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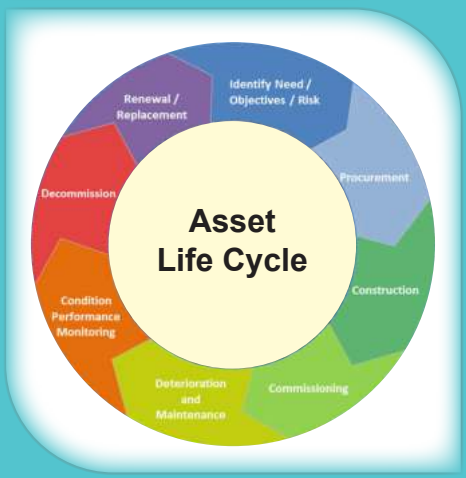

SHIP O&M: ALCM & MAINTENANCE ANALYTICS

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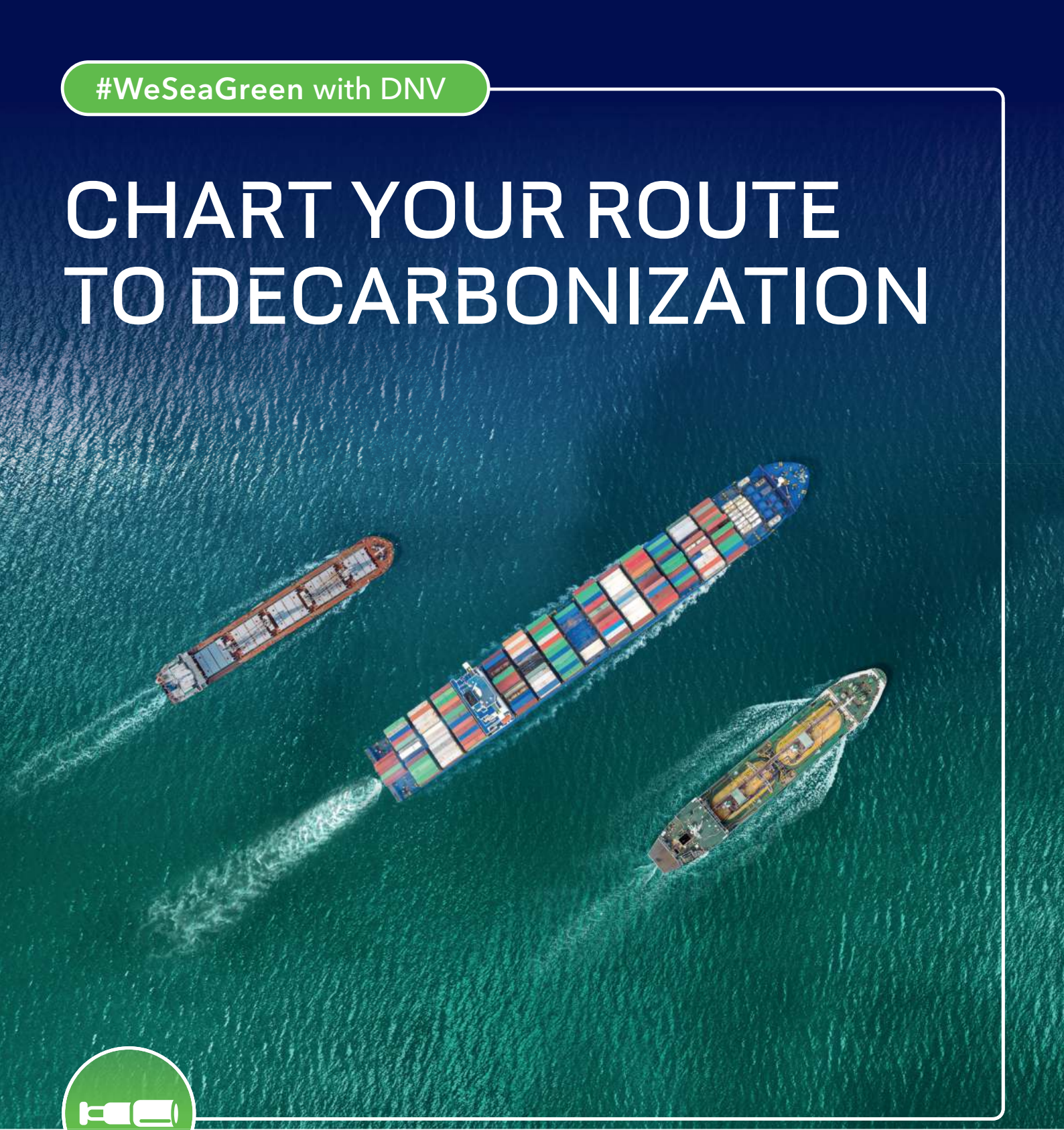

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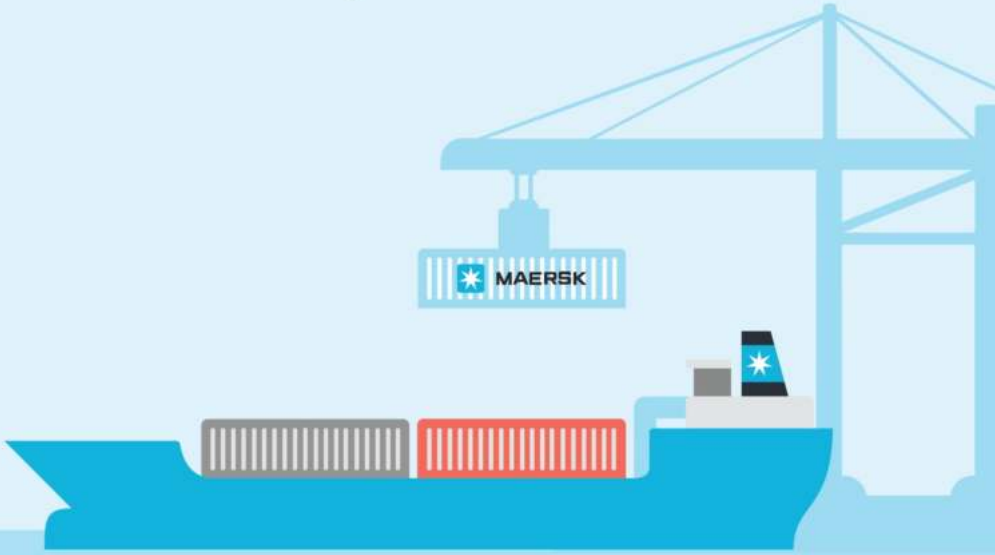

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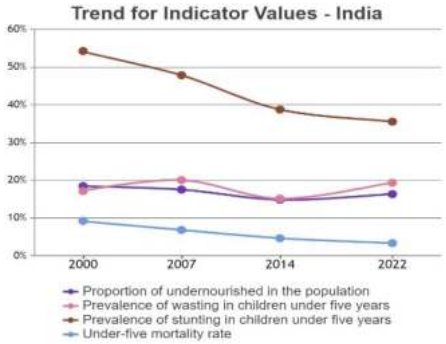
EDITORIAL

If even a single man goes without food, we will destroy this world.

- Subramanya Bharathi (Tamil Nationalist poet)

The COP27 (scheduled this month) will see commitments revisited and new lines drawn. COP 26 gave directions relying on technological solutions for non-emitting electricity (n-electricity), renewables and carbon capture & storage. Currently our n-electricity generation is 4 kWh/person/day and we need to be at 8 times that. Likewise, our CCS capability is at 6kg/person/year and we have to be at 600 times that for reckoning. It is unlikely we reach these figures by 2050. A not very recent review of the emission mitigation measures observes that we might take 400 years to achieve energy transformations keeping up the technology-dependent measures at a given rate.



(Source: globalhungerindex.org)

Adding to this climate change conundrum is the food and nutrition adequacy. In spite of encouraging figures on poverty mitigation, food production/distribution indices, improved accessibility to nutritious/balanced food etc., India slipped to 107 (121 countries ranked) in the Global Hunger Index. On this not-very authoritative survey, there are complaints on population sampling, framing of the questionnaire, the standing of the group issuing such reports etc. However, a reality check would help. Rather than looking at poverty alleviation figures, the metrics from four factors [See chart] of undernourishment (almost same), child stunting (good drop), child wasting (gone up) and child mortality (good drop) may be considered. Maybe we might be needing a combination of Norman Borlaug, M.S. Swaminathan and the likes (for Greener Revolutions), good sense and political will, of course. Else, we may destroy this world with volition, which will solve the food & nutrition problem once and for all.

In this issue...

We may say that the importance of maintenance cannot be comprehended as much as by a marine engineer. The macro-objective is to get longevity and thereby keep the asset useful during its lifetime. The maintenance approaches have undergone sea changes and in that what was considered a cost centre is seen as a value creator in perspectives. With its multi-disciplinary envelope, Asset Life Cycle Management (ALCM) has become an effective tool in making timely interventions to keep actions aligned to the objectives. Prabhu Duplex educates on ALCM and maintenance analytics and establishes the relevance to marine engineering practices with case studies etc. There will be more on this.

We follow this with Part 2 of the Maritime Anomaly detection discussions. Herein, Hema Karnam explains the types of anomalies and methods to detect them. The anomalous behaviour patterns etc., are easily comprehensible and Hema tries to explain the methods also in understandable terms. From a simple approach of forming grids of the area to be surveyed to the Bayesian network of acrylic graphs, the discussions are quite absorbing. The explanations of abnormal behaviour and spoofing add spice to the discussions.

The concluding Part 3 of the Drone discussions come next. Dr. Srinivasan *et al*., explain the merits of drone employment and details of how the data collection was done. The advantages of drone usage are being realised in ship operations and the metrics provided (payload, speeds etc.) give us a better understanding of the drones. Back to the context, we are sure to see more drones buzzing on our coasts for other intense studies too.

Continuing, we feature a not-so-past study on emissions and remedies, based on survey of seafarers etc. This could be of interest to many.

Under Technical Notes, Lube Matters carries talks on rolling (ball) bearing lubrication. This has some good tips which would be of value to practicing engineers.

MER Archives: We have dug out the November 1982 pages and there are attention-grabbing sections in this also (check out the Postbag extract on the CO_2 Systems).

In the Heritage Hourglass, Dennard traces the urbanisation and maritime trade. Overseas trade, influencing the urbanisation of Southern states (particularly Tamilnadu) bring the discourse in level with the present focus on the Chola era etc.

While you flip through these pages, I hope that you get to browse through the inaugural issue of the Institute's Newsletter soon.

Dr Rajoo Balaji
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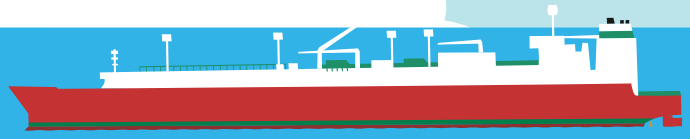

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Administration Office
IMEI House
Plot No. 94, Sector - 19, Nerul,
Navi Mumbai 400 706.
Tel. : +91 22 2770 16 64
Fax : +91 22 2771 16 63
E-mail : editormer@imare.in
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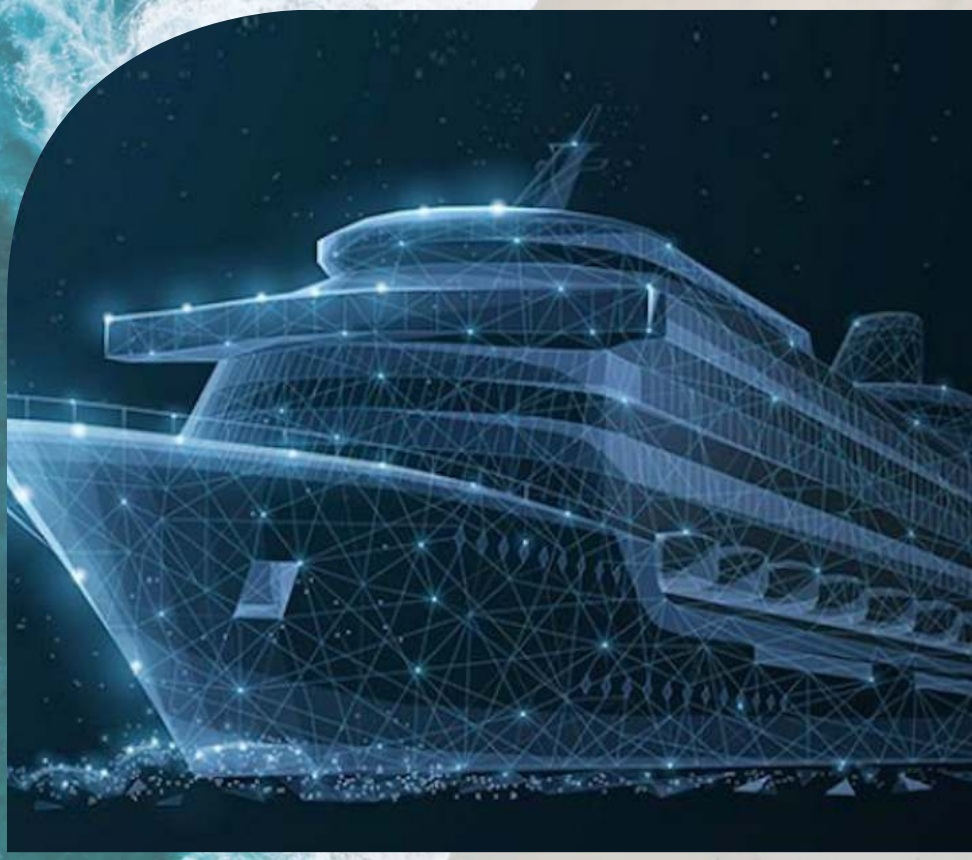

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ASSET LIFE CYCLE PLANS AND THE USE OF MAINTENANCE ANALYTICS FOR MAINTENANCE DECISION MAKING

Prabu Duplex

1. Introduction

This work focuses on ship management in a life cycle perspective. The goal is to provide a helpful guideline for the implementation of asset life cycle management philosophies. With this guideline, companies can improve the reliability and availability of equipment and reduce maintenance costs. Before introducing the high-level asset lifecycle plan, the main maintenance concepts which can be used in the lifecycle of the vessels is introduced first followed by the opportunities of using innovative maintenance analytics is discussed. In the end special emphasis is given to methodologies that help to evaluate more advanced predictive maintenance technique and process for innovating the current RCM-based maintenance policies.

2. Asset Management Concepts

Over the last decades, the field of maintenance has undergone a major transformation. It has developed

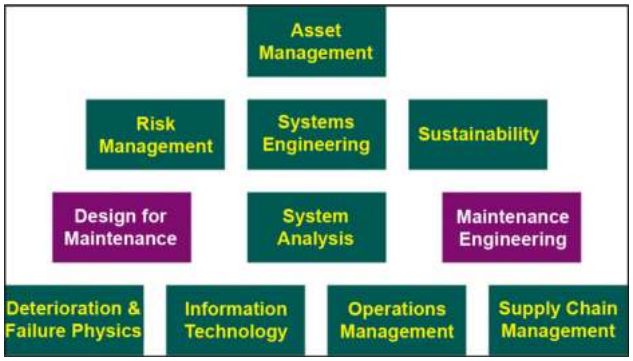

Figure 1. Maintenance: a multidisciplinary subject [18]

> *Asset Management is thus the 'realization of value' from these assets, which relates to the services the assets provide*

from a cost centre [11] to a creator of value [13], which is also reflected in the definition of the ISO 55000 standard on Asset Management [2]. A typical hierarchy of asset management is shown in **Figure 1**. In the following paragraphs, the first section will discuss the general concept of asset management and asset lifecycle management. The next sections will summarise the most important maintenance concepts of Reliability Centered Maintenance, Total Productive Maintenance and Condition Based Maintenance [1] that are currently implemented across the maritime sector.

2.1 Asset Management

In the ISO 55000 standard on Asset Management, Asset Management is defined as the "coordinated activity of an organization to realize value from assets". The ultimate goal of Asset Management is thus the 'realization of value' from these assets, which relates to the services the assets provide. Pudney (2010) defines Asset Management as "an organisation's coordinated multidisciplinary practice that applies human, equipment and financial resources to physical assets over their whole life cycle to achieve defined asset performance and cost objectives at acceptable levels of risk whilst taking account of the relevant governance, geo-political, economic, social, demographic and technological regimes".

2.2 Asset Life Cycle Management (ALCM)

It is crucial to take a multidisciplinary approach towards Asset Management, to be aligned with the corporate objectives, and to focus on the complete lifetime of the asset. A typical lifecycle of capital assets is shown in **Figure 2**. Asset Life Cycle Management (ALCM) has been introduced to describe this "ideal" way of doing Asset Management based. ALCM is characterised by the following criteria [9, 6]:

1. a multidisciplinary practice;
2. in which the whole life cycle of a physical asset is taken into account;
3. with the goal of achieving certain specified objectives;
4. within acceptable limits of risk and relevant regimes; and
5. it should determine the allocation of resources.

