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TECS - a Dedicated Software for Thermal Engine Calculation

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TECS - a Dedicated Software for Thermal Engine Calculation

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Abstract. This paper addresses the thermal engine calculation problematics using a dedicated software program (TECS) in order to determine the indicated and effective engine parameters using different fuels (liquid or gaseous). The diagram indicated thus obtained by TECS can contribute to verify the judicious use of thermal energy, obtained through combustion of fuel and its transformation into Mechanical Work. The analysed thermo-dynamic processes can analytically and graphically determine the polytrophic exponents of compression and decomposition in values close to the stoichiometric calculations. The TECS software is addressed to the current and future electro-mechanical naval engineers with concrete concerns in verification, analysis and calculation of thermo-dynamic processes that govern the operation of the ship internal combustion engine. It can be a starting point eloquently in appreciation of fair uses thermal energy on board.

1. Introduction

In internal combustion engines, physical and chemical phenomena that support the qualitative and quantitative changes in the formation of the fuel mixture between air and fuel lead to thermodynamic processes characterized by heat, mass and mechanical work exchanges with the external environment.

Thermodynamic cycle of an internal combustion engine (four stroke) consists of a diagram composed by an isobar, an isocor, and two adiabates. By analyzing the thermodynamic cycles of internal combustion engines, we can say that compression-ignition engines can have the same optimum performance when using different types of fuels. Thus, using the most productive software environment for engineers and scientists (Matlab), the TECS Application was developed as a Graphic User Interface (GUI), presenting academic and practical applicability, and also supporting researchers in calculating and validating specific parameters for the theoretical thermal cycle for naval engines.

2. TECS Application

For easier user interaction with the computing environment, TECS was developed in Matlab as a Graphical Interface.

In the TECS environment initialization, certain parts of the application are made visible or invisible, so that interaction with the computing environment to be user intuitive as possible. After reading (or setting) the initial parameters, the user must select the process which calculate the parameter whose value he wants to find. Depending on the process selected, the list of apps will show the calculated parameters from that process.

The TECS interface is structured in two zones, the left side being the input parameters area and the output parameters area, respectively the right side. For the desired calculation, selecting an item from the list of output parameters is done by choosing the option from a drop-down list located on the right side of the interface.
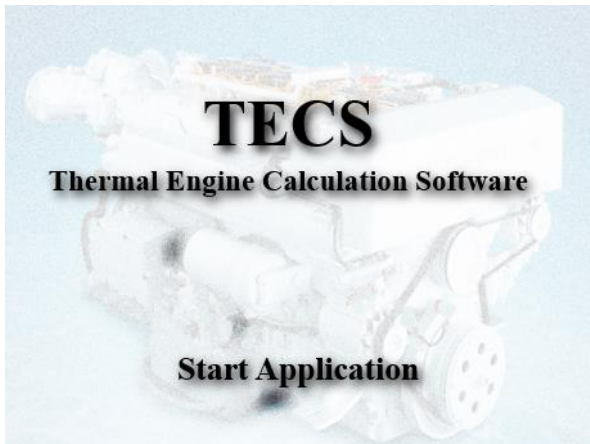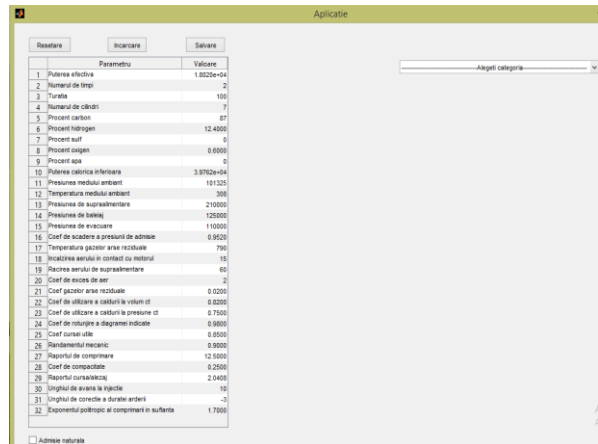
Figure 1. TECS Main Interface

