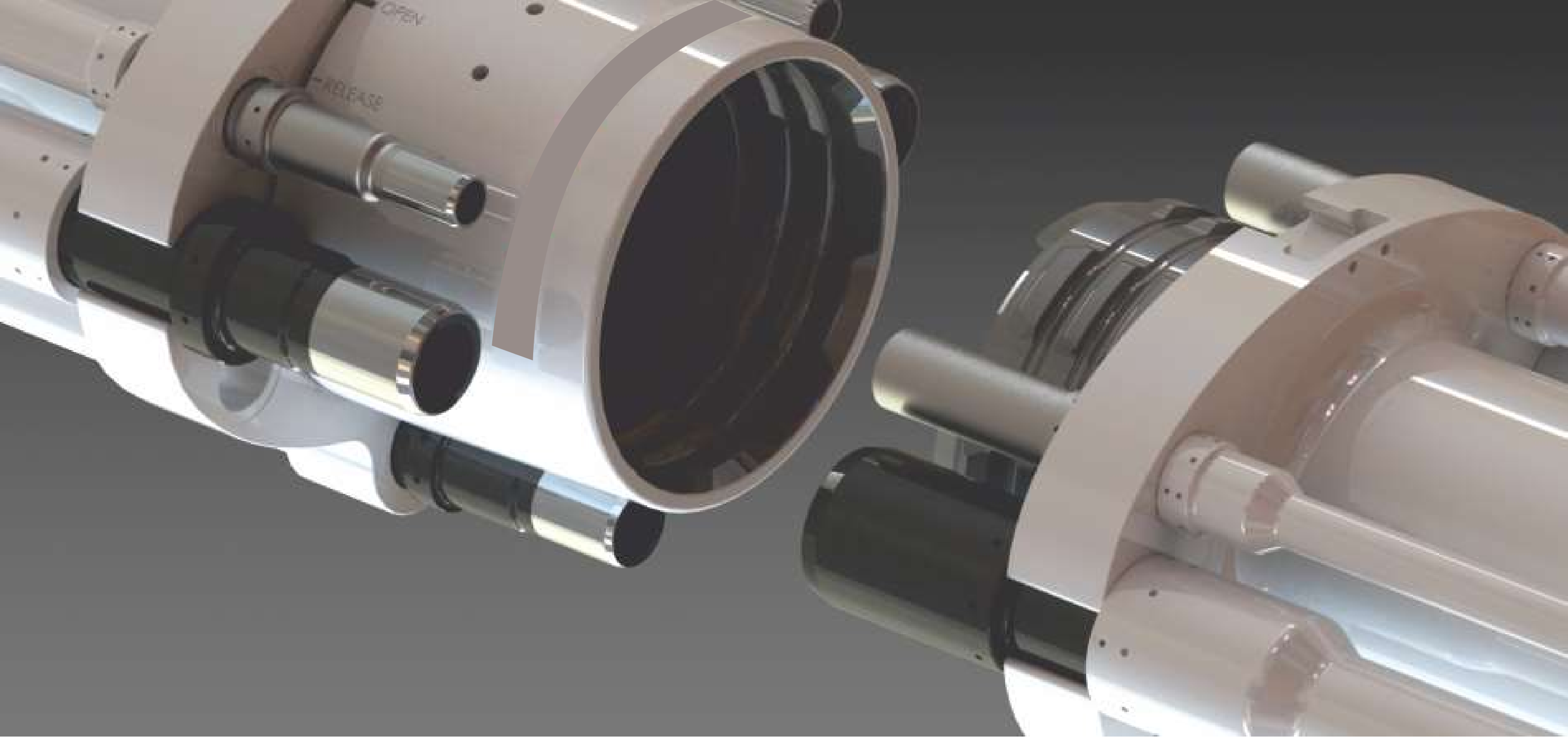
ABOUT THE AUTHORS

__Dr. N. Vedachalam__ is currently a Senior Scientist with NIOT, Chennai. His 25 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.

__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.

Email: veda1973@gmail.com





In-Line and Cross-Flow Response Interactions during Vortex Induced Vibration of Marine Risers

Vidya Chandran[1], **Sheeja Janardhanan**[2]

[1]Department of Mechanical Engineering, SCMS School of Engineering and Technology, Karukutty, Kerala, India
[2]School of Naval Architecture and Ocean Engineering, Indian Maritime University, Visakhapatnam, Andhra Pradesh, India

ABSTRACT

The paper presents a simplified method for understanding the interaction between in-line and cross-flow responses using computational fluid dynamics simulations. Interaction between the responses in the in-line and cross-flow directions in vortex induced vibrations of cylindrical risers in the marine environment is still not fully understood. The trends of variation of hydrodynamic and structural parameters as well as pattern of shedding have been determined numerically to understand the effect of the in-line degree of freedom as well on the riser response and hydrodynamic force coefficients and the results show that a single degree of freedom riser is more susceptible to lock in vibration.

KEYWORDS: *Vortex Induced Vibration, In-line, Cross-Flow, Force Coefficients, Response*

1. INTRODUCTION

Drilling riser is a pipe laid vertically from the oil well at the ocean bed to the offshore drilling platform. It conveys the drilling fluid and mud to and from the drill site Marine drilling risers are used especially with floating rigs which are less stable and in particular cases where disconnection of the platform from the seafloor may be required quite often. **Figure 1** shows various layouts of marine risers depending on the constructional specification of platforms. **Figure 2** shows different

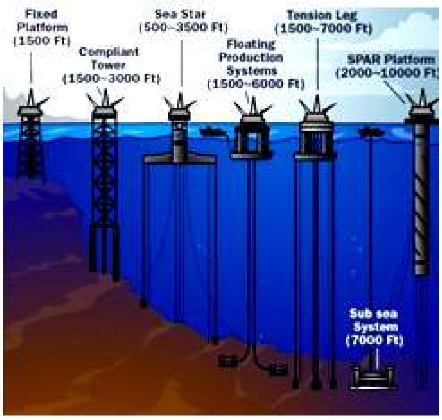


***Figure 1** Constructional variation of offshore platforms with drilling depth [1]*

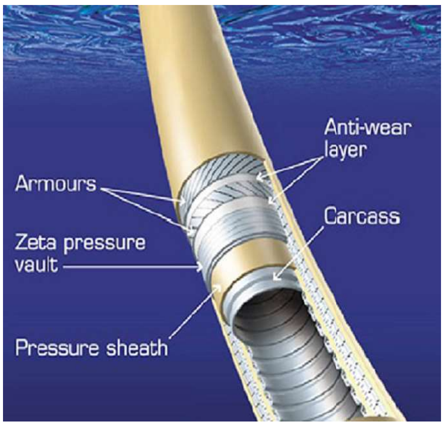


***Figure 2** Cross section of a typical flexible riser[1]*

Marine drilling risers are used especially with floating rigs which are less stable and in particular cases where disconnection of the platform from the sea floor may be required quite often

Properties	Values	Units
Diameter (*D*)	0.076	m
Aspect ratio (*L/D*)	13.12	-
Flow velocity (*V*)	0.5	m/s
Reynolds Number of flow (Re)	3.8 x 10^4	-
Mass ratio (*m**)	0.66	-

Table 1 Riser model specifications and flow characteristics

layers used in the construction of a flexible riser.

The marine risers, which are classified as **bluff bodies**, and when encountering fluid flow, alternate vortices are shed in the wake of the structure due to boundary layer separation. This alternate vortex shedding happens at a discrete frequency depending upon the flow Reynolds Number (*Re*). When the vortex shedding frequency matches with the natural frequency of the riser structure, it resonates with high amplitude of oscillation. These large amplitude vibrations, that occurs during "lock-in" of risers are catastrophic and needs to be arrested for the safety of crew working on the floating platforms and also for extending operational life of the risers. Vortex induced vibration (VIV) of marine risers poses all the challenges in the deployment and operation of marine risers.

There have been lot of research in the recent past to understand their behaviour under various sub-sea flow conditions. But most of the studies have concentrated on understanding the wake characteristics and estimating hydrodynamic loading and response of either stationary cylinder or cylinder with a single degree of freedom (1DOF)[2].

Few results have been reported for study of hydrodynamic response of cylinder with two degrees of freedom (2DOF) in both in-line (IL) and cross-flow (CF) directions. IL vibrations have significant impact on the shedding pattern and also on the amplitude of CF vibrations [3].

The first of its kind discussions were reported in the case of flow around cylinder with 2DOF [4]. They established the effect of reduced velocity (U_r) on the effect of forced and free 2DOF response [4]. The effect of IL response on CF response depends on the ratio of natural frequencies in both the directions

$$\left(\eta_b = \frac{f_{nCF}}{f_{nIL}}\right).$$

During lock in, if the natural frequency in the IL direction is twice that in the CF direction, resonance occurs in both directions leading to premature failure of the riser [5]. Also it has been observed that IL response amplitude is a function of U_r and stability parameter, whereas the CF response amplitude is a function of U_r and flow velocity [6]. Wake characteristics, hydrodynamic force coefficients and response vary significantly when both IL and CF vibrations occur simultaneously. Hence there is a need for prediction of response that hold good for the combined IL and CF vibration.

2. PROBLEM DESCRIPTION

In the present paper a riser model with outer diameter 0.076 m has been numerically analysed using two dimensional (2D) computational fluid dynamics (CFD). Specifications of the riser and the flow condition in listed in **Table 1**. The incoming flow velocity is fixed as 0.5 m/s to maintain the flow regime uniform at Re = 3.8 x 10^4 which corresponds to the ocean condition encountered by a real marine riser used for petroleum extraction in offshore industries [7]. In this paper an effort has been made to study the effect of IL vibration on the amplitude of CF vibration and also on the wake characteristics.

2.1. Mathematical Model

The riser has been modelled as a 2D cylinder with 2DOF in the CF and IL directions. The equations of motion for the riser can be represented as Eq. (1) and (2)

$$m\ddot{Y} + c\dot{Y} + kY = F_L(t) \qquad (1)$$

$$m\ddot{X} + c\dot{X} + kX = F_D(t) \qquad (2)$$

Where *Y* is the displacement in CF direction and *X* is the displacement in the IL direction. The excitation forces are lift force, F_L (t) and drag force. F_D (t). The excitation forces are periodic in nature due the alternate shedding of vortices, which causes the riser to oscillate in CF as well as IL directions. The riser is observed to oscillate with frequency equal to frequency of vortex shedding (f_v) in the CF direction and at double the frequency in the IL direction during lock in. Lock in can be defined as the resonance condition during which the vortex shedding frequency lock on to the natural frequency of the riser in the cross flow direction. A simple representation of the mathematical model of riser with 2DOF is represented in **Figure 3**.

The riser is modelled with zero structural damping in the CF and IL directions. k_x and k_y are stiffness coefficients in the IL and CF directions respectively. In the present study $k_x = k_y$. For such a specific case the natural frequencies in both directions will be same and hence $\eta_b = 1$

2.2. Fluid Domain Extends

Figure 4 (a) shows the computational domain for the CFD simulation of VIV of an elastically mounted cylinder with 2DOF. The origin of the Cartesian coordinate system is located at the centre of the cylinder. The length of the

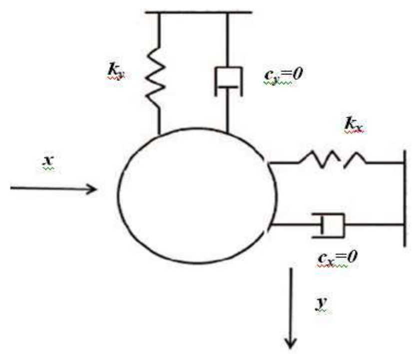


Figure 3 Representation of mathematical model of riser with 2DOF

domain is 40D with the cylinder located at 10D away from the inlet boundary. The cross flow width of the domain is 20D with the centre of the cylinder at the middle.

Detailed views of the mesh around the cylinder along with the computational domain after meshing have been shown in Figure 4 (b) and (c) respectively. There are 307 nodes around the circumference of the cylinder and the minimum element size near the rigid wall boundary has been computed from boundary layer theory to be 0.0001D [8].

The non-dimensional element size represented as $y+$, next to the cylinder surface is found to be less than unity. For cylinder wall a no slip boundary condition has been applied assuming the surface to be smooth. Inlet boundary has been treated as velocity-inlet with inflow velocity, V = 0.5 m/s. Outlet boundary has been treated as pressure outlet, the gradients of fluid velocity are set to zero and the pressure with zero reference pressure. On the two transverse boundaries, symmetry boundary condition has been applied. Grid independency study has been carried out for the present grid in the previous work done by the authors [9].

2.3. Flow Model

Numerically this problem has been treated as a case of two-way fluid structure interactions (2way FSI). Modeling and meshing has been performed in ANSYS ICEM CFD and solving using ANSYS FLUENT. Flow around the cylinder is modeled using the transient, incompressible Reynolds Averaged Navier-Stokes equation (RANSE) based solver with k – ω SST as the turbulence model. RANSE solver does the virtual averaging of velocities over an interval of time and hence for a specific interval, the velocity vector appears to be constant in a RANSE solver. In the present work an optimised fine grid is used to compensate for this drawback of the solver enabling it to capture the physics of Von-Karman Street eddies.

The governing equations are discretised using finite difference method. Non iterative time advancement (NITA) scheme with fractional time stepping method (FSM) has been chosen for pressure-velocity coupling of the grid. A least-squares- cell (LSC) based scheme has been used for gradient in spatial discretisation and a second order upwind scheme as convective scheme.

2.4. Structural Model

An elastically mounted cylinder can be mathematically represented by Eq. (1) and (2). These equations of motion are solved using a six degrees of freedom solver (6DOF), an integral part of the main solver by defining the cylinder as an object with 2DOF in transverse direction. A user defined function (UDF) compiled in C programming language has been hooked to the cylinder dynamic boundary conditions. The governing equations for the motion of the centre of gravity of the cylinder in the CF and IL directions are solved in the inertial coordinate system. Velocity in the CF and IL directions are obtained by performing integration on Eq. (3) and (4).

$$\ddot{y} = \frac{1}{m}\sum F_L \qquad (3)$$

$$\ddot{x} = \frac{1}{m}\sum F_D \qquad (4)$$

Where $\ddot{X}$ and $\ddot{y}$, are accelerations in the IL and CF direction respectively, m is the mass of the cylinder and F, resultant fluid force acting on the cylinder in the respective direction. Position of the centre of gravity of the cylinder (CG) is updated after solving the equations of motion of a spring mass system represented by Eq. (1) and (2). Mass of the cylinder is given in the UDF as in Eq. (5) and (6).

$$m = m_b + m_a \qquad (5)$$

$$m_a = (1 + C_A)m_b \qquad (6)$$

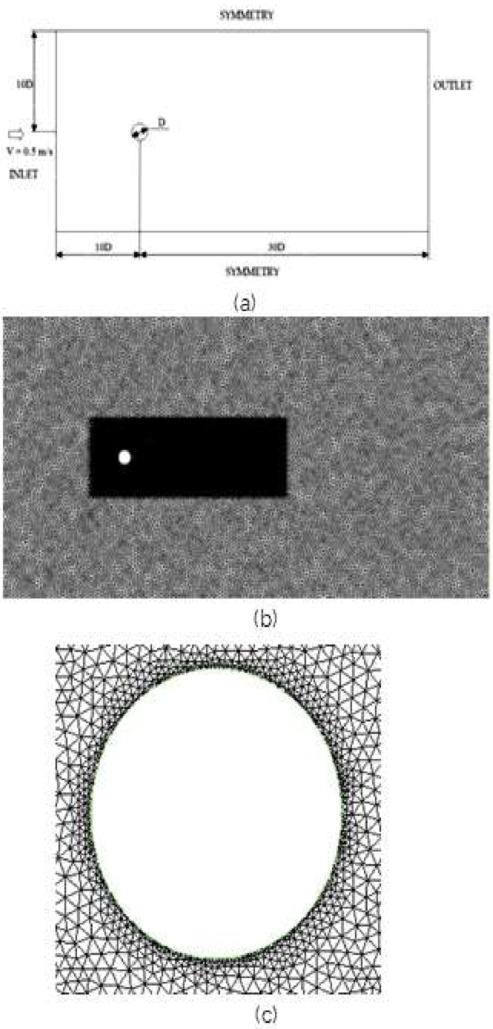


Figure 4 (a) Computational domain
(b) computational mesh
(c) mesh around the cylinder

Where m_a is the added mass and m_b is the mass of the cylinder. Added mass coefficient C_A for the aspect ratio of the present model is found to be equal to 1.0 [10].

Analysis has been performed assigning the cylinder 2DOF with $k_x = k_y$ so that the natural frequencies of the cylinder in both directions remain equal. The results are compared with the case when the cylinder has only 1DOF in the CF direction. Amplitudes of CF response are compared with existing results [9] and also the shedding patterns in both cases have been analysed.

3. RESULTS AND DISCUSSIONS

From the numerical analysis of cylinder with 2DOF it has been observed that the hydrodynamic force coefficient in the CF direction, C_L shows an increase of 17.4% than that for 1DOF case. This result is comparable with the findings of previous research in the field which shows an increase in the lift coefficient value by permitting an extra degree of freedom [11].

RMS value of C_D is constant for both cases with a very small decrease of 4% with 2DOF case. C_L oscillates about zero with almost equal frequencies for both the cases. But the frequency of oscillation of C_D is lesser by 7.2% for 2DOF case. The values of important hydrodynamic and structural parameters of both cases are shown in **Table 2**.

The non-dimensional amplitude in the CF direction obtained with 2DOF is 11.3% more than that with 1DOF. *X/D* is approximately 0.2. Time histories of major parameters obtained from the 1DOF analysis are shown in **Figures 5(a) – (d)** and that for 2DOF in **Figures 6(a) – (d)**. Frequency of oscillation of the cylinder in the CF direction obtained from 1DOF case is found to be more closer to the theoretical value of vortex shedding frequency obtained from the normal value of *St* = 0.2 (f_v=1.3). For the 2DOF case, the frequency of oscillation deviates from the vortex shedding frequency.

For 2DOF case, the frequency of oscillation of C_L and the oscillation frequency of cylinder in the CF direction remains same. In 1DOF case, C_L oscillation frequency remains same as that in the 2DOF case, but the cylinder vibration frequency in the CF shifts towards the natural frequency of cylinder in CF direction.

In the present analysis, the natural frequency in both directions are specifically fixed to be equal to the theoretical value of vortex shedding frequency. Hence the phenomenon can be looked upon as the lock-in of vortex shedding frequency on to the natural frequency of the cylinder. It can be concluded that a cylinder with 1DOF is more prone to lock in vibration compared to that with 2DOF.

