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Optimising Container Containment

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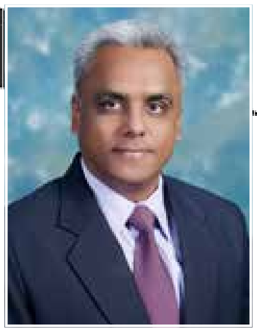
EDITORIAL



Climate change is sometimes misunderstood as being about changes in the weather. In reality, it is about changes in our very way of life.
- Paul Polman

Two news items in recent times need a closer look. The first one is the deal signed by India Ports Global Ltd., with Ports and Maritime Organisation of Iran for operating the Shahid Behesti terminal at Chabahar port. Chabahar, possibly the only oceanic port of Iran, has been in India's trade plans since the 1970s. It stands as an example of how geopolitical factors make things difficult for even the well-intended projects. Iran's pendulum has swung from pro-US leaning (Shah's period) to facing the US wrath with sanctions. Adding to the complex equations are Pakistan's disrelish to India and its chumming up to China. When Chabahar becomes fully functional along with the Zaranj-Delaram highway, it would bring benefits to Afghanistan, the Central Asian countries and the Russian ports too. Chabahar could become the paradigm of how ports can bring peace to disturbed regions.

The second report relates to the climate. While many regions melted in the summer heat, things became more fluid... there were rains, floods and flash floods in a few regions. While the El Nino and La Nina are the fashionable reasons we hear, is there a pattern of flip-flop climate changes we are witnessing? Could be.

Indian Ocean is supposed to have warmed well since the beginning of 20th Century. This warming and addition of heat is not limited to the surface but also to the depths. The ocean's acidification has also increased (expected levels to be < pH 7.7 by the end of 21st Century). And there is more to this. The melting of ice and the consequential shift of the waters towards the equator has slowed down the planet. (earlier, the melting had made the earth spin faster and also flattened the poles). Blame it on the climate change for this diametrically opposite effect.

So, what are we looking at?

A perennial marine heat wave situation, a severe decrease in primary productivity (the energy conversions in the ecosystem) and deleterious effects on all that is in the sea. Other than the rapid weather changes, which affect us immediately, we might be looking at changes in the way we live and deal with our ecosystems.

In this issue...

We start with stacking the containers. The four student-Authors approach the problem of stacking/arranging containers using a heuristic approach. Solutions for containing the containers in port and onboard abound in the domain. However, such approaches being proposed by marine engineering students is heartening. This paper was placed second in the IMU's Conference deservingly. This is an easy read you should not miss.

We move to the Part B of the Silent ship designs. This part describes the hydrodynamic re-design of the hull geometry on the forward region. This has been an effective deterrent for the generated bubbles. These designs are being applied to the new acoustic-compliant research vessels and also in the conversions of old vessels. The first interesting discussion is on the three types of underwater shapes. The narrative engages in bubble-diversion design considerations, CFD studies on streamlining and the analyses thereof, and identifying the hull-location for the sensors. This is an interesting read for any naval architecture enthusiast.

Next, we feature one more prize winning paper by students. Ammonia is getting as much attention as Hydrogen. The Nautical students have culled information and put together a case for Ammonia. In the same support for students' efforts (ibid), this paper gets space and all students get encouragement. We would expect some feedbacks from experienced mariners on such works.

The MER Archive-dive from June 1984 has a few informative takeaways: residual fuels, improving turbocharger efficiencies, one transaction on the electrical equipment installation designed to be affected by fires amongst others. Readers are urged to visit these pages and share some of their experiences of working with such designs. This is a perennial appeal under this space.

In the Competency Corner Elstan Fernandez concludes the alternator troubleshooting in the Part C of the series. Under Heritage Hourglass, Khushie Bhulla describes the mythological story on churning of the oceans.

While awaiting the new Government to assemble in order, we look forward to better winds for shipping. With good wishes to the Nation, here is the June 2024 MER for your reading pleasure.

Dr Rajoo Balaji
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An Integrated Rule Based Heuristic Approach for Optimisation of Container Stowage on Seaport Terminals Using Machine Learning

Prasad Pande, Nishant Pandey, Prasad Pansare and Anmol Singh Dadial

Abstract: One of the most pressing issues in the maritime sector revolves around the efficient relocation of containerised cargo within seaport terminals. Even minor adjustments in cargo processing procedures can yield remarkable outcomes, including substantial cost savings and a noteworthy reduction in the carbon emissions. The paper delves into crafting a more efficient stowage plan for the port terminal. It suggests forming clusters considering factors such as destination port, container size, weight, and type. The study extensively explores a rule-based heuristic approach, evaluating its effectiveness and investigating its potential for optimising the storage plan.

Keywords: Heuristic algorithm, Machine Learning, POD, Carbon Footprint

1. Introduction

Containers revolutionised the international sea freight market nearly fifty years ago, introducing a unit-load concept that has since gained widespread acceptance. These standardised, uniform boxes have become the cornerstone of efficient cargo handling, eliminating the need for unpacking at each transfer point. The containerisation trend has only grown stronger due to its numerous advantages, such as protection against weather and theft, simplified scheduling, and improved cargo control.

When discussing containers, a common reference is the standard container, measuring twenty feet (20') in length. Other containers are often measured in twenty feet equivalent units (TEU), with properties like weight, special handling requirements (e.g., for reefer or oversized containers) [1]. The positive forecast for container freight transportation suggests a continued upward trajectory in the future. This surge in container shipments places higher demands on seaport container terminals, logistics, management, and technical equipment. The resulting increased competition among seaports emphasises the importance of success factors such as trans-shipment time, loading and discharging rates, and overall operational efficiency. The rapid turnover of containers becomes a crucial competitive advantage, minimising the time ships spend at berths, hence, reducing trans-shipment costs. The containerisation trend has transformed the landscape of international sea freight, emphasising efficiency, standardisation, and rapid cargo turnover as key drivers in the highly competitive market of container seaports. Container turnover at major seaport terminals has experienced substantial growth, as shown in **Figure 1,** depicting the container turnover for the ten largest terminals from 2017 to 2021.

Container terminals commonly utilise various types of handling equipment, including Quay Cranes (QC), Yard Cranes like rubber-tired gantry cranes (RTG), rail-mounted gantry cranes (RMG), and various configurations of RMGs such as double, twin, or triple. Additionally, internal vehicles like yard trucks, straddle carriers, chassis, automated guided vehicles (AGV), and land cranes are employed for tasks such as loading trains. External transportation modes such as trucks or trains are also integral to the operation.

Container terminals commonly utilise various types of handling equipment, including Quay Cranes (QC), Yard Cranes like rubber-tired gantry cranes (RTG), rail-mounted gantry cranes (RMG), and various configurations of RMGs such as double, twin, or triple.

Figure 2 illustrates a typical layout of a container terminal, depicting three primary sections: the Sea-side comprising the Vessel, the Quay, and the Internal transport areas; the Storage Yard; and the Land-side encompassing external transport areas and the gate. Each piece of equipment is designated to operate within specific sections of the container terminal, as delineated in **Figure 2.**

The **Container Relocation Problem** involves managing a set of uniform containers stored in two-dimensional last-in-first-out (LIFO) stacks. The primary objective is to efficiently retrieve containers from these stacks while minimising the need for relocation maneuvers. Relocations happen when accessing containers not situated at the stack's top, which are deemed unproductive moves. The quantity of relocations significantly impacts operational efficiency within container terminals, closely tied to the loading sequence and re-handling strategies. Hence, this study aims to showcase the efficacy of employing both k-means and rule-based heuristics to tackle the container stowage challenge. The ultimate objective is to devise an optimised stowage plan utilising Python code that integrates the aforementioned algorithms.

2. Literature Review

Containerised cargo was introduced in 1956 through the vessel "Ideal X". Over time, it developed into a sophisticated business model, eliminating the need for unpacking at transfer points. These containers were designed for efficient freight handling. There have been several methods applied to optimise the container stowage problem.

Some of the approaches have been illustrated in the chronological order of the time of their publication.

The method of Kozan;

Kozan discusses the most important factors of transmission effectiveness of multimodal vessel outstations. The image shows a network model describing the logistics structure of the terminal and the progress of holders. Its purpose is minimisation of the total prosecution time as the sum of vessel running and transport times [2].

The Method of Lim

Lim reformulates the problem as a defined form of a two- dimensional quilting problem and studies a graph-theoretic representation. In this reformulation, this particular pier design problem is shown to be NP-complete [3].

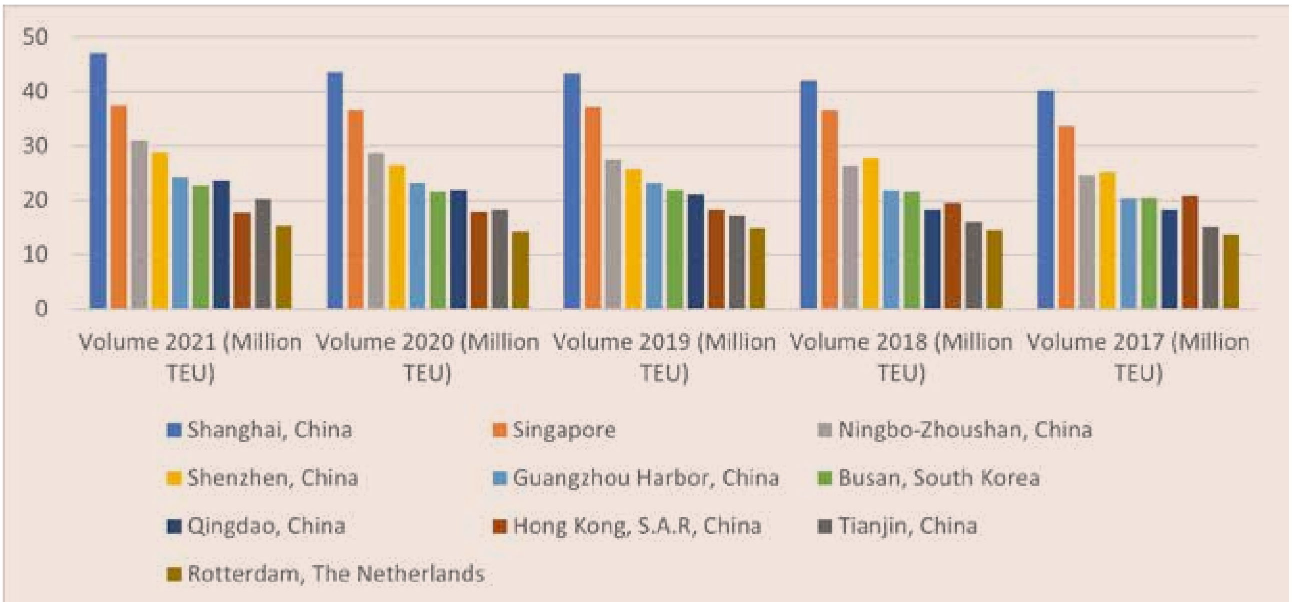

Figure 1. Trend of container operations from 2017 to 2021

The Method of Wilson and Roach

The stowage problem was decomposed into two sub problems: Master Bay Planning Problem, Slot Planning Problem. MBPP involved distributing containers into ship bay sections, while SPP used the master bay plan to allocate slots for stowage. Additional studies focused on sub-problems, with various heuristic and mathematical models presented [4].

Limitations and shortcomings: These approaches, however, often overlooked stowage planning for full container liner shipping routes, leading to potential re-handling issues. Shortcomings includes potential difficulties in accurately estimating container sizes, challenges in handling irregularly shaped items, and limitations in addressing dynamic changes in cargo dimensions or weight during the planning process. Additionally, it may not consider certain practical constraints in container loading, leading to suboptimal results in real-world scenarios.

The Method of Kim and Hong

They adopted a branch and bound method to address the container relocation problem. In this approach they divided the containerisation problem into a numbers of sub problems and chose the one which was least expensive [5].

The Container Relocation Challenge pertains to the efficient management of containers stored in two-dimensional stacks within a terminal environment.

Limitations and shortcomings: It turned out to be time- consuming and computationally expensive for large and complex systems. The number of sub problems grew exponentially with the size of the problem and the bounds were not tight enough to eliminate many sub problems. This resulted in requirement of more iterations, memory space and computing time.

In summary, different types of optimisation algorithms including the exact and heuristic bones were proposed in the literature to address the CRP, and several types of machine literacy ways similar as the decision tree, the neural network and so on were espoused to parameter estimation and system optimisation in a wide range of operation. In the CRP, however, the algorithms that combines the optimisation styles and the machine literacy ways are veritably spare. Inspired by the fact that further precious information regarding the structure of the optimal result can be uprooted and facilitates the result for large scale cases, we're motivated to make such an attempt in this regard.

3. Problem Description

Given a layout of container stacks within the terminal, the objective is to minimise the number of relocations required to access specific containers, thereby enhancing

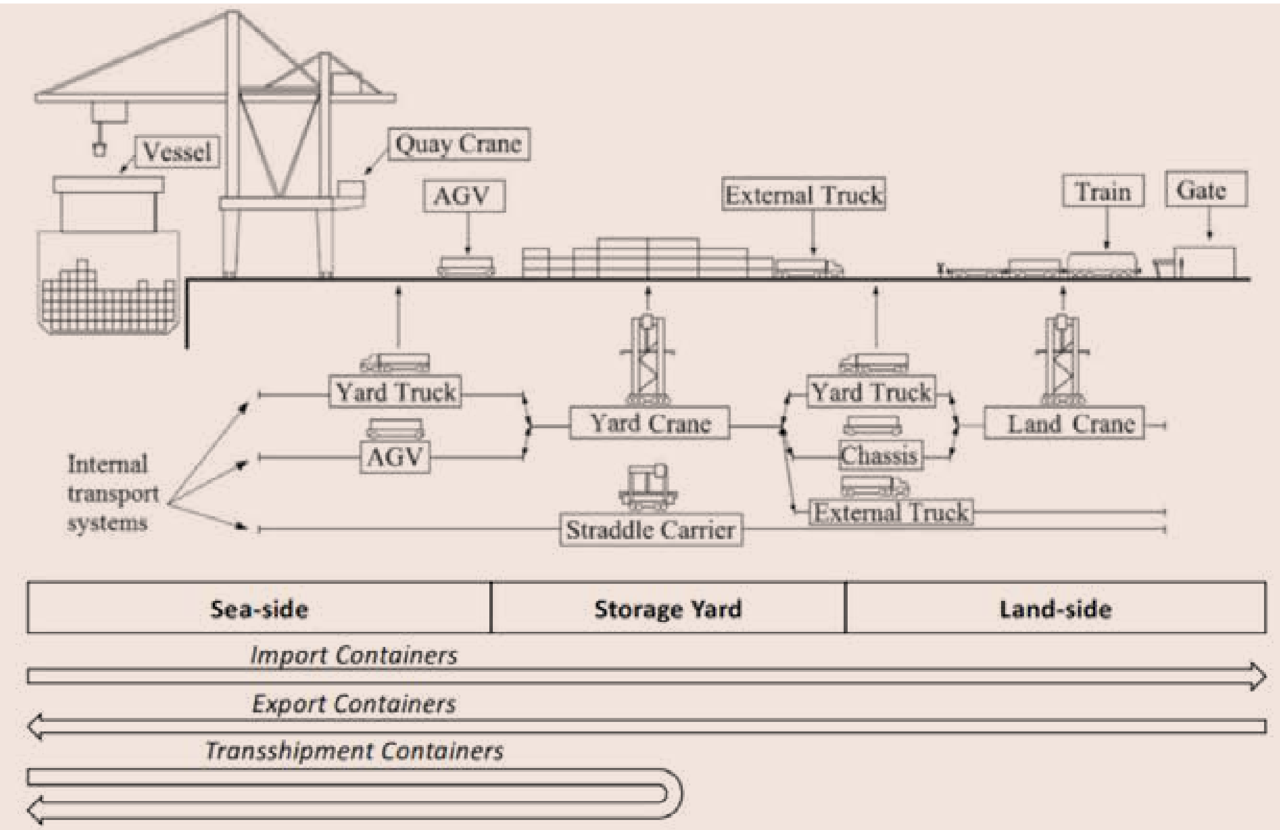

Figure 2. Basic outline of port terminals [6].

operational efficiency and reducing resource wastage.

