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Mechatronics of Automobile: Motor's Electronic Control Unit Performance and the Insufficient of Injection System

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ABSTRACT

Extensive studies were investigated Mechatronics of Automobile since the synergistic combination of classical electro-mechanic of automobile , computer science and automatic engineering were integrated to together at the beginning of the conceptual stage for the design of new models of automobile. More automobiles involve more pollution after fuel consumption. Although motors' performance had been proving through its electronic computerized control unit, also called calculator, the limitation and the insufficient functional problem of motor's injection system remain unsolved. To overcome this problem at different angle in contrast with early studies and conclusions, this paper focuses on motor's electronic computerized control unit, such as Motronic injection system performance to highlight limitation and insufficient of motor's injection system by using requirement and constraint analysis of electronic system on the sensors, calculators and injectors before the consequences of the failures of Mechatronics key elements in the motor's injection system. The results show that electro-chemistry constraints, hardware and software requirements .This paper support the hypothesis that hybrid engine is more perfect for reducing fuel consumption and avoiding harmful gas emission than an internal combustion engine or an electric motor one alone.

1. Introduction

The term Mechatronics was coined in Japan[1].Many definitions were published later and can be summarized as innovation in either pure mechanicals systems or pure electro-mechanicals systems which are the integration design of computer control together with information processing using sensors and actuators [2-4].According to early researchers definitions , we suggest that Mechatronics can be defined as electronic computerized unit control in real time of any phenomena's movement , using sensors and actuators. This electronic computerized unit control is being embedded with both information and a self diagnostic system .Since Mechatronics is inspired from multidisciplinary [1-4]; it is referred as multi-applications areas include automobile. Mechatronics of Automobile involves all the vehicle subsystems such as security, comfort, communication, self-diagnostic, transmission and motor combustion. In this paper Mechatronics applied to automobile's motor is investigated .Electronic management of the motor also called electronic computerized control injection system is analyzed in this research. More and more, automobiles bring us many advantages with comforts and at the same time problems of fuel consumption and environment pollution which consist of carbon monoxide, lead particles and so on .These particles exposed to the sunshine change in to chemical smoke which may be caused cancer and other diseases [5]. However the synergistic combination of air induction system ,fuel delivery system, electronic sensors and injectors through an integrated computer control process design's approach can perform easily the motor injection system[6].

In the past years extensive researchers were carried out on engine fuel consumption, emission control system through fuel injection system performance using gasoline fuel injection or diesel fuel injection [7-10] .A number of articles in literature have suggested that the necessity of reducing fuel consumption and the emission of harmful gas in vehicle [11-13].Since Mechatronics of automotive has revolutionized the classical automotive mechanic, all sub-systems of the vehicle are controlled and regulated by electronic devices. Multiplexing technology, Controller Area Network (CAN) or Vehicle Area Network (VAN), makes information's traffic smooth in the vehicle and particularly in the engine injection system. The electronics' engine management is investigated in this paper. Despite the recent progress reviewed in the performance of motor computerized electronic control unit using electronic sensors and injectors, the excesses fuel consumption and the pollution exhaust gas problems are still remaining since they are a few study highlighting the limitation and insufficient functional of injection system.

The key contribution of this paper is to let out not only the limitation functional of injection system but also the insufficient of injection system in order to provided it more efficient and avoid both excess fuel consumption and pollution problems.

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This paper is concerned both performance and insufficient of injection system through a Motronic system as a study case and Electronics constraint analysis with the consequences of Mechatronics key elements' failures in motor's injection system.

The outline of this paper is following as: Section2 recalls brief background of Mechatronics and Mechatronics field's applications such as Mechatronics of automobile. Section3 describes the performance of Mechatronics of motor through injection system before the advantage of injection system through typical Motronic system as application.Section4 focuses on limitation and insufficient of injection system trough electronics constraint analysis and failure of Mechatronics key elements. Finally section5 end our research which includes the future challenge in hybrid motor.

2. Brief Backgrounds of Mechatronics and Mechatronics Field's Applications

This section gives a brief notion of Mechatronics and it survey before the fields of application in Mechatronics. More details on Fundamentals of Mechatronics and its applications should refer to [3-4, 14-15].

2.1 Brief Notion of Mechatronics

Mechatronics was born 1963 in Japan. A senior engineer Tetsura Mori of the company Yaskawa used the term for the first time .It was described as an automatic control of electro-mechanical system using sensors and electrical actuators [14].From 1980, a novel technique has been developed and applied such as computer processing unit controlled electric signals system. Interdisciplinary engineering provides optimal solution for complex technical's problems such as motor's combustion through carburetor. To overcome the problem of carburetor, several techniques using Mechatronics solution such as injection system has been designed and applied to an internal combustion of motor which this paper is focused on. Since Mechatronics integrated at the beginning of conceptual stage design different technologies [15], it involves: electronic sensors technology, calculator technology, actuators technology and signal system technology to be integrated in classical automobile mechanic technology to overcome the difficulties that arose when the carburetor was used.

