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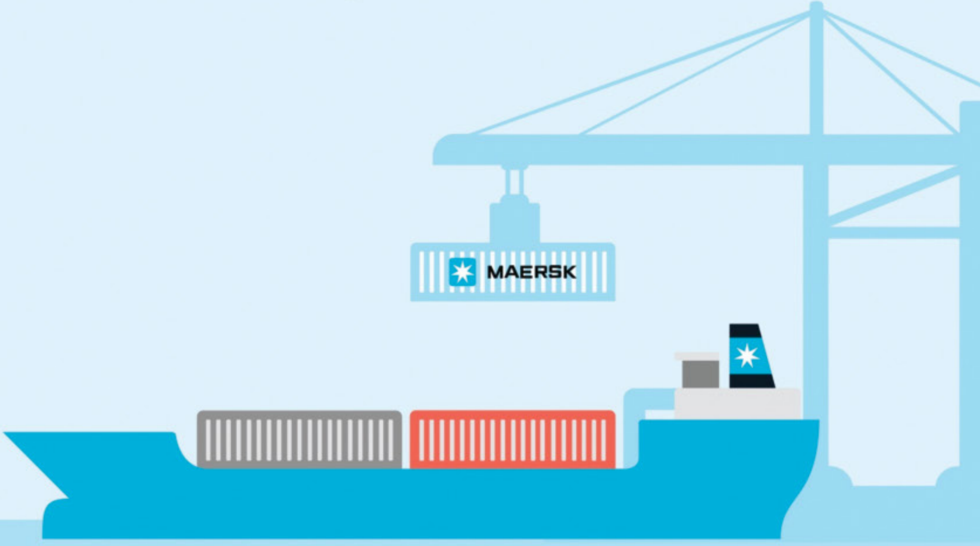

EDITORIAL

The Earth does not belong to us; we belong to the Earth.
- Chief Seattle

The 80th MEPC sitting had GHG reductions on top of the agenda. Much of the other agenda items prevailed on adoption of various guidelines and measures for mitigating air pollution, special areas, prevention responses, underwater noise, ballast water, special areas and energy efficiency of ships. A significant adoption was on the life cycle GHG intensity of marine fuels. Life Cycle Assessment (LCA) measures the GHG emission potential of the fuel (Carbon intensities can also be measured) from production stages (well) till the end use for the fuel (propeller or the electric generator in the case of a ship). The propeller end is referred to as the 'wake' and the assessment is from Well to Wake (the well to tank and tank to the wake), which can also be assessed separately and summed up for any renewable fuel. The potential can be compared to a base petroleum fuel and also juxtaposed with planned trajectories.

In context, a few allied initiatives could be of interest. The Cargo Owners for Zero Emission Vessels (coZEV), with support of Aspen Institute is one to look at. Target: By 2040, all cargoes shall be carried by zero-emission vessels. And coZEV is gaining momentum with many multinational companies jumping in. Another enterprise is the 'Poseidon Principles for Marine Insurance'. Insurers will help measure the climate alignment (refers to the global efforts of bringing GHG metrics in line with 1.5°C targets) of hull and machinery and compare it with the target trajectories for 50% and 100% CO_2 reductions. These measures will aim to decarbonise by 2050. The goals appear more ambitious than that of IMO but appear earnest. There are other initiatives also.

As such, shipping runs the risk of increasing its emission contributions from 3% to 10% by 2050, as demand for maritime transport is expected to grow 173% (from 2008 levels). Mankind's dream chase of 'silver bullet solutions' for emission-elimination is surely on. All these strategies reflect an underlying characteristic of a collective responsibility to correct the situation of our planet. Since the IR 1.0 it is a perverse sense of ownership which had driven to the over exploitation and the over scarring, as also driving the Anthropocene. If only a better sense had prevailed that the belonging pertains only to mother nature, the heat and haze would have been lesser and the climate, comfortable.

In this issue...

In our on-going series on maintenance of marine machinery, we focus on lubricating oils. Uday Purohit presents an easy read on simple focus areas on lubricating oils. The takeaway from the article are the ISO specifications on oil cleanliness and the Beta factor discussions. This will connect well with the practicing marine engineers.

Prabu Duplex continues his maintenance management discussions and in this instance, elucidates on the Value Engineering (VE) concept. An interesting part is the historical aside on how Larry Miles conceived the idea of Value Analysis while working in General Electric and the traction given by US navy for Value Analysis techniques. The 'verb + noun' construct for VE, the job plan evolving from the multidisciplinary-stakeholders workshop, FAST-diagram (Function Analysis System Technique) generation, convergence on 80/20 Rule are valuable takeaways. In all, this is a thought provoking read.

Following this is an interesting discussion on 'Seaworthiness'. Dr. B.K. Saxena elucidates the concept and goes on to differentiate the seaworthiness construed for cargo, shipboard equipment etc. Dr. BKS intersperses his explanations with court rulings and observations. The crux of the matter is the insurance and the ownership of responsibility. He posits the concept with the modern emerging technology of autonomous ships, calling for a better understanding of seaworthiness with reference to the context. Marine surveyors and managers will find this thought provoking.

We continue with the Alternate Fuels discussions (Part D) by Daga et al. Herein the Authors bring a few brief comparisons from the viewpoint of storage capacities, costs, emissions, production etc.

MER August 83 archives carries discussions on stern seals and interestingly on the launch of a training ship also.

Under Lube Matters, Sanjiv Wazir continues on tribology of engine components and this time moves with the piston rings. Much we had wished to bring out a thematic issue on Lubricating Oils, we could squeeze in only a couple. However, it is with a gratifying feeling we publish the 25th write-up of Lube Matters. Sanjiv's support and efforts in keeping a column going with no sag in the interest need a mention with due compliments.

While we await the floods to recede back into the seas from our northern hills and plains, here is the August issue of MER for your reading pleasure.

Dr Rajoo Balaji
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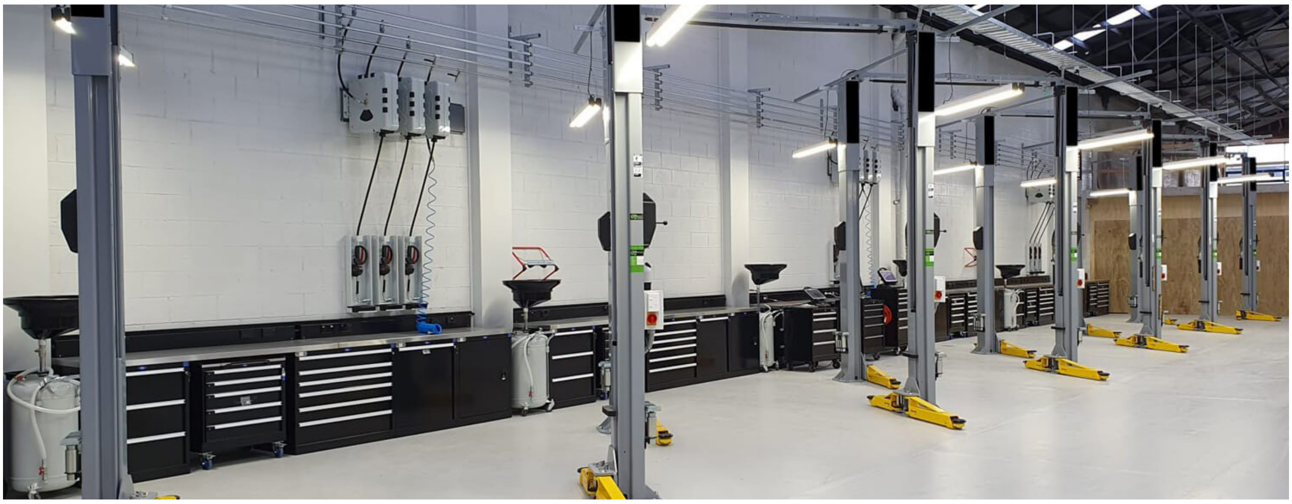
Lubricating Oil Management: Equipment Reliability, Cost Efficiency, and Longevity



Uday Purohit

Abstract

This article explores the crucial role of lubricating oil in the maintenance of machinery and equipment, highlighting its impact on reliability, operating costs, and equipment lifespan. With over half of machinery failures attributed to poor lubrication, effective oil management is essential. The relevance of this subject matter to the maritime field lies in the industry's heavy reliance on machinery for various operations.

The study delves into the functions of lubricating oil, including lubrication, heat removal, contaminant transportation, and sealing. Emphasis is placed on the importance of maintaining clean oil and the sources of contamination, such as wear and tear and ingression. The article discusses the significance of oil quality in relation to equipment lifespan and component performance.

Key points of discussion include the detrimental effects of oxidation and varnish deposits on equipment, as well as industry standards for oil cleanliness, such as ISO 4406. The importance of regular oil sampling and analysis is also highlighted.

The article concludes by stressing the need for proper oil management practices, including filtering new oil and using kidney loop filters. By effectively managing oil quality, the maritime industry can optimise equipment performance, reduce failures, and improve operational efficiency.

1.0 Lubricating Oil plays an important role in the maintenance of machinery and equipment. Oil quality is critical to the reliability, operating cost and lifespan of equipment. More than half of all machinery failures occur due to poor lubrication. This article seeks to emphasise the importance of oil and how it can be managed effectively.

2.0 Functions of Oil

Lubricating oil has the following main functions:

- **a.** Lubrication
- **b.** Removes heat
- **c.** Washes away the contaminants (to be trapped by the filters)
- **d.** In hydraulic systems, it also functions as a seal in control system components such as spool valves.

Lubricating oil must form a stable film between moving parts preventing metal to metal contact. Thus the oil needs to be viscous. Viscosity is related to its load bearing capacity. Any reduction in the viscosity during operation will result in a reduction in its load bearing ability. Additives in oil ensure their usability for different applications. Anti-foaming, detergent, and extreme pressure are some common additives.

Oil contamination is primarily from 4 sources: generated in the system due to wear and tear; ingresses due to either leaking components in the system or bad maintenance practices; from fresh oil added to the system as top up; contaminants that are left over (such as welding slag) after maintenance work

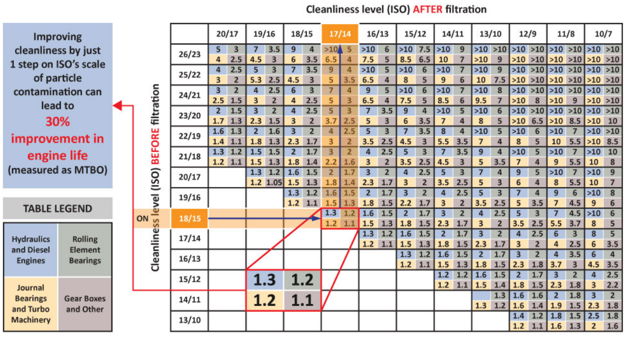


Figure. 1 Oil quality and life of components

(As an example cleaning oil from 18/15/12 to 17/14/11 can increase the life of rolling bearing elements by a factor of 1.2, of Hydraulics and Diesel engines by a factor of 1.3, of Journal bearings by a factor of 1.2 and of Gear boxes by a factor of 1.1.) (Source: Noria Corp.)

Reducing moisture in oil from 2500 ppm to 156 ppm can lead to **5X improvement in machine life** (measured as MTBF)

Moisture level (ppm) AFTER filtration

Moisture level (ppm) BEFORE filtration	2	3	4	5	6	7	8	9	10
50,000	12,500	6,500	4,500	3,125	2,500	2,000	1,500	1,000	782
25,000	6,250	3,250	2,250	1,563	1,250	1,000	750	500	391
10,000	2,500	1,300	900	625	500	400	300	200	156
5,000	1,250	650	450	313	250	200	150	100	78
2,500	625	325	225	156	125	100	75	50	39
1,000	250	130	90	63	50	40	30	20	16
500	125	65	45	31	25	20	15	10	8
260	63	33	23	16	13	10	8	5	4
100	25	13	9	6	5	4	3	2	2

1% water = 10,000 ppm • Estimated life extension for mechanical systems utilizing mineral-based fluids.

Example : By reducing average fluid moisture levels from 2500 ppm to 156 ppm, machine life (MTBF) is extended by a factor of 5.

Figure. 2 Effect of moisture on oil life.

(As an example, keeping water contamination to less than 156 ppm as compared to 2500 ppm will enhance oil life by a factor of 5 times.) (Source: Noria Corp.)

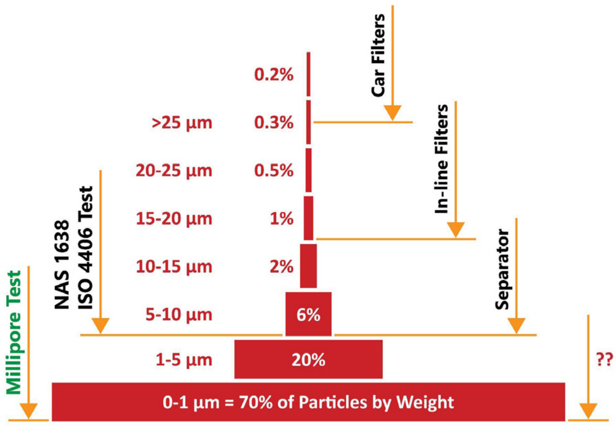


Figure. 3: Oil Pyramid

(Source: Noria Corp.)

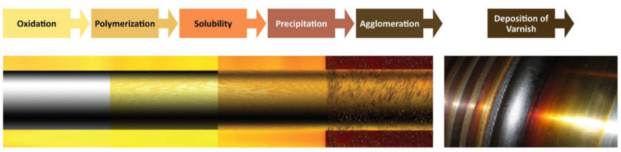


Figure. 4: Oxidation Stages (deposits on hydraulic components)

3.0 Importance of Keeping Oil Clean

According to the US Bureau of Standards, oil does not mechanically wear out and thus, theoretically, can be used indefinitely. Yet, more than half of all machinery failures are attributed to bad oil or poor lubrication conditions. It is perhaps the most ignored commodity in any industry.

Oil contamination is primarily from 4 sources: generated in the system due to wear and tear; ingresses due to either leaking components in the system or bad maintenance practices; from fresh oil added to the system as top up; contaminants that are left over (such as welding slag) after maintenance work.

4.0 The Oil Pyramid

The old school of thought proposed that as long as the size of particulate matter in lubricating oil was considerably smaller than the clearances in moving parts, these particles were harmless and would simply pass through the system without causing much harm.

The Oil pyramid shows, typically, the distribution of particles by size in lubricating oil. Over 90% of particulate matter is less than 5 microns and 70% particulate matter is less than 1 micron. Online and return line filters in engine and hydraulic circuits are typically 8 ~12 microns. Centrifugal separators may remove particles up to 5~8 microns. Online filters thus do not trap almost 90% of the particulate matter in oil systems.

These small particles, less than 5 microns in size, are the cause of concern to us. Small in size but with large surface areas; in the presence of heat, moisture and pressure, they act as catalysts that promote oxidation. Oxidation is the nemesis of oil.

5.0 Stages of Oxidation

The brown sludge that we observe in the bottom of hydraulic tanks is varnish and sludge, the products of oxidation. Diesel engine oils also oxidise, but in 4s engines the oil discolours quickly due to the soot from combustion products and therefore varnish is not visible. Most control components in hydraulic systems 'fail' because of the hard brown coloured varnish deposits on them which restrict free movement.

Figure. 4: Oxidation process (Oxidation drastically deteriorates the oil quality, reduces its load bearing capacity and accelerates wear and tear. This in turn generates larger quantities of fine particulate matter, and the chain reaction continues.)

6.0 Standards of Oil Cleanliness -ISO 4406, NAS

The primary function of filters is to remove particulate matter from the system. Having filters in the system by itself is no guarantee that the oil will be clean. What needs to be monitored must be measured. Therefore, regular oil sampling (the better solution is online monitoring which will be discussed later in this article) and analysis is an important tool to monitor oil health. While most companies send out oil samples from their machinery at periodic intervals for routine analysis at laboratories, the 'particle count' is seldom requested.

Typically, the Industry uses two 'codes of cleanliness'. NAS used to be the industry standard, but is now outdated. The current standard in the Industry is ISO

4406. The standard specifies the particle sizes of 4, 6 and 14 microns in a 1 ml sample of oil. For example, ISO 4406 19/17/14 implies the oil has up to 500,000 particles of 4 microns or more, 130,000 particles of 6 microns or more and 16,000 particles of 14 microns or more. The ISO 4406 table is reproduced as **Figure 6**.

The minimum recommended cleanliness levels for hydraulic oil is 19/17/14. Certain applications will require oil to be maintained to higher standards of cleanliness.

7.0 New Oil is Not Clean

It must be stressed that new oil from barrels is seldom clean enough to be used directly in your hydraulic systems. Bulk oil from refineries is 'packaged' at commercial facilities in barrels of different sizes. These barrels are not free of debris and contaminants. Often, the system oil

Figure. 5: Varnish deposits on spools (Primary reason for control equipment failures.)

ISO Cleanliness Code 4406		
ISO Code Number	Number of particles per ml of fluid	
	More than	Up to and including
24	80,000	160,000
23	40,000	80,000
22	20,000	40,000
21	10,000	20,000
20	5,000	10,000
19	2,500	5,000
18	1,300	2,500
17	640	1,300
16	320	640
15	160	320
14	80	160
13	40	80
12	20	40
11	10	20
10	5	10
9	2.5	5
8	1.3	2.5
7	0.64	1.3
6	0.32	0.64

Figure. 6: ISO 4406 table

is cleaner than the 'so-called' new oil. The use of a portable transfer pump to refill the system tank is another source of contamination. It is therefore strongly advised that oil from any storage facility - barrels or storage tanks, must be filtered before adding it to system oil.