The Container Relocation Challenge pertains to the efficient management of containers stored in two-dimensional stacks within a terminal environment. This problem arises due to the need to retrieve containers from these stacks while minimising the number of relocations required.[9]

The challenge can be described formally as follows:

Let $S = \{S_1, S_2, ..., S_n\}$ represent a set of two-dimensional stacks, where each stack S_i contains a variable number of containers stacked in a last-in-first-out (LIFO) manner. The objective is to devise an optimal strategy for retrieving

The Container Relocation Challenge shares similarities with various optimisation problems, including the Traveling Salesman Problem (TSP) and the Vehicle Routing Problem (VRP)

target containers from the stacks, minimising the number of relocations required.

- Stack Configuration: Each stack S_i can be represented as a two-dimensional array or matrix, denoting the arrangement of containers within the stack.
- Target Container Identification: Given a target container to retrieve, denoted as C_t, the algorithm must determine its current location within the stacks.
- Relocation strategy: To retrieve C_t efficiently, the algorithm needs to identify the minimum number of relocation maneuvers required to access C_t without disturbing other containers unnecessarily.

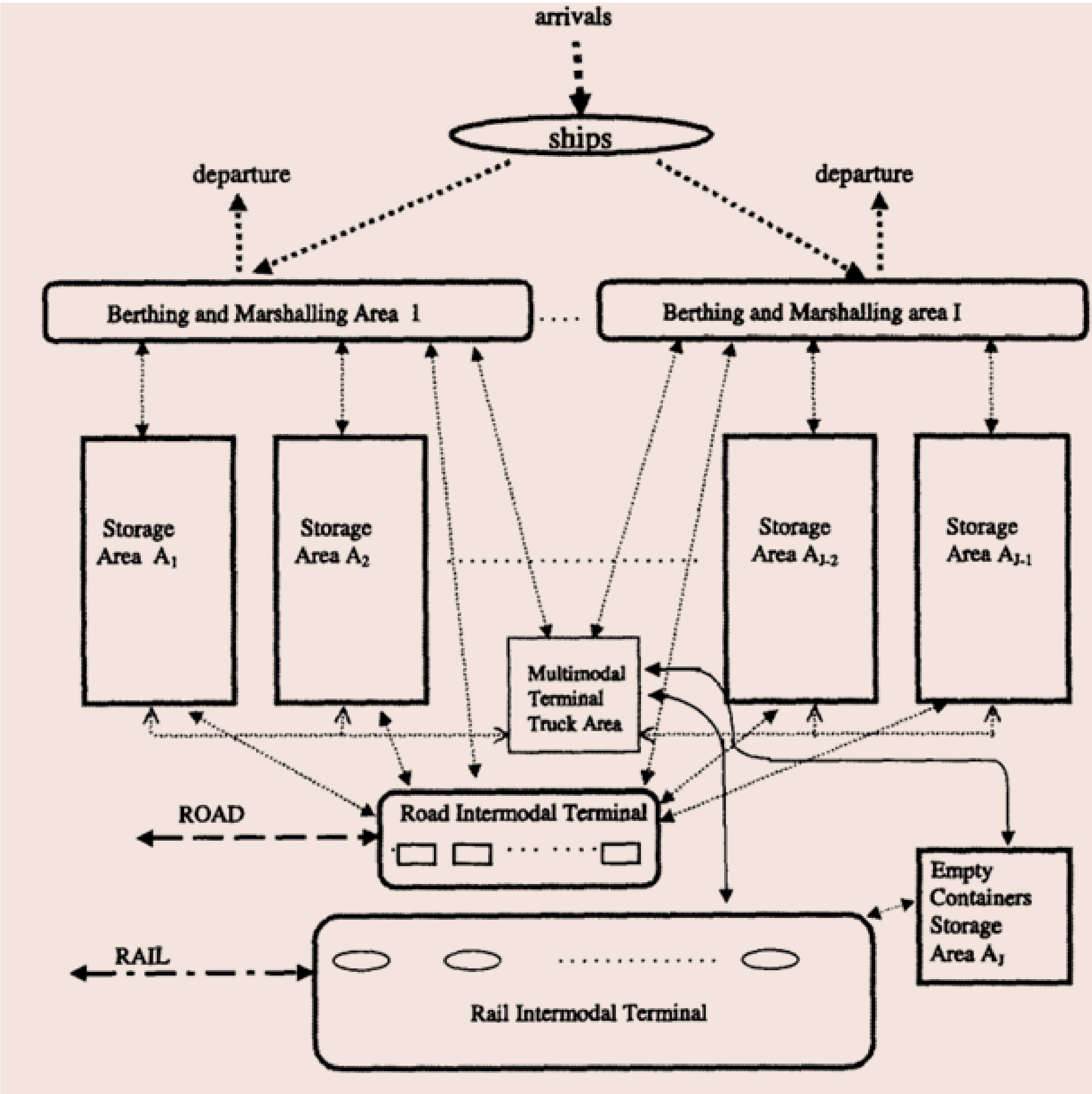

Figure 3. Flowchart of port operations [7].

- Objective Function: The primary objective is to minimise the total number of relocations needed to retrieve all target containers within a given time frame.
- Decision Variables:

$$x_{ij} = \begin{cases} 1, & \text{if container } C_i \text{ is relocated to the top of stack } s_j \\ 0, & \text{otherwise} \end{cases} \quad (1)$$

- Objective Function:

Minimise, representing the total number of relocations

$$\sum_{i=1}^{n} \sum_{j=1}^{n} x_{ij} \quad (2)$$

- Constraints:

$$\sum_{j=1}^{n} x_{ij} = 1, \text{ensuring each container is relocated to only one stack} \quad (3)$$

$$\sum_{i=1}^{n} x_{ij} \leq 1, \text{ensuring each stack receives at most one container} \quad (4)$$

Additional constraints may be added to account for stack capacity limitations and operational constraints.

The Container Relocation Challenge shares similarities with various optimisation problems, including the Traveling Salesman Problem (TSP) and the Vehicle Routing Problem (VRP). These problems involve finding optimal routes or sequences to Minimise travel distances or costs, akin to minimising relocations in the Container Relocation Challenge [8].

The Key shortcomings in the conventional method include:

- *Movement of Internal Transfer Vehicles (ITVs)*: Placement of containers in clusters governs the movement of ITVs on the terminal. Improper planning can result in haphazard movement of the ITVs, clashing of routes and traffic, resulting in delay.
- *Idle time of Rubber Tyre Gantry cranes (RTGs)*: These cranes need adequate space to operate. When due to improper cluster formation, the operation of all the RTGs is concentrated on one portion of the stack, some RTGs stand idle while others compensate for the idle ones, causing wastage of resources.
- *Overload of Quay Cranes (QCs)*: Often times it is observed that the containers handled per hour for every QC is different, causing some QCs to be overloaded while the others standing idle. These inefficiencies result in increase of cost per container handled, and also increases the carbon footprint generated. Following is a detailed demonstration of how the formation of cluster affects the overall moves and time required for handling the containers.

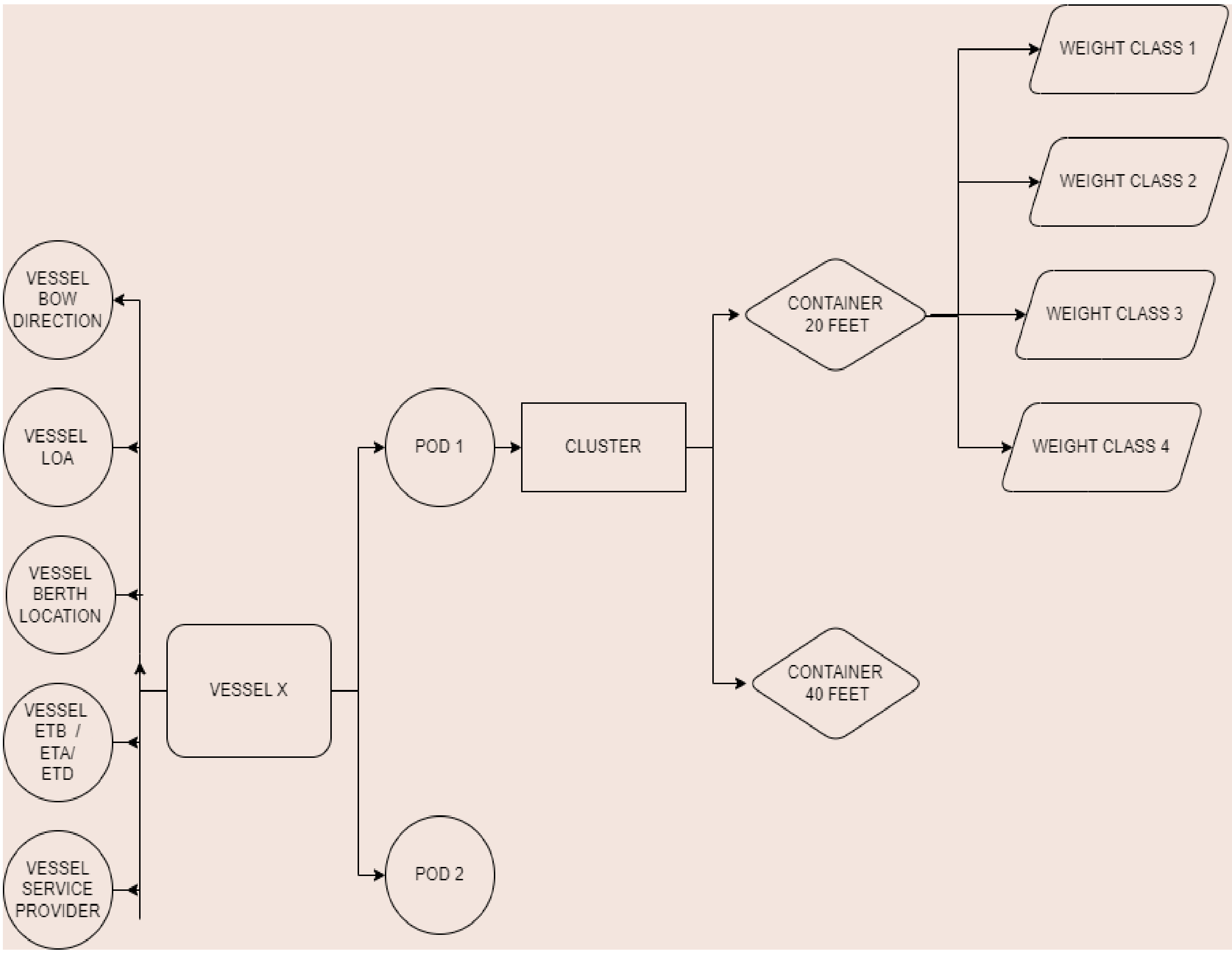

Figure 4. Governing parameters for 'clusterisation' of containers

> *We have considered the factors such as port of discharge, type of containers and their weight class and have applied a rule based heuristic algorithm integrated with Machine Learning (ML)*

4. Solution

We have addressed the underlying issue with the help of a program with rule based heuristic algorithm and machine learning as its core principles as follows:

4.1 Stage 1:

Segregation of Data. The program begins by taking an Excel file ('shipdataset EXPORT.xlsx') containing data on multiple ships and their respective container details. It reads this data and creates separate Excel sheets for each vessel, segregating the data based on the 'VESSEL' column.

4.2 Stage 2:

Clustering of POD (Port of Discharge). It takes the segregated Excel file ('split d ata.xlsx') created in *Stage 1* and reads each sheet (ship data). Utilises TF-IDF vectorisation on the 'POD' (Port of Discharge) data and performs Kmeans clustering on it. Adds a 'Cluster' column to each ship's data based on the clustering results and saves this updated information into a new Excel File.

4.3Stage 3:

In *Stage 3,* the process involves reading the clustered output file ('clusteredoutputfilefinal.xlsx') from *Stage 2* and employing a rule-based heuristic approach for sorting and classification. The heuristic approach for sorting and classification.

The heuristic rules, based on 'TEU' and 'WEIGHT' columns, guide the sorting within each cluster. For instance, the rules might prioritise sorting by 'TEU' values and use 'WEIGHT' as a tiebreaker. This heuristic ensures an efficient and systematic sorting process. The data is then categorised into different groups/classes according to specified condition, reflected in 'Class' columns. The sorted and classified information is saved into a new Excel file, streamlining data analysis and interpretation.

4.4 Stage 4:

Allocation of containers to bays and slots reads the modified file ('weight classification cluster file.xlsx') generated from *Stage 3*. Arrange containers from different ships into bays and slots based on several conditions including 'TEU', 'CLUSTER', and 'ARRIVAL DATE'. Allocates bays and slots to containers in a way that optimises the available space. Generates a final Excel file ('final container arrangement updated.xlsx') with the allocation details. The program's execution begins by receiving input data regarding ships and containers, then systematically processes and manipulates this data through the aforementioned stages, ultimately producing a final allocation arrangement of containers into bays and slots for efficient management handling at the port.

4.5 Flowchart:

- The PORT OF DISCHARGE is taken into consideration as there are different port of discharges for a particular ship
- The containers are then arranged in CLUSTERS
- The containers are arranged in clusters according to the size of the containers i.e. 20 ft. and 40 ft.
- Then the containers are then arranged according to WEIGHT CLASSES
- While making the clusters parameters like vessels estimated time of arrival, time of berthing, berthing location, bow direction, service provider etc., are also taken into consideration.

5. Mathematical Modelling:

To develop a mathematical model for clustering containers using the k-means algorithm and a rule-based heuristic algorithm, we need to consider various factors including the intended port of discharge, weight of containers, available space on the terminal, desired transfer rate of containers, and the type of container in use. Let's denote the following variables:

- *N: Total nuber of containers.*
- *K: Number of containers.*
- x_i*: Vector representing the attributes of container i.*
- μ_k*: Centroid of cluster k.*
- ω_i*: Weight of the container i.*
- s_k*: Available space in cluster k*
- *r: desired transfer rate of containers.*
- t_i*: Type of container for container i*

We aim to Minimise the intra-cluster variance, considering the distance between containers and their respective centroids.

5.1 Objective Function: The objective function is to Minimise the total intra-cluster variance, which can be expressed as:

$$J = \sum_{k=1}^{K} \sum_{i=1}^{N} \delta_{ik} \parallel x_i - \mu_k \parallel^2 \quad (5)$$

Where is an indicator variable that equals 1 if container i belongs to cluster k, and 0 otherwise.

5.2 Constraint:

1. Space Constraint:

The total space occupied by containers in each cluster should not exceed the available space:

$$\sum_{i=1}^{N} \delta_{ik} . \omega_i \leq S_k \, \forall k \quad (6)$$

2. Transfer Rate Constraint:

The rate of transferring containers should meet the desired transfer rate:

$$\frac{\sum_{i=1}^{N} \delta_{ik}}{t_i} \geq r \, \forall \, k \quad (7)$$

3. Type of Container Constraint:

Certain types of containers may have specific requirements or restrictions. For instance, hazardous containers must not be clustered with non-hazardous ones.

5.3 K-means algorithm:

Initialisation: Randomly select *K* containers as initial centroids.

