ISSN 2250-1967

MARINE ENGINEERS REVIEW INDIA

JOURNAL OF THE INSTITUTE OF MARINE ENGINEERS (INDIA)

Volume : 17 Issue : 12 November 2023 ₹ 90/-

Advancements in Anti-Submarine Warfare

The Institute of Marine Engineers (India)

IMEI HOUSE, Plot No.94, Sector-19, Nerul, Navi Mumbai.

Tel: +91 – 9967875995/ 9773363542 / 9594204403/ 022-27711663
Email: training@imare.in. Website: www.imare.in

REGISTRATION OPEN FOR Following DGS APPROVED COURSES (Online)

- Basic Training for Ships using Fuels covered within IGF code ***Course Id – 5311*** (OFFLINE) – (4 Days) - 6th Nov 2023/ 27th Nov 2023
- Assessment, Examination and Certification of Seafarers ***Course Id – 1062*** (OFFLINE) – (12 Days) - 20th Nov 2023
- Advanced Training for Ships using Fuels covered within IGF code ***Course Id – 5312*** (OFFLINE) – (5 Days) - 20th Nov 2023
- MEO Cl. I (FG) : 2- months course (OFFLINE) - 1st Nov 2023 / 02nd Jan 2024 / 01st Mar 2024 / 01st May 2024 / 01st July 2024 / 02nd Sept 2024/ 01st Nov 2024 (followed by Simulator course) **Discount on combined bookings of Class I Course with Simulator**
- MEO CLASS III (NCV_CEO) Upto 3000kW – STCW 2010: 2 month course (OFFLINE) 1st Nov. 2023/ 01st July 2024
- MEO Cl. III (NCV_SEO) Part-A - STCW 2010: 2-month course (OFFLINE) – 1st February 2024/ 1st August 2024
- MEO Cl. III (NCV_SEO) Part-B - STCW 2010: 4-month course (OFFLINE) – 1st November 2023/ May 2024
- MEO Cl. IV (NCV) - STCW 2010 -4 months course (OFFLINE) – 2nd January 2024 / 01st July 2024
- MEO CL. II (FG): 4-month Course (OFFLINE) – 1st Nov 2023/ 1st December 2023/ 02nd Jan 2024 / 01st Feb 2024 (Discount on combined bookings of Class II Courses with Simulator)
- REFRESHER & UPDATING TRAINING (RUT - 3 DAYS) COURSE FOR REVALIDATION OF COC FOR ALL ENGINEERS and ETOs (OFFLINE) – 7th Nov 2023/ 22nd Nov 2023/ 7th Dec 2023/ 20th Dec 2023
- ENGINE ROOM SIMULATOR MANAGEMENT LEVEL (3 DAYS) COURSE FOR MEO CLASS I (OFFLINE) – 04th Nov 2023 / 29th Dec 2023 / 02nd Jan 2024
- ENGINE ROOM SIMULATOR MANAGEMENT LEVEL (5 DAYS) COURSE FOR MEO CLASS II (OFFLINE) – 25th Nov 2023 / 01st Dec 2023 / 26th Dec 2023 / 02nd Jan 2024
- ENGINE ROOM SIMULATOR OPERATIONAL LEVEL (3 DAYS) COURSE (OFFLINE) – 7th Nov 2023/ 11th Nov 2023/ 14th Nov 2023 / 18th Nov 2023 / 21st Nov 2023
- MEO Cl. IV(FG) non mandatory course (2months duration) – On request
- 2 weeks Induction course for Naval candidates – Commencing soon
- Familiarisation Training Course For Liquefied Natural Gas (LNG) Tanker Operations (Online) - On request

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

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

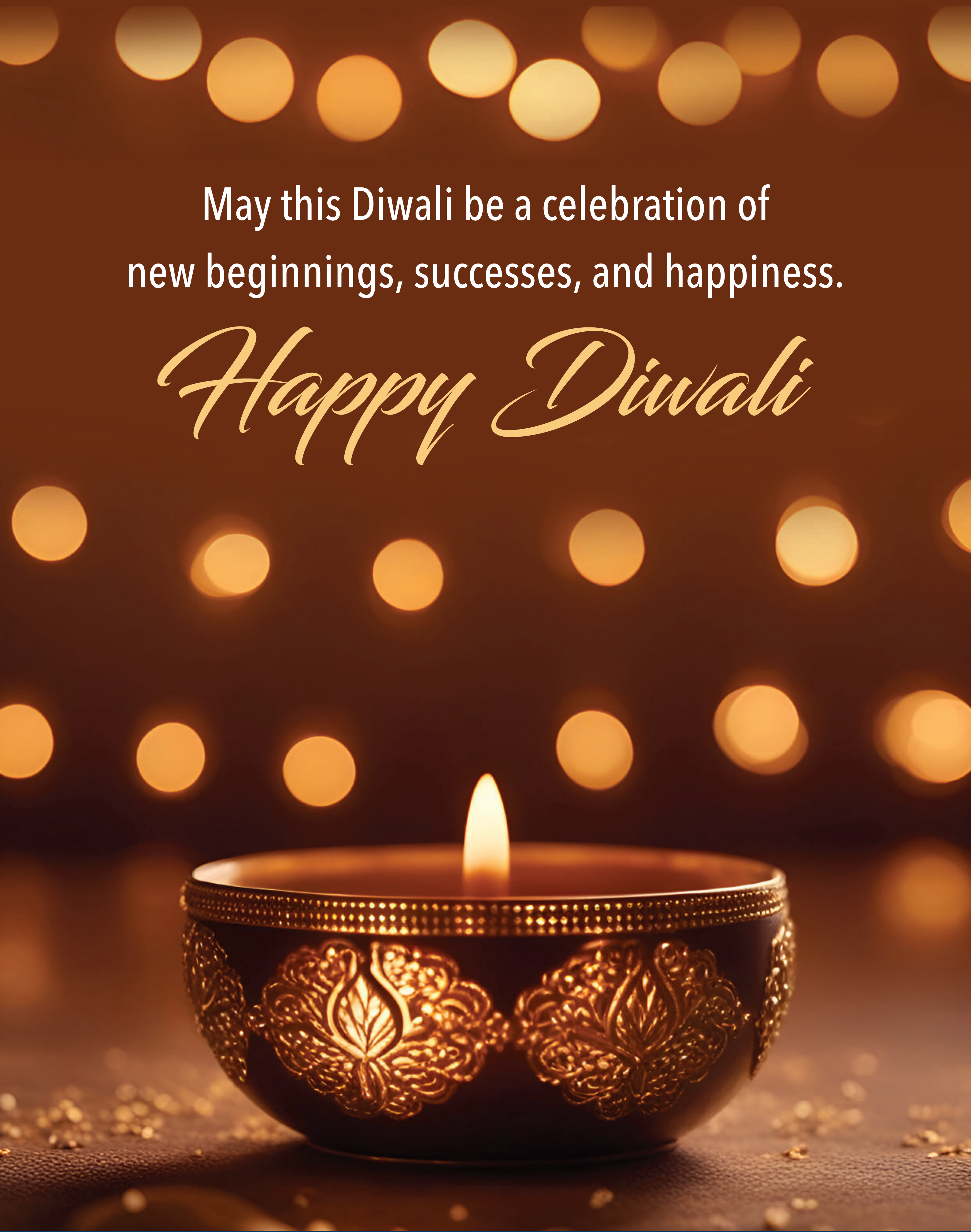
For enquiries contact on training@imare.in

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



Setting the standard

ANGLO-EASTERN

EDITORIAL

The pessimist complains about the wind;
the optimist expects it to change;
the realist adjusts the sails.
- William Arthur Ward

The just concluded, third edition of the Global Maritime India Summit played out to a predictable script. Withstanding the venue shift (Pragati Maidan, New Delhi to BKC, Mumbai), compacted/crowded sessions and the humid ambience, a palpable tonal shift was the Amrit Kaal 2047 based on Blue Economy, an extended horizon from the vision of 2030. The refrain was also in tune: 'Ports for Prosperity; Ports for Progress; Ports for Productivity'.

An introspection at some picks from the wish list would help. The mantra of 'Make in India-Make for the World' needs more meaningful constructs. To illustrate, our Indian made tanks were considered too heavy for the western front and hence not preferred by the Army, while we are positing ourselves as an economical defence equipment manufacturer. Such self-checks on quality are needed, especially while fashioning a vision for ship building. Given an employment multiplier of 6.4 (amongst the highest), ship building (defence and merchant ships), could become an ideal poster-boy for Make in India.

Next, though the EXIM trade has breached over US$450 billion, the trade imbalance needs a correction. In the vision of progress, the Sagarmala projects and asset monetisation need traction. Availability of credit, hinterland connectivity, and adaption to changing technologies need immediate attention. Port Community System and Single Window Systems (read digitalisation) are the thrust areas to stay meaningfully modern and productive.

Productivity parameters require a serious overhaul. A case in point could be the vessel turnaround time, which averages 50.01 hours for all the Indian ports (2022-23 figures computed till December 2022); container ships average marginally over 27 hours (only major ports considered). Whereas the global average for a developing country is around 8 hours. Still on productivity, the Indian ports have rather done well on time to move a container, varying from 2.8 to 0.6 minutes depending upon the number-lots of TEUs.

The impetus from the Summits of 2016 and 2021, the investment sign-ups of 2023 edition totalling over INR 10 lakh crores could be the optimistic winds of change the industry has been hoping for. However, improvements in the way of doing things would be the readjustment needed for sailing into the amritkaal. That would be more realistic.

In this issue...

We start diving under with Dr. Vedachalam and Dr. Sudarshan. This two-part series will educate on Antisubmarine warfare, particularly on the technologies. The first part describes the detection and neutralisation of hostile submarines (localise-classify-eliminate). The major takeaways lie in the sonar technology discussions. As always, Dr. Veda makes it digestible.

Following this is a marine material related discussion. Dr. Saikiran and Dr. Balaji talk on corrosion mechanism and mitigation techniques. Proceeding from anodization, the article explains Plasma Electrolytic Oxidation (PEO). The merits of PEO and the limitations are briefly introduced. This is an easy read.

Under Technical Notes, Hare Ram Hare and Prabhu discuss the merits of additive printing. We bring a riveting rudder repair experience under Spanner in the Works. Ramesh Vantaram elucidates with details. There are takeaways for the experienced and those preparing for examinations.

'Lube Matters' slides on into stern tube lubrication and seals.

The picks from the MER Archives (Nov 83) are certain to evince interest in all practising marine engineers. The writeups on mechanical seals/gland packing, the Westphalia separator and the rudder bearing should connect well.

We also have the second part of the Periplus write-up, tracing maritime history. This will be a leisurely read.

The clanging of 107 medals (from Asian Games) inside the Cricket World Cup will possibly be the sweetest of sounds in November. While we await that music, here is the November 2023 issue for your reading pleasure.

Dr Rajoo Balaji
Honorary Editor
editormer@imare.in

Happy Diwali

IMI INTERNATIONAL MARITIME INSTITUTE

(An ISO 9001 : 2015 Certified Institution, Approved by DG Shipping, Govt. of India) (Graded A1 Outstanding by IRS)

D.G. Shipping Approved Advanced STCW Courses

AFF	Course duration - 5 days	18 December
R.AFF	Course duration - 1 day	10 November, 17 November
PSCRB	Course duration - 5 days	11 December
R.PSCRB	Course duration - 1 day	09 November, 16 November
MFA	Course duration - 4 days	15 November, 11 December
SSO	Course duration - 3 days	26 December
RUCE	Course duration - 4 days	11 December

ACES	-	08 January 2024 - 19 January 2024
VICT	-	11 December - 22 December 2023

For course booking please contact
8750055674 / 8750055662 / 8750055687

DGS APPROVED ENGINE SIMULATOR COURSES every Monday

• Diesel Engine Combustion Gas Simulator	15 November
• Engine Room Simulator (Management Level)	20 November
• Engine Room Simulator (Operational Level)	27 November

- Special package for MEO competency / simulator courses and Advance STCW courses
- Deluxe residential facility available

BIGF	Course duration- 05 days	20 November
AIGF	Course duration- 05 days	28 November

EVERY MONTH COMMENCES

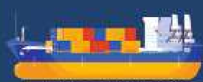
MEO CLASS I
COURSE FEE Rs. 25,000/-
Call : +91 87500-55664

MEO CLASS II
COURSE FEE Rs. 32,000/-
Call : +91 87500-55675

Registrations open for next batch of B Tech / DNS / GME / ETO / GP Rating / CCMC

PRE-SEA COURSES

Diploma in Nautical Science	Course Duration : 1 Year	Commences: February & August
B.Tech Marine Enginering	Course Duration : 4 Year	Commences: August
Graduate Marine Engineering	Course Duration : 1 Year	Commences: May & November
Electro Technical Officer	Course Duration : 4 Months	Commences: March, July & November
CCMC	Course duration - 6 Months	Commences January and July
GP RATING	Course duration - 6 Months	Commences January and July



To book your online course scan the QR code

For Course Booking: +91 9650657755 admissioncell@imi.edu.in | www.imi.edu.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, printed by Corporate Prints, Shop No.1, Three Star Co-op. Hsg. Society, V.P Road, Pendse Nagar, Dombivli (E) - 421 201. District – Thane

Print Version: **Corporate Prints**

Typesetting & Web designed by:
Kryon publishing (P) Ltd.,
www.kryonpublishing.com

In This Issue

ARTICLES

COLUMNS

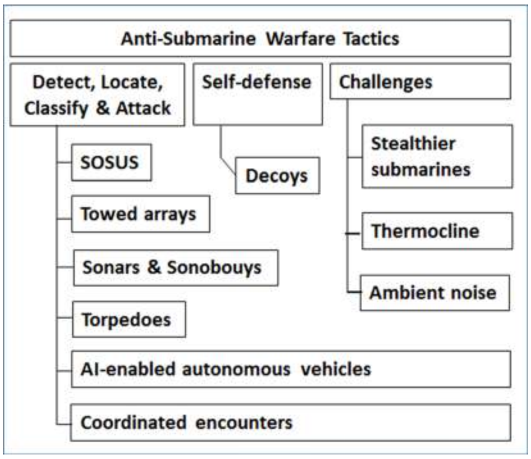
Cover Photos provided by
Dr. Vedachalam.

Technological Trends in Anti-Submarine Warfare

N.Vedachalam, K Sudarsan

Introduction

Submarines are not only pivotal to naval campaigns, but with their growing cruise and ballistic missile capabilities, they are an important part of deterrence, subsea warfare, as well as capable of carrying out any major land offensive. They are most survivable for carrying out a reliable and secure retaliatory second strike. Even before a conflict arises, a submarine's ability to deploy military strength to an area without being detected is strategically invaluable. While the speed, endurance, quietness and stealth features of submarines is in the uptrend, development of Anti-Submarine Warfare (ASW) weapons and systems with abilities to neutralise an opponent's underwater force is a sine quo non. The article is published in two parts. This first part discusses the ASW technologies that have matured over the past few decades capable of detecting, localising, classifying and eliminating hostile submarines.



Evolution of submarines and ASW technologies

Submarines are used for a variety of applications, primarily for strategic and military purposes. **It was in 1776 the first submarine Turtle was designed by David Bushnell and built with the intention to break the British naval blockade in New York harbour (an attempt to attach a time-bomb to HMS Eagle) during the American Revolution.**

During World War II (1939-45) submarine technologies advanced significantly. The Germans, who were operating their U-Boats in the Atlantic Ocean, adopted the principle of a 'snorkel' (allowing the boat to recharge its batteries while staying submerged). During 1941, Japan utilised the 'midget subs' for a coordinated attack on Pearl Harbour in the Pacific Ocean, where the United States had been operating their submarines. The Cold War period (1945-91) dictated much of the advancement in subsea warfare capabilities, the significant being the launch of USS Nautilus, the first nuclear powered submarine in 1954. **The standardisation of the submarine design with double hull, shock and collision withstand capabilities, safe design with redundancy and the definition of Safety Operational Envelope (SOE) / Manoeuvring Limitation Diagram (MLD) have significantly contributed to the reduction in submarine incidents.**

As on date, 42 countries have submarines as a part of their naval fleet. The submarine count by North Korea, the United States, China, Russia, Japan, South Korea and Iran are 71, 67, 59, 49, 22, 19, and 17, respectively. The present Typhoon (others being Borei and Ohio) class nuclear submarine having displacement of ~48000 Tons and 167 crew capacity can remain submerged up to 4 months. The technological breakthrough in the distressed submarine crew rescue capabilities (including reconnaissance, rescue and crew decompression) and the active role of the International Submarine Escape and Rescue Liaison Office (ISMERLO) in coordinating international submarine search and rescue operations are significant milestones in submarine history hitherto.

During early 20th century, the European countries and the US that pioneered research in submarine warfare, later understood the potential threats due to submarines and the importance of undersea surveillance, advanced their hydrophones and passive sonar technologies, offering great sense of security during the 2nd World War. During the cold war, both the US and Soviet Union that made significant developments in undersea surveillance and ASW technologies employed effective measures to detect and track each other's submarines (mainly ballistic missile submarines and nuclear-powered submarines that remain as the main stay of credible nuclear deterrence), as well as protect their own submarines from ASW systems.

The early first generation ASW tactics depended to a great extent on static defences, such as underwater mines and chain-link nets to prevent the movement of submarines into secure areas. Torpedo nets were hung from ships as an anti-submarine defence measure to block torpedoes from reaching their hulls. With the evolving tactic/counter-tactic nature of ASW, submarines began countering torpedo nets by adding net cutting blades to the front of their torpedoes. Ships countered submarines by towing grappling hooks connected to explosive charges in the hope of snagging a submarine or throwing charges overboard in the direction of a suspected vessel.

The second generation ASW tactics took a new dimension with the invention of the hydrophone in 1915 and quartz sandwich transducer in 1971, followed by the discovery of the Deep Sound Channel (DSC) in 1960 in which experiments were done to demonstrate transmission of low frequency sound over long distances utilising the natural sound channels. This Sound Fixing and Ranging (SOFAR) channel typically lies at 1 km water depth acts as a wave guide capable of guiding acoustic energy halfway around the planet with an attenuation of ~0.5 x 10^{-3} dB/km) enabled detection of submarine noise from longer distances. In the popular Heard Island feasibility test **(Figure.1),** detonation of 150kg of TNT in the channel off-Perth was recorded on hydrophones that were located at the SOFAR axis off-Bermuda at a distance of ~ 20000 km.

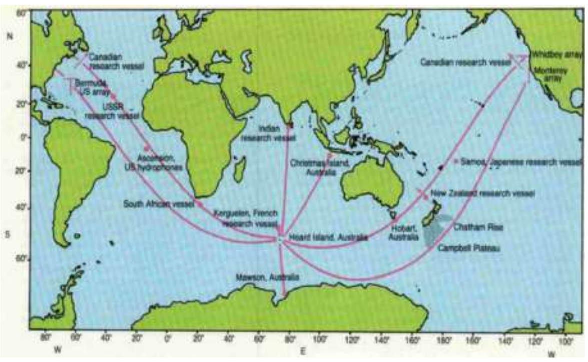


Figure.1. Description of the Heard Island experiment

Simulations are carried out using Bellhop modelling and simulation software to understand the effective acoustic propagation range of low frequency acoustic signal inside the SOFAR channel **(Figure.2).** It can be seen that the SOFAR channel acts as a waveguide with low attenuation enabling long distance reception of low frequency sound.

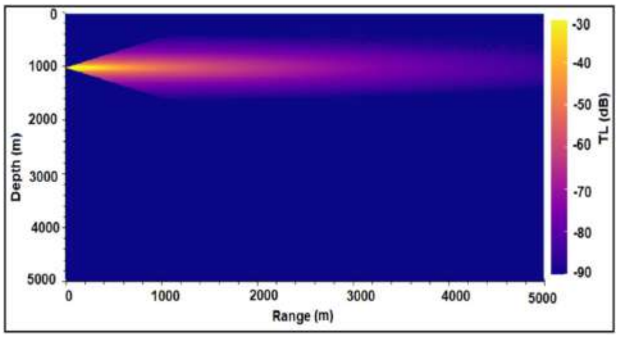


Figure. 2. Sound propagation through low-loss SOFAR channel

This led to the development of undersea Sound Surveillance System (SOSUS) that used sea bottom mounted hydrophone arrays connected by underwater cables to shore facilities, to identify /detect hostile submarine positions by underwater localisation techniques.

The first SOSUS was established in 1962 along a stretch from Barbados to Nova Scotia. It comprised of 333m long horizontal array of 40 hydrophones laid on the sea floor at a depth of 435m off-Bahamas. Subsequently, British Isles and Eastern Atlantic came under the SOSUS coverage, and in 1970 SOSUS covered important junctions in the Atlantic Ocean, enabling near-continuous track of submarines. During 1981, US deployed 36 SOSUS installations in various areas of US and Europe and created an Integrated Undersea Surveillance System (IUSS) sourcing information from SOSUS, multiple surface warships and submarines. Thus, SOSUS provided robust ASW capability for the nations to protect their waters by detecting and tracking hostile submarines undertaking deterrent patrol. Naval intelligence agencies collected and maintained the database of hostile submarine signatures, which helped to identify entry of enemy submarines.

