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Internal combustion engine performance of 125 cubic centimeters single-cylindrical two-time when implementing a programmable computerized fuel electronic injection system for karting competition

Abstract

In motorsport there are many disciplines, karting is one of the variants. It is regarded as the school of great pilots. In this activity it is required to implement technological advances. The adaptation and implementation of the electronic fuel injection control system to the two-time single-cylinder internal combustion engine of 125 cubic centimeters of carburetor displacement is presented, to be used in Karting competencies, to raise its characteristic mechanical parameters such as: torque, effective power, fuel consumption optimization, by properly configuring and calibrating the programmable computerized electronic system, by adjusting the injection and ignition time. The results are validated through the development of measurement tests on the engine dynamometer, track speed (kartódrome), with mathematical analysis, which confirms the feasibility of performing mechanical-electronic truffles and adaptations and software settings that can be implemented in this type of automotive units, which mark an interesting technological novelty.

Keywords: Ecu, electronic gasoline injection, 2-time combustion engine

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Introduction

The need to reduce the emissions coming from automobiles encourages the attempts to study different engine configurations and new combustion strategies. In this case, a two stroke engine able to operate in Controlled AutoIgnition (CAI) and Spark Ignition (SI), the fuel supply is performed by a direct injection (DI) air-assisted fuel injection system.[1] In nut sport when preparing a competitive engine it is not enough just to make mechanical modifications, it is necessary to select and size electrical and electronic components so that in conjunction with calibration, adjustment of the software and the computerized module the power, torque of the combustion engine is increased, making it more efficient so that it has optimal performance during its operation. Karting is a nut sport, considered worldwide as the basis for entry into the world of motorsport.[2] states that: "Not only Formula One drivers such as: Fernando Alonso, Ayrton Senna, Michael Schumacher, Carlos Sainz, Lewis Hamilton and Max Verstappen have been formed, to name just a few Formula One champions, who made their first experiences on top of a go-kart, even many drivers who triumph in modalities such as rally and touring cars have gone through karting.[2] Engine electronic control technology has become one of the key technologies to solve the problems of energy and emissions.[3] For the development of automotive fuel control system, the more extensive use of rapid prototyping tools in accordance with the V model to carry out research.[4,5] In the process of development, the controller needs a lot of basic data, but the data must be tested through a large number of experiments, therefore, the controller takes a long development cycle and high costs. There must be a method combining software simulations and hardware experiments.[6] The electronic fuel injection control system is installed to the 125 cubic centimeters displacement two-time carburetor monocylindrical engine, which is used for karting competitions. Adaptation includes: an ITB acceleration body, programmable automotive computer, sensors: throttle position, coolant temperature, crankshaft position, intake pressure; actuators: injector, petrol pump, ignition coil. The proper calibration and adjustment of the ECU results in improvements in each of the tests carried out with the dynamometer in terms of mechanical performance of the i.e. such as: torque, power and fuel consumption, relative to the initial parameters, from when performing with carburetor.

To achieve optimal combustion it is necessary to calibrate the Electronic Control Unit (ECU), through the use of dedicated free-use software. The ECU controls: fuel injection, air-fuel ratio with lambda probe and regulates ignition spark. These three parameters are very important for both combustion optimization.[7,8] Combustion engines are concerned, emission is the important parameters for which the other design and operating parameters have to be optimized.[9]

Materials and methods

The use of specialized measuring equipment such as: The dynamometer with its data collection hardware and software, fuel consumption verification kit, precision stopwatch, Karting vehicle and testing protocol, guarantees the results for its dissemination.

Rotax max 125 cubic centimeters motor

125 cubic centimeters engine, two-time, cylindrical mono Figure 1, the technical specifications are detailed in Table 1, obtained from the manufacturer's manual.[10]

Figure 1 Motor rotax max 125 cubic centimeters.

