Electronically Controlled Diesel Engine
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Abstract: ECDE meets the demand on precise control of electronic control in diesel engine. The basic ship engine runs on crude oil. The quantity of fuel consumption depends on the quality of crude oil (diesel) i.e. hydraulic oil. The engine basically features dual overhead camshaft which causes delay in fuel consumption system. To overcome the drawback of diesel engine we replace the camshaft with microcontroller which controls the timing of the opening & closing valves & injecting fuel. The idea is the master slave concept of microcontroller. All the timing parameters are controlled by a master. ECDE ensures reduction in fuel consumption solves problem of load on fuel engine & controls timing of intake & exhaust. Specific fuel consumption & mechanical efficiency remain same for both mechanical & electronic injection system. Hence by using embedded controlled fuel injection system in single cylinder diesel engine, saving in fuel is ensured.

1. INTRODUCTION

The idea behind the electronically controlled diesel engine is the concept of the intelligent engine that analyzes the operation of the engine and controls different parameters of the engine (fuel injection, exhaust valve, cylinder lube oil and turbo charging system). It controls the timing which is required to make the diesel run at ease, the intelligent diesel does monitoring and evaluating the condition of the engine. It can actively protect the engine from damage due to the overload, lack of maintenance and maladjustment. It has an ability to manually control more variables than the current camshaft system. The intelligent engine has manual controls along with the operators which can specifically design programs that give efficient output such as fuel economy, emission, turbo output to improve system’s performance under different loads.

![Figure 1. Schematic of an internal combustion engine piston and cylinder arrangement.](image)

Diesel aims to produce mechanical energy from chemical energy stored in fuels. The engine uses a conventional arrangement of cylinders and pistons which is also found in other types of internal combustion engines, as gasoline engines. Conceptually, the diesel engine achieves high performance and excellent fuel consumption by compressing the air contained within the Cylinder at high pressure and injecting a small amount of fuel into highly compressed air.

The temperature generated during the compression of the air makes this small amount of pulverized fuel evaporates. Mixture of pulverized fuel with the existing hot air in the combustion chamber causes the vaporized fuel to reach its auto-ignition temperature and burn. Thus releasing the energy stored before. Along with the burning of fuel, energy in the form of heat is released increasing the pressure inside the cylinder. This energy released raises the pressure in the cylinder that is applied to the surface of the piston, causing it to return to the PMI (bottom dead center) as in Figure 1. This cycle is known as a boom cycle, power cycle or duty cycle because this cycle is that the expansion of gases produces work by applying pressure to the piston surface.
1.1Replacing the Camshaft

The convenience of the camshaft is that it not only keeps the timing of the opening and closing valves and injecting fuel through its cams but is also responsible for the mechanical force that is required to actually open and close the valves and power the port and helix fuel pump.

The camshaft less intelligent system uses the rotation of the engine to power an axial pistonpump that pressurizes a hydraulic oil system. Electronically controlled servo system directs the hydraulic pressure to derive In FI (Intelligent Fuel Injection) and In VA (Intelligent Valve Actuation) systems.

1.2 The ECDE is divided into these main groups of components

- Electronicsensors for registering operating conditions and changes. A wide array of physical inputs is converted into electrical signal outputs.
- Actuators, solenoids convert the control unit’s electrical output signal into mechanical control movement.
- ECM (Electronic Control Module) or Engine ECU (Electronic Control Unit) with microprocessors assimilates information from various sensors in unison with programmed software and gives required electrical signal into actuators and solenoids.

