Modeling and Programming for a Computer Controlled Direct Gasoline Fuel Injection System of SI Engine

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Abstract-- **A computer controlled direct gasoline fuel injection (DGI) system has been modeled, programmed and constructed for a four-stroke SI engine. Locally available materials have been used for this experimental model. All the old model vehicle were equipped with carburetor for air fuel mixing and later on electronic fuel injection system has been introduced for maintaining better air fuel ratio and mixing in many late model vehicles. Later on Japan introduced direct gasoline fuel injection system in their SI engine but it is not yet commercialized in many under developed countries. Direct gasoline fuel injection (DGI) system has the advantage of fulfilling proper air fuel ratio in various operating conditions and loads providing minimum air pollution. In four stroke engine, fuel needs to be supplied once in every two revolution. A logic control and program is necessary to control and supply fuel supply once in the cylinder at every two revolution. A program has been made to control the system. Fuel injection period was maintained by opto-isolator sensor in this model. But fuel injection period need to be varied depending on operating condition and loads. Further research is necessary to develop this model and program depending upon engine loads. The designed DGI system is found to work properly with the designed constant speed of 3000 rpm. The development of this model with variable speed and load is necessary for improvement of vehicle performances and emission control.**

1. INTRODUCTION

Nearly thirty percent of the population in USA is involved with automotive business. Internal combustion engines are widely used in the field of transportation, irrigation, power generation etc. Cylinder is the heart of energy generation of IC engine where energy is generated from combustion of air-fuel mixture. The fuel system mixes gasoline or similar fuel with air to make a mixture which is burned in the engine cylinder. Early model automobiles used carburetor for supplying the air- fuel mixture. The construction of the carburetor is relatively simple and it has been used almost exclusively on gasoline engines in the past. However, the recent demands for cleaner exhaust emissions, more economical fuel consumption and improved drivability etc, the carburetor now must be equipped with various compensating devices, making it a more complex system. In place of carburetor, therefore, EFI system was used, assuring the proper air-fuel ratio by injecting fuel in the intake manifold depending upon various driving conditions. EFI (Electronic Fuel Injection) system was comparatively successful to maintain correct ratio fuel air mixture to the cylinders in various speed and loads. In EFI system air- fuel mixing is done in the intake manifold or intake port outside cylinder. An electronic control unit or computer controls one or more injectors. When the engine needs fuel, a signal from ECU opens the injector. After getting signal from ECU, the fuel is injected in the intake manifold of the engine. But it got some disadvantages and inaccuracy in providing measured fuel quantity in each cylinder which can be meet up by direct gasoline fuel injection system.

In a direct gasolinefuel injection engine, the injectors are mounted in the cylinder head and they spray fuel directly into the combustion chamber. Compared with port fuel injection, GDI is more difficult and expensive. But the payback for the added complexity is higher torque, dramatically reduced emissions and increased engine efficiency. This is because fuel can be injected in the measured and exact quantity with injection time and location that its needed. The high injection pressure and air temperature help to atomize and vaporize the fuel in the combustion chamber. But more importantly the chamber shape, injector location and injection timing and duration, all work together to create what is called a stratified charge. The air -fuel mixture is richer close to the spark plug and leaner out towards the edges of the chamber. Engines generate their worst emissions just after cold start. During worm-up of a DGI engine, a small shot of fuel is injected just before the exhaust valve opens. There's still enough heat and oxygen in the chamber for this charge to ignite and the heat from that after burn gets the catalyst up to operating temperature just seconds after cold start. The injectors are either open or closed, not pulsed as in a port injection system. Since the fuel flows directly into the combustion chamber instead of impinging on the intake valve, the nozzle can be designed to form a 'cloud' of fuel with a specific size and shape.

