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IIRE Journal of Maritime Research and Development

Maritime sector has always been influencing the global economy. Shipping facilitates the bulk transportation of raw material, oil and gas products, food and manufactured goods across international borders. Shipping is truly global in nature and it can easily be said that without shipping, the intercontinental trade of commodities would come to a standstill.

Recognizing the importance of research in various aspects of maritime and logistic sector, IIRE through its Journal of Maritime Research and Development (IJMRD) encourages research work and provides a platform for publication of articles, manuscripts, technical notes, papers, *etc.* on a wide range of relevant topics listed below:

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Editorial

This issue dedicates itself to publishing selected research papers of the highly successful 'International Maritime Research Confluence' (IMRC 2020) organized by IIRE at Mumbai on 13th and 14th February 2020 at the IRS (Indian Register of Shipping) Auditorium.

Truly a pioneering attempt in the country to address maritime research and bring together the industry, academia and government, the Symposium addressed the following six major areas of the maritime domain in its 6 sessions over two days:

Towards Blue Economy; Human Resources Development & Management; Data Analytics; Ship Operations; Ports & Logistics; and Technological Advancements.

The presentations, deliberations and interaction were within the framework of Sustainable Development goals established by the United Nations as a 2030 agenda, and the aim was to strategize the growth of the shipping sector, particularly in the India context, in a sustainable way.

This attracted the participation of professionals and academicians from all sectors of the industry: Ship Owners, Ship Yards, Investors and Decision Makers, Port and Terminal Authorities, Ship Managers, HSSEQ Professionals, Designers and Engineers, Individual Researchers and Authors, Academic Establishments, Equipment and Machinery Manufacturers, Manning and Crewing Agencies, Classification Societies and Maritime Authorities.

The students and scholars participated through poster presentations.

This issue carries one paper each of presenters from Singapore, Bangladesh, Hong Kong and India respectively and the students section has 3 papers based on which poster presentations were made.

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IIRE Journal of Maritime Research and Development (IJMRD)

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TACKLING CHALLENGES IN COMMERCIAL SHIPPING THROUGH TECHNOLOGY

Punit Oza

Abstract

Three major challenges are shaping the future of commercial shipping today. One, the family owned companies are moving to professional management thereby allowing the chartering professionals to move into a deal-making role, which was usually reserved for the family members in the company. Two, the old-school mentoring and training is nearly non-existent with knowledge gaps existing in senior professionals and lack of patience in the younger professionals entering the industry. Three, information was the key reason why deals were made in past but today the data is universally available and the key to deal-making is the ability to analyse the data in order to extract value for both the shipping company as well the customer. This paper aims to explore how we can leverage technology to confront these challenges. Technology can reskill the chartering professionals with deal-making skills such as negotiation techniques and insight selling. Video and Virtual Reality tools can build sustainable and flexible training modules which can fill in knowledge gaps, while engaging the younger professionals in an interactive manner. A knowledge vault will also be created in the process, helping future generations and securing the experiential knowledge of senior experts. A customized analytics program for the chartering professionals can raise awareness of the value of data among the professionals and provide historical trends and analysis in order to drive more data-driven decision making rather than gut feel based, which is not sustainable. It is also clear that while quite a few tasks can be automated, the relationship-based model of deal making will ensure that people are right at the centre of any successful shipping company.

Key words: Digital Transformation, Process Re-engineering, Data analytics, Commercial Shipping. Today, Transformation is a buzz word doing the rounds in all companies and sectors around the globe and the maritime sector is very much in the middle of this wave as well. The starting point is to determine what are the main pillars which support a transforming organisation.

1. THREE PILLARS SUPPORTING A TRANSFORMING ORGANISATION:

The first pillar is Sustainability. As an organisation transforms itself, it needs sustainable processes and systems which are dynamic and rise above the individual users. The processes and systems will live on well beyond the users and need to stand that test of longevity and adaptability. The second pillar is Transparency. As they say, “what you see is what you get”. It is important to establish clear and transparent processes and systems, which will help the entire organisation recognise the strengths, weaknesses and gaps within the organisation. The final pillar is Profitability. Eventually the organisation needs to remain profitable to survive and grow. There are many ways you can gauge the efficiency and results of a transformative process and system but eventually it will be profitability - the ability to contribute to the bottom line - as the final straw on the camel’s back.

2. KEY TRENDS IN COMMERCIAL SHIPPING:

In order to truly transform, we must address the fundamental question - why transform? Things are going well right now so why change it? These are natural questions and the ones that any management team should be asking. The answers lead us to identifying the key trends in commercial shipping.

One, Family owned shipping companies are undergoing a "sea change" (pun intended). When we look at companies such as MSC, Maersk, PCL and even Klaveness - these family owned companies are moving towards professional managers taking over the running of the company. In the past, the shipping companies were dominated by the family members controlling the company and they were in effect the "deal-makers" and the chartering managers in these companies were essentially doing the backend jobs - running voyage estimates and negotiating the contracts. This has meant that the knowledge of systems and processes has become the benchmark of expertise for chartering professionals - an end. As the companies have become more professionalized and the technology is now quickly taking over these systems and processes, these chartering managers are expected to take over the task of deal-making. This will also mean that a whole new set of skills need to be imparted to these professional managers. This is one of the key reasons why digital transformation is essential - to unlock the true potential of the chartering professionals.

Two, the old school way of teaching and passing knowledge from seniors to the youngsters through mentoring does not exist. The intent to mentor is missing and, in some cases, so is the knowledge, especially in those senior personnel who came into the industry in the heady years of 2003 to 2008, when the market was on fire. These senior managers never got trained, due to no fault of their own, in the basic concepts of shipping and that means they are not able to pass on any "knowledge" to the younger generation. In addition, the younger generation is much more impatient and prefer to learn through technology rather than the old school methods.

Three, gone are the days when information was key to getting a deal done. Today, data is the new "oil", but it is becoming more and more democratized. Nearly all of us have access to the same data. The power of data and the impact of its objectivity is unparalleled. However, the key is not data itself but the way we analyse it. It will be analytics that will set you apart and get the deal done. Gut feel and memory were usually behind decisions taken but they are limited

in scope, extremely subjective in nature and linked to an individual. Data Analytics allows us to make objective and data-driven decisions, although the task of making that decision still lies with humans.

3. ACTIONS TO CAPITALIZE ON THE KEY TRENDS:

It is important to remember that technology is not the end point but only an enabler which allows you to get to the end point - which is to solve real pain points.

First action is that the process must start from the top. The vision of digital transformation must be laid down by the top management and communicated in clear terms to the entire organization and possibly written into one of the broad goals of the company. The digital transformation must be brought into the organization in the same fashion as traffic from two lanes merge into one in an expressway. The main elements of this merging of lanes are setting of traffic rules (Chief Executive Officer - CEO - sets these rules), the cars themselves (Chief Digital Officer - CDO - provides these technology vehicles and products) and finally the drivers who are driving these cars (Chief Human Resource Innovators - CHRO - ensures that the personnel using these products are adequately skilled). Thus CEO, CDO and CHRO must combine their energies to build this vision and implement it.

Second action is to get the buy-in from existing staff. Not only are the existing staff a reservoir of knowledge and experience, they are also, most likely, the biggest revenue earners in the team. They need to be on board. Their obvious questions are - why do I need to transform? I know my business well and am making good money for the company, so why change? Am I making my own job redundant? Over the years, knowledge and proficiency in systems & contracts was considered an end. This must change. It is important to use technology to standardize and automate processes and at the same time, re-skill employees with skills such as Insight Selling, Marketing and Negotiation Skills in order to turn process experts into dealmakers. This will unlock their true value and get their crucial buy-in in the transformation process.

Third action is to attract young talent and more importantly retain them. The younger generation are looking for colleagues that they enjoy working with and a sense of purpose. Digital transformation ticks both these boxes. The Digital transformation journey is as exciting

as a treasure hunt. You have been given the destination and a set of clues and it is up to you to solve the riddles and reach the treasure. When you make this an exciting process and involve the younger talent, they will simply love this process. Often, the younger talent is not given credit for their ideas and in some cases, not even given a voice on the table. This must change. The young talent are digital natives with very little baggage from past and that should be a positive attribute to bring about Digital Transformation. A key use of technology with the existing staff is to vault their knowledge by creating videos and presentations on various topics of expertise and disseminating them across the organization. Remember to give them full credit to them, which is obviously well deserved and will motivate them even more. This technological tool will also help bridge the knowledge gap of seniors as they are unlikely to acknowledge the gap publicly and learn the basic concepts along with other colleagues but learning those concepts on their own phone or laptop is quite acceptable. These tools also ensure buy-in from the younger talent.

Final action is to equip the organisation with the power of Data Analytics. This will actually involve Data Literacy (ensuring that each employee is aware of the power of data and thereby entering it more responsibly), Data Access (so that each employee can see how powerful data is helping his job and also enabling him or her to contribute better) and finally Data Tools (to visualise the data in order to capture insights and therefore drive decision making). These three elements will combine to create Data Democracy, which will ensure that the organisation truly moves towards data analytics in an efficient and purposeful manner.

4. TORVALD KLAVENESS - SPECIFIC BUT GENERIC EXAMPLES:

While the above lays out the conceptual clarity, it is best to give a few examples to link them up with real world. At Klaveness, we are already on our way to transforming the organisation from within and I was quite fortunate to start that process by heading the Processes, Systems and Competence (PSC) team.

We have adopted the PSI approach to transformation. The first stage is Problem Identification followed by Solution Development and finally there is Implementation and Follow up. The problem identification stage involves identifying specific problems/challenges faced by charterers and operators, such as inefficiencies (time wasted), quality issues, any issues which limit decision making and has high degree of complexity. It is important to prioritize these by

impact of problem and the feasibility of being able to solve it. The solution development stage involves developing solutions for problem in cooperation with end-users, IT and other relevant stakeholders. Solutions can be standardization/change of process, implementing new/changing systems, *etc*. The key is to start by putting together a prototype or "minimum viable product/solution" and adjust based on feedback from end-users. The most important part is the implementation and follow up. This involves ensuring implementation of new solutions in cooperation with IT and other stakeholders, follow-up on usage/adherence, measure impact of solution (*i.e*. has it solved the problem?) and thereafter further adjust solutions based on feedback from end-users.

In order to re-skill and up-skill the employees - young and new - we believe in training from within. We were keen to build flexible & customized training modules, creating ownership in the process & ensuring monitoring use of training modules, thereby focusing the energies of the leaders on those team members who were lagging. These modules ensured vaulting the knowledge in one technological arena and have the added advantage of ensuring the training material is current and dynamic. Finally, the technological modules ensure that proper motivation and incentives can be provided to the staff. The in-house online training resource is aptly named "Klaveness Academy"

We also realised quickly that collaboration within the organisation must become more contextual. Emails are long and usually contain multiple issues and subject matters. As we go back to search these old emails, it is usually impossible to extract the context. Further emails are essentially a static platform, which means that any updates need to be resent and circulated by fresh emails, thereby overloading the staff with messages with too much content. We believed that we needed to replace emails (especially internal communication) with a platform ideally suited to capture knowledge, learnings, documents, standard formats in one place which could be centrally updated and automatically disseminated. We have thus successfully replaced all internal communications and replaced this with the MS Teams platform. We also ensured that we created visualisation tools to share the data insights across the entire organization using MS Power BI. These dashboards solved one key issue - it created a single version of truth and one source of data for all. This has produced much more efficient and streamlined discussions and captured comments and insights from multiple sources in one place, thereby positively influencing decision making. Over and above this, it also helps democratizing the data and motivating analytical reasoning within the organization.

5. KEY TAKEAWAYS TO A SUCCESSFUL TRANSFORMATION:

Combining the generic trends and actions outlined above with our experience in Klaveness, we can outline some key takeaways as listed below.

a. Transformation is not an option but a necessity!
b. Data is NOT the key - Data Analytics is!
c. Eliminate insecurity among senior talent through re-skilling and motivate younger talent by providing them a voice & a purpose.
d. Technology is your friend - use it in difficult times to solve problems.
e. Transform from within and then move outside to focus on customers.
f. Use the Problem/Solution/Implementation Approach.
g. Seeing is believing - Aim for a few small wins to reaffirm belief.
h. Vision set out by CEO and executed by CDO & CHRO.
i. Step by step approach is good enough but these steps must move the company in the right direction.

6. CONCLUSION:

I truly believe that technology is a great leveller. Eventually, we will move towards standardization and more of the shipping products will become "homogenous" in nature. The only differentiating factor will be the people and the service they are giving to their customers. All things being equal, the team that offers a better service and value to their customers will win and the focus will move back to adding value to the customer. However, for all other things to be equal, the companies need to also catch up on digital transformation and technology. Thus, it is essential to embrace this for all companies. Remaining static in an ever-changing world in nothing short of suicide.

ABOUT THE AUTHOR:

Punit Oza

Mr. Punit Oza has over 26 years of experience in Dry Bulk Shipping, holding senior management positions in leading shipping companies. Over the last 2 years, he has been very closely involved in the transformation and competence building within Torvald Klaveness and since January 2020, he has moved into the board of Klaveness Asia Pte Ltd.

Punit is a Senior Adjunct Fellow in Maritime and Port Authority of Singapore (MPA) Academy and a guest lecturer at Singapore Management University and BAC College, Singapore, which is affiliated to University of London. He is a board member of Singapore Maritime Foundation (SMF) and a member of the Trade and Connectivity sub-committee of Singapore Government's Future Economy Council (FEC). He chairs the Singapore branch of Institute of Chartered Shipbrokers (ICS).

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IMPLEMENTATION OF CONTROLLING THE PRIVATE RECRUITMENT AND PLACEMENT SERVICES UNDER MLC 2006: A CASE STUDY OF BANGLADESH.

Sabbir Mahmood

Abstract

In 2006, the ILO adopted the MLC, 2006 a comprehensive framework convention which codifies the human, labour and social rights of seafarers, through unifying the legal regime of labour law and international maritime law. The success story of the MLC, 2006 will be written only after effective implementation of the convention at a national level and will be tested by the experience of more than 1.6 million seafarers working on board plying the world's ocean.

The manning agencies and recruiting companies played a vital role to supply the seafarer for maritime industry and stabilize the maritime labour market. However, without an effective control and supervision system, it is very likely for seafarers to be exploited by some greedy manning agents. Therefore, Regulation 1.4 of title 1 of MLC 2006 provides legislative framework to prevent the exploitation by regulating the recruitment and placement service providers. The implementation of regulation 1.4, including its standard and guidelines are most critical in the convention, as they envisage multi directional activities and various forms of state responsibilities.

The ultimate goal of the provision is to ensure efficient, adequate and accountable system for finding employment by seafarers without any charge, harassment or exploitation. Research shows that, the charging to seafarer for employment and many other irregularities are still going on in many developing countries, though they are signatory to the convention. The quantitative analysis of the study helps to find out the seafarer's situation of the employment and dealing of RPS. We further conducted qualitative survey and desk study of the existing laws and institutions of Bangladesh to find out the capability of competent authority to implement the Regulation 1.4 of MLC 2006. Finally, we have identified the gaps and make recommendations on an approach that could be taken by Bangladesh to ensure successful implementation of regulation 1.4 of MLC.

Key Words: Seafarer, Recruitment, Control, Accountable, Charge, License.

1. INTRODUCTION:

Maritime transport is the backbone of world trade, which carries about 90 per cent of the cargo through 50,732 ships (UNCTAD, 2018), crewed by 1.6 million seafarers (BIMCO-ICS, 2015), those are tolerating unique pressures and risks in their work place. International Labour Organization (ILO) is working to prevent the exploitation of seafarers, confirming decent working environment and establish labour rights. ILO adopted the Maritime Labour Convention, 2006 (MLC, 2006) on 23 February 2006 on an almost unanimous basis which is popularly lauded as the 'fourth pillar' of international maritime law as well as 'bill of rights for seafarers' (Moira L. McConnell *et al*, 2011).

However, the success of the MLC, 2006 is dependent to large extent on effective national implementation of the convention, particularly by flag State, port state and labour supplying state. Ultimately, its success will be truly tested by the experience of seafarers working on board, plying the world's ocean. The job market of seafarers is open and competitive, as such the ship-owners are interested to recruit the seafarers from various sources. The manning agencies and recruiting companies played a vital role to supply the seafarer for maritime industry and stabilize the maritime labour market (Zhang, 2016). However, without an effective control and supervision system, it is very likely for seafarers to be exploited by some greedy manning agents. Therefore, Regulation 1.4 of title 1 of MLC 2006 provides legislative framework to prevent the exploitation by regulating the recruitment and placement service providers.

The implementation of regulation 1.4, including its standard and guidelines are most critical in the convention, as they envisage multi directional activities and various forms of state responsibilities. In Bangladesh, the seafarer's number is very small, and the job market is limited. As such, the risk to exploit the seafarer prior employment is high. Therefore, it is timely to carry out a study analysing the existing institutions, legal regime, policy, customary practice in seafarer's employment market to identify the critical issues in relation to the recruitment and placement of seafarer in national and foreign ships. The purpose of the study is also to identify gaps and make recommendations on possible solutions and approaches that could be taken to ensure successful implementation of Regulation 1.4 of MLC, 2006, so that the seafarer may have access to an efficient, adequate and accountable system for finding employment on board ship, without any kind of harassment and financial burden.

2. REGULATION 1.4 RECRUITMENT AND PLACEMENT:

The seafarers found the regulation very important, as they are concern about the exploitation through the largely unregulated middle person services. The MLC provides the right of access to an efficient, adequate and accountable system for finding employment on board ship without charging to the seafarer. The convention specifically prohibits any kind of fees or charges, directly or indirectly from seafarers for employment other than the cost of medical certificate, seafarer's book, passport or similar travel document, excluding the cost of visas, which must be borne by the ship-owner. The seafarer has the right of free access to the information of employment and right to appear for any job without any barrier for which he is qualified. The

seafarer has the right to complain any unfairness or wrongful acts against RPS and solution of those issues.

The provision of MLC does not impose obligation on member state to have private RPS, through providing phrase where and if while regulating the private RPS (Moira L. McConnell *et al*, 2011). It is also equally clear that regulation 1.4 does not require that ship-owners to use such service but rather that, if the service used that must be certified, licensed or regulated in accordance with the convention. The provisions are directed at discouraging ship-owners from using private RPS that are not regulated, especially for the case where seafarers are from the country that do not ratify the MLC,2006.

The responsibility to implement the provisions are mainly on labour supplying state, which is unique in MLC,2006, in comparison with any other maritime convention. A key strategic point is that, the flag state and labour state responsibilities at the shipboard level is not explicitly set out in regulation 1.4. The guidelines of ILO provides suggestion, to check the national websites of the competent authority regarding the licensing or regulating of RPS (ILO, 2012). The use of certified, licensed or regulated private RPS by Ship-owners is also included in the list set out in Appendices A-5-I and A-5-III of the MLC,2006, which is subject to verification during flag state and port state inspection. The guidelines suggested checking through interviewing the crew in private that they have not paid a fee or have been informed of their rights or the RPS does not operate a blacklist.

3. IMPLEMENTATION OF REGULATION 1.4 IN BANGLADESH:

Bangladesh is a maritime State and Bangladeshi seafarers' have a long-standing role in the world's seafaring workforce. There are about 4000 ratings and 8000 officers enlisted in Government shipping office and out of which at present, about 2000 rating and 4000 officers are engaged in national and foreign flagships. The two government operated institutions and seven private maritime training institutes for training and education of officers, crew are the entry point and home ground for producing seafarers for international market. According to the Department of Shipping (DoS) record, there are sixty licensed private manning agents in Bangladesh, working to arrange employment of seafarers for national and foreign flag vessels. The Shipping Office of Chittagong is responsible for monitoring and control the employment,

engagement and discharge of seafarer in accordance with national and international laws under the supervision of DoS, Dhaka.