Often high pressure hydraulic systems do not have full flow filters on the pressure side but are equipped with return line filters

8.0 Online Filters, Return Line Filters

Online filters in lubrication systems (engines, turbines etc.) and hydraulic systems are full flow filters, generally located after the pump. There are practical limitations to the media pore size of these filters. The primary condition is that oil flow to the system cannot be restricted. Very fine pores are prone to getting clogged more often thus potentially restricting flow to critical components downstream. Also, in high pressure hydraulic systems, a clogged filter will cause a great pressure differential and therefore the filter media will be prone to rupture. Full flow filters are therefore designed accordingly, their primary function being to ensure adequate oil flow to the system and to prevent 'larger than clearance' particles from damaging the components.

Another factor to note is that almost all full flow filters have a bypass valve. If the pressure differential across the filter increases, the bypass valve opens allowing full flow of 'unfiltered oil' to the components. This is not desirable but necessary in case the filter gets clogged. Filter media pore sizes must necessarily be large enough to prevent frequent clogging.

Often high pressure hydraulic systems do not have full flow filters on the pressure side but are equipped with return line filters. Return lines are always larger in diameter than pressure lines and have a gradient towards the return oil tank. This is to ensure that oil flow to the tank is unhindered. For this reason, the media pore size on the return line filters typically are 8 to 10 microns.

Cleanliness Code Comparison	
ISO CODE	NAS CLASS
23/21/18	12
22/20/18	-
22/20/17	11
22/20/16	-
21/19/16	10
20/18/15	9
19/17/14	8
18/16/13	7
17/15/12	6
16/14/12	-
16/14/11	5
15/13/10	4
14/12/09	3
13/11/08	2
12/10/08	-
12/10/07	1
12/10/06	-

Figure. 7: NAS is an outdated standard. Table shows comparison with the ISO 4406 standard

9.0 Beta Ratio of Filters

While all filters, including non-genuine ones may look alike, the Beta ratio of the filter is one important factor that defines its cleaning efficiency. The filter size, say 5 microns, is a general reference to its filtering efficiency. It does not imply that every particle greater than 5 microns will be trapped in the filter. Obviously contaminant particles come in varying sizes and have different profiles. It is unrealistic to expect that any media can trap every particle beyond a certain size. The Beta Ratio becomes useful in judging the filter efficiency.

For example, ß3=100 means that for this filter, whose nominal rating is 3 microns, for every 100 particles of 3 micron or more 1 particle will go through the filter downstream. Beta ratio can be used to calculate the efficiency of the filter.

Filtration efficiency = (Beta Ratio-1) /Beta ratio, expressed as a percentage. A Beta ratio of 100 yields a filtration efficiency of 99%. It also means the same filter of 3 microns (nominal size) will have several ß ratios at say 5, 7, 10, 100 microns.

When using replacement filters, always discuss the Beta Ratio with your supplier along with other filter parameters such as filter media, nominal filter rating, bursting pressure, internal bypass valve setting etc.

10.0 Bypass Kidney Loop Filtration Systems

The most efficient method to keep oil clean is to install kidney loop bypass filtration systems. These typically have very low flow rates and have depth filters (discussed later). Typical flow rates could be as low as 1 litre/ minute and the system is generally designed with its own pump and motor so that it is independent of the main system and can operate 24x7, even when the main equipment is stopped. The flow rates are designed to give between 1.5 and 2 passes of sump oil every 24 hours.

As an example, consider an oil sump of 6000 litres capacity. Desired flow rate for the kidney loop filter is between 9000 and 12000 litres per 24 hours. Considering that each filter housing can pass only 1 litre/ minute or 1440 litres/24 hours, the system will incorporate between 6 and 9 filter housings depending upon the running hours of the main equipment.

Media pore size in bypass filtration systems will vary depending upon the application. In our experience for trunk type diesel engines a 3-micron filter is fit for purpose. Smaller media size will choke the filter more often. Keep in mind that in the trunk type 4 stroke engine, oil contamination by soot is very high. The soot discolours the oil; however, colour of oil is no indication of its cleanliness.

For hydraulic systems we would recommend bypass, kidney loop filters of 0.1 micron.

When using replacement filters, always discuss the Beta Ratio with your supplier along with other filter parameters such as filter media, nominal filter rating, bursting pressure, internal bypass valve setting etc

11.0 Depth Filtration

Online full flow filters are generally radial flow type, the oil passes through the filter media either inside out or outside in radial direction. Consequently, retention time in the filter media is small. We recommend kidney loop filters with depth filtration. The filter cartridge consists of long strands or capillaries of chemically impregnated cellulose fibre material. Oil is forced through these capillaries under pressure and must traverse the entire length of the capillary. The cleaning process is therefore more thorough due to the longer retention time of the oil in the filter media.

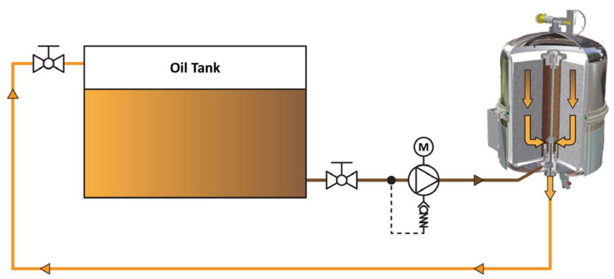


Figure. 8: Kidney Loop filtration system with independent motor and pump

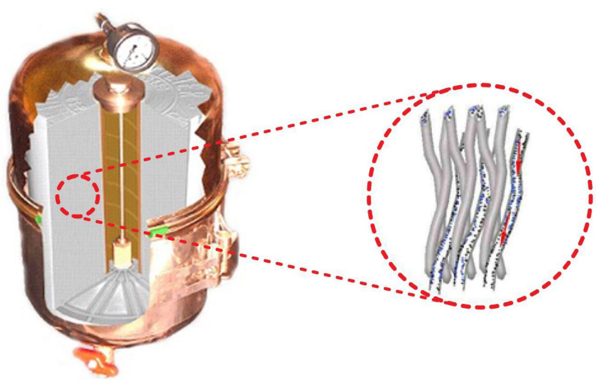


Figure. 9: Capillary like fibres in depth filters

12.0 Measure What You Need to Monitor

Oil sampling and lab analysis is a well settled practice in almost every industry. While it is a good indicator of the oil health of the equipment, there are more modern methods available to do this job. The traditional method of collecting oil samples and sending them to labs for analysis is an unreliable method to measure oil health. Consider the following:

- The sampling point and collection container could be dirty
- The sampling point may be different every time a sample is withdrawn resulting in varying results
- Transit time to the lab could be long, causing oil to deteriorate and oxide in transit
- Accuracy of testing in the lab is always a question mark

Additionally, considering transit time of the sample to the lab, the test results often come in too late for the equipment operator to make any sense or use of the results. The oil could have been drained and replaced or the machinery could have failed. In both cases the results are useless and defeat the purpose of oil analysis reports as a tool for better maintenance.

13.0 Online Oil Quality Monitoring sensors

Several online sensors are available in the market today which relay real time online data on Oil Quality. Some sensors measure only water or viscosity which might be adequate for some applications. I prefer the 'go- no go' type of sensor. These sensors work on the principle of

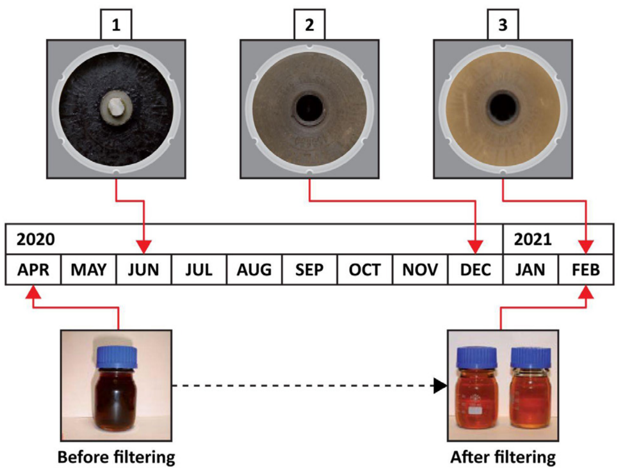


Figure. 10: Filtration: Effects on Deposits
(Figure shows the improvement in colour of oil over a period of 10 months in a hydraulic system of 6000 litres using 0.1-micron kidney loop filters)

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measuring the dielectric constant of the oil. Any change in any of the parameters of the oil - viscosity, particle contamination, dilution, additive depletion, flash point etc. will change the constant value and alert the user. Long term trends can be established giving the operator an insight into the health of the equipment itself. We have seen that as the mean time to overhaul decreases, the oil deteriorates faster.

The approach is that if the oil, as indicated by the single sensor, is fit for use for the hours of operation as specified by the manufacturer, no action is required. It is only if oil deteriorates earlier than expected that samples should be drawn and sent to a lab for detailed analysis.

14.0 Field Data

We have been installing bypass filtration systems for over six years now, on a variety of equipment, and field results are very encouraging.

a. Using bypass kidney loop filtration systems (even of 0.1 microns' size) did not affect the additives in the oil.

b. On high speed engines we have been able to increase oil life by a factor of 3 to 4 times. In most cases the oil was replaced even though it was fit for further use.

c. In all cases, where the filtration system was installed on engines, the crankcase colour (cleanliness) significantly improved after six months, the hard soot deposits were washed away. The engine components were visibly clean.

d. We observed much lesser carbon deposits in the cylinder and on the piston crown when the engine was opened for overhaul.

e. In hydraulic oils, the 0.1-micron filter significantly improved the condition of oil in the system over a period of weeks.

f. In a Gas Turbine based power plant, the 0.1-micron filter was able to reduce varnish in the oil significantly.

g. The 0.1-micron filter was able to reduce the Varnish content in steam turbine oil significantly. Varnish is a form of lubricant degradation causing the formation of undesirable deposits. In turbine systems, few failure conditions can disrupt operations as quickly and completely as a varnished control valve. The MPC value is the only procedure worldwide that can be used to quantify an oil's potential to form varnish. The higher the MPC index is, the more undissolved particles are present in the oil. The 0.1-micron filter was able to significantly reduce the MPC value.

h. Chief Engineers report that the Oil Quality Monitoring sensor is a powerful tool to maintain the condition of the oil. In one case diesel contamination was quickly detected and further complications avoided. Several sites where these sensors are fitted have stopped sending samples to the lab for analysis.

15.0 Sustainability

Using bypass kidney filtration systems in conjunction with Online Oil Quality monitoring systems gives the following advantages:

- Significant benefit in improving MTBO of the equipment. Cleaner oil means longer life of equipment
- Reduced operational costs.
- Oil life can be significantly enhanced

Besides lower operating costs, the more compelling reason to use similar systems to increase oil and filter life is to move towards cleaner and greener maintenance practices. Both the disposal of used oil and discarded filter cartridges is a nightmare to handle and continuously increases the carbon footprint and thus the burden on our planet earth. It is simply common sense and 'earth sense' to use the oil for longer intervals.

16.0 Recommendations

Some recommendations:

1. Pay attention to the charts - **Figure. 1** and **Figure. 2**
2. Oxidation is the nemesis of lube oil refer **Figure. 3.** Bypass kidney loop filtration systems can play an important role in managing oil quality. Depth filters give far better results than conventional ones
3. Understand the ISO 4406 standard of oil cleanliness
4. Get regular particle count done on hydraulic system oil
5. New Oil is not Clean oil. Refill oil only through a 5-micron filter.
6. Remember the Beta Ratio and its importance in oil filtration
7. Measure what you must monitor - Online Oil Quality Monitor sensors are the solution.
8. If you continue to send samples to the lab for analysis, take care to collect the sample properly. Get it quickly to the lab. The more time the sample spends in your premises the greater the error in the result.
9. It is time to look at prolonging oil life not just as a maintenance issue but as a responsibility to the environment.

About the author

Uday Purohit is a Marine Engineer by profession and a first generation entrepreneur. He is alumni of DMET, Kolkata. He is inspired by people, new technologies, challenges, new business ideas and his main area of interest is in the design of engineering systems. He is the Founder and Managing Director of Neptunus Power Plant Services Pvt Ltd. Uday is also the Immediate Past President of the Institute of Marine Engineers (India) and was the Hon. Editor of the MER. He is an avid reader, keen golfer and is widely travelled.

Email: Uday.purohit@neptunus-power.com

Value Engineering for Maintenance Management

Prabu Duplex

Abstract

Value Engineering is a specialty engineering activity within Systems Engineering according to the INCOSE Systems Engineering Handbook [INCOSE, 2015], but what makes Value Engineering a 'specialty,' and what can it offer Systems Engineers or to multi-disciplinary projects? In this article three Value Engineering concepts are described, which are the pillars of Value Engineering: **1) the definition of value, 2) the use of multi-disciplinary workshops, and 3) the application of function diagramming with the FAST method.** Each of these concepts is explained and ideas are put forward how to incorporate them in more commonly used Systems Engineering processes or multidisciplinary projects. A case study has been included incorporating the three pillars, to show the application of value engineering to improve maintenance management in the maritime sector. With this article, we aim to inspire ship management firms to include the value concepts in their daily work, their thinking, and their creations.

1. Introduction

Value engineering is a design method to deliver engineered solutions that fulfil the needs of the client and involved stakeholders at the right costs. It helps to clarify the subjective perception of value, as perceived by clients and designers, and uses processes and tools that can add value in a Systems Engineering environment. Value Engineering uses a structured process, team-based engineering activities, analytical reviews of functions, and creative techniques to improve value. For example, by improving solutions that are underperforming their intended functions, or that perform well enough, but simply cost too much. The three Value Engineering concepts that we explore in this article are: **1) the definition of value, 2) the use of the Value Engineering workshop, and 3) the function analysis with the FAST method.**

> *"Value engineering is a design method to deliver engineered solutions that fulfil the needs of the client and involved stakeholders at the right costs"*

1.1 Overview

The value methodology is a systematic process used by a multidisciplinary team to improve the value of a project through the analysis of its functions. Value is defined as a fair return or equivalent in goods, services, or money for something exchanged. Value is commonly represented by the relationship: Value = Function/Resources, where function is measured by the performance requirements of the customer and resources are measured in materials, labour, price, time, etc. required to accomplish that function. In **Figure 1** value is defined for a mobile phone that we use every day. A value methodology focuses on

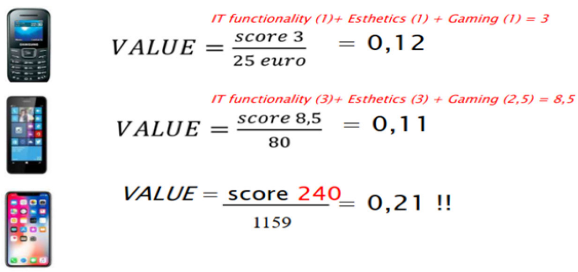

Figure 1: Value calculation of a mobile phone [16]

> *Function analysis can be enhanced through the use of a graphical mapping tool known as the Function Analysis System Technique (FAST), which allows team members to understand how the functions of a project relate to each other*

improving value by identifying alternate ways to reliably accomplish a function that meets the performance expectations of the customer.

Function Analysis is the foundation of a value methodology and is the key activity that differentiates this body of knowledge from other problem-solving or improvement practices. During the Function Analysis Phase of the Job Plan, functions are identified that describe the work being performed within the scope of the project under study. These functions are described using two word, active verb/measurable noun pairings, for example one function of a hammer is to apply force. The team reviews the project's functions to determine those that could be improved. These may be project functions that seem to be performed inefficiently or with more than expected cost. These functions become the focus of the value methodology team in their endeavour to improve the project.

The identification and naming of project functions enables clear thinking by limiting the description of a function to an active verb that operates on a measurable noun to communicate what work an item or activity performs. This naming process helps multidisciplinary teams build a shared understanding of the functional requirements of the project and, as a result, it allows them to identify where opportunities for value improvement exist in the project.

Function analysis can be enhanced through the use of a graphical mapping tool known as the Function Analysis System Technique (FAST), which allows team members to understand how the functions of a project relate to each other.

A fundamental tenet of a value methodology is that basic functions (the necessary purpose of the project) must be preserved. This is because the basic function reveals the usefulness of the project and the reason for its existence. For example, the basic function of a wristwatch could be "indicate time." Other secondary functions support the basic function. These secondary functions typically provide esteem, dependability, or convenience value for the user. An example is a gold watchcase that performs an aesthetic function which pleases both customers and those whom they want to impress.

The value methodology is applied using a process known as the "Job Plan." **The purpose of the Job Plan is to guide the Study team through the process of identifying and focusing on key project functions in order to create new ideas that will result in value improvements**. While a Value Study is guided by the function-based Job Plan, it can be further supported by many commonly used business improvement techniques.

1.2 History of the Value Methodologies

Value Analysis was conceived in the early 1940s by Lawrence D. Miles [10] while he was employed by General Electric, a major defence contractor which was facing the scarcity of strategic materials needed to produce their products during World War II. Mr. Miles realised that if value and related innovation improvements could be systematically "managed," then General Electric would have a competitive advantage in the marketplace. With that in mind, Mr. Miles accepted the challenge and devised the function analysis concept, which he integrated into an innovative process he later termed 'value analysis'.

Mr. Miles understood that products are purchased for what they can do—either through the work they perform or the pleasing aesthetic qualities they provide.

Using this as his foundational information, he focused on understanding the function of the component being manufactured. He questioned whether the design could be improved or if a different material or concept could achieve the function.

To focus on the function itself, he used an active verb and a measurable noun in combination to characterise the benefit that a part's function provides. He then searched for other ways or methods to achieve the benefit of that intended function. From this research, function analysis, the key foundation of value methodologies, was developed and has become a tool to help individuals and teams manage the way a concept is understood.