Figure 2. TECS Main Page

Thus, by selecting the desired option (the first item in the list will be selected automatically), the Calculate Button becomes active and thus, the submenu options become available and implements the complex calculation algorithm part that is the subject of this application, respectively subselection.
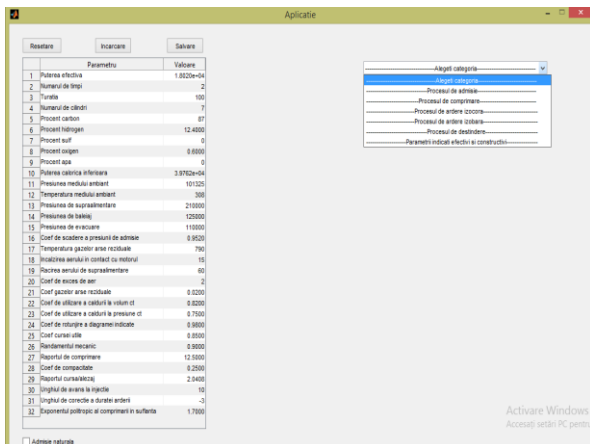

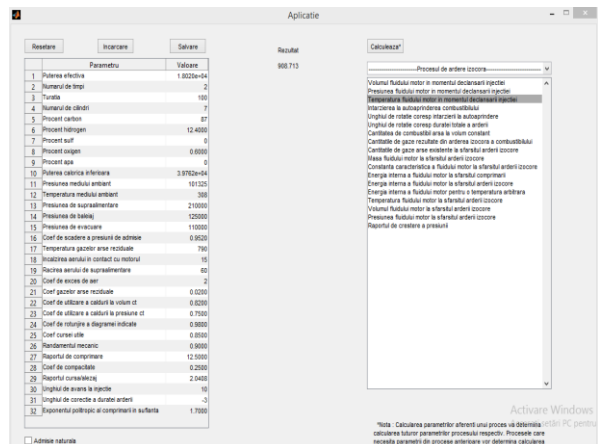Figure 3. TECS Selection List Option of the desired output s

Figure 4. Selection of the desired output parameter

When you press the Calculate Button, complex calculus actions are triggered by the input parameters, the selected items from the above mentioned lists, and the previously calculated parameters.

2.1. The TECS Inputs

The initial parameters determine the properties of the engine and depend on the nature and the way it was designed and the type of fuel used, taking into account the environment protection.

The initial parameters list required for engine thermal calculation: Effective power, Stroke, RPM, Number of cylinders, The percentage of carbon, The percentage of hydrogen, The percentage of sulfur, The percentage of oxygen, The percentage of water, Lower caloric power, The environmental pressure, Ambient temperature, Supercharge pressure, Scavenging pressure, Exhaust pressure, The intake pressure drop coefficient, The temperature of the flue gas, Air heating in contact with the engine, Cooling the overfill air, The coefficient of excess air, The coefficient of residual flue gas, The coefficient of heat utilization at constant volume, The coefficient of use of heat at constant pressure, The coefficient of rounding of the indicated diagram, The coefficient of working stroke, Mechanical efficiency, The compression ratio, The coefficient of compaction, The stroke/bore ratio, Injection feed

