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The Dynamics of the Otto Engine

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Abstract: The dynamic calculation of a certain mechanism and of the piston crankshaft mechanism, used as the main mechanism for Otto internal combustion engines, also implies the influence of external forces on the actual, dynamic kinematics of the mechanism. Take into account the strong and inertial engine forces. Sometimes weight forces can also be taken into account, but their influence is even smaller, negligible even in relation to inertial forces that are far higher than gravitational forces. In the present paper, one carry out an original method of determining the dynamics of a mechanism, applying to the main mechanism of an Otto or diesel engine. The presented method of work is original and complete. Relationships (1) express the velocity of the center of gravity to calculate the moment of inertia (mechanical or mass, of the whole mechanism) reduced to the crank (2). In dynamic calculations, the first derivative of the reduced mechanical inertia moment, derived by the angle FI (relations 3-4), is also required. For dynamic calculation, it is also necessary to determine the expression of the total torque momentum and crank-resistance forces (relations 5-6). The differential equation of the machine (7) is arranged under the more convenient forms (8) to solve it. It is easily observed that a second-degree equation has been reached, which is solved by the known formula (9).

Keywords: Machines, Mechanisms, Applied Computing, Forces, Velocities, Powers, Dynamics, Engines, Thermal Engines

Introduction

The gasoline engine wears us every day about of 150 years. The Old Engine Otto (and his brother, Diesel) is today: Younger, more robust, more dynamic, stronger, more economical, more independent, more reliable, quieter, cleaner, more compact, more sophisticated and especially still necessary. At the global level, we can eliminate roughly 60,000 cars a year, but millions of new cars appear annually (Table 1), (Amoresano *et al*., 2013; Anderson, 1984; Bishop, 1950; Choi and Kim, 1994; De Falco *et al*., 2013a; 2013b; Ganapathi and Robinson, 2013; Heywood, 1988; Hrones, 1948; Karikalan *et al*., 2013; Leidel, 1997; Petrescu, 2012a; 2012b; Rahmani *et al*., 2013; Ravi and Subramanian, 2013; Ronney *et al*., 1994; Sapate and Tikekar, 2013; Sethusundaram *et al*., 2013; Zahari *et al*., 2013).

There is a lot of discussion about the removal of the Otto engine, but nothing has yet been prepared to take its place.

Let's talk a little about electric motors. An electric motor is an electrical machine that converts electricity into mechanical energy. If we talk in reverse, we are dealing with converting mechanical energy into electricity and is made by an electric generator. Generators and electric motors are extremely important, today more than ever.

Table 1: World cars produced

Year	Cars produced in the world
2011	59,929,016
2010	58,264,852
2009	47,772,598
2008	52,726,117
2007	53,201,346
2006	49,918,578
2005	46,862,978
2004	44,554,268
2003	41,968,666
2002	41,358,394
2001	39,825,888
2000	41,215,653
1999	39,759,847

Most electric motors work by interacting with a magnetic field of an electric motor and the winding currents to generate force. In some applications, such as regenerative braking with traction motors in the transport industry, electric motors can also be used in the reverse direction as generators to convert mechanical energy into electricity, that is, they recover energy that otherwise would lose.

Electric motors can be found in as diverse applications as industrial fans, blowers and pumps, machine tools, household appliances, power tools and disc drives, electric motors can be powered by DC sources such as Be batteries, cars or rectifiers; through AC (AC) sources, such as from the mains, inverters or generators. Small motors can be found in electric watches. General purpose motors with very standardized dimensions and features provide a convenient mechanical power for industrial use.

The largest of the electric motors are used for ship propulsion, pipe compression and pumping-storage applications with a rating of 100 megawatts and today are increasingly used in industrial robots and in mechatronic mobile systems. Electric motors can be classified by types of power sources, internal construction, applications, output type of motion and so on.

Electric motors are therefore used to produce linear or rotary forces and must be distinguished from devices such as magnetic solenoids and loudspeakers that convert electric power into motion but do not generate usable mechanical powers which are referred to as actuators and transducers.

Perhaps the first electric motors were simple electrostatic devices created by the Scottish monk Andrew Gordon in the 1740s. Only today, after nearly three hundred years of existence, the electric motors begin to be put to work at their full capacity.

However, in transports, although they have gone a long way, electric motors could not take the place of the Otto motor home, obviously primarily due to technical problems, then for reasons of dynamics and thirdly due to social reasons.

Powering a car with electricity is difficult today, compared to vehicles equipped with internal combustion engines.

The Otto engine still remains more dynamic than electric motors.

Globally, two out of three jobs depend directly or indirectly on the automotive and machine-building industries, in particular of the Otto classical engines.

If the current mode of production suddenly changed, almost half of the world's jobs would disappear, resulting in an extremely serious global social crisis (Aversa *et al*., 2016a; 2016b; 2016c; 2016d; 2017a; 2017b; 2017c; 2017d; 2017e; Berto *et al*., 2016a; 2016b; 2016c; 2016d; Mirsayar *et al*., 2017; Cao *et al*., 2013; Dong *et al*., 2013; Garcia *et al*., 2007; Garcia-Murillo *et al*., 2013; He *et al*., 2013; Lee, 2013; Lin *et al*., 2013; Liu *et al*., 2013; Padula and Perdereau, 2013; Perumaal and Jawahar, 2013; Petrescu, 2012a; 2012b; Petrescu and Petrescu, 1995a; 1995b; 1997a; 1997b; 1997c; 2000a; 2000b; 2002a; 2002b; 2003; 2005a; 2005b; 2005c; 2005d; 2005e, 2016a; 2016b; 2016c; 2016d; 2016e; 2013; 2012a; 2012b; 2011; Petrescu *et al*., 2009; 2016a; 2016b; 2016c; 2016d; 2016e; 2017a; 2017b; 2017c; 2017d; 2017e; 2017f; 2017g; 2017h; 2017i; 2017j; 2017k; 2017l; 2017m; 2017n; 2017o; 2017p; 2017q; 2017r; 2017s; 2017t; 2017u; 2017v; 2017w; 2017x; 2017y; 2017z; 2017aa; 2017ab; 2017ac; 2017ad; 2017ae; Petrescu and Calautit, 2016a; 2016b; Reddy *et al*., 2012; Tabaković *et al*., 2013; Tang *et al*., 2013; Tong *et al*., 2013; Wang *et al*., 2013; Wen *et al*., 2012; Antonescu, 2000; Antonescu and Petrescu, 1985; 1989; Antonescu *et al*., 1985a; 1985b; 1986; 1987; 1988; 1994; 1997; 2000a; 2000b; 2001).