Bangladesh as a labour supplying state provides mandatory provision to have approved license issued by Department of shipping through specific procedure to engage any seamen. The Seamen Recruiting Agents License Rules 2005 (SRAL Rules), widened the scope of work of RPS, providing that, the licensee will perform the duties to engage seamen in both Bangladeshi and foreign ships, which was earlier applicable for foreign vessel only. The law imposes imprisonment for maximum six months period or fine not exceeding ten thousand taka or both for violation of that provision. The Bangladesh legislation prohibits the receiving of any money or security from seafarer without the prior approval of the Government. The law also provides obligation to the RPS to submit the return of any amount of money received from the seafarer, which has been approved by the DoS during renewal of license.

Bangladesh has a unique legal framework to protect the seafarers from stranding. The private RPS must deposit security of 5,00,000/ Taka to the competent authority, which will be handled according to the law. The Government may forfeit the security money if the RPS acts fraudulently or provide false document. The forfeited money may be utilized to compensate the seafarer for his unpaid wages or repatriation or for any welfare of the seafarer. Bangladesh legislation provides responsibility to the licensee to arrange repatriation if any seafarer stranded in foreign port. The private RPS in Bangladesh is responsible to confirm the payment of wages in current month to the seafarer or to his nominated person. If any seafarer become sick or injured or died the RPS shall arrange for repatriation, payment or treatment as applicable. The private RPS shall try to resolve any dispute or problem regarding wages or condition of employment in consultation with Shipping Master. However, the Bangladesh legislation does not explicitly address the responsibility of competent authority to closely supervise and control the RPS, but the requirement of renewal of the license after every 2 years and mandatory audit by competent authority provides the mechanism to monitor and control the activities of private RPS. The complaint handling procedure and punishment for any wrongful act is also unique in Bangladesh. According to law, the competent authority may suspend license for three months upon receipt any complain considering the nature of complain. The competent authority may withdraw the license if the private RPS found guilty of following acts:

a. If violate any law, rules or condition of license
b. Found negligent or incapable to perform the duties
c. If failed to preserve all business document for last three years
d. If refused to submit the business document to the authority
e. If provide any false document in favor of any person

4. EFFECTIVENESS OF IMPLEMENTATION OF REGULATION 1.4:

Despite the regulation 1.4 and enforcement criteria, the cost free recruitment service is not realistic in the current maritime labour market of many countries (Dragomir Cristina, Utureanu Simona). One of the study of Romanian manning agency revealed that, *"there are crewing agencies in Romania that unjustifiably demands return airfare, seafarer's book or administrative fees, at least at the moment of initial registration of seafarer in the agency's database.* (Dragomir Cristina, Utureanu Simona)" The situation of Bangladesh is similar to China as both countries national legislation permits all kind of charges subject to approval and as long as they are publicized, which is below than international standard (Zhang, 2016).

A quantitative survey was conducted to find current problems among 105 participants through Google form. All the respondents were seafarers and most of them were junior engineers, junior officers and trainees working in different shipping companies in operation level. From the study, it has been revealed that, about 58 percent participant paid money to get the employment prior joining the ship, among which less than 1000 USD is 11% and more than 3000 USD is 15%.

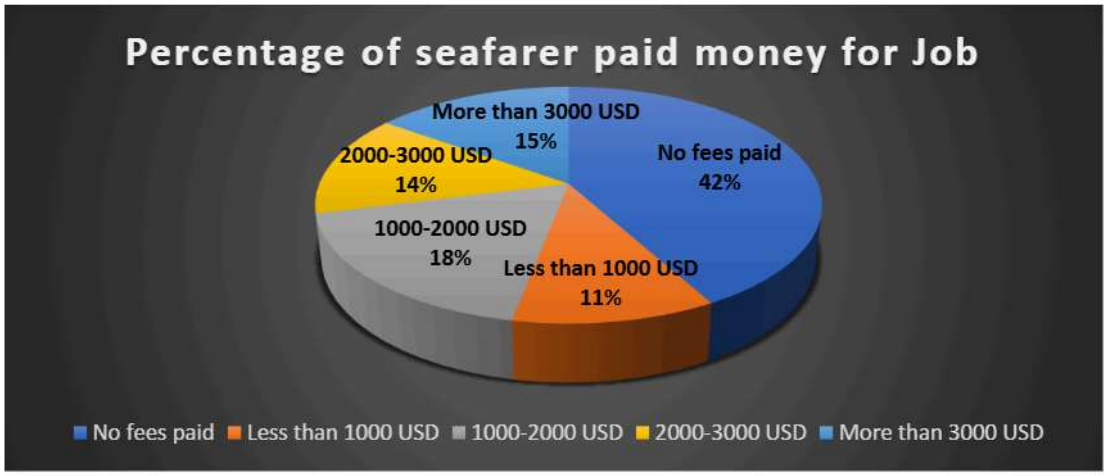

Figure 1: Charges/Fees incurred by seafarer for employment

From the survey, we have found that, despite the violation of MLC by private RPS by taking fees or money for providing employment on board, the cadets, and junior officers are not willing to report the incident to the competent authority. The major two reasons of non-disclosure of the facts of paying money are threat from the manning agent and avoidance of complicacy, which is about 31 and 22 percent respectively.

Figure 2: Reasons of non-disclosure regarding violation of MLC by private RPS

From the qualitative survey, we have found that, the shipping office or Department of Shipping or even the seafarers' union are unwilling to take any action against manning agent without written complain, though there are plenty records and incidents of charging the seafarer for employment. It has been found that, some investigation has been done against few manning agents for forgery or violation of national law, yet the license has not been suspended. According to the paragraph 6 of regulation 1.4 the RPS should be closely supervised and controlled by competent authority, but no legal provision is available in this regard, except renewal of license in every two years. The convention provides the obligation on competent authority more than only issuing license or certificate to the RPS. The member state has the flexibility to adopt laws and mechanism for close monitoring of the process. The member state should ensure that the RPS established within its territory is conducting the business through verifiable operational practices. Transparency and clearly publicizing the cost may reduce the

exploitation of seafarer by RPS. The national law may provide mechanism to publish the demand or requirement of seafarer's job in conspicuous places like DoS's or shipping Master's office or in on line media, so that the activities of the RPS and employment of seafarers may be monitored in transparent and progressive way.

The emphasis is given on adequate machinery and procedures for the investigation of complaints concerning the activities of seafarer recruitment and placement services in accordance with paragraph 7 of regulation 1.4. The convention preferred the committee for investigation, incorporating ship-owners and seafarer's representatives. In Bangladesh, the Government normally form committee consisting of officers from various department, without any specific obligation to keep ship-owner and seafarer's representative. There are no specific guidelines in convention on smooth procedure to lodge a complaint, so that the seafarer is fear free and will not be blacklisted by the manning agents. The competent authority may take into cognizance of any secret reporting without exposing the name of person concern and investigate the issue.

The guidelines though not mandatory but very important to achieve the purpose of the convention. The arrangement for the collection and analysis of all relevant information on the maritime labour market, including the current and prospective supply of seafarer will assist to determine the production of appropriate number of seafarer, which will protect the ship-owner and seafarer both from over supply and over demand.

5. RECOMMENDATIONS:

1. The existing national law for controlling recruiting and placement services, SRAL rules to be updated in compliance with the provision of MLC 2006. Especially the provision of approval and declaration of money received by RPS is contradictory to the MLC, which should be explicitly mentioned that, no fees or charges should be incurred on seafarers for the employment. The law should provide financial and penal punishment for the violation of such rules, including suspension and withdrawal of license.

2. There should be a complaint box in DoS's office, Shipping Master's office and all other offices of Maritime Administration including seafarers' union, which should be opened and handled by a committee comprising members from competent authority, ship-

owners and seafarers' representative. The online and social media platform also may be utilized to receive the complaints from seafarer. The confidentiality should be strictly maintained by the committee, which should be mentioned in the national law. A complaint register should be maintained, with follow up of each complain. The committee should take into cognizance of the unnamed complain and make investigation.

3. The effective implementation of closely supervision and controlling by competent authority should be developed. The various reporting mechanism such as the list of principals, monthly reporting of seafarers employed by manning agents, submission of standard SEA, *etc.* should be introduced. At present, the RPS license is valid for two years in Bangladesh, which may be reduced to one year for better close supervision.

4. The grading system may be introduced to categorise the performance of RPS, following some standard procedure, which will be helpful for ship-owners and seafarers to receive the service. If any investigation is under process against any RPS that may be reflected in DoS's web site including suspension of any manning agent.

5. The competent authority of labour supplying state may develop the communication with flag state to ensure that the ship-owners or representative of ship-owners from that flag state is not making any undue pressure on manning agents of labour supplying state to impose fees or charge directly or indirectly on seafarer. The mutual agreement among both countries may mitigate the problem.

6. The port state control has less opportunity to involve in checking the implementation of the regulation 1.4. The seafarer may be instructed to submit the copy of license and other documents of RPS to prove the compliance of the regulation, which may be verified by the port state control.

7. The labour supplying state should enhance the investigation capacity as required by the paragraph 7 of the regulation 1.4 through implementing adequate machinery and procedures to handle the complaints against RPS, involving the representative of ship-owners and seafarers.

6. CONCLUSION:

The Maritime Labour Convention 2006 is undoubtedly a milestone to establish the seafarer's right on board and ashore and unique to support the seafarers even prior employment. Regulation 1.4 provides the measures to ensure the seafarer an efficient and well-regulated recruitment and placement system. From the above study, it has been revealed that, without the integration and broader involvement of competent authority, ship-owner, seafarer, unions and RPS provider the elimination of harassment and financial burden of seafarer prior joining ship is not possible. The effective implementation of regulation 1.4 of MLC, 2006, especially the close supervision, monitoring, and control of RPS and investigating the complaint is mandatory to provide efficient, adequate and accountable employment system to seafarer.

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A CRITICAL REVIEW OF THE INDIAN PORTS AND SHIPPING SECTOR

Jagmeet Makkar

Abstract

The United Kingdom's registered trading fleet was the 18th largest in the world (by deadweight) in 2018, just below the Indian registered fleet. However, London was second on the International Shipping Centre Development Index for a few years before it fell to third place in 2018 and 2019, just after Hong Kong. It may seem that for a country or a port to be a significant International Maritime Centre, it is not necessary to have a large volume of tonnage under its registry. This may be true, provided there is a strong period of maritime history, such as starting from Lloyd's Coffee House of 1686! The seed is still the tonnage for the development of maritime cluster. While the hardware (tonnage and port infrastructure) is said to make up just 20%, maritime services and the general environment contribute 80% towards the development, sustainability and growth of a successful international maritime centre. The ownership or control of the hardware is generally fragmented and presents its own challenges. The major contributor (80%), fortunately, offers an opportunity for action-oriented collaboration and focus on economic transformation, which in turn leads to sustainable development, knowledge and imagination hotspots and employment opportunities across the industry. This paper focuses on growth of controlled tonnage and other areas that need to be addressed in order to achieve a sustainable and significant position on the world's stage for India.

Key words: Indian, shipping, port, maritime, Port infrastructure, Hinterland Logistics, Maritime services, Cargoes, International maritime registry, Indian Coast, International Maritime Centre, Shipbuilding, Repairs, Strategic, Research & Development, Maritime Skills, Training, Ship Management Centre, Commercial Constraints, Coastal Shipping, Cabotage, Incentives, Sagar Mala, Bharat Mala, Unnati

1. EXECUTIVE SUMMARY:

Progress has been made in the Indian Shipping, Port Infrastructure and the Ancillary Services since independence, more so in the last 5 years. This brief paper looks at what more needs to be done, rather than discussing in detail the initiatives and incentives provided to the industry and industry players. Shipping is a global industry. Assuming that our intention is *not* inwards looking whereby, we perceive Indian Shipping for India bound and outbound captive cargoes only, a lot needs to be done to provide a level playing field for the Indian Shipping to compete in the international arena. We see city states like Singapore and Hong Kong doing well as major international maritime centers, there is no reason why we cannot have such international maritime centers along our extensive coastline. In additional to contributing to national strategic needs, this will also lead to creation of effective maritime clusters creating employment, innovation, knowledge enhancement, encouraging Green Shipping & Ports and help India become a world leader in port and maritime investment and services. While time is of essence for the implementation of Sagar Mala project, the development of hinterland logistics infrastructure is a condition precedent for any meaningful outcome. Risk management is another key area requiring a serious thought, whereby pollution, wreck removal and third-

party liability exposure may be internationalised without having to resort to uneconomically enhancing the local insurance capacity. With the progressive approach and political will of the present government, it should be possible to move in that direction, making full use of the disruptive changes caused by rapidly evolving information technology through private participation (wholly or in partnership with the PSUs).

2. LEVEL PLAYING FIELD:

Shipping has not been a profitable industry since the last 10 years even for those who operate in a cost friendly environment. Indian Shipping, with its cost heavy structure and high "daily break even" is seriously struggling.

Shipping Industry requires a level playing field to compete and grow. Question is "whether the Indian Owners are able to compete at the world stage?" Regrettably, the answer is "no". In that case "what are the key factors and what can be done about these factors?"

Some of the challenges that the Shipowners face in India are tax structure/regime (some of these are minimal alternative tax, dividend distribution tax, withholding tax liability on interest paid to foreign lenders and on charter hire charges paid to foreign owners.

Question may be asked "why should we make an exception to the Shipping Industry in this regard?". As mentioned, shipping is international and there are alternatives to the stakeholders who will gradually, if already not, move away to more friendly business environment and regimes and the resulting harm to the growth of our economy, employment, creation of knowledge, innovation and maritime expertise could be very serious. The indirect benefits of a healthy maritime industry are tremendous and will far outweigh the loss of tax revenue on a decreasing private ship owning. One of the ways this can be addressed is by establishing independent international registries in the maritime clusters, as mentioned earlier, that provide similar or better incentives to the shipowners under their flag. Other areas that will go a long way are reduced cost of capital from local lenders, competitive insurance premiums and less salary taxes on the seafarers serving Indian Shipping Industry. Shipping is as good as the people who serve and manage it. Losing the cream of seafarers to the foreign flag definitely does not help the cause of quality Indian Shipping.

3. INDIAN COAST & GROWTH OF INDIAN INTERNATIONAL MARITIME CENTERS:

Key factor contributing to the growth of these maritime centers is political will and government policy. Singapore is an example of focused government policy to attract the best from the overseas by providing incentives which are not just limited to tax holidays or reduction in tax. Investment and encouragement to grow the ancillary services such as legal, financial, information technology, training, arbitration, mediation, ship management, agency, infrastructure, *etc*. to support the main stream shipping and port industry has positioned Singapore as one of the best, if not the best, international maritime centers. There is no reason why this cannot be replicated along the maritime clusters, with preferably their own international registries, along our magnificent coast. The counter argument that we generally hear is that "Singapore and Hong Kong" are city states with ease of implementation of policies, for whatever reasons, which cannot be replicated in Indian maritime cities. This may be true to some extent but not a disheartening deterrent. In any case, there are several good lessons to learn from them and implement this learning in our context while striving hard, with a strong and focused policy. One of the ways could be collaboration with, for example, Singapore to develop one of the less congested port or near port cities with modern infrastructure, even if the present level of maritime services is not significant. Such collaboration could also be in the area of innovation required to comply with IMO environmental regulations (IMO 2020 and IMO GHG 2050), seeking to enhance operational efficiency and competitiveness, among others. Identifying and developing potential international maritime centers and/or maritime clusters will encourage public-private partnerships and take on the role of a key enabler in attracting new technology, fostering strategic alliances and boosting investments.

Establishment of an independent Indian International Ship Registry (IISR) in such a port or near port city, with similar or better benefits offered by other international registries with help grow the registered tonnage which may be beneficially owned by Indians and non-Indians. This way, the transition need not depend upon changing of existing rules which could be cumbersome and a compromise effort but reliant on an entirely new set of rules for the international registry. The indirect benefit of such an initiative will be a great contributor to regional and national economy, employment and knowledge creation. Some of the industries that will grow, providing substantial employment potential, may be ship management, operations, agency, finance, insurance, legal & alternate dispute resolution, hospitality,

transportation, supplies of necessities, service industry, *etc*. The employment down the supply chain will continue to grow over time and is expected to be sustainable. There are examples of such models (also called Second Registries) such as Isle of Man, Norwegian International Ship Register (NIS) and a few more. Compared to most other nations, India has the advantages of growing economy and international interests that seek to be part of this growth. Tonnage registered under say Indian International Ship Registry (IISR) may be allowed to trade on the Indian Coast like the national flag, which could be an added attraction.

4. PORT INFRASTRUCTURE:

The initiatives taken by the present government are commendable. However, there are areas which need to be addressed as top priority to make these initiatives effective as foreseen under the plan. We need to eliminate the bottlenecks between the port berths and the cargo destination point. Some of these bottlenecks that need to be looked fd1into are the warehousing, rail sidings, rakes, roads and other infrastructure jigsaw pieces. A chain is as strong as the strength of its weakest link. Millions of dollars invested in ports to install the state of the art equipment will only be justified if the entire multi-modal logistic chain works efficiently. Miles long lines of stagnant trucks and road tankers and lack of rail rakes do not help the cause. The effect on environment through Green House Gas emissions and noise pollution will have to be minimised, sooner than later. Thus, expeditious modernisation of infrastructure leading to an efficient intermodal system is crucial to the success of a port and its investor. The hinterland logistics development, across the country, should be looked as a national project with less dependence/reliance for decision making on individual authorities at the local or state level.

Risk management perspective is crucial for efficient and profitability of the ports. It is very important to determine whether there is a structured risk management framework to identify and manage risks, seeking alignment between the port objectives and the risk management plan.

Increased research is required for Greening of Ports based on the range of tools available to port authorities such as pricing, monitoring and measuring, market access control and environmental standard regulation and the functional activities in ports, namely shipping traffic, cargo handling and storage operations, intermodal connection, industrial activities, and port expansion[1].

Risk Management and Greening of the Ports are some of the area that require a critical audit of prevailing processes and developing an action plan across the entire spectrum.

5. SHIPBUILDING & SHIP REPAIR:

The pillars of the Shipbuilding industry are cost-effective and skilled manpower base, availability of suitable grades of steels, machinery and equipment, design and technology know-how, research and development to be ahead of market needs and new regulations. Time delivery, reliability of the product and after sales service are important.

Shipbuilding industry is already very crowded, and the existing shipyards worldwide are struggling due to building overcapacity. Only those who have consolidated, have focused product lines with lowest cost for good quality ships are able to survive. The importance of Shipbuilding in India should be more strategic and defense oriented. Investing into shipbuilding, simply to increase India's global shipbuilding share may not be, at this stage, recommended. A better use of resources would be to develop and build upon the ship repair facilities, retrofitting for regulations compliance, maritime clusters and controlling the mind of shipping through investment in research and development.

6. RESEARCH & DEVELOPMENT:

With the cargo volumes expected to double by 2050 at a conservative growth rate of 2-2.5% annually against a backdrop of carbon dioxide emissions reduction by 50%, shipping industry is facing a big challenge ahead. The change from sailing ships to steam and then to diesel ships, the revolution was based on making the best of the low hanging fruit *i.e.* the fossil fuels, be it coal or oil, and now, we must find alternatives and that too soon, considering the average age of the ships being in the range of 25-30 years. Non-fossil fuel propulsion may take significant research, investment, prototype and trials before success. From Indian perspective, development of safer small modular reactors using thorium could be groundbreaking. India is said to have world's largest reserves of thorium in the range of 963.000 tons.

