UNIVERSITY OF PITESTI *SCIENTIFIC BULLETIN*
FACULTY OF MECHANICS AND TECHNOLOGY **AUTOMOTIVE series, year XVII, No.21 (2)**

THERMIC ENGINES RUNNING IN A SINGLE REGIME

Nicolae CHIOREANU[1*]; Şerban CHIOREANU[2]; Dinu FODOR[1]
[1]University of Oradea, Romania, [2]Renault Technologie Roumanie, Romania

Abstract*: The new concept concerning engines running, consist in energy supply of the motor machine from an energy accumulator . Charging the energy accumulator is made by an energy generator, which is running in a single regime (monoregime) with maximum efficiency. The concept involves the development of engines, made from following components: energy generator, energy accumulator and motor machine****,*** *in which two energy transformations occurs: the primary transformation and the secondary transformation. The primary transformation is realized by the energy generator, which transforms the input energy (thermal energy) to another form of energy (fluid energy). The energy produced by the generator is stored in the energy accumulator. The secondary transformation is realized by the motor machine, which takes over the energy stored in the accumulator and transforms it in mechanical energy, usually under the form of a rotation movement. The engine is running efficiently if the energy generator, fulfils the following conditions: to produce a form of energy that can be easily stored in the energy accumulator and can be easily transmitted to the motor machine; to run in a single regime, automatic, on the principle* ***start-stop****, characterized by starting automatically, when the energy in the accumulator has the minimum admitted value, and stopping automatically, when the energy in the accumulator has the maximum admitted value. The energy forms which fulfil the above mentioned conditions are: the hydrostatic energy; and the pneumatic energy.*
The monoregime engines belong to the category of hybrid termohidraulic. They represent an absolute novelty. At the new engines two energy transformations occurs: thermic energy is transformed into a hydrostatic or pneumatic energy (through the energy generator); the hydrostatic or pneumatic energy is transformed into mechanic energy (through hydraulic or pneumatic engines). The monoregime engines characterized by the following specific features: running in a single regime (monoregime); without moment's idle running. We estimate the following advantages (compared to the nowadays drive systems by internal combustion engines): less fuel consumption, reduced pollution (it is much easier to optimize a single regime, compared to infinity, as to produce the current engines); simple construction; and good viability. Also, the monoregime engine can to assume, total or part, the transmission functions (control torque, speed and direction of rotation), including the function of braking with the recuperation energy.
The new concept as for the running of engines in a single regime (monoregime engines), represents a new research direction, obviously, is much easier to optimize a single regime, compared to an infinity, as to produce the current engines.

Keywords: monoregime, hydraulic accumulator, hybrid engine

GENERAL CONSIDERATION

The engine is the main part of the drive system from the motorized machine. It aims to transform a certain form of energy (thermal energy) into mechanical energy, usually in the form of a rotating motion. In a drive system, the mechanical energy transmission from driving motor of the working machine in a continuous mode to produce, by coupling the engine shaft at the parts of working machine, directly or through a transmission [1, 4, 5, 8]. The scheme of the system drive is as follows: the transmission **TR**, which there is to insert between the motor machine **MM** (thermal engine) and the working machine **ML**, change the mechanical parameters of the engine shaft (torque M_1, angular

* Corresponding author. Email: serban.chioreanu@daciagroup.com

velocity ω_1) (Figure 1). Changing the mechanical parameters of the transmission is assessed by the transmission ratio: $i_{12} = \omega_1/\omega_2 = M_2/M_1$.

The run drive system is stable, if the power produced by the driving motor is equal to the power needed to the working machine drive: $P_1 = P_2$ or $\omega_1 \cdot M_1 = \omega_2 \cdot M_2$. In general, the power needed to the working machine varies during the running progress of the drive system. To ensure a stable running system, is necessary to vary the driving motor power exactly as well as the power of the working machine. Varying the driving motor power is to carry out by energy consumed dosage devices (flow of fuel or flow of thermic agent) [1, 4, 5]. If the power needed to the working machine is constant, the driving motor to run in stationary regime. The torque and angular velocity is constant: $M_1 = ct.$; $\omega_1 = ct.$ If the power needed to the working machine is variable, the driving motor to run in transitory regime. The torque and angular velocity is variable: $M_1 \neq ct.$; $\omega_1 \neq ct.$ The transitory regime is the transition period a stationary regime to another, of the driving motor. The variation of the driving motor is more intense with both the operating conditions of the driving motor are more difficult and efficiency is lower.