angle in advanced, Correction angle of combustion duration and The polytrophic exponent of compression in the blower.
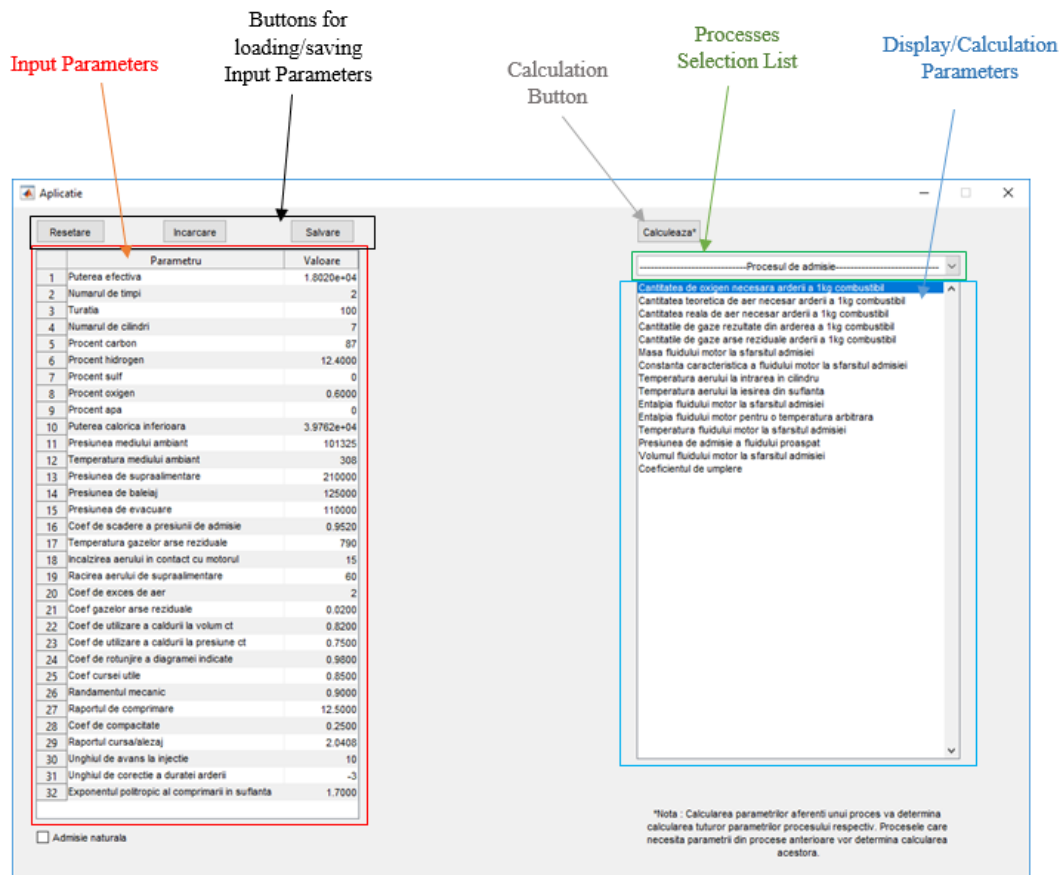

Figure 5. The TECS Input Area

The application allows two ways to load input parameters: from an external file or directly into the TECS Application, and then saved into a file. The input parameters area is structured by the "Parameters" | "Value ", so the above-mentioned parameters, in the number 32, can also be inserted manually strictly in the order listed. The order of parameter insertion is essential. After reading (or setting) the initial parameters, the user must select the process and sub-process to be calculated and displayed.
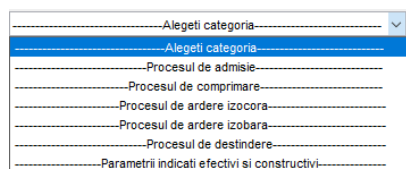

Figure 6. Processes Selection List

Depending on the selection, the parameters that can be calculated are shown, of course, for the desired process. After selecting an item from the parameter list, the Calculate Button becomes active and the result is displayed, too by executing it.

2.2. TECS Outputs.
The order of the processes in the list is not random, for calculating the parameters related to a process at the bottom of the list it is necessary (almost) all the parameters that can be calculated from the processes above it, from the drop down list. In the implementation of the Calculate Button, it is