This observation can be related to the shifting of the vortex shedding pattern from two singles (2S) to two pairs (2P) mode when motion in IL direction is arrested. The shedding patterns for 1DOF and 2DOF cases are shown in **Figure 5(a)** and **Figure 6(a)** respectively. *St* obtained also is with the range of normal value for cylinders during lock in. Even though the values of C_D for both cases are almost same, the oscillating frequency varies significantly.

The trajectory of oscillation of cylinder in 2DOF case is represented in **Figure 7**. A clear eight figure trajectory is observed which is typical for VIV of cylinders [11]. Also it has been observed that the motion the IL direction lags behind that in CF direction by a phase angle 30°. The represented trajectory in **Figure 7** corresponds to 30° phase lag [12].

4. CONCLUSIONS

Accounting for an additional degree of freedom seems to have significant effect on the magnitude of lift coefficient but the frequency of oscillation of C_L remains constant for both the cases. C_D is independent of the degree of freedom of the cylinder but the frequency of oscillation varies significantly. Oscillation amplitude of the cylinder in the CF direction is more in 2DOF case which can be related to the increase in C_L.

It has been clearly observed that with 1DOF, the cylinder is more susceptible to lock in vibration since the vortex shedding frequency locks on to the natural frequency of the cylinder in the CF direction. But with 2DOF, no such shifting of frequency is observed. Shedding pattern shifts from 2S during 2DOF motion to 2P when motion in IL direction is arrested. An eight figure trajectory typical for VIV is obtained from the

It can be concluded that a cylinder with 1DOF is more prone to lock in vibration compared to that with 2DOF

Parameters	1DOF	2DOF ($\eta_b = 1$)
C_L	0.57	0.69
C_D	1.49	1.43
$f_{osc\ C_L}(f_v)$	1.16	1.14
$f_{osc\ C_D}$	2.5	2.32
f_{CF}	1.26	1.15
f_{IL}	-	3.28
St	0.18	0.17
Y/D	1.06	1.2
X/D	-	0.17

Table 2 Hydrodynamic and structural parameter off cylinder with 1DOF and 2DOF

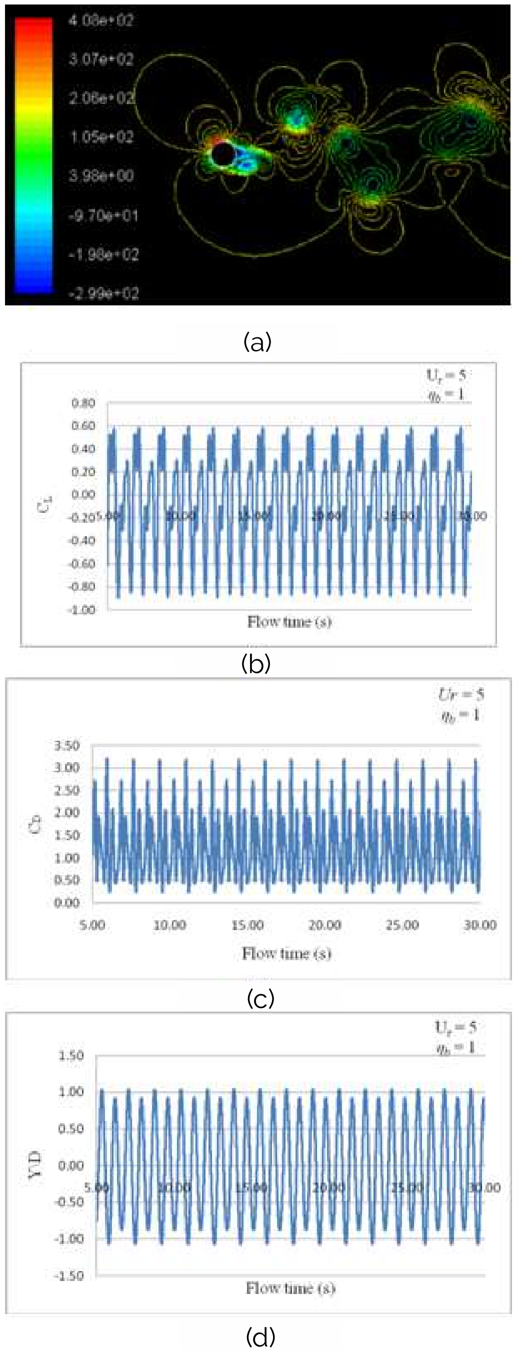


Figure 5 Pressure contours and Time histories of various hydrodynamic and structural parameters (a) Vortex shedding pattern behind cylinder with 1DOF showing 2P mode (b) CL of cylinder with 1DOF (c) CD of cylinder with 1DOF (d) Motion history of cylinder with 1DOF

2D simulation. Hence the efficacy of 2D CFD as a tool to predict response of cylinder with 2DOF under VIV is accomplished. The observations made above are definitely strong inputs in the design deployment and operation of marine risers.

5. REFERENCES

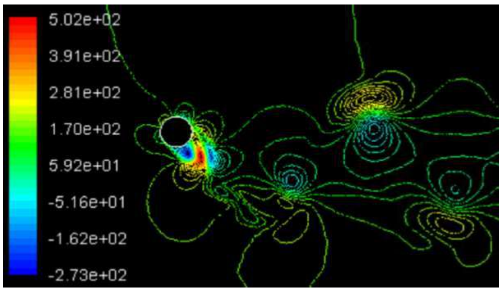
1. Bai, Y., and Qiang B., *Subsea engineering handbook*. Gulf Professional Publishing, Vol. 1, pp. 28, 2018.
2. A. Khalak, C. H. K. Williamson, 'Investigation of the relative effects of mass and damping in vortex induced vibration of a circular cylinder', *Journal of Wind Engineering. Ind. Aerodyn. vol. 69-71, pp. 341 – 350*, 1997.
3. Jauvtis, N. and Williamson, C. H. K., 'The effect of two degrees of freedom on vortex-induced vibartion at low mass and damping', *Journal of Fluid Mechanics 509, 23 – 62, 2004.*
4. Moe, G. and Wu, Z. J., 'The lift force on a cylinder vibrating in a current', *Journal of Offshore Mechanics and Arctic Engineering 112, 297- 303*,1990.
5. T. Sarpkaya., 'Hydrodynamic damping, flow-induced oscillations, and biharmonic response', *ASME Journal of Offshore Mechanics and Arctic Engineering,117:232-238*, 1995.
6. Yin, D.,Experimental and Numerical Analysis of Combined In-line and Cross-flow Vortex Induced Vibrations.*Ph D Thesis, Norwegian University of Science and Technology pp 7*, 2013.
7. Narendran, K., Murali, K., Sundar, V., 'Vortex-induced vibrations of elastically mounted circular cylinder at Re of the O (10^5)', *Journal of Fluids and Structures, 54, 503 – 521*, 2015.
8. Schlichting, H., 'Boundary layer theory', *McGraw-Hill Book Company, New York*, 1979.
9. Chandran, V., Sekar, M., Janardhanan, S., Menon, V., 'A numerical study on the influence of mass and stiffness ratios on the vortex induced motion of an elastically mounted cylinder for harnessing power', *Energies, 11, 2580*, 2018.
10. Naudascher, E.; Rockwell, D., 'Flow induced vibration – An engineering guide', *Dover Publications Inc, Mineola, New York, USA*, 2005.
11. Williamson, C.H.K., Govardhan, R., 'Vortex induced vibrations' *Annual review of fluid mechanics, vol. 36 pp 413 – 455*, 2004.
12. W, Jie., L, Halvor., M, L, Larsen., L, Stergios., B, Rolf. 'Vortex-induced vibration of a flexible cylinder: Interaction of the in-line and cross-flow responses', *Journal of Fluids and Structures 63 238–258*, 2016.

ABOUT THE AUTHORS

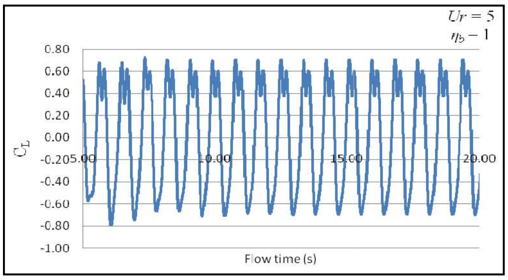
Dr. Vidya Chandran *is Associate Professor in the Department of Mechanical Engineering, SCMS School of Engineering and Technology, Cochin. She has a PhD in Vortex Induced Vibrations from Karunya University, India. Her research interests include Vortex Induced Vibrations, Marine Clean Energy and Under Water Robotics.*

Dr. Sheeja Janardhanan *is Associate Professor in the School of Naval Architecture and Ocean Engineering, Indian Maritime University, Vishakhapatnam, India. She has a PhD in Numerical Ship Hydrodynamics from Indian Institute of Technology Madras, India. Formerly she worked as Professor and Head, Department of Mechanical Engineering, SCMS School of Engineering and Technology, Ernakulam and also as Surveyor in the Research and Rule Development Division of Indian Register of Shipping, Mumbai, India. Her research interests include controllability of surface ships, underwater robotics, vibrations of risers and computational fluid dynamics.*

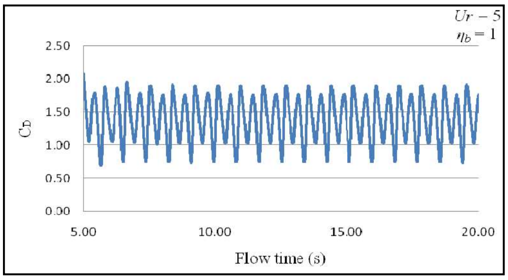
Email: *sheejaj@imu.ac.in*



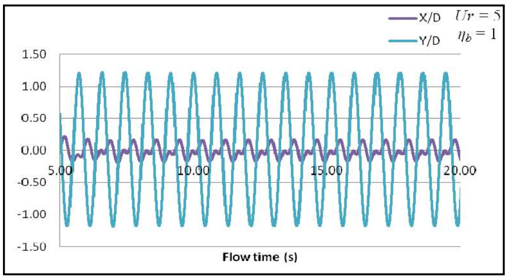
(a)



(b)



(c)



(d)

Figure 6 Pressure contours and time histories of various hydrodynamic and structural parameters (a) Vortex shedding pattern behind cylinder with 2DOF showing 2S mode (b) C_L of cylinder with 2DOF (c) C_D of cylinder with 2DOF (d) Motion history of cylinder with 2DOF

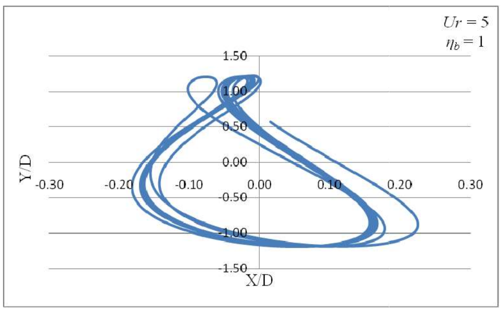


Figure 7 Trajectory of the cylinder with 2DOF motions under VIV

ELECTION NOTIFICATION

IME (I) GOVERNING COUNCIL AND BRANCH & CHAPTER COMMITTEE ELECTIONS 2021-2023, AN UPDATE

Elections for The Institute of Marine Engineers (India) have commenced as we speak.

VOTING (15 MAY 2021 – 01 AUGUST 2021)

- As a Corporate Member, you can now exercise your franchise at the forthcoming elections at IME(I) using the standard Ballot Paper or, alternately, by e-Voting-- by those who have so opted prior to 5th of May 2021.

BALLOT PAPER VOTING

a) The despatch of Ballot papers, by ordinary post, commenced on15 May 2021 and if you haven't received these please do write to the undersigned and we shall send you a set of duplicate ballot papers.

b) The envelop with the duplicate ballot paper will bear a stamp "Duplicate Ballot Paper" with the same serial no. allotted earlier. Dispatch of such duplicate ballot paper by The Institute will revoke the validity of the original ballot paper even if it has been dispatched by the member earlier or dispatched after receiving duplicate ballot paper, to avoid double voting.

c) The last date for receiving ballot papers at the Institute's office in Nerul, Navi Mumbai shall be **01 August 2021.**

d) Ballot Papers should only be MAILED via ordinary Indian Post, in the Reply-Paid Envelopes you would have received with the printed BRP No. NMD/BRP/91/2021-22 (Business reply Envelop License Number), and NOT sent by courier; Ballot papers from overseas Members may be couriered.No ballot paper(s) must be delivered by hand/ in person at the Head Office.

e) Ballot Papers received after 1700 hours on Thursday, 1st August 2021, for whatsoever reason, will not be considered for counting

f) All received ballot papers shall be deposited in a sealed box -- which any paid-up Corporate Member of the Institute can examine, externally, for effectiveness of the sealing arrangement, between 1000 hrs. & 1100 hrs. and 1600 hrs. & 1700 hrs. on normal working days.

E-VOTING

a) E-Voting went on line from 15 May 2021 and this option shall be available up until 1700 hrs on 01 August 2021.

b) Those who have opted for e-Voting should have received an email, with a Member's ID and Password. Please contact us if you haven't.

c) Those who have opted for e-voting shall not receive paper ballot papers.

COUNTING OF VOTES

1. The date and time of counting of votes shall be announced by the Election Officer. Venue shall be the IME(I) Head Quarters at IMEI House in Nerul, Navi Mumbai. Results shall be published in the MER.
2. Members who wish to be present at the time of counting should let the Election Officer / Scrutinizing officer know.

Should any member have any questions/suggestions in this regard, they may contact the undersigned.

Election officer

electionofficer@imare.in

The Institute of Marine Engineers (India), IMEI House, Plot no. 94, Sector 19, Nerul East, Navi Mumbai 400 706

Ship Recycling, Market Imperfections and the Relevance of a Consortium of Ship Recycling Nations in the Indian Subcontinent

Dr. Emil Mathew

ABSTRACT

Ship recycling operation is widely considered as one of the most hazardous activities in the shipbuilding industry. It causes significant environmental pollution and severe health risks. Accidents during the operation result in loss of life or injury to the unorganised workforce engaging in this activity. The costs arising from negative impact on the environment or loss caused to workers are not reflected in the market price of ship recycling. Stringent environmental and labour compliance standards enforced over the past few decades in developed nations have substantially increased the costs, shifting the recycling operations to nations in the Global South where these operations entail lower cost. This paper provides an overview of the ship recycling industry and highlights the consequential adverse effects on environment and human beings in the nations engaged in ship recycling and also elaborates on the guidelines proposed by international organisations to address these issues. It is argued that unless the externalities on the environment and human health are not taken into account, a sustainable model of ship recycling cannot be achieved. The paper proposes the formation of a consortium by recycling nations particularly India, Pakistan and Bangladesh, whose synergies will help to safeguard the interests of the workforce and environment in these countries. A ship recycling industry fund, under the auspices of International Maritime Organisation exclusively for meeting the cost of ship recycling, is also mooted for consideration. Availability of this fund, along with efficient policy formulations initiated by the consortium of major ship recycling nations, can play a major role in addressing the externalities and turning the recycling operation environment- and labour-friendly.

KEYWORDS: *Ship Recycling, Externality, Ship Recycling Nations*

INTRODUCTION

For centuries, shipping has been the cheapest mode of transport of large volume of goods and currently, almost 90 per cent of the goods by volume and 70 per cent by value are transported by sea. Different types of commercial ships such as general cargo ships, bulk carriers, automobile carriers, tankers and cruise ships were developed over the course of the 20th century to meet specific transportation requirements. Typically, ships have an average life of 25–30 years (Frey, 2015) and end-of-life ships are recycled. Almost 95 per cent of the parts of a vessel are dismantled and reused (Jain et al 2013). Ship recycling, dismantling, demolition and breaking are the terms used interchangeably to refer to breaking of ships to make their parts reusable. Ship recycling is influenced by market fluctuations. The ships that eventually become available for recycling depends on many factors such as lower freight rates due to lower demands, obsolescence, uneconomic repair costs, need for cash by ship owners, regulatory requirements, introduction of innovative technology, changes in the trading patterns and lower resale value in second hand markets (Stopford 2009; Buxton 1991; Karlis et al. 2016; Mikelis 2018; Gourdon

2019). It is estimated that almost 1 per cent of the world's merchant fleet is demolished every year (Frey, 2015). The number of ships to be recycled is expected to go up as the number of ships manufactured has been increasing over the years.

Until the beginning of the 1980s, it was mostly the developed nations were engaged in ship demolition activities. But when strict enforcement of environmental and labour safety standards began in these countries, the cost of dismantling at shipping yards touched an unaffordable level (Frey, 2015; Mikelis 2018). The additional costs, ensuing from regulations exerted pressure on the ship-owners in the developed nations to search for cost-efficient channels of dismantling. When it was realised that the developing nations did not have stricter regulations on environment and labour standards, they became attractive locations for ship recycling operations. While excess supply of labour and lower wages because of poor enforcement of labour rights brought down the recycling cost, the developing countries were either unaware or unmindful of the consequences of handling hazardous materials. The absence of regulatory enforcement in developing nations proved to be cost-effective as ship-owners and recyclers carried out dismantling operations without investing on environmental protection and labour welfare. End-of-life ships were therefore sent to developing nations after the 1980s (Mikelis 2018; Gourdon 2019).

The process of recycling puts enormous pressure on the natural as well as human resources of the nations where dismantling happens. Recycling leads to the discharge of large quantities of hazardous waste into soil, air and water around the recycling yard and the degradation of the coastal environment endangers the life of living organisms in its vicinity. The working atmosphere is highly accident-prone, as the labour force in the shipbreaking operations work under high-risk conditions. Accidents and illnesses arising out of handling hazardous waste may have a long-lasting effect on the labourers' entire lifetime. Only the interventions of various international organisations to protect labour rights and environmental standards in ship-dismantling nations gradually raised awareness about these vital issues (Hossain et al. 2008).

Even as the ship-owners benefit from lower cost of dismantling, recycling nations have to bear additional expenditure from their own pockets to maintain quality of life around the dismantling shore and those of people involved and this cost is not passed on to beneficiaries. Similarly, medical expenses borne by the labourers, either due to accidents or illnesses faced during the dismantling operations, are not met by both the beneficiaries – ship-owners and recyclers. External costs arising from clean-up of the coastal environment and expenses borne due to accidents and illnesses of labour force are the negative externalities of the recycling industry. These costs are not reflected in the market price of recycling ships. The inclusion of these external costs would add to the total social cost of dismantling services. In the normal course, the cost of ship recycling should be adequate enough to cover the social costs, such as the external costs spent on environmental protection and those that accidents and illnesses suffered by the workforce entail. In the absence of regulations to internalise these costs, ship-owners have a tendency to over-exploit the environment as well as labour by dismantling more ships, which eventually may lead to an inefficient allocation of the resources. Hence, imperfections in the ship recycling market calls for corrective interventions.

