Students’ Edition of BRINICLE
in Collaboration with
IIRE JOURNAL
of
MARITIME RESEARCH & DEVELOPMENT
(IJMRD)

ISF Institute of Research and Education (IIRE)

MARCH 2019
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Maritime sector has always been influencing the global economy. Shipping facilitates the bulk transportation of raw material, oil and gas products, food and manufactured goods across international borders. Shipping is truly global in nature and it can easily be said that without shipping, the intercontinental trade of commodities would come to a standstill.

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

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ABOUT INDIAN MARITIME UNIVERSITY – MUMBAI PORT CAMPUS

Indian Maritime University – Mumbai Port Campus comprises of two premier institutes, Lal Bahadur Shastri College of Advanced Maritime Studies and Research (LBS CAMSAR) & Marine Engineering and Research Institute (Former D.M.E.T.). LBS CAMSAR is the post sea training institute whereas MERI Mumbai is the pre – sea training institute.

LBS CAMSAR was founded in October, 1948 under the recommendations of the Merchant Navy Training Committee as Central Government premier post sea training institute for Merchant Navy Officers of Navigation & Engineering. And since then, it is offering the comprehensive range of courses for Merchant Navy Officers.

Marine Engineering and Research Institute (M.E.R.I.), formerly known as Directorate of Marine Engineering Training (D.M.E.T.), was established in the year 1949 by the Govt. of India, when the need was felt to train Marine Engineers separately. And since then, it is imparting the education and training to the cadets with a goal of producing the best marine engineers and nautical officers for the world with adopting the latest technology to meet the latest and demanding requirements of the shipping fraternity.
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MESSAGE FROM THE CONVENER

It is very heartening to note that Indian Maritime University – Mumbai Port Campus (Marine Engineering & Research Institute) is organizing a two days Technical Fest Brinicle in association with Maritime Training Trust, D.G Shipping on 28th & 29th March, 2019. This fest is an initiative taken by Maritime Training Trust with an objective of enhancing the maritime knowledge of the participants and to provide all the stakeholders of Maritime Industry an opportunity to gain a great deal of insight into the “emerging technologies”.

I am thankful to IIRE Journal of Maritime Research and Development for collaborating with us. It is pleasing to note that the twelve accepted papers dwell on maritime subjects ranging from Artificial Intelligence, IoT, Inland waterways in India, Sustainable Development, which will dominate the industry in the coming years.

As the success of the event depends ultimately on the people who have worked in planning and organizing it, so I would like to thank the members in all the committees for their great efforts on this success.

Hare Ram Hare
Convener, Brinicle
Editorial

IIRE efforts to ingrain culture of research continues unabated.

A specific seminar is planned in March 2019 at Mumbai bringing researchers, industry and academia together to discuss and highlight the importance of research in the maritime sector.

Yet another opportunity arose when the Indian Maritime University – Mumbai Port Campus invited IIRE to collaborate in the presentation and publication of research based papers of their young cadets pursuing graduate maritime courses. Twelve papers were selected after a process of review which are now being published in a Special edition of the IIRE Journal of Maritime Research and Development. It was heartening to see papers dwelling on some contemporary themes like, Technology inroads into shipping, Sustainable Shipping, Coastal & Inland Waterways that is finding lot of thrust in India. Block-chain technology, Artificial intelligence, Energy efficiency are the areas covered in some of these selected papers. Papers chosen for publication in the Journal was the reward propagated and this brought in much encouragement and healthy competition. The moot idea was once again to engrain the discipline of research in the impressionable minds of the young cadets finding their sea-legs in a dynamic and highly operationalized and challenging shipping environment.

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METHANOL AS SHIP FUEL AND ONBOARD CCS

Sahil Kazi
Shitanjal Srivastava

Abstract
We live in a world where we are addicted to fossil fuels. We use them to power our ships, to make electricity, to make plastic and so on & eventually contributing to the greenhouse-effect which threatens our world. This paper is regarding the usage of METHANOL as ship fuel. A detailed comparison has been done between four of the available technologies which will unfasten the ships from its restrictions. There will also be a discussion on capturing & storing of carbon dioxide onboard which will be later on converted to Methanol

1. INTRODUCTION:

IMO - The 2020 Global Sulphur limit:

IMO has set a global limit for sulphur in fuel oil used on board ships of 0.50% m/m (mass by mass) from 1 January 2020. This will significantly reduce the amount of sulphur oxide emanating from ships and should have major health and environmental benefits for the world, particularly for populations living close to ports and coasts.

Four technology variants are investigated:

- Scrubber
- WHR
- LNG System
- Methanol System with WHR
2. **SCRUBBER:**

It is a large piece of equipment fitted in the exhaust system of the ship and is mainly designed to water wash the exhaust gas. It uses sea water or fresh water mixed with caustic soda and sprays it over the exhaust gas containing Sox which gets converted into sulphuric acid. It is designed with a holding tank for zero discharge which stores the sulphuric acid. This mechanism cuts off the Sox emission.

