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MAOS - Oxygen Minimum Amount Calculation Software for Thermodynamics Processes

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Abstract. The present paper aims to exhibit a dedicated software tool (MAOS) which determine the amount of fresh air introduced into each cylinder for 2 and 4-stroke naval engines, taking into account the current "Fuel-Efficient and Non-Polluting Engines" trends. The quantity of air, known as 'fresh load', determines the quality of the fuel's oil oxidation processes and the heat transfer inside the piston's head. Thus, in order to maintaining the oxidation process, the software determine the active component in the fresh load, represented by the oxygen and the excess of air, known as alpha. The software comes to the attention of young naval engineers as a validating current computing techniques precursor, using existing theoretical methods.

1. Introduction

Combustion is the combustible compounds rapid oxidation process by which thermal energy is released. In terms of thermodynamic combustion, the process is analyzed globally. The combustion process mechanism, called the kinetics of combustion, an extremely complex chemical phenomenon, and the intermediate products of combustion, have constituted the starting point for the development of this software tool called MAOS - Oxygen Minimum Amount Calculation Software for Thermodynamics Processes.

Fuel is a substance that, by combustion or oxidation, produces a significant amount of heat and can therefore be used as an economic source of heat.

To be considered fuel, a compound must meet the following conditions:

- react exothermic with oxygen at high speed and at high temperatures;
- the combustion resulting products are not toxic;
- sufficiently widespread in nature, cheap and not show other, more economic uses;
- the combustion products are not corrosive to the surfaces they come in contact with.

Thus, taking into account the combustible compounds rapid oxidation process, the MAOS tool determine the alpha active component of the fresh load, represented by the oxygen and the air excess.

2. Fundamentals for developing MAOS

The MAOS embed the calculation of the combustion process, based on the combustion chemical reactions of combustible elements in order to determine the resulting heat, the amount of the required air to carry out these reactions and the volume of gases resulting from combustion process.

Thus, the importance of the amount of air required for combustion is essential for MAOS software in order to determine the sufficient oxygen supply because an insufficient amount will cause an incomplete combustion, and excess air, inherently oxygen, diminishes the combustion temperature or increases the amount of exhaust gases produced.

Also, the Combustion Equations and the amount of gas resulting from combustion is taken into account by MAOS in order to adjust the flue gas outlet pipe, resize the chimney and also to dimension the heat recovery systems from the result burning gases.

2.1. MAOS Combustion Equations

For each element in the fuel component, MAOS uses the oxidation (burning) process equations for calculating the oxidation of Carbon, Hydrogen, Sulfur, and, if Carbon oxidation is incomplete, Carbon Dioxide oxidation as well.

2.2. Fuels combustion process calculation (gaseous, solid and liquid fuels)

The required Oxygen Amount for a fuel unit complete combustion is called the minimum combustion oxygen (O_{min}). This unit can be calculated by summing the volumes of oxygen entering the combustion equations of each fuel component, taking into account the volume of oxygen contained in the fuel, too.

$$O_{min} = {}^{1}/_{4} * \left(h + {}^{c}/_{3} + ({}^{s-o}/_{8})\right)$$

Thus, if in the fuel composition the oxygen is present, having the participation mass (o), it does not have to be inserted from the outside.

$$O_{min} = 22.414 * \left({}^{h}/_{4} + {}^{c}/_{12} + ({}^{s-o}/_{32})\right)$$

Considering that the minimum oxygen required for combustion is provided from the dry air, therefore it does not contain humidity, and the volumes' participation of oxygen in air is 21%, the minimum amount of air required for combustion, also called minimum combustion air (L_{min}) can be calculated.

$$L_{min} = {}^{O_{min}}/_{0.21}$$

If air has humidity, the minimum air required for combustion is calculated taking into account, in the normal state, the dry air density (ρN air) and the humidity density (ρN um).

$$L_{min} = {}^{O_{min}}/_{0.21}\left(1 + x * {}^{\rho\text{N air}}/_{\rho\text{N um}}\right)$$

The actual volume of air entering the combustion process, also known as the actual combustion air (L), can be determined using a parameter called the excess air coefficient, or more simply, the excess air ($\lambda = L/L_{min}$).

The required air is calculated if the amount of fuel to be burned, mcb [kg], is known.

$$V_{aer} = mcb * \lambda * L_{min}$$

The minimum combustion gas volume will obtain also if the combustion is carried out in stoichiometric conditions, i.e. using the minimum combustion air (λ = 1).

$$V_g^{min} = V_{CO2} + V_{H2O} + V_{SO2} + V_{N2}$$

Thus, the combustion equations of the combustible elements lead to the calculation of the partial volumes of each element in the combustion gas composition ($V_{CO2}; V_{H2O}; V_{SO2}; V_{N2}$). Finally, the volume of dry gases (V_g^{us}) is obtained by subtracting the volume of water vapor (V_{H2O}) from the total volume (V_g^t).

$$V_g^t = V_g^{min} + V_{aer}^{exces} = V_g^{min} + (\lambda - 1) * L_{min};$$
$$V_g^{us} = V_g^t - V_{H2O}.$$

3. MAOS Software

Written in C++ language, the MAOS algorithm comes to meet young naval engineers in order to validate the current used computing techniques, using existing theoretical methods.

