Course Material

Name of the Course : Mechatronics

Name of the Unit : Introduction to Mechatronics Systems

Name of the Topic : Concept and Components of Mechatronics systems and Importance of Mechatronics in automation

Objectives: To understand the various definitions and concept of the mechatronics and also to impart knowledge about the various components of mechatronics which are very much essential to understand the emerging field of automation.

Outcomes: Upon successful completion, the student should be able to understand the principles of the basic components and implement their ideas to ddemonstrate the basic structure of mechatronics system.

Pre-requisites: To have a basic knowledge of various measurement systems and working principle of different electrical systems.

1. The spring material used in a spring control device should have the following property.

   (A) Should be nonmagnetic
   (B) Most be of low temperature coefficient
   (C) Should have low specific resistance
   (D) All of the above

2. A galvanometer has

   (A) Air friction damping
   (B) Fluid friction damping
   (C) Eddy current damping
   (D) Spring coil damping

3. The resistance can be measured most accurately by

(A) Voltmeter-ammeter method
(B) Bridge method
(C) Multimeter
(D) Megger

4. To measure the flux, devices used are based on

(A) Voltaic effect
(B) Piezo-electric effect
(C) Hall effect
(D) Photo-voltaic effect

5. Wagner earthing device is used to eliminate errors due to

(A) Electrostatic coupling
(B) Electromagnetic coupling
(C) Both A and B
(D) None of the above

6. The repeat accuracy of an instrument can be judged from its

(A) Static error
(B) Linearity error
(C) Dynamic error
(D) Standard deviation of error

7. An instrument to be used for measurement and control should preferably have

(A) Dead zone and dead time
(B) Linear output and fast response
(C) Non-linear output
(D) A highly damped response

8. Which instrument has identical calibration for AC as well as DC values?

(A) Hot wire type
(B) Moving coil type
(C) Induction type
(D) Moving iron type

9. The thermocouple instruments do not have

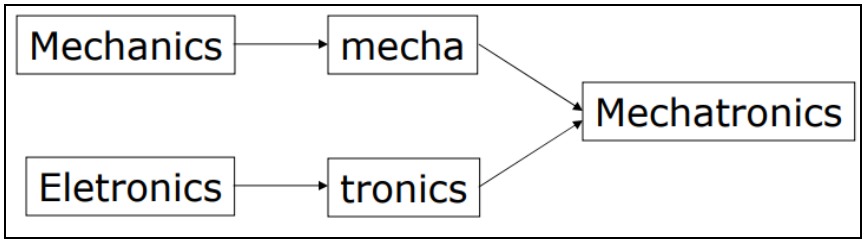
(A) High sensitivity
(B) Absence of frequency error
(C) Independence of ambient temperature
(D) High degree of measuring accuracy

10. The advantages of moving coil permanent magnet type instrument are

(A) Low power consumption
(B) No hysteresis loss
(C) Efficiency eddy current damping
(D) All of the above

1. Definitions of the term Mechatronics

(i) T. Mori (1969) expressed the word 'mechatronics' that it is composed of **mecha** from mechanics and **tronics** from electronics. 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.



(ii) W. Bolton (1995) expressed the term mechatronics that is the Integration of electronics, control engineering, and mechanical engineering.

(iii) D. M. Auslander and C. J. Kempf (1996) defined as it is the application of complex decision making to the operation of physical systems.

(iv) F. Harshama, M. Tomizuka, and T. Fukuda (196) expressed as, it is the synergistic integration of mechanical engineering with electronics and intelligent computer control in the design and manufacturing of industrial products and processes.

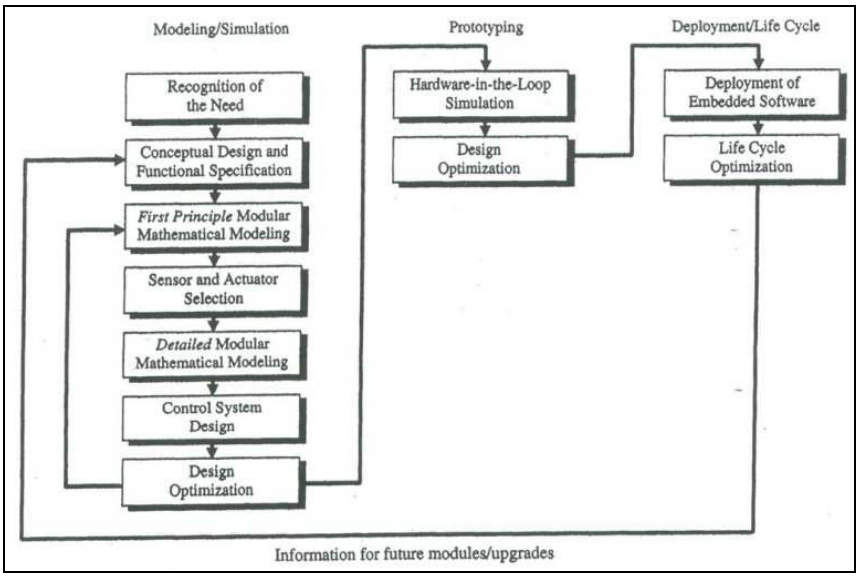
(v) It is the synergistic use of precision engineering, control theory, computer science, and sensor and actuator technology to design improved products and processes defined by S. Ashley (1997).