Post-1980 marked the development of third generation ASW including Surveillance Towed Array Sensor Systems (SURTASS) with ships trailing long hydrophones capable of up-linking acoustic intelligence through satellite back to ground stations. This was later upgraded to Low-Frequency Active sonars (LFA) having the capability to detect quitter submarines at long distances. Further developments, include Rapidly Deployable Surveillance System (RDSS) for tactical applications, which could be dropped into the ocean at a short notice and transformed into mini-SOSUS on the ocean floor. This was used in areas where underwater surveillance was not available or not practical. The RDSS include acoustic interceptors such as sonar buoys (sonobouys) and towed passive devices such as the Magnetic Anomaly Detector (MAD), that could accurately track large metallic underwater objects. Present generation ASW systems feature Intelligence, Surveillance and Reconnaissance (ISR) capabilities enabled by an inter-connected network of surface ships, aircraft, other submarines.

Challenging ocean environment and sonar technologies

Determining the position of the underwater hostile submarine (target) precisely is the primary requirement in ASW. Sound velocity in the oceans varies between 1450 and 1570 m/s depending on the temperature, salinity and water depth. It increases at ~ 4.5 m/s/°C, ~ 1.3 m/s/ psu (salinity) and ~1.7 m/s/100m. The sound velocity variation with depth is called sound velocity profile (SVP). Variations in these physical properties cause sound waves to refract/bend when they travel obliquely through layers of water. This creates inaccuracy in the position of the underwater targets during acoustic/sonar imaging. Hence location-specific SVP is an important input required for precise localisation and sonar images used for identification of underwater targets.

Hydrophones are the key elements in passive sonar. Presently mature hydrophone technologies include piezo-electric, piezo-resistive, accelerometer-based, capacitive, fibre-optic, needle, acousto-electric, membrane, Lorentz force, multimode and inertia types. The desirable characteristics of a hydrophone include low-size, high sensitivity, high free-field voltage sensitivity (FFVS), high noise resolution, large signal to noise ratio (SNR), large dynamic range, high bandwidth, good linearity and high spatial resolution (**Table.1**). Sensitivity of a hydrophone reflects its ability to transform acoustic pressure to an output voltage for normally incident, quasi-planar acoustic pressure waves as a function of frequency. If the sensitivity (expressed in dB (re: 1V/Pa)) over the frequency band is approximately uniform in the pressure spectrum, it simply requires multiplying a scale factor (S). For broadband signals (e.g. nonlinear signals containing multiple harmonics) the sensitivity vary considerably over the frequency band in the pressure spectrum and the deconvolution can provide a significant improvement in the accuracy compared with scaling.

Table. 1. Maturity level of hydrophone (passive sonar)

Hydrophone Type/Factor	S	R	A	D	B
Piezo-electric	H			L	M
Piezo-resistive	M		H	L	M
Accelerometer based	L		M		M
Capacitive	H	H		L	M
Fibre-optic	H		M	L	H
Needle	H			M	H
Acoustic-electric	H	M	H		M

S- Sensitivity; R- Resolution; A- Accuracy; D- Directivity; B- Bandwidth; L – Low; M- Moderate; H -High

Active sonar comprises of an array of omnidirectional transmitters and receivers. Active sonar imaging is the construction of images in range and direction from the backscattered echoes from transmission pulses to estimate the acoustic reflectivity of the scene to the highest possible geometrical resolution.

> *Presently mature hydrophone technologies include piezo-electric, piezo-resistive, accelerometer-based, capacitive, fibre-optic, needle, acousto-electric, membrane, Lorentz force, multimode and inertia types*

Multi-beam sonars (MBS) are a type of active sonar system used to characterise the sea floor and detect objects in the water column or along the sea floor. MBS are categorised into side scan, sector scan and synthetic aperture sonar (SAS). Multiple physical sensors of the sonar called transducer array, sends and receives sound pulses to map the seafloor/objects **(Figure.3).** The sea floor depth or bathymetry is computed by measuring the time it takes for the sound to leave the array, hit the floor and return to the array. The functionality of the active sonar is based on the sonar equation defined as:

$$SE = SL-2\ TL+BS-NL$$

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

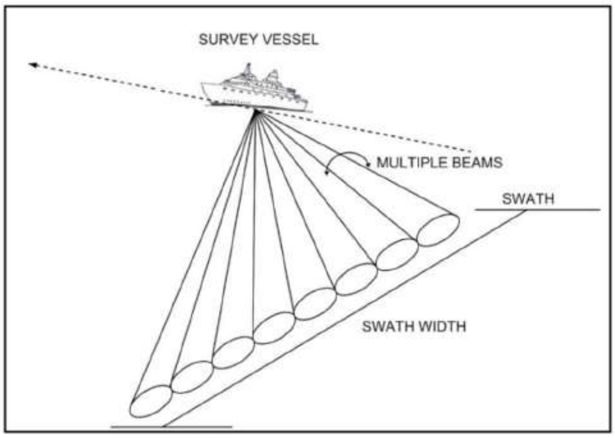


Figure.3. Rendering showing the beams and swath of an MBS

The dimension of the swath in the across track or athwart ship direction (perpendicular to the path of the ship) is called the swath width **(Figure.3),** and it can be measured either as a fixed angle or as a physical size that changes with depth. MBS employ beam steering technique to convert the amplitude and phase information recorded by the hydrophone array into the amplitudes of echoes observed by the array at discrete angles. Beam steering technique is used to create a series of "virtual" hydrophone arrays, each sensitive to a different angle. The data from the hydrophones forms many steered beams that have beam widths in the athwart ship direction of ~2°, and spacing of ~ 1° between their axes. Beam-forming is implemented using digital signal processing (DSP) by means of digitally delaying the channels in the array so that the array looking direction is steered to either side of the bore sight. The signal is then summed over the array for each range of interest (delay-and-sum). The beam steering angles that emerge from the Fast-Fourier-Transform (FFT) processing is limited to a discrete set of angles depending on λ/d and N, the number of hydrophones in the array.

> ***Beam steering technique is used to create a series of "virtual" hydrophone arrays, each sensitive to a different angle***

The azimuth (along-track) resolution of the sonar is the ratio between the acoustic wavelength and the length of the array, example, 1:100 means a resolution of 1m at 100m range. A longer array will increase this ratio, but fitting such a long array in a ship/submarine is impractical. Operation at a higher frequency increases the ratio, but limits the achievable range of the sonar due to higher absorption in the saline sea water medium. These challenges are overcome using a Synthetic Aperture Sonar (SAS). The principle of imaging using SAS is based on the coherent coordination of data collected over multiple locations such that the along-track resolution is improved **(Figure.4).**

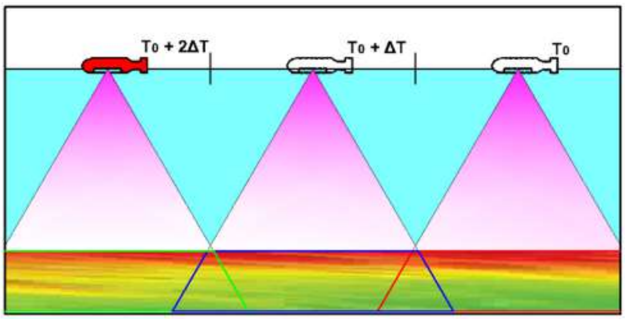


Figure.4. Principle of synthetic aperture sonar

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

Speed x Range = Constant, for a given sonar design

With the present technological maturity, with the SAS with inputs for precise attitude and heading reference system (AHRS), by covering a range of 200m on each side of the ship/submarine cruising at 2 m/s, it is possible to have on-board high resolution of up to few centimetres and well as co-registered images, covering ~2 km^2/h. Due to the spatial sampling requirements the maximum ship/submarine velocity Vsas achievable for distortion-free sonar imaging is a function of the physical aperture length (L) and ping repetition interval (PRI). Therefore, the following condition to be satisfied.

$$V_{sas} \leq L/2\,PRI$$

With precise attitude inputs and with the recommended ship/submarine velocity, SAS offers a trade-off between sonar range and resolution. SAS provides over 25 times greater resolution at a range with 3 times increase in area that is covered compared to conventional side-scan MBS.

Other submarine acoustic array types include planar and conformal arrays. The conformal array is favourable in practical active sonar systems as it offers superior acoustic performance, but its relatively complicated structure requires sophisticated analysis and design. Submarines mainly use their bow and towed arrays for monitoring the places and track targets in the perimeter but both of them have some limitations. The aperture of the bow array is limited by submarine width because it is located in front and towed array requires a winch and long tow cable which causes some installation and manoeuvring problems. These disadvantages can be overcome with flank arrays. The flank array sonar is an array of hydrophones placed along the submarine hull for passive acoustic monitoring. Thus, a large aperture array can be obtained along the submarine hull with flank array. As a disadvantage, this type of array suffers from interference with submarine's self-noise.

The Continuous Active Sonars (CAS) use swept linear frequency-modulated signals transmitted at 100% duty cycle to detect, classify, and localize submarines. CAS offers the benefit of improved detection and continuous tracking relative to traditional pulsed active sonar. The recent advances features in ASW sonar technologies include triple-array design to simultaneously resolve the left/right ambiguity issues and transmitter with high source level, bandwidth and coverage of entire 360° panorama allowing simultaneous target detection and Doppler measurement from all directions. Thus, the comprehensive, high-performance sonar portfolio meets all of today's challenges in the detection, tracking and classification of underwater targets from shallow to blue water. The matured ship/submarine/air-borne ASW systems are summarized in **Table.2.**

Anti-submarine Warfare Tactics

Searching and detecting a hostile target (submarine) is done using passive sonar and active sonar searches. In ASW, an active sonar pulse from an anti-submarine asset can be detected by the hostile submarine based on the characteristics of the outgoing ping that give clues on the identity/location of ASW asset. **Hence active sonar is not frequently used by military submarines the use of active sonar on submarines is likely to severely reduce the submarine's stealth and would only be used in demanding circumstances.** Passive sonar search is more

Table. 2. Ship/submarine/air-borne ASW systems

Configuration	ASW Systems
Surface ship/ Shipborne	Hull-mounted Sonar, Bow-mounted sonar, Stern-mounted, SAS, Towed Passive Arrays, Towed Active Arrays, Decoys/Torpedo
Sub-surface/ Submarine borne	Active array, Passive surveillance array, Intercept array, Flank array, Conformal array, Towed array sonar.
Airborne	Rapidly Deployable Surveillance System (RDSS) including Dipping/ dunking sonar, Sonobouys (active/ passive), MAD
Seabed arrays (Fixed)	Fixed and moored hydrophone sensors

defined, tactful and skilful, but more time-consuming with the increasing Area of Uncertainty (AoU). The datum is a point on the chart which grows in uncertainty and distance over time, and is a function of type of submarine, whether it is operated by diesel or Air Independent Propulsion (AIP) or by nuclear power.

Once detected, ASW tactics shall be followed, by which the target submarines would be driven within the organised barriers. Then, a ship-based helicopter or land-based aircraft would conduct sweeps in potential areas of submarine presence and utilise sonobouys to precisely localise their location. Further, surface ships or submarines shall be engaged in the pursuit of forcing the hostile submarine to the sea surface or destroy the submarine using depth charges or ASW missiles or rockets.

Detection, localisation and classification of a hostile submarine

Reliable encounter from a ship/submarine using torpedoes require precise underwater localisation (relative position determination) of the hostile submarine. The techniques for underwater localisation involve determining the range and bearing of the arriving acoustic wave front from the submarine. The range and bearing estimation techniques are based on Received Signal Strength (RSS) and Time Delay Estimation (TDE), respectively. The RSS technique is based on the strength of the acoustic signal from the hostile submarine that reaches the passive hydrophone array, and TDE techniques are categorised into Time of Arrival (ToA), Time of Flight (ToF) and Time Difference of Arrival (TDoA).

Determining the RSS for range determination involves computing the magnitude of the acoustic signal Transmission Loss (TL) originating from the hostile submarine to the ASW system receiver array, considering the effects of geometrical spreading, absorption and scattering using underwater propagation channel beam/ ray tracing numerical modelling and simulations. The TL is decibels(dB) is generally calculated using the following empirical relationship:

$$\mathrm{TL} = \mathrm{A}\log r + \frac{\alpha r}{1000}$$

where 'α' is the absorption coefficient in db/km, 'r' is the range in m, 'A' equals 10.

Recent numerical modelling and simulation software (such as Bellhop, Kraken, Scooter) incorporate water depth of directional acoustic sources (here hostile submarine as transmitter), hydrophone receiver, source beam pattern, geo-acoustic properties of the bounding media including altimetry, bathymetry and the location-specific Sound Velocity Profile (SVP) as inputs. They compute the TL considering the effects of surface reflection, surface duct, bottom bounce, convergence zone, deep sound channel and reliable acoustic path. **Figure.5** shows the Bellhop modelling and simulation results depicting Eigen ray pattern and pressure plot (TL) with a submarine at 500m water depth (transmitting low frequency) and sea surface receiver.

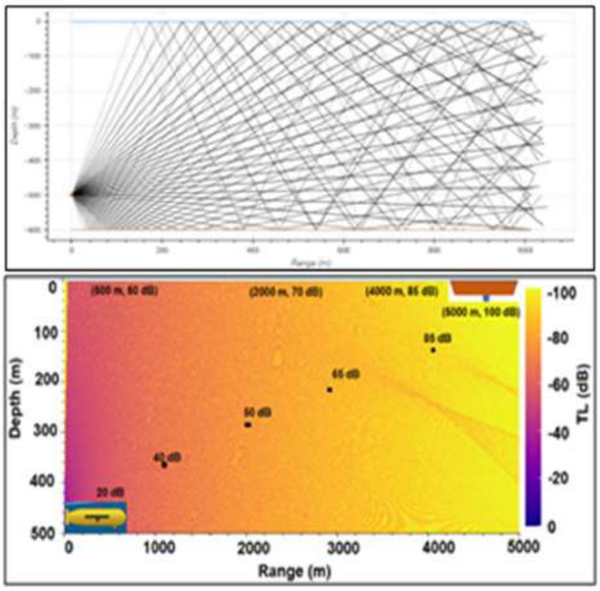


Figure. 5. Eigen ray & pressure (TL) plot with sub at 500m

The TDOA is a technique that compares the ToA of an acoustic signal to different hydrophones in order to estimate the angle of arrival of the acoustic signal **(Figure.6).** The array of reception hydrophones has known relative positions among them so that it is possible to compare the different times of arrival or phase differences. To improve the determination of the TDoA between the hydrophones, DSP system calculates the difference of phase between the received signals. If the distance between hydrophones (baseline) is greater than the wavelength of the acoustic signal, the phase alone is not sufficient to determine the TDoA. Time-domain correlation is thus combined with the phase difference calculation to remove the ambiguity and obtain a TDoA with a time resolution that is beyond the sampling period used in the DSP system.

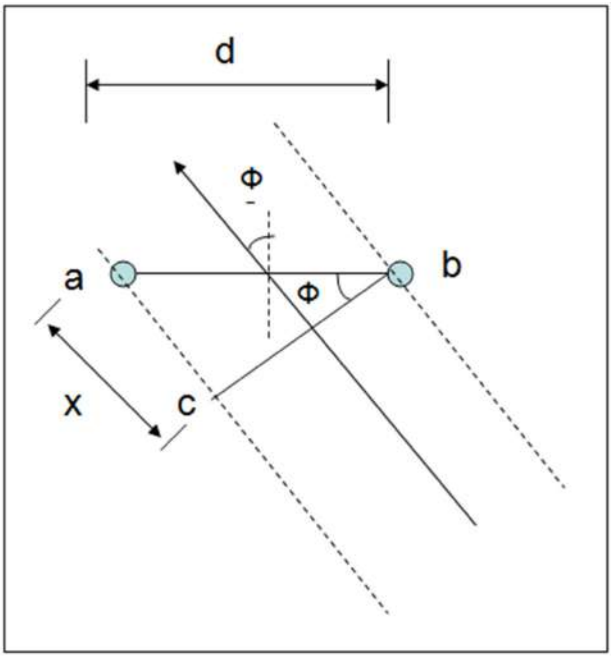


Figure. 6. Principle of bearing angle computation

The bearing angle is calculated based on the TDoA between the hydrophones separated by distance d **(Figure.5),** in which d is the distance between the hydrophones, x is the extra distance travelled by the wave front to reach transducer a after reaching transducer b; Sin Φ = (x/d).

If ΔT is the time taken for the wave front to cover the distance of x and c is the velocity of sound then,

x = ΔT * c ; and Sin Φ =ΔT* (c /d)

Let Φ be the phase difference between wave front at b and a. A phase difference of 2 radians corresponds to a time difference λ/c, where λ is the wavelength. Hence the phase difference of corresponds to a time difference of distance of

ΔT = * ((1/2)*)*(λ/c)

The bearing angle of the hostile submarine/target with respect to passive sonar detector is calculated as:

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

Localization of target submarine

Precise localization is the key requirement for a reliable encounter. Helicopters can fly out of ASW ships, well beyond the horizon to contribute to the ship's situational awareness thus acting as force multipliers. Airborne ASW have the advantages of greater range, persistence and coverage. Airborne ASW begins with the datum point as its destination. As the datum expands, modern helicopter/aircraft equipped with dipping sonar, sonobuoys and MAD are used. Localization using sonobuoys involve deploying multiple surface detectors **(Figure.7)** taking into consideration target submarine speed, helicopter speed, sonobuoy detection range and time-since-detection.

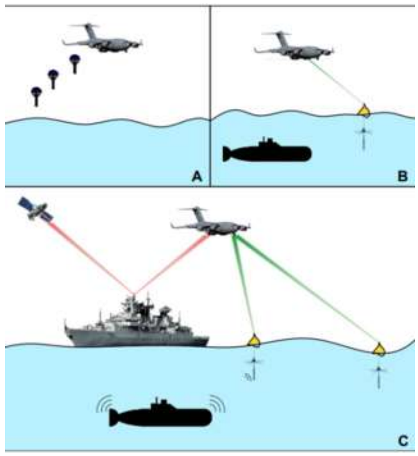


Figure.7. Principle of underwater localization using sonobouys

Once the range and bearing of the target are determined from multiple detectors, localization of the target submarine is done based on triangulation and lateration. Triangulation includes geometric, geometric circle interaction, iterative methods and multiple beacons methods. Lateration relies on the range between the target submarine to be localized and multiple reference nodes. The most typically employed lateration technique is the multi-lateration. **The principle of underwater localization based on trilateration of the hostile submarine using deployable sonobuoys is depicted in Figure.8.**

Passive Directional Frequency Analysis and Recording (DIFAR) sonobouys and Directional Command Active Sonobouys System (DICASS) sonobouys, have detection ranges of 2–3 nm. It requires about twenty sonobouys to create a field capable of monitoring ~13 nm on a side. Newer MAC active sonobouys systems could achieve ~8 nm detection ranges and therefore require only half as many sonobouys to cover the same area

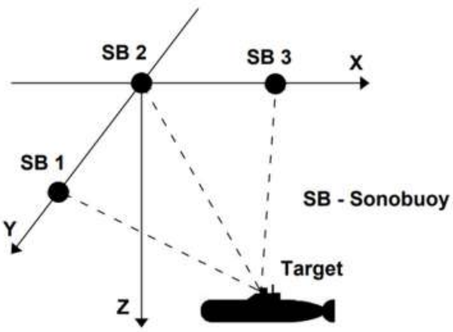


Figure.8. Principle of trilateration in localization

Classification of target submarine

While the submarine is precisely located, at the same time, the submarine has to be classified based on the received acoustic signature (sound spectrum). The submarine's noise level or source level (SL) is the intensity of sound in a given frequency band at a distance of 1m from the submarine within a receiver's direction. The SL frequency of the spectrum constitutes a mixture of the continuous and discrete components. The continuous part of SL spectrum is characterized by a maximum in the area of 50-100 Hz. At frequencies greater than 200 Hz, the SL falls by 6 dB when the frequency is doubled. The discrete components are the most visible signs of the submarines' SL spectrum since they are detected even at low speeds, when submarines produce minimal noise. Further, the aggregate of the discrete components of the noise spectrum, called as the acoustic portrait, is unique for each submarine, which is used to classify it by comparing it with databases. Noise from the propulsors and flow along the hull, increases in proportion to submarine speed raised to the fifth or sixth power, and flow-generated noise tends to dominate the contribution from machinery at higher speeds **(Figure.9).**

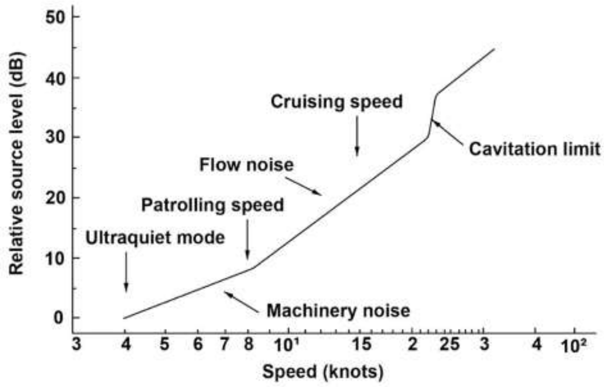


Figure.9. Constituents of submarine acoustic signature at speed

At speeds < 8 kts machinery noise dominates the acoustic signature, and increases with speed. Flow noise and propulsion noise begins to dominate above 8 kts and increases with speed at a greater rate than machinery noise. The highest noise levels are produced after the onset of cavitation, although submarine propulsors are designed so that cavitation is unlikely to occur, especially when submerged.

The acoustic signature is not only dependent on the machinery line-up and speed; it also changes over time due to the maintenance of machinery, as well as bio-fouling of the hull which increases drag and consequently propulsion noise and flow noise. Modern tools such as DSP, machine learning and artificial intelligence-based systems helps in reliably classify a hostile submarine based on databases.