2.2.1 Consideration of life time impacts

Existing methods for Asset (Life Cycle) Management do not explicitly consider changes in the operating environment of the assets, nor do they offer clear guidance or tools to effectively manage assets over their complete life cycles. Therefore, Ruitenburg [8] introduced the Lifetime Impact Identification Analysis (LIIA). Lifetime impacts concerns the ability of an asset to live up to the objectives as set by the organisation. In order to identify the opportunities and threats to the organisational objectives, the TECCO perspectives (technical, economic, compliance, commercial and organisational) can be used [16]. These five perspectives together give a multidisciplinary insight in the main lifetime impacts regarding the future of the asset.

The Asset Life Cycle Plan (ALCP) is a practical method (which includes the LIIA) to effectively control the identified lifetime impacts to the strategic objectives, by executing interventions to correct the impact on the objectives. This method will be used in section 3 to create an outline for a high level asset lifecycle plan. If maintenance plays a more prominent role during the asset lifecycle, this will create an optimal balance between suppliers, owners and maintainers. Such a new balance as illustrated in **Figure 3** will clarify the assignment of tasks to the relevant organisation, thus enabling a more

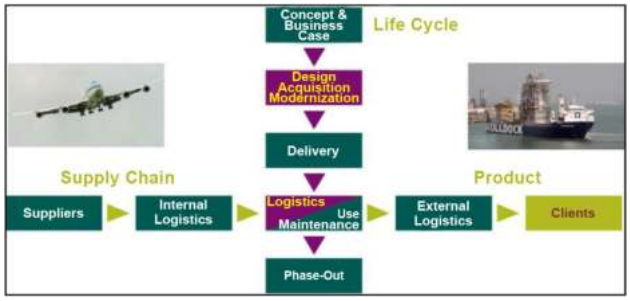

Figure 2. Typical life cycle of assets[18]

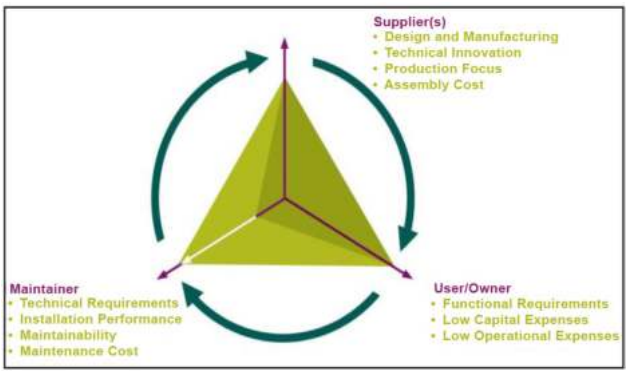

Figure 3. Integrated approach for performance during life cycle[18]

targeted approach to the integral asset management from a maintenance perspective in the decision-making.

2.3 Total Productive Maintenance (TPM)

Total Productive Maintenance (TPM) was developed in Japan and is based on the American concept of Preventive Maintenance (PM). TPM contains five elements [5] as follows:

- TPM aims to maximise equipment effectiveness (Overall Equipment Effectiveness).
- TPM establishes a thorough system of PM for the equipment's entire life span.
- TPM is implemented by various departments (engineering, operations, and maintenance).
- TPM involves every single employee, from top management to workers on the floor.
- TPM is based on the promotion of PM through motivation management: autonomous small group activities.

The goal of TPM is to achieve zero break downs and zero defects by continuously improving on the five elements by means of five activities.

2.4 Reliability Centered Maintenance (RCM)

Reliability Centered Maintenance (RCM) was developed in the aviation industry, to assess the reliability of the

Total Productive Maintenance (TPM) was developed in Japan and is based on the American concept of Preventive Maintenance (PM)

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designs of new airplanes [10]. RCM can be defined as a "process used to determine what must be done to ensure that any physical asset continues to do what its users want it to do in its present operating context" [4]. The four main principles underlying RCM state that RCM is about:

- the preservation of asset functions;
- the identification of failures modes that can defeat these functions;
- the prioritisation of these failure modes; and
- the selection of the right preventive maintenance task for each high priority failure mode.

CBM can be defined as "a maintenance program that recommends maintenance actions based on the information collected through condition monitoring"

2.5 Condition Based Maintenance (CBM)

Where RCM and TPM are clearly defined maintenance concepts, Condition Based Maintenance (CBM), or maintenance analytics, is rather a large collection of different but similar approaches to maintenance [12]. CBM can be defined as "a maintenance program that recommends maintenance actions based on the information collected through condition monitoring" [3]. This distinguishes CBM from RCM and TPM: where RCM and TPM recommend maintenance actions directly based on numerous tools, data and expert knowledge, CBM starts with condition monitoring. CBM is therefore dependent on knowing the actual condition of the asset: condition monitoring.

2.6 Differences and Similarities of Maintenance Concepts

RCM, TPM and CBM are the three most often used maintenance concepts. Based on the definition of ALCM [6] and the assessment of these concepts based on the five criteria of ALCM as introduced in the last section, it was found that [7]:

- Rather than multidisciplinary, their focus lies dominantly on technical and organisational issues, and mainly engineering, operations and maintenance specialists are involved
- Rather than the complete life cycle, they focus on short and medium term operational and tactical issues
- Their focus lies on the maximisation of reliability, equipment effectiveness or the reduction of failures and maintenance costs, which may or may not be (indirectly) related to the pursuit of corporate objectives
- Change in these goals or in the context of the assets (e.g. operating context, regulations or market demand) is not considered, which is crucial in ALCM
- Resources are mainly used for preventive maintenance (and condition monitoring), but the limited availability of resources (in terms of spare parts, equipment, man power and money are not always taken into account; and – from a more practical point of view – TPM and CBM (and some versions of RCM) suffer from limitations of the available data, even though it is well-known that data availability and reliability is a challenge in practice.

Based on these findings, companies needs to determine the applicability of the concepts in the different phases of the asset lifecycle. This will be taken into consideration in the outline of the new Asset Life Cycle Plan as will be introduced in the next section.

3 High-Level Asset Lifecycle Plan

This section introduces an outline for a high-level asset lifecycle plan (in the period say for example 2022-2042) based on the practical twelve-step approach [9] to develop an Asset Life Cycle Plan (ALCP), that supports asset managers in taking long-term strategic decisions in a timely and effective manner. Furthermore, the applications of different maintenance concepts when applicable are discussed.

3.1 Asset Life Cycle Plan - Theoretical outline

The identification of lifetime impacts is a crucial step to ensure continuous value creation with an asset over its complete lifetime. However, knowing these impacts in itself does not necessarily result in the desired performance of the asset, nor in an alignment of the operation with the asset with the corporate objectives [7]. In line with this, a simplified outline for the ALCP based on the structure of an ALCP as proposed by [7] is discussed as follows.

Strategic objectives and function: lists the main corporate goals relevant for the asset, as well as the main strategic developments and decisions that are relevant, for example, the aim to enter new markets. Additionally, it states how the asset contributes to these goals.

Current situation and performance: gives an overview of the main characteristics of the asset (population), including its age, main components, replacement value, and a brief summary of the current maintenance policies. It lists the current performance of the asset, related to the strategic objectives and goals relevant for the asset.

Lifetime impacts: this section lists the main lifetime impacts that impact the value the asset will have for the company in the future. Lifetime impacts are listed for all five TECCO perspectives. Attention is paid to both positive as well as negative lifetime impacts.

Expected performance and costs: based on the current performance and the impact of the lifetime impacts identified, the expected performance on the asset objectives is presented, as well as the costs of the asset.

Life cycle management: this section recommends actions to be taken to keep the asset valuable to the company. This may include additional maintenance, design changes, overhauls, modernisation projects, preventive replacement, and actions to collect information needed to manage the asset more effectively in the future.

List of actions: gives an overview of the main actions resulting from the ALCP, including projected start and end dates and the responsible person or department.

3.2 Asset Life Cycle Plan – A case study

This section demonstrates the fictional application of the ALCP as a case study. The high-level Asset Life Cycle Plan (ALCP) is considered to be valid for the period of 2022 – 2042 with an emphasis on the first decade. As a fictional demonstrator, this ALCP is not complete (exhaustive).

Strategic objectives and function

Assume a company has acquired 5 new Offshore Support Vessels (OSV) in 2022 to be deployed all over the world. By utilising these 5 newly built and state-of-the-art vessels, the company aims to offer high quality and future proof services at acceptable operational costs levels.

Current situation and performance

The OSVs are delivered in 2022. These 5 vessels were purchased for €10 million each, which brings the expected replacement value of the entire fleet to €50 million. The designed lifetime of the vessel is 30 years and a mid-life overhaul is scheduled in the year 2032. In order to control availability, reliability, maintenance costs and safety, the following maintenance policies have been put into place:

- Carbon build-up in the engines are to be monitored and predicted in order to enable reliable operation of the propulsion system and the ability to plan for taking timely measures.
- The surfaces that are exposed to the elements, such as the hull and the structures on the deck and the deck itself, are re-painted every 30 months in a shipyard.
- Every 5 years, the critical components of the propulsion system are revised or replaced in a drydock.
- Every 2 years, an independent organisation is contracted to inspect each vessel for compliancy with regard to safety and emissions. This operation can take place outside a ship yard.
- In sub-zero climatic conditions, the deck crane must be inspected and prepared before use to ensure reliable operation

Lifetime impacts

The following potential life time impacts have been determined while analysing multidisciplinary TECCO perspective [16]:

Technical lifetime impacts:

There is a high probability of carbon build up in the diesel engines when used at low speeds, a typical characteristic of the use of this vessel. Due to the novelty of the vessels, there is a lack of useful historical condition data of critical systems.

Economic lifetime impacts:

In 2030, the contract with a customer will expire. In 2023, a tactical decision is required about whether the current contract will be extended or if it will be renegotiated in collaboration with another shipping company to enable more favourable rates.

Commercial lifetime impacts:

Over the years assume customers demand ever increasing requirements with respect to noise and stability characteristics. Therefore it is expected that in the medium-term future, the design characteristics will make it more competitive than the older vessels that are operated by most competitors.

Compliancy lifetime impacts:

- The state-of-the-art design of the vessel is designed to comply with current international compliancy standards and is specified to exceed performance in some areas, such as safety and emissions.
- There is a long term trend towards more stringent international rules & regulations with regard to environmental emissions caused by marine vessels. The diesel engine might be susceptible to non-compliance with future regulations.

Organisational lifetime impacts:

40% of the chief engineers and captains will reach retirement age between 2020-2025.

Expected performance and costs

The target availability for each individual vessel is set to 45 weeks per year. The reliability of each ship is expected to not fall below 98% (measured in the full hours that the vessel is reliably operating divided by the total amount of scheduled operating hours). The yearly costs for each vessel during regular operations are expected to average €750k under typical operational conditions. After 20 years, a mid-life overhaul is scheduled in which all critical systems are revised or replaced. This modernisation activity is expected to cost €5 million per vessel.

Life cycle management

Given the current considerations over the life cycle, the vessel requires a number of Asset Management activities at their disposal to maintain the life cycle value of their fleet of 5 vessels:

- A Condition Based Maintenance (CBM) program should be implemented to manage the condition of the engine with respect to the carbon build up.
- A level of Repair Analyses (LoRA) should be used to determine the optimal supply distribution and stock level of spare parts.
- Before the year 2020, a proactive recruitment should be initiated to allow knowledge transfer between the experienced retiring personnel and new captains in training.
- In the 20th year of the vessel, a modernisation overhaul is recommended in order to adapt to future contextual considerations to stay competitive.
- Developments in research techniques should be monitored in order to anticipate future client wishes and requirements.
- A redesign of the deck crane should be considered to enable better all-weather performance.

List of actions

Based on the discussion in the previous paragraph, a year wise list of actions to be done and associated costs can be tabulated. Special emphasis needs to be given for activities (RCM, CBM, TPM) that should be continuously evaluated.

4. Advanced Maintenance Analytics

A methodology to introduce maintenance analytics in the asset life cycle plan and its subsequent benefit in asset life cycle management is discussed in this section.

Advanced maintenance techniques can help in making better maintenance decisions, such as ensuring just-in-time maintenance, corporate business planning or lifetime extension of physical assets. This can be initiated in four steps namely, project initiation, monitoring & data collection, advanced maintenance techniques and decision making [15]. This is schematically shown in **Figure 4**.

As shown in the **Figure 4**,

1. project initiation stage, critical component suitable for prognostic techniques can be selected based on FMECA and four quadrant analyses (based on high downtime and failure frequency per year).
2. focuses on the monitoring process and the collection of (available) data from historical records and monitoring systems for prognostic analysis.
3. the selection of the type of maintenance analysis can be made from experience-based, reliability statistics, stressor-based, degradation-based, or mechanism based methods.

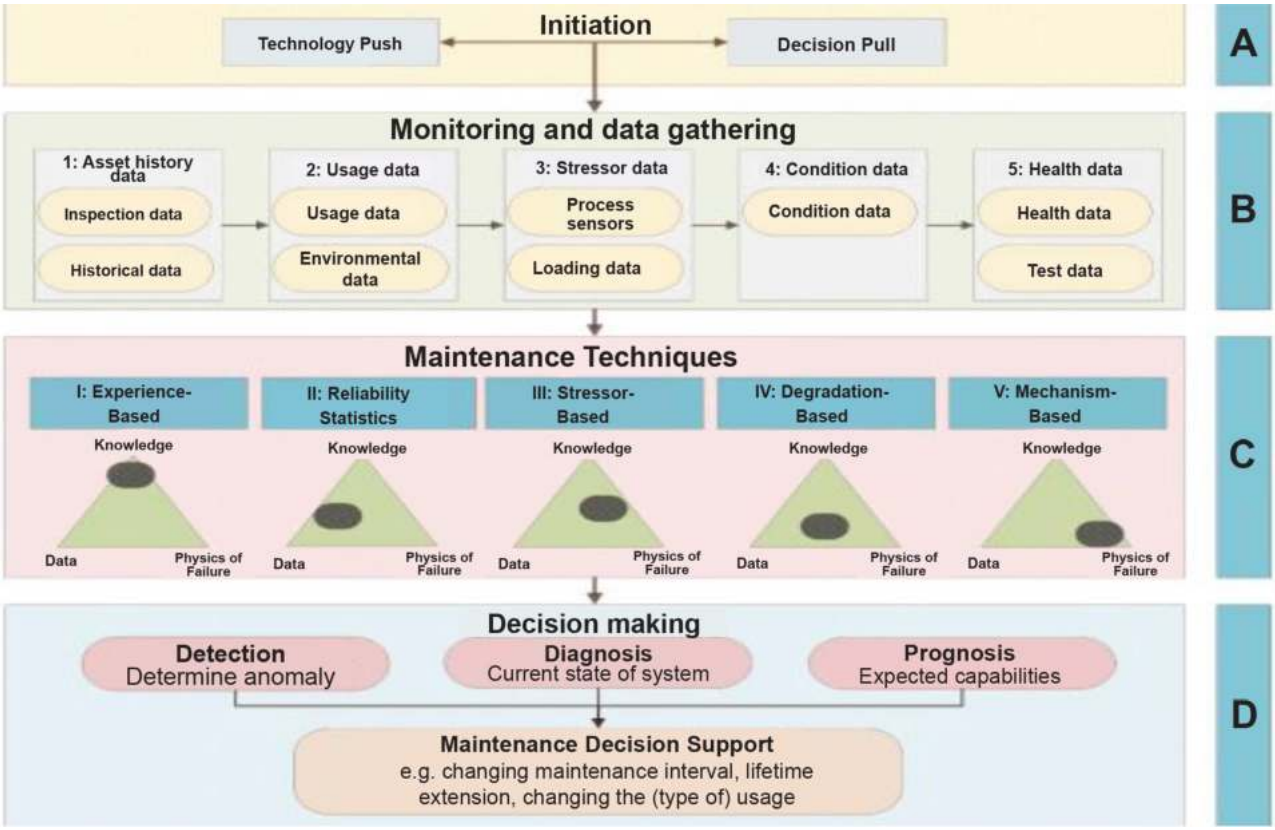

Figure 4. Steps to informed maintenance decision making using maintenance analytics[17]

4. anomaly detection, diagnosis or prognosis of the remaining capabilities will be made.