To correct the imperfections arising from negative externalities, international organisations have come up with guidelines to improve the conditions of workers as well as the coastal environment in recycling nations. However, lack of a legal framework for the guidelines (Greenpeace 2000), poor bargaining power of workers (Frey, 2015; Saha et al 2013) and lack of consensus on shipbreaking among recycling nations (Terao 2011; Pelsy 2008) created a vicious circle, resulting in the continuing onslaught of the problem. Though international agencies have proposed various guidelines, they could not be implemented successfully as the recycling nations have not become parties to these regulations. Excess supply of labour in recycling nations coupled with lack of awareness about the implications of handling hazardous materials left workers with poor bargaining power. Moreover, competition among major ship recycling nations in the Indian subcontinent led to a lack of collective bargaining power to demand the external cost of recycling from ship-owners.

The first section of this paper examines the factors leading to the transfer of ship recycling operations from developed to developing nations, the nature of recycling markets and the negative externalities arising from increased expenditure of workers and costs for the protection of coastal environment. The next section on international conventions throws light on the various guidelines suggested by different international bodies and the loopholes to circumvent the guidelines. The absence of legal framework for enforcing guidelines, poor bargaining power of workforce and lack of consensus among competing recycling nations on shipbreaking have exposed the vulnerability of the workers and the environment of recycling nations. In the third and the last section, the paper suggests the constitution of a consortium of ship recycling nations guided by an international organisation to represent the interests of the workforce engaged in the industry. Further setting up of a ship recycling fund, raised and maintained by the international organisation, to meet the external cost of recycling imposed on workers and the coastal environment is also proposed.

HISTORY OF SHIP RECYCLING

Ship recycling activities underwent several transformations in the last century and recycling operations gradually moved out of developed nations and entered the developing nations of South Asia. Japan was the largest shipbreaking nation in the mid-1960s. But, by mid-1970s, Taiwan had overtaken Japan and continued to be the number one till the end of 1980s. China eventually joined Taiwan, Japan and South Korea in shipbreaking and

Nations	2016	2017	2018
Bangladesh	15.3	11.0	14.8
Pakistan	9.7	6.9	7.1
India	12.8	10.0	6.9
China	5.2	5.7	0.4
Other	1.6	1.7	1.6
Total	44.7	35.3	30.8

Table 1: Composition of the Ship Recycling Market (million deadweight)
Source: Clarksons Research 2019.

East Asia emerged as the global centre of shipbreaking in the late 1980s and in the early 1990s. The volume of ship dismantling was 50,000 GT per year in the 1970s, quadrupling to 200,000 GT in the mid-1980s (Terao 2011). The United States also undertook shipbreaking operations till the mid-1970s. China took the lead in 1990s, and India, Bangladesh and Pakistan from South Asia soon joined the shipbreaking nations' list (Rousmaniere et al 2007; Pastorelli 2014). Thus, the concentration of shipbreaking had changed since the 1990s, moving from East to South Asia. According to Clarksons Research of 2019, in the year 2018, 30.8 million dead weight tonnage of vessels were dismantled. About 93 per cent of the recycling was carried out in these three nations of the Indian sub-continent (Table 1).

Studies by Terao (2011) have established a positive link between ship scrapping and economic development of certain nations such as the United States, Japan, Taiwan and Hong Kong. All these nations depended on capital-intensive techniques for ship dismantling, which involved methods other than beaching, and supposedly less environmentally damaging. Beaching method basically involves grounding and imbedding the vessel by driving it to a sandy shoreline at a high speed (Greenpeace 2000). The developing countries engaged in this form of ship-breaking, have little or no port facilities to support the beaching process. East Asian nations like Japan, Taiwan, and South Korea had undertaken ship demolition in an established wharf in ports using heavy equipment for initial disassembly before dismantling ships into small iron plates and scraps using labour-intensive techniques (Tearo 2011). However, by the 1980s, the size of vessels meant for scrapping as well as the tonnage to be scrapped increased and this necessitated dependence on beaching, since alternate methods to accommodate bigger vessels required additional investments in the yards or in other facilities.

The methods of beaching and labour-intensive techniques used extensively for recycling operations manifested in increased accidents and coastal degradation. The occurrence of accidents, stricter implementation of labour rights and environmental and safety standards in developed nations resulted in escalated costs of the recycling operations. According to Sawyer (2002), by the early 1990s, shipyards of Europe, the United States and East Asia discontinued dismantling and moved to other profitable operations. The environmental and health consequences of dealing with hazardous materials such as asbestos, polychlorinated biphenyls (PCBs), tributyltin (TBT) and lead found in superstructures of ships forced state officials to shut down the dismantling operations in most of these nations (Greenpeace 2000; Saha et al. 2013; Pelsy 2008; Sawyer 2002). In contrast, cheaper dismantling methods, poor enforcement of environmental and safety standards and excess supply of labour, unaware of their rights, made the dismantling operations more attractive in the Indian subcontinent and hence the global centre of dismantling shifted (Frey 2015; Pastorelli 2014; Greenpeace 2000; Mikelis 2018). Besides, the presence of child labour at dismantling yards brought the cost of recycling further down, though it produced socially unjustifiable outcomes (Pastorelli 2014; Saha et al 2013).

At present, the three major centres of shipbreaking in South Asia are Alang in India, Chittagong in Bangladesh and Gaddani in Pakistan. The presence of natural yards suitable for breaking by beaching made them the favoured locations to adopt an inexpensive method of dismantling (Patrizia 2015). More than 90 per cent of the vessels owned by the developed world (Frey 2015) are dismantled in developing nations of the Indian subcontinent (Greenpeace 2000). Ship recycling ensures sustainable reuse of the materials of a ship without resorting to extraction of natural resources heavily, but the practices followed at the yard for dismantling in developing nations are deplorable (Gourdon 2019; Mohanraj 2013). Shipbreakers of South Asia make meagre investment on fixed equipment and capitalise on the supply of abundant cheap labour that usually migrate from the interior parts of these nations and are subjected to work in an atmosphere of absence of regulations on safety gadgets in degraded environment. The ship demolition market does not reflect the external costs on labour force and environment, or the market does not internalise the negative externalities of ship recycling market. The actual cost of ship recycling on the society is much higher consequent to the presence of external costs of ship recycling and hence, the negative externalities result in the emergence of public bad or market failure.

SHIP RECYCLING MARKET

In the ship recycling markets, the owner who is interested in selling the vessel usually approaches the brokers who are familiar with various cash buyers, who purchase end-of-life vessels for reselling to recyclers. After several rounds of negotiations with the cash buyers, the ship broker mediates the sale, for which he obtains a certain percentage of value of the contract as commission for his services. The cash buyer takes the legal ownership of vessel and resells it to recyclers (Karlis et al 2016). The ship-owner has to deregister the ship and the cash buyer does not reregister the ship or obtain new statutory certificate from a flag state, if the voyage to the recycling yard is within domestic waters. On the other hand, if it has to cross international borders to the recycling yard, the cash buyer has to crew the ship, reregister, obtain valid statutory certificates and insure it for a short duration. A number of open registries or flag of convenience, mostly from the grey or blacklisted nations by Paris Memorandum of Understanding, are preferred for the end-of-life voyage of vessels (Mikelis 2018; Patrizia 2015). The costs involved in reregistration, documentation and insurance are to be borne by the cash buyer as the ownership is changed to him.

The recycling yards of top three nations of the Indian subcontinent charge competitive prices to attract cash buyers (Terao 2011). Since the competition in the recycling market is intense, profitability depends either on revenue maximisation or cost reduction, or both, followed by recyclers. Revenue generation of recyclers is volatile, subject to prices of reusable steel and other recyclable items, in addition to the domestic currency exchange rate with the US dollar (Karlis et al. 2016; Mikelis 2018). A World Bank study (2010) released a comparative analysis of revenue and costs to the buyer generated from ship recycling yards of Bangladesh and Pakistan. It indicated that for a ship costing the same for recycling, Bangladesh had a profit margin of 15 per cent, whereas it was only 3 per cent in Pakistan (Table 2). Difference in profitability is accounted by mostly the wage differentials and overall cost of dismantling, consisting of labour costs, taxes, tariffs and duties and financial cost. The recycling nations are competing to quote a higher price to make their yards attractive, even by foregoing basic investment expenditures to maintain minimum environmental and labour standards.

Typically, the financial liability of the ship-owners ends with the transfer of vessels to the recycling yards. The responsibility of ensuring safe working conditions and environment-friendly recycling process lies completely with the yards. Preparing an inventory of hazardous materials and their replacement on board, monitoring for soil, air and water protection, waste storage, waste transport, training of personnel, ensuring personal protection equipment, build structure for cutting zones and waste disposal are the responsibilities of recyclers, in addition to complying with regulations and standards (Gourdon 2019). In the absence of regulations, the negative externality generated from the recycling operation would be transferred on to the environment and to the workers. A globally competitive ship recycling market does not give due importance to the estimation of negative externalities on human beings and environment unless an external legal sanction is imposed on the ship-owners and recycling yards. Therefore, the present system does not impose obligations on ship-owners during the ship's life and instead shift the burden of recycling on to the recycling nations and the workers involved in the process, ignoring the real capacity of developing nations to assimilate such imperfections (Pastorelli 2014). It is ideal to incorporate the external cost of recycling operations into the market price through 'beneficiaries' pays' principle. Under this principle, all the parties who had benefitted from vessels during its life cycle are made liable to contribute towards external cost judiciously.

Category	Element	Bangladesh	Pakistan
Revenue	Steel	4,771,500	4,992,800
	Other recyclable items	842,000	512,700
	Total Revenue	5,613,600	5,505,500
Costs	Purchase of ship	3,848,000	3,848,000
	Investment costs	21,900	18,300
	Financial costs	147,900	265,700
	Labour costs	92,700	233,400
	Consumables	302,200	230,000
	Taxes, tariffs and duties	263,000	693,600
	Rents, levy and permits	2700	500
	Other costs	13,800	51,300
	Total costs	4,692,200	5,340,800
Profits	Profit	921,400	163,600
	Per cent	15	3
	USD/ LDT	62	11

Table 2: Ship Recycling Finance (in USD), *Source: World Bank (2010)*

EXTERNAL COSTS OF SHIP RECYCLING ON WORKERS' HEALTH AND ENVIRONMENT

The market imperfections in recycling market calls for internalising the negative externalities, both on the coastal environment and workforce. If these are left unregulated, producers of externalities, both ship-owners and recyclers, may continue to produce these externalities by over-exploiting the resources, which would result in an inefficient resource allocation (Morris 2013). First, external costs of ship dismantling are largely dependent on four cost variants: (i) costs involved in removal of structural components requiring special treatment; (ii) costs of removing operational waste generated within ship's operational period; (iii) costs involved in improving the capacity of the ship recycling yards; and (iv) the costs to deal with on board generated wastes (Choudhary 2011). Second, external costs on human safety and health relate to the costs of accidents and illnesses faced by the labour force while handling hazardous wastes at the yard. Improper information sharing on long-lasting harmful health effects of handling hazardous waste materials on the life of labour results in asymmetry of information in the labour market. The excess supply of labour in the recycling nations, combined with improper knowledge of the risks of accidents and harmful effects of working in the recycling industry, expose the labour force to a potentially dangerous environment with no cover. Therefore, the wages received by the employees are not inclusive of medical expenses to restore their health to a normal stage in case they are afflicted with ailments during their work. Besides, administration and monitoring costs incurred by public authorities and agencies for monitoring coastal environment too constitute part of the external costs of implementing recycling regulations. The yards with poor enforcement regulations on environmental and labour standards allow ship-owners to escape from internalising these external costs.

Migrant unskilled workers from the interior parts of the nations, having no capacity for bargaining either by lack of inherent knowledge or regulatory checks, are forced to work without adequate protective gadgets in these recycling yards. Moreover, the yards do not provide training facilities to upgrade skills of the workers, who are employed on contract for a short duration. Most of the work in these yards is labour-intensive and quite often results in accidents. But these workplaces are ill prepared to render any adequate medical attention to these accident victims. The International Labour Organisation (ILO) describes shipbreaking as involving high levels of fatalities, accidents and work-related diseases and to be the most dangerous of all occupations (ILO 2019; Pastorelli 2014). The international conventions, treaties and regulations to safeguard the working conditions are not strictly adhered to in most of the yards. A report submitted by Technical Experts Committee constituted to study the conditions of workers in Alang, India, observed that the incidence of fatalities in shipbreaking industry is 2 per 1000 workers, while the all India incidence of fatal accidents during the same period in the mining industry, which is considered to be the most accident prone, is 0.34 per 1000 workers (Sahu 2014).

In the study (Sahu 2014) conducted between April 2013 and May 2014 on the condition of the workers at Alang, it was noted that only a small clinic was available at the yard for medical assistance and the facility is ill equipped to treat patients who suffer from fatal accidents. Further, there is no means to address the health issues of an average of 90–100 workers who turn up with minor injuries each day. The bills of the workers treated in hospitals are not settled by the Employees State Insurance Corporation. Further, lack of registration of migrant workers in district records, unauthorised deductions from wages, lack of overtime wages, delay in payment and lack of insurance protection are some of the routine problems faced by the workers. The workers are not provided adequate protective gears to work in a risk-prone atmosphere for long hours and they have to live without basic housing, sanitation, electricity, drainage systems, drinking water and education for their children. Alang-Sosiya in India provides employment opportunities for around 35,000 unorganised migrant workers directly and for thousands indirectly in allied activities. The National Institute of Occupational Health, Gujarat, carried out x-rays of 94 workers of Alang in 2006–07 and found 15 of them suffering from early stages of asbestos poisoning (Sahu 2014).

Chittagong in Bangladesh, another major recycling site, employs over 50,000 people directly in scrapping activities and around 200,000 workers depend on the shipbreaking industry through allied activities. Workers in Chittagong revealed that after 10 years of hard work in the yard, depreciating health conditions forces them to retire from recycling operations and 66 per cent of them are aged between 20 and 39 years (Hossain et. al: 2008). Another study on Chittagong gave insights on multiple diseases and health hazards faced by the workers such as abdominal, urinary, muscle and skin problems and nutritional deficiency due to close proximity of toxic metal, oil and chemical contamination, excessive workload, long working hours, irregular eating, insufficient diet and unsafe drinking water (Zakaria et al., 2012). The medical expenses arising from illnesses and deterioration of health are borne by the workers and market wages do not include these external costs. A study by Jobaid et al. (2014) revealed that even though shipbreaking is considered to be one of the dangerous jobs, the employment of children was considered to be lucrative as the wages paid to them were low. In Chittagong the child employees aged between 7 and 18 years constituted around 10 per cent of the total workers at the yard. It raises concerns on the long-term sustainability and survival of child labourers. A study (Memon et al 2016) on the living conditions of Gaddani, Pakistan, indicated that the workers stay in unhealthy circumstances without proper infrastructure, education and medical facilities. The infrastructure provided to counter severe health risks was not sufficient to meet the requirements. Lack of proper treatment of wastes was one of the reasons behind the recurring nature of health issues.

The hazardous and polluting substances from the vessels contaminate the environment and degrade coastal areas, marine environment, fisheries and result in loss of biodiversity (Demaria 2010; Aktaruzzaman et al 2014). The external costs on the environment provide an insight into the extent of exploitation of the environmental resources, which the ship-owners and recyclers treat as available free of cost in recycling nations. In the absence of a proper disposal procedure for asbestos, one of the widely used materials for ship building, the surrounding areas get exposed to asbestos fibres, which is one of the causes behind cancer and asbestosis. Heavy metals, paints, coatings, anodes and electrical equipment that are removed without appropriate protective measures are likely to expose human organs to various levels of hazards that may produce different types of cancers. Oil discharged from the ships causes damage to the marine ecosystem and leads to a reduction in the level of oxygen content in the sea water, which may adversely affect the marine biodiversity. The continuous discharge of wastes and other harmful substances into the coastal waters may affect the coastal ecosystem and the life span of mangroves and other aquatic organisms (Mohanraj 2013). The release of bilge and ballast water into the sea causes pollution of sea water and beach sand. During dismantling, disassembling of air conditioning and refrigerating systems result in the release of chlorofluorocarbons that could be hazardous to the ozone layer. The cost incurred to bring the environment back to its pristine beauty is the external cost that recycling slaps on the environment.

INTERNATIONAL CONVENTIONS TO REGULATE RECYCLING OPERATIONS

The questions of workers' safety and environmental pollution were not the major concerns of the dismantling yards for a long time until a major accident occurred in Taiwan, killing many workers in 1986 (Terao 2011). The statistics of occupational accidents of Kaohsiung City, Taiwan, in 1984 indicated that among 86 serious occupational accidents, 27 occurred in the shipbreaking industry with an overall mortality rate of 2.1 per 1000, which ultimately led to the ban of shipbreaking industry in 1986 (Liu 2003). Shipbreaking yards of South Asia, which employ huge labour force and are engaged in large-scale dismantling operations without paying due regard to human safety and coastal pollution, invited the attention of international organisations and associations (Sahu 2014; Terao 2011). The international regulations for the transboundary movement of hazardous wastes were included in the Basel Convention of 1989 (Basel Convention 1989). International organisations called for regulatory measures in the conference of Parties of the Basel Convention on the Control of Transboundary Movements of Hazardous Wastes and their Disposal in UNEP, and also in international bodies such as the ILO and International Maritime Organisation (IMO). In 2002, Basel Convention published the 'Technical Guidelines for the Environmentally Sound Management of the Full and Partial Dismantling of Ships'. The ILO published the 'Safety and Health in Shipbreaking: Guidelines for Asian Countries and Turkey' in 2003. The IMO came up with 'IMO Guidelines on Ship Recycling' in 2003. Lack of legal sanctity reduced the effectiveness of these guidelines to voluntary adoption by the parties involved. Under the auspices of IMO, a diplomatic convention called the 'Ship Recycling Convention' was held at Hong Kong in 2009 (Terao 2011; Mikelis 2018). The Convention identified security or worker safety, proper treatment and disposal of hazardous materials and formulation of a ship recycling plan as duties of a recycling yard.

The Hong Kong Convention specifies regulations during different stages of the life of a ship: design, manufacturing, operation, recycling preparation and demolition. At the manufacturing stage, the shipbuilders must collect material declarations of raw materials, parts and machinery from subcontractors, and create an inventory based on that information. Later on, the ship-owners take up the responsibility for inventory management till the vessel is taken for recycling. They also are required to draw up a Ship Recycling Plan in coordination with recycling yards before demolition. The Convention requires the yards to obtain approvals from competent authorities of recycling nations and be subject to periodic inspections where the dismantling is to be undertaken. The Convention shares the responsibility with all the stakeholders who take part in in the building, operation and recycling of the ship (Jain et al. 2013).

