MECHATRONICS

1. ABSTRACT

Mechatronics (or Mechanical and Electronics Engineering) is the combination of mechanical engineering, electronic engineering and computer engineering.

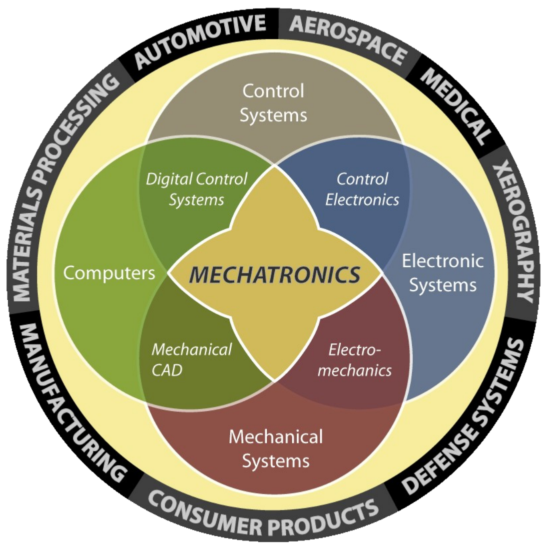
The purpose of this interdisciplinary engineering field is the study of automata from an engineering perspective and serves the purposes of controlling advanced hybrid systems. The word itself is a portmanteau of 'Mechanics' and 'Electronics'.

2. INTRODUCTION

Engineering cybernetics deals with the question of control engineering of mechatronic systems. It is used to control or regulate such a system (see control theory). Through collaboration the mechatronic modules perform the production goals and inherit flexible and agile manufacturing properties in the production scheme. Modern production equipment consists of mechatronic modules that are integrated according to a control architecture.

The most known architectures involve hierarchy, polyarchy, hetaerachy (often misspelled as heterarchy) and hybrid. The methods for achieving a technical effect are described by control algorithms, which may or may not utilize formal methods in their design. Hybrid-systems important to Mechatronics include production systems, synergy drives, planetary exploration rovers, automotive subsystems such as anti-lock braking systems, spin-assist and every day equipment such as autofocus cameras, video, hard disks, CD-players.

3. HISTORY



Aerial Venn diagram from RPI's website describes the various fields that make up Mechatronics

Mechatronics is centred on mechanics, electronics, control engineering, computing, molecular engineering (from nanochemistry and biology) which, combined, make possible the generation of simpler, more economical, reliable and versatile systems. The portmanteau "Mechatronics" was first coined by Mr. Tetsuro Mori, a senior engineer of the Japanese company Yaskawa, in 1969. Mechatronics may alternatively be referred to as "electromechanical systems" or less often as "control and automation engineering".

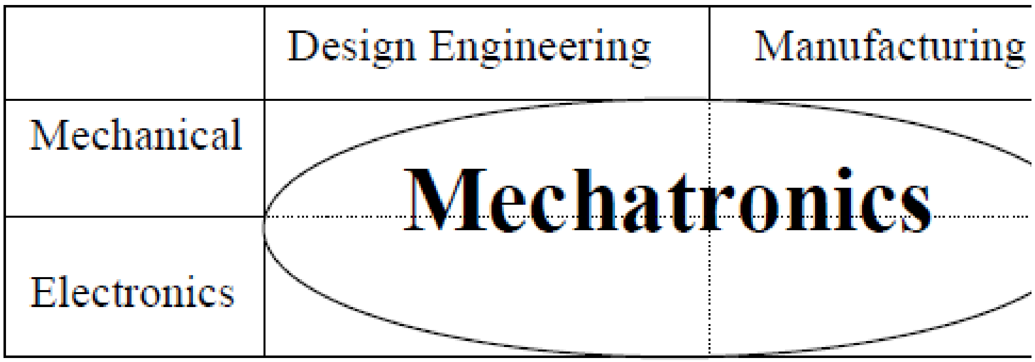


Figure 1 Graphical representation of Mechatronics

Mechatronics is a word originated in Japan in 1980s to denote the combination of technologies which go together to produce industrial robots. A formal definition of Mechatronics is ``the synergistic integration of Mechanics and Mechanical Engineering, Electronics, Computer technology, and IT to produce or enhance products and systems. A graphical representation of Mechatronics is shown in Fig. 1. Examples of such systems are Computers, Disk drives, Photocopiers, Fax machines, VCR, Washing machines, CNC machine tools, Robots, etc. Today's modern cars are also mechatronics product with the usage of electronic engine management system, collision detection, global positioningsystem, and others. Figure 1 Graphical representation of Mechatronics.

Even though many people believe that the presence of mechanical, electrical, electronic components, and computers make a system mechatronics, others do not feel the same as there is nothing wrong with the individual identity. Hence, the term

Mechatronics should be used to represent a different meaning, namely, “a design philosophy,” where mechanical, electrical, electronics components, and IT should be considered together in the design stage itself to obtain a compact, efficient, and economic product rather than designing the components separately. This is illustrated in Fig. 2. The concept of mechatronics is very important today to meet the customers’ ever increasing demands and still remain competitive in the global market. Very often a mechanical engineer without the mechatronics background is considered equivalent to a mechanical engineer without the engineering drawing knowledge. In India, we always look towards west for our technological requirement even though Indians.

4. APPLICATION

- Automation, and in the area of robotics
- Servo-mechanics
- Sensing and control systems Automotive engineering, in the design of subsystems such as anti-lock braking systems
- Computer engineering, in the design of mechanisms such as computer drive.
- Crack detection.

5. AUTOMATION

KUKA Industrial robots engaged in vehicle underbody assembly

Automation (ancient Greek: = self dictated), roboticization or industrial automation or numerical control is the use of control systems such as computers to control industrial machinery and processes, reducing the need for human intervention.

In the scope of industrialization, automation is a step beyond mechanization. Whereas mechanization provided human operators with machinery to assist them with the physical requirements of work, automation greatly reduces the need for human sensory and mental requirements as well. Processes and systems can also be automated.

Automation plays an increasingly important role in the global economy and in daily experience. Engineers strive to combine automated devices with mathematical and organizational tools to create complex systems for a rapidly expanding range of applications and human activities.

