INDUSTRIAL AUTOMATION

Basic concepts and applications

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INDUSTRIAL AUTOMATION

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SYNOPSIS

The Industrial Automation e-book prepares mechatronics students the fundamental concept of industrial automation including the mechanical system and sensory devices in based on process specification. It also gives student an understanding of modern industrial automation technology.

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INTRODUCTION

INDUSTRIAL AUTOMATION

CHAPTER 1:
INTRODUCTION INDUSTRIAL AUTOMATION

1.1 DEFINITION OF INDUSTRIAL AUTOMATION

Industry

Systematic economic activity that may be connected to trade, service and manufacture.

Automation

The Greek words "Auto" (self) and "Matos" are the origin of the word "automation" (moving). Therefore, automation is the means by which "move by itself" systems operate. But in addition to this original meaning, automated systems perform substantially better than what is achievable with manual systems in terms of strength, accuracy, and speed of operation.

A technique based on the use of mechanical, electrical, and computer systems in handling processes and industrial process control is referred to as automation. Automation technology was first used when machines began to replace manual labour and workers.

Industrial Automation

the use of machines for jobs that were once completed by humans. Although the term "mechanization" is frequently used to describe the straightforward substitution of machines for human labour, automation typically evokes the incorporation of machines into a self-governing system. Figure 1.1 depicts a manufacturing line application of industrial automation{1}.

Figure 1.1 : Industrial Automation Application In Car Manufacturing

What is Industrial Automation?
https://www.youtube.com/watch?v=tw-79FiRYKA

YouTube

1.2 ADVANTAGES/DISADVANTAGES OF INDUSTRIAL AUTOMATION

ADVANTAGES	DISADVANTAGES
INCREASE PRODUCTIVITY	HIGH START UP COST
INCREASE PRODUCT QUALITY	COMMISSIONING COST
REDUCE LABOR COST	MAINTENANCE COST
SOLVE PROBLEM FACE BY SHORTAGE SKILL WORK FORCE	OBSOLESCENCE COST
INCREASE LABOR REQUEST IN OTHERS SERVICE SECTOR	
SAFER WORK CONDITION	
INCREASED MANUFACTURING FLEXIBILITY	
CONTROLLED AND FASTER INVENTORY TURNOVER	
REDUCE MATERIAL WASTAGE DUE TO HUMAN ERROR	

1.3 AIM OF AUTOMATION

Automation aims to reduce and eliminate direct worker engagement in process interactions.Only by installing automatically controlled machinery, then only the aim is achievable. In the industrial, the labor's function has changed from direct engagement to indirect by involving in programming and/or monitoring the automated machinery.

1.4 TYPES OF AUTOMATION

There are 3 types of the automation which are fixed automation, flexible automation and programmable automation

Fixed Automation

This type of automation is suitable for machine that is design for specific product and cannot be usage on different type product, product that has been modified or the product has been stop manufacturing. It is suitable for high volume production

Flexible Automation

This automation is suitable for different product in the same time by same manufacturing system.

Programmable Automation

This type of automation is suitable for low volume production and different type of product need to be manufacture.

Three different types of automation fixed automation, flexible automation and programmable automation have its own function based on the production line needed. In the production line, some line may produce variety of product but some line require to produce the product in mass quantity. This is the reason that choose the correct types of automation is important based on the production need. The product variety are inversely proportional to the product quantity based on the different types of automation.

The product variety and product quantity relationship with the different types of automation are shown in the Figure 1.2.

