



4TMono V1.0

User Manual

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SOFTWARE FEATURES

4TMono is a four stroke spark ignition simulation software; it's capable to estimate the performances of such engines and it's therefore an excellent tool both in design and tuning phase. The software utilization is very simple and allows the visualization of many motoristic variables useful in the field of internal combustion engines. 4TMono can visualize more than 60 graphs for every simulation, in such manner, every part of the engine can be observed adequately: the advantages of 4TMono are then, the possibility to study and optimize "4 stroke engines" with the possibility to get information that can't be easily obtained in experimental way.

Such results can be printed like 'Files', so they can be used as input data for other programs and also in text format '.txt', easily printable.

The technical features of 4TMono are:

- "Two zones" combustion model; during the combustion phase, the gas in the cylinder is divided in two components: the "mixture" and the "combustion products". Such combustion products are in chemical equilibrium, while the mixture is retained to be at constant composition. The combustion model utilized is the "Blizard-Keck";
- Zero-dimensional turbulence model over all the thermodynamic cycle; such model supply the initial values for the combustion and for the heat transfer between gas present in the cylinder and its walls; also heat transfer is divided in "two zones";
- Blowby: model for the calculation of the mass lost of mass across the piston rings;
- Calculation of the chemical equilibrium of the combustion products; it take in consideration 13 chemical elements: $N_2, N, NO, NO_2, O_2, O, OH, H, H_2, H_2O, CO, CO_2, Ar$, while the mixture is composed by: N_2, O_2, H_2O, Ar ;
- Monodimensional model for inlet and exhaust ducts: the model used is "Two Step Lax-Wendroff" + TVD, in which it takes account of the variation of cross sectional area, friction losses, heat transfer, variation of the thermodynamic properties of the gas and of its composition;
- Monodimensional model for the boundaries of the ducts; the method used is the "CIR", and the solution is calculated every instant in non linear systems of equations instead of load solutions from disk;
- Three-dimensional discharge coefficients maps for inlet and exhaust valves; such coefficients, it's known, depend both from the valve lifting, and from the pressures ratio upstream and downstream of it;

- Perfect mixing during the overlap period of the valves (scavenging);
- Model for the knock;

For the other features about this software please view the scientific documentation.

In this version is possible to simulate the following typologies of engines:

- Mono-cylinder engines or engines with the cylinders fluidodynamically independent, i.e. there aren't pipe junctions or connections between ducts of different cylinders;
- Engines with 2 or more valves for each cylinder;
- Variable advance timing with Rpm;
- Variable air-fuel ratio with Rpm;
- Variable inlet valve timing with Rpm;
- Variable exhaust valve timing with Rpm;
- "AIR BOX": or to the box in which there is the air filter; in this version it's possible to take account of the inlet soprappressure at high vehicle velocity;
- Exhaust Box;
- 8 different type of fuels:

OCTANE; $H/C=2.25$; stechiometric air-fuel ratio=15; octane number=100;

UNLEADED GASOLINE; $H/C=1.65$; stechiometric air-fuel ratio=14.37; octane number=96;

LEADED GASOLINE; $H/C=1.87$; stechiometric air-fuel ratio=14.64; octane number=98;

METHANE; CH_4 ; stechiometric air-fuel ratio=17.23; octane number=120

PROPANE; C_3H_8 ; stechiometric air-fuel ratio=15.67; octane number=112

METHANOL; CH_4O ; stechiometric air-fuel ratio=6.47; octane number=106

ETHANOL; C_2H_6O ; stechiometric air-fuel ratio=9 ; octane number=106

HYDROGEN; H_2 ; stechiometric air-fuel ratio=34.07; octane number=112

- Partial load.

1. SYSTEM REQUIREMENTS

The minimum requirements to install and to execute 4TMono are:

- IBM PC compatible;
- CD Player;
- 256 VGA graphic card with resolution 800x600 DPI ;
- Browser Internet 4 or better;
- 20 free Mb on hard disk;
- Usb port

4TMono can be executed on the versions of Microsoft Windows 9X/ME/NT/XP.

For a good utilization of the program it is recommended however a PC with processor Pentium III or better, 128 Mb of RAM, obviously with faster PC there are shorter times of execution.

2. INSTALLING AND LAUNCHING 4TMONO

When you buy Rtz-Soft 4TMono V1.0 you will receive:

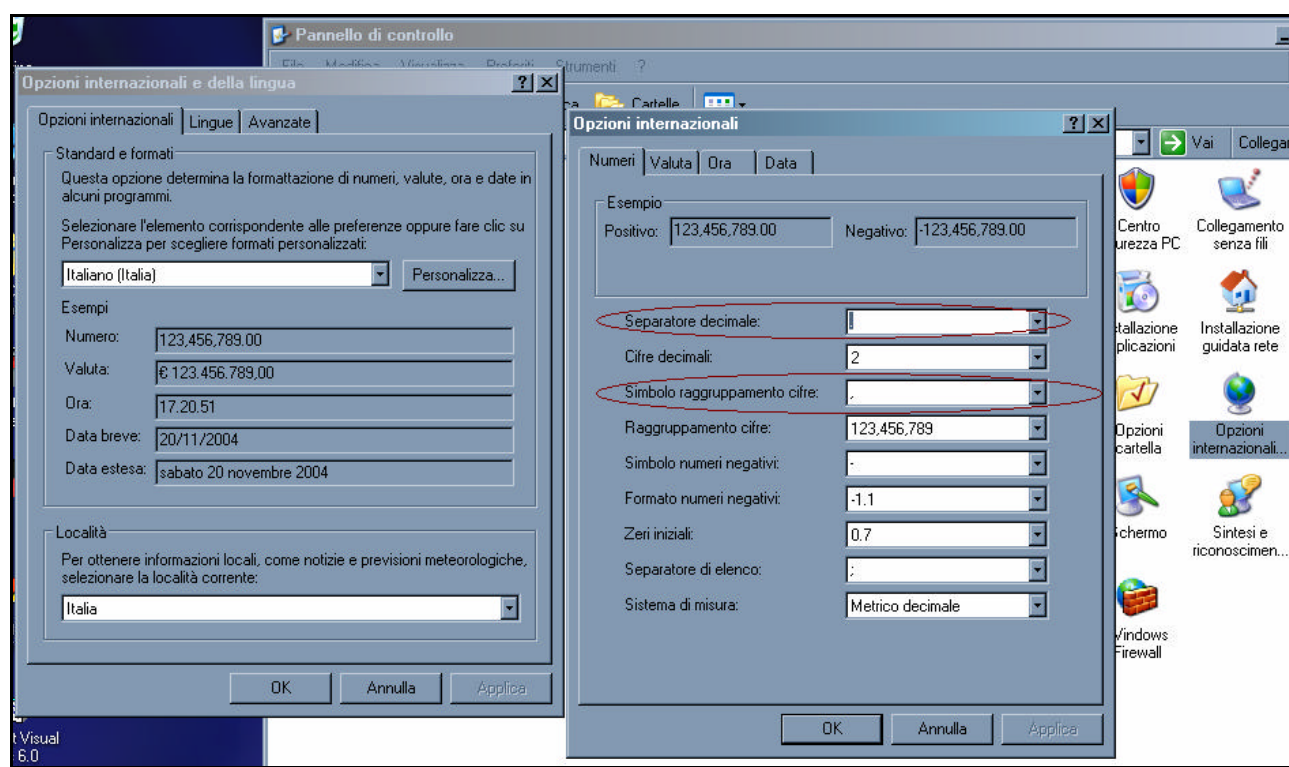
- Software installation Cd;
- Online Manual (Pdf format) , within the installation Cd;
- Scientific documentation in (Pdf format), within the installation Cd;
- Hardware key.

To use Rtz-Soft 4TMono you need to install the “Hardware key” in a USB port: without this key it's not possible to use the software.

To launch 4TMono is necessary to click on the icon

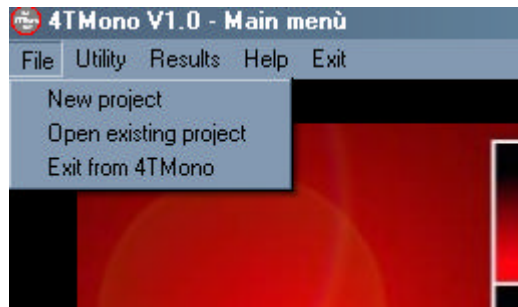
Start→Programs→RTZ-Soft→'4TMono'.

It's necessary also to convert the decimal separator from " , "(comma) to " . "(dot). This is possible going to windows Control panel → international and language options → “Numbers” and there make these modifies.



3. 4TMONO MENU'

The menu bar, located on the top left of the main window has 4 options: File, Utility, Results, Exit, that will be explained.