2. COMPONENTS

2.1 Sensors

- Injection pump speed sensor - monitors pump rotational speed
- Fuel rack position sensor - monitors pump fuel rack position
- Charge air pressure sensor - measures pressure side of the turbocharger
- Fuel pressure sensor
- Air cleaner vacuum pressure sensor
- Engine position sensor
- Temperature sensors - measure various operating temperatures
  - Intake temperature
  - Charge air temperature
  - Coolant temperature
  - Fuel temperature
  - Exhaust temperature (Pyrometer)
  - Ambient temperature
- Vehicle speed sensor - monitors vehicle speed
- Brake pedal sensor - operates with cruise control, exhaust brake, idle control
- Clutch pedal sensor - operates with cruise control, exhaust brake, idle control
- Accelerator pedal sensor
- Driver input switches - cruise control, idle increase/decrease, engine/exhaust brake
- Injector needle movement sensor - monitors the actual injection time and feeds the information to the ECU.

2.2 Electronic Control Unit

The ECU collects and processes signals from various on-board sensors. An ECU electronic module mainly contains microprocessors, memory units, analog to digital converters and output interface units. A number of different maps can be stored in the onboard memory depending upon the parameters. Depending on the application it allows the ECU to meet the specifications of engine and vehicular requirements. The operating software of the ECU can be adapted for various types of engines and vehicles without the necessity
of hardware Modification. Usually the position of the ECU is in the cab or in a suitable position in the engine bay where additional environmental conditions may require cooling of the ECU as well as a requirement for better dust, heat and vibrations insulation.

2.3 Actuators and Solenoids

Electro-magnetic actuators are mainly located on the fuel pump to transfer electrical signals into mechanical action in this case fuel rack actuator and or fuel stop solenoid depending on requests from control unit full fuel or no fuel quantity.

2.4 Electronic Fuel Injection System

The construction of fuel injection system of electronic type is shown in Fig 2. An embedded system is a computer system designed to perform one or a few dedicated functions with real-time computing constraints. It is a complete embedded device that includes hardware and mechanical parts. Embedded systems control many devices which are in common use today.

![Figure 2. Fuel System of Electronic Type](image)

The IC engine embedded system is known as Engine Management System. An engine management system is a type of electronic control unit that determines the amount of fuel, injection timing and other parameters that an internal combustion engine needs to keep running. It does this by reading values from multidimensional performance maps, using input values (e.g. Engine speed) calculated from signals coming from sensor devices monitoring the engine. Before ECU’s, air/fuel mixture, is directly controlled by mechanical and pneumatic sensors and actuators.
3. METHODOLOGY

Mechanical controlled engine is converted into electronic controlled engine. The injection quantity from the mechanical engine is calculated for different loads and speeds then it is stored in the memory of Electronically Controlled Unit in the form of lookup table.

In electronic fuel injection system, air flow sensor, crankshaft position sensor, speed sensor, exhaust gas temperature and load sensor are used to give input to the Electronic Control Unit. The ECU will calculate the load and speed calculations from inputs from the sensors. The fuel pulse width is calculated by ECU from lookup table using this load and speed. This fuel pulse width is given to the electronic fuel injector through driver circuit. Electronic fuel injector injects the fuel according to the operational requirement of the engine.

3.1 SENSOR DETAILS

Air valve sensor, crankshaft position sensor, load sensor, temperature sensor are used in this electronic fuel injection system. Due to weak signal strength and noises, some of the sensors require signal conditioning. Crankshaft position sensor, speed sensor use various signal conditioning boards. Sensors are fitted at different places of the engine. Load sensor is fitted at the dynamometer to get the engine load condition.

3.2 CRANK SHAFT POSITION SENSOR

The crankshaft position sensor sends the information of the position of piston to find the timing of the injection which is fitted at the extreme end of the crank shaft including magnets and soft iron core wound by coil and toothed wheel designed to rotate in linkage with the crankshaft. Toothed wheel has 58 teeth and 2 tooth gaps that are used for identifying the cylinder position. The revolution of toothed wheel makes the crank angle sensor to generate 58 signals from which the exact timing at which the start of the delivery of fuel is arrived.