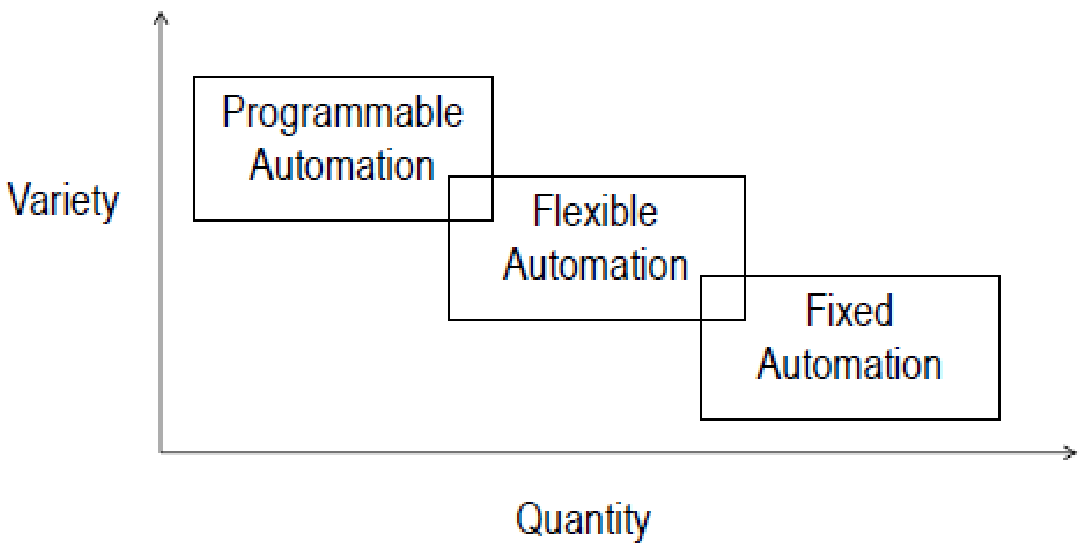

Figure 1.2 : Industrial Automation Application In Car Manufacturing

1.5 AUTOMATION IN PRODUCTION SYSTEM

- Robot Industry.
- Automatic machine tool for producing component.
- Automatic assembly machine.
- Automatic material handling and product storage.
- Automatic product inspection for quality control.
- Feedback control and computerized process control.
- computer system for planning, data collection and decision making for supporting manufacturing activities.

1.6 AUTOMATION AND ROBOTIC

Automation refer to a technology which based on the usage of mechanical, electronic and computer system in handling process and manufacturing process control.

Robotic is the main component in the industrial automation which will effect on human labor aspect on each level from lower skill labor until higher skill labor.
***** Conclusion** robot is part of industrial automation.

1.5 BASIC CONCEPT OF AUTOMATION TERMINOLOGY

Link and Joint	Joints or axes found in the manipulator (robotic arm). Axis consists of two types, major axis comprising the base, shoulder and elbow and minor axis comprising wrist pitch, wrist roll and wrist yaw.
Degree of Freedom	The number of real movement and level of complexity of the task can be done by a robot is determined by the degree of freedom available to a robot. In general, the robot has three degrees of freedom, namely the axis of x, y and z. These robots are more sophisticated with more axes of motion.
Orientation Axes	Movement of robots end effector or minor axes to go where directed. Rotary degrees of freedom
Position Axes	Part of a robot can move to a spot within its work envelope, using devices that tell it exactly where it is. Translatory degrees of freedom.
Tool Centre Point (TCP	It is the point of action for tool mounted on the robots tool holes. Tool midpoint is the reference point of tools controlled by the robot.
Work envelope/ workspace	Volume / area where the robotic arm can perform task / work.
Speed	The rate of movement from point to point done by robots under the control of the program. It is a measure of the speed of the device.

1.5 BASIC CONCEPT OF AUTOMATION TERMINOLOGY

Payload	The maximum burden can be moved / transferred by the robot during the programme control. It includes gripping and lifting heavy products / components. During this load lifting robot arm maintains its repeatability and reliability.
Repeatability	The degree ability of a robotic arm to detect targets have been set correctly and then return to its original point in the work cell. The robot has a high repeatability will be able to repeat the task with the right repeatedly without error.
Accuracy	The degree of ability that can be made by a robotic arm to move to a certain point in the work cell as we enter the coordinates in the off-line programming station (off-line programming).
Settling Time	The time-instant when the actual output converges to the desired output is known as the *settling time.*

1.5 BASIC CONCEPT OF AUTOMATION TERMINOLOGY

Control Resolution	The potential of the robot's positioning system to split the range of motion of each joint into precisely spaced points. Resolution is the capability of a robotic vision system to identify objects that are closely berween each other. The level of which the system can provide details about an item within an object is referred to as resolution. It provides an exact evaluation of image quality. It is also known as definition. In a robotic vision system, the resolution is the “sharpness” of the image.
Coordinates	Points are programmed in the cells identified job position by using the values of the coordinates x, y and z of the tools midpoint and extension angles at the wrist axis robot arm is pitch, roll and yaw.

EXERCISE

1. Please state the advantages of application automation in manufacturing
2. Please compare 3 different types of automation
3. What are the advantages of automation to a human?
4. Explain the terminology of the degree of freedom.

CHAPTER 2

APPLICATION AUTOMATION SYSTEM

CHAPTER 2:

APPLICATION AUTOMATION SYSTEM

2.1 AUTOMATION SYSTEM

Automation system is an integration of sensors, controls, and actuators designed to perform a function with minimal or no human intervention. The Figure 2.1 show the example of automatic welding robot as part of the automation system.

Figure 2.1 : Automatic Welding Robot

Automation system is important as our world have move toward to the Industry Revolution (IR) 4.0. Automation and the automation and robotic start as early as the Industry Revolution 3.0.

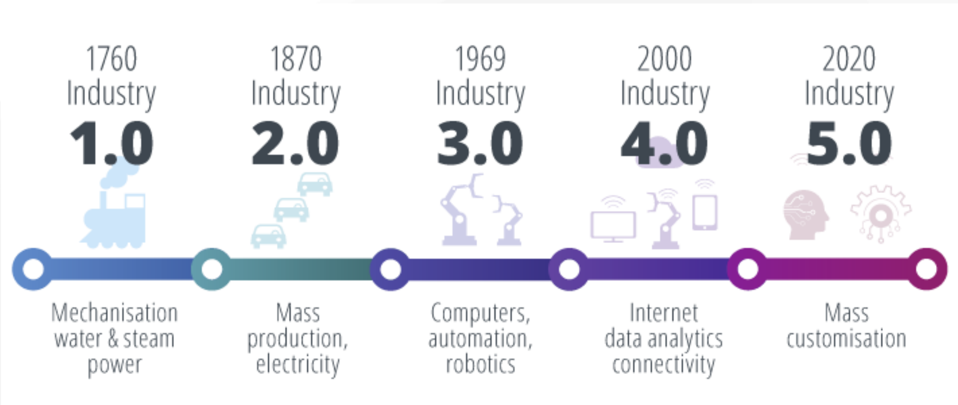

Figure 2.2 : Timeline of Industrial Revolution

In IR4.0, automation creates a manufacturing system whereby machines in factories are augmented with wireless connectivity and sensors to monitor and visualise an entire production process and make autonomous decisions.