3.1 FILE

Clicking on the menu **FILE** it's possible to choose the following options:

3.1.1 New Project:

With this option an empty project will be opened in which it's possible to specify all the dimensions of the engine: many windows will be opened and inside of them the necessary values will be introduced to make a simulation. If all of the values weren't introduced or if reasonable values were not introduced, the program will inform the user at the moment of the closing of the window; in the same way, when when you decide to start a simulation the program will advice of any omitted or wrong values.

3.1.2 Open existing Project:

Clicking on this option a window will be opened in which it will be necessary to specify an existing project previously created from 4TMono; such file has an extension “. dat”.

3.1.3 Exit from the program:

Clicking on this option it will be ask subsequently to Exit from the program and, if this is the action wanted, it will be necessary to click on “OK” to exit definitively.

3.2 UTILITY

In this menu three options will appear, and the role of them is that to supply some tools for the project's building. Particularly:

- **Piston position and crank angle:**

Clicking on this option it will be opened a window in which is possible, knowing the manovellism geometry, to obtain the value of the piston displacement in mm. knowing the crank angle and vice versa. This is specially useful if for example it is known the value of the advance of the engine in mm. from the TDC and we want to calculate it in crank degrees before the TDC; is possible also the opposite operation.

The input data for these calculations are:

Piston position

Stroke mm.

Con rod mm.

Offset mm.

Known value

☒ crank degree BTDC

☐ mm. BTDC

Calculate

Piston position mm. 2.4686

Crank radius mm. 34

Top dead center angle 0

Bottom dead center 0

Main menù

the engine stroke;

the connecting rod length;

the piston offset.

The exit data instead are:

The piston displacement in mm.: (if the crank angle is known) or the crank angle in function to the piston displacement;

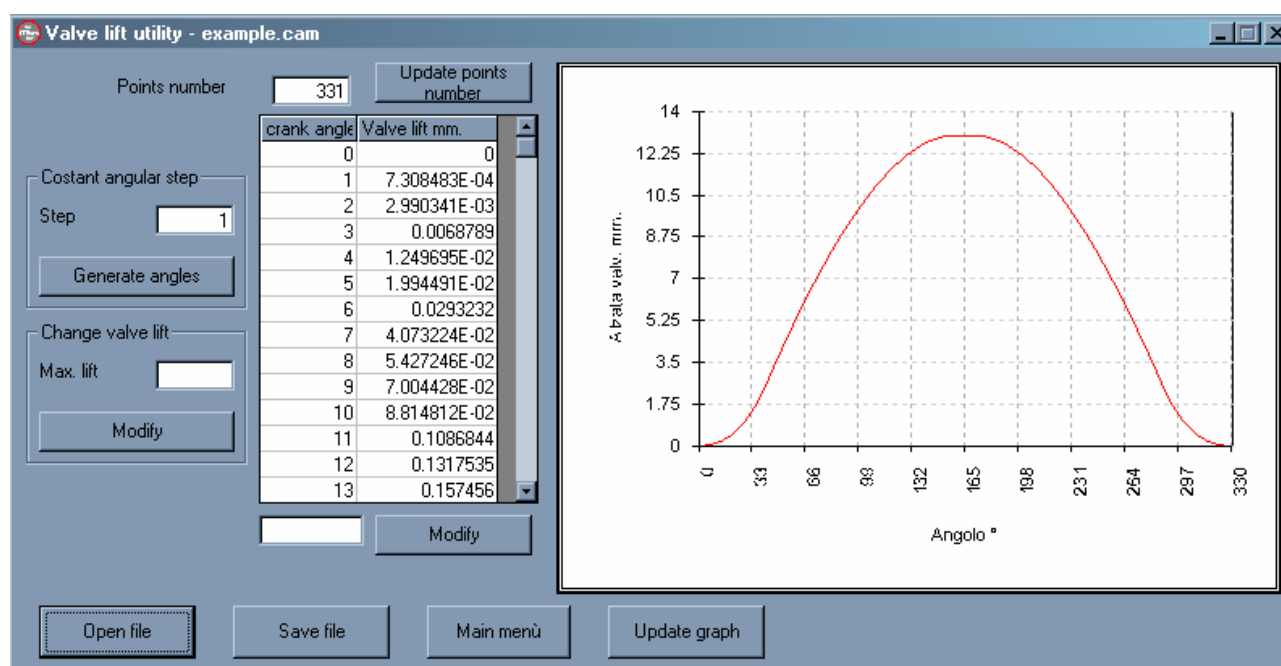
The crank radius : if the offset is different from zero the crank radius is not more the half of the stroke, therefore also this is useful information;

TDC crank Angle relative to the vertical line : if the offset is not zero the TDC will be not relative zero;

Angle of BTC relative to the vertical line: In the same way like above.

- **Create valve lift profile file:**

4TMono has a sufficiently comprehensive method of a lot of the most spread valve lift profiles. If however there is particular profile to test, it is possible to create it in the window that it will be opened after clicking on "Create valve lift profile file".



In this window the profile of valve lift will be specified for points, i.e. for every degree (or fraction of degree) of crank the value of the valve lift will be introduced in mm.

The profile is begun to write from the angle zero, i.e. the moment in which the valve begins to lift coincides with the zero.

Before beginning to write such values it is necessary to specify how many points will be written.

There are then two tools that try to facilitate the creation of a valve lift file:

the first one produces, knowing the number of points that the user will specify and from the angular increment chosen, all the column that represents the angles;

the second, starting from an existent profile, allows to change max valve lift.

The project has to be saved to be used subsequently from the simulator, clicking on the button 'Save file'.

It is possible also to open an existing file to modify it, clicking on the button "Open file".

To close the utility it is sufficient to click on "Main Menu".

It is possible then also to visualize a graph with the created profile and to see if it was written correctly or if the profile corresponds to that desired.

- **Create discharge coefficients file:**

Discharge coefficients utility - BL-500cc-2V-inlet.dsc

Number of points of valve lift Number of points of pressure

Inflow

	Lift ratio					
	0	0.2	0.4	0.6	0.8	1
2	0.94	0.96	0.96	0.79	0.785	0.84
1.8	0.96	0.96	0.885	0.785	0.785	0.84
1.6	0.965	0.97	0.875	0.775	0.76	0.84
1.4	0.98	0.98	0.875	0.765	0.76	0.83
1.2	0.985	0.98	0.88	0.765	0.74	0.81
1	1	0.98	0.88	0.775	0.76	0.8

Pressure ratio

Outflow

	Lift ratio					
	0	0.2	0.4	0.6	0.8	1
2	0.93	0.885	0.86	0.75	0.73	0.715
1.8	0.94	0.96	0.84	0.74	0.69	0.69
1.6	0.915	0.93	0.82	0.73	0.66	0.71
1.4	0.875	0.85	0.74	0.64	0.615	0.66
1.2	0.83	0.83	0.71	0.57	0.54	0.58
1	0.785	0.78	0.665	0.54	0.52	0.54

Pressure ratio

4TMono has a lot of configuration files for discharge coefficients; nevertheless if the user has specific maps of an engine, it is possible to create the files and then introduce them in the simulator with the utility 'Creates file discharge coefficients'.

Within the window, there are:

- a grid in which the user introduces the discharge coefficients for the flow "from duct to cylinder" (inflow);
- a grid in which the user introduces the discharge coefficients for the flow "from cylinder to duct" (outflow);
- a field in which is necessary to introduce the number of points in which the user must specify the 'Lift valve/Max valve lift';
- a field in which is necessary to introduce the number of points in which the user must specify the 'upstream/downstream Pressure ratio'.

With these tools is possible to create easily the map of the discharge coefficients.

To change only some values of an existing map (loaded with the button 'Open file') it is sufficient to click on the field wanted and, below the grid, change the value contained in the box, after that to click on 'Modify'.

To close the utility it is sufficient to click on 'main Menu'.

3.3 RESULTS

In this menu we have the following options:

View graphic results:

Clicking on this option it will be possible to view the results of the simulation in graphic format: at the conclusion of each simulation, 4TMono will create a file '.out', i.e. a file that contains the results that can be visualized like graphs.

First it will be asked what file '.out' to be opened and, then, will appear a series of graphs on the main window of 4TMono and a series of buttons that will allow to change the pages, each with a different set of graphs. For further details look at the chapter. 5.

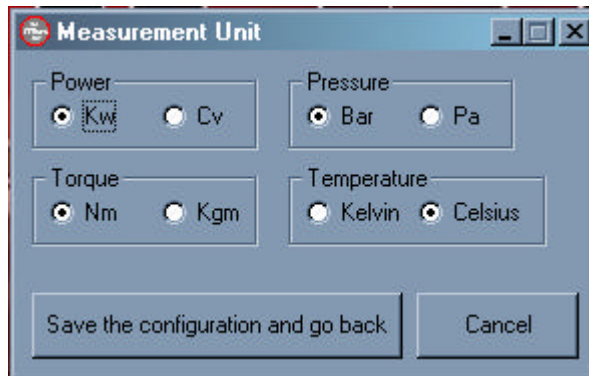
View the results in text mode:

Clicking on this option it will be possible to view the results of the simulation in text mode. In the same way of the results in graphic mode, 4TMono will create some files '.txt' that contain the results of the simulation in text mode and that are then visualized in the main window of the program.