These specialised teams typically address project-related issues such as increased sales revenue, improved product performance, and reduced resource usage.

The U.S. Army and Navy, and other companies, soon realised the success of Larry Miles' methods. As the application of value analysis expanded, there was also a change in context—from review of existing parts to improving conceptual designs. This was one of two factors that marked the emergence of value engineering. The other was a desire by the U.S. Navy to use the Value Analysis techniques for project improvement in the early 1950s when there was a moratorium on hiring "analysts." Since engineering positions were available, individuals practicing this new discipline were employed as "Value Engineers."

As the value methodology gained in popularity, a group of practitioners formed a learning society to share insights and advance their innovative capabilities. **Thus, in 1959, the "Society of American Value Engineers" was incorporated in Washington, DC.**

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Soon, the value methodology was used to improve the value of projects in government, the private sector, and the manufacturing the construction industries and value concepts spread worldwide.

Concurrent with this growth, a number of other value improving tools, techniques, and processes emerged, many of which were complementary to and were integrated with the value concepts. In an effort to attract the developers and practitioners of these emerging methods to membership, the name of the society was changed to "SAVE International" in 1996.

1.3 Applicability (When to Use Value Engineering)

A final question we want to address is: 'When is the best time to use Value Engineering?' Within the Systems Engineering process, a Value Engineering process is often used for three reasons: Value Planning, Design Validation and Trouble Shooting. When Value Engineering is applied for Value Planning, it means that at the start of the system development process, a Value Engineering workshop offers a playground where functional analysis, requirements analysis, requirements validation and the value definition of the system are coupled together and offer a quick acceleration and focus in the system development process.

When Value Engineering is applied for Design Validation, it is not only used to validate the system, but also to put the system to a test in terms of customer value and ever-changing customer preferences, needs and concerns. Finally, Value Engineering can also be used for troubleshooting. Often to solve problems such as a lack of acceptance of the system architecture and design, difficulty to control the overall costs of the system, conflicting system requirements, difficulty to align with existing design standards and possibly uncertainty due to changing customer preferences.

Value methodologies can be applied during any stage of a project's development cycle (**Figure 2**), although the greatest benefit and resource savings are typically achieved early in development during the conceptual stages. At this point, the basic information of the project is established, but major design and development resources have not yet been committed. The reason this is the best time to apply a value methodology is because the manner in which the basic function of the project is performed has not been established, and alternative ways may be identified and considered.

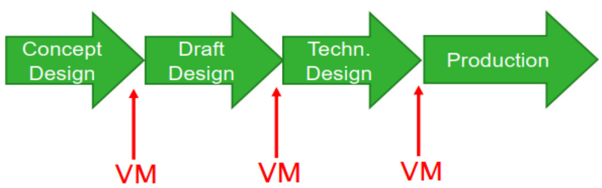

Figure 2: Value engineering in project development life cycle [16]

Examples of these applications are: Construction projects could benefit by identifying improvements for various project phases: concept development, preliminary design, final design, procurement and construction.

Manufactured products, whether consumer, industrial, or defence, may be studied with a focus on either the design or manufacturing process of that product. A product may be the subject of a value study at any time during the product's life. A value study can be applied at the onset of the product development to better understand the customer's needs, identify the functions necessary to satisfy those needs, and develop the initial concept. Throughout the design development, value methodology can be used to refine and enhance the concept, based on the latest facts. Even after a product has been introduced and is in production, a Value Study can be used to further enhance the product and respond to changing customer and economic conditions. A value methodology can be used to either develop new ways to manufacture a product or change an existing process.

Business systems and processes may also be the subject of Value Studies. Many elements of a business or an organisation may be improved through the application of a value methodology. This may be from the development of business plans and organisational studies to improving existing business processes.

Service organisations can benefit from the use of value methodologies. In the past value methodologies have been used to improve processes and procedures in the medical industry (operating rooms, emergency rooms, etc.) and the legal system (police systems).

Value methodologies may be applied more than once during the life of the project. Early application of a value methodology helps to get the project started in the right direction, and repeated applications help to refine the project's direction based on new or changing information. The later a Value Study is conducted in project development, more likely implementation costs will increase.

A value methodology may be applied as a quick response study to address a problem or as an integral part of an overall organisational effort to stimulate innovation and improve performance characteristics. Value methodologies may be used to enhance an organisation's quality programs, new product development activities, manufacturing processes, and architectural and engineering design.

2. The Definition of Value

Value is defined as a simple equation, although notations vary a little:

Value = Function/Cost (SAVE International, 2015), or as Value = Needs/Resources, or as Value = (Function + Performance)/Costs (European Standard EN 12973:2000).

In his work Techniques of Value Analysis and Engineering, founding father of Value Engineering, Lawrence Miles (Miles, 1962), included the concept of function as a component of value and underlined that value is established by the customer's (or the user's) needs and requirements. In a VE-context, functions are formulated by a 'verb' + 'noun' (emit light), and state what the system should do. Performance defines how well the function should perform (300 lumens, during 24 hours, with 0.5 W energy consumption). This principle has resulted in the definition of value as it is used today, stating that customer value is about balancing functional performance with the resources necessary to achieve this performance. The value equations show that the value of a system can be improved by modifying the required resources throughout the system life-cycle and by adding functional performance that fulfils or exceeds the expected performance of the customer.

3. The Value Engineering Workshop

The second concept of Value Engineering we explore in this article is the Value Engineering Workshop. As mentioned in the previous sections, value is subjective and related to customer and other stakeholders' perceptions and views. It needs to be deliberately and explicitly explored and defined carefully. This is done in a multidisciplinary stakeholder (MDS) workshop, including a Value Engineering team that consists of designers, cost engineers and major stakeholders (system users, interface users, other departments, and maintenance engineers).

In the MDS Workshop, Multidisciplinary teams help explore domains that are unknown for some or most of the team members, and help explore impacts on domains that are hard to access. The workshop follows a structured and systematic seven-step design process (**Figure 3**), which is called the 'job plan' and is based on American ASTM (2018) and the European EN standard (European Standard EN 12973:2000). By conducting the workshop, the concept of value is explored and defined in such a way that it generates the support of the entire team.

The steps of the job plan are:

1. inform each other to gain the same level of knowledge of the system design, and develop a value profile;
2. analysis of the system functions in a so called FAST-diagram (Function Analysis System Technique),

> *In a VE-context, functions are formulated by a 'verb' + 'noun' (emit light), and state what the system should do*

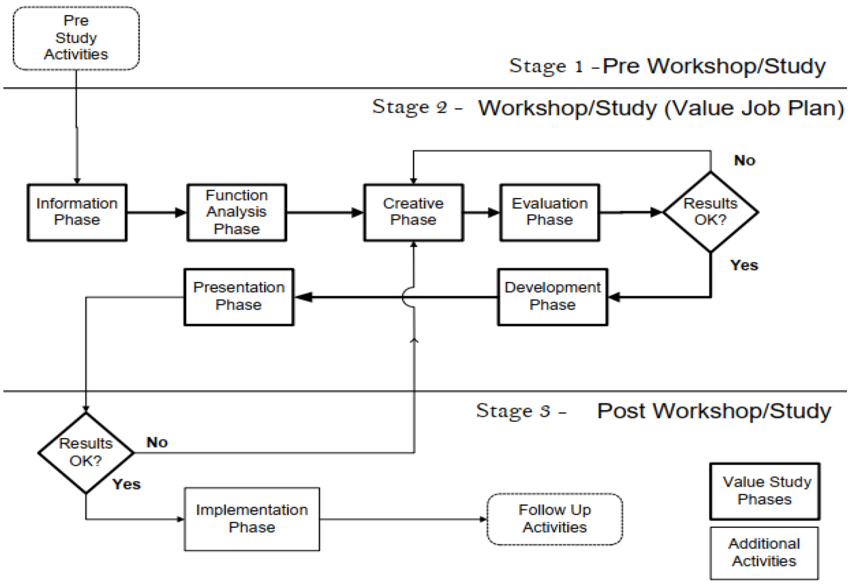

Figure 3: Job Plan [10]

specification of the performance of functions (FPS), and other relevant analyses;

3. a creative phase in which the Value Engineering team generates alternative ideas that improve systems value, using earlier analyses, and by applying several creative techniques;
4. evaluation and selection of the generated ideas;
5. further development of the ideas (multiple iterations are possible), making trade-offs including cost and performances;
6. draw conclusions on potential improvements of the system, define the next actions for implementation, and formulate advice for higher-level management and decision-makers, including issues where the Value Engineering team 'agrees to disagree';
7. presentation to the management/decision makers. Such a value study generally encompasses three stages:
    - Pre-Workshop (Preparation)
    - Workshop (Execution of the six phase Job Plan)
    - Post-Workshop (Documentation and Implementation)

Decision making happens after the Value Engineering study and most often not by the participants. This gives the participants peace of mind to go beyond standards, current practices, and usual habits and methods. This, in turn, enables innovations, cooperation between team members, lowering tension among people, giving room for better listening (and analysing), and preventing 'jumping to conclusions.' It also enables better decision-making because the advice given by the team is transparent, traceable, and often complete (unless the wrong people were in the Value Engineering team). The advice should show where, how and when functions and performances can improve for a good price: adding value to an existing design.

In Value Engineering workshops, people are in the same room at the same time, sharing the same information, and analyses, and inspire each other with creative solutions and shared judgments. That contrasts with the often-used design methods in which regular meetings, email sequences and filled SharePoint must facilitate the communication on the system designs, but which often distracts from value creation. Value Engineering workshops, or similar types of workshops that explore value in a multidisciplinary and condensed way, should be embedded in regular design processes to take advantage of the long term methods (often systems engineering processes) and the intermittent validation and optimisation from the value perspective. The Value Engineering based creativity techniques improve the generation of alternatives, giving more inspiration than just specifications.

In the MDS Workshop, Multidisciplinary teams help explore domains that are unknown for some or most of the team members, and help explore impacts on domains that are hard to access

The duration for executing the Job Plan in a value study depends on several factors: the size and complexity of the project, the stage of project development, the estimated cost of the project, etc. A typical duration for the Workshop Stage is five-days, which does not include the Pre-Workshop and Post-Workshop efforts. Projects with a concise scope or a low level of complexity may be performed in less time. Sufficient time should be allotted to adequately apply the value methodology process and document the team's findings. Shortening the time needed to execute the Job Plan phases may result in a less-than optimal result. Projects of very large scope or complexity may require 10-15 days or more to achieve the study's objectives. Consideration of these factors is important to ensure that the proper time is allocated and needs to be addressed as part of the upfront planning for a value study.

4. The Fast Diagram

The final concept of Value Engineering that we discuss in this article is the use of the FAST diagram. The FAST diagram is scheme with functions that are connected to one another through a specific HOW-WHY logic. The FAST diagram example shown in **Figures 4 and 5** visualises HOW-WHY relations between functions. Questioning the reasoning was practiced already by the philosopher Socrates (400 BC) and the FAST diagram is doing the same. It creates the opportunity to ask for all reasons of existence of system functions. It validates the existence of the functions both to client and the designer.

What questions would you ask to the designers of the traffic and cemetery (see the function diagram **Figures 4 and 5**)?

In Value Engineering workshops, people are in the same room at the same time, sharing the same information, and analyses, and inspire each other with creative solutions and shared judgments

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Does it inspire for other solutions because you know more potential solutions for a function?

What questions would you have for the client?

Not only are there more solutions possible for a function, but there are also more functions possible that can fulfil a higher order function. This function model stimulates new reasoning and alternative function models and, hence, can lead to improved systems. By such analysis one can find alternate ideas to replace building guest staying blocks in a cemetery to containers as shown in **Figure 6** (Based on 80-20% rule the functions that are too expensive is found to be protecting personnel). The value analysis is shown in **Figure 7**.

In addition, the FAST diagram allows for allocating costs to functions (**Figure 5**), as the objects that fulfil functions cost money. This makes it possible to show the price of a specific functional chain of reasoning. So, the question 'does the function make sense from an economic point of view' becomes part of the investigation into the system. That often leads to alternative designs.

Finally, the FAST is an additional method to model the functionality of the system and can be used complementary to other types of function analysis, each of which is has specific advantages in certain contexts, such as:

- Defining the different states of a system by using the state/mode analysis
- Defining the functional interaction between the system and its environment by using sequence diagrams
- Defining the sequence of the functions by using functional flow diagrams
- Analysing the different failure modes and depending on the effect add mitigation functions with the failure mode, (criticality) & effect analysis (FMECA)
- Reasons for existence of a function, visualised with FAST diagrams.

5. Application of Value Engineering for Maintenance Management

In this section value engineering concepts explained in the previous sections are applied practically to introduce new maintenance concepts in the maritime sector. A few years ago, a shipping company aimed at decreasing the unexpected downtime of their vessels. The reason for this was that the low technical availability led to reduced safety (technical problems at sea) and reduced operational flexibility. As these two factors are the important, the company decided to change their maintenance policy. They introduced a preventive maintenance method, making using of the maker's manual. This maintenance policy turned out to be very conservative. It increased technical availability, but because of increased maintenance efforts, operational availability decreased. The company needs to reduce preventive maintenance tasks without safety risks (unexpected downtime) [8]. The goal is to increase operational availability at a lower cost.

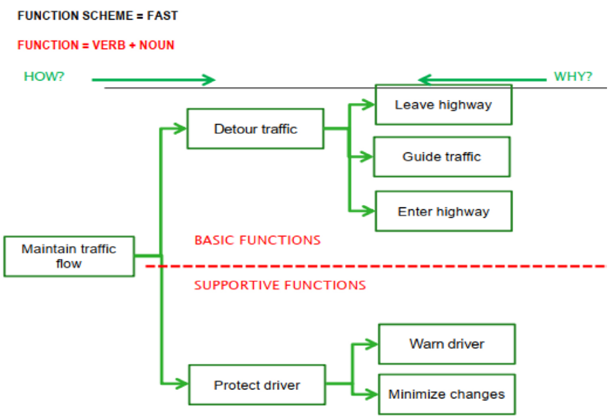

Figure 4: FAST diagram to maintain traffic flow [16]

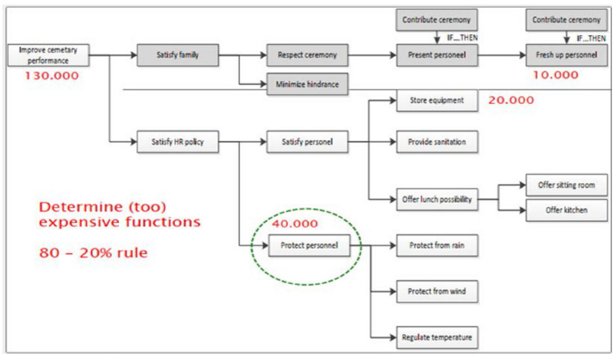

Figure 5: FAST diagram to improve cemetery performance[16]

Figure 6: Current solution (L), Alternate solution (R) [16]

	Personnel satisfaction	Visitor opinions	Maintenance performance	Overall performance	Costs (k Euro)	Value
Container and caravan	1,3	3,3	2,1	6,7	55	122
Current	2,3	3,3	1,3	6,9	130	53

Figure 7: Comparison of value for various design alternatives [16]

5.1 Information Phase

This part can be carried out in coordination with managers and maintenance technicians of maritime companies, service providers and data analytics partners who are largely involved in the present project of improving operational availability at a lower cost. The key stake holders of this project can be:

- Potential users of the system: Operators, maintenance managers and technicians.
- Supervisors: From University and the company.
- Project managers: From service providers and asset managers.

To begin the phase, the underlying need of the project can be introduced to stake holders as mentioned below.

The primary objective is to design for operational feasibility, in order to ensure that system is available and operating in an efficient and effective way in accomplishing its specified mission. It depends on (1) inherent reliability of the system and (2) maintainability, the ability of the system to be maintained and returned to service rapidly and efficiently. The focus will be on improving operational availability (A_o) at a lower investment.

$$A_o = \frac{MTBM}{MTBM+MDT}$$

Which can further expressed as,

$$\text{System effectiveness} = \frac{availability}{life\ cycle\ cost}$$

In this phase, ways to increase MTBM (mean time between maintenance) at a lower budget can be discussed. Reducing MDT (active maintenance time, logistics delay time, and administrative delay time) is optional because MTBM is found to have more feasible solutions than reducing MDT. It also to be noted that reliability of the system is high due to excessive preventive maintenance interval and inherent reliability levels of the system. Maintenance analytics (condition based maintenance) has potential to increase MTBM, and the same will be focused in detail. In the beginning latest trends in maintenance analytics and monitoring techniques can be discussed (based on literature review and stakeholder experience). It has potential in increasing MTBM and reliability levels of components. Applying these techniques, however, is often technologically and economically challenging.

Outcome

This phase brings all team members to a common, basic level of understanding including tactical, operational, and specifics of the subject. Stake holders shall be updated about the motivation, current state, constraints and deliverable milestones of the project. Stake holders will discuss their needs and available resources in this meeting. Following which, researcher can present the conceptual solution to them. Opportunities and the threats of the project can be discussed in detail.

5.2 Functional Analysis Phase

The aim of this part is to establish an overview of the whole system from a functional point of view. Basic functions and supportive functions are organised and analysed in detail, by means of FAST diagram. As shown in **Figure 8** and **Table 1**, the objective of improving maintenance policy can be supported by satisfying operational availability (primary), technical availability & enhanced work practices (secondary). Improving logistics network is bit ambitious, because the ships will be away from shore in certain missions. Therefore, logistics part is not included in discussions. In the meantime, it can be ascertained that increased spare parts investment cannot satisfy the requirement and buying additional ships is an expensive alternative. Therefore, these factors need not be considered for availability and reliability discussions. The main focus will be on maintenance analytics which is a proven technique in the industry to increase maintenance intervals and reliability of components in uncertain environments. The FAST diagram starts from the highest technical performance measure, which is crucial for the *output and of high interest to the partners*. By moving on the in the X-axis to the right by asking the question "how", By answering this questions a cost effective condition monitoring technique can be designed that helps to achieve the value goal as shown in **Figure 8**.