2.3 BASIC COMPONENT OF AN AUTOMATION SYSTEM

Power

To accomplish the process and operate the automated system.

Program of Instruction

To direct the process.

Control System

To actuate the instructions.

In the Figure 2.1 show the process flow of automation system between the power, program of instructions, control system and process.

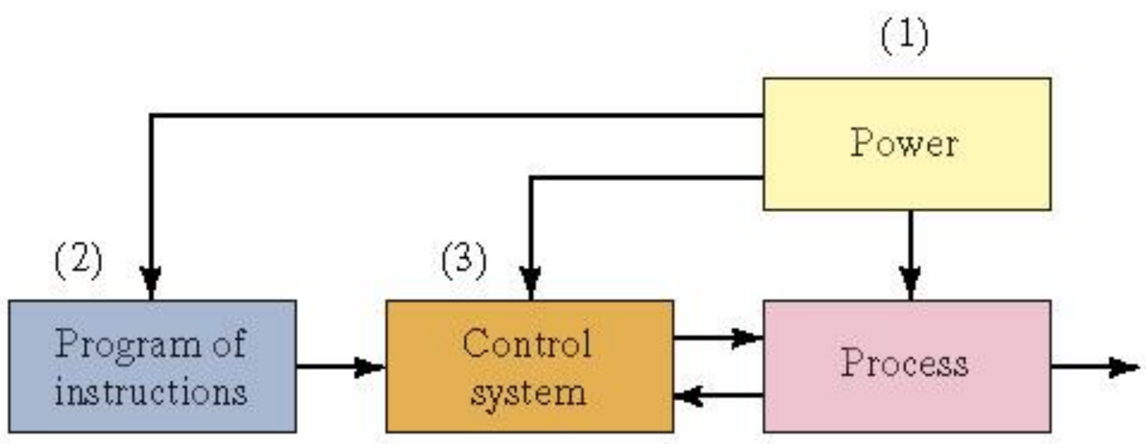

Figure 2.3 : Process Flow of Automation System

2.4 POWER IN AUTOMATION SYSTEM

Power for the process

To drive the process itself

To load and unload the work unit

Transport between operations

Power for automation

Controller unit

Power to actuate the control signals

Data acquisition and information processing

Can be readily converted to alternative forms, e.g., mechanical, thermal, light, etc.

Low level power can be used for signal transmission, data processing, and communication

Can be stored in long-life batteries

2.5 PROGRAM OF INSTRUCTIONS IN AUTOMATION SYSTEM

Set of commands that specify the sequence of steps in the work cycle and the details of each step

- Example: CNC part program
- During each step, there are one or more activities involving changes in one or more process parameters

Examples:

- Temperature setting of a furnace
- Axis position in a positioning system
- Motor on or off

The following are examples of automated work cycles in which decision making is required:

Operator interaction

Automated teller machine

Different part or product styles processed by the system

Robot welding cycle for two-door vs. four door car models

Variations in the starting work units

Additional machining pass for oversized sand casting

2.6 CONTROL SYSTEM

1. Closed-loop (feedback) control system – a system in which the output variable is compared with an input parameter, and any difference between the two is used to drive the output into agreement with the input.