After having specified the file '.txt' to open, on the screen will appear a window that contains in text mode all the information results of a simulation. Easily consultable and printable through a button situated on the right top in the main window

Unity of measure:

In 4TMono is possible also to change the measure unity of the results; allowing to choose, by the user, the measure unity desired.



The parameters that can be customized are:

- Power:

The possible measure unities are :

Kilowatt (Kw);

Horses (Cv);

- Torque:

The measure unity is:

Newton x meter (Nm);

Kilograms x meter (Kgm)

- Pressure:

The measure unity is:

Pascal (Pa);

Bar;

Temperature:

The measure unity is:

Kelvin (K);

Celsius C.

3.4 HELP

Manual:

With this option the present help will be visualized. For further information on the features of 4TMono see the web site www.rtz-soft.com or to send an e-mail to info@rtz-soft.com.

Scientifica documentation

With this option the scientific documentation of 4TMono will be opened in an Adobe Acrobat Reader window: in this document there are all the equations utilized to build this simulator.

For further information on the features of 4TMono see the web site www.rtz-soft.com or to send an e-mail to info@rtz-soft.com

About:

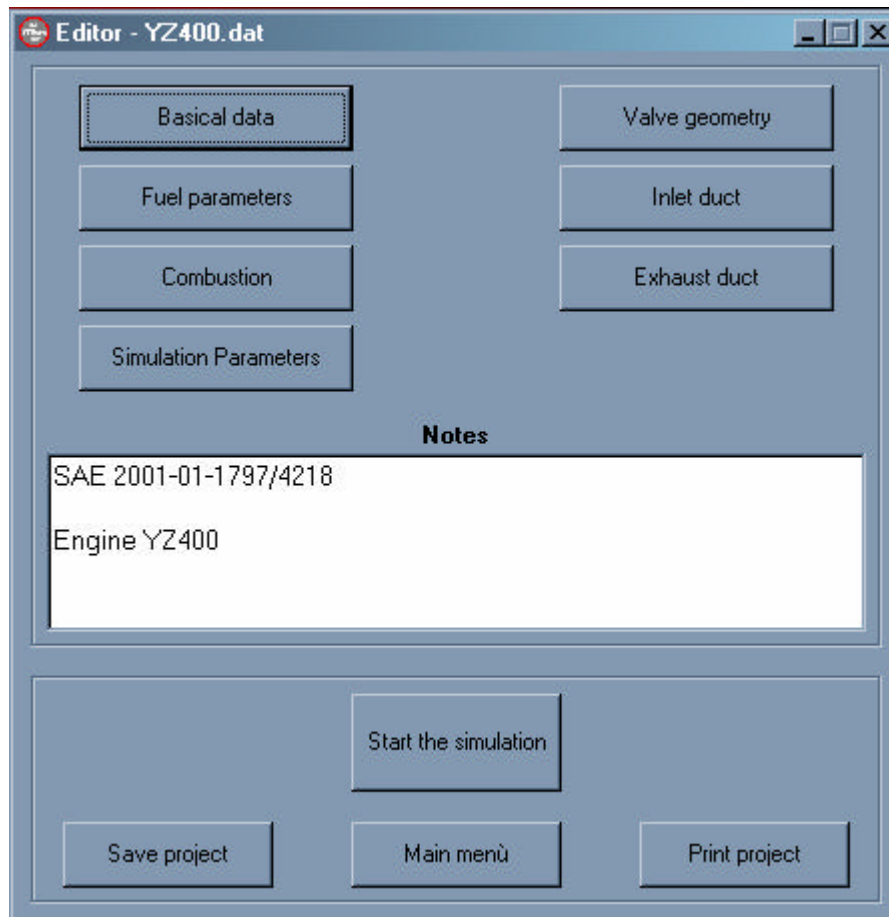
In this window are visualized the information relative to the version of the software and to the site web where it's possible to find further information on the software and how contact the author.

3.5 EXIT

Clicking on this option, a window will be opened that will ask to exit the software; it is equivalent to the option 'Exit 4TMono' from the menu 'File'.

4. THE EDITOR

The editor is the fundamental window both for the insertion and editing of the projects, and for the creation of the results files.



In the editor the data of an engine are subdivided in varied groups that will be explained; there is then a space to write the comments to the type of engine in exam, for example the modifies made ecc. and also the button like those for carry out the simulation, save and printing of the projects.

4.1 BASIC DATA

Clicking on the button "Basic data" a window will be opened in which can be specify the basic dimensions of the engine in examination.

Basical data

Number of Cilinders: 1

Bore mm.: 92

Stroke mm.: 60.1

Con rod mm.: 102

Offset mm.: 0

Combustion chamber volume cc.: 34.78

Crevices Volume cc.: 0.2

Calculate Combustion chamber volume cc.

Swept volume cc.: 400

Compression ratio: 12.5

Calculate

The Volume is 34.7826086956522 cc.

Main menù **Back**

The values to introduce are:

Number of the cylinders:

like already said before, 4TMono can simulate engines multicilinder that have not fluidodinamic connections and if there are more cylinders, in this field the number can be specified:

Bore mm.:

Stroke mm. :

Connecting rod mm. :

Offset mm. :

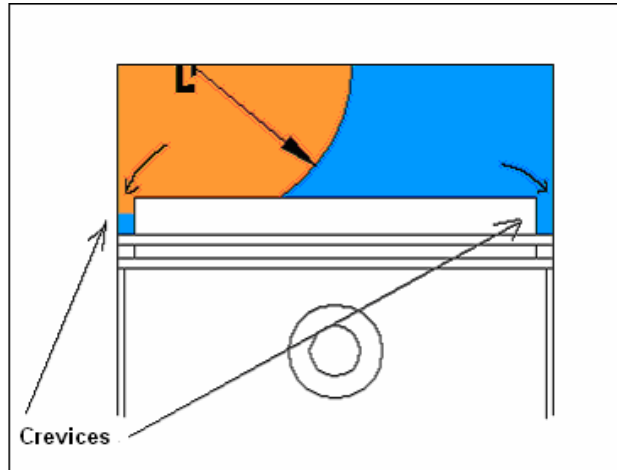
If the engine presents an offset between the piston axis and the crankshaft axis, this value can be introduced here;

Combustion chamber Volume cc. :

In this field it can be introduced the value of the combustion chamber volume. It does not consider the volume of the spark plug filleting;

- **Volume interstizi cc.:**

Within the combustion chamber, there are many little “zones”, in which the flame front can't penetrate (during combustion). Such volumes are for example the volume between the lateral walls of the cylinder, the piston and the top ring.



Schematic representation of the crevices within an engine considered in the software during simulation.

There is then an useful tool for the calculation of combustion chamber volume knowing the unitary swept volume and the compression ratio; this tool is made to facilitate the operation of the data insertion;

For return back in the editor it is sufficient to click on 'Back', 4TMono will do therefore a check of the data introduced and will report eventual mistakes, while if the user wants to go back without having completed all the fields, it will be necessary to click on 'main Menu'. In this case all the modification carried out from the last rescue will be lost

4.2 FUEL PARAMETERS

In this window there are reported the most important variables relative to the fuel that will be used and particularly:

Fuel Parameters

Fuel type

☐ Octane
 ☐ Ethanol
☐ Leaded gasoline
 ☐ Methane
☒ Unleaded gasoline
 ☐ Propane (CLG)
☐ Methanol
 ☐ Hydrogen

Octane number

Load Partialization 0.01-1

Variable equivalence ratio ?

☐ No
 ☒ Yes

Rpm Equivalence ratio

	1	2
Rpm	1000	5000
Equivalence ratio	1.18	1.15

- **Type of fuel:**

in this version were implemented 8 different types of fuels; choose which is the most similar to the fuel used by the engine;

- **Octane number;**
- **Partial load:**

Such value represents the fraction of area crossable by the gas through the inlet throat (carb, butterfly ecc.). If the engine works at wide open throttle such value will be 1, while if the butterfly will leave only $\frac{1}{4}$ of the area that would have been had if it will be all open, then such value will be 0.25. The value has to be greater of zero and to be not greater than one.

- **Variable air-fuel ratio:**

	1	2
Rpm	2000	4000
Equivalence ratio	1	1.17

If the engine is carburetted (but also with injection system), is known that the air-fuel ratio is variable. In this case is taken that this value change with the RPM, i.e. the user can specify for every RPM the relative value. In this field the user must specify if this is retained variable or not:

If it is fixed, it will ask to introduce only the value of equivalence ratio and will be the same for all of the RPM;

If it is variable there will be a grid to compile in which one column represents the RPM and in the other the user must specify the value of the equivalence ratio.

