Electronic Control Unit for motorcycle based on the platform for Arduino Mega 2560 for the migration of systems to the carburetor to electronic fuel injection systems

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***Abstract*—This project consists of the design and implementation of a control unit electronics based on the Arduino mega 2560 hardware platform to migrate systems based to carburetor motorcycles fuel injection systems to so reduce the formation of pollutants produced, making use of preventive environmental technologies.**

Keywords—ECU;RPM; CO;TunerStudio

I. Introduction

The use of electronic elements in recent decades has been a fundamental pillar for the development of devices that help the progress of the industries in its different areas, both so the automotive industry has not been back in use these technologies and thus have developed vehicles less polluting and more efficient in terms of fuel consumption and all this governed from the electronic control unit.

But not all vehicles make use of these technologies, there are vehicles that make use of mechanical components such as carburetor which generate problems for the environment, for that reason has been chosen to develop an electronic Control Unit for control of electronic injection of fuel in this case for motorcycles since they still make use of the carburetor fuel feed system.

For the electronic Control Unit the Arduino Mega 2560 platform was selected as unit of processing and control logic because it is affordable, cross-platform because we working on operating systems both Windows and Linux, its programming environment is flexible since beginners as advanced programmers can make use of the hassle and also that both the compiler as the hardware is open source eliminating payments for licenses.

In this way and with the use of the electronic Control Unit in used motorcycles in four-stroke combustion engines shall be obtained a reduction of emissions of exhaust gases as electronic control unit together with the information provided by the sensors will inject the exact amount of fuel contributing in this way to the preservation of the environment and the quality of the air, as well as the health of the people.

II. Basic Concepts

A. Electronic control unit

The electronic control unit is the computer of the system, also called the engine control unit, is responsible for the calculations necessary to determine the injection time and on time at the right time based on the data provided by the different engine sensors.

The ECU is composed of many elements for its operation, is made up of the hardware which is the set of electronic components and on the electronic board, the software stored on EEPROM memories and that together with the CPU do all the calculations for the operation of the actuators, there are many varieties of these modules being one more sophisticated than others depending on the technology used in its design. Figure 1 shows the block diagram of an ECU.

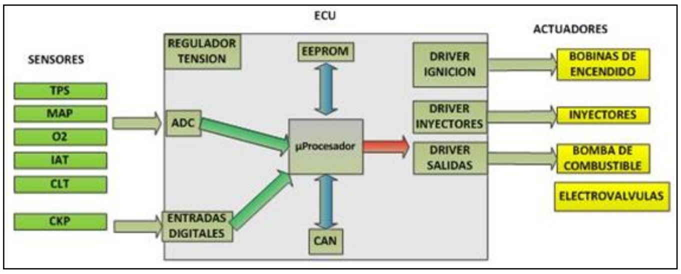

Fig. 1. Block diagram ECU.

III. Design

A. Hardware design.

It is the design of the electronics required for the interconnection of sensors and actuators of the engine, to be in an environment where the generation of noise can be a problem for the operation of the electronic control unit [23], for such reason is needed the signal conditioning circuits which adjust the signal coming from the sensors [6] and also contain circuits of amplification for the interconnection of the actuators.

1) Circuit conditioning signal TPS sensor:

The TPS sensor signal conditioning circuit consists of a pass under the liability of the first order filter, consists of resistance R1 and capacitor C2, its main function is to eliminate the noise that is coupled to the data line, on the other hand the diode Zener D1 protects the pin of the microcontroller by possible voltage peaks higher than 5.1 V.

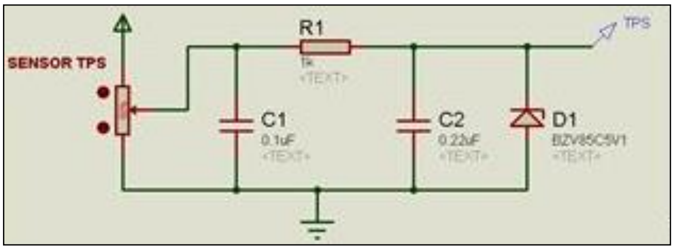

Fig. 2. Cicuit conditioning TPS sensor.