Many roles for humans in industrial processes presently lie beyond the scope of automation. Human-level pattern recognition, language recognition, and language production ability are well beyond the capabilities of modern mechanical and computer systems. Tasks requiring subjective assessment or synthesis of complex sensory data, such as scents and sounds, as well as high-level tasks such as strategic planning, currently require human expertise. In many cases, the use of humans is more cost-effective than mechanical approaches even where automation of industrial tasks is possible.

Specialised hardened computers, referred to as programmable logic controllers (PLCs), are frequently used to synchronize the flow of inputs from (physical) sensors and events with the flow of outputs to actuators and events. This leads to precisely controlled actions that permit a tight control of almost any industrial process.

Human-machine interfaces (HMI) or computer human interfaces (CHI), formerly known as man-machine interfaces, are usually employed to communicate with PLCs and other computers, such as entering and monitoring temperatures or pressures for further automated control or emergency response. Service personnel who monitor and control these interfaces are often referred to as stationary engineers.[2]

5.1 Impact

Automation has had a notable impact in a wide range of highly visible industries beyond manufacturing. Once-ubiquitous telephone operators have been replaced largely by automated telephone switchboards and answering machines. Medical processes such as primary screening in electrocardiography or radiography and laboratory analysis of human genes, sera, cells, and tissues are carried out at much greater speed and accuracy by automated systems. Automated teller machines have reduced the need for bank visits to obtain cash and carry out transactions. In general, automation has been responsible for the shift in the world economy from agrarian to industrial in the 19th century and from industrial to services in the 20th century.

The widespread impact of industrial automation raises social issues, among them its impact on employment. Historical concerns about the effects of automation date back to the beginning of the industrial revolution, when a social movement of English textile machine operators in the early 1800s known as the Luddites protested against Jacquard's automated weaving looms often by destroying such textile machines— that they felt threatened their jobs.

One author made the following case. When automation was first introduced, it caused widespread fear. It was thought that the displacement of human operators by computerized systems would lead to severe unemployment.

Critics of automation contend that increased industrial automation causes increased unemployment; this was a pressing concern during the 1980s. One argument claims that this has happened invisibly in recent years, as the fact that many manufacturing jobs left the United States during the early 1990s was offset by a one-time massive increase in IT jobs at the same time. Some authors argue that the opposite has often been true, and that automation has led to higher employment. Under this point of view, the freeing up of the labour force has allowed more people to enter higher skilled managerial as well as specialised consultant/contractor jobs (like cryptographers), which are typically higher paying. One odd side effect of this shift is that "unskilled labour" is in higher demand in many first-world nations, because fewer people are available to fill such jobs..

At first glance, automation might appear to devalue labor through its replacement with less-expensive machines; however, the overall effect of this on the workforce as a whole remains unclear. Today automation of the workforce is quite advanced, and continues to advance increasingly more rapidly throughout the world and is encroaching on ever more skilled jobs, yet during the same period the general well-being and quality of life of most people in the world (where political factors have not muddied the picture) have improved dramatically. What role automation has played in these changes has not been well studied.

5.2 CURRENT EMPHASIS

Currently, for manufacturing companies, the purpose of automation has shifted from increasing productivity and reducing costs, to broader issues, such as increasing quality and flexibility in the manufacturing process.

The old focus on using automation simply to increase productivity and reduce costs was seen to be short-sighted, because it is also necessary to provide a skilled workforce who can make repairs and manage the machinery. Moreover, the initial costs of automation were high and often could not be recovered by the time entirely new manufacturing processes replaced the old. (Japan's "robot junkyards" were once world famous in the manufacturing industry.)

Automation is now often applied primarily to increase quality in the manufacturing process, where automation can increase quality substantially. For example, automobile and truck pistons used to be installed into engines manually. This is rapidly being transitioned to automated machine installation, because the error rate for manual installment was around 1-1.5%, but has been reduced to 0.00001% with automation. Hazardous operations, such as oil refining, the manufacturing of industrial chemicals, and all forms of metal working, were always early contenders for automation.

Another major shift in automation is the increased emphasis on flexibility and convertibility in the manufacturing process. Manufacturers are increasingly demanding the ability to easily switch from manufacturing product A to manufacturing Product B without having to completely rebuild the production lines. Flexibility and distributed processes have led to the introduction of Automated Guided Vehicles with Natural Features Navigation.

5.3 AUTOMATION TOOLS

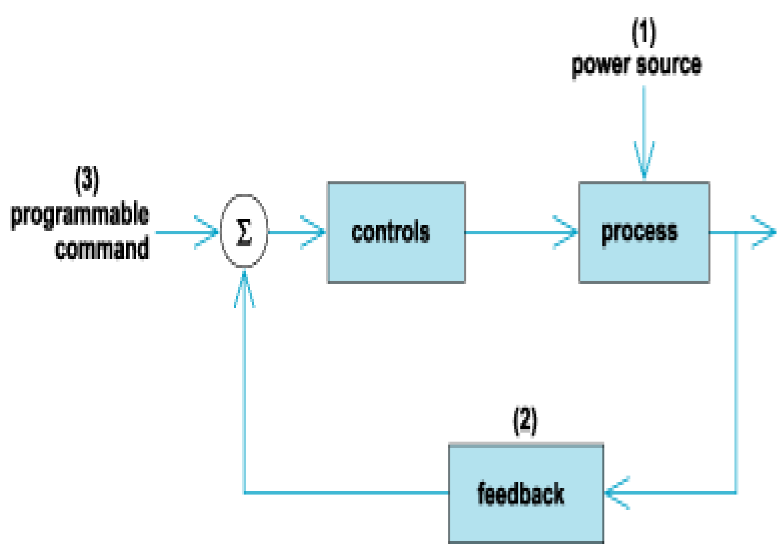
Different types of automation tools exist:

- ANN - Artificial neural network
- DCS - Distributed Control System
- HMI - Human Machine Interface

- SCADA - Supervisory Control and Data Acquisition
- PLC - Programmable Logic Controller

Automation plays an increasingly important role in the global economy and in our daily lives. Engineers strive to combine automated devices with mathematical and organizational tools to create complex systems for a rapidly expanding range of applications and human activities. To meet these challenges, the IEEE Robotics and Automation Society will establish a major archival journal on Automation Science and Engineering to publish the abstractions, algorithms, theory, methodologies, models, systems, and case studies that can be applied.