2. Open-loop control system – operates without the feedback loop

Simpler and less expensive

Risk that the actuator will not have the intended effect

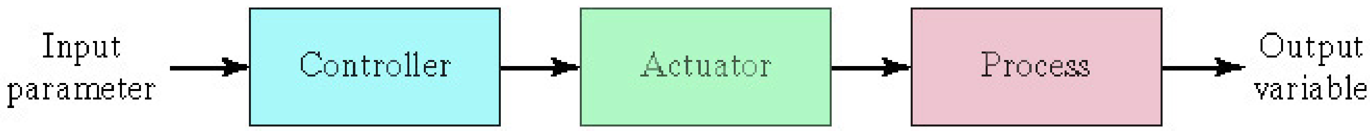

Figure 2.4 : Open-Loop System

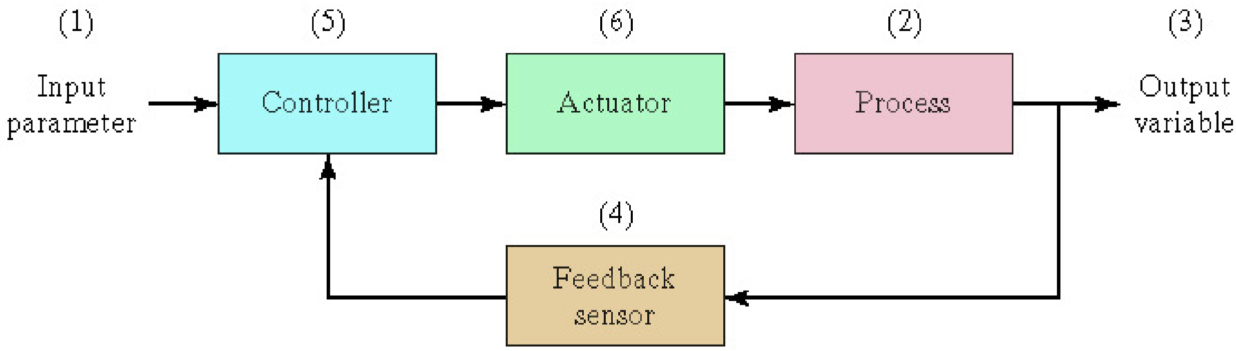

Figure 2.5 : Closed-Loop System

2.6.1 OPEN LOOP SYSTEM

- Actions performed by the control system are simple
- Actuating function is very reliable
- Any reaction forces opposing the actuation are small enough as to have no effect on the actuation

2.6.2 CLOSED LOOP SYSTEM

- A process can be kept on set point within a given accuracy.
- Corrections to process disturbances are automated.
- Unstable processes can be stabilized.

2.7 LEVEL OF AUTOMATION SYSTEM

1. Device level – actuators, sensors, and other hardware components to form individual control loops for the next level

2. Machine level – CNC machine tools and similar production equipment, industrial robots, material handling equipment

3. Cell or system level – manufacturing cell or system

4. Plant level – factory or production systems level

5. Enterprise level – corporate information system

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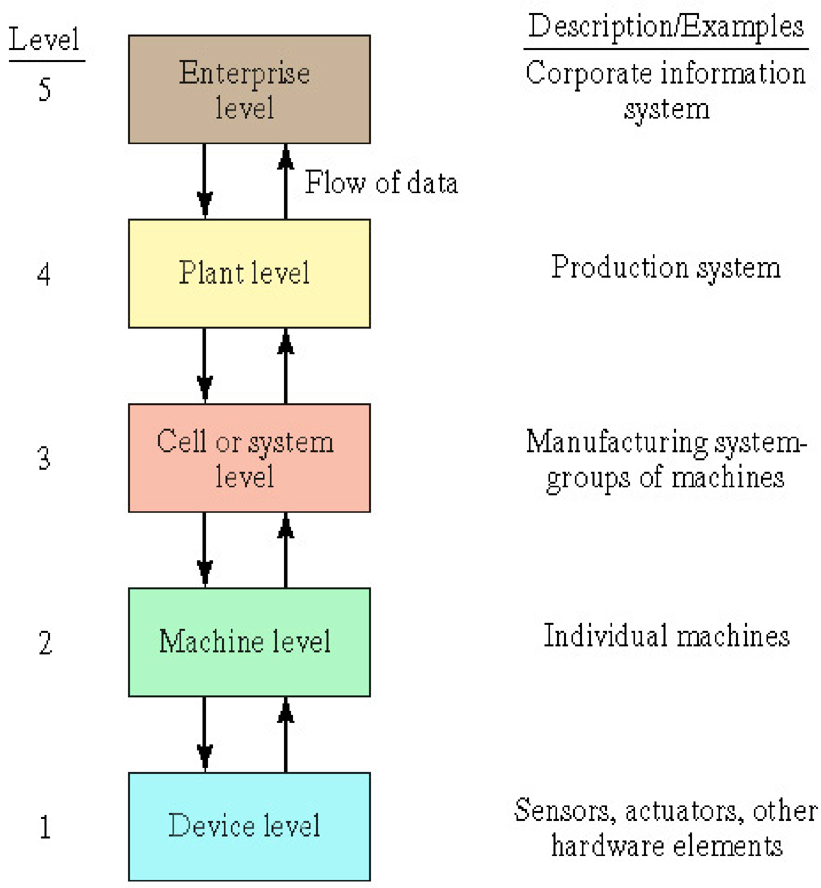


Figure 2.6 : Level of Automation System

2.8 APPLICATION AND FUNCTION OF AN AUTOMATION SYSTEM

An automation systems must be able to handle as many tasks and processes as possible quickly, easily and without errors.

Application Examples: Single Station Manned Cells

Most industrial production operations are based on the use of single station manned and automated cells. Let us expand the list here:

A CNC machining center. The machine executes a part program for each part. The parts are identical. A worker is required to be at the machine at the end of each program execution to unload the part just completed and load a raw work part onto the machine table.