2) Circuit conditioning signal CLT - IAT sensors:

CLT and IAT sensors are sensors that vary their resistance according to the temperature variation, these sensors are NTC (negative coefficient) type i.e. its resistance value decreases as the temperature increases. The CLT and IAT sensors signal conditioning circuit consists of a formed by R3 voltage divider and the sensor in this way is obtained a variation of voltage as it varies the resistance of the sensor, a filter passes under liability of first order formed by R2 resistance and capacitor C4, its main function is to eliminate the noise that is coupled to the data line , on the other hand D2 Zener diode protects the pin of the microcontroller by possible voltage peaks higher than 5.1 V.

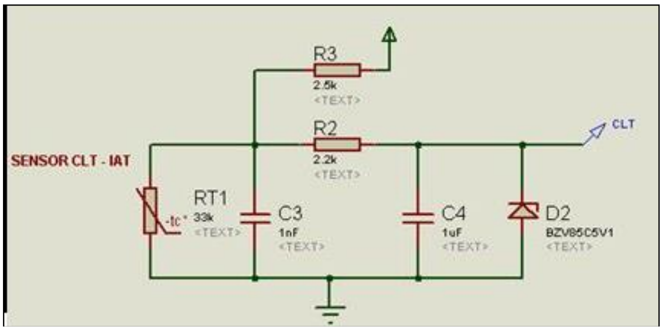

Fig. 3. Circuit conditioning CLT – IAT sensors.

3) Circuit conditioning signal MAP sensor:

The MAP sensor signal conditioning circuit consists of a pass under the first order passive filter, filter is formed by R4 resistance and capacitor C6, its main function is to eliminate the noise that is coupled to the data line, on the other hand the diode Zener diodes D3 protects the pin of the microcontroller by possible voltage peaks higher than 5.1 V.

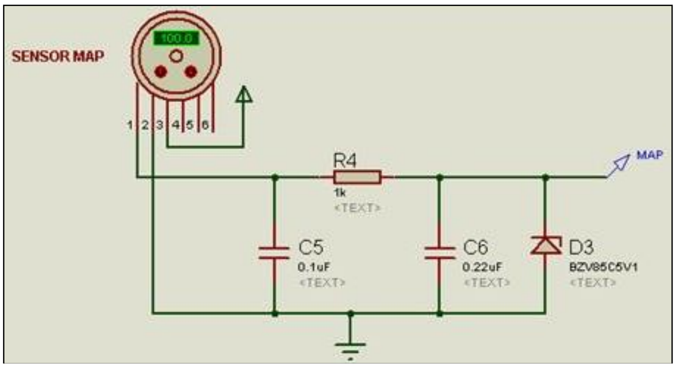

Fig. 4. Circuit conditioning MAP sensor.

4) Circuit conditioning signal CKP sensor and ignition coil:

This circuit was an HEI module this module contains all necessary electronics to perform the following functions:

Internally connects the CKP sensor on pins PN of the module, this module transforms the sinusoidal signal of the CKP sensor signal to be sent to the Arduino mega 2560 card by R pin rectangular, this signal will be the crankshaft position, once processed this signal the Arduino mega 2560 card sends to the HEI by pin module and the signal for activation of the ignition coil for the activation of the ignition coil the HEI module has internally a power transistor capable of resisting the current in the coil. Figure 5 shows how the HEI module is formed internally.

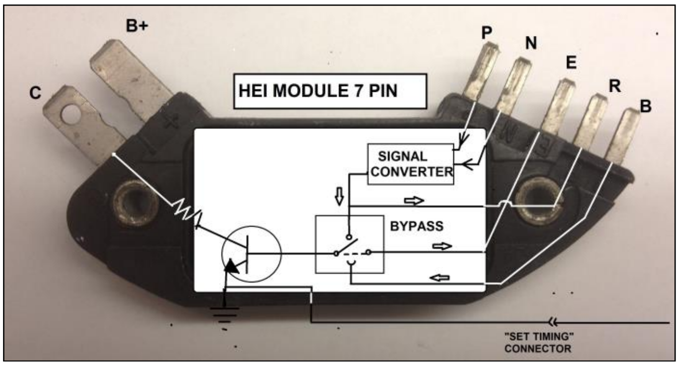

Fig. 5. HEI Module.

