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MECHATRONICS IN AUTOMOBILES

TANUJA P. MOTE[1], MEENAL. R. MAJGE[2] & GOURI. P. BRAHMANKAR[3]

[1]Lecturer, E&TC Department, SVCP, Pune, Maharashtra, India

[2]Sr. Lecturer, E&TC Department, SVCP, Pune, Maharashtra, India

[3]Lecturer, E&TC Department, SVCP, Pune, Maharashtra, India

ABSTRACT

Technical products realize the need of integrating mechanics with digital electronics and information processing. This results into an integrated system called mechatronic system. Mechatronics has a lot of influence on a large variety of products in the area of mechanical, electrical and electronic engineering. It has changed the basic design, for example, of conventional electromechanical components, machines, vehicles and precision mechanical devices with increasing intensity. The main objective behind is to build smart products and “intelligent” machines. This paper presents about the elements of mechatronic system and its evolution in the field of automobiles. With the automation in technology, automobiles seem to be our basic need in day-to-day life. We expect better performance, safe drive, user friendly and security in the ongoing development of Automobiles. Modern mechatronics can be applied to make these expectations come true with smarter mechanisms, via improved efficiencies, speed controls and system interaction. This paper highlights on some of the mechatronic systems used in automobiles.

KEYWORDS: Mechanical, Electronics, Mechatronic, Sensors, Actuators, Automobiles

INTRODUCTION

Mechatronics is a concept of *Japanese* origin and can be defined as the application of electronics and computer to control the motions of mechanical systems. In other words, technologies and developed products will be incorporating electronics more and more into mechanisms, intimately and organically, and making it impossible to tell where one ends and the other begins. In broad sense, the term mechatronics refers to “The synergistic integration of mechanical engineering, with electronics and intelligent computer control in the design and manufacturing of industrial products and processes”.

Mechatronics employs the fields of mechanical, electrical, control and computer engineering at the stage of design itself as shown in figure 1. Mechanical aspect is employed in terms of various machines and mechanisms, where as various electric prime movers viz. AC/DC, servo motors and other systems are used which constitute electrical aspect. Control aspect is used to develop various electronics-based control systems to enhance or replace the mechanics of the mechanical systems. Computers are used for various softwares to control the control systems; product design and development activities; materials and manufacturing resource planning, record keeping, market survey, and other sales related activities.

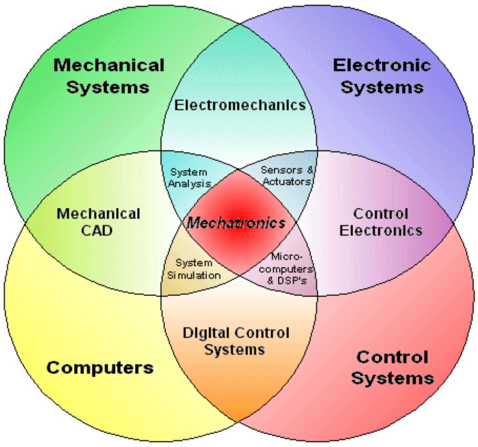

Figure 1: Integration of Mechatronic System

BLOCK DIAGRAM OF MECHATRONIC SYSTEM

The main elements of the mechatronic system are shown in figure 2 below.

Microprocessors and Integrated Circuits

It is a digital device which receives information in digital form. According to stored programs this information is processed. It is a chip capable of performing arithmetic and logic functions according to a defined program. Microprocessor processes or utilizes the information gathered from the sensor system and generates the signals of appropriate level and suitable kind (current or voltage) which will be used to actuate the required actuator.

