

Fossil Fuels Combustion Challenges

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ABSTRACT

With globalization there is growing demand for energy which is scarce and about 90% of global trade is carried by sea. Fossil fuels are consumed to provide energy services and about 95% of human primary energy needs comes from fuels. Though the world is transitioning from fossil fuels to sustainable renewable energy sources, the demand for fossil fuels will continue for several decades. Meanwhile fuel prices are sky rocketing and increasing global warming awareness with the regulatory authority imposing globally more stringent restrictions on carbon emissions, finding efficiency in fuel consumption and effective emission controlling is becoming a daunting task. In the operation of a vessel fuel costs accounts to nearly 30% of the operational costs and for this reason fuel consumption is an area of grave concern. To maximize profits and to reduce environment impact, it is paramount for marine diesel engines to burn fuels efficiently and curtail the harmful carbon emissions. All companies are thriving to improve the efficiency of their vessels with an aim to lower the overall operational costs. In response diesel engines have to be operated cost-effectively and scrupulously maintained so as to keep the specific fuel consumption under control. To measure and monitor the performance of the diesel engine, indicator cards must be taken at regular intervals. Many new technological alternatives that can sustain are emerging from research to reduce fuel consumption, carbon emissions as well meeting stringent environmental regulations. There are several optimization measures like EEDI, SEEMP, and PMS enforced thru statutory authorities towards attaining fuel economy. Thus the measures encouraging application of fuel economy principles are the environmental concerns, economy effect and the regulatory authority framework.

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Introduction:

“It is extremely likely that human influence has been the dominant cause of the observed warming since the mid-20th century”. IPCC report on Climate Change

Fuels are dense repositories of energy that are consumed to provide energy services and about 95% of human primary energy needs comes from fuels. Fuels vary considerably in terms of energy, cost, density and environmental impact. When a fuel is combusted it undergoes some process changes and it gives a form of

energy. Fuels for combustion are extracted from crude oils mined from the earth through extraction process and these oils are known as mineral oils containing a large number of hydrocarbons with different boiling points.

Crude oil as such cannot be used as fuel for engines but many products are extracted by breakdown the heavier hydrocarbons to get lighter oils. The lighter oils like kerosene, gasoline, can be used as fuels to be burnt in diesel engines and some heavy engines can

burn residue oils known as heavy fuel oil. This heavy oil is a by-product of crude oil after extraction of light distillates products.

Fuels to burn in a diesel engine are largely influenced by the engine speed, design of the combustion chamber, compression ratio, injection timing, ignition quality and viscosity of the oil, as not all fuels can be used in any one engine. The general characteristics and properties of fuels for a diesel engine to be considered are flash point, viscosity, specific gravity, calorific value, carbon residue, chemical composition etc. Fuels used in marine environment are lower grade fuels, as ships and dredgers deploy massive engines to propel which consume huge quantities of fuel each day, they are forced to use low grade cheap fuel oils.

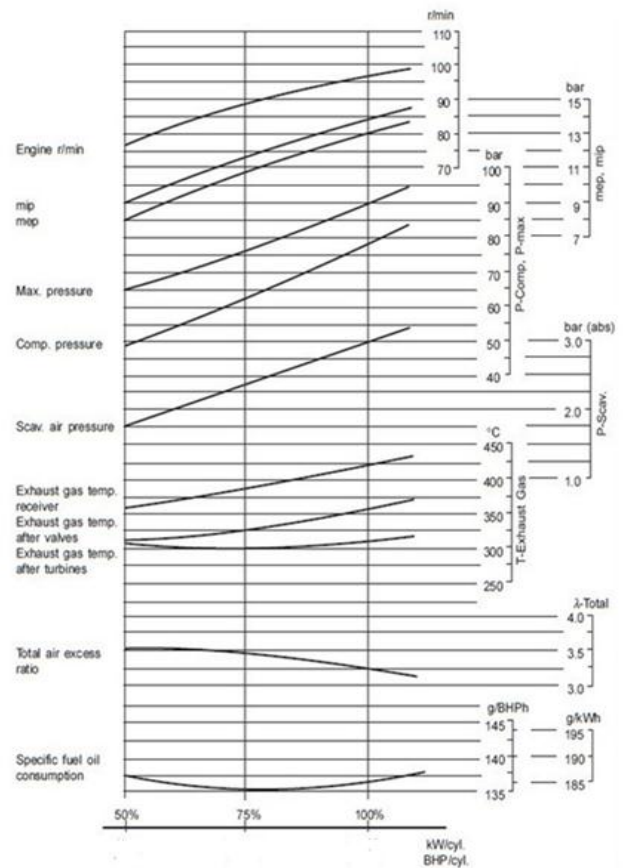
The fuel cost is the most important dynamic parameter for the operational cost of the vessel. In the operation of a dredger the costs involved per dredging one cubic metre of soil, fuel costs form a major share of the expenses. The fuel cost accounts for nearly 30% of the operational costs of a vessel, for this reason fuel consumption is an area of serious concern.