Ship hull-mounted and Towed Array Sonars

Surface combatants need highly effective and efficient sonar systems. Searching a hostile submarine over a wide area is done using Towed Array Sonars (TAS) comprising of a system of hydrophones and is tugged a considerable distance behind a ship/submarine using a cable **(Figure.10).** These hydrophones are often kilometres away thus greatly improving the Signal-to-Noise (S/N) ratio. TAS are effective in detection and tracking of faint sounds from submarines. It has a superior resolution and has a wider range than ship hull-mounted sonar **(Figure.11).** This covers baffles which is the blind spot of hull-mounted sonars.

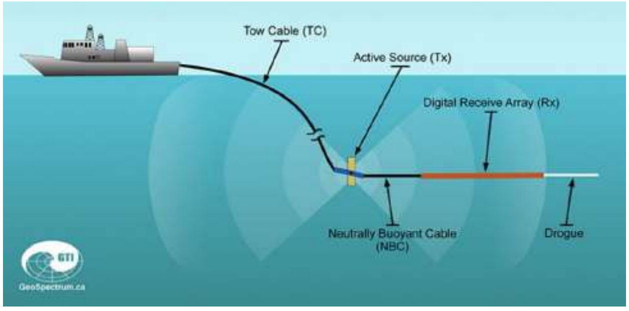


Figure.10. Principle of towed array sonar

The direction of the TAS is an important consideration and it should be determined if the tow cable is in a stable position or on a straight line. Typical TAS comprises of array section extending to 100+ meters, vibration isolation module, towing cable of 100+ meters, tail rope of 10+ meters, on-board systems for handling the cable array including the launching device and cable cutter in case of emergency. Modern TAS is capable of detecting submarines at distances >50km. Current developments in the optical fibre technologies could enable longer arrays with more hydrophones with better accuracy and sensitivity.

Figure. 11. View of ship hull placed sonar

The recent Active Towed Array Sonar (A-TAS) is a low-frequency ASW sonar system that operates simultaneously in active and passive detection modes and provides high-resolution target detection. The detection ranges of such sonar exceed the weapons' range of hostile submarines, thereby denying the enemy an offensive capability. This type of sonar provides excellent performance up to very long ranges, including over-the-horizon surveillance. Because of the good sound propagation of echoes and target noise in the low- frequency band, the system is capable of operating below acoustical layers. Superior performance is ensured by the high source level, the high dynamic range and the large bandwidth.

In the second part....

The next (second) part shall discuss in detail on the technologies for eliminating hostile submarines, as well as carrying out Intelligence, Surveillance and Reconnaissance (ISR) activities. The technical and environmental challenges in carrying out reliable ASW and the strategic technologies will also be discussed.

References

1. Navy Large unmanned surface and undersea vehicles, 2023, Congressional research service report, R45757
2. Amit Ray, Forecast of Chinese SSBN force levels, 2020, Maritime affairs: Journal of the National Maritime Foundation of India.
3. Elizabeth Mendenhall, Fluid foundations: Ocean transparency, Submarine Opacity, and strategic nuclear stability, Journal of military and strategic studies, Vol 19, Issue 1, 2018.
4. Amit Ray, Considerations and challenges in silencing submarines, https://indiannavy.nic.in/insshivaji/sites/default/files/paper_on_considerations_and_challenges_in_silencing_submarines.pdf
5. The world's recent torpedoes, https://www.naval-technology.com/features/featurethe-worlds-deadliest-torpedoes-4286162/#catfish
6. Aaron Amick, How war ship hunt for enemy submarines, 2020, https://www.thedrive.com/the-war-zone/36885/how-warships-above-the-waves-hunt-for-enemy-submarines-down-below
7. VBN Jyothi, R Ramesh, N.Vedachalam, Assessment of maturity of subsea navigation and positioning systems, Marine Engineers Review Journal, March, April & May 2023
8. Torpedo Defence Suite For Surface Vessels, https://www.navalnews.com/event-news/imdex-asia-2023/2023/05/rafael-unveils-torbuster-sp-torpedo-defense-suite-for-surface-vessels/
9. N.Vedachalam, Challenges in locating objects lost in the ocean, Marine Engineers Review Journal, July 2022.
10. Prakash Pannerselvam, Rajaram Nagappa, R Ganesh, Underwater Domain Awareness, 1st edition, 2022, https://doi.org/10.4324/9781003298380

About the author

Dr. N. Vedachalam is currently Scientist G in Deep Sea Technologies division of National Institute of Ocean Technology (NIOT), Ministry of Earth Sciences, India. He is the technical lead for India's first indigenously-developed deep-water manned scientific submarine Matsya6000. He holds a Bachelor's degree in Electrical and Electronics engineering from Coimbatore Institute of Technology (1995) and PhD in Techno-economics of marine gas hydrates from College of Engineering - Anna University, India. His 27 years of experience include industrial power, process, offshore and subsea domains at Aditya Birla group, General Electric & Alstom Power Conversion in France. Technical exposure includes development of multi-megawatt subsea power and control systems for Ormen Lange subsea compression pilot; Ocean Thermal Energy Conversion and wave energy systems; subsea renewable power grids; unmanned and manned underwater vehicles; ocean observation technologies and industrial systems. His research interests include energy, subsea robotics and reliability. He has more than 100 publications in indexed journals, holds an international and two national patents in subsea robotics and subsea processing. He is a recipient of the national meritorious invention award in 2019 for the development and usage of underwater robotic vehicles. He is a member of Indian Naval Research Board, member of Bureau of Indian Standards and was the Secretary of IEEE OES - India Chapter. He is a regular contributor to MER.

Email: veda1973@gmail.com

Dr. K. Sudarsan is former Scientist-G and Associate Director at Naval Physical and Oceanographic Laboratory(NPOL), Defence Research and Development Organization (DRDO), Kochi. He holds a Bachelor's degree in Aeronautical Engineering from Madras Institute of Technology (1979) and Masters (MS) and Ph.D. in Ocean Engineering from IIT, Madras. Has 34 years of experience and was responsible for technology development indicatives with focus on the indigenisation programme of critical component technologies required for ASW in the areas of underwater mechanical systems for Indian Navy. He has published nearly 30 papers in leading national and international journals and conferences. He is a recipient of NPOL & DRDO Technology Group Awards for the development of underwater sensors in 2007 and 2009. He has been deputed to Canada and Russia for advanced training programs in the area of ASW systems. He was nominated member for preparation of vision document on Ocean Technology and 12th five-year plan (2012-17) for Ministry of Earth sciences, GOI. He is a Member of Institution of Engineers (India) and Life Member of Ocean Society of India. He is currently the Chairman of Techno-Financial Evaluation Committee and Member of Technical Committee for Manned Submersible Program of NIOT, Chennai

Email: ksud57@yahoo.com

PLASMA ELECTROLYTIC OXIDATION AND ANODIZATION AS SURFACE MODIFICATION TECHNIQUES FOR MARINE APPLICATIONS

Amruthaluru Saikiran,
Rajoo Balaji

Abstract: Anodization and Plasma Electrolytic Oxidation (PEO) are emerging environmentally benign electrolytic processes for developing corrosion-resistant ceramic oxide coatings for maritime applications. Electrolytic techniques outperform the conventional coating processes in terms of adherence, scratch, and erosion resistance along with compactness due to the conversion of metal into their corresponding oxides in the electrolytic techniques, unlike the deposition in the conventional techniques. This article presents an overview of the corrosion phenomena and its mitigation measures, with a focus on the anodization and PEO processes and their effects on the performance characteristics of metals.

Keywords: Marine Corrosion, Electrolytic Coating Techniques, Corrosion Resistance, Adhesion, Ceramic Coatings

INTRODUCTION

Corrosion is one of the most severe problems the marine industry experiences. Corrosion is a chemical/electrochemical reaction that deteriorates any material. Metallic materials used in marine applications undergo electrochemical aqueous corrosion reactions on exposure to the corrosive saline environment. Corrosion of the ferrous, nonferrous metallic materials mostly occurs due to the most oxidizing chloride ions which are the major constituent in the oceanic salts. Cathodic protection methods (i.e., sacrificial anode, impressed current) are widely being used for protecting the structural components like hull, rudder etc., whereas the other functional components are protected by the application of protective coatings (Cheng et al., 2022, Silva Campos et al., 2022). Cathodic protection methods convert the corroding metal to more electropositive (cathodic) compared to the other electronegative metal (anode), whereas the coating techniques mitigate the corrosion by avoiding the contact of the corrosive medium with the metal (M), thereby preventing the following corrosive reactions to occur.

$$M \rightarrow M^{+} + e^{-} \quad (1)$$

$$H_2O + 2e^{-} \rightarrow H_2 + 2OH^{-} \quad (2)$$

$$M^{+} + OH^{-} \rightarrow MOH \quad (3)$$

$$M^{+} + Cl^{-} \rightarrow MCl \quad (4)$$

> *Corrosion of the ferrous, nonferrous metallic materials mostly occurs due to the most oxidizing chloride ions which are the major constituent in the oceanic salts*

Metal undergoes oxidation at the anodic site thereby releasing metal cations and electrons according to equation 1.

Water dissociates into hydrogen and hydroxyl ions at the cathodic site by the reduction reaction as mentioned in equation 2.

Metal cation reacts with the anions (Chloride, hydroxyl) thereby forming metal hydroxides and metal chloride at the anodic site as cited in equations 3 and 4. Metal reaction

> *Plasma electrolytic oxidation (PEO) and anodization are the electrolytic coating techniques in which the metal to be coated will be dipped in the electrolyte, which is an aqueous solution of various salts and additives intended for the improvement of coating characteristics*

with chloride ions thereby forming corresponding metal chloride is often termed as the corrosion reaction, which has to be prevented.

Coating techniques eliminate the possibility of direct metal contact with the chloride species thereby preventing the corrosion reaction. Spray coating and painting are the widely used coating techniques in the marine industry. The corrosion protection capabilities of the spray coating and painting will be limited by their poor adhesion and erosion resistance. Delaminated or detached coatings will result in aggravated corrosion at the damaged spot making it anodic compared to the coated region. Since the area of the uncoated region will be small compared to the uncoated, the corrosion current density (corrosion current/unit area) will be tremendously high thereby leading to severe pitting corrosion at the damaged spot. The aforesaid issues can be surmounted by the development of thick, highly adhesive and erosion-resistant coatings. Adhesion of all the mechanically bonded coatings will be limited due to the absence of a metallurgical bond between the metal and the coating. A metallurgical bond between the metal and coating can be better achieved by using the electrolytic coating techniques, in which the top layer of the metal itself converts to its corresponding oxide alike the deposition on the metal surface in the above-mentioned coating methods. Plasma electrolytic oxidation (PEO) and anodization are the electrolytic coating techniques in which the metal to be coated will be dipped in the electrolyte, which is an aqueous solution of various salts and additives intended for the improvement of coating characteristics.

ANODIZATION

Anodization is an electrolytic coating technique widely being employed to fabricate coatings on the valve metals such as Aluminium, Titanium, Zirconium, Magnesium, Niobium etc., and their alloys attributing to their ability to naturally form thin oxide layer on exposure to the atmosphere (Zhao et al. 2022). The metal which needs to be coated through the anodization process will be dipped into the electrolyte and connected to the positive terminal of a DC power source equipped with a variable frequency and duty cycle setup. The negative terminal of the same power source will be connected to the inert/ noble metal relative to the metal that needs to be coated which will also be in contact with the electrolyte. Hence stainless steel or platinum will be widely used as depicted in **Figure 1.**

The coating process can be performed in two modes:

(a) constant current mode and (b) constant voltage mode.

In the constant voltage mode, the operating voltage will be held constant, and the coating current/current density (current/surface area of the sample) will be varying, whereas in the constant current mode, coating current and hence current density will be kept constant thereby resulting in the variation in the voltage. Constant current mode will be widely used in comparison with the constant voltage mode because of the better control over the voltage-current characteristics of the power source in the constant current mode. During the coating formation, the electrolyte will deionize under the influence of the applied electrical field and the ions will diffuse through the electrolyte towards the oppositely charged terminals of the DC power source. The metal of our interest (M) will get oxidized since it is connected to the negative terminal of the power source thereby producing metal cations on the surface which will react with the anions diffused through the electrolyte thereby forming corresponding metal oxides on the surface of the sample to be coated. Since the formed oxide layer is ceramic, the further coating growth will be impeded due to the reduced diffusion kinetics of the metal cations and anions through the oxide layer owing to its electrical resistivity,

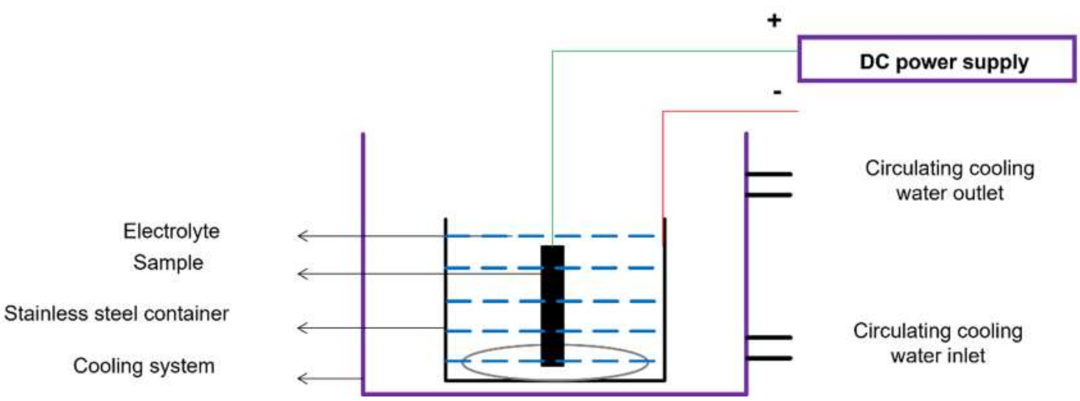


Figure. 1. Experimental setup for the fabrication of anodization and PEO coatings

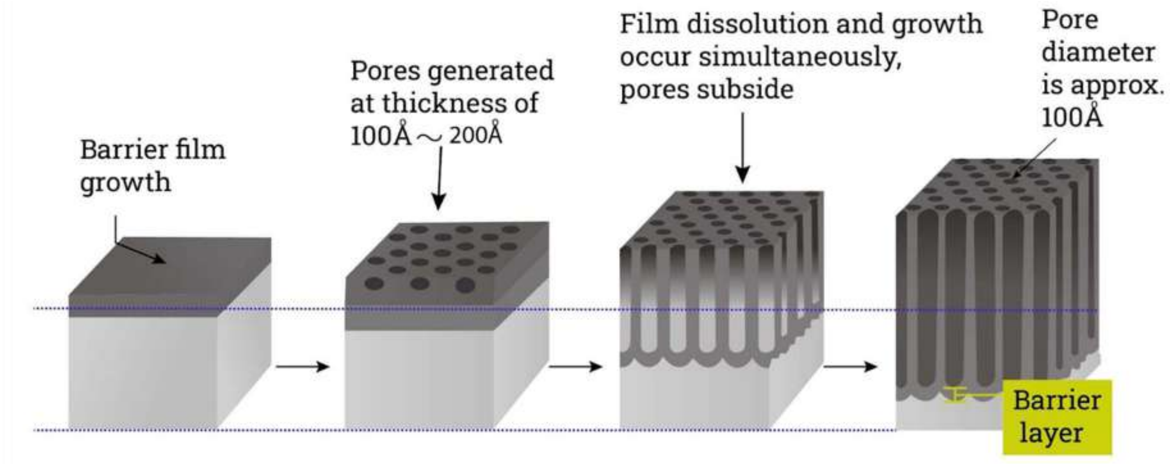


Figure. 2 Coating formation through anodization process
(https://www.iqsdirectory.com/articles/aluminum-anodizing/anodized-aluminum.html)

and hence the coating kinetics will be hampered as the time progresses. Electrolytes being employed for the anodization technique will be acidic which will perforate the formed oxide layer, thereby resulting in the formation of numerous fine pores through which further diffusion of metal cations and anions from the electrolyte continues, and the coating growth continues to increase as depicted in **Figure 2.** The formed oxide layer will be columnar-structured depicting the porous tube-like structures formed due to the etching action of the acidic electrolyte (Klimas et al., 2022).

The porous structure of the coating renders it to be hydrophilic, which is essential for biomedical applications which is evident from the surface micrograph presented in **Figure 3.** The coating morphology can be manoeuvred to a converging tubular structure with reducing diameter as we move away from the metal surface, or the diameter of the entire tubular structure can be reduced to make the coating hydrophobic, which is more suitable for marine applications. The morphology of the coating can be manoeuvred by altering the duty cycle and frequency. **An increase in the frequency results in a smoother coating on the ground of a very short pulse duration. An increase in the duty cycle produces a thick coating but with relatively rough surface morphology ascribing to the higher duration of the positive pulse.** The corrosion resistance of the coatings can be improved with the development of hydrophobic surfaces majorly by reducing the pore diameter by altering the electrical parameters or by the post-coating chemical treatment techniques using various silanes. The hydrophobicity of the coatings will be ascribed to the entrapment of air bubbles between the nanostructures which will resulting in cushioning effect for the water molecules, thereby avoiding direct contact of water with the sample (Javanpour et al., 2022).

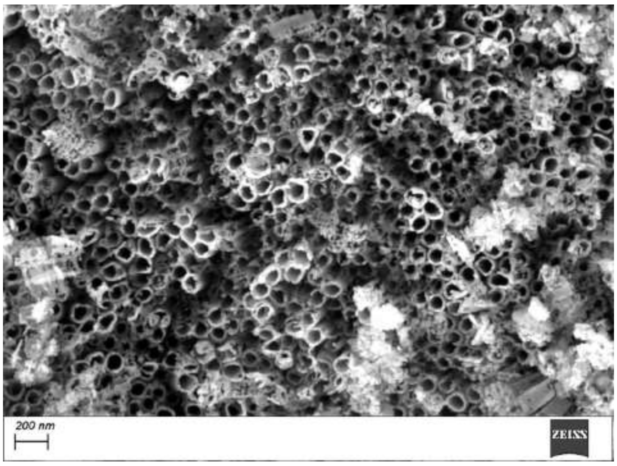


Figure. 3. Surface micrograph of anodized Ti sample (Salman et al. 2021)

The coatings formed through the anodization technique will be amorphous, which can be converted to crystalline by the heat treatment subsequent to the coating formation. The crystallinity of the coatings will further promote corrosion resistance. The corrosion resistance of the coatings can also be altered by varying the electrolyte composition, thereby altering the phase composition of the coatings. The various properties of the coatings can be tailor-made by altering the electrolyte composition and electrical parameters. **Since the coatings obtained by the anodization are ceramic, they exhibit superior corrosion resistance and wear resistance compared to mechanical coating techniques like painting.** Yet, the coatings formed through the anodization exhibit lacuna in providing corrosion resistance attributed to the restriction in the coating thickness (1- 10 μm). The corrosion resistance along with the adhesion and wear resistance can be improved further with the plasma electrolytic oxidation.

PLASMA ELECTROLYTIC OXIDATION

Plasma electrolytic oxidation is an electrochemical technique similar to anodization. The experimental setup of the PEO process will be analogous to that being employed for the anodization except for the electrolyte and capacity of the power source. Alkaline electrolyte

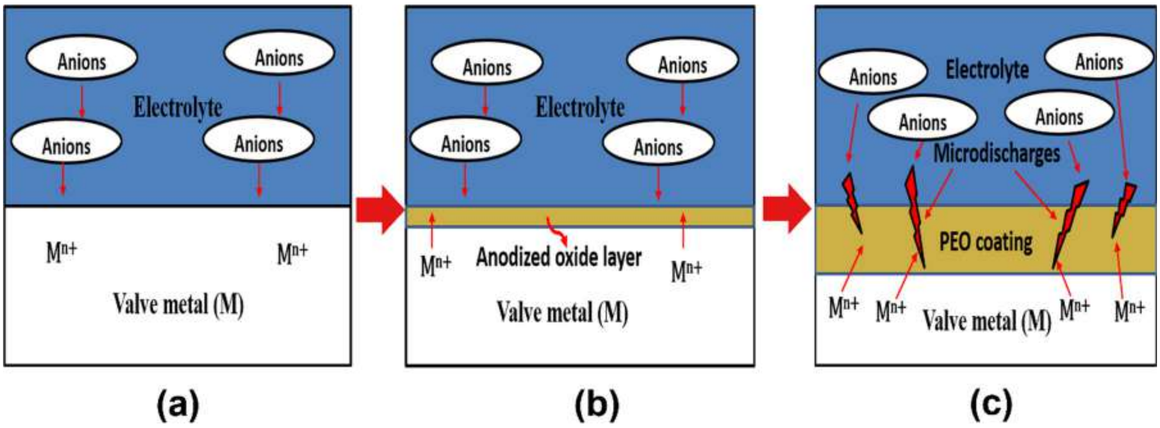


Figure. 4 (a) Initial stage of PEO process (b) Anodized oxide layer formation (c) PEO coating formation by the micro discharges (Rameshbabu et al. 2019)

solution will be used for the fabrication of PEO coatings, unlike the anodization. The power source used for the PEO coating process will be of higher capacity (1000 V; 20 A) compared to that used for the anodization (300 V; 5 A) owing to the higher current densities and voltages encountered during the coating formation in the PEO process. Coating forms through the process similar to anodization during the initial stages, and the formed oxide layers restrict the further growth in the coating thickness.