(vi) It is the field of study involving the analysis, design, synthesis, and selection of systems that combine electronics and mechanical components with modern controls and microprocessors by D. G. Alciatore and M. B. Histand (1998).

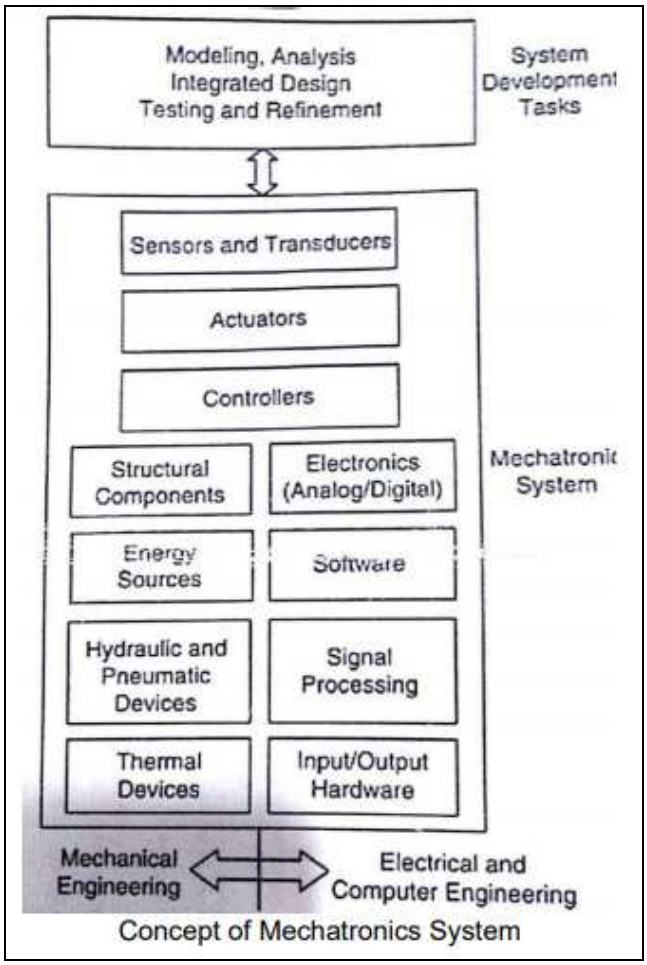
2. Mechatronics-based Product Realization

- Systems engineering allows design, analysis, and synthesis of products and processes involving components from multiple disciplines.
- Mechatronics exploits systems engineering to guide the product realization process from design, model, simulate, analyze, refine, prototype, validate, and deployment cycle.
- In mechatronics-based product realization: mechanical, electrical, and computer engineering and information systems are integrated throughout the design process so that the final products can be better than the sum of its parts.

Mechatronic Design Process



3. Concept of Mechatronics design



4. Evolution Level of Mechatronics

i. Primary Level Mechatronics

This level incorporates I/O devices such as sensors and actuators that integrates electrical signals with mechanical action at the basic control levels.

Examples: Electrically controlled fluid valves and relays

ii. Secondary Level Mechatronics

This level integrates microelectronics into electrically controlled devices.

Examples: Cassette players

iii. Third Level Mechatronics

This level incorporates advanced feedback functions into control strategy thereby enhancing the quality in terms of sophistication called smart system.

Examples: Control of Electrical motor used to activate industrial robots, hard disk, CD drives and automatic washing machines.