Assignment Step: Assign each container to the nearest centroid based on Euclidean distance.

$$\delta_{ik} = \begin{cases} 1 \;\; if \; k = argmin_j \parallel x_i - \mu_j \parallel^2 \\ 0 \;\; otherwise \end{cases} \quad (8)$$

Update Step: Update the centroids based on the mean of containers in each cluster.

$$\mu_k = \frac{\sum_{i=1}^{N} \delta_{ik} . x_i}{\sum_{i=1}^{N} \delta_{ik}} \quad (9)$$

Repeat steps 2 and 3 until convergence.

5.4 Rule-based Heuristic Algorithm:

1. Initialisation: Initialise clusters based on predefined rules or heuristics, considering attributes such as port of discharge, weight, and container type.
2. Refinement: Refine the clusters iteratively by considering constraints and objectives, such as minimising intra-cluster variance and meeting transfer rate requirements.

By combining the k-means algorithm with a rule-based heuristic approach, we can effectively cluster containers in a port terminal, optimising space utilisation, transfer rate, and other relevant factors.

6. Conclusion

The effect of using the machine learning integrated heuristic approach on reduced relocation movements of containers, optimal use of space available on the port terminal, maintaining a desired rate of discharge and limiting crane travel distances has been deeply examined and the core principles have been applied in creating a program that gives an optimised plan for 'clusterisation' of the container. The efficacy of the rules defined in the suggested algorithm, determines the quality of the output. We have considered the factors such as port of discharge, type of containers and their weight class and have applied a rule based heuristic algorithm integrated

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with Machine Learning (ML). The stowage plan we get is optimised and with every iteration it improves itself and gives more optimised results.

Acknowledgement

We deeply appreciate Associate Prof. Mr. Sachin Vyavyahare's invaluable guidance in helping us understand containerisation better. His insights in mathematical modelling have significantly enriched our learning experience. Additionally, we are thankful to Capt. Vijay Damley for organising a visit to the port, allowing us to see first-hand how maritime logistics work. Both Mr. Vyavyahare and Capt. Damley's efforts have broadened our understanding of the subject, and we are truly grateful for their contributions.

References

[1] A. Van de Ree, 1969. Unitized Cargo Transportation. The Journal of Navigation, *22*(3), pp.311-325, in press.
[2] Preston, P. and Kozan, E., 2001. An approach to determine storage locations of containers at seaport terminals. *Computers & Operations Research*, *28*(10), pp.983-995.
[3] Wang, N., Zhang, Z. and Lim, A., 2014. The stowage stack minimization problem with zero re-handle constraint. In *Modern Advances in Applied Intelligence: 27th International Conference on Industrial Engineering and Other Applications of Applied Intelligent Systems, IEA/AIE 2014, Kaohsiung, Taiwan, June 3-6, 2014, Proceedings, Part II 27* (pp. 456-465). Springer International Publishing.
[4] Wilson, I.D. and Roach, P.A., 1999. Principles of combinatorial optimisation applied to container-ship stowage planning. *Journal of Heuristics*, *5*, pp.403-418.
[5] Tuan, C.H., Park, S., Hong, S. and Kim, K.H., A Heuristic Algorithm for Generating Stowage Plans.
[6] Jun Li, Yu Zhang, Jie Ma, and Sanyou Ji, "Multi-Port Stowage Planning for Inland Container Liner Shipping Considering Weight Uncertainties" vol 6, pp 3-4, 2018, in press.
[7] Canrong Zhanga, Hao Guana, Yifei Yuana, Weiwei Chen, Tao Wu. "Machine learning-driven algorithms for the container relocation problem" transportation research part b, pp 104-105, 2020, in press.
[8] Mordecai Avriel, Michal Penn, Naomi Shpirer "Container ship stowage problem: complexity and connection to the coloring of circle graphs", pp 272-273, 1999, in press.
[9] Galle, V., Barnhart, C. and Jaillet, P., 2018. Yard crane scheduling for container storage, retrieval, and relocation. *European Journal of Operational Research*, *271*(1), pp.288-316.

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Silent ships – Acoustic-friendly Design for Ocean Research Vessels: Part B

M. Palaniappan & N. Vedachalam

Abstract

An eco-friendly maritime transport is the key to sustainable development. Part A of this series discussed the impact of anthropogenic noise on marine ecology, propagation pattern of ship URN in shallow and deep-oceans, noise sources, regulations for silent/quiet ship notation and the maturing URN reduction technologies. This section (Part B) describes an acoustic-friendly design for ocean research vessel with a specific focus on effective mitigation techniques for bubble sweep-down, which helps to significantly improve the multi-beam sonar performance in hydrographic/ research vessels. A modified forward hull geometry, first-of-its-kind hydrodynamic re-design approach for creating an effective bubble diverter is explained using numerical models.

"When the vessel moves forward, the waves generated due to wind and wave action are ingested into the bottom region of the vessel, the path in which sonar transducers are mounted"

Introduction

The performance of an Oceanographic Research Vessel (ORV) is normally measured by the quality of data it can collect during surveys. ORVs are fitted with acoustic sonar transducers at the bottom of the vessel for this purpose. This interferes with the acoustic transmission and deteriorates the functional performance of the acoustic transducers. Many a time, it is misunderstood by the scientists or difficult to differentiate the poor quality of data, whether it is due to malfunctioning of acoustic transducers or vessel design-related issue. Currently this issue is managed by keeping the underwater transducers in a separate structure below the keel as an appendage. Based on its shape and installed location, **bubble sweep-down (BSD)** over the transducer face is avoided to some extent, but with a penalty on added resistance.

This part of the article series describes the hydrodynamic re-design of the hull geometry in the forward region for an effective bubble diverter bow for new acoustic-compliant research vessels and conversion of old vessels into ORV.

The critical factors to be considered while designing ORVs are installation of sonar systems at the right location to avoid the nuisance of BSD. To remedy the problem of BSD, it is important to understand the conditions for formation of bubbles and the mechanism of BSD under the vessel hull in the region where the transducer is located. Bubbles are formed due to the interaction of surface wind and waves, resulting in air bubbles in the layer of water near the surface.

A major concern in achieving the maximum efficiency from modern acoustic transducers is the reduction of bubbles across transducer faces, the control of BSD patterns and the reduction of cavitation bubbles. To mitigate the detrimental effects of BSD which are worse at higher speeds and sea states, several design solutions have been attempted. External bottom-mounted acoustic transducers have been tried which are fairly effective, though they add to appendage drag, and are also vulnerable to physical damage. Bubble diverter fence, gondola and cow catchers are some of the common shapes have been tried out, but all have penalties in the form of increased resistance. Hence bubble diversion by hydrodynamic design of the hull is an effective alternative.

> *"When the vessel moves ahead, the forward shape of the vessel, which is generally of nabla-type bulb design, encourages the flow downward and the ship motions, mainly pitching, aggravate the BSD down towards the hull bottom"*

Bubble sweep down and CFD simulations

The BSD phenomena is driven by two factors. The first one is the formation of the bubbles and the second is the bubble transport. In a typical BSD **(Figure. 1),** bubble formation occurs continuously at the ocean surface, mainly due to wind and waves and their interaction with the ship structure. The density of bubbles and depth of bubble penetration are proportional to wind speed and vessel speed.

Figure 1. Representation of BSD path

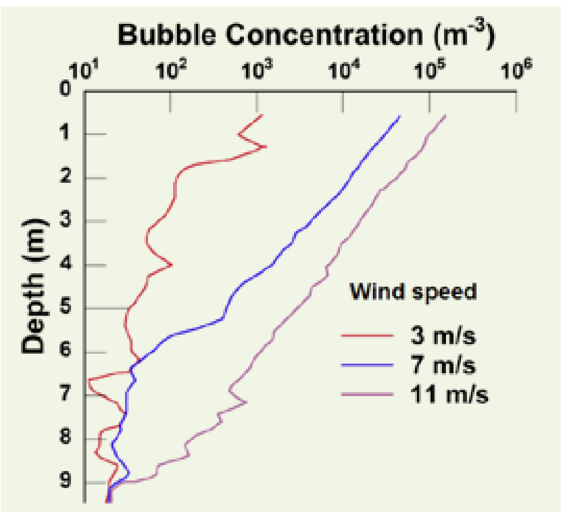

Figure 2. Mean bubble concentration as a function of depth for various wind speeds

Bubble concentration as a function of depth for various wind speeds is shown in **Figure.2.** In the vicinity of the bow, wave build up due to the stagnation pressure, steep wave formation and its breaking and mix up with the atmosphere causes bubble formation in the waves. Turbulent conditions occur and if there is additional pitching motion, and this aids bubble formation even more, increasing the number of bubbles formed. Ventilation can also occur due to specific geometric shapes at the stem; flow disturbance due to thruster openings can also cause bubble formation around the ship body.

Prior studies have established that the bubbles generated by the above process will follow the streamlines i.e., follow the flow path along the hull towards the aft or sides of the hull. Bubbles are buoyant due to their lighter density and tend to rise-up. Therefore, they tend to follow a path slightly above the actual fluid streamlines. A streamline study is considered a reasonably good approach to trace the approximate path of bubble transport.

With the knowledge of bubble growth and sweep-down mechanism as described above, it is evident that the key to alleviation of bubble nuisance at the sonar transducer region is to re-define the hydrodynamic flow pattern. The key to understanding the BSD path is by assessing the streamlines especially emanating from the upper bubble dense regions of flow at the bow. The streamlines of flow at a deeper depth of the hull are less important since they do not carry so many bubbles and therefore, they do not interfere with the sonar transducer.

Analysis of Externally-Mounted Sonar Array

Computational Fluid Dynamics (CFD) is an effective tool to investigate hull form improvements, as well as for quantifying the BSD effects.

As a part of this study, a group of acoustic transducers are placed below the keel in a separate structure as an appendage. Depending on the shape and location, added resistance and flow diverting characteristics vary. To validate the applicability of the same to this study, three different shapes are analysed as options for conversion design. **They include Gondola, flush-mounted and cow-catcher types.**

***Gondola*:** In this configuration, Gondola is connected to the hull through struts. Which ensures that streamlines pass through the gap between gondola and the hull **(Figure.3).** However, deeper the submergence of gondola, more the bubbles will escape, but it's the additional weight and drag offers more resistance. Hence a trade-off is to be obtained to fix the dimensions.

Flush-mounted: In flush-mounted configuration, array of structure containing scientific components is flush mounted to the keel at the centre-line of vessel **(Figure.4).** Flush-mounted arrangement and the smooth edges offers minimum disturbance to the flow, that resulted in lower resistance. But the streamlines flow over the appendage and hence resulting in poor flow-diverting characteristics.

Cow-catcher: In this configuration, a U-shaped structure is bent towards inward with a reverse angle of slope in the transverse sections as well as at the leading edge **(Figure.5).** This is also attached to the hull through flush-mounted configuration. This shape has the advantage of both flow diverting characteristics, as well as lesser added resistance.

Detailed analysis of above shapes using CFD has been carried out. In every stage, flow pattern around the transducer array has been studied along with added resistance due to the appendage. **Figure. 3-5** show different configuration and the streamline pattern around the structure when vessel moves forward. Gondola design gives high flow diversion, but at the cost of high added resistance, as this being a large appendage. Flush-mounted design offers poor flow diversion with lower added resistance. In the cow catcher design, inverted U shape gives better bubble diverting performance than the flush-mounted. However considering the combined effects of adverse resistance and flow diverting characteristics, the cow-catcher is identified as the best option among the three **(Table.1 and 2).**

Bubble sizes vary from 20 microns to 200 microns and are concentrated around the vessel hull within 4-5 m depth from the surface water

The above options are mitigating techniques for operating vessels with a compromise on hydrodynamic properties. This is well-suited for a conversion design. Ideal choice for a new ORV would be diverting the bubbles in the forward region itself by effecting suitable modification in the forward shape.

Bubble Diverter Flow- Approach Methodology

An attempt has been made to modify the under-water hull form mainly at the sides starting from the bow using different areas of cross-section in the forward region and lengths of the modified shape at the forward region towards aft. The form development uses a computer aided surface development tool to interactively shape the hull form within the constraints of constant volume of displacement. To demonstrate the effectiveness of the hull form for BSD mitigation, the scope of the study is limited to three hull variants, which have been developed using RHINO. The limited models used bring out the influence on the BSD effect of each form. Using a commercially available CFD code, the method next investigates the trace of the streamlines as they reach the bottom in the vicinity of the transducer location in the bottom centreline of the vessel. The method considers the relevant depth

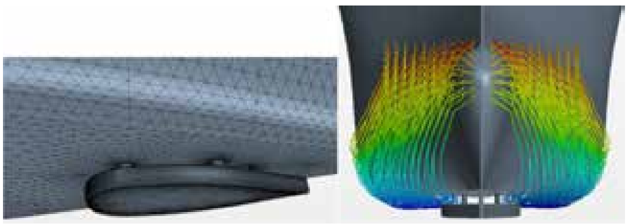

Figure 3. Arrangement of gondola and streamline pattern

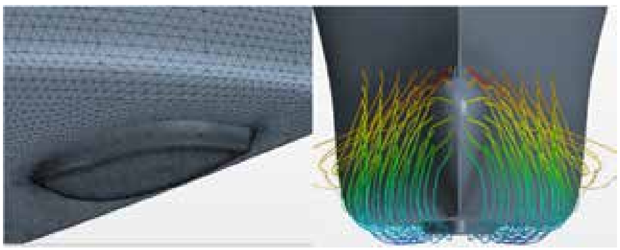

Figure 4. Arrangement of flush mounted appendage and streamline pattern

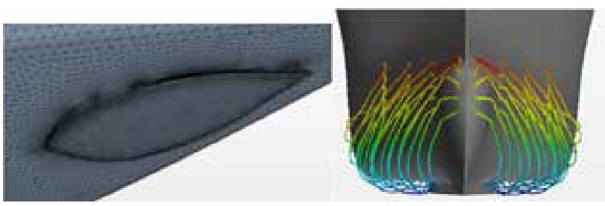

Figure 5. Arrangement of cow catcher and streamline pattern

Table 1. Assessment of various shapes of sonar array

Shape of sensor array	Added weight	Added resistance	Flow diverting effect
Gondola	High	High	Very good
Flush mounted	Low	Low	poor
Cow catcher	Low	Medium	Good

Table 2. Resistance comparison of various shapes of sonar array

Shape of sensor array	Rt (N)*	Added resistance
Original bulbous bow hull	70.2	0
With Gondola	84.0	+19.7%
With Flush-mounted	76.8	+9.4%
Cow-catcher	78.0	+11.0%
*Resistance at design speed and draft - CFD Results		

Table 3. Description of the vessel considered for the analysis

Parameters	Units	Prototype
Length overall	m	80.00
Length between perpendicular	m	74.42
Beam	m	17.60
Draft, mean	m	4.60
Design speed	Knots	13.50
Operational speed	Knots	10-11
Displacement	m^3	3791
Water line length	m	77.7
Wetted surface area	m^2	1529

region at which bubbles occur, as well as the pitching motion of the vessel. On this basis, the relatively more favourable hull form is evolved. The merit criteria are therefore bubble avoidance at the sonar transducer space as well as favourable drag characteristic for the given hydrodynamic hull form.

CFD Analysis for the hull forms

The flow simulation is performed for each variant of the hull form. The particulars of the candidate vessel are given in **Table. 3** and this vessel has a bulbous bow, as shown in **Figure. 6.** As a first step, checks are performed to calibrate the numerical model by way of comparison of CFD drag results with experimental results on model scale. The same basic hull form is then re-developed in 4 variants namely, the original hull form but without the bulbous bow and 3 other parametric variants with systematically developed bubble diverting bow side shapes. The 4 variants of the hull form have been evolved later and are shown in **Figure.7.** The hull forms are developed for nearly constant displacement. The CFD yields the streamlines and their proximity to the keel centre-line at the bottom.