To some extent, it is evident that the research in the space of ship design, propulsion and safety, *etc*. is driven by regulatory environment, which itself is reactive by nature. However, research in trade, commercial and financing of ships needs to be generally driven by the industry. Even

if the Universities encourage post graduate and doctorate research projects, I strongly believe that input from the industry of its experience and expectations will go a long way to make such research outcomes useful, which will then help improve the efficiency, competitiveness and returns of our industry.

Purpose of effective and useful research is to identify and analyse the trends and their impact on future of shipping. The objectives must be forward looking and drive innovation. Hence, the importance of maritime research for competitiveness and sustainability cannot be understated. India needs a new focus bringing together policy makers, industry and academia to achieve this purpose. To this effect working together of IIT Madras, IMU and a few leading Scandinavian and Singaporean universities may be looked at. Development of a R&D fund on the lines of MINT (Maritime Information & Technology Fund) Singapore may be considered. Other bodies that can guide us are Light House (Swedish Maritime Competency Centre), ECMAR (Maritime Council for Maritime Applied Research and Development), *etc*.

7. PORT & MARITIME TRAINING:

There is an old saying "Give a man a fish and you feed him for a day. Teach a man to fish and you feed him for a lifetime". Port and Maritime Education & Training does exactly that. Furthermore, Shipping is a highly competitive global industry where we have seen the source of shipboard manpower continuously shift to low cost base. From Europe to Asia and within Asia, India plays an important part for supply of the maritime officers and ratings. With India's pivotal role in the movement of cargoes, there is a growing need for qualified staff, both afloat and ashore. An aspect that is of great importance to develop skilled manpower is learning and development. As Henry Ford (Founder, Ford Motor Company) very famously said: "The only thing worse than training your employees and having them leave is not training them and having them stay." These are words to live by, especially in such a rapidly changing world. Our senior leaders expect us to understand the organisational strategy and impact from environmental and economical regulations. Our managers expect us to show continuous improvement in performance and take on greater responsibility. Our direct reports expect us to be an effective manager, with a strong focus on their development. Our clients - whether external or internal - expect us to know and understand their business in order to serve them better. All things considered - not only is continual development of soft skills such as leadership and communication absolutely vital, but continued enhancement and broader perspective in

professional skills, which at first, we might consider 'irrelevant' as they are not explicitly within our 'job description' is very important as well.

With the rapidly changing business and regulatory environment, it is essential that managers and the staff across the maritime and port industry are regularly trained. There is no substitute to relevant and practical quality training.

Supporting the maritime training is looked at very seriously in countries such as Hong Kong and Singapore where government has established maritime training and cluster funds (Hong Kong: Maritime & Aviation Training Fund; Singapore: Maritime Cluster Fund) to provide grants to individuals who enroll and successfully complete the approved courses. Key to success of these initiatives is speedy approval of courses and the disbursement of grant to individuals with minimum administrative hurdles. There is no reason why this cannot be easily implemented in India.

8. COASTAL SHIPPING:

It is a pity that Coastal shipping only accounts for 6-7 percent of total domestic freight on a tonne-kilometer basis as compared to Japan and the EU which is roughly five to six times higher, and the same is about seven times higher in China. At present, about 60 % of the cargo is transported through the roads, 31% by rail, and 6-7% by coastal shipping while the International benchmarks are 25-30% road; 50-55% railways, 20-25% share of waterways. We have some way to go which is mainly dependent upon the hinterland logistics development. It is recommended that all ports are developed and managed directly under the Central Government. This is to ensure a common vision, use of common federal services (referred to later in this paper) and similar standards with regards to risk management, disaster control & management and operations.

8.1. Hinterland Logistics Challenges:

In addition to growth of the country and increasing population, the increasing pressure on the rail and road is also due to the fact that major consumption centers are land-locked and the cargo generating centers are far from the ports. Research shows that the integrated logistics cost in case of coastal shipping is economically viable only if the producers/consumers of the

shipped goods are within a distance of around 100 Km from the loading/unloading point at the port side. This last mile connectivity often proves to be a challenge in India driving up the overall cost of transportation via coastal shipping.

The poor connectivity and infrastructure between coastal areas and hinterland and poor road network and rail connectivity across ports in India are areas that need to be tackled most expeditiously and in a structured manner. The only effective and efficient way is to have a common development program under one authority, thus avoiding a fragmented approach.

8.2. Commercial Constraints:

High tariff structure at private ports

Statutory: Duty structure is not trade friendly with impact on bunker price, spare parts, stores for ship owners, *etc*.; Bunker prices are 20% more expensive than international prices due to duty structure; Complex Taxation (Freight Tax, Income Tax for seafarers, Tax on hire, *etc*.)

Cabotage law prevents foreign ships to participate freely; Delay in getting government clearance for foreign ships to participate in coastal shipping.

Operational: Multiple handling; Road/Rail are direct point to point whereas Ocean Going must deal with Ocean, Port, Road/Rail leading to delay/additional costs; Congestion; Bunkering facilities do not exist in many ports. It is recommended that parallel steps are taken to minimise, if not entirely possible to eliminate, the statutory and commercial constraints while at the same time meeting with the hinterland logistics challenges.

There are several initiatives and incentives taken by the Government since 2014, that should not be undermined, and these are steps in the right direction.

8.3. Initiatives by the Government:

100 % FDI for port & harbour construction & maintenance; Ports sector in India has received a cumulative FDI of US$ 1.64 billion between April 2000 and December 2018; Govt. of India

has approved grants to the state Govt worth Rs. 2,300 crores (about $355 million) for developing berths for coastal shipping.

Project UNNATI: improvement in the operations of major ports.

116 initiatives were identified out of which 91 initiatives have been implemented as of end 2018.

8.4. Sagar Mala and Bharat Mala Incentives:

The government has taken several measures to improve operational efficiency through mechanisation, deepening the draft and speedy evacuations. In March 2018, a revised Model Concession Agreement (MCA) was approved to make port projects more investor-friendly and make investment climate in the sector more attractive.

Special Freight Train Operator [SFTO] Policy of Indian Railways allows private sector participation in railway operations to enhance efficiency and connectivity between port and Hinterland.

8.5. Sagar Mala Initiatives: Increase port-rail and port-road connectivity:

About 114 road and 23 rail connectivity projects (worth INR 25k Crores) have been identified; 111 national waterways projects have been taken up for development; 15 multi-modal logistics parks have been arranged; 14 Coastal Eco Zones (CEZ) have been identified.

The zones would be converted into manufacturing hubs, supported by port modernisation projects, and could span 300–500 km of the coastline; 29 potential port-connected industrial clusters have been identified; Paradip & Haldia have been identified to be developed as 2 smart industrial port cities; 6 new major ports to be developed India's present port capacity is 1,500 MTPA, objective is to ramp up to 3,000 MTPA by 2025.

Objectives are to attract investment in harbour crafts, ferries, Ro-Ro, multipurpose vessels and also create huge employment opportunities; increase the share of Indian ship owners from

current level of 10%; opportunities for setting up ship repair facilities, bunkering facilities, dredging, dry docking, *etc*.

8.6. Incentives by the Government:

10 year tax holiday to enterprises that develop, maintain and operate ports, inland waterways and inland ports; A cash incentive of 50 paise per tonne per nautical mile to manufacturers for moving cargo on the Kerala Coast; Container shippers will get incentives in the form of ₹1,000 per TEU in terminal handling charges and reduction in vessel related charges at ports by another 20 per cent for new coastal cargo; Different scale of rates for coastal vessels on berth hire, pilotage & port dues (about 60% discount) @ govt. Ports; 80% discount offered on vessel and cargo related charges on Ro-Ro vessels for transportation of vehicles;

8.7. Cabotage relaxation:

In May 2018, Govt allowed foreign flagged ships to carry containers for transshipment Commodities like fertilizer and Agri products have also got relaxation on Cabotage. Introduction of RSV vessels (River sea vessel). Specialised coastal vessels with reduced operating cost. Abolition of TAMP

9. FEDERAL SERVICES APPROACH IN PORTS:

If every port in India (especially the non-private) manages all its functions, there is a strong possibility of inefficient utilisation of resources, dilution of standards and increased overall risk. With today's advanced technology, there is no reason why many of the functions cannot be centralised and best practices applied across the ports.

Some of these could be risk evaluation, identification, transfer versus retention and management of risk; common disaster response and management systems; standard procedures which should be regularly audited and bench marked against each other; sharing of feedback across the ports to avoid similar errors; planned maintenance system and cost efficient inventory control of spares; learning and development, *etc*.

One way to look at the entire structure may be like a multinational with some decentralised functions while retaining centralised federal services that are applied across the organisation.

10. RECOMMENDATIONS FOR FURTHER REFORMS AND DEVELOPMENT:

- ***Level Playing Field:*** Mainstream Indian Shipping requires level playing field in order to compete globally. Reforms required in tax structure, cost of lending, cost of insurance premiums, ease of paperwork/approvals.
- ***Indian International Ship Registry (IISR) & International Maritime Centers (IMC):*** Development of World Class International Maritime Centers along the Indian Coast. Two of them may also be developed as Second Registers (*e.g.* Indian International Ship Registry) that attracts Indian and non-Indian shipowners to register ships. This will lead to development and growth of maritime clusters.
- ***Encouraging & Supporting Green Shipping & Ports:*** Provide incentives to Ships employing Greener technologies including priority berthing. ESG (Environment, Social and Governance) are becoming an increasing fact of life for the Global Shipping Sector. We not only must do this but should also see to be taking proactive steps.
- ***Port Infrastructure development and management:*** In order to have an effective growth agenda and its implementation, it is recommended that this is done under the Central Government.
- ***Ports Operations and Risk Management:*** A common risk assessment, evaluation and management approach, keeping existing insurance capacity and need for international markets in perspective.
- ***Shipbuilding & Ship Repair:*** Shipbuilding focus only strategic and defense while investment essential for ship repair and retrofitting shipyards. To employ resources where needed.
- ***Research & Development:*** R&D fund and coming together of policy makers, industry and academia is essential.
- ***Education & Training, Learning & Development:*** Initial training followed by continuous professional development. Support from Government on similar lines as the leading international maritime centers are providing.

- ***Coastal Shipping Constraints:*** It is recommended that parallel steps are taken to minimise, if not entirely possible to eliminate, the statutory and commercial constraints while at the same time meeting with the hinterland logistics challenges.
- ***Coastal Shipping & IISR:*** There is expected to be a sea of change if International Registries model is adopted. Indian and Foreign Shipowners registering ships in India with freedom to operate on Indian coast could be the way forward.
- ***Federal Services Approach for Ports***: This will lead to increased efficiency, better risk management and standardisation.

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Jagmeet's vast and diversified knowledge and experience is evident from his professional fellow and memberships. He is a fellow of the Royal Institute of Naval Architects (UK), Institute of Marine Engineers (India), Hong Kong Institute of Arbitrators and Institute of Chartered Shipbrokers (UK). He is also a member of the Chartered Institute of Arbitrators (UK), Singapore Chamber of Maritime Arbitration, Hong Kong Maritime Arbitration Group, Association of Maritime International Commercial Interests and Expertise (India) and a supporting member of LMAA (London Maritime Arbitrators Association). He serves as a member of the Education and Training Committee (Global) of the Institute of Chartered Shipbrokers (ICS).

Jagmeet is available to contribute to the growth of Indian Shipping and Port Industry.

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CARGO HANDLING ON BOARD CHEMICAL TANKERS: EFFECT ON SEAFARERS - AN EMPIRICAL STUDY.

Sajith Babu

Abstract

Increasing trends in accidents/ incidents on board Chemical tankers are a rising concern for the entire Chemical seaborne trade. IMO through its comprehensive International Conventions and Codes have provided an international standard for the safe carriage of chemical cargoes. Most of the shipping accidents are caused by human error. Even when the ISM code helps in establishing a safety culture, it is never fully attained unless the seafarer's on-board work hand in hand with their respective shipping company or managers. Shipping companies finally ends up paying a heavy price due to the poor decision making of seafarer's, which may directly or indirectly lead to a maritime casualty. It is highly common that seafarers working onboard chemical tankers will be carrying cargoes which they have never heard of or carried in the past. Even then, the seafarers are required to carry out all operations onboard very professionally and safely without compromising on the local and international rules and regulations. A thorough understanding of safety and health hazards and also about the emergency procedures is vital to all crew members directly involved with the operational part of the cargo carriage. This paper is based on an empirical study of day-to-day operations on board ships with the help of questionnaires and how seafarers can be practically guided on chemical tankers to safely handle cargo operations. The relationship between crew knowledge gained through studies and their work efficiency on board chemical tankers needs to be assessed. Valuable inputs from this study will turn out to be effective for various training techniques being developed. In future, advanced training tools using machine learning will be developed using the various end results from this study.

Key words: Chemical tanker, Incidents, Maritime casualty, Training.

1. INTRODUCTION:

Chemical tanker as the name suggests is a specialized type of tanker ship used for the transportation of petrochemical cargoes in bulk (Akyuz and Celik, 2015). As per Annex II of the International Convention for the prevention of pollution by ships (MARPOL, 1973/78), chemical tanker is a ship constructed, equipped or adapted for carrying in bulk liquid products as listed in Chapter 17 of the International Bulk Chemical Code. The design and equipment of chemical tankers are such that it can be used for shipment of a wide range of products simultaneously in the same voyage. Apart from oil tankers and gas tankers, chemical tankers are built to carry multiple cargoes with varying characteristics and hazards at the same time. Capability of handling multiple cargoes adds to the complex nature of construction of these kinds of ships. The smaller size of ships, presence of numerous numbers of tanks which usually ranges between 10-50, individual submersible pumps for all tanks, cargo heating arrangements, tank cleaning hoses and portable tank cleaning machines, nitrogen generators, gas freeing blowers, cargo hoses and reducers of various sizes are unavoidable sights onboard a chemical tanker. These ships are also stronger and stable compared to other ships due to the segregation

capability and the number of tank divisions which are created to carry various parcels together (CDI, 2013). Chemical cargoes on board chemical tankers are usually transported in small parcels, since most of the cargo receivers require lesser quantities as compared to the transportation of crude oil or clean petroleum products. Thus, various parcels of chemical cargoes are normally carried in the same vessel without the risk of mixing. These tankers are also called as parcel tankers.

Even though there are several rules and regulations laid down by regulatory bodies of maritime industry, maritime casualties have not reduced due to human error (Noroozi *et al*., 2014). Due to increased shipping activities worldwide, high level of safety performance is required to counter human error which can even lead to loss of life, harm to marine environment and also equipment's on-board ships (UNCTAD, 2015). Recent research studies indicate that risk management plays a pivotal role in minimizing human error occurrence. Proactive solutions used by a number of safety practitioners have led to the introduction of various risk-based approaches (Hameed *et al*., 2016; Akyuz and Celik, 2015, 2016; Prasad and Gaikwad, 2015).

2. LEGAL FRAMEWORK AND LITERATURE REVIEW:

International conventions and codes framed by the International Maritime Organization - IMO, govern the operation of chemical tankers. SOLAS Chapter VII- Carriage of dangerous goods and MARPOL Annex II- Regulations for the Control of Pollution by Noxious Liquid Substances in Bulk, are the two major Conventions which require chemical tanker ships to comply with the International Code for the Construction and Equipment of Ships Carrying Dangerous Chemicals in Bulk - IBC Code. The IBC code helps by providing international standards required by ships for safe carriage by sea, of the various chemicals and liquid substances as per Chapter 17 and 18 of the code (IBC Code, 2016). The IBC code assigns one of the ship types to each chemical tanker, taking into account the degree of the hazards of the products carried by the respective ships. The products normally possess one or more hazardous properties which includes flammability, toxicity, reactivity, corrosivity and other environmental hazards.

Unlike conventional tankers, chemical tankers are classified into 3 different types. Classification has been done based on cargo to be carried and structural requirements needed

to sustain and survive damage. IBC code clearly indicates that ships subject to the code shall be designed to the following standards as per the type of ship:

Type I: Chemical tanker ships which are built mainly to transport specialized and sophisticated products under chapter 17 of IBC code, and which possess very severe environmental and safety hazards and require maximum preventive measures to avoid an escape of such cargo. These ships are assumed to sustain even if damage occurs anywhere in its entire length (IBC Code, 2016).

Type II: Chemical tankers intended to transport products under chapter 17, which possess appreciably severe environmental and safety hazards and require significant preventive measures to avoid an escape of such cargo are called Type II ships (IBC Code, 2016).

Type III: Chemical tankers which can transport products under chapter 17 which possess sufficiently severe safety and environmental hazards and a moderate degree of containment is required to increase survival chances in a damaged condition (IBC Code, 2016).

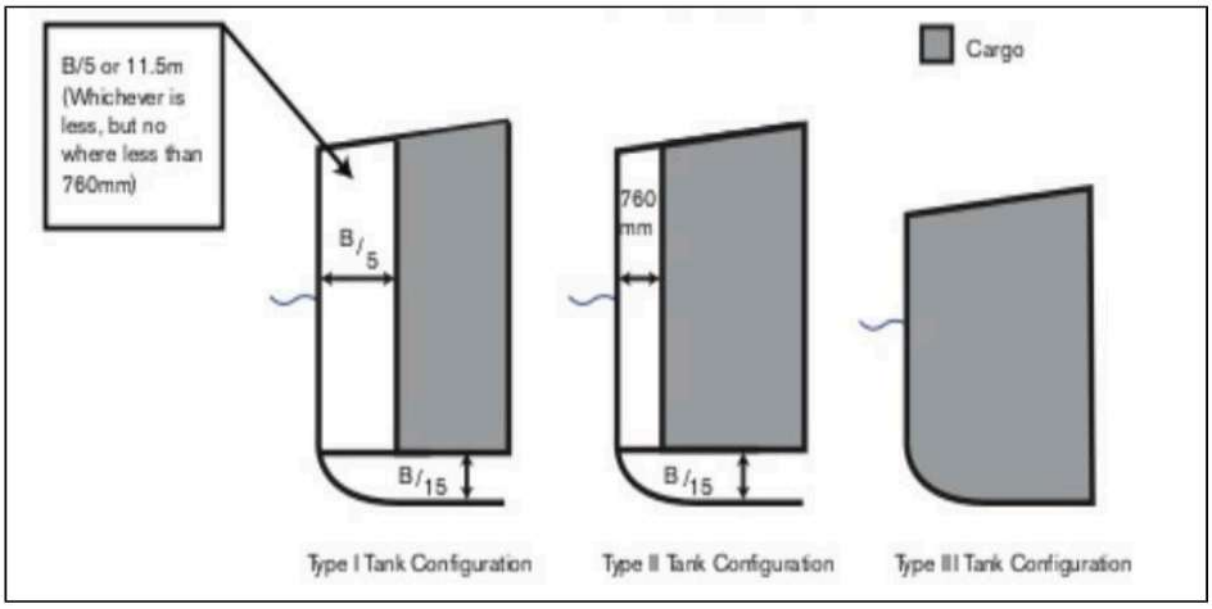

Figure 1: Tank configuration as per IBC Code

It can be clearly stated from the above classification that Type I chemical tankers are those intended to carry products which can present maximum hazard, followed by Type II and then Type III ships which carry products of lesser hazards (Figure1).