Table 1: Primary and secondary goals

Goal (primary)	Supporting decisions (secondary)
Improve maintenance policy	Improve reliability
Improve availability	Enhance work practices

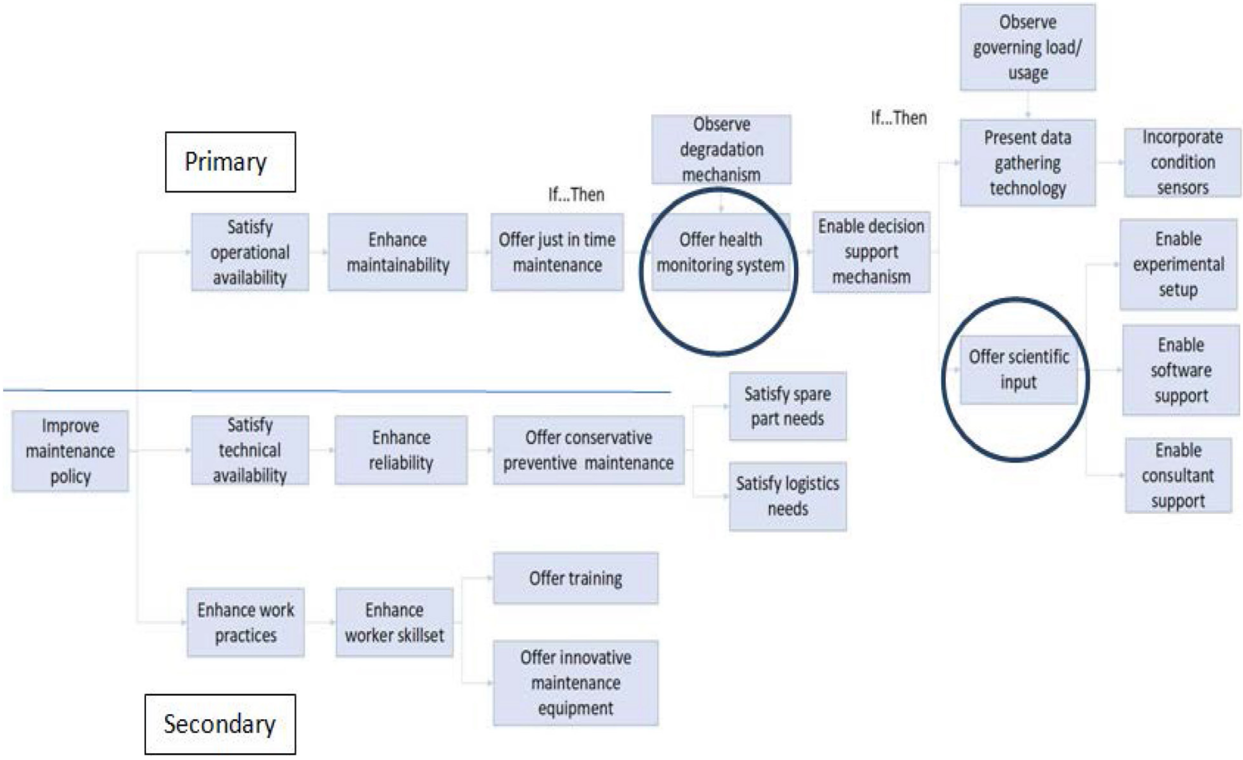

Figure 8: FAST Diagram

Outcome:

The most expensive function (80/20 rule) shall be identified in this phase. It can be proved that offering health monitoring system to few critical equipment, and offering scientific input for the chosen decision support system will be more expensive, and the same will be optimised in the upcoming sections.

5.3 Creative Stage

In this stage alternative ways can be identified in order to satisfy a function. The alternatives per function will be combined to form redesigned system in the upcoming stages. This can be done by identifying key functionalities (80/20 rule), and requesting stake holders to identify various ways to perform that function. A session of brainstorming can to be organised in order to stimulate ideas. By comparing the result, a critical view of the problem can be established. At the end, the solutions that ensure the minimal requirements can be considered.

In this project, it is possible to monitor whole engine system with various sensors. This will incur massive costs for setting up sensors and diagnostic systems. Therefore, the first focus is to identify alternate ways for the function "offering health monitoring system". As shown in **Table 2**, in order to apply health monitoring system, many components can be chosen from an engine that represents the engine system. The chosen component must be critical to the engine system and capable of driving 80% of overall maintenance cost.

Finally, in order to impart prognosis capability (decision support system), sensors and mathematical models are required. In the beginning of the project building experimental set up could be a solution that incur major budget allocated for model development. Sensors are

Table 2: Alternatives per function

Step 1	*Step 2*
Function: Offer health monitoring system	*Function: Offer scientific input*
Monitor bearing (main, small end big end bearings)	*Enable experimental setup*
Monitor piston assembly (rings, piston head, cylinder liner)	*Support numerical simulations (licensed version)*
Monitor inlet & exhaust valves	*Formulate degradation algorithms based on observational case studies*
Monitor turbocharger	*Outsource data analytics to consultants*
Monitor lubrication system	*Support with data analytics (in-house)*
Monitor fuel injectors, fuel pump	
Monitor engine control unit	
Monitor crank shaft, cam shaft	

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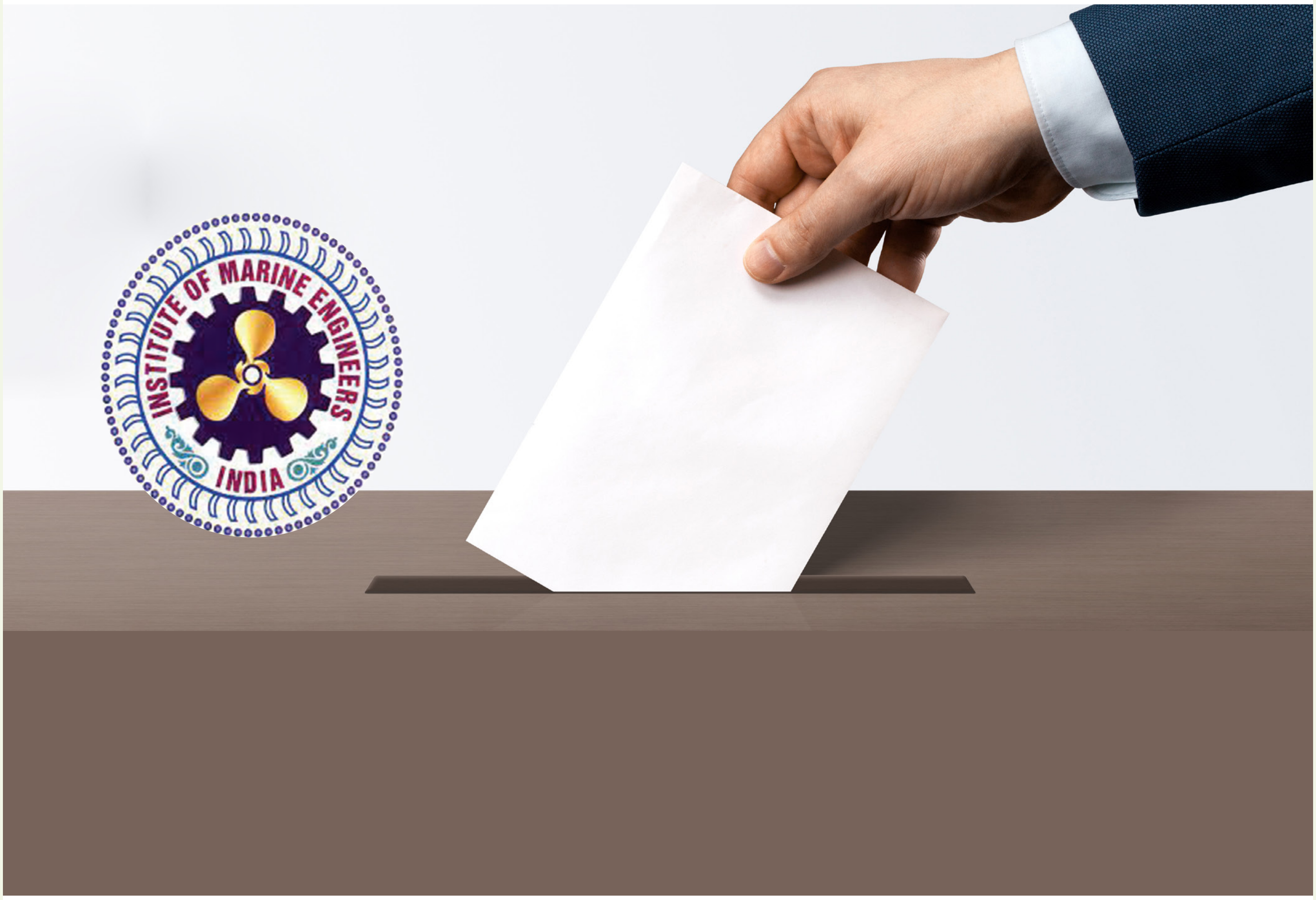

- Election process of The Institute of Marine Engineers (India) for the term 2023-25 by e-voting is on-going.
- **The e-voting commenced from 15 July and shall continue until 17:00 Hrs. on 31 August 2023 for the post of Vice-President only.**
- All other posts in the Head office (Governing Council), Branches and Chapters were uncontested.
- Corporate Members should have received by now the email from our e-voting service provider CDSL, with the login credential of the Member's ID and Password to enable them to vote online. Corporate Members, who have not yet received the login credential from CDSL, are requested to contact directly the undersigned by email at electionofficer@imare.in with copy to administration@imare.in.
- Counting of e-votes will take place at **10:00 Hrs, on 02 September 2023** at IME(I) House, Nerul. Corporate Members, desiring to witness the counting, are to inform the undersigned with copy to the Administration by email latest by 17:00 Hrs. on Wednesday, the 23rd August 2023.

Election Officer
The Institute of Marine Engineers (India)
IME (I) House
Plot No. 94, Sector 19,
Nerul (East), Navi Mumbai – 400 706
(electionofficer@imare.in)

Table 3: Critical component selection

Part	Component	Failure Mode	Mechanism	In Q1 at (high downtime)	RPN
Diesel engine	Inlet & exhaust valves	Worn	Wear	Company 1	660
	Piston (+springs)	Seized Fouled	Wear, fatigue fouling	Company 2, Company 3	600
	Bearing (main, connecting-rod, crank shaft)	Worn, damaged	Wear, human error, mis-alignment	Company 1, Company 2, Company 3	384
	Piston (+springs)	Seized Fouled	Wear, fatigue fouling	Company 2 Company 3	600
Frequency converter	Bearing (+housing)	Worn	Wear	Company 1, Company 3	550

cheap nowadays; however, building a mathematical model will be most expensive. Offering scientific input (mathematical model) will be expensive and takes 80% of the cost. Numerical simulations in combination with experiments, needs to be done in order to build mathematical models. The task can be done in house or can be outsourced to consultants. **Table 2** summarises alternate solutions for function "offer scientific input".

5.4 Evaluation Phase

The most promising solutions will be brainstormed and ranked in this phase. This can be done with sticky notes or writing down in A3 sheet. However, FMECA templates can also be used to rank the solutions in a structured way. FMECA sheets can be distributed to stake holders, so that they can assign RPN number (criticality, probability, detectability), and rank engine components to be monitored. Based on the outcome a suitable component can be identified. *As seen in* **Table 3** *inlet and exhaust valves could rank high in the FMECA list depending on the company's perspective.*

The next step is to identify key solution for the function "scientific input". This can be done by voting for the identified alternatives. As seen in **Table 4**, *literature based values and real time empirical value determination methods ranks higher in the order.*

Table 4: Scientific alternates

No	Function: Offer scientific input
1	Literature based values
2	Real time empirical value determination
3	Hardness tester
4	Valve tester
5	Universal tribo tester
6	Non-linear FEM solver MARC
7	Data mining
8	OEM advice

5.5 Development Phase

A critical analysis on the evaluation phase is needed in this part, in order to further develop the previously identified solutions. The aim is to analytically define the best solution for each function. The importance of a function is judged by its weight; therefore, a weight function is to be designed in order to have a global idea of the most important functions out there.

Based on the findings from the evaluation phase, inlet and exhaust valves ranked high in the FMECA list and the observed failure mechanism is wear. Wear models can be developed and integrated in the form of decision support tool. The exhaust valve wear model is typically a mathematical model and the design dependent parameters can be obtained from an experimental setup consists of universal valve tester, tribo tester and hardness tester or can be derived from numerical simulations. As exact value of such an experimental/ numerical setup is unknown it is assumed as default X. Implementation time, scientific value, accuracy can be the key criteria that can be used to compare alternate designs such as observational case studies and OEM advice. As seen in **Table 5** *experimenting with empirical or* observation based values *perform well than other alternatives. Costs come down with such an approach; however,* the model accuracy is retained. The more accurate the model is, it makes better predictions, so that failures can be avoided, and MTBM can be extended subsequently. The attained value/ cost can be translated into system effectiveness that is availability per life cycle cost. In this way one can find alternate ways that can substitute experimental / numerical setup without compromising on accuracy and ensure practicability.

$$\text{System effectiveness} = \frac{availability}{life\ cycle\ cost}$$

Additional Explanation

Developing physics based mathematical model (for decision support tool) is feasible, by considering the failure phenomena in diesel engine valves. In order to develop mathematical model, material properties

Table 5: Compare alternative designs(numbers for representation)

Predictive decision support tool for inlet & exhaust valve						
Solutions	Implementation time	Scientific value	Accuracy	Overall performance	Costs	Value
Supplement with experimental setup/ Simulations	3/20	7/20	7/20	0.85	X	0.85
Supplement with empirical, literature or observation based values	7/20	6/20	7/20	0.95	0.5X	1.9
Provide OEM advice	8/20	7/20	7/20	1.1	1.25X	0.88

Figure 9: Preliminary solution of experimental setup (L) [3], Final solution (R)

need to be established. This can be done by means of experiments, numerical simulations or from literature. Relying of literature values will be ideal choice because of time and budgetary constraints. So they are preferred, and in case of simulations academic licensed software is preferred, which come under free licensing agreement from partnering Universities. Similarly, certain experiments will require purchasing new equipment. After discussion with material science experts it can be decided to proceed initial model development with empirical values. After a first validation campaign adjustments will be made accordingly. Data driven approach or OEM advice needs additional investment in the form of qualified manpower, infrastructure investments or paid contract agreements. Even though data driven approach or OEM advice can predict valve degradation, remaining useful life time (RUL) calculation by such approaches are in evolving stages, so they rank less. The preliminary and final solution is shown in **Figure 9**.

5.6 Presentation Phase

The solution to develop and implement inlet & exhaust valve wear model, will be presented to senior managers for their approval. A final decision to implement changes will be based on financial business case study, in order to justify the investment in maintenance analytics techniques.

6. Conclusion

Value engineering, is introduced briefly in this work in the context of improving maintenance management. The opportunities to incorporate concepts from the Value Engineering perspective in systems engineering processes, tools and activities are also discussed. Three key concepts are described and demonstrated through a practical example in the form of maintenance management. The focus is on identifying the concepts that add value to engineered systems, valued highly by its users. Value engineering thus offers outstanding concepts to improve designers' goals. We hope to inspire engineering practitioners to weigh, rethink and adapt methods, and invite the ship management firms to further explore and experiment together. From this work, one can also realise value engineering potential to solve real world problems or design new systems / components. A firm basis is provided in this work, so that the design process can take place as smoothly and efficiently as possible, there by new technologies, process can be introduced in the industry.

7. Acknowledgement

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About the author

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

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Importance of the Concept of Seaworthiness

Dr. Brijendra K. Saxena

Abstract

An unseaworthy ship presents a risk and can lead to damage to cargo, environment, other properties, and of course to life. It must therefore be obligatory on the part of those responsible that only a seaworthy ship must be sent to the sea. Seaworthiness relates to technical, commercial and legal aspects. This paper touches on various legal issues related to unseaworthiness. The requirement of seaworthiness is part of the public law and also the private law. The paper addresses different points of the private law related to various contracts that operate in ship operations. This paper discusses unseaworthiness and its consequences under the carriage of cargoes and charter parties; and also insurance. The discussions are based on different aspects of seaworthiness and the relevant case law.

Keywords:

Seaworthiness; due diligence; obligation

Introduction:

Seaworthiness is an extremely important concept in ship operations and has a bearing on the technical, commercial, human, operational and legal aspects of the operations of a ship. An unseaworthy ship is not only a hazard to its crew and cargo but also to other ships, port facilities, environment etc. This concept has developed over past few centuries and resulted in the notion under the common law where the owner of a ship carrying cargo is required to take care of the cargo and would be held liable for damage caused unless the damage was due to the act of God, King's enemies or inherent vice of the cargo. This led to the requirements for a seaworthy ship.

Though the concept of seaworthiness initially developed with respect to the care of the cargo, its scope enlarged. Today, seaworthiness affects the relationships of the ship owner with many other stakeholders like charterers, underwriters, flag and port states, crew etc. It therefore has become a part of both the international public as well as private law.

Many legal regimes, both the relevant laws and the contractually recognised rules address this issue and their treatment on the issue could be different, especially contractual terms agreed and the applicable law. Under the common law the ship owner's duty is absolute whereas under the often used Hague Visby Rules the duty is only of due diligence in providing a seaworthy ship. This duty may be expressed or implied and this may lead to some issues.