Ambition level 5 (highest if ranked from 1 to 5) will suit ship propulsion systems because of the varied operating conditions. Finally, the investment required to implement such decisions are analysed with various business cases (using ROI, NPV methods) to make a final decision. In the case study we discussed earlier, assume there is no means to obtain exact engine operational profile, such as usage and load history (operation profile varies continuously). This is critical for applying physics based maintenance model, applicable for cylinder liner wear prediction.

However this can be customised upon requirement. If investment is made in such equipment, the maintenance task can be switched from time based to condition based prognostic methods. Secondly sensor data for certain engine parameters such as temperature, pressure and vibrations are available, but diagnosing and finding patterns is an issue. As we see advancements in data analytics, new department can be integrated for analysing sensor data based on data mining algorithms, if that is not feasible outsourcing options needs to be explored.

Finally if we look into RAMSHEEP (Reliability, availability, Maintenance, Safety, Health, Environment, Economics, Politics) perspective as discussed in [14] and shown in **Figures 5 and 6**, the system condition will be monitored in real time by decision support tools (based on maintenance analytics). In this way unexpected failures can be reduced and reliability of the component is improved. Maintenance activities can be scheduled (preponed or postponed)

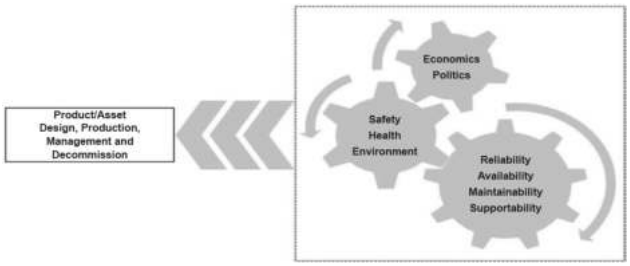

Figure 5. RAMSHEEP: RAMS, SHE and EP elements working together as parts of a gearbox.[14]

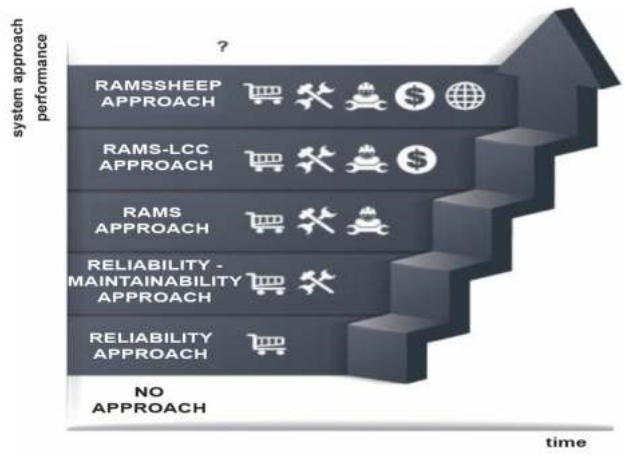

Figure 6. Evolution of the approaches forasset management [14]

without affecting ship's availability. Equipment failure most of the times affect other components in the cluster, there by affecting the maintainability of the system.

By real time monitoring, failures can be predicted to a certain extent, and as a result maintainability can be improved. Health, Safety Maintenance activities in ships involves high risks due to hazardous work environment and operations. **As an example, hydraulic jacks used to open pre tensioned bolts require an operational pressure of 900 bars, which needs to be handled properly, else such high pressure will lead to fatal accidents.** By extending the maintenance interval, workers mean exposure level to such hazards can be reduced. Ship managers are in extreme pressure to maintain ships in allocated budget. On successful implementation of such methods, substantial cost savings to the company. Such methods results in smart logistic solutions (spare parts supply & maintenance coordination), which reduces carbon foot print and higher operational efficiency.

5 Conclusion

In the current society, environmental awareness becomes more important. The politics are shifting in the direction of more environmentally friendly way of working and regulation where by, the old fashioned diesel engines are replaced for new technologies such as electric propulsion, fuel cells etc. In the present scenario, the environmental regulations are stricter than before. It is going to be more stringent in the upcoming days. Therefore, correct asset management is important to keep the system up-to-date with current environmental and political regulations.

Assumptions in the lifecycle of engines such as "there are no alternate energy sources" available could be a dangerous decision that needs to be avoided. The technical feasibility is however a hurdle for implementation of innovative types of maintenance analytics that has to addressed by continuous techno-economic feasibility studies as demonstrated in **Figure 7.** When the system need to be replaced or a new system being acquired (as per environmental norms), the corresponding maintenance policies per phase need to be wisely used. Finally companies should frequently explore innovative types of maintenance analytics by combining the different methods and acquire information which is necessary.

6 Acknowledgement

This is an academic group work for maintenance engineering and management course, performed during the first year of Professional Doctorate in Engineering (PDEng) program at the University of Twente. The course was coordinated by Prof. Jan Braaksma and Prof. Tiedo Tinga who held positions in Dynamics based maintenance (DBM) and Design Production and Management (DPM) research groups respectively. I thank them for their valuable support.

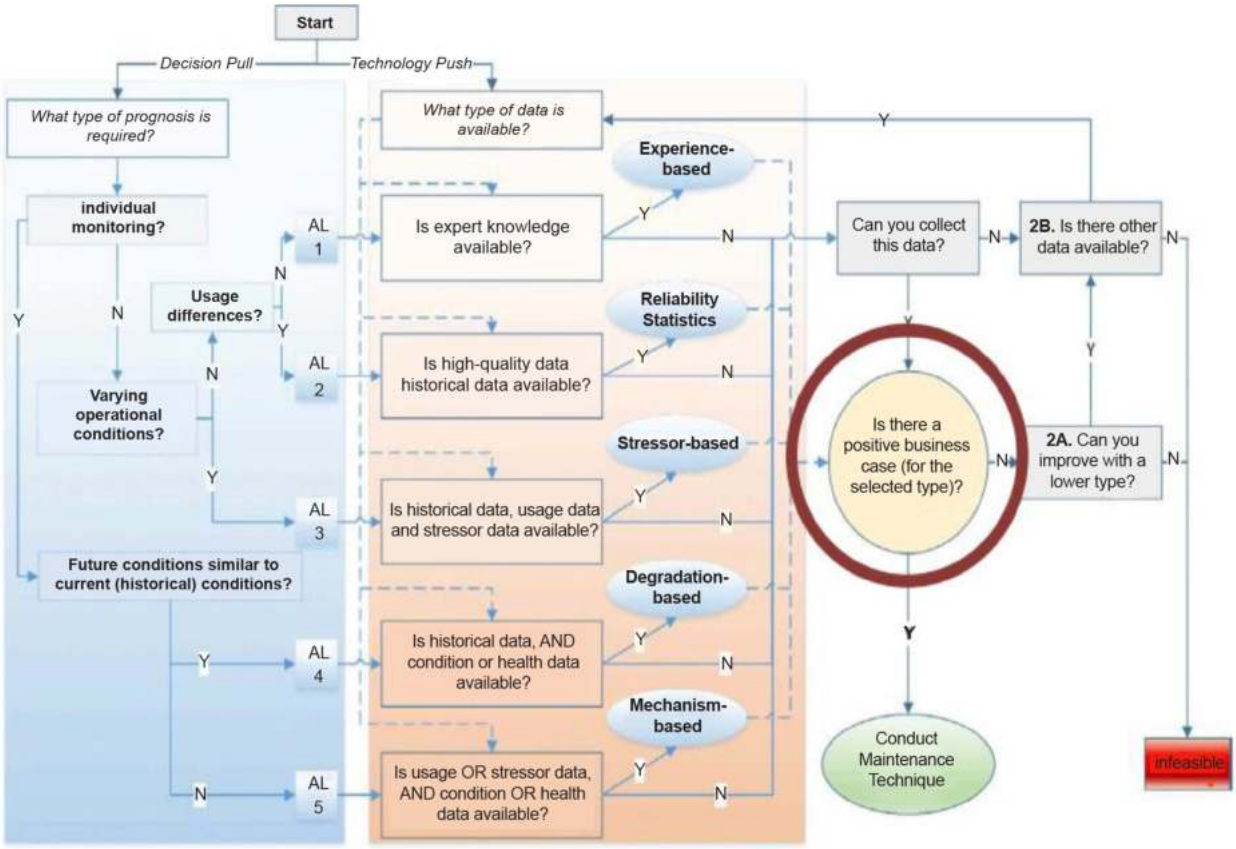

Figure 7. Flowchart for selecting the type of maintenance analytics[17]

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About the Author

Prabu Duplex had sailed as a marine engineer between 2005- 2013. He graduated from a Professional Doctorate in Engineering (PDEng) program at the University of Twente, in the Netherlands. He also worked in a research group called "Dynamics Based Maintenance (DBM)" which actively focuses on developing innovative predictive maintenance methods for a wide range of industries. His work involved in developing physics based mathematical models to predict the life time of diesel engines components in maritime propulsion systems. He has also a Masters degree in Naval Architecture. Presently, he is working temporarily as a junior reliability engineer in a Polish based firm 'info-marine' which offers predictive based maintenance solutions for merchant navy. He is open for careers in design or research activities in naval, wind, offshore or predictive maintenance domains.

Email: prabumn@gmail.com

MARITIME ANOMALY DETECTION: CLASSIFICATION OF RECENT RESEARCH APPROACHES (PART 2):

RESEARCH APPROACHES FOR MARITIME ANOMALY DETECTION

Hema Karnam Surendrababu

1. Classification of Research approaches for Maritime Anomaly Detection

Based on the literature survey of the various approaches that have been used in maritime anomaly detection, the recent approaches can be broadly classified into two types – 1. Classification based on Anomaly type. 2. Methods Based Classification.

1.a. Classification based on Anomaly Types

In this classification, the abnormal vessel behaviour is classified based on detecting outliers in various attributes of AIS data such as position, speed or vessel specific behaviour or intent of the vessel [3]. The research approaches can be classified into three types according to the type of anomalies detected are elaborated below and summarised in **Table 1.**

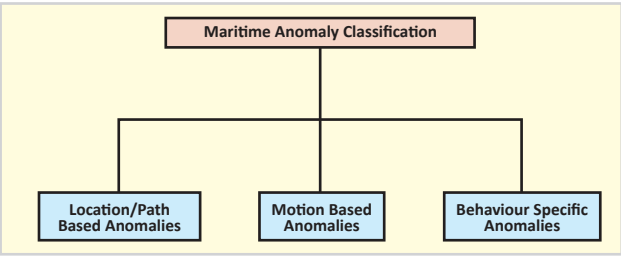


Figure 2. Maritime Anomaly Classification

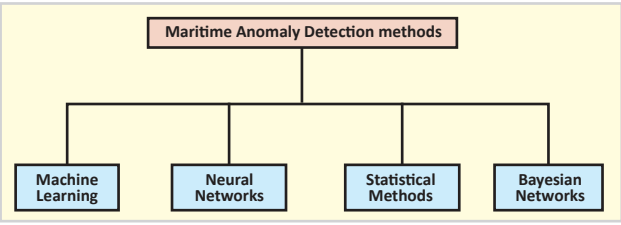


Figure 3. Methods Based Classification

i. Location or path-based Anomalies

In this category, anomalous behaviours can be further classified as vessels that deviate from standard routes, travel outside designated shipping lanes or vessels that infringe on a closed zone. In [11], an unsupervised clustering algorithm is used to detect both path based (positional) and motion based (kinematic) anomalies in traffic patterns, based on vessel features such as momentary location (latitude and longitude coordinates), velocity (latitude and longitude directions), and course shape. This approach makes use of a Gaussian Mixture Model (GMM) and an Expectation Maximisation (EM) algorithm, where normal vessel motion is modelled using complex probability distribution functions.

In the GMM approach, the entire surveillance area is divided into square grids, and the position-velocity vector in each grid is modelled using multivariate Gaussian Probability Distribution Functions (PDF). Each of the Gaussian components has parameters such as mean value and covariance value, that are representative of the training dataset. The parameters of each of the Gaussian components are calculated using an EM algorithm. The EM algorithm constitutes of two steps, the expectation, and the maximisation. In the expectation step, for each training datum, the probability that it was generated by a particular distribution is computed using Baye's rule.

Once the parameters of the PDF are estimated from the expectation step, they are updated in the maximisation step using a maximum likelihood criterion as described in [11]. An anomaly is said to be detected if the likelihood of an observation calculated from the probability distribution

Table 1. Anomaly classification and Potential applications

Anomaly Category	Author & Publication Reference	Year of Publication	Detected Anomaly	Potential Application
Location based	V.P Janeja et. al, [17]	2004	Route deviation Zone mismatch to activity	Environmental monitoring (Detect illegal fishing)
	R. Laxhammar [11]	2008	Route deviation	Monitoring criminal activities (Piracy, drug smuggling)
	R. Laxhammar et. al [12]	2008	Route deviation	Monitoring criminal activities
	Baldacci et. al [18]	2009	Route deviation	Monitoring criminal activities
	N. Willems et. al [14]	2009	Route deviation Potential collision	Safety management (Collison risk avoidance)
	S. Mascaro et. al [13]	2009	Route deviation Vessel Loitering	Monitoring criminal activities
	R. Lane [15]	2010	Route Deviation Zone entry Unexpected AIS activity	Monitoring criminal activities Environmental monitoring
Motion Based	Kazemi et. al [19]	2013	Route deviation Unexpected port arrivals	Monitoring criminal activities
	Anneken et. al [20]	2015	Unexpected AIS activity	Monitoring criminal activities
	Keane, K.R et. al [21]	2017	Unusual high speeds, U turn	Safety management
	Patroumpas, K. et. al [22]	2016	Route deviation Unusual stops/delays Close approach	Monitoring criminal activities
Behaviour Specific	Kowalska et. al [23]	2012	Route deviation	Monitoring criminal activities
	F. Katsilieris et. al, [26]	2013	Vessel spoofing Zone entry	Monitoring criminal activities
	Pollata.G, et. al, [24]	2015	Vessel Loitering	Monitoring criminal activities
	C. Ray et.al, [28]	2015	Vessel spoofing	Monitoring criminal activities/ Environmental monitoring
	C. Iphar et. al, [29]	2015	Vessel spoofing	Monitoring criminal activities/ Environmental monitoring
	Mazzerella et.al, [25]	2017	Unexpected AIS activity	Monitoring criminal activities/ Environmental monitoring
	L. Patino et. al, [31]	2017	Vessel loitering	Monitoring criminal activities/ Environmental monitoring
	I.Kontopoulos et. al, [27]	2018	Vessel spoofing	Monitoring criminal activities/ Environmental monitoring
	D. Filipiak et. al, [30]	2018	Vessel Loitering	Monitoring criminal activities/ Environmental monitoring

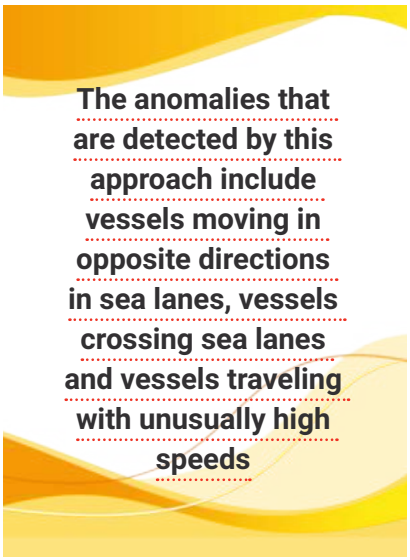
is below a certain predetermined threshold. The anomalies that are detected by this approach include vessels moving in opposite directions in sea lanes, vessels crossing sea lanes and vessels traveling with unusually high speeds.

The limitation of this approach is that the anomalies that it detects are more elementary in nature, and the approach by itself is prone to false alarms if the threshold that is chosen is too low. A comparative analysis of two methods for anomaly detection in sea traffic such as the Gaussian Mixture Model (GMM), and the Adaptive Kernel Density estimator (KDE) was proposed in [12], where the Adaptive KDE method was found to model the normal traffic patterns of the data more accurately than the GMM technique.

In the KDE technique, which is also known as the Parzen window method, no assumptions are made regarding the underlying probability distribution of the training data. The PDF for the training data is estimated using the Kernel window described in [12], where the parameters of the PDF are estimated using the Kernel Window and the training data set. The kinematic location-velocity vector which is representative of the vessel motion patterns is

extracted from the AIS data. Based on the historic AIS data and the Kernel window, anomalies are detected using the estimated PDFs and a probability threshold as discussed above.

Also, some of the limitations of both the techniques include not accurately modelling the sea lanes which gives rise to suboptimal performance of the anomaly detectors. The approach in [12] attributes the suboptimal performance to not fully exploiting all aspects of the vessel data such as the vessel type, vessel origin, and destination along with other contextual information such as the season and time of the day during the modelling process.