To maximize profits and to reduce environment impact, it is paramount for marine diesel engines to burn fuels efficiently and curtail the harmful emissions. Marine industry of the present times is gripped with two major concerns, one on reducing fuel consumption and the other for controlling carbon emissions.

In response to these major concerns diesel engines have to be operated cost-effectively and are to be scrupulously maintained so as to keep the specific fuel consumption to the minimum. An engine is said to be running smoothly or maintained well if it can be operated at the rated load and at the rated rpm. If ever there is mismatch between these two key parameters the engine is telling of the eminent problem either the engine is consuming more fuel or the engine is overloaded and both these conditions are not accepted in today's competitive and dynamic marine world.

As an important step to overcome these problems it is very pertinent to carefully study the engine manufactures sea trail data, engines shop trial data and various other data sources like performances curves of the engines. A good understanding of all these parameters will assist the engine operator to easily diagnose the problem with reasonable accuracy. A characteristic performance curve for an engine is appended below, the engine operator by super imposing the operational measured parameters on this performance curves will be able to infer a ton of information, and thereby he can identify the problem and can restore the engine parameters to the desired normal values. The performance curve shown below is for a two stroke engine, but even for a four stroke engine the difference is not much, in either case it will support the engine operator to detect and analyse.

Performance Curve for a Two Stroke Diesel Engine



From the above performance curve following information can be inferred,

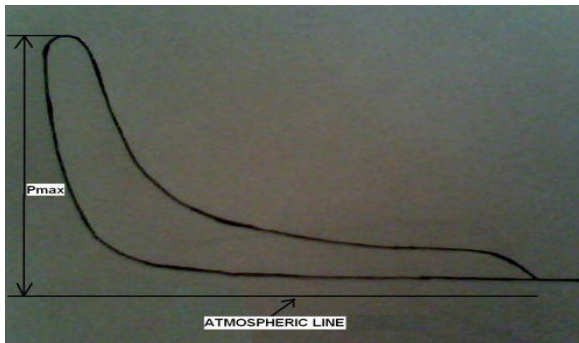
1. Maximum pressure developed inside the cylinder and this can be compared with the engine load as per engine manufactures sea trail data. This will indicate the working condition of the fuel injectors, fuel injection pumps, fuel timing, compression pressure inside the cylinder etc.
2. Compression pressure when compared with engine manufactures sea trail data will tell the condition of piston, piston rings, exhaust valves, bumping clearance.
3. Scavenge air pressure when compared with engine manufactures sea trail data will show that the super charging turbocharger and its associated equipment like the air cooler, scavenge valves or ports are in good working condition.
4. Exhaust gas temperatures when compared with engine load as per manufactures sea trail data will signify that proper combustion is taking place inside the cylinder with no after burn, fuel timing is proper, turbocharger working efficiently, scavenging is happening well in the engine.
5. Engine rated rpm with the engine load when compared with engine load as per manufactures sea trail data will ascertain whether the engine is overloaded or not at a given MCR for the engine.