Furthermore, is it a duty or an obligation of a ship owner and is it limited to providing a seaworthy ship at the commencement of the passage or is it a continuing duty? What happens when a ship is on time charter, who is operating as the carrier – who has the duty towards seaworthiness? These are some of the issues related to the subject. The interpretation of the term by the courts has been developing and the legal aspects of the seaworthiness are constantly evolving.

A November 2021 landmark judgment of the English Supreme Court also addresses this issue. In another recent case where a container ship lost some containers on board in bad weather, the court found that the vessel was unseaworthy.

Yet another issue is to consider how the doctrine of seaworthiness will be applied on semi as well as fully autonomous ships. Such ships are technologically a possibility and recent developments have confirmed that. However, compliance with legal issues, including seaworthiness would remain a challenge.

Seaworthiness defined:

Seaworthiness is defined under s334(5) of the Indian Merchant Shipping Act 1958 as – *"A ship is "unseaworthy" within the meaning of this Act when the materials of which she is made, her construction, qualifications of the master, the number, description and qualifications of the crew including officers, the weight, description and stowage of the cargo and ballast, the condition of her hull and equipment, boilers and machinery are not such as to render her in every respect fit for the proposed voyage or service."*

Today, seaworthiness affects the relationships of the ship owner with many other stakeholders like charterers, underwriters, flag and port states, crew etc

A more specific definition of seaworthiness was provided in a case in 1905 and is appended below:

"A vessel must have that degree of fitness which an ordinary careful and prudent owner would require his vessel to have at the commencement of her voyage having regard to all the probable circumstances of it .... Would a prudent owner have required that it (defect) should be made good before sending the ship to sea, had he known of it? If he would, the ship is not seaworthy."[1]

In an old case Lord Collins commented that seaworthiness is a variable and relative standard. It would depend on particular ship, particular voyage, particular geographical region, cargo carried, and the specific season etc.[2]

Seaworthiness and Carriage of Cargo

Cargo owned by a party is carried on a ship that is owned by the ship owner. This cargo would be carried under a contract which may be a voyage charter or evidenced in a bill of lading. Under the contract, the carrier, who may be a ship owner or a time charterer, is expected to take care of the cargo. Not only that this situation is like bailment and as Bailee the ship owner needs to take care of the cargo. Probably the first case where the duty of the ship owner on this issue was emphasised by the court, almost 700 years ago, in a 1348 case.[3] Over the years this doctrine developed and under English law, in the absence of any specific agreed terms, the ship owner would be liable for the loss or damage to the cargo unless it happened due to an act of God, act of King's enemies or any inherent vice of the cargo.

Hague Visby Rules (HVR) are the most commonly used rules incorporated under the contract of the carriage of goods as evidenced under a bill of lading or under a voyage charter. Art III.1 of these rules specifies:

"The carrier shall be bound, before and at the beginning of the voyage, to exercise due diligence to (a) make the ship seaworthy; (b) properly man, equip and supply the ship; (c) make the holds, refrigerating and cool chambers, and all other parts of the ship in which goods are carried, fit and safe for their reception, carriage and preservation."

This can be separated in few different requirements. The carrier is required to exercise 'due diligence' to do some specific tasks, one of these being 'to make the vessel seaworthy' before and at the beginning of the voyage. This is different from the common law where such duty is absolute.

The interpretation of 'before and at the beginning of the voyage' was given in a case where the court ruled that it refers to the starting of the loading till the departure from the loading port.[4]

The requirement of seaworthiness is further classified as – 'properly manned'. This relates to the crew. The earlier interpretation of this was limited to the sufficiency of the crew and their qualifications. However, now the competence is also considered as a subset of 'properly manned'. This is discussed further in the paper. 'Properly equipped' relates to the adequacy of the equipment on board and their level of functioning. 'Properly supplied' relates to various supplies that are needed for the successful completion of the voyage. These can be bunkers, fresh water, food etc.

An interesting comment was made regarding the functioning of the machineries in a very old case. Lord Moncrieff commented that: *'a steamer without steam is as little the vessel which the charter-party describes, and which the defenders undertook to furnish, as a sailing vessel without sails would have been'*[5]

In a case the court ruled the vessel must have sufficient bunkers to reach the destination. However, the voyage may include bunkering ports. In that case the ship must have sufficient bunkers to reach "a particular convenient or usual bunkering port on the way." Furthermore, the bunkering stops should be fixed not later than the start of the voyage.[6]

The last part is regarding the fitness of the cargo compartments to receive that particular type of cargo. The requirement is referred as 'cargo worthiness' and in a case the court commented that the vessel must be fit to receive the contemplated cargo and the presence of residue of other cargo on board which may affect the planned cargo would make the vessel un-cargo worthy.[7]

In another case a heavy lift vessel was delivered from the ship building yard and during the first loading operation the loading hook broke due to a defect. The vessel before delivery was inspected by a reputable class. The court arrived at the conclusion that the carrier has failed to exercise due diligence to make the vessel seaworthy, with regard to testing of the hooks.[8]

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The duty of exercising due diligence also extends to include the contractors appointed by the ship owner. In fact, it was commented that the requirement of due diligence under Art III 1 of Hague Rules covers the subcontractors. This duty of 'due diligence' is not delegable and the carrier would be vicariously liable for the negligence of the workers of its subcontractors.[9]

The carrier is required to exercise 'due diligence' to do some specific tasks, one of these being 'to make the vessel seaworthy' before and at the beginning of the voyage

Seaworthiness Under Charter:

Charter party is the formal written contract between a charterer and a ship owner. Voyage charter is a contract of the carriage of cargo whereas time charter is a contract of leasing. In a voyage charter party specific condition regarding the duties of the ship owner would be included. However, if nothing is mentioned or referred regarding seaworthiness, common law requirements would be implied. The other important issue is that the duty to provide a seaworthy ship is only at the specific time e.g. at the commencement of the loaded passage in a voyage charter or at the time of delivery in the time charter. Both possibilities are addressed in different charter parties.

The issue of fitness of the vessel for specific voyage was mentioned in charter parties as earlier as 1531 and 1538 which require that the vessel was 'strong and staunch and sufficiently vitalled and apparelled' for the intended voyage, together with 'good and able maryners'.[10]

Many standard charter parties provide reference to seaworthiness expressly. *"The Vessel on delivery shall be seaworthy and in every way fit to be employed for the* intended service".[11]

"The Owners are to be responsible for loss of or damage to the goods .... in case the loss, damage .... has been caused by personal want of due diligence on the part of the Owners or their Manager to make the Vessel in all respects seaworthy and to secure that she is properly manned, equipped and supplied".[12]

Some charter parties may not directly mention the word 'seaworthy' but give a reference to it. "*Owners shall exercise due diligence to ensure that from the time when the obligation to proceed to the loading port(s) attaches and throughout the charter service - (a) the vessel and her hull, machinery, boilers, tanks, equipment and facilities are in good order and condition and in every way equipped and fit for the service required; and (b) the vessel has a full and efficient complement of master, officers and crew and the senior officers shall be fully conversant in spoken and written English language and to ensure that before and at the commencement of any laden voyage the vessel is in all respects fit to carry the cargo specified".*[13] The requirements under this clause are much more stringent as it requires ship owner to exercise due diligence *"throughout the charter service"*. Such warranty is usually not found in voyage charter parties.[14]

Of course the requirement of providing a seaworthy ship is always implied even if there is no direct reference in the charter party. A vessel had to go to a port of refuge and the voyage terminated as major repairs to the main engine had to be carried out. The cargo got damaged and had to be disposed of. The cause of main engine damage was established as the presence of foreign material in the lubricating oil which led to the failure of bearings. The owner was aware of the problem and the ship was considered as unseaworthy at the commencement of the voyage and the owner was held liable.[15]

It is relevant to note that the duty of providing a seaworthy ship is at the time of the start of the voyage and does not cover the total duration of the voyage. Furthermore, if the voyage is performed in different legs, the vessel must be seaworthy at the commencement of sailing for each leg. This was once again confirmed in a 2011 case when the court commented that the requirement of seaworthiness applies, if the voyage is in different stages, to the commencement of each separate stage.[16]

Hong Kong Fir is a classic case regarding the issue of seaworthiness under time charter. The vessel had extensive engine breakdowns and repairs for quite some time in the initial charter period. The court addressed the question if the vessel was 'in every way fit for the cargo service'. The court ruled that the crew was incompetent, some were engaged without exercising due diligence and therefore the owner was in breach of want of due diligence.[17]

The issue of seaworthiness is also included in the bareboat charter. The often used charter party Barecon 2001 requires that the *"(a) Owners shall before and at the time of delivery exercise due diligence to make the Vessel seaworthy and in every respect ready in hull, machinery and equipment for service under this Charter. .... (b) The Vessel shall be properly documented on delivery in accordance with the laws of the flag state"*[18]

The requirement has been altered in the latest version of this charter party. The clause in the Barecon 2017 requires that the vessel must be delivered *'in a seaworthy condition and in every respect ready for service'*. Importantly this does not refer to the requirement of 'due diligence' but provide an 'absolute' obligation. This however, can be watered down by including a specific 'clause paramount' in the charter party.[19]

Seaworthiness and Marine Insurance:

Seaworthiness, in reference to marine insurance, is defined in .39(4) of the Marine Insurance Act 1906 as *"a ship is deemed to be seaworthy when she is reasonably fit in all respect to encounter the ordinary perils of the seas of the adventure insured"*. This may seem to be rather straight forward; however, it is necessary to consider what can be 'reasonably fit'.

Under the MIA, there is an implied warranty of seaworthiness and the warranty is defined in 33(1) as *"A warranty means a promissory warranty, by which the assured undertakes that some particular thing shall or shall not be done, or that some condition shall be fulfilled, or whereby he affirms or negatives the existence of a particular state of facts."* Furthermore, the warranties can be implied or expressed in the policy.

General average is when some extraordinary sacrifice or expenditure is made intentionally, with an objective of saving the properties on board ship, on the happening of real and substantial event threatening the voyage

Section 39(1) of the MIA specifies that in a voyage policy there is an implied warranty of seaworthiness.

"39. Warranty of seaworthiness of ship (1) In a voyage policy there is an implied warranty that at the commencement of the voyage the ship shall be seaworthy for the purpose of the particular adventure insured."

It is important to understand the difference in treatment of a breach of a warranty under the law of contract and under the law of insurance. In contract a warranty is a term of the contract and the agreed party can claim damages for any loss resulted from the breach from the other party. The warranty in the Indian Marine Insurance Act 1963 is applicable from the 'commencement of the voyage' as given above and relieves the underwriter from any liability from the time of the breach. As per s35(3), *"A warranty .... must be exactly complied with, whether it be material to the risk or not. If it be not so complied with, then, subject to any express provision in the policy, the insurer is discharged from liability as from the date of the breach of warranty"*. Therefore, if the vessel departs in an unseaworthy condition and has a damage due to a risk under the Inchmaree Clause of the ITC (Hull) the underwriter will be able to deny the liability.[20] A similar requirement was in the s33(3) of the 1906 MIA of the UK but the 2015 amendments and the enactment of the Insurance Act 2015 in the UK has changed the effect of the breach.

The situation is slightly different in a time policy and the same is addressed under section 39(5) of the English act.

"(5) In a time policy there is no implied warranty that the ship shall be seaworthy at any stage of the adventure, but where, with the privity of the assured, the ship is sent to sea in an unseaworthy state, the insurer is not liable for any loss attributable to unseaworthiness." The wordings are similar in the Indian act too.

The relevant question is that at what point this implied warranty needs to be fulfilled? Under the voyage policy the vessel must be seaworthy at the time of commencement of the policy.

This position, if applied in a time policy, would lead to some difficulty. It is quite possible that the 12-month cover may commence from a date/ time when the vessel is at sea and it is not reasonable to except that it must be seaworthy. In an 1853 case the judge commented that as that time the ship may not necessarily be in a condition that may be required as seaworthy.[21] It would therefore not be logical to apply the same yardstick of seaworthiness in a time policy as required in a voyage policy under the law.

Another aspect is that the loss must be 'attributable to unseaworthiness' – which means that the loss must have resulted from the said unseaworthiness. In an old case the ship was unseaworthy due to two reasons, namely insufficient crew and damage to the hull. The owner knew about the shortage of crew but not about the hull damage. It was established that the loss was due to the damaged hull. Hence the court ruled that the insurer can only deny liability if the damage happened due to unseaworthiness and the owner was privy to this information. This was not there in this case.[22]

The application of the warranty in the hull policy is straightforward. There would be a breach of the contract if the ship is sent to sea in an unseaworthy condition and the same would be dealt with as per the Act. However, the situation is little complicated in a cargo policy. This is handled in the ICC Cargo clauses: "*5.1 In no case shall this insurance cover loss damage or expense arising from unseaworthiness ... unfitness .... of vessel or craft .... for the safe carriage of the subject-matter insured, where the Assured or their servants are privy to such unseaworthiness or unfitness, at the time the subject matter insured is loaded therein."*

Thus a cargo owner can only be denied a claim if the damage to cargo occurred due to the unseaworthiness and the cargo owner was privy to this knowledge at the time of loading the cargo.

Human Worthiness:[23]

The ships are manned and operated by the crew which ensures that the cargo and the vessel move from one point to the other efficiently, without any loss to the assets, including life and the environment. The importance and relevance of the crew is specified in some international conventions. The seafarers are trained as per the requirements of the STCW Convention. However, their performance, especially in some contingency situations, depend on many different factors. Most of them are beyond the scope of this paper. Another aspect is that in the event of a loss or damage situation, whether the respective crew member/s was 'negligent' or 'incompetent'? The associated implication is that the action of an 'incompetent' crew may result in vessel being called unseaworthy. This dilemma of deciding between negligent and incompetent was opined in an old case. "

Negligence is the omission to do something which a reasonable man, guided upon those considerations which ordinarily regulate the conduct of human affairs, would do, or doing something which a prudent and reasonable man would not do".[24]

It is important to differentiate between negligence and the incompetence of the crew members. The action of negligence would not lead to the vessel being referred as unseaworthy whereas action by an incompetent person may.[25]

Eurasian Dream is a classic case on the issue of competence of the crew.[26] Here the master and some other crew members were found incompetent as they could not react timely at the time of the fire. The court ruled that besides other things, the ship owner needs to exercise due diligence in selecting the crew, especially the senior officers. The court, in this case, provided some guidelines so that such due diligence may be provided:

(1) *The appointment of a generally competent master/ crew (e.g. by inspecting the seaman's documents, interviews and inquiries from previous employers to ensure that the person is reasonable fit for the position he is hired); and*

(2) The specific competence of the master in relation to the vessel and the voyage in question.[27]

In a fairly recent case, the chief officer of a fishing vessel was stabbed fatally by a crew member. The widow of the chief officer, besides other civil and criminal cases, filed a case on unseaworthiness. During the trial it was established that the crew member had a history of violence and care was not taken by the master of the vessel while engaging the said crew member. The ship was therefore unseaworthy. However, the owner had no knowledge or privy to this information.[28]

Seaworthiness and ISM Code:

The importance and the reliability of the required documentation was established in a case where the court ruled that *"...... seaworthiness included the legality of the vessel and her documentation ....".*[29] In the same case the Court of Appeal ruled that the documentation required to establish seaworthiness was the ones required by law of the flag state or other states. Documentation required by other organisation would not come in this category.

The DP under the ISM Code requires conveying the critical information to the top management. This can be construed that the owner is privy to the information and as such he may not be able to avoid liability. The relationship of the roles of the DP and the seaworthiness can be in the area of crew training, physical condition of the vessel, and the documentation. The DP must ensure that the required documentation is on board.[30] In the Apostolis case the judge ruled that regular communication between the master and the management company made it impossible for the office to deny knowledge of the activity on the ship.[31]

A large container ship ran aground in Singapore and the cargo interest pleaded for unseaworthiness due to the incompetence of the second officer. The owner of course tried to take shelter of the HVR exemption of liability due to 'negligence of the master, crew etc.'. The vessel was held unseaworthy as the owner could not prove establishment of a recruitment policy and its compliance.[32]

Similarly, in the earlier referred case of the Eurasian Dream, the master had never sailed on a car carrier before. He was instructed to read more than 100 safety and technical manuals. Most documentation on board was of other types of ships and confusing to the crew. There was no evidence of any emergency drills being conducted.[33] At the time of the casualty the vessel did not have to comply with the requirements of the ISM Code, however, this had to be done on a later date and the presence of such documentation was inconsistent with the spirit of the Code.

In a recent case the court ruled that there was an issue regarding training for firefighting of the crew. However, the owner did not seek more information and turned a blind eye.[34]

In a case where the underwater pipeline was damaged as the vessel anchored near it, the issue of using incorrect navigational charts was addressed. In the House of Lords, it was commented that it was not only enough to place a competent master and leave all navigational issues to him. The updated chart was available on-board but was not used. The damage was due to the actual fault of the owner.[35] Similarly, in another case the issue of improper charts along with the unavailability of the echo sounder, and inoperative boiler resulted in vessel being referred as unseaworthy at the commencement of the voyage.[36]

Seaworthiness and General Average:

General average is when some extraordinary sacrifice or expenditure is made intentionally, with an objective of saving the properties on board ship, on the happening of real and substantial event threatening the voyage. In such case all the property owners, including the cargo owners, are required to contribute proportionately for the GA amount. The cargo owners may refuse to pay the GA contribution if they are able to prove that the vessel was unseaworthy at the time of sailing from the last port.

This happened in a recent case when a vessel was considered unseaworthy because of a defective passage plan.