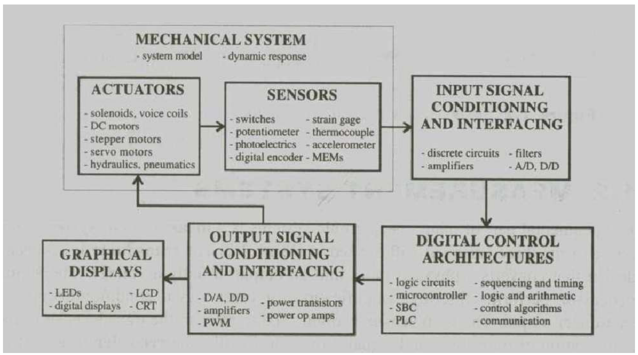

Figure 2: Block Diagram of Mechatronic System

Signal Conditioning and Interfacing Devices

Mechatronic systems consist of energy and information domains. Data processing is done in digital devices while physical detection in sensors and power output in actuator requires analog capability. Various electronics based auxiliary devices viz. Analogue-to-Digital Converter (ADC), Digital-to-Analogue Converter (DAC), Op-amps, Modulators, Linearization circuits, etc. are used to condition the signals which are either received by the microprocessor from the sensors or are sent to the actuators from the microprocessor.

Sensors

It is a sensing device that converts physical quantity and chemical composition into electric, pneumatic or hydraulic output signals. Some of modern sensors developed for mechatronics applications are Pressure sensors for automotive manifold air pressure, accelerometers for airbag systems etc.

Actuators:

The actuator converts control signal into action on the control element. The actuator often supplies large force or torque to manipulate some control element such as valve, switch etc.

Modern actuators for mechatronic applications ultrasonic motors, micro motors etc.

APPLICATIONS OF MECHATRONICS IN MECHANICAL FIELD

Mechanical systems can be dedicated to a large area of mechanical engineering. According to their construction, they can be subdivided into mechanical *components, machines, vehicles, precision mechanical devices* and micromechanical *components*. Figure 3 shows some examples of mechatronic components, machinery and vehicles. Examples for *precision mechatronic devices* are gyros, laser and ink jet printers, hard disk drives. Mechatronic products in the field of *microelectromechanical systems* (MEMS) are piezoelectric acceleration sensors, micro actuators and micropumps.

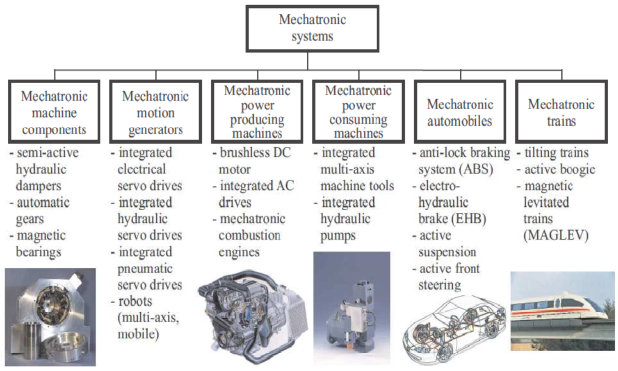

Figure 3: Examples of Mechatronic Products

With the convergence of advanced in-vehicle electronics, communication-technology, the automobiles of today is undergoing a completer-invention.

EVOLUTION OF MECHATRONICS IN AUTOMOBILES

The evolution of modern mechatronics can be illustrated with the example of the automobile. Until the 1960s, significant electronics in an automobile was the only radio. All other functions were entirely mechanical or electrical, such as the starter motor and the battery charging systems. There were no “intelligent safety systems”, except the bumper and structural members to protect occupants in case of accidents. Seat belts, introduced in the early 1960s, were completely mechanically actuated and were aimed at improving occupant safety. All engine systems were controlled by the driver and/or other mechanical control systems. For example, a mechanical distributor was used to select the specific spark plug to fire when the fuel–air mixture was compressed. The time of the ignition was the control variable. The mechanically controlled combustion process was not good in terms of fuel efficiency. Modeling of the combustion process showed that, to increase the fuel efficiency there exists an optimal time when the fuel should be ignited. This time depends on load, speed, and other measurable quantities.

The electronic ignition system was one of the first mechatronic systems to be introduced in the automobile in the late 1970s. The Antilock Brake System (ABS) was also introduced in the late 1970s in automobiles. The Traction Control System (TCS) was introduced in automobiles in the mid-1990s. The Vehicle Dynamics Control (VDC) system was introduced in automobiles in the late 1990s.

Hydraulic assisted power steering goes back until around 1945. This classical steering was continuously improved, especially in adapting the required force or torque support to the speed. Later developments realized this reducing support with increasing speed by electronically controlled electromagnetic by-pass valves, also called “parameterizable steering”. Figure 4 above shows some mechatronic steering systems. Since about 1996 electrically assisted power steering (EPS) is on the market for smaller cars, (1996).