Table 1 Rotax max motor data sheet

Engine type	Rotax max
Cubic capacity.	125cc.
Design	2-time cylindrical mono motor.
Power	22KW/29 HP.
Weight	23.1Kg.
R.P.M. power	15 KW/8500rpm.
Turning moment R.P.M.	17 Nm/8500rpm.
Gear	None.
Idle.	1500 rpm at 2000rpm.
Maximum revolutions	12200 rpm.
Ignition unit.	Ignition coil
Spark plug.	Dense IW 31, M14x1.25
Electrode calibration	0.45–0.7mm.
Fuel.	Super.
Engine lubrication.	2-time synthetic oil mixture.
Mixing ratio.	1:50 (2% oil).
Clutch.	Centrifugal clutch.

Programmable computer and software

It is the control unit of the ECU engine, type Megasquirt 2 extra, Figure 2, receives signals from the sensors, processes the injection activation and ignition for the operation of the engine, the adjustment interface is the Tuner Studio software to control all variables in real time.

Figure 2 Megasquirt 2 extra.

Go-kart chassis

CRG chassis model FS4, Figure 3, tubular chrome-molybdenum alloy 28mm diameter that with minimal modifications adapts to the two-course Rotax Junior Max engine.

Figure 3 Chassis "CRG FS4".

Dynamometer

Inertial test bench, is a frame with an inertia steering wheel attached to a secondary axis that keeps the distance of the chain at values similar to that of the Go-kart, has all the elements of the dynamometer incorporated in its structure,[11] as shown in Figure 4.

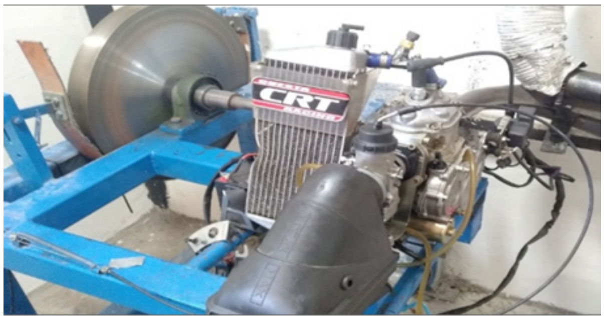

Figure 4 Rotax engine on the dynamometer.

GS software for dynamometer

The dynamometer, uses the GS software to obtain the curves in real time at the revolutions that configure it, allows you to visualize the graphs of: power vs rpm, torque vs rpm, rpm vs Figure 5 time.

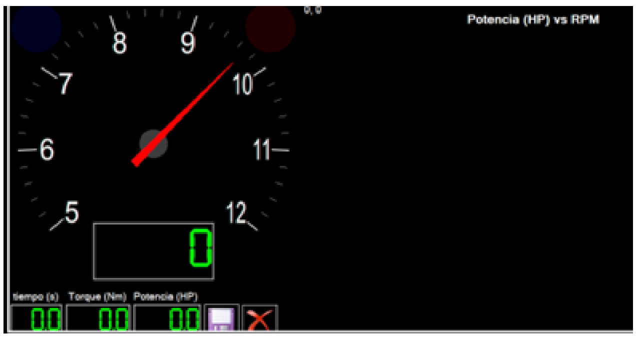

Figure 5 Test bench acquisition interface.

Mychron 5

It is a personal chronograph, automatically displays lap times and important information for the pilot as shown in Figure 6.

Calculations of fundamental parameters

To calibrate the performance of the Rotax Max engine, several technical data is considered as well as the fundamental parameters,

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the tests are carried out at the Cotopaxi kartodrome located in the city of Latacunga - Ecuador, at an altitude above sea level of 2769m, are used,[12–14] the following equations:

Figure 6 Mychron 5.

$$Nv = \frac{G_1}{G_0} * 100\ \% \qquad \textit{Ec. 1}$$

$$Nv = \frac{G_1}{G_0} * 100\ \% \qquad \textit{Ec. 2}$$

$$Vm_{aire} = G_0 * RPM. \qquad \textit{Ec. 3}$$

$$M_{Fuel} = \frac{Vm_{aire}}{AFR * RPM} \qquad \textit{Ec. 4}$$

$$N = \frac{60000}{2\,x\,I\,x\,T} \qquad \textit{Ec. 5}$$

$$N_i = \frac{V_T * pme * RPM}{600} \qquad \textit{Ec. 6}$$

$$N_e = \frac{\tau * RPM}{9550} \qquad \textit{Ec. 7}$$

Where:

M_{aire} : Air mass (gm).