The IBC Code mentions that any cargo offered for bulk shipment should be indicated in the shipping documents by the product name under which it is listed in Chapter 17 or 18 of the code or the latest edition of MEPC.2/Circular or under which it has been provisionally assessed. The importance of MSDS - Material safety data sheets, and its availability to all concerned for the safe carriage of the cargo must be strictly followed. MSDS normally gives a full description of the physical and chemical properties, emergency procedures in case of fire, spillage, personnel contact, first aid measures and ecological effects.

Shipboard Occupational Health and Safety Programme – SOHSP, should have active involvement of people involved at all levels like Master, Officers and Engineers on board, crew and even the office person in charge (MSC-MEPC.2/Circ.3, 2006). Shipboard and shore side employees should be involved in developing, implementing, evaluating and modifying the SOHSP. Both should work together to achieve occupational health and safety goals. Systems for detecting, reporting and correcting non-conformities should be present in the programme. Standard Operating procedure framed by the company gives a benchmark to the personnel actually involved in the operations.

There are four main groups of liquid chemicals transported by sea: organic chemicals, inorganic chemicals, vegetable/animal oils and fats, and molasses (Hammer, 2013). Chemicals like methanol, ethanol, xylenes, toluene and glycols form part of the organic chemicals group. Chemicals like sulphuric acid, nitric acid, caustic soda and phosphoric acid are classified as inorganic chemicals. As per research carried by Drewery research consultants in 2008, 48% of chemical seaborne trade consisted of organic chemicals, 17.5% of inorganic chemicals and 26.8% included vegetable and animal oils and fats which included palm oil, soya bean oil, sunflower oil and rapeseed oil. Molasses shipments are comparatively small and involve transportation of molasses cane, base oils and molasses beat sugar. Chemical tankers which are normally called as oil/ chemical carrier also carries oil and petroleum products like jet fuel, naphtha, gasoline, gasoil, lube oil and various other lube oil additives. The number and variety of unconventional liquid cargoes being transported in bulk by water continues to steadily increase. The transportation of bulk chemicals by sea not only requires purpose-built ships and equipment, but also seafarers who have received specialist training, both theoretical and practical, in order to understand the properties of various chemicals and the potential hazards involved in cargo operations (ICS, 2004). SWOT analysis methodology has also been used to assess the safe carriage of liquid chemicals by tanker ships (Arslan and Er, 2008). It is highly

common that seafarers working onboard chemical tankers will be carrying cargoes which they have never heard of or carried in the past. Even then, the seafarers are required to carry out all operations onboard very professionally and safely without compromising on the local and international rules and regulations.

3. VARIOUS PROPERTIES OF CHEMICAL CARGO CARRIED ON SHIPS:

Prior loading chemical cargoes onboard ships, MSDS sheets must be referred to and properly studied well in advance to get a thorough idea about the various chemical properties of the same. Some of them are:

3.1. Flammability:

The flammability limit of a cargo is defined as the range of concentration of flammable vapor which can lead to an explosion upon ignition. Flammable vapors are normally defined as % by volume in air. LEL (lower explosive limit) forms the bottom of the range below which there is insufficient vapors to support combustion and UEL (upper explosive limit) forms the upper limit above which there is insufficient air to support combustion (IMDG code, 2018).

3.2. Toxicity:

Toxicity is a property of a chemical which causes harm to living organisms and can eventually lead to serious injury or death. Depending on the nature of the product, toxicity can be defined as chemical, biological or physical. Toxic cargoes are clearly identified in IBC code chapter 17 under column-k. Oral toxicity (swallowing), dermal toxicity (absorption through skin, eyes and mucous membranes) and inhalation toxicity (inhaling toxic vapors) are three major means of toxic exposure onboard ships (IMDG code, 2018).

3.3. Reactivity:

Even though most of the chemicals carried on board ships are chemically stable, there are some which require certain precautions to be taken so that they remain in a stable condition. Some of the reactive chemicals are inherently unstable and some react in a dangerous manner when in contact with air, water or other materials (IBC code, 2016). Reactive and unreactive group

of chemicals can be easily referred to from USCG compatibility chart. According to USCG, a mixture of two chemicals is considered hazardous and incompatible when, under specified test conditions, the temperature rise of the mixture exceeds 25^0C or a gas is produced as a result of the reaction.

3.4. Static accumulator cargoes:

Liquid chemical cargoes having a conductivity reading of less than 50pS per meter are considered as nonconductive cargoes. Accumulation of an electric charge is very significant in these kinds of cargoes and special measures must be taken so as to mitigate the effects of static electricity. Static sparking can occur during loading, unloading, steaming, gas freeing, cargo tank cleaning, sampling/ gauging and even during adding of cargo inhibitors (IBC code, 2016).

3.5. Corrosivity:

These are chemical properties of a substance which tends to destroy human tissues on contact. Acids and alkalis are the most common corrosive products which can cause severe burns in a very short exposure time. Some are corrosive when in contact with water while others are corrosive when in contact with moist air (IBC code, 2016).

4. EMPERICAL STUDY:

Shipboard hierarchy has been found out to be the major reason behind most of the accidents in the marine industry (Fortland, 2004). In every accident, an act or omission by a human being plays some role or the other. Personnel at the management level should be well aware of the procedures to be followed and should guide others in the process. Incidents onboard chemical tankers are at times very serious and even leading to death due to the hazardous nature of cargo carried on board. The hazardous characteristics of cargo carried on chemical tankers makes them potential risk for human life and marine environment (Akyuz and Celik, 2015). IMO with their recent amendments in SOLAS have introduced mandatory requirements for operations including tank cleaning and inserting. Even though a lot of rules and regulations are in place, the results of the study have given many insights to the real time activities on board chemical tanker ships.

For the purpose of the study, seafarers on board ship has been classified as per Table 1.

Table 1: Classification of crew- Rank wise.

Senior Officer	Master, Chief Officer.
Junior Officer	Second Officer, Third Officer, Trainee Officer.
Crew	Bosun, Pump man, Able body seaman, Ordinary seaman.

The following areas of interests have been shortlisted from questionnaires answered by seafarers at various ranks (Figure2) working on chemical tankers and who were playing an active and direct role in the cargo operations of the ship. The study was mainly concentrated on seafarers working onboard chemical tankers. For the purpose of getting more accurate results only seafarers working on deck department, from deck officers to deck crew were included. A total of 38 senior officers, 60 junior officers and 120 crew members were included in this study. The survey was conducted on ships of a reputed shipping company whose fleet comprises of more than 25 ships of IMO Type II and III sailing worldwide. From the questionnaire four major areas are addressed in this study:

1) Minor incidents involving contact with cargo
2) Use of personal gas meters
3) Understanding of MSDS
4) Training on board ships

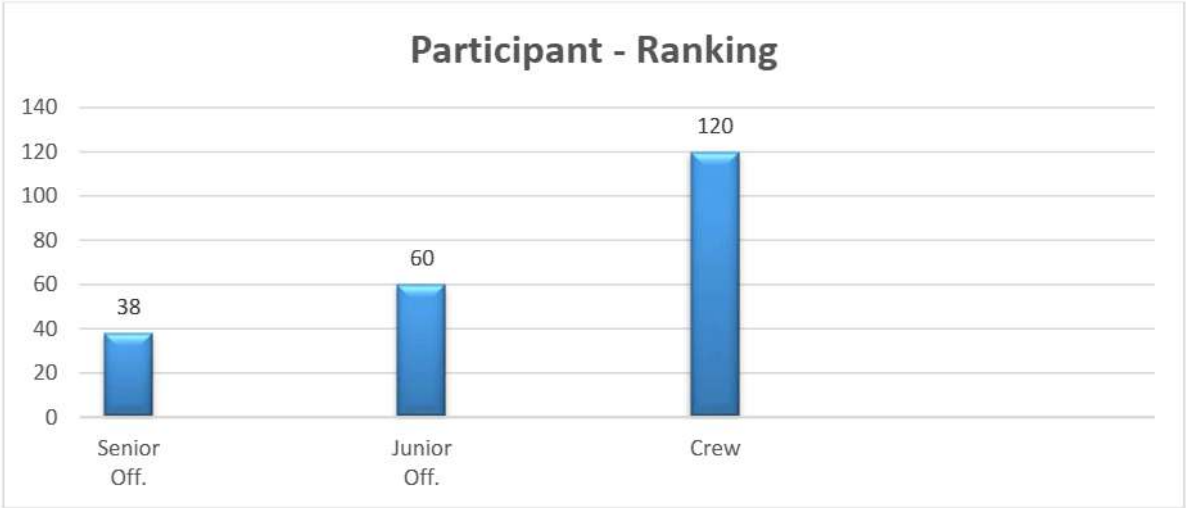

Figure 2: Category of crew included in the study.

5. RESULTS OF THE STUDY:

5.1. Minor incidents involving contact with cargo:

During cargo operations on board ships, there are a lot of instances where crew get exposed to the cargo if not properly dealt with. For the purpose of this study, minor incidents have been categorized as those in which crew members have experienced small leakages or spills on board the ship which were of negligible nature and well within the TLV - threshold limit value, range of that particular cargo.

Figure3 indicates the percentage of crew members who have been accidentally in contact with cargoes due to various reasons. First part of the graph represents crew members who were involved in accidental contact with cargo. Situations involve loading, discharging, tank cleaning, hose connection, hose disconnection, cargo sampling, tank mop/ dry and even cofferdam purging.

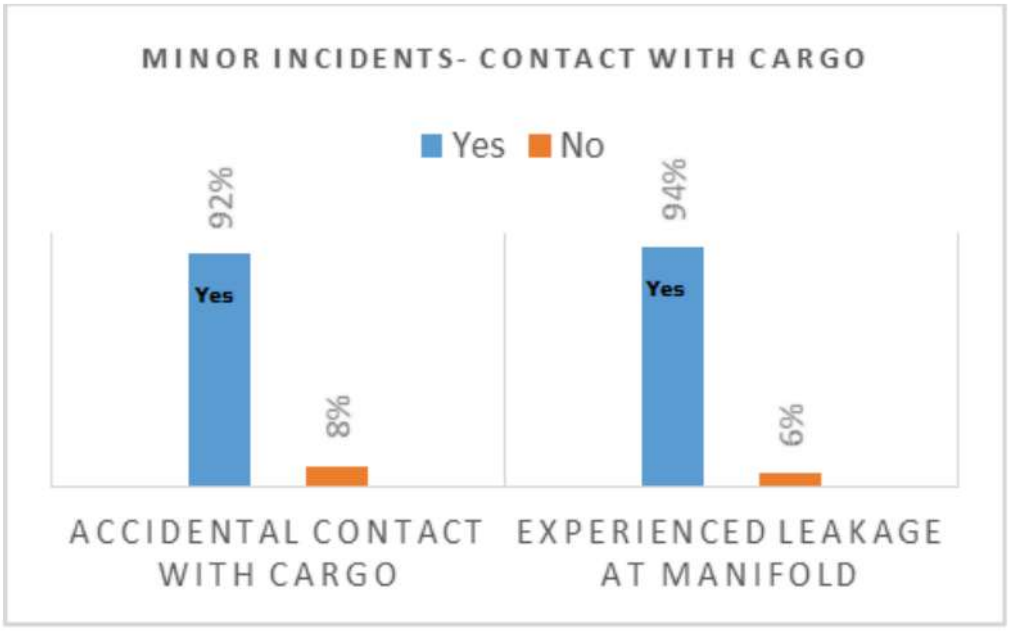

Figure 3: Minor incidents- contact with cargo.

Second part of the graph represents crew members who have actually experienced leakages at manifold during various stages of cargo operations. Cargo manifolds of a tanker are a major area which is most susceptible for leakages due to the fact that they are opened up every time for connecting and disconnecting the shore connections at port facilities.

5.2. Use of personal gas meters:

Personal gas meters are to be used by ship's crew working on deck, so that they are not exposed to the cargo vapors which can be harmful for human life. Personal gas meters have alarms set at points which can alert the crew in case of a presence of specific vapors and even when the work must be stopped prior to exceeding TLV limits. Hence proper and timely use of personal gas meters should be done by the crew to prevent being exposed to harmful vapors. Figure4 indicates the results of the study, in which use of personal gas meters for cargo operations and tank cleaning operations have been separately carried out.

It can be clearly noted that seafarers who have used gas meters during cargo operations have not used the same during tank cleaning operations. The above-mentioned fact can be directly related to the rules and regulations, ships must strictly comply when at port.

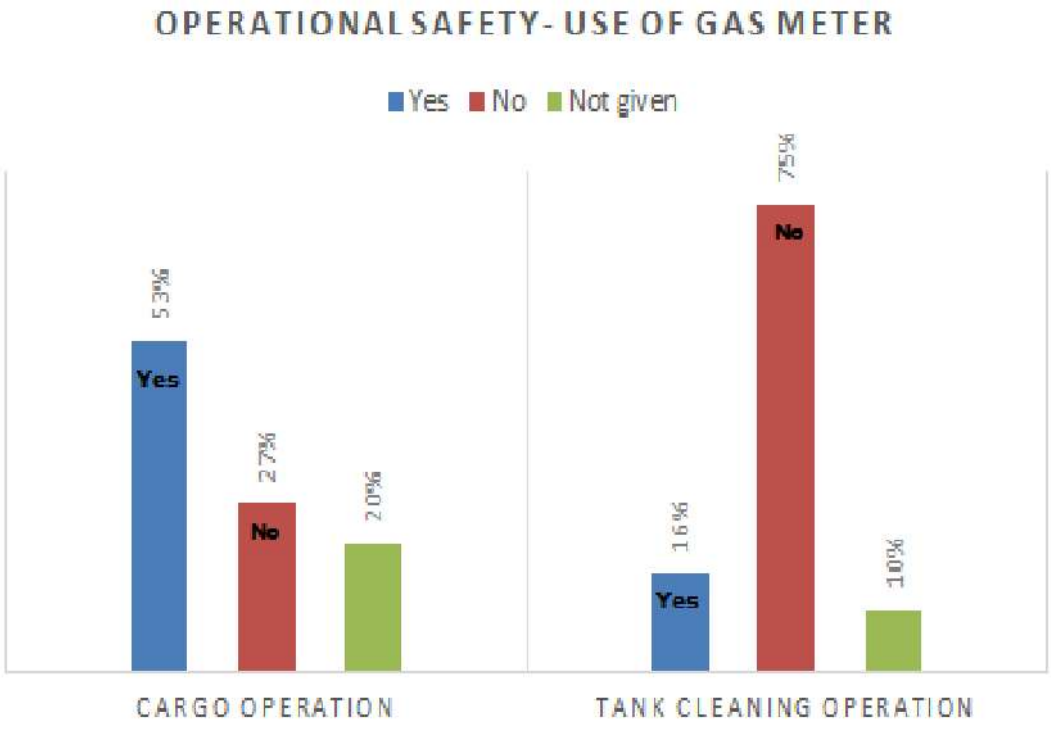

Figure 4: Use of personal gas meters.

While ships are alongside at berth, the terminal authorities also monitor the personal protective equipments being used by the ship crew. This in turn has led to following the rules strictly while at port. Tank cleaning operations on the other hand are done normally out at sea and hence there are no other third parties involved in monitoring the operations on board the ship.

20% of the seafarers also states that they had asked for gas meters during cargo operations but were not given the same by person in charge. 10% seafarers experienced the same during tank cleaning operations.

5.3. Understanding of MSDS:

Material safety data sheets (MSDS) give a detailed safety data overview of the cargo being dealt with. These sheets should be available with every person dealing with the cargo be it a shipper, charterer, receiver, port facility and also the ship crew. Information on the MSDS sheets is of vital importance as it helps in the diagnosis and treatment of a casualty when a chemical exposure has occurred (ICS, 2004). Proper understanding of MSDS sheets are required for safely handling the cargo throughout the voyage. Figure5 clearly indicates the level of importance seafarers give in understanding MSDS. These sheets give several important information pertaining to first aid measures, exposure controls, personal protection, chemical properties and even toxicological information. Cargo to be loaded can be refused by the vessel, in case sufficient information necessary for the safe transportation of the cargo is not available (IBC Code, 2016). MSDS also contain contact details of shippers who have a wider knowledge of dealing with medical emergencies for that particular cargo.

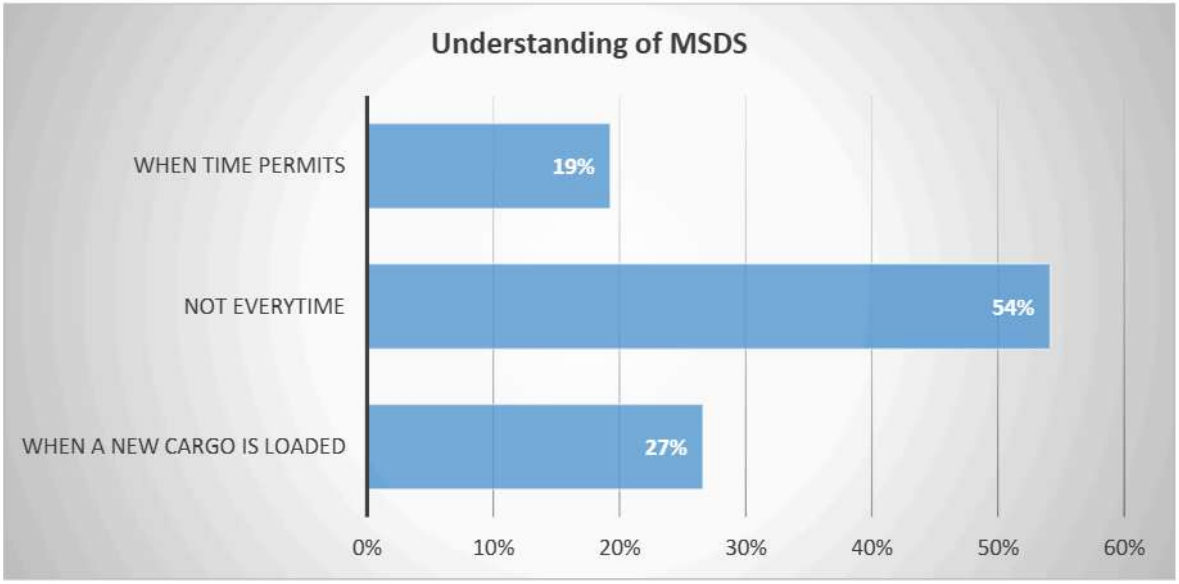

Figure 5: Understanding of MSDS.

Results show that 54% seafarers were of the opinion that, not all times they tried to read and understand the MSDS prior loading a new cargo. While 27% seafarers tried to read and

understand the data sheets whenever a new cargo was being loaded, 19% seafarers read the MSDS only when they get time. This clearly indicates that many seafarers directly dealing with cargo operations are still not aware of the information they can gain from these MSDS.

5.4. Training on board ships:

Training onboard ships are an integral part of improving seafarer efficiency. Effective training and protection programs do not stop after the initial training. Success of the trainings must be evaluated and refresher trainings are to be offered on both a routine and as-needed basis (MSC-MEPC.2/Circ.3, 2006). Specialized theoretical and practical training for every cargo being carried gives the seafarers better understanding of the unique characteristics and be aware of the potential hazards involved while handling them. Computer based training (CBT) programs are readily available on all ships which gives the seafarer a lot of awareness. Apart from this, practical training onboard ships by senior officers helps in giving a much clearer picture to the crew members who are involved in cargo operations. Awareness of the consequences helps in taking precautionary measures at the right time.