6. Specific fuel oil consumption as per the engine load when compared with the manufactures sea trail data will manifest if the engine fuel consumption compares correctly with engine load.

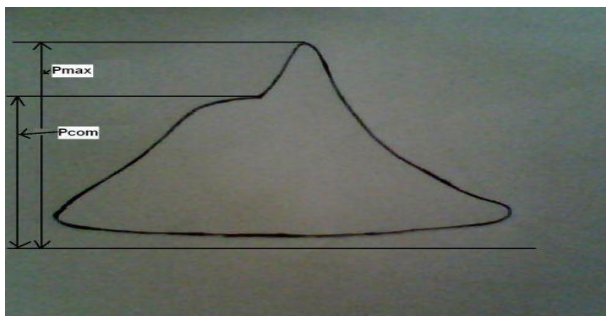
The diesel engine has to perform at the rated power and at the rated rpm within allowable limits of temperature, pressure and specific fuel oil consumption, but to determine and to interpret that information we have to measure the performance of the engine and the above performance curve can serve as a template. The power generated by the engine is directly related to the manner in which the fuel is burnt inside the engine. To better understand and to monitor the complete combustion process inside the cylinder, indicator cards must be taken at regular intervals of time. There are different types of indicator diagrams to indicate the power developed by the engine, to determine peak and compression pressures, fuel combustion inside the cylinder, scavenging and exhausting gas exchange process inside the engine.

Indicator Diagrams

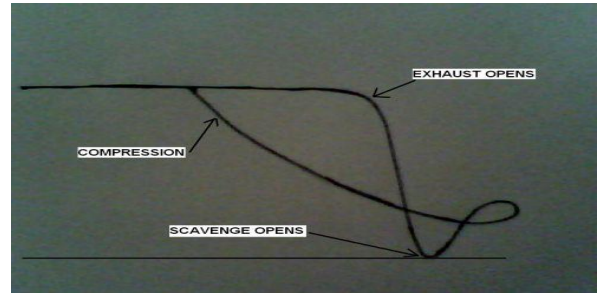
1. **Power card** diagrams are drawn in phase with the piston movements, and the area covered by this diagram represent the work done during that cycle and power produced in the cylinder.



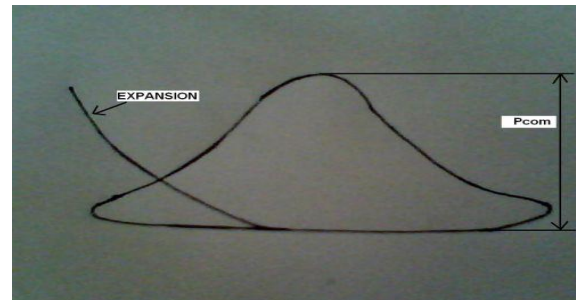
2. **Draw card** diagrams are 90° out of phase diagrams with the piston movement, they illustrates the pressure changes during combustion, faulty injectors or improper fuel timing.



3. **Light spring** diagrams are taken with light compression spring in phase with the piston movement and this diagram shows any pressure changes during scavenging and exhaust.



4. **Compression** diagrams is taken in a similar manner to the power card but with the fuel pump cut-off, and this diagram shows the maximum compression pressure.



Important qualities for consideration with marine fuel:

Fuel to burn inside the engine efficiently and specific fuel consumption to correspond with the engine load, we have to very cautiously control certain important aspects of the marine fuel.

- a) Fuel treatment and this includes eliminating impurities like sludge, water, heavy particles from fuel by subjecting the fuel to centrifuge with proper heating for easy separation. The right temperature of the fuel helps to maintain the required viscosity at the time of injection and also controls Sox and Nox emissions.
- b) Fuel injector and fuel pump injection timing are of utmost importance for proper combustion of fuel. The fuel injector should open at the required opening pressure, the nozzle holes clear with no fuel dripping, spray pattern for proper penetration of the fuel particles into the combustion chamber.
- c) Compression pressure is very critical for internal combustion engine wherein heat for combustion is provided thru high compression pressure created inside the cylinder. The rated compression pressure can be achieved if the cylinder components like piston, piston rings, liners are maintained in good working condition.
- d) Scavenging is the process of exchanging the gases present in the cylinder with a charge of uncontaminated fresh air and the performance of a diesel engine to a large extent depends on the efficiency of scavenging.