Vc : Cylinder volume m^3 .

ρ_{air} : Air density $\left(\frac{Kg}{m^3}\right)$.

Nv : Volumetric efficiency (%).

G_0 : Air mass under ideal conditions (gm).

Vm_a : Air mass in the kartódrome (gm).

Vm_{aire} : The speed at which air enters the engine ($\frac{gm}{min}$).

RPM : Revolutions ($\frac{rev}{min}$).

M_{Fuel} : Fuel mass to be provided (gm).

AFR : Air-to-fuel ratio.

I : Number of cylinders.

T : Opening time of the injector ms .

N_i : The power indicated (kW) .

V_T : The total displacement $_{pme}$.

pme : Effective mean pressure (bar).

N_e : Effective power (kW)

τ : Torque (Nm) .

Table 2 shows the calculated values, which are necessary to be able to carry out the correct programming of the ECU.[15,16]

Table 2 Calculated values

Air mass (gm).	$M_{air} = 0,1506\, gm$
Volumetric efficiency (%).	$Nv = 93,19\ \%$
The speed at which air enters the engine ($\frac{gm}{min}$).	$Vm_{air} = 1581,3 \frac{gm}{min}$
Fuel mass to be provided (gm).	$M_{Fuel} = 12,05\,x\,10^{-3}\ gm$
Injector opening time.	$T = 2,46\, ms$
Power indicated	$N_i = 15,13\, kW$
Effective power.	$N_e = 15,12\, kw$

Connection diagram

When implementing a programmable computerized electronic fuel injection system, sensor adaptations and programmable system actuators must be made Figure 7.[15,16]

Results and discussion

Results on the inertial test bench

A test was carried out with its initial configuration (carburetor) and three tests with different programming to the electronic fuel injection control software, at the dynamometer and at the Cotopaxi kartódrome, in the city of Latacunga - Ecuador 2769m.s.n. at an atmospheric pressure of 1018hPa. The maximum power obtained with the carburetor engine, test No.1, generates the yellow curve Figure 8, with 12.91HP at 10163rpm, the maximum torque obtained is in the red curve Figure 9, is 10.90Nm at 6143rpm.[16] The second test is with the injection injection system, with the extra Megasquirt 2 programmable ECU, with base map, configured through the tunerstudio software, with the air-fuel ratio with the value of 12.5:1 and angle to the tooth of 130 degrees. The curves have a power elevation, in the green curve Figure 10, with 14.60HP at 9707rpm and the maximum torque was obtained in the yellow curve Figure 11, with 11.21Nm at 8762rpm. The third test calibrates the air ratio: fuel to 14.7:1 through Tunerstudio software, which is ideal for air-fuel mixing. The maximum power shown in the blue curve Figure 12 is 14.55HP at 9163rpm and its maximum torque was produced in the blue curve Figure 13, with 11.79Nm at 8513rpm with small variations as is the case with the required fuel an increase in power and torque values. For the fourth test the combustible air ratio is maintained but changed at the angle of the tooth with a feed of two degrees with the value of 128, the VE board is modified injecting more fuel from 4000 to 14000 rpm taking into account the opening angle of the intake

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butterfly. With the degrees of ignition feed and calibration, the highest obvious power was obtained in the Figure 14 lilac curve, at 17.84 HP at 9118 rpm and the maximum torque was obtained in the red curve Figure 15, at 15.12Nm at 8079rpm.