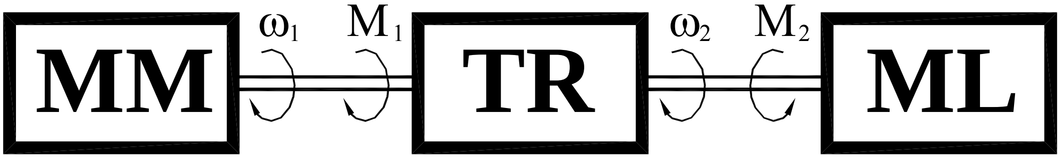

Figure 1. The scheme of the drive system

The most wide spread engines are *internal combustion engines* used mostly for propulsion of the motor vehicles. At these engines, the working regime is evaluated through the following sizes: *rotational speed* n; load coefficient χ; and the temperature of the walls of the combustion chamber [1, 4, 5]. The load coefficient χ is to define by the ratio between the moment produced by the engine M_1 and a reference moment, which is usually the maximum effective moment M_{1max}, during the rotational speed n, $\chi = (M_1/M_{1\max})_n$. The temperature of the walls of the combustion chamber is evaluated conventionally through the temperature of the cooling liquid or the temperature of the exhaust gases. Because of the *direct* link between the engine and the rolling elements, the regime of functioning must vary according to the rolling conditions. Due to the continuous transmission of mechanical energy from the engine to the car rolling elements, the engine power must vary in terms of running (loading regime with variable load). In these circumstances, the effective efficiency η_e depending on the speed and the rotation to vary (Figure 2a). *The maximum effective efficiency* η_{emax} is realized at a *single* load (*$\eta \approx 0,85$*) and of rotational speed, in all the other regimes the values of the effective efficiency are smaller, $\eta_e < \eta_{emax}$. In operation, an engine for a vehicle produces a variety of regimes: *light running 20-30 % ; acceleration 20-25 % ; deceleration 17-20 % ; constant speed 30-40 %* [1, 5].

In a certain period of time the driving motor produce a *middle efficiency* $\overline{\eta}$. The coefficient of efficiency ***e*** is defined by the following report: $e = \overline{\eta}/\eta_{e\max}$ [1, 7]. In *variable* regime*,* the efficiency coefficient is *sub-unit*<**1**. The current engines, used to operate automobiles, realizes the following values of the efficiency coefficient, e≈0,5-0.6 [1, 5]. Obviously, the efficiency is maximum if the engine run in a single regime, with an *effective efficiency* at the maximum value (***e=1***). Operating conditions at variable load, the value effective efficiency is *optimally*, if the engine operating regime is to vary according to the curve which links the maximum of the load curves (interrupted line) (Figure 2) [1, 5]. Optimal functioning of the car engine is ensured by a complex electronic system, called *electronic system of the propulsion group* [1, 7]. Obviously, if the engine would run only in one regime (monoregime) with maximum efficiency, independent of the rolling motor car, would result following advantages: a substantial *reduction* in fuel consumption; constructive *simplicity*, *no* electronic system of the propulsion group [3, 4].