In the constant current mode, the power source increases the voltage as the coating thickness increases to maintain the constant current density overcoming the resistive behaviour of the formed oxide coating. The potential across the coating thickness continues to increase at a faster rate till it reaches the breakdown voltage corresponding to the formed oxide layer, which then leads to the avalanche breakdown of the formed oxide layer, thereby creating the numerous fine discharge channels, through which the further diffusion of metal cations and anions from the electrolyte continues, thereby forming metal oxide in the discharge channels (Aliasghari et al., 2020).

Due to the high breakdown voltage, the energy density will be very high inside the discharge channels which raises the pressure and temperature (up to 10,000 K) inside the discharge channels. The high temperature existing in the discharge channels melts the formed oxide and the prevailing high pressure helps in ejecting the molten metal oxide out of the discharge channels like a volcanic eruption. The ejected molten metal oxide will be subsequently quenched by the surrounding electrolyte. The coating thickness continues to grow through the repeated breakdown of the formed oxide layers (Saikiran et al. 2021). The schematic representation of the PEO process is presented in **Figure 4.**

The oxide layer formed at the initial stages of the coating will be amorphous, analogous to that obtained through the anodization, which on further exposure to the multiple ejections undergoes heat treatment resulting in the crystallization. The coating will be a porous structure with elevated surfaces near the pores indicating the formation of discharge channels and ejected metal oxide around the discharge channels which is evident from the surface micrograph depicted in **Figure 5.**

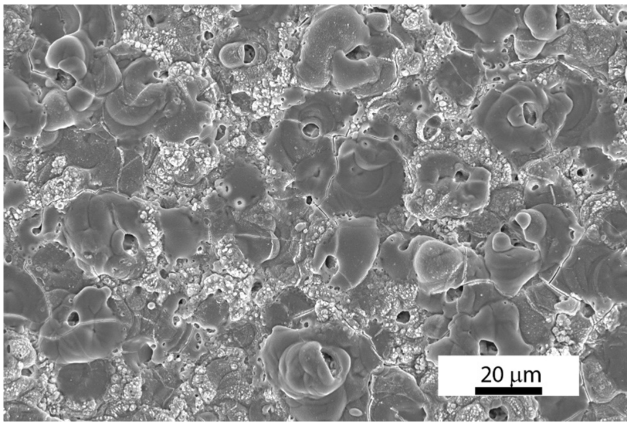


Figure. 5 Surface micrograph of PEO-coated aluminized steel sample
(Saikiran et al. 2019)

The PEO coating will exhibit a two-layered structure with an evident outer porous layer and a dense inner layer. Compact inner layer with relatively less porosity and defects provide the required corrosion resistance to the metal. **Figure 6** depicts the two-layered structure with the inner dense layer represented by red lines and the outer porous layer represented by green lines.

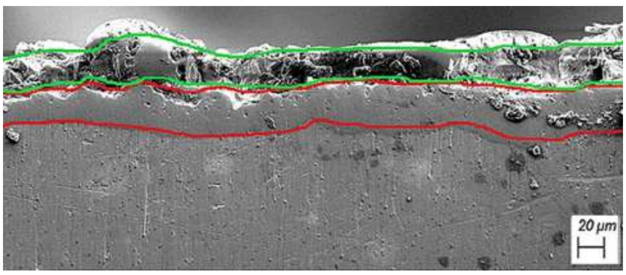


Figure. 6. Cross-Sectional Morphology of PEO-coated AA 7075 depicting two-layered structure (Premchand et al. 2022)

The performance of the coatings can be manoeuvred by altering the electrical parameters, and electrolyte composition similar to the anodization. The addition of nanoparticles will further improve the anti-corrosion properties. **The PEO process with nanoparticle addition is often termed plasma electrolytic oxidation coupled electrophoretic deposition (PEO-EPD)** (Lokeshkumar et al., 2022). The size of the nanoparticle will decide the method of incorporation nanoparticle into the coating. Active incorporation will lead to the closure of the pores formed during the ejection of molten metal oxide, thereby reducing the porosity which in turn increases the corrosion resistance by arresting the seepage of the corrosive medium through the pores. Reactive incorporation will involve the partial or incomplete melting of the nanoparticles after getting entrapped in the pores thereby leading to the formation of a new phase with enhanced properties, unlike the active incorporation. Nanoparticles will be neutral and hence to drive the nanoparticles towards the metal sample, they will be charged with the help of chemicals. The type and size of the nanoparticle will be decided on the intended properties. The PEO-EPD process requires higher operating voltages compared to the PEO. Mechanical properties (thickness, hardness, erosion resistance etc.,) along with the functional properties of the coatings can be altered by varying the nanoparticles.

Despite the superior performance and great manoeuvrability, the PEO process cannot be used to fabricate coatings on the larger components since the component has to be immersed in the electrolyte during the coating formation. The PEO process has been used to synthesize coatings on non-ferrous alloys till recent years, since the naturally formed oxide layers on the ferrous alloys will be non-protective due to their lower Pilling-Bedworth ratio. Recent studies on PEO have proved that the PEO technique can be used to develop coatings on ferrous alloys by pre-treating ferrous alloys with valve metals, which enables them to be coated using the PEO method.

CONCLUSIONS

Plasma Electrolytic Oxidation (PEO) and Anodization can effectively provide a solution to corrosion. PEO technique enables to fabricate corrosion-resistant ceramic coatings with superior properties i.e., high thickness, adhesion strength, scratch resistance, erosion resistance, hardness, antibiofouling etc. compared to conventional mechanical painting, dip coatings and thermal spray coatings with excellent control over the properties of the coatings. The electrolyte chemistry, nanoparticles, additives, and electrical parameters were shown to have a significant impact on the corrosive behaviour of the coatings. The coatings' anticorrosive effectiveness can be improved by manoeuvring the electrolyte composition and electrical parameters.

REFERENCES

1. Cheng, X., Xia, J., Wu, R.J., Jin, W.L., Pan, C.G. (2022). Optimisation of sacrificial anode cathodic protection system in chloride-contaminated reinforced concrete structure. J. Build. Eng., 45, 103515.
2. Silva Campos, M.D.R., Blawert, C., Scharnagl, N., Störmer, M., Zheludkevich, M.L. (2022). Cathodic protection of mild steel using aluminium-based alloys. Materials, 15:4, 1301.
3. Zhao, H., Chen, X., Xinjieyuan, L., Wang, X. (2022). Effect of Different Sealing Treatments of Oxide Films on Corrosion Resistance of Anodized ZL101A Aluminum Alloy in Simulated Marine Atmospheric Environment. Int. J. Electrochem. Sci., 17:2, 220851.
4. Saikiran, A., Premchand, C., Manojkumar, P., Lokeshkumar, E., Rama Krishna, L., Rameshbabu, N. (2022). Effect of sodium aluminate in the borax-based electrolyte on corrosion resistance of plasma electrolytic oxidation coatings fabricated on galvanized steel. Trans. Indian Inst. Met., 75, 813 - 825.
5. Lokeshkumar, E., Saikiran, A., Ravisankar, B., Parfenova, L. V., Parfenov, E. V., Valiev, R. Z., Rameshbabu, N. (2022). Superior properties and behaviour of coatings produced on nanostructured titanium by PEO coupled with the EPD process. Surf. Topogr.: Metrol. Prop., 10:1, 015020.
6. Klimas, V., Naujokaitis, A., Jankauskas, S., Jagminas, A. (2022). Anodising of aluminium in formate solutions with formation of porous alumina arrays. Trans. IMF, 100:6, 333 - 341.
7. Salman, S.A., Devi Janani R., Saikiran A., Rameshbabu N. (2021). Development of photocatalytically active coating on cp-Ti by anodization. Mater. Today: Proc., 46:2, 1050-1055.
8. Javanpour, B., Azadbeh, M., Mozammel, M. (2022). Modification of the single tetraethoxysilane-treated anodized aluminium by the trimethoxy (propyl) silane retreatment for corrosion protection. J. Appl. Electrochem., 52:1, 67-83.
9. Rameshbabu, N., Ravisankar, B., Saikiran, A., Parfenov, E. V., Valiev, R. Z. (2019). Surface modification of CP-Ti metallic implant material by plasma electrolytic oxidation. IOP Conf. Series: Mater. Sci. Eng., 672:1,012012.
10. Aliasghari, S., Rogov, A., Skeldon, P., Zhou, X., Yerokhin, A., Aliabadi, A., Ghorbani, M. (2020). Plasma electrolytic oxidation and corrosion protection of friction stir welded AZ31B magnesium alloy-titanium joints. Surf. Coat. Technol., 393, 125838.
11. Saikiran, A., Hariprasad, S., Arun, S., Rameshbabu, N. (2019). Effect of electrolyte composition on morphology and corrosion resistance of plasma electrolytic oxidation coatings on aluminized steel. Surf. Coat. Technol., 372, 239-251.
12. Premchand, C., Hariprasad, S., Saikiran, A., Lokeshkumar, E., Manojkumar, P., Ravisankar, B., Venkatraman, B., Rameshbabu, N. (2021). Assessment of corrosion and scratch resistance of plasma electrolytic oxidation and hard anodized coatings fabricated on AA7075-T6. Trans. Indian Inst. Met., 74:8, 1991-2002.

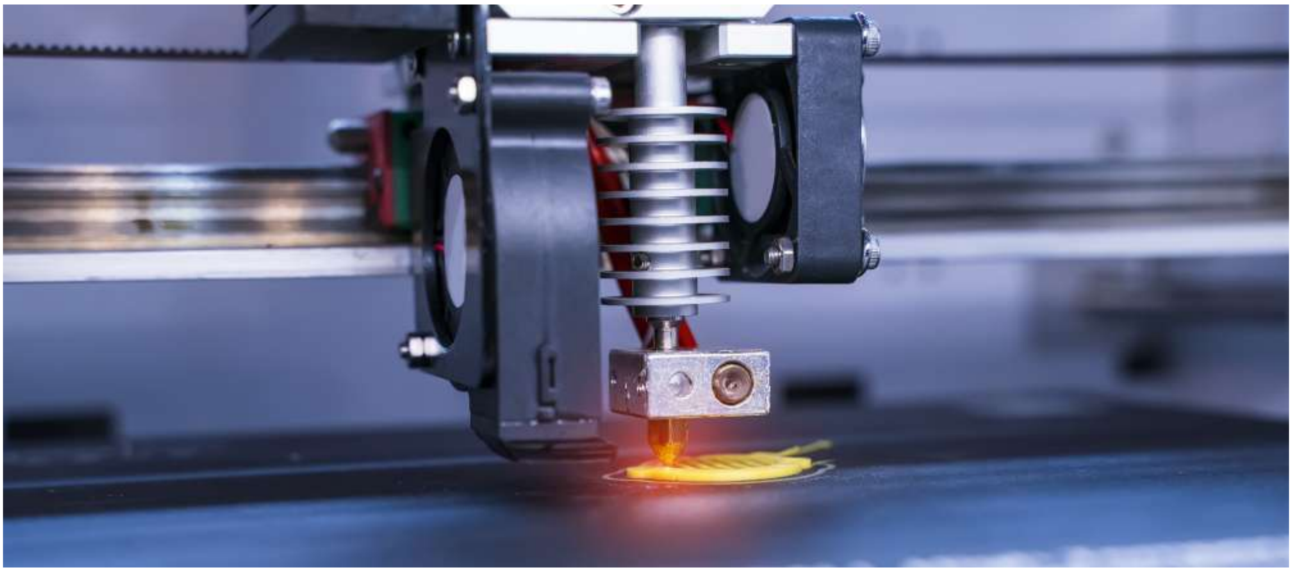
About the author

Dr. Amruthaluru Sai Kiran is currently working as an Assistant Professor in the School of Marine Engineering and Technology, IMU Chennai Campus. He holds a Bachelor's degree in Mechanical Engineering from Sri Venkateswara University, Tirupati, and the Doctorate degree from NIT Trichy in "Surface Modifications of IF Steels by PEO". His areas of interest include Plasma Electrolytic Oxidation, Anodization, Biomaterials, Surface Engineering, and Corrosion Protection. He has about 20 Scopus and SCI indexed articles to his credit. He is an active reviewer for many Scopus and SCI indexed journals.

Email: asaikiran@imu.ac.in

Dr. Rajoo Balaji is a Marine Engineer, and is currently the Pro Vice Chancellor of Indian Maritime University. He also contributes as the Honorary Editor of MER.

Additive & Distributive Manufacturing Technology for Marine Spare parts



Hare Ram Hare, Shrikrishna S Prabhu

Abstract

Additive manufacturing (AM) and distributive manufacturing (DM) are the new technologies in manufacturing sector for efficient and faster production of the products. This basically includes 3D printing of products as per the design and further to ensure efficient delivery of the same digital interface operations are executed with the help of IOT, data and web analytics. AM includes various methodologies to manufacture a product and some of these are: Selective laser sintering/ melting (SLM/SLS), Electron beam melting (EBM), Laser engineering net shape (LENS), Wire and Arc additive manufacturing (WAAM), Single pass jetting (SPJ), Atomic diffusion additive manufacturing (ADAM), Nanoparticle Jetting (NPJ) and many more. AM has several advantages over traditional manufacturing techniques. Implementation of AM and DM in marine industry has a vast scope due to dynamic nature of this field. Current methods are not much efficient as both the producer and customer of spare parts are facing discrepancies and irregularities in the entire process. Perfect execution of AM and DM would revolutionise the entire supply chain of marine spare parts.

Keywords: Additive manufacturing (AM), Distributive manufacturing (DM), 3D printing, Internet of Things (IOT).

INTRODUCTION

In this rapidly evolving world, every process and task involved in smooth functioning of an organisation need to be efficient and well planned. To achieve this, organisations are implementing various technologies which mainly focus on integration of physical and digital world. Targeting the sector of machine part designing and manufacturing, the race between peers to achieve the above-mentioned goal has already begun and everyone involved are trying to achieve utmost efficiency by implementing additive and distributive manufacturing of their products. This new technology consists of **3D printing** of products (here parts of a machine) according to the customer requirements and need basis being the just in time model predicting delivering and manufacturing of the same. Further each and every aspect during the entire process is exceptionally transparent as real time updates are provided to each involved parties which is achieved by incorporation of **IoT, web data analytics and block chain**. The concept if applied in marine spare parts supply chain would revolutionise entire supply chain of spare parts to the vessels leading to significant advantages for the shipping industry.

ADDITIVE MANUFACTURING (AM)

Additive manufacturing process is a 3D printing of parts usually in layers by depositing parent material along with binding material to get the final product. Conventional manufacturing involves selecting material and removal of excess material to obtain a required shape and tolerances. AM reduces the material wastage and drastically reduces the Green House Gas (GHG) emissions by eliminating the chemical and thermal processes needed for material treatment.

For printing the objects, it is needed to use Computer Aided Design (CAD) or 3D object scanners which guide the printer according to various parameters fed into the memory. Parent data may include dimensions of product, blueprint showing design of the product, material specifications which facilitates the printer memory/ operating system to create a program sequence required to execute the printing operation. Primary step consisting CAD of a product plays a vital role in determining the degree of accuracy of finished product. It demonstrates the simulation of actual product in 3D as well as entire printing in layers which helps the manufacturer to precisely monitor the operation before and during execution. Products of various combination of materials or parent material can be manufactured by this method. Some of the prominent materials which are under research/ are in use are shown below:

Metals	Electronics and hydraulics	Smart Materials	Special Materials
• Nickel Alloys • Titanium • Stainless Steel • Aluminium Alloys	• Conductors • Soild-Liquid printing • Multi material printing	• Shape memory polymer (SMA) • Shape memory alloy (SMP)	• Textile • Food • Concrete

AM can be performed by various methodologies and techniques which can be adopted on the basis of genre of product, material used in manufacturing, operating conditions and many other factors. AM offers wide range of techniques depending upon the requirements of producer and same are shown in **Figure 1.**

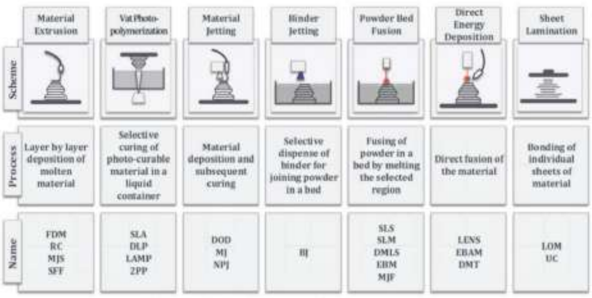


Figure 1: Additive manufacturing different methods with abbreviations

With respect to products which have metals (process termed as **MAM Metal additive manufacturing**) as their parent material, four main techniques are preferred. These are: i) Powder bed fusion ii) Direct energy deposition iii) Material jetting iv) Binder jetting. First two methods are the most preferred ones in the industry.

Table 1: Expansions of abbreviations

Sr	Abbreviation	Full form
1.	SLM/SLS	Selective laser sintering/melting
2.	EBM	Electron beam melting
3.	LENS	Laser engineering net shape
4.	WAAM	Wire and Arc additive manufacturing
5.	NPJ	Nanoparticle Jetting
6.	ADAM	Atomic diffusion additive manufacturing
7.	SPJ	Single pass jetting

The entire additive manufacturing process can be summarised as follows:

1. The product requirements are identified according to the customer.
2. Using CAD or any other design techniques, 3D designs are made involving all the dynamics acting upon the product (fluid, thermal, vibration and stresses etc).
3. Simulation of the product is done to ensure it works according to the requirements and specifications.
4. The functioning of 3D printer according to the entered parameters and co-ordinates is verified by using simulation.
5. 3D printer is supplied with parent material (e.g. Metals) and binder material which acts as temporary adhesive for printing the product.
6. Printing operation commences by ejection of mixture in molten form of metal and binder material from a nozzle which is continuously monitored by the system. (Printing techniques may vary according to the application).
7. After green product is formed (complete product after initial printing including binder material), it is submerged into an adhesive removal solution which helps in removal of binding material. The product at this stage is called as brown product.
8. Then it is sintered (the process of compacting and forming a solid mass of material by heat or pressure without melting it to the point of liquefaction) which helps in binding the metal molecules in the product to fuse together to gain its hardness and strength.
9. If required surface finishing is done or else the product can be directly used in the required location.

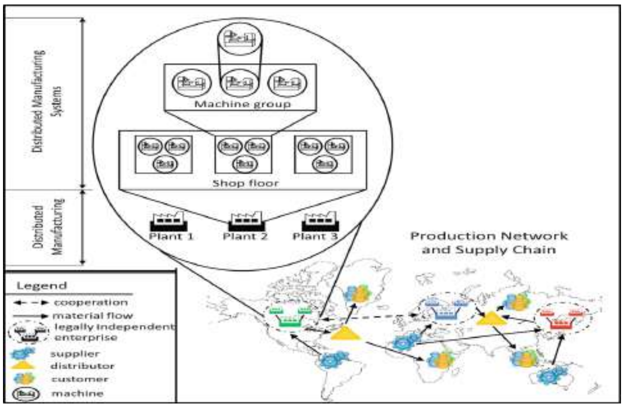
Advantages of using AM

- Highly precise, accurate and efficient products can be manufactured
- Product of unusual shape can be made without much difficulty.
- Least wastage of parent material which is used in manufacturing the product.
- Faster manufacturing of products.
- Limits the use of man power in production.

3. DISTRIBUTIVE MANUFACTURING (DM)

DM involves manufacturing of single product in different segments at various locations and assembling the segment at assembly point. **Between each of the process execution linkage is established by IoT (Internet of Things), data and web analytics and block chain which facilitates real time feed to the concerned machines.** The access of feed is not limited to manufacturer but also shared with customer for ensuring transparent delivery aspect of product.

Manufacturing of each segment involved is performed by AM process, far from assembly point, reason being the savings of capital made by the producer on setting up additional work stations for specific segment manufacturing. Various manufacturers at distinct locations which are fraction of manufacturing a product are basic manufacturers of the required segment of the final product i.e. from the date of establishment, corporation is involved in fabricating the similar segment which is required in the product. They do not need specifically installed machineries for completing the required target or order. Thus, it is a win-win situation for both parent producer and sub producer as



parent saves investment on new machinery installation and sub producer acquires business. As described earlier each node being connected by IoT, data and web analytics makes it easier in predicting each and every checkpoint in manufacturing until final product is obtained. This helps in executing just in time model where inventory, stocking capital are saved and delivery timings are optimised. The digital aspect involved in the entire process is made customer friendly by formation of user-friendly interface which is accessible from any device. **Figure 2** shows a basic layout of DM.

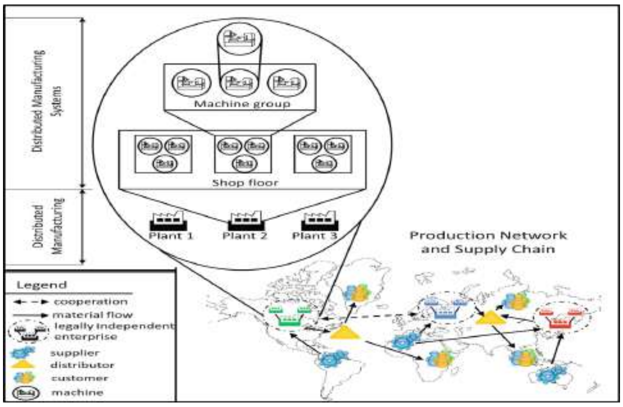


Figure 2: Distributive manufacturing basic layout

4. AM AND DM IMPLEMENTATION IN MARINE SPARE PARTS:

Shipping industry being very dynamic in nature requires its vessel to function efficiently at all times and for this all machineries should be in perfect state. This demands availability of all spares as and when required by the ship's crew. But due to dynamic environment of this field, in-time spare part distribution and delivery operation are a major challenge for both customers and manufacturers. The factors being many, some of them include sudden change in ship's schedule, discrepancies in product, lack of availability of product, delivery issues and the list goes on.