3.3 SPEED SENSOR

The Speed sensor is placed at the coupling between the engine and the dynamometer which is used to find the engine speed. It generates 4 pulse signals per revolution of the output gear. Then ECM receives the pulse signal that will be used for idling speed adjustment. Speed sensor finds whether the engine is at idling or running. When current flows it receives 0.5V, when the sensor does not operate and it receives a 12V signal, to detect engine speed.

3.4 FUEL INJECTOR DETAILS

It is the injector’s job to inject into the combustion chamber exactly the correct amount of fuel at precisely the right time. For this, the injector is triggered by signals from the ECM. The injector has an electromagnetic servo-valve. It is a high-precision component which has been manufactured to extremely tight tolerances. The valve, the nozzle, and the electromagnet are located in the injector body. Fuel flows from the high-pressure connection though an input throttle into the valve control chamber. The pressure inside the injector is same as there is in the pump, and the fuel is injected through the nozzle into the combustion chamber. Excess fuel flows back to the tank through the return line. By controlling injectors, via ECU maximum RPM & fuel cut off on overrun is achieved.

The mechanical fuel injection system is replaced by electronic fuel injection. The advent of electronic control over the diesel injection pump has allowed many advances over the purely mechanical system. The production of high pressure and injection is still mechanical with all current systems. The advantages of the electronic injection system is improved performance, increased comfort, reduced smoke at acceleration, more precise control of fuel quantity injected, better control of the start of injection, idle speed control, drive by wire system and output to data acquisition systems etc.

3.5 MICROCONTROLLER

The configuration of microcontroller chosen for the experiment is at mega 328 micro controller;
• Two 8-bit Timer/Counters with Separate Prescaler and Compare Mode
  – One 16-bit Timer/Counter with Separate Prescaler, Compare Mode, and Capture Mode
  – Real Time Counter with Separate Oscillator
  – Six PWM Channels
  – 8-channel 10-bit ADC in TQFP and QFN/MLF package
  • Temperature Measurement
  – 6-channel 10-bit ADC in PDIP Package
  • Temperature Measurement
  • Programmable Serial USART
  – Master/Slave SPI Serial Interface
  – Byte-oriented 2-wire Serial Interface (Philips \textsuperscript{I}{2}C compatible)
  – Programmable Watchdog Timer with Separate On-chip Oscillator
  – On-chip Analog Comparator
  – Interrupt and Wake-up on Pin Change

• Special Microcontroller Features
  – Power-on Reset and Programmable Brown-out Detection
  – Internal Calibrated Oscillator
  – External and Internal Interrupt Sources
  – Six Sleep Modes: Idle, ADC Noise Reduction, Power-save, Power-down, Standby, and Extended Standby
  • I/O and Packages
  – 23 Programmable I/O Lines
  • Operating Voltage:
    – 1.8 - 5.5V

3.6 I2C PROTOCOL

A simple bi-directional 2-wire bus is used for efficient inter-IC control. This bus is called the Inter-IC or I2C-bus. At present, NXP's IC range includes more than 150 CMOS and bipolar I2C-bus of compatible types used for performing communication functions between intelligent control devices (e.g. microcontrollers). The I2C bus physically consists of 2 active wires and a ground connection. SDA stands for Serial Data Line and SCL stands for Serial Clock Line are two active wires.

Every device connected to the bus has its own unique address, no matter whether it is an MCU, LCD driver, memory, or ASIC. Each of these chips can act as a receiver and/or transmitter, depending on the functionality. An LCD driver is only a receiver, while a memory or I/O chip can be both transmitter and receiver.

![Figure 3. A sample schematic with one master (a microcontroller), three slave nodes (an ADC, a DAC, and a microcontroller), and pull-up resistors $R_p$.](image)

The I2C bus is a multi-master bus which means that more than one IC capable of initiating a data transfer can be connected to it. The I2C protocol specification states that the IC that initiates a data transfer on the bus is considered as the Bus Master. Consequently, at that time, all the other ICs are considered to be Bus Slaves.
3.7 BLOCK DIAGRAM

Figure 4. General Block diagram.
CONTROLLED OUTPUT

1. EXHAUST OPEN
2. EXHAUST CLOSE
3. INJECTOR OPEN
4. INJECTOR CLOSE
5. SPEED

Figure 5. Block diagram of output pin specification.