5.4 ELEMENTS OF AN AUTOMATED SYSTEM



Because of the growing ubiquity of automation, any categorization of automated tasks and processes is incomplete. Nonetheless, such a categorization can be attempted by recognizing two distinct groups, automated manufacturing and automated information processing and control. Automated manufacturing includes automated machine tools, assembly lines, robotic assembly machines, automated storage-retrieval systems, integrated computer-aided design and computer-aided manufacturing (CAD/CAM), automatic inspection and testing, and automated agricultural equipment (used, for example, in crop harvesting). Automated information processing and control includes automatic order processing, word processing and text editing, automatic data processing, automatic flight control, automatic automobile cruise control, automatic airline reservation systems, automatic mail sorting machines, automated planet exploration (for example, the rover vehicle, Sojourner, on the Mars Pathfinder mission), automated electric utility distribution systems, and automated bank teller machines. See also Assembly machines; Computer-aided design and manufacturing; Computer-integrated manufacturing; Flexible manufacturing system; Inspection and testing; Space probe; Word processing.

A major issue in the design of systems involving both human and automated machines concerns allocating functions between the two. This allocation can be static or dynamic. Static allocation is fixed; that is, the separation of responsibilities between human and machine do not change with time. Dynamic allocation implies that the functions allocated to human and machine are subject to change. Historically, static allocation began with reference to lists of activities which summarized the relative advantages of humans and machines with respect to a variety of activities. For example, at present humans appear to surpass machines in the ability to reason inductively, that is, to proceed from the particular to the general. Machines, however, surpass humans in the ability to handle complex operations and to do many different things at once, that is, to engage in parallel processing. Dynamic function allocation can be envisioned as operating through a formulation which continuously determines which agent (human or machine) is free to attend to a particular task or function. In addition, constraints such as the workload implied by the human attending to the task as opposed to the machine can be considered. See also Human-factors engineering.

It has long been the goal in the area of automation to create systems which could react to unforeseen events with reasoning and problem-solving abilities akin to those of an experienced human, that is, to exhibit artificial intelligence. Indeed, the study of artificial intelligence is devoted to developing computer programs that can mimic the product of intelligent human problem solving, perception, and thought. For example, such a system could be envisioned to perform much like a human copilot in airline operations, communicating with the pilot via voice input and spoken output, assuming cockpit duties when and where assigned, and relieving the pilot of many duties. Indeed, such an automated system has been studied and named a pilot's associate.

Machines exhibiting artificial intelligence obviously render the sharp demarcation between functions better performed by humans than by machines somewhat moot. While the early promise of artificial intelligence has not been fully realized in practice, certain applications in more restrictive domains have been highly successful.

These include the use of expert systems, which mimic the activity of human experts in limited domains, such as diagnosis of infectious diseases or providing guidance for oil exploration and drilling. Expert systems generally operate by (1) replacing human activity entirely, (2) providing advice or decision support, or (3) training a novice human in a particular field. See also Expert systems.

5.5 TYPES OF AUTOMATION

Although automation can play a major role in increasing productivity and reducing costs in service industries—as in the example of a retail store that installs bar code scanners in its checkout lanes—automation is most prevalent in manufacturing industries. In recent years, the manufacturing field has witnessed the development of major automation alternatives. Some of these types of automation include:

- Information technology (IT)
- Computer-aided manufacturing (CAM)
- Numerically controlled (NC) equipment
- Robots Flexible manufacturing systems (FMS) Computer integrated manufacturing (CIM)

Information technology (IT) encompasses a broad spectrum of computer technologies used to create, store, retrieve, and disseminate information.Computer-aided manufacturing (CAM) refers to the use of computers in the different functions of production planning and control. CAM includes the use of numerically controlled machines, robots, and other automated systems for the manufacture of products. Computer-aided manufacturing also includes computer-aided process planning (CAPP), group technology (GT), production scheduling, and manufacturing flow analysis. Computer-aided process planning (CAPP) means the use of computers to generate process plans for the manufacture of different products. Group technology (GT) is a manufacturing philosophy that aims at grouping different products and creating different manufacturing cells for the manufacture of each group.

Numerically controlled (NC) machines are programmed versions of machine tools that execute operations in sequence on parts or products. Individual machines may have their own computers for that purpose; such tools are commonly referred to as computerized numerical controlled (CNC) machines. In other cases, many machines may share the same computer; these are called direct numerical controlled machines.

Robots are a type of automated equipment that may execute different tasks that are normally handled by a human operator. In manufacturing, robots are used to handle a wide range of tasks, including assembly, welding, painting, loading and unloading of heavy or hazardous materials, inspection and testing, and finishing operations.

Flexible manufacturing systems (FMS) are comprehensive systems that may include numerically controlled machine tools, robots, and automated material handling systems in the manufacture of similar products or components using different routings among the machines.

A computer-integrated manufacturing (CIM) system is one in which many manufacturing functions are linked through an integrated computer network. These manufacturing or manufacturing-related functions include production planning and control, shop floor control, quality control, computer-aided manufacturing, computer-aided design, purchasing, marketing, and other functions. The objective of a computer-integrated manufacturing system is to allow changes in product design, to reduce costs, and to optimize production requirements.

6. ROBOTICS

An example of the eventual convergence of Detroit-style automation and electronic computing is the development of the industrial robot. Long a feature of science fiction, the first robots were merely armlike mechanical devices, specially designed to handle one particular task. Their utility was limited to applications where high temperature or other factors made it impossible or dangerous for people to perform the same tasks. However, programmable robots appeared as early as 1954, when Universal Automation offered its first product, the Unimation robot. Although General Motors installed such a robot on a production line in 1962, sales of robots were quite limited until the 1970s.