The equivalence ratio is an adimensional value and is the ratio between stoichiometric air-fuel ratio and the desired air fuel ratio: in practice it is greater than 1 for the rich mixtures and less for the lean; if it is equal to 1 obviously is stoichiometric.

The best value for the equivalence ratio from the point of view of the performances is about 1.1-1.2 while the best one for the low consumptions is approximately 0.9.

For return back in the editor it is sufficient to click on 'Back', 4TMono will do therefore a check of the data introduced and will report eventual mistakes, while if the user wants to go back without having completed all the fields, it will be necessary to click on 'main Menu'. In this case all the modification carried out from the last rescue will be lost.

4.3 COMBUSTION

In this window the most important parameters regarding the combustion of the engine.

The screenshot shows the 'Combustion' window with the following sections:

- Variable advance timing ?**: Radio buttons for 'Yes' (selected) and 'No'.
- Rpm**: Input field with value '5000'.
- Advance BTDC**: Input field with value '25'.
- Buttons**: 'Add', 'Modify', and 'Delete'.
- Table**:

	1	2
Rpm	1000	5000
Advance BTDC	5	25
- Combustion model**:
 - Radio buttons for 'Wiebe' and 'Turbulent' (selected).
 - Combustion Chamber**: Radio buttons for 'Emispheric' and 'Disc' (selected).
 - Spark position**: Input field with value '0.31'.
 - Spark electrodes distance mm**: Input field with value '0.9'.
 - Turbulence parameter**: Input field with value '1.5'.
- Temperatures**:
 - Cylinder liner temperature °C**: Input field with value '150'.
 - Piston temperature °C**: Input field with value '250'.
 - Head temperature °C**: Input field with value '300'.
- Buttons**: 'Main menù' and 'Back'.

The fields that have to be filled up are:

- **Variable advance timing:**

in this field it is specified if the advance timing is variable or not; this procedure is conceptually the same to that for the setting of the values relative to the "Variable air-fuel ratio", i.e. if the advance is fixed, it will be necessary to specify only that value, while in the second case it will be necessary to edit a grill associating to an RPM its advance.

If the model used is "Wiebe" then it's necessary to input the following data:

- **Combustion duration in degrees:**

After which the combustion is started, (time of incubation or ignition delay) it will be necessary to specify its duration. This value generally is about 40-60 and depends a lot from the shape of the combustion chamber and from the turbulence level present in the cylinder.

- **Combustion parameters:**

In this field the user has to introduce all of the values relative to the combustion; that are:

1. Time of incubation of the combustion in degrees:

from the moment of the ignition of the spark, there a little time in which the combustion is not appreciable, such value generally is about 10-20 degrees, and generally the higher values correspond for higher RPM..

- **AWiebe:** is a representative value of the quantity of mixture that burns during the combustion: for $A_{wiebe}=6.906$ the mixture that burns is 99.999% of the present one in the cylinder; generally is a values of experimental nature;
- **MWiebe:** is a representative value of the quality of the combustion, named also “shape factor”. For low values of M_{wiebe} , most of the combustion happens in the first degrees, while for high values in the end. Such value is about 1-2 (for a 4 stroke engine about 1.5) and is a value of experimental nature; .

If the user haven't experimental data, it's possible to define some common values that are sufficient for most of the applications:.

The user could define:

Time of incubation in degrees: 0

Combustion duration: 50-60 degrees (or however a value that try to take the advance nearest possible to the real one; if the anticipation is high, generally means that the combustion duration is long);

A_{wiebe} : 6.9;

M_{wiebe} : 2.

If the model used is “Turbulent” then it’s necessary to input the following data:

- **Combustion chamber type** : “disc” o “emispheric”;

For the disc shaped chamber it’s necessary to insert also:

- **Spark plug position;**

This value is representative of the distance of the spark plug from the extremity of the combustion chamber: if it's '0' then the spark plug is completely offset, while if it's 0.5 it's centred.

Generally it's convenient to use the Disc shaped chamber and set this value to 0.3, and make the calibration with the experimental data.

- **Plug electrodes distance mm.;**
- **Turbulence parameter;**

This value is about unity and if experimental data are not available, leave this value to 1.5

However for higher values we have higher turbulence levels, vice versa for the lower ones: the range of this value is between 0.5 and 3.

- **Cylinder walls temperature:** in this field it will be necessary to introduce the temperature of the cylinder liner: generally such value should not exceed 180 °C (indicating value 150°C);
- **Piston temperature:** such values generally fluctuates around 200-250 °C;
- **Head temperature:** such value generally fluctuates around 250-300 °C;
- **Heat transfer coefficients:** to evaluate the heat transfer between cylinder and its walls it's necessary put in 3 coefficients of the following: $Nu = a \cdot Re^b \cdot Pr^c$.

These three parameters are generally evaluated experimentally and, if experimental data are not available, use the following values:

a=0.07;

b=0.8;

c=0.33.

For return back in the editor it is sufficient to click on 'Back', 4TMono will do therefore a check of the data introduced and will report eventual mistakes, while if the user wants to go back without having completed all the fields, it will be necessary to click on 'main Menu'. In this case all the modification carried out from the last rescue will be lost.

4.4 SIMULATION PARAMETERS

In this window there are all of the parameters necessary to lead the simulation of a specific project.

The screenshot shows a software window titled "Simulation parameters". It contains several groups of input fields and buttons. The top-left group has four text boxes for "Initial Rpm" (4500), "Final Rpm" (11000), "Rpm for graphic output" (9000), and "Rpm Step" (250). The top-right group, under "Condizioni ambientali", has three text boxes for "Ambient temperature °C" (20), "Ambient pressure bar" (1.01325), and "Humidity % Vol." (50). The bottom-left group, under "Simulation parameters", has two radio buttons for "Auto" and "Manual" (selected), and four text boxes for "Inlet pipe step factor mm." (5), "Exhaust pipe step factor mm." (10), "Minimum number of iterations" (10), and "Maximum number of iterations" (30). The bottom-right group, under "Dynamic Airbox", has two radio buttons for "Yes" (selected) and "No", and two text boxes for "Global gear ratio" (4.5) and "Traction wheels radius mm." (250). At the bottom are two buttons: "Main menù" and "Back".

These parameters are:

- **Initial RPM;**
- **Final RPM;**
- **RPM for graphic output;**
- **RPM step;**

With these four parameters the user must specify the initial RPM and final RPM of the simulation, while in this interval with the parameter "RPM step" can specify the step; the "RPM for graphic output" is that in which 4TMono gives better informations, because it creates a number of graphs, not only with the RPM, but also with the crank angle.

- Simulation parameters:

In this case there are two options:

1. **"Auto": 4TMono will determine automatically the better configurations to lead the simulation;**

2. "Manual" : the user must specify some parameters to define, that are:

a) Pipe step factor of inlet duct mm.;

b) Pipe step factor of exhaust duct mm.;

The simulation models of the internal combustion engines, divide the ducts in many little segments (that have the length of the "pipe step factor") for study the behaviour of the gas and therefore for supply the necessary values for the study of the cylinder thermodynamics: every duct is divided in many small segments, and the two values above formulated are their length.

These variables influence strongly the accuracy of the results, but also the times of computation, because with smaller values of pipe step factor the results are more accurate, but the computation time is longer. Generally for the inlet duct, a value of 10 mm. is more than sufficient while for the exhaust it can be used a value of 20 mm.

In the definition of these values, it's important to keep in mind that the pipe step factor have to be always sufficiently smaller of the smallest segment of duct, otherwise the information of them can be lost during the simulation.

c) Minimum number of iteration;

during a simulation, 4TMono, for each RPM, carries out a certain number of iteration (or revolutions of crankshaft) before passing to the successive one: generally are sufficient not much iterations to have good results. In this field it will be introduced its lower value, i.e. even if the simulator arrives to sufficiently small error before this value, it will still continue in that RPM, until it will exceed it.

d) Maximum number of iteration;

It is not sure that however that in every configuration the program reach a sufficiently small value of the error for each Rpm, i.e. it doesn't arrive at convergence and therefore it's well to specify also the maximum number of iteration beyond which the simulator doesn't go, to pass then to the successive Rpm. In the hypothesis above described, 4TMono makes however a media of the all the variables on more iteration to make the error however low.

- **Ambient temperature °C;**

- **Ambient Pressure Bar;**
- **Humidity %Vol.**

These instead are the ambient conditions in which the engine is simulated.

Regarding the inlet conditions, the vehicle velocity could influence the engine performance.

The valued to be added, to take account of this phenomenon are::

- **Global gear-ratio;**

This is the ratio between the engine Rpm and the traction wheels rpm.