Alternative Technologies:

The growing concerns globally are to reduce carbon emissions and fuel consumption, lot of research is done to find alternatives and technology that will

sustain. There are some latest technologies that are commonly used to minimize operating costs besides meeting stringent environmental regulations.

1. Using LNG as alternative fuel in engines, it produces 25% less carbon dioxide and very lower levels of particulate matter Nox and no Sox. It complies with exhaust gas emission standards without the need for exhaust gas after-treatment. The cost of LNG is cheaper compared to fossil fuels resulting in saving on fuel cost.
2. Propeller Boss Cap Fins attachment to the hub of the ship propeller which generates counter swirls and improves the propulsion efficiency. This device can recover the energy loss of a propeller hub vortex in the propeller wake stream. In the research it is found that this energy saving device can save fuel when compared to the same type of vessel not fitted without Propeller Boss Cap Fins.
3. Bulbous bow is designed to the bow of the vessel in an efficient manner so that the water flow changes around the hull causing less drag and helps in cutting thru the water and reducing wave making resistance. The effect of the bulbous bow is to cause a reduction in the effective power required to propel the vessel, thus helps in saving fuel consumption.
4. Blended fuels as variable alternatives for combustion are bio-diesel, bio-methanol and bio-methane. These blended fuels burn with low emissions and engines can be operated at lower temperatures, they come cheaper than fossil fuels and give a significant cost saving on fuels.
5. Using alternative drive trains like, CPP drive train, two speed propulsion gear boxes, direct driven propulsion, electric drive propulsion, hybrid drive train, all these drives operate on partial power, this provides for reduction in fuel consumption.
6. Air lubrication system is a novel method to minimize the friction between the ship's hull and sea water using air bubbles known as bubble technology. These air bubbles helps reduction in the frictional resistance and this enhances the propulsive efficiency, reducing fuel consumption and other associated emissions.
7. Fuel cell technology is already being developed in the automobile industry and this would sooner or later find way into the marine environment. Having battery packs in the MW range may prove expensive, but battery charging during shore stay of the vessel may provide the solution, and fuel cell technology by itself is a very clean technology.
8. Nano technology is a way of using lub oil additives like inorganic fullerene tungsten disulfide, when these additives are added to the existing lub oil, the nano particles in the additives fill up the cracks, micro cracks and micro fissures in the metal surfaces. This results in reduction of friction of the moving

parts, reduced temperature, better performance, less fuel consumption and emissions.

9. Glass flake reinforced coatings to the underwater hull provides protection from marine growth and fouling. These coatings over a period of time become hydro dynamically smoother and this keeps the hull roughness at an optimum level and results in a major savings in fuel.
10. Fuel oils hold paraffinic and asphaltic particles causing improper atomization and poor combustion. This incomplete combustion results in excessive formation of soot and smoke coupled with loss of power. Therefore additives play an important role to optimize the efficiency of the fuel oil, stabilize the fuel to increase power and also to prevent engine damage.

Optimization measures for fuel economy:

1. In order to measure the energy performance for new vessels, IMO have launched the concept of an Energy Efficiency Design Index (EEDI). The EEDI for new ships is an important technical measure for promoting the use of more energy efficient and less polluting equipment and engines. IMO introduced another tool called Ship Energy Efficient Management Plan (SEEMP) for existing vessels to measure and control carbon emissions from on board engines.
2. In order to have a better understanding of fuel consumption is to install fuel flow measurement counters against manual soundings of tanks. These counters provide accurate measurement of fuel consumption for performance monitoring purposes with engines. This automatic measuring system intends for continuous recording of fuel flow rate, understanding average fuel consumption trends with real time data. It also will manifest if the engine specific fuel consumption compares correctly with engine power output.
3. Operating the vessels in a continuous manner is a complex and challenging task, with a Planned Maintenance Systems (PMS), one can manage the vessels in a smarter, greener and safer way. A planned maintenance system allows operators to plan, perform and document vessel maintenance at intervals complying with Class and manufacturer requirements. A PMS on board vessels is mandatory according to the International Safety Management Code (ISM). An effective planned maintenance system not only helps meet safety and environmental objectives laid out in the ISM Code, it is also an investment in the protection of the assets. The PMS will ensure that machinery or the equipment operates at an optimal operational level that would in turn save energy consumption and thereby the operating costs, increasing shelf life of the components, lasting longer, performing better and also ensures an eco-friendly work environment with low energy consumption and high environmental safety.