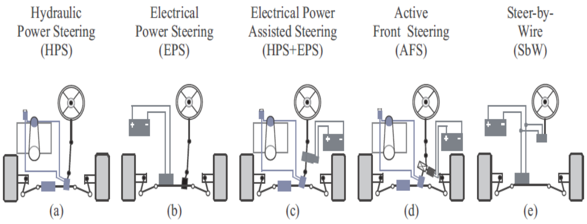

Figure 4: Mechatronic Steering Systems: (a) Conventional Hydraulic Power Steering (HPS) (Since about 1945); (b)Electrical Power Steering (EPS) for Smaller Cars (1996); (c) Electrical Power Assisted Steering (HPS+EPS) for Larger Cars; (d) Active Front Steering (AFS): Additional Wheel Angles Generated by a Planetary Gear and a DC motor (2003); (e) Steer-by-Wire (SbW)

For larger cars the hydraulic power steering (HPS) is paralleled by electrical power steering (EPS), allowing electrical inputs for, e.g. automatic parking. A recent development is the *active front steering* (AFS) introduced in 2003, where additional steering angles are generated with a DC motor acting on a planetary gear. By this construction the mechanical linkage to the wheels is maintained and electrical inputs can be superimposed. This enables to increase the steering gain with lower speed, a higher dynamic steering and allows yaw changes and side wind compensation.

In automobiles today, typically, 8, 16, or 32-bit CPUs are used for implementation of the various control systems. The microcontroller has onboard memory (EEPROM/EPROM), digital and analog inputs, A/D converters, pulse width modulation (PWM), timer functions, such as event counting and pulse width measurement, prioritized inputs, and in some cases digital signal processing. The 32-bit processor is used for engine management, transmission control, and airbags; the 16-bit processor is used for the ABS, TCS, VDC, instrument cluster, and air conditioning systems; the 8-bit processor is used for seat, mirror control, and window lift systems. Today, there are about 30–60 microcontrollers in a car.

MECHATRONIC SYSTEMS IN AUTOMOBILES

Here we are presenting some of the common mechatronic systems used in the new generation automobiles today.

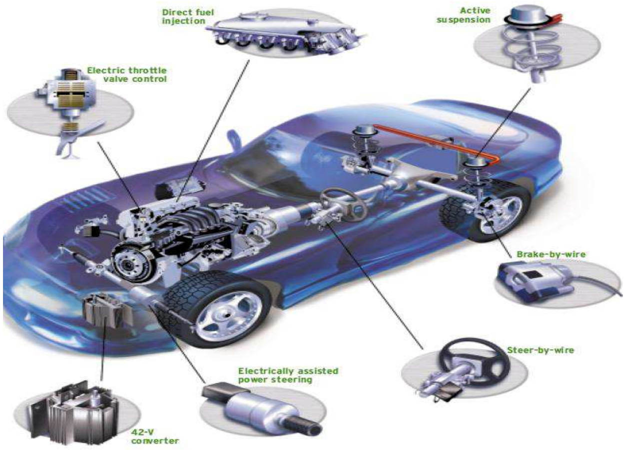

Figure 5: Mechatronic Systems in Automobile

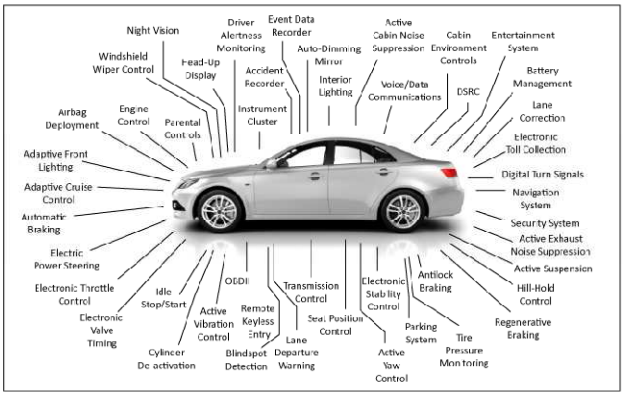

Figure 6: Top- End Model of the Car

Figure 5 below indicates some of the prominent mechatronic systems in the automobiles and figure 6 depicts today's top end model of a car which can be considered as a rolling computer due to vast number of mechatronic systems incorporated in it.