The usage of Bayesian Networks for anomaly detection was discussed in [13]. A Bayesian Network can be considered as a network of nodes and edges connected together in a directed acrylic graph. The nodes characterise the observed variables, and the edges in the graph characterise the conditional probability of the observed variables. The joint probability distribution of the observed variables is learnt using a Bayesian Network as discussed in [13]. The probabilities that are thus computed are averaged over a time window, and if the average probability falls below a certain threshold, then an anomaly is said to be detected.

Bayesian Networks have been less explored for anomaly detection but have considerable advantages over other methods such as GMM and Neural Networks, in that they are easily understood, can incorporate expert knowledge into the systems, and unlike the Neural Networks which has a Blackbox functionality, Bayesian Networks can aid in explaining the reasoning behind anomaly detection instead of just flagging the anomalies.

Using the approach in [13], a wide variety of anomalies are detected which include vessels travelling in unusual patterns, vessels that make no landfall, vessels behaving against their ship type etc. In this technique, two different models were developed for anomaly detection where in the first approach focused on detecting anomalies for each time step in a track, whereas the second approach focused on detecting anomalies by considering a track as a whole, and also by combining both the approaches for better model performance. However as discussed in [13], further improvement of the models can be achieved by varying the selection of ship attributes, identifying track starting and ending points, and by varying the approaches used to calculate track probabilities.

In [14], an approach based on density fields is developed for visualisation of vessel traffic. The anomalies detected using this approach include vessels travelling outside shipping lanes, vessels travelling in potentially dangerous directions such as vessels travelling against the main traffic flow, potential risk of collisions, drifters. Although a wide variety of maritime use cases are explored using this visualisation technique, there is still scope for improving the density field computations by including the environment contextual information such as weather or elevation as inputs to the algorithm.

Positional anomalies such as deviation from standard route and zone entry, that are detected from the AIS transmissions are discussed in [15]. In the approach described in [15], A Bayesian Network approach is used for calculating the probabilities of possible destinations based on historic data. Based on the observed vessel data and the computed probabilities, the hypothesis of whether a ship is travelling to its stated destination or not is tested and validated. This approach also describes methods to detect zone entry anomalies that occur when a ship is said to have entered a restricted zone. Additionally, the method also describes the process to compute the probability that a ship will enter a zone within a specific period of time.

In [16], anomalous behaviours such as deviations from shipping routes, zone mismatch to activity, and infringing on closed zones are identified using feature vectors. The models use Voronoi diagrams to partition regions into different areas based on the feature vectors and detect potential anomalies based on the association between a geospatial trajectory and areas not normally associated with the trajectory. In [17], the sea lanes are modelled using a Gaussian distribution with feature vectors that use course over ground, position, and speed over ground as variables. The feature vectors corresponding to sea lanes are extracted using many image processing techniques which include filtering, edge detection and clustering. The anomalies that are detected include ships travelling outside shipping lane. However, this method can detect anomalies on the main sea lanes only and is prone to many false positives.

ii. Motion based Anomalies

Motion based anomalies can be described in terms of anomalous vessel behaviours observed in vessel motion such as vessels traveling with very high or low speeds, vessels not heading to destined ports and/or having unusual course shapes as described in [13].

In [18], a maritime surveillance framework and decision support system is developed based on expert rules system derived from subject matter experts in order to analyse various anomalies which include vessels not heading into ports, unexpected port arrivals, vessels showing unusual trip patterns and mismatched arrival times. Unlike a data driven approach, an expert rule system is a knowledge

driven approach, where rules are formed from experts' knowledge, and then applied to the input data for data classification or knowledge discovery.

In the approach described in [18] expert rules to detect anomalies were derived from Coastguards and other maritime experts. Examples of the rulesets that are used include "If a vessel entered a port without informing the port, then anomaly", "If vessel A which normally travels between ports X and Y, suddenly goes to port Z then anomaly" [18] etc. These rules can potentially detect anomalies such as unusual trip patterns and vessel entering port without notice etc.

While a majority of the existing literature detect anomalies that are artificially generated or based on a simulated dataset, the approach described in [19], creates the ground truth of the anomalies based on real data. This is achieved by establishing the anomalies in real data using an annotated dataset created in Python. The approach evaluates GMM and KDE algorithms with the above datasets to detect kinematic anomalies. In [12], GMM and KDE algorithms are used to model normal vessel motion, using which anomalous behaviours such as vessels traveling at unusually high speeds and/or travelling in the opposite direction of the sea traffic are detected.

An unsupervised methodology that autonomously detects vessels motion based on a geospatial context dependent statistical model is described in [20]. In this approach, complex vessel behaviours are modelled using local statistical models. The models use two types of attributes, a contextual attribute that is derived from the object's geospatial location and the behavioural attributes derived from velocity, acceleration calculated at the track points.

To detect anomalies, chi square statistic is computed for a track, or equivalently the log posterior probability of a track, and these conditions are tested under the Statistical null hypothesis of the normal vessel behaviour. If any of the above tests result in the rejection of null hypothesis, an anomaly is said to be detected. The anomalies that are detected include a ship that is rapidly accelerating as it exits the harbour, a ship's high speed as it enters a harbour, a ship that executes a U turn and moves at a high speed, a ship's rate of turn with respect to its speed and acceleration.

In [21], an online maritime event monitoring and tracking tool is developed that detects changes in vessel trajectories that evolve over time. Based on the analysis of vessel trajectories, this approach detects both instantaneous and long-lasting trajectory events such as speed change, gaps in reporting, long term stop etc. This approach works on predefined rule sets that define various anomalous behaviour such as suspicious delays, vessels rendezvous, package picking etc. The complex event recognition tool that is developed is used for real time maritime surveillance and detects kinematic anomalies such as fast approaching vessels and also

When the newly detected vessel stationary areas do not match with knowledge available a priori, further analysis with respect to the vessel kinematic features such as Course over Ground (COG) and Speed Over Ground (SOG) is conducted to establish if a vessel is loitering

potential dangerous or suspicious maritime events such as suspicious delays/stops or package picked up at sea.

iii. Behaviour Specific Anomalies

In this category, the specific anomalous behaviours such as smuggling, drug trade, loitering, spoofing that require an ensemble of anomaly detectors are studied.

A non-parametric Bayesian approach that is based on Gaussian Processes (GP) is used in [22], to model normal vessel behaviour. Deviations from the proposed models are used to detect nefarious and illegal activities at sea such as piracy, drug or people smuggling etc. The modelling of normal vessel behaviours using a Gaussian process requires that behaviours are unimodal, i.e., one normal behaviour at a single position. The GP is characterised by a mean function and the covariance function. Based on the training AIS datasets, GP regression processes are used to predict vessel velocity and heading for unseen vessel positions (location information). The covariance function of the GP is used in identifying anomalous vessel activity.

The proposed model learns the abnormal behaviour by exploiting the AIS velocity information for a particular latitude and longitude, and detecting unusual tracks that characterise illegal behaviours such as people smuggling, terrorism etc. However, the scope of this work is limited to modelling anomalous behaviours for a particular ship instance from historic AIS data and can be further refined by real time anomaly detection process. The computational complexity of the GP approach is reduced using an active learning approach that trains on a representative subset of the training data instead of the entire training dataset, as described in [22].

In [23], anomalies such as loitering are detected using speed gating algorithms. This approach analyses vessel stationary areas off the shore to detect where the vessel has stopped or is moving at unusually slow speeds using an unsupervised spatial clustering algorithm. Using this

algorithm, a dictionary of waypoints and route objects are formed, where waypoints are clustered into different areas such as vessel stationary areas, exit and entry points etc. When the newly detected vessel stationary areas do not match with knowledge available *a priori*, further analysis with respect to the vessel kinematic features such as Course over Ground (COG) and Speed Over Ground (SOG) is conducted to establish if a vessel is loitering.

As AIS is a self-reported system, the AIS transponder can be intentionally switched on and off to obfuscate illegal activities at sea. In [24] an approach is developed to detect if the AIS message dropouts that occur is anomalous behaviour or not by exploiting the Received Signal Strength Indicator information available at the AIS Base station. This approach consists of building two normality models, one where the historical AIS data received at a base station is used to build a normality model for the base station, and the other is a single vessel model that is built based on the theoretical aspects that affect the electromagnetic signal propagation from the vessel AIS antenna to the AIS base station in an open sea environment.

The features for building this single vessel model include the distance between the vessel and the Base station and the height of the antennas. In the event of the occurrence of an AIS dropout, the missing AIS message is reconstructed based on each of the above two models, and features that are extracted from each of these models are used to compute a risk level. The individual risk levels for each of the models are then combined to form a final risk level which is compared with a threshold to detect an anomalous/intentional AIS switch off.

iv. Spoofing Studies

The security evaluation of AIS has shown that the AIS is highly vulnerable to different types of attacks such as spoofing, hijacking in both RF frequency and via software/email used by the AIS online service providers [8]. Ship spoofing is a form of deception, where an attacker impersonates another ship's identity or other AIS positional information such as location. Additionally, ship spoofing can also be performed by creating false AIS data representing a non-existent ship. The current survey found that very few publications [25] [26] [27] [28] focus on detecting spoofing from the AIS data.

In [25], spoofing or intentionally misreporting the location by a vessel is detected by exploiting the corresponding RADAR measurements and information from the RADAR tracking system. This approach employs statistical hypothesis testing, where trustworthy AIS data is tested for under the null hypothesis, and spoofed AIS data is tested under the alternative hypothesis. It is assumed that the AIS data follows a Gaussian distribution,

and for the spoofed AIS data a biased distance is added to the vessel position.

A joint PDF based on RADAR measurements, AIS data and spoofing distance is estimated using Clairvoyant Likelihood Ratio test and Generalized Likelihood Ratio test as described in [25]. These tests are used to compute the likelihood maximisation for each of the hypothesis, which in turn can be used to detect vessel spoofing.

In [26], the problem of vessel spoofing is tackled based on an approach that determines the average speed that is required to move between two reported AIS positions. This is calculated based on a "Haversine distance and the time required to cover that distance based on the consecutive time stamps reported by AIS" [26].

The approach discussed in [27] detects AIS spoofing based on a message-based approach rather than a signal based approach that is most frequently used. In the message-based approach, the data is assessed from an external and internal point of view of the user and the supplier respectively. In measuring the internal quality, the focus of the approach in [27] is on assessing quality dimensions of the data which include completeness, currency of the data, integrity, reliability etc. The approach suggests a method for AIS message integrity verification by computing a coefficient for data integrity using mathematical processing of Shannon's information theory. By assessing the integrity of AIS messages through the development of such approaches, the study claims that falsification or spoofing of AIS data can be detected.

In a similar message analysis-based approach, the study in [28], is currently in the process of developing techniques that detect abnormal spoofing behaviour using a combination of online and offline processing techniques such as spatiotemporal analysis, behaviour analysis, position reports from ships and other contextual data analysis of AIS messages.

Loitering can be considered as abnormal vessel movements such as a vessel moving at abnormally low speeds for its class at high sea. Additionally, loitering can also be defined as, "boat spending abnormally long time on the same area or performing slow movements around a bigger ship but without displacing itself a significant distance" [30]. In [29], AIS variables such as Speed over (SOG), Course over Ground (COG) and location are used in a big data approach for loitering detection and present a recognised maritime picture. In [30], various activity zones are analysed with respect to statistical properties that reflect zone occupancy and transition between various zones. Using this approach, loitering of skiff boats around a protected ship is discovered in [30].

Loitering can be considered as abnormal vessel movements such as a vessel moving at abnormally low speeds for its class at high sea

[All References shall be published with the concluding Part 3 of the manuscript.]

About the Author

Hema Karnam Surendrababu is currently a PhD scholar at the National Institute of Advanced Studies (NIAS), Bengaluru (affiliated to The University of Trans-Disciplinary Health Sciences & Technology, Bengaluru, India). She works as a part of the International Strategic and Security Studies (ISSSP) Group at NIAS. Her research experience comprises of Signal/Image Processing and Cyber security. Her current research focus is on the usage of Artificial Intelligence techniques for Maritime Anomaly Detection.

Email: hemaskarnam@nias.res.in

ADAPTING THE DRONE TECHNOLOGY FOR MARINE APPLICATIONS – A HIGH RESOLUTION WATER QUALITY MEASUREMENT SYSTEM USING DRONE (PART 3)

R.Srinivasan, V.Gowthaman, Tata Sudhakar, G.A. Ramadass

5.0 ADVANTAGES OF DRONE BASED OCEAN OBSERVATION SYSTEM

- Real time error free data collection is ensured with human safety during operation and it is one of the cost-effective way of data gathering at shallow water area.
- It is the most suitable autonomous technology for water quality observation at estuaries and river mouths.
- An adaptable technology for in situ measurements at Coral reef area without disturbances to the environment.
- Minimise the use of coastal observation moored buoy installations, which are vulnerable at shallow water region. This technology shall be applied easily for monitoring the ocean top layer.
- It will reduce the human based water sampling process. Instant data collection at any required location is possible.
- Large area can be covered within short time span and it requires fewer human resources. Also, this type of observation finds application in nuclear leak area where humans can't be fit.

Eco friendly way of data collection and data acquiring can be done even in locations inaccessible to humans

Eco friendly way of data collection and data acquiring can be done even in locations inaccessible to humans. The proto type units will be checked and tested at laboratory conditions to fully comply for the individual sensor functionality test, sensor interface test with electronics, complete communication control test as per data sampling protocol and data telemetry protocols. The electronics enclosure to be fitted with drone will be tested for water ingress properties. The drone and its subcomponents will undergo its components level test / full integration test; vibration test will be carried out for the fully integrated drone and measurement setup for the full load condition. Detailed test protocols indicating sustaining range and threshold will be prepared.

6.0 FIELD DEMONSTRATIONS & OBSERVATIONS

As part of adapting the drone (Unmanned Aerial Vehicle) technology for marine applications, Ocean Electronics Group at National Institute of Ocean Technology (NIOT) has recently conducted a field study on the drone stability (static & dynamic) with CTD sensor and instrumentation payload using a 10 kg lifting capacity drone. This study comprises two sections. First one is the dry test wherein the stability of drone is observed while lifting the CTD sensor as a swing load hanged with 4 m signal cable and hovering at various speed from 3 – 7 m/sec. The second section is the actual measurement cyclic test of CTD sensor assembly immersed up to the depth of 1 m in a lake/pond type of water body. This field study provided a suitability and confidence in adapting a drone (Unmanned Aerial Vehicle) for ocean observation applications.

a) Ocean Data Collections

Dry test

In this test, the CTD sensor assembly and 3 m coaxial cable weighing 4.75 kg and the mini data acquisition system, battery packs and telemetry (Open-source processor and Wifi gadget) weighing another 2.25 kg is mounted at appropriate locations in the drone assembly. The electronic gadget assembly is fitted at the bottom section just below the drone electronics controller. The CTD sensor is fitted at one end of the communication cable with a supporting nylon wire. This end is fitted at the bottom section of the drone and the other end is connected with the CTD sensor. The CTD sensor is made to hang almost 3 m from the drone. Drone is operated to lift the CTD sensor assembly to the height of 15 m wherein the static and dynamic load acting on the drone is monitored. Then the drone is made to fly horizontally 100 m with various speeds from 3 – 7 m/sec. Drone is tested with a total instrumentation payload of 7 kg.

Measurement cyclic dip test in water body

In this test, the drone was made to lift and carry the attached CTD sensor & instrumentation assembly and dips in the water body up to the depth of 1 m at various planned locations. Drone is set in to a lock position mode in every measurement location for more than 3 minutes and the data sets are relayed using Wifi telemetry. The data collected from the CTD sensor is lively received and plotted in the handheld device. The lifting, hovering and static & dynamic stability of drone is studied by operating at various speeds. The sequence of operations performed with CTD sensor data collection using the drone is shown in **Figure 15**. Alternate method such as winch with rope mechanism to lower and raise the instrument payload also under considerations.

Figure 15. Sequence of operations performed with CTD data collection using Drone

b) Sea water sampling using Drone

In this test, the automatic water sampler instrumented with necessary electronics and blue tooth devices for

Figure 16. Automatic Sea water sample collection using Drone

Figure 17. Beach topography & high Tide Line mapping using Drone

setting various parameters is mounted at appropriate locations in the drone assembly. One end of the water sampler is rigidly tied at the bottom of the drone as shown in the **Figure 16**. The water sampler is made to hang almost at 4 m down from the drone. Drone is operated in such a way to lift the water sampler to the height of 12 to 15 m and the static and dynamic load acting on the drone due to the water sampler attachment is monitored for few minutes and then the drone is flown to 300 m horizontal distance with a speed between 4 to 5 m/sec. The total payload weight attached is 5.2 kg before sampling and 6.5 kg after collected the sea water sample.

c) Beach Topography & High tide mapping

Recently carried out the beach topography and high tide line mapping works using the DJI - II type of light weight Drone in support of other groups of NIOT (Coastal and environmental Engineering group) near Uthandi coastal area (IMU- Chennai campus).