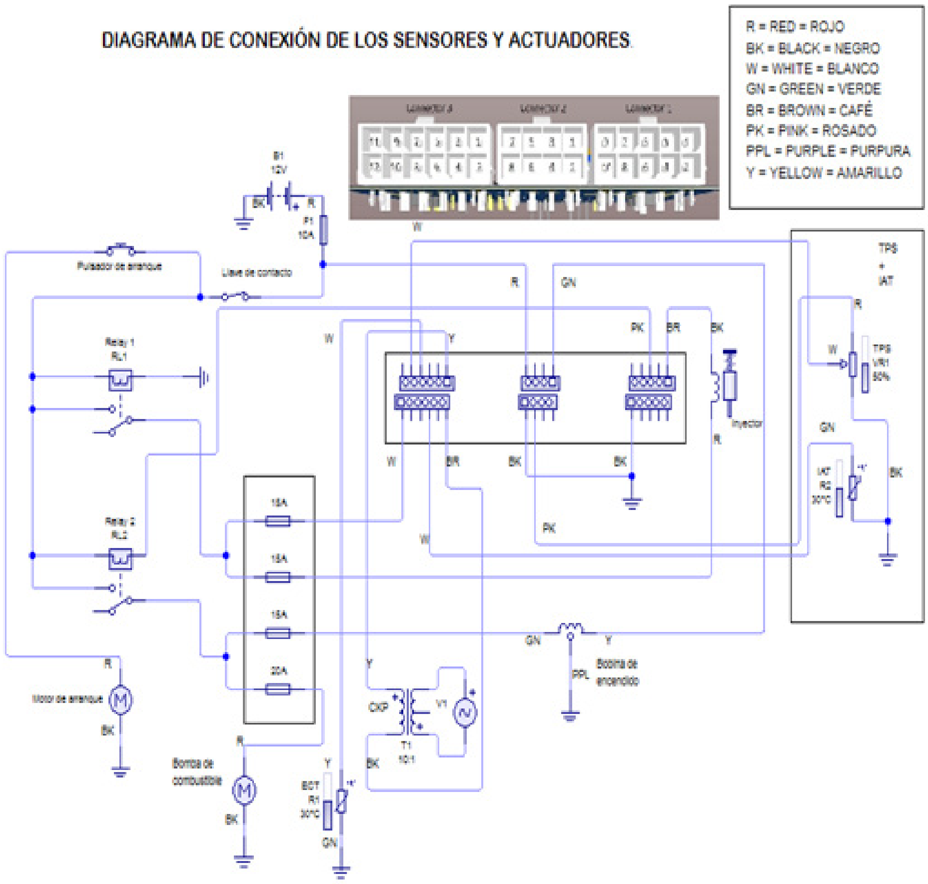

Figure 7 Connection diagram of sensors and actuators.

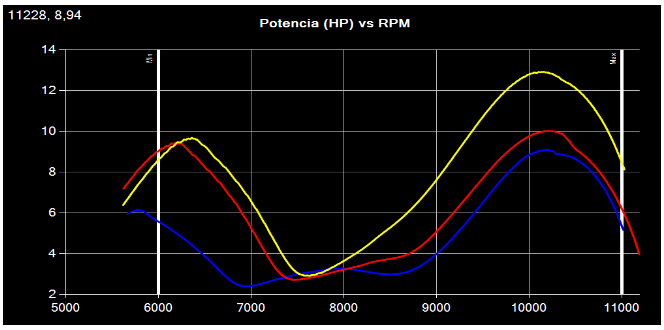

Figure 8 Power curves of test No. 1 to carburetor with shiglor 162.

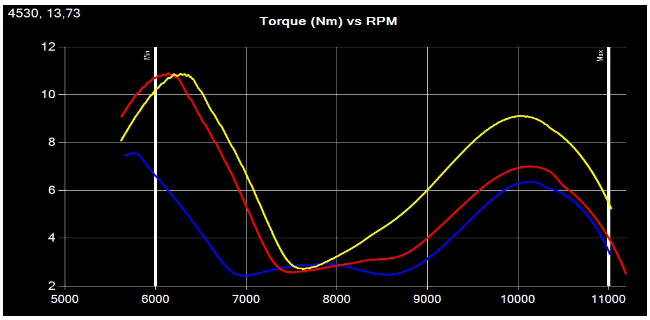

Figure 9 Torque curves from test No. 1 to carburetor with shiglor 162.

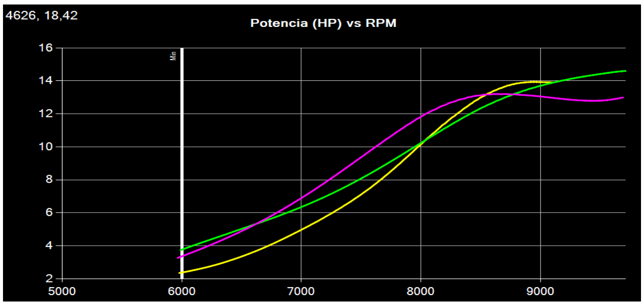

Figure 10 Test power curves No. 2 with the basemap.

