Marine Propulsion Engine Behaviour using Fossil Fuel and Methanol

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Abstract. Considering the upgoing price of fossil fuel and requirements are becoming more and more stringent regarding pollutant emissions, the need of replacing the fossil fuel with a cheaper and less pollutant one emerges. The TECS software deal with thermal engine calculation problematics in order to determine, for different fuels types (liquid or gaseous), the indicated and effective engine parameters and also for verification, analysis and calculation of thermo-dynamic processes. As a result, the maritime industry is investigating alternative fuels for shipping. Methanol is an attractive alternative because it reduces polluting emissions and is expected to be cheaper in the future. This paper analyses the maritime engine performance when using fossil fuels as well as methanol.

Key words: TECS Software, indicated, effective, constructive parameters, mechanical work.

1. Introduction

The gravity of environmental pollution caused by fossil fuels has been a critical issue throughout the world for many years. Shipping industry cannot overlook this burden because the pollutant flue gases coming out of the ships funnels contribute to air pollution and result in serious environmental damage. In addition, the exhaustion of fossil fuel has led the world to find alternative solutions. Therefore, it has been decided to impose stricter environmental regulation on the maritime industry to reduce pollutant emissions.

The regulation stipulates that sulfur content must be limited to 0.1% in controlled areas (SECAs) by 2015. All the more, nitrogen oxide controlled areas (NECAs) entered into force in Caribbean since 2016 and will be introduced in Europe in 2021. Many research has been done to find low-emission alternative fuels. Diesel has been widely used as alternative fuel in SECAs instead of heavy fuel oil because no heavy fuel contains less than 0.1% sulfur. However, the much higher price of diesel than heavy fuel oil cannot be ignored.

In addition, not only sulfur and nitrogen oxides, but also greenhouse gases from the combustion of fossil fuels are a serious environmental problem because they accelerate global warming. The effort to reduce carbon dioxide emissions has been achieved by the International Maritime Organization (IMO). They have introduced the Energy Efficiency Design Index (EEDI) that indicates the carbon dioxide emissions of ships.

This paperwork explores combustion modeling performances of the engine using fossil fuel as well as methanol.
A major challenge for burning methanol is to overcome its poor self-ignition caused by low Cetane value. The introduction of pilot injection ignition may be the solution because the fuel pilot injection can induce methanol burning. An advantage of dual premixed fuel engines is that of engine modification cost which is relatively lower than a direct injection one.

2. Determination of the indicated, effective and constructive parameters of the marine engine

In this chapter, using TECS Software, the results obtained from engine design calculation under the condition of operating on different fuels will be presented.

Thus, using Matlab, the TECS Software was developed in order to supporting researchers in calculating and validating specific parameters for the naval engines theoretical thermal cycle [2].

![Figure 1. TECS Selection List Option for outputs](image1)

![Figure 2. Selection of the desired output parameter](image2)

Centered on TECS, complex computational actions are triggered by input parameters, selected elements from desired lists, and previously calculated parameters [2].

2.1. The TECS Inputs

Taking into account the environment protection, the properties of the marine engine are related to the input parameters, the nature and the way it was designed and the type of used fuel. The initial parameters list required for engine thermal calculation [5] can be loaded from an external file or directly into the TECS Application.

2.2. The TECS Outputs

The sequence for calculating the parameters related to a process is known, since each current process will be immediately calculated only if the previously process it has been verified, calculated and validated.

![Figure 3. Output Graphic for the desired parameter](image3)
Based on the input parameters, for the desired processes, the TECS [2] targeted results are consistent to a thermodynamic cycle of naval engine. Finally, the indicated, effective and constructive parameters for the chosen engine running on lighter, heavy fuel oil and methanol are shown in Table 1.