The empirical difference between mechanics, electro-mechanics and Mechatronics is that the last one embedded the first two with computer control in using sensors and actuators .Mechatronics system is an integrated conceptual design in the synergistic combination of electronic computerized unit control in real time of any phenomena's movement, using sensors and actuators. This electronic computerized unit control is being embedded with an information system and a self diagnostic system.

The key elements of this emerging technology have been shown in Fig1.Now days Mechatronics engineering is in correlation with classical engineering such as mechanical, electrical, computer science, and control engineering described at Fig 2. Form Fig1, it's shown that, sensors, computer unit, communication, information system and actuator are the Mechatronics key elements.

Sensors

Sensors and transducers involve always the application of some law of physics (chemistry) principle that relates to the quantity of interest to some measurable event. They measure input physical variable properties which are often analog measurement such as temperature, mass, sound, position, speed, acceleration, angular, torque, pressure, oxygen content, light transmission, and so on in to output voltage signals which content information to feed to the computer.

Computer Processing Unit

It is the "brain" of the power decision system unit. They receive the output information in voltage signals form from the sensors .Information are stored and organized in set of data formats instructions' and will be examined along the selections instructions in the microprocessors.

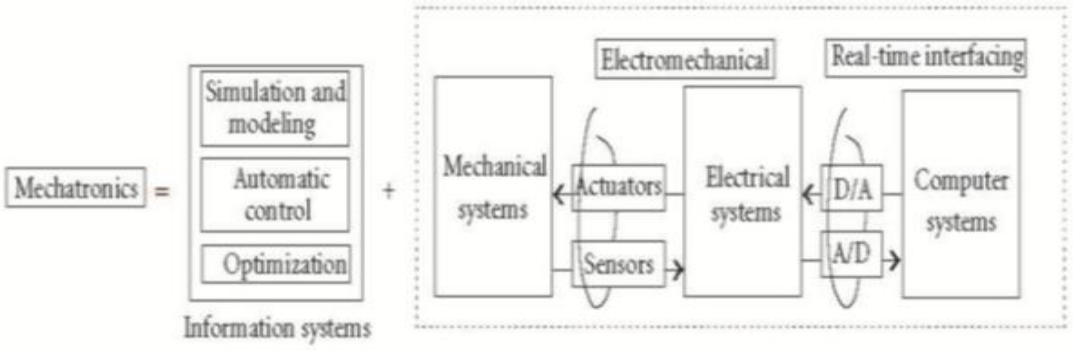

Fig.1. Mechatronics Keys Elements [2].

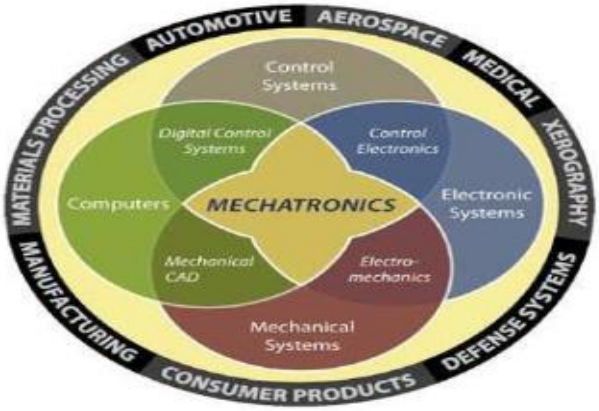

Fig. 2. Multidisciplinary.(Source :Rensselaer Polytechnic Institute).

Microprocessors

It is a Single Large Scale Integration (**SLSI**) chip that contains many digital memories circuit where perform arithmetic, communication, and control function. The packaged on a printed circuit board of a microprocessor with other components such as interface (input/output) and memory chips is referred as microcomputer as shown in Fig-3. This is developed in two categories describe as **Personal Computer** (**PC**) where the main constraints are high speed and large word size while the second category is a **Microcontroller**, which is a single **Integrated Circuit** (**IC**) containing the microprocessor memory, input/output capabilities and other on-chip resources.

Actuators

The actuators act in order to response for the Computer Processing Unit. Since Mechatronics involves any phenomena's computerized electronics movement control using sensors and actuators, in Mechatronics of motor, the air/fuel mixture movement is computerized electronically controlled using sensors and injectors. The actuators (injectors in Mechatronics of motor) movement's feed air/fuel mixture by creating an open or close movement due to the speed or the acceleration of the motor. In this paper we focus on electronic injector as actuator associated to the electronic sensor.

