Note on Modern Trends in Heavy Vehicle Electrical/Electronic Systems

B. S. SASTRY

Combat Vehicles Research and Development Establishment, Avadi, Madras-600 054

Received 22 January 1981

Abstract. The paper presents an overview of some of the aerospace control systems that are being successfully adopted in the field of Armoured Fighting Vehicles. An automatic electronic transmission controller for an epicyclic gear box with a torque converter to select the forward and reverse speeds in a sequential logic has been developed. Transducers developed for monitoring various engine and transmission parameters are being used for Electronic Fuel Injection (EFI), variable valve timings and electronic governing.

1. Introduction

Spectacular aerospace developments and giant strides in the digital data processing field have brought in a new revolution in heavy vehicle control systems. Electronic systems which can monitor, diagnose, display and control almost an endless variety of vehicle parameters are available today. The electronic control systems in diesel engines, automatic transmission and suspension of fighting vehicles are discussed in the paper.

Diesel Engines

Electronic Fuel Injection

The basic function of EFI (Fig. 1) is to provide to the engine cylinders precise quantities of fuel in the correct proportion with air to achieve the desired engine performance, good fuel economy, proper emission levels and pleasing drivability. The fuel is controlled by electrically actuated solenoid injection valves. The injection phasing and duration is controlled by an electronic control unit (ECU) which computes the needed quantity of fuel from measurements of intake—manifold pressure, engine speed and air temperature combined with a knowledge of engine physical and operating parameters, engine phasing and engine temperaures. This system approach is commonly referred

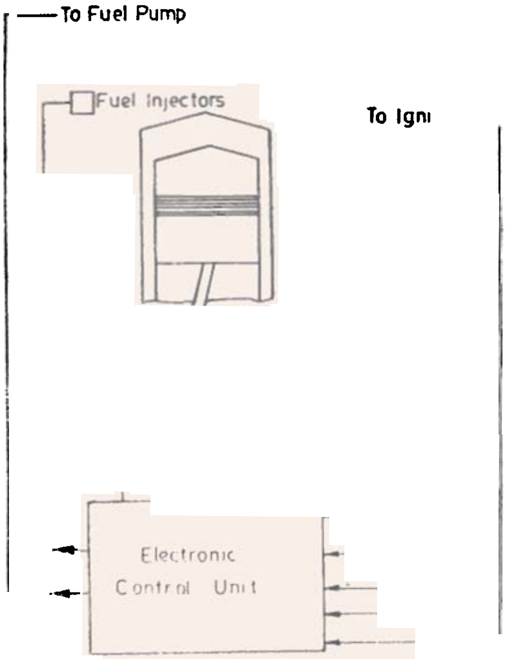

Figure 1. Electronic fuel injection system.

to as the speed density concept because an intake—manifold pressure sensor and an engine speed sensor are used to compute air flow.

Electronic fuel injection requires a systems approach to manufacturing. Several manufacturing processes must be applied ranging from highly specialised electronics and precision electrohydraulic injectors to conventional mechanical air flow control valves and precision transducers.

Electronic Governing

Electronic governing is now increasingly adopted for diesel engines and gas turbines The schematic drawing (Fig 2) illustrates the installation of an electronic governor. Actual speed is determined by a magnetic pickup mounted adjacent to a convenient gear on the diesel engine. The error existing between the desired speed and the actual speed is conditioned by a proportional integral—derivative controller. It causes the electro mechanical actuator to change the fuel flow to correct the speed error.

Helenoid actuators to simulate cam operated valves at engine speeds of 6000 *rev/min*

Advances in electronics and the advent of micro-processors now provide accurate means of sensing, monitoring and processing signals, giving information on the operation of many types of complex systems. However, to make use of these techniques it is essential to convert the signals into tractive force as quickly as possible thus achieving a fast interface response between the logic and power to be controlled.