Materials and Methods

Figure 1 shows the kinematic scheme of an Otto internal combustion engine (Petrescu, 2012b).

Relationships (1) express the velocity of the center of gravity to calculate the moment of inertia (mechanical or mass of the whole mechanism) reduced to the crank (2). In fact, squares of the velocities weight centers (S_2 and S_3) of the mechanism are required (Mirsayar *et al*., 2017; Cao *et al*., 2013; Dong *et al*., 2013; Garcia *et al*., 2007; Garcia-Murillo *et al*., 2013; He *et al*., 2013; Lee, 2013; Lin *et al*., 2013; Liu *et al*., 2013; Padula and Perdereau, 2013; Perumaal and Jawahar, 2013; Petrescu and Petrescu, 1995a; 1995b; 1997a; 1997b; 1997c; 2000a; 2000b; 2002a; 2002b; 2003; 2005a; 2005b; 2005c; 2005d; 2005e, 2016a; 2016b; 2016c; 2016d; 2016e; 2013; 2012a; 2012b; 2011; Petrescu *et al*., 2009; 2016a; 2016b; 2016c; 2016d; 2016e; 2017a; 2017b; 2017c; 2017d; 2017e; 2017f; 2017g; 2017h; 2017i; 2017j; 2017k; 2017l; 2017m; 2017n; 2017o; 2017p; 2017q; 2017r; 2017s; 2017t; 2017u; 2017v; 2017w; 2017x; 2017y; 2017z; 2017aa; 2017ab; 2017ac; 2017ad; 2017ae; Petrescu and Calautit, 2016a; 2016b; Reddy *et al*., 2012; Tabaković *et al.*, 2013; Tang *et al.*, 2013; Tong *et al.*, 2013; Wang *et al.*, 2013; Wen *et al.*, 2012; Antonescu and Petrescu, 1985; 1989; Antonescu *et al.*, 1985a; 1985b; 1986; 1987; 1988; 1994; 1997; 2000a; 2000b; 2001):

$$\begin{cases} y_B = r\cdot\sin\varphi + l\cdot\sin\psi;\ \ r\cdot\cos\varphi + l\cdot\cos\psi = 0 \Rightarrow \\ l\cdot\cos\psi = -r\cdot\cos\varphi; \cos\psi = -\lambda\cdot\cos\varphi; \sin\psi = \sqrt{1-\lambda^2\cdot\cos^2\varphi} \\ -l\cdot\sin\psi\cdot\dot{\psi} = r\cdot\sin\varphi\cdot\omega \Rightarrow \dot{\psi} = -\lambda\cdot\dfrac{\sin\varphi}{\sin\psi}\cdot\omega \\ \ddot{\psi}\cdot\sin\psi + \dot{\psi}^2\cdot\cos\psi = -\lambda\cdot\cos\varphi\cdot\omega^2 \Rightarrow \\ \ddot{\psi} = -\dfrac{\lambda\cdot(1-\lambda^2)\cdot\cos\varphi\cdot\omega^2}{\sin^3\psi} \\ v_B \equiv \dot{y}_B = r\cdot\cos\varphi\cdot\omega + l\cdot\cos\psi\cdot\dot{\psi} = \\ = r\cdot\cos\varphi\cdot\omega\cdot\left(1+\lambda\cdot\dfrac{\sin\varphi}{\sin\psi}\right) = r\cdot\dfrac{\sin(\psi-\varphi)}{\sin\psi}\cdot\omega = s_B^{'}\cdot\omega \Rightarrow \\ \Rightarrow s_{G_3}^{'} \equiv s_B^{'} = r\cdot\dfrac{\sin(\psi-\varphi)}{\sin\psi} \Rightarrow s_{G_3}^{'2} \equiv s_B^{'2} = r^2\cdot\dfrac{\sin^2(\psi-\varphi)}{\sin^2\psi} \\ \begin{cases} x_{S_2} = r\cdot\cos\varphi + a\cdot\cos\psi \\ y_{S_2} = r\cdot\sin\varphi + a\cdot\sin\psi \end{cases} \Rightarrow \begin{cases} \dot{x}_{S_2} = -r\cdot\sin\varphi\cdot\omega - a\cdot\sin\psi\cdot\dot{\psi} \\ \dot{y}_{S_2} = r\cdot\cos\varphi\cdot\omega + a\cdot\cos\psi\cdot\dot{\psi} \end{cases} \\ \begin{cases} \dot{x}_{S_2} = -r\cdot\dfrac{l}{l}\sin\varphi\cdot\omega + a\cdot\lambda\cdot\sin\psi\dfrac{\sin\varphi}{\sin\psi}\omega = -\lambda\cdot(l-a)\cdot\sin\varphi\cdot\omega \\ \dot{y}_{S_2} = r\dfrac{l}{l}\cos\varphi\omega + a\lambda^2\cos\varphi\dfrac{\sin\varphi}{\sin\psi}\omega = \lambda\cos\varphi\left(l + a\lambda\cdot\dfrac{\sin\varphi}{\sin\psi}\right)\omega \end{cases} \\ s_{G_2}^{'2} = x_{S_2}^{'2} + y_{S_2}^{'2} = \lambda^2(l-a)^2\sin^2\varphi + \lambda^2\cos^2\varphi\left(l+a\cdot\lambda\cdot\dfrac{\sin\varphi}{\sin\psi}\right)^2 \\ s_{G_2}^{'2} = \lambda^2\cdot\left[(l-a)^2\cdot\sin^2\varphi + \left(l+a\cdot\lambda\cdot\dfrac{\sin\varphi}{\sin\psi}\right)^2\cdot\cos^2\varphi\right] \end{cases} \tag{1}$$