5) Circuit conditioning signal battery voltage sensor:

The circuit consists of a voltage divider formed by resistors R7 and R8 which limited that there is an output voltage within the range from 0 V to 5 V.

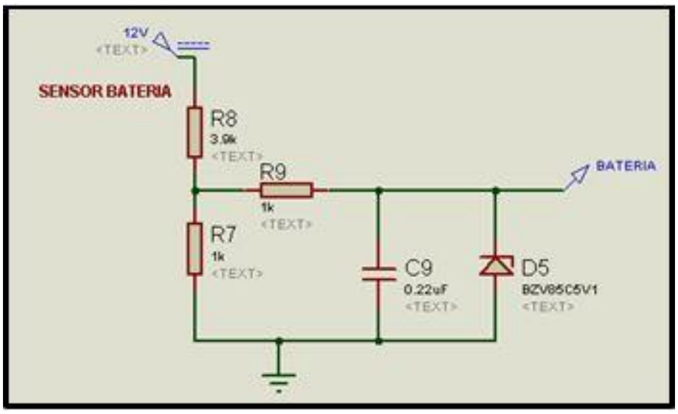

Fig. 6. Circuit conditioning signal battery voltage sensor.

6) Signal amplification circuit injector and fuel pump:

The injector and fuel pump operates with a voltage of 12 V, directly from the microcontroller pin not can be fed to the nozzle since their voltage is 5 V, by such reason you need a voltage amplifier circuit.

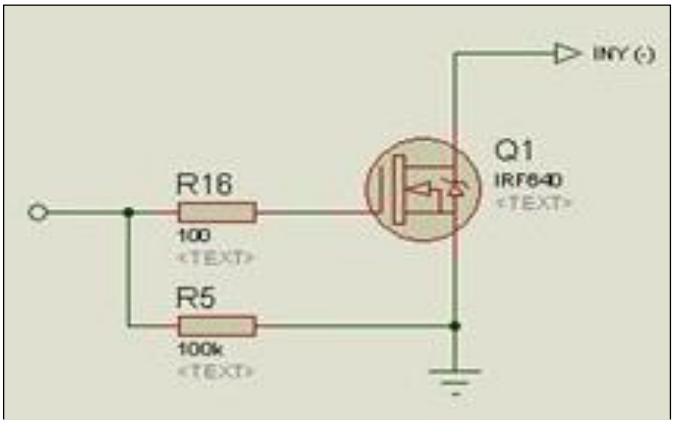

Fig. 7. Amplificationcircuit injector – fuel pump.

7) Power supply circuit:

The supply circuit as shown in the figure corresponds to the supply voltage which provides a constant voltage to the electronic control unit. Because the motorcycle battery has a voltage of 12 V to 14 V approximately, this voltage must be regulated to a value of 5 V, most used controller is the LM7805 provides a voltage of 5 V and a current of 1 A capacity for this way both sensors, actuators and electronic control unit to operate in a normal manner.

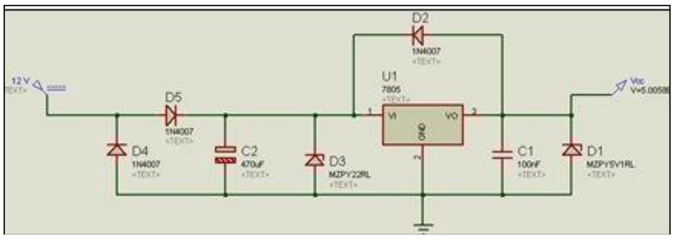

Fig. 8. Power supply circuit.

8) Circuit design:

ARES software was used for the design of the PCB, it is designed in a fiberglass sides and plate with a design which if it adheres easily on the Arduino mega 2560 card as if out a commercial shield, thus optimizing space making all electronic control unit occupies a small space. Figure 9 shows the design in 2D and 3D of the electronic card.