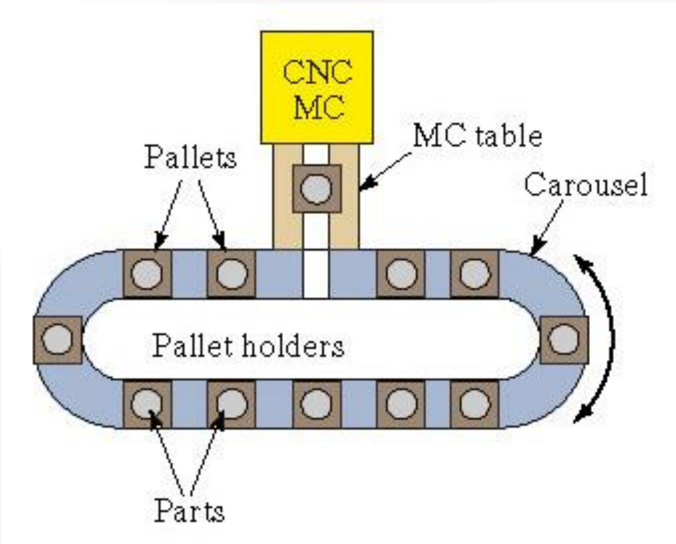


Figure 2.7 : Single Celled Automation System

2.9 MANUFACTURING SYSTEM

A collection of integrated equipment and human resources, whose function is to perform one or more processing and/or assembly operations on a starting raw material, part, or set of parts

Equipment includes

- Production machines and tools
- Material handling and work positioning devices
- Computer systems
- Human resources are required either full-time or periodically to keep the system running

Examples

- Single-station cells
- Machine clusters
- Manual assembly lines
- Automated transfer lines
- Automated assembly systems
- Machine cells (cellular manufacturing)
- Flexible manufacturing systems

2.10 COMPONENTS OF A MANUFACTURING SYSTEM

1. Production machines
2. Material handling system
3. Computer system to coordinate and/or control the preceding components
4. Human workers to operate and manage the system
5. In virtually all modern manufacturing systems, most of the actual processing or assembly work is accomplished by machines or with the aid of tools

2.11 CLASSIFICATION OF PRODUCTION MACHINES:

Manually Operated Machine

Manually operated machines are controlled or supervised by a human worker. The machine provides the power for the operation and the worker provides the control. The entire work cycle is operator controlled.

Semi-Automated Machine

A semi-automated machine performs a portion of the work cycle under some form of program control, and a worker tends to the machine for the remainder of the cycle. Typical worker tasks include loading and unloading parts

Fully-Automated Machine

Machine operates for extended periods (longer than one work cycle) without worker attention