During the 1960s, many universities participated in the development of robots, and although many concepts carried over into the industrial robotics field, these did not immediately result in commercial adoption. It was Japanese companies that moved rapidly into robot utilization in the 1970s. Kawasaki Corporation purchased the Unimation robot technology, and by 1990 forty companies in Japan were manufacturing industrial robots.

The shock accompanying the rapid penetration of the domestic auto market by Japanese auto companies led American corporate leaders to adopt Japanese methods, speeding up the diffusion of industrial robotics in the United States.

7. THE MICROCHIP'S ROLE IN THE SUCCESS OF AUTOMATION

A key technical and economic factor in the widespread success of various forms of automation technologies in the 1980s and 1990s was the development of the microprocessor.

This tiny electronic device was invented in the United States in the late 1970s, intended for use in calculators and computers. However, its utility as an industrial process controller was almost immediately exploited. Less well known to the public than the microprocessor, a similar device called the microcontroller outsells the microprocessor today. The original applications for the microcontroller were as an electronic replacement for electromechanical devices called process controllers, such as the ones used in chemical plants. Process controllers incorporated logic circuits that were usually not programmable.

They were used to regulate multistep industrial processes using a timed cycle. A familiar example of such a device is the electromechanical switch/timer used on home washing machines for many years. Process controllers using microprocessors or microcontrollers allowed convenient reprogramming, and eventually these were linked together to provide overall monitoring and control of plant activities from a remote central computer or control room.

8. SENSING AND CONTROL SYSTEM

A control system is a device or set of devices to manage, command, direct or regulate the behavior of other devices or systems.

There are two common classes of control systems, with many variations and combinations: logic or sequential controls, and feedback or linear controls. There is also fuzzy logic, which attempts to combine some of the design simplicity of logic with the utility of linear control. Some devices or systems are inherently not controllable.

The term "control system" may be applied to the essentially manual controls that allow an operator to, for example, close and open a hydraulic press, where the logic requires that it cannot be moved unless safety guards are in place. An automatic sequential control system may trigger a series of mechanical actuators in the correct sequence to perform a task. For example various electric and pneumatic transducers may fold and glue a cardboard box, fill it with product and then seal it in an automatic packaging machine.

In the case of linear feedback systems, a control loop, including sensors, control algorithms and actuators, is arranged in such a fashion as to try to regulate a variable at a set point or reference value. An example of this may increase the fuel supply to a furnace when a measured temperature drops. PID controllers are common and effective in cases such as this.

Control systems that include some sensing of the results they are trying to achieve are making use of feedback and so can, to some extent, adapt to varying circumstances. Open-loop control systems do not directly make use of feedback, but run only in pre-arranged ways.

8.1 LOGIC CONTROL

Pure logic control systems were historically implemented by electricians with networks of relays, and designed with a notation called ladder logic. Today, most such systems are constructed with programmable logic devices.

Logic controllers may respond to switches, light sensors, pressure switches etc and cause the machinery to perform some operation. Logic systems are used to sequence mechanical operations in many applications. Examples include elevators, washing machines and other systems with interrelated stop-go operations.

Logic systems are quite easy to design, and can handle very complex operations. Some aspects of logic system design make use of Boolean logic.

8.2 LINEAR CONTROL

Linear control systems use linear negative feedback to produce a control signal mathematically based on other variables, with a view to maintaining the controlled process within an acceptable operating range.

The output from a linear control system into the controlled process may be in the form of a directly variable signal, such as a valve that may be 0 or 100% open or anywhere in between. Sometimes this is not feasible and so, after calculating the current required corrective signal, a linear control system may repeatedly switch an actuator, such as a pump, motor or heater, fully on and then fully off again, regulating the duty cycle using pulse-width modulation.

8.3 FUZZY LOGIC

Fuzzy logic is an attempt to get the easy design of logic controllers and yet control continuously-varying systems. Basically, a measurement

in a fuzzy logic system can be partly true, that is if yes is 1 and no is 0, a fuzzy measurement can be between 0 and 1.

The rules of the system are written in natural language and translated into fuzzy logic. For example, the design for a furnace would start with: "If the temperature is too high, reduce the fuel to the furnace. If the temperature is too low, increase the fuel to the furnace."

Measurements from the real world (such as the temperature of a furnace) are converted to values between 0 and 1 by seeing where they fall on a triangle. Usually the tip of the triangle is the maximum possible value which translates to "1."

Fuzzy logic then modifies Boolean logic to be arithmetical. Usually the "not" operation is "output = 1 - input," the "and" operation is "output =

input.1 multiplied by input.2," and "or" is "output = 1 - ((1 - input.1) multiplied by (1 - input.2))."

The last step is to "defuzzify" an output. Basically, the fuzzy calculations make a value between zero and one. That number is used to select a value on a line whose slope and height converts the fuzzy value to a real-world output number. The number then controls real machinery.

If the triangles are defined correctly and rules are right the result can be a good control system.

When a robust fuzzy design is reduced into a single, quick calculation, it begins to resemble a conventional feedback loop solution. For this reason, many control engineers think one should not bother with it. However, the fuzzy logic paradigm may provide scalability for large control systems where conventional methods become unwieldy or costly to derive. Fuzzy electronics is an electronic technology that uses fuzzy logic instead of the two-value logic more commonly used in digital electronics.

8.4 PHYSICAL IMPLEMENTATIONS

Since modern small microcontrollers are so cheap (often less than $1 US), it's very common to implement control systems, including feedback loops, with computers, often in an embedded system. The feedback controls are simulated by having the computer make periodic measurements and then calculating from this stream of measurements (see digital signal processing, sampled data systems).

Computers emulate logic devices by making measurements of switch inputs, calculating a logic function from these measurements and then sending the results out to electronically-controlled switches.

Logic systems and feedback controllers are usually implemented with programmable logic controllers which are devices available from electrical supply houses. They include a little computer and a simplified system for programming. Most often they are programmed with personal computers.

Logic controllers have also been constructed from relays, hydraulic and pneumatic devices, and electronics using both transistors and vacuum tubes (feedback controllers can also be constructed in this manner).

9. ANTI LOCK BRAKING SYSTEM

An anti-lock braking system, or ABS (from the German, Antiblockiersystem) is a safety system which prevents the wheels on a motor vehicle from locking while braking.