So, analysing all the issues, a point around product manufacturing techniques and just in time delivery arises which demands use of newer methodologies such as AM and DM. This would facilitate the vessels to place an order for a spare knowing all the dynamics involved in entire process by means of digital interface of DM and exact estimation of delivery at its next port. Also, manufacturers need not stock pile their ware houses with finished spares as they may manufacture it as and when ordered. Further, newer and better technologies are incoming these days which force the manufacturers to stop making of older spares leading to disruption in availability of that spare for an old vessel making it troublesome for the crew to run the vessel. This issue is eliminated if AM and DM are brought in action as manufacturer can make a spare with the help of designs available with them as required solving this major issue.

Current implementation of AM and DM in the industry:

Manufacturers have already started implementing AM and DM at testing phase in the manufacturing of propellers of small sized vessels. The manufacturing process consists of a multi pass welding using a hi-tech robot solution i.e. the wire deposit in 3D or wire arc additive manufacturing (WAAM).

The blade is built layer by layer with a wire fusion by automatic arc welding using a hi-tech robotic arm. This concept consists of a propeller with hollow blades, with or without stiffeners which allows both a mass reduction and an increase in hydrodynamic performance compared to a solid propeller. Although it is potentially extremely complex or even impossible to build with a classical process, the WAAM process offers new possibilities in which the balance between weight and hydrodynamic performances of propellers is redefined. The design of a hollow blade is made in two phases: a first optimisation of the "outer" shape of the blades (wetted surface) dedicated to the enhancement of the hydrodynamic performances and second optimisation is done of the blade structure (of the cavity) in order to reduce the overall propeller mass, without compromising on blade mechanical strength. See **Figure 3 (a)** for construction.

Figure 3.: a) 3D printed propeller b) Robotic arm used in 3D printing

Various companies like Alfa Laval, DNV GL, Maersk tankers, Man energy solutions and many more in 2016 formed a technological development group for green ship of the future which aimed in undertaking development for using 3D printer onboard the ship. An attempt was made for the same by equipping them with CAD enabled desktop and 3D printer. Crew was asked to test new technology and to print parts that are not critical for the ship's operation and safety and which are often being damaged or are difficult to order. Items that have been printed during this test are for example, powder extinguisher end nozzle, lathe lever knobs etc. i.e. small items of non-critical use. **Table 2** shows the small and mid-size components which can be manufactured by 3D printing.

Table 2: List of small and mid-size components which can be manufactured by 3D printing

Division of parts	Parts
Highly Feasible for 3D Printing without Class Certification	Bearing shell, compressor housing, top cover of fuel pump, condenser, shaft, valve plug, bearing nut, couplings, nozzle ring, piston ring, plunger barrel, rotary cup, spindle guide, tapered bush, compressor blade, thrust collar.
Highly Feasible for 3D Printing with Class Certification	Air compressor elbow, Anti-Polishing ring, Banjo plug, Bearing bush, Bearing cover; Bleed screw, Bursting disc, Connecting rod, Cooling water jacket, Crank pin, Drive pinion, Flange Gasket, Couplings Flexible coupling, Gear; Guide pin, Handle axle, Hatch cover packing, Impeller; Needle roller bearing, Nozzle tip

The technological advancements in this sector are advancing at a rapid pace. Researchers have developed sophisticated, compact and precise robotic technology which is highly adaptable and easy to integrate with current levels of advancement. So, to 3D print a specific part on board a vessel will no longer possess any challenge for the crew. **Figure.4** shows the advance 3D printing arm which can be easily integrated with any robotic arm without any difficulty. The arm has capabilities to print using various materials such as stainless steel, mild steel, carbon steel, titanium, nickel, copper. Traditional manufacturing methods rely on overall properties of a material. The materials are usually homogeneous and isotropic which are probably over-designed for an application. A part may undergo only tensile loads and never a bending load but a homogeneous and isotropic material will have better bending characteristics inherently. With advances in computations, understanding of the material properties and the ability to develop materials for specific requirements, lighter materials with desired properties can be customised for the application. This can lead to reduction in weight and only possible with advanced manufacturing methods like AM and enhanced availability through DM.

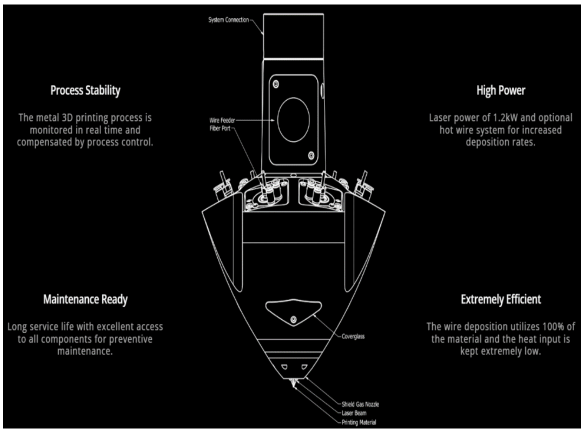


Figure.4: a) Advanced robotic arm time for 3D operation b) Robotic arm 3Dprinting impeller

Going further there are possibilities of linking ships stores to the digital interface which would prompt ship crew to order new spares as soon as the last one is out of the store. This data of stores can be gathered from the ship's store monitoring system thus eliminating last moment orders which lead to disruption in operations. The data of spares can be classified based on their importance and availability as shown in **Table 3** which would make easier for crew to manage the inventory thus reducing excess inventory holding costs. Hence the scope for savings just on spare part management is large if AM and DM are implemented.

Table 3: Spares priority chart

RANK	Frequency of Demand	Inventory Portfolio	Availability
1	Very rarely demanded Hasn't been ordered in more than five (5) months	Insignificant stock in inventory	Rare/ obsolete part

INSTITUTE OF MARINE ENGINEERS (INDIA)
GOA BRANCH

IMEI HOUSE in Goa has a well - furnished guest house specially built for the members of IMEI who are visiting Goa for official work, for attending seminars or classes and for leisure.

The guest house has following salient features:

- Spacious hall for seminars and training
- Six well furnished AC rooms for double occupancy
- Located close to Dabolim airport (approximately 2 km)
- Famous Bogmalo Beach is just 1 km away from the guest house
- Room tariffs are highly economical for members as compared to prohibitive hotel rates in Goa

Room booking can be done by members on email to either

admin@imare.in or imehousegoa@gmail.com

Address of IMEI House:
IMEI House, D27- Rangavi Estate, Dabolim, Goa -403801
Contact Number: 7972529309

2	Little demand Has been ordered <5 times in past five (5) months	Small inventory stock	Difficult/ expensive to produce or obtain
3	Moderate Demand Has been ordered <15 times in the past five (5) months	Relatively moderate inventory stock	Standard availability
4	Frequent Demand Has been ordered >15 times in the past five (5) months	Large inventory stock	Readily/ inexpensive to produce or obtain
5	Very High Demand Has been ordered >30 times in the past five (5) months	Very large inventory	Constantly available

Seeing the other side of the coin, the present-day manufacturing of spares is limited to specific materials which may hinder spare production consisting the combination of different material restricting the use of AM. Further durability and strength are essential factors of a spare parts which need to be satisfied as per standardisation set by authorities. AM being in initial stage raises questions for these factors at some extent for high performance spare parts. Another fact to be noticed is the large initial investment which is to be made by manufactures though it will be repaid by means of profit they make by production. As of now AM is suitable for small and limited production as each machine is capable of producing single spare at a time hence temporarily eliminating its use in mass production units. But the research works are currently underway for finding out optimum solutions these current issues and scientists are hoping, considering to make AM capable of manufacturing any part as required.

5. CONCLUSION

AM and DM show the future of manufacturing and distribution of spares in the marine industry. Hence it should be implemented as soon as possible to revolutionise the industry and take it to new standards.

REFERENCES

[1] **The role of additive manufacturing in the era of industry 4.0**: Ugur M Dilberoglu, Bahar Gharehpapagh, Ulas Yaman, Melik Dolen: Department of Mechnaical Engineering, Middle East Technical University, Ankara 06800, Turkey. https://www.sciencedirect.com/science/article/pii/S2351978917303529-

[2] **Distributed manufacturing: a new form of localised production**?: Jagjit Singh Srai Department of Engineering, University of Cambridge, Cambridge, UK, Gary Graham and Patrick Hennelly University of Leeds, Leeds, UK, Wendy Phillips and Dharm Kapletia Bristol Business School, The University of the West of England, Bristol, UK, and Harri Lorentz Turku School of Economics at the University of Turku, Turku, Finland. https://www.emerald.com/insight/content/doi/10.1108/IJOPM-08-2019-0600/full/pdf?title=distributed-manufacturing-a-new-form-of-localised-production

[3] **Possible Applications of Additive Manufacturing Technologies in Shipbuilding: A Review**: Marcin Ziółkowski and Tomasz Dyl: Department of Marine Maintenance, Faculty of Marine Engineering, Gdynia Maritime University, Morska Street 81-87, 81-225 Gdynia, Poland

[4] **On the benefits of metallic additive manufacturing for propellers**: Pol Muller: SIREHNA, Nantes, France; Guillaume Rückert, Patrice Vinot: NAVAL GROUP, Nantes, France

[5] A comprehensive literature review on spare parts logistics management in the maritime industry. https://www.sciencedirect.com/science/article/pii/S2092521221000778.

[6] https://www.treatstock.com/guide/article/106-what-is-metal-3d-printing- Metal 3D printing.

[7] https://youtu.be/UdiwBiw5dyo -Metal 3D printing.

[8] https://youtu.be/fzBRYsiyxjl- The Material Science of Metal 3D Printing.

[9] https://youtu.be/Ev-MM9cGKiQ -An Introduction to Additive Manufacturing/3D Printing.

[10] https://youtu.be/t4S0mKjXtT4 - What is additive manufacturing?

[11] https://youtu.be/03o4633jGKE - Distributive Manufacturing (DM).

About the author

Hare Ram Hare (F8893) is currently attached as Assistant Professor (Marine Engineering) at Indian Maritime University @ Mumbai Port Campus, Mumbai. He graduated in B.E. (Mech. Eng.), and has a MEO Class-I (Motor) CoC. His research interests include Emission control, AI, Block chain Technology, New emerging Technologies.

hareram@imu.ac.in

Shrikrishna S Prabhu is a student of Marine Engineering (B. Tech) at IMU Mumbai Port Campus.

LUBE MATTERS # 28

TRIBOLOGY OF STERN TUBE SEALS

Sanjiv Wazir

Introduction

On most ships, the engine drives the propeller via a propeller/tail shaft. The propeller shaft transmits the engine power to the propeller and the propeller thrust to the ship's hull via the thrust bearings. The propeller shaft passes through the ship's hull through a stern tube, which is welded to the hull. The propeller shaft is supported in the stern tube, usually by two journal bearings, which support the weight of the propeller and the shaft. These bearings are lubricated by the stern tube lubrication system which fills up the stern tube with oil, so that the shaft and the bearings are completely submerged, to minimise friction in the bearing and allow maximum power flow to the propeller to overcome water resistance. **Figure 1.**

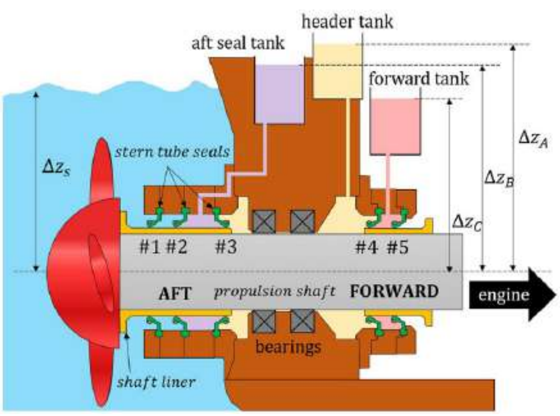


Figure. 1: Stern tube and sealing arrangement (1)

The ends of the stern tube are sealed by the aft and forward stern tube seals. These prevent the ingress of seawater into the stern tube, while limiting the spillage of the lubricant from the stern tube into either the sea or the engine room. In the most common design, the aft seal pack consists of 3 rotary lip seals, and the forward seal pack consists of 2 rotary lip seals. Stern tube seals are amongst the largest rotary lip seals made.

Stern Tube Lubrication System

Figure.1 depicts the most widely used type of stern tube sealing and lubrication system.

The propeller of a vessel is usually underwater. The outermost seal is subject to widely oscillating hydrostatic pressure between ballast and loaded conditions, and due to rise and fall of waves. Seal #1 also continuously faces the water side and is subject to degradation by sea water. It works as a dirt excluder and is the most rapidly worn-out seal. Hence Seal #2 also faces the water.

The space between the Seals #2 and #3 are pressurised by the head from one or two oil tanks. The hydrostatic pressure in this space can be set by filling the tank to particular heights. Seals #3 and #4 face the oil lubricating the stern tube bearings. Seal #5 prevents the leakage of the lubricant into the engine chamber. Seal # 1 dissipates heat to the sea water. All the other seals dissipate heat to oil.

Figure. 2: Stern tube seal cross-section (1)

Figure. 3: Stern tube seal Aft package (1)

The seals are mounted on the shaft liners, usually of Chrome steel. Garter springs hold the seals tight against the liner surface. The shaft liner can be machined to the surface finish required and can be easily replaced when damaged by grooving or corrosion.

Stern tube seals are usually made of highly inert elastomers that are capable of withstanding elevated temperatures, and resist degradation from sea water, and lubricants. All the seal rings in the two packs are of the same type, irrespective of their position. However, they all work under different hydrostatic pressures.

Rotary Lip Seal Lubrication

Rotary lip seals have been used for more than a century. They require lubrication, otherwise they will run hot, degrade, and fail. Surprisingly, their working mechanism is not yet fully understood. Extensive research has been conducted on the underlying principles. Several processes have been identified. **However, as yet there is no generally accepted theory that can accurately predict the performance of rotary lip seals.** It is believed that in most cases a continuous lubricant film is produced beneath the sealing lip and the shaft, preventing direct asperity contact and minimising friction. The thickness of the film depends on shaft speed, oil temperature, oil viscosity and the pressure or radial load exerted by the sealing lip on the shaft.

Unlike journal bearings or thrust bearings, rotary lip seals do not have a convergent gap profile in the direction of motion (circumferential rotation), hence there is no apparent source for hydrodynamic film formation. But, like in journal or thrust bearings, rotary lip seals fail when the viscosity of the lubricant drops too low. It is possible that several mechanisms develop simultaneously, and, depending on the application and running conditions, one or another mechanism lubricates rotary lip seals.

“Stern tube seals are usually made of highly inert elastomers that are capable of withstanding elevated temperatures, and resist degradation from sea water, and lubricants”

“Unlike journal bearings or thrust bearings, rotary lip seals do not have a convergent gap profile in the direction of motion (circumferential rotation), hence there is no apparent source for hydrodynamic film formation”

The asymmetric contact pressure profile is understood to be one mechanism of hydrodynamic film formation. This pressure profile is controlled by designing the proper oil side angle, air side angle, and spring offset distance. The larger angle on the oil side creates a larger pressure profile on the oil side. The garter spring is offset to the air side and helps maintain the air side angle, **Figure. 4.** The resulting pressure profile allows oil film formation in the sealing area, and along with the reverse pumping exhibited by rotary seals, wherein the rotary lip seal pumps fluids from the back side to the spring side of the seal, **Figure. 5,** forming a leak-less seal.

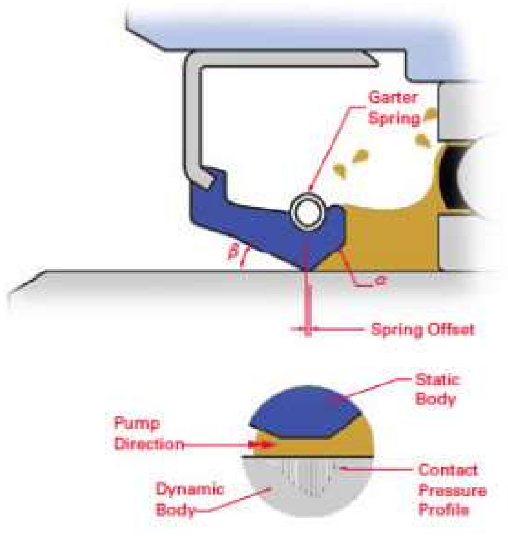


Figure. 4: Dynamic sealing action

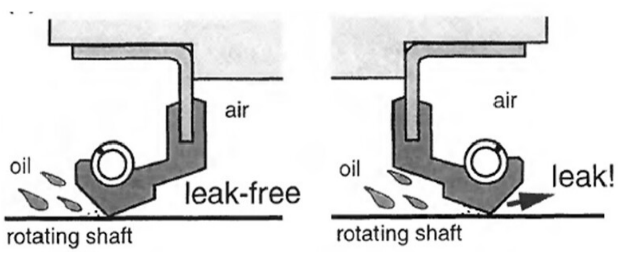


Figure. 5: Phenomenon of reverse pumping

ANGLO EASTERN MARITIME TRAINING CENTRE

AEMTC MUMBAI : 401, Fourth Floor, Leela Business Park, Marol, Andheri-Kurla Road, Andheri (East), Mumbai-400 059.
T. +91 22 6720 5600 / 611 / 612 |
A.O.H. +91 8657408962 / +91 9820917656
aetr.bom@angloeastern.com
Capt. K. N. Deboo, Mr. Francis Akkara, Mr. Ivor Wilson

AEMTC DELHI : A-101, Dayanand Colony, Lajpat Nagar- 4, New Delhi - 110 024
T. +91 11 2642 6801 / 802 / 2647 2831 / 2647 1129
aetr.del@angloeastern.com
Capt. Prashant Gour, Ms. Sukhjeet Kaur

Anglo Eastern Maritime Training Centre | aemaritimetrg | www.maritimetraining.in

www.maritimetraining.in

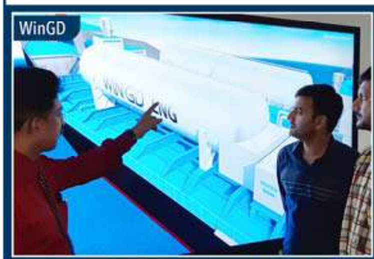
MAN | PrimeServ MAN

ME-C Control System Standard Operation
(OEM Approved Course)

November 2023: 20 - 24 | December 2023: 11 - 15

For bookings: aetrbom@angloeastern.com
PrimeServ.academy-cph@man-es.com

WIN GD
Winterthur Gas & Diesel



Advanced Course UNIC - Controlled X-DF Engines (OEM Approved Course)

November 2023: 27 - 01 | December 2023: 11 - 15

For bookings: +91 22 67205611 / 12 / 18

WÄRTSILÄ

Wartsila RT Flex Engine
Conducted by Wartsila Switzerland
(OEM Approved Course)

November 2023 : 20 - 24
December 2023 : 04 - 08

D. G. Approved Courses

	D. G. Approved Courses	November 2023
1.	Engine Room Simulator - Management Level	16-22
2.	Engine Room Simulator - Operational Level	06-08, 27-29
3.	High Voltage Safety & Switch Gear Course at (Management Level)	06-10
4.	High Voltage Safety & Switch Gear Course at (Operational Level)	06, 16

Value Added Courses

	Value Added Courses	November 2023
1.	Practical Marine Electrical (Basic) - Module 1	20-24, 27-01 Dec
2.	Practical Marine Electrical (Advance) - Module 2	06-08, 27-29
3.	Electronics for Marine Engineers - Module 4	09-10, 30-01 Dec
4.	Instrumentation, Process Control & Programmable Logic Controllers - Module 5 & 6	20-24, 04-08
5.	Auxiliary Diesel Engine and Maintenance Course	06-10, 20-24, 27-01 Dec
6.	Bridge Manouervering & Engine Control - Operational Level	02-03, 30-01 Dec
7.	FRAMO Cargo Pumping System (Advance)	27-29
8.	Hydraulics for Engineers - Basic	27-29
9.	Hydraulics for Engineers - Advanced	16-17, 27-28
10.	Maritime Crew Resource Management (MCRM)- CAE Accredited	06-09, 27-30
11.	Machinery Breakdown Safety Campaign - 1	10
12.	Machinery Breakdown Safety Campaign - 2	03, 24, 08
13.	Machinery Maintenance - Skill Enhancement - Module 2	20-24, 27 - 01
14.	Machinery Maintenance - Skill Enhancement - Module 3	20-23
15.	Machinery Maintenance - Skill Enhancement - Module 4	06-08, 27-29
16.	Maritime Safety Management - Module 1 (Occupational & Behaviour Based Safety)	22-24
17.	Maritime Safety Management - Module 2 (Risk Assessment)	06
18.	Maritime Safety Management - Module 3 (Shipboard Safety Officers)	07
19.	Maritime Safety Management - Module 4 (Accident Investigation)	08

VACANCY Faculty position | Location: AEMA Karjat

Training Superintendent – Nautical

Qualifications and Experience

- Master Mariner Class I – COC from India/UK. Other Specialized Training courses and certification.
- Master of min 1 yr. command experience. Preference shall be given to a Master with Oil tanker experience.
- 2 to 3 years in ship operation, experience as Master preferrable. Oil tanker experience and in teaching will be preferred.
- Proficient in interacting with Senior Leadership on board and ashore. Strong analytical problem-solving and managerial skills.
- Should be interested in modern teaching methodologies and must have a strong desire to be in the teaching profession.