2.11 CLASSIFICATION PRODUCTION MACHINE

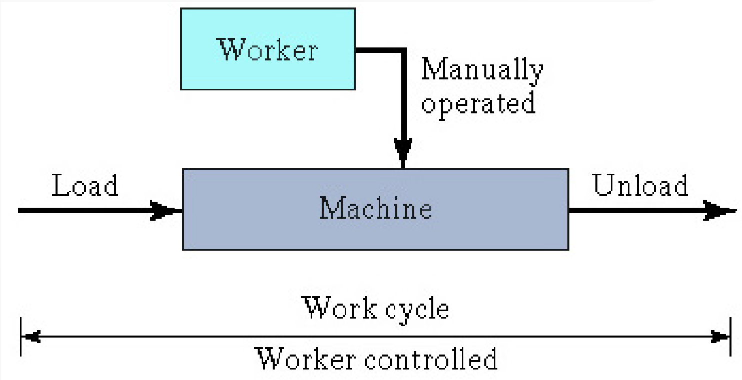


Figure 2.8 : Manually Operated Machine

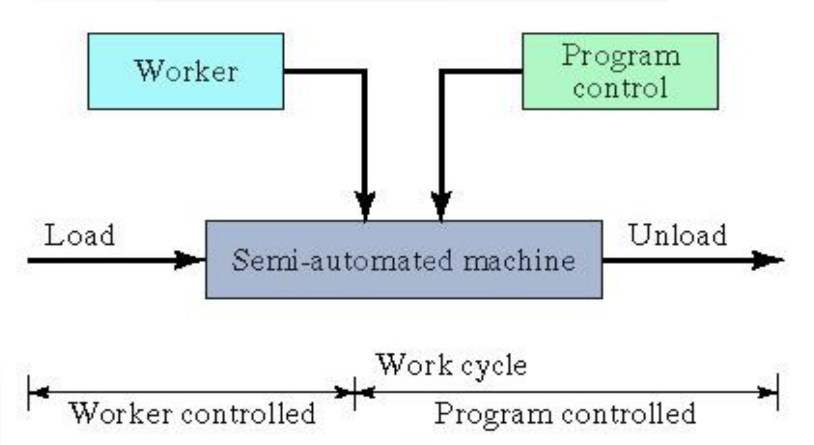


Figure 2.9 : Semi-Automated Machine

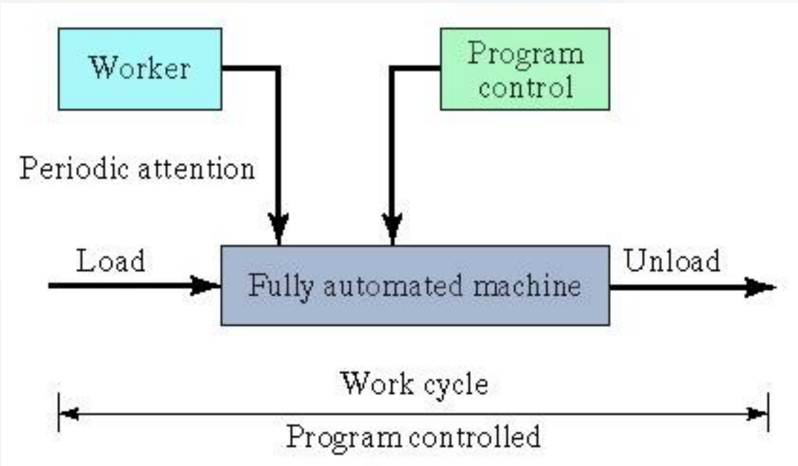


Figure 2.10 : Fully-Automated Machine

CHAPTER 2:

APPLICATION AUTOMATION SYSTEM

EXERCISE

1. What is the 5 levels of automation ?
2. Please give one example of level 2 automation?
3. What is the basic element of automation systems?
4. Please state the different between open-loop system and closed-loop system.
5. Please state the advantages of automation system.

CHAPTER 3

MECHANICAL SYSTEM: COMPONENTS, DYNAMICS AND MODELING

CHAPTER 3:

MECHANICAL SYSTEM: COMPONENTS, DYNAMICS AND MODELING

3.1 ELEMENTARY MECHANICAL CONCEPTS

A mechanism is used to produce mechanical transformation in a machine.

This transformation may convert :

- speed to a another speed
- one force to another force.
- one torque to another torque.
- force into torque.
- one angular motion to another angular motion
- rotation motion into liner motion
- linear motion into rotation motion

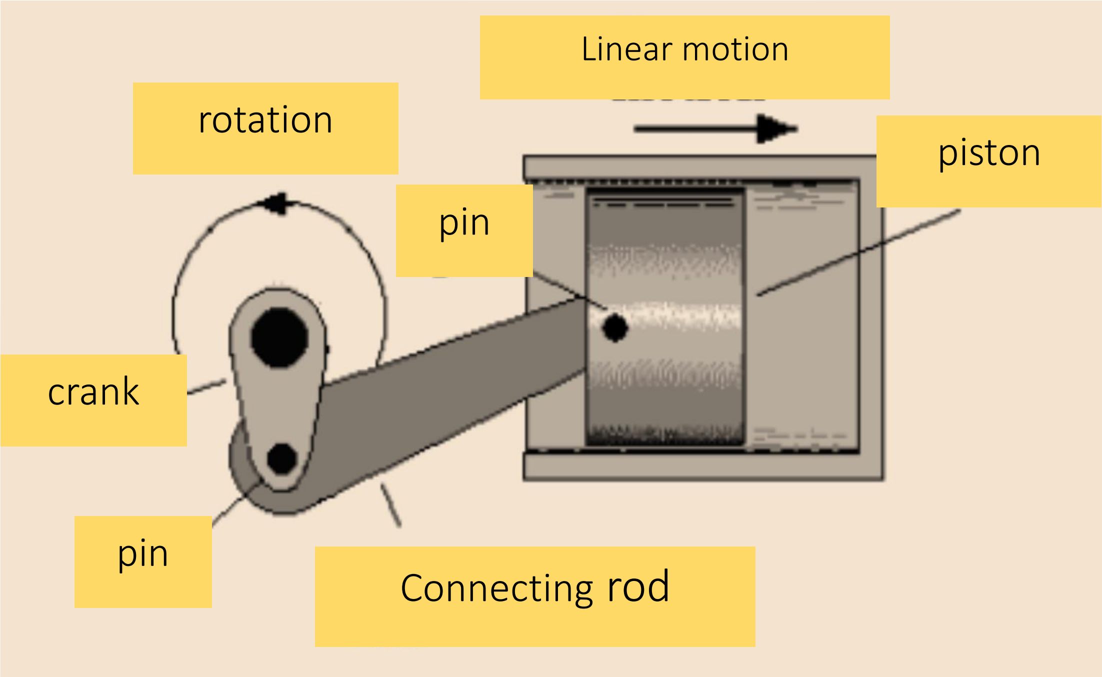


Figure 3.1 : A Crank, Connecting Rod And Piston Mechanism [1]

How a crank can operate?

https://youtu.be/HLvYTJVOWi4

SCAN ME

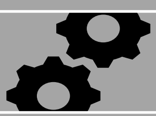
If the crank is turned, angular motion is converted into linear motion of the piston and input torque is transformed into force on the piston. If the piston is forced to move, the linear motion is converted into rotary motion and the force into torque.

The input is connected to a motor turning at constant speed. This makes the rocking arm move back and forth and the head (that carries the cutting tool) reciprocates back and forth. Depending on the lengths of the various parts, the motion of the head can be made to move forwards at a fairly constant cutting speed but the return stroke is quick.

