Development of a mock-up for engineering education in automotive electronics

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ABSTRACT

In the educational area of automotive engineering, specifically in the study of internal combustion engine it is necessary to use instructional systems that are able to simulate, test and obtain specifics data of the operation. This occurs because the systems involved on the vehicles are so complex due to the fact that engine is a mix of thermodynamic, mechanical, electrical, electronic and chemical elements.

In order to solve a part of that problem, the automotive industry creates an “alive engine” called mock-up. This mock-up is an ordinary engine assembled in a mechanical base, equipped with all the necessary components for turning it on and, therewith, it is possible teach the workers how the engine performs.

But it still had a problem. This mock ‘up was able to show and explain only the mechanical, thermodynamic and chemical elements, because the electrical and electronic elements weren’t important to be showed for the whole workers.

Faculty Technology of Santo André (FATEC - SA), and some companies see the importance of knowing the automotive electronic. So we developed a mock-up with all the mechanical elements, in the same way automotive companies does, but we also added an intersecting of all sensors and actuators and, further, an intersecting with the electronic control unit (ECU) of the

engine. Therefore, it is possible to show the students how the engine works completely, from ordinary mechanical systems to complex electronic controls.

The goal of this paper is to develop a mock-up with the intersecting of the electronic element, to show how the mechanical assembly, the electrical and electronic connection, the sensors, actuators and ECU's intersecting and, mainly demonstrate how this system can help the student's knowledge. Besides that, it will be presented the signals obtained through the ECU's intersecting (CAN – Controller Area Network, oxygen sensor, MAP – Manifold Absolute Pressure etc) and others achieved results.

1. Introduction

The first steam engine was constructed by French Jesuit missionaries, Ferdinand Verbeist and Philippe Marie Grimaldi, in China about 1665. [5] Still in the seventeenth century another idea came up: was the use of gunpowder in order to try to produce a linear movement in a piston inside a cylinder. However these inventions weren't efficient enough that were only used to inspire others, as the two steam powered vehicles built by Nicholas Cugnot from 1765 to 1770 [8], or the replacement of the steam by heat air in order to improve the efficiency of the engine and later with the oil exploration the replacement of the gas fuel by liquid fuel. [3]

Researches about internal combustion engine increased, and the steams engines became obsolete. So in 1862 the French physicist Aphonse Beau de Rochas described the four theoretical cycles of an internal combustion engine which worked with fuel derived from oil that was: intake, compression, ignition (done through a spark) and exhaust. But this engine has only assembled in 1876 by a German engineer Nikolaus Otto and it was named Otto's Engine. [6]

Although Otto was the internal combustion engine inventor, he didn't inserted it in automobile. He left this task to Gottilieb Daimler and Carl Benz carry out independently for the first time in the same year and, then the new concept of automobile was created. This concept had already had some electrical components such as the spark plug used in Benz's cars. With these ideas from Daimler and Benz and also from new companies (Ford, Renault, GM and others), that were going into market to dispute with them, the evolution of the vehicles was being constant and, it occurred quickly changes in engine' s and car's mechanical, for example the carburetor's and transmission' s creation.

All of this new invention improves the security and convenience of the driver and the person inside the vehicle. With that Cadillac in 1911 implanted the starter on engines and the electrical lights in the car as standard items. The twenties, with the World War was also a good decade to automobiles industries with releases of electrical windshields, brake in the four wheels, four valves for each cylinder and front suspension, besides to create the series production. One decade after came the automatic transmission's invention, the appearance of car bodies and trunk and, the beginning of a history that remained for decades: the invention of the first Volkswagen's car.

Some automobiles industries, first European an after Japanese and American respectively, introduced a different conception of engine control on cars. They separated the ignition and injection control module starting an inclusion of electronic elements to do the control of each one. First, around 1966 they use an electro-mechanical injection to improve the gas dynamics that enter in cylinders composed of air/fuel mixture. But this solution wasn't sufficient. So, it was invented the electronic carburetor which had a simple electronic control system of fuel dosage that after was replaced by the throttle body injection (TBI) in the seventies. [1]

Nevertheless, only TBI wasn't enough to achieve the necessaries results. Therefore with the microprocessor's and microcontroller's creation around 1980, the single point electronic fuel injection (just one injector) came to solve many problems, such as emissions control and fuel economy. Obviously with the support of a lot of sensor and actuators like the injector nozzle, stepper motor to control the engine when it was in idling and MAF (Mass Air Flow), oxygen and others sensors. [2]

With the electronic fuel injection (EFI) carburetors were becoming more obsolete and in the nineties they were almost extinct and the EFI evolved, breaking the paradigm that mechanicals components were absolutes and the electronics components were insecure. It created a new away of control the engine and automobiles accessories using just an electronic control module (ECU) that read and processed the sensor's signal and generated pulses to command some actuators.