Training Superintendent – Engineering

Qualifications and Experience

- Post graduate degree in respective subject or B.Tech in Engineering Streams
- Master of min 1 yr. command experience. Preference shall be given to a Master with Oil tanker experience.
- 2 to 3 years in ship operation, experience as Master preferrable. Oil tanker experience and in teaching will be preferred.
- Proficient in interacting with Senior Leadership on board and ashore. Strong analytical problem-solving and managerial skills.
- Should be interested in modern teaching methodologies and must have a strong desire to be in the teaching profession.

For Pre Sea Training Courses kindly contact **Anglo-Eastern Maritime Academy** (A Division of Anglo-Eastern Institute) **DNS Course :** 011 68170837 | **GME / ETO Course :** 011 68170831 | aema.edu.in

1st in India and 2nd in the world to receive distinction by DNV SeaSkill Benchmarking

It was also observed that sealing surfaces with more micro-asperities showed better sealing characteristics, while excessively smooth sealing surfaces showed a more erratic behaviour, leading to leakage. The concept of hydrodynamic action on a microscopic level has often been used to explain the performance of rotary lip seals. When the shaft rotates, the microscopic wedges formed between the seal and shaft surface asperities generate a hydrodynamic fluid load carrying capacity capable of partially or fully supporting the radial force of the seal lip. Furthermore, the compressed asperities are tangentially distorted in the circumferential direction due to friction leading to a shaft-seal topography resembling a micro-screw pump (2), **Figure. 6.**

The concept of hydrodynamic action on a microscopic level has often been used to explain the performance of rotary lip seals

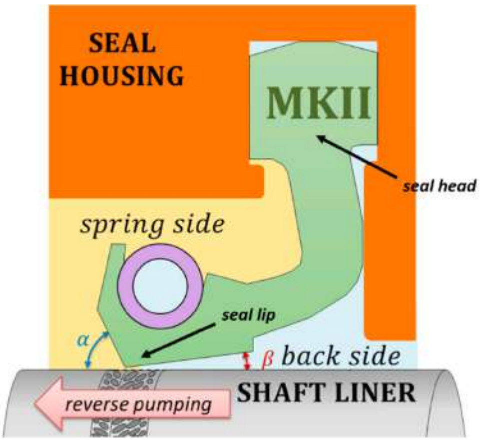


Figure. 6: Mechanism of sealing by shaft topography and reverse pumping

Consequently, the rotation of the shaft induces a flow in one direction preventing the leakage in the opposite direction. This sealing mechanism is known as the reverse, upstream or back pumping of rotary lip seals. Note this mechanism could also induce leakage of oil to the water side, in Seal # 2 **Figure. 1.** Such leakage of stern tube lubricant to the environment depends on parameters such as seal design, vessel type, draught, shaft diameter and ship condition (2).

If the seal fails due to misalignment, wear, or overheating, leakage will develop in the other direction i.e., from the spring side toward the back side. In the case of Seal #2, in **Figure. 1,** this will cause water ingress to the oil side.

Although the asymmetric contact theory and microscopic hydrodynamic film theory can explain many of the phenomena observed in rotary lip seals, they disregard shaft-seal misalignment which has repeatedly shown to play a significant role when it comes to wear rate, contact temperature, and the lifespan of sealing components.

The loss of the seal–shaft concentricity can be due to radial and angular misalignments. Radial misalignment refers to the offset between the bore and shaft axes (parallel misalignment), i.e., keeping the axes parallel. The second type of misalignment, which is also known as skewness, refers to the difference in orientation between the shaft and bore axes (3).

Both radial and angular misalignments can be constant (static) or variable in time (dynamic). Misalignment between the seal and the shaft can result from the bearings internal and mounting clearances, the shaft out-of-roundness, manufacturing tolerances, radial vibrations, shaft loading or speed-induced wobbling of the shaft. Temperature and Viscoelasticity of the seal material affects the follow ability of the seal material and will also lead to a misaligned operation (3).

Based on extensive analysis using well established EHL theory-based models, along with physical testing and measurements, it is believed that the behaviour of rotary lip seals cannot be captured solely by the traditional Stribeck curve. Additional variables such as axial and angular misalignments, hydrostatic pressure gradient, surface roughness, presence of hot spots at the seal contact, characteristics of the seal material must be included. It is a work in progress.

Conclusion

Stern tubes are a key component of the propulsion system for any ship. One of its most critical components is the stern tube seal which keeps sea water out and allows the propulsion shaft to spin. In addition to safety, they are also very important to maintain high operational efficiency. They must, therefore, be maintained well to ensure their long-term integrity and smooth operation.

References

1. Dr. Xavier Boras, Stern Tube Sealing System, Tribonet, 23.03.2022
2. Dr. Xavier Boras, et al, Stern tube seals operation: A practical approach, Advances in Mechanical Engineering, 26.02.2021
3. Dr. Xavier Boras, Misalignment-Induced Micro-Elastohydrodynamic Lubrication in Rotary Lip Seals, MDPI, 10.02.2020

About the author

Sanjiv Wazir is a mechanical engineer from IIT-Bombay. He is a marine engineer and a consultant on marine lubrication. Sanjiv is a Certified Lubrication Specialist (CLS) from the Society of Tribologists & Lubrication Engineers (STLE), USA; a fellow of the Institute of Marine Engineers (India); and a member of the Tribology Society of India. He often lectures on tribology and lubrication. For MER, he has written a series of articles on tribology & lubrication issues under "Lube Matters," He can be reached at sanjiv.wazir@gmail.com

REPAIR TO RUDDER STOCK, RUDDER AND PINTLES AFTER CONTACT DAMAGE

Ramesh Vantaram

Overview

While transiting the Suez Canal on 28 April 1991, the fully-laden vessel M.V. Chennai Polivu sustained contact damage with the Canal bank. The contact resulted in damage to the rudder stock, rudder, pintles and other associated fittings. From the diver's preliminary report indicated that the rudder stock had twisted 25° to Port; the rudder blade was bent and the lower pintle was bent. Salvage Association Surveyor boarded the vessel and presented his recommendations for repairs.

Based on the diver's report the Salvage Association Surveyor assessed the probable extent of damage as under. The repair specifications were generally based on his assessment.

1. *Rudder blade to be part-cropped and renewed in way of cracks or indentations along with the associated internals. Rudder to be pressure tested post repair;*
2. *Rudder stock palm to be checked for cracks and re-machined;*
3. *Rudder upper and lower castings to be checked for cracks;*
4. *Alignment of the pintle bores to be checked;*
5. *Upper and lower pintle bushes to be renewed and machined as per correct alignment;*
6. *Stainless sleeves on both pintles to be renewed and machined to proper clearance;*
7. *Jumping bars to be cropped and renewed;*
8. *`Both pintle-bush cover plates to be renewed;*
9. *Alignment of stock to be checked for axial distortion in fwd - aft and port - stbd. directions and rectified as far as practicable;*
10. *Rudder stock to be grit blasted and checked for cracks;*
11. *Chemical analysis of stock material composition to be carried out prior any welding work;*
12. *Keyway on stock to be built up by welding and new key way to be milled. New key to be manufactured;*
13. *Heat treatment (annealing) to be carried out as per classification rule after completion of welding work on stock;*
14. *Stainless steel sleeve in way of carrier bearing to be renewed and machined to correct clearances;*
15. *Rudder to be coupled to stock after machining of stock palm with service bolts. Rudder flange and stock palm coupling bolt holes to be re-reamed. 6 Nos. new coupling bolts to be manufactured;*
16. *Tiller keyway to be built up by welding and new keyway cut. Heat treatment methods to be complied with;*
17. *Carrier bearing to be inspected;*

Due to the flawed assumption that the upper part of the top pintle was concentric with the rudder carrier bore, the three "distorted" bores were calibrated

18. *Thrust collar contact face to be re-machined;*

19. *Rudder stock gland to be repacked and*

20. *Rudder horn to be inspected for cracks rudder alignment to be checked from tiller to lower pintle housing.*

The vessel was towed from Port Said to Dunkerque where cargo was discharged. The vessel was thereafter towed to Antwerp for repairs at ANTWERP SHIPREPAIR. The vessel entered the dry dock on the 10th June 1991.

On first inspection the damaged looked far greater than the divers report, for instance, the extent of damage the rudder blade deviated by about 1 metre from the axis! The repairs were carried out from 11th June 1991 to 11th July 1991.

The following report gives a detailed account of the various components under three main topics.

1. The Rudder horn and components contained therein
2. The Rudder and fittings and
3. The rudderstock.

THE RUDDER HORN

As a result of the accident, the rudder horn got twisted causing the pintle bores to go out of alignment. For alignment and smooth operation, the rudder carrier bore, the upper and lower gudgeon bores of the rudder horn must be CONCENTRIC. The first task was to determine the shift in the true centre line and to relocate the same. Any re - boring would have to be done with respect to this centreline. Refer to **Illustration #1**.

At the very outset, it was assumed that the rudder horn upper gudgeon was "TRUE", i.e. insulated against the damage. This assumption meant that the upper gudgeon was concentric with the rudder carrier bush. The vessel's superintendent Mr. B.N. Bhat was not so convinced though, and kept nagging the shipyard team to have a re-think. They dismissed his concern by citing their vast experience in ship repair etc. and managed to calm him, at least for the time being!

The boring bar was adjusted till there was virtually "NIL" deflection during one complete revolution

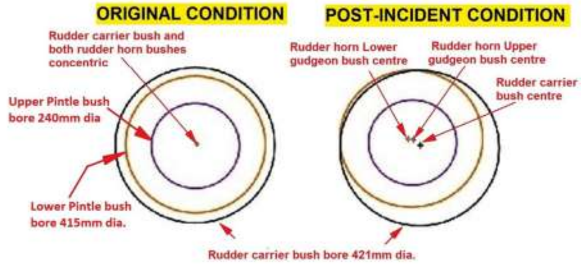


Illustration #1

To determine the centre line, a piano wire was drawn from the rudder carrier bore to the upper and lower pintles. Due to the flawed assumption that the upper part of the top pintle was concentric with the rudder carrier bore, the three "distorted" bores were calibrated. Following were the results as indicated in **Table - 1:**

The results indicate that the true centre line has relatively shifted to a maximum of 22.6mm (45.20÷2) towards Stbd. and 6.4 mm (12.80÷2) towards Aft. With the piano wire as reference, a proof circle was made on the upper and lower sides of both the rudder horn gudgeons. Next a boring bar was located between the two gudgeon bores with the proof circle as references. The upper gudgeon was re-bored completely. **While the lower gudgeon was being rebored, the shipyard team realised that the perpendicularity of the boring tool with respect to the rudder carrier bore was never considered!** This is critical that the rudder load is carried uniformly on the bearing disc. Only when there is perpendicularity, will the split bearing ring, bolted to the stock, sit squarely on the bearing disc. There would also be misalignment with respect to the steering rams. Mr. Bhat's concern was indeed vindicated!

Boring operation was stopped and the true centre line was once again determined, only this time, the boring bar was passed through the upper gudgeon bore and the rudder carrier bore. A dial gauge was located on the boring bar and the boring bar was turned through one full revolution.

The boring bar was adjusted till there was virtually "NIL" deflection during one complete revolution. This ensured the perpendicularity of

Table -1

STATION	FWD	AFT	PORT	STBD	F-A	P-S
Upper Gudgeon bore – Top end	**REFERENCE POINT**					
Upper Gudgeon bore – bottom end	139.9	139.1	140.55	138.01	0.80	2.54
Lower Gudgeon bore – Top end	229.88	218.75	244.05	205.67	11.13	38.38
Lower Gudgeon bore – bottom end	230.75	217.75	247.36	202.16	12.80	45.20

boring tool with respect to the rudder carrier bush. Proof circles were again marked. The bar was removed again and a piano wire was again set up. This time around piano wire was both perpendicular to the rudder carrier bearing disc and also concentric with the rudder carrier bore

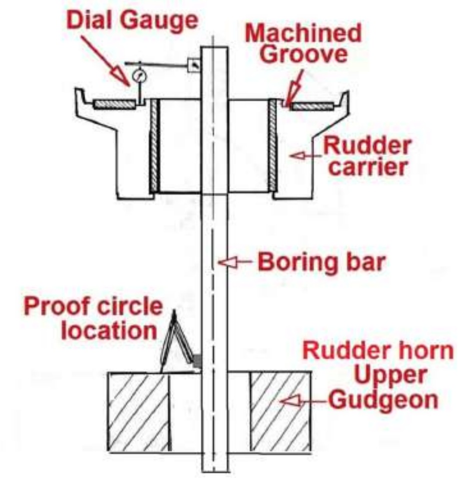


Illustration #2

Following were the results as indicated in **Table - 2**

Comparing the data in **Table 1 with Table 2**, the shift in centre line is striking. It should be recollected that the by this time the upper bore was completely rebored and the lower one was in the process of being rebored. Once the true shift of centre line was determined the next process was to re-bore the Gudgeon (already wrongly re-bored) to restore the concentricity of all the bores.

The upper gudgeon re-boring was taken up first and went off well. **However, while re-boring the lower gudgeon, a sleeve was discovered in the gudgeon! It can only be presumed that sleeve was a shipyard fitment during the construction stage.** In order to dislodge the sleeve, the gudgeon had to be bored to a greater diameter than calculated. It was decided to introduce a mild steel sleeve into the gudgeon, to avoid an excessively thick phenolic resin bush which would be both impractical and expensive.

It was decided to introduce a mild steel sleeve into the gudgeon, to avoid an excessively thick phenolic resin bush which would be both impractical and expensive

A mild steel sleeve was machined and shrunk fit into the gudgeon by cooling with dry ice. The upper and lower edges of the mild steel sleeve were chamfered, the sleeve was then welded to the gudgeon both top and bottom sides. Now, it could be safely concluded that the rudder stock bore and the pintle bores were coaxial.

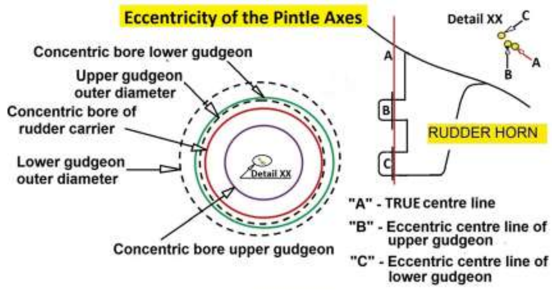


Illustration #3

The rudder horn was also carefully inspected for cracks and was found free of any cracks. The Aft peak tank was inspected internally to check the condition of rudder horn to ship's hull weld seam. The welding was found intact

THE RUDDER STOCK

The Rudder stock was disconnected from the steering rams and rudder and removed to work shop. The stock was aligned on the bed to check the distortion. Result showed that in an athwartship plane, the distortion was 51mm and in a fore and aft plane, the distortion was 12 mm. Refer to **illustration #4**.

The repair included:

(A) Correction of bend in both planes

(B) Re-welding and machining of stock in way of the tiller cone and rudder carrier bush

(C) Machining a new keyway on the cone and dressing the keyway for the split bearing ring

(D) Skimming of palm and aligning it with rudder flange

(E) Making new coupling bolt holes.

Table - 2

STATION	FWD	AFT	PORT	STBD	F-A	P-S
Rudder carrier bore	**REFERENCE POINT**					
Upper Gudgeon bore – Top end	143.80	139.93	144.63	137.95	3.87	6.68
Upper Gudgeon bore – bottom end	143.43	139.23	145.25	137.22	4.20	8.03
Lower Gudgeon bore – Top end	234.34	215.23	249.62	-	19.11	-
Lower Gudgeon bore – bottom end	234.50	212.16	252.11	-	21.89	-

The rudder stock was heated in the mid-section and an overhead load of 9 tons was placed on it. This process of heating and overhead loading was continued until the bends were corrected as far as possible. Refer to **illustration #5**. Calibration of the rudder stock was again taken

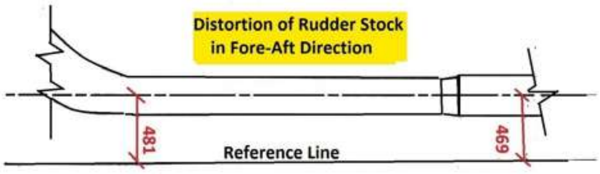


Illustration #4

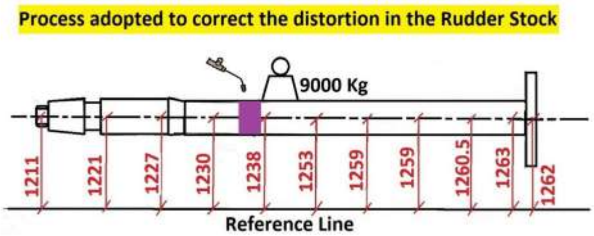


Illustration #5

Due to the distortion, the original keyway was no longer relevant. To make a new keyway, the taper section had to be completely built-up with weld metal. To achieve this, the rudder stock was mounted on a special jig to facilitate the welding to be down-hand to minimise the possibility of weld defects. It was continuously rotated while welding was being carried out on the taper section and the rudder carrier bush section.

Once the welding was completed, the rudder stock was subjected to heat treatment/stress relieving, as per requirement. **After heat treatment, the rudder stock was aligned and calibrated.** The result showed no changes due to the Post Weld Heat Treatment.

The stock was grit-blasted and tested for cracks with Dye Penetrant. No cracks were found; thereafter the rudder stock was transferred to the Machine shop where machining of taper and the carrier bush section were carried out. Refer to **Illustration #6**.

As the original design, the carrier bush section was fitted with the stainless sleeve. This sleeve was also manufactured in the workshop. Before final alignment, the sleeve was shrunk fitted on to the rudder stock and sealant compound applied at the lower interface to prevent ingress of sea water between the rudder stock and the stainless sleeve.

> *"The most important aspect of the re-construction was to ensure that the upper and lower casting bores were co-axial"*

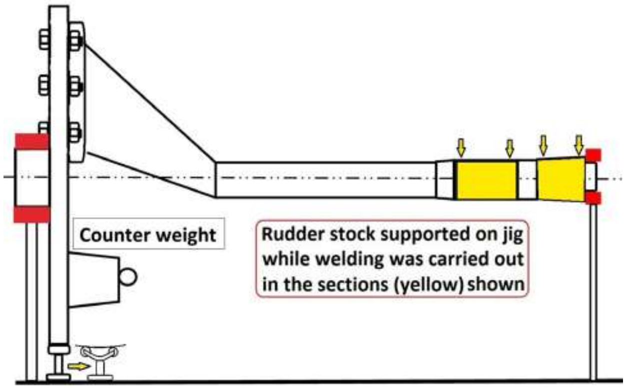


Illustration #6

While machining the taper on the Rudder Stock, there was a slight deviation from the original taper, therefore the taper of the tiller bore had to be corrected to match the stock taper. This taper was also checked with blue and bedding found satisfactory. The keyway in the tiller was dressed and distortion removed. In the process, the keyway width increased. A new key was manufactured.

RUDDER

The rudder was disconnected from the stock after removal of coupling bolt. Since the pintles were bent the forward section of the rudder between the rudder horn gudgeon was cut and removed. The rudder was then lowered with the pintles in place. Refer to **illustration #7**. **Since the upper and lower sections of the rudder were not damaged, it was decided that this portion could be reused.** The damaged mid-section was cut and removed along with the internals. The lower rudder casting was cut and removed from the plating. A crack was visible in the lower rudder casting about 100 mm was cropped off the casting. Refer to **Illustration #8**.

The casting was then checked for cracks with Penetrant dye and none was detected.

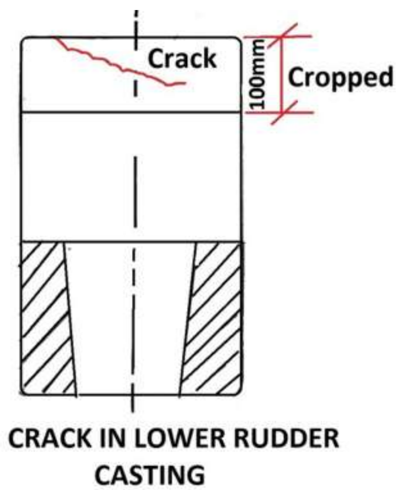
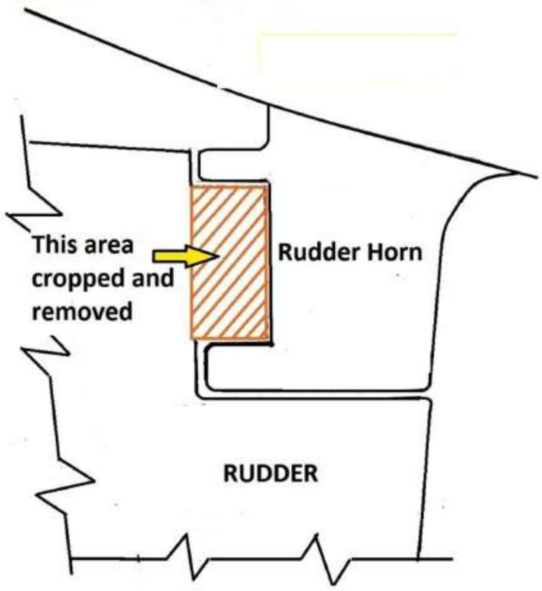


Illustration #8

The upper casting also was checked for cracks with dye. None were found.