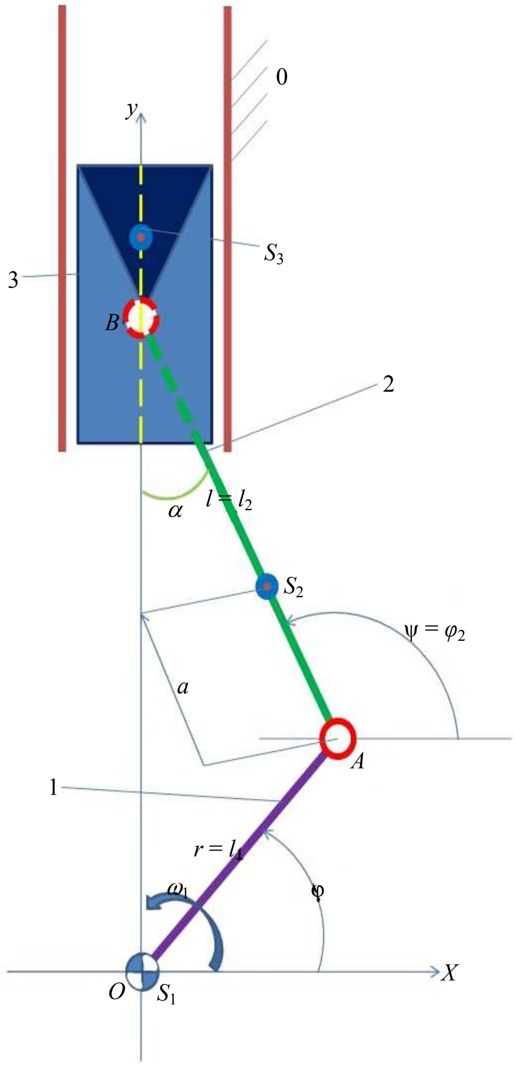

Fig. 1: The kinematic scheme of an Otto internal combustion engine

$$\begin{cases} J^* = J_{G_1} + J_{G_2}\cdot\psi^{'2} + m_2\cdot s_{G_2}^{'2} + m_3\cdot s_{G_3}^{'2} \Rightarrow \\ J^* = J_{G_1} + J_{G_2}\cdot\lambda^2\cdot\dfrac{\sin^2\varphi}{\sin^2\psi} + m_3\cdot r^2\cdot\dfrac{\sin^2(\psi-\varphi)}{\sin^2\psi} \\ +m_2\cdot\lambda^2\cdot\left[(l-a)^2\cdot\sin^2\varphi + \left(l+a\cdot\lambda\cdot\dfrac{\sin\varphi}{\sin\psi}\right)^2\cdot\cos^2\varphi\right] \end{cases} \tag{2}$$

In dynamic calculations, the first derivative of the reduced mechanical inertia moment, derived from the angle φ (relations 3-4), is also required (Petrescu, 2012b):

$$\begin{cases} J^{*'} = J_{G_2}\cdot\lambda^2\cdot\dfrac{\sin(2\varphi)\cdot\sin^2\psi + \lambda\cdot\sin^2\varphi\cdot\sin(2\psi)\cdot\dfrac{\sin\varphi}{\sin\psi}}{\sin^4\psi} + m_2\cdot\lambda^2\cdot\sin(2\varphi)\cdot\left[(l-a)^2 - \left(l+a\cdot\lambda\cdot\dfrac{\sin\varphi}{\sin\psi}\right)^2\right] \\ +2\cdot m_2\cdot a\cdot\lambda^3\cdot\cos^2\varphi\cdot\left(l+a\cdot\lambda\cdot\dfrac{\sin\varphi}{\sin\psi}\right)\cdot\dfrac{\cos\varphi\cdot\sin^2\psi + \lambda\cdot\sin^2\varphi\cdot\cos\psi}{\sin^3\psi} + \\ +m_3\cdot r^2\cdot\dfrac{\lambda\sin^2(\psi-\varphi)\sin(2\psi)\dfrac{\sin\varphi}{\sin\psi} - \sin\left[2(\psi-\varphi)\right]\sin^2\psi\left(1+\lambda\dfrac{\sin\varphi}{\sin\psi}\right)}{\sin^4\psi} \end{cases} \tag{3}$$

$$\begin{cases} J^{*'} = J_{G_2} \cdot \lambda^2 \cdot \dfrac{\sin(2\varphi)\cdot\sin^2\psi + \lambda\cdot\sin^2\varphi\cdot\sin(2\psi)\cdot\dfrac{\sin\varphi}{\sin\psi}}{\sin^4\psi} + m_2\cdot\lambda^2\cdot\sin(2\varphi)\cdot\left[(l-a)^2 - \left(l + a\cdot\lambda\cdot\dfrac{\sin\varphi}{\sin\psi}\right)^2\right] \\ +2\cdot m_2\cdot a\cdot\lambda^3\cdot\cos^2\varphi\cdot\left(l + a\cdot\lambda\cdot\dfrac{\sin\varphi}{\sin\psi}\right)\cdot\dfrac{\cos\varphi\cdot\sin^2\psi + \lambda\cdot\sin^2\varphi\cdot\cos\psi}{\sin^3\psi} \\ +m_3\cdot r^2\cdot\dfrac{\lambda\sin^2(\psi-\varphi)\sin(2\psi)\dfrac{\sin\varphi}{\sin\psi} - \sin[2(\psi-\varphi)]\sin^2\psi\left(1+\lambda\dfrac{\sin\varphi}{\sin\psi}\right)}{\sin^4\psi} \end{cases} \tag{4}$$

For dynamic calculation, it is also necessary to determine the expression of the total torque momentum and the crank-resistant strength (relations 5-6):

$$\begin{aligned} &M_m - M_r + M_m^i - M_r^i = 0 \Rightarrow M_m - M_r \\ &= -\left(M_m^i - M_r^i\right) \Rightarrow M_m - M_r = -M_m^i - (-)M_r^i \end{aligned} \tag{5}$$

$$\begin{cases} M^* = M_m - M_r = -\left(M_m^i - M_r^i\right) = J^*\cdot\omega_m^2\cdot D\cdot D' \\ -\int M_m^i\cdot d\varphi = J^*\cdot\omega_m^2\cdot D\cdot D' - J^*\cdot\omega_m^2\cdot\int D\cdot D' d\varphi \\ = J^*\cdot\omega_m^2\cdot D\cdot D' - J^*\cdot\omega_m^2\cdot\dfrac{1}{2}D^2 = J^*\cdot\omega_m^2\cdot D\cdot\left(D' - \dfrac{1}{2}D\right) \\ 2\cdot M^* = J^*\cdot\omega_m^2\cdot D\cdot\left(2D' - D\right) \end{cases} \tag{6}$$

We now have everything we need to solve the dynamic (motion, Lagrange) equation of the machine, written in a differential form (7) (Petrescu, 2012b):

$$J^*\cdot\varepsilon + \frac{1}{2}\cdot\omega^2\cdot J^{*'} = M^* \tag{7}$$

The differential equation of the machine (7) is arranged under the more convenient forms (8) to solve it:

$$\begin{cases} 2\cdot J^*\cdot\omega\cdot\dfrac{d\omega}{d\varphi} + \omega^2\cdot J^{*'} = 2\cdot M^* \\ 2\cdot J^*\cdot\omega\cdot d\omega + \omega^2\cdot J^{*'}\cdot d\varphi = 2\cdot M^*\cdot d\varphi \\ (\omega_m + d\omega)\cdot d\omega\cdot 2\cdot J^* + (\omega_m + d\omega)^2\cdot J^{*'}\cdot d\varphi = 2\cdot M^*\cdot d\varphi \\ \omega_m\cdot d\omega\cdot 2\cdot J^* + (d\omega)^2\cdot 2\cdot J^* + \omega_m^2\cdot J^{*'}\cdot d\varphi \\ +(d\omega)^2\cdot J^{*'}\cdot d\varphi + 2\cdot\omega_m\cdot J^{*'}\cdot d\varphi\cdot d\omega - 2\cdot M^*\cdot d\varphi = 0 \\ \left(2\cdot J^* + J^{*'}\cdot d\varphi\right)\cdot(d\omega)^2 \\ +2\cdot\omega_m\left(J^* + J^{*'}\cdot d\varphi\right)\cdot d\omega - \left(2\cdot M^*\cdot d\varphi - \omega_m^2\cdot J^{*'}\cdot d\varphi\right) = 0 \end{cases} \tag{8}$$