Sawada et. al. [1] investigated and confirmed the possibility of using stratified scavenging and lean combustion as alternative technologies for reducing THC and CO emissions, in a two-stroke cycle engine. Two different types of engines were used. One is a prototype two-stroke cycle engine with leaner combustion technology and air-head stratified scavenging, the other one is current two-stroke cycle engine with Schnurle scavenging. THC was measured on a wet basis while CO and CO2 were measured on dry basis. The prototype engine with Air-head stratified scavenging and leaner combustion reduced specific THC output to 1/5 compared to current Schnurle scavenging engine. This suggests that the engine can conform to CARB 1999 or Tier 2 emission standards regarding THC, CO and NO_x emission without sacrificing mechanical simplicity and light weight.

Nuti, et al. [2] extended the research experiment on the 'phylogeny' of the Hi-Tech 2T SI engine in Piaggio started on the early 70s. Several solutions to this problem have been introduced for the past twenty years. An analysis has been conducted to determine the extent of research activities in this area,. Through this analysis, the ultimate possibilities of the 2T SI engine have been clarified.

Fansler et al. [3] performed individual-cycle exhaust-hydrocarbon measurements on a direct-injection two-stroke-cycle engine. Time-resolved hydrocarbon (HC) concentration data were obtained using a fast flame-ionization detector. The resulting data were converted to individual-cycle exhaust mass flow. Two types of air-assist fuel injectors were evaluated using simultaneously acquired individual-cycle heat-release data, exhaust-HC mass data, and in-cylinder spray/combustion visualization. Results of this study were used in conjunction with previous imaging and heat-release studies to clarify the principal mechanisms leading to unburned HCs from this two-stroke engine

Johnson et al. [4] applied an electronic direct fuel injection (EDFI) system to a 1100cc two-stroke PWC engine. This effort proved to be very successful. In particular, it demonstrated the ability to meet the EPA regulated spark ignited marine engine HC + NOx emission standard for the model year 2006. The system showed a 76.3% reduction in weighted mass hydrocarbon emissions.

Zhao F. et al. [5] designed to inject gasoline directly in to the combustion chamber of four stroke, spark ignition engines which is an important worldwide initiative of the automotive industry. The thermodynamic potential of such engines for significantly enhanced fuel economy, transient response and cold start hydrocarbon emission levels has led to a large number of research and development projects that have the goal of understanding, developing and optimizing gasoline direct injection (GDI) combustion systems. The process of fuel injection, spray atomization and vaporization, charge cooling, mixture preparation and the control of in-cylinder air motion are all being actively researched. The new technologies such as high-pressure, common-rail, gasoline injection systems, and swirl-atomizing gasoline fuel injectors, along with computer control capabilities, have enabled the current new examination of the direct injection, stratified-charge (DISC) gasoline engine.

2. DESIGN AND OPERATION PRINCIPLES OF DIRECT GASOLINE FUEL INJECTION (DGI) SYSTEM

The design and fundamental operation principles of direct gasoline fuel injection system is done by thee vital units i.e. sensing units, controlling unit and actuating units. The sensing units provide signals to microprocessor or computers. Microprocessor or computer which processes the input signal and provide signal to actuators. Actuators receive senses from processor or computer and provide output signals to actuators or fuel injector in the cylinder.

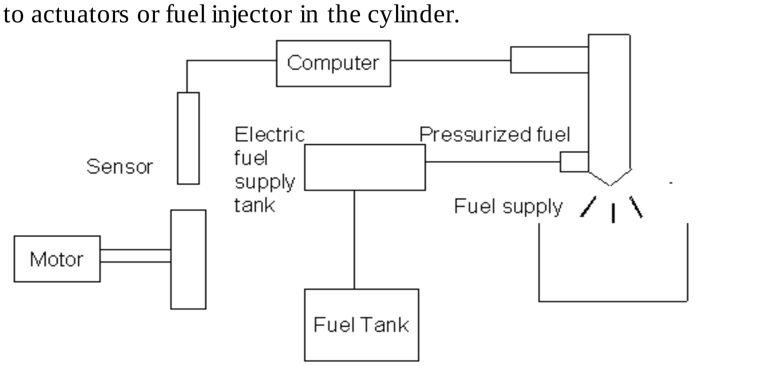

Fig. 1. Schematic Diagram of Direct Gasoline Fuel Injection System for a Four Stroke SI Engine