Thus, starting from the initial settings that the user sets, these also representing the program inputs (related to the engine and fuel type), MAOS software are used for Fuel combustion analytical determination used in internal combustion engines.

4. The INPUT

The MAOS algorithm inputs are: Cylinders Number, Engine Stroke Number, Engine Bore, Piston Stroke, Average Piston Speed, Average Effective Pressure, RPM, Each Cylinder Power, Effective Power and Fuel Type. Based on input data and on Excess Air and Residual Flue Gases Coefficients, the software displays the Amount of Oxygen Required for Complete Combustion, the Total Theoretical Air Amount and the Total Real Air Amount.

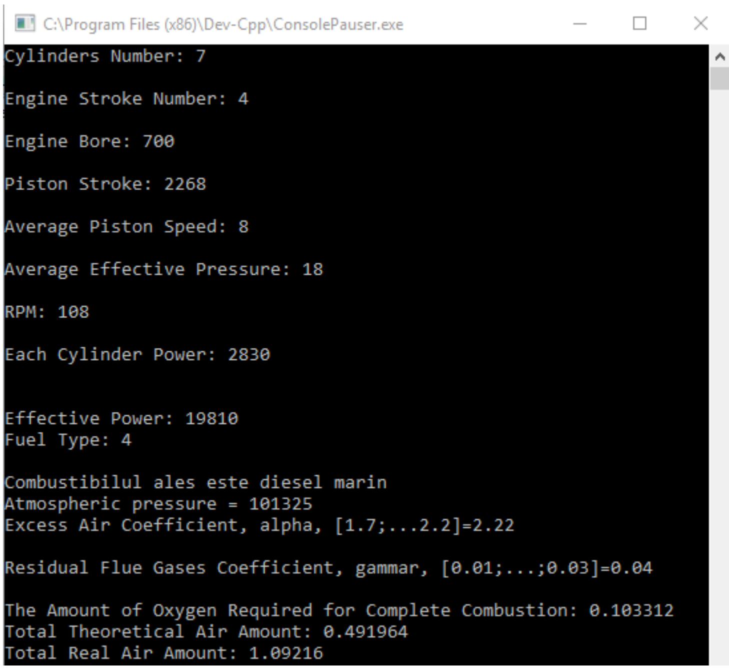

Figure 1. *The amount of oxygen required for complete combustion, Total Theoretical Air and Total Real Air Amount.*

5. The results

The MAOS software comes to the attention of young naval engineers as a validating current computing techniques precursor, using existing theoretical methods.

Based on the INPUT data, the MAOS displays the following:

- Ot=(c/12+h/4+(s-o)/32)/100, display Required quantity of oxygen for complete burn;
- Lt=Ot/0.21, display Theoretical quantity of total air;
- L=alpha*Lt, display Real quantity of total air;
- Vco=c/1200, display The amount of carbon dioxide resulting from burning one kilogram of fuel;
- Vho=(9*h+w)/1800, display The amount of water vapor resulting from burning one kilogram of fuel;
- Vo=0.21*((alpha-1)/alpha) *L, display The amount of oxygen resulting from burning one kilogram of fuel;
- Vn=0.79*L, display The amount of nitrogen resulting from burning one kilogram of fuel;
- Vso=s/3200, display The amount of sulfur dioxide resulting from burning one kilogram of fuel;

- Vga=Vco+Vho+Vso+Vo+Vn, display The total amount of flue gas resulting from burning one kilogram of fuel;
- Vgar=gammar*Vga, display The total amount of waste flue gas resulting from burning one kilogram of fuel;
- Vgaru=Vgar-(gammar*Vho), display The total amount of dry flue gas resulting from burning one kilogram of fuel;

```
By burning one kilogram of fuel, results:
The amount of carbon dioxide: 0.0725
The amount of water vapor: 0.062
The amount of oxygen: 0.126041
The amount of nitrogen: 0.862807
The amount of sulfur dioxide: 0
The total amount of flue gases: 1.12335
The total amount of burnt residue gas: 0.0449339
The total dry amount of burnt residue gas: 0.0424539

--------------------------------
Process exited with return value 0
Press any key to continue . . .
```

Figure 2. *The MAOS algorithm outputs: The amount of: carbon dioxide, water vapor, oxygen, nitrogen, sulfur dioxide, total amount of flue gases, total amount of burnt residue gas and total dry amount of burnt residue gas, by burning one kilogram of fuel.*

6. Conclusion
The MAOS software is addressed to electro-mechanical naval engineers with particular concerns in verification, analysis and calculation of thermo-dynamic processes that manage the operation of the ship internal combustion engine. MAOS software can be a departure point for "Fuel-Efficient and Non-Polluting Engines" trends.

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