A rotating road wheel allows the driver to maintain steering control under heavy braking by preventing a skid and allowing the wheel to continue interacting tactilely with the road surface as directed by driver steering inputs. While ABS offers improved vehicle control in some circumstances, it can also present disadvantages including increased braking distance on slippery surfaces such as ice, packed snow, gravel, steel plates and bridges, or anything other than dry pavement. ABS has also been demonstrated to create a false sense of security in drivers, who may drive more aggressively as a result.

Since initial widespread use in production cars, anti-lock braking systems have evolved considerably. Recent versions not only prevent wheel lock under braking, but also electronically control the front-to-rear brake bias. This function, depending on its specific capabilities and implementation, is known as electronic brake force distribution (EBD), traction control system, emergency brake assist, or electronic stability control.

9.1 OPERATION

A typical ABS is composed of a central electronic control unit (ECU), four wheel speed sensors — one for each wheel — and two or more hydraulic valves within the brake hydraulics. The ECU constantly monitors the rotational speed of each wheel, and when it detects a wheel rotating significantly slower than the others — a condition indicative of impending wheel lock — it actuates the valves to reduce hydraulic pressure to the brake at the affected wheel, thus reducing the braking force on that wheel. The wheel then turns faster; when the ECU detects it is turning significantly faster than the others, brake hydraulic pressure to the wheel is increased so the braking force is reapplied and the wheel slows. This process is repeated continuously, and can be detected by the driver via brake pedal pulsation. A typical anti-lock system can apply and release braking pressure up to 20 times a second.

The ECU is programmed to disregard differences in wheel relative speed below a critical threshold, because when the car is turning, the two wheels towards the center of the curve turn slower than the outer two.

For this same reason, a differential is used in virtually all roadgoing vehicles.

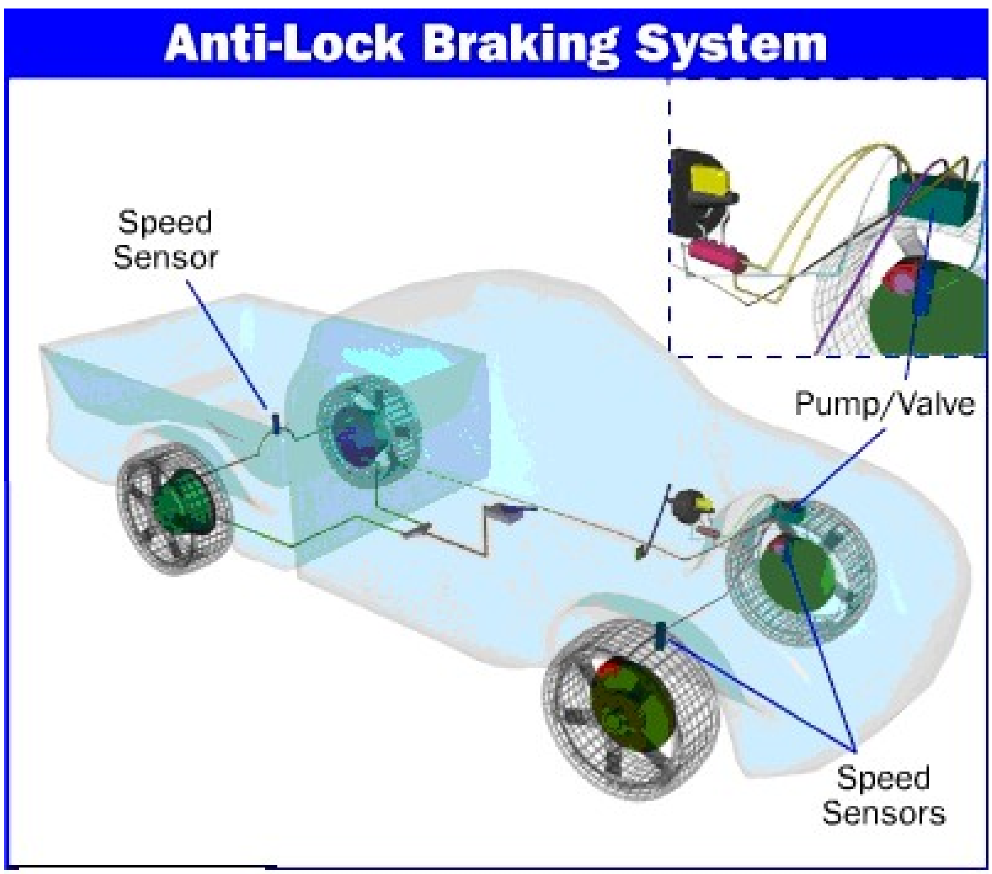
If a fault develops in any part of the ABS, a warning light will usually be illuminated on the vehicle instrument panel, and the ABS will be disabled until the fault is rectified.

9.2 ADDITIONAL DEVELOPMENTS

Modern Electronic Stability Control (ESC or ESP) systems are an evolution of the ABS concept. Here, a minimum of two additional sensors are added to help the system work: these are a steering wheel angle sensor, and a gyroscopic sensor. The theory of operation is simple: when the gyroscopic sensor detects that the direction taken by the car does not coincide with what the steering wheel sensor reports, the ESC software will break the necessary individual wheel(s) (up to three with the most sophisticated systems), so that the vehicle goes the way the driver intends. The steering wheel sensor also helps in the operation of Cornering Brake Control (CBC), since this will tell the ABS that wheels on the inside of the curve should brake more than wheels on the outside, and by how much.

9.3 RISK COMPENSATION

Anti-lock brakes are the subject of some experiments centered around risk compensation theory, which asserts that drivers adapt to the safety benefit of ABS by driving more aggressively. In a Munich study, half a fleet of taxicabs were equipped with anti-lock brakes, while the other half had conventional brake systems. The crash rate was substantially the same for both types of cab, and Wilde concludes this was due to drivers of ABS-equipped cabs taking more risks, assuming that ABS would take care of them, while the non-ABS drivers drove more carefully since ABS would not be there to help in case of a dangerous situation.[9] A similar study was carried out in Oslo, with similar results. RC devices. Voltage ratings vary from product to product, but most servos are operated at 4.8 V or 6 V DC from a 4 or 5 cell battery.