The rectangular area of 2 km in length and 100 m in width was mapped by taking a 15 MP HD camera images at 1 HZ. The image of beach topography and high tide line map derived from drone technique is shown in **Figure 17**.

CONCLUSION

Adapting the modern drone technology towards marine applications such as water quality monitoring is most viable method to collect data on ocean parameters more specifically at shallow regions. It would enormously reduce human efforts and errors when compared to coastal moored buoy systems by covering vast area with in short span of time. Design considerations such as type of drone, thruster capacity, fail safe operational needs, battery pack, high resolution instrumentation payload, battery packs for the minimum Sea operation of 60 minutes, and Computational fluid dynamic analysis for the drone and instrumentation payload is studied in detail.

The study also demonstrated and studied the functional suitability of drone for marine applications which will largely support the Ocean Data collections process. Demonstration and availability of drone based high resolution Water Quality Measurement System will definitely set a new trend and bench mark in ocean data collection covering large area. Network and constellation of more drones will aid in the quick completion observation in a defined area for strategic and operational requirement of authorities in large extent.

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About the Authors

Dr. R. Srinivasan is currently Scientist-F in National Institute of Ocean Technology (NIOT), Earth System Science Organization (ESSO), Ministry of Earth Sciences, GoI. He is the technical lead for the indigenization of Drifting Buoys with INSAT Communication, Development of capacitive coupled contactless conductivity measurement type CTD sensor and Adapting Drone and its Technology for Ocean Observation Applications. He received his B.E. from the Bharath Institute of Science and Technology, Madras University, Chennai, India in 1998 and Ph.D. degree in Electronics and Communication Engineering from VISTAS, Chennai, India in 2022. He is consistently working on the development of new ocean observation technologies and systems in the last two decades. He is member in IETE-India, Instrumentation Society of America (ISA), OSI-India and Board of Studies - VISTAS, Chennai. He has published more than 30 peer reviewed articles in indexed National/International journals and he was granted with 3 Indian patents. He worked at Kaleesuwari Refineries Limited before joining NIOT. He is researching in areas like indigenization of Ocean observation systems, sensors, Instrumentation and high resolution measurements. **Email:** rsrinivasan.niot@gov.in

V. Gowthaman received his Diploma in Mechanical Engineering in1984. He is working as Scientific Officer Grade-II in Ocean Electronics Group at NIOT since 1997. He received the Best employee award from Ministry of Earth Science, GoI in 2010. He has published over 14 Journal articles and granted with 4 Indian patents. He had worked for 9 years at National Institute of Oceanography before joining NIOT. His areas of interests are: Development of new innovative technologies for ocean applications and ocean observation platforms.

Dr. Tata Sudhakar received his M.Tech. (2004) and Ph.D. (2021) degrees in Electronics and Communication Engineering from Sathyabama University, Chennai, India. He heads the technology division groups - Ocean Electronics and Ocean Observation Network at NIOT. He received the National Geo Science Award for excellence from Ministry of Mines, Govt. of India in 2013, the recipient of Best Scientist award from Ministry of Earth Sciences, Govt. of India in 2016 and IETE – Thoshniwal Award in 2017. He has published over 30 Journal articles (peer reviewed) and presented over 60 papers in National/International Conferences. He has granted with 5 Indian patents. He had 15 years of Oceanography experience in National Institute of Oceanography prior joining NIOT. His areas of interests are development of new innovative technologies towards ocean applications, sensors, and Instrumentation.

Dr. G. A. Ramadass is presently the Director of the NIOT, Chennai. His research areas include Deep Sea Technology, Deep sea Mining, Underwater Acoustics and Marine Instruments. Presently he is coordinating a project for the development of Indian Manned Scientific Submersible 'MATSYA 6000'. Since the inception of NIOT he has been leading different technology development projects. In 2010 he won the National Geosciences award under the Exploration of Oil and Natural Gas category and NRDC award for the year 2017. He led NIOT team during the 34th Indian Scientific Expedition to Antarctica in February- March 2015. A doctorate from Indian Institute of Technology, Madras and M.Sc from IIT, Kharagpur, he handled technology development programmes leading to products and patents. He has been the Chief Scientist of several cruises and scientific explorations on-board various research vessels. He has a number of publications in the international journals, international conferences and four international patents.

NEW REGULATIONS – IMPACT OF IMPLEMENTATION OF SULPHUR 2020 REGULATION ON SEAFARERS

Ca. Ramadass Venkatarao, Aprajita Bhardwaj

I. Background

International Maritime Organization (IMO), under the objective to control harmful impact of shipping on environment, develops the regulations and guidelines to reduce pollution from ships through "International Convention for Prevention of Marine Pollution from Ships (MARPOL)". After series of studies and discussions, MARPOL Annex VI, which addresses the emissions from ships, was modified vide regulation, 14.1.3 reducing the limit of Sulphur oxide emissions from ships. This new regulation, hereinafter called Sulphur 2020, sets a limit of Sulphur content, in the fuel to not to exceed 0.50% m/m. It was agreed that 01 Jan 2020 as the effective date of implementation.

There had been continuous changes in the regulations limiting the Sulphur content (Sulphur Cap) in the fuel. Sulphur cap is 0.1% m/m when the ships are trading near the coasts of European Union and United States of America, commonly known as Sulphur Emission Control Areas and 0.5% m/m in coastal waters of China. Sulphur cap was however set at 3.5% globally, in rest of the areas. The new regulation brought down the cap to 0.5% m/m globally from 01 Jan 2020.

While there are many ways to comply the regulations, the most common approaches are either of the three methods viz, (1) cleaning all the fuel tanks and commence using of compliant fuel with Sulphur level below 0.5% m/m (VLSFO or LSMGO), (2) installation of scrubbers that would clean the exhaust gas and reduce the Sulphur emission within the stipulated level or (3) using of alternate fuel system complying with the emission requirement.

II. Introduction

Increased environmental awareness is one of the social trending that forces to simulate changes by means of new regulations. (Robins, SP, Judge T.A, Vohra N, Organizational Behaviour, 2012,). In order to effectively implement the change, extensive guidelines were developed by International Environmental Protection Committee (IEPC) of IMO, Flag States, and other industry bodies such as Classification Societies, OCIMF, Intertanko, etc. for the consistent shipboard implementation plans. (MEPC.1/Cir 878, IMO, Guidance on the Development of Ship Implementation Plan for the Consistent Implementation of 0.5% Sulphur Limit under Marpol Annex VI , 2018) The guidelines covered various factors including risk assessment, mitigation plan, modifications of tanks and cleaning of tanks, segregation capability, procurement of compliant fuel, change over plan, impact on the machinery system, related documentation, and reporting. However, varied levels of difficulties were foreseen prior implementation date such as possible challenges in availability of compliant fuel, unsure about the effective models of scrubbers, lack of shipyards availability and the possible fines by authorities for non-compliance.

Societal and technological change is one of the extra organisational stressors for the people of an organization (Luthens, 2011). Uncertainty about the possible future threat disturbs the ability to cope and results in anxiety (Grupe & Nitschke 2013). Whenever there is an external demand, Stress can be defined as a nonspecific response of the body to any demand made on it (Huffman, 2004,). Whenever there is an external demand there is an internal stress. To cope with this stress, it is essential for the seafarer to become well adapted to the expectations. The earlier regulations such as Maritime Labour Conventions, (2006), lifeboat design modifications have brought similar stresses to the seafarers.

> *Whenever there is an external demand, Stress can be defined as a nonspecific response of the body to any demand made on it*

In order to upgrade the safety of the vessels where open lifeboats were used, IMO, through SOLAS (International convention of Safety of Life at Sea), implemented regulations to have fully enclosed life boats and arrangements of hooks that could facilitate the boats being released with all ship complement inside the boat without any external assistance. However, the hook mechanism caused many accidents, and it has been widely believed that lifeboats that were meant to save lives has killed many. Even though many modifications were brought in for safety, there are still cases where the seafarers get injured or killed due to the hook mechanism(Mora T, et al, 2010).

Many a times policies and regulations meant for the larger good impacts certain sections of the society. On 08th November 2016, Government of India announced demonetisation of currencies of denominations 500 and 1000. The aim of the demonetisation was to curb black money and terrorism which was widely accepted and agreed by the society. However, the weaker section of the society, who were relying mainly on the currency transaction suffered a major blow and impacted them economically as well as psychologically. (Mukhta Naik, 2018).

This is also evident that when Government of India enforced lock down to contain the spread of covid19 in March 2020, many migrant workers and the section of the people who live on daily wages had a severe impact.

While at a larger picture, every individual is appreciative of the new regulation (Sulphur 2020) and the importance of environmental impact, the overall implementation models did not adequately identify stressors encountered by the seafarers who are at the sharp end of the implementation.

III. Need of the study

Many administrations announced severe fines and punishments for non-compliance to the new regulation Sulphur 2020. Singapore Government announced prison of 2 years and heavy fines for captains and owners of the ship which would not comply with the requirement. Many countries did not agree to the use of scrubbers within their coastal waters.

All these collectively created extra stress and anxiety amongst the seafarers, managers, operators, and ship owners.

The present study is needed to

1) Know seafarers' understanding of the regulations,
2) See how the seafarer perceive the problems in the implementation of new regulation.
3) Understand how the regulation actually impacted on the seafarer after implementation.
4) Evolve methods by which this can be effectively addressed.

IV. Objective of the study

Objective of the study is to

1) Highlight concerns perceived by the seafarers when complying with this new regulation and
2) Identify the actual difficulties faced followed by the implementation.

V. Method of Investigation (Methodology)

Research design

This study is exploratory in nature as Sulphur 2020 is a new regulation and therefore the problems encountered would be novel in nature.

The following measures were undertaken for the study:

- To get a detailed understanding of the regulations, the Research Scholar examined various related regulations and consulted experts in the relevant area.
- Based on the discussions, the research scholar developed questionnaire to identify what are the challenges a seafarer would expect in the implementation of program prior implementation of the regulation.
- Collect the incidents that happened in relation to the Sulphur 2020 after implementation (1st January 2020) till 15 November 2020.
- Analysis and interpretation of the findings.

VI. Data Collection – Sampling

For this study, convenient sampling method was used. Sample size consisted of 148 sailing seafarers who participated in the survey. Mean age of the sample was 35 years with average shipping experience of 12 years and sailing experience (sea time) of 10 years.

Sample distribution is shown below:

Details	Engine Officers	Deck Officers	Total
Senior Officers	42	39	81
Junior Officers	25	42	67
Total	67	81	148

Based on the seniority and the department following groups were formed.

1) All participants (All Engine and Deck, Senior and Junior Officers). N =148
2) All Senior Engineers (Chief Engineers and Second Engineers), n=42
3) All Senior Officers (Masters, Chief Engineers, Chief Officers, Second Engineers), n=81
4) All Engineering officers (Chief Engineer, Second Engineer, Third engineer, Fourth Engineer and Electrical officers), n=67.

VII. Tools used for the study

The survey questionnaire was prepared by the research scholar who probed about different aspects of implementation of the new regulation and challenges foreseen during implementation.

The questions were generated after interviewing ten senior office superintendents who are well versed with the regulations. While there are multiple ways to implement the regulation, this study is focused only on two popular models, installing scrubber onboard which would clean the exhaust gas to reduce the emission or using compliant fuels such as Very Low Sulphur Fuel oil or Low Sulphur Marine Gas oil.

Since the senior superintendents (from Office) were experts in fuels, engine, new regulations and in the implementation, it was important to know which method was preferred (of the two) and the pros and cons of that system. This information can be sought by simple direct questions which were made the part of the interview. The interview with the superintendent consisted of one closed ended question on the preference to scrubber system or compliant fuel. The other was open ended on the major advantages challenges that are faced in those approaches.

The questions asked were:

Considering a ten-year-old vessel, which is the best method for implementing the new regulation – Scrubber installation or using compliant fuel?

What are the major challenges you foresee in both above approaches?

Interview with senior superintendents revealed various issues that may be faced by the seafarers because of new regulation which has potential to cause anxiety and stress.

It was identified that following were the various conditions that has the potential to cause anxiety and stress to seafarers,

Extra Workload

Physical and mental fatigue

Work related incidents

Penalisation / Criminalisation due to non-compliance

Additional procedures and paperwork

Neglect of other machinery

Approach by various Port State control authorities

Level of training provided by the companies

Additionally, following were considered as the conditions having potential to cause anxiety and stress when using new scrubber installations for compliance:

Hazard inside Engine Room due to additional sea water pipes.

Hazard due to passing of scrubbed water pipelines in Engine Room

Machinery related problem within scrubber operations.

Following were considered as additional conditions having potential to cause anxiety and stress when compliance fuel usage is considered for compliance:

Increase in machinery issues due to compliant fuel

Fear of punishment when usage of compliant fuel (especially if fuel was found to be higher in Sulphur content)

Compatibility issue of the fuel

Additional challenges during fuel change over procedures.

With all such inputs, questionnaire was made with brief introduction of the regulation and demographic details. Eleven statements of concerns were raised under scrubber installation as the mode of compliance and Twelve statements under using compliant fuel as the mode of compliance.

The statements were to be read and their feeling to be answered using a Likert scale ranging from 1-10 where 1 being low and 10 being high.

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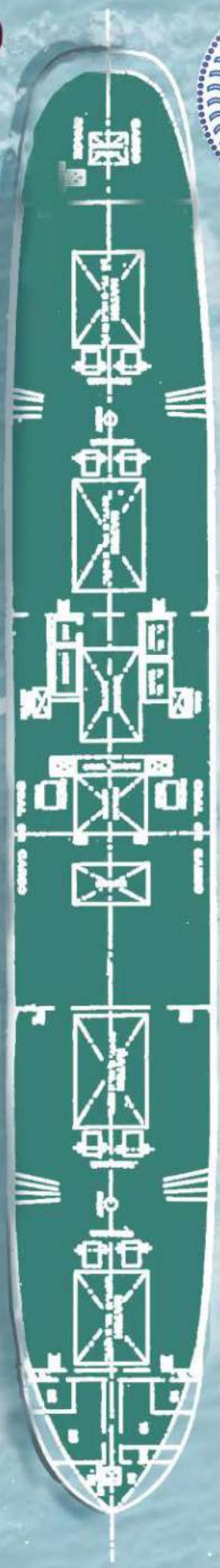

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Additionally, to understand how the seafarers are prepared to handle the stress and anxiety, seven more questions were asked, which are as follows:

Do you think you are fully prepared to handle the new regulation without any issue?

How do you intend to handle the additional pressure due to new regulation

Gain More knowledge by attending seminar

Read more materials

Avoid joining vessel until the situation is settled

Face the challenge as it is without any preparation.

Any other feedback – an open-ended question

Willingness to share contact details

If yes, then details of e mail and telephone number.

Final questionnaire was shown to the experts for verifying the content validity.

From a fleet of 221 vessels, a list of various issues was obtained following the implementation of Sulphur 2020 for a period from 01 Jan 2020 to 15 November 2020. A qualitative study was done on the types of issues faced and reviewed against the results obtained prior to the implementation.

Procedures: Final questionnaire was given to the seafarers who were visiting the organisation for training program as hard copies. The filled in forms were transferred to a digital code using Microsoft excel. The data was statistically analysed.

Analysis: Mean of the scores and standard deviation were calculated for the entire group and sub-groups. T scores were used for comparing groups based on their seniority.

All participants (All Engine and Deck, Senior and Junior Officers). N =148, All Senior Engineers (Chief Engineers and Second Engineers), n=42, All Senior Officers (Masters, Chief Engineers, Chief Officers, Second Engineers), n=81, All Engineering officers (Chief Engineer, Second Engineer, Third engineer, Fourth Engineer and Electrical officers), n=67.

Additionally, based on analysis many other sub-groups data, interpretations were made by comparison of means.

- Seniors, more than juniors, feel that scrubber installation might affect their daily workload, functioning and increase hazards and machinery problems.
- There is no difference between seniors and juniors on anxiety and stress level due to regulations change.
- There is no significant difference between seniors' and juniors' perception of problem they face due to fuel compliance.
- All groups felt that scrubber installation as the option for compliance will create more stressful condition than opting for use of compliant fuel.
- The highest level of concern was Anxiety created due to approach taken by various port State control authorities.
- Hazards of additional pipelines carrying large quantities of sea water inside the engine room was felt to be the next high concerned condition.
- Criminalisation of seafarers due to non-compliance was the next high concern followed by extra workload for ship staff and additional procedures and paperwork.