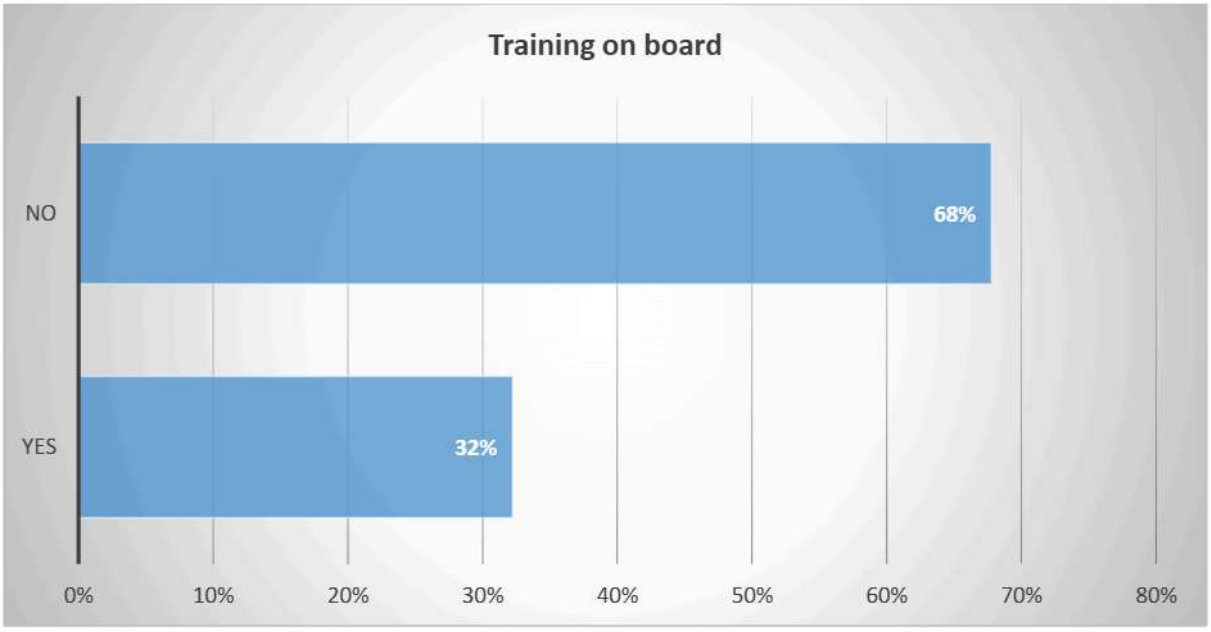

Figure 6: Interest taken by senior staff in training seafarers on board.

Study as per Figure6 shows that 32 % of the seafarers agree to the fact that senior officers were interested in imparting training on ships while 68% of the seafarers claim that senior officers were not interested in training them.

During shipboard operations, practical demonstrations and training should be given to less experienced seafarers. Familiarity gained through regular practice will lead to use of shipboard equipment's confidently.

6. CONCLUSION:

Although the number and severity of marine accidents have reduced in the past years due to improved equipment's, well implemented safety management systems, improved regulations, identification and implementation of best practices, incidents still occur with catastrophic consequences. Human error still plays a major role in all accidents. In this study seafarers working on board chemical tanker ships were used for collecting information regarding the day to day shipboard operations. The above statistical information helps in ascertaining the basic mistakes which finally lead to a major incident or accident on board. Information on health and safety hazards obtained from personnel directly involved with the work are the best sources since they can also suggest effective control measures in abating the same. Besides practical conclusions, this study has also revealed theoretical insights as follows:

i) Effectiveness of on-board practical training and increased team awareness
ii) Difficulties in effective implementation of international regulations
iii) Impact of continuous monitoring by senior officers
iv) Effect of commercial pressure on senior management which in turn affects the safety framework
v) New skill sets and improved training technologies required for ever increasing automations

Situational awareness of crew members on chemical tankers can obviously break the chain of errors which leads to an accident. Managing crew fatigue by efficiently allocating workloads will be key towards safe operations. Ergonomic aspects taken in account while designing a ship will indirectly give significant increase in work efficiency. It is only when people carry out their duties reliably and safely, operations on board a chemical tanker can be successfully completed.

In conclusion, this study has revealed reasons for human errors caused on-board ships which leads to minor or major incidents. Reducing these errors can definitely increase work efficiency

and reduce injury and incident rates. Well managed ships are safe to work and earns more profit not just for the ship owner but also to everyone associated with the import and export of cargo. The conversion of all possible weaknesses and threats identified in this study into potential strengths can improve the safe working environment on ships and increase overall productivity. The findings will be used as inputs for further research for implementing safe operational procedures on chemical tanker ships.

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STUDENTS SECTION

IMO SULPHUR 2020 CAP SOLUTIONS

Shivansh Tejashwi

Abstract

High Sulphur content in fuel oils is harmful to the marine ecosystem as crude oil containing sulphur when used for combustion, causes emission of **sulphur oxides(SOx)** along with other harmful substances which if inhaled, cause critical damage to human respiratory system as well as are also acidic in aqueous medium which is enough to hinder aquatic ecosystem in several obscure ways, one of the noted concerns being emission of **ozone depleting substances(ODS).**

Regarding this, International Maritime Organization (IMO) in October 2016 ruled out that sulphur emissions (**permissible limit**) are to be reduced from **3.5% (m/m) to 0.5% (m/m)** by **1st January 2020**. The solutions suggested by IMO in accordance with the complex and ever-changing dynamics of the maritime sector are mentioned below.

I. Use of **Very Low Sulphur Fuel Oil (VLSFO)**
II. Use of **Scrubbers**
III. Use of **Liquefied Natural Gas (LNG)**
IV. Use of **Marine Gas Oil (MGO)**

This paper will further deal with the issues faced along the course of implementation of the respective regulation, such as initial setup cost, maintenance and repair, hiked fuel cost, availability and accessibility of quality resource and skill, dynamics of market and practical feasibility to name a few along with suggestive solutions and modifications.

Key words: *Sulphur, Emissions, Sulphur 2020 Cap, VLSFO, MGO, Scrubbers, LNG, Synthetic Oil*

1. SULPHUR IN FUEL:

Sulphur is a basic chemical component which naturally occurs in crude oil. HFO (Heavy Fuel Oil) is a heavy viscosity residual fuel oil having a tar like appearance extracted from the crude oil which is used as a prime fuel for ships because of its low cost. Basic composition of HFO includes 85%Carbon,11%Hydrogen and 4%Sulphur.

2. NECESSITY OF SULPHUR IN FUEL:

Sulphur in HFO provides lubricity for high pressure components such as injectors and fuel pumps. It also prevents severe wear and tear in "old seals" and lengthens the working life of pumps which may otherwise give in to critical damage and even breakdown. Reduced Sulphur content results in the reduction of aromatic compounds which can result in failure of some seals.

3. HARMFUL EFFECTS OF SULPHUR:

The high Sulphur content in fuel oil is harmful to marine environment, as when used for combustion it causes emission of high amounts of Sulphur oxides (Sox) which are harmful if directly inhaled leading to critical damage to respiratory system and also mix with water vapors to produce Sulphuric acid. Causing several hindrances to aquatic ecosystem in many obscure ways, one to be noted is aiding the depletion of ozone layer.

4. SULPHUR CAP 2020:

IMO's Marine Environment Protection Committee (MEPC 70), in October 2016, decided that the global cap on the Sulphur content of fuel oil will be reduced from 3.5 percent to 0.5 percent m/m from 1 January 2020. The decision by MEPC in October 2016 to affirm the effective date of 1 January 2020 (more than three years before entry into effect of the 0.50% limit) is intended, in part, to provide sufficient time for Member States and industry to prepare for the new requirement.

5. GUIDANCE FOR COMPLIANCE WITH IMO SULPHUR 2020 CAP:

The new global limit for Sulphur that is 0.5 percent m/m is achievable in one of two ways: by burning fuel that has a Sulphur level that complies with the 0.5% m/m cap or by installing approved emission abatement technology – commonly referred to as scrubbers on board. Although the options suggested by IMO are efficient at cutting down SO_X emissions to according to the regulations, they are still not peerless.

6. ENCOUNTERED PROBLEMS:

6.1. LNG

a. methane slip
b. low energy density (up to 75% more storage volume)
c. handling and storage (up to $6-8 million for retrofitting)
d. Low availability
e. unstable long-term pricing

f. Increased CO emissions

6.2. MGO

a. Incompatible with existing engines for long term basis
b. low lubricity
c. low viscosity
d. higher pricing
e. low availability

6.3. VLSFO

a. High manufacturing cost ($450 per tonne)
b. specialized engine required (up to $3-4 million of retrofitting costs)
c. low viscosity (2.25 times more storage volume)
d. low availability (65% more expensive than MGO)
e. faster degradation in marine environment

6.4. Scrubbers

a. Heavy maintenance routines (can add up to 6-8% in fuel bill)
b. Handling of wash water
c. More space required
d. High installation cost (up to $3-9 million)

7. PROPOSED SOLUTIONS TO THE MENTIONED PROBLEMS:

- **Low temperature operation:** While dealing with VLSFO/ULSFO, which are less dense compared to HFO, engines can be made to run at a comparatively lower temperature than normal operating temperature as to deal with the density changes without altering the engine. It also lowers the thermal stress on the engine components, increasing its durability.

The suggested cooling is to be achieved by a dual network of seawater cooling and ammonia cooling networks. On top of being cost effective, the choice of coolants is easily available.

- **Selective separation of Sulphur:** The main reason of VLSFO/ULSFO being costly is the manufacturing process. Desulphurization processes are very costly, hence the increase in price of finished product. Selective adsorbents such activated carbon and zeolite 13X can be used to separate out Sulphur from oil, reducing the overall cost of the finished product.

- **Use of catalytic bundles:** Catalytic bundles similar in construction to catalytic tubes being used in automobiles can be used in ships in the place of scrubbers. Usage of ammonia based catalytic bundles is suggested rather than using platinum based catalytic tubes which are relatively costly. Ammonia based catalytic bundles are easily producible, cost effective and also occupy less space in comparison to scrubbers which require a water storage, wastewater storage and pumps to handle the water flow, along with rigorous maintenance routines.

- **Use of synthetic oil:** Synthetic oil can be produced onboard ships from CO_2 in flue gases through Fischer-Tropsch process and reused in the engine without any alterations. These synthetic fuels contain trace amounts of Sulphur and Nitrogen and, in theory, are carbon neutral. This negates the need for VLSFO/ULSFO and scrubber arrangements as the limit of SO_X is m/m, *i.e.* it is based on the total mas of flue gases produced.

8. CONCLUSION:

Based on the above report, it can be concluded that the narrowed down limit of SO_X emissions defined by the provisions ruled out by IMO Sulphur 2020 Cap have led to a contrasted change in the supply and demand levels of various fuels, along with opening up new opportunities for research, which will further lead to the creation of an even more cost effective and eco-friendly fuel in the near future.

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HYBRID PROPULSION SYSTEM

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Abstract

Regional and global air pollution from marine transportation is a growing concern. In descending the sources of such pollution, researchers have now become more interested in tracking where along the total fuel life cycle, these emissions occur.

Mechanical power and electric power work together in the propulsion train optimizing the propulsion efficiency for ships with a flexible power demand. The combination of mechanical power by dual fuel engine and electrical power by electrical motors through hydrogen fuel cells delivers propulsion power, providing the right amount of power and torque to the propeller in each operation mode.

Dual fuel engine- The dual fuel engine is an excellent solution for fulfilling IMO TIER 3 NOX as well as the increasingly stringent Sulphur fuel caps. The dual fuel engine uses both gas-oil mixture and natural gas as fuel. That adds to the security of energy supply. The thermal efficiency of dual fuel engine is 36%, so that the availability of gas at a price 10% less than that of fuel oil make it worthy for consideration.

Hydrogen fuel cells-a fuel cell is a device that converts chemical potential energy (energy stored in molecular bonds) into electrical energy. A PEM (proton exchange membrane) cell uses hydrogen gas and oxygen gas as fuel. The product of the reaction in the cell are water, electricity and heat.

Our Hybrid propulsion systems include a dual fuel engine, hydrogen fuel cell and electric motor ,typically allowing the diesel , gasoline or LPG engine to do the heavy work when needed , and allow the electric system to respond to lighter loads such as low-speed cruising or providing power for lights and electronics.

Using these two in connected manner we get one of the most efficient propulsion systems.

Key word: Hybrid propulsion, Dual fuel engine, Hydrogen fuel cells.

1. DUAL-FUEL ENGINE:

A dual-fuel engine is an engine designed to burn predominantly natural gas but with a small percentage of diesel as a pilot fuel to start ignition. The engines operate on a cross between the diesel and the Otto cycle. In operation, a natural gas–air mixture is admitted to the cylinder during the intake stroke, then compressed during the compression stroke. At the top of the compression stroke the pilot diesel fuel is admitted and ignites spontaneously, igniting the gas–air mixture to create the power expansion. Care has to be taken to avoid spontaneous ignition of the natural gas–air mixture, but with careful design the engine can operate at close to the compression conditions of a diesel engine, with a high-power output and high efficiency, yet with the emissions close to those of a gas-fired spark-ignition engine. However, efficiency tends to fall, and emissions of unburned hydrocarbons and carbon monoxide rise at part load.

Typical dual-fuel engines operate with between 1% and 15% diesel fuel. Since a dual-fuel engine must be equipped with diesel injectors, exactly as if it were a diesel engine, a dual-fuel engine can also burn 100% diesel if necessary, though with the penalty of much higher emissions.

Diesel engines can operate with much higher compression ratios than spark ignition engines and this allows them to achieve higher efficiencies. The large disparity in efficiency between a spark ignition engine and a diesel engine has prompted engine developers to search for a way of achieving the efficiency of a diesel engine in spark ignition engine. This is the origin of the dual-fuel engine which has been the most successful of these hybrids

A gas metering control unit is used to control the gas mass flow rate. The gas flow rate provides a similar linear relationship to the power output as for the diesel level. This enables the diesel and gas power produced to be calculated and the engine to be protected against overload. The diesel side of their engine is powered by a mechanical injection system which is connected to an electric actuator. The figure provides a schematic view of the system.

In dual fuel mode, this diesel controller is still responsible for the actual speed/power control. An additional control loop then controls the optimum gas quantity. This enables the diesel injection system to respond dynamically to rapid fluctuations or step changes. If the load is disconnected, the engine can quickly be switched back to pure diesel operation. This prevents the diesel level from falling below the minimum required for combustion and thus causing misfires.

1.1. Further Improvements:

A total energy system implies on-site power generation in which the energy input from either liquid fuel (diesel engines) or a combination of gaseous and liquid fuels (dual-fuel engines) is maximized by recovering the waste heat from the generating process. By so doing the overall thermal efficiency of generation may be raised from 37% to about 80%.

1.2. Advantages:

1. LPG-powered engines guarantee the lowest unburned hydrocarbons emissions (-95% compared to 2- stroke engines and –42% compared to 4-stroke gasoline engines / -92% and –34% compared to LPG engines).
2. Dual fuel engine results in high CO2 savings and high variable cost savings.
3. A power station based on multiple dual-fuel engines in parallel offers high flexibility, both in fuel use and in output. This increases the reliability of power supply.
4. The key advantage of dual-fuel engines – which typically primarily use liquefied natural gas (LNG) but can also run on heavy fuel oil or marine diesel oil – is that their owners can select the most economical fuel under different conditions.

2. HYDROGEN FUEL CELL:

A fuel cell is a device that converts chemical potential energy (energy stored in molecular bonds) into electrical energy. A PEM (Proton Exchange Membrane) cell uses hydrogen gas (H_2) and oxygen gas (O_2) as fuel. The products of the reaction in the cell are water, electricity, and heat. This is a big improvement over internal combustion engines, coal burning power plants, and nuclear power plants, all of which produce harmful by-product.

2.1. How does it work:

Pressurized hydrogen gas (H_2) entering the fuel cell on the anode side. This gas is forced through the catalyst by the pressure. When an H_2 molecule comes in contact with the platinum on the catalyst, it splits into two H+ ions and two electrons (e-). The electrons are conducted through the anode, where they make their way through the external circuit (doing useful work such as turning a motor) and return to the cathode side of the fuel cell.

Meanwhile, on the cathode side of the fuel cell, oxygen gas (O_2) is being forced through the catalyst, where it forms two oxygen atoms. Each of these atoms has a strong negative charge. This negative charge attracts the two H+ ions through the membrane, where they combine with an oxygen atom and two of the electrons from the external circuit to form a water molecule (H_2O).

All these reactions occur in a so-called cell stack. The expertise then also involves the setup of a complete system around core component that is the cell stack.

The stack will be embedded in a module including fuel, water and air management, coolant control hardware and software. This module will then be integrated in a complete system to be used in different applications.

Due to the high energetic content of hydrogen and high efficiency of fuel cells (55%), this great technology can be used in many applications like transport (cars, buses, forklifts, *etc.*) and backup power to produce electricity during a failure of the electricity grid.

2.2. Advantages:

- By converting chemical potential energy directly into electrical energy, fuel cells avoid the "thermal bottleneck" (a consequence of the 2nd law of thermodynamics) and are thus inherently more efficient than combustion engines, which must first convert chemical potential energy into heat, and then mechanical work.
- Direct emissions from a fuel cell vehicle are just water and a little heat. This is a huge improvement over the internal combustion engine's litany of greenhouse gases.
- Fuel cells have no moving parts. They are thus much more reliable than traditional engines.
- Hydrogen can be produced in an environmentally friendly manner, while oil extraction and refining are very damaging.

3. HYBRID PROPULSION SYSTEM:

Mechanic and electric power work together in the propulsion train, optimizing the propulsion efficiency for ships with a flexible power demand. The combination of mechanical power, delivered by dual fuel engine, and electrical power by hydrogen fuel cell. Delivers propulsion power, which assures the ship a broad operational capability, providing the right amount of power and torque to the propeller in each operation mode. Whereas a diesel-mechanic propulsion system is designed according to its maximum power demand, which, for example, is fixed for a tanker or cargo vessel according to the most hours of the operation profile, a

hybrid propulsion plant is better prepared for changes in operation during the vessel's trip or even the vessel's life.

Hybrid propulsion systems can be differentiated between configurations, where the diesel engines and the E-motors work in parallel on the propeller (CODLAD), or where either the diesel engine or the E-machines are used (CODLOD).

Hybrid-electric systems include dual fuel engine and hydrogen fuel cell to run electric motors typically allowing the diesel, gasoline or LPG engine to do the heavy work when needed, and charge the electric system and allow it to respond to lighter loads such as low-speed cruising or providing power for lights and electronics.

The advantages of all-electric or parallel-electric boats are the reductions in pollution, noise, vibration, and potentially, cost.

In a parallel hybrid system, both the dual fuel engine and the electric motor can provide power to the propeller.