The Court held that seaworthiness would cover issues like updated charts. The Court commented that *"the prudent owner would have required the defective passage plan to be made good before the vessel set to sea, and indeed that it was "inconceivable" that the prudent owner would have acted otherwise."* The ship owner did not comply with his obligation under Art III 1 of exercising due diligence in the drawing up of the passage plan. The Court further commented that this duty of exercising due diligence in providing a seaworthy ship was non-delegable.[37]

Seaworthiness and Autonomous Ships:

The advancement of technology has resulted in the possibility of autonomous ships. While building such ships is a technological challenge the bigger and more complex issues are their legal implications. The issues regarding seaworthiness are touched here.

Such ships would be controlled by a shore-based team. Will that be accepted as 'properly manned'? What will have to be done by a ship owner to demonstrate 'exercising due diligence' under HVR if this function is sub-contracted to a vendor? This question would need to be answered in eventualities like collision; damage to the cargo or any other property etc. when that has been caused due to malfunctioning of the artificial intelligence system. Furthermore, how the issue will be addressed when a time charterer or a multimodal transport operator is the 'carrier'? The liability of the ship owner and other parties would be based on the answer to this question. The industry would need to find solutions to these issues before autonomous ships become globally accepted commercial vessels.[38]

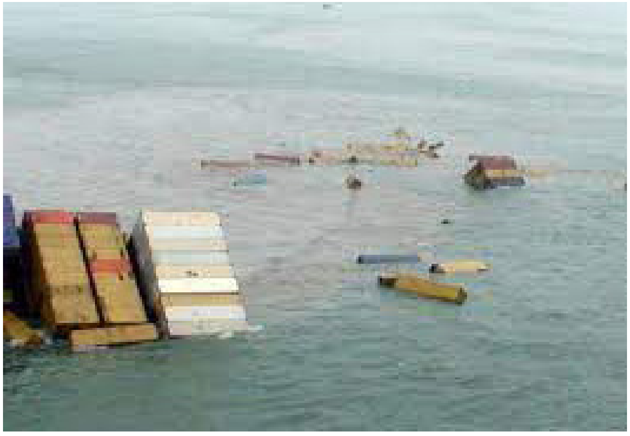
Implications of Unseaworthiness:

The implications of an unseaworthy ship remain substantial and this can affect different stakeholders. In carriage of cargo the carrier would not be liable for the loss or damage to the cargo if that was caused by the unseaworthiness unless it was caused by want of due diligence as mentioned in the HVR and given below:

Neither the carrier nor the ship shall be liable for loss or damage arising or resulting from unseaworthiness unless caused by want of due diligence on the part of the carrier to make the ship seaworthy, and to secure that the ship is properly manned, equipped and supplied, and to make the holds, ……… fit and safe for their reception, carriage and preservation.[39]

Furthermore, the onus of proving the exercise of due diligence shall be on the carrier.

If the loss/ damage is caused by two reasons, one unseaworthiness and the other e.g. an act of God for



which the owner is not liable under Art. IV 2(d) of the HVR; he cannot take benefit of that exemption.[40] In a case it was ruled that unseaworthiness does not lead to liability on ship owner unless it has caused any damage and a claim has been raised.[41]

As mentioned earlier in Hong Kong Fir the vessel was unseaworthy and was off hire for a period of 5 months out of a 24-month however, the time charter was not considered to be frustrated. Thus unless the unseaworthiness goes to the root of the contract and deprive the other party substantially the contract would continue and the aggrieved party can only claim damages for loss.[42]

Importantly the time charterer, as a disponent owner, becomes responsible for the contractual performance as per the subsequent charter. The continuation of the time charter can have serious repercussion on the charters down the line. In Hong Kong Fir the vessel left US East Coast with coal on 9th March and the cargo was delivered in Japan by 25th May![43] Another contrary approach was seen in a case when a pump, that was essential for the cargo work, could not be repaired. The court ruled that the charterer could cancel the charter.[44]

In insurance under the MIA 1906 and also under the Indian MIA 1963 the warranty in a contract must be complied. The underwriter is discharged from liability if there is a breach of this warranty, even if the damage is not a result of this breach. This position is changed in English law under the 2015 amendments to MIA 1906 and the enactment of the Insurance Act 2015.

Deviation is usually not permitted at sea unless it is for saving of life. This is amply recorded in various instruments. The question of deviation of an unseaworthy ship was addressed in a case. The court ruled that "it is the presence of the peril and not its cause" that results in deviation. The continuation of the voyage would be riskier for the lives and therefore the deviation could be justified.[45]

Conclusion:

The implications of an unseaworthy ship are substantial and with far reaching consequences affecting different stakeholders. As discussed in the paper, this issue relates to not only the technical aspects of the operation of the ship but also many other aspects. These could be the preparation of the vessel for loading; planning of the voyage; sufficiency and competence of the crew; availability of systems for different operations; etc. to name a few. The issue of the seaworthiness is extremely brittle and can easily be affected by many things. This was aptly commented by Lord Diplock in the landmark case of Hong Kong Fir as *"It can be broken by the presence of trivial defects easily and rapidly remediable as well as by defects which must inevitably result in a total loss of the vessel."*[46] It is also seen that the interpretation of unseaworthiness has evolved in last few decades and the courts have provided yardsticks about these. It is imperative that the senior shipboard staff and also the operating personnel in the office understand the importance and relevance of this and take steps that may be required. Furthermore, for autonomous ships a completely different understanding of unseaworthiness will be necessary.

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Alternative Fuels and Technologies for Decarbonization in Maritime Field – A Preliminary Analysis (Part D)

**S. Daga, K.M. Doshi,
S. Gupta, D.R. Sonawane**

Part D

Comparison Of Fuel Candidates – Onboard Storage Capacity:

The Alternative fuel candidates have different energy contents and different densities. Hence they would require storage capacities which exceed the present capacities (if the frequency of bunkering was to be kept unchanged). **Figure. 1** provides an estimate of the increase in storage capacities relative to HFO for various alternative fuels.

It can be observed that use of all alternative fuels would necessitate comparatively higher storage capacity when compared to HFO. The increase in capacity required is significantly high when hydrogen fuel is considered. Even for Ammonia and Methanol, the storage capacity would have to be more than doubled for existing ships. For biodiesels in form of FAME and HVO the increase in capacity required is nearly 20-30%.

Comparison Of Fuel Candidates – Cost Of Energy:

The cost of Alternative Fuels would be another important consideration for the maritime industry. **Figure. 2** presents the costs per tonne of each alternative fuel (as if it were to be used 'neat'). The prices were as of 1 April 2022 and obtained from various commodities and marine fuel websites. **Figure. 2** also juxtaposes the fuel cost in terms of energy capacity per unit volume (considering that Alternative fuels have different densities and energy contents).

It can be observed from **Figure. 2** that the conventional marine fuels are priced economically in terms of the cost as well as the energy content of the fuels. Methanol and LNG fuels appear to be competitive as compared to the conventional fuels. Biodiesels are expensive to be used

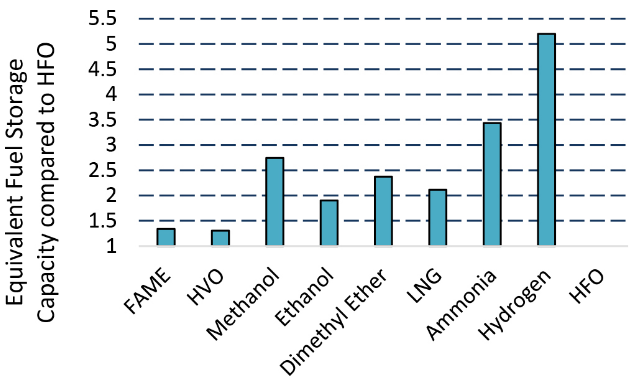

Figure. 1: Equivalent Capacities of Storage required for Alternative Fuels when compared with HFO

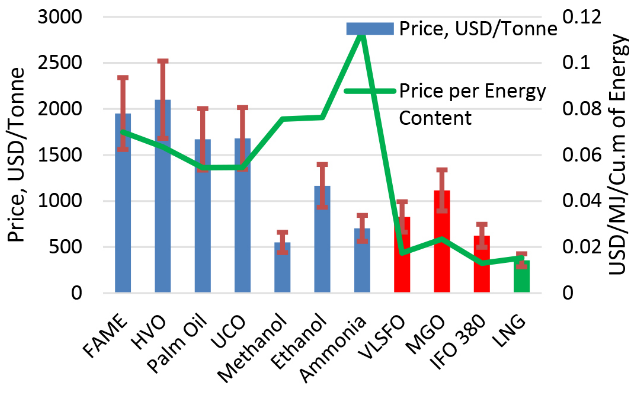

Figure. 2: Comparison of the Costs of Alternative Fuel Candidates as compared with conventional marine fuels

onboard as the prices are very high as compared to the conventional marine fuels.

Comparison Of Fuel Candidates – CO_2 Equivalent Emissions:

The equivalent CO_2 emissions resulting from use of Alternative Fuels are presented in **Figure. 3**. The Well-Wake approach has been used for evaluating the emissions (which are obtained from various references, hence a range of values is provided).

It can be observed that there is a wide range of CO_2 emissions when considered for any given fuel. Thus, the effect of the production pathway is clearly visible. **Figure. 3** also depicts that the Ammonia and Hydrogen Fuels may also lead to more emissions than conventional marine fuels if the pathway for their production is not appropriate. Hence **Figure. 3** brings out the importance of considering the Well-Wake approach and the life cycle of these fuels. Interestingly, **Figure. 3** also brings out that not all fuels of biological origin may be suitable to reduce the CO_2 equivalent emissions. For example, fuels obtained from Forestry Products processing and Bio-Ethanol may lead to more emissions.

Comparison Of Fuel Candidates – Global Production:

It is also important to understand the global availability of the various fuels so as to conclude whether there can be a preferred fuel candidate for the Marine Industry to consider. **Figure. 4** presents the total annual production capacities globally of the various alternative fuel candidates as of April 2022. Conventional Marine Fuels are also presented in the plot for easy comparison. The comparison provides the ordinate in terms of equivalent HFO (tonnes) recognising that the energy contents and densities of each fuel are different and that it may not be logical to directly compare the masses of the fuel versus one another.

"Methanol and LNG fuels appear to be competitive as compared to the conventional fuels"

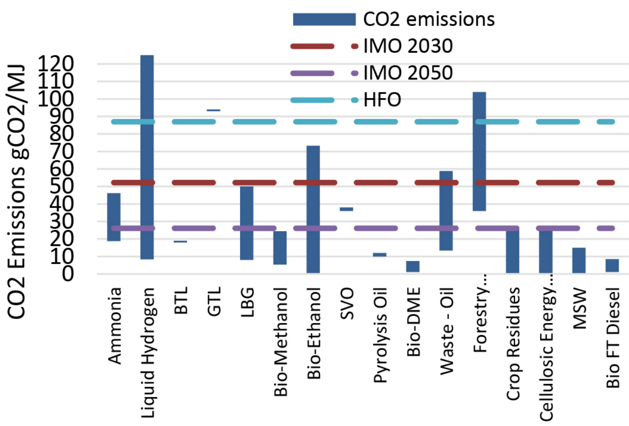

Figure. 3: CO_2 equivalent emissions using different fuels (including biofuels and biodiesels)

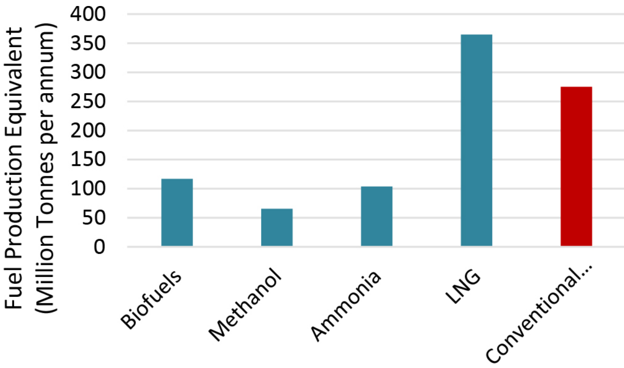

Figure. 4: Global Production Capacities of Alternative Fuels as compared to Conventional Marine Fuels

It can be observed that neither of the alternative fuel candidates have the production capacities to as to support replacement of the conventional marine fuels individually. Regarding LNG production, even though greater than the conventional marine fuel production, it should be remembered that this would be shared by the land-based industries also. Likewise, biofuels and methanol would be in demand from the land-based industries as well. Hence, it is not so trivial to replace the conventional marine fuels; this would require time.

Other GHG Emissions From Alternative Fuel Candidates:

When comparing the use of Biodiesels onboard ships (tank – wake) very low or zero CO_2 emissions (since the CO_2 released is the same CO_2 which had been captured previously by the biological source), lower SO_x emissions (Hojem & Opdal, 2007; McGill et al, 2013), lower particulate matter emissions Hojem & Opdal, 2007). The NO_x emissions would however need to be checked (Winnes et al, 2019; Hojem & Opdal, 2007). This would also depend upon the particular feedstock used to produce the biodiesel.

As regards use of Methanol and Ethanol, the trend is expected to follow the trends from the biodiesels. However, the CO_2 reduction would depend if the methanol and ethanol are sourced by biological or waste resources. It has been reported that the emissions of SOx, NOx and PM are reduced compared to the conventional marine fuels (IRENA, 2019). 95% reduction of PM has been reported when using methanol as compared to HFO (Thepsithar et al, 2020).

As regards the use of Ammonia, CO_2 emissions would be practically reduced to zero as ammonia does not have carbon content. The SOx and PM emissions would also be reduced. However, the ammonia slip and the NOx and N_2O emissions (result of ammonia which has not been combusted) would have to be monitored. N_2O is singled out as a major concern to be resolved by Taruishi (2020).

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It is envisioned that exhaust gas cleaning systems (EGCS) would be necessary (Alfa Laval et al, 2020) for the purpose of reducing NO_x emissions. These may use the selective catalytic reduction (SCR) technology. Jansson et al (2020a) recount possibility of formation of hydrogen cyanide (toxic gas) as reaction between hydrocarbon and ammonia however also noting that release of this gas has not been reported so far.

As regards the use of Hydrogen as fuel, CO_2 emissions would be practically reduced to zero as hydrogen does not have carbon content. It is also expected that the NOx, SOx and PM emissions would also be significantly reduced.

OTHER ASPECTS TO BE CONSIDERED FOR ALTERNATIVE FUELS:

The following aspects are also to be considered when deciding the future course:

1. Biodiesels and Bio-methanol/ethanol obtained from food crops are not strictly desirable as they may affect the food prices creating food scarcity. These fuels would also be in demand from the land transport and aviation transport sectors (which may also be willing to pay higher prices).
2. Biodiesel production may also lead to direct or indirect land use change. e.g. to grow a particular crop, forests may have to be cleared or the existing soil cover would have to be taken off which may release CO_2 to the air. Use of fertilizers for production of 'energy' crops may lead to release of NOx to the atmosphere. Thus there are implications of using Biodiesels holistically which must be considered.

All References shall be provided in the last part of the series.

[This paper was presented at INMARCO (November, 2022)]

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LUBE MATTERS # 25

TRIBOLOGY OF MARINE DIESEL ENGINE COMPONENTS II - PISTONS RINGS

Sanjiv Wazir
Certified Lubrication Specialist

Introduction

The cylinder liner-piston ring (CLPR) interface is the major contributor of mechanical losses in any engine. CLPR running behaviour plays a major role in the improved reliability and extended overhaul intervals of engines.

Advances in tribology have made this possible.

Piston Rings

Piston rings are fitted as a pack, which may consist of 2–5 rings, including at least one compression ring. Depending on the engine type, the ring pack may also have oil control rings.

Functions of Piston Rings (1)

They seal the combustion chamber from the cylinder crankcase to prevent combustion gases (or blow-by) penetrating the crankcase and to prevent the lubricating oil being sprayed around in the crankcase from penetrating the combustion chamber.

They help regulate the oil film. They spread the lubricant evenly over the liner surface. Excess oil is usually scraped away by an oil scraper ring.

Pistons absorb over 70% of the heat of combustion. Piston rings (especially compression rings) help dissipate the heat to the liner.

Ring Shape

Common to all piston rings are:

(a) a split, so they can be expanded and slipped over the piston head into the recessed grooves cut in the piston. The slots usually have butt, angled or lap type joints.

(b) non-circular, and with the outer diameter somewhat larger than the cylinder bore. This enables it to exert a definite pressure over the whole circumference in the circular liner. This pressure can be distributed evenly around the circumference. However, usually a negative ovality is preferred to reduce loading in the slot area during operations **Figure. 2**.