Note that that the pin and slider must be able to slide in the slot or the mechanism would jam. This causes problems in the solution because of the sliding link.

Prismatic

- a sliding joint
- in some fields of engineering such as robotics.



Revolute

- The pin joints allow rotation of one part relative to another.

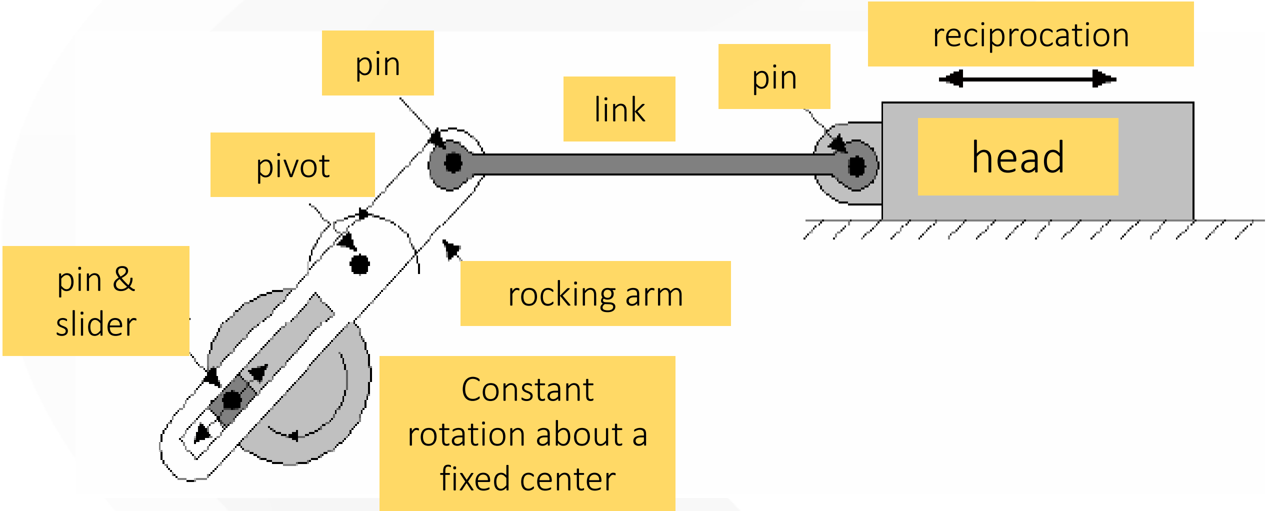


Figure 3.2 : Whitworth quick-return mechanism[1].

The main point is that the motion produced is anything but simple harmonic motion and at any time the various parts of the mechanism have a displacement, velocity and acceleration.

The acceleration gives rise to inertia forces and this puts stress on the parts in addition to the stress produced by the transmission of power. For example the acceleration of a piston in an internal combustion engine can be enormous and the connecting rod is subjected to high stresses as a result of the inertia as well as due to the power transmission.

Simulation of Whitworth quick-return mechanism

https://youtu.be/s3G3au-EyAQ

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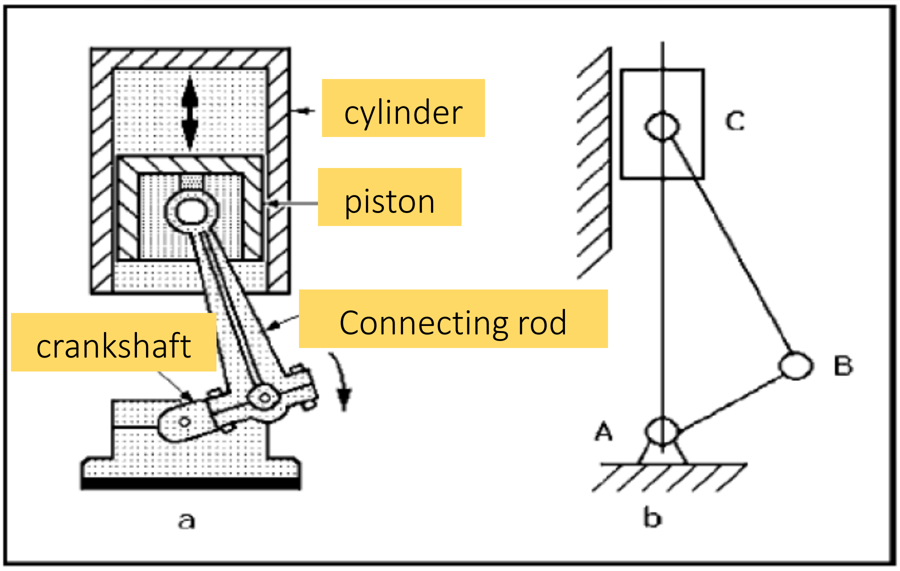


Figure 3.3 : Cross section of a cylinder of an internal combustion engine showing piston reciprocation (a) and the skeleton outline of the linkage mechanism that moves the piston (b). [1].