It is easy to see that we have reached a second-degree equation, which is solved by the known formula (9):

$$\begin{cases} d\omega = \dfrac{-\omega_m\cdot\left(J^* + J^{*'}\cdot d\varphi\right)}{2\cdot J^* + J^{*'}\cdot d\varphi} \\ \pm\dfrac{\sqrt{\omega_m^2\left(J^* + J^{*'}d\varphi\right)^2 + \left(2M^*d\varphi - \omega_m^2 J^{*'}d\varphi\right)\cdot\left(2J^* + J^{*'}d\varphi\right)}}{2\cdot J^* + J^{*'}\cdot d\varphi} \\ d\omega = \omega_m\cdot\dfrac{-\left(J^* + J^{*'}\cdot d\varphi\right)}{2\cdot J^* + J^{*'}\cdot d\varphi} \\ +\omega_m\cdot\dfrac{\sqrt{\left(J^* + J^{*'}\cdot d\varphi\right)^2 + d\varphi\cdot\left(2J^* + J^{*'}\cdot d\varphi\right)\cdot\left[J^*\cdot D\cdot\left(2D' - D\right) - J^{*'}\right]}}{2\cdot J^* + J^{*'}\cdot d\varphi} \end{cases} \tag{9}$$

Considering the calculated angular velocity obtained instead of the constant, dynamic speeds and accelerations are obtained. We will keep track of several dynamic acceleration charts, obtained for different lengths of crank and rod. In Fig. 2 the length of the rod is slightly larger than that of the crank, which worsens the dynamics of the mechanism (Petrescu, 2012b).

In Fig. 3, the length of the rod has increased very little and the dynamic operation of the piston is already greatly improved. Peaks are not so sharp anymore.

By further increasing the length of the rod, while maintaining the constant length of the crank, more rounded accelerations, which are closer to sinusoidal shapes (Fig. 4-6), are obtained.

Dynamic elongations are generally smaller than kinematics.

Next, the angular acceleration values, ε, starting from the Lagrange Equation 7, already presented, will be determined (Petrescu, 2012b).

Arrange Equation 7 in form (10) to explain the variable ε to be determined:

$$\varepsilon = \frac{2\cdot M^* - \omega^2\cdot J^{*'}}{2\cdot J^*} = \left(D\cdot D' - \frac{1}{2}D^2 - \frac{1}{2}\cdot\frac{J^{*'}}{J^*}\right)\cdot\omega^2 \tag{10}$$

The variable angular velocity ω is now known so that the angular acceleration value can be determined directly, which occurs in the real cinematics of the mechanism, at the dynamic operating modes.

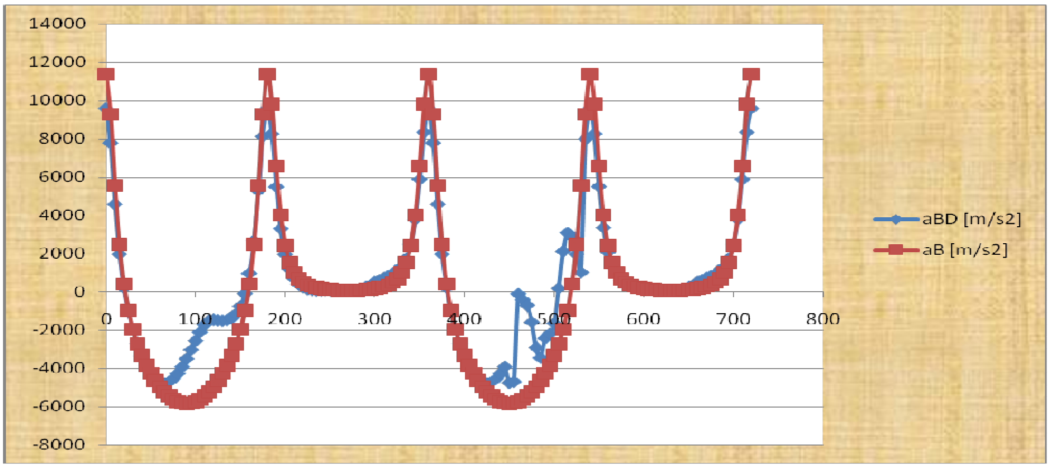

Fig. 2: Dynamic synthesis of the engine; r = 0.03 [m], l = 0.031 [m], n = 3000[rot/min]

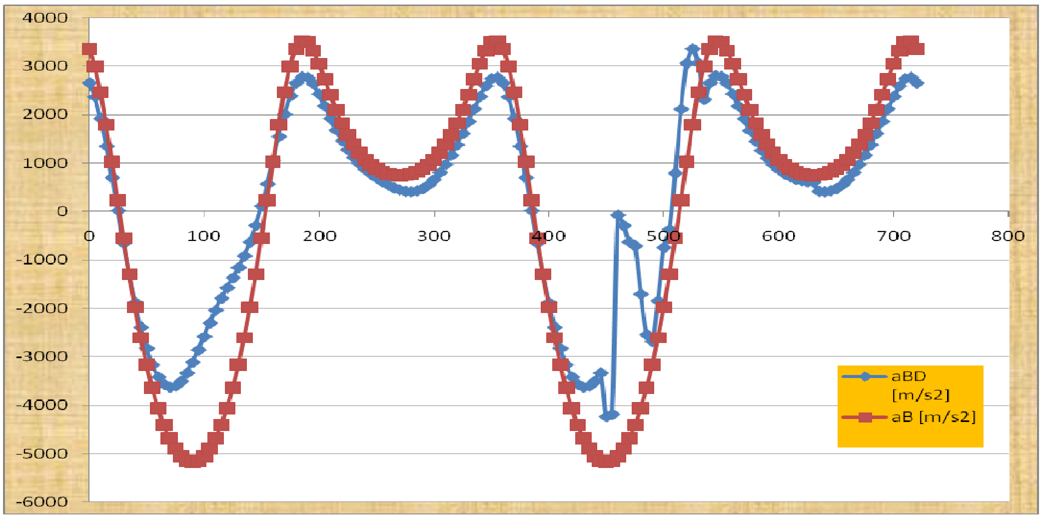

Fig. 3: Dynamic synthesis of the engine; r = 0.03 [m], l = 0.04 [m], n = 3000[rot/min]