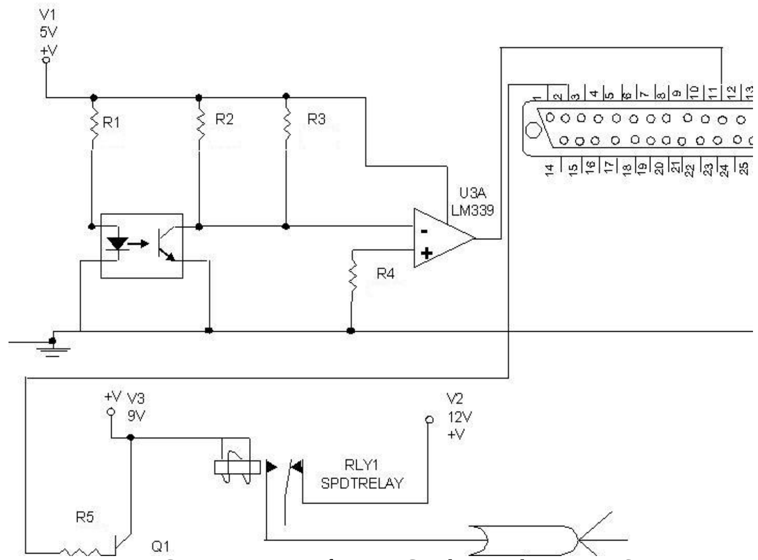

Fig. 2. Circuit Diagram of Direct Gasoline Fuel Injection System

The fuel injector is an electro-mechanical device which meters, atomizes and directly supplies fuel into the cylinder based on signals from the controller. All engines used one injector per cylinder. The injectors are installed with an insulator/seal on the cylinder wall to isolate the injector from heat and to prevent pressure leakage of the cylinder. The fuel delivery pipe serves to secure delivery of fuel to the injector. In a direct fuel injection engine, the fuel must be injected in a short period of time and at pressures at least 40 times higher than in port fuel injection.

The electric fuel pump supplies the fuel to the injectors under pressure. As soon as the injector receive signals from the computer, its needle valve is opened by electrically operated solenoid valve and fuel injection start with desired spray pattern. An electric solenoid valve in the injector opens and closes the valve. The solenoid valve is magnetized to lift valve against spring force when a voltage is applied. Fuel sprays out as long as the valve raised. When the computer cut off signals the solenoid valve coil is demagnetized spring pushes the valve back down onto its seat. This stops the fuel spray. Each opening and closing of the injector valve is an injector impulse.

2.1SENSORS AND ITS OPERATION PRINCIPLE

In this research work, an opto-isolator has been used as a sensor.

Opto-isolator:

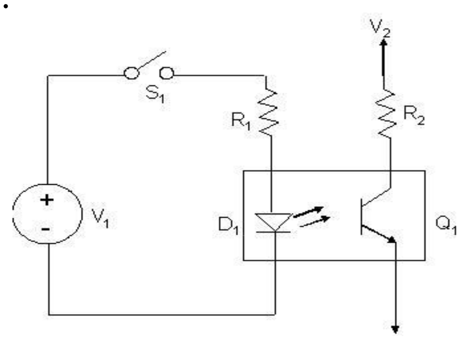

Fig. 3. Circuit Diagram of an Opto-isolator

An opto-isolator (or optical isolator, optocoupler or photocoupler) is a device that uses a short optical transmission path to transfer a signal between elements of a circuit, typically a transmitter and a receiver, while keeping them electrically isolated.