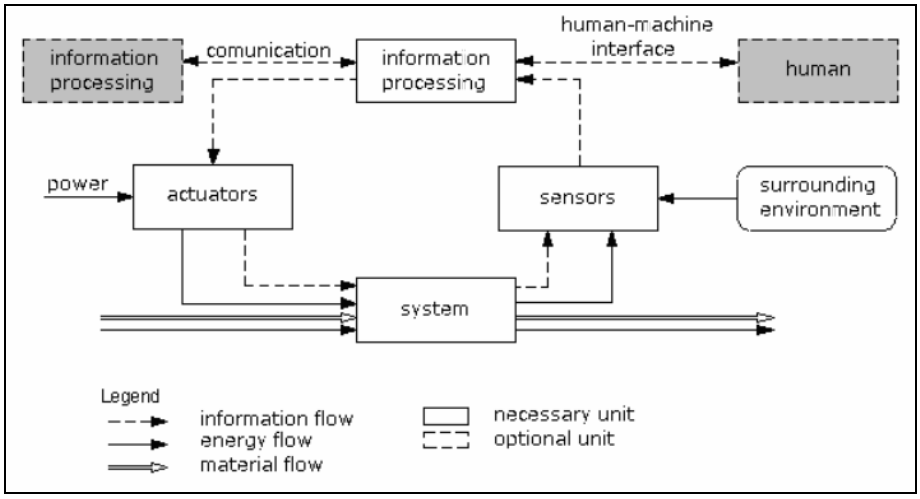
iv. **Fourth Level Mechatronics:**

This level incorporates intelligent control in mechatronics system. It introduces intelligence and fault detection and isolation (FDI) capability systems

5. Basic structure

The basic structure of the mechatronic system which carries the sensors, actuators, and devices for information processing. The surrounding environment, in which the mechatronic system operates, is also important. A diagram of this structure is shown in Figure. The system has usually a mechanical, electro mechanical or hydraulic structure or it is a combination of these structures. It means that a given physical system can be generally understood as a respective system that can be represented by a hierarchically structured mechatronic system. A task of sensors is to determine a chosen state variable value of the system.

In this case, the sensors can be physically represented by the measured values or software sensors so called observers. The sensors supply input variables for the information processing, at present usually digital, i.e. discrete in terms of values and time. The information processing is usually done by a microprocessor although it can be also done by a fully analog electronics or combined (hybrid) analog/digital electronics. The information processing determines actions needed to affect appropriately the state variables of the system. An implementation of the actions is directly in the system by actuators.



The goal of the mechatronic system is a spatial integration with other functional elements in the area of sensors as well as in the area of actuators. It would create an intelligent unit, i.e. an intelligent sensor (integration of a measured values sensor, an analog/digital converter and a microprocessor) and an intelligent actuator (an integration of a digital/analog converter, an adapter circuit or a power amplifier, or even a microprocessor). The intelligent sensor measures analog physical quantities, for example pressure, temperature, velocity, it digitalizes 8 measured values and transfers the signal – suitably adjusted – to information processing devices. The intelligent actuator is directly activated by the digital signal coming from the corresponding information processing device.

Signals are converted to analog variables, amplified and then handed over, e.g. to create force or movement. A closer look at relations between the system, the sensors, the information processing and the actuators shows that a description of the relations using flows is useful.

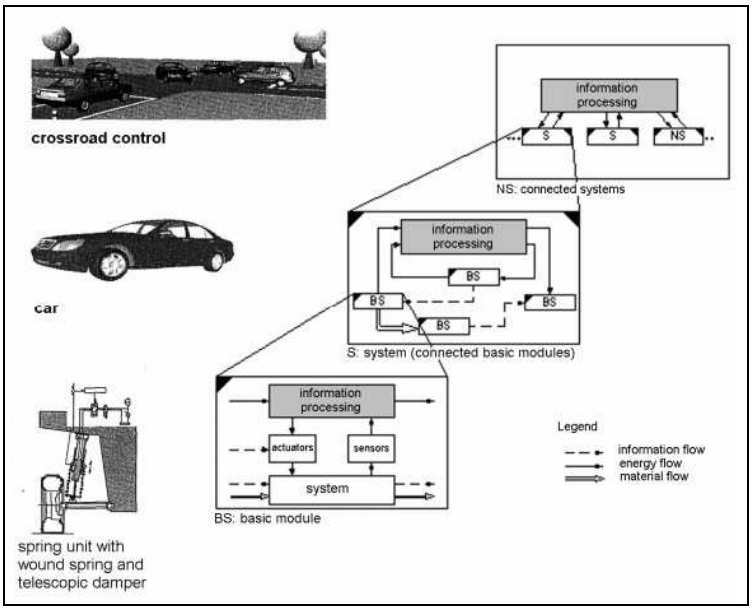
In principle, there are three different types of flows:
(i) material flow, (ii) energy flow, and (iii) information flow.