- **Traction wheels radius mm.**

For return back in the editor it is sufficient to click on 'Back', 4TMono will do therefore a check of the data introduced and will report eventual mistakes, while if the user wants to go back without having completed all the fields, it will be necessary to click on 'main Menu'. In this case all the modification carried out from the last rescue will be lost.

4.5 VALVES GEOMETRY

In this window there are all the values relative to the inlet and exhaust valves: the approach is precisely the same both type of valves and in this section will be explained only the inlet one.

The parameters that have to be set are:

- **Inlet cam profile:**

The law of the valve movement, and therefore indirectly the profile of the cam that moves it, have to be known to carry out a simulation. In 4TMono there are 3 different ways to define such problem, that are:

1. **Polinomial:**

The valve profile is treated as a polynom of the following manner:

$$y = L_{\max} - \left(a \cdot q^2 + cp \cdot q^p + cq \cdot q^q + cr \cdot q^r + cs \cdot q^s \right)$$

where

y: valve lift;

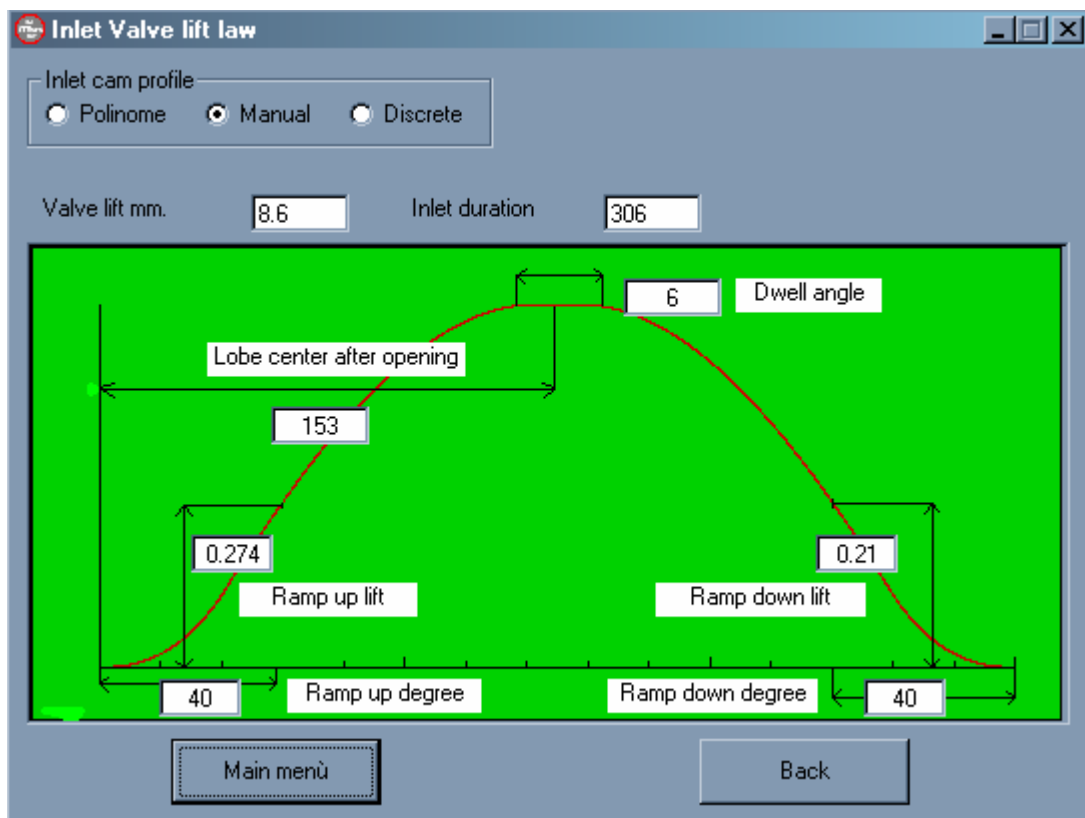
L_{\max} : maximum valve lift (input value);

q : crank angle;

p, q, r, s : polynom exponents;

a, cp, cq, cr, cs : polynom coefficients (calculated automatically).

2. **Manual:** with this option 4TMono allows to the user to customize many parameters hypothesizing that it is divided in 5 parts (as you can see in the figure located below) :



- **Ramp up:** for this phase the user have to specify two values: the duration and its final lift expressed as the ratio between its height and max lift. These values are generally 40° the first one and about 0.2-0.25 the second;
- **Main lift up:** this is the main phase of the curve;
- **Dwell:** expresses the duration in degrees of that part of curve in which the lifting remains constant and equal to the max lift: generally such value is about 5-10 degrees, but it can be also null;

- **Lobe center after opening:** Here it is specified the duration of the rise phase in degrees. If the profile is symmetrical, then this value is equal to the half of the total inlet duration.
- **Main lift down:** it is the same of the main lift up.
- **Ramp down:** also this phase is conceptually identical to the Ramp up.

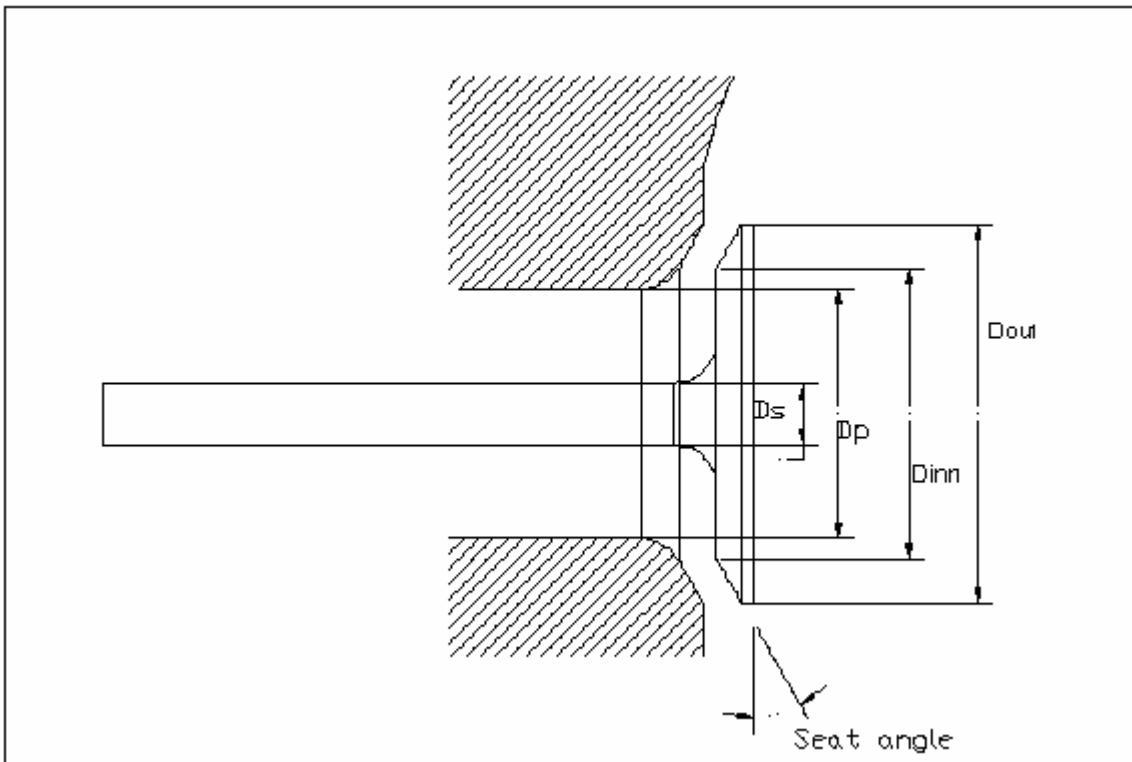
3.) **Discrete:** in this manner, if the user had a own lift profile, and therefore a file opportunely created with the utility "Create valve lift profile file", it can be specified here.

- **Variable timing:**

If the engine in examination has the capacity of to vary the angle of opening of the inlet valve, then is possible also to keep account of this phenomenon. The method to compose the grid, or of to introduce the angle of opening of the valve, is conceptually the same of the case of the variable air-fuel ratio or of the advance timing.

- **Valve dimensions:**

to define correctly the geometry of the inlet valves, is necessary to specify the following values:



1. Number of valves for each cylinder:

2. outer valve diameter mm. :
3. inner valve diameter mm. :
4. Port diameter mm. :
5. valve steam diameter mm.

The graph of the figure quoted above gives an idea of them.