The Hong Kong Convention is a revolutionary step taken by international bodies to lower the unequal sharing of responsibilities of recycling nations and to provide mechanisms for sustainable or green recycling. The Convention, which was considered as an important step, is not devoid of defects. Exemptions given to ships less than 500 GT, exclusion to non-commercial ships, neglect of guidelines on material disposal and treatment facilities at yard, failure to suggest an alternate method to beaching for dismantling, absence of proper incentives and support mechanisms for dismantling, reflagging of ship to non-party state and absence of third party control by other nations are the areas that nations can easily circumvent the regulations (Terao 2011; Jain et.al., 2013; Patrizia 2015). Though considered to be a revolutionary stage in the process of green recycling, lack of legal sanctity of the Convention and mechanisms for implementation make it voluntary for the nations to enforce them. Therefore, the Convention could not produce any significant impact on improving the conditions of the recycling yards.

In 2013, European Union Ship Recycling Regulation (SRR) was adopted to reduce dumping of toxic substances in developing nations with the intention to prevent their negative impact on environment and human beings. This regulation insists the European owners to ensure on board the listing of hazardous substances and to provide a ready-for-recycling certificates to recycle yards. The loopholes in SRR such as lack of financial incentive mechanism for ship recycling, complications associated with reflagging of vessels before the final journey, failure to suggest an alternate method to beaching and lack of restrictions on the use of flag of convenience permit the European owners to circumvent the EU SRR (Patrizia 2015; Pastorelli 2014).

Though the guidelines of international organisations had loopholes using which stakeholders circumvented them, the suggestions provided in these guidelines could be treated as revolutionary measures to correct the imperfections in the ship recycling market. They created an awareness about labour rights and the need for upholding environmental compliance standards in recycling nations. Considering the long-term goal of achieving sustainability, the suggestions put forth may have to be collectively adhered to by all the stakeholders to reduce the implications of negative externality.

PROPOSAL FOR A CONSORTIUM OF SHIP RECYCLING NATIONS

The guidelines provided by international organisations since the Basel Convention in 1989 could be treated as revolutionary steps to frame policies to reduce the consequences of negative externalities inherent in ship recycling activity. However, the suggestions of the HKC and the EU SRR had certain loopholes, which led to the non-adherence of these suggestions by different stakeholders of recycling. This study examines the problems of negative externalities experienced by the marginalised sections of ship recycling nations and the importance of a collective representation. As discussed earlier, the recycling nations have less stringent rules and regulations to ensure quality of the environment and life of the workforce. These nations are compromising on the coastal environmental quality to gain employment and financial benefit, which is an imminent need. Thus, the bargaining position of the workers in the recycling operations and coastal population of the recycling nations are almost nil and if left unregulated, it may lead to further exploitation of the existing resources. Having understood that around 90 per cent of the ship recycling operations are carried out in three nations of the Indian subcontinent and the workers lack organised support, a consortium of these nations can represent their interests to a greater extent to the wider maritime community.

The top three ship recycling nations of the Indian subcontinent share some commonalities such as use of labour-intensive techniques and beaching method while dismantling ships. The composition, nature and the problems of labour force of these nations are uniform in addition to the environmental degradation and deteriorating biodiversity of their coasts. This provides ample opportunity for the formation and sustenance of a consortium by these nations comprising India, Pakistan and Bangladesh. Since sustainability of the coastal environment and poor stature of the workers are major concerns globally, guidance from an international organisation may be beneficial to the recycling nations. An international organisation, preferably, an organisation under the UN like International Maritime Organisation (IMO) could act as a supporting agency to provide guidance. The need for constituting such a consortium should be highlighted to the recycling nations by IMO. In the absence of such a consortium, there may not be any incentive on the part of either the recycling yards or the ship-owners to voluntarily implement workforce-friendly and environment-protecting policies that may require certain financial investments. Since India, Bangladesh and Pakistan are currently member nations of the IMO, it would be easy to formulate and implement policies under its guidance and also to monitor the internal operations of these recycling nations.

As long as the group interest is placed at the fore with utmost importance, ignoring the competing interests of each of these nations, the consortium is expected to sustain for a long period. If any one of these nations places highest importance to their individual interest over the collective interest of the group, the consortium is likely to break apart. The consortium established should not aim at maximising the individual profit, but has to act as a forum to represent the collective interests of the deprived labour group and prevent the environmental damage caused by the recycling yards. The international organisation has to oversee the functioning of the consortium on a regular basis to ensure its sustainability; otherwise, the collective bargaining power of the marginalised sections as a whole may be lost. In the absence of a consortium, ship-owners would prefer that recycling yard which costs them less and give continuity to the current state of external costs.

The consortium should work in collaboration with the labour and environmental departments of these three nations. Besides the routine task of conducting meetings with the labour and environmental departments, the consortium has to estimate the external costs of ship recycling on environment and human life and the calculation may be done on the basis of 'beneficiaries' pays' principle. Appropriate estimations have to be made by taking the benefits enjoyed by ship-owners, considering the specificities of vessels, both under construction and those in operation. Similar to the funds generated in European nations for the recycling of vehicles, a recycling fund may be generated at the time of construction of the vessels (Gourdon 2019). For the existing ships in operation, a percentage of annual operating costs may be set aside towards the recycling fund. The fund so generated and managed by the international body may be transferred on to the recycling nations during dismantling based on the regulatory measures adopted and enforced in these nations. At the national level, yard license issuing authority in collaboration with international organisation may enforce regulations on ship-owners and recyclers. The local monitoring authority may be given the power to issue licenses and also the power to impose tax on ships that call at the recycling yards. The tax so collected could be used by local authority for the provision of developing the yard facilities including safety gadgets, potable drinking water, healthy food, medical facilities, training to the workers, awareness about handling hazardous materials, toilet and living conditions besides ensuring insurance in the event of accidents. The responsibility to ensure a healthy work atmosphere should be guaranteed by the national authority issuing license to the yard and the authority may also be made responsible to check the quality of air, water and atmosphere regularly.

Some of the loopholes of the HKC discussed earlier could be addressed significantly under the new arrangement if we approach them from the perspective of recycling nations. The HKC neglected the treatment of the hazardous materials at the yard. Proper and regular monitoring of the yard may be carried out by the domestic authority of each nation, since the recycling fund may be used to allocate funding to them on the basis of the corrective steps taken by the recycling yard. The recycling fund created with the assistance of an international organisation could act as a proper incentive and support mechanism at the time of ship dismantling. A portion of the recycling fund may be set aside every year for the development of technology to deal with issue of the treatment of hazardous materials. The issue related to the exclusion of non-commercial ships may be addressed by adopting a differential approach to ships on the basis of their specificities and appropriate policies may be framed by the international organisation in consultation with the consortium for the ships that are on their end-of-life journey headed towards the yards of these recycling nations.

Ship recycling operations of these three nations have the potential to provide employment to many unorganised migrant workers from interior regions of their countries. Moreover, the geographical advantage to follow beaching method for recycling could be looked upon as a cost-effective method of recycling of bigger ships. It is expected that the consortium set up to represent the interests of workforce and coastal community of ship recycling nations can address their problems to a great extent and can improve the quality of the environment and workers. Thus it is imperative to support the need for a representative body for the marginalised, as it could lead to a cost efficient outcome for the entire maritime community.

ACKNOWLEDGEMENT:

The author would like to thank Dr. Rajoo Balaji for his critical and insightful comments on the earlier draft of this paper.

REFERENCES

1. Aktaruzzaman, M, et al (2014), Ecological Risk Posed by Heavy Metals Contamination of Ship Breaking Yards in Bangladesh, *International Journal of Environmental Research*, 8 (2): 469–478.
2. Basel Convention on the Control of Transboundary Movements of Hazardous Wastes and their Disposal, Basel, 22 March 1989, 28 Int'l Leg. Mt. 657

(1989).

3. Buxton I (1991), The Market for Ship Demolition, *Maritime Policy & Management*, 18 (2): 105–112.

4. Choudhary Gopal Krishna (2011), An analysis of the creation of a global ship recycling fund in the framework of the Hong Kong International Convention for the Safe and Environmentally Sound Recycling of Ships, Thesis submitted in Master of Science in Maritime Affairs, World Maritime University, Malmo, Sweden.

5. Clarksons Research (2019), Shipping Intelligence Weekly, Issue No.1371.

6. Demaria, Federico (2010), Shipbreaking at Alang-Sosiya (India): An Ecological Distribution Conflict, *Ecological Economics*, 70: 250–260.

7. Frey, R. Scott (2015), Breaking Ships in the World-System: An Analysis of Two Ship Breaking Capitals, Alang - Sosiya, India and Chittagong, Bangladesh, *Journal of World- Systems Research*, 21(1): 25–49.

8. Gourdin Karin (2019), Ship recycling: An Overview, OECD Science, Technology and Industry Policy Papers, No. 68.

9. Greenpeace International (2000), *Shipbreaking: A Global Environmental, Health and Labour Challenge*. Amsterdam, The Netherlands: Greenpeace International.

10. Hossain M. Shahadat et al (2008) Occupational Health Hazards of Ship Scrapping Workers at Chittagong Coastal Zone, Bangladesh, *Chiang Mai Journal of Science*, 35 (2): 370–381.

11. ILO (2019), Shipbreaking: A Hazardous Work, http://www.ilo.org/safework/areasofwork/ hazardous- work /WCMS _110335/lang--en/index.htm accessed 22/06/19

12. Jain K. P et al (2013), Critical Analysis of the Hong Kong International Convention on Ship Recycling, *International Journal of Environmental and Ecological Engineering*, 7 (10): 684– 692.

13. Jobaid Md. Imrul et.al (2014), Ship Recycling and its Environmental Impact: A Brief Overview of Bangladesh, *IOSR Journal of Business and Management*, 16 (10): 31–37.

14. Karlis Thanasis et al (2016) Ship Demolition Activity: A Monetary Flow Process Approach, *Scientific Journal of Maritime Research* 30 (2016): 128–132.

15. Liu Yi-Kuen et al (2003), Mortality among Former Shipbreaking Workers- A 13 Year Retrospective Follow up Study in Taiwan, *Journal of Occupational Health*, 45: 36–42.

16. Memon Ahmed Ali et al (2016), Comprehensive Analysis of Existing Infrastructure Conditions Correlating Ship Breaking activities and Its Implications on Workers and Community: A Case study of Gaddani Town and Ship Breaking Industry, Baluchistan, Pakistan, *American Scientific Research Journal for Engineering, Technology and Sciences*, 17 (1), 245–257.

17. Mikelis Nikos (2018), The Recycling of Ships, http://www.gmsinc.net/gms_new/assets/ads/folder.pdf

18. Mohanraj T P (2013), Ship Recycling Industries and Its Environmental Impacts: A Comparative Study, ISSN 2321-4171. jsslawcollege.in/wp-content/uploads/2013/12/SHIP-RECYCLING-INDUSTRIES-AND-ITS-ENVIRONMENTAL-IMPACTS-A-COMPARITIVE-STUDY.pdf

19. Morris Jeffrey (2013), Environmental Costs and Externalities, Sound Resource Management Group, Inc. Prepared for the Oregon Department of Environmental Quality, https://www.oregon.gov/deq/FilterDocs/mmexternalities.pdf

20. Pastorelli Silvia (2014), EU Ship Recycling Regulation: What's in it for South Asia? EU-Asia at a Glance, European Institute for Asian Studies, Brussels.

21. Patrizia, Heidegger, et al (2015), What a Difference a Flag Makes? Why Ship Owners' Responsibility to ensure Sustainable Ship Recycling Needs to Go Beyond Flag State Jurisdiction, NGO Shipbreaking Platform, Briefing Paper, April 2015, Brussels.

22. Pelsy Florent (2008), The Blue lady Case and the International Issue of Ship Dismantling, 4/2 *Law, Environment and Development Journal*, 135, available at http://www.lead-journal.org/ content/08135.pdf

23. Rousmaniere Peter et al (2007), Shipbreaking in the Developing World: Problems and Prospects, *International Journal of Occupational Environmental Health*, 13 (4): 359–368.

24. Saha Ripon Kumar et al (2013), Safety Management for Bangladeshi Ship Breaking Industries Perspective, *Global Journal of Researches in Engineering & Industrial Engineering*, 13(5): 9–14.

25. Sahu, Geetanjoy (2014), Workers of Alang- Sosiya: A Survey of Working Conditions in a Ship- Breaking Yard, 1983–2013, *Economic and Political Weekly*, 49: 52–49.

26. Sawyer John E (2002), Shipbreaking and the North–South Debate: Economic Development or Environmental and Labour Catastrophe, *Penn State International Law Review*, 20 (3): 535–562. Article 4.

27. Stopford M, (2009), *Maritime Economics*, London: Routledge.

28. Terao, Tadayoshi (2011), From Shipbreaking to Ship Recycling: The Relocation of Recycling Sites and the Expanding International Approach, Kojima and Michinda (ed.) *Economic Integration and Recycling in Asia: An Interim Report*, Chosakenyu Hokokusho, Institute of Developing Economies.

29. World Bank (2010), Ship Breaking and Recycling Industry in Bangladesh and Pakistan, http:// documents.worldbank.org/curated/en/872281468114238957/The-ship-breaking-and-recycling-industry-in-Bangladesh-and-Pakistan

30. Zakaria N.M. Golam, et al (2012), Underlying Problems of Ship Recycling Industries in Bangladesh and Way Forward, *Journal of Naval Architecture and Marine Engineering*, https://www.banglajol.info/index.php/JNAME/article/view/10515/9431

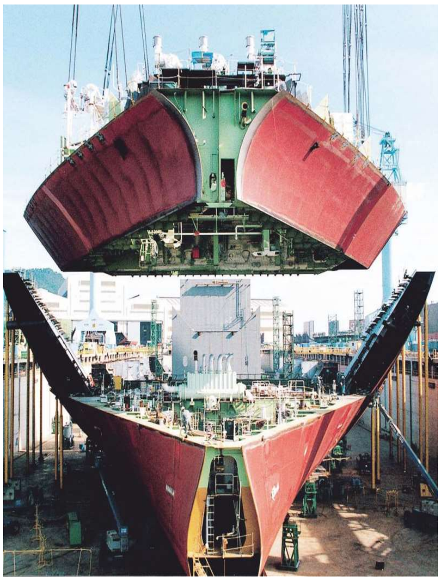
(This article was first published in the Journal of International Maritime Safety, Environmental Affairs and Shipping).

This article may be cited as: Emil Mathew (2021) Ship recycling, market imperfections and the relevance of a consortium of ship recycling nations in the Indian subcontinent, Journal of International Maritime Safety, Environmental Affairs, and Shipping, 5:2, 23-31, DOI: 10.1080/ 25725084. 2021.1921994

ABOUT THE AUTHOR

Dr. Emil Mathew *has a PhD in Economics and is currently working as Assistant Professor at School of Maritime Management, Indian Maritime University, Chennai Campus.*

Email: emilameya@gmail.com / memil@imu.ac.in



Class Action / Industry Moves

DNV ADDS NEW CLASS FOR CLOUD-BASED SIMULATION

DNV has revised its ST-0033 Maritime Simulator Systems standard with the introduction of a new class D for all function areas covering cloud-based simulation. The new standard sets an industry first, and DNV is ready to begin certification of simulators that are compliant. The use of remote methods to deliver training programmes for seafarers has increased during the COVID-19 pandemic as a result of restricted or impossible physical attendance at training and examination centres. The DNV ST-0033 Maritime Simulator Systems has been revised frequently since its initial publication in January 2000.

For more information, please visit:

https://www.dnv.com/maritime

WÄRTSILÄ COOPERATES WITH AUSTRALIAN COMPANY ON HYDROGEN PROPULSION

Wärtsilä has signed a Memorandum of Understanding (MoU) with Global Energy Ventures (GEV) of Australia, a company specialising in delivering compressed shipping solutions for transporting energy to regional markets, under which the two companies will cooperate on the inclusion of Wärtsilä propulsion systems in GEV's compressed hydrogen (C-H2) ships. The cooperation aims at advancing GEV's Approval in Principle (AiP) application for a new 430t C-H2 vessel, and to demonstrate the availability of an efficient, low-emissions propulsion system for the vessel.

For more information, please visit:

https://https://www.csi-newsonline.com/news/article/wrtsil-cooperates-with-australian-company-on-hydrogen-propulsion.html aip-for-methanol-dual-fueled-tanker-design/

CLASSNK GRANTS AIP TO TSUNEISHI SHIPBUILDING FOR CONCEPT DESIGN OF LNG-FUELED BULKER "KAMSARMAX GF"

Courtesy of TSUNEISHI SHIPBUILDING

Leading Classification Society ClassNK granted an Approval in Principle (AiP) based on its Rule Part GF (regulation for ships using low-flashpoint fuels) incorporating "International Code of Safety for Ships using Gases or other Low-flashpoint Fuels (IGF Code) to TSUNEISHI SHIPBUILDING Co., Ltd. for their concept design of an LNG-fueled bulker "KAMSARMAX GF". ClassNK has conducted its review and issued the AiP on the concept design of the "KAMSARMAX GF", which has installed a dual-fuel engine using LNG as the main fuel and an IMO Type C Fuel tank according to its Rule Part GF.

For more information, please visit:

https://www.classnk.com/hp/en/hp_news.aspx?id=6265&type=press_release&layout=1

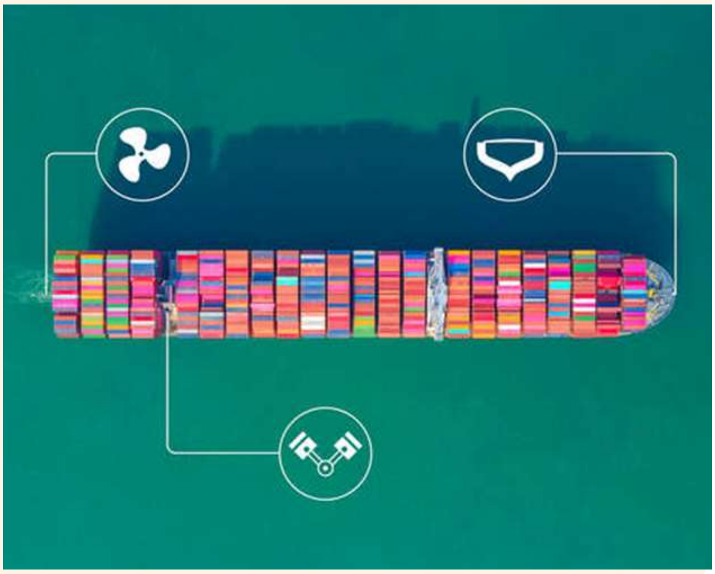
DNV COMPLETES SUCCESSFUL CONCEPT VERIFICATION REVIEW OF ODFJELL OCEANWIND'S WINDGRID™ FLOATING WIND POWER SYSTEM

DNV, the world's leading classification society, has completed a concept verification review of Odfjell Oceanwind's WindGrid™ (WindGrid) system for Mobile Offshore Wind Units (MOWUs). DNV's review confirms the technical feasibility of the WindGrid system, and that expected reductions in CO2-emissions for North Sea applications are in the range of 60-70%, compared to generation of electricity from conventional gas turbines.