Current vehicles are expelling less gas than before, consequently they are also becoming more economical. When the automobiles industry saw these results, they started to invest more and more in technology, so cars were becoming more comfortable, safety and practical. However, on other hand with new communication's architectures (CAN, LIN, Flex ray), replacement of the single point injection by the multi point injection (works with one injector for each cylinder) and new inventions like cruise control, airbag, anti-lock breaking system and others, the vehicles were much more complex.

Automobile complexity made the industries changed develop and training strategies, creating new methods to do it. The first of these methods was the use of an alive engine that was assembled in a mechanical support (mock-up) and allowed developers test the engine more efficiently, besides helping on the worker’s training. The second is a method used today, the virtual mockup.

According to Schutzer [7] the use of virtual systems to develop and test new products is growing, aiming always the cost reduction. The built of physical prototypes demand time and financial resources, therewith companies are currently deciding by digital mockups to development’s initials steps of theirs products, that allow the identifications and analysis of possible project mistakes. Companies like Volkswagen and BMW, both from Germany, stated in the nineties to develop prototypes based in digital mockups. However, many companies still use to final product’s tests and development physical environment. [4]

Although the purpose of this paper is to show that physical mock-up’s systems can be losing space in the automotive industries, the educational area it is still very important that student’s learn about it, mainly in automotive electronic, where the student needs to have contact with the sensor’s and ECU’s signals. In this case is indispensable the intersecting of the ECU’s pin outs to allow the access to the signals generated by sensors and by ECU as well to control the actuators. As a result, we had to build a physical mockup to analys the benefits and show in this paper the achieved results of this experience. We also want explain all electrical mechanical and electronic component’s installations and constructions.

2. Mechanical, Electrical and Electronic Installations

In this paper the engine used and described is a flexible 1.8 engine General Motors from Brazil. The figure 1 shows a similar GM engine 1.8 that was used in the development of the project.

After the engine’s choice, the next step was to fix it on a mechanical base. In the automotive area was observed that similar assembled are made by automotive companies, aiming the worker’s training. Additionally the Lençois Paulista’s SENAI have a great knowledge of this systems construction. In both the main objective is the learning of mechanical, chemical and thermo dynamical of the engine, consequently don’t include the ECU’s intersecting.

The mechanical engine's fixation was done at Polytechnic School University of São Paulo and the base was developed in a steel structure using aid components like rubber cushions and an empty gearbox to minimize the support's vibration and avoid futures fatigue's problems.

Figure 1: GM engine used to development of the mockup.

The fuel tank was constructed in a little version with inox steel where was linked an electrical fuel pump. Others components installed were: radiator, dashboard, ignition key, gas pedal, alternator, battery, water reservoir, cold start system, an ECU manufacturing by Delphi Automotive and aluminum box where all the fuses and relays of the engine stay.

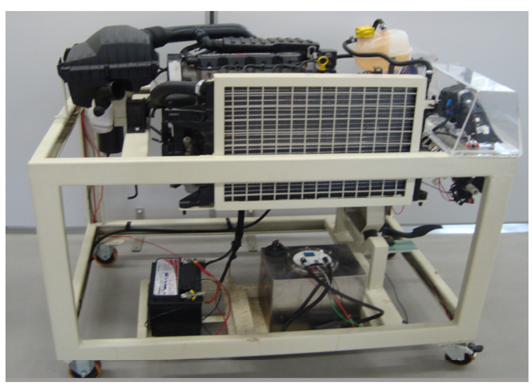

Figure 2: Developed Mock-up

With all the accessories, components and engine installed (Figure 2), two parts are necessary: the electrical connections and the ECU's intersecting. The electrical connection was done with reference in the own electric schematic of the car and the intersecting was developed of two forms: the first in an acrylic box with terminals and switches, but with this way the system was injured by bad contact. So the second form solved that problem, because was developed in a printed circuit board.

2.1 ECU’s Intersecting

The ECU’s intersecting aims to facilitate signal’s observation, generating by the sensors and by the ECU to command some actuators.