10. SERVOMECHANISM

10.1 INDUSTRIAL SERVOMOTOR

The grey/green cylinder is the brush-type DC motor. The black section at the bottom contains the planetary reduction gear, and the black object atop the motor is the optical encoder for position feedback. This is the steering actuator of a large robot vehicle.

A servomechanism, or servo is an automatic device which uses error-sensing feedback to correct the performance of a mechanism. The term correctly applies only to systems where the feedback or error-correction signals help control mechanical position or other parameters. For example an automotive power window control is not a servomechanism, as there is no automatic feedback which controls position—the operator does this by observation. By contrast the car's cruise control uses closed loop feedback, which classifies it as a servomechanism.

Servomechanisms may or may not use a servomotor. For example a household furnace controlled by thermostat is a servomechanism, yet there is no motor being controlled directly by the servomechanism. A common type of servo provides position control. Servos are commonly electrical or partially electronic in nature, using an electric motor as the primary means of creating mechanical force. Other types of servos use hydraulics, pneumatics, or magnetic principles. Usually, servos operate on the principle of negative feedback, where the control input is compared to the actual position of the mechanical system as measured by some sort of transducer at the output.

Any difference between the actual and wanted values (an "error signal") is amplified and used to drive the system in the direction necessary to reduce or eliminate the error. An entire science known as control theory has been developed on this type of system.

Servomechanisms were first used in military fire-control and marine navigation equipment. Today servomechanisms are used in automatic machine tools, satellite-tracking antennas, automatic navigation systems on boats and planes, and antiaircraft-gun control systems. Other examples are fly-by-wire systems in aircraft which use servos to actuate the aircraft's control surfaces, and radio-controlled models which use RC servos for the same purpose. Many autofocus cameras also use a servomechanism to accurately move the lens, and thus adjust the focus. A modern hard disk drive has a magnetic servo system with sub-micrometre positioning accuracy.

Typical servos give a rotary (angular) output. Linear types are common as well, using a screw thread or a linear motor to give linear motion. Another device commonly referred to as a servo is used in automobiles to amplify the steering or braking force applied by the driver. However, these devices are not true servos, but rather mechanical amplifiers. (See also Power steering or Vacuum servo.)In industrial machines, servos are used to perform complex motion.

10.2 *HISTORY*

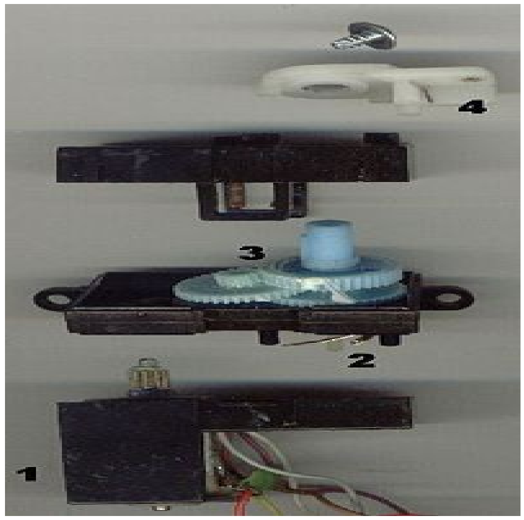
James Watt's steam engine governor, an automatic speed control, is generally considered the first powered feedback system. The windmill fantail is an earlier example of automatic control, but since it does not have an amplifier or gain, it is not usually considered a servomechanism.

The first feedback position control device was the ship steering engine, used to position the rudder of large ships based on the position of ship's wheel. This technology was first used on the SS Great Eastern in 1866. Steam steering engines had the characteristics of a modern servomechanism: an input, an output, an error signal, and a means for amplifying the error signal used for negative feedback to drive the error towards zero.

Electrical servomechanisms require a power amplifier. World War II saw the development of electrical fire-control servomechanisms, using an amplidyne as the power amplifier. Vacuum tube amplifiers were used in the UNISERVO tape drive for the UNIVAC I computer. Modern servomechanisms use solid state power amplifiers, usually built from MOSFET or thyristor devices. Small servos may use power transistors.

The origin of the word is believed to come from the french “Le-Servomoteur” or slavemotor, first used by Farcot in 1868 to describe hydraulic and steam engines for use in ship steering.

11. RC SERVOS



1. Small R/C servo mechanism.
2. electric motor.
3. position feedback potentiometer.
4. reduction gear. actuator arm

RC servos are hobbyist remote control devices servos typically employed in radio-controlled models, where they are used to provide actuation for various mechanical systems such as the steering of a car, the flaps on a plane, or the rudder of a boat.

RC servos are composed of a DC motor mechanically linked to a potentiometer. Pulse-width modulation (PWM) signals sent to the servo are translated into position commands by electronics inside the servo. When the servo is commanded to rotate, the DC motor is powered until the potentiometer reaches the value corresponding to the commanded position.Due to their affordability, reliability, and simplicity of control by microprocessors, RC servos are often used in small-scale robotics applications.

The servo is controlled by three wires: ground (usually black/orange), power (red) and control (brown/other colour). This wiring sequence is not true for all servos, for example the S03NXF Std. Servo is wired as brown(negative), red (positive) and orange (signal). The servo will move based on the pulses sent over the control wire, which set the angle of the actuator arm. The servo expects a pulse every 20 ms in order to gain correct information about the angle. The width of the servo pulse dictates the range of the servo's angular motion.

A servo pulse of 1.5 ms width will set the servo to its "neutral" position, or 90°. For example a servo pulse of 1.25 ms could set the servo to 0° and a pulse of 1.75 ms could set the servo to 180°. The physical limits and timings of the servo hardware varies between brands and models, but a general servo's angular motion will travel somewhere in the range of 180° - 210° and the neutral position is almost always at 1.5 ms.

Servo motors are usually powered from either NiCd or the more environmentally friendly Ni MH packs common to most RC devices. Voltage ratings vary from product to product, but most servos are operated at 4.8 V or 6 V DC from a 4 or 5 cell battery.