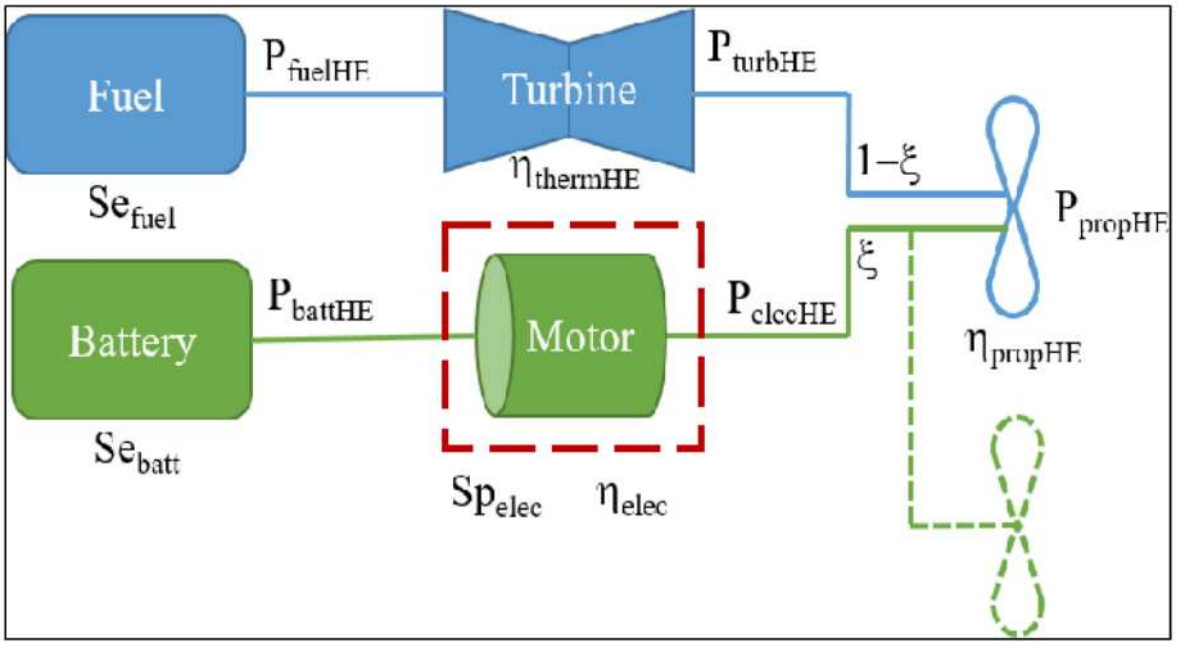

Figure 1. Electric Drive System

3.1. Advantages of hybrid propulsion system:

- Flexible use and highest efficiency.
- The propeller can be driven by the diesel/LPG engine, and / or by the electric motor, resulting in a highly redundant and reliable propulsion system.
- Part-load in a conventional system.
- Part-load in an electrical system.
- In hybrid mode, the engine and the propeller can operate with variable rpm (combination mode) and the network frequency and voltage are fixed and stable.
- Reduced plant operating costs due to the possibility to operate the main engines and auxiliary gensets in a range where the required amount of power is provided by a combination of engines which run near or at their optimal loading with their minimal specific fuel oil consumption.
- As a result of high plant efficiency over a wide range of operation modes, not only fuel oil consumption is lower, but fuel related emissions like SOX and CO2 are also reduced. Further pollutants are reduced as there is less incomplete combustion that intensively occurs in the low-loaded engines.
- In E-mode with variable-speed E-motors less noise is caused and pressure side cavitation on the propeller is reduced, as it can be operated at an optimal speed / pitch ratio. Propeller speed and pitch can be controlled independently. Additionally, the underwater noise signature can be reduced. This especially offers benefits at slow speed sailing.
- Depending on the operational modes of the vessel the main engines and the auxiliary engines run less hours per year and, when in operation, on higher loads. Both lead to less required maintenance.
- Large variation of operation modes appropriate for a flexible power demand, for slow speed operation up to boosting. This results in an optimal overall plant operational capability with fast system responses and a high plant flexibility.
- While mechanical optimization is often determined by one or a few operational modes, the electrical drive capability tremendously increases flexibility. “Off-designs” for hybrid propulsion systems are fewer compared to pure mechanical system designs.

3.2. Disadvantages of hybrid propulsion system:

- Lower overall energy efficiency for ships running at full-rated speed all the time due to losses.
- Higher initial capital cost.
- Different and improved training for ship's crew as the system is completely different from mechanical system and involves major automation.

4. CONCLUSION:

In recent years, the concept of a hybrid drive, especially for inland vessels, has been developed. The hybrid propulsion system can be beneficial from both economic and ecological point of view. It can be a onetime investment. The advantage of hybrid propulsion is particularly visible when the ship is operating at a low speed. Moreover, the major benefit resulting from hybrid propulsion in electric mode was significantly reduced noise pollution. It may be essential factor for urban or environmentally protected areas. The Hybrid propulsion system showed that there is possible to lower operating costs due to lower fuel consumption. However relative benefit resulting from using hybrid propulsion is strongly dependant on the specific aspect of route (*i.e.*, speed limits, current) and vessel speed. If the combustion engine works for most of the time at optimum load (80% of full power), then the fuel savings are minimal. However, if the travel includes different power demands, resulting *i.e.*, from speed limits, then the fuel savings can reach up to 40%. Addition to that use of hydrogen fuel cells for providing the electrical power makes it more environment friendly. This technology can be used as an upgradation in existing technology.

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EFFECT OF THE BOTTOM OPENING OF THE MOONPOOL ON THE HYDRODYNAMICS OF A CONCEPTUAL FPSO

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Abstract

We present a CFD analysis conducted on various bottom opening designs of the conceptual FPSO vessel equipped with circular moonpool. FPSO's are generally ship-shaped offshore structures equipped with LNG tanks and liquefaction plants. Moonpool is a vertical opening in the floating body used for launching and retrieving subsea equipment. The moonpool could be found in different shapes from rectangular, as in drillships, to circular section shape, as in Floating Production Units. The main advantage of it is that the operations can be carried out without the influence of the dynamic effects of waves and currents. Still, there are several problems associated with moonpool operations such as the excessive motions of the water column inside the moonpool in either Piston or Sloshing mode. The bottom opening has a significant role to play on the operation through the moonpool not only in case of the FPSOs but also in the other vessels integrated with the moonpools. In this paper, the underwater shape of the moonpool of an FPSO moonpool is varied, and the hydrodynamics of the vessel is monitored. CFD had proven to be a useful tool to not only capture the complex dynamics of the water-free surface motion but also to evaluate the hydrodynamic forces. In the study, it was found and established that bottom opening governs the amplitude of oscillation inside the moonpool, the nature and magnitude of the response of the vessel.

Key words: Moonpool opening, water column oscillations, hydrodynamic drag, CFD

NOMENCLATURE:

FPSO	Floating Production Storage and Offloading
ITTC	International Towing Tank Conference
RANSE	Reynolds-Averaged Navier Stokes Equations
SIMPLE	Semi-Implicit Method for Pressure-Linked Equations
VOF	Volume of fluid
CFD	Computational Fluid Dynamics
DFBI	Dynamic Fluid Body Interaction
OWC	Oscillating water column
CFL	Courant-Friedrichs-Levy

1. INTRODUCTION:

Moonpools are designed as vertical openings through the decks and the hull structures to support the required underwater operations on FPSOs, marine research vessels, drilling ships, and offshore platforms. A moonpool is a part that shields the operations from the outer conditions and makes the water surface accessible with certain safety. A moonpool affects not

only the transit performance of the vessel but also the static performance of the platform in waves. The water column inside the moonpool oscillates in various modes during transit or operations. These oscillations can be significant under resonant situations, such as piston motions, and sloshing. In recent times, modified features and additional structures are installed such as in the recess type moonpool, appear in FPSOs and drillship's moonpool design, which provide better equipment arrangement and operations characteristics. However, the impacts introduced by these additional appendages on relative water motions inside moonpool need to be analysed. Fukuda (1974) carried out experimental investigations in a towing tank to determine the water behaviour inside the moonpool and the effects on the vessel motions and obtained an empirical relation to identifying the resonant frequency of the water motions. Aalbers (1984) developed a mathematical model to describe the water behaviour inside moonpool and conducted related model tests. Molin (2001) assumed an infinite length and beam of a barge equipped with a moonpool and mathematically derived the natural oscillation frequency using linear potential theory. Kristiansen and Faltinsen (2008) investigated the impacts of fluid viscosity and free-surface effects by a nonlinear numerical wave tank coupled with an inviscid vortex tracking method. Wei *et al.* (2011) analysed the moonpool size effects on the hydrodynamics of an FDPSO and carried out experiments to obtain the overall loads imparted by sloshing coupled with the ship motion. In recent years, CFD tools have been employed to study the sloshing phenomenon as potential theory solutions tend to overestimate the water motions response inside the moonpool. These motions can affect subsea operations through a moonpool. When the vessel gets excited at a frequency equal to the natural frequency, the significant elevation of the water column could be expected in the moonpool. Another challenge is the added resistance to motion of the body experienced by the platform in the presence of moonpool oscillations in the transit condition. An increase in the vessel motions and the water column oscillation inside the moonpool results in the augmentation of vessel resistance during transit. Many methods have been implemented to decrease the oscillations inside the moonpool, in which either the vessel oscillations are reduced using motion stabilisers or structures.

The present study concentrates on analysing the different types of openings of moonpool at the bottom and its effect on the behaviour of the water column oscillations. This shall shed light on the moonpool hydrodynamics, its influence on ship motions which will be helpful for the new design concepts of the pipe lying vessels, FPSOs or similar platforms.

2. METHODOLOGY:

The first step is the geometrical modelling of the body. The closed geometrical form of the body is easier for meshing. Glitches in body geometry creation can create different problems in meshing. Next, the kind of boundaries are identified, inlet, outlet, slip-walls, no slip-walls, and symmetry. Symmetry is a boundary employed when half-hull is imported to reduce the number of total cells, thus saving computational time. In this case, the flow must be symmetric around the hull. Therefore, sway, roll, and yaw motions cannot be simulated when this boundary condition is employed. Each boundary has different conditions and values of physical variables. Then using the DFBI module, the mass properties are injected in the solver and desired quantities calculated. These will be described in the subsequent sections.

2.1. Geometric Modelling:

The 3D model (Figure1) was created using CAD modelling software using the bottom to top approach. Surfaces are created using curves defining the transverse frames of the hull obtained from the lines-plan drawings, and the surfaces are joined to create a solid model. In the prototype, a hull and a moonpool section complete the conceptual FPSO design. The CAD model includes all geometric features that are significant to the fluid flow.

Table 1 The principal particulars of the FPSO

Principal Dimension (SI units)	Prototype
LOA (Overall)	480
LBP (Between Perpendiculars)	450
Breadth	68
Depth	43
Moonpool Diameter	25
Draught	18

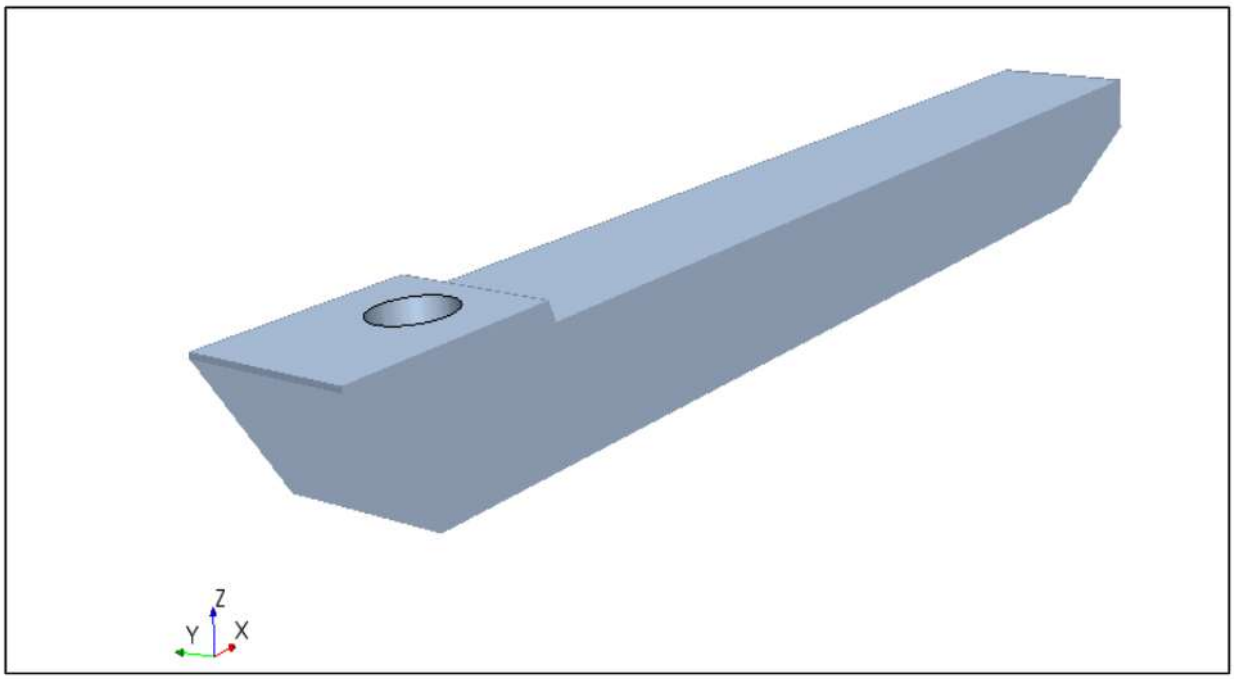

Figure 1: 3D CAD Model of the FPSO

Two types of modifications were done in the present analysis:

1. Additional Structure at the bottom
    - **Design-1 (Ring at the edge of opening)**- A small ring of 1 m depth, inner diameter 20.0 m, and outer diameter 25.0 m are attached to the circumference of the moonpool at the bottom. (Figure 2)
    - **Design-2 (Disc at the centre of the moonpool)**- A circular disc of diameter 13.0 m and depth 1.0 m is placed in the centre of the moonpool at the bottom. (Figure 3)

2. Modification of the moonpool shape at the bottom
    - **Design-3** Providing inclination at the front end of the moonpool (Figure 4)
    - **Design-4** Providing inclination at the rear end of the moonpool (Figure 5)
    - **Design-5** combination of above two. (Figure 6)

The views of different CAD models are shown in Figure 2 to Figure 6. The specific dimensions of the prototype are listed in Table 1.

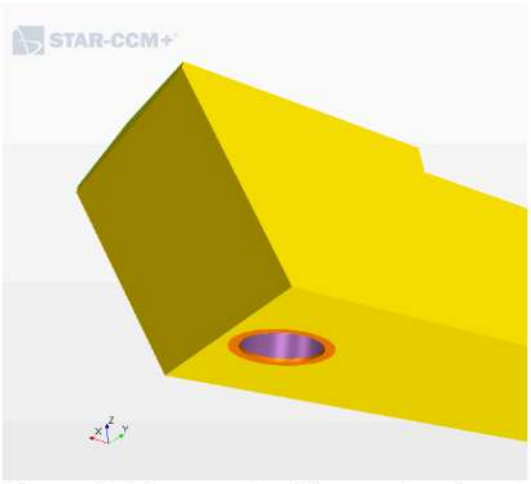

Figure 2: Moonpool with an outer ring at the bottom

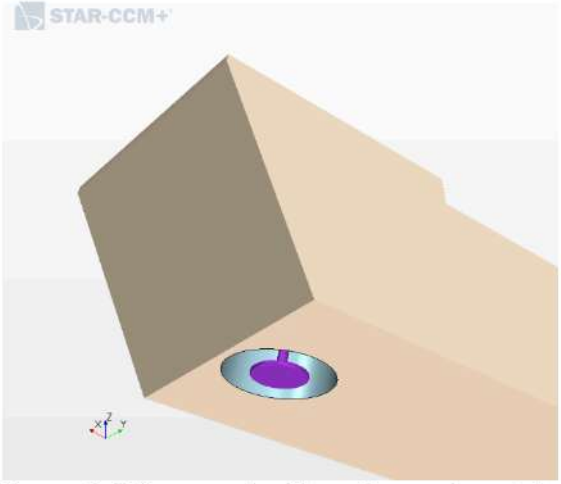

Figure 3: Moonpool with an inner ring at the bottom

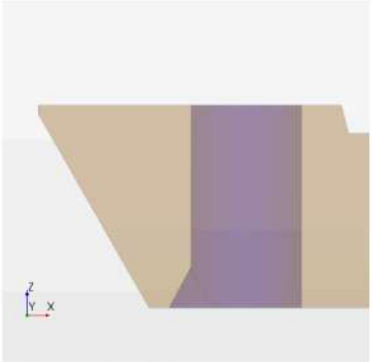

Figure 4: Slope at the front end

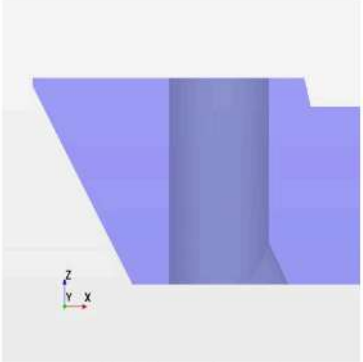

Figure 5: Sloped at the rear end

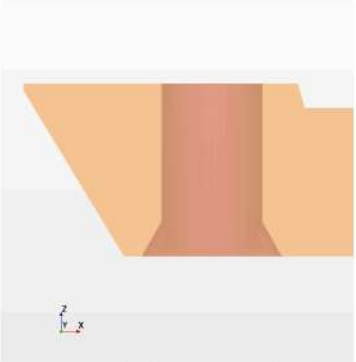

Figure 6: Slope on both ends

2.2. Closed Volume and Fluid Regime:

The fluid domain around the FPSO generated to perform the CFD simulations, is a rectangular parallelepiped, modelled based on the ITTC recommended guidelines. The boundary conditions on the computational domain were given as the actual physical conditions.

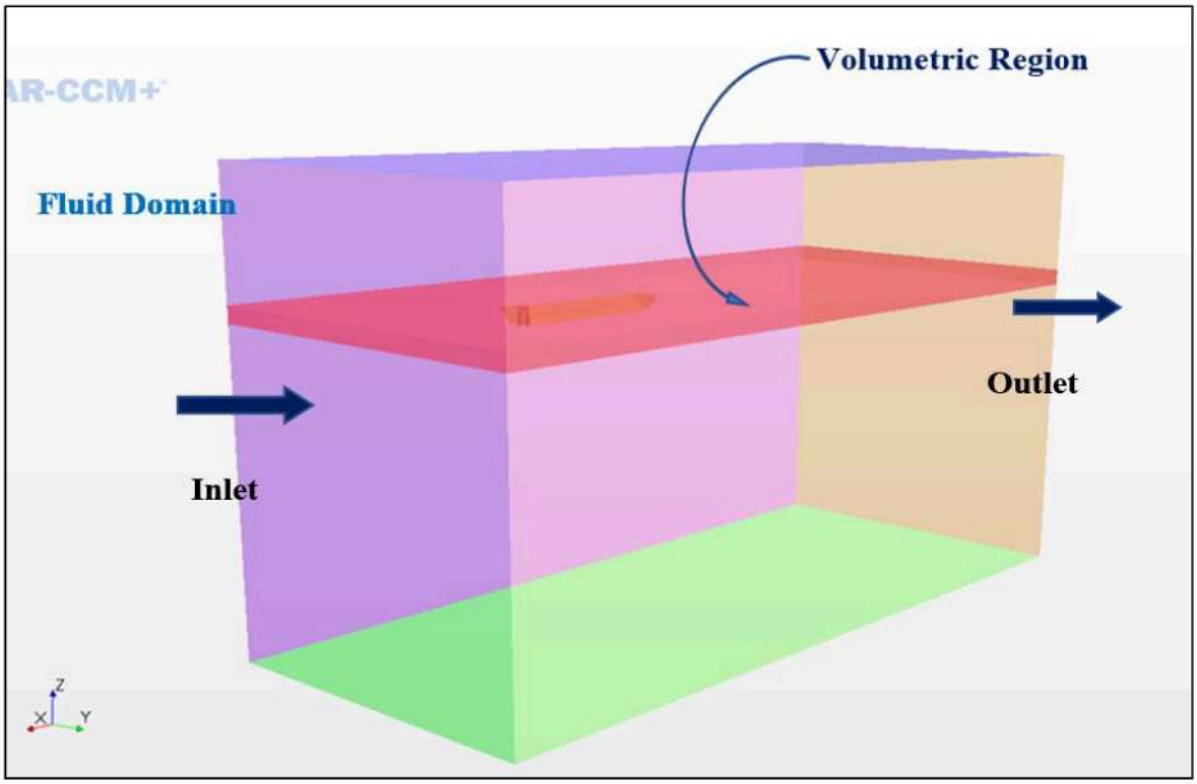

Figure 7: Computational domain and boundaries

The different boundaries of the fluid domain are shown in Figure 7. At the inlet boundary, a uniform inflow velocity with magnitude equal to that of the platform tow speed is specified for a calm water tow condition. For tow in a seaway condition, the inlet boundary also includes the specification of appropriate parameters of the incident wave. However, the present analysis is limited to the calm water conditions.