4. Power generated on board can be managed efficiently when main engines the powerhouse of the vessel are exploited at the rated MCR with minimal idling and low load operation, this will minimize fuel consumption. When the vessel is idle or is at jetty depending on the power demand only those engines and power consumers need to remain switched on and others can be switched off. Unlike ships with dredgers on multiple fronts fuel savings can be achieved, such as, by limiting the quantity of dredge material via the overflow duct operation, de-hoppering with only one pump, avoid using dredge pumps overboard discharge for quick turning, cleaning the hopper with no residual cargo in the hopper, avoiding full bunkers, avert from placing heavy spares on board, planning dredging cycle in consultation with port authorities due to restricted waters.

5. Crew awareness of a vessel is significantly influencing the performance of that vessel in a very large way, by optimizing the production and achieving maximum efficiency, but also by maintaining the vessel. The wear and tear on a vessel is of a large influence of the performance and the crew is in the first position to observe this and to take action to mitigate the negative effects. The crew should be placed with more power of attorney and more responsibility to manage their vessel, to carry out maintenance and repair on board and to order spares. If you want to be a real competitor in the market there is a need to enhance the competences of the operational crew. Reducing fuel consumption can only be achieved if all the on board personnel involved are aware of the impact of their day to day tasks on energy consumption and the way they can help save energy. By creating awareness and interest in energy efficiency with deeper understanding can be promoted via training programmes and by developing and implementing fleet energy management programme for the company as per IMO and ISO: 50001 requirements.

6. Trim optimization can be made by taking draught and trim measurements during the voyages. Using of Computational Fluid Dynamics (CFD) method for ship hydro dynamic analysis to define the optimal trim as a function of various speeds and loaded conditions.

7. During the operation of the vessel, the paint film on the hull will break down. Erosion will start, and marine plants and barnacles, etc. will grow on the surface of the hull. The hull has been fouled and will no longer have a technically smooth surface, which means that the frictional resistance will be greater. The total resistance, caused by fouling, may increase by 25% to 50% throughout the lifetime of a ship. Experience shows that hull and propeller fouling with barnacles and other marine growth may cause an increase in ship resistance up to 40%, and drastically reduction of the ship speed. In general for every 25 μm increase of the average hull roughness, the result will be a power

increase of 2% to 3%, or a ship speed reduction of about 1%. Hull and propulsion performance can be enhanced by frequent underwater inspection of hull and propeller condition from fouling and by polishing underwater the propeller blades and partial cleaning of the hull.

There is growing demand for energy with globalization and fossil fuels are consumed to provide energy services. The world is transitioning from fossil fuels to sustainable renewable energy sources but the demand for fossil fuels will continue for several decades. With increasing global warming awareness and stringent restrictions on carbon emissions, fuel prices are sky rocketing and finding efficiency in fuel consumption and effective emission controlling is becoming an overwhelming task. The fuel costs are accounting as major chunk of the operational costs of a vessel is an area of serious concern. Marine diesel engines have to burn fuels efficiently and curtail the harmful carbon emissions with an aim to lower the overall operational costs. New technological alternatives are emerging to reduce fuel consumption and carbon emissions within the regulatory authority framework. Moreover, the statutory authorities are enforcing several optimization measures for attaining fuel economy. Thus the marine industry is absorbed in improving fuel efficiency and reducing carbon emissions and this will continue to grow with globalization and increasing global sea trade.

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