A common implementation involves an LED and a light sensor, separated so that light may travel across a barrier but electrical current may not. When an electrical signal is applied to the input of the opto-isolator, its LED lights, its light sensor then activates, and a corresponding electrical signal is generated at the output. Unlike a transformer, the opto-isolator allows for DC coupling and generally provides significant protection from serious over voltage conditions in one circuit affecting the other. With a photodiode as a detector, the output current is proportional to the amount of incident light supplied by the emitter. The diode can be used in a photovoltaic mode or a photoconductive mode. In photovoltaic mode, the diode acts like a current source in parallel with a forward-biased diode. The output current and voltage are dependent on the load impedance and light intensity. In photoconductive mode, the diode is connected to a supply voltage and the magnitude of the current conducted is directly proportional to the intensity of light. An opto-isolator can also be constructed using a small incandescent lamp in place of the LED; such a device, because the lamp has a much slower response time than an LED., will filter out noise or half- wave power in the input signal. In so doing, it will also filter out any audio or higher frequency signals in the input. It has the further disadvantage, of course, that incandescent lamps have finite life spans. Thus such an unconventional device is of extremely limited usefulness, suitable only for applications such as science projects. The optical path may be air or a dielectric waveguide. The transmitting and receiving elements of an optical isolator may be contained within a single compact module, for mounting, for example, on a circuit board; in this case, the module is often called an opto-isolator. Thr photo sensor may be a photocell, or an optically triggered SCR or Triac. Occasionally, this device will in turn operate a power relay or contractor. Several types of opto-couplers. The figure indicate above, detect the presence of an object in between them. They are interruptible. The middle one detects reflections from objects in front of it

2.2 CONTROLLER

Contrary to some "informed" opinions and numerous suggestions from movies, computers can not think for themselves; when properly programmed, however, they can carry out explicit instructions with blinding speed and almost flawless consistency.

2.2.1 COMPUTER PROGRAM AND FLOW CHART FOR CONTROLLING FUEL INJECTION SYSTEM

The Program for the controlling of direct gasoline fuel injection system has been developed and its flow chart is described herewith.

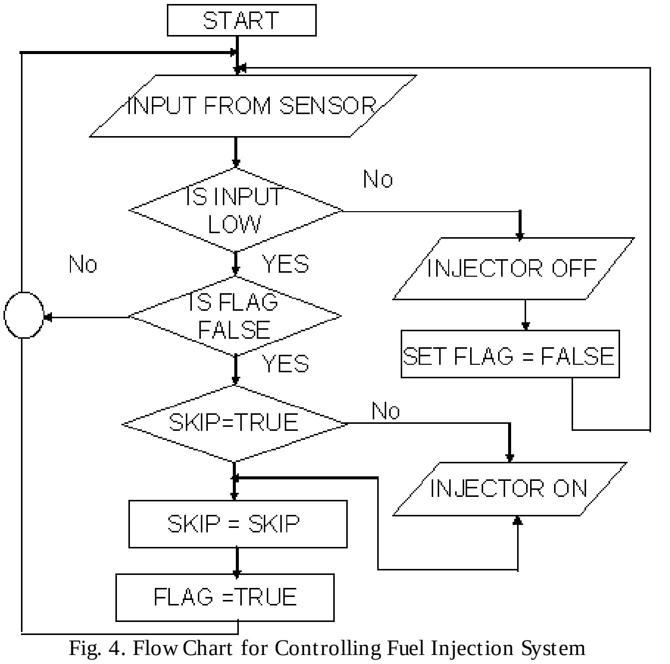

Fig. 4. Flow Chart for Controlling Fuel Injection System

2.2.2 COMMUNICATIONS SIGNALS

A computer uses voltage values as communication signals, thus voltage is often referred to as a signal or a voltage signal. There are two types of voltage signals: analog and digital. An analog signal's voltage is continuously variable within a given range and time is used for the voltage to change. An analog signal is generally used to convey information about a condition that changes gradually and continuously within an established range. Temperature-sensing devices usually give off an analog signal. Digital signals also vary but not continuously, and time is not needed for the change to occur. Turning a switch on and off creates a digital signal; voltage is either there or it is not. Digital signals are often referred to as square wave signal.