Helenoid actuators are fast acting solenoids with a low armature mass and short magnetic circuits (Fig. 3a). The accelaration for a given stroke is constant and independent of the force required. Acting through rocker arms, these devices produce an intial force

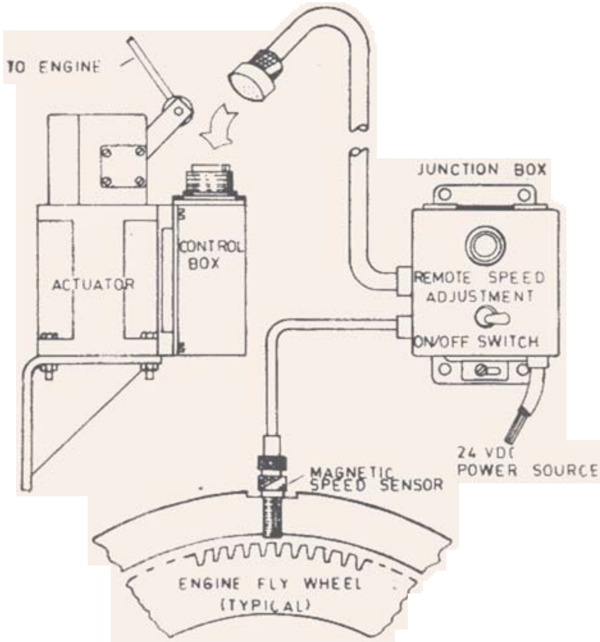

Figure 2. Electronic governing system installation includes magnetic speed sensor which feeds through remote speed control potentiometer to control box signal from the control box to the actuator coil determines setting of the actuator position.

of 1600 N increasing to 4000–5000 N. Such high forces are necessary to overcome valve stiction and inertia, valve spring forces, and gas pressure. Travel time which is constant over the engine speed range, is equal to that of a cam operated valve operating at an engine speed of 6000 rev/min.

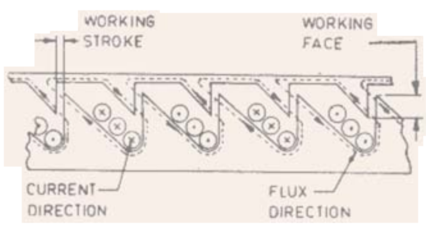

Figure 3(a). Helenoid.

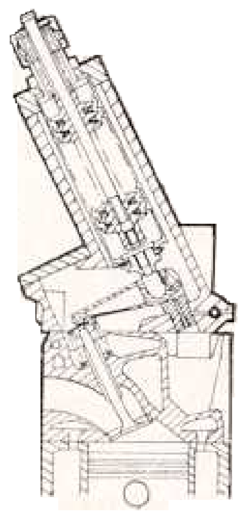

Figure 3(b). Helenoid valve actuator.

An electronic controller, responding to crankshaft angle signals, permits all valve parameters, namely timing, open period and valve overlap to be readily adjusted whilst the engine is running to obtain optimum engine performance over the entire speed range. The helenoid application is being used as an aid to engine research and development (Fig. 3b) but ultimately once the controller has been optimised, it could be programmed to give the same performance from a production engine.

Starter Motor

Recent developments in the starter motor include constant mesh types using over running clutches and built in gear reduction units. The axial movement of the starter to engage with the flywheel involves complex design and power loss in batteries during engagement. The over running clutch reduces the weight and eliminates complexity of the engagement mechanism and protects the starter against the high reverse loads that are fed back from the crank shaft during back firing. The gradual gear reduction through an epicyclic gear train or a compound gear train enables the use of higher module gears to withstand the complex stresses developed during transmission of the cranking torque to crank the engine. The modular concept of design now being adopted for many of the commercial vehicle sub-systems can also be adopted for the design of starting system. It should be possible in future to standardise the requirements of gear reduction units alongwith the over running clutches for starters ranging from 10 to 15 HPs and 15 to 20 HP. This will greatly reduce the tooling costs and individual design of each drive unit and engagement for a given starter.