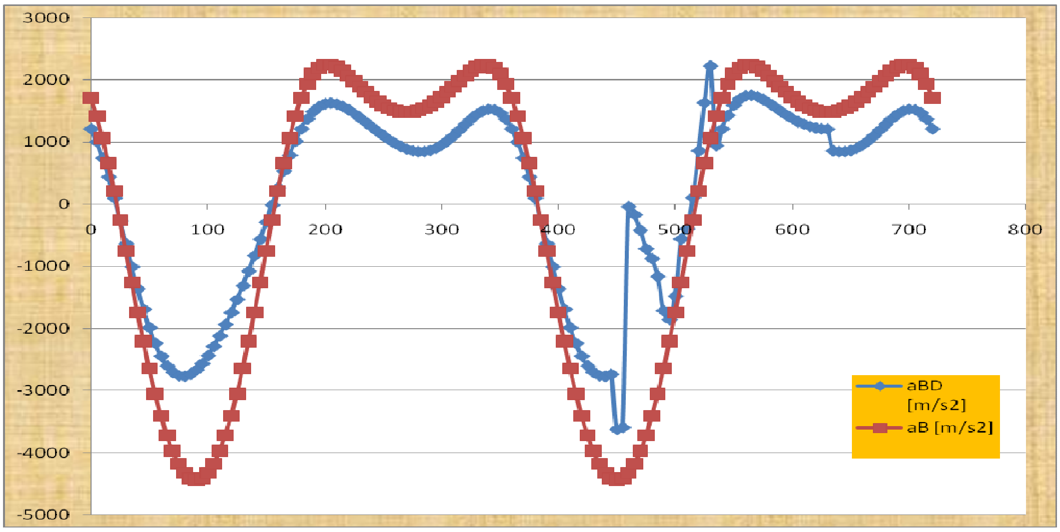

Fig. 4: Dynamic synthesis of the engine; r = 0.03 [m], l = 0.06 [m], n = 3000[rot/min]

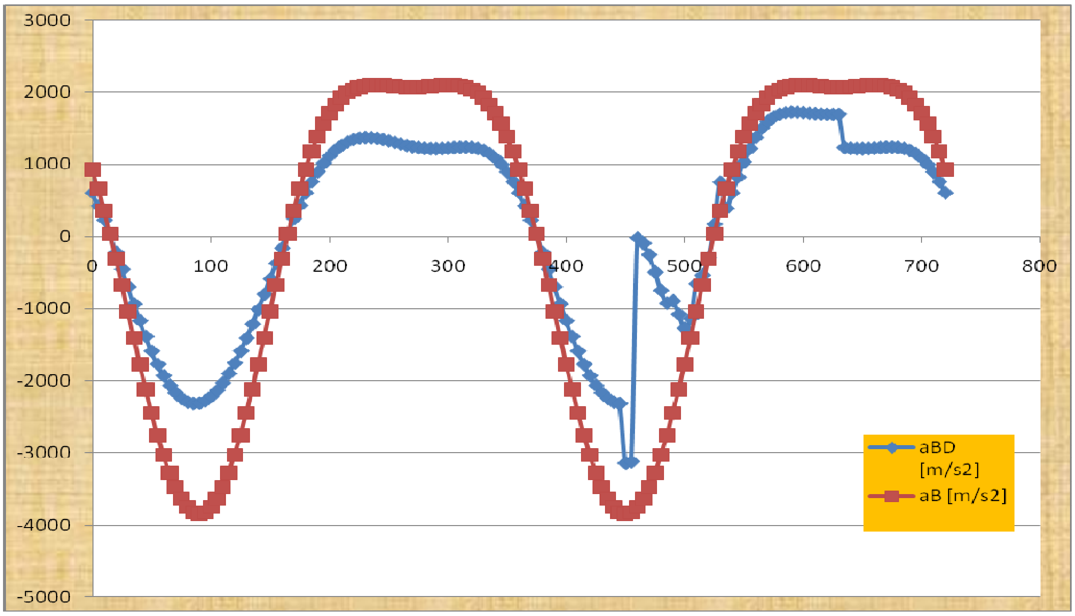

Fig. 5: Dynamic synthesis of the engine; r = 0.03 [m], l = 0.1 [m], n = 3000[rot/min]

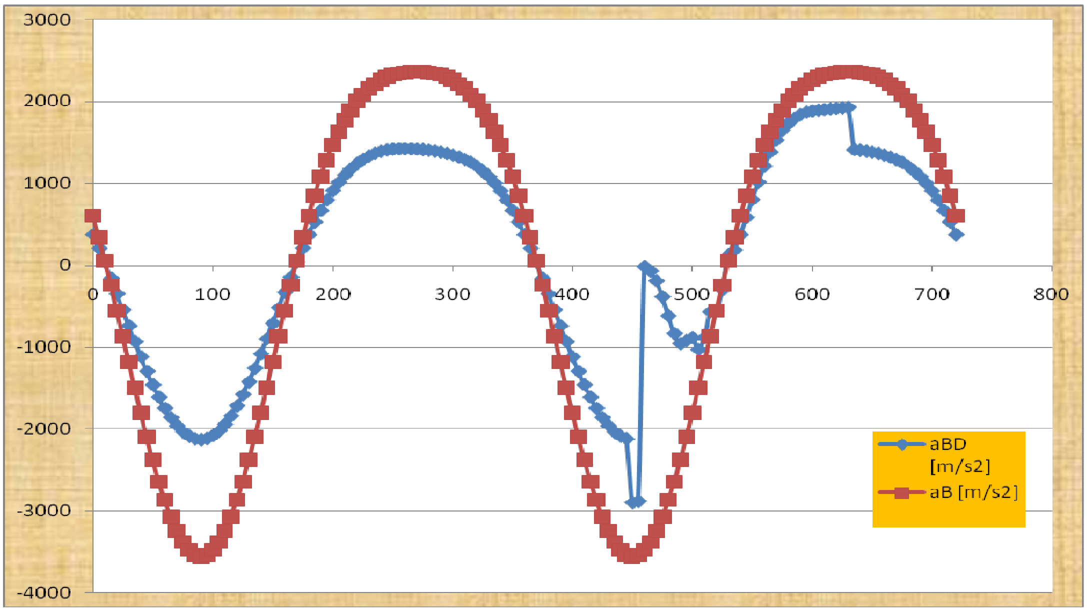

Fig. 6: Dynamic synthesis of the engine; r = 0.03 [m], l = 0.15 [m], n = 3000[rot/min]