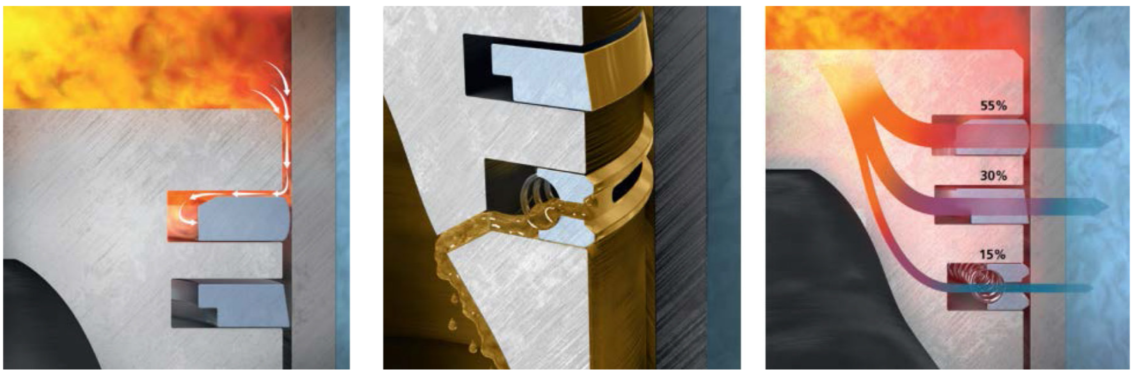

Figure. 1: Role of piston rings a) gas sealing b) oil film control c) heat dissipation (2)

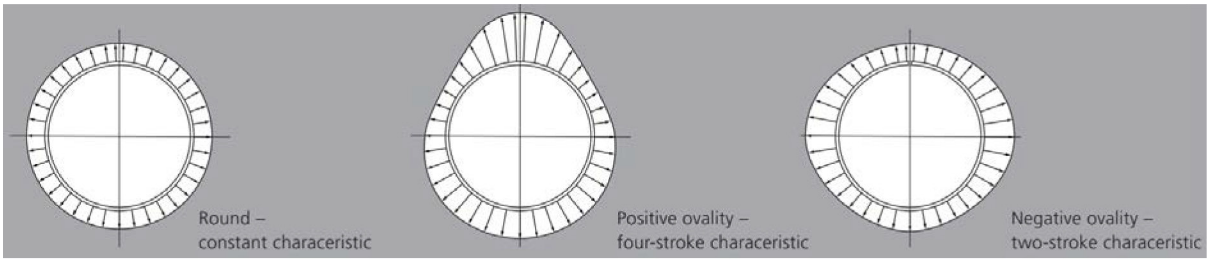

Figure. 2: Radial pressure distribution due to ring shape (1)

Radial Contact Pressure

Up to 90% of the total pressure of the compression rings on the liner is due to the combustion pressure acting on the back face of the compression rings during engine operation, **Figure. 3**. However, the combustion pressures are of significance only for a small proportion of the engine cycle and acts mainly on the top compression ring. The gas pressure behind the first compression ring varies according to the cylinder pressure. With a gas pressure acting on the piston ring, the contact pressure and thus the conformity is greatly increased.

> *"With a gas pressure acting on the piston ring, the contact pressure and thus the conformity is greatly increased"*

The pressure on the second ring can vary according to the joint clearance in the top ring. The gas pressure behind the second compression ring is significantly lower than the pressure behind the first compression ring. The gas pressure behind the oil ring stays roughly equal to the pressure on the crank chamber (TPE**) or scavenge space pressure (XHDE*) throughout the whole work cycle.

Shape of Running Face

The radial ring pressure distribution depends on the shape of the running surface. The objective of this running surface is to enable formation of a hydrodynamic oil wedge between the ring and the liner. To get a good oil film between ring and liner, rectangular cross section rings with flat running surface (with chamfered edges) were normally used.

For modern high-power engines, symmetrical or asymmetrical barrel shaped running surfaced rings are used, especially for the first ring. In the flat face rings, the force is higher, whereas in the barrel faced rings, as the compression pressure can also act on the running surface side of the barrel-shaped ring and counteract some of the force owing to ring pre-tension, it relieves the pressure against the liner wall, which reduces the wear rate during running-in, **Figure. 4**.

An optimised asymmetrical barrelled running surface enables low lubricant consumption as the additional angle on the running surface prevents the upper edge of the ring coming close to or touching the liner and transporting oil upwards into the combustion chamber, **Figure. 5**.

Ring Sealing surfaces

Piston rings don't only seal the sliding surface against the cylinder liner. Sealing of the ring bottom surface

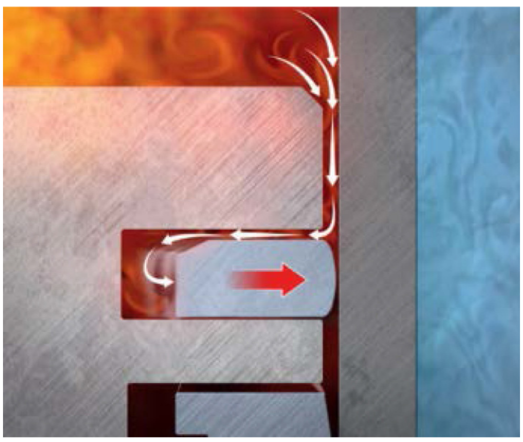

Figure. 3: Increase in compression pressure during combustion (2)

Figure. 4: Gas pressure on a taper faced ring (2).

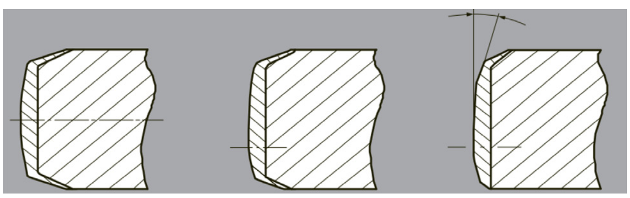

Figure. 5: Compression ring profiles (1)

Figure. 6: (a) Sealed groove (b) leaking seal during intake (c) leaking seal during compression (2)

> *To get a good oil film between ring and liner, rectangular cross section rings with flat running surface (with chamfered edges) were normally used*

against the groove bottom surface is equally important to seal of the rear side of the ring, **Figure. 6(a)**. Without this, oil or combustion gases can pass by the ring via the rear side of the ring.

Dirt or wear of the groove bottom/top will result in leakage of gas and oil transfer. The unevenness of the grove does not allow proper sealing, and the greater groove height allows the ring to move more freely. The ring lifts easily off the grove bottom and allows greater leakage **Figure. 6 (b) (c)**. Hence it is not helpful to fit new rings in worn grooves. Considering the importance of the groove bottom surface for sealing, when measuring ring groove clearance, insert feeler gauge in the top gap.

Ring conformance with liner (3)

Deviations from cylindricity of cylinder liners cause local variations in the contact pressure between the piston rings and the cylinder. The wear of the cylinder liner and the likelihood of bore polishing and piston ring scuffing are likely to be higher on areas subjected to higher contact pressure. In the case of severe out-of-roundness, areas of particularly low contact pressure between ring and liner are subjected to increased risk of combustion gas blow-by.

> *Deviations from cylindricity of cylinder liners cause local variations in the contact pressure between the piston rings and the cylinder*

Piston and Piston Ring Movements

Primary movement

The primary motion of the piston rings is equal to the reciprocating piston motion. Piston and ring speed varies as per crank angle, from zero at TDC and BDC, to top speed at mid-stroke. The piston ring acceleration influences the phenomenon of ring lift.

The secondary motions of the piston are caused due to the clearance between the piston and cylinder liner that allows lateral movements and tilting of the piston according to the forces and moments acting on it. These too effect the piston ring movements (3).

Secondary Movements

The piston ring secondary motions can be divided into ring motion in the radial direction, ring rotation, ring lift, and ring twist. These types of motion result from different loads acting on the ring, such as inertial loads arising from the piston acceleration and deceleration, oil film damping loads, loads owing to the pressure difference across the ring, and friction loads from the sliding contact between the ring and cylinder liner, **Figure. 7**.

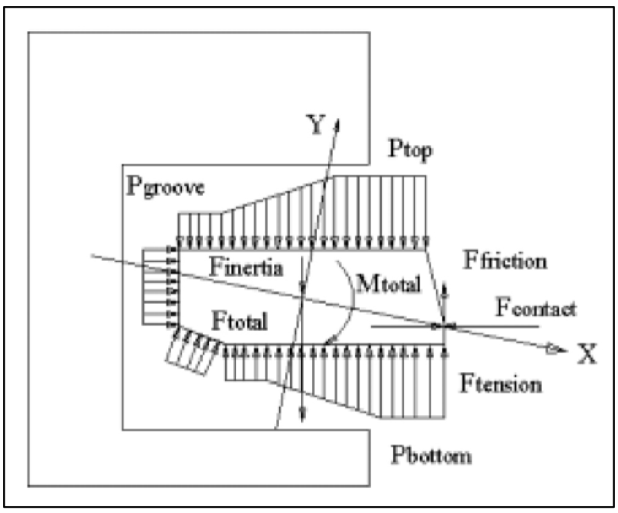

Figure. 7: Forces acting on piston ring (3)

Radial Ring Movement

The rings do not move radially forwards and backwards. Rather, it is the piston that changes the bearing surface from one liner wall to the other side of the of the liner bore, due to its reversing movement at TDC and BDC. This leads to the relative radial movement of the ring within the piston ring grooves, **Figure. 8**.

Ring rotation

To run-in and seal properly, piston rings must be able to turn in their ring grooves. This ring rotation is created the piston rocking motion in the TDC and BDC region. Honing cross-hatching also aids ring rotation, **Figure. 8**.

Axial movement

Ideally the rings should always remain in contact with the bottom groove side. This seals the ring against passage of gas or oil on the rear side of the ring, **Figures. 6 (b)** and **(c)**. The upstroke and down stroke of the piston and reversal of direction causes inertial forces to lift the ring from the bottom groove side. An oil film in the grove can dampen this movement. However, if groove is worn and ring clearance is excessive, the ring lifts off the groove base and can cause ring flutter, **Figure. 9**.

Sealing effect is lost. In the intake cycle, if the down stroke of the piston and resulting vacuum in the combustion chamber lifts the rings of the groove base, the oil will be sucked past the bottom and rear side of the ring into the combustion chamber, **Figure. 6 (b)**. Excessive oil consumption will result.

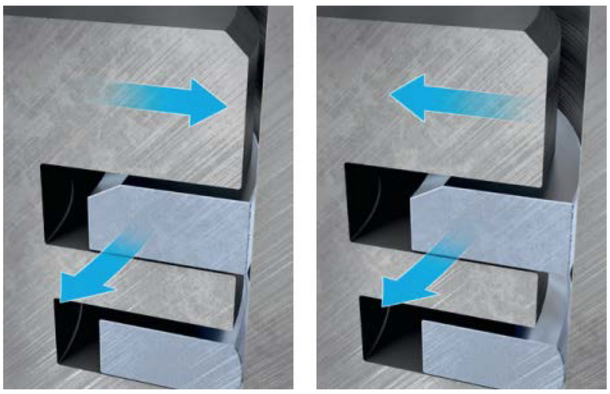

Figure. 8: Radial movement and ring rotation

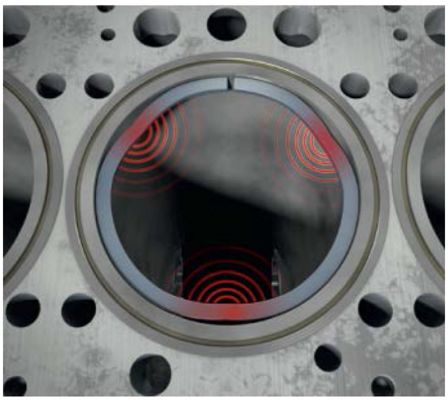

Figure. 9: Ring flutter due to lifting of the ring from the sliding surface.

Since the ring grooves and their surfaces are a critical part of the piston sealing system, affecting the blow-by of the combustion gases and the oil consumption, the surfaces of the flanges must be machined to very high accuracy and finish. To improve wear resistance of the piston grooves in heavy oil burning engines, the grooves are either induction hardened, or chromium plated. The bottom face of the top compression ring is also often coated in heavy duty engines, see **Figure. 13**, top ring.

Ring Twist

As a result of inertial forces and excessive ring height clearance, twisting of the ring about its centre can occur, Fig. 11. The ring twist affects the access of the gas pressure flow behind and between the piston rings, which causes non-uniform contact pressures and reduced conformity. By twisting, different sections of the face surface of the ring alternate to form the ring/liner contact, and this leads to a non-uniform contact pressure, that affects the operation of the ring, the oil film formation and the friction between the ring and the liner, the wear of the ring and cylinder liner, and the blow-by across the ring pack.

Oil Control Ring

Oil control rings distribute oil on the liner wall and scrape the surplus oil from the liner wall. Oil rings usually have two scraping lands. The scraped oil from the top scraper is drained out of longitudinal slats or bores between the ring lands to rear of the ring, **Figure. 11**. This scraped oil is usually guided to the inner side of the piston through bores so that it can drain back to the sump.

Lubrication of Piston Rings

Oil is needed at the piston ring and liner interface to provide a lubricant film to reduce friction, prevent wear, and transport heat from the piston and the ring-liner interface. The oil is also needed in the ring groove for preventing the ring from sticking to the groove. The oil film should be thick enough to avoid scuffing or bore-polishing, but not so thick as to escape into combustion chamber and burn up.

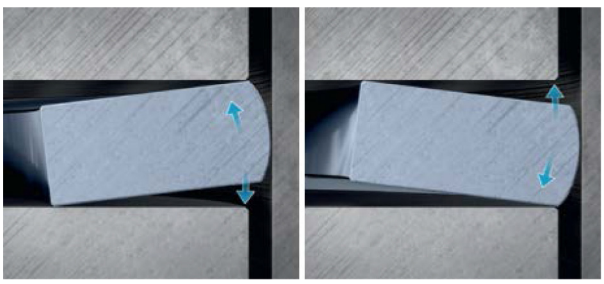

Figure. 10: Ring twist

Figure. 11: Oil control ring (2)

In TPE** oil is supplied to the piston and piston rings from the crankcase, directly or indirectly. The oil supply method usually depends on the size of the engine and on the required amount of oil. Smaller, high-speed engines use splash lubrication. Larger engines have the oil supplied to the piston from the main bearing or bearings to the crankshaft, connecting rod, gudgeon pin. Oil escaping from the ends on the gudgeon pin, and the splashing of oil dropping from the piston inner side by the con-rods, lubricates the liner and rings.

In XHDE*, and large TPE, cylinder lubrication lubricates the ring pack.

Lubrication Regimes and Friction between Rings and Liners

The ring-pack area experiences different friction and lubrication regimes according to oil availability in the ring pack; lubricant properties; viscosity; radial tension of the ring; gas pressures; the running face profiles of the ring; engine speed; liner and land temperatures; and surface texture.

> *Where oil availability is low owing to less oil supply or oil is forced away from the ring surface area due to strong gas forces over the ring, or at start-up, oil starvation can occur*

At mid-stroke where the piston ring sliding velocity is high and gas pressure on the rear of the ring is low, normally hydrodynamic lubrication prevails, so long as there is enough oil available at the leading edge of the ring. Around the TDC and BDC regions, where the speed is lower and/or the pressure on the rear of the ring is high, conditions favour mixed lubrication, with an additional lubricant film squeeze effect at the dead centres.

Recent theoretical and experimental work indicates the possibility of elasto-hydrodynamic lubrication also playing a role, especially in the case of highly loaded top compression ring in the expansion stroke. The top ring elastically flexes its shape in the cylinder/line bore due to the combined action of gas pressure, ring tension, lubricant reaction, and oil friction during the reciprocation of the piston assembly. In such a scenario, the hydrodynamic action may be elasto-hydrodynamic in nature, not out of elastic deformation of the contacting parts due to extremely high concentrated contact as occurs in ball bearings, but because of the global deformation of the flexible compression ring. As

> *Larger engines have the oil supplied to the piston from the main bearing or bearings to the crankshaft, connecting rod, gudgeon pin*

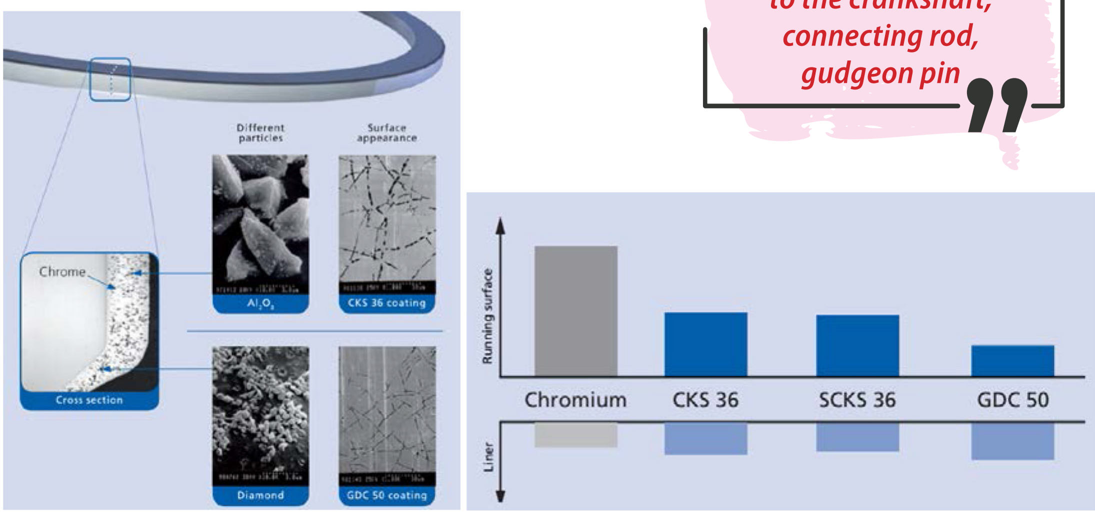

Figure. 12: Chrome-ceramic (CKS), and Chrome- diamond like carbon (GDC) coating structure and running surface wear of different coatings (1)

piston ring reciprocates, a wave of compression ripples up and down the liner. Combined with the effect of pressure on oil viscosity (Refer to Viscosity-Pressure Coefficient α, in LM 9), this enhances the oil film thickness at the ring-liner interface by EHD (4).

Where oil availability is low owing to less oil supply or oil is forced away from the ring surface area due to strong gas forces over the ring, or at start-up, oil starvation can occur. Increasing speed increases the oil film thickness to certain level, after which, the speed is too high for the oil film to withstand. Under such conditions boundary lubrication provides protection. Anti-wear additives like ZDDP, friction modifiers like molybdenum dialkylthiocarbamate (MoDTC) and Ca-additives that may form wear-resistant layers of $CaCO_3$. control wear in the boundary friction conditions.