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

DNV LAUNCHES NEW DIGITAL EEXI CALCULATOR

DNV has launched the EEXI Calculator – a digital tool to support customers in ensuring their compliance with the upcoming Energy Efficiency Existing Ship Index (EEXI). The regulation is expected to be adopted at this week's 76th meeting of the Marine Environment Protection Committee (MEPC 76). If so, it would take effect in January 2023. The EEXI regulation is a medium-term component of the International Maritime Organization's (IMO) roadmap towards reducing global shipping's carbon intensity by 40 per cent over the next decade, using 2008 as a baseline. The aim of the EEXI is to assess the energy efficiency of existing ships, focusing solely on their design.



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

(Class Action /Industry Moves Compilation: Rashmi Tiwari)

CHENNAI

TECHNICAL SEMINAR ON 'BLUE ECONOMY'

IME(I) Chennai Branch Conducted an online Technical Meet on 5th May 2021 at 1800hrs.

The theme of the webinar was **"Blue Economy - Role of Weather, Climate and Coastal Hazards"** presented by Dr. R. Venkatesan, Scientist G & Head Ocean Observation Systems, NIOT, Ministry of Earth Sciences, Chennai.

The technical meet commenced with an introduction to the concept and ground rules by Shri. Sanjeev S. Vakil, Secretary, IME(I) Chennai branch. Shri. Anil Kumar Chairman IME(I) Chennai welcomed the guest speaker, audience and members of the Institute. Shri. Muthusamy, EC Member, introduced the speaker. The presentation of the technical meet was well received and participants joined from various parts of India and also few who were sailing on board. The session was followed by Q&A session which was moderated by Shri. B. Jayakumar, Vice chairman and Shri S. Ramesh, EC Member.

An online feedback about the session was conducted wherein various Marine Engineers and Deck Officers of the shipping fraternity participated. The Vote of thanks was given by Shri. Suresh Shenoi, Treasurer, Chennai branch.

Bol Bada Saab Bol

(This section is for quick QA and easy read on marine engineering matters)

Picture & Words: CE Ramesh Subramanian

Octogenarian Chief Engineer A.K. Ramanujan continues his talks. And CE Ramesh throws light on modern equipment.

All sketches have been done by CE Ramesh Subramanian.

Hydraulic motor: (Figure A) The motor is robust and can take a lot of rough handling. The main output shaft is rotated by the forces of the Piston acting on the eccentric Cam. The oil is distributed to the correct piston by the oil distributor and exhausted oil is collected by the Oil Distributor and returned back to the tank.

In motors with dual speed, the eccentricity of the cam can be changed, thereby the displacement can be changed. This results in high speed for mooring operations and low speed for anchoring operations. This can be achieved by the pilot oil coming through the control oil grooves acting on the displacement (changing) piston.

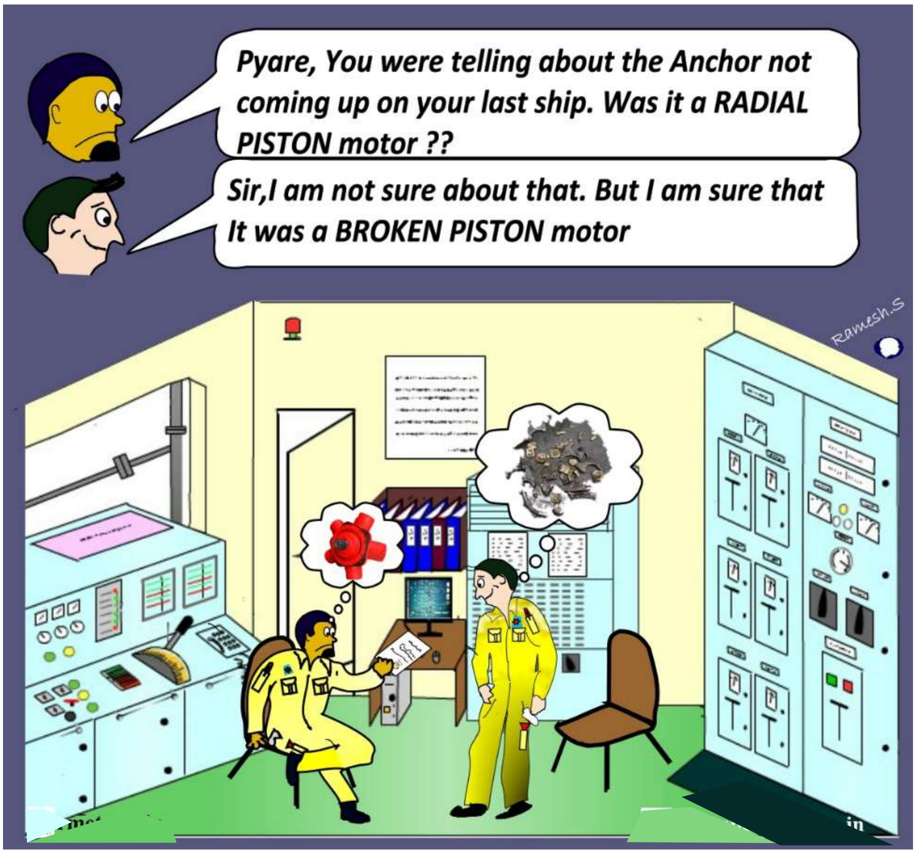
Maintenance: If oil is kept clean, there is actually no need for maintenance. It can even last for the lifetime of the vessel.

TYPES OF ELECTRIC MOTORS

The electric motor driving the gear pump is a three phase double squirrel cage motor with high slip capability combined with higher rotor current capacity because of the two layers (radially) of copper bars embedded in the iron rotor. The sketch of this rotor is reproduced in **Figure B**.

As the name suggests, the rotor of this motor has two squirrel-cage windings located one above the other as shown.

The outer winding consists of bars of smaller cross-section and short-circuited by end rings. Therefore, the resistance of this winding is high. Since the outer winding has relatively open slots and a poorer flux path around its bars **(Figure B, right)**, it has a low



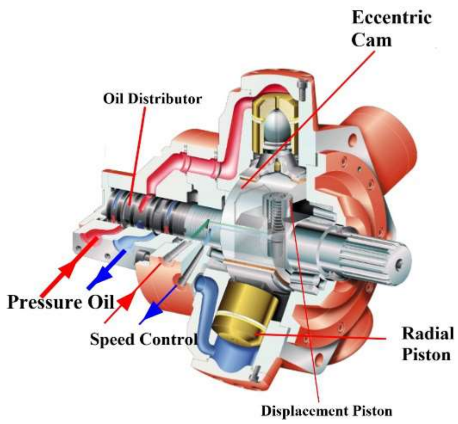


Figure A

inductance. Thus the resistance of the outer squirrel-cage winding is high and its inductance is low.

The inner winding consists of bars of greater cross-section short-circuited by end rings. Therefore, the resistance of this winding is low. Since the bars of the inner winding are thoroughly buried in iron, it has a high inductance. Thus the resistance of the inner squirrel cage winding is low and its inductance is high.

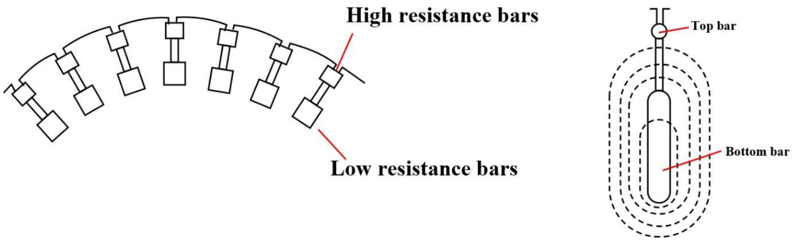


Figure B

Working

When a rotating magnetic field sweeps across the two windings, equal EMFs are induced in each.

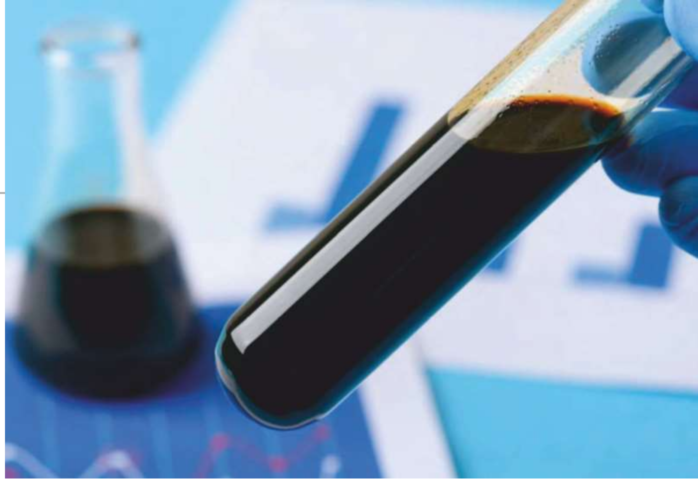
(i) On starting, the rotor frequency is the same as that of the line (i.e., 50 Hz), making the reactance of the lower winding much higher than that of the upper winding. Because of the high reactance of the lower winding, nearly all the rotor current flows in the high-resistance outer cage winding. This provides good starting characteristics of a high-resistance cage winding. Thus the outer winding gives high starting torque with a low starting current.

(ii) As the motor accelerates, the rotor frequency decreases, thereby lowering the reactance of the inner winding, allowing it to carry a larger proportion of the total rotor current. At the normal operating speed of the motor, the rotor frequency is so low (2 to 3 Hz) that nearly all the rotor current flows in the low-resistance inner cage winding. This results in good operating efficiency and speed regulation.

Points to Ponder/Data to Dig

1. Compare the speed control in Hydraulic and Electric windlasses.
2. Identify typical pressures and currents for both types.
3. List out the safeties in both types.

Talks will continue...



LUBE MATTERS 1
USED OIL ANALYSIS: COMMON TESTS

Sanjiv Wazir

INTRODUCTION

Lubricating oil is as important for an engine as blood for a human. Just as a lot of information about human health can be obtained from blood tests, similarly UOA can give deep insight into the machine's condition.

The practice of Used Oil Analysis (UOA) started more than 75 years ago when an American railroad company started using wear metal detection in used oil to assess the health of locomotive engines. Now UOA is one of the most potent tools of NDT and plays a central role in any planned/condition-based/predictive maintenance program for all kinds of machinery.

Regular testing of machinery lubricants enables us to:

- **Assess the condition of the oil** - to provide recommendations on its suitability for further use and to optimize oil change intervals.
- **Check for contaminants in the oil** - ingress of water, dirt, fuel, process fluid, wrong oil grade can significantly reduce oil life and accelerate wear.
- **Assess the condition of the machine** - to provide early warning of impending problems, and help reduce shutdown frequency, prevent equipment failure, improve production efficiency, and reduce maintenance expenses. All resulting in significant economic benefits.

UOA comprises of a series of Physical & Chemical tests along with Spectrometry, Particle count, Ferrography, IR, PQ, etc.

COMMON TESTS/TESTED PARAMETERS FOR MARINE LUBRICANTS

Kinematic Viscosity

Viscosity is the most important property of any lubricant. Kinematic Viscosity is a measurement of resistance to flow at a specific temperature in relation to time. The two most common reference temperatures for checking lube oil viscosity are 40 ˚C and 100 ˚C. Viscosity is generally measured by a kinematic method and reported in centistokes (cSt). In UOA, the sample's viscosity is compared to that of the new oil to determine whether the oil has thickened or thinned excessively. KV is tested for all lube samples.

Viscosity Index (VI) of lubricant is calculated based on viscosity values at 40 ˚C and 100 ˚C and can identify the lubricant grade as mono/multigrade.

Water Contamination

Water is a frequent contaminant in lubricants and its presence can lead to rapid oil degradation and loss of equipment life. It is particularly damaging for bearing lubrication. Water content is often measured by Karl Fischer titration test, which can check for all forms of water: dissolved, emulsified, and free. Crackle test & FT-IR may be used as screening tests for water content. Water content is tested for all UOA samples and is usually expressed as a percentage.

Base Number (BN)

Base Number (BN) is a measure of the acidity neutralisation potential of the lubricant. Products of combustion are the main source of acids. It is an important property for engine oils & an indirect indicator of detergency. BN is tested only for over-based engine oils.

Acid Number (AN)

Acid Number (AN) is the quantity of acid or acid-like derivatives in the lubricant. AN is usually measured in non-crankcase oils. The AN of a new oil is not necessarily nil since some oil additives can be acidic in nature. Increase in AN from that of the new lubricant is monitored. Increases in AN usually indicate lubrication oxidation or contamination with an acidic product.

Both BN & AN are titration tests using standard reagents and the results are expressed in mgKOH/g.

Water Contamination

Base Number (BN)

Flash Point

Change of lube flash point is mainly influenced by fuel contamination and to a certain extent by high temperature oil degradation. Above 200 ˚C the test is a FLASH/NO FLASH test. Below 200 ˚C Flash Point is measured. Usually only engine oil & thermal oil samples are tested for FP.

Insolubles/Soot

Insolubles represent a measurement of all solids in a lubricant. The nature of solids depends on the system. In diesel engine oils, Soot is the main component, and its level is good indicator of combustion efficiency. In other machinery, wear debris, dust and oil oxidation products are the main components. Lubricating oils are typically soluble in pentane. Oxidation products are typically insoluble in pentane, but soluble in toluene. Wear debris, soot, sand and asphaltenes are typically insoluble in both pentane and toluene. This test determines the amount of pentane insolubles and toluene insolubles in lubricating oils. The results are expressed as a percentage.

Fourier Transform Infra-Red (FTIR)

FTIR is a quick method for determining chemical changes in a lubricant. The instrument checks for changes of various characteristics by measuring the shift in infrared absorbance at specific wavelengths of a used oil sample, in comparison with levels in a fresh oil sample. The results are presented as a plot of infrared light absorbed against wavelength and expressed as 'Absorbance per 0.1mm' **(Figure 1).**

It is particularly good for measuring oxidation & nitration; somewhat less reliable but cost effective for measuring contaminants like fuel, water, soot, glycol, etc. Since it relies on comparison with fresh oil results, future tests should preferably be carried out in the same lab.

(More on FTIR in a later article on the subject)

Oxidation

Lubricating oil in engines and other machinery combines with available oxygen under certain conditions to form a wide variety of harmful by-products. High temperatures, excessive aeration, presence of catalyst materials (e.g., metallic wear particles) accelerate the oxidation process. By-products of oxidation form lacquer deposits, organic acids, corrode metal parts and thicken oil (increase viscosity). Most lubricants contain antioxidant additives which retard the rate of oxidation. Tested by FTIR and expressed as Abs/0.1mm.

Spectrometry

Metallic elements in the oil sample are measured by various spectroscopic methods. Most commonly ICP Emission Spectrometry (ICP - Inductively Coupled Plasma) is used. Wear, additive & contaminant elements can be measured. The results are usually expressed in ppm. Most spectroscopic methods have a limitation on size of particles that can be measured. ICP-ES does not effectively measure particles larger than 5 - 7 µm as larger particles are not fully vaporised in the plasma due to mass effects and so wear element concentration can be underestimated in cases of particularly high wear.

(More on Spectrometry in a later article on ELEMENTAL ANALYSIS)

Particulate Quantifier (PQ)

As the oil sample is brought into proximity to a controlled magnetic flux field in the PQ instrument, this magnetic flux distorts proportionally to the number of ferromagnetic debris within the sample. The amount of distortion is expressed as the "PQ Index" and is independent of particle size. PQ is a valuable adjunct to spectrometry.

Particle Count

Measuring the number of particles in the lubricant sample helps determine the overall cleanliness of the system being monitored. PC is primarily used for hydraulic systems. Reducing particulates in the lubricant can greatly increase the life of these systems. With the increasing use of marine 2-S main engine system oil for the Servo/Hydraulic systems of the engines, particle counting of Mn Eng. servo/hydraulic systems has assumed great importance.

(More on PC in a later article on MEASURING OIL CLEANLINESS)

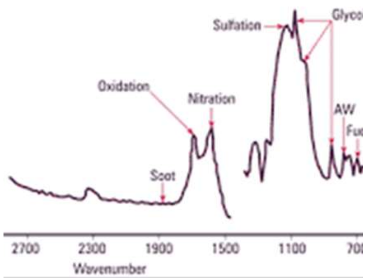
Trend Analysis

A single UOA report is like a paragraph. Trend analysis tells the story. Trend Analysis helps establish patterns within data that can be important for identifying problems early, which if left undetected could later lead to catastrophic failures. The historical trended data may also enable prediction of certain outcomes.

Sampling

Successful UOA begins with sampling. How, when and where a sample is taken from the lubrication system is especially important. This is because only a small amount of oil is collected during sampling. Hence it is essential to collect a truly representative sample of the system. Bad data is worse than no data. If samples are collected incorrectly, the oil analysis is a waste of time, effort & money.

(More on this in a later article on COLLECTING UOA SAMPLES)



FTIR Spectra

ICP Spectrometer

REFERENCES:

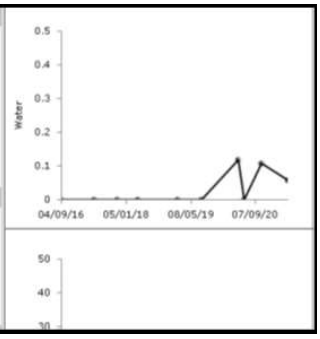
1. *Used Engine Oil Analysis-User Interpretation Guide, CIMAC No. 30/2011*
2. *Oil Analysis Explained, Machinery Lubrication 12/2013*
3. *Test Instrument photos from LUKOIL Marine-Tribocare Lab & Spectro Scientific*
4. *Title photo from STLE*

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

New Oil	Alert Value.	Analysis			
		Appearance	**Clear**	Clear	Clear
103		KV@40°C[mm²/s]	**90.85**	102.0	104.3
14.3	<10.7 or >17.9*	KV@100°C[mm²/s]	**12.85**	13.48	13.94
	>0.5*	Water[%wt]	**0.06**	0.11	<0.05
10	<5*	BN[mgKOH/g]	**9.2**	9.4	9.6
237	<170*	Flash Point[°C]	**184**	>200	>200
	>2.5*	Soot/Insoluble[%wt]	**0.10**	0.10	0.10
		PQ Index/2ml	**<10**	<10	<10
		Wear Elements [ppm]			
	>100*	Aluminium (Al)	**<1**	1	1
	>50*	Chromium (Cr)	**<1**	<1	<1
	>50*	Copper (Cu)	**55**	47	8
	>150*	Iron (Fe)	**3**	2	2
	>50*	Lead (Pb)	**4**	4	1
	>30*	Tin (Sn)	**<1**	<1	<1



Excerpt from LUKOIL UOA Report for an Emg. Generator engine oil sample

Alternative Fuel – Anticipated Issues & Proposed Solutions

Menon Ashwin Pramod
B.Tech. (Marine Engineering), Third Year, Tolani Maritime Institute, Talegaon, Pune

ABSTRACT

The Maritime Industry, despite being conservative to changes, has recently been looking into alternative fuels for running their ships. This newfound interest in alternative fuels can be primarily attributed to the emission standards of harmful gases like sulphur oxides and nitrogen oxides being progressively tightened by the IMO under Annex VI of MARPOL. These fuels come with several benefits for both the environment and companies alike. They will positively impact the environment with significant reductions in greenhouse gas emissions, which will help decarbonise the environment and curb climate change.