Streamline analysis

From the literature, it is understood that the bubble density is highest within the 1.2 m depth from the surface. As per ICES survey speed of a vessel is recommended in the range of 10-11 knots. As a worst case scenario, streamline studies are performed at the design speed of 13.5 knots and analyse the stream lines emanating from the sea surface till 1.2m depth from the bow region of a vessel.

Streamline traces are shown in **Figure. 8** and the co-ordinates are given in **Figure. 9 and 10** for the initial points at bow taken at 0.3 m and 1.2m depth, respectively, below the water surface. The water from the surface is

Figure 6. Candidate vessel hull form

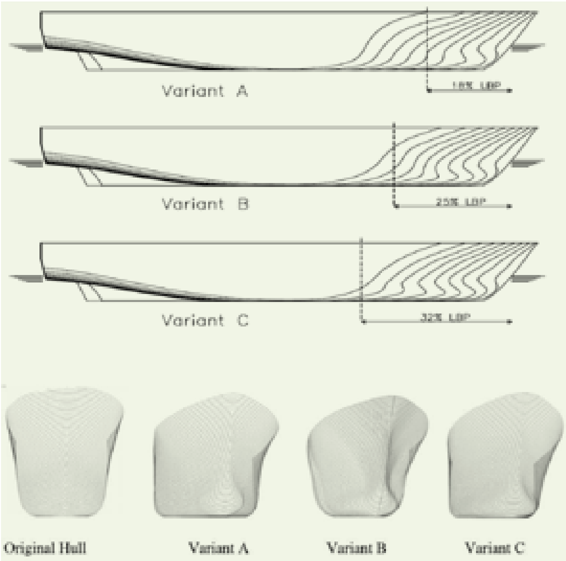

Figure 7. The reference hull form and the 3 parametric variants A, B and C represented in two views for clarity

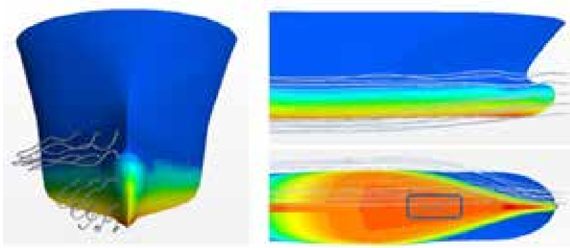

Figure 8. Typical streamline trace of a bulbous bow hull

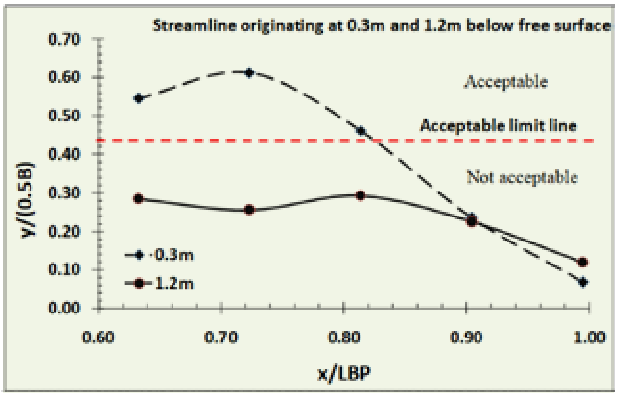

Figure 9. Bulb form – Streamline traces in the X-Y plane

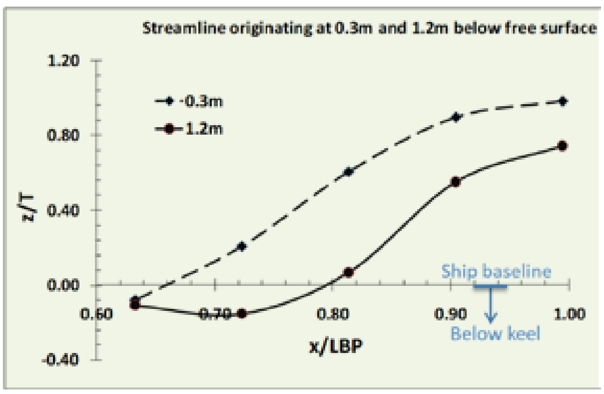

Figure 10. Bulb form – Streamline traces in the X-Z plane

Streamline traces visualize the flow path of the bubble-mixed water flow at different depths below the surface emanating from around the bow of the vessel hull

drawn to 20% below the keel line **(Figure. 10)** at a width of about 50% of the half breadth (4.4 m from the centre-line **(Figure. 9)** at a point 35% behind the fore-body of the vessel. The particles emanating from 1.2 m depth are drawn relatively closer to the centre-line to a distance within 30% of the half breadth (2.64 m from the centre-line **(Figure. 9)** at the point 35% behind the fore-body. The sonar transducer array (based on typical manufacturer data) measures about 5m in breadth and the above streamline trace location is therefore considered too close to the proximity of the sonar transducer. A limiting distance of 1.5 times the sonar transducer half breadth i.e., not less than 3.75 m, is set as the closest point for the bubble-containing streamline trace near the transducer. Hence a non-dimensional half breadth of 0.43 is the limiting barrier for the bubble streamlines trace.

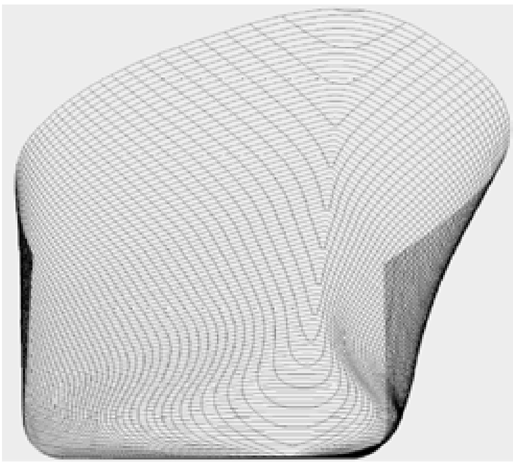

Figure 11. Perspective view of modified BDB hull shape

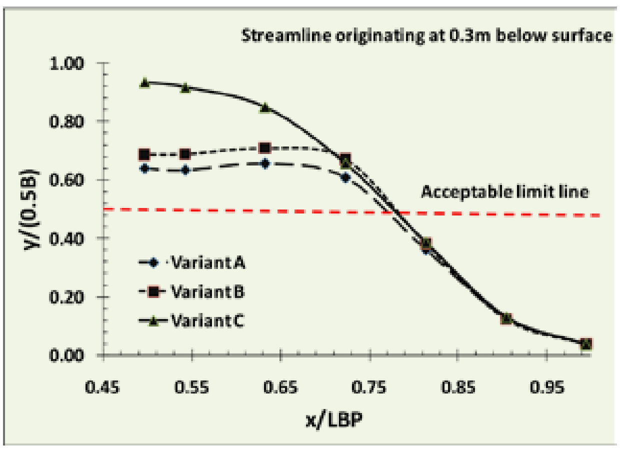

Figure 12. Streamline traces in the X-Y plane

The above-mentioned consideration prescribing the limiting barrier is indicated as a limiting line in the streamline X–Y plots in the subsequent results. The bubbles have the possibility of spreading along the breadth as well as the depth. So long as the bubble streamlines do not cross the limiting line barrier towards the centre line of the vessel, irrespective of depth, it can be taken that the BSD has been mitigated. Therefore, the subsequent graphs depict the 3-D nature of flow around the hull as the flow takes place stern-ward of the ship. For clarity the 2-D plot in the X–Y plane and the X–Z plane are also projected. In the X–Y plane the safe limiting barrier is indicated as a dotted line.

For illustration refer **Figure. 9,** the streamline emanating from the bow region at 1.2m depth is well within the undesirable side of the barrier line, hence bubbles are sure to interfere with the sonar transducer in this case. The streamlines emanating between 0.3 m and 1.2 m depth below the surface spread to the side and the bottom. Since one trace line is within the barrier line, this is not acceptable. With higher winds, the traces get closer to the centre-line.

Streamline analysis for bubble diverter bow variants

The CFD results are given for the original hull form, but without bulb and for the 3 variants to obtain the resistance, as well as BSD streamline trace. All the

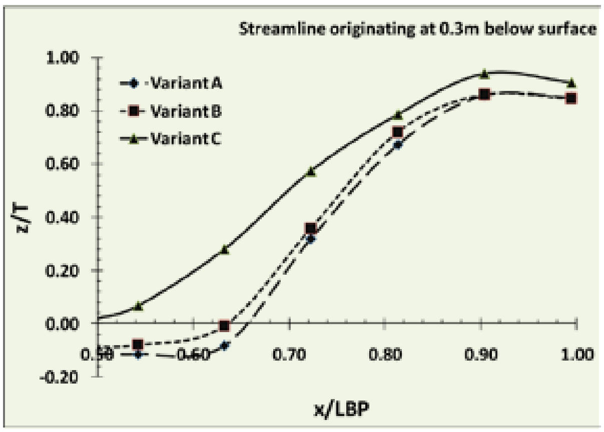

Figure 13. Streamline traces in the X-Z plane

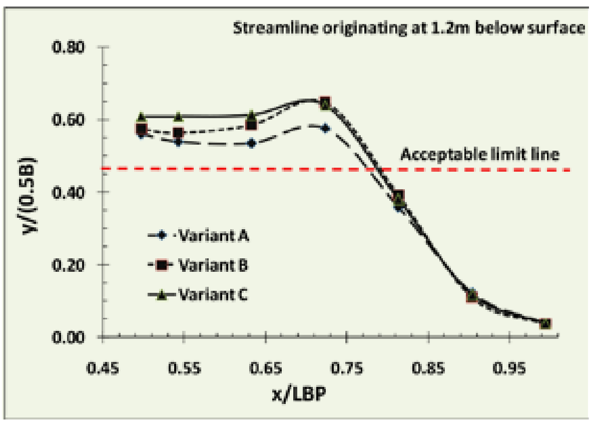

Figure 14. Streamline traces in the X-Y plane

variants are set to a common speed of 13.5 knots in the study. Variant C with a diverter length parameter of 0.32 and diverter area parameter of 0.145, offers the most favourable resistance among the 4 hull forms created. The streamline trace for the two different emanating depths of 0.3 m and 1.2 m are given in **Figures. 12–15.** For both depth levels at the start of the streamlines (0.3 m and 1.2 m) and for all the variants considered, the streamline traces are at more than 50% of the half breadth away from the bottom keel centre-line at the location of the sonar transducer. The streamline traces stay away even at 50% of the LBP from the forward perpendicular. Hence the purpose of BSD mitigation is achieved in all cases in this evaluation study. From the resistance point of view, Variant C is identified as best option. Perspective view of variant C hull form is shown in **Figure.11.**

The streamline originating 1.2 m below the free surface in the forward region of the vessel is traced in **Figures. 14 and 15,** which depicts all the three variants are diverting the flow towards vessel side beyond 52% of half breadth distance (in X–Y plane). Similarly in the X–Z plane, the streamline touches the base line at 35% aft of the forward perpendicular and far away from the bottom keel centreline.

Below 11 knots speed, the Variant C performs even better than the hull form with the bulbous bow. **Figure. 16** shows the resistance values for two forms – Bulbous bow and Bubble Diverter Bow Variant C for different speeds.

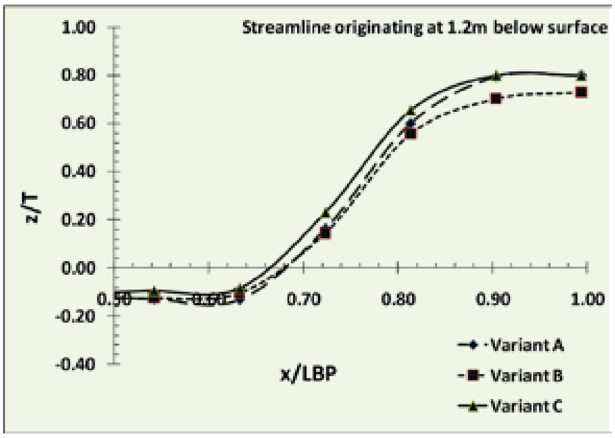

Figure 15. Streamline traces in the X-Z plane

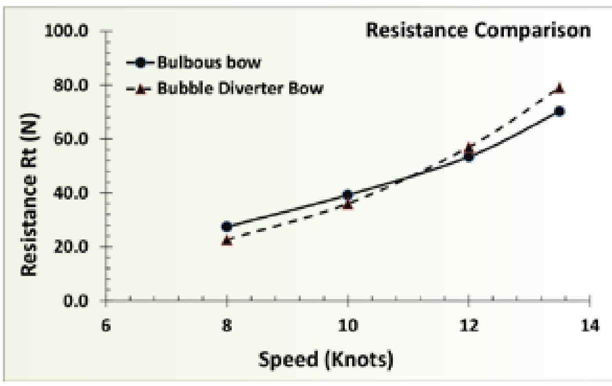

Figure 16. Comparison of resistance at various speeds

The Bubble Diverter Bow is superior till the speed of 11 knots. Hence, while all the 3 variants have effective bubble streamline diversion, Variant C with its cross-sectional area parameter of 0.145 also has minimum resistance, which is favourable.

Figure 17a. shows the streamlines generated at 0.3 m below the free surface for BDB variant C. For all speed ranges the effectiveness of the Bubble Diverter Bow is seen as the flows are completely outwards and therefore the bubbles are effectively diverted avoiding BSD.

The results also suggest that right up to the mid-ship region is a favourable location for sensor array installation. Similarly, streamlines generated at 1.2 m below the free surface, move along the hull well outwards at a distance of 55 to 70% of half breadth for all speed ranges. Depth-wise at all speeds these streamlines reach the bottom at a delayed length i.e., at 37% of LBP from FP **(Figure. 17b).** The results confirm that the critical streamlines are completely away from the ship centreline **(Figure. 18),** and therefore the sonar transducer can be mounted at or near the mid-ship, utilizing minimal pitch related motion without speed restriction.

