LABORATORY ASSEMBLY FOR ANALYSIS OF FUEL INJECTION SYSTEMS IN THE MODERN INTERNAL COMBUSTION ENGINES

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ABSTRACT

The complexity of the processes taking place in a system of fuel injection management for an internal combustion engine requires extra effort for a proper understanding of the operating principles. This paper is intended to be an intuitive practical application able to simulate the complex electronic control of injection, through a PC and specialized software. The application provides an intuitive and friendly analysis of the processes occurring during the operation of an injection computer. Moreover, the system allows the determination of the gasoline amount injected by the various types of fuel injectors, in a certain period of time and at different pressures of the fuel, depending on the load, speed and thermal regime of the engine. The laboratory assembly for a fuel injection system is intended as an experimental stand with exclusive didactical applicability. We want to observe the main characteristics of a fuel feeding and injection system, as the identification of components for the control system, data acquisition system and fuel injection system, the analysis of the different types of signals that can be used to actuate the injectors, the establishing the principles of injector operation in accordance with the control electronics, the visualization of the injection cadence and amount injected, depending on the engine speed and load, the programming of injection computers etc.

Keywords: fuel injection, modern internal combustion engines, laboratory assembly

1. INTRODUCTION

Modern fuel injection systems are designed specifically for the type of fuel being used. Some systems are designed for multiple grades of fuel (using sensors to adapt the tuning for the fuel currently used). Most fuel injection systems are for gasoline or diesel applications.
The functional objectives for fuel injection systems can vary. All share the central task of supplying fuel to the combustion process, but it is a design decision how a particular system is optimized. There are several competing objectives such as: power output, fuel efficiency, emissions performance, ability to accommodate alternative fuels, etc. The fuel injection in modern internal combustion engines is currently carried out exclusively under electronic control. In most cases, the control unit is represented by the “injection computer”. This unit acts on the execution elements (injectors, spark plugs, motors, valves, regulators etc.) using signals which are influenced by the reaction parameters coming from the position sensors, speed, pressure, temperature, etc. The modern digital electronic fuel injection system is more capable at optimizing these competing objectives consistently than earlier fuel delivery system. We want to observe the main characteristics of a fuel feeding and injection system, as follows:

- ✓ identification of components for the fuel injection system;
- ✓ establishing the principles of injector operations in accordance with the control electronics;
- ✓ visualization of the injection cadence and amount injected, depending on engine speed and load;

The application provides an intuitive and friendly analysis of the processes occurring during the operation of an injection computer. The assembly is designed so as, via a PC running an application in the LabVIEW programming environment. In order to obtain variable pressures on the supply line and on the common rail, the fuel pump was connected to a circuit which, by reducing or amplifying voltage, decreases or increases the pressure.

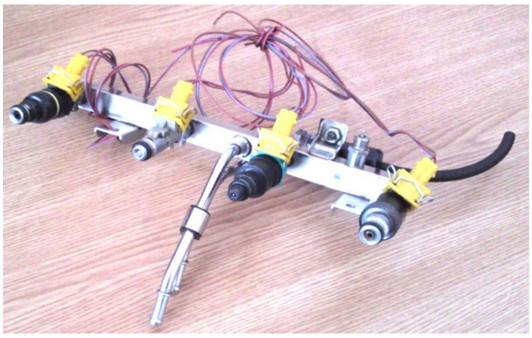
2. MATERIALS and METHODS

The assembly described below is intended as an experimental stand with exclusive didactical applicability, and is consisting of two distinct parts:

- ✓ the software (represented by the Labview application, which controls the injector opening), and
- ✓ the hardware (represented by the fuel circuit and injector rail).

Figure 1 presents an overview of the application hardware. For easier identification of the experimental stand components, we chose a solution that enabled us to easily observe and even disconnect all the components. Based on the geometrical shape of a fuel rail fitted on the Opel Astra G engine, made in 2007, we designed a container in which the injectors supply gasoline, container that enables us to watch the quality of the pulverized fuel flow shape. Moreover, the device contains four tubes for the quantitative determination of fuel consumption, at different regimes of engine operation and various rail pressures.

Figure 1 Overview of the application hardware


a.


b.


c.

Figure 2 The rail with the different type of fuel injectors, a– overview, b – mounted on the stand, c – details of injectors nozzle

To see the shape of the injector nozzle heads, we designed a system that enables the rail to rotate around its horizontal axis (Figure 2). The injectors are placed on the rail, where the fuel is brought from the tank, previously passed through a pressure regulator which is intended to maintain the rail pressure within a certain range. The fuel tank houses the electric fuel pump, the level sensor with mobile buoyant, element that converts the level into a set of electrical parameters in the form of an adjustable resistor with cursor.
When the fuel injectors are electrically activated, a hydraulic valve (consisting of a nozzle and plunger) is mechanically or hydraulically opened and fuel is sprayed into the cylinders at the desired pressure. Since the fuel pressure energy is stored remotely and the injectors are electrically actuated, the injection pressure at the start and end of injection is very near the pressure in the accumulator (rail), thus producing a square injection rate. If the accumulator, pump and plumbing are sized properly, the injection pressure and rate will be the same for each of the multiple injection events.