**Challenges:**
- It requires a huge amount of money to install onboard
- High maintenance required
- It does nothing about CO2 emission
- It cuts either Sox or NOx at one time which means that it will not be able to cope up with the long-term IMO regulations

3. **WHR- WASTE HEAT RECOVERY:**

Fuel is burnt in the engine and the exhaust goes out of it. Although the energy from fuel released in the engine is already used by the engine, but the heat is still there in the exhaust. Now this heat in the exhaust can be used to heat the water and generate system.

- The smoke passes through a “WATER TUBE BOILER”. The heat is taken by the water in the tubes and steam is generated. This steam than comes to STEAM DRUM and from there it is used for different purposes.
- From the steam drum it is passed through a set of regulator and finally reaching to a steam turbine and with this steam turbine, alternator is attached which generates electricity
- When the engine runs at a higher rpm, let’s say 60+ there is so much exhaust generated that it is too much to be used for steam generators. So this excessive exhaust is passed through a gas turbine which is attached on the same shaft as steam turbine
This system also has shaft *generator and motor* combination. It acts as generator when steam turbine is not generating enough electricity as per the consumptions and acts as motor when there is excess of electricity produced by the turbine. When it acts as motor, it helps the shaft of the engine to turn, thus deducing load in engine and less fuel consumption.

So WHR is a very intelligent system which works together and the kind of efficiency this system has is really excellent.

**Challenges:**
To make it run, you need additional pumps, condensers, regulators and other more things.

**Advantages:**
- Reduced carbon footprints as only main engine is consuming fuel
- Number of auxiliary machinery can be reduced like generators

MAERSK, MSC etc. has already installed WHR on their ships.
4. LNG TECHNOLOGY:

Modelling Assumptions:

The MAN B&W ME-GI (Gas Injection) engine series is best in terms of engine performances like output, speed, thermal efficiency etc. The control concept of the ME-GI engines comprises of 3 different fuel modes –

- **Only fuel mode**: when maneuvering or when no gas fuel is available, the engine is run on conventional fuel system
- **Only gas mode**: constant gas injection when enough and constant gas supply is available, with fuel oil quantity for injection depends upon engine load
- **Fuel and gas mode**: both oil and gas fuel is used in the cylinder liner with oil fuel about 6-8 % depending upon the load of the engine

FUEL PRICE SCENARIO:

![Fuel Price Scenario Graph]

- HFO 2.7% S
- MGO 0.1% S
- LSHF 0.5% S
- LNG

<table>
<thead>
<tr>
<th>Year</th>
<th>Fuel Price Scenario</th>
</tr>
</thead>
<tbody>
<tr>
<td>2010</td>
<td>10 USD/mmBTU</td>
</tr>
<tr>
<td>2015</td>
<td>15 USD/mmBTU</td>
</tr>
<tr>
<td>2020</td>
<td>20 USD/mmBTU</td>
</tr>
<tr>
<td>2025</td>
<td>25 USD/mmBTU</td>
</tr>
<tr>
<td>2030</td>
<td>30 USD/mmBTU</td>
</tr>
</tbody>
</table>
MGO and LSHF are expected to increase faster than HFO and LNG with stronger increase in demand. The starting year for the fuel price scenario is 2101 and 650 USD/T (=15.3 USD/mmBTu) for HFO and 900 USD/T (=21.2 USD/mmBtu) for MGO are set. LNG is set at 13 USD/mmBTu which includes small scale distribution costs of 4USD/mmBTu. It is assumed that distribution cost doesn’t increase over time.

**BENEFITS:**

- A low carbon content of LNG compared to traditional ship fuels enables a 20-25% reduction of CO$_2$ emissions.
- LNG is expected to be less costly than MGO which will be required to use within the ECAs if no other technical measure is implemented to reduce Sox emission.

**CHALLENGES:**

- BUNKERING of LNG
- More space needed on board for storage
- High skilled personnel’s required
- High maintenance required

5. METHANOL TECHNOLOGY:

**Modelling Assumptions:**

The MAN ME-LGI (Liquid Gas Injection) two stroke engine is capable of dual fuel operation according to the diesel cycle. The engine is based on the proven concept of ME-GI engine series concept that has been developed since early 90s and is used on both sea and land. When operated in Gas or Methanol a burst of pilot fuel is used to initiate the combustion. The cylinder head is fitted with two fuel oil valves and two gas valves that can be exchanged for valves suited for methanol. A common rail system is used to supply gas and oil-controlled valves is used to control the injection timing. Similar to high compression diesel the risk of methanol contamination is very low as the fuel is injected to the ongoing combustion.
FUEL PRICE SCENARIO

EUROPE - 419 euro / MT
UNITED STATES - 485 USD/MT
INDIA - 500 USD/MT

Current price of methanol in India is INR 25-27 per liter which is costlier than what we buy from other countries. It is estimated that a 1600 tons per day of methanol plant will require a capital expenditure of approx INR 1200 crores which would be able to produce methanol at INR 17-19 per liter which is comparable with the cost of imported Methanol. We will talk about the mass production of Methanol in India in later part of this paper.