2.2.3 BINARY CODE

A Computer converts a series of digital signals to a binary number made of 1s or Os; voltage above a given value converts to one and zero voltage. Each 1 or 0 represents a bit of information.

2.2.4 INTERFACE

The microprocessor is the heart of a computer, but it needs several support functions, one of which is interface. A computer has an input and output interface circuit. The interface has two functions: it protects the delicate electronics of the microprocessor from the higher voltages of the circuits attached to the computer, and it translates input and output signals. The input interface translates all analog input data to binary code; most sensors produced an analog signal. It is sometimes referred to A/D, analog to digital. The output interface, D/A, translates digital signals to analog for any controlled functions that need an analog voltage.

Interfacing to the PC Parallel Printer Port

- 8 output pins accessed via the DATA Port.
- 5 input pins (one inverted) accessed via the STATUS Port
- 4 output pins (three inverted) accessed via the CONTROL Port.
- The remaining 8 pins are grounded.

Use of a PC Printer Port for Control and Data Acquisition

A PC Printer port is an inexpensive and yet powerful platform for implementing projects dealer with the control of real world peripherals. The printer port provides eight TTL outputs, five input and four bi-directional leads and it provides a very simple means to use the PC interrupt structure. This article discusses how to use program the printer port. A larger manual which deals with sue topics as driver circuits, optoisolators, control of DC and stepping motors, infrared and rad remote control, digital and analog multiplexing, D/A and A/D is available.

2.3. OUTPUTS AND ACTUATORS

All outputs on the Data port are true logic. That is, writing a logic one to a bit cause the corresponding output to go high. That is, outputting a logic one to a bit cause a logic zero on the corresponding output. This adds some complexity in using the printer port, but the fix is to simply invert those bits using the exclusive OR functions prior to outputting.

2.3.1 ELECTRIC FUEL PUMP

Fuel is delivered from the tank by an electric fuel pump. Fuel flows through the fuel filter to the fuel rail (fuel delivery pipe) and up to the pressure regulator where it is held under pressure. The pressure regulator maintains fuel pressure in the rail at a specified value above cylinder pressure. This maintains a constant pressure drop across the fuel role, which brings a number of important performance benefits compared to the compromise solution offered by carburetors.

3. EXPERIMENTAL PROCEDURE

After design, construction of the model of the experimental setup, the injection timing for a constant speed (3000) rpm has been calculated. The calculated injection time is 1.38 milliseconds or 25^0 rotation of the flywheel. And the amount of fuel injected per cycle is 0.27×10^{-3} milliliters. The cross sectional area of the injector nozzle is 0.00052 mm^2 for suction pressure 2 bar. The flywheel was rotated at a designed speed of 3000 rpm by a model engine or motor.

4. RESULTS & DISCUSSION

During the experiment with the model, the fuel is found to inject in cylinder and the program controlled the fuel injection at every alternative cycle. The performance of the test was found satisfactory.
Taking consideration of all parameters of SI engine, this model may be improved to use in DGI system engine.

5. CONCLUSIONS

The following conclusions are made from this research work.

(i) The present model has been designed with a constant speed (3000 rpm) and it is found to work properly.

(ii) Future development of this model and program with variable engine operating conditions i.e. variable speeds and loads may be useful in the real design fields of direct gasoline fuel injection system of a SI engine.

NOTATIONS

CARB	Emission standard (California air research bureau)
Tier	Emission standard
CO	Carbon monoxide
CO_2	Carbon dioxide
NO_x	Oxides of nitrogen
THC/HCs	Total hydro carbon/ hydro carbons

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