VIII. Review of incidents that happened post implementation onboard the ships.

After implementation of the regulation in 01 Jan 2020, the incidents happened were followed in an organisation which was managing about 221 vessels. Out of the 221 vessels, 59 were fitted with scrubber installation to comply with the regulation. Remaining 162 vessels carried out fuel change over procedures and started using compliance fuel.

From 01 Jan 2020 until 15 November 2020, there were about 45 issues reported in relation to the new regulation. Of which, 34 issues were related to scrubber and 11 related to use of compliant fuel.

Of the 59 vessels where scrubber was fitted as the means of compliance, 34 issues were reported. This can be categorised as follows:

- Malfunction of scrubber equipment – 21
- Leakage from the scrubbed water system – 6
- Leakage from the seawater pipelines for scrubber – 4
- Possible penalisation due to potential non-compliance – 1
- Work related incidents related to scrubber fittings – 2

Issues reported on the scrubber usage was reviewed against the initial risk assessment to identify the gaps. In one of the vessels, there was a minor fire incident while the installation of scrubber was in progress without any injury to the personnel.

Of the 162 vessels where, compliant fuel was used as the mode of compliance to the regulation, 11 incidents were reported.

The categories are as follows:

- Fuel compatibility issues – 3
- Issues on machinery due to compliant fuel – 6
- Work related incidents – 2

These incidents were also reviewed against the risk assessment that was prepared prior to the implementation. This was to identify the gaps in identification of hazard, estimated risk and effectiveness of the control measure against the conditions at which incidents occurred at the later stage. For those ships where supply of compliant

The mean of the data are as follows:

		Overall		Senior Eng Officers		All seniors		All Engineers	
S.No	Statement		Com		Com		Com		Com
		Scrubber	Fuel	Scrubber	Fuel	Scrubber	Fuel	Scrubber	Fuel
1	Extra workload for ship staff	6.84	4.99	6.92	4.71	7.26	4.98	6.89	4.53
2	Fatigue related problems	6.1	4.5	6.13	4.17	6.51	4.37	6.08	4.13
3	Work related incidents	6.19	4.44	6.58	4.67	6.65	4.49	6.26	4.39
4	Additional Paperwork	6.87	5.28	6.71	4.75	6.95	4.93	6.74	5.05
5	Penalisation / Criminalisation	6.51	5.07	6.96	4.88	6.95	4.86	6.89	4.79
	Neglect of other machinery								
6	issues	5.91	4.01	5.88	3.96	5.98	3.79	5.66	3.79
7	Anxiety due to PSC approach	7.14	5.84	7.33	5.79	7.47	5.74	7.08	5.61
	Level of training provided as of								
8	now	6.22	5.93	5.54	5.21	5.77	5.67	5.76	5.32
	Additionally for Scrubbers								
	Additional Hazard due to								
1	Pipeline Passing thro	6.34		7		7.07		6.24	
	Additional hazard due to								
2	scrubbed water pass thro	6.28		6.71		6.79		6.39	
	Machinery problems in scrubber								
3	operations	6.41		6.79		6.91		6.37	
	Additionally for Compliant Fuel								
	Machinery problems due to new								
	fuel		4.86		5.38		4.98		5.24
	Fear of punishment while								
	complying compliant fuel		5.69		5.38		5.56		5.29
3	Compatibility issues		5.79		5.71		5.93		5.68
4	Fuel change over procedures		5.68		5.46		5.86		5.24

fuel was planned, management of cleaning the tanks with high Sulphur fuel posed big challenge. The ship crew were not familiar and not having enough equipment and machinery onboard to manage the large volume of sludge from the old fuel which had to be landed ashore. In one of the ships, while landing the sludge using containment boxes, damage occurred during crane handling, causing minor spill on the jetty which resulted in fine.

IX. Results and Findings

The mean scores of the responses indicated that certain conditions caused more anxiety and stress than others. They are analysed in the rank order of seriousness.

Scrubber installation as the means of compliance had higher concerns compared to the usage compliance fuel.

Scrubber installation on the board the ships for cleaning the exhaust gas is a major project involving high cost. The scrubber installation would need large volume of space in the engine room and funnel deck areas. There would be pipelines carrying sea water from sea chest and pumped up to the higher most deck on the ships. Additionally, the water that scrubbed the exhaust gas would be acidic. The treated water would pass down from higher decks to bottom part of engine room through pipelines. Leaking from these pipes can cause flooding and injury to the seafarer working in the vicinity.

The Compliant fuel usage, on the other hand, does not require major modification or installation of machinery. It requires extensive cleaning of fuel oil tanks that presently carry high Sulphur. The ships are built mostly with machinery designed for running in high Sulphur fuel. Whereas compliant fuel would have varied lubricity and different composition compared to the regular high Sulphur Fuel. Machinery manufacturers and experts suggested adding of chemicals to the compliant fuel, changes to the setting of the machinery and modifications to the regular maintenance schedule to address the potential issues in the usage.

The highest concern was the anxiousness created due to the **approach by port authorities** who would verify the compliance. This condition scored highest means in both models of compliance. All the regulations are verified for compliance by flag state authorities and by classification societies prior issue of certificates and during periodical inspections. Additionally, the port State Authorities of the country where the vessel calls, would carry out inspections of the vessels and impose fines, issue findings and may detain the vessels for non-compliance. There were many communications in this regard from various port State authorities. Singapore government announced 2 years of imprisonment and fine for the masters and ship owners of the vessels who do not comply. Such communications and their past experiences might have caused anxieties.

Second highest concern was the **hazard due to sea water pipelines** carrying huge amount of water. There was a video popularly spread through social media of a popular incident, where the leakage from such pipe would be flooding the engine room. Leaks in these pipelines can cause flooding in the engine room as well as injury.

Seafarers are worried about being penalised by the authorities for non-compliance. **Criminalisation of seafarers** is the most talked in the maritime industry. Judiciary of the port states invariably establish blame on the crew for accidents where loss of life during any incident and pollution prevention. It has been established at various occasions that are the common occurrences where the seafarers are penalised by the authorities and invariably imprisoned and kept along with criminals. This condition has scored next high with fear of non-compliance due to any failure.

Next concern raised by the seafarers are the **additional procedures and paperwork**. Every new regulation is bringing additional levels of paperwork and procedures creating huge workload for the seafarers.

X. Limitations

The study was done on the seafarers working in one organisation. Other seafarers from different organisations were not considered. Since regulation being common for all organisations, researcher considered taking information from one organisation. Data was only taken from the seafarer who were on leave and visited the organisation for training. Sailing seafarers were not considered.

XI. Conclusion

Seafarers were able to foresee the problem that might arise in the new regulations. Even though many publications and guidelines were available for the easier transit to the new regulations, the organisations and the seafarers experienced anxiety and stress prior to and during the implementation process. The studies imply that organisations and industry bodies must consider more possible scenarios for the failures and develop related solutions to mitigate same. The studies also imply that many associated studies such as making efficient models of scrubber, alternate means for reducing emission levels, technological solutions to machineries when using compliant fuels etc.

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Email: v.ramadass@gmail.com; dr.aprajitabhardwaj@gmail.com

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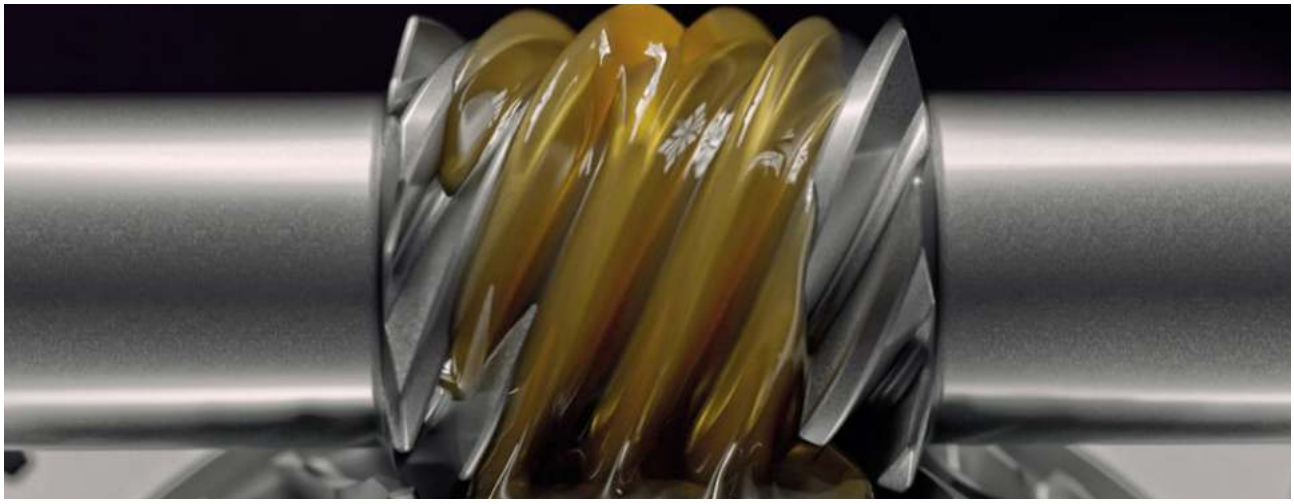
LUBE MATTERS # 17

ROLLING ELEMENT BEARING (GREASE) LUBRICATION



Sanjiv Wazir

Introduction

The main function of the lubrication of rolling element bearings is to prevent or reduce friction and wear between rolling and sliding contacting surfaces. Lubrication is one of the most important influencers of bearing performance and bearing life.

Rolling & sliding contacts in a bearing

Rolling contact mainly occurs between the rolling elements (ball/roller/needle roller) and raceways (inner and outer rings). Sliding motion is caused by elastic deformations of the parts rolling against each other, the curved geometry of the rolling surfaces, etc. In a roller bearing, sliding contact also occurs between the cage and rolling elements or between the roller end faces and ring surfaces (1).

Other functions of the lubricant in the bearing are:

- anti-corrosion protection
- heat dissipation from the bearing (in the case of oil lubrication)
- flushing out of wear particles and contaminants (recirculating oil lubrication with filtration of the oil)
- support the sealing effect of bearing seals (grease collar).

Grease Lubrication

While both oil and grease are used for bearing lubrication, over 90% of rolling element bearings are grease lubricated. Most medium-capacity electric motors (shaft size 10 mm -100 mm) are fitted with rolling element bearings and are grease lubricated. Motor bearing grease lubrication can be considered as the main example for this article.

How grease works

Grease consists of base oil, thickener, and additives. The oil is held in the matrix formed by the thickener fibres.

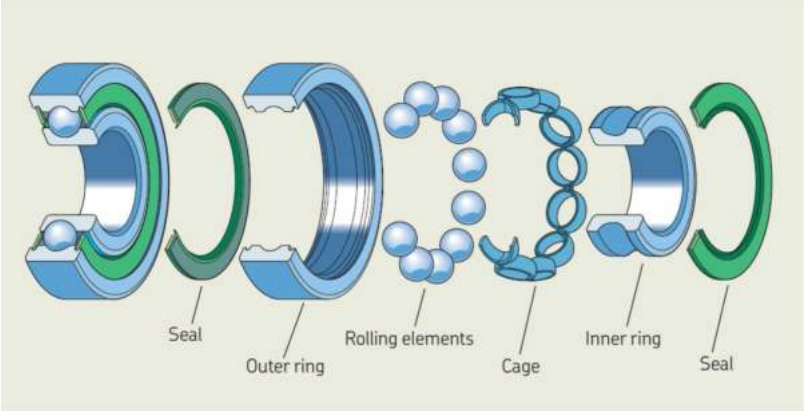


Figure 1. Sealed Bearing Components, (1)

While both oil and grease are used for bearing lubrication, over 90% of rolling element bearings are grease lubricated

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The thickener carries and retains the oil (+additives) in and around the rubbing zones (2).

The flow of grease and/or oil that is separated from the grease (grease bleed) in a rolling bearing is very complex due to the complex internal bearing geometry, large shear variation and complex rheology (3).

Churning mode: Grease lubrication in a rolling bearing starts with a "churning phase" characterised by macroscopic grease flow, which leads to a temperature rise (4). This mode describes the condition when thickener is also present in the lubricating film between the rubbing surfaces. This can also occur while re-greasing, or if excessive grease has been packed into the grease cavity.

When thickener is present between the rubbing surface, the rolling elements need to plough through the grease, resulting in increased friction and temperature. As the rolling elements repeatedly run over the fibres of the thickener, the fibres get crushed into smaller sizes. These smaller fibres are no longer able to form the matrix for holding the oil. As the small fibres and oil mix up, the viscosity of the oil- fibre mix also changes. The combined effect of all these changes is increased friction, rise in temperature and rapid degradation of the grease (4). Hence it is important to transition from the churning phase at start up to the bleeding phase as soon as possible. This can be achieved by correct initial filling and using the recommended regrease quantity and regrease interval.

(An exception where churning mode is helpful: Rolling bearings operating at very low speeds under heavy loads should be lubricated with a grease that has a high viscosity base oil containing EP additives and the thickener should contribute to the surface separating film).

Bleeding mode: During the churning phase, grease reservoirs are formed from where oil separation takes place. This, so-called "grease bleed", plays an important role in the tribological performance of the bearing. The bleed oil, together additives and small amounts of thickener, is the principal mode of lubrication of the bearing contacts (3). At higher load/speed, the stress on the surrounding grease increases, and more oil bleeds out of the grease into the rolling area. When stress reduces, the oil gets reabsorbed into the thickener matrix (4).

Bearing Seal Configurations and Grease

Bearings are supplied in different sealing configurations: open, shielded and sealed.

Open bearings are easy to grease/regrease. They run cooler than the shielded and sealed bearings, and there is no risk of the shield collapsing. However open bearings are more prone to entry of contaminants, grease churning, and escape of grease to the motor windings.

Shielded bearings are fitted with metal shields in the outer race. There is a gap between the shield and the inner race (125 to 375 µm) that allows grease to enter and exit the bearing cavity. Shields may be fitted on both sides (2Z) * or one side (Z)*, (**Figure 2**). Bearings may be installed with a single shield facing the grease supply, or a single shield facing the motor, or double shields.

The shield(s) help reduce grease churning, regulate the flow of grease to the bearing, restrict the entry of contaminants, reduce the risk of grease entry into the motor windings. However, shields cause the bearing to run hotter (than open bearings) and where shield is facing the grease supply, regreasing must be done with caution to avoid the risk of shield being pushed into the bearing.

Sealed bearings are fitted with elastomer seals most commonly on both sides (2RS**) or one side (RS**) (**Figure 3**). The seals are snap-fitted in the outer race & seals against the inner race. 2RS bearings are lubricated before the seals are fitted and are not expected to be regreased. These bearings are "lubed for life" bearings. (**Figure 3**).

While the seals prevent contamination or loss of the grease, they do not allow heat loss from the bearing and hence these bearings (and grease) run hotter (than open and sealed bearings). Hence their life is shorter than bearings that allow relubrication because the oxidative life of the base oil at elevated temperatures now becomes the limiting factor. These bearings are typically used in small motors (<7.5KW).

Greasing Principles

Initial Fill

In general, during installation, grease is filled about one third to one half of the free volume of the bearing,

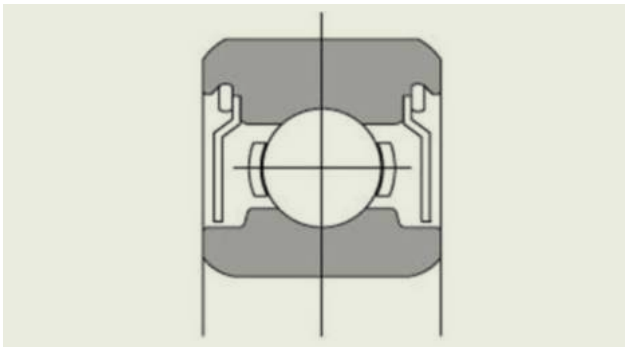

Figure 2. Double Side Shielded Ball Bearing (2Z). Note gap between shields and inner race (5)

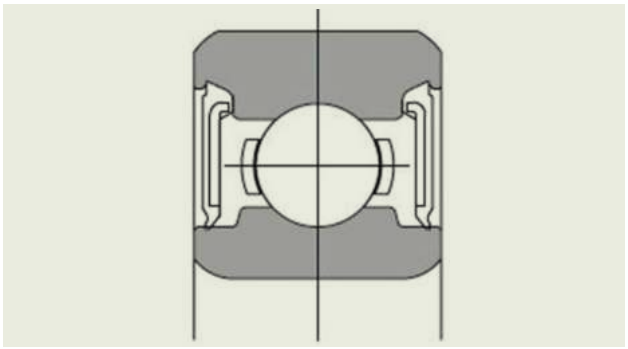

Figure 3. Double Side Sealed Ball Bearing (2RS). No gap between shields and inner race (5)

**** Z, 2Z, RS, 2RS are SKF terminology. Other bearing makers may use different terms.**

> *Open bearings are easy to grease/regrease. They run cooler than the shielded and sealed bearings, and there is no risk of the shield collapsing*

though this may vary with the structure and inside space of the housing.