BENEFITS:
• Fulfils SECA regulations (Sulphur Emission Control Areas)
• It is highly available in chemical market- today in surplus.
• It can be used with high efficiency in Marine diesel engines after minor modification using a small amount of pilot fuel (dual fuel)
• Lower risk of flammability
• Higher octane number fuel

Methanol produced from natural gas, together in one process and used in ship fuel would achieve twice overall CO2 emission reduction obtainable from the use of biomass alone.

6. DETECTION OF HARMFUL GASES IN ATMOSPHERE:

A team of researchers from the Indian Institute of Science (IISc) have developed a novel sensor to detect harmful gases in the atmosphere. The sensor, which can catch a single nitrogen dioxide molecule among millions of other molecules, is one of the most sensitive in the world. Also, unlike other NO2 sensors, which perform at high temperatures, the new sensor works even at room temperature.

An optical fibre is usually used for communication purposes, but by ingeniously modifying its clad, we are able to use it in different applications like gas and bio sensing.

7. CONVERSION OF CO2 TO METHANOL:

Scientists have developed a new catalyst that uses a special formulation of palladium and copper. This process is carried out by ARTIFICIAL PHOTOSYNTHESIS.

**Artificial Photosynthesis:**

A replicating natural photosynthesis system we could convert the energy from the sun into fuel. This would be open up a whole new world of renewable energy opportunities for us. However, we soon run into a few challenges. The natural photosynthesis system is very complicated at a molecular level.
The Process of Artificial Photosynthesis:

It consists of four steps and is aimed at mimicking natural photosynthesis:

- **LIGHT HARVESTING** – trapping light particles or photons and concentrating their energy in the reaction centre.
- **SEPARATION OF CHARGE** - In the reaction centre, sunlight is used to separate the different electrical charges: positive ‘holes’ and electrons.
- **SPLITTING WATER** - the positive charges obtained from the charge separations are used to split water into hydrogen ions (protons) and oxygen.
- **FUEL PRODUCTION** - The easiest way hydrogen gas can be made on the surface of the noble metals such as platinum. However, scientists are busy looking for a substitute as noble metals are expensive and scarce, and therefore difficult to commercialize. As we said, at this point the production of S2 gas is main focus.

\[
\begin{align*}
2H^+ + 2e^- & \rightarrow H_2 \\
CO_2 + 2H^+ + 2e^- & \rightarrow CO + H_2O \\
CO_2 + 2H^+ + 2e^- & \rightarrow HCOOH \\
CO_2 + 4H^+ + 4e^- & \rightarrow HCHO + H_2O \\
CO_2 + 6H^+ + 6e^- & \rightarrow CH_3OH + H_2O \\
CO_2 + 8H^+ + 8e^- & \rightarrow CH_4 + 2H_2O 
\end{align*}
\]

This is partially an artificial production of the Calvin cycle.

*But now the challenge rises that how can we capture and store carbon dioxide onboard...???

8. **ONBOARD CCS – CARBON CAPTURE & STORAGE:**

Carbon capture and storage is a complex, emerging process currently being put through its paces at various pilot power plants around the world. In its originally intended form, the basic CCS process involves the separation of CO2 from a fossil fuel power station’s post-combustion flue gas, removing its emission from the power generation cycle and transmitting it for storage or industrial use. If we can use CCS **onboard** than we will be able to separate CO2 from the exhaust gas and can store it so that we can convert it into Methanol again.
So the basic CCS process involves the separation of CO2 from the exhaust gas and transmitting it for the storage for conversional use.

The big challenges are that you have a limited amount of space onboard and of course constant movement of ship. It also creates a very strong requirement for extra safety and risk management.

We can place the CCS at the aft of the funnel, so behind the accommodation space of the vessel on a raised deck. Eventually it will be less risky and it will not take any cargo space.

9. CONCLUSION:

- In this paper we have been able to create a never-ending cycle where we cut off the emission of Sox and NOx using METHANOL system with WHR and the reduced
amount of CO2 is captured again by the CCS and taken to on land power plants where it is converted again to METHANOL and is used for fueling ships.

- Reducing emission of these gases also help in reducing many natural calamities like we recently faced – KERALA floods, which was caused due to the disturbance in weather cycle.
- Creating power plants and mass-producing METHANOL in India using CO2 will help in reducing its cost to 16-17 INR per liter.
- It will also help the MAKE IN INIDA initiative as power plants will be first set up in India which will help in prolonging the chain of employment.

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