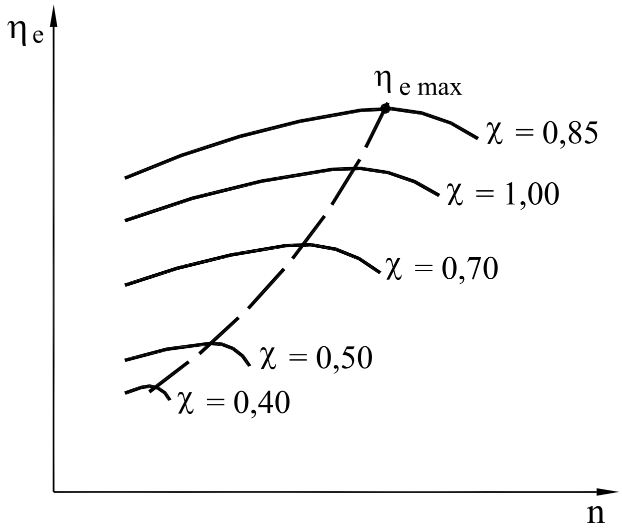

Figure 2. The efficiency variation depending on the operating regime

NEW CONCEPT FOR THE RUNNING OF ENGINES

The new concept as for the running of engines is to consist, in the motor machine from *energy accumulator* of *energy supply*. Charging the *energy accumulator* is made of an *energy generator*, which running in a *single regime* (monoregime) with *maximum* efficiency. The concept involves the development of engines, generally consist of: *energy generator* **GE**, *energy accumulator* **AE** and *motor machine* **MM,** in which two energy transformation occur, the *primary* transformation and the *secondary* transformation (Figure 3) [3, 4]. *The primary transformation* is realized by the energy generator, which transforms the input energy (thermal or electric) to another form of energy (different from the mechanic energy – fluid energy). The energy produced by the generator is stored in the energy accumulator **AE**. *The secondary transformation* is realized by the motor machine **MM**, which takes over the energy stored in the accumulator and transforms it in mechanical energy, usually under the form of a rotation movement.

The engine running is as follows: the generator **GE** transmits the produced energy to the accumulator **AE** until the energy in the accumulator reaches its maximum admitted value. In this moment, the accumulator automatically stops running until the energy in the accumulator drops to the minimum admitted value/level. In this way, the generator **GE** may run *in one regime only* with maximum efficiency, independently from *the working regime* of the motor machine **MM**. The motor machine takes over the energy from the accumulator and transforms it in mechanic energy according to the consumption realized by the working parts of the system. The energy flow can go both directions generator-accumulator and reverse, or accumulator-motor machine and reverse.

The engine running efficiently if the energy generator **GE** fulfils the following conditions: to produce a form of energy that can be *easily stored* in the energy accumulator **AE** and can be *easily transmitted* to the motor machine **MM**; to running *in a single regime, automatic*, on the principle ***start-stop***, characterized by *starting automatically*, when the energy in the accumulator has the minimum admitted value, and *stopping automatically*, when the energy in the accumulator has the maximum admitted value.

Figure 3. The running scheme of monoregime engines

The energy forms which fulfil the above mentioned conditions are: the *hydrostatic energy*; and the *pneumatic energy*. *The hydrostatic energy* can be used in a *large scale* of power and application domains. The hydrostatic drives are well known and considered to be superior compared to the other existing drives [6, 7, 9]. *The pneumatic energy* may be used at low power. In general, the pneumatic drives, is used in restricted areas of activity.
After to the energy form that we produce, generators are classified in: *hydrostatic generators* and *pneumatic generators*. The hydrostatic generators which transform the thermal energy are called *thermohydraulic monoregim generator. The energy accumulator* is a normal hydraulic accumulator (7). The *motor machine* is a rotational hydraulic engine(s) with adjustable capacity. These types of engines allow the variation of the rotation on a large scale and can recover the braking energy [6, 7, 9]. *The monoregime engines* belong to the category of hybrid *termohidraulic* engines. They represent an *absolute novelty*. Hybrid engines are known hybrid *thermoelectric* engines (hybrid series and parallel hybrid) which produce *three conversions* energy: the thermic energy is transformed in mechanic energy (through the heat engine); the mechanic energy is transformed in electric energy (through electric energy generator); the electric energy is transformed into mechanic energy (through electric engines) or it is stored in electric accumulators. The new engines there to produce *only two energy transformations*: thermic or electrical energy is transformed into a hydrostatic or pneumatic energy (through the energy generator); the hydrostatic or pneumatic energy is transformed into mechanic energy (through hydraulic or pneumatic engines).
The new concept as for the running of engines in a single regime (monoregime engines), represents *a new research direction*, obviously, is much easier to optimize a single regime, compared to an infinity as to produce the current engines.

MONOREGIME THERMIC ENGINES

The monoregime thermic engines transform the thermo energy, to obtain by combustion of fuel (petrol, Diesel oil, non-conventional fuels), into mechanic energy, generally as a rotary motion. The main parts of engine are: the *thermohydraulic monoregim generator* **TM**; the hydraulic accumulator **AH**, and the hydraulic engine **MH** (Figure 4).

The engine is equipping more with the fuel reservoir **RC** and the reservoir for hydraulic fluid **RH**. The *thermohydraulic monoregim generator* transforms the thermo energy to obtain by combustion of fuel in hydrostatic energy. The hydrostatic energy produced by *thermohydraulic generator* is to stock in the *hydraulic accumulator*. The hydraulic engine supply of energy is through the command system engine **SCM**. The hydraulic engine transforms the hydrostatic energy into mechanic energy necessary to drive the working machine.