12. CRACK DETECTION

Evaluating the physical condition of an oil pipeline is critical to the pipeline operator for ensuring pipeline safety. Non Destructive Testing

(NDT)is one of the important methods used for evaluation and quality control of metal components. During testing , the metal component does not get damaged.

Ultrasonic testing , radiography magnetic particle testing and eddy current testing are some of the NDT methods.

12.1 RADIOGRAPHIC TESTING

Radiographic Testing (RT), or industrial radiography, is a nondestructive testing (NDT) method of inspecting materials for hidden flaws by using the ability of short wavelength electromagnetic radiation (high energy photons) to penetrate various materials.

Either an X-ray machine or a radioactive source (Ir-192, Co-60, or in rare cases Cs-137) can be used as a source of photons. Neutron radiographic testing (NR) is a variant of radiographic testing which uses neutrons instead of photons to penetrate materials. This can see very different things from X-rays, because neutrons can pass with ease through lead and steel but are stopped by plastics, water and oils.

Since the amount of radiation emerging from the opposite side of the material can be detected and measured, variations in this amount (or intensity) of radiation are used to determine thickness or composition of material. Penetrating radiations are those restricted to that part of the electromagnetic spectrum of wavelength less than about 10 nanometres.

Inspection of welds

The beam of radiation must be directed to the middle of the section under examination and must be normal to the material surface at that

point, except in special techniques where known defects are best revealed by a different alignment of the beam. The length of weld under examination for each exposure shall be such that the thickness of the material at the diagnostic extremities, measured in the direction of the incident beam, does not exceed the actual thickness at that point by more than 6%. The specimen to be inspected is placed between the source of radiation and the detecting device, usually the film in a light tight holder or cassette, and the radiation is allowed to penetrate the part for the required length of time to be adequately recorded.

The result is a two-dimensional projection of the part onto the film, producing a latent image of varying densities according to the amount of radiation reaching each area. It is known as a radiograph, as distinct from a photograph produced by light. Because film is cumulative in its response (the exposure increasing as it absorbs more radiation), relatively weak radiation can be detected by prolonging the exposure until the film can record an image that will be visible after development. The radiograph is examined as a negative, without printing as a positive as in photography. This is because, in printing, some of the detail is always lost and no useful purpose is served.

Before commencing a radiographic examination, it is always advisable to examine the component with one's own eyes, to eliminate any possible external defects. If the surface of a weld is too irregular, it may be desirable to grind it to obtain a smooth finish, but this is likely to

be limited to those cases in which the surface irregularities (which will be visible on the radiograph) may make detecting internal defects difficult.

After this visual examination, the operator will have a clear idea of the possibilities of access to the two faces of the weld, which is important both for the setting up of the equipment and for the choice of the most appropriate technique.

Defects such as delaminations and planar cracks are difficult to detect using radiography, which is why penetrants are often used to enhance the contrast in the detection of such defects. Penetrants used include silver nitrate, zinc iodide, chloroform and diiodomethane. Choice of the penetrant is determined by the ease with which it can penetrate the cracks and also with which it can be removed. Diiodomethane has the advantages of high opacity, ease of penetration, and ease of removal because it evaporates relatively quickly. However, it can cause skin burns.

12.2 BASIC PRINCIPLES OF EDDY CURRENT INSPECTION

Eddy current inspection is one of several NDT methods that use the principal of “electromagnetism” as the basis for conducting examinations. Several other methods such as Remote Field Testing (RFT), Flux Leakage and Barkhausen Noise also use this principle.

Eddy currents are created through a process called electromagnetic induction. When alternating current is applied to the conductor, such as

Copper wire, a magnetic field develops in and around the conductor. This magnetic field expands as the alternating current rises to maximum and collapses as the current is reduced to zero. If another electrical

Conductor is brought into the close proximity to this changing magnetic field; current will be induced in this second conductor. Eddy currents are induced electrical currents that flow in a circular path. They get their name from "eddies" that are formed when a liquid or gas flows in a circular path around obstacles when conditions are right.

Eddy Current Inspection

Eddy current inspection is used in a variety of industries to find defects and make measurements. One of the primary uses of eddy current testing is for defect detection when the nature of the defect is well understood.

In general, the technique is used to inspect a relatively small area and the probe design and test parameters must be established with a good understanding of the flaw that is to be detected. Since eddy currents tend to concentrate at the surface of a material, they can only be used to detect surface and near surface defects.

In thin materials such as tubing and sheet stock, eddy currents can be used to measure the thickness of the material. This makes eddy current a useful tool for detecting corrosion damage and other damage that causes a thinning of the material.

The technique is used to make corrosion thinning measurements on aircraft skins and in the walls of tubing used in assemblies such as heat exchangers. Eddy current testing is also used to measure the thickness of paints and other coatings.

Eddy currents are also affected by the electrical conductivity and magnetic permeability of materials. Therefore, eddy current measurements can be used to sort materials and to tell if a material has seen high temperatures or been heat treated, which changes the conductivity of some materials.

Eddy current equipment and probes can be purchased in a wide variety of configurations. Eddyscopes and a conductivity tester come packaged in very small and battery operated units for easy portability. Computer based systems are also available that provide easy data manipulation features for the laboratory. Signal processing software has also been developed for trend removal, background subtraction, and noise reduction. Impedance analyzers are also sometimes used to allow improved quantitative eddy-current measurements. Some laboratories have multidimensional scanning capabilities that are used to produce images of the scan regions. A few portable scanning systems also exist for special applications, such as scanning regions of aircraft fuselages.

12.3 ULTRASONIC TESTING

In ultrasonic testing, very short ultrasonic pulse-waves with center frequencies ranging from 0.1-15 MHz and occasionally up to 50 MHz are launched into materials to detect internal flaws or to characterize materials. The technique is also commonly used to determine the thickness of the test object, for example, to monitor pipe work corrosion.

Ultrasonic testing is often performed on steel and other metals and alloys, though it can also be used on concrete, wood and composites, albeit with less resolution. It is a form of non-destructive testing used in many industries including aerospace, automotive and other transportation sectors.