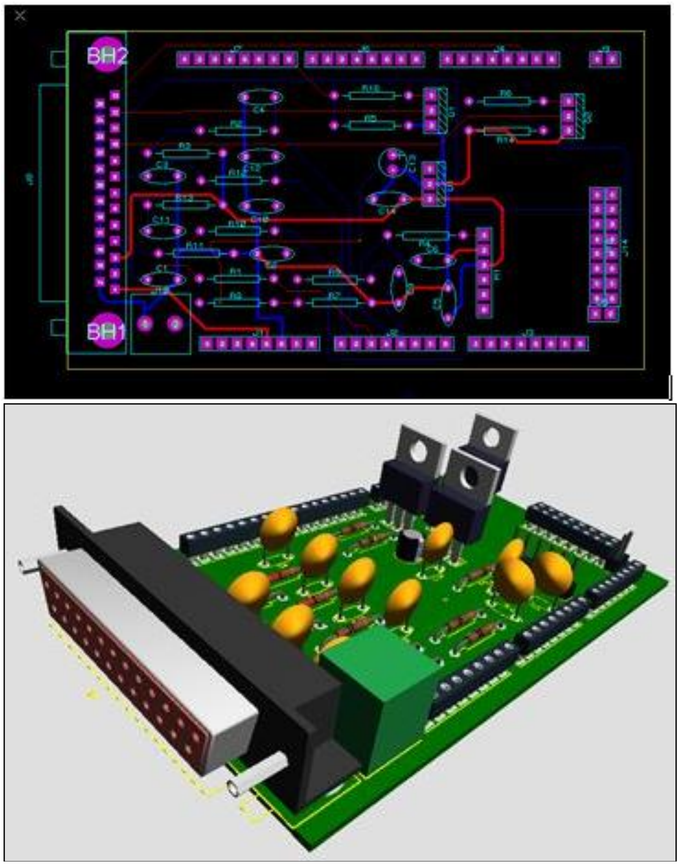

Fig. 9. 2D and 3D view electronic card..

IV. Implementation and Operational Test

A. Implementation electronic card.

Figure 10 shows the implementation of the electronic control unit, where it consists of the electronic card in which they connected sensors and actuators of the engine and the Arduino Mega 2560 card, also shows how the electronic board adheres to the Arduino mega 2560 card.

Fig. 10. Electronic control unit.

B. Installation of sensors and actuators

Figure 11 shows the installation of the sensors, MAP, TPS, IAT, CLT, oxygen and as an actuator Sensor in the intake manifold fuel injector, also shown as installed on the engine.