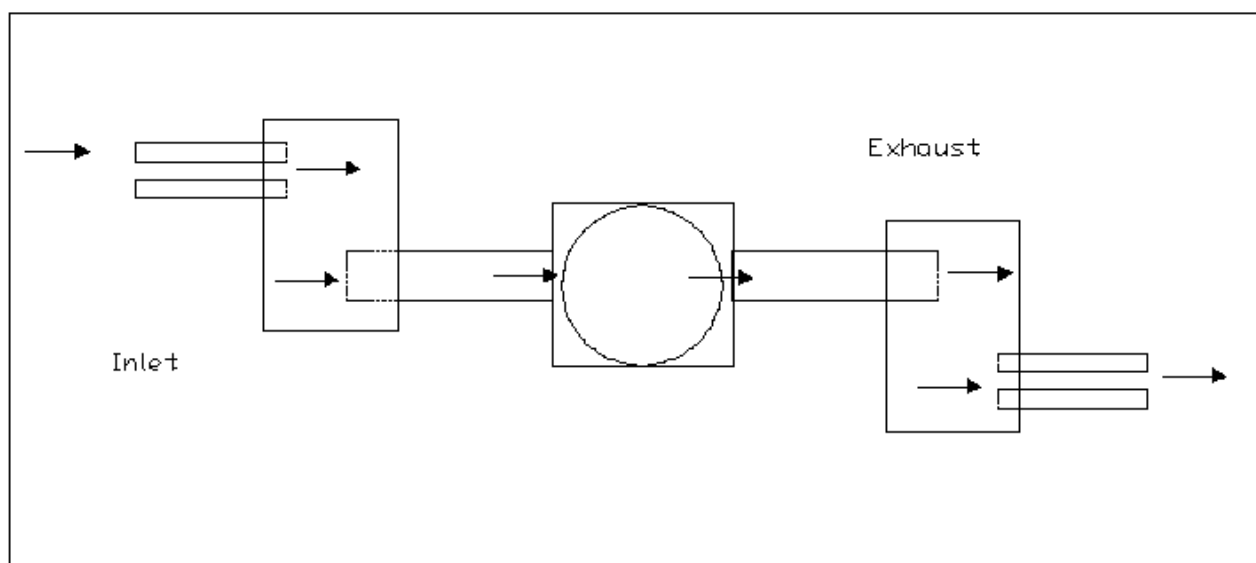
Discharge coefficients file:

in this field it will be necessary to specify the file that contains the information regarding valve discharge coefficients. Such file can be built with the utility "Create discharge coefficients file ", or can be chosen between those defaults of 4TMono.

For return back in the editor it is sufficient to click on 'Back', 4TMono will do therefore a check of the data introduced and will report eventual mistakes, while if the user wants to go back without having completed all the fields, it will be necessary to click on 'main Menu'. In this case all the modification carried out from the last rescue will be lost.

4.6 INLET DUCT

The maximum configuration of this version of 4TMono is that reported in the figure below:



It is had therefore in inlet and in the exhaust the possibility to introduce a box and a certain number of ducts before them (in inlet) and after (in exhaust).

When the grid representative of the ducts will be composed, it will be necessary to respect the direction of the arrows: it is begun therefore to compile the segments of the ducts from left to right; the upper graph is explanatory.

The window "Inlet duct" begins with the request of the presence of an inlet box and, in base to the answer of the user, will appear a series of fields relative to such volume to fill up.

N.	Init. diam. mm.	Lenght. mm.	Fin. diam. mm.
1	30	100	30

In the positive case it will be necessary to introduce the following data:

- **Number of ducts:** it is hypothesized that upstream of the volume there is a number greater than one of equal ducts.
- **Volume cc. :** Here have to specify the box volume in cc.
- **Box temperature °C;** to keep account of the heat exchange between the gas and his walls this value is necessary. Nevertheless this value is generally very similar to the environment temperature;
- **Duct temperature:** The same of the previous value ;
- **Belmouth entry /Belmouth exit:** here have to specify the end duct type, plain or belmouth: obviously the last gives better performances;

To introduce the data relative to the duct, it is subdivided in segments and for every segment the user must insert:

Initial diameter,

Segment length,

Final diameter.

The convention, like previously explained, is to introduce the values of the segments from left to right: in the previous case the first segment (and therefore the first line of the grid) will be that on the left at contact with the atmosphere (or with the volume if is present). It is necessary however to add a further length for every end with the atmosphere about the half of the diameter ($0.5 \cdot D$) to keep account of the end effects (the part sketched in the figure submitting represents only the left end).

Main duct

The figure below represents the main duct:

N.	Init. diam. mm.	Lenght. mm.	Fin. diam. mm.
1	43.8	80	43.8
2	43.8	36	39
3	39	16	40.5
4	40.5	43	40.5
5	40.5	20	38.5

- **Belmouth entry:**

Like for the previous case it is specified the type of end (that on the left in the figure), while for the opposite one, there will be the valve;

- **Inlet duct temperature:**

Here it is introduced the value of the main inlet duct temperature; in this case the value would be greater than the environmental temperature and if it is not known, a value included between 60-80°C would be sufficiently reasonable;

- **Duct composition grid:**

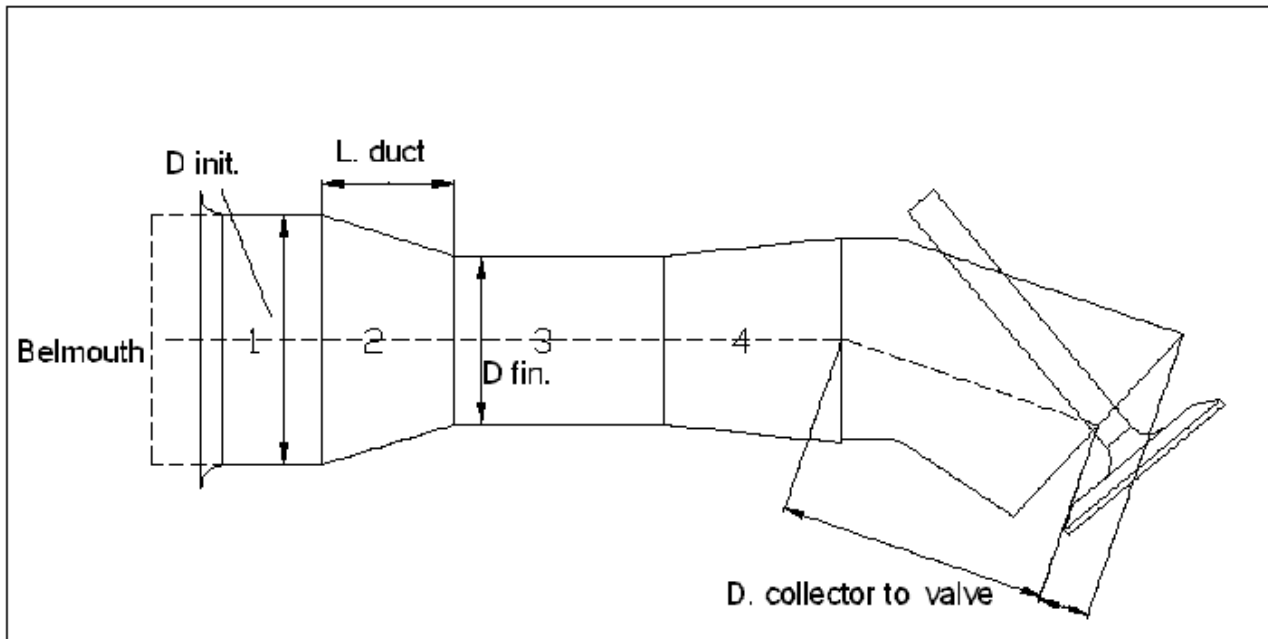
to introduce the data relative to the duct, it is subdivided in segments and for every segment are introduced:

Initial diameter,

Segment length,

Final diameter.

The convention, like previously explained, is to introduce the values of the segments from left to right: in the previous case the first segment (and therefore the first line of the grid) will be that on the left at contact with the atmosphere (or with the volume if is present). It is necessary however to add a further length for every end in contact with the atmosphere about the half of the diameter ($0.5 \cdot D$) to keep account of the end effects of end (the part sketched in the figure represents only the left end).



- **Distance collector-valve mm. :**

to introduce this value is necessary to have special caution. To introduce a value sufficiently precise, is necessary to introduce besides the mean value of such segment, (as it can be seen in the figure) a further length of the order of the half of the valve diameter.