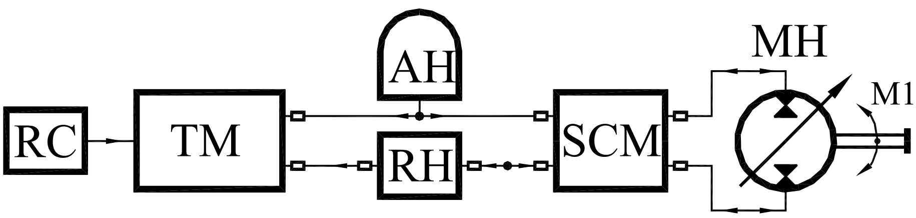

Figure 4. The running scheme of monoregime thermic engines

The thermohydraulic monoregim generator

The main part of the *thermohydraulic monoregim generator* consists of two cylinders: *the motor cylinder* **CM** and the *hydraulic cylinder* **CH** linked coaxially, and inside them the free piston **PL** has an alternating-rectilinear motion (Figure 5) [3, 4].
The free piston is the only mobile part, without articulated elements [2]. The starting-stopping of the head strokes piston to not adversely affect the running of the generator, because the speed and kinetic energy is zero at the ends of the stroke. Because of the movement of the piston, between the walls of the cylinder and the piston four chambers with variable volumes are formed: *the thermal chamber* **T**;

the compression chamber **C**; *and the hydraulic chambers* **H1** and **H2**. The piston motion is made under the action of the pressure forces of the gases from the thermal and compression chambers, and of the pressure forces of the hydraulic liquid from **H1** and **H2** chambers. In the thermal room take place the *processes of the thermal cycle,* in the compression room take place processes of air aspiration necessary to supercharge or to form an accumulation of pneumatic energy necessary for the movement of the piston. In the hydraulic chambers take place *processes of pumping* (suction-discharge) of the hydraulic liquid. The piston movement is coordinated by the *automatic command system* **SAC**. Information regarding the piston position is provided by the *transducers* **TH**. The piston moves between pvm (point of minimal volume) and pvM (point of maximum volume). The forces which operate on the piston are the $\boldsymbol{F_M}$, force created by the pressure of the gases in the thermal and compression chamber, and the $\boldsymbol{F_H}$ force, created by the pressure of the hydraulic liquid from **H1** and **H2** chambers. The F_M force has a great variation (exponential) during the stroke progress of the piston, and the F_H force is quasi-constant.

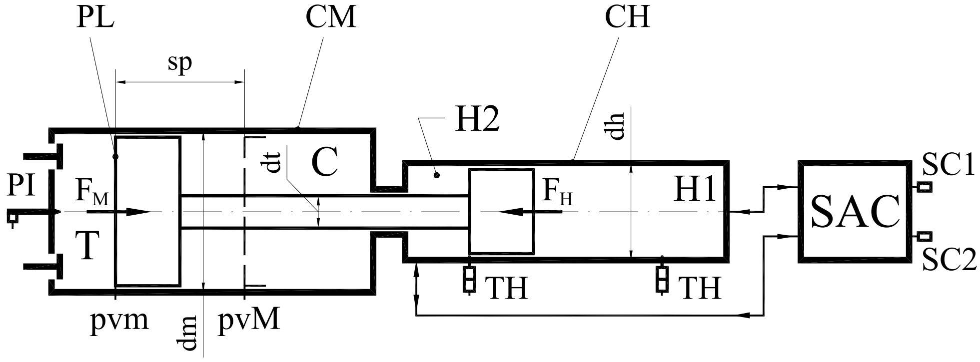

Figure 5. The running scheme of thermohydraulic monoregim generator

The thermodynamic processes of the thermal cycle from thermohydraulic generator are identical to the thermodynamic cycles of internal combustion engines. As the internal combustion engines, thermal cycle from thermohydraulic generator can take place at two strokes *(two stroke thermohydraulic generator*) or at four strokes (*four stroke thermohydraulic generator)*. The hydraulic energy to stock in the hydraulic accumulator the progress duration a thermal cycle is determined by the following relation:

$$W_H = \eta_{tp} \cdot \oint [p_T(x) - p_C(x)] \cdot dV \tag{1}$$

where: η_{tp} is total efficiency of the generator; $p_T(x)$ is the function of variation of the pressure gas in the thermal chamber; $p_C(x)$ is the function of variation of the pressure gas in the compression chamber; x is the position piston from the origin point of the coordinates axis.