Generators

The search for high performance generators has led to the adoption of aircraft practice. The recent developments in magnetic materials, insulating materials and efficient cooling medium resulted in the high specific output, multistage excitation, brushless oil cooled alternators producing 650 Amps at 28 V DC. The output of these generators are controlled within 28 V $\pm$ 0.75 V with solid state sealed regulators. The solid state networks in the regulator provides voltage regulation, current limiting and over voltage protection. The negative feedback in the circuits provide stable, steady state operation and quick response to load and transient conditions.

3. Transmission

Automatic Transmission

An automatic transmission matches engine torque to the torque demand set by the terrain and operating conditions. Microprocessors are being used and as in other applications the appeal of the microprocessor in electronic transmission control is that it reduces the cost and size while increasing the reliability of the control unit.

A schematic diagram of an automatic transmission of 55 tonne heavy vehicle is shown in the sketch (Fig 4).

The control system initiates all gear changes at predetermined transmission output speeds in the two modes of operation 'maximum performance' with the accelerator pedal at full or 'normal driving' with the accelerator pedal at all other operational angles.

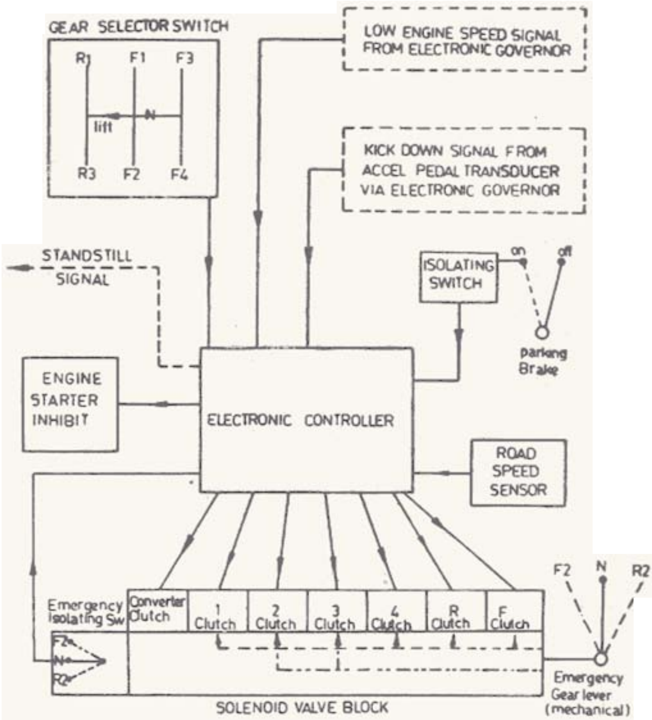

Figure 4. Automatic transmission controller of heavy vehicle.

Both the required gear and direction of travel are engaged through the operation in the correct sequence of plate clutches. These are applied by hydraulics initiated by electrical signals transmitted from the control system through solenoid valves. The operation of the control system, is automatic with provision for manual limitation of gear upchanges. A road speed sensor is mounted adjacent to the transmission pump and is connected electrically to the control system. The control system ensures that all gear changes are made within pre-determined speed ranges. An automatic transmission matches engine and transmission at optimum torque levels, ensures maximum fuel economy and protects the transmission from possible damage through misuse.

Active Suspension

Since much advances have taken place in the outer limits of control and stabilisation within the turret, attention has to be paid to the hull stabilisation also. The suspension should provide a stable platform for firing the main armament regardless of the vehicle speed or terrain conditions.

The active suspension system concept is an automatic control system which is designed to operate in such a way that the vehicle hull becomes a stabilised space reference platform. The objective of this system is to significantly reduce the armoured vehicle hull disturbances such that the entire crew can function effectively at much higher vehicle speeds during the off road terrain conditions. The hull as a stabilised space referenced platform stabilises the entire crew.