The first intersecting was developed in an acrylic box (Figure 2.a) with some terminals and switches. The sensor’s wires were welded in a connector that was the same one used on the engine’s whip and came until a “false” ECU where was connected. This “false” ECU made the intersecting idea functional, because from this ECU it was possible connecting the sensor with the acrylic box, however with the engine’s vibration some signals were unstable.

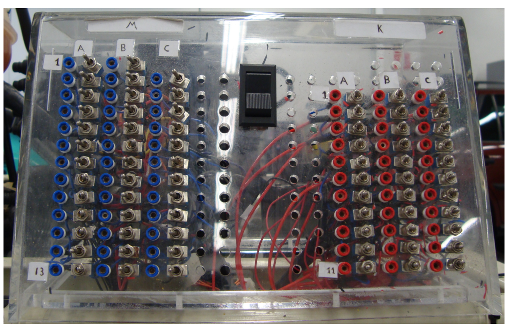	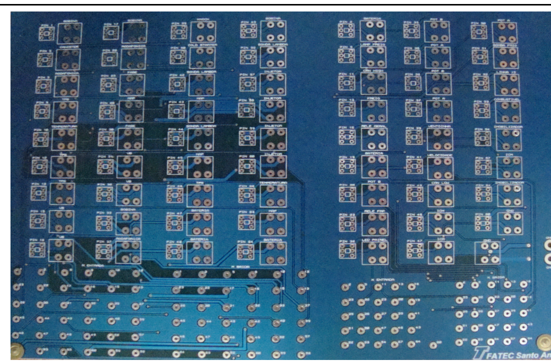
A	**B**

Figure 3: First intersecting whit box acrylic (A), Printed Circuit Board of the second intersecting (B).

So the idea of transforming the acrylic box in a printed circuit board seemingly solved this problem. The main idea of this board was to finish with all bad contact that appeared when the wire was welded directly on the terminals and switches. For this, was developed two boards: one with the same connectors of the “false” ECU replacing it and changing the method of fixation from simple connectors for a welded connection and, the other one (Figure 2.b) with two terminal(one for read signals and one to inject signal) and one bottom (to turn off the original ECU’s signal) for each ECU’s pin.

The intersection through terminals and bottoms or switches allows student’s developed projects replace a piece of ECU’s architecture (software) to parallels architectures that have the same functionality, beyond the measurement of signals become more accessible.

3. Results and Discussions

Before the mock-up's construction, few classes were done by practicing, because the only work instrument of the teacher was the vehicle and, to prepare an experience in it, it spend a longer time. With mock-up became easier to go to a training laboratory and have a better understanding of the mechanicals parts and mainly electronics comportment of the engine.

The skill of understanding electronics comportment comes from the simple access to the ECU's, sensors and actuator signals that associated with a scope allows the students see any signal generated to engine's control. An example of it is the synchronisms signals, as shown in figure 4 where are the signals of phonic wheel (blue) and phase sensor (yellow) synchronizing the injector nozzle's pulse to make its actuation at the right moment.

Other advantage of the mock-up is the opportunity that students have to test it new projects done in the lasts semesters. With intersecting it is possible to turn off some or all ECU's and sensor's signals and capture, read and process them, generating pulses to the actuators with only a microcontroller and some external drivers.

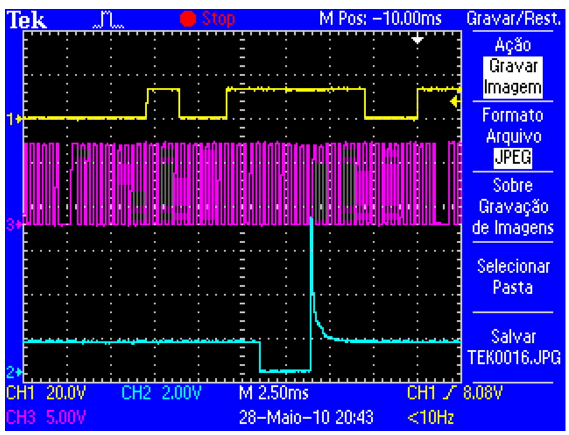

Figure 4: Synchronisms signals caught on the scope.

4. Conclusions

The development of this mock-up proved to be extremely appropriate to studies and researches on the engine electronic management area, allowing a better understanding of internal combustion engines operation associated with electronics signals which are generated by sensors to ECU that send pulses to the actuators.

This project allows that the student test architectures and applied software developed by him, both for search in technical subjects.

5. Acknowledgments

FATEC Santo André for contributing in technical discussions.

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