Conclusion

To mitigate the problem due to bubble sweep-down for oceanographic research vessels fitted with bottom mounted sonar transducers, many solutions have been attempted with limited or no success. In the case of vessels designed with bulbous bow, the bubble occurrence and sweep-down is equally persistent, if not aggravated due to the influence of flow under the shape of the bulbous bow and pitching action leading to bubble entrapment. For a conversion design, array of acoustic

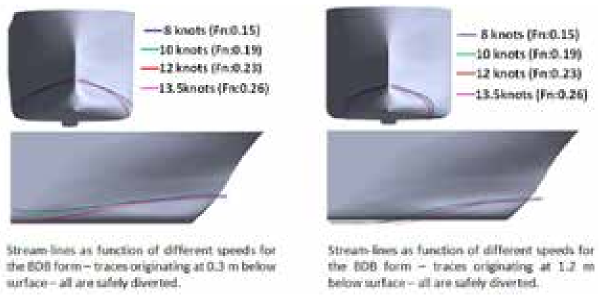

Figure 17a. & 17b. Comparison of resistance at various speeds

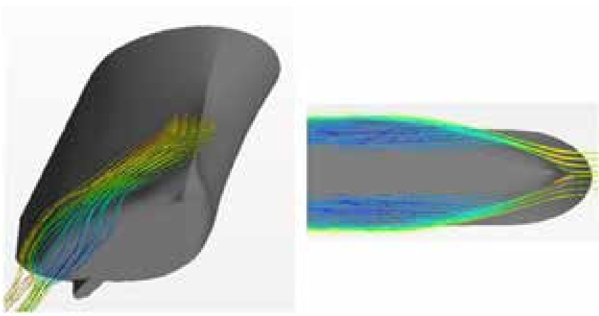

Figure 18. Perspective view of streamline around Bubble Diverter Bow

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Diesel Engine Gas Combustion Simulator for MEO Class I	3 Days	27th June 2024/ 1st July 2024/ 4th July 2024/ 29th August 2024/ 2nd September 2024/ 5th September 2024/ 29th October 2024/ 4th November 2024/ 7th November 2024/ 28th December 2024	Rs. 12000/-	CLICK HERE
Engine Room Simulator Management Level for MEO Class II	5 Days	1st June 2024/ 25th June 2024/ 1st July 2024/ 26th July 2024/ 1st Aug 2024/ 27th Aug 2024/ 2nd Sep 2024/25th Sep 2024/ 1st Oct 2024/ 26th Oct 2024/ 1st Nov 2024/ 26th Nov 2024/ 2nd Dec 2024/ 26th Dec 2024	Rs.14000/-	CLICK HERE
Engine Room Simulator Operational Level for MEO Class IV	3 Days	10th June 2024	Rs. 7500/-	CLICK HERE
Refresher Updating Training Course for all Engineers (RUCE)	3 Days	10th June 2024/ 24th June 2024/ 8th July 2024/ 22nd July 2024	Rs. 7000/-	CLICK HERE
Basic Training for Ships using Fuels covered within IGF code Course	5 Days	3rd June 2024/ 17th June 2024/ 01 July 2024/ 22nd July 2024/ 05th Aug 2024/ 26th Aug 2024/ 02nd Sep 2024/ 23rd Sep 2024	Rs. 15500/-	CLICK HERE
Advanced Trg. for Ships using Fuels covered within IGF code	5 Days	11th June 2024/ 09th July 2024/ 20th August 2024/ 17th September 2024	Rs. 21500/-	CLICK HERE
Assessment, Examination and Certification of Seafarers	10 Days	15th July 2024	Rs. 15500/-	CLICK HERE

sensors mounted in a structure (cow catcher design) as an appendage in the forward one-third length will alleviate the bubble sweep down issue with a compromise on total resistance. To mitigate the problem of bubble sweep-down a bubble diverter bow form has been developed through computer aided surface definition process with parametric variants and examined for performance. The criterion is set by obtaining the streamlines emanating from the typical bubble generating area at the forward in the bow region within the draft of the vessel and checking for the proximity of the trace within the half breadth region at the bottom in the vicinity of the sonar transducer area.

The results show that it is possible to avoid the bubble sweep down at the critical location of the sonar transducer right down to almost the mid-ship length and well out of the way of the transducer location in the centerline. The parametric study on the hull forms also gives the most favourable hull in terms of resistance reduction. By setting a limiting speed of 11knots, the bubble diverter bow form achieves mitigation of bubble sweep-down as well as favourable resistance, compared with a bulbous bow form. The development of the bubble diverter bow form is reported as a new solution to bubble mitigation for oceanographic research vessels, and can be considered for any vessel by thorough hydrodynamic investigation during the design stage. **The proposed innovative concept is being protected through patent number 471384 granted on 21st Nov 2023 by The Patent Office of the Government of India**

References

1. Azcueta, R. (2000). Ship resistance prediction by free-surface RANS computations. Ship Technology Research-Schiffstechnik, 47(2), 47-62.
2. G. Karafiath, J.M. Hotaling and J.M. Meehan, Fisheries Research Vessel hydrodynamic design minimizing bubble sweep-down, in: OCEANS, 2001. MTS/IEEE Conference and Exhibition, Vol. 2, IEEE, 2001, pp. 1212–1223.
3. S.M. Sebastian and J.W. Caruthers, Effects of naturally occurring bubbles on multibeam sonar operations, in: OCEANS, 2001. MTS/IEEE Conference and Exhibition, Vol. 2, IEEE, 2001, pp. 1241– 1247.
4. G.B. Deane and M.D. Stokes, Scale dependence of bubble creation mechanisms in breaking waves, Nature 418 (2002), 839–844. doi:10.1038/nature00967.
5. D. Rolland and P. Clark, Reducing bubble sweep-down effects on research vessels, in: OCEANS 2010 IEEE – Sydney, IEEE, 2010, pp. 1–7.
6. ICES, 2007, Collection of acoustic data from fishing vessels. ICES Cooperative Research Report No. 287. 83 pp.
7. M.Palaniappan, N.Vedachalam, Climate-resilient and eco-friendly shipping : Mapping the trends Marine Technology Society Journal, July/Aug 2022, Vol 56, No 4, Pages 91-103.

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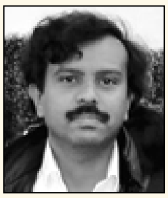

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Green Shipping and Environmental Sustainability - Ammonia Fuel Cells

Vaibhavi Pare,
Aditya Gaikwad

Abstract: The shipping industry faces significant sustainability challenges, primarily due to its reliance on polluting heavy fuel oil, leading to carbon emissions and environmental harm. However, there is optimism in adopting alternative fuel sources, such as fuel cells, offering cleaner and more sustainable energy solutions. This transition has the potential to reduce the industry's carbon footprint, improve environmental performance, and align with global efforts to combat climate change and protect ecosystems, providing a glimpse of a more responsible and sustainable future for shipping.

Keywords: Sustainability; carbon; waste; fuel cells

1. Introduction

The maritime industry faces challenges in adopting new technologies and/or operational practices to comply with increasingly strict international, national, and local regulations aimed at reducing Sulphur Oxides (SOx), Nitrogen Oxides (NOx), Particulate Matter (PM), Carbon and Greenhouse Gas (GHG) emissions from ships

The adoption of the Initial International Maritime Organization Strategy on Reduction of Greenhouse Gas Emissions from Ships by IMO Marine Environment Protection Committee (MEPC) Resolution MEPC.304(72) in April 2018 shows IMO's dedication for the Paris Agreement. The IMO strategy includes initial targets to reduce the average carbon dioxide (CO_2) emissions per transport work from 2008 levels by at least 40 percent by 2030, and 70 percent by 2050. These targets also seek to reduce the total annual GHG emissions from shipping by at least 50 percent by 2050. Technical approaches, operational approaches and alternative fuels may be used to achieve these goals , ammonia (NH3) is a zero-carbon fuel that may enhance the global market relatively quickly and help meet the GHG reduction target for 2050 set by the IMO. Ammonia offers ship owners and operators a zero-carbon tank-to-wake emissions profile, regardless of the source of the fuel meeting SDG (Sustainable Development Goals).

> **The use of ammonia as a fuel is expected to grow due to its zero- carbon content, easier distribution, storage and bunkering compared to hydrogen, and its suitability with existing and emerging technologies for propulsion and power generation**

2. Literature Survey

The American Bureau of Shipping[2] recognizes Low Carbon Ammonia as a potential fuel for decarbonisation in its own right. Low-carbon ammonia can have great significance in global decarbonisation, in both traditional and new ammonia markets. Existing technologies and supply chains[3] can enable efficient transportation for long distances. With some challenges Ammonia slip is the biggest displayed as emission of NOx -a potent GHG through Zeldovich Mechanism[4] is yet to be counteracted.

So, in near future ammonia will be seen dominating the current wave of hydrogen export projects. But to be successful, the myriad potential suppliers[1] will have to understand the true scale of the future low-carbon ammonia market.

3. Ammonia as a fuel for zero carbon footprints

Ammonia has a potential role as a marine fuel on the basis of energy system modelling. Additionally, suggestions may proceed in the motion of an innovation for an alternative ship propulsion system fuelled by ammonia. Study from Kim et.al. in the Journal of Marine Science and Engineering published in march 2020 proved ammonia fuelled ships to be capable of reducing GHG-emissions by 83.7% projected to marine fuel use in year 2050.The use of ammonia as a fuel is expected to grow due to its zero- carbon content, easier distribution, storage and bunkering compared to hydrogen, and its suitability with existing and emerging technologies for propulsion and power generation. The figure below shows projected marine fuel use until 2050 as the industry strives to meet the GHG (Green House Gas) emissions-reduction targets mandated by the IMO. The use of ammonia as marine fuel provides solutions for decarbonization of the global fleet.

> "For combustion, ammonia can be burned either in an IC engine (compression ignition with pilot fuel/spark ignition) or used in fuel cells"

4. Characteristics of NH3 (ammonia)

Ammonia is a compound of nitrogen and hydrogen and is a colourless gas with a characteristic pungent smell at atmospheric pressure and normal temperatures. At high pressure ammonia becomes liquid, hence it is easier to transport and store. Ammonia is the second most widely used chemical, supporting the production of fertilizers, pharmaceuticals, and many other chemical applications.

TABLE 1. PROPERTIES OF AMMONIA[2]

Ammonia Property	Value
Energy Density (MJ/L)	12.7
Latent Heat of Vaporization (MJ/kg)	188
Heat of Vaporization	1371
Autoignition Temperature (°C)	651
Minimum Ignition Energy (MJ)	680
Liquid Density (kg/m^{3})	600
Critical Temperature (°C)	132.25
Critical Pressure (bar)	113
Flammable Range (%)	15.15 to 27.35

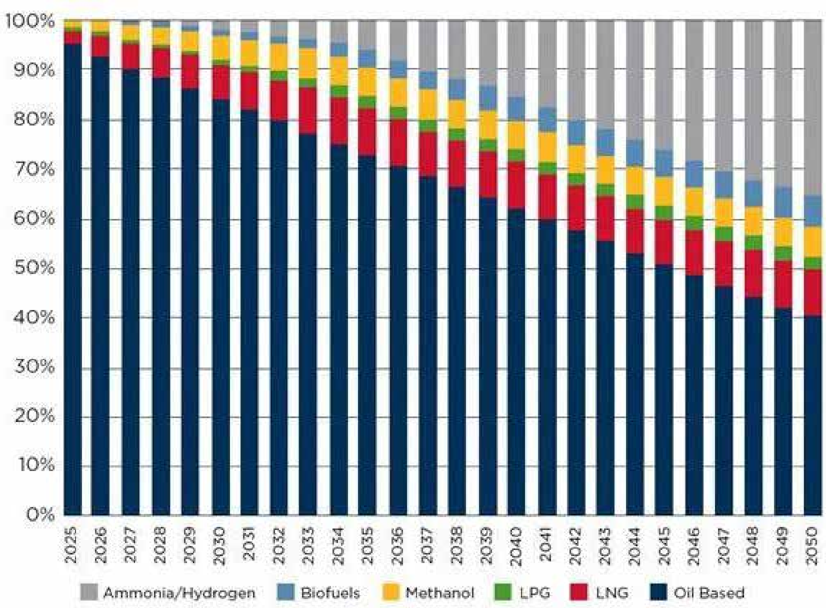

Figure 1. Projected Marine Fuel Use By 2050

4.1 Low Fire Risk:

Ammonia is a flammable gas with narrow flammability range. Its flammable range in dry air is between 15.15% and 27.35%. It has an auto ignition temperature of 651 °C. The risk of an ammonia fire is less compared to other fuels because of its narrow flammability range, relatively high ignition energy (2-3 orders of magnitude higher than common hydrocarbons) and low laminar burning rate (more than four times less than methane [< 0.010 m/s]).

4.2Renewable Production

It can be produced from fossil fuels such as natural gas as feedstock, or with renewables. The reason why ammonia is considered over hydrogen as a fuel is that when used as a fuel, hydrogen is also zero carbon however, if it is produced from non-renewable feedstock, such as non-renewable natural gas through a process using energy not from renewable source, the process could produce significant emissions, which may be hazardous for the environment.

4.3 Storage

Ammonia maintains a liquid state either at -33.6 °C and 1 bar or 8.6 bar and 20 °C. Industrial scale storage uses low temperatures, which requires energy to maintain. This option may have a lower capital cost than pressurization in some cases, due to the lower storage design pressures[7]. However, pressurized storage in

Type C tanks (approximately 18 bar) may be a convenient marine solution and would eliminate the need for additional re-liquefaction equipment to be installed onboard.

4.4Bunkering

Ammonia can be stored at liquid form pressurized, semi-refrigerated or fully refrigerated depending on the needed volume for safe storage, varying from small pressurized 1,000-gallon nurse tanks up to liquefied 30,000-ton storage tanks at distribution terminals. During transfer from one tank to another, either 'cold inbound' or 'warm inbound' is chosen as a result of the transferred volume and re-refrigeration process. The capacity of an onshore full pressure non-refrigerated tank is usually limited. The overall handling can be energy intensive. Three modes of future ammonia bunkering via truck, tank or ship are envisaged.

However, NOx emission is relatively high in practical combustion, which is a main challenge of ammonia combustion

5. Ammonia vs Hydrogen-which one to pick up for SGD?

Hydrogen offers a high energy content per mass, high diffusivity, and high flame speed. Hydrogen as a fuel has been demonstrated in internal combustion (IC) engines, gas turbines, and fuel cells. However, it requires cryogenic storage (-253 °C or lower) and dedicated fuel supply systems for containment. Significant technical advances are needed before hydrogen can be considered a viable, large scale, commercial fuel option, particularly for marine applications where energy content on a volumetric basis is low for hydrogen (9.93 GJ/m^3) and application would therefore significantly impact ship design. Energy loss during storage and boil off gas generation are also challenging for application. Compared to hydrogen, ammonia storage is more practical due to its energy density and liquefaction temperature **(see Figure 2).**

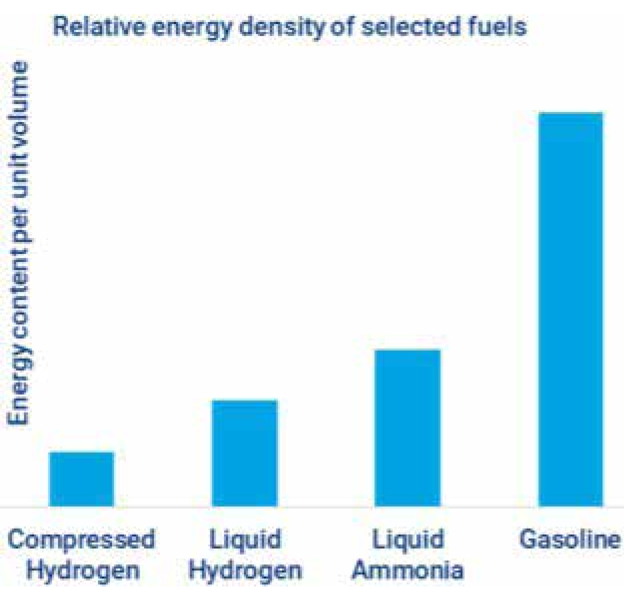

Figure 2. Energy Density Of Selected Fuels
(Source: Wood Mackenzie)

6. Combustion and Propulsion

For combustion, ammonia can be burned either in an IC engine (compression ignition with pilot fuel/spark ignition) or used in fuel cells. Ammonia has a high auto-ignition temperature, a high heat of vaporization and a narrow flammability range. Due to these characteristics, ammonia typically requires a pilot fuel injection. Burning ammonia in IC engines produces water, nitrogen, unburnt ammonia, and possible additional NOx (Nitrous Oxide) due to the high temperatures and pressures involved. Even though the compound itself along with the combustion is carbon-free, these ammonia and NOx by- products need to be managed. Nitrous oxide (N_2O) is a potent GHG with a greenhouse warming potential. The NOx produced may need to be treated with an after-treatment process. These engines and aftertreatment solutions would therefore need to meet existing NOx emissions limits and regulations.

The balanced chemical equation for the combustion of ammonia is as follows:

$$4NH_3 (g) + 3O_2 (g) \rightarrow 2N_2 (g) + 6H_2O (l) \qquad (1)^4$$

When ammonia is completely combusted, it only produces Nitrogen and water without involving the production of NOx. However, NOx emission is relatively high in practical combustion, which is a main challenge of ammonia combustion. NOx is mainly composed of thermal NOx and fuel NOx. Former is usually produced by the oxidation of Nitrogen at temperature up to 1800K. The extended Zeldovich mechanism is widely used to describe the formation of thermal NOx.