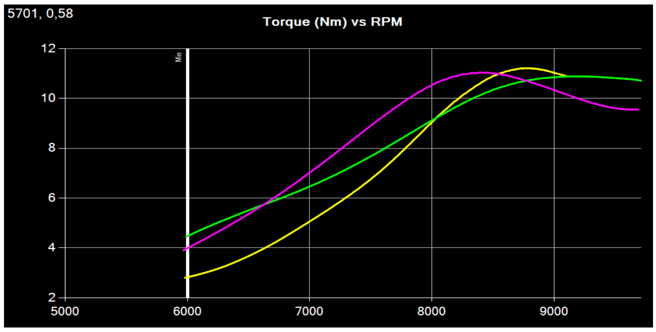

Figure 11 Test torque curves No. 2 with the basemap.

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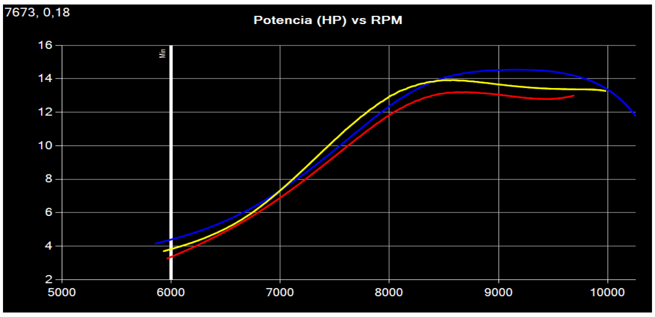

Figure 12 Power curves of test No. 3 with the first calibration.

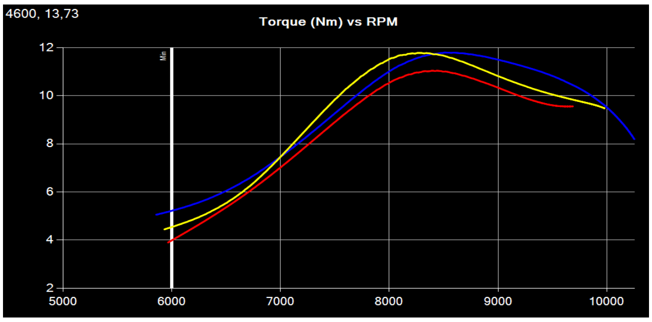

Figure 13 Torque curves of test No. 3 with the first calibration.

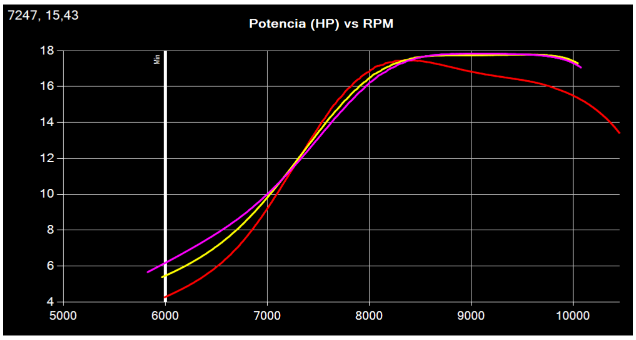

Figure 14 Power curves of test No. 4 with the second modification.

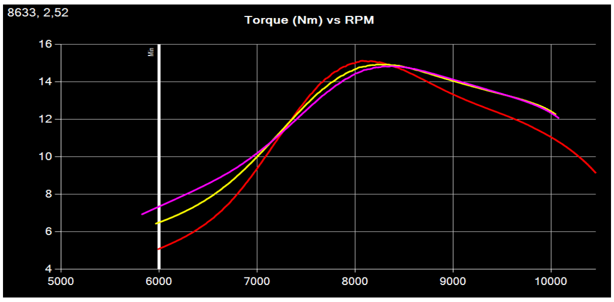

Figure 15 Test torque curves No. 4 with the second modification.