It is now time to restore the kinematics of the mechanism (relations 11-12), considering the existence of the angular acceleration, ε, of the crank (Petrescu, 2012b):

$$\begin{cases} \cos\psi = -\lambda\cdot\cos\varphi - \sin\psi\cdot\dot{\psi} = \lambda\cdot\sin\varphi\cdot\dot{\varphi}, unde\,\dot{\varphi} = D\cdot\omega; \dot{\varphi}^2 = D^2\cdot\omega^2 \\ \Rightarrow \dot{\psi} = -\lambda\cdot\dfrac{\sin\varphi}{\sin\psi}\cdot\dot{\varphi} - \cos\psi\cdot\dot{\psi}^2 - \sin\psi\cdot\ddot{\psi} = \lambda\cdot\cos\varphi\cdot\dot{\varphi}^2 + \lambda\cdot\sin\varphi\cdot\ddot{\varphi} \\ \ddot{\psi} = \dfrac{-\cos\psi\cdot\dot{\psi}^2 - \lambda\cdot\cos\varphi\cdot\dot{\varphi}^2 - \lambda\cdot\sin\varphi\cdot\ddot{\varphi}}{\sin\psi} \Rightarrow \\ \Rightarrow \ddot{\psi} = \dfrac{-\lambda\cdot\left(1-\lambda^2\right)\cdot\cos\varphi\cdot\dot{\varphi}^2 / \sin^2\psi - \lambda\cdot\sin\varphi\cdot\varepsilon}{\sin\psi} \end{cases} \quad (11)$$

$$\begin{cases} \ddot{\psi} = \dfrac{-\lambda \cdot \left(1-\lambda^2\right) \cdot \cos\varphi \cdot \dot{\varphi}^2}{\sin^3\psi} - \dfrac{\lambda \cdot \sin\varphi \cdot \varepsilon}{\sin\psi} \\ y_B = r \cdot \sin\varphi + l \cdot \sin\psi \\ v_B = r \cdot \cos\varphi \cdot \dot{\varphi} + l \cdot \cos\psi \cdot \dot{\psi} \\ a_B = -r \cdot \sin\varphi \cdot \dot{\varphi}^2 + r \cdot \cos\varphi \cdot \ddot{\varphi} - l \cdot \sin\psi \cdot \dot{\psi}^2 + l \cdot \cos\psi \cdot \ddot{\psi} \\ a_B = -r \cdot \sin\varphi \cdot \dot{\varphi}^2 + r \cdot \cos\varphi \cdot \varepsilon - l \cdot \sin\psi \cdot \lambda^2 \dfrac{\sin^2\varphi}{\sin^2\psi} \cdot \dot{\varphi}^2 + l \cdot \lambda \cdot \cos\varphi \cdot \left[\dfrac{\lambda \cdot \left(1-\lambda^2\right) \cdot \cos\varphi \cdot \dot{\varphi}^2}{\sin^3\psi} + \dfrac{\lambda \cdot \sin\varphi \cdot \varepsilon}{\sin\psi}\right] \\ a_B = -r \cdot \sin\varphi \cdot \dot{\varphi}^2 + r \cdot \cos\varphi \cdot \varepsilon - r \cdot \lambda \cdot \dfrac{\sin^2\varphi}{\sin\psi} \cdot \dot{\varphi}^2 + r \cdot \lambda \cdot \dfrac{\sin\varphi \cdot \cos\varphi}{\sin\psi} \cdot \varepsilon + r \cdot \lambda \cdot \left(1-\lambda^2\right) \cdot \dfrac{\cos^2\varphi}{\sin^3\psi} \cdot \dot{\varphi}^2 \\ a_B = r \cdot \left\{\left[\lambda \cdot \left(1-\lambda^2\right) \cdot \dfrac{\cos^2\varphi}{\sin^3\psi} - \sin\varphi - \lambda \cdot \dfrac{\sin^2\varphi}{\sin\psi}\right] \cdot \dot{\varphi}^2 + \left[\cos\varphi + \lambda \cdot \dfrac{\sin\varphi \cdot \cos\varphi}{\sin\psi}\right] \cdot \varepsilon\right\} \\ a_B = r \cdot \omega^2 \cdot \left\{\left[\lambda \cdot \left(1-\lambda^2\right) \cdot \dfrac{\cos^2\varphi}{\sin^3\psi} - \sin\varphi - \lambda \cdot \dfrac{\sin^2\varphi}{\sin\psi}\right] \cdot D^2 + \dfrac{\sin\left(\psi-\varphi\right)}{\sin\psi} \cdot \left(D \cdot D' - \dfrac{1}{2} \cdot D^2 - \dfrac{1}{2} \cdot \dfrac{J^{*'}}{J^*}\right)\right\} \end{cases} \tag{12}$$

Results

The way Fig. 7 shows the acceleration diagram obtained (Petrescu, 2012b).

Taking into account the variable angular velocity and the existence of variable cranial angular acceleration, the effect due to the dynamic crank angular displacement of the crank should also be considered. This is dynamically imposed by the crankshaft, so we will have to replace the rotation angle (or position) of the crank with its dynamic value computed as a compressor, since the crankshaft moves only after the laws imposed by it itself, Motor moments and other times a permanent drive force that drives all the shaft and hence all the cranks (spindles), drive due to the engine's all-wheel drive, inertia forces and extra high inertia imposed by the engine's steering wheel. The dynamic variation of the position angle obviously exists, but it can only be imposed by the crank itself, that is, the dynamics of the motor shaft itself.