- **Visualize duct profile:**

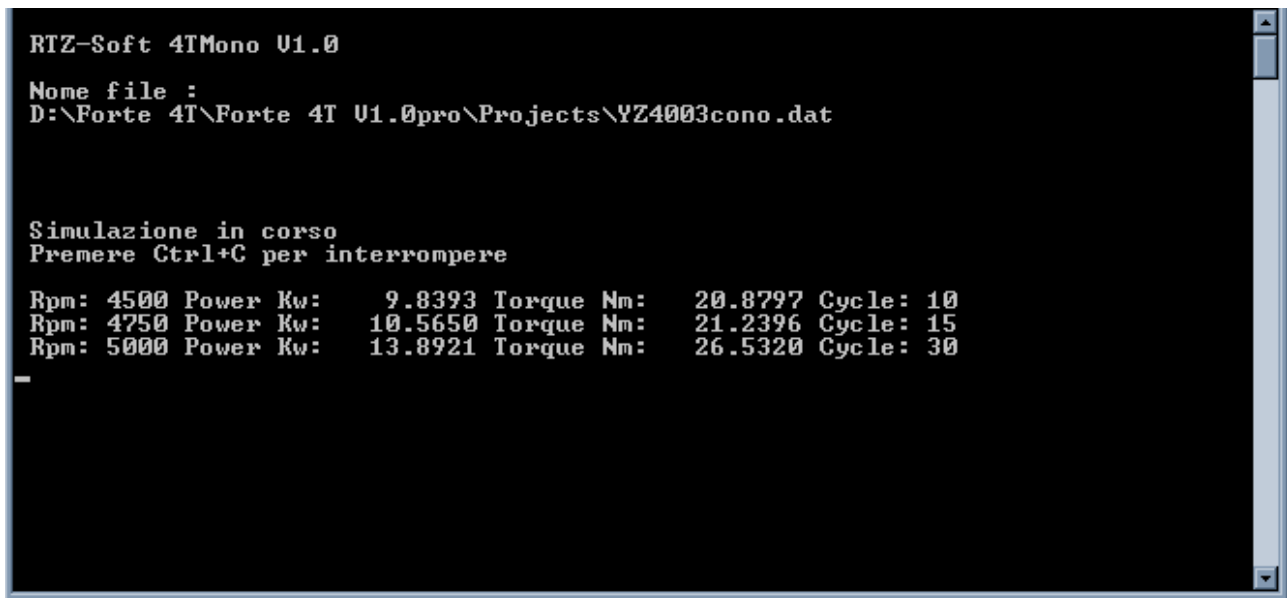
to have an idea of the duct introduced, clicking on this button will appear a graph that will visualize it.

For return back in the editor it is sufficient to click on 'Back', 4TMono will do therefore a check of the data introduced and will report eventual mistakes, while if the user wants to go back without having completed all the fields, it will be necessary to click on 'main Menu'. In this case all the modification carried out from the last rescue will be lost.

4.7 EXHAUST DUCT

This is the same of the inlet case and therefore for every information return to the previous section.

4.8 RUNNING THE SIMULATION

A screenshot of a software window titled "RTZ-Soft 4TMono V1.0". The window has a black background with white text. It displays the file path "D:\Forte 4T\Forte 4T V1.0pro\Projects\YZ4003cono.dat". Below this, it says "Simulazione in corso" and "Premere Ctrl+C per interrompere". At the bottom, there is a table of simulation data with three rows and six columns: Rpm, Power Kw, Torque Nm, Cycle, and two unlabeled columns. The data shows values increasing from 4500 to 5000 Rpm and 9.8393 to 13.8921 Kw, with torque and cycle values also increasing.

Rpm	Power Kw	Torque Nm	Cycle		
4500	9.8393	20.8797	10		
4750	10.5650	21.2396	15		
5000	13.8921	26.5320	30		

If the user has chosen to run the simulation, will appear a window in which will be visualized in real time the results. For all of the time of the simulation it will be not more possible to perform other operations on 4TMono, and is dissuaded from use other programs, in fact the simulation will use all the resources of the PC, and less operations there are in course, more rapid will be the simulation.

4.9 SAVING THE PROJECT

To save the current project, there is the button 'Save project'. All the files are saved with an extension '.dat', so that can be re-used subsequently.

4.10 MAIN MENU'

If it is wanted to return to the main menu, is sufficient to click on this button, but is necessary to remember always to save the modifies, otherwise they will be lost.

4.11 PRINTING THE PROJECT

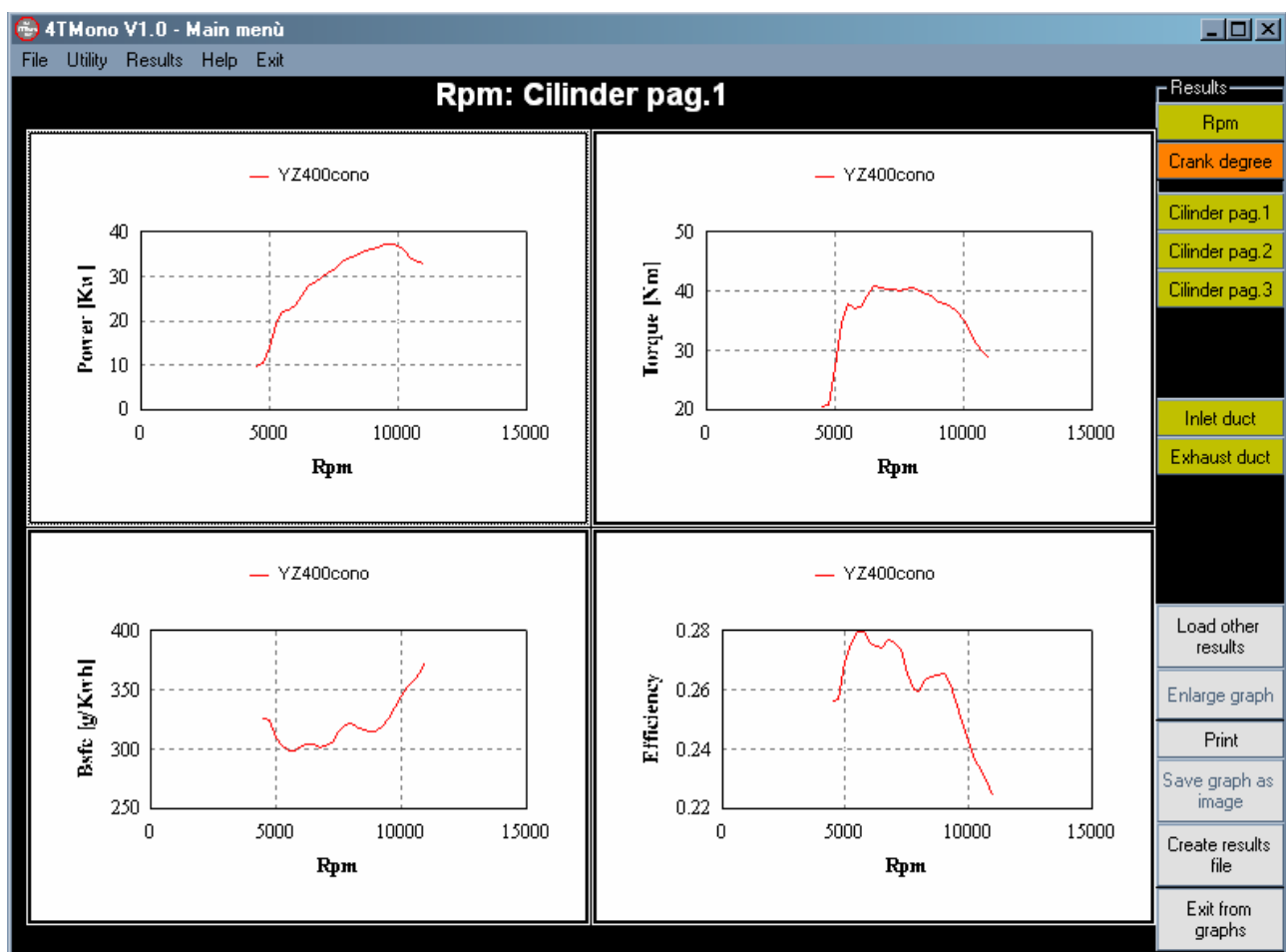
If the user wants to print a copy of the current project, is sufficient to click on 'Print the project'. 4TMono will create a document with all of the input parameters.

5. RESULTS

The results of a simulation can be presented both in graphic form and in text form.

When it is chosen the option "View simulation graphs" from the menu "Results" will appear a screen for the selection of the results file: such file have an extension '.out' and preserve the name of the initial project. For example if the project simulated it is called 'G50.dat', the results file will be 'G50.out'.