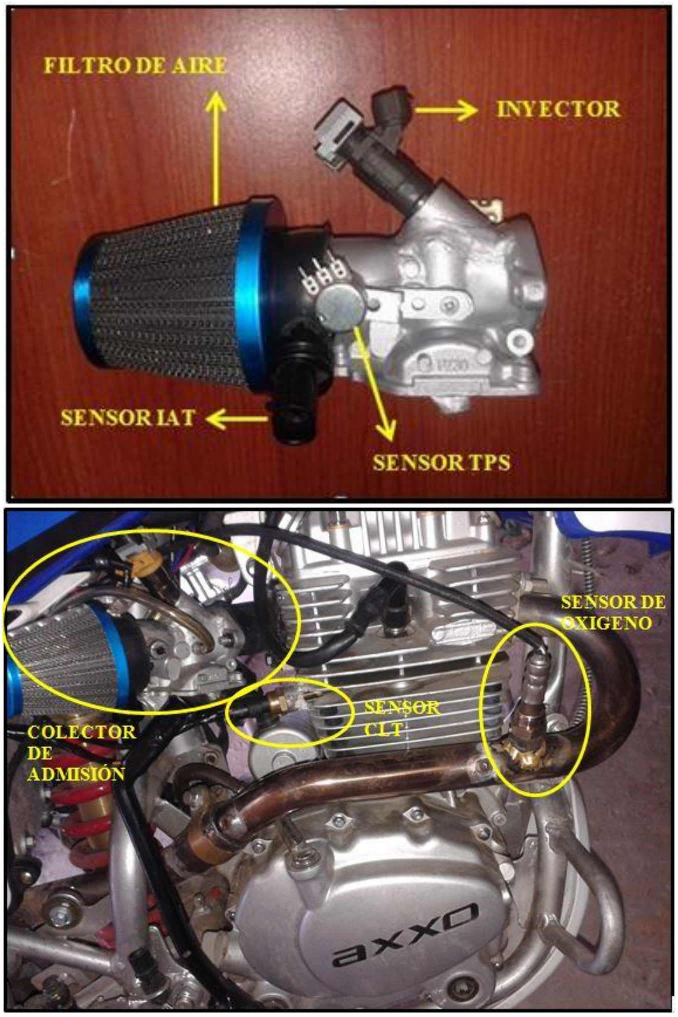

Fig. 11. Installation of sensors and actuators.

For the installation of the fuel feed system consists of the fuel pump, this will generate enough pressure to inject the fuel to the engine, this fuel pump is external, i.e. it does not have to be inside the fuel tank, in addition you will need a pressure regulator which control the excess pressure in the fuel Thus if there is an excess of pressure fuel will be returned to the fuel tank. Figure 12 shows how all of these elements are connected.

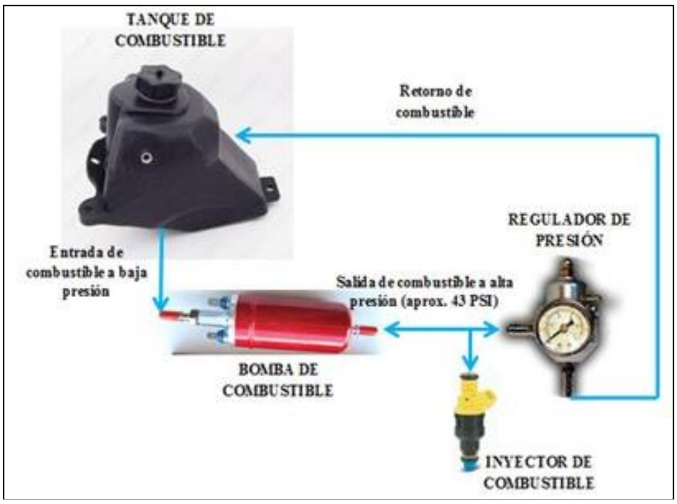

Fig. 12. Installation fuel pump and pressure regulator.

C. Performance test

1) Testing pulse width injector:

This test is to verify if the calculated theoretical value of the pulse width of the injector is consistent with the value obtained in the actual operation. The equation that corresponds to the pulse width [20]:

$$\boldsymbol{PW = REQ_{FUEL} * VE * MAP * \gamma Enrich + \gamma Accel + InjOpen} \qquad (1)$$

The necessary data will be obtained from the panel of instruments of TunerStudio, the first test was performed around 1500 RPM and the second test at 3000 RPM.

- Test 1 (1500 RPM)

  Data:

  - $REQ_{FUEL} = 14{,}7\ ms$
  - $VE = 6\%$
  - $MAP = 44\ kPa$
  - $\gamma Enrich = 102\%$
  - $\gamma Accel = 10\%$
  - $InjOpen = 1\ ms$

Replacing data in (1) must be:

$$PW = 1.495\ ms$$

Figure 13 shows the value of pulse-width of the fuel injector in the TunerStudio instrument panel.

Fig. 13. Pulse width injector at 1500 RPM in TunnerStudio.

In addition to the value obtained in the software TunerStudio was also obtained the value of the pulse width using an automotive oscilloscope, Figure 14 sample characteristic of injector waveform, as well as the duration of the pulse width.