3.8 OPERATION

The injection of fuel or the quantity of fuel injected has an influence on engine starting, idling, power and emissions. The engine ECU is programmed (“mapped”) with relevant data to where the fuel rack position has an equivalent signal for the amount of fuel being injected. The driver requests the torque or engine speed requirements via accelerator pedal potentiometer by sending a signal to the engine ECU which then, depends on its mapping and data collected from various sensors, calculates in real time the quantity of injected fuel required, thus altering the fuel rack to the required position. The driver can also input additional commands such as idle speed increase to compensate e.g. for PTO operation which can be either variably set or has a preset speed which can be recalled. The road speed function can be used to evaluate vehicle speed and possibly activate a speed limiter (Heavy Vehicles), or maintain or restore a set speed (cruise control). Additional functions can include exhaust brake operation which, when activated, will result in the fuel pump rack position being set to zero delivery or idle. The engine ECU can also interface with various other vehicle systems e.g. traction control and carries out self monitoring duties and self diagnostic functions to keep the system working at an optimal level.

To ensure the safe operation in case of failure, the limp home mode functions are also integrated into the system, for e.g. If the pump speed sensor fail the ECU can use an alternator speed signal function for engine RPMscounters as a backup signal. At mega 328 controller are used for each cylinder control unite.

ADVANTAGES

- Several potential improvements for the main engines are provided by the intelligent, camshaft less, diesel engines.
Variable electronically-controlled timing of fuel injection and exhaust valves for lower specific fuel consumption and better performance parameters.

Lower RPM speed, including better astern and crash stop performance is offered by electronic controls.

The operator can more precisely control fuel consumption and improve emission characteristics with the smarter InFI system.

4. RESULT

The Diesel engine is the most efficient energy source in the areas of Transportation, Agriculture, and Power Generation. Mechanical fuel control is most widely used in all these areas of applications. However to ensure reduction in fuel consumption, embedded controlled fuel injection system for a five cylinder diesel engine is designed and tested. Fig 6 shows that the Total Fuel Consumption (kg/hr) in Electronic Fuel Injection System is significantly reduced due to accuracy in the delivery of diesel.

<table>
<thead>
<tr>
<th>Brake Power (KW)</th>
<th>Fuel consumption in Mechanical System (Kg/hr)</th>
<th>Fuel consumption in Electronic System (Kg/hr)</th>
<th>Reduction in Fuel Consumption (Kg/hr)</th>
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<td>0</td>
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Performance and fuel consumption tests are conducted for both mechanical and electronic controlled fuel injection systems. Load sensor, Air flow sensor, Speed sensor, Exhaust sensor and crankshaft position sensor are used to give the load, speed and piston position of the engine to the ECU in electronic controlled fuel injection system. Based upon these inputs, the ECU determines the fuel injection requirements and corresponding fuel pulse widths are generated. This in-turn regulates the fuel supply to the injector through driver circuit. The results show that an improvement in Total Fuel Consumption. Specific Fuel Consumption & Mechanical Efficiency remain same for both Mechanical & Electronic Injection System. Hence by using embedded controlled fuel injection system in a five cylinder diesel engine, saving in fuel is ensured.

5. CONCLUSION

We can enhance this project by adding some features like telemetry database management which would have complete details regarding utility of fuel a well as Data transparency between ship & the base station. ECDE ensures reduction in fuel consumption solves problem of load on fuel engine & controls timing of intake & exhaust. Specific fuel consumption & mechanical efficiency remain same for both mechanical & electronic injection system. Hence by using embedded controlled fuel injection system in single cylinder diesel engine, saving in fuel is ensured. This research can be very useful in shipping, transportation & can serve for the betterment of transportation system.
REFERENCES