checked whether the parameters from the previous process have been calculated for the current process, and otherwise, it will first calculate the parameters of the previous process.
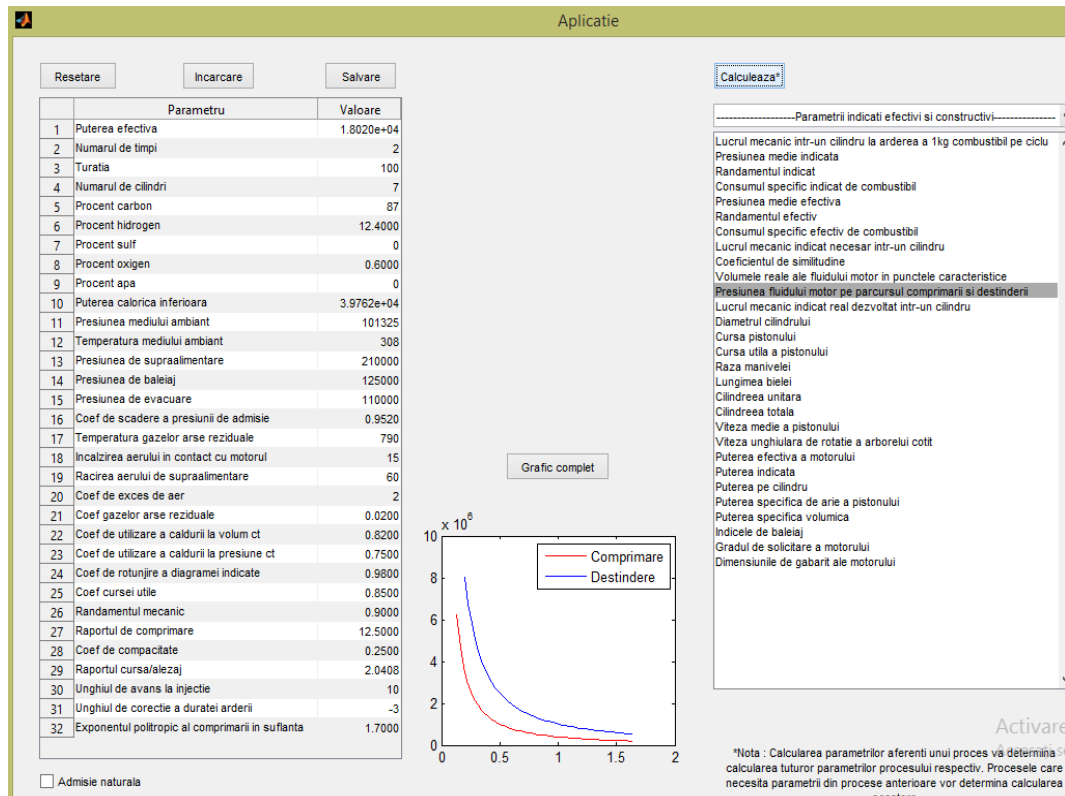

Figure 7. Output Graphic for the desired parameter

Since recursive computation processes occur, each current process will be immediately calculated only if the previously process it has been verified, calculated and validated.

3. The Results

A thermodynamic cycle is all the states through which a thermodynamic system passes during transformations, starting from a certain state until it returns to the same state. Thermodynamic cycle of an internal combustion engine (four stroke) consists of a diagram composed by an isobar, an isocor, and two adiabates. Based on the input parameters, for the following processes, the targeted results are consistent to the following processes: Admission, Compression, Isocor Burning, Isobar Burning, Relaxation, Effective and Constructive Parameters.

3.1. The Admission Process (Induction/Intake stroke)

The air admitted amount directly influences the air-fuel mixture combustion process with immediate consequences on the energy efficiency of the engine and the emission of pollutant gases.

The admission process consists of the introduction of a fresh load in the cylinder for each cycle, consisting only of air for compression-ignition engines or the air-petrol mixture for spark-ignition engines.

From this stage, it follows: The oxygen amount required to burn 1kg of fuel, the theoretical amount of air required to burn 1kg of fuel, the actual amount of air required to burn 1kg of fuel, the resulting gases quantities from the burning of 1kg of fuel, the resulting flue gases amount from the combustion of 1kg of fuel, Engine fluid mass at the end of admission, the engine fluid characteristic constant at the end of the admission, Air temperature at the cylinder inlet, Air temperature at the blower outlet, Engine fluid enthalpy at the end of admission, Engine fluid enthalpy for an arbitrary temperature,

Engine fluid temperature at the end of intake, Fresh fluid admission pressure, Engine fluid volume at the end of admission and the filling coefficient.

3.2. The Compression Process (Compression stroke)

Compression increases the pressure and temperature of the fresh load with the following engine operation implications:
- Achieving the conditions for the formation of the fuel and air mixture in order to ensure the best homogeneity of the mixture;
- Increased energy obtained by combustion of fuel as a result of improving the oxidation reaction conditions of combustible substances;
- Obtaining the auto-ignition temperature of the fuel.