Electronic Ignition System

The electronic ignition system consists of a crankshaft position sensor, camshaft position sensor, airflow rate, throttle position, rate of throttle position change sensors, and a dedicated microcontroller determining the timing of the spark plug firings.

Antilock Brakes System (ABS)

Antilock Brakes are essentially an enhanced or improved version of ordinary brakes. The ABS as shown in figure 7 works by sensing lockup of any of the wheels and then modulating the hydraulic pressure as needed to minimize or eliminate sliding.

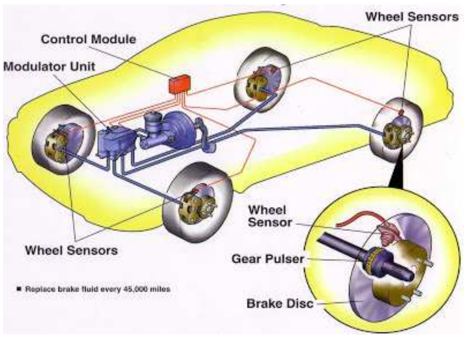

Figure 7: Antilock Brake System (ABS)

The antilock brake system is designed to prevent the wheels from locking up and skidding when braking hard or when braking on wet or slick surfaces. This adds a significant margin of safety for everyday driving by preventing dangerous skids and allowing the driver to maintain steering control while trying to stop. The way an *anti-lock braking system* works is on/off. If a wheel is locked in braking because of low road friction, this is sensed and the braking moment on the wheel is simply released to let the wheel once again not slip on the surface. Then the braking moment is applied again. This can be done very quickly. So this is not a control system in smoothly modulated control.

Traction Control System (TCS):-

The TCS works by sensing slippage during acceleration and then modulating the power to the slipping wheel. This process ensures that the vehicle is accelerating at the maximum possible rate under given road and vehicle conditions.

Vehicle Dynamic Control System (VDC):-

The VDC works similar to the TCS with the addition of a yaw rate sensor and a lateral accelerometer. The driver intention is determined by the steering wheel position and then compared with the actual direction of motion. The TCS system is then activated to control the power to the wheels and to control the vehicle velocity and minimize the difference between the steering wheel direction and the direction of the vehicle motion. In some cases, the ABS is used to slow down the vehicle to achieve desired control.

Steer-By-Wire Enhances Car Wheel Control:-

Figure 8: Steer-by-Wire System

Only wires (green) relay signals from a car's steering wheel to its front wheels in a front-wheel steer-by-wire system shown in figure 8. And an electrically actuated motor, not a mechanical link with the steering wheel, turns the front wheels.

Cruise Control System in Car:-

This is also a smoothly modulated closed loop control system as shown in figure 9. The cruise control system controls the speed of a car by adjusting the throttle position. A mechatronic throttle is shown in figure 10. Instead of pressing a pedal, cruise control actuates the throttle valve by a cable connected to an actuator. Actuator is a small DC motor on throttle valve, which controls air into engine. There are two cables connected to a pivot that moves the throttle valve. One cable comes from the accelerator panel, and another from the actuator. When the actuator is engaged, it adjusts the throttle by moving the cable connected to the pivot, when the cruise control system is engaged the pedal moves up and down since the actuator also pulls on the cable that is connected to the gas pedal. The throttle valve controls the power and speed of the engine by limiting how much air the engine takes in.