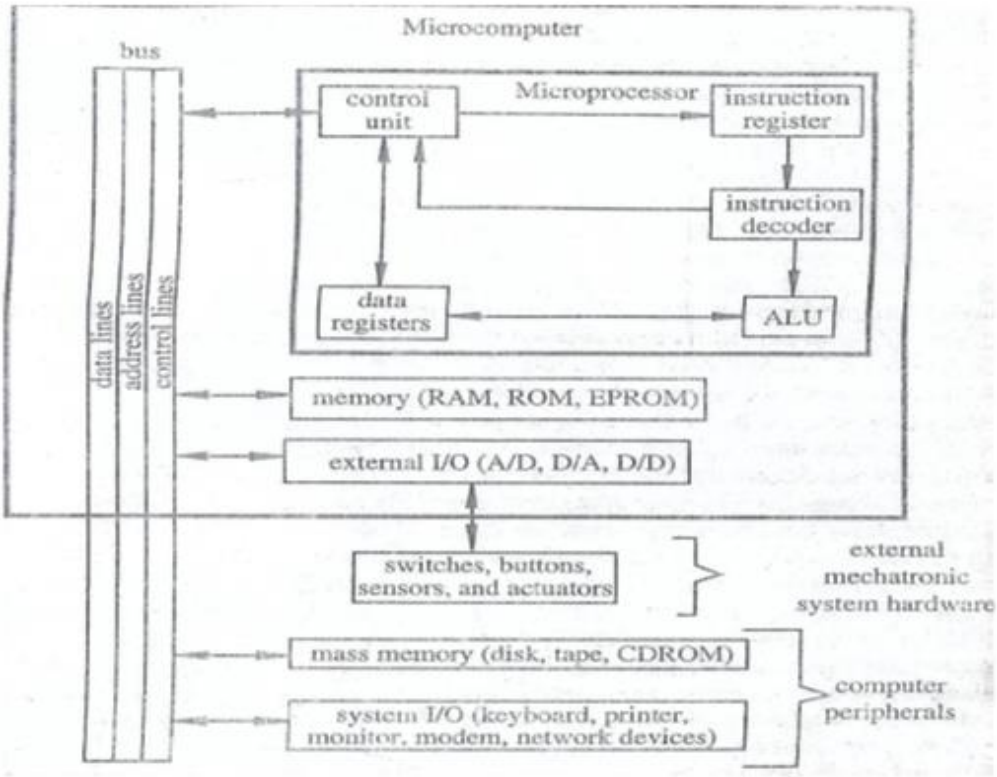

Fig. 3. Microcomputer Architecture [17].

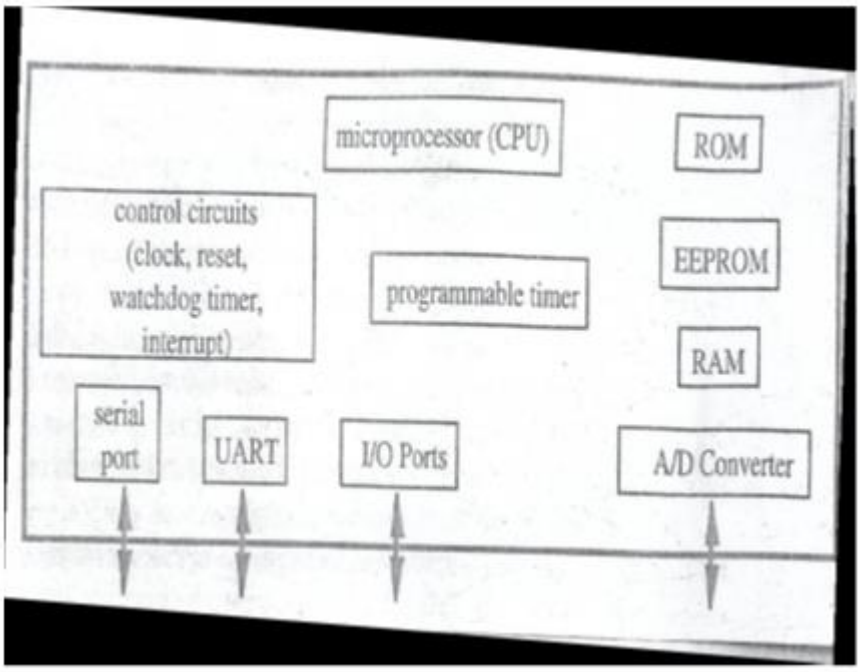

Fig. 4. Microcontroller Architecture [17].