Figure 3 The accelerator pedals and the front panel of the application with LabVIEW interface

The entire assembly is interconnected. The command originating from the accelerator pedal was realised through a USB port, providing a signal to a wide range of values, in progression, that increase according to the pedal pushing force (Figure 3). The accelerator pedal will be the frequency control element for controlling the injectors. In contrast with the other parameters of the signals, the signal provided by the pedal is controlled by a physical element, not a virtual one.
We developed four electronic circuits, one for each injector. The voltage of the rectangular continuous signal supplied by the electronic device is 0V, or 5V in case of peak voltage. These rectangular signals (90 degree offset) serve the need to open or close the injectors instantly. The parameters to be set to determine for how long the injectors will be opened or closed, will be determined by changing the duty cycle of the signal that will determine the modification of the opening or closing frequency. To simulate the signals, we used the function "Simulate Signal" found in the LabVIEW library. If the direct control is required, or during the process, the signal simulation parameters can be modified in real time by means of control elements placed on the front panel of the application.

3. EXPERIMENTAL MEASUREMENTS

The behaviour of the injection pump to the supply voltage variations can be established by determining the correlation between the voltage variations and the pressure values of the fuel supplied by the pump. As mentioned, changing the supply voltage of the injection pump leads to pressure change in the injector rail.

The graph presented in Figure 4 shows the variation of the pressure supplied by the pump versus the supply voltage of the pump.

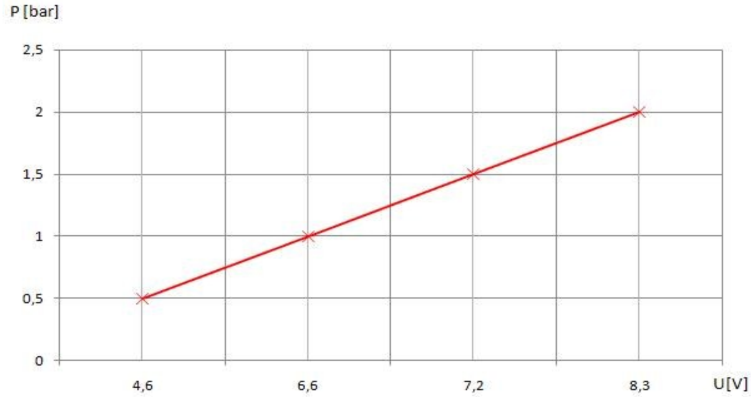


Figure 4 Variation of the fuel pressure versus the supply voltage of the pump

We decided to carry out measurements at a constant 2 bar pressure, at various simulated speeds. The cutting interval was 5 min.

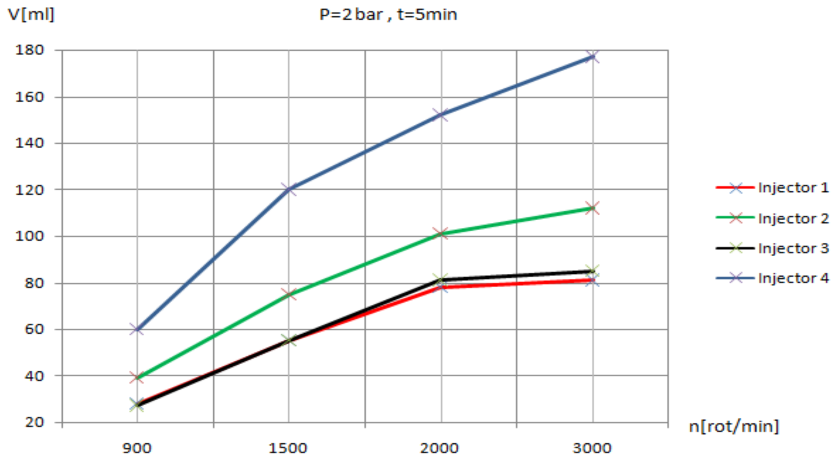


Figure 5 The injected fuel amount versus the injector speed and type

We have measured the amount of fuel injected by each injector, for various speeds, at the same pressure supplied by the pump (Figure 5).
The researches use data collected from the didactical use at the Thermal Machines and Road Vehicles Laboratory of the Faculty of Engineering Hunedoara, in the University Politehnica Timisoara, as well as laboratory experiments carried out on a unique, complex and original assembly.

4. CONCLUSIONS

By making the application presented in this paper, we targeted the following aspects with didactic character:
- ✓ familiarization with the phenomena related to fuel injection into internal combustion engines;
- ✓ showing how the simulation of continuous pulsed signals realises the injector control;
- ✓ being available identical signals to control the various types of fuel injectors, we revealed the structural differences among them in terms of quality and quantity;
- ✓ possibility to observe, in real–time, the form of the injector control signals in the assigned window, placed on the front panel of the application;

- ✓ possibility of measuring the flow rate supplied by each injector, by using a set of graduated tubes, in which the injectors are flowing the fuel;
- ✓ the observation of the fuel flow quality (geometric shape, number of spray holes, etc.) is facilitated by moving the injector rail in the top of the metal frame, where the glass bowl is placed, which is provided with return to the tank;
- ✓ a LED strip facilitates watching the moments when the injectors are flowing the fuel, the injector operation cadence in terms of speed, and the ignition order;
- ✓ by using the LabVIEW development utility tool, we demonstrated how to realise complex simulation software without the need for "command line" programming knowledge, but only using diagrams with mathematical function blocks;
- ✓ in contrast to the similar stands on the market, it also offers a budget solution, the costs being substantially reduced if choosing this option instead of other brand products.

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