The value of total efficiency of the thermohydraulic generator is dependent on the energy losses that occur the progress duration a thermal cycle: loss of energy produced by the forces of friction; energy loss caused by the hydraulic fluid viscosity; the energy consumed to move the piston of the strokes of the fresh load admission and the exhaust gases, if the four-stroke thermohydraulic generators, etc.

The power thermohydraulic monoregim generator is determined by the following relation:

$$P_H = f_{ct} \cdot W_H = p_{ha} \cdot Q_p \tag{2}$$

where: f_{ct} is the progress frequency of the thermal cycles; p_{ha} is the hydraulic fluid from the hydraulic accumulator; Q_p is the thermohydraulic monoregim generator flow.

By solving the equations (1) and (2) (computation of the thermodynamic cycle) is obtained and the following sizes: the diameter d_m of the motor cylinder; the length of stroke s_p of the piston motion; and the minimum volume of the thermal chamber.

During the compression stroke progress of the fresh load the hydraulic chambers are in connection with the hydraulic accumulator. The feature function $F_C(x)$ for the compression stroke is defined by the following relation:

$$F_c(x) = \frac{m_p \cdot w_{pc}^2(x)}{2} - L_C(x) \tag{3}$$

where: m_p is the mass piston; $w_{pc}(x)$ is the function of variation of the piston speed to the compression stroke; $L_C(x)$ is the function of variation of the mechanical work developed of the compression stroke, by the gas pressure of thermal and compression the chamber, and the hydraulic liquid pressure of the hydraulic chambers.

During the expansion stroke progress of the flue gases the hydraulic chamber H1 are in connection with the hydraulic accumulator and the hydraulic chamber H2 are in connection with the hydraulic fluid. The feature function $F_D(x)$ for the expansion stroke is defined by the following relation:

$$F_d(x) = \frac{m_p \cdot w_{pd}^2(x)}{2} - L_D(x) \tag{4}$$

where: $w_{pd}(x)$ is the function of variation of the piston speed to the expansion stroke; $L_D(x)$ is the function of variation of the mechanical work developed of the expansion stroke, by the gas pressure of thermal and compression the chamber, and the hydraulic liquid pressure of the hydraulic chambers.

If the kinetic energy theorem to apply to the compression stroke and to the expansion stroke of the piston, to obtain the following system of equations:

$$\begin{cases} F_c(x_0 + s_p) - F_c(x_0) = 0 \\ F_d(x_0) - F_c(s_p + x_0) = 0 \end{cases} \tag{5}$$

where: x_0 is the position pvm from the origin point of the coordinates axis; s_p is the length of stroke of the piston motion.

The solutions of the system equations (5) to represent, the size of the diameter $\mathbf{d_h}$ of the hydraulic and the size the diameter d_t of piston rod.

The function of variation of the piston acceleration from the expansion stroke of the flue gases is defined by the following relation:

$$a_{pd}(x) = \frac{d}{d\tau} w_{pd}(x) = w_{pd}(x) \cdot \frac{d}{dx} w_{pd}(x) \tag{6}$$

The piston mass is determined from the condition of limiting the maximum piston speed of the expansion stroke from a certain value $w_{p\ max}$. Maximum speed is the point x_a where the piston acceleration is zero:

$$a_{pd}(x_a) = 0 \tag{7}$$

The solution of the equation (7) to represent, the size of the coordinate x_a . If the kinetic energy theorem to apply between pvM and the point x_a, obtain the relation of computation for piston mass:

$$m_p = \frac{2}{w_{p\max}^2} \cdot L_D(x_a) \tag{8}$$

The time of progress of one stroke i of the piston, is determined by the relation:

$$\tau_{pi} = \frac{s_p}{\overline{w}_{pi}} = \frac{s_p^2}{\int_{x_0}^{x_0+s_p} w_{pi}(x) \cdot dx} \tag{9}$$

where: $w_{pi}(x)$ is the function of variation of the piston speed of the stroke ***i***; $\overline{w}_{pi}$ is the piston average speed of the stroke ***i***.

The frequency with which it conducts thermal cycle is calculated by the relationship:

$$f_{ct} = \frac{1}{\sum_{i=1}^{\nu} \tau_{pi}} \tag{10}$$

where: ν the number of piston strokes of one thermal cycle, ν=2, 4.