In ultrasonic testing, an ultrasound transducer connected to a diagnostic machine is passed over the object being inspected. The transducer is typically separated from the test object by a couplant (such as oil) or by water, as in immersion testing.

There are two methods of receiving the ultrasound waveform, reflection and attenuation. In reflection (or pulse-echo) mode, the transducer performs both the sending and the receiving of the pulsed waves as the "sound" is reflected back to the device. Reflected ultrasound comes from an interface, such as the back wall of the object or from an imperfection within the object. The diagnostic machine displays these results in the form of a signal with an amplitude representing the intensity of the reflection and the distance, representing the arrival time of the reflection. In attenuation (or through-transmission) mode, a transmitter sends ultrasound through one surface, and a separate receiver detects the amount that has reached it on another surface after traveling through the medium. Imperfections or other conditions in the space between the transmitter and receiver reduce the amount of sound transmitted, thus revealing their presence.

At a construction site, a technician tests a pipeline weld for defects using an ultrasonic phased array instrument. The scanner, which consists of a frame with magnetic wheels, holds the probe in contact with the pipe by a spring. The wet area is the ultrasonic couplant that allows the sound to pass into the pipe wall.

ADVANTAGES

1. High penetrating power, which allows the detection of flaws deep in the part.
2. High sensitivity, permitting the detection of extremely small flaws.
3. Only one surface need be accessible.
4. Greater accuracy than other nondestructive methods in determining the depth of internal flaws and the thickness of parts with parallel surfaces.
5. Some capability of estimating the size, orientation, shape and nature of defects.

6. No hazardous to operations or to nearby personnel and has no effect on equipment and materials in the vicinity.
7. Capable of portable or highly automated operation.

DISADVANTAGES

1. Manual operation requires careful attention by experienced technicians
2. Extensive technical knowledge is required for the development of inspection procedures.
3. Parts that is rough, irregular in shape, very small or thin, or not homogeneous are difficult to inspect.
4. Surface must be prepared by cleaning and removing loose scale, paint, etc, although paint that is properly bonded to a surface usually need not be removed.
5. Couplets are needed to provide effective transfer of ultrasonic wave energy between transducers and parts being inspected unless a non-contact technique is used. Non-contact techniques include Laser and Electro Magnetic Acoustic Transducers
6. Inspected items must be water resistant, when using water based couplets that do not contain rust inhibitors.

12.4 SMART PIG FOR PIPE INSPECTION

A pipeline inspection gauge or pig in the pipeline industry is a tool that is sent down a pipeline and propelled by the pressure of the product in the pipeline itself. It is the chief device used in pigging.

A pig in a cutaway pipeline

A "**Pig**" launcher/receiver, belonging to the natural gas pipeline in Switzerland.

There are four main uses for pigs:

1. physical separation between different liquids being transported in pipelines;
2. internal cleaning of pipelines;
3. inspection of the condition of pipeline walls (also known as an Inline Inspection (ILI) tool);
4. Capturing and recording geometric information relating to pipelines (e.g. size, position).

The original pigs were made from straw wrapped in wire used for cleaning. They made a squealing noise while traveling through the pipe, sounding to some like a pig squealing. The term "pipeline inspection gauge" was later created as a backronym. One kind pig is a soft, bullet shaped polyurethane foam plug that is forced through pipelines to separate products to reduce mixing. There are several types of pigs for cleaning. Some have tungsten studs or abrasive wire mesh on the outside to cut rust, scale, or paraffin deposits off the inside of the pipe. Others are plain plastic covered polyurethane. Pigs cannot be used in pipelines that have butterfly valves.

Inline inspection pigs use various methods for inspecting a pipeline. A sizing pig uses one (or more) notched round metal plates that are used as gauges. The notches allow different parts of the plate to bend when a bore restriction is encountered. More complex systems exist for inspecting various aspects of the pipeline. Intelligent pigs, also called smart pigs, are used to inspect the pipeline with sensors and record the data for later analysis. These pigs use technologies such as Magnetic flux leakage (MFL) and ultrasonic to inspect the pipeline. Intelligent pigs may also use calipers to measure the inside geometry of the pipeline.

In1961 the first intelligent pig was run by Shell Development. It demonstrated that a self contained electronic instrument could traverse a pipe line while measuring and recording wall thickness. The instrument used electromagnetic fields to sense wall integrity. In 1964 Tub scope ran the first commercial instrument. It used MFL technology to inspect the bottom portion of the pipeline. The system used a black box similar to those used on aircraft to record the information. A pig has been used as a plot device in three James Bond films: Diamonds Are Forever, where Bond disabled a pig to escape a pipeline, The Living Daylights, where a pig was modified to secretly transport a person through the Iron Curtain, and The World Is Not Enough, where a pig was used to move a nuclear weapon through a pipeline.

A pig was also used as a plot device in the Tony Hillerman book The Sinister Pig where an abandoned pipeline from Mexico to the United States was to use a pig to transport illegal drugs.

13. BENEFITS OF MECHATRONICS SYSTEM

- ENHANCED FEATURED AND FUCTIONALITY.
- MORE USER FRIENDLY
- PRECISION CONTROL
- MORE EFFICIENT
- LOWER COST.
- FLEXIBLE DESIGN(REPROGRAMABLE)
- SAFE
- SMALLER

14. ADVANTAGES OF MECHATRONIC SYSTEM

- Simplified mechanical design
- Rapid machine setup
- Cost-effectiveness
- Rapid development trials
- Possibilities for adaptation during commissioning
- Optimized performance, productivity, reliability

15. DISADVANTAGES OF MECHATRONIC SYSTEM

- Different expertise required
- More complex safety issues
- Increase in component failures
- Increased power requirements
- Lifetimes change/vary
- Real time calculations/mathematical models.

CONCLUSION

The purpose of this interdisciplinary engineering field is the study of automata from an engineering perspective and serves the purposes of controlling advanced hybrid systems. Hybrid-systems important to Mechatronics include production systems, synergy drives, planetary exploration rovers, automotive subsystems such as anti-lock braking systems, spin-assist and every day equipment such as autofocus cameras, video, hard disks, CD-players.

16. REFERENCE

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