Comparison of power values

Taking the best curves and values of each of the tests performed of power Table 3, is referenced to the 9500rpm and 6500rpm for comparison Figure 16, it is observed that with the system to carburetor the power is low, with the injection system there are no losses and its power increase is uniform without loss as shown in Figure 17.

Comparison of torque values

Taking the best curves and values of each of the tests performed by torque Table 4, is based on 9500rpm and 6500rpm for comparison Figure 18, there is a higher torque with the system at carburetor in low revolutions compared to the injection system, as the revolutions increase its torque decreases and with the injection system you have a significant difference of almost double in high revolutions,[16] specifically at 7500rpm as shown in Figure 19.

Table 3 Comparative power table

Power (HP)				
Rpm	**Carburetor**	**Test 2**	**Test 3**	**Test 4**
6000	8,60	3,36	4,39	6,20
6500	8,97	5,27	5,62	7,82
7000	6,61	6,98	7,28	10,05
7500	2,94	9,71	9,58	13,42
8000	3,63	11,81	12,43	16,18
8500	5,49	13,20	14,14	17,63
9000	7,63	13,11	14,50	17,73
9500	10,77	12,88	14,47	17,80
10000	12,74	12,80	13,56	17,38
Power averages	7,49	9,90	10,66	13,80

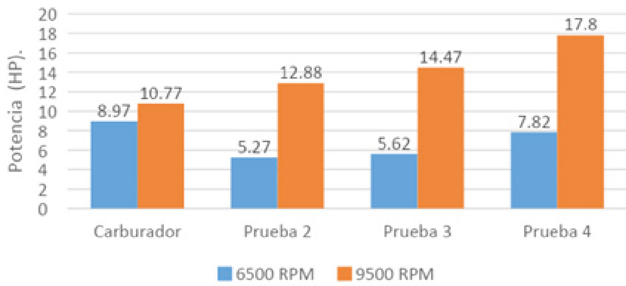

Figure 16 Power values in measurement tests.

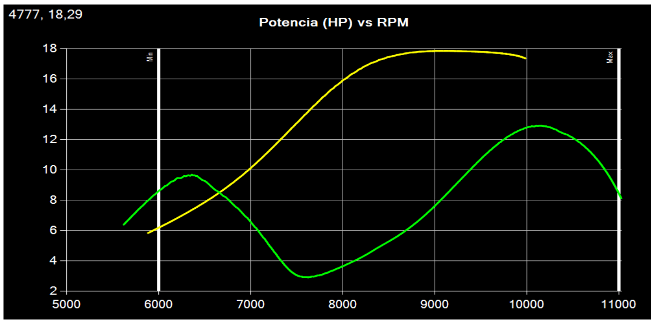

Figure 17 Comparative power curves.

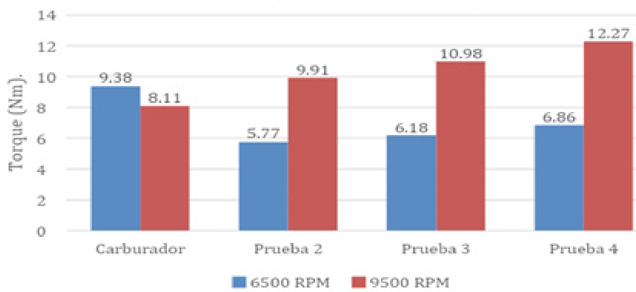

Figure 18 Comparative torque scale.

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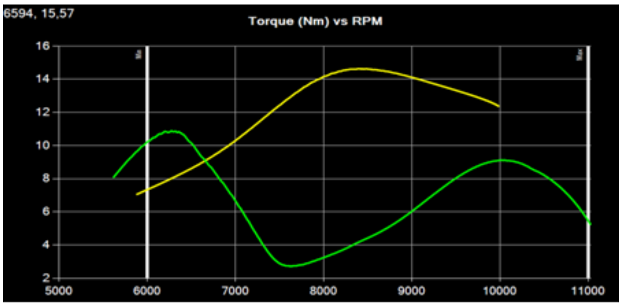

Figure 19 Comparative torque curves.