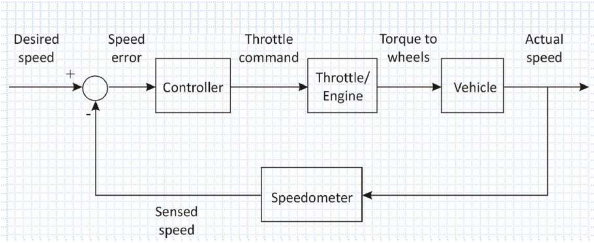

Figure 9: Cruise Control System in Car

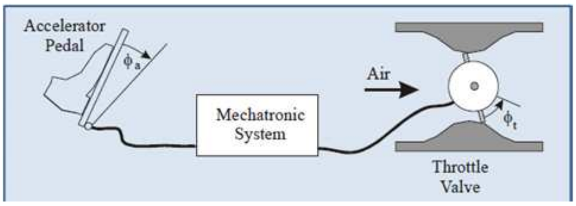

Figure 10: Mechatronic Throttle

Car Engine Management

Car engine management system consists of many electronic control systems involving microcontrollers, the engine control system being one, its aim is to control the amount of fuel to be injected into each cylinder, ignition, Engine revolution limit, turbochargers wastage control, variable cam timing and gear controls. The system consists of sensors supplying, after suitable signal conditioning, the input signals to the microcontroller and its providing output signals via drivers to actuate the actuators. Figure 11 shows some of these elements in relation to an engine.

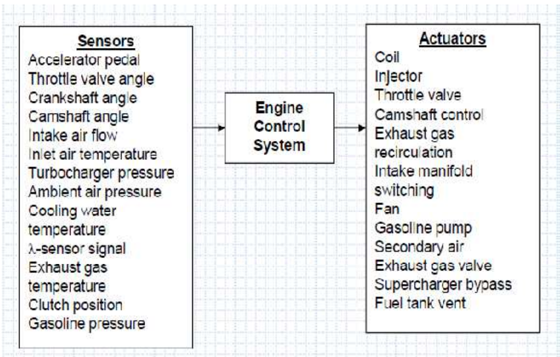

Figure 11: Mechatronic Elements of Engine Control System

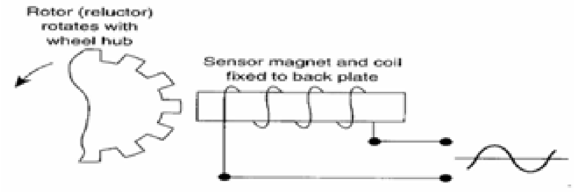

Figure 12: Engine Speed Sensor

The engine speed sensor is an inductive sensor as shown in figure 12, basically a toothed metal disk mounted on the crank shaft and stationary detector that functions to cover a magnetic coil through which the current passes through, as these metal teeth begins moving past the coil, the magnetic field is distracted and thus a wave of pulses in the current is created.

The temperature sensor is usually a ther mist or whose resistance varies according to the temperature. The mass air flow sensor may be a hot wire sensor, as air passes over a heated wire it will be cooled, the amount of cooling depending on the mass rate of flow. When temperature reaches more than 300 centigrade the sensor becomes permeable to oxygen ions and a voltage is induced between the electrodes.

Mechatronic Suspension

The vehicle suspension system is responsible for driving comfort and safety as the suspension carries the vehicle-body and transmits all forces between body and road. An example of suspension system is shown in figure 13. In order to positively influence these properties, semi-active or/and active components are introduced, which enable the suspension system to adapt to various driving conditions. *Semi-active suspensions* allow to adapt the damping characteristic of a shock absorber to varying load and suspension deflection by, e.g. an active throttle-valve *Active suspensions* as shown in figure 14 provide an extra force input in addition to existing passive springs. They may be realized as hydraulic, hydro pneumatic or pneumatic systems. The required energy for passenger cars and an operating range between 0 to 5Hz is about 1-

2 kW and between 0-12Hz is about 2-7 kW.

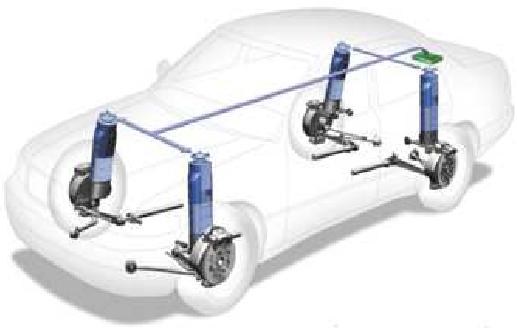

Figure 13: Bose Suspension System

Figure 14: Active vs Passive Suspension

Airbag Inflation

The goal of an airbag is to inflate rapidly during automobile collision and prevent the passenger's from striking interior objects. Majority cases of death are due to seat belt not worn. The airbag and inflation system stored is in the steering wheel The bag itself is made up of a thin nylon fabric, which is folded into the steering wheel or dashboard or, more recently, the seat or door.