In conclusion, the thermohydraulic monoregim generator *characterized* by the following features: *running in a single regime* (monoregime), automatic running on the principle *start-stop*; without moment's *idle running*; have *only one mobile element* an alternating-rectilinear motion.

Hydraulic accumulator

The hydraulic accumulator is the type hydro-pneumatic accumulator [6, 7, 9]. The accumulator have the role to accumulate the energy produced by the thermopump, necessary for proceed the resistance strokes of thermal cycle and for the hydraulic engines supply. Also, the accumulator amortized the flow pulsations and the hydraulic shocks. The pressure from accumulator is quasi-constant, it varies between two limits**:** $p_{h\ min}$ is the minimum pressure; $p_{h\ max}$ is the maximum pressure. The media extreme pressure to represent, the size the nominal pressure from accumulator: $p_{ha} = (p_{h\min} + p_{h\min})/2$. The hydro-pneumatic accumulator works best when the ratio of the extreme pressures is the following values: $p_{h\max} / p_{h\min} = 1{,}1 \div 1{,}2$ [10]. The accumulator parameters are: the total volume V_{ta}; and the nominal pressure p_{ha}. The efficient volume of accumulator is determined by the relation:

$$V_{ua} = V_{H1} + \frac{Q_p}{f_c} \qquad (11)$$

where: V_{H1} is the capacity cylinder of the hydraulic chamber **H1** .
If the pressure variation $(p_{h\max} - p_{h\min})$ is small, the result is a decrease of the total volume of accumulator and increase the frequency of start-stop the generator. The total volume of the accumulator must be large enough to absorb the flow pulsations and the hydraulic shocks. Because of to the way in conception, the increased frequency of stop-start does not affect in any way the running of the generator.

Hydraulic engine

The hydraulic engine transforms the hydrostatic energy into mechanic energy in the form of a rotation movement. The volume capacity V_M of the engine is variable in order to can control the speed. Also, the engine is a reversible machine, in order to can recover the mechanical braking energy through it re-transform in hydrostatics.
The torque M_1 from the shaft of the hydraulic engine is determined by the relation:

$$M_1 = \frac{1}{2\pi} \cdot p_{ha} \cdot V_M \qquad (12)$$

The stability of motion, the control and the direction of rotation change of the motor shaft to carry out by hydraulic control system engine **SCM** .

RESULTS AND DISCUSSION

The monoregime thermic engines are characterized by the following specific features: running in a *single regime* (monoregime); without moment's *idle running*. We estimate the following advantages (compared to the nowadays drive systems by internal combustion engines): *less fuel* consumption, *reduced pollution* (it is much easier to optimize a single regime, compared to infinity, as to produce the current engines); *simple* construction; and good *viability*. Also, the monoregime thermic engine can to *assume* total or part, the transmission functions (control torque, speed and direction of rotation), including the function of braking with the recuperation energy.
The main directions in order to perfecting of the internal combustion engines are: reducing *the fuel consumption*; and reducing *the emissions* of noxious pollutants [1, 5, 8].
The ways to *reduce the fuel* consumption during the thermal processes are: *over compression* at *the spark ignition engines*, until the detonation limit (through optimal spark start, by modifying the architecture of the combustion chamber, and slat mixture); the burning of lean mixtures at *the spark ignition engines*, α>1 (dosage coefficient), by modifying the combustion chamber and uneven distribution of the fuel mixture (the mixture turning into layers); reducing the heat loss, through partially or totally insulating (with ceramics) of the combustion space (adiabatic engine); the growth of the compression ratio(ε=19-23) at *the compression ignition engines* and of the maximum pressure of the cycle (*p_{gmax}=90-130 bar*); the *prolonged expansion* of the combustion gases; the *supercharge*;