At the side, top, and bottom boundaries of the fluid domain, the normal inflow velocity to these boundaries is taken as zero, which implies that the flow is entirely tangential at these boundaries. At the outlet boundary, the condition specified is pressure, the value of which is taken as the sum of hydrostatic and atmospheric pressures. The platform surface is considered as a boundary with no-slip, which implies that the velocity of the fluid particles adjacent to this boundary will attain the same velocity of the boundary. If the outer boundaries are not sufficiently away from the platform surface, the flow reflections from these boundaries may affect the solutions. In such a case, either numerical damping must be introduced at these boundaries or extend the fluid domain to obtain accurate results.

2.3. Grid Generation:

Mesh generation was achieved using ICEM-CFD. It is the discretised representation of the computational domain. The finite volume method is used in the present study to model the free surface (multi-phase). The surface mesh is employed to triangulate the surfaces while meshing. Trimmed hexahedrons and prismatic near-wall layers were used to cluster the volume mesh. The grids were refined locally inside the moonpool, and finer meshes used close to the free surface to capture the flow variations accurately. Prism layer cells are used near the wall (hull) surface to capture the gradients and resolve the boundary layer. This assessment of the distance to the wall is based on the computation of the skin friction as a function of the flow Reynolds number. This distance is defined in terms of the non-dimensional parameter $y+$ (Eq.1).

$$\frac{y}{L_{PP}} = \frac{y^+}{Re\sqrt{C_f/2}} \tag{1}$$

Where y is the requisite cell size, L_{PP} is the length between perpendiculars of the ship, Re is the Reynolds number, and C_f is an estimate of the skin friction coefficient (Eq.2), based on the ITTC standard procedure. This gives an approximation of the skin friction coefficient at mid-ships.

$$C_f = 0.075/(\log_{10} Re - 2)^2 \tag{2}$$

Grid independence tests are conducted to avoid any fluctuations in the solution concerning the computational mesh density. Cell count for the meshes varies between 1.8-2.9 million. Figure8 shows the mesh around the vessel and inside the moonpool. An enlarged view of the meshing inside the moonpool is shown in Figure 9 & Figure10.

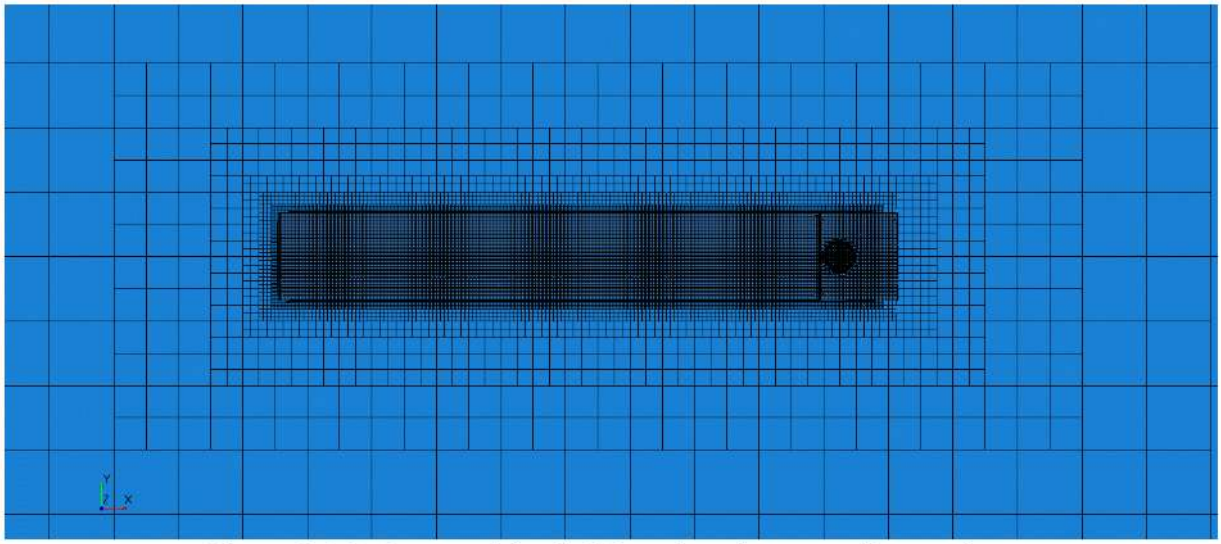

Figure 8: Mesh around the FPSO and on the water-free surface

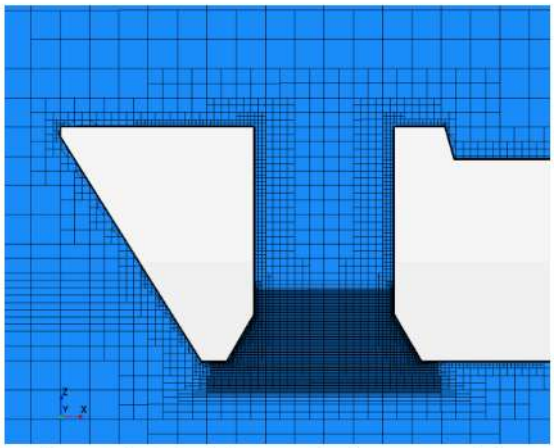

Figure 9: Meshing at the bottom of the moonpool (Side View)

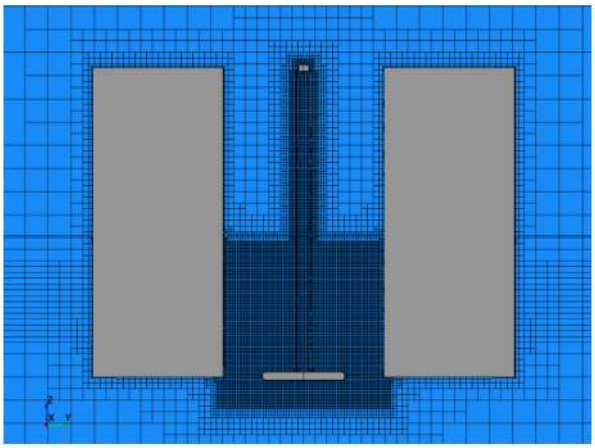

Figure 10: Meshing inside the moonpool (Profile View)

2.4. Boundary Conditions and Physics Setting:

In the present case wall with no-slip, the condition is applied to the vessel surfaces while side boundaries, top ceiling, and bottom floor of the domain are specified as velocity inlet with zero velocity and at inlet boundary, the velocity is equal to the vessel speed in the direction of fluid flow relative to the vessel. Outlet condition is specified to the downstream flow boundary, where neither the flow velocity nor the mass flux is known, with hydrostatic pressure due to initial wave created through VOF Waves at the design draft as described in the previous section. Additionally, volume fractions of water and air, corresponding to the initial wave, are specified to both inlet and outlet boundaries for the free surface flow. DFBI and VOF modules were initiated with the mass properties of the prototype and calm water conditions. The physical

models and parameters chosen for the simulation of the present analysis are depicted in Table 3.

Table 2: Boundary conditions

Boundary	Condition
Inlet	Velocity inlet
Top, bottom, side	Velocity inlet with zero velocity
Outlet	Pressure outlet
Body	No-slip wall

Table 3: Physical model parameters

Parameter	Model Chosen
Temporal Discretisation	First-order upwind
Pressure-Velocity Coupling	SIMPLE algorithm
Free Surface Modelling	VOF method
Turbulence Model	Realisable k-epsilon
Wall Treatment	Two-layer all y+
Flow Type	Segregated

Numerical point-probes inside the moonpool on the water-free surface, as shown in Figure 11, are generated to capture the amplitude and the mode of oscillations.

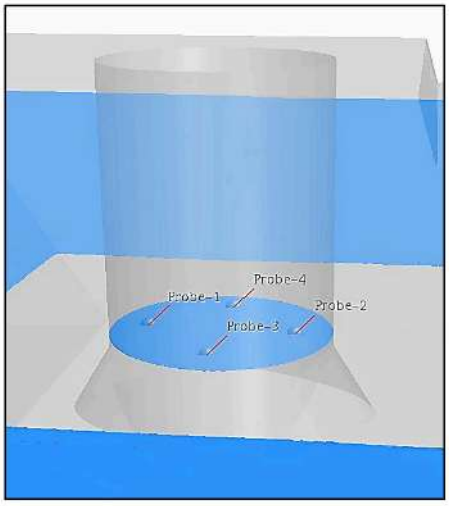

Figure 11: Probes placed inside the moonpool

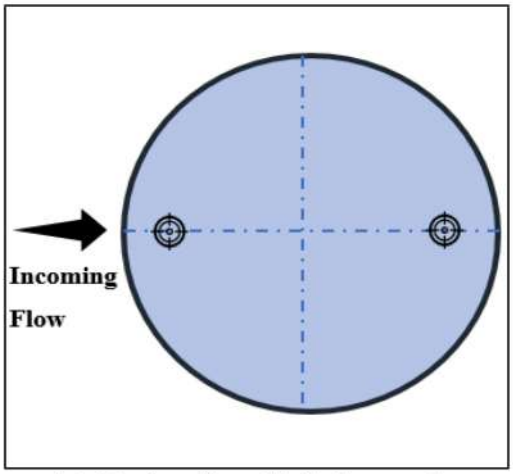

Figure 12: Probes for which the results are presented (Top view of the moonpool section)

The FPSO surfaces constructed as a rigid body and the motion equations are solved using 6-DOF solver DFBI. Starting time step value, 0.01s was calculated by the CFL condition.

For the one-dimensional case,

$$C = \frac{u\,\Delta t}{\Delta x} \leq C_{max} \tag{3}$$

Where the dimensionless number C is called the Courant number, and C_{max} is the CFL criterion, for the present analysis

$$C_{max} \leq 1 \tag{4}$$

u is the velocity in m/s, Δt is the time step in seconds, Δx is the minimum cell size.

3. RESULTS AND DISCUSSION:

The water-free- surface inside the moonpool undergoes various types of motions such as few modes of sloshing and the piston mode. The solver used in the present study provides the visualisation of these motions through different methods meticulously.

3.1. Oscillating water column inside the moonpool:

The motion of the water column inside the moonpool when FPSO is advancing at 6 knots in the calm sea, was captured for different designs using local velocity vectors shown in Figure 13 to Figure 17 and compared with the moonpool with no appendages as depicted in Figure 18.

Figure 13 and Figure 14 present the velocity field inside the moonpool with a disc at the centre and a ring at the circumference respectively. The difference in vortex patterns at the edge of the moonpool is evident at the bottom entry.

The moonpool with a disc at the centre has three separate zones in which vortices are formed and shredded while the patterns in the moonpool with ring show vortex patterns such as the moonpool with no attachments. When the leading edge of the moonpool has been provided with a ramped entry, the vortex generated at the bow of the hull does not shed the hull at the entry of the moonpool, but it enters the moonpool. The reverse of this was observed in the design- 4. The design-5 provides smoother entry and exit of the vortices as compared to all designs.

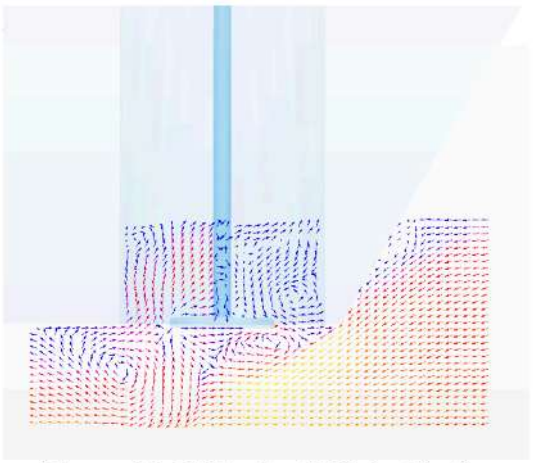

Figure 13: Velocity field inside the moonpool (Design-1)

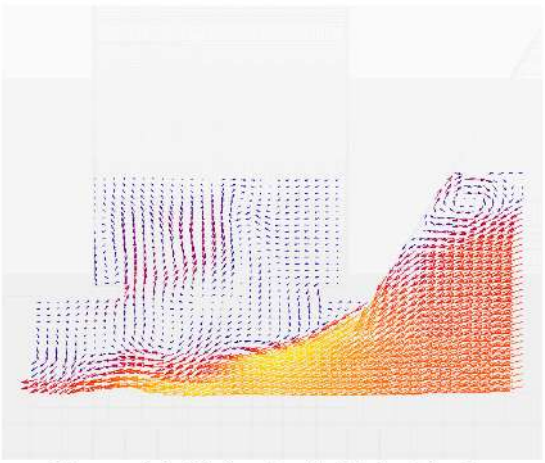

Figure 14: Velocity field inside the moonpool (Design-2)

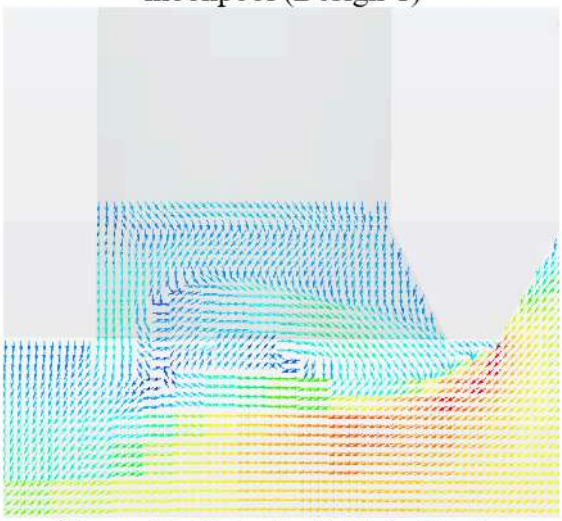

Figure 15: Velocity field inside the moonpool (Design-3)

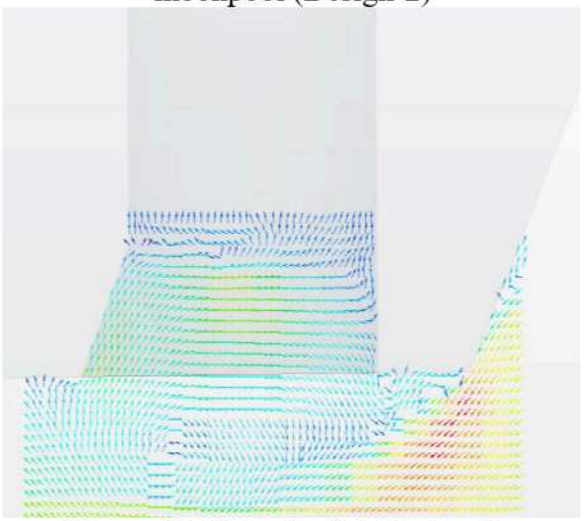

Figure 16: Velocity field inside the moonpool (Design-4)

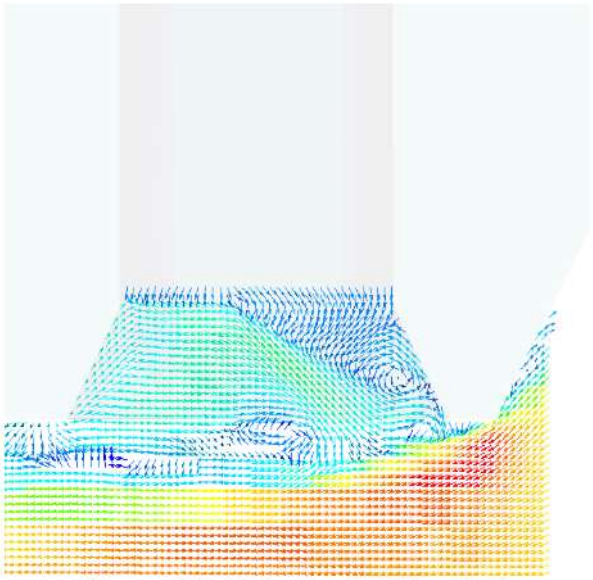

Figure 17: Velocity field inside the moonpool (Design-5)

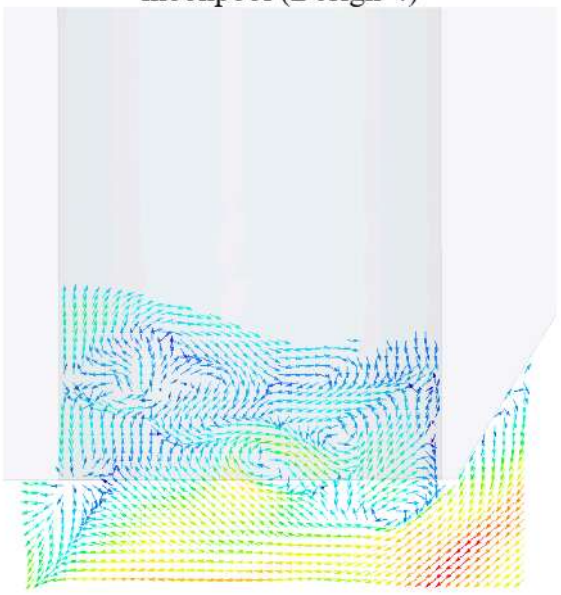

Figure 18: Velocity field inside the moonpool

3.2. FPSO Response:

The oscillating water column inside the moonpool and its interaction with the moonpool walls induces the sinusoidal motions in the calm water conditions. The piston mode motions affect the heave of the FPSO, while the sloshing mode influences the pitch response.

In the present analysis, the FPSO could heave and pitch freely while moving with a speed of 6 knots in the calm water conditions. Heave and pitch responses of the FPSO are presented form Figure 19 to Figure 22.

The pitching amplitude of FPSO is of the same order for all designs. However, there is a little difference in the periods. Moonpool with a ring at its circumference shows lower pitching amplitude as compared to the design -2.