Advance systems have solid state crash sensors that contain a piezoelectric crystal or a micro machined accelerometer, a device used to measure acceleration or vibration shock built into a microchip that produces an electrical signal when jolted.

The airbag's inflation system is by the reaction of sodium azide with potassium nitrate to produce nitrogen. Hot blasts of the nitrogen inflate the airbag

Power Door Locks

In this system the door lock/unlock switch actually sends power to the actuators that unlock the door. In more complicated systems, the body controller decides when to do the unlocking. The body controller is similar to a computer which monitors all of the possible sources of locking and unlocking signal in a car. The system monitors the radio frequency and unlocks the doors when the correct digital code is received from the radio transmitter. When the actuator moves the latch up, it connects the outside door handle to the opening mechanism. When the latch is down, the outside door handle is disconnected from the mechanism so that it cannot be opened.

Inside a Car Door

In a specific interval of time, the body controller supply power to the door lock actuator to unlock the door. The construction of actuator system is very simple. A small electric motor turns a series of spur gears that serve as a gear reduction. The last gear drives a rack-and-pinion gear set that is connected to the actuator rod. The rotational motion of the motor is converted to linear motion by the rack in order to move the lock.

Sensors that Can Make Cars Safer

Micro Electromechanical Systems (MEMS) is an enabling technology for the cost-effective development of sensors and actuators for mechatronics applications. Already, several MEMS devices are in use in automobiles, including sensors and actuators for airbag deployment and pressure sensors for manifold pressure measurement. Integrating MEMS devices with CMOS signal conditioning circuits on the same silicon chip is another example of development of enabling technologies that will improve mechatronic products, such as the automobile.

Accelerator Pedal-Throttle Position Sensor

The throttle position sensor (TPS) shown in figure 15 responds to the accelerator pedal movement.

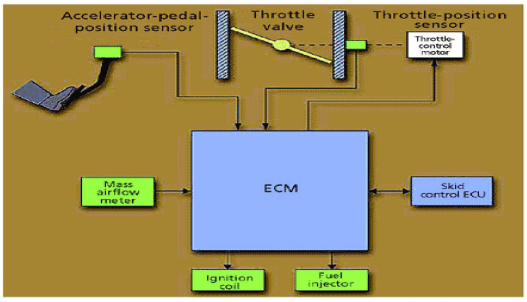

Figure 15: Throttle Position Sensor

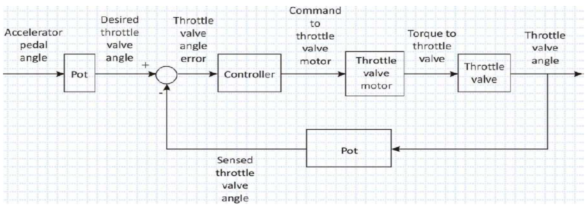

Figure 16: Throttle–by-Wire Control System

Sensor used is a potentiometer on throttle valve. Actuator is a small DC motor on throttle valve, which controls air into engine. Plant is throttle valve, which is controlled. There is also a potentiometer on the accelerator pedal that sense its angle. This is turned into a desired value for the throttle valve. It need not necessarily be 1:1. Throttle –by- wire control system shown in figure 16 is a smoothly modulated control system as opposed to ABS system. This is a positioner system. Accelerator pedal position is constantly changing with normal driving. The pedal itself just becomes a way to express a wish.

CONCLUSIONS

In this paper we discussed briefly about the mechatronic system and its elements.

Also we have seen different mechatronic systems incorporated in the vehicles making it as an advanced vehicle control system. Mechatronics plays a vital role in different applications of mechanical engineering. In many applications, purely mechanical solutions are not efficient and neither precise as mechatronic solutions. Today's design aspect of automobiles concentrates largely on increased comfort, safety and security. As a result automobiles engineering systems requires multi-disciplinary design teams like mechatronic systems. Thus mechatronics is a complete solution for building such automobiles which are highly intelligent and increasingly reliant on electronics for having safety, security, comfort,whims and fancies in life.

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