The reactions of thermal NOx have three important pathways as elaborated in the equations below:

$$N_2 + O = NO + N, \qquad (2)^4$$

$$N + O_2 = NO + O, \qquad (3)^4$$

and

$$N + OH = NO + H, \qquad (4)^4$$

The first reaction limits the reaction rate and usually it takes place when the temperature is above 1800K. Therefore, controlling temperature is an effective way to reduce thermal NO production. Ammonia has high heat of vaporization (1,371 kJ/kg), which results in considerable evaporative cooling of the mixture after injection and reduces the cylinder temperature at the start of combustion, helping to control NOx formation. Conclusively, an appropriate combustion technology is required, also evaluation of the exhaust emissions to ensure NOx compliance with the regulatory limits needs to be done.

Ammonia is incompatible with various industrial materials, and in the presence of moisture reacts with and corrodes copper, brass, zinc and various alloys forming a greenish/blue colour

6.1 Solid Oxide Fuel Cells (SOFC)

To use NH_3 in fuel cells, the hydrogen contained in the molecule must be separated out. Although it is possible to achieve this through an external reformer so that the hydrogen can be used in low temperature fuel cells such as a polymer electrolyte membrane (PEM), using ammonia directly in high-temperature fuel cells such as a solid oxide fuel cell (SOFC) can be a more efficient solution. There are also other advantages of using ammonia in SOFC, such as high electrical efficiency, the absence of NOx production and the lack of vibration. Fuel cell development is not as mature as IC engines and typically has a higher cost. These factors are expected to show gradual improvement as research continues. An additional shortcoming of SOFC compared to PEM is the sensitivity of the solid oxide ceramic materials used to heat gradients, which requires relatively long and careful start up and shut down procedures and often lasts for hours. Ideally, SOFC plants should be run continuously to minimize the risk of permanent damage. This would typically require the use of batteries for energy storage to accommodate fluctuations in load demand. As an ongoing research Viking Energy[5], an offshore vessel, retrofitted with a 2MW ammonia fuel cell, allowing it to sail completely on clean fuel for up to 3,000 hours annually. It is a proof of the concept project for long range zero-emission large ship voyages. The ammonia fuel cell system will be installed in late 2023. Yara International is contracted to supply green ammonia produced by electrolysis. This will be delivered to Viking Energy in containers for easy and safe refuelling. The project also tests the viability of sustainability sourced ammonia in a solid oxide fuel cell system for a commercial ship

6.2Propulsion and Engine:

The ME-LGIP engine, which is designed to operate on LPG and closest to the expected configuration for burning ammonia, is also entering service for burning LPG on LPG carriers. The ME-LGIP engine can be used with ammonia with slight modifications to the fuel-delivery system to supply ammonia at approximately 70 bar and inject it into the cylinder at 600–700 bar. Ammonia slip will need to be carefully controlled. The high-pressure direct-injection systems used in DF (dual fuel) engines, such as the MAN ME- LGIM and ME-LGIP, can inject fuel at optimum levels and timing to avoid ammonia slip. NOx emissions can be further reduced by using exhaust gas recirculation, or SCR aftertreatment for the exhaust gas.

7. Challenges

7.1 Combustion

Ammonia handling in ships is sufficiently feasible as it has already been handled as cargo and reductant in Selective Catalytic Reduction (SCR) systems for many years. Ammonia as fuel for IC engines is under development. A challenge inherent in its combustion is the large percentage of pilot fuel required for ignition, alternative to which can be provided through fuel cells. Slow flame velocity, ignition temperature, narrow flammability range and lower heat of combustion are issues for ammonia ignition. Engine control strategies by engine manufacturers can address these issues. The advent of electronic engine controls and existing DF technologies, including the Diesel process used by MAN Energy Solution's ME-LGI engine shows promise in addressing these issues in the near future.

7.2 Flammability:

Ammonia can react with halogens, interhalogens and oxidizers and may cause violent reactions or explosions. Therefore, ammonia should be stored in a cool, well-ventilated location, away from sources of ignition, and separate from other chemicals, particularly oxidizing gases (chlorine, bromine, and iodine) and acids. Dilution systems may be utilized to avoid the flammability range of ammonia, large ammonia fires can be extinguished through water spray, fog, or foam but care needs to be taken to prevent environmental contamination from diluted water/runoff.

Table 2. Advantages And Challenges Of Nh

Advantages	Challenges
Carbon free – no CO_2 or soot	Toxicity
Low flammability risk	Fuel
infrastructure Produced through Renewable energy	Lack of regulations
Easily reformed to hydrogen and nitrogen	Engine development at design
stage Easily stored and transported	Cost
Established commercial product	Corrosiveness
Easily liquefiable	Increased NOX emission

7.3 Corrosion:

Ammonia is incompatible with various industrial materials, and in the presence of moisture reacts with and corrodes copper, brass, zinc and various alloys forming a greenish/blue colour. This increases drag as the hull gets corroded increasing the ton-mile hence reducing efficiency of the fuel. Ammonia is an alkaline reducing agent and reacts with acids, halogens and oxidizing agents. Materials are to be carefully selected when ammonia is used onboard a vessel. Iron, steel and specific non-ferrous alloys resistant to ammonia should be used for tanks, pipelines and structural components where ammonia is used. Stress corrosion cracking is induced and proceeds rapidly at high temperatures in steel when oxygen levels of more than a few ppm in liquid ammonia are introduced. The IGC Code outlines the requirements for piping components, cargo tanks and equipment in contact with ammonia liquid or vapor.

"The additional space for fuel, due to lower energy density, may require larger vessels sizes, decreased cargo space or more frequent bunkering"

7.4. Volume occupation as a challenge

As ammonia has low energy content it will require larger tanks for storage and their location on board will be a critical design factor. When ammonia is used as a fuel, the changes in vessel arrangement are dependent on the location and type of ammonia tank/containment system. Cargo capacity also is expected to decrease based on the use of ammonia combustion engine or ammonia fuel cell arrangement employed. The additional space for fuel, due to lower energy density, may require larger vessels sizes, decreased cargo space or more frequent bunkering. Novel power generation systems such as fuel cells may also change the architecture of the current engine room. Thus decrease in cargo capacity may be compensated through fuel cells by additional space of the engine room.

6.5Craft Design

For ammonia fuelled vessels, the specific vessel arrangements will vary depending on the actual fuel pressure and temperature settings of the fuel. The prime mover selected and fuel storage conditions will also affect vessel design. The link between the fuel storage, fuel preparation and fuel consumer is much more interdependent than with conventional fuels. It is critical that equipment and system design decisions consider this interdependence. For ammonia fuelled ships, the main systems require different or additional concepts in ship designs are the ammonia fuel containment system, associated ammonia bunker station and transfer piping, a fuel supply system, boiloff gas handling, reliquefication, gas valve unit/train, nitrogen generating plant, vent piping systems and masts, and for some ammonia tank types, additional equipment for managing tank temperatures and pressure. Deluge systems, personal protective equipment, independent ventilation for ammonia spaces, emergency extraction ventilation and closed fuel systems may also be required. A practical ammonia tank location that does not compromise safety or cargo capacity and operations is a challenge.

Ammonia requires about 2.4 times more tank volume than Heavy Fuel Oil (HFO) to generate the same energy. Ammonia tanks need to comply with the requirements of the IGC (The International Code of the Construction and Equipment of Ship's carrying Liquified Gases in Bulk) and IGF(International Code of Safety for Ships using Gases or other low-flashpoint fuels) Codes on minimum distances from the hull's shell, accommodation space, design and safety requirements, etc. The IGC Code contains specific material requirements for ammonia fuel containment under Section 17.12 and these would be expected to be applied, as applicable, for marine fuel storage tanks

6.6Fuel Supply

The purpose of the fuel supply system (FSS) is to deliver fuel at the correct temperature and pressure to the engine. The use of low flashpoint fuels and gases introduces complexity to the fuel supply and consumer systems and creates a greater interdependence between the key systems over conventional fuel systems. For fuels using cryogenic/ pressurized liquefied storage, such as ammonia, the fuel can be pumped or pressure fed, directly in liquid form. The FSS can be one of the more complex and expensive systems required for gas fuelled applications. The FSS needs to ramp fuel supply quantities depending on the engine fuel demand. This transient fuel demand can be a challenge, particularly when maintaining fuel supply readiness in times of high demand or zero demand, without causing a shutdown of the FSS. It may also not be part of the engine Original Equipment Manufacturer (OEM) supply, but solely designed to comply with the engine OEM's specifications.

8. Conclusion

This study evaluates ammonia as a potential marine fuel, focusing on environmental impacts and spill concerns. Ammonia's swift concentration decrease reduces long-term spill worries compared to HFO. Dual fuel engines, especially in LPG carriers, are considered a promising entry point, with expected ammonia engines by 2024. While ammonia is carbon-free, unaddressed combustion emissions pose environmental risks. NOx emissions can be mitigated with exhaust gas treatments like SCR, and future engine tests must minimize ammonia slip. Stringent regulations are crucial for N2O emissions due to their high GWP. Research is needed on emissions from burning ammonia with other fuels, and fuel cells could offer emission-free alternatives, though not yet commercially viable for deep-sea shipping. Ammonia's global production infrastructure supports shipping demand, but green ammonia supply is currently limited, requiring increased production. Synergies with other sectors, like agriculture, also needing green ammonia, exist. Developing robust certification systems for green ammonia is imperative. In conclusion, ammonia, as a carbon-free post-fossil fuel, emerges as a promising marine fuel candidate, potentially cost-effective compared to alternatives, contingent on addressing emissions and scaling up green ammonia production.

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References

1. American Bureau of Shipping (ABS) publication[2]- Setting the Course to Low Carbon Shipping: Pathways to Sustainable Future
2. Computational Analysis of the Extended Zeldovich Mechanism[4], November 2014; https://www.researchgate.net/publication/278391595_Computational_Analysis_of_the _Extended_Zeldovich_Mechanism
3. Characteristics of an SI Engine[8] Using Direct Ammonia Injection, Department of Mechanical Engineering, Iowa State University; https://nh3fuelassociation.org/wp-content/uploads/2013/10/nh3fcx-song-charng- kong.pdf
4. Large Scale Ammonia Storage and Handling[7], D. Webb, pp. 1–37, 2008.
5. The offshore vessel to run on ammonia-powered fuel cell; https://www.fch.europa.eu/press-releases/ major-project-convert-offshore-vessel-run- ammonia-powered-fuel-cell
6. Press release article[3], January 11,2022 'What role will Ammonia play in global hydrogen trade'; https://www.hellenicshippingnews.com/what-role-will-ammonia-play-in-global-hydrogen-trade
7. Press Release Article[1], July 14,2021 by Panos Koutsourakis, The Maritime Executive, powering a low carbon fuel; https://maritime- executive.com/editorials/powering-a-low-carbon-future-with-methanol-as-a-marine- fuel
8. Master's Thesis[6] Emtiaz Ali Brohi, Chalmers University of Technology, 'Ammonia as fuel for internal combustion engines?' Applied Mechanics.

[This was presented at the Transtech 24 event and secured the first prize]

Troubleshooting of Alternators Part 3C

Elstan A. Fernandez

1.15 Parallel Operation of Alternators

Some paralleling problems and causes, which can occur, are mentioned in the following paragraphs:

a) Oscillating kW meter, ammeter, and voltmeter.

Cause: Engine governing. Replace by known serviceable unit. This may also be caused by electronic governors with insufficient speed droop (less than 2%).

b) Unbalanced ammeter readings. kW meters balanced and stable.

Cause: Circulating current through incorrect voltage settings, droop CT connections are reversed or insufficient droop.

c) Unbalanced ammeter readings on no load or rapidly rising currents as soon as the contactor is closed.

Cause: Incorrect voltage settings or droop CT connections are reversed.

d) Unbalanced kW and ammeter readings as load is increased or decreased.

Cause: Dissimilar governor speed regulation, or very sensitive governor control (electronic). If the governor is set at less than 2% speed regulation, the kW load sharing will be poor.

e) Unbalanced ammeter readings as load is increased. The kW meters are balanced.

Cause: Droop circuit settings are not identical, or one droop kit is reversed, or the droop CT is not in circuit.

Apart from the above problems, certain peculiarities may exist which are in no way detrimental to the operation of the sets. They may, however, confuse the operator into thinking that a fault exists.

The most common query results from voltage oscillation during the initial paralleling procedure. When an additional set is being connected to the busbars with the synchroscope / lamps switched on, a point may be reached where the incoming machine voltage starts to fluctuate. This only occurs when the frequency difference is at its greatest. As the frequencies approach each other, no further instability is noticed. This is not, however, a function of the stability circuit within the AVR, but relates to 'pick-up' problems associated with the switch board's wiring.

Symptom	Possible Cause	Tests and Remedies
Circuit breaker will not close when attempting to parallel the machines.	The circuit breaker is fitted with 'Check Synchronising' protection, which prevents out of phase paralleling).	Ensure that the synchroscope is indicating that machines are in-phase, or close to the eleven o'clock position, (when rotating in a clockwise direction). Ensure that the speed difference between the incoming set and the bus bar is low enough to prevent rapid rotation of the synchroscope, (or rapid fluctuations of the lights), before closing the circuit breaker.
	Phase rotation of one machine is different to the other	Check the phase rotation of each individual generator. No Attempt to parallel must be made until the phase rotations are all identical. Reverse two phases on the generator, which has a different rotation.
	The generator is over or under-excited which can be identified by the power factor meter	Adjust the AVR using the voltage trimmer
Circuit breaker will not close when attempting to parallel the machines.	Voltage difference too high between the incoming Generator and the Bus bar.	The voltage on the incoming set can be up to 4% higher than the bus bar Voltage. This is normal. Do not adjust original no-load Voltage settings. If difference is greater than 4%, check for excessive droop on the loaded Generator(s).
Difficulty in maintaining a stable in-phase condition, prior to synchronising.	Governor drift on one or more of the engines.	Let engines stabilise (warm up) before paralleling. If speed is still drifting check governors and engine condition.
	Load variation on the bus-bar causing speed / frequency changes at the time of synchronising.	Disconnect any rapidly varying load. Check that there is no likelihood of a motor or automatic load starting when synchronisation is attempted. Do Not attempt to parallel if the load current is highly unstable.
Frequency (Hz), unstable when on load in parallel.	Engine speed droop too 'tight' or cyclic irregularities (instability), between the engines. (Check kW meters for rapid shifting of kW power between sets).	Increase the engine governor speed droop, to 4% droop, (no load to full load). Check for "sticky" governors on a new engine. Check engines for cyclic problems, (firing, out of balance, etc).
Voltage fluctuates during synchronisation, (stable before and after).	This symptom usually results from line pick-up between the Generators, through the synchronising panel and/or protection circuits, (earth leakage etc), that can form a temporary 'closed loop' link between the Generators during synchronisation.	The fluctuation will decay when the Generators approach synchronism, (almost identical speeds), and will disappear completely when the circuit breaker is closed. The synchronising equipment, earth leakage protection, and/or wiring circuits, in the switchboard can produce pickup problems.
Current rises rapidly without control as the incoming circuit breaker Is closed.	Parallel droop equipment reversed on one of the Generators.	Check the droop CT's for reversal. (See previous text in this section). Reverse lead S1-S2 on the droop CT. Check the excitation voltage, the generator with reversal will have highest the excitation voltage.