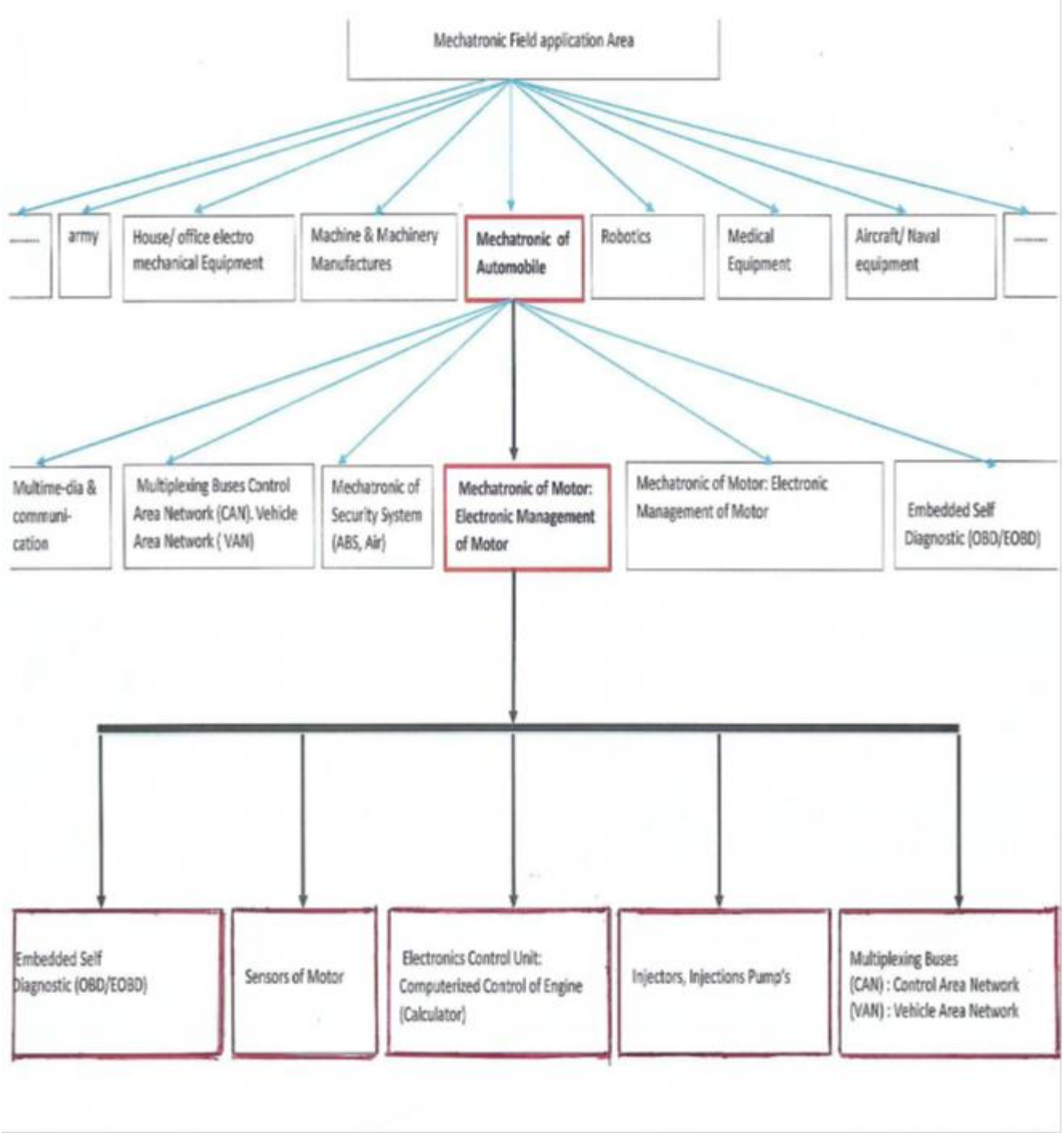

Fig. 5. Mechatronics Fields Application Area.

2. 2 Fields Area Application

Mechatronics intervenes with all those three sectors such as primary, secondary and tertiary. Since Mechatronics is inspired from multidisciplinary technology fields, their applications areas are numerous and involve those that concern mixed system and particular electromechanical system such as naval equipment, aircraft equipment, army equipment, medical equipment, measurement and test tools, industrial and manufacture, robotics, office and house equipment, machine and machinery desig , at last but not the least automobile which motor's injection system is developed in this work. Now days, the types of devices and applications areas that can incorporate Mechatronics technology is still growing such as application of Mechatronics of motor. The traditional mechanics of automobile's motor boundaries become increasingly fuzzy and Mechatronics grows and evolves further injection system as shown in Fig5.

3. Mechatronics Applied to the Motor of Vehicle Through Injection System

This section focuses on electronic management of vehicle's motor performance analysis through automotive computer electronically control and can be evaluated by three targets' performance: **sensor**, **calculator** and **injector**. Motor electronic management is an electronic computerized unit control in real time of air/fuel mixture movement using sensors and actuators (injectors). This electronic control unit is being embedded with an information system and an integrated on board diagnostic system for the feedback control and all together through multiplexing communication such as bus **CAN** (Controller Area Network) or **VAN** (Vehicle Area Network).