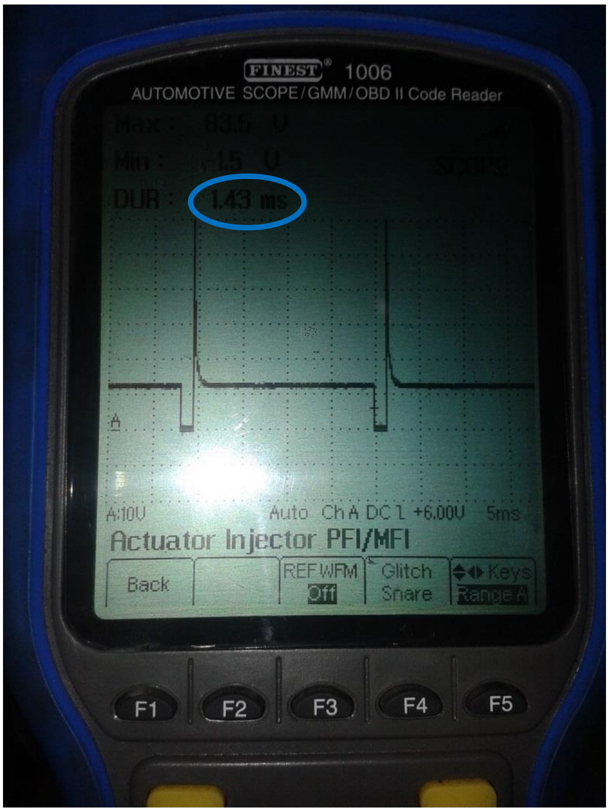

Fig. 14. Pulse width injector at 1500 RPM in oscilloscope.

- Test 2 (3000 RPM)

  Data:

  - $REQ_{FUEL} = 14{,}7\ ms$

- $VE = 24\%$
- $MAP = 80\ kPa$
- $\gamma Enrich = 103\%$
- $\gamma Accel = 10\%$
- $InjOpen = 1\ ms$

Replacing data in (1) must be:

$$PW = 4.007\ ms$$

Figure 15 shows the value of pulse-width of the fuel injector in the TunerStudio instrument panel.

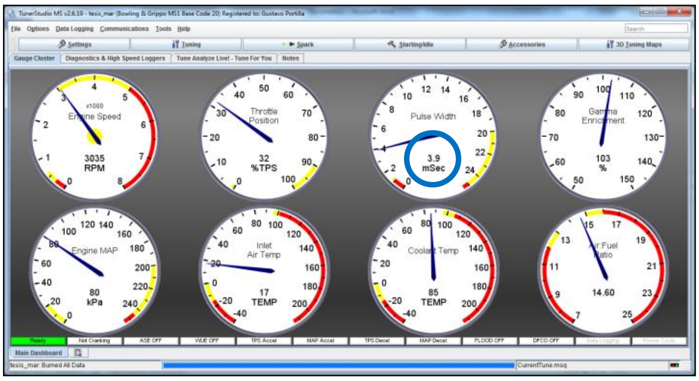

Fig. 15. Pulse width injector at 3000 RPM in TunnerStudio.

In addition to the value obtained in the software TunerStudio was also obtained the value of the pulse width using an automotive oscilloscope, Figure 16 sample characteristic of injector waveform, as well as the duration of the pulse width

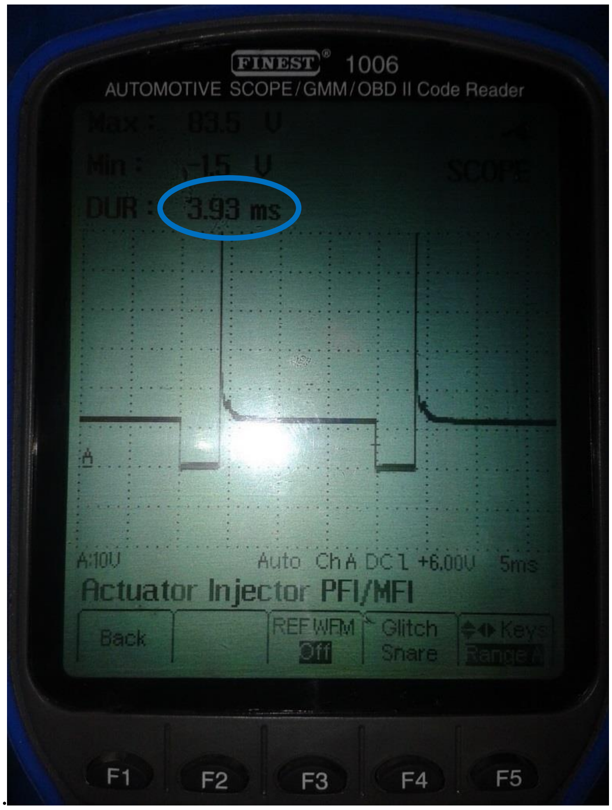

Fig. 16. Pulse width injector at 3000 RPM in oscilloscope.