Symptom	Possible Cause	Tests and Remedies
Circulating current on both generators at no load, (current Is stable).	Voltage difference (excitation level) between the Generators.	Check Voltages at No Load, (identical frequencies), and ensure all Generators have identical voltages at no load. Do not adjust when load sharing.
	Parallel droop equipment reversed on BOTH Generators. (Unlike ONE droop reversal, which is a highly UNSTABLE condition).	Check all droop CT's for reversal, as suggested in previous test.
	Incorrect setting of parallel droop equipment.	Check settings of droop trimmers. Check droop CT's are in correct phase. Check CT output to AVR S1- S2 is correct. (See previous text).
Ammeters showing unbalanced Readings after adjustment of The kilowatt meters.	Voltage difference (excitation levels) between the machines.	Test the machines individually for exact voltage at No-Load.
	Parallel droop equipment incorrectly adjusted.	Adjust as stated in previous text.
	Improved regulation equipment affecting the load sharing. (Pre 1989 machines only.)	Short out the improved regulation equipment and test again. Re-adjust if this is causing the problem. Remove improved reg. equipment if AVR's are changed to a later model.
Kilowatt readings become unbalanced as load Is increased or decreased.	Engine governors are incompatible, or new governors 'sticking, giving unequal kW sharing over load variations.	The engine governors must be adjusted to give similar No-Load / Full Load characteristics. Check for 'sticky' governors on new or repainted engines. Electronic governors should be set with a minimum 2% speed droop to ensure satisfactory kilowatt load sharing. If tighter speed regulation is required, an isochronous kW load sharing system should be installed.
Ammeter readings become more unbalanced as load Is increased.	Difference in Parallel droop level settings and in no load to full load voltage regulation of the AVR's. (These settings are the major contributing factors to the load/voltage characteristics of the machine, and therefore must be set to give equal characteristics to the machines with which it is paralleled.)	Run the generators singly, and apply the load at approximately 25%, 50% and 100%. Take Voltage readings at each level and compare them with the other Generators. Adjust the control systems to remove regulation differences. Repeat the above with as much inductive load as possible i.e., motors, transformers etc. Adjust the parallel droop trimmers, to achieve equal inductive load sharing.
Voltage regulation is poor for a single running machine.	Excess amount of parallel droop in circuit.	For normal voltage regulation as a single running machine, a shorting switch should be fitted across the parallel droop transformer. (S1 - S2). This should be clearly marked 'Single' 'Parallel' operation. (See previous text).
kW meters unstable, engines 'rocking' on their mounts.	Electronic engine governor speed 'droop' characteristics set too tight.	At least 2% engine droop is essential for kW (Active current) sharing. If 1% or less speed regulation is required, isochronous governing and kW load sharing system.

1.16 Overcoming Winding Contamination in Brushless Alternators

Inspect the stationary and rotating winding periodically for cleanliness. The chief engineer or his appointed representative will supervise internal inspection of the ship service generator. *Never inspect internal generator components while the prime mover is operating, or the generator is connected to the switchboard bus.* Always secure the prime mover fully and ensure that other power sources such as the emergency generator or shore power, cannot erroneously feed the generator being serviced. Textbook maintenance practices mention removal of dirt by vacuuming and removal of grease and oil by wiping with lint-free rags. These methods rarely serve the purpose intended. Contamination prevention is the key.

Inspect the generator prime mover for gasket and seal leaks. Check the adjacent piping and deck plates for liquids and particles. Once the windings become contaminated, there is no thorough and safe method to clean the generator windings on board the vessel. The only effective remedy is the removal of the generator, its complete disassembly, chemical cleaning and baking. When contamination is found, use the megger to check the insulation values. **Always disconnect the rotating rectifier, voltage regulator and any other components that house semiconductors and sensitive components.**

Compare readings with the appropriate technical manual, with other known good generator readings, or against historical documentation. As per I.E. Rules (Rule 48), the test voltage for equipment of different voltage ratings must be as follows:

- Low voltage and Medium Voltage Equipment - 500 V for 1 minute
- High voltage up to 33 kV – 1000 V for 1 minute

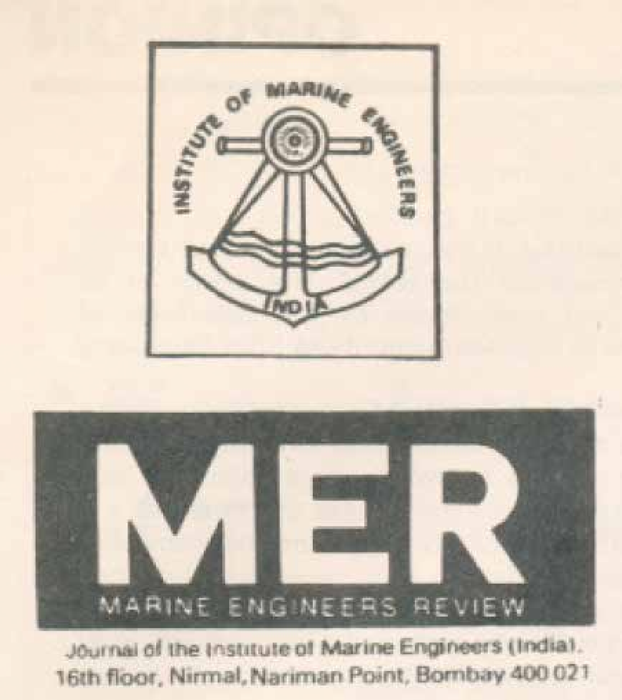
Remember that when a megger is being used to test the insulation of an alternator, the resistance value of a dry, clean winding will continue to rise as test potential is maintained, becoming steady as the dielectric-absorption effect of insulation stabilizes.

About the author

Elstan Fernandez has an experience of 44 years in the Maritime and Energy Industries. He has been an Author / Co-author of 80 Books. He holds the statuses of Chartered Engr, FIE, MIET (UK), MLE[SM] Harvard Square (USA). He is the Joint Inventor with a Patent for Supervised BNWAS and won the Promising Indian of the Year in 2017.

Email: elstan.a.fernandez@gmail.com

Going Astern into MER Archives...



The Editorial continues on the issue of merging the weak shipping companies and the viability studies to be undertaken to address this. It is reported that the Government might not take up the study, rather it would be by the shipping companies. The Editorial observes that the viability study has been a non-starter due to *'varying approach and parameters adopted by different shipping companies in respect of improvement in revenue earnings, escalation and descalation* (Hon.Ed: read, decrease) *in cost coupled with the lack of documentary evidence for verification of current projections, the reasonableness and validity of the current projected picture and these would require to be assessed by the experts of the SDFC and shipping ministry before adopting the same as a base for future projections and assessments of future scenarios'.*

The complex sentence must be a true representation of the more complex nature of the viability study. Whereas it makes one wonder if such things can be reduced under possibly two factors: no-cargo non-productive periods and the earnings bottom-line.

The next section, 'Opinion' discusses registry of ships and an oncoming UNCTAD conference on the same. Another paragraph discusses how a turbocharger can be coupled to the crankshaft to add to the power. An RTA engine arrangement of turbocharger coupled to the crankshaft through a gearing is mentioned. Anyone with experience on such arrangements for those times?

Following this we see an interesting article on predicting the ignition quality of residual fuel oils. A dual pump arrangement and two equations are provided to resolve residual fuel burning.

Anyone who worked on this system?

More fuel topics follow... Laboratory methods for ignition quality assessments, emulsified fuels, an insightful piece on matching the cylinder oil consumption to engine load, fuel treatment studies and the fuel talks end with a small write-up on measuring the sediments.

Another one which adds value to the issue is the article on Salvage Contract.

Then the technical talks continue on improving the efficiency of turbochargers.

Under 'Ship Conversion' there is a description of a conventional cargo ship of 15000dwt transformed into a training ship. The pictures are too feeble in clarity and not reproduced. One can still check the June 1984 issue.

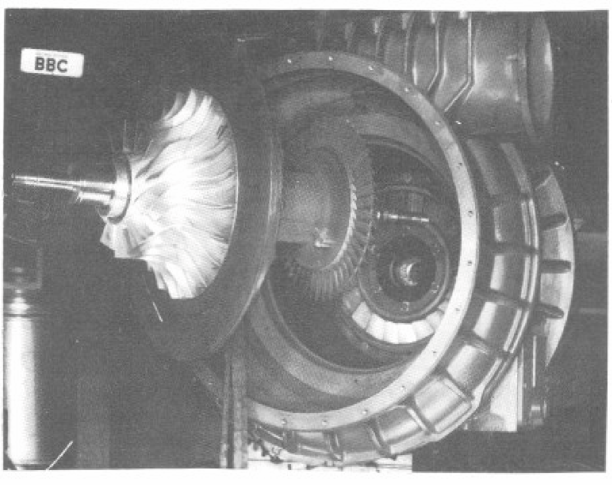
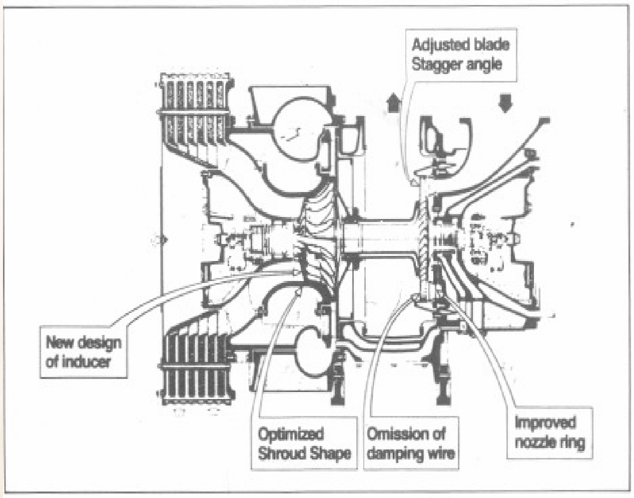


Fig 1: The VTR 4A's improved components result in better efficiency.



The Transactions Section has one absorbing paper on ' The Design and Installation of Ships' Electrical Systems to minimise the Effects of Fire'. Few sections are extracted and inserted. The bulkhead penetration drawings would be of interest to those appearing for CoC examinations.

Another paper finding place under Transactions is the one on towing gear on board. 'The Towing Connection' discusses a lighter but stronger towing connection for ships. This arrangement could be the predecessor to the ETA arrangements which appeared soon after.

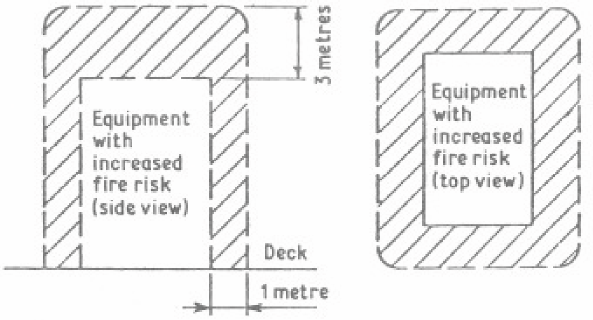


FIG. 7 Cables for essential systems should be routed to avoid high fire-risk areas (shaded)

FIG. 1 Switchboard fault leading to release of ionized gases

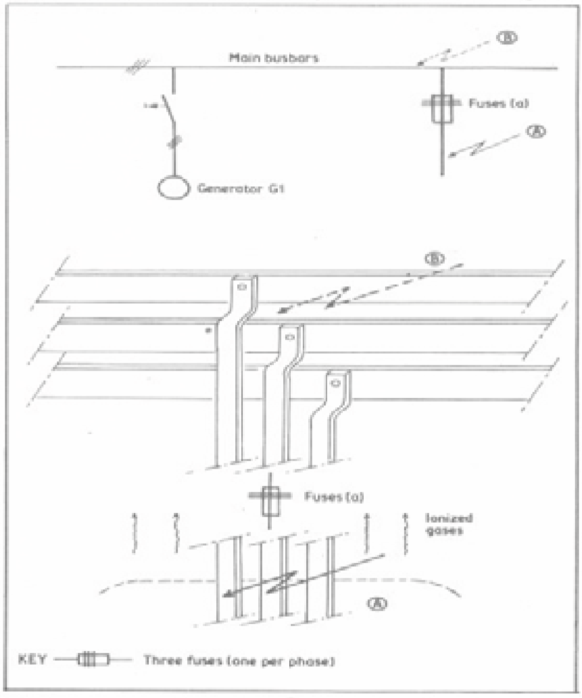


Table I: Characteristics of materials commonly used in marine electrical cables

(1) MATERIAL	(2) COMMON ABBREVIATION	(3) cm^3 HCl EQUIVALENT RELEASED PER GRAM OF COMPOUND	(4) LIMITING OXYGEN INDEX (ASTM D2863)	(5) COMPARATIVE SMOKE EMISSION DATA SDR (%)[a]	 MSO (%)[b]
Ethylene propylene rubber	EPR or EPDM	0	19–21	unknown	unknown
Polychloroprene	PCP or Neoprene	75–110	27–37	51–69	84–96
Chlorosulphonated polyethylene	CSP or Hypalon	60–100	29–32 38–40[c]	11 35[c] 61[e]	24 66[c] 94[e]
Cross-linked polyethylene	XLPE	0	16–17	36	91
Polyvinyl chloride (sheaths)	PVC	170–250	25–27 32–35[d]	69 51[d] 42[f]	89 81[d] 54[f]
Polyvinyl chloride (insulation)	PVC	125–175	25–27 32–35[d]	69 51[d] 42[f]	89 81[d] 54[f]

[a]SDR = Smoke density ratio. (Measure of total amount of smoke emitted during test.)
[b]MSO = Maximum smoke obscuration, a comparative figure.
[c]So-called flame retardant CSP.
[d]So-called flame retardant PVC.
[e]So-called Heavy Duty CSP.
[f]So-called Low Smoke PVC.

Table II: Characteristics of newly developed or modified materials used in marine electrical cables

(1) MATERIAL	(2) COMMON ABBREVIATION	(3) cm^3 HCl EQUIVALENT RELEASED PER GRAM OF COMPOUND	(4) LIMITING OXYGEN INDEX ASTM D2863	(5) COMPARATIVE SMOKE EMISSION DATA *NBS Smoke Chamber ASTM E-662/79*[a]	 *Arapahoe Smoke Chamber*[b]
Chlorosulphonated polyethylene	CSP Low smoke CSP	54 31	35–37 31–33	460 70	7–8 4.5–5.5
Polyvinylchloride (sheath) (1) High oxygen index (2) Low acid gas evolving	PVC	 181 34	 36–38 25–27	 630 230	 11—13 7.5–8.5
Polyvinylchloride (insulation)	PVC	169	24–26	380	9–11
Vinyl ethylene acrylate (sheath)	EAR	0	24–35	65	3
Ethyl vinyl acetate (sheath)	EVA	0	>30	unknown	3
Polyolefin copolymer (insulation): cross-linked non cross-linked		0 0	25–27 29–31	unknown, presumably low unknown, presumably low	
Polyolefin copolymer (sheath): cross-linked non cross-linked		0 0	37–43 44–50	unknown, presumably low unknown, presumably low	

[a]The NBS smoke chamber method measures optical density of the smoke.
[b]The Arapahoe method determines the amount of carbon particles formed by the combustion of the material.