After to have chosen the results file will appear a screen like this:



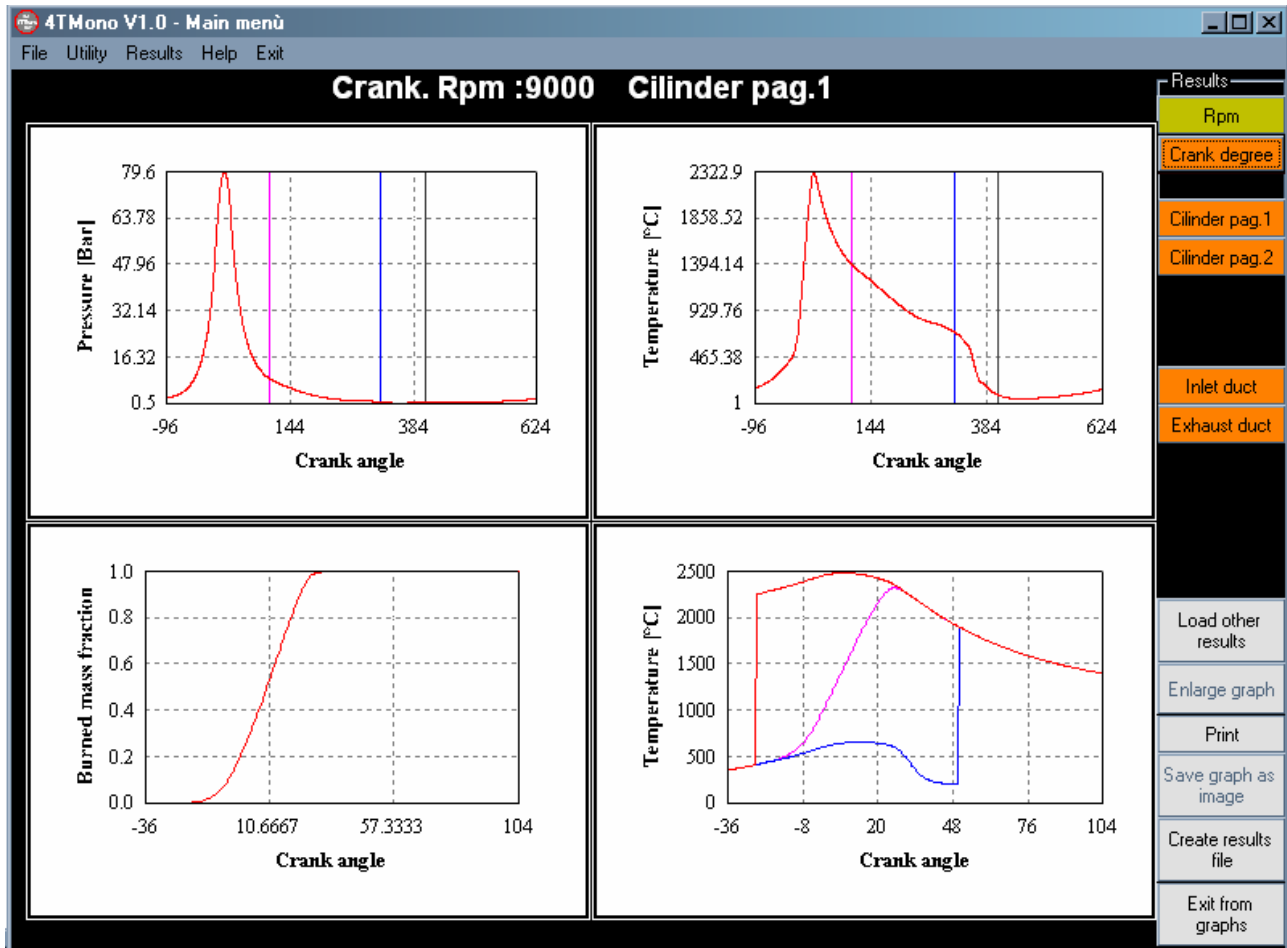
In the centre of the page there are 4 graphs and to the right there are a certain number of buttons that serve to choose the type of graphs that has to be visualized and some operations that can be accomplished over them.

Clicking two times on a graph it will appear an enlargement of that which will carry it to have dimensions larger than the original ; to restore then the initial dimensions is necessary again to click two times on the graph.

The graphs are divided in two groups:

- **RPM:** here are grouped all of the graphs presented with X axis as RPM and every button will present 4 graphs:
 1. **Cilinder pag.1:** here are reported the graphs of Power, Torque, specific Consumption and thermal efficiency.
 2. **Cilinder pag. 2:** here are reported the graphs of BMEP, Max pressure in the cylinder, MAX Temperature in the cylinder and knock index. If knock index is greater than one, there is detonation.
 3. **Cilinder pag.3:** here are reported the graphs relatives to the engine scavenging, that are: scavenging efficiency, delivery ratio, Volumetric Efficiency, trapping efficiency.
 4. **Duct before the inlet box:** here are reported the graphs of mean Temperature, mean Pressure, mean Speed and mean Purity of such duct;
 5. **Inlet box:** here are reported the graphs of mean Temperature, mean Pressure and mean Purity of such box;
 6. **Main inlet duct:** here are reported the graphs of mean Temperature, mean Pressure, mean Speed and mean Purity of such duct;
 7. **Main exhaust duct:** here are reported the graphs of mean Temperature, mean Pressure, mean Speed and mean Purity of such duct;
 8. **Exhaust box:** here are reported the graphs of mean Temperature, mean Pressure and mean Purity of such box;
 9. **Duct after the exhaust box:** here are reported the graphs of mean Temperature, mean Pressure, mean Speed and mean Purity of such duct;

- **Crank angle:** When it is specified the "RPM for graphic output", it is established on what regime are wanted further output informations. In fact, at that RPM, will be visualized graphics with X axis as crank angle:



1. **Cylinder pag.1:** In this page there are the graphs of Pressure, Temperature, the combustion curve and the graphs relative to the temperatures of the mixture, of the combustion products and of the mean between the two;
2. **Cylinder pag.2:** In this page there are the graphs of the pressure in the cylinder, the inlet and exhaust valve lift, the pressure-volume diagram and of the Work;
3. **Duct before the inlet box:** here are reported the graphs of Temperature, Pressure, Speed and Purity of such duct;
4. **Inlet box:** here are reported the graphs of Temperature, Pressure and Purity of such Volume;
5. **Main inlet duct:** here are reported the graphs, Pressure, Speed and Purity of such duct;

6. **Main exhaust duct:** here are reported the graphs of Temperature, Pressure, Speed and Purity of such duct.
 7. **Exhaust Box:** here are reported the graphs of Temperature, Pressure and Purity of such box;
 8. **Duct after the exhaust box:** here are reported the graphs of Temperature, Pressure, Speed and Purity of such duct.
- **Load other results:** if the user wants to compare more results it is sufficient to click on this button and will appear a window for the selection of other projects; it does not exist a superior limit to the maximum number of results that can be visualized, obviously with a lot of curves visualized the graphic will be more muddled.
 - **Enlarge graph:** If the graph was already enlarged is possible to enlarge further a part of it specifying the inferior and superior limit of it. Clicking on this button will appear a window in which it's possible to specify such limits in base to the part of graph that the user wants to visualize.
 - **Print:** If the user wants to print the graphs visualized in the main window, is necessary to click on this button. The graphs visualized in that moment will be printed, i.e. if in the main window are visualized 4 graphs, will be printed 4 graphs, in the case instead that a graph is enlarged, then it will be printed alone in foreground.
 - **Save graph as image:** is simile to the previous case, with the difference that the graph or the graphs will be saved as ". bmp" image.
 - **Create file results:** If the user wants to use the results of 4TMono as input data for other programs is possible to create some files with all of the results: in the directory "Results" it will be created a file for every variable. Every file will be constituted by two columns of numbers: one will be the RPM (or the crank angle) and the other will be the variable of interest (power, torque or the pressure with the crank angle).
 - **Exit from the graphs:** exit out from the graphs page.

6. GLOSSARY

In this chapter are reported the definitions of the main motoristic parameters presented in this software: it will be neglected those simpler (Power, Torque etc.)

BMEP: Breake mean Pressure;

IMEP: Indicated mean Pressure;

FMEP: Friction mean Pressure (represents the mechanical losses of the engine);

Scavenging efficiency: it is the ratio between the mass of mixture and the total mass present in the cylinder at the end of the inlet phase; it is remembered that generally in the cylinder are always present the products of the combustion of the previous cycle. It is practically an index of the "Quality" of the fluid substitution phase.

Delivery ratio: it is the ratio between the total mixture sent in the engine from the inlet valve and a reference mass; the last is the product between a reference density (at the temperature of 20°C and pressure of 1 atm) and engine swept volume. It is an index of the quantity of air aspirated from the engine.

Charging efficiency: is the ratio between the mixture really retained at the end of the inlet phase and the reference mass definite before. It is also the relation between the scavenging efficiency and the delivery ratio.

Trapping efficiency: is the ratio between the mixture really retained at the end of the inlet phase and the total mixture sent from the inlet valve. It is also this an index of the quality of the fluid substitution.

Purity: represents the fraction of mixture present in the fluid inside a duct; if such value is 1 then the gas is constituted only by mixture, while if equal to 0 is composed only by combustion products.

Detonation index: This index supplies information on the mixture and precisely if during the phase of combustion arrives at knock. If such value is greater than 1 it can be retained that there is knock, the opposite if is smaller than 1.