3.1 Vehicle Motor Performance Analysis through Automotive Computer Electronic Control

The motor performance is measured from it power to move passenger and goods in real time .This measurement

system involves the chemical energy transfer to mechanical energy through the burning of an air/fuel mixture .Electronics, computer science, control engineering, information system are integrated in the measurement system and signals system to optimize both the needed quantity air/fuel mixture and it burning through injector by replacing the classical carburetor. The injection system becomes an electronic computerized unit control in real time of air/fuel mixture movement using sensors and injectors as shows in Fig 6.

• **Performance of measurement system and transfer of signal system through motor's sensors**

The measurement system of air/fuel mixture is composed of these three basic sections described as: **Transducer - Signal processor - Recorder**

-Transducer section is a sensing which measures and transfers the physical input air, fuel and air/fuel mixture information and related into an output voltage signal.

-Signal processor section performs filtering, amplifying, conditioning on the transducer output which can be ready to be used by the calculator .The combination functional of both transducer and signal processor are called **sensors system**.

In practice, air/fuel mixture needed is dependent of: the flow, pressure and temperature of air, water temperature in the circuit water, level and temperature of fuel air/fuel mixture startup and its quantity, ignition of air/fuel mixture, motor rotation speed frequency of valve opening and so on…

All of this input information are measured and transfer to an output voltage signal by different motor's sensors. Smart sensors, which perform signal preconditioning and integrated communication interface for monitoring both their own operation and report a malfunction are also called ''sensotronic'' [16]: they are high performance of sensors which means Mechatronics sensoring solution with integrated communication interfaces.

-Recorder section is a display that maintains the sensors data which are either shown on a vehicle board or reported malfunctions with failure.

The performance of measurement system of the sensor is to supply the correct amount of air/fuel mixed with correct amount of the air and fuel to the cylinders through the injectors as show in Fig 7.

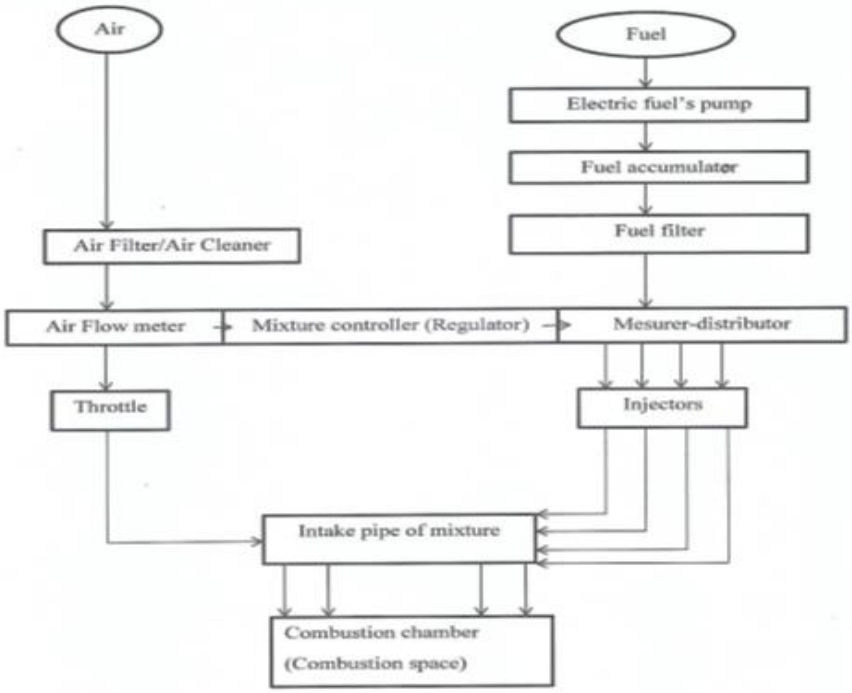

Fig. 6. General Frame Circuit in Injection System.