Table 4 Torque comparison table

	Torque (Nm).			
Rpm	**Carburetor**	**Test 2**	**Test 3**	**Test 4**
6000	10,21	3,96	5,19	5,11
6500	9,38	5,77	6,18	6,86
7000	6,67	7,02	7,46	9,38
7500	2,78	8,87	9,52	13,16
8000	3,27	10,58	11,04	14,96
8500	4,56	11,02	11,72	14,71
9000	5,98	10,4	11,51	13,35
9500	8,11	9,91	10,98	12,27
10000	9,12	3,96	9,59	11,05
Average torque.	6,67	7,94	9,243	11,20

Fuel consumption tests

The measurement of fuel consumption is carried out on the track obtaining the data from Table 5 and that for its best compression they are presented in Figure 20.

Table 5 Data obtained in consumption tests

Condition	RPM	Time (s)	Test 1 (ml)	Test 2 (ml)	Test 3 (ml)	Average (ml)
Carburator	8500	15	46	45	46	45.66
Map 1	8500	15	40	43	41	41.33
Map 2	8500	15	35	34	36	35.00
Map 3	8500	15	30	32	32	31.33

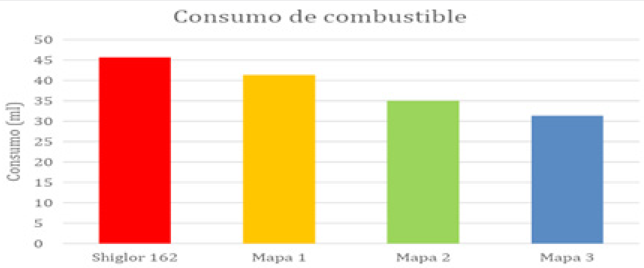

Figure 20 Comparison of fuel tests.

Track speed and performance tests

It was performed on the track of the Galloopaxi kartódrome, has a length of 1.06Km, consists of 12 defined curves of which 5 of them are closed curves in U (3 left and 2 right) and 6 fast curves, has two long lines in which the maximum speed is reached, the curves to the left are represented with blue, red curves to the right and green sections are the lines of the track, as shown in Figure 21. In the on-track tests it was possible to demonstrate the behavior of the engine under working conditions, such as the load by the weight of the chassis and the pilot, friction and adhesion, in the following Table 6 are analyzed and compared the results obtained in the on-track tests with their different variables.[16]

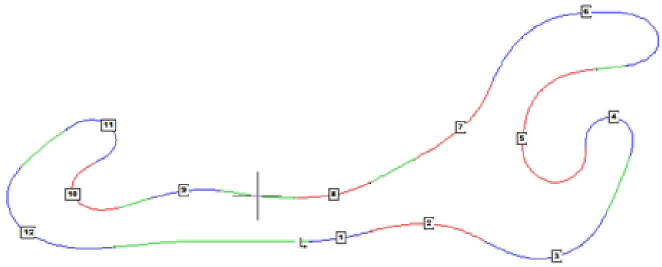

Figure 21 Test circuit established.

Table 6 Parameters obtained in track tests

Test No.	1	2	3	4
Type of admission	**Carburetor**	**Map 1**	**Map 2**	**Map 3**
Lap time (s)	51.99	50.86	50.260	49.82
Maximum revolutions (rpm)	14182	14641	14572	14654
Minimum revolutions (rpm)	2535	4123	4698	5643
Maximum speed (km/h)	103.16	106.86	106.86	108.47
Minimum speed (km/h)	41.04	45.50	46.67	45.50

Conclusions

With the proper calibration of the ECU Electronic Control Unit and specific and dedicated software programming, applied in the automotive industry, more efficient combustion engines are achieved, without making mechanical modifications. In the injection system there are no loss of power or torque, as it is directly proportional to the revolutions; even maximum power and torque values are obtained at lower revs, compared to the carburetor system. By performing the respective tests on the inertial test bench and obtaining average values of each test it was obtained that by implementing the programmable electronic injection system there is an increase of 45.72% in power and an elevation of 40.41% in torque compared to the conventional system to carburetor. The engine with the injection system performed better on both the dynamometric and track test bench so its implementation is feasible. The electronic injection system with its programmable ECU presents the decrease in fuel consumption consumption of 31.38% compared to the fuel consumption of the conventional system to carburetor comparing the test with shiglor 162 with the Best Performance Map 3 test, which denotes that there is better use of the energy produced by the fuel. By comparing the results obtained in the tests the electronic injection system with programmable computer ECU, with respect to the carbureted system obtained an improvement of 2,166 seconds in the best lap time, an improvement of 472 maximum rpm achieved, representing a 3.33% increase in the maximum rpm of the track engine, compared to the final speed, due