Angular variable velocity is determined with relation (13):

$$\omega^D = D^C \cdot \omega \tag{13}$$

Depending on time, the derivative of the position angle can be passed (expressed and according to the position angle, φ) according to the relation (14). If in its classical cinematic derivative it is 1, in the dynamic kinematics where this dynamic coefficient exists, the derivative of the position angle according to the position φ is the value D generally different from the value 1. The crank is dynamically influenced directly by the shaft the engine on which it is built, so that its dynamics will be compressor type that is driving it from the motor shaft (crankshaft):

$$\frac{d\varphi}{dt} = \frac{d\varphi}{d\varphi} \cdot \frac{d\varphi}{dt} = \varphi' \cdot \omega = D^C \cdot \omega \tag{14}$$

We deduce from the relationship (14) the expression (15). Further, by integrating the dynamic coefficient D in relation to the variable φ, we get the expression (16), which is its value, φ_D i.e., the mathematical expression of the dynamic position angle:

$$\varphi' \equiv \varphi'^D = D^C = \sin^2\psi = 1 - \lambda^2 \cdot \cos^2\varphi \tag{15}$$

$$\begin{cases} \varphi \equiv \varphi^D = \int D^C d\varphi = \int \left(1-\lambda^2 \cdot \cos^2\varphi\right) d\varphi = d\varphi \\ = \int \left\{1 - \lambda^2 \cdot \left[\dfrac{\cos(2\varphi)}{2} + \dfrac{1}{2}\right]\right\} d\varphi = \int \left[1 - \dfrac{\lambda^2}{2} - \dfrac{\lambda^2}{2} \cdot \cos(2\varphi)\right] \\ = \left(1 - \dfrac{\lambda^2}{2}\right) \cdot \varphi - \dfrac{\lambda^2}{4} \cdot \sin(2\varphi) \\ \varphi^D = \left(1 - \dfrac{\lambda^2}{2}\right) \cdot \varphi - \dfrac{\lambda^2}{4} \cdot \sin(2\varphi) \end{cases} \tag{16}$$

By overlapping the dynamic effect of the position in the dynamic systems presented above, the acceleration diagram of Fig. 8 is obtained (Petrescu, 2012b).

The dynamic effect seems to be good for the movement of the mechanism because it restricts the elongation of the acceleration, but when these areas are constrained with peaks, oscillations are created in the respective areas, which produce vibrations, beats, noises and even shocks, Better notable by the variable angular velocity model and dynamic positions (no longer considering the effect of ε variable) (see diagram in Fig. 9).

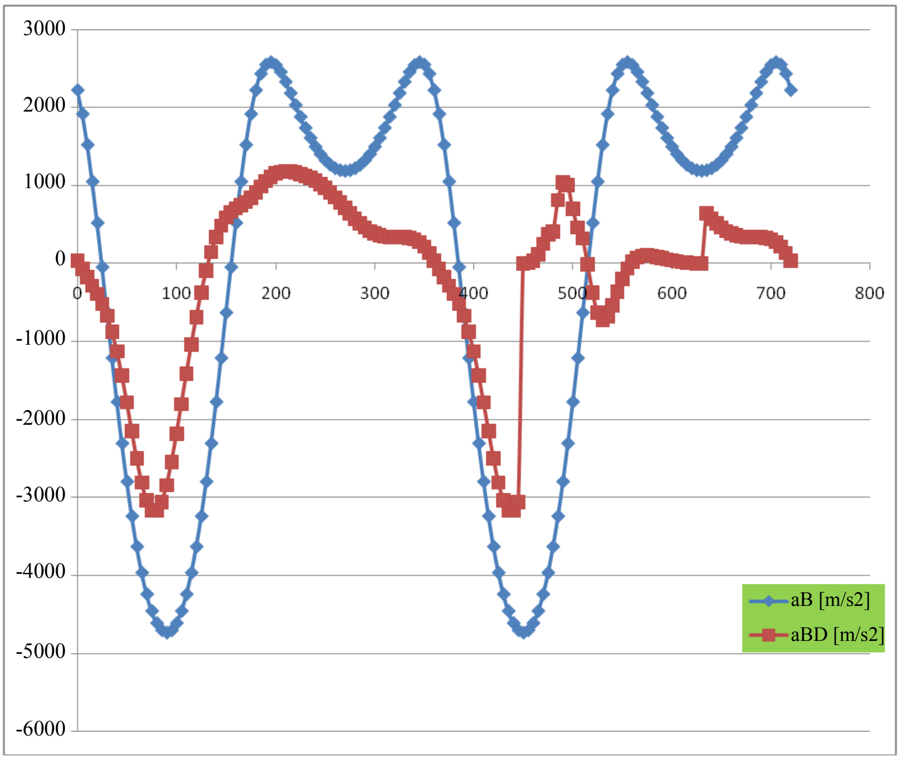

Fig. 7: Diagram of dynamic piston accelerations taking into account and the existence of angular acceleration ε: r = 0.03 [m], l = 0.05 [m], n = 3000[rot/min]

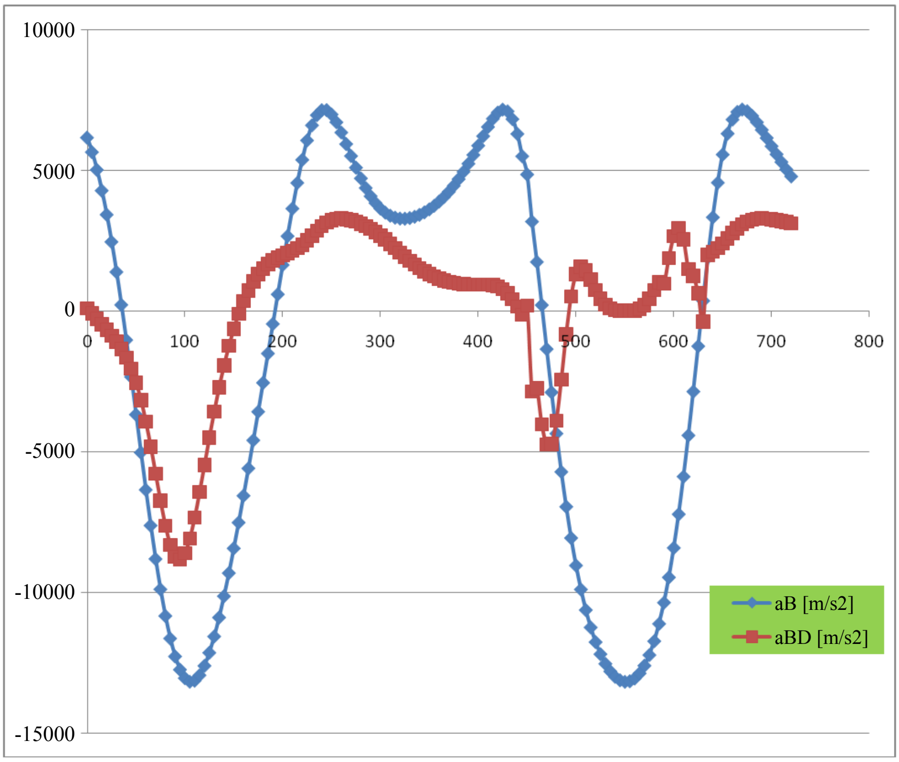

Fig. 8: Diagram of dynamic piston accelerations taking into account variable angular velocity ω^D, of angular acceleration ε and the variable value of the dynamic position angle: r = 0.03 [m], l = 0.05 [m], n = 5000[rot/min]