optimizing the thermal regime depending of the load and cycle frequency; reducing the loss through friction. It is well known that the polluting emissions *depend* on the way the operating regime of the engine. The main measures to reduce *pollution* are: to *control the quality* of the fuel mixture; to *optimize* the architecture of the combustion chamber; to modify the *advance* of the spark/injection; to modify the *compression* ratio; to modify the length of simultaneous *opening* of the valves. Changing these parameters depending on the operating regime can to make with complicated devices, and in some cases these changing are impossible (for example, changing architecture the combustion chamber). *In conclusion*, the optimization as for the *diminution* of the fuel consumption and of the emissions of noxious pollutants, it is *much more difficult* to realize at the engine which a variable regime running.
At the *thermic monoregime engines*, implementation the measures as for the reduction of the fuel consumption of the emissions of noxious pollutants it is *easy* and *efficient* without the need of special (automatic) devices of regulation. The thermic part (the thermohydraulic generator) running *in a single regime* (monoregime) with *maximum* efficiency, and without moment's *idle running*. Also, reducing fuel consumption is achieved through the recuperation of the braking. The compression ratio and the maximum pressure of the gases from the thermohydraulic generator of compression ignition can be increased, because the tightness (in the segment) is better and the friction is reduced (there is no radial forces, the piston is powered only by axial compression and stretching forces). At present engines, the prolonged expansion through the boosting of the capacity cannot be applied because of some great disadvantages (the size and weight-power ratio grows, the cubic power and the mean pressure falls). Through *prolonged expansion*, the *efficiency* overall grows and the *noise level* falls. *In conclusion*, the experimental research for a greater efficiency is made easier by the functioning of the thermic part of the only single raided engine.
Due to the *way* in conception, the new thermic engines are simpler in terms of construction, with the current. The thermic part no possess: *mechanisms* of transformation to rectilinear-alternative movement (motor mechanism, came with the mechanism, etc.); *systems for control* the parameters for the running duration; and *starting* system. The monoregime thermic engine *can to assume* part (with one hydraulic motor) or total (if in each work element coupling a hydraulic motor), the transmission functions. Also, the monoregime thermic engine can achieved the *braking* in efficient mod with energy recovery, by passing the motor machine from the motor regime to the pump regime. Because of the constructive simplicity and the absence of the systems of regulation, the new drive systems with monoregime thermic engines a reliability will be greater than the present.
The monoregime concept represents a *new research direction*, which allows *new types of engines* to implement with increased performance and lower consumption of fuel (4). The new engines *can to assume* part or total of the transmission functions.
For example, in the event of motor vehicles driven by monoregime thermic engines, partially to eliminated the transmission (clutch, reduction gear, gearbox, longitudinal transmission) when the monoregime thermic engine have a single motor machine (hydraulic engine), or totally to eliminated the transmission when the monoregime thermic engine have two or four motor machines (hydraulic engines) [6, 7, 9]. The hydraulic engines if to pass as pump regime produce the braking (an efficient braking can be made, without blocking the wheels) and with braking energy recovery. Also, removes the control systems (the electronic system of the group of propulsion, the electronic command of the velocity steps, etc.), and starting system. *In conclusion*, the new motor vehicles driven by monoregime thermic engines will have performance indices as least the same as the automatic transmission motor vehicles (enhance dynamics, without clutch pedal and speed change lever), and obviously, with superior energetic indices (operating only on the most efficient regime in terms of fuel consumption and pollutant, without moments of light running, and the possibility to recover the braking energy).

REFEREENCES

[1]. APOSTOLESCU, N., SFINȚEANU D., *The car with alternative fuels* (in Romanian)*,* Technical Publishing House, Bucharest, 1989.
[2]. CERNEA, E., *Thermic machines with free pistons* (in Romanian)*,* Technical Publishing House, Bucharest, 1963.

[3]. CHIOREANU, N., *Monoregime thermic engines* (in Romanian), University of Oradea Publishing House, Oradea, 2006.
[4]. CHIOREANU, N., CHIOREANU Ș., *Engines for non-conventional motor vehicles* (in Romanian), University of Oradea Publishing House, Oradea, 2006.
[5]. GRÜNWALD, B., *The theory, the computation, and construction of engines for road motor vehicles* (in Romanian), Technical Publishing House, Bucharest, 1980.
[6]. MAZILU, I., MARIN, V., *Automatic hydraulic systems* (in Romanian), Romanian Academy Publishing House, Bucharest, 1982.
[7]. OPREAN, A., MARIN, V., DORIN, AL., *Hydraulic drives* (in Romanian), Technical Publishing House, Bucharest, 1976.
[8]. STOICESCU, A., *Design of the attractive an fuel consumption performances of motor vehicles* (in Romanian), Technical Publishing House, Bucharest, 2007.
[9]. VASILIU, N., VASILIU, Daniela, SETEANU, I., RĂDULESCU, Victorița, *Fluid mechanics and hydraulic systems. Fundamentals and applications,* Vol. II, (in Romanian), Technical Publishing House, Bucharest, 1999.