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to the maximum rpm gain there is an increase of 5.31km/h faster with the injection system than with the carbureted system, representing a 5.15% gain in final speed. The loss of revolutions per minute in slow corners was much less, having a result of 3108 rpm greater than with the carburetor representing a gain of 122.6% in minimum rpm, which guarantees a higher output speed in slow corners achieving a speed of 45.5km/h, achieving a gain of 4.46km/h than with carburetor, this represents a 10.86% gain in slow-curve output speed. Variations in ECU programming influence the required fuel consumption, degrees in ignition feed resulting in an increase in the power and torque values evident in the tests carried out. Engine performance improved in relation to the original parameters obtained by calculations taking into account technical data as well as fundamental parameters. The torque and power curves generated, which thanks to the implementation of the electronic injection system gained in these aspects.

Acknowledgments

None.

Conflicts of interest

The authors declare that there is no conflict of interest.

References

1. López JJ, Molina S, García A, et al. Analysis of the potential of a new automotive two-stroke gasoline engine able to operate in spark ignition and controlled autoignition combustion modes. *Applied Thermal Engineering*. 2017;126(5):2017;126(5)834–847.
2. Salazar J. Ecuador forms great pilots through karting. 2019.
3. Li HY. Research on Current Situation and Development of China Automobile Energy Saving Standard Regulation. Beijing. SAE-China Congress & Exhibition; 2013.
4. He YL. Automotive electronic control technolog. Beijing. Beijing university of aeronautics and astronautics press; 2013.
5. Gao HY, Wenchang Lu, Zhe Shang. Rapid prototype development of engine ECU based on MotoTron platform. *Design and Manufacture of Diesel Engine*. 2008;3:16–20.
6. Wei C, Chen M, Jiang Y. Electronic control fuel injection system based on GT-POWER and MotoTron. *Procedia engineering*. 2017;174:773–779.
7. Iodice Senatore. Amic-experimental analysis of the behaviour of state-of-the-art medium-sized motorcycle emissions under real urban conditions. *In t J Automot Mech Ing*. 2015;12(1):3018–3032.
8. Iodice. Senatore High performance new motorcycle exhaust emissions in hot and cold conditions. *In t J Environ Sci Technol*. 2015;12(10):3133–3144.
9. Onawumi AS, Fayomi OSI, Okolie STA, et al. Determination of a spark ignition engine's performance parameters using response surface methodology. *Energy Procedia*. 2019;157:1412–1422.
10. Rotax New Age Karting. Repair Manual for ROTAX Engine Type. 2010.
11. Horacio Resio Devices. (s/f). Inertial test bench for go-kart and motorcycle.
12. Banish. Engine Management: Advanced Tuning. 2007.
13. Tinizaray Romero DG. Electronic reprogramming of the injection control and ignition of the CBR 600 F4i engine, for the Formula Student vehicle. Latacunga: Department of Energy and Mechanics, University of the ESPE Armed Forces. 2015.
14. Ocaña A. Automotive Treaty, The technique in the twentieth, 21st centuries. Editorial CIE Dossat. 2000.
15. Erazo G, Corral A, Quiroz L, et al. Influence of the use of specialized software in the automotive industry to drive internal combustion engines, XII Ibero-American Conferences on Software Engineering and Knowledge Engineering 2017, JIISIC 2017 - Held in conjunction with the Ecuadorian Congress of Software Engineering, CEIS 2017 and the Congress of Software Engineering Applied to Control systems and automation, ISASCA 2017;2017:255–265
16. Galarza Noroña, Jorge Raúl, Gallo Vera, et al. Electronic truffle of the two-time single-circuit rotax max 125 cubic centimeters engine fuel feed system, for use in karting competition. Department of Energy Sciences and Mechanics, University of the ESPE Armed Forces. 2020.