The mechatronic system, shown in above Figure which consists of units connected by three types of flows. The most visible are energy and material flows. Flows connecting the base system and environment with sensors and actuators have a character of energy flow as well as information flow – energy flows for measurement requirements (sensors) as well as for action execution (actuators) but energy is transferred as well – control signals of actuators and measurement signals of sensors. Tools for information processing use the information flow from sensors and also generate the information flow for the actuators. One main energy flow affecting, directly or indirectly, the system can be noticed in case of energy flows. Communication with a human or a system user is usually realized by a special human-machine interface. The connection is represented by the information flow in both cases.

6. Modularization and hierarchization

Complex mechatronic systems are usually made by synergetic integration of different mechatronic modules, i.e. elements of system or components connected to groups, jointly executing a certain function. It is not recommended to make the integration at one level but it is necessary to separate the configuration according to the principle of hierarchization because the modules contain and constitute different functions. A higher-level system is made if more basic modules are connected together by its functional mechatronic structure and mechanic supporting structure.

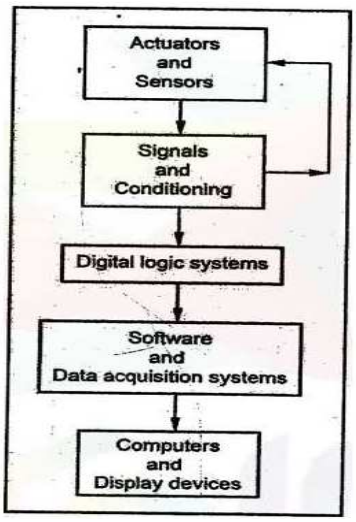
At this higher level, the other tasks are realized according to the events monitored by a sensor system and evaluated by the information - processing unit. A target value for the subordinate basic mechatronic modules is generated at this level of hierarchic structure as well as error diagnosis and algorithm monitoring. Another hierarchic level, at which the basic modules and already grouped systems are simply connected by the information processing units, is suitable if the mechatronic system would do other tasks, for example process of learning or adaptation.



A sample of mechatronic system's hierarchical structure is shown in the above Figure. The basic modules at the first level (e.g. a spring unit with wound spring and telescopic damper) are connected to the second level (e.g. car) by the information processing. The created systems are connected together by information processing (e.g. crossway control) at the third level. A spatial integration of related equipment is also an important task as well as functional integration of the mechatronic modules. Modules of equipment have to be integrated through defined interfaces to create a whole system with individual hierarchical levels (mechatronic units). A simultaneous considering of both integration tasks leads to the optimally constructed mechatronic systems.

7. Basic Elements of Mechatronics System

The various elements in typical mechatronic systems are shown in Figure.



(i) Sensors and actuators

Sensors and actuators mostly come under mechanical systems. The actuators produce motion or cause some action. The sensors detect the state of the system parameters, inputs, and outputs. The various actuators .used in the mechatronic system are pneumatic and hydraulic actuators, electro-mechanical actuators, electrical motors such as DC motors, AC motors, stepper motors, servomotors, and piezoelectric actuators. The various types of sensors used in the mechatronic system are linear arid rotational sensors, acceleration sensors, force, torque and pressure sensors, flow sensors, temperature sensors, proximity sensors, light sensors.

(ii) Signals and conditioning

The mechatronic systems deal with two types of signals and conditioning such as - input and output. The input devices receive input signals from the mechatronic systems via interfacing devices and sensors. Then it is sent to the control circuits for conditioning or processing. The various input signal conditioning devices used in the mechatronic system are discrete circuits, amplifiers, Analog-to-Digital (A/D) converters, Digital-to-Digital (DZD) convertors. The output signals from the system are sent to output/display devices through interfacing devices. The various output signal conditioning devices used in the mechatronic system are Digital-to-Analog (D/A) converters, Display Decoders (DD) converters, amplifiers, power transistors, and power op-amps.

(iii) Digital logic systems

Digital logic devices control overall system operation. The various digital logic systems used in the mechatronic system are logic circuits, microcontrollers, programmable logic controllers, sequencing and timing controls, and control algorithms.

(iv) Software and data acquisition systems

The data acquisition system acquires the output signals from sensors in the form of voltage, frequency, resistance etc. and it is inputted into the microprocessor or computer. Software is used to control the acquisition of data through DAC board. The data acquisition system consists of a multiplexer, amplifier, register, and control circuitry and DAC board. The various data acquisition systems used in the mechatronic system is data loggers, computer with plug-in boards, etc.