Although many alternate fuel sources are available, only a few are practically viable for the propulsion of ships. Some of the fuels under review are LNG, Biofuels, Hydrogen and Ammonia. Currently, LNG leads the race due to their attractive prices and abundant supply. Even though the companies have shown considerable interest in using alternate fuels, there are several barriers like limited availability, compatibility issues, high production costs, increased storage space and regulation issues that need to be broken before such fuels are introduced on a large scale. Considering the promising studies and proposed solutions, Alternate Fuels are set to be game-changers in the maritime industry.

KEYWORDS: *Alternate fuels, LNG, Biofuels, Barriers, Solutions*

I) INTRODUCTION

Alternative fuels are fuels that can serve as a substitute for fossil fuels wholly or partly and help reduce the pollution caused by the transport sector. The Maritime Industry has been a consumer of fossil fuels for propulsion and power generation and although it's a clean and efficient mode of transportation requiring only 2-3 grams of fuel per ton*km, it has been one of the largest contributors to Nitrogen oxide and Sulphur oxide emissions with a share of 13% and 12% of the global emissions, respectively. It is also responsible for around 2.2% of global CO_2 emissions due to fossil fuel use [1][2]. Another significant issue is the amount of particulate matter spewed out by the ships (1.2-1.6 million metric tons), resulting in around 60000 deaths due to cardiopulmonary and lung cancer annually [2]. With these emissions continuing to rise and the reserves of traditional fossil fuels depleting rapidly, alternate fuels will play a significant role in creating an environmentally friendly and sustainable shipping industry.

This paper scrutinises some of the alternate fuels considered as viable replacements to the current marine fuels. We will discuss the potential challenges we face in shifting to such cleaner fuels and proposed solutions to overcome these challenges.

II) ALTERNATE FUELS UNDER REVIEW

Some alternative fuels with the potential to be used as a marine fuel are LNG, Hydrogen, Ammonia, Biofuels, and renewable energy sources like wind and solar energy. But at the moment, all other fuels except LNG and Biofuels are not feasible enough. The biggest hurdle preventing the use of most alternative fuels are their Physicochemical characteristics such as low flashpoints, higher volatilities, different energy content and toxicity. Another problem faced is that the IGF Code, a mandatory safety code for gas-powered ships does not recognise most of the proposed alternate fuels which limits the use of these fuels.

Ammonia has a very low energy density and is highly toxic and corrosive [3]. Similarly, Hydrogen also requires a lot of space and needs to be cooled to -253°C to be stored as a liquid [9]. It is also very flammable and very costly to produce. The space of renewable energies as marine fuels has seen several technological advancements like Rotor Sails, Solar Panels, Kites, and Wind Sails which harness wind and solar energy to propel the ship. But at the moment, it is not a feasible solution for deep-sea shipping and can only be used to assist in propulsion partially. Considering these points, LNG and Biofuels can be looked at as the most feasible solutions in the current scenario.

A) *Liquified Natural Gas*

Liquified Natural Gas or LNG has been widely accepted as the most mature and viable alternate fuel currently available. Over the past decade, new technological innovations like hydraulic fracking have led to LNG being readily available, making it competitive in costs

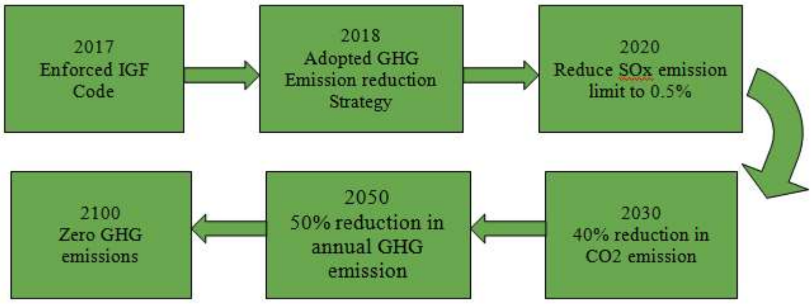


Fig 1: IMO Decarbonisation Strategy

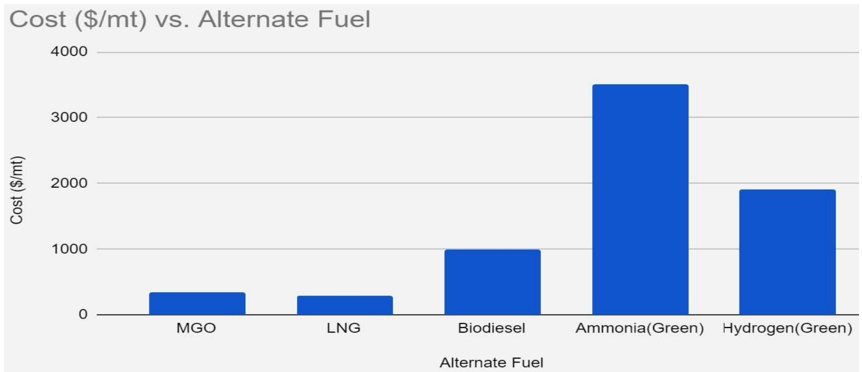


Fig 2: Comparison of Cost of Different Fuels [10]

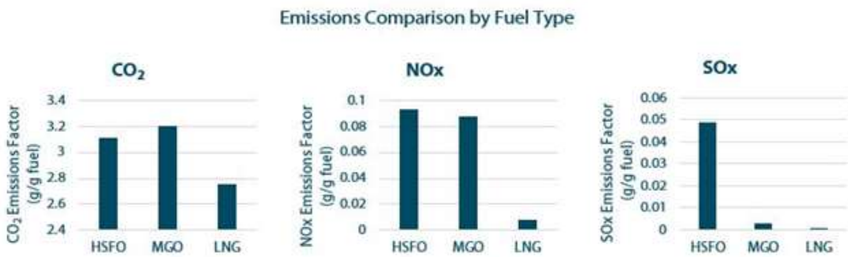


Fig 3: Comparison of Emissions by Fuel Type (Source: breakthroughfuel.com) [11]

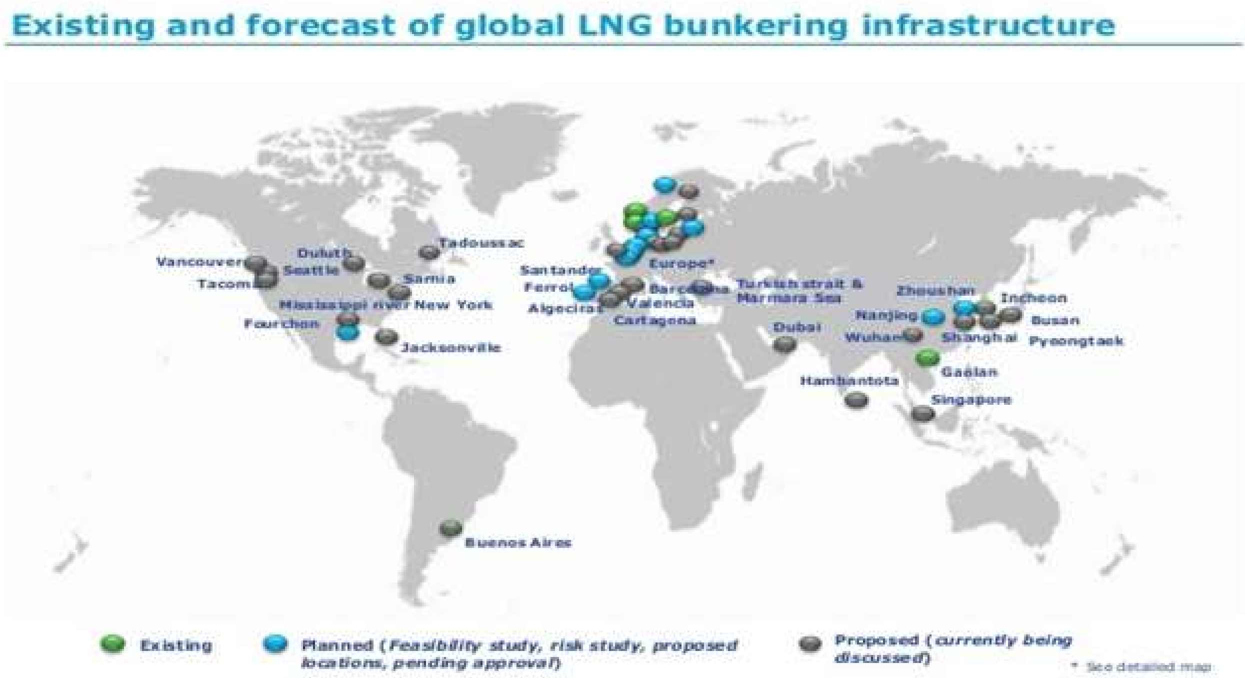


Fig 4: Global LNG Bunkering Infrastructure 2014 (Source: safety4sea.com) [12]

with distillate fuels. An LNG powered ship is future-proof to new emission regulations and will yield a higher return on investment than scrubber systems and LSFO. From an environmental perspective, LNG is an excellent alternative fuel as it eliminates SOx and particulate matter emissions by almost 100%, NOx emissions by 85%, and CO_2 emissions by around 21% [4].

These advantages have led to a significant annual growth of 20-40% in the number of LNG powered ships over the last decade [5]. We have also seen the market for LNG powered vessels from the short-sea to deep-sea shipping space with over 400 vessels either in operation or under construction. The number of LNG bunkering facilities has also increased in recent years, with them being either operational or under construction in 9 out of 10 major bunkering locations worldwide and around 20 bunker vessels are also either in use or under construction for remote bunkering [5].

Some of the challenges preventing shipping companies from using LNG-powered ships are:

- **High Capital Cost:** LNG being a Non Drop-in fuel is not compatible with the existing engines and fuel systems and hence the ships have to be retrofitted with Gas Engines and fuel systems or new vessels have to be constructed. Additional crew training is also required to handle these ships. These require large amounts of capital, which prevents companies from adopting LNG as a marine fuel.
- **Large Fuel Storage Volume:** LNG has a considerably low energy density and requires twice as much fuel storage space as a liquid fossil fuel for the same amount of endurance [2].
- **Need for De-Bunkering**: Fuel tanks have to be emptied with the help of de-bunkering facilities when the vessel is kept in anchorage for a long time. Otherwise, the natural gas will boil-off, causing large amounts of methane losses to the atmosphere [2].
- **Methane Slip:** It is the emissions of unburnt methane caused by the scavenging in the cylinder and the ventilation from the crankcase. This is considered as greenhouse gas emissions and is extremely dangerous for the environment.

Some of the solutions to these challenges that have been either proposed or put into action are:

- Governments and other organisations can grant fundings for further research and as an incentive to make companies add LNG-powered vessels to their fleet. Some of these funds that have already been granted are the Norwegian NOx fund, Ocean Fund, and TEN-T program. Companies have also upgraded their training facilities for providing their crew with LNG handling training.
- In order to combat the storage issue, several companies are developing storage tanks that can be placed anywhere on the vessel like astern of the ship, in superstructures, or under cargo space [6]. One such solution is the GTT Membrane tank, which optimises fuel holding capacity with the help of adaptable geometry, lightweight structure, etc.
- The challenge of bunkering and de-bunkering is diminishing with time as LNG continues to gain popularity, and the number of bunkering facilities, bunker vessels, and bunker barges increases.
- Over the past decade, the methane slip of Otto engines has reduced significantly and can be reduced further by using Exhaust Gas Recirculation or by using catalysts like palladium for exhaust gas after-treatment [2][7].

B) *Biofuels*

Some of the biofuels with the potential to be used as marine fuels are Pyrolysis oil, Ethanol, Algae Fuels, and biodiesels like FAME. Some other options are Bio-LNG and Bio-Methanol. These biofuels are Drop-in fuels to a certain extent, meaning they are compatible with the current diesel engines and fuel systems. They are practically sulphur-free and also help in reducing greenhouse gas emissions significantly more than LNG. They are also safe for the marine environment as they degrade very quickly [2].

Even though some Biofuels have shown promising results, several challenges stop them from being seen as an alternative for the current marine fuels. They are:

- **Availability:** Securing necessary volumes of biomass for commercial production is a challenge.
- **Storage and Oxidation Stability:** Biofuels, especially biodiesel, degrade over time and form contaminants of peroxides, acids, etc [2]. They also tend to oxidise quickly and hence can cause corrosion of tanks.
- **Price:** Currently, they are not competitive in pricing with fossil fuels and hence are not attractive enough for commercial shipping.
- **Lack of applicable regulations:** Current Regulations don't cover the use of Biofuels.

Although Biofuels are not a viable solution due to these challenges, some proposed solutions can help them become an attractive solution in the - next decade. They are:

- Fundings can be granted for projects for mass production of biofuels sustainably. One such fund is the European Commission fund for the production of FAME. The US Navy has also given orders for several Biofuels like algae fuel and FAME [2]. This will also help in reducing the price of such biofuels.
- The storage issue can be combated by avoiding storage periods of over six months and by using a fuel monitoring program. Antioxidants can also be used to increase storage life [8].
- Research has to be done on how to produce biomass at a large-scale and more focus should be given to find suitable algae strains for large-scale production [9].
- IMO is working on introducing regulations for use of Biofuels under the IGF Code with the formal approval expected in the coming years.

III) CONCLUSION

The biggest topic of discussion in the Maritime world for the last decade has been alternate fuels and emission reductions. Although IMO 2020 brought significant reductions in emissions, there are still a lot of issues and alternate fuel is the solution to all these problems. At the moment, there is no silver bullet but LNG is the most mature solution. But it should be looked at only as a bridge towards better solutions as it's not sustainable due to its method of production and GHG emissions. As we look for a carbon-free economy, fuels like Hydrogen, Ammonia and Biofuels will play very important roles provided they can be produced in a large and feasible manner. Renewable energies like wind and solar energy will also have a role to play, but the extent of their impact can only be understood with further research.

The Earth, as we know is in grave danger and in order to hand over a hospitable planet to the future generations, we have to shift to alternate fuels. But for this to happen, governments, maritime agencies, ship-owners and classification societies have to come together and show an active interest in carrying out studies, creating safety standards and regulations and most importantly accepting the solutions put forward.

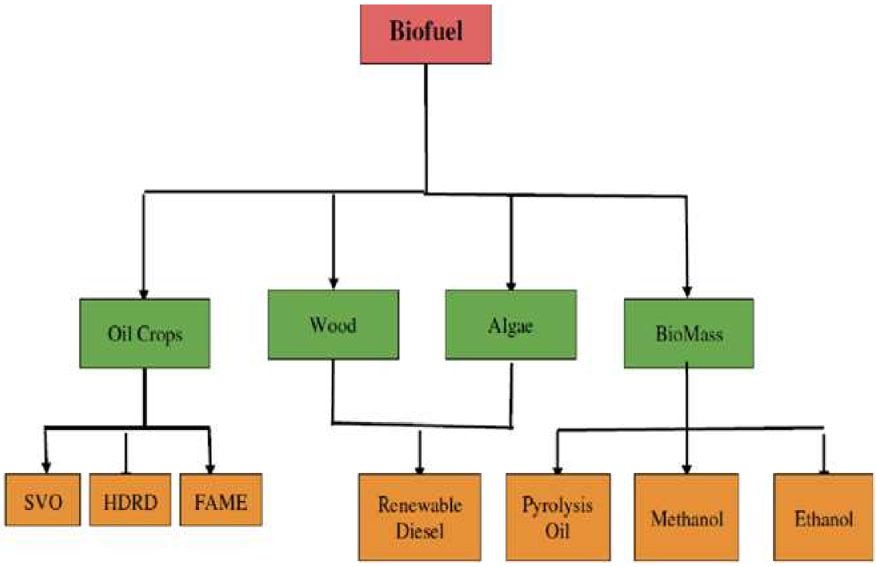


Fig 5: Types of Biofuel and their Sources

IV) REFERENCES

[1] Mohseni, S., van Hassel, *E., Sys, C. et al. Economic evaluation of alternative technologies to mitigate Sulphur emissions in maritime container transport from both the vessel owner and shipper perspective. J. shipp. trd. 4, 15 (2019). Available:https:// doi.org/10.1186 /s41072-019-0051-8 ,[accessed on 3 /11/2020]*

[2] *Kamaljit MOIRANGTHEM, David BAXTER, Alternative fuels for marine and inland waterways, EU Publications, EUR 27770, 10.2790/227559, Available:https://op.europa.eu/en/public ation-detail/-/publication/eb3e8e7c-ecd6-11e5-8a81-01aa75ed71a1/language-en#, Page 6, 13, 17, 18, 20, 21, [accessed on 3/11/2020, 4/11/2020, 5/11/2020]*

[3] *Kokarakis John, The case of ammonia as a marine fuel, safety4sea.com, Available:https://safety4sea.com/cm-the-case-of-ammonia-as-a-marine-fuel/, [accessed on 4/11/2020]*

[4]*Environmental benefits of LNG-fuelled marine vessels, fortisbc.com, Available: https://www. fortisbc.com/ est/marine /environmental-benefits-of-lng-fuelled-marine-vessel, [accessed on 4/11/2020]*

[5] *Steve Esau, LNG as a marine fuel: Key considerations, safety4sea.com, Available:https://safety4sea.com/cm-lng-as-a-marine-fuel-key-considerations/, [accessed on 4/11/2020]*

[6] *Vignesh Balasubramaniyan, Properties Of Membrane Tanks For Transportation Of LNG Cargo On Ships, Marine Technology, marineinsight.com, Available: https://www.marineinsight.com/tech/properties-of-membrane-tanks-for-transportation-of-lng-cargo-on-ships/, [accessed on 4/11/2020]*

[7] *Trakakis Antonis, Methane slip from LNG fueled engines, Opinions, safety4sea.com, Available:https://safety4sea.com/methane-slip-from-lng-fueled-engines/, [accessed on 4/11/2020]*