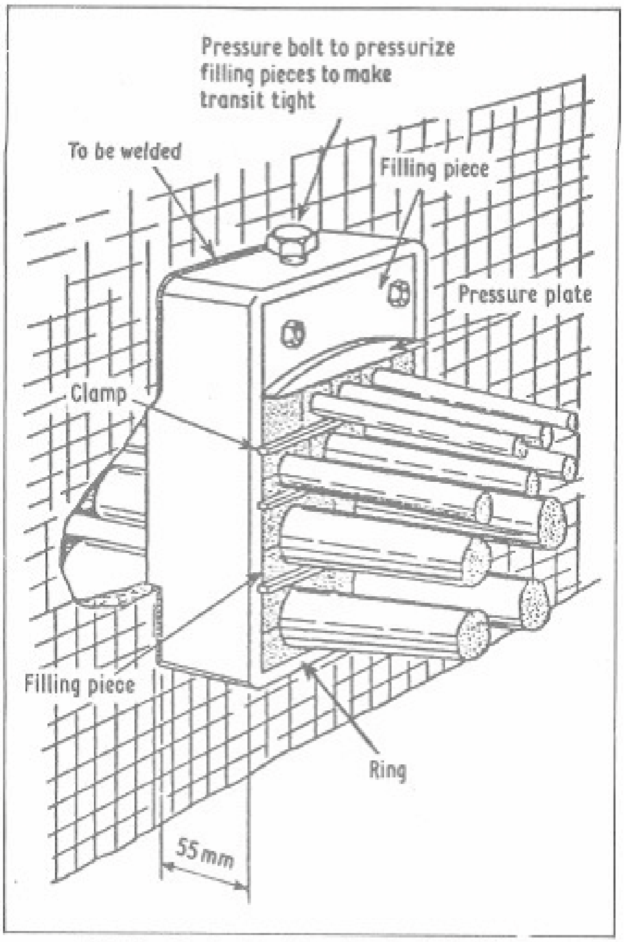
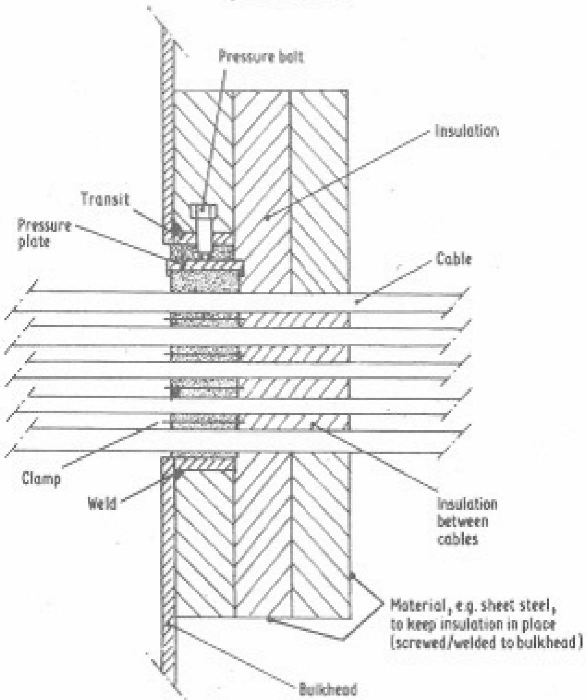


FIG. 8 Standard bulkhead or deck gland box

FIG. 9 Bulkhead gland box with thermal insulation for 'A' class penetrations



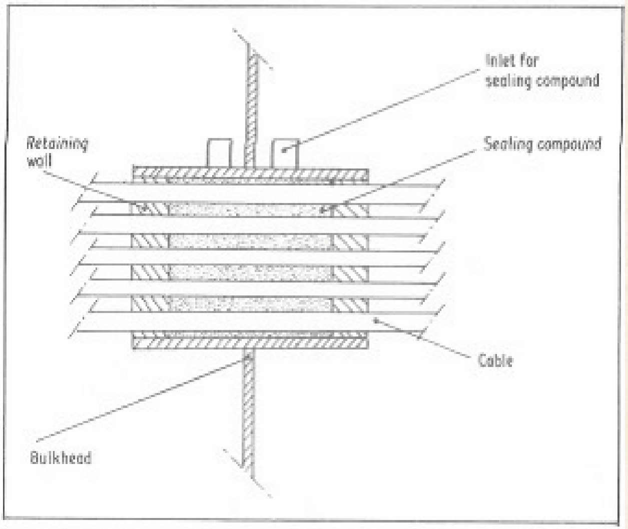
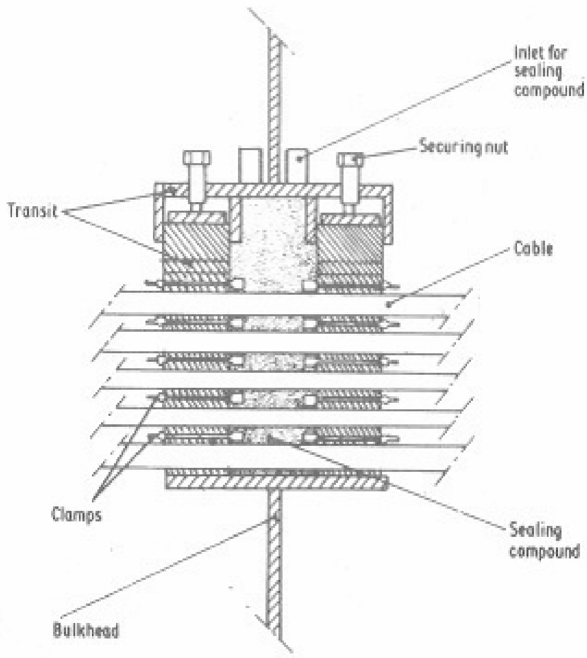
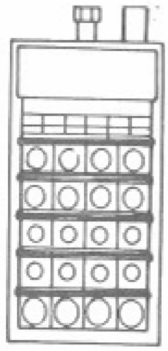


FIG. 10 Bulkhead penetration for 'A' class penetration

FIG. 11 Bulkhead penetration for 'A' class penetration





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

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"It was the best of times, it was the worst of times, it was the age of wisdom, it was the age of foolishness, it was the epoch of belief, it was the epoch of incredulity, it was the season of Light, it was the season of Darkness, it was the spring of hope, it was the winter of despair, we had everything before us, we had nothing before us, ..."

Charles Dickens comes to our minds as we reflect upon the state of shipping today. Juxtaposed between Trade Wars, Galloping Technology, Regulatory Challenges and Climate Change issues, we could be looking like a deer caught in the headlights, unable to comprehend where our future lies.

The Lehman Brothers crisis of September 15, 2008, now close to 15 years ago; yet we have not been able to overcome its impact, just as we have never been able to avoid the odd bout of flu every winter, and of course the Covid-19. There has been a continuous stream of regulations, in the wake of galloping technology, escalating political gamesmanship across nations, and also with safety management continuing to be an issue, duty of care towards crew remains questionable.

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The Ocean's Mirror: Reflecting on Samudra Manthan

Kushie Bhulla

The *Samudra Manthan*, also known as *Amrit Manthan* or the Churning of the Ocean (of Milk), is an ancient and highly symbolic mythological event that has captured the imaginations of countless history enthusiasts. Rooted in Hindu scriptures and mythology, this captivating tale weaves together elements of discovery, jealousy, desire, and divinity. With its deep spiritual significance, the *Samudra Manthan* explores the eternal conflict between good and evil, offering profound insights into the human yearning for transcendence and the quest for a blissful and immortal existence. From the chance encounter between *Indra* and *Rishi Durvasa* to the churning of the ocean and the emergence of treasures, this timeless story resonates across cultures and continues to inspire artistic representations that embody it.

> *As the churning continues, the ocean bestows various gifts, including Kamadhenu, the wish-fulfilling cow, the Kalpavruksh, the celestial tree granting boons, and Mahalaxmi, the goddess of wealth and prosperity. Finally, Dhanvantari, the physician of the gods, emerges with the ultimate treasure—the Amrit or Somras.*

The narrative unfolds when *Indra*, the King of Gods, encounters the sage *Rishi Durvasa* by chance. In a thoughtless act, *Indra* leaves a garland gifted by the sage on the tusk of *Airawat*, his divine elephant. The scent of the flowers annoys *Airawat*, causing him to trample it. Enraged by this disrespect, *Rishi Durvasa* curses the *Devas* (Gods), and subsequently their powers begin to diminish, making them vulnerable in their battle against the *Asuras* (demons). To counter this decline, *Vishnu* suggests that the Devas churn the ocean to obtain the *Amrit* or *Somras*, the nectar that grants immortality, thereby restoring their strength to fight the *Asuras*. With this goal in mind, the Devas agree to a truce with the *Asuras*. They both join forces to churn the ocean.

The *Mandara* Mountain is chosen as the churning stick, and *Vishnu* takes his second avatar as *Kurma*, a tortoise, upon whose shell the mountain is placed. *Vasuki*, a

Depiction of the Churning of the Ocean at Angkor Wat Temple in Cambodia | Source: artifactsblog

serpent, volunteers as the rope to facilitate the churning process. Initially, the churning releases a potent poison called *Halahal*, which *Shiva* graciously consumes to protect the world. As the churning continues, the ocean bestows various gifts, including *Kamadhenu*, the wish-fulfilling cow, the *Kalpavruksh*, the celestial tree granting boons, and *Mahalaxmi*, the goddess of wealth and prosperity. Finally, *Dhanvantari*, the physician of the gods, emerges with the ultimate treasure—the *Amrit* or *Somras*.

The representation inherent in the episode is profound and has been depicted in various artistic representations both inside and outside of India. It finds its depiction in symbols, paintings, metaphors, even on temples, sculptures and has references to real-life locations. It is even said to be the first play composed by *Brahma*, according to *Natysastra* of *Bharat Muni*[1]. It may be crucial to note that the episode of the *Samudra Manthan* is not looked at as a mythical occurrence in isolation, each individual portion in the story has a deep meaning of its own, such as the *kurma* or the tortoise, said to be *Vishnu's* second avatar—*Kurma* with 'self-controlled man' in religious texts and suggests that it was the 'emblem of stability' in myth and *Vaastu Shaastra*.[2]

[1] Desai, 2013
[2] Toraskar, 2019

> ***"The most recent depiction of the Samudra Manthan is seen recently on the walls of the New Parliament Building"***

Legend has it, that when the *Dhanvantri* came out with the bowl of *Amrit* or *Somras*, he handed it down to Vishnu. From whom, one of the *Asuras* attempted to snatch the bowl—this led to a tussle between the *Devtas and Asuras*. During the tussle a few drops of the *Amrit* fell on the ground and four significant *tirthas*—Trimbakeshwar, Prayagraj, Ujjain and Nasik—came up. The Kumbh Mela, a commemoration of this event is held at these places, the largest of them is held in Prayagraj.

In the context of my understanding, the gifts during the churning of the ocean symbolize its transformative power. The ocean represents abundance, sustenance, and opportunity like in *Kamadhenu* and *Kalpavruksh*. It mirrors prosperity and interconnectedness, akin to *Mahalaxmi's* blessings. However, challenges like *Halahal's* poison remind us of the need to protect and preserve this vital resource for a sustainable future. The episode emphasizes the dual nature of the ocean—offering both opportunities and responsibilities to humanity.

The reliefs and sculptures depicting the *Samudra Manthan* are most often found in temples associated with Shivism such as Gondesvara Temple in Sinnar and Kiradu Somesvara Temple in Rajasthan, Mallikarjuna Temple in Pattadakal, Cave no. 19

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Albeit a representation of the eternal struggle between good and evil, knowledge and ignorance, and the forces of light and darkness. Samudra Manthan reflects the universal theme of the eternal conflict between virtue and vice, with the Devas representing righteousness and the Asuras embodying greed and ego

at Udaigiri in Badami, Shanchiya Mata Temple in Osiya among others. All of their depictions are astutely similar, yet different and unique. The most recent depiction of the *Samudra Manthan* is seen recently on the walls of the New Parliament Building. A 75 ft long mural depicting the Churning of the Ocean was commissioned and designed by Naresh Kumawat to adorn the halls of the Lok Sabha. Not all depictions of the *Samudra Manthan* are the same. In some depictions such as the Gondeswara Temple, Mount *Mandar* has been personified while the reliefs in Someswar Temple depicts only one *Asur* holding the mouth of *Vasuki*.

The episode popularly finds a depiction in the sculptures and carvings on the southern section of the east gallery of the Angkor Wat temple complex in Cambodia. 88 *Asuras* and 92 *Devtas* (differentiated from the Asuras with crested *mukuts*) are depicted churning up the ocean complete with *Vasuki* and Mount *Mandar*. Interestingly, on the carvings at Angkor Wat, the sculpture also depicts Hanuman in attendance along with *Brahma*, *Shiva* and *Mahalaxmi*.

More recently a display of the episode is found on the Suvarnabhumi Airport in Bangkok. Apart from the similarity in the story and the novelty of the piece, the depiction blends Indian and Thai elements, underscoring the universal resonance of the story.

Albeit a representation of the eternal struggle between good and evil, knowledge and ignorance, and the forces of light and darkness. Samudra Manthan reflects the universal theme of the eternal conflict between virtue and vice, with the *Devas* representing righteousness and the *Asuras* embodying greed and ego. The Samudra Manthan also illustrates the concept of cause and effect, where actions have consequences, and the pursuit of power and desires can lead to both positive and negative outcomes. It emphasizes the importance of balance, selflessness, and cooperation in achieving collective goals and overcoming challenges.

Ultimately, the whole moral of the episode lies in *Amrit,* which brings into focus the eternal conflict between good and evil, personified by the *Devas* and *Asuras*, and explores the human yearning for a blissful and immortal existence, transcending the limitations imposed by conflict and the impermanence of mortal life. In its essence, the *Samudra Manthan* reminds us of the profound spiritual quest for transcendence, offering insights into the nature of existence and the eternal struggle between light and darkness.

Thus, the story of the *Samudra Manthan,* with its rich allegory and timeless themes, continues to inspire and resonate with individuals, imparting lessons about the pursuit of enlightenment and the eternal battle between good and evil.

References

1. Toraskar, S. (2019). *A Unique Composition of Samudra-manthan Panel from Kiradu, District Barmer, Rajasthan*. (PDF) a Unique Composition of Samudra-manthan Panel From Kiradu, District Barmer, Rajasthan | Sitaram Toraskar. Academia.edu. https://www.academia.edu/44859786/A_Unique_Composition_of_Samudra_manthan_Panel_from_Kiradu_District_Barmer_Rajasthan
2. *The Ratnas of Samudra Manthan | Amar Chitra Katha*. (2021, May 14). Amar Chitra Katha |. https://www.amarchitrakatha.com/mythologies/the-ratnas-of-samudra-manthan/
3. *Samudra Manthan (Churning of Ocean)*. (n.d.). INDIAN CULTURE. http://indianculture.gov.in/museum-paintings/samudra-manthan-churning-ocean
4. S, R., Parameswaran, A., & Prasad, K. (2018, July 2). *The Story of Samudra Manthan - Depiction on Angkor Wat | Beyonder*. Beyonder. https://beyonder.travel/south-east-asia/cambodia/the-story-of-samudra-manthan/
5. *What is the underlying symbolism of the 'Samudra Manthan'?* (n.d.). Quora. https://www.quora.com/What-is-the-underlying-symbolism-of-the-Samudra-Manthan
6. *Meet sculptor Naresh Kumawat, who crafted a 75 ft long Samudra Manthan mural inside new parliament building*. (2023, May 30). The Indian Express. https://indianexpress.com/article/lifestyle/art-and-culture/sculptor-naresh-kumawat-75-ft-long-samudra-manthan-mural-new-parliament-building-8636345/
7. *Bhagvad Puran* https://lakshminarayanlenasia.com/wp-content/uploads/2017/03/Bhagavata-Purana_1stTime.pdf
8. *Bangkok Airport Samudra Manthan Structure* . (n.d.). [Video]. YouTube . Retrieved June 7, 2023, from https://youtu.be/H46o6GBXIBE
9. *Kumbh Mela and Sangam | District Prayagraj, Government of Uttar Pradesh | India*. (n.d.). Kumbh Mela and Sangam | District Prayagraj, Government of Uttar Pradesh | India. https://prayagraj.nic.in/tourist-place/sangam/#:~:text=According%20to%20legends%2C%20Vishnu%20was,the%20devout%20can%20attain%20salvation.
10. An Epic in Stone: Angkor Wat's Churning of the Ocean of Milk | Artifacts.blog.com | Retrieved July 28, 2023 from https://artifactsblog.com/

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