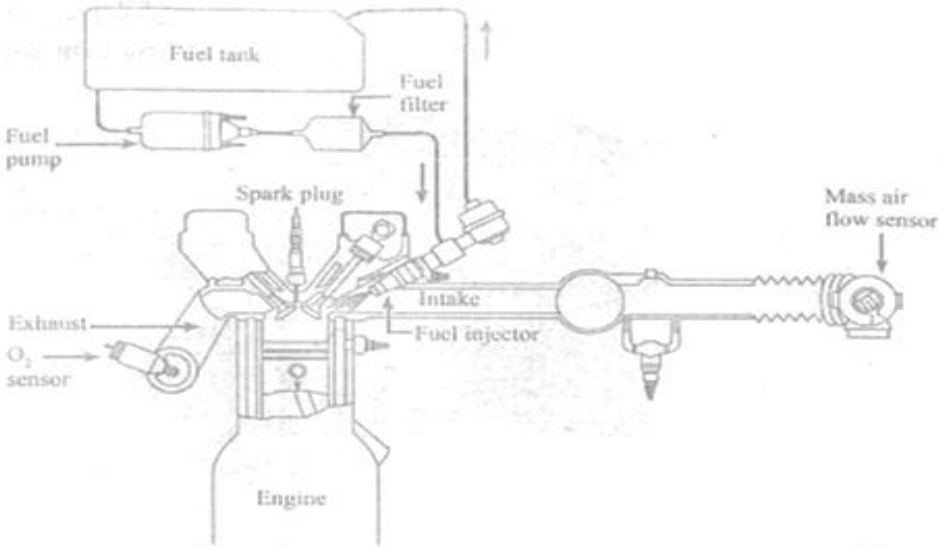

Fig. 7. Performance of Measurement in Air/Fuel mixture[7].

The important performance characteristic of motor's vehicle sensors are: **repeatability, accuracy, reliability on operating range, and linearity**.

- **Motor Injection System performance through the calculator**

Electronics management system of the motor is controlled by the calculator which integrates both ignition timing system and fuel injection system. The integration of the two systems involves the calculator's high performance which is described as follow: The simultaneous control of ignition and fuel injection manages better the motor than control of either one alone. The calculator controls the actual need of the engine from data stored in its memory and the feed electronics' sensors information. Adding calculator's performance are self diagnostic for troubleshooting, control of injector pressure and rate, control of injection quantity and timing. Since the measurement system of the sensor feed data to the calculator in the form of voltage signal, the calculator processes these voltage signal according to its internal program and then signals the injectors to act the desired control over the motor combustion that require a feed back control for the self diagnostic.

- **Motor Injection System performance through the Injector**

Injectors are devices that deliver the fuel in response to the electric signal feed by the calculator. It is the response to the output command issued by the microprocessor which lies in the calculator. The injector movement's feed air/fuel mixture by creating open or close movement due to the speed or acceleration of the motor.

Now days each vehicle has its own electronic computerized control unit system. Mechatronics of motor is designed to management air/fuel mixture continuously (or discontinuously) in real time and make adjustment. The computer unit analyzes data from the input sensors and based on the inputs and the instructions stored in its memory , the computer directs the outputs devices to make necessary changes for the injection system. Electronic control unit has also flexibility advantage to meet a variety of different vehicle engine combination of calibration. Critical quantity that determine an engine's performance easily can be changed by changing data is stored in the computer's memory. In this paper we recall the difference between the significant advantage of high performance of motor electronics controlled unit by injector system versus carburetor system as study case.

3.2 Study Case: Engine Carburetor Disadvantage versus Motronic Fuel Injection System

The three important principles of carburetor are atomization, vaporization and distribution which are respectively described as: breaking up the fuel into fine particles, changing it to a vapor and distributing the vapor to the cylinders. Practically the carburetor provides rich mixture and inaccurate. Air/fuel mixture is not feed in real time. To reduce a fuel consumption and avoid emission of harmful gas according to the regulation of the law, new injection methods through variable valve timing, stand-still shut-off of the engine are innovated for the real needs: fuel injection system arisen. In this paper our study case is a Motronic injection system which has many advantages and performance versus carburetor.

In this study case, Motronic provides in real time more exact fuel control. Motronic systems also call engine's electronic management which is the **ECU** (Electronic Control Unit), does not need many pails that carburetors have. The two basic functions of Motronic are ignition and injection systems. The important of the system is the sensing of engine speed at the crankshaft. An inductive sensor detects crankshaft angular velocity from its magnetic field which is induced by the ring gear. The signal is used to define the ignition advance angle. The ignition section includes the high level electric distributor which is directly related to the camshaft. The electronic control unit determines the ignition time as a function of engine speed and load. Motronic system is implemented on a large number of programs such as exhaust gas regulation, idle speed control, knock control and so on. The experiments are still performed under air/fuel mixture using electronic computer unit for injection system. However the conventional methods of injection system describe in literature don't found the best solution for both the limitation functional and the insufficient of injection system. In this paper we shall try to let out in next section the requirements and constraints of electronic system which have directly consequences on electronic management of motor. Hardware (Materials) and software functional problems are the keys of the subsystem.