[8] *Guideline for Ship owners and Operators on Managing Marine Distillate Fuels Containing up to 7.0 % v/v FAME (Biodiesel) , CIMAC Working Group 7 –Fuels (WG7), Available:https://www.cimac.com/cms/upload/workinggroups/WG7/CIMAC_WG7_Guideline_for_Ship_Owners_and_Operators_on_Managing_Distillate_Fuels_May_2013.pdf, Page 5, [accessed on 5/11/2020]*

[9] *Christos Chryssakis, Océane Balland, Hans Anton Tvete, Andreas Brandsæter, Alternative Fuels for Shipping, Available:https://transportemaritimoglobal.files.wordpress.com/2014/01/dnv-gl-alternative-fuel-2014-positionpaper.pdf, Page12,13, [accessed on 4/11/2020]*

[10]*Ship and Bunker News Team, BLUE Insight Sets Out Current Cost of Alternative Fuels, Available:https://shipandbunker.com/news/world/643434-blue-insight-sets-out-current-cost-of-alternative-fuels, [accessed on 4/11/2020]*

[11]*Matt Muenster, LNG Opportunities & Challenges as a Marine Fuel, Available:https://www.breakthroughfuel.com/blog/lng-opportunities-and-challenges-diversifying-shippers-marine-fuel-portfolio/, [accessed on 4/11/2020]*

[12]*Lars Petter Blikom, LNG Opportunities & Challenges as a Marine Fuel, DNV GL, Available:https://safety4sea.com/lng-bunkering-infrastructure-around-the-world-2/, [accessed on 4/11/2020]*

[This paper was adjudged second in the INSA (Indian National Shipowner's Association) Technical Paper Competition held on-line on 20 February 2021]

TRANSTECH 2021

An All India Technical Seminar TRANSTECH 2021, (14th edition), was organised by Tolani Maritime Institute (TMI), in association with The Institute of Marine Engineers (India), Pune Branch and The Institution of Engineers (India), Pune Local Centre from 28th to 30th April 2021 in Webinar Format. TRANSTECH, 2021 set its main theme as **"Efficient Shipping on Clean Oceans".**

With 8 participating institutes, 12 of the finest papers were presented out of the total 47 full length papers received and 5 models exhibited. The models and presentations predicated on the Sub Themes of : *Alternative Fuels, Hull Form Optimisation, Coatings and Corrosion, Zero Emission Technologies, Life Cycle Analysis of a Ship, Vessel Performance Optimisation, Advancements in Sensor Technologies in Shipping*, and *System Integration - Automation & Digitalisation on Ships.*

The first two days witnessed interactive sessions with several papers presented by maritime and shipping dignitaries. The Chief Guest & Key Note Speaker on the first day, Dr. Ketan Kotecha, Director of Symbiosis Institute of Technology delivered a detailed address on *"Artificial Intelligence for All"*, correlating its utility with the maritime industry. He also released the **"Book of Proceedings for TRANSTECH 2021"**and the yearly **"Technical Bulletin of TMI".** which publishes the research papers contributed by the Faculty and Cadets of Tolani Maritime Institute. Guest Speaker, Capt. Gajanan Karanjikar, President of All Indian Maritime Pilots' Association shared his insights on the topical theme of "Blue Economy" which is the pathway to a stable and sustainable future as our oceans are much larger than all the continents combined. Key Note Speaker, Dr. Sanjay E. Talole, Scientist and Group Director of Systems and Control group at the Research and Development Establishment (Engineers), shared his cognizance on "Disturbance Estimation and Rejection based Control of Marine Vessels".

On the third day recorded videos of the 5 models were exhibited. The Chief Guest on the third day, Dr. Gopinath Chandroth, an accredited Marine Accident Investigator from MAIB, UK, delivered an interactive address on "Marine Accident Investigation and Prevention", a pressing issue that deserves more exposure and attention.

After careful assessments and deliberations, cash prizes for the winning papers and models were announced and awarded. These were sponsored by The Institute of Marine Engineers (India), Pune branch and Tolani Maritime Institute, Pune.

With over 350 attendees on the Zoom webinar platform and 550 viewers on YouTube, TRANSTECH 2021 marked as a grand success.

(News Write-up: Cadet Sunami Kotian, TMI)

HIMT

FEES SLASHED UPTO 50%

COURSE CATEGORY	ONLINE COURSES	HIMT OLD FEES	DISCOUNT	NEW DISCOUNTED FEES W.E.F. 15TH JUNE
Refresher courses	RPST	2900	1000	1900
	RFPFF	2900	1000	1900
	RAFF + RFPFF	5900	1000	4900
	RPSCRB + RPST	5900	1000	4900
	RMFA	3900	2000	1900
	RMC	4900	2000	2900
Basic Modular	BST	14900	7000	7900
	OCTCO	4900	1000	3900
	STSDSD	3900	2000	1900
	PSSR	6900	2000	4900
Advanced Modular	SSO	4900	1000	3900
	PSCRB	9900	4000	5900
	AFF	9900	4000	5900
	MFA	6900	3000	3900
	CHEMCO	14900	7000	7900
	GASCO	14900	6000	8900
	TASCO	12900	5000	7900
Simulator	HV-O	4900	2000	2900
	HV-M (Blended)	18900	9000	9900
Competancy	MEO CLASS II	42900	5000	37900

For the courses that include Practicals, Part B (for practicals) will be charged separately.

Starts 5th July, 2021

VICT

Vertical Integration Course For Trainers (Earlier called TOTA)

~~18900~~

DISCOUNTED FEES

8900

SPECIAL DISCOUNT FOR WOMEN SEAFARERS

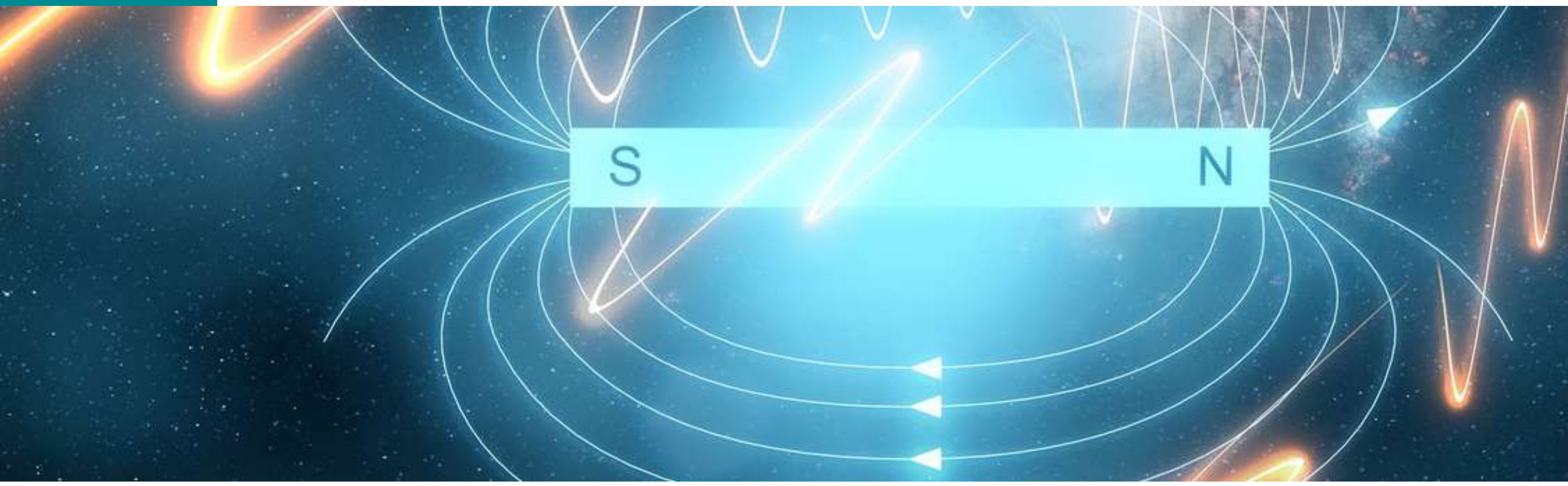
50% OFF on all Basic Modular Courses

25% OFF on all Advanced Modular Courses

10% OFF on all Competency Courses

Book online at www.himt.co.in

*Limited period only



Electricity and Magnetism: Conservation and Storage of Energy (PART 3)

Part 2 of this discussion was published in MER June 2021 issue.

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

POWER ANGLE

Refer to **Figure 11**. The generated EMF in the alternator armature is indicated by E; the voltage at the alternator terminal is V. At no load, these two values will be same. When the alternator is on load, with a load current I, voltage drop in the armature (due to the impedance of the armature), requires that the EMF will need to be greater. The relation between these is shown by the alternator phasor diagram (**Figure 11**).

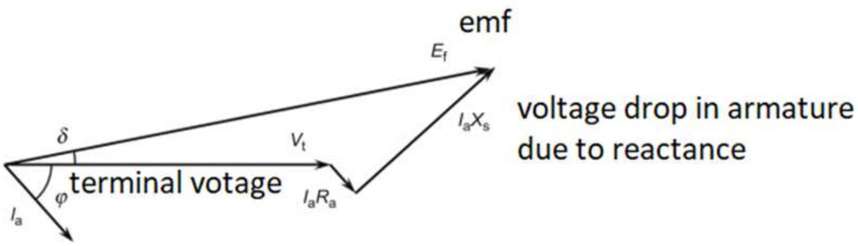


Figure 11

From **Figure 11**, it can be seen that as the Load current increases, Voltage drop in the armature will increase and to maintain the same terminal voltage V, EMF will need to be increased. The angle between EMF and Voltage is called power angle (δ). In the case of an alternator, it is the same as load angle. The function of the AVR is to increase the current in the main field. This increases the magnetic flux and EMF is increased. From the phasor diagram, it can also be seen that when an alternator is on load, its EMF and Terminal voltage are not in phase.

ROTOR POSITION DURING SYNCHRONISING

During the synchronising operation, one of the conditions to be satisfied is that the incoming alternator's voltage must be in phase with the corresponding voltage (R of incoming and R of bus bar) of the running generator. In other words, at the time of closing the breaker, the instantaneous values of the two voltage wave forms should be nearly same. If the two alternators are at the same rpm, it only means that their frequencies will be same. Instantaneous values of EMF (and Voltage) depend on the **instantaneous rotor position**.

To ensure that voltage wave forms are in phase, the rotor positions have to be considered. Since the running alternator is on load, the rotor will be at the "load angle" with respect to the stator field. The incoming alternator will be without load, hence its "load angle" will be zero. As the incoming alternator rotor rotates slightly faster than the running alternator's rotor, it will come to the correct position and then move away. When the pointer of the synchroscope is at 12 o' clock, there is no phase difference between **voltage wave forms** of the two alternators.

EFFECT OF STRENGTH OF MAGNETIC FIELD

When an alternator is running alone, if the rotor magnetic field is made stronger (excitation increased), EMF and terminal voltage will increase.

When two alternators are running in parallel, if the excitation of one alone is increased, then the effect is different. EMF of the alternator will increase; however, terminal voltage will not increase as it is parallel to the other alternator. The increased EMF will result in higher current; due to the increased voltage drop, terminal voltage will remain same. Since the KW remains same (no additional fuel from the prime mover), power factor drops. This can be seen from the **Figure 12.**

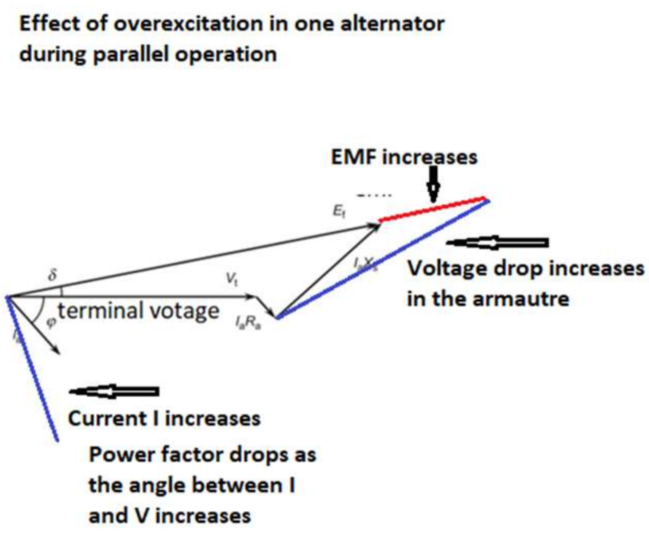


Figure 12

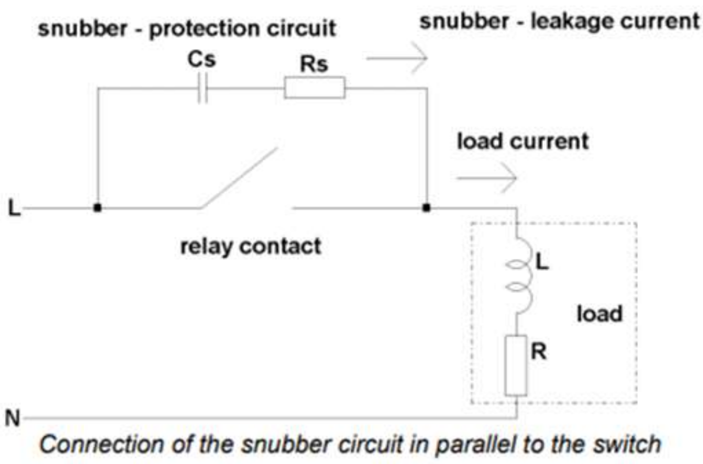


Figure 13

This is a commonly seen phenomenon onboard where two alternators will be sharing KW equally and their current and individual pf will differ. The alternator with higher current will have a lower pf.

The reverse effect is seen when the excitation level is lower. Current will drop and pf will improve. This anomaly can be rectified by adjusting the excitation levels and make them equal. A simple check is to ensure the no load voltage of both alternators are equal and adjust the AVR voltage setting if required. If required further droop setting of the AVRs will need to be adjusted. Unequal excitation levels in alternators running in parallel can lead to problems. The overexcited alternator can get overheated as its current will be higher. Under excitation can lead to instability problems and even to loss of synchronism. In extreme cases it can potentially lead to severe damage due to a phenomenon called "pole slip".

FURTHER EFFECTS OF STORED ENERGY

The ability to store energy in a magnetic field is used in many applications. The choke used in a fluorescent lamp stores energy and releases it to produce a high voltage spike which strikes the arc in the lamp.

This also has many potentially harmful effects. Whenever the current through an inductive circuit is interrupted, the stored energy will give a "kick back". Often this produces an arc in the switch. With semiconductor switches such as transistors, this "kick back "can cause damage.

Hence these circuits utilise a snubber circuit, such as RC snubber across the switch, or the load to protect the energy from the semiconductor. In **Figure 13**, Resistance and Capacitor are connected across the contact of the relay. With the contact closed (this can be a semiconductor switch as well), there will be no potential difference

A simple check is to ensure the no load voltage of both alternators are equal and adjust the AVR voltage setting if required

across and no current will flow through the RC.

When the contact opens, (for switching off the inductive load), a large voltage spike can appear across the contact. The energy in the spike will be dissipated in the resistor to protect the switch.

In Figure 14, the snubber is connected across the load to suppress the spike at the source itself.

Summary: The two articles written on the subject of electricity and magnetism in the context of conversion and conservation of energy are only an introduction to the subject. Engineers are encouraged to study this further as this principle is universal.

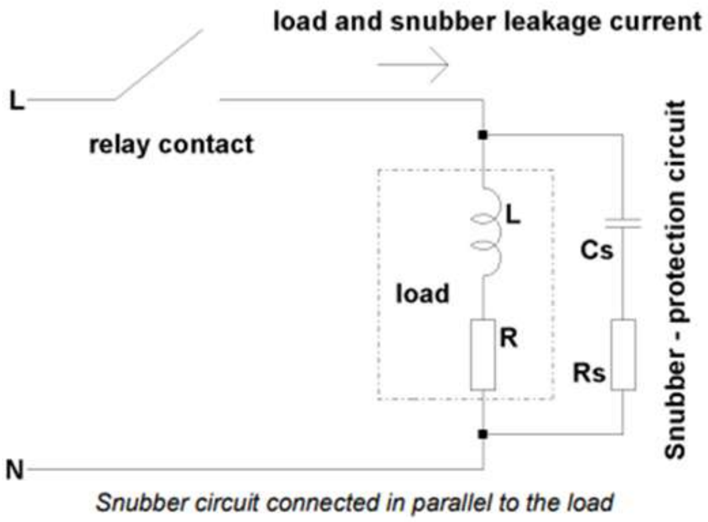


Figure 14

ABOUT THE AUTHOR

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

Email: vrv@himtmarine.com

INVITING APPLICATIONS FOR THE POST OF ACADEMIC CHAIR AT IMU

The Institute of Marine Engineers (India) is dedicated to spreading learning in Marine Engineering. The IMU, with campuses across 6 cities, is poised to play a key role in the development of trained human resources for the maritime sector. The IME(I) and IMU have agreed in principle to set up an IME(I) sponsored 'Academic Chair' at the IMU. This is the first position of its kind at IMU and the IME(I) is honoured to partner in this venture.

The President, on behalf of the Governing Council, invites applicants for the position of the Chair, which is expected to be installed no later than August 2021. IMEI Chair is a position at IMU, supported by IMEI funding or sources external to the University. It is being created in order to engage professionals from Industry who have demonstrated excellence in professional contribution at a level that brings external recognition to the University. This position is intended to be an interface for a wider interaction with industry.

This position will be governed by the applicable policies of IMU. The Chair shall be located in one of the Campuses of the University and shall be provided academic, administrative and logistic support extended to Professors of the school/university. Additional facilities that may become necessary shall be provided with the approval of Vice Chancellor on the recommendation of Campus Director.

The ideal candidate will have a strong academic background and good connections within the Maritime Industry and Shipping circles. The candidate would be required to interact with the Academic Council of the IMU and Industry at large, guide soft research projects at the IMU relevant to Industry and influence the Academic Council of the IMU to tailor the syllabus to Industry needs.

Interested candidates may apply in confidence, with their CV and enclosing a brief presentation on why they consider themselves to be the ideal candidate for this prestigious post, within 30 days to:

The President, IME(I)

email: president@imare.in marking a copy to: uday.purohit@gmail.com

Figure 1 NOAA archaeologist documenting the wheel and stern of the schooner FT Barney, Credits: NOAA ONMS

COLUMN

Heritage Hourglass

Application of GIS & GPS in Marine Archaeology

Saba Purkar, Project Research Associate, Maritime History Society

Underwater cultural heritage is one of the crucial fields that is rapidly gaining popularity in India. India being the protruding landmass in the Indian Ocean has by default been a centre of maritime activity since ancient times with the earliest Maritime activities dating back to the Indus Valley Civilisation. Due to India's unique coastal geographical features, it has been the hub of trading activity even after the imposition of Samudrolanghan. Traders and invaders alike kept drifting onto the Indian shore with or without a purpose, thus turning India into a vivacious melting pot of culture. Despite the rich maritime culture that India inherits, academically we have barely scratched the surface of ancient Indian maritime history.