At installation, Open, RS & Z bearings for low-speed operation should be filled 100% and the housing also completely filled. For high-speed applications the bearing free space should be 1/3rd filled.

2RS & 2Z bearings are factory filled with a high-grade grease that fills about 1/3rd of the free space in the bearing. The housing cavity should be filled 80-90% with grease that will act as a seal to keep contaminants out.

2RS and 2Z should not be re-lubricated. The service life of these bearings is determined by the ***grease service life, rather than the bearing fatigue life.***

When greasing bearings, the grease should be distributed evenly in the free space between the rolling elements and raceways. The bearings should be turned by hand until all internal surfaces are covered.

Mixing greases with of different types (of thickeners) should be avoided, unless compatibility has been confirmed.

EP type greases are usually used in heavily loaded bearings. In electric motor bearings, EP performance is usually not required. EP additives are usually corrosive, and care should be taken to avoid EP type grease leaking into motor windings.

SKF recommend freshly greased bearings should be operated at low speeds during the running-in period. This enables excess grease to be displaced and the remainder to be evenly distributed within the bearing. (6)

Freshly greased bearings initially run with a relatively high frictional resistance due to the churning of excess grease, which takes time to work its way out of the rubbing zone. If they are run at high speeds without a running-in period, the temperature rise can be considerable. For open bearings, this time can be minimized by applying the required quantity of grease distributed evenly on both sides of the bearing during assembly (4). A grease with good channelling properties helps move/keep the bulk grease away from the contact areas, minimizing churning and frictional losses.

Pre-fill Any Long Grease Delivery Pipes

For motors sent to external firms for repair/overhaul, specify the grease that is to be used or find out what they have filled.

More bearings fail from over-greasing than under-greasing. OEM specified regreasing quantity and frequency is a good starting point for regreasing schedule. Over time, these may be altered as based on user experience and performance record, especially under adverse ambient conditions (dusty, water/seawater spray, vibrations/high temperature, etc).

Skidding and slipping of roller bearings

The high rotational resistance caused between the rollers and cage when a large quantity of grease is tightly packed in the bearing, can cause a lightly loaded bearing to skid. E.g., When a motor is tested under “no-load” condition after an overhaul.

Also, under low load conditions there may not be enough frictional contact between the rolling elements and the inner raceway. Instead of rolling, the elements begin to slip/slide on the raceway. This mainly occurs under low load and high acceleration/deceleration conditions.

When heavy sliding/skidding occurs, the lubricant film thickness is not thick enough to separate the contacting parts resulting in damage. Damage may be indicated by a high pitched, shrieking sound after some running.

Some Tips for Re-greasing Motor Bearings

- Bearing should be re-greased when the motor is operational or shortly after stopping while the grease is still hot and less viscous.
- Identify grease in use and apply grease from same thickener family or a grease that is known to be compatible with the existing grease.
- Use different grease guns for different greases. Ideally colour mark the guns for quick identification.
- Remove the grease relief/purge plug from the housing.
- Ensure purge hole is clear. High temperature or long gap between regreasing may solidify old grease/ thickener and block the hole.
- Clean the grease fill fitting (Zerk) to prevent contamination entering the spaces.
- Clean the grease gun fitting to prevent contamination being pumped in.
- Check OEM specified regreasing quantity.
- Note pumping capacity of grease gun (grams/stroke) if mentioned or measure it before putting a grease gun to use.
- Determine number of strokes that are required to pump in the specified amount.

- Pump slowly (about 3 -5 seconds per stroke) until the specified quantity has been supplied or until fresh grease flows out of the relief/purge plug.
- If back pressure is felt, stop pumping.
- Allow the motor to run for 10-30 minutes before refitting the purge plug.
- Motor runs warmer for some time after regreasing. If proper quantity has been filled, temperature will return to normal shortly.
- Over-greased bearing temperature may not drop after the initial rise. Bearing expands faster than housing, causing bearing tolerances to decrease and temperature to rise further.
- Ultrasound monitoring of the bearing, as the grease is being pumped in, can help determine how much to apply and when to stop further greasing.

Conclusions

Bearings have been and will continue to be one of the primary usage of greases. Proper lubrication has a major impact on bearing life. The art of grease lubrication of bearings is more complicated than it might appear at first glance. Understanding its "mechanics" is key to equipment well-being.

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About the Author

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

He can be reached at sanjiv@lukoil.com.

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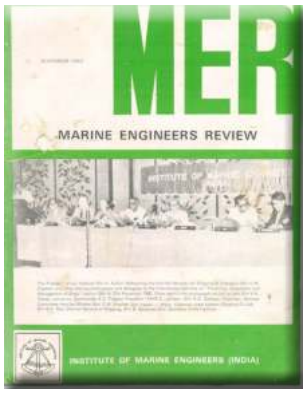
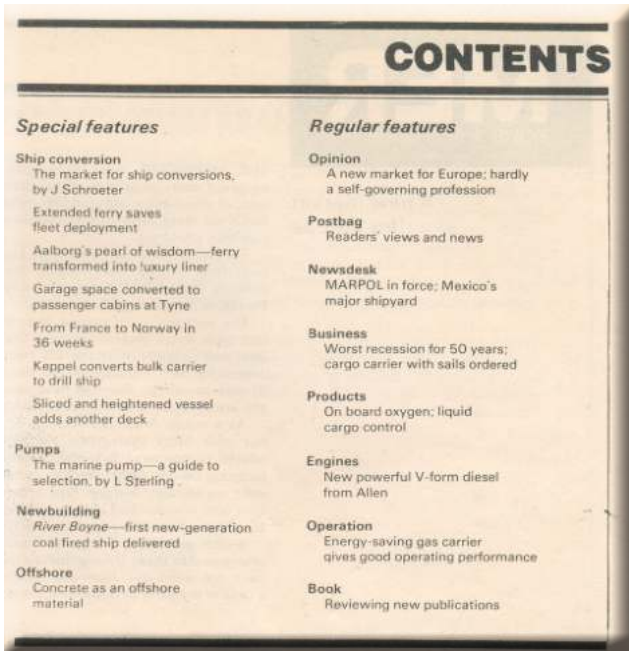


MER... Four decades back... The November 1982 Issue

This issue has some interesting sections. I would choose the conversion by Aalborg... the ferry transformed into a luxury liner. The attachment of sponsoons (addition of deadweight and displacement) from 'a little aft of midship to around the stern' has been a successful remedy for such conversions. There is at least one Indian vessel I am aware of, where such modification did well with time.



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Operation
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Book
Reviewing new publications

The next on is on the selection of pumps, which I am sure will be of interest to all. Some excerpts have been inserted.

The marine pump—a guide to selection

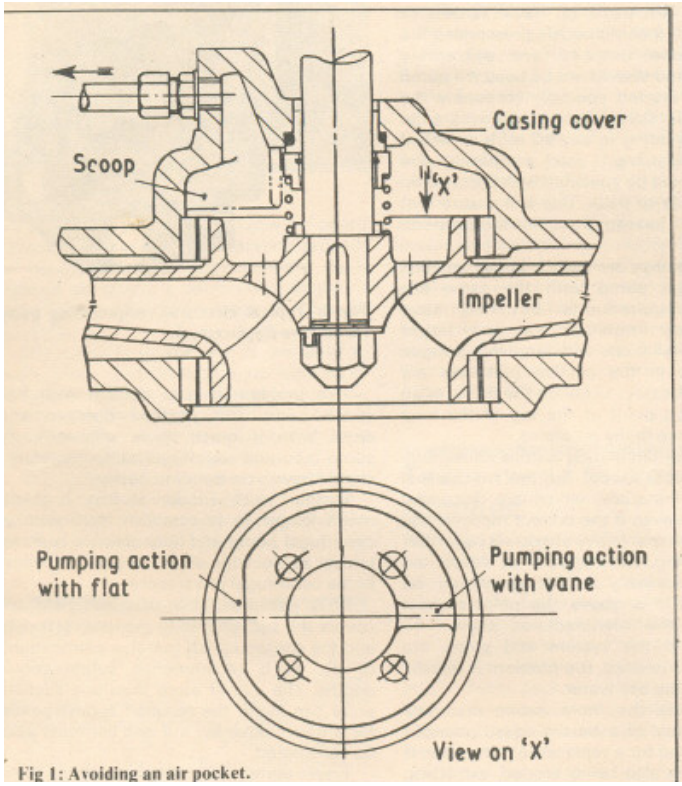

Fig 1: Avoiding an air pocket.

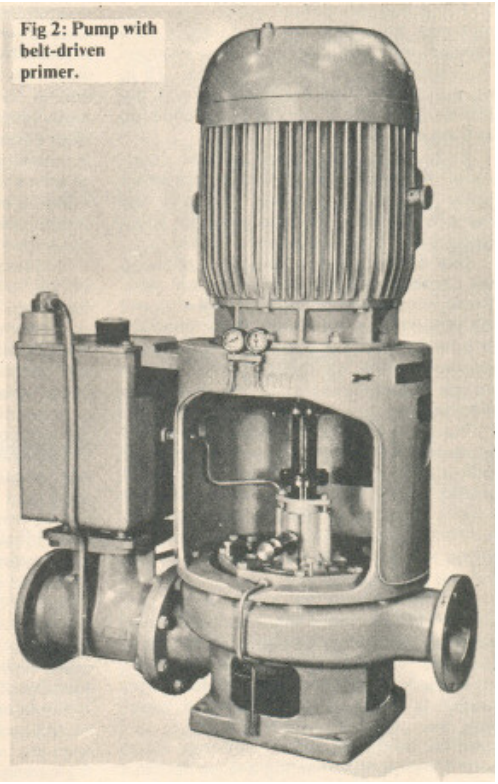

Fig 2: Pump with belt-driven primer.

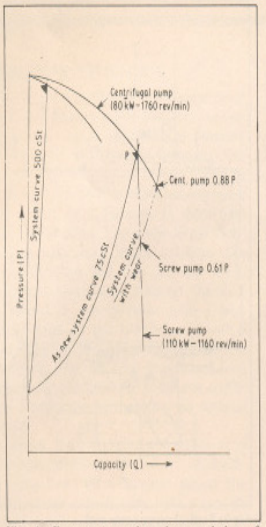

Fig 4: Pressure/capacity characteristics of various types.

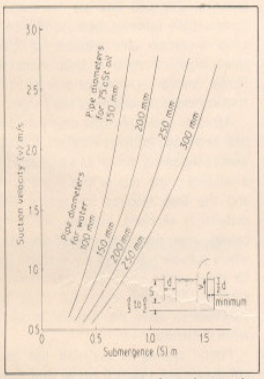

Fig 5: Submergence depths for various suction diameters. It is essential that sufficient oil covers the suction bell to prevent vortexing.

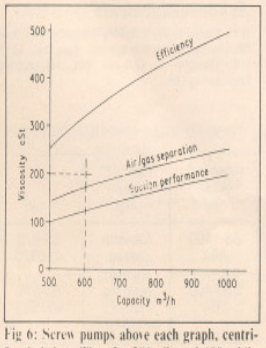

Fig 6: Screw pumps above each graph, centrifugals below. Thus for 200 cSt and 600 m³/h, a centrifugal pump is more efficient.

face loadings at all pressur
seals are recommended for
balanced seals above this
degree of dry running can b
balanced seals, provided s
the faces are

Bearings

The question of intern
bearings arises on all rotar
rotary, positive-displacemer
ing a liquid with good lubrica
internal bearings permit the
shaft seal. A centrifugal pu
liquid will also normally only have one mechanical seal and the use of internal bearings gives a simpler construction.

For a pump on static lift the bearing arrangement should be reconsidered. If priming is confined to start-up, internal bearings should be used. However, on stripping duty the likelihood of dry running indicates use of external bearings.

On viscous liquids, such as fuel oils, with limited lubricating properties, the problem is a little more complex; but, as the pumps are usually positive-displacement and the need for complete stripping is infrequent, the use of internal bearings and one seal is an advantage.

On pump-room cargo pumps both mechanical seal and internal bearings are problems because of the air/gas handling. The design should aim at external bearings and minimum mechanical seals. This would normally mean centrifugal pumps with an upper bearing bracket on vertical pumps, and 'back' pull-out on horizontal types. On the positive displacement pumps—usually timing-geared double-screw—the gears must be external to the pumped fluid as must one set of bearings. This means at least two mechanical seals.

If the pumps are vertical, the timing gears should be at the top. To avoid mechanical seals and external bearings at the bottom where maintenance is extremely difficult, internal bearings should be used. Their extraction and replacement should be carefully examined, not only on the drawing, but also on the installed pump. These internal bearings can only be used if a feed can be brought to them from upstream of the non-return valve to ensure lubrication during stripping. As internal bearings on such liquids have a shorter life external bearings should be used on horizontal pumps even though this means two more mechanical seals.

With liquids such as molasses, positive-displacement rotary pumps must be used. The aim should be one shaft-sealing point, which means internal bearings. Very low running speeds will give a reasonable life, both to the bearings and the shaft seal. The slow running also creates less heat.

Fresh-water pumps are usually centrifugal, either on a flooded suction or primed only on start-up. Internal bearings should be used, unless a large axial thrust has to be taken, when, usually, an external anti-friction thrust bearing should be used.

On sea-water pumps internal bearings, whilst having a shorter life than external, seem to give adequate service; a simpler construction seems to indicate their choice. If the sea-water is highly polluted with

On pump-room cargo pumps, bearings, both mechanical seal and internal bearings are problems because of air/gas handling. The design should aim at external bearings and minimum mechanical seals.

especially if ready availability of spares is considered. In future, as more vertical pumps are used on land, the special requirements of marine pumps will tend to become standard features of the land-based vertical pump.

However, there should be special ISO standards for vertical centrifugal pumps, provided the marine world takes part in their formation. An ISO standard for horizontal, end-suction centrifugal pumps (ISO 2858/BS 5257) has been in existence for several years with obvious advantages.

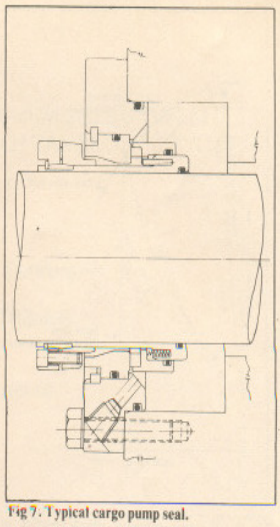

Fig 7. Typical cargo pump seal.

Materials

Non-centrifugal pumps are usually on

With liquids such as molasses, positive displacement, rotary pumps must be used. …

Very low running speeds will give a reasonable life both to the bearings and the shaft seal

live up to expectations. Soundness of

Table shows the Recommended materials.

Note the use of tufnol.

to cast and flaws are often present in the difficult-to-cast sections characteristic of centrifugal pumps. Other, more exotic, materials (eg, cupro-nickle) are less readily available. Table 1 recommends materials which, in a correctly designed system, should give a good life at a reasonable price and not create untoward problems with spares.

In fresh-water systems a gunmetal impeller is recommended as the extra life is cost-effective compared with a cast iron impeller.

Asbestos-based phenolic resin can, and been used for large impellers. It is not considering, except as a palliative for bled pump, due to loss in efficiency he time required for spares. This al is excellent, however, for pump wear rings and should be used suitable tube sizes are available (ie, ost pumps up to 200 mm diameter n). The 'dry' clearance must be sed to allow the material to swell when immersed.

Plastic coating of materials has also attracted much research but to date there are too many failures on the awkwardly shaped pump castings to permit wide usage.

A BS publication DD 38 is recommended for study of metals used in pumps.

Acknowledgements

With thanks to the following companies for their help in preparing this article—Cannings Seals Ltd, Dawson & Downie Ltd, Hamworthy Engineering Ltd.

Table 1: Recommended materials for various parts.

Piece part / Duty	Pump casing	Impeller	Impeller* wear ring	Casing** wear ring	Shaft
Sea-water pump	BS 1400 LG4	BS 1400 AB2	BS 1400 AB2	Asbestos based phenolic resin (eg tufnol, ferrobestos)	BS 970 431S29
Fresh-water pump	BS 1452 GR260	BS 1400 LG4	BS 1400 LG4		BS 970 431S29

*Should be fitted on sea-water pumps fresh water pump fitting is optional.
**Where material size is available, otherwise BS 1400 LG4.