| Parameter                                                                 | Diesel            | Heavy fuel       | Methanol         |
|---------------------------------------------------------------------------|-------------------|------------------|------------------|
| Indicated work done in one cylinder                                       | 14239415 [J]      | 13274091 [J]     | 7399384 [J]      |
| Mean indicated pressure                                                   | 1238768 [Pa]      | 1317761 [Pa]     | 1427139 Pa       |
| Indicated efficiency                                                      | 0.33828 [%]       | 0.34373 [%]      | 0.36891 %        |
| Indicated specific fuel consumption                                       | 0.25339 [Kg/kWh]  | 0.27203 [Kg/kWh] | 0.48964 [Kg/kWh] |
| Mean effective pressure                                                   | 1139666 [Pa]      | 1212340 [Pa]     | 1312968 [Pa]     |
| Effective efficiency                                                      | 0.31121           | 0.31624          | 0.3394           |
| Effective specific fuel consumption                                       | 0.27542 [Kg/kWh]  | 0.29569 [Kg/kWh] | 0.53222 [Kg/kWh] |
| Similarity coefficient                                                    | 0.27514815        | 0.29549231       | 0.53081878       |
| The actual volumes of the combustion fluid at the characteristic points of the operating cycle| 3.42134027[m3]    | 3.21624762 [m3]  | 2.96975004 [m3]  |
|                                                                             | 0.26318002[m3]    | 0.24740366 [m3]  | 0.22844231[m3]   |
|                                                                             | 0.46830146[m3]    | 0.45466771 [m3]  | 0.43827576[m3]   |
| The real indicated work developed in an analytical cylinder               | 3917949 [J]       | 3922392 [J]      | 3927732 [J]      |
| Engine effective power                                                    | 66410 [kW]        | 66485 [kW]       | 66575 [kW]       |
| - percentage error                                                        | 1.8567 [%]        | 1.7454 [%]       | 1.6116 [%]       |
| Indicated power                                                           | 72184 [kW]        | 72266 [kW]       | 72365 [kW]       |
| Power per cylinder                                                        | 5534 [kW/cil]     | 5540 [kW/cil]    | 5548 kW/cil      |
| Specific power of the piston area                                          | 5132 [kW/m2]      | 5355 [kW/m2]     | 5654 [kW/m2]     |
| Specific volumic power of the piston                                       | 1752 [kW/m3]      | 1866 [kW/m3]     | 2023 [kW/m3]     |
| Engine load factor                                                        | 609684 [N/m*s]    | 597876 [N/m*s]   | 583045 [N/m*s]   |

3. The main differences of the indicated and effective parameters which may be observed when using light, heavy marine fuel oil as well as methanol

The indicated mechanical work obtained in a methanol engine cylinder is less than that achieved using light or heavy fossil fuel oil, but the effective mechanical work developed in a cylinder is slightly higher when using methanol.
Likewise, the actual(real) indicated mechanical work developed in an analytic cylinder is higher for methanol, thus the smallest is in the case of light fuel oil.

Mean indicated pressure and mean effective pressure are slightly higher in the case of methanol and the smallest values are those of light fuel oil.

The indicated and effective efficiencies have close values for the three types of fuel, methanol having the highest value and light fuel oil having the lowest one.
Effective and indicated specific fuel consumption is higher for methanol, the smallest being for light fuel oil.

The methanol generates an effective engine power, indicated power, cylinder power, specific piston area power and a specific piston volumic power that are higher than generated by heavy or light fuel oil.

Emissions of nitrogen oxides produced by burning methanol are 30% lower compared to burning diesel. This is mainly due to the higher evaporation heat of methanol which helps lowering the ignition temperature in the cylinder.

Carbon oxide emission is reduced when using methanol. Furthermore, the chemical structure of methanol contains oxygen. Thus, during the combustion process, more oxygen is available for combustion. This helps reduce carbon oxide emissions because lack of oxygen is one of the reasons for carbon oxide emissions.
4. Conclusions

The TECS software is addressed to naval electro-mechanical engineers who have to deal with thermal engine calculation problematics, in particular with the verification, analysis and calculation of thermo-dynamic processes concerning the thermal energy obtained through combustion of fuel and its transformation into Mechanical Work. Following calculations, we have concluded that differences in engine parameters in the use of light, heavy fuel oil and methanol are not so high.

The biggest differences are encountered at the indicated and effective specific fuel consumption, having high values when using methanol, in comparison to light or heavy fuel oil values due to methanol’s inferior calorific value, which is almost half of a fuel oil calorific value, hence is necessary to introduce a higher amount of fuel to achieve equivalent performances.

Methanol indicated mechanical work achieved in a cylinder is lower than that produced by light or heavy fuel oil.

Indicated efficiency and effective efficiency have close values for the three types of fuels, the biggest value is attributed to methanol and the lowest is attributed to light fuel oil.

Higher engine power values are achieved when using methanol, followed by the power produced with heavy fuel oil, ultimately, light fuel oil.

From the pollution and emissions point of view, methanol represents a good solution to reduce pollutant emissions. Moreover, methanol is considered as an ecological fuel as it is a miscible substance in water and decomposes easily in the environment.

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