The system concept is conceived on the basis that the existing suspension forms the closed loop system. The shock absorbers are converted to servo-controlled torquers which add or subtract from the suspension system torsion bar torque as required to minimize hull disturbances relative to speed and off-road terrain conditions. This controlled torque applied through the shock absorbers (control cylinders) is derived from employing pitch and roll inertial sensors which measure hull (perturbations) disturbances and direct a system electronic controller unit to operate the servo valves at the actuators such that the pitch rate and roll rate of the hull are minimised for all disturbances input conditions. System components consist of the following (Fig 5).

(1) Hydraulic actuators (shock absorbers)

(2) Dual axis rate gyro package sensing pitch and roll

(3) Accelerometer package sensing vertical acceleration

(4) Electronics controller unit which contains the power supply, controller electronics and microprocessor to combine the rate and acceleration signals to command a proper reaction of each of the controller and road wheels

(5) Hydraulic servo valves, manifolds, filter, accumulative and tubing for connection to an engine driven hydraulic pump

(6) Electrical harnesses

The active suspension has the potential to be a major advance in reaching the stated optimum mobility goals of our armoured fighting vehicles.

4. Conclusion

With the increasing demand for sophisticated automotive control system specially in heavy vehicles only electronic controls have the high density, flexibility and speed to meet the requirements at reasonable cost.

As technology evolves, second and third generation systems can be produced with drastic reduction in cost and size alongwith a corresponding improvement in reliability, primarily due to circuit and system integration. Also in future we can expect to see more integration of electronic functions. It is advantageous to integrate a new control

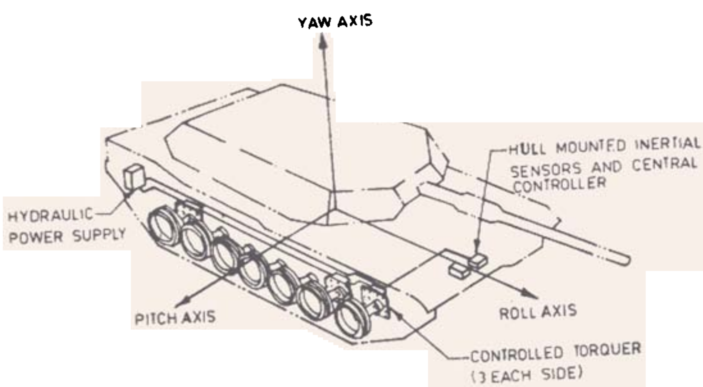

Figure 5. Active suspension.

to an existing system rather than simply to design a new unit or control system. Sensors, memory and in some instances, even actuators can be shared. A single microprocessor can be used for digital instrument panel, electronic governing, electronic fuel injection, exhaust gas regulations (EGR) and automatic transmission control. Integrated electronic control provide both digital displays of various engine and transmission parameters to the driver as well as perform all the control functions of engine and transmission.

The input/output interfaces namely the solenoids, actuators and their conversions are to be developed to take advantage of the power of modern microprocessor controls. Precision transducers to convert mechanical parameters to electrical signals and the actuators to convert the electrical signals to drive fuel racks, valve gear and electro hydraulic servo valves are considered to be weak links particularly in our country.

It is important to remember that most vehicle systems utilising electronics have mechanical inputs and outputs and in most cases mechanical engineers have the system responsibility. Therefore it is essential that the mechanical system designer must familiarise himself with the advantages of electronic control systems.

References

1. Myrow Seneczko, N., *Machine Design*, **51** (1979), 86.
2. Davind Freedman, M., *Auto Engg.*, **85** (1977), 34.
3. Stefamides, E. J., *Design News*, **26** (1971), 48.
4. Fred Schreier, M., *IDR.*, **7** (1975), 347.
5. Jerome Rivard, G. *SAE Transactions*, **4** (1974), 3917
6. Peter Massy, A., *Captain*, *Armor*, **78** (1979), 35.
7. 'Mckinley James, L. & Bent Ralph, D., 'Electricity & Electronics for Aerospace Vehicles', 187.