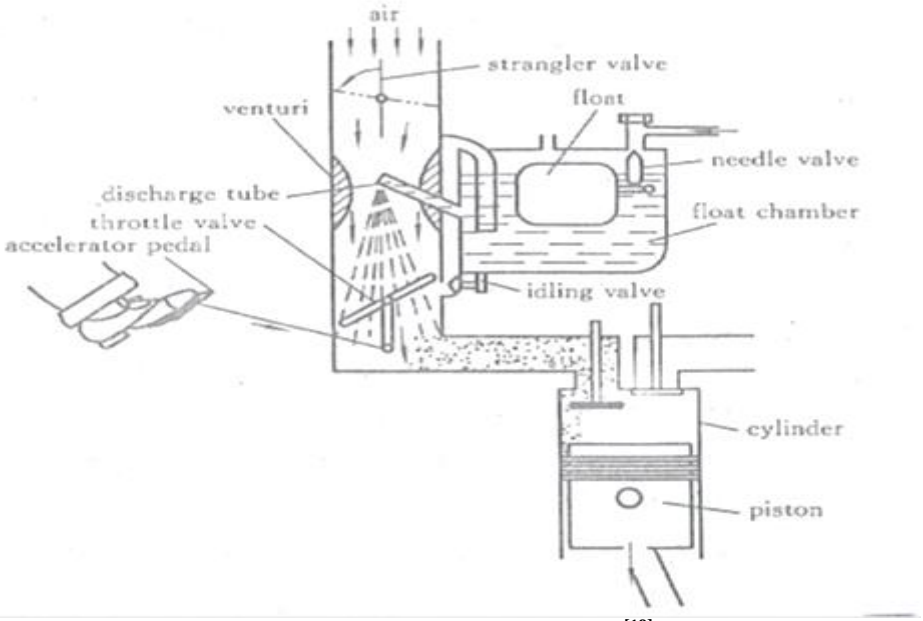

Fig. 8. Engine Carburetor System [18].

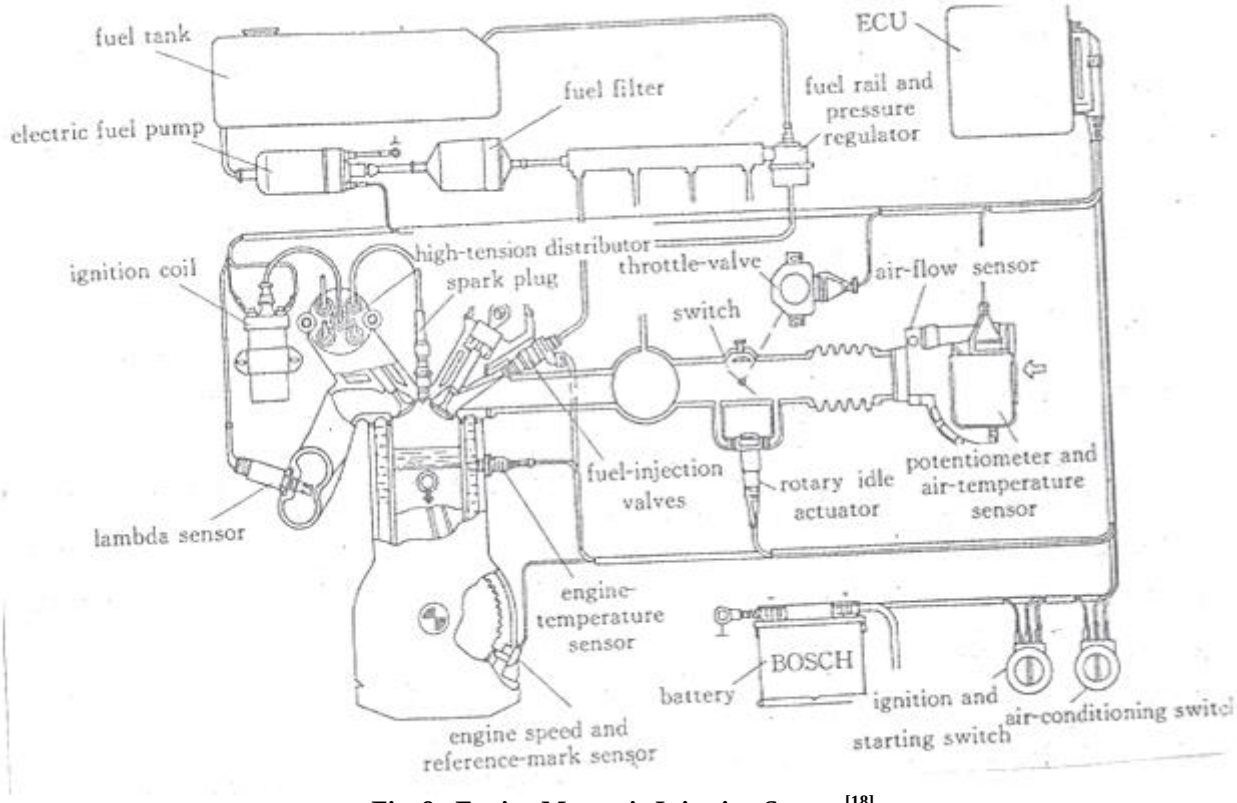

Fig. 9. Engine Motronic Injection System[18].