(v) Computers and display devices

Computers are used to store a large number of data and process further through software. Display devices are used to give visual feedback to the user. The various display devices used in the mechatronic system are LEDs, CRT, LCD, digital displays, etc.

8. Fields of application

i. High-speed laser cutting and engraving systems of extreme accuracy,
ii. Measuring systems with optical and mechanical scanning,
iii. Micro-assembly systems,
iv. Wafer inspection and machining.

Remote Robot Arm Manipulation

Remote Emergency Notification System

Type X

The Smart Walker

Smart Irrigation System

Safe N Sound Driver

Remote Emergency Notification System

Smart Cane

9. Real life applications of Mechatronics

i. In Health Care

Robotic surgery has been around since 2000, when the da Vinci Surgical System was approved by the FDA. The robot includes a camera on one arm and surgical equipment on the other. Using a robot to perform surgery has many benefits, including being less invasive, which leads to faster recovery and less risk of infection.

New surgical robots are being developed for eye surgery, targeting lung cancer, knee surgery, and laparoscopic surgeries. One robot, called CorPath, is enabling surgeons to perform procedures from a distance. In December 2018, CorPath was used by a surgeon to conduct an elective procedure on a patient that was 20 miles away. Read more about this revolutionary procedure.

ii. Around the House

Refrigerators that can order milk when you are running low. Washers that text you when the load is ready for the dryer. Vacuums that carry cats around the house while they clean your hardwood floors. All of these devices are available due to mechatronics. And, of course, who is ever without their smart phone? A cell phone's camera, for example, uses mechatronics to take cute pictures and videos of your cat riding that robotic vacuum.

iii. In the Car

Mechatronics engineering has saved thousands of lives through the advent of anti-lock brakes and stabilization, air bag inflation, and fully autonomous vehicles. The U.S. Postal System is even testing autonomous trucks to deliver the mail.

iv. In Manufacturing

The manufacturing process has become largely automated, and that is frequently due to integration of mechatronics. Industrial robots perform consistently and quickly, enabling manufacturers to keep up with demand while reducing costs. Like many other areas, manufacturing has adopted smart technology to ensure efficiency.

v. For Exploration

The Mars rovers Spirit and Opportunity provided a view of the red planet that had never been seen, sending to Earth a combined 342,432 pictures. Some proposed uses for mechatronics in space exploration include robotic arms on the International Space Station, development of life-sustaining systems on the moon or otherwise uninhabitable planets, or flying robots to examine planets' surfaces.

Test after completion

1. Which of the following are characteristics of mechatronic products and systems?

   (A) Functional interaction between mechanical, electronic and information technologies
   (B) Spatial interaction of subsystems in one physical unit
   (C) Intelligence related to the control functions of the mechatronics system
   (D) All of the above

2. A group of components which can complete certain tasks or achieve certain desired results in a desired manner while working together is called as_____

   (A) Output system
   (B) Sequence system
   (C) Control system
   (D) All of the above

3. In which system does the output not affect the process in any way?

   (A) Open loop system
   (B) Closed loop system
   (C) Both a. and b.
   (D) None of the above

4. Which of the following cannot be an input that is given to the PLC?

   (A) Manual switches
   (B) Relays
   (C) Sensors
   (D) None of the above

5. On-off Control is also called as _____.

   (A) One position control
   (B) Two position control
   (C) Four position control
   (D) Half position control

Conclusion

- The various definitions and concepts of mechatronics system are thoroughly studied to impart and develop the new mechatronics design.
- The working principle and various stages of the elements of mechatronics components are discussed in stage by stage.
- Mechatronics consists of integration of mechanical engineering with electronics, computer systems, and advanced controls to design, construct, and operate products and processes.
- In the industry is currently an increasing demand to acquire the core skills of mechanical engineers and electrical engineers as well as management and business.
- Their knowledge enables them to solve a wide range of mechanical, electrical and software problems, allowing them to participate in and lead multidisciplinary design teams.
- The knowledge gained from the fundamentals of the various mechatronic systems on the real life applications.

Demo Videos

https://www.youtube.com/watch?v=4Eaou2pOGGo

https://www.youtube.com/watch?v=bVD2w2drhaU

https://www.youtube.com/watch?v=3WBdpbhR4AU

References

1. W. Bolton, "Mechatronics", Pearson Education, 3rd Edition, 2007.
2. Michael B. Histand and David G. Alciatore, " Introduction to Mechatronics and Measurement Systems", McGraw-Hill International Editions, 2007. 3rd Edition