Marine archaeologists being the 'Underwater Heritage detectives' retrieve cultural data that was lost/sunk which fills the gaps of the existing history. The previous underwater explorations undertook in India are that of Poompuhar and Tranquebar on the east coast and Goa, Somnath, Vijaydurg, Dwarka, Bet Dwarka, and Lakshwadeep on the western coast of India. Marine Archaeology is an emerging field in India and is still in its nascent stage. The rapid growth of scientific knowledge has immensely contributed in the development of archaeological sciences. The application of technology is diverse in archaeology and it is only in the 21st century that it rapidly took off in India. Initially, the survey of any archaeological site was done manually by volunteers scaling and mapping the field. In the field of marine archaeology, it is diving expeditions to survey the site.

Nowadays several advanced methods such as Aerial photography, Global Positioning System (GPS), Geographic Information System (GIS) and Remote sensing have immensely enhanced and made the process easier. There are fewer assumptions made and more accurate results obtained with help of these sciences. The use of technology especially in marine archaeology has advanced tremendously over the years and made underwater sites more accessible. The use of equipment such as **side-scan sonar** and **multi-beam sonar** (can look through waters of low visibility) and **sub-bottom profilers** (equipment that can penetrate deep into the sea bed) has caused findings of more and more archaeological shipwrecks and other databases all over the world.

Figure 2 Underwater GPS Navigator Credits: Blueprint Subsea

GPS Applications

GPS applications in Archaeology were limited to taking coordinates in India. Since GPS was made available globally, it is progressively used in archaeology for taking a site map survey, and initial geospatial survey. Geospatial survey is the first step taken before a physical survey of any site in archaeology. With the use of apps like Google Earth, through satellite imagery one can survey the landscape and pinpoint locations, view them in various topographical maps, and even compare existing land with its past conditions. However, during the physical survey, several hand-held GPS devices are used to take points and record routes.

Using GPS underwater has to be more meticulous and advanced than the common GPS we use in our day-to-day life. The Fusion Acoustic Positioning System (APS) is often used for industrial purposes but is gaining popularity in marine archaeology. It is used to position underwater ROVs (remotely operated underwater vehicles) or structures on the seabed. APS measures distance and depth and generates position reports using advanced positioning techniques. This information is transmitted to the diver and the ROVs which includes standard sentences used by GPS receivers. This method can be used as an underwater GPS receiver which feeds data to other survey programs. All measurements, positions, and quality figures are time-stamped and logged in a database so they can be replayed or analysed after the dive.

GIS Aplications

The most important factor of site management in archaeology is the location of sites and knowing the factors that threaten their preservation. This information forms an exhaustive database and the most effective tool to deal with this information is GIS which comes with the capacity to combine all disciplines for managing an underwater site. GIS comes under 'Spatial technologies' which means any information related to the acquisition, storage, and manipulation of spatial data. In less than ten years, GIS has progressed from exotic experimental tools, requiring costly workstations and only available to a few specialist researchers, to widely available technological platforms for the routine analysis of spatial information.

Archaeology, in common (with all disciplines concerned with the interpretation of geographically located material), has witnessed an uncharted transformation of the methodological tools it uses for spatial records and analysis. But if GIS is used with poorly

Figure 3 Sample Google Earth Map

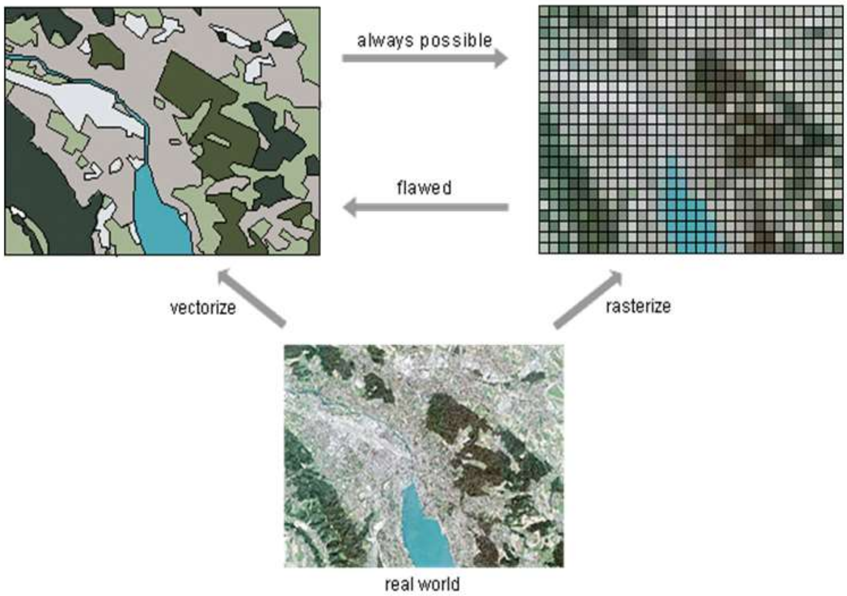


Figure 4 GIS Vector and Raster Data , *Credits: GITTA*

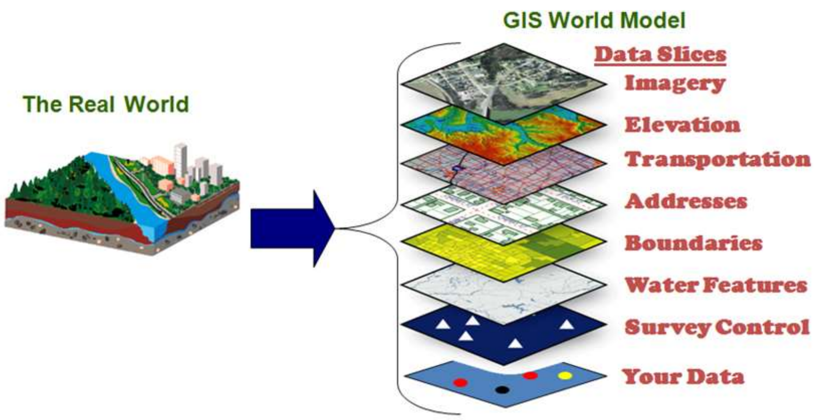


Figure 5 GIS Model, *Credits: Admit*

The unstable underwater atmosphere and Salinity poses a major threat to the Submerged artefacts

collected data, it might lead to false conclusions. So, good caution must be exercised while using GIS.

As a discipline, archaeology often deals with a large amount of spatial data, which differs in scale from the relative locations of archaeological sites upon any landmass, down to the positions of individual artefacts within excavated contexts. Archaeologists have long had an innate recognition of the importance within spatial configurations and have spent considerable amounts of energy developing ever more efficient ways of recording it because past can only be reconstructed by connecting material resources to their context.

Most of the data that archaeologists discover is spatial in nature. By the position of the feature or artefact itself, there may also be a series of relationships between the locations of features and artefacts, revealed by significant patterns and arrangements relative to other features and things. These other things can be features of the environment for example rivers or particular combinations of resources; other archaeological features such as shipwrecks, submerged market-towns, or ceremonial centres. GIS combines layers of data which is stored in a database and provides new information and insight concerning a single site or a cluster of sites. GIS facilitates to catalogue and quantify artefacts as well.

GPS might be a relatively new technology but is widely used in many disciplinary contexts nowadays. There is no true definition of GIS as its applications are varied, depending on the context it's used for. For archaeologists the use of GIS makes large scale data handling extremely easy. In the context of Underwater Archaeology, one would define GIS as a computer system whose main purpose is to store, manipulate and analyse present information for a geographic space. It is important to acknowledge that a GIS is not just a single, monolithic computer program as it is a combination of several different software technologies. GIS can facilitate mapping and providing potential sites and also the management and conservation of the sites. In terms of underwater archaeology, GIS is crucial in project planning and modelling, combining databases of several stakeholders, visual analysis, and decision making.

Data Entry

Data entry tools facilitate to get spatial information into the GIS. The most widely recognised element of the data entry system is the digitising program. This allows paper records to be accurately registered and converted to a digital format. A few other methods of data entry are: lists of co-ordinates from national and regional monuments registers; maps scanned and imported in raster format; data generated by survey instruments such as total stations and GPS read by the GIS, and pre-existing digital data (e.g., excavation plans stored in CAD and hydrographic data) can be directly imported.

Spatial Database

Data within the spatial database are generally organised into layers, each of which represents a unique theme. A spatial database can be similar to a set of thematic maps, with each component sheet showing some different characteristics of the study area. A typical map shows roads, rivers, and contours all on one sheet. In the spatial database, this map is split into separate layers with one layer for the contour map, one layer for the river network, and so on. Maps in GIS are generated in raster and vector format.

Most GIS applications allow the internal spatial database to be linked to an external database management system (DBMS). After this, information stored in the DBMS about the spatial features held within the thematic layers, which is termed attribute data, is transferred to the GIS. It can also be used to add or modify the data in the external database. This type of facility is useful in larger organisations that may already have a substantial investment in their database system, and who therefore wish to integrate GIS into their existing information technology strategy. So far as manufacturers of GIS are concerned, it is equally convenient, as it frees them from having to 'reinvent the wheel' by writing a DBMS, report writer, forms interface, and so on for their systems.

The visualisation and reporting system is frequently connected with the interface of the GIS. This is because the most perceptive method of interacting with spatial data and constructing queries is often to 'point' at a visual representation of a map. In addition, many systems provide functions like printing maps, available graphics files, and alternative methods of representing the data on screen or paper. Three-dimensional net or block diagrams are some of the popular alternatives.

Manipulation & Analysis

The manipulation and analysis subsystem commonly constitutes many different functions for carrying out operations on the spatial database. These can be used to convert data or tackle analyses. If the manipulation and analysis block were removed, the results could either be computer-aided mapping (CAM) or computer-aided design (CAD) software. What gives GIS its unique identity are its manipulation and analysis features. In more advanced systems, the manipulation and analysis functions are directly available, and users also have a programming interface to automate repetitive sequences of tasks and to construct new analysis functions.

The old manuscripts such as Kutchi navigation Travelogues are rich in seafaring knowledge And is the proof that indians mastered seafaring A long time ago

In conclusion, data manipulation is the ability of a GIS to generate new layers from existing ones. This leads to a distinction between primary layers, such as the location of water bodies, or underwater archaeological sites, and secondary layers, which are derived from these. Primary layers are often digitized from maps, or imported directly from databases.

In a way, both GIS and GPS go hand in hand and are vital for large-scale and small-scale projects. The most commonly available GIS software application is QGIS which is free for public use but has its own limitations. This software is good for small-scale projects. ArcGIS is a paid version with added features hence is mostly used for large-scale industrial projects. Revisiting the sites using GIS software has the potential to yield new outcomes and with the appropriate use of the given scientific analyses, colossal information can be retrieved during future maritime heritage projects. The unstable underwater atmosphere and salinity poses a major threat to the submerged artefacts. Hence it becomes a race against time to preserve our underwater cultural heritage. The old manuscripts such as Kutchi navigation travelogues are rich in seafaring knowledge and is the proof that Indians mastered seafaring a long time ago. The artefacts such as ceramics and shipwrecks are the proof of cultural exchange between civilizations. It is crucial to study and conserve our heritage as it is a vital part of our communities' legacy and cultural identity.

REFERENCES

1. *D. Wheatley, M. Gillings. Spatial Technology and Archaeology. Taylor and Francis, 2002.*
2. *Peter Holt. The application of the fusion positioning system to marine archaeology, 2004.*
3. *Manithaphone Mahaxay, et al. Geographical Information Systems (GIS) in Underwater Archaeology. UNESCO Bangkok, 2012.*

ABOUT THE AUTHOR

***Saba Purkar** is a Research Associate with Maritime History Society. An Archaeologist by profession, she has completed her Masters in Archaeology from University of Mumbai with a specialisation in Sciences of Archaeology. She has a keen interest in Maritime Archaeology and its allied disciplines and is academically inclined to probe further into this field. She also has a knack for learning languages.*

Email: purkarsaba34@gmail.com

COLUMN

In The Wake

Eliminating Emissions

The decarbonisation debates are on again... there are emissions to be abated... eliminated.

IMO's mandatory measures are kicking in...

IMO's targets (cryptic summary): Big target: Bring down GHG by 40% by 2030; 50% by 2050 (base 2008 stats.).

Medium term C intensity Target: Reduce 2% every year between 2023 – 2026.

Ships to be given ratings: Best will be 'A'; Worst 'E'.

As always (and as usual) US and EU are pressing for stricter/stronger measures (Choke more to Choke less?).

What measures are targeting shipping?

EU is contemplating on including shipping in its Emissions Trading Scheme (ETS).

How does this work?

Under a 'Cap & Trade' method, the higher limit for emissions is set for sectors (e.g., power; manufacturing; airlines etc.). Sector organisations can buy and sell the 'emission allowances' to cover their emissions. The Catch: Since the allowances are capped, there will be a demand; the more your emissions are, buying these will become more expensive. If you are still beyond the limits, you will be fined. If you are good boy, and keep the emissions under limits, the reward: Keep the balance or can trade them also. BTW, the collected funds will be used for infrastructure development of alternate fuels.

Tech Talks

Still emitting....

The Regulations are stifling... the financing options are pressing with Poseidon Principles... charterer's demands (transparency under environmental/ social/ corporate governance), the OEM equipment costs, retrofits etc., add to the burden... and above all the unclear performance guarantee of technologies on offer...

LNG gives CO_2, CH_4, NOx; Ammonia gives N_2O; Hydrogen gives NOx.

Is there any silver bullet, one shot, one-size-fits-all solution for emission reduction?

Yes. There appears one scrubber solution in the horizon for all pollutants... SOx, NOx, CH_4, N_2O, HN_3 and CO_2... (any more?). The test on this 'universal green converter' have been promising.

The Converter uses Carbon capture; manages SOx & NOx by reducing the pollutants to intermediate levels (reduction to ammonium sulfates/nitartes). This could become the mother of all scrubbers?

From looking out for emissions to looking inside the confined spaces....

A 'NoMan' Inspection Tool is being developed, which uses laser scanners/cameras mounted on poles/tripods (made of resilient, endurable carbon fibre). This overcomes the technical limitations of drones. Considering safety (couple of confined space disasters recorded recently), this will be of good help.

For July...

1 July: National Doctors Day (looks like we have to be remembering and celebrating this for some more times to come). And... there is one more related Day...

6 July: World Zoonoses Day; With vaccines scoring as the fast moving/high-in-demand consumable, this day and Louis Pasteur cannot go unremembered.

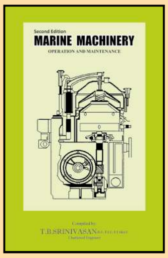
- Rajoo Balaji

THE END VIEW

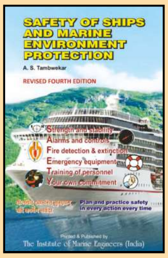
Idea, Words & Drawing: Ramesh Subramanian

Marine Machineries
2nd Edition
By T.B. Srinivasan

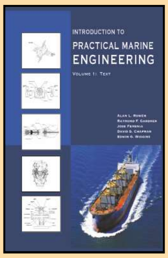
List Price - Rs. 450
For Members - Rs. 400
For Students - Rs. 350



Safety of Ships and Marine Environment Protection
4th Edition
By A.S. Tambwekar
List Price - Rs. 400
Member's Discount - 10%

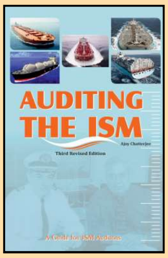


Introduction to Practical Marine
(Two Volumes–Indian Edition)
List Price (per set) - Rs. 700
Price for Members - Rs. 600
Engineering Price for Students - Rs. 500
Bulk Orders, 25 or more sets - Rs. 500



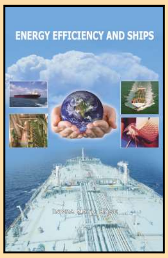
Auditing the ISM – A Guide for ISM Auditors
3rd Edition (Hard Bound)
By Ajoy Chatterjee

List Price - Rs. 1200
Price for Members - Rs. 1100



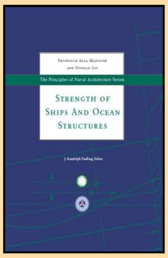
Energy Efficiency and Ships
By Indra Nath Bose

List Price - Rs. 800
Price for Members - Rs. 700



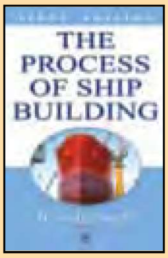
Strength of Ships and Ocean Structures

List Price - Rs. 425
Price for Members - Rs. 375
Price for Students - Rs. 300



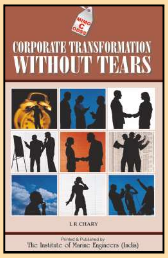
The Process of Shipbuilding
By Rajesh Singh

List Price - Rs. 900
Price for Members - Rs. 800



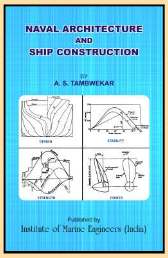
Corporate Transformation Without Tears
By Dr. L.R. Chary

List Price - Rs.150
Price for Members - Rs.135
Price for Students - Rs. 105



Naval Architecture and Ship Construction
By A.S. Tambwekar

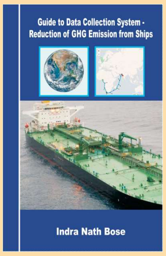
List Price - Rs. 400
Price for Members- Rs. 350



MER (I) Archives Now on CD
Inaugural Issue
September 1980 – Rs.300
1982-2006 – Rs.250 per year
Cost of the full set for 26 years – Rs.10000
(Price inclusive of postage within India)

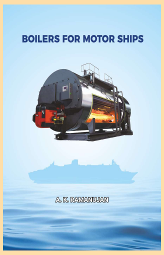
Guide to Data Collection System Reduction of GHG Emission from Ships
By Indra Nath Bose

List Price - Rs. 600
Price for Members - Rs. 500



Boilers For Motor Ships
By A. K. Ramanujan

List Price - Rs. 500
Price for Members - Rs. 400



For placing orders, please contact:
IMEI House, Plot No. 94, Sector 19, Nerul, Navi Mumbai-400706.
Phone: 91-22-27701664, Email: administration@imare.in, All Postage charges extra

Published on 5th of every month
and Posted on 5th & 6th of every month at
Mumbai Patrika Channel Sorting Office, G.P.O., Mumbai - 400 001.
'Licence to post without prepayment'

"Reg. No. MCS/090/2018-20"
RNI No. MAHENG/2006/19917
W.P.P. Licence No.:
MR/Tech/WPP-336/ South/2018-20

IME(I) House, Nerul, Navi Mumbai