The values of the obtained theoretical calculations match experimental values both with the oscilloscope as well as software TunerStudio, the table 1 shows the theoretical and experimental value.

TABLE 1. PULSE WIDTH INJECTOR VALUES

Test	Pulse width injector		
	Theoric value	***Experimental value in TunerStudio***	***Experimental value in Osciloscopio***
1500 RPM	1.495 ms	1.4 ms	1.43 ms
3000 RPM	4.007 ms	3.9 ms	3.93 ms

2) Test fuel efficiency:

This test made measuring the time it takes the amount of 30mL of fuel to 2000 RPM at idle, this was it done system into carburetor so both also based to electronic fuel injection system. Figure 17 shows the time duration of the quantity of fuel delivered.

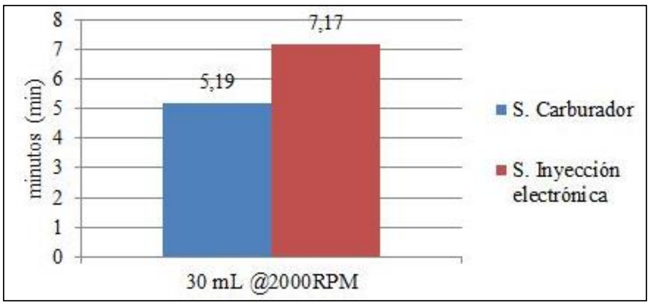

Fig. 17. Test fuel efficiency.

In this way there is based to electronic fuel injection system consumes 27% less compared to the system bases to carburetor. This test made in this way since so you can know accurately long fuel since the working conditions in which the engine is known as to the doing it dynamically to exist changes of speed, acceleration and braking of motorcycle, it is not known which of the two systems consume more fuel.

3) Test greenhouse gas emissions:

For the test of gas emission the emission of carbon monoxide, discussed both for carburettor system as well as to electronic fuel injection system. The test was carried out in two ways: State of idle which is when the engine is running minimum 1500 RPM approximately and another test in which the engine is located at 5000 RPM approximately. The results of the gas concentration are given in percentage %.

In accordance with Figure 18 the emission of carbon monoxide in a carburetor system produces 93% more than a system based on electronic fuel injection engine rotation speed of 1500 RPM.

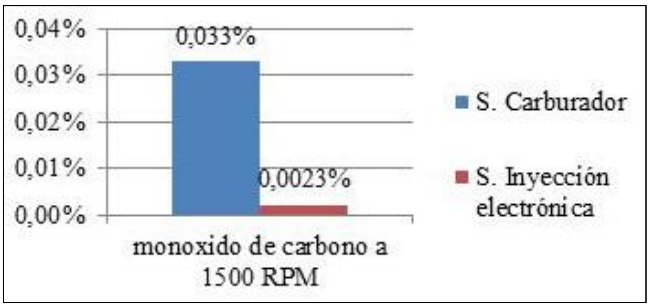

Fig. 18. Test carbon monoxide emissions at 1500 RPM..

Similarly was carried out the test at a speed of rotation of the engine of about 5000 RPM, carburettor system produces 78% more carbon monoxide compared with the system based on electronic fuel injection as shown in Figure 19.

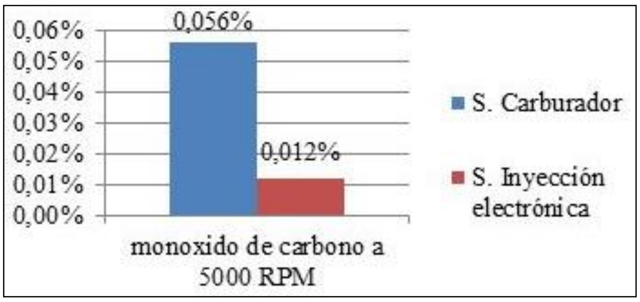

Fig. 19. Test carbon monoxide emissions at 5000 RPM.

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