From this stage, it follows: Coefficients of specific molar average heat of the engine fluid, the average polytrophic exponent of compression, Motor fluid pressure at the end of compression, Motor fluid temperature at the end of compression and the volume of the engine fluid at the end of the compression

3.3. The Isocore Burning Process (Combustion/Power/Expansion stroke)

Subjecting a gas to an isocore transformation involves the constant ratio of its pressure and temperature. An isocore transformation takes place at a constant volume and the gas pressure changes directly in proportion to the temperature. A consequence is that the external mechanical work is null. The heat changed into such a process is transformed entirely into the internal energy variation of the system, materialized by the variation in system pressure and temperature.

From this stage, it follows: The engine fluid volume at the time of the injection, Engine Fluid Pressure at Injection, the engine fluid temperature when the injection is triggered, Delay at the self-ignition of fuel, the rotation angle corresponding at the self-ignition delay, the rotation angle corresponding to the total combustion duration, the burned fuel amount at constant volume, the resulting gases quantities from the isocore fuel combustion, the existent exhaust gases quantities at the end of the isocore combustion, the engine fluid mass at the end of the isocore combustion, the characteristic constant of the engine fluid at the end of the isocore combustion, the internal energy of the engine fluid at the end of the compression, the internal energy of the engine fluid at the end of the isocore combustion, the internal fluid of the engine fluid for an arbitrary temperature, the engine fluid temperature at the end of the isocore combustion, the engine fluid volume at the end of the isocore combustion, the engine fluid pressure at the end of isocore combustion and the Pressure increase ratio.

3.4. The Isobare Burning Process (Combustion/Power/Expansion stroke)

An isobar transformation takes place at constant pressure and the gas volume changes directly in proportion to the temperature.

From this stage, it follows: The fuel amount burned at constant pressure, the existent exhausted gases quantities at the end of combustion, the engine fluid mass at the end of isobare combustion, the engine fluid characteristic constant at the end of isobare combustion, the engine fluid enthalpy at the end of isocore combustion, the engine fluid enthalpy at the end of isobare combustion, the engine fluid enthalpy for an arbitrary temperature, the engine fluid temperature at the end of combustion, the engine fluid pressure at the end of combustion, the engine fluid volume at the end of combustion and the pre-release ratio.

3.5. The Exhaust Process (Exhaust stroke)

During this cycle, the exhaust gas is pushed out in the atmosphere. When the piston reaches the upper dead end point, Cycle 4 ends and the engine restarts another cycle, starting with aspiration of the fuel mixture.

From this stage, it follows: The molar average specific heat coefficients of the engine fluid, the average polytrophic exponent of the exhaust, Volume of engine fluid at the end of exhaust, Motor

fluid pressure at the end of exhaust, Motor fluid temperature at the end of exhaust, Exhaust ratio, Pressure drop ratio and Residual flue gas temperature.

3.6. The Effective and Constructive Parameters

Knowing the engine fluid state measurement at the characteristic points of the operating cycle, it is possible to determine the values of the indicated and effective cycle parameters as well as the main engine dimensions.

From this stage, it follows: Mechanical work in a cylinder when burning 1kg of fuel per cycle, Average pressure indicated, Yield indicated, Specific fuel consumption, Average effective pressure, Effective yield, Specific fuel consumption, the indicated mechanical work per cylinder, the coefficient of similarity, the engine fluid actual volumes in the characteristic points, Motor fluid pressure during compression and combustion, the developed actual mechanical work in a cylinder, Diameter of the cylinder, Piston stroke, Piston useful stroke, the crank radius, the length of the crank, Cylindrical unitary, the total cylindrical, Average piston speed, Angular rotation speed of the crankshaft, Actual power of the engine, the power indicated, Cylinder power, Specific power of piston area, Volumetric specific power, Scavenger index, Engine load rating, Engine overall dimensions.

4. Conclusions

The TECS software is addressed to naval electro-mechanical engineers who have to deal with thermal engine calculation problematics in order to determine the indicated and effective engine parameters using different fuels types (liquid or gaseous). The software can be a starting point eloquently in verification, analysis and calculation of thermo-dynamic processes and, also in appreciation of fair uses thermal energy on board, obtained through combustion of fuel and its transformation into Mechanical Work.

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