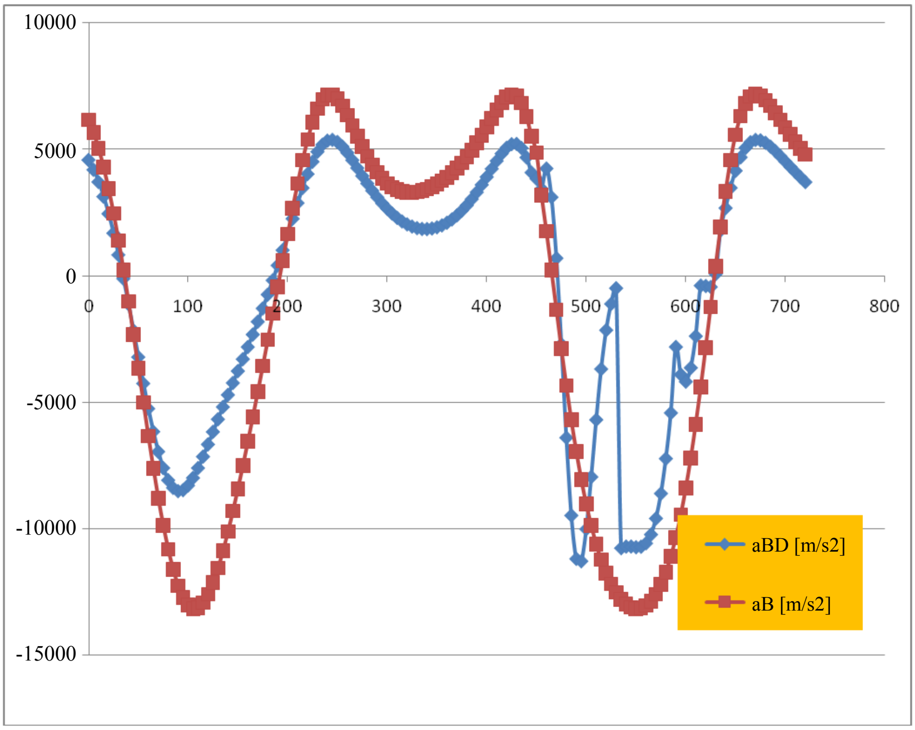

Fig. 9: Diagram of dynamic piston accelerations taking into account variable angular velocity ω^D, of angular acceleration ε and the variable value of the dynamic position angle: r = 0.03 [m], l = 0.05 [m], n = 5000[rot/min]

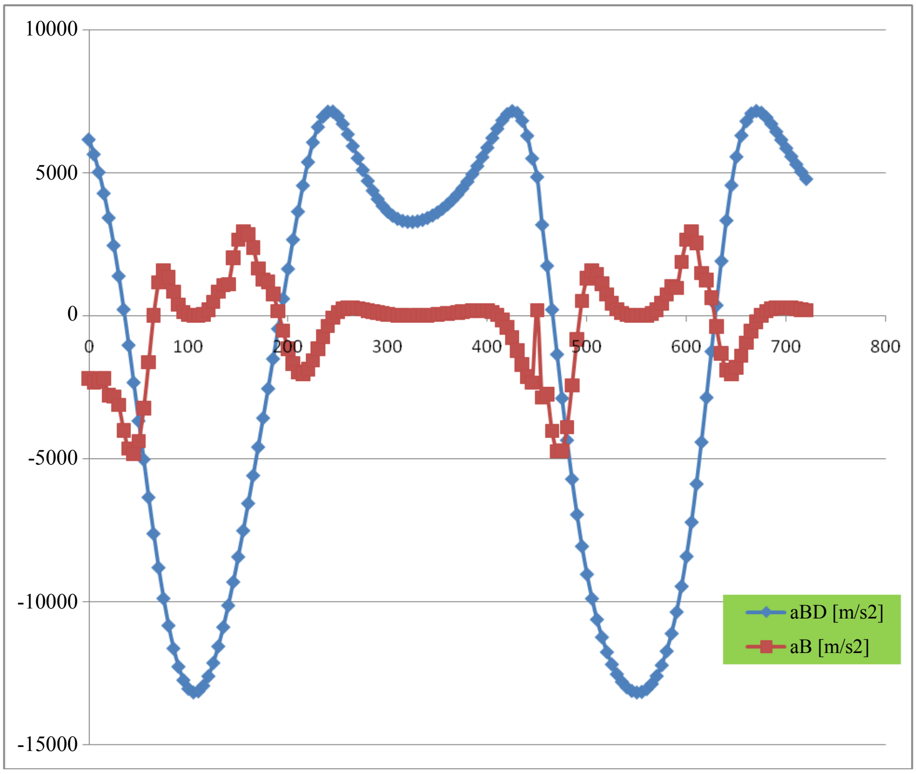

Fig. 10: Diagram of dynamic piston accelerations taking into account variable angular velocity ω^D, of angular acceleration ε and the variable value of the dynamic position angle: r = 0.03 [m], l = 0.05 [m], n = 5000[rot/min]

Discussion

There are four vibration zones instead of one for the Stirling engine for two complete rotation of the motor shaft, but all times are engine times (see the acceleration diagram in Fig. 10). The Stirling engine vibrations will be more significant than those of an Otto engine, but the Stirling engine's theoretical efficiency is much higher.

Unfortunately, it is not fully realized in practice because it would require a temperature difference between the hot and cold sources much higher than those normally used so that the two engines become somewhat close in terms of their qualities and defects.

However, the Otto engine was imposed on cars, with higher and better dynamics, greater adaptability to the different working regimes imposed, the Stirling engine having problems especially at the transient and startup modes (Petrescu, 2012b).

Conclusion

If an external combustion engine could not beat the Otto internal combustion engine when mounted on cars, the same thing did not happen in the field of general vehicles where the Diesel internal combustion engine" As well as the external Watt steam combustion, used for a long time on vehicles, locomotives, boats, boats, etc., but also as a stationary engine in plants, where the Stirling engine also performs very well. The steam engine can work at higher yields and with good dynamics and the disadvantages of burning lower fuels such as coal can be eliminated by burning oil, gas, alcohols, hydrogen, etc., or by vapor heating by other modern processes, with Induction resistors, etc.

Let's not forget that the diesel engine was first created to work with peanut oil or plant oil. If diesel has become extremely polluting, we do not have to immediately dispose of the diesel engine, but it's enough to pass it on vegetable oils or hydrogen.

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Ethics

This article is original and contains unpublished material. Authors declare that are not ethical issues and no conflict of interest that may arise after the publication of this manuscript.

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