4. Limitation and Insufficient of Injection System Trough Electronics Constraint and Mechatronics Key Elements Failure

The revolution of Mechatronics in electronic engine management is still growing with great success but is not yet achieved because of certain requirements and constraints related even to the electronic technology with hardware and software problem

4.1 Requirements and Constraints

The requirements and constraints imposed for the proper functioning of the electronic system have a direct impact on the performance of the injection system which is subjected to numerous constraints such as:

-Default to the thermal resistance,

-Incompatibility between electrochemistry and electromagnetism because of the chemical substances quality of the fuel with a high effect of electromagnetic disturbance,

- Poor resistance to mechanical vibrations due to the state of the roads often degraded in the developing countries,

- Lack of tightness in the climatic,

-The high cost of designing, manufacturing and optimizing the injection system

-Lack of qualified technicians for the both preventive and curative maintenance of the injection system

-Lack of knowledge about the notion of Mechatronics in general and even Mechatronics applied to automotive,

-Problem of the competence in microelectronics sensors that evolve towards the nano electronics

-Hardware, Software and functional design problem of Electronic Unit Control (ECU)

On the other hand, the problems related to the limitation of the injection system are also related to the lack of performance of the sensors, calculators and actuators resulting from a discontinuity of information through the multiplexing data buses and a failure of the transmission systems where feedback control supposed to be an embedded diagnostic system. The injection system will become more complex as the electronics will cover the entire electronic engine injection system.

As an illustration, the fact that during the direct injection fuel is injected during compression then the air / fuel mixture is heterogeneous or the full control of the air / fuel ratio is not possible: consequence of the presence of toxic gas [8]

Hardware problem: the malfunction of the injection pump.

-Injectors often drive a bad fuel spraying, the return of unbalanced injectors and injectors at low pressure.

Injector's pump failures such as: Pump leak, clogged fuel filter, pressure drop of the pump, the injector pumps too much pressure.

The limitation and / or insufficiency of the injection system depend on five factors:

- Functional limitation of the sensors
- Functional limitation of the calculators
- Functional limitation of the injectors

-Communication deficiency during injection through the multiplexing system and data buses.

-The system of control and self-diagnosis are not effective

4.2 Other Problems: Fuel Problems

Fuel problems: unlike gasoline, diesel oil is adversely affected by cold temperature.

Water in the fuel is another problem that can cause starting and performance problem, (so if the filter or separator is iced up, the fuel tank needed to be drained to get rid of the water), fuel contamination by certain bacteria.

Fuel line and injection pomp contamination

Fuel delivery problem: injector timing has to be accurate, injection pump problem, air in fuel problem,

Injector problems: dirty injection will lean out the air /fuel mixtures, causing a loss of power, diesel injector operate at much higher pressures than gasoline operation.

To regulate the air/fuel mixture, the engine computer needed to know how much air was being sucked into the engine.

Pressure problem: if an engine is hard to start when hot, fuel may be boiling in the rail because the system isn't holding residual pressure when the ignition is shut off.

5. Conclusion

Mechatronics had been an electronic computerized unit control in real time of any phenomena's movement, using sensors and actuators. This electronic computerized unit control had been embedded with both information and self diagnostic systems. Fuel consumption was reduced and harmful gas emission was avoided by applying Mechatronics technology on automobile's motor. This paper presented Motronic which involved motor's electronic control unit performance and the insufficient of injection system. The performance of computerized engine control involved three subsystems performances. Firstly, input air/fuel mixture measurement information were transfer to output voltage signals information by the engine sensors. The sensors performed filtering, amplifying, conditioning, and let out voltage signal information which could be used by the electronic unit control. Secondly ,the electronic unit control processed and performed the sensor data according to the computer internal program and then signaled the injector subsystem .Thirdly , injectors acted the desiderate control movement to perform the subsystem by feeding to the combustion chamber the air/fuel mixture in real time that required adjustment since it was a closed loop subsystem. Motor's electronic control unit performance quantities were determined and could be changed easily by changing the data stored in the computer memory; wrong signal gave bad performance. We suggested that the limitation and insufficient of motor's injection system by using requirement and constraint analysis of electronic system on the sensors, calculators and injectors were the electro-chemistry constraints, hardware and software optimal functional requirements .Adding insufficient were the fuel quality problem which impacted the injector optimal functional.

An hybrid engine power system which combined two motion power source such as an internal carburant combustion engine included the computer injection system and an electric motor will take more advantage of the benefits provided by these two power sources while compensating for each other's than fuel injection system alone.

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