MER NOVEMBER 1982

Another article of intrigue is the one proposing concrete as a constriution material for offshore strutures and also for ships. A picture of the proposed LNG tanker with 'monoolithic concrete hull reinforced by both presetressed and unstressed steel'.

We have inserted 2 interesting discussions from the Post Bag. The one on CO_2 is worth a read and contemplation, especially for the sailing, practicing marine engineers.

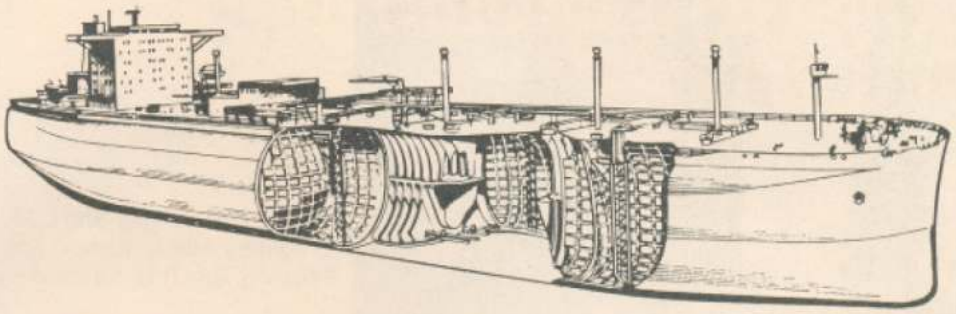

Fig 2: A concrete LNG carrier with the hull reinforced by prestressed and unstressed steel. This was developed by Dytam, and complies with IMO's requirements.

Corrosion of tin-base babbit bearings

Sir,

The following case history seems to support the conclusions contained in the paper on tin-base babbit bearings by Dr R W Hiley, published in the Transactions of 1979, Volume 81.[1]

The case concerns a Ljungström radial-flow turbo-alternator developing 18·80 MW at the economical rating and 23·50 MW at the mcr. The unit was commissioned in March 1972 and subsequently operated under base load in regular service until bearing failure in 1974.

Inspection showed all the classical symptoms of electro-chemical corrosion. Each turbine bearing revealed to a varying degree, hard black surface layers and patches which proved to be highly resistant to penetration of a knife blade. The latter rough hardness test is indicated in Bryce and Roehner's paper.[2]

Prior to bearing failure, a lubricating oil analysis had revealed chloride contamination, indicating tube failure in the sea-water cooled lubricating-oil heat exchanger. Further analysis, based on the Institute of Petroleum's Method IP 77/72 'Salt Content Crude Petroleum and Products' revealed an NaCl content of 0·003% by weight, equivalent to 30 ppM or 1·1 gal of sea water per 1000 gal lubricating oil change. This rate of contamination could account for the electro-chemical corrosion.

Electro-chemical corrosion and subsequent bearing failure was also diagnosed for a failure in the right-hand closed circuit alternator air cooler, employing sea water as the primary coolant. This had developed leaking tubes and, due to sea-water contamination of the cooling air, the insulation resistance on the right-hand alternator rotor had fallen to 40–50 x 10^3 ohms, compared with the required 12 x 10^6 ohms at 40°C.

The following additional factors would have contributed to the onset of electro-chemical corrosion in the bearings.

1. The circulating currents in the circuits, which are especially heavy before the contra-rotating alternators lock into step at 1200 rev/min.
2. The electro-static dc shaft voltage, generated by the flow of steam over the turbine blade.
3. Possible bonding faults in the earthing strap associated with the turbo-alternator.

I might add that the Committee of Enquiry were more inclined to blame the bearing failure on lack of lubricating oil but, knowing that these were four interconnected lubricating circuits, plus the independent auxiliary start-up/shut-down turbo-driven lubricating oil pump, I was reluctant to accept their hypothesis. After 18 years as a sea-going marine engineer, followed by 23 in power stations, I felt able to recognise the characteristics of bearing failure due to lack of lubrication.

H W Alcock

Victoria, Australia

[1] Hiley, R W 1979 'Corrosion of tin base babbit bearings to form tin oxides' Trans IMarE, Vol 91 (TM3) pages 52–66.
[2] Bryce, J B, Roehner, T G 1961 'Corrosion of tin base babbit bearings on marine steam turbines' Trans IMarE, Vol 73 pages 377–392.

Points to ponder:

1. **Electro-chemical corrosion**
2. **Seawater tube failure in coolers leading to LO contamination (tests showing increased Chlorides)**

Additional factors for EC Corrosion:

1. **Heavy circulating currents (alternators)**
2. **Electro-static dc shaft voltage (from steam flow over turbine blade)**
3. **Bonding faults in earthing straps**

faltering cargo movements. Freddie Laker, on the other hand, lost everything because he had no such clause. Under what circumstances is such a risky switch allowed?

Mr Chao sees no disadvantage in giving a personal guarantee as security. But no business is free from risk. What happens if several of a company's charters go bankrupt?

I wonder if Mr Chao believes that the sun will never set for Hong Kong shipowners. Their strength, I believe, stems from long-term charters due to their Japanese and other connections. But others too could get favourable terms The problem of long-established shipowners is that their fleets are ageing and Hong Kong ships are relatively new. They are more economical to operate, and further dramatic improvements in fuel consumption may be expected.

The charterer's choice will always be for the newer ship with low fuel consumption. Once the Hong Kong shipowners too have a majority of over five year olds, how do they expect to cope?

B S Makhija

Hong Kong

The Editor,
Marine Engineers Review,
16th Floor, Nirmal,
Nariman Point,
BOMBAY - 400 021.

Post Bag

Dear Sir,

We have gone through in detail about the problems connected with CO2 system malfunction mentioned by you in your magazine 'Marine Engineers Review', August, 1982, Problems under Page No. 17.

We would like to give our views and clarifications for the same.

The incident referred in August, 1982, issue of Marine Engineers Review regarding failure of CO2 system on Swedish Club Vessel has been studied by us in detail. It is noted that the wire transfer system was broken leading to non operation of the CO2 system. There could be only two reasons, one that the wire transfer system has been jammed and second the system might have kept locked, for some reason.

To the best of our knowledge all the CO2 system has alternate manual provision for operating the system in the event of failure of Remote Operation System through wire transfer or pilot cylinder each cylinder can be operated manually also.

It appears that the engine crew of this ship tried to extinguish the fire with portable extinguishers which resulted in loss of time. The flare up of fire due to loss of time could be the reason for extensive damage and it also might have created substantial panic resulting in wrong operations and manual operations of the system might have been overlooked.

We believe that all CO2 system on board are type tested and proven for its efficiency, by classification society. It will not be possible to inspect all the components in the CO2 system at the time of survey to the minutest details by the surveyors. Certification by Ship repairers and ship crew is also considered by the surveyors while revalidating the licence.

It is obvious that the defect in a CO2 system cannot be revealed in view of its idle nature. Hence it becomes more necessary to test the system assembly, various operating mechanisms periodically by the engineers on the board ship. Weighing of Pilot cylinder, checking easy movement of wire transfer system, blowing of pipe lines, testing of smoke detection system, etc. are to be included in the routine maintanance chart alongwith other equipment, for CO2 system also to avoid failures.

The Ship crew must be conversant with the operation of the CO2 system including manual operation of the system from individual cylinder.

Since need for a CO2 system is a remote one, the normal care rendered to other system on a ship has not been given to CO2 system. Normally CO2 system are looked into at the time of renewal of ship licence or repairs etc. only or in case of emergency.

CO2 system has proved beyond recognition its worthiness in saving billions of rupees damages compared to one failure which in fact may be due to lack of maintenance.

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Urbanisation to Imperialism in South India: Maritime Trade in the centre of Economics and Politics

Dennard D'Souza

Introduction

India has a history of urban settlements dating to the period as early as the middle and late chalcolithic era (Circa 3000 BP). Most of these urban settlements were geographically located in the hinterlands of the Indian subcontinent centred around perennial water sources like rivers. These rivers were instrumental in mass cultivation of crops which created a surplus that could be traded for other commodities hence giving rise to diverse lines of production. The locus of these early hinterland urban cultures was the Ganga valley on the eastern flank of India and the Indus valley which lay to the west.

The Indus valley cosmopolis in the hinterlands had an extensive maritime outreach which radiated from its foreland posts Like Lothal and Dholavira. These foreland posts were connected to the overland trade routes and production centres in the hinterland often reaching as far as Afghanistan. Such patterns of economic expansion into the maritime domain were not witnessed in the Ganga valley given the limited archaeological evidence that is at hand. However, south India experiences two waves of urbanisation, one stimulated in parts by overseas trade and the second led by expansion of agriculture through the institutions of Brahmadeyam and Temples which culminated in the rise of Chola imperialism.

First Urbanisation by Overseas Trade in South India

The patterns of first urbanisation in South India are rather different to those witnessed in the earlier northern regions. They seem to have emerged from secondary urban developments like interregional, intraregional and overseas trade. The overseas trade is likely to have been one of the major stimuli for urbanisation in southern India, especially Tamil Nadu and its outlier areas. These early phases of urbanisation in South India did not necessarily result in state formation as the early Tamil society did not emerge from its tribal bases to evolve into a full-fledged state society.[1]

Early South India even at the heights of urbanism was majorly trading in forest and hill products which were exchanged for the exotic-luxury items of western trade.[2] The westward trade with Rome formed the backbone of the maritime economy of lower peninsular India and the products bartered by the Indians at the ports of exchange show produce which were predominantly procured from forest habitats.

Second Urbanisation - A Mixed Bag of Maritime and Hinterland Trade

The second phase of urbanisation in South India saw two trajectories of urban development. One was located in the hinterlands centered around the river valleys, the other one was situated on the littorals adjacent to entrepots. Cities in the hinterland were political centres coupled with some commercial activities while cities on the littoral were exclusively commercial settlements. The former was cultivated as administrative or political centres by the agency of the state while the latter grew up organically from commercial settlements attached to port sites which saw overseas traffic.

Some examples of such binate hinterland-coastal urban developmental trajectories are seen in the Chola city of Thanjavur in relation to port town of Nagapattinam, the Chera city of Vanchi/Karuvur in relation to port town of Muchiri and the Pandya city of Madurai in relation to the port town Korkai. Wherein Thanjavur, Karuvur and Madurai were situated in Tamil heartland, the urban centres of Nagapattinam, Muchiri and Korkai evolved on the coastal front.

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The second phase of urbanisation in peninsular India in the early medieval period also saw an increase in settlements of Brahmins in clusters called as Brahmadeyams and Agraharams and flourishing of temple centres which were endowed with vast tracts of arable lands. These land grants were ploughed into large scale agricultural activities which added to the state revenue and also gave an impetus to other forms of production. The Brahmadeyams and Agraharams acted as agencies of wealth distribution in South India.

They employed a retinue of temple functionaries which included artisan and peasants, who helped in clearing forests and converting arid tracts into arable land which increased agricultural production. Towns developed in the periphery of the temples which became the nucleus of social, cultural, economic, and political life of the South Indian economy. The temple and the Brahmin settlements became a critical apparatus in the process of urbanisation of the Southern Indian peninsula. The early medieval (6th- 12th) period in South India was the period of state formation as it was also the period that marked the second urbanisation in South India.

Creation of Merchant Guilds

In some cases, Temple Towns provided fertile grounds for the economic activities which led to the formation of institutionalised groupings called 'merchant guilds'. The Ainnurruvaru's were one such guild which was incorporated in the Deccan heartland of Aihole but whose activities radiated into the overseas domain as far as Southeast Asia[3]. The guilds contributed immensely to the urban character of South India. Within the period of 8th CE, another phenomenon seems to have been developed as a by-product of urbanisation, this was the creation of 'Nagarams'. The quorum of these Nagaramas consisted of merchants called Nagarattar. The Nagarattar in later days would become pivotal in the maritime trade with Southeast Asia in the late medieval period. On the western coast of Tamilakam, the outlier areas (modern day Kerala) there were frequent trade interactions of West Asian merchants like the Arabs, Persians, Jews and Syrian Christians. These merchants made the ports on the western coast their homes where they established periodic settlements during the impending period after the monsoons.

These port towns became the staging point for multidimensional maritime transit routes from where goods would proceed to either the markets of China, the Red Seas or the overland trade routes that were connected to the marketplace of the hinterland. West Asian merchants were content to trade their products with ships that arrived from China on the Western coast of India, which was a terminal for various trade routes both land and overseas. West Asian merchants seldom continued the voyage beyond South Asia for the markets of China,[4] rather they preferred to barter goods on the Indian shores and return to their homelands.

The major ports of this transit route were Muchiri/ Makotai and Kollam. The foreign merchant (consisting of West Asian merchants) guilds called the 'Anjuvannam' were given trading rights by the local Rajas for conducting trade in these urban centres. Kollam which was one of the major trading ports on the Western coast of India was not a free marketplace but rather administrative marketplaces where the interests of multi ethnic residential communities were checked[5] and regulated.

Urbanisation Leading to Chola Imperialism

Agrarian surplus resulting in urbanisation was a factor that contributed to the Chola imperial ambitions. The imperial projects like the grand temples of Brihadeshwara and Gangaikondacholisvaram among many other temple complexes were possible because of the agrarian reforms brought in by the Chola, which helped the Chola state to generate excess revenue.

Territorial expansion was limited to territories within the Indian subcontinental region which include the insular extensions of Sri Lanka and Maldives. The Chola state was initially not very inclined with the revenues generated through the maritime trade revenue; their concern was majorly on the agrarian front. Over a period of time, Cholas realised the lucrative nature of the maritime trade and the port cesses on various luxury goods delivered to the Chola ports by seafaring merchants drew royal interest in promoting this trade.[6]

Rajaraja was interested in the eastern Indian Ocean trade route for the reason to acquire prestige necessary to attract the traders to the Chola ports. This is recorded in the Chinese dynastic histories which record Rajaraja's embassy to China in 1015 CE.[7] The Srivijayans were a major hurdle to the prestige of the Chola's which triggered the naval attack on Srivijaya by the Chola's.

The conquest of Kadaram (Srivijaya) was one of the greatest military achievements of the Chola emperor Rajendra. Of his many naval conquests the invasion of Srivijaya was by far the farthest from the homeland an Indian naval fleet ever attempted to undertake an expedition. The invasion of Srivijaya on face value appears to be motivated by economic expediency of the Chola state however closer examination shows that there was a subtle attempt at exerting hegemony in the spirit of

The conquest of Kadaram (Srivijaya) was one of the greatest military achievements of the Chola emperor Rajendra. Of his many naval conquests the invasion of Srivijaya was by far the farthest from the homeland an Indian naval fleet ever attempted to undertake an expedition

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imperialism which was the mainstay of Rajaraja and Rajendra Chola's state policy of territorial expansion.

The invasion of Kadaram was a success and resulted in economic gains for the Chola state but the conquest did not translate into addition of territory. This would have been a deliberate move by the Cholas to whom this may have appeared economically inviable on account of the added burden of logistics to maintain an overseas territory which is remotely distant to the homeland. The Cholas however maintained control over Srivijaya through proxy with the help of merchant guilds.

The merchant guilds were instrumental in forwarding the economic agenda of the Chola state. They provided governance in oversea territories in absence of the state administrative apparatus. Thus, the chola imperial state was a product of the preceding centuries of urbanisation in south India. The imperial ambition of the Cholas was induced by urbanisation which was mediated by the Agrarian revolution and the revenue accrued by the maritime trade.

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About the Author

Dennard H Dsouza works at the Maritime History Society as a Senior Research Associate. He has a master's degree in Ancient Indian Culture History and Archaeology from Saint Xavier's College, Mumbai. Currently his work entails documentation and research of India's Naval and Cultural legacy on the Trans Indian Ocean Routes. His other interest areas are in the study of ancient polities of the East and intermingling of Cultures, Religion and Art as a result of trans regional movement. He also keenly observes current global trends and the application of history to augment policy.

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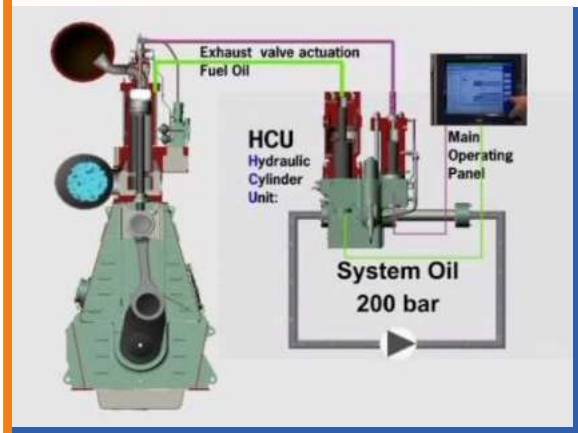

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