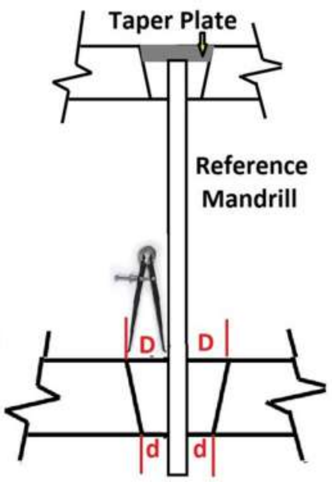


The Rudder blade was cropped as shown and un-shipped along with the Pintles in place. The re-assembly was carried out in the same manner in reverse order.

Illustration #7

In order to reconstruct the mid-section of the rudder, a jig was fabricated. The upper and lower sections of the rudder were placed on the jig and mid-section was reconstructed. The most important aspect of the re-construction was to ensure that the upper and lower casting bores were co-axial. This was achieved by passing a "reference" bar between both bores.

The upper casting was taken as the reference bore and lower casting was there from aligned. After getting both the bores in alignment, the rudder lower casting was welded to the internals. Extreme care was taken to avoid welding distortion. After completion of constructions, the rudder was pressure tested to 0.21 Kg/cm^2.



Rudder casting alignment during re-construction of Rudder

Illustration #8

It was decided that the lower pintle will be made about 20 mm over-size on diameter, this allowance would enable the lower casting to be rebored, in case any distortion due to welding appear. After re-construction, the rudder was grit blasted and coated with red oxide primer and transferred to the machine shops for further work.

The rudder was mounted on a table and aligned such that both pintle bores were parallel to the base. It should be recalled that elaborate alignment procedures were carried while reconstructing to ensure concentricity of both bores. A boring bar was set up in the lower pintle bore while a milling machine was used for the upper pintle bore. Both bores were rebored and recesses for the 'O' rings made. The pintles were fitted into the bore and tapers were checked with blue. The taper in the castings were polished were ever necessary until satisfactory bedding was achieved.

GENERAL

Both the upper and lower pintles were renewed. The lower pintle stainless steel sleeve was also machined. The upper pintle stainless steel sleeve was reused as there was negligible distortion. The sleeves were heated and shrunk fitted onto the pintles. **The taper on the pintles was made after the boring of the taper in the rudder castings was completed.** The pintles were gauged and there after the phenolic resin bush internal diameters were machined with required clearances. The phenolic resin bushes were fitted in the respective gudgeon and the cover plate welded on to the gudgeon. Only the lower phenolic resin bush cover plate was renewed, 6 new coupling bolts were manufactured. Six washers 20 mm thick had to be made and these were used to compensate the material skimmed off the stock palm and rudder flange. The old coupling-bolt nuts were used. The split bearing ring faces were skimmed off by 1 mm on each half to ensure that the diameter of the bore would effectively be reduced. The bearing ring was then machined to give a nip of 0.2 mm on the stock diameter. The key way was found to be true. However, the keyway on the rudder stock had distorted and was corrected. This called for manufacture of a step key. The wider part fitted into the rudder stock. The bearing disc of the rudder carrier had some rubbing marks and few indentations. 0.5 mm was skimmed off and eventually only 3 or 4 fitting marks of a depth of say 0. 4 mm and area of 100 mm^2 remained. The same was fitted back and the grease points checked. All was found in order.

RUDDER TO RUDDER STOCK COUPLING

The rudder stock was coupled to the rudder with service bolts. The rudder stock and rudder were aligned. Clearances between the rudder flange and stock palm were checked. To save time and material, it was decided to skim off a larger portion from the rudder flange, in a plane angular to the base. About 8mm was skimmed of the rudder flange. The rudder stock palm was slightly

THE INSTITUTE OF MARINE ENGINEERS (I)

METC - KOLKATA

FULL TIME FACULTY

In pursuit of exxcellence in Maritime Education & Training we need dedicated and motivated Full-Time faculty for **IGF Code Courses (Basic), Passenger Ship Familiarization (Crowd Management) & Ship Security Officer Course** being conducted at IME(I), METC - Kolkata.

1. Qualifications & Experience:

• IGF Basic Course

- Master Mariner (FG)/ MEO Class I(Motor / Motor & Steam)
- Hold COP for Advanced training for ships using fuels covered within the IGF code or Advanced Training for Gas Tanker Cargo Operations
- Sailing experience in Gas Tanker / Dual Fuel Engine
- "Training of Trainers & Assessors '' (TOTA) / VICT Course Certificate
- Have not less than 5 years of sea going service on board merchant vessels above 3000 kW or 500 GT, of which, have served, at least 1 year at management level.
- AECS Course

• Ship Security Officer Course

- Master Mariner (FG)
- Ship Security Officer Course Sailing experience in Gas Tanker / Dual Fuel Engine
- "Training of Trainers & Assessors '' (TOTA) / VICT Course Certificate
- Experience in Maritime Security related matters and ISPS
- AECS Course

• Passenger Ships Familiarization Course (Crowd Management)

- Master Mariner
- At least 5 years' service on Merchant ships of which at least one year should have been in the rank of Master
- Passenger ship Safety (Crisis Management) Course Certificate and experience as Master or Chief Officer on Passenger ship for at least 6 months
- "Training of Trainers & Assessors '' (TOTA) / VICT Course Certificate
- AECS Course

2. Additional Desirable Experience and Skills:

- Teaching experience at least 2 years (For Faculty)
- Preferably having experience in a Maritime Training Institute as a principal (For Principal)
- Conversant with computers (MS Office)

Forward your application to training@imare.in with a cc to hgs@imare.in:

The Hon. General Secretary,

The Institute of Marine Engineers (India) "IMEI HOUSE"

Plot No: 94, Sector -19, Nerul, Navi Mumbai - 400 706,Tel: 022 27701664/ 27711663
M: 8454847896 Website: www.imare.in

skimmed and the stock was again re-coupled to the rudder. Gaps between the two faces were checked and accordingly the rudder stock palm was finally skimmed.

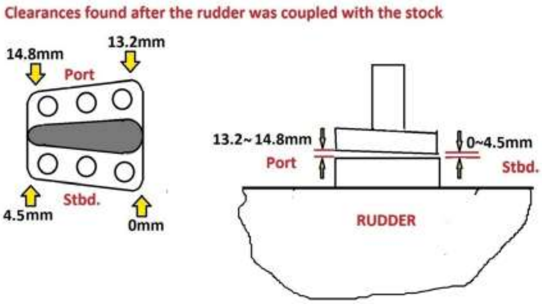


Illustration #9

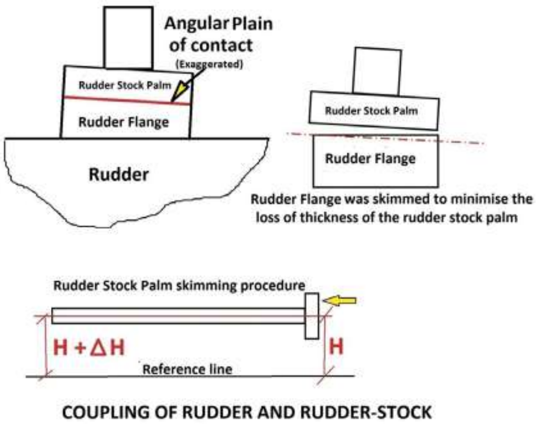


Illustration #10

FINAL ALIGNMENT

Due the angular plane of contact, between the rudder stock and rudder, the stock had to be rotated in a counter clockwise direction while facing aft.

The rudder and stock were coupled together and aligned such that the rudder stock, upper and lower pintle was coaxial. This was done with two of the six fitted coupling bolts in place. Result showed that the rudder and rudder stock were in alignment within acceptable limits. The remaining four coupling bolt holes were reamed and bolts were fitted. Finally, the key way for the tiller was cut on the rudder stock cone.

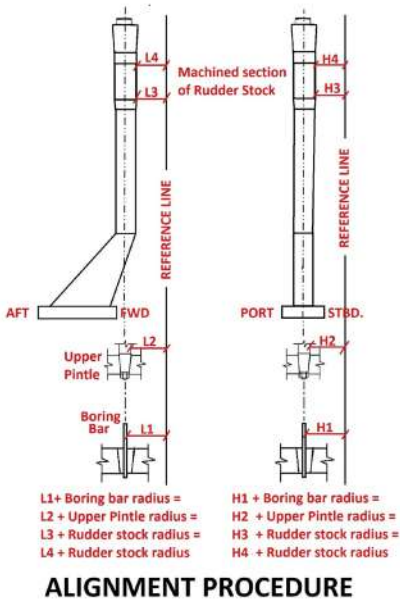
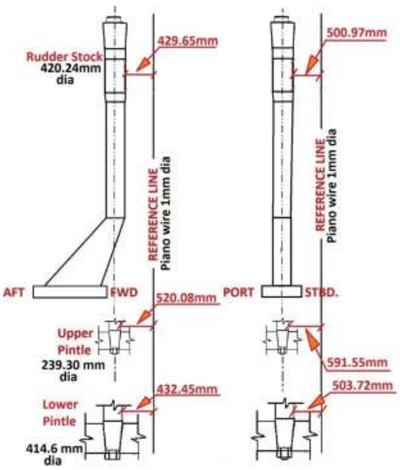


Illustration #11



Location	Forward – Aft Axis			Port – Starboard Axis	
Lower Pintle	432.45 +207.30 = 639.75	0.00		503.72 +207.30 = 711.02	0.00
Upper Pintle	520.08 + 119.65 = 639.73	- 0.02		591.55 +119.65 = 711.20	+ 0.18
Rudder Stock	429.65 +210.12 = 639.77	+ 0.02		500.91 + 210.12 = 711.03	+ 0.01

Illustration #12

Sea trials were conducted and the steering performance was found to meet the SOLAS requirement. The vessel was ready to set sail again!

About the author

Ramesh Vantaram is an alumnus of D.M.E.T. (1974-1978). The sea career started with The Shipping Corporation of India. After obtaining MEO Cl II certificate, he served with Hongkong- Borneo Shipping Company. After obtaining MEO Cl I certificate in 1983, he served with Anglo Eastern Management Services until 1987. Thereafter he was associated for 3 years with an FAO (UN) regional Project known as The Bay of Bengal Program. The objective of the project was to provide fisher-folk with a viable alternative to Outboard Motors on their FRP boats. The work-scope involved Prototype testing of power tiller engines and multiple propulsion systems.

He worked with Lloyd's Register of Shipping from April 1992 to June 2005 at Chennai, Ahmedabad and Marmagoa. Just before and soon after his stint with LRS, he served as Chief Engineer, with South India Shipping Company and United Ocean Ship Management Co.

In 2008, he joined Great Offshore as Head of Quality, Health Safety and Environment, in charge of the Company's International Safety Management and Integrated Management System Certification processes.

In 2014, he moved to Ocean Sparkle Limited as Senior Vice President and served as Regional Head of North West Region. In 2018, took over as Head of Quality in charge of the Company's Integrated Management System and Certification.

In February 2022, he retired from Ocean Sparkle Limited and took up part-time teaching. Currently he is a visiting faculty at the Institute of Marine Engineers (India) at Navi Mumbai. He regularly writes technical articles especially for student readers in iMélange.

A RELOOK AT THE FIRST NAVIGATIONAL GUIDE (Part 2)

Map of the Periplus

K R A Narasiah

39th para says "The ships lie at anchor at Barbaricum, (another ancient place near the modern port of Karachi) but all their cargoes are carried up to the metropolis by the river, to the King. There are imported into this market a great deal of thin clothing, and a little spurious; figured linens, topaz, coral, storax, frankincense (a hardened resin that comes from the trunk of the Boswellia tree), vessels of glass, silver and gold plate, and a little wine. On the other hand, there are exported costus, bdellium, lycium, nard, turquoise, lapis lazuli, Seric skins, cotton cloth, silk yarn, and indigo. And sailors set out thither with the Indian Etesian (south bound) winds, about the, month of July, that is Epiphi: it is more dangerous then, but through these winds the voyage is more direct, and sooner completed".

While the following paragraphs are descriptive of the coast, the part that is of great interest to us is the fiftieth onwards. "Beyond Barygaza (Baroach) the adjoining coast extends in a straight line from north to south; and so this region is called Dachinabades (Dakshinapatha - Deccan plateau) for dachanos in the language of the natives means 'south.' The inland country back from the coast toward the east comprises many desert regions and great mountains; and all kinds of wild beasts -- leopards, tigers, elephants, enormous serpents, hyenas, and baboons of many sorts; and many populous nations, as far as the Ganges."

51st paragraph says, "Among the market-towns of Dachinabades there are two of special importance; . . ." followed by another important paragraph for us that is 53. ". . . Beyond Calliena (Kalyan) there are other market-towns of this region. . .then . . .Sesecrienae(Saurashtra) and that of the Aegidii(Goa), and that of the Caenitae (near Karwar), opposite the place called Chersonesus(Karwar) (and in these places there are pirates), and after this the White Island. Then come Naura(Cannanaore) and Tyndis (Thondi of the west coast; there is one on the East coast as well), the first markets of Damirica, and then Muziris (Pattanam in Kerala during Sangam period known as Musiri) and Nelcynda(Neendakara?), which are now of leading importance. Thondi is mentioned in the Sangam literature in Purananuru (48:1-6) as that of Chera king Seraman Kokodhai Marban.

The name Muziris is mentioned in *Agananuru* (of Sangam) in its 149th poem by one Erukkaattur Thayang kaNNinar; it says "*Cheras' Periyaru flowing with force* (where the port of Musiri was situated) *Yavanas' ships come with gold and leave with pepper. . .")* The Periplus and Sangam poetry can be compared though Sangam poetry is of a time at least two centuries after the Periplus was recorded.

It is worth recalling here, to understand how well the port of Musiri was functioning, a document discovered in Egypt in 1980 and first published in 1985 known as the *Muziris papyrus* that is now preserved in a Vienna Museum. This papyrus document mentions a loan agreement made by an Egyptian merchant and a merchant in Muziris, for exporting cargo. It also estimates the value of goods and a 25% tax for the items. Since an Egyptian merchant gave this agreement to the government as a guarantee for a loan, this agreement survived through the ages. And another important factor to note is that the co-directors of excavations at Berenike, Dr. Steven E. Sidebotham, (I had the good fortune of interacting with him) a historian at the University of Delaware, and Dr. Willeke Wendrich, an archaeologist at the University of California at Los Angeles – say that their research showed that the maritime trade route between India and Egypt in antiquity appeared to be even more productive and lasted longer than scholars had thought and it was not an overwhelmingly Roman enterprise, as had been generally assumed. The artefacts at the site indicated that the ships might have been built in India and were probably crewed by Indians. ''We talk today about globalism as if it were the latest thing, but trade was going on in antiquity at a scale and scope that is truly impressive,'' Dr. Wendrich said.

Dr. Steven Sidebotham

Sidebotham's book explains the trade aspect. He says "Ptolemic documents suggest that, after expenses the skipper got 50% of the profit and this can show why such hazardous trips were undertaken. Vienna's Papyrus document says the cargo cost was 6.93 mill drachmas. The cargo was a Gangetic nard (used for flavouring wine, anointing the dead for perfumes, cooking etc.,) ivory and fabric on board a ship *Hermapolon* from Muziris." That is clear indication that the maritime trade was well advanced in the very early stages of CE itself.

Continuing with the Periplus, its 55th paragraph says, "There is another place at the mouth of this river, the village of Bacare (Vakkarai), to which ships drop down on the outward voyage from Nelcynda (it is felt by the researchers that Nelcynda was located in what is today Alumthuruthu-Kadapra near Chengannur), and anchor in the roadstead to take on their cargoes; The kings of both these market-towns live in the interior.

It is worth remembering here that Pliny the Elder in his book *Naturalis Historia* calls the port Neacyndi and states that Bacare near Nelcynda was preferred to the one at Muziris as the latter was infested with pirates and because the road head was far from the sea. Claudius Ptolemy, the Alexandrian geographer, in his book *Geographia* dated to 2nd century calls this port Melkynda. It was also known as Nincylda and Nikinna, and says the port was part of the territory ruled by the Pandyas of Madurai (Neendakara and Niranam were often identified with Nelcynda).

56th paragraph says, "They send large ships to these market-towns on account of the great quantity and bulk of pepper and malabathrum (a leaf of medicinal and aromatic value) … spikenard from the Ganges, malabathrum from the places in the interior, transparent stones of' all kinds, diamonds and sapphires, and tortoise-shell; that from Chryse Island, and that taken among the islands along the coast of Damirica. They make the voyage to this place in a favourable season who set out from Egypt about the month of July, that is Epiphi.

58th paragraph is also of interest to us as it says, ". . . Beyond this there is another place called Comari, at which are the Cape of Comari and a harbour; hither come those men who wish to consecrate themselves for the rest of their lives, and bathe and dwell in celibacy; and women also do the same; for it is told that a goddess once dwelt here and bathed."

It is of special interest to us as here the writer seems to have interacted with locals and got some legends told to him and sincerely repeats the same. It also makes it clear that Kanyakumari was known even then very well and the story of the Goddess has been well remembered and was popular.

Now we come to one of the most informative record in 59th paragraph. "From Comari toward the south this region extends to Colchi (Korkai), where the pearl-fisheries are; (they are worked by condemned criminals); and it belongs to the Pandian Kingdom. Beyond Colchi there follows another district called the Coast Country (Chola Kingdom), which lies on a bay, and has a region inland called Argaru (This was originally identified by K A N Sastri as Uraiyur; subsequently it is established as Alagankulam and during excavations here a potsherd was found with a Roman ship figure that confirmed the place was indeed Alagankulam).

Again 60th para is of significance to us. "Among the market-towns of these countries, and the harbours where the ships put in from Damirica (Thamizhagam) and from the north, the most important are, in order as they lie, first Camera (This is the most famous Puhar or Kaverippumpattinam about which a full Sangam song *Pattinappalai* is written, then Poduca(originally thought to be Puducherry; later identified as Arikamedu- about this later) then Sopatma(Markanam); in which there are ships of the country coasting along the shore as far as Damirica; and other very large vessels made of single logs bound together, called Sangara; but those which make the voyage to Chryse and to the Ganges are called Colandia, and are very large. There are imported into these places everything made in Damirica, and the greatest part of what is brought at any time from Egypt comes here, together with most kinds of all the things that are brought from Damirica and of those that are carried through Paralia". Paralia in Greek means the sands of the beach.

61. "About the following region, the course trending toward the east, lying out at sea toward the west is the island Palaesimundu, (now SriLanka) called by

THE INSTITUTE OF MARINE ENGINEERS (I)

METC - GOA

PRINCIPAL & FULL TIME FACULTY

In pursuit of exxcellence in Maritime Education & Training we need dedicated and motivated Full-Time faculty for **IGF Code Courses (Basic), Passenger Ship Familiarization (Crowd Management) & Ship Security Officer Course** being conducted at "IMEI HOUSE" Goa

1. Qualifications & Experience:

• IGF Basic Course

- Master Mariner (FG)/ MEO Class I(Motor / Motor & Steam)
- Hold COP for Advanced training for ships using fuels covered within the IGF code or Advanced Training for Gas Tanker Cargo Operations
- Sailing experience in Gas Tanker / Dual Fuel Engine
- "Training of Trainers & Assessors '' (TOTA) / VICT Course Certificate
- Have not less than 5 years of sea going service on board merchant vessels above 3000 kW or 500 GT, of which, have served, at least 1 year at management level.
- AECS Course

• Ship Security Officer Course

- Master Mariner (FG)
- Ship Security Officer Course Sailing experience in Gas Tanker / Dual Fuel Engine
- "Training of Trainers & Assessors '' (TOTA) / VICT Course Certificate
- Experience in Maritime Security related matters and ISPS
- AECS Course

• Passenger Ships Familiarization Course (Crowd Management)

- Master Mariner
- At least 5 years' service on Merchant ships of which at least one year should have been in the rank of Master
- Passenger ship Safety (Crisis Management) Course Certificate and experience as Master or Chief Officer on Passenger ship for at least 6 months
- "Training of Trainers & Assessors '' (TOTA) / VICT Course Certificate
- AECS Course

2. Additional Desirable Experience and Skills:

- Teaching experience at least 2 years (For Faculty)
- Preferably having experience in a Maritime Training Institute as a principal (For Principal)
- Conversant with computers (MS Office)

Forward your application to training@imare.in with a cc to hgs@imare.in:

The Hon. General Secretary,

The Institute of Marine Engineers (India) "IMEI HOUSE"

Plot No: 94, Sector -19, Nerul, Navi Mumbai - 400 706,Tel: 022 27701664/ 27711663
M: 8454847896 Website: www.imare.in

the ancients Taprobane (old maps show this name for SriLanka) ..."