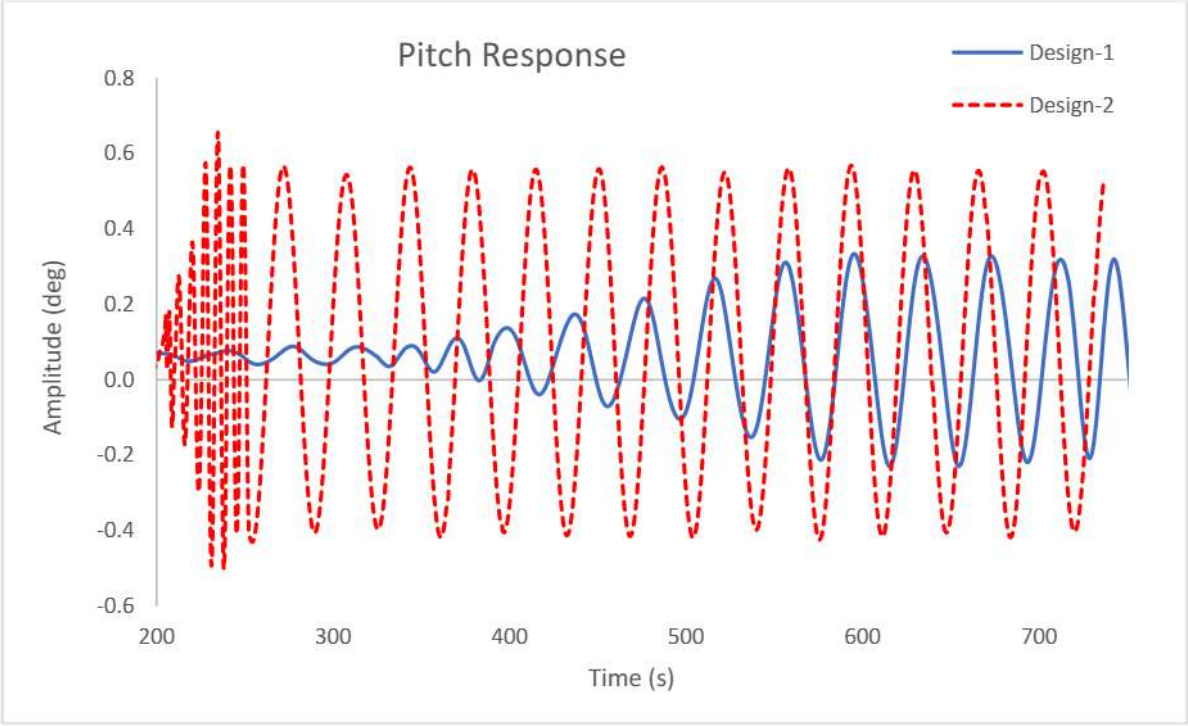

Figure 19: Pitch response of the FPSO moonpool at 6 knots (Design-1 and Design-2)

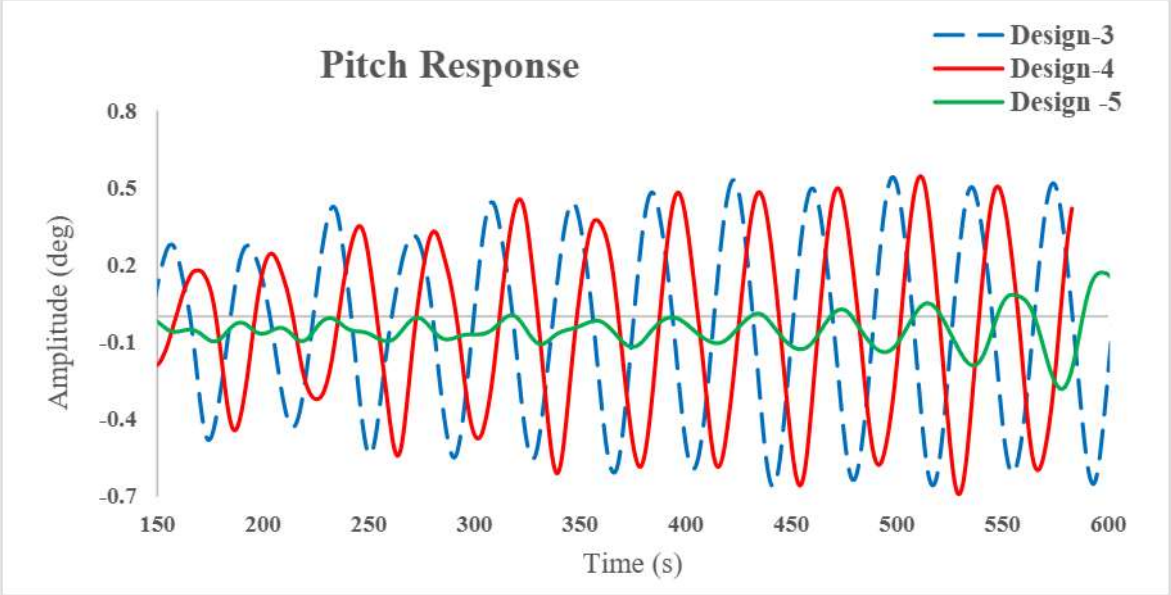

Figure 20: Pitch response of the FPSO moonpool at 6 knots
(Design-3, Design-4, and Design-5)

However, it has minimal effect on the pitching period. It not only takes longer for the deign-5 to achieve the steady-state but also it has the lowest response compared to all designs.

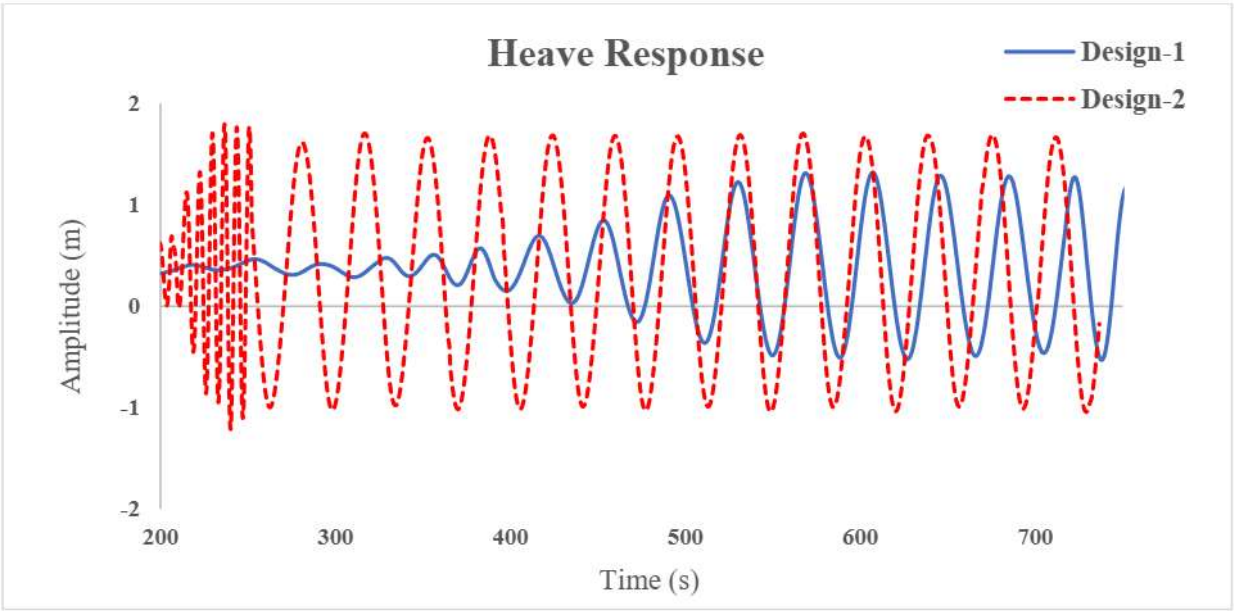

Figure 21: Heave response of the FPSO moonpool at 6 knots
(Design-1 and Design-2)

Such as the pitching, all designs have somewhat similar heave motion response. The periods of heave for all designs are of the same magnitude as in the pitching motion. Design- 1 and Design-5 show small heave motions initially, with Design-5 has the least heaving response.

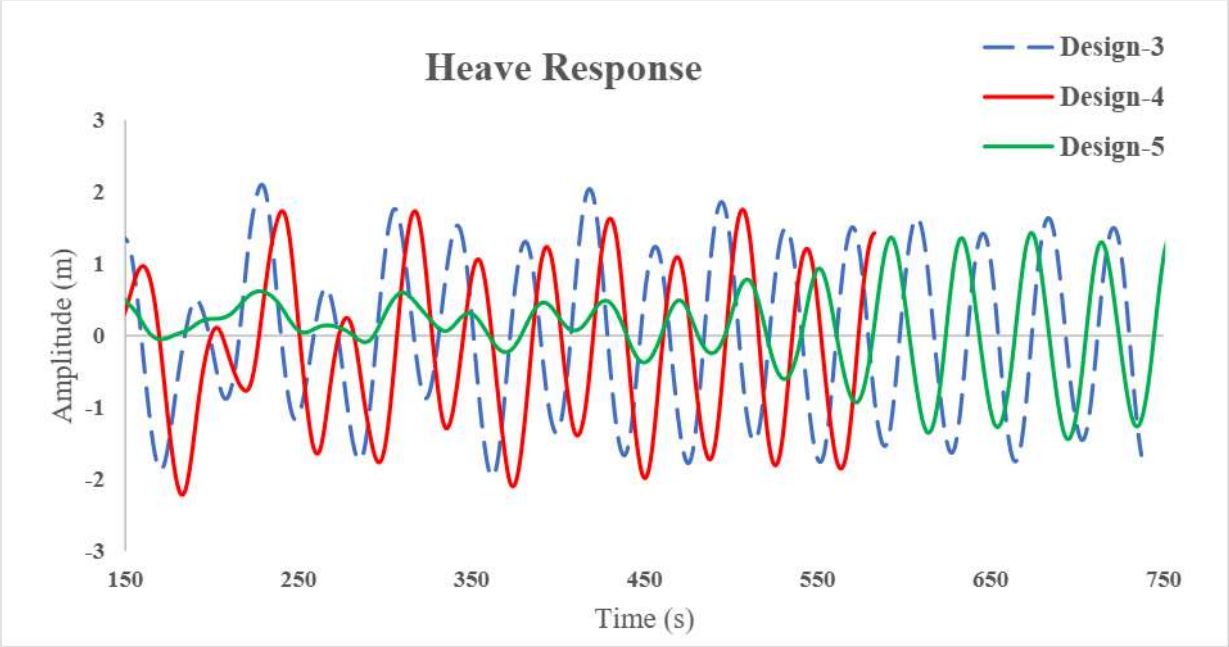

Figure 22: Heave response of the FPSO moonpool at 6 knots
(Design-3, Design-4, and Design-5)

3.3. Amplitude of OWC:

Both Piston and Sloshing modes were observed inside the moonpool with the difference in the amplitudes in the motions.

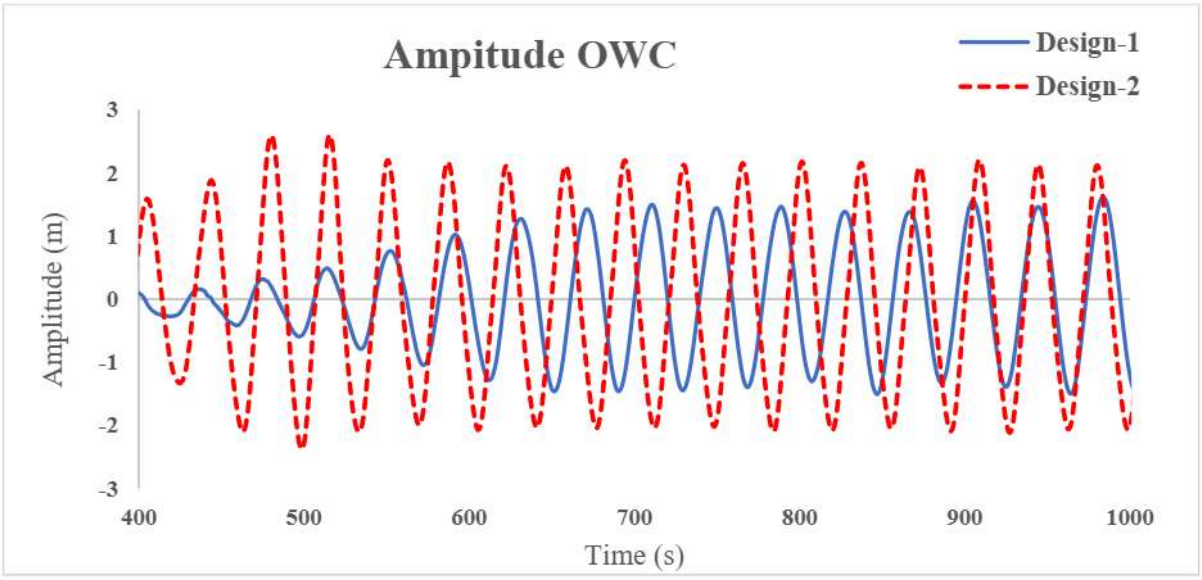

Figure 23: The amplitude of the standing waves inside the moonpool at 6 knots
(Design-1 and Design-2)

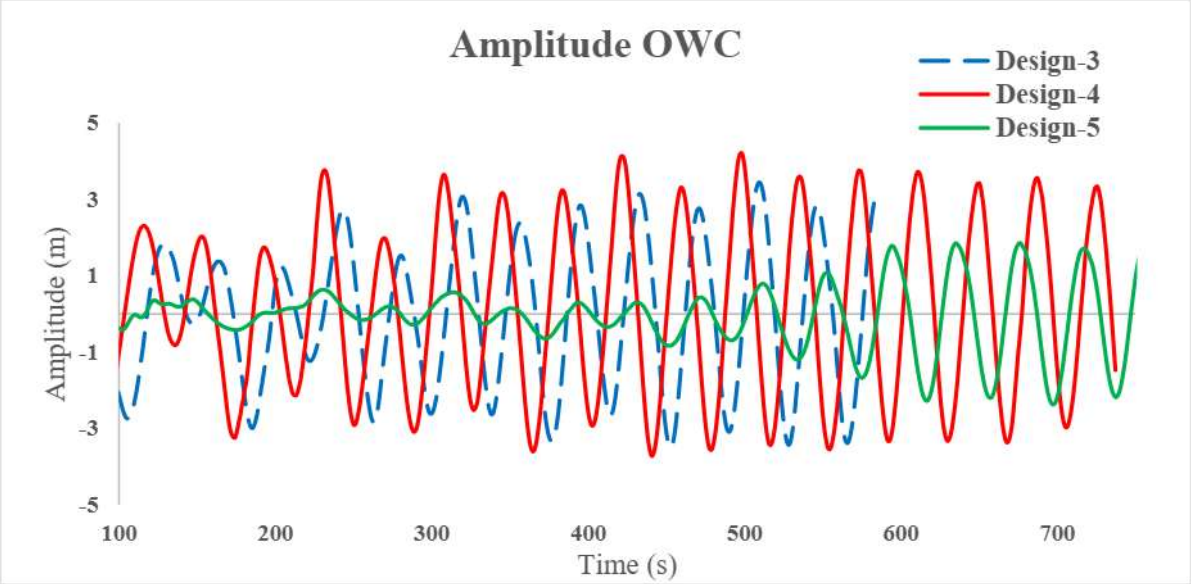

Figure 24: The amplitude of the OWC inside the moonpool at 6 knots (Design-3, Design-4 and Design-5)

Figure 23 and Figure 24 illustrate the amplitude of the oscillating water column when the FPSO is moving forward at 6 knots, recorded at the points shown in Figure 12. The water column shows a sinusoidal response which is in accord with the FPSO motion responses. The amplitude of the OWC shows lower amplitudes for the design-1 and design -5.

4. CONCLUSIONS:

CFD analysis shows that the vessel shows similar behaviour in pitch and heave motions for all designs at all speeds, but the results presented here are only for the speed of 6 knots. The motion response of the FPSO for various designs has different periods of oscillations, but there is no vast difference in the magnitudes of the motions. This is due to a very minute difference in the wetted surface areas of the designs. The pitch and heave response of the FPSO take longer to achieve the steady-state due to the vortices shedding pattern, when the ramp is provided to the leading edge and well as trailing edge of the moonpool. FPSO and OWC are sinusoidal in nature due to the standing waves inside the moonpool and its interactions with the FPSO hull. The disc at the centre and the ring at circumference provide the viscous damping to the motions inside the moonpool. The analysis has established that CFD is a useful tool to understand and capture the motion of the free surface inside the large moonpools.

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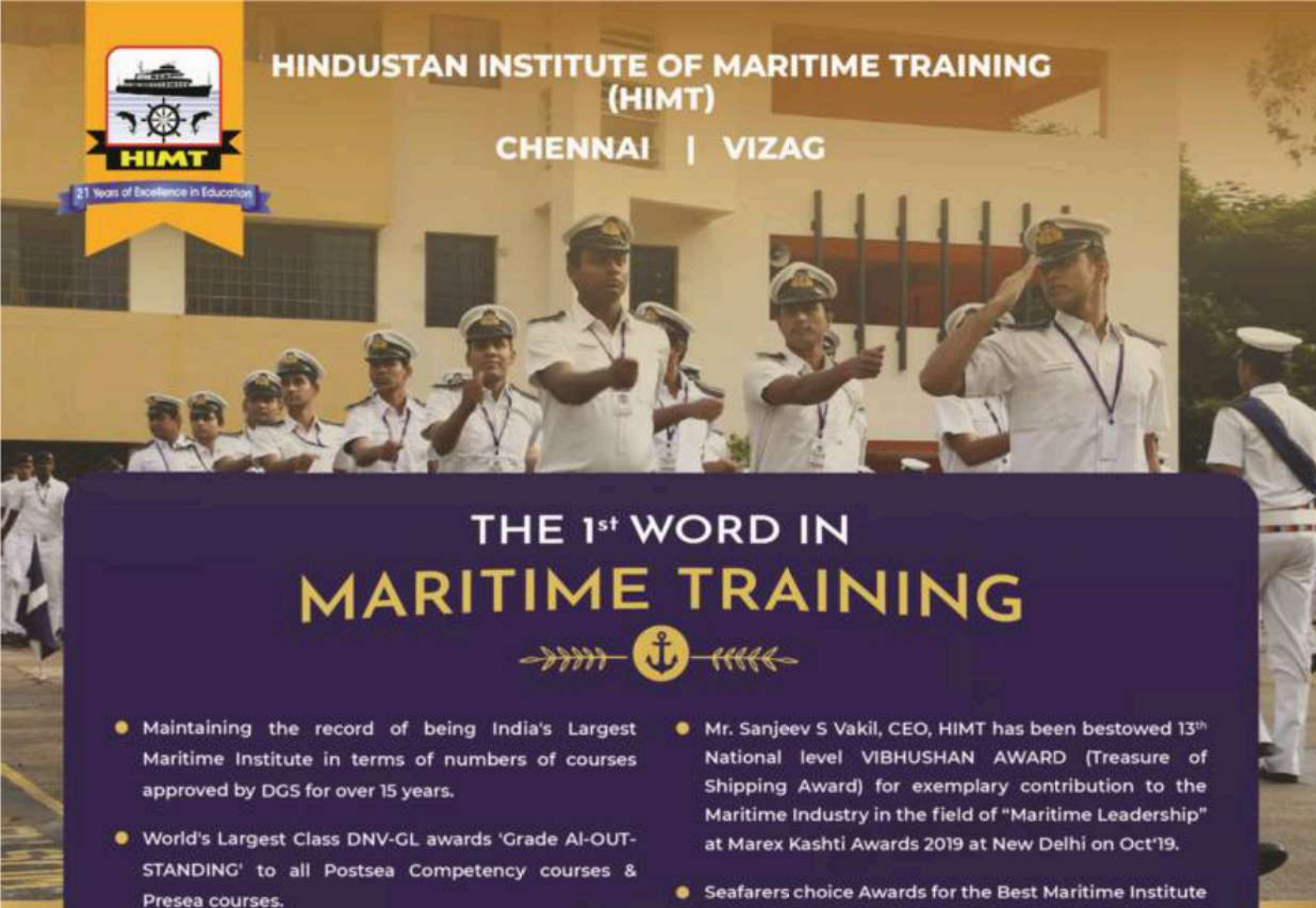

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