Oil film thickness studies have indicated minimum values in the order of 0–2 µm just after the TDC and BDC, and maximum values in the order of 5–20 µm in the mid-stroke region.

Ring Coating

Important requirements of piston ring material are high resistance to wear and corrosion, and low drop in elasticity at high temperatures. Grey cast iron is the main material used for rings. From a tribological point of view, the grey cast iron is beneficial, as the dry lubrication effect of the graphite phase of the material can help under conditions of oil starvation. Furthermore, the graphite phase can act as an oil reservoir that supplies oil at start-up or similar conditions of oil starvation.

Coatings for rings are widely used, especially for compression rings. The most widely used coating is chrome-ceramic, used in abrasive and corrosive conditions, where running conditions are severe, **Figure. 12**.

Recent developments in coatings include structured chrome-ceramics (SCKS); plasma sprayed molybdenum, metal composites, metal-ceramic composites (e.g., Cermet used in MAN engine rings), or ceramic composites. These may be applied as a uniform coating or an inlay coating material. Physical vapour deposited (PVD) coatings, are also used for increased wear and scuffing resistance.

Current ring packs

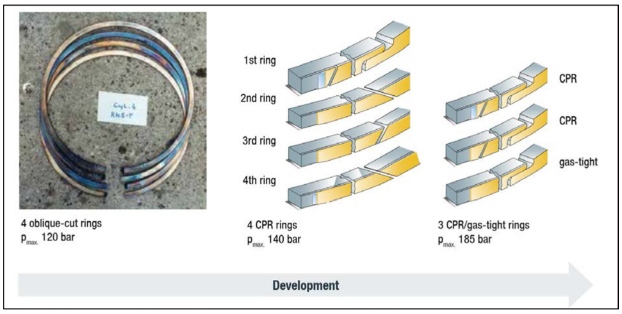

Figure. 12: 2-Stroke slow speed crosshead engine ring pack development (MAN) (5)

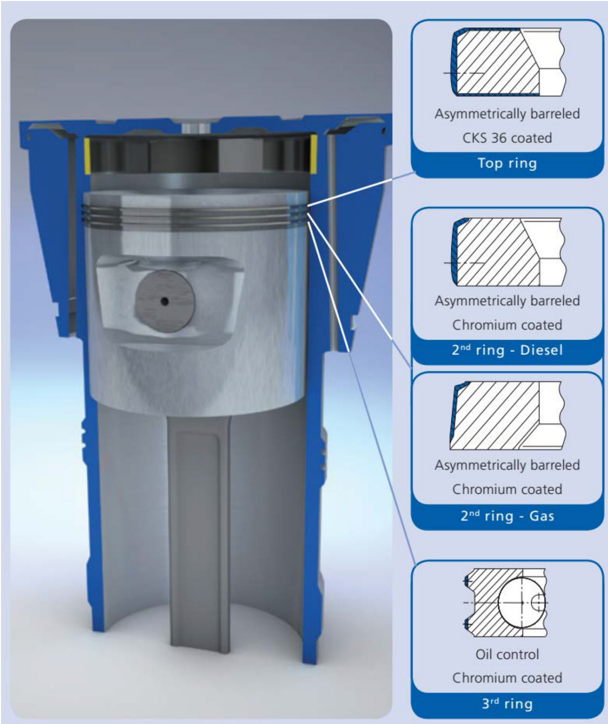

Figure. 13: Ring set for 4-Stroke TPE (1)**

Conclusion

The piston rings are critical components in IC engines and separate the hostile conditions of the combustion chamber from the crankcase. Their optimum tribological performance is crucial to minimise frictional power loss, fuel consumption, oil consumption, blow-by and harmful exhaust emissions.

*XHDE = Crosshead Engine

**TPE = Trunk Piston Engine

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About the author

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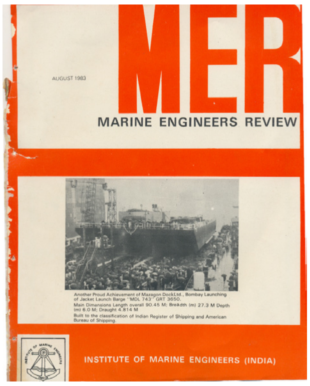
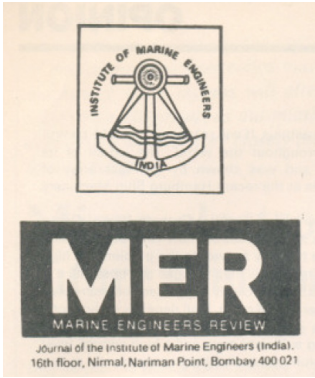
GOING ASTERN INTO MER ARCHIVES





MER... Four decades back... The August 1983 Issue

The issue's Editorial talks about another dual-class deal between IRS and BV. IRS has come a long way since establishment in 1975 in logging tonnage and engaging in research. This is followed by a lament on rising costs of cadet training and the conducive status of training in Philippines. A suggestion to go for a training ship, it says (should be run by a commercial enterprise, it says).

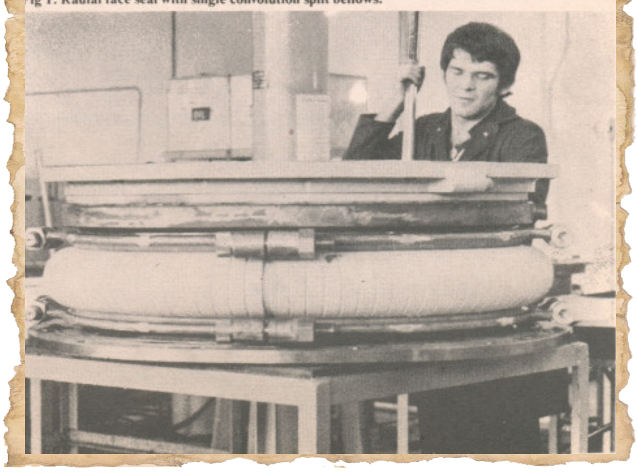
The first article goes for a shaft generator on a Sulzer super long stroke engine.

The next one is on an ever-interesting topic of stern tube seals. The discussions include comparison of lip and radial face seals, materials, cooling for seals etc. Two photos are inserted. We may reflect upon the design of the rope guard.

The next one is again a short, one-page technical note of propeller selection. A few points for reflecting upon (from the note) on optimum propeller diameter and speed for CPPs:

1. Maximum propeller diameter is influenced by maximum draft and the shape of the hull.
2. Propeller Efficiency: Depends on propeller and hull efficiency; poor hull efficiency can affect adversely.
3. Propeller of equal diameter (FPP?) at less diameter and speed will reduce vibration and noise.

Fig 1: Radial face seal with single convolution split bellows.



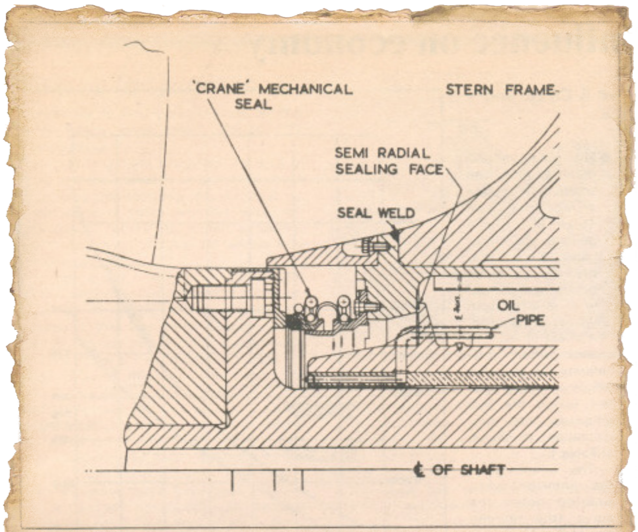


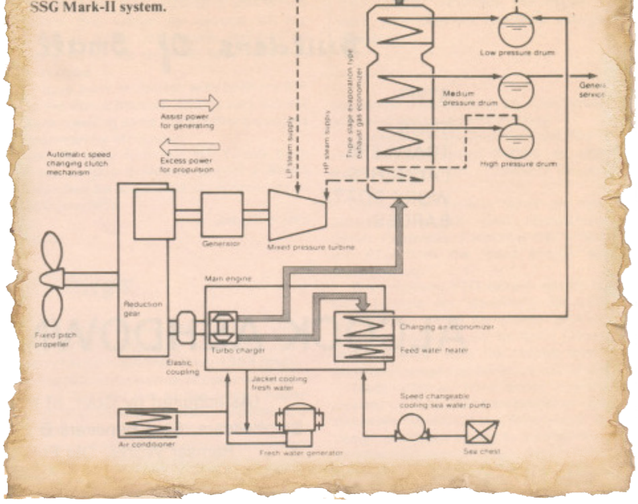
Fig 2: Example of a well-designed rope guard.

There is one write-up on plain shaft bearings and thrust bearings.

Another interesting find is the article on nuclear propelled merchant ship. This talk has gained currency and in the present times, there are talks on Molten Salt Reactor (salt being used for cooling) types and thorium based plants (weaponisation scope being less) being fitted on ships.

The POSTBAG has two letters of interest, one on bacterial attack on lube oils and another on engine driven pumps. Attention is drawn to the mention of a scoop cooler. If anyone has worked on scoop coolers/ condensers, they may share the experience in the MER pages.

Schematic design of the SSG Mark-II system.



The NEWSDESK carries an item on a super-economy bulk carrier. The arrangement is shown in the figure for you to work out how the system extracts the heat in a better fashion. Some would have sailed on such improved systems.

The NEWBUILDING has a training ship (supposed to be the largest at that period) launch which operates as a bulk carrier. With a grain capacity of 1238000 cu.ft., the vessel has a provision for 240 senior officer trainees, 30 senior officers (Chief Engineers/Masters). Machineries: B&W LGF + B&W-Holeby Gensets, Aalborg Boilers etc. (typical of any ocean going bulk carrier). Anyone seen, worked on this vessel?

POSTBAG

Subsidies and safety

Sir,
I read with some considerable interest Opinion's comments upon the various utterances of Mr I Sproat (MER May).

One comment from me: Why did not Opinion remark upon foreign subsidies for foreign ships? Does not this practice effectively negate all efforts on the part of the British ship operators to compete?

I now refer to an item in a national newspaper criticising Mr I Sproat's attitude to the safety of sea-going personnel, and of the revised regulations concerning this important matter. Could MER comment?

B P J Murray
W Sussex

Mr Murray is right to point our our omission to state that some foreign owners get subsidies which make them more competitive than UK ships. However, we have mentioned this fact many times in the past and Mr Sproat is only too aware of it, but still he does little to offset the imbalance!*

The second point Mr Murray makes concerns revised safety regulations, much of which is covered in the following letter by Capt Briand—Editor. (*Mr Sproat has now been replaced as Under-Secretary for shipping by Mr D Mitchell—see August 'Bulletin').

More foreign crews?

Sir,
I read with some concern your editorial comment (May MER) concerning the proposed actions of our Junior Trade Minister, Mr I Sproat.

Whilst quite rightly drawing attention to the petty contributions proposed by the Minister and their general ineffectiveness in reducing the decline of the British fleet (another 126 ships in the past 12 months), you omitted any mention of the following: 'In a completely unexpected and ominous development, Mr Sproat has announced that British Safety Regulations will no longer apply to UK flag ships bareboat chartered to foreign operators. He has also rejected DoT regulations for safe movement about ships'.

It may be worth defining the term 'Bareboat (or Demise) Charter'. As the name indicates, the shipowner hires out the "bare boat" and the charterer is responsible for appointing the staff and crew and has complete control of the vessel as if it were his own. All costs and expenses in running the ship are for the charterer's account.

So the above definition, coupled with Mr Sproat's announcement mentioned above, makes, I would submit, a very lethal package.

It also makes a convenient political answer for Mr Sproat in the long term as he will be able to submit statistics showing a growth in employment of British Flag vessels whilst conveniently not disclosing the fact that British sta'f and crews are no longer employed. Or have I got it completely wrong?

I would be very grateful if you would publish this letter as several of my colleagues show remarkable lethargy in waking up to the fact that their very jobs are at stake.

I have been in contact with both my MP and the Prime Minister on this very subject and concerning some of the other proposals announced by Mr Sproat.

In the reply from the MP I have been invited to give evidence, should a Select Committee be appointed. So it does pay to lobby your MPs.

John P Briand
Master

Oil bugs

Sir,
I read with interest Mr Lamb's article 'Infection of lubricating oils: some cases and remedial measures' (May 1983 MER).

Regarding the source of contamination, I believe that fuel can be the carrier. Apparently, after leaving the sterile conditions of the refinery all hydrocarbon fuels become subject to mild airborne or waterborne contamination. These micro-organisms exist rather harmlessly in moisture-free fuel. The presence of a small amount of water, however, and odd stagnant areas in the system provide conditions for any micro-organisms present, to metabolize.

The reported increase in bacterial attack is, I believe, related to the increase in the amount of fuel held under unsatisfactory long-term storage conditions. This applies to vessels laid-up and is a major problem with unsold petrol and diesel road vehicles.

B Wedderburn
Conservation Systems Ltd,
London SE20

Main-engine-driven pumps

Sir,
I read with interest Mr J E Church's proposals regarding main-engine-driven pumps (MER April 1983).

As Mr Church states, the principles involved have been well proven in the past, and are still virtually universal on medium and high-speed diesel installations. However, I would like to comment on some of the points raised.

Concerning the section on 'Requirements': the after end of the engine need not be congested if the engine room is suitably designed. Two statements appear to be contradictory, eg, 'engine driven pumps must operate continuously during manoeuvring and 'transfer of drive from main engine to electric . . . whilst manoeuvring . . . must be fully automatic'.

If one assumes that the normally engine-driven pumps are electric-driven during warm up etc, why not use the entirely independent electric pumps on these occasions? This is fairly common practice with medium-speed installations.

Furthermore Mr Church stated 'The PTO must be sufficiently flexible to absorb sudden acceleration . . . without the use of clutches'.

Clutches of various types are readily available, reliable, and comparatively cheap. Personally, I would prefer to isolate the PTO from the main engine whilst manoeuvring.

The proposed PTO system seems to be very suitable for retrofitting to existing engines, but surely the greater part of the economic savings will be lost? Once the ship has been built, the money spent on duplicate pumps can hardly be recovered.

Most engines have some system of gearing or chains and sprockets to drive a camshaft. I believe it would be easier at the design-and-build stage, to arrange for one or more high-speed PTOs to be available.

Many medium-speed diesels have pumps sized so that they can operate from about half to full-speed with direct-coupled lube oil jacket water and seawater pumps. Only the lube oil pump needs to be oversized because, as engine revolutions drop then so does the power, and thus the need for cooling is also reduced.

A similar system could eliminate the need for the engine-driven pumps to be driven electrically at engine slow-down. If necessary the independent pumps could be started automatically. The independent and engine-driven pumps could be permanently open to their respective systems via non-return valves.

The proposed battery bank would need to be very large to be able to supply an emergency fire pump for any significant period of time, and possibly an air compressor and/or steering motor as well.

The capital cost of the battery, duplicated dc switchboard and cabling, is likely to be high. It does not seem to be included in the budget assessment.

If the vessel is to run independent of the electric power supply, the air compressor and steering motor could be powered from the PTO.

There is the possibility a further economy could be made by eliminating a continuously driven seawater pump with the use of a keel cooler or a 'scoop' supplied cooler. It is appreciated both these methods have disadvantages that may outweigh the benefits.

Although the fore-going appears critical of main engine-driven pumps, I hope the criticism is constructive. In principle I agree with Mr Church that this method can offer significant economies.

P E Pratchett
Hakes Bay,
New Zealand

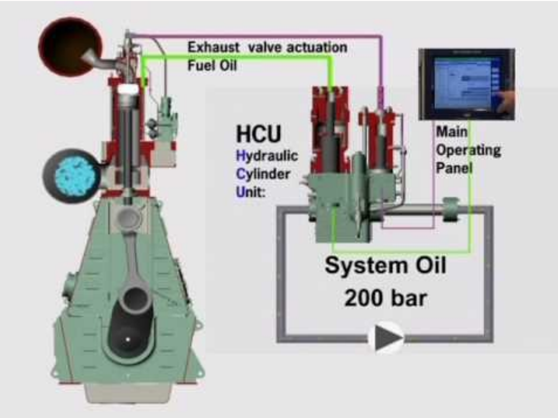
The Editor reserves the right to edit, and shorten reader's correspondence.

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

MASSA Maritime Academy, Chennai

The Institute of Marine Engineers (India)

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



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

Course Aims and Objectives:

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

Coverage / Program Focus:

This course deals with the following training areas:

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

Entry Requirement / Target Group:

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

DATE & TIMING	:	**29th, 30th, 31st August 2023 / 26th, 27th, 28th September / 25th, 26th, 27th October 2023 | 8:00 am - 4:00 pm IST**
VENUE	:	Web Platform / Zoom. **APPLICATION LINK:** https://forms.gle/e4As7kCucR5xoJBm9
REGISTRATION & PAYMENT	:	Rs. 15,000/- /- per participant – inclusive of taxes. For IME(I) Members 13,500/- per participant - inclusive of taxes. Payment to be made to: https://imare.in/buy-online.aspx (Under Category - Value added Courses) *10% discount available for IME(I) members*
FOR MORE INFORMATION	:	**@IME(I) - email:** training@imare.in, Ms. Anukampa **(M)**. 9819325273, **(T)** 022 27701664 / 27711663 / 2771 1664. **@ MASSA Maritime Academy Chennai - email:** mmachennai@massa.in.net Ms. Saraswathi, **(T)** 8807025336 / 7200055336 .

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

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