62nd paragraph says, "About these places is the region of Masalia (Today's Masulipatnam) stretching a great way along the coast before the inland country; a great quantity of muslins is made there. . . there is the region of Dosarene(Odisha) yielding the ivory known as Dosarenic. Beyond this, the course trending toward the north, there are many barbarous tribes, among whom are the Cirrhadae, a race of men with flattened noses, very savage; another tribe, the Bargysi; and the Horse-faces and the Long-faces, who are said to be cannibals. (obviously the writer must have heard from the locals some legends about some tribes, that they chose to call *Kiradhakas.)*

Some additional notes of importance:

About Arikamedu (mentioned in the 60th Para as Poduca, located on the Coromandel Coast of India, is the most important site for study of Indian sea trade with the Mediterranean region during Imperial Roman times. The site has been excavated previously in the 1940s and 1950s, but because of many unresolved problems, during three seasons from 1989 to 1992, new excavations were carried out as a collaborative project of the University of Pennsylvania Museum and Madras University. Dr. Vimala Begley, who has previously edited Rome and India: The Ancient Sea Trade (1991), conceived the project. (*The Ancient Port of Arikamedu: New Excavations and Researches 1989-1992. Edited by Vimala Begley contributors Steven Sidebotham; Noboru Karashima, and others).*

Purananuru (30: lines 10-15) say, the ships that enter *Puhar (Kaverippumpattinam)* do not have to lower their sails or lighten the laden weight. Even today, in many ports, ships enter only after reducing their speed, assisted by tugs and in some ports the ships have to be lightened to ensure that they don't run aground due to restricted draft conditions. That in Puhar, then, the ships could enter as said shows that the port was wide and deep enough.

Author's Acknowledgement Note: *During my research, I had spoken to Dr Steven Sidebotham who led some important excavations both in India and Middle East. He was extremely helpful. In fact, once he was not in Delaware, he gave me the contact of his secretary, who helped me with details. Similarly, I have met DR. R Krishnamurhti internationally known numismatologist, who attended my lecture on Periplus once in Chennai who worked with Dr Vimala Begley, who led the excavation in Arikamedu. I have been fortunate to meet such stalwarts and so I am more or less assured about the contents of my article.*

Main sources of information:

1. The Periplus of the Erythraean Sea –	
Travel and Trade in the Indian Ocean by a merchant of the First Century	
Translated from the Greek and annotated by	Wilfred H. Schoff
(Published in 1912)	
2. A Concise History of South India	Noboru Karashima
3. Foreign Notices of South India	K A Nilakanta Sastri

About the author

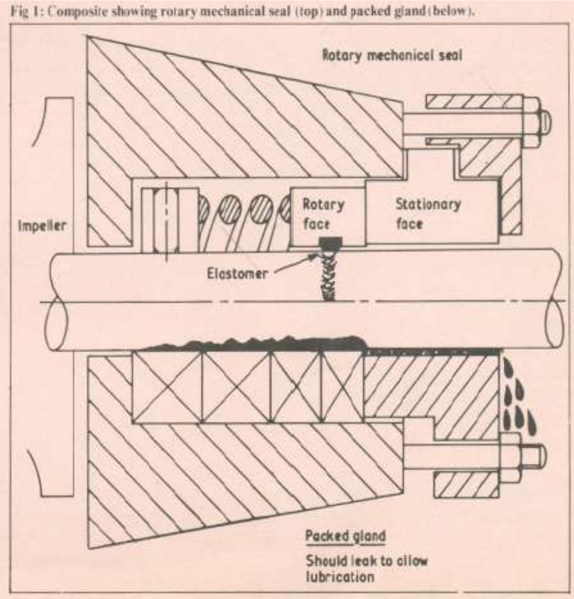
K R A Narasiah is a well-read writer in Tamil and English and a recipient of Awards (four instances) by Tamil Nadu State Government for Tamil literature. He did his marine engineering training in the Naval Training centre, I N S Shivaji (1949-1953) and sailed on board naval ships for 10 years. While in Navy he was deputed to Harland & Wolff Shipyard in Belfast to standby during the construction of the India's first Aircraft Carrier I N S Vikrant and later, took over as its first Indian Flight Deck Chief. Selected through the UPSC, he joined Vizag Port in 1965 as a marine engineer, where he rose to the position of the Chief Mechanical Engineer in 1986 and retired in 1991.He was called by the Indian Navy during the liberation struggle of Bangladesh and served under the Eastern Naval Command. He also worked as a Consultant for Indian Ports Association. He was also a visiting faculty for the NIPM, IIPM, AMET University and other marine Institutes. In 1994 The World Bank invited him to join as a marine consultant (ports) for a mission for Emergency rehabilitation programme of Cambodia where he served with distinction from 1994 to 1996. He was also a consultant to Asian Development Bank for port development. He contributes to The Hindu regularly as a reviewer of Books and to the Times of India for its South Pole columns. His main area of research continues to be the colonial and maritime history.

Email: narasiah267@gmail.com

Going Astern into MER Archives

The Editorial is usable today also. It laments on the state of ship repair industry. Lack of infrastructure, funding are cited for the sad state of affairs. We need to add lack of vision also. We move on to two interesting articles, one on mechanical seals and one on gland packing. The explanation for the closing pressure being maintained higher (old CoC question) can be of interest. Few Figures are inserted to get the readers' attention.

Fig 1: Composite showing rotary mechanical seal (top) and packed gland (below).



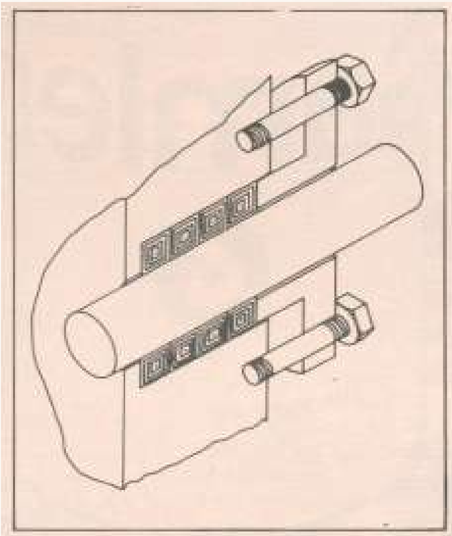


Fig 1: Design of common packed gland.

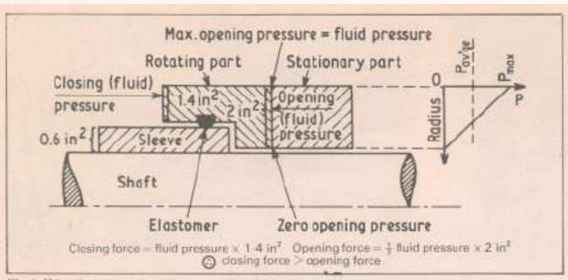


Fig 4: Why the balanced seal has a smaller closing force.

Table 1: Interface speed limits in m/s (ft/min) of dry packed glands sealing on stainless steel.

Base material	Maximum product temperature 20°C	50°C	100°C	Remarks
Asbestos	0·1 (20)	0·025 (5)	—	Temperature and speed limits can be increased by suitable fillers. Consult manufacturers
PTFE	0·4 (80)	0·05 (10)	—	Limits can be extended but initial leakage will be inevitable due to high thermal expansion
Aramid	0·5 (100)	0·055 (11)	—	Refer comments on ptfe graphite. Fillers significantly improve performance
PTFE graphite	0·75 (150)	0·06 (12)	—	Limits can be increased with lower initial leakage than with pure ptfe
Graphite	1·25 (250)	0·5 (100)	0.2 (40)	Consult packing manufacturer for extension of limits

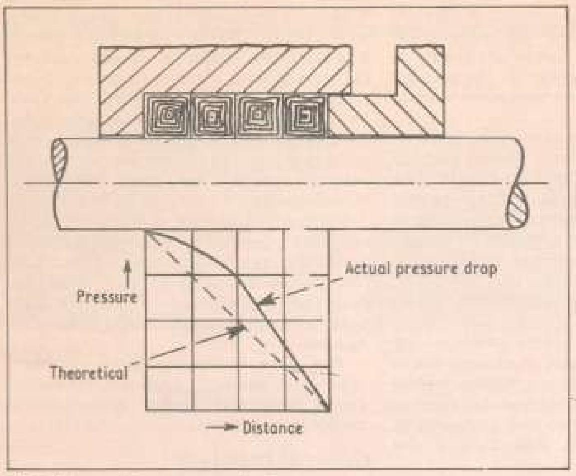


Fig 2: Pressure drop across each ring.

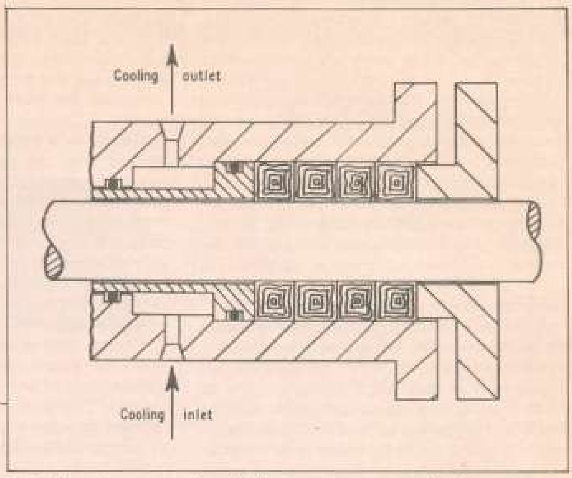
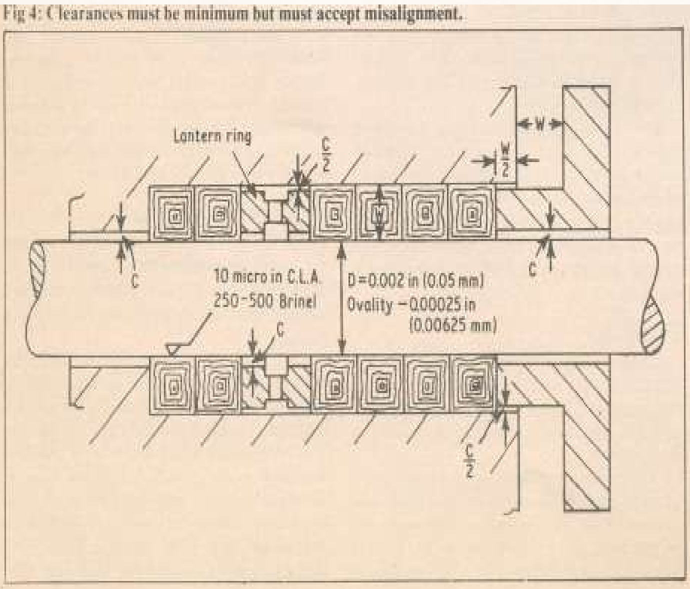


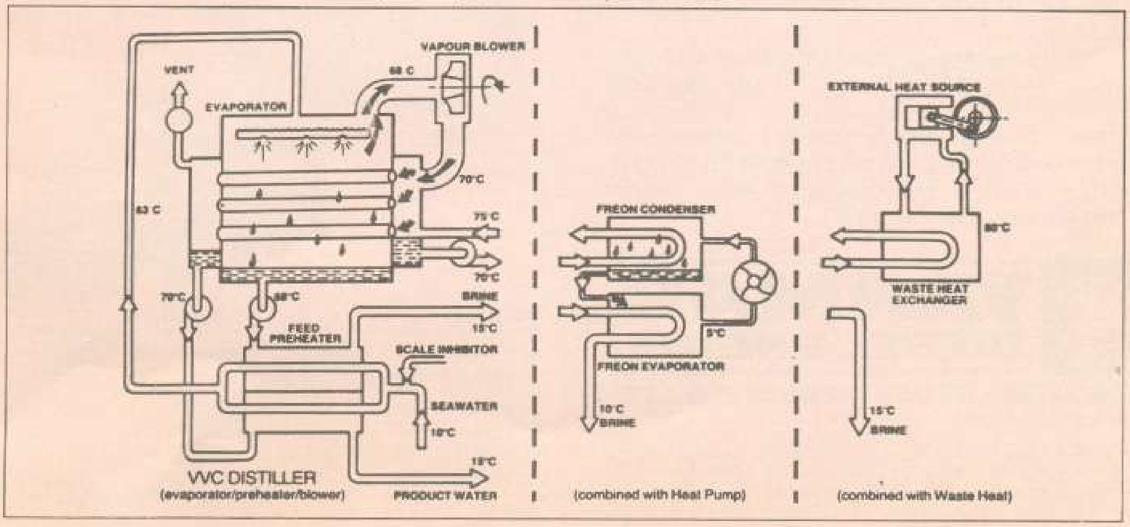
Fig 3: Inserting an annulus will eliminate cross contamination.

Fig 4: Clearances must be minimum but must accept misalignment.



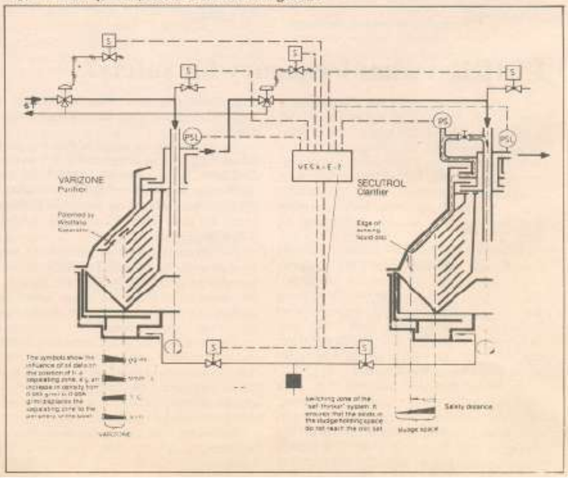
There is a one page write up on Vacuum Vapour Compression system. FW generation is always an interesting topic.

Fig 1: Schematic of the VVC process, also showing the arrangement with back-up heat sources.



Then comes the problem topic on rudder bearing replacement. Guess this will go well with the problem featuring in the **Spanner in the Works** column. Under NAVAIDS, GPS and EPIRB are projected as new technologies coming in. One discussion introduces Westphalia's Varizone-Secutrol separator-clarifier.

Fig 2: Varizone purifier/Secutrol clarifier arrangement.



The POSTBAG carries one letter in support of the Soviets and their standards being better. One letter (aligned well with the earlier discussion on seals) throws in a solution for carbon ring breakages. It is proposed that the carbon seal is cut into two halves (carefully) and put in place (replacing the broken elements without removing the pump etc.) and secured well with bonding agent. This is worth further discussion. Experienced MEs may pitch in.

POSTBAG

The Soviet threat

Sir,
I found your write-up of the symposium "The challenge of Soviet shipping" ("The USSR's Maritime Threat", September MER) quite revealing. True, the domination of the world trade routes by the Hammer and Sickle is a threat to the future of Western shipping, a threat that is all the more ominous for our inability to understand (or our reluctance to accept) what its true nature is.

We all know that Russian merchant seamen are spies, pawns of the KGB, enduring low living standards and meagre food rations whilst locating our submarines with their sonar. We know full well that they are thoroughly bad boys all round. All this is as irrelevant as it is true. The real threat is of an entirely different order of magnitude to the playing of spy games.

Anyone who reads the technical journals of the USSR Ministries of Shipbuilding and Merchant Shipping (but who does?) must be impressed by the vitality and technical quality of Soviet shipbuilding and marine engineering. Our counterparts are dedicated professionals and well informed; many have learned English in order to read our technical literature. How many of us have learned Russian in order to read theirs? The merits of our technology are admitted and discussed in their journals. Techniques are tested and adopted by an extensive R&D organisation serving all their 16 shipping companies.

Beating the air in moral indignation about the potential use of Soviet ships for military purposes or the things their seamen are up to with their electronic spying equipment is a luxury we can no longer afford. Either we should face the real issue squarely or we should all pack up and go home.

The real threat is that Soviet ships are rendering shippers a better service for a better price than ships of the Western merchant fleets. This is the nitty-gritty of the matter (which seems to have escaped discussion).

Soviet merchant seamen are well trained, disciplined and professionally competent. Most of their ships are modern and well equipped. They are building more and more.

The last nine words of your article, Sir, were well chosen.

G G Watson
East-West Engineering Design Studies Reg,
Montreal

Total economy

Sir,
Mr Hall's letter (MER July) commented on the Kincaid-B&W engine-driven pump arrangement with Stothert & Pitt pumps.

In my original paper, from which the MER article was extracted, I did refer to this and considered it sometime ago for new ships then being contemplated, but these were to have Doxford engines which were less adaptable to the power off-take. In fact it was the help and enthusiasm of Mr Hall of Stothert & Pitt which caused me to pursue, to this day, my belief that a simple and less expensive way must be found to make a large diesel self-servicing, independent of electric power, and consequently able to produce the reduced amount of auxiliary electric power from exhaust gases, with a surplus for effective control, etc.

Total economy, in fact, was achieved with the famous three-cylinder Doxford engine built in large numbers in the 1930s, by attaching the lube oil and circulating water pumps to the scavenge pump levers, with all steam stand-by pumps and steam dynamo engines from a 2-furnace cylindrical composite boiler. Therefore, at sea the only fuel for the entire ship was that burned by the main engine.

I thought it a pity that Doxford abandoned their lever driven pumps when they became unsuitable for their larger engines, without designing a satisfactory new system. This I did myself after considering the Stothert & Pitt system. However, I found this very heavy and too expensive, due to the comparatively low pump spindle speeds and it was then that I decided to make use of the same standard vertical high speed pumps as were in production for independent electric pumps. I do not therefore understand Mr Hall's contention that, by comparison, my system is cumbersome! Quite the opposite.

J E Church
Yorkshire

Split seal rings

Sir,
I would like to comment and offer suggestions on the problems of various mechanical seals in the hope that manufacturers may take note.

The most common problem with these is that the carbon seal rings break, leading to excessive leakages from the pump gland and subsequent loss of pumping efficiency. In order to renew or replace the carbon ring, in some cases the pump has to be dismantled to slide the ring along the shaft. This is time-consuming and laborious compared to the ordinary gland packing which can be done in-situ in a short time.

I suggest that the carbon ring be made in two halves with a bonding agent smeared onto the mating surfaces and with a locating pin. This will not affect the carbon ring diameter. Whenever carbon replacement is necessary, only the gland cover is removed and the new two-piece carbon ring is glued together around the shaft. This can be done in-situ without stripping the pump.

My suggestion is based on a practical point of view. I tried it on a bilge pump; the carbon seal ring had crumbled into pieces. I carefully cut a spare carbon ring into two halves. The result was satisfactory; no leakage and the pump efficiency was not impaired.

S A Balarabe
Nigerian National Shipping Line,
Liverpool

Slanted drilling

Sir,
The description of the Morecambe gas field development (MER September) referred to the drilling rigs having been designed and built by Haverton Hill Fabrications. In fact, the design of the rigs was carried out for HHF in the Lincoln offices of KCA Engineering, which is jointly owned by KCA Drilling and Zenith Cape.

The design, somewhat different to the artist's impression of an earlier concept shown in the article, is of interest since it is the first of its type to be produced in Britain. Two rigs have now been constructed and are the largest slant rigs in the world.

The design is such that each rig can be transported between the fixed platforms in the Morecambe field onboard a jack-up barge from which it can also drill in the vertical mode. After transfer, by hydraulic jacking, to one of the fixed platforms, the rig can be manoeuvred around the periphery to one of the sixteen vertical or slant (nominally 30 deg) drilling slots.

In each of these positions provision is made for the services, required to operate the rig, to be provided from the jack-up located alongside the platform.

G P Foden
Newark, Notts

Centralised power

Sir,
It is with interest that I read the article on centralised hydraulic power systems in the September MER. The idea of centralising the various hydraulic systems has, as stated, many obvious advantages to the shipowner and builder.

However, if a centralised power pack is to be used for several systems on board ship then the number of pumps in the power pack has to be increased from the usual two to one pump for each system or group of systems. This then allows flexibility of operation and means that the hydraulic system can be fully operational if one or two pumps are removed for maintenance or repair. The use of several pumps allows for more than one standby for each system but also allows for the demands of various systems, which can be very different, to be satisfied.

The ideas expressed in the article are sound but there is an over simplification of ways of achieving the desired effect. Centralised power units are in use in many ships, a dredger being a good example, and it is not a new concept for this company.

D I Cunningham
Young & Cunningham Ltd,
Glasgow

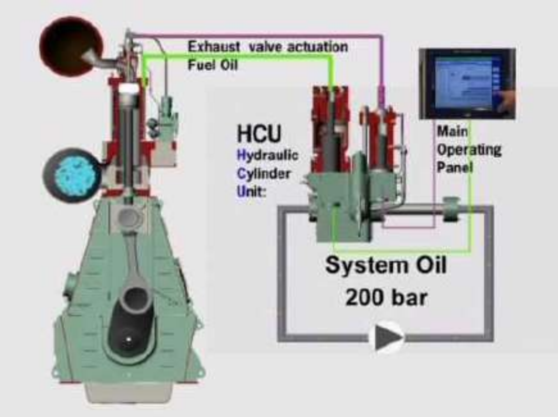
The Editor welcomes readers' correspondence but reserves the right to edit and shorten letters.

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

MASSA Maritime Academy, Chennai

The Institute of Marine Engineers (India)

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



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

Course Aims and Objectives:

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

Coverage / Program Focus:

This course deals with the following training areas:

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

Entry Requirement / Target Group:

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

DATE & TIMING : **28th, 29th, 30th November 2023/ 26th, 27th, 28th December 2023**
8:00 am - 4:00 pm IST

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

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

FOR MORE INFORMATION : **@IME(I) - email:** training@imare.in, Ms. Anukampa
(M). 9819325273, **(T)** 022 27701664 / 27711663 / 2771 1664.
@ MASSA Maritime Academy Chennai - email: mmachennai@massa.in.net
Ms. Saraswathi, **(T)** 8807025336 / 7200055336 .

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

Published on 5th of every month
and posted on 5th & 6th of every month.

"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