The input is connected to a motor turning at constant speed. This makes the rocking arm move back and forth and the head (that carries the cutting tool) reciprocates back and forth. Depending on the lengths of the various parts, the motion of the head can be made to move forwards at a fairly constant cutting.

Machines

- devices used to alter, transmit, and direct forces to accomplish a specific objective
- Eg: chain saw

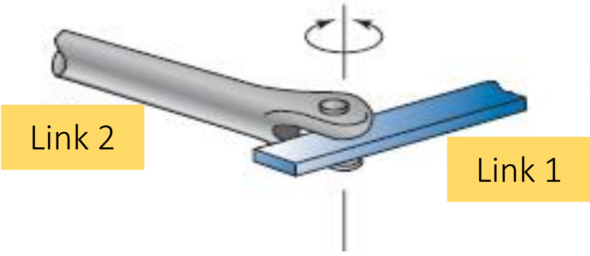
Mechanisms

- mechanical portion of a machine that has the function of transferring motion and forces from a power source to an output

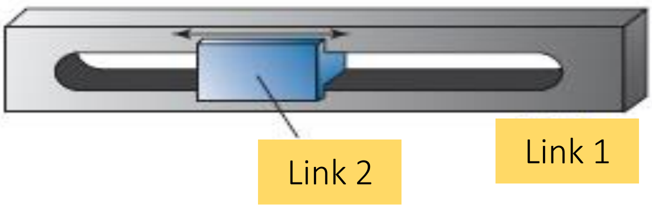
What is the difference in between machines and mechanisms?

Terms	Descriptions
Linkage	• A mechanism where rigid parts are connected together to form a chain.
Links	• Individual parts of the mechanism • Rigid bodies and are connected with other links to transmit motion and forces
Joints	• A movable connection between links and allows relative motion between the links.
Full joints	• The revolute and sliding joints
Frame	• A part that exhibits no motion
Cam joints	• Allows for both rotation and sliding between the two links that it connects. • Because of the complex motion permitted, the cam connection is called a *higher-order joint*, also called *half joint*
Simple link	• A rigid body that contains only two joints, which connect it to other links
Complex joints	• A rigid body that contains more than two joints
Sliding joints	• It allows linear sliding between the links that it connects • Also called a *piston* or *prismatic joint*

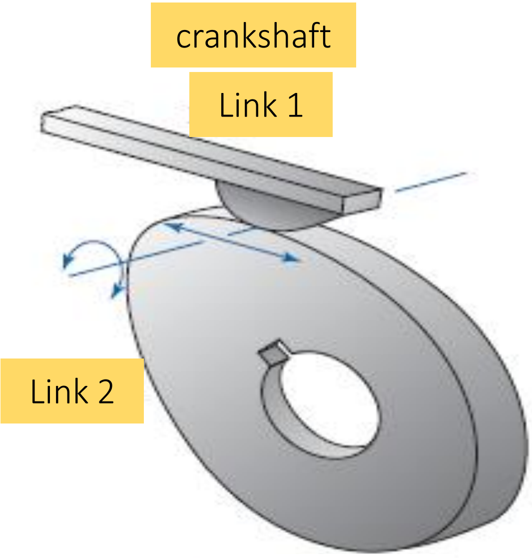
Distinguish the working principle of links and joints



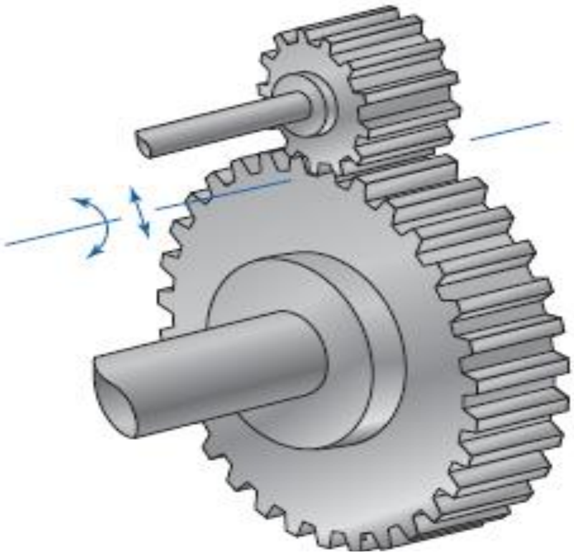
(a) pin



(b) sliding

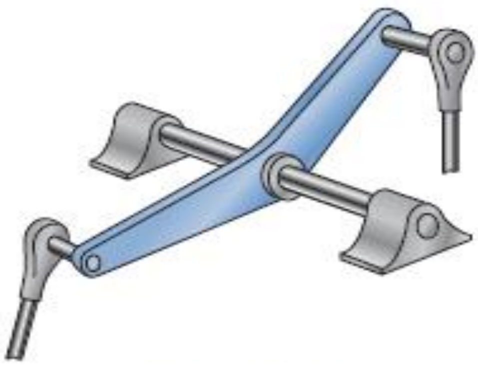


(a) cam joint



(b) Gear joint

(a) simple link



(b) complex link

Types of joint and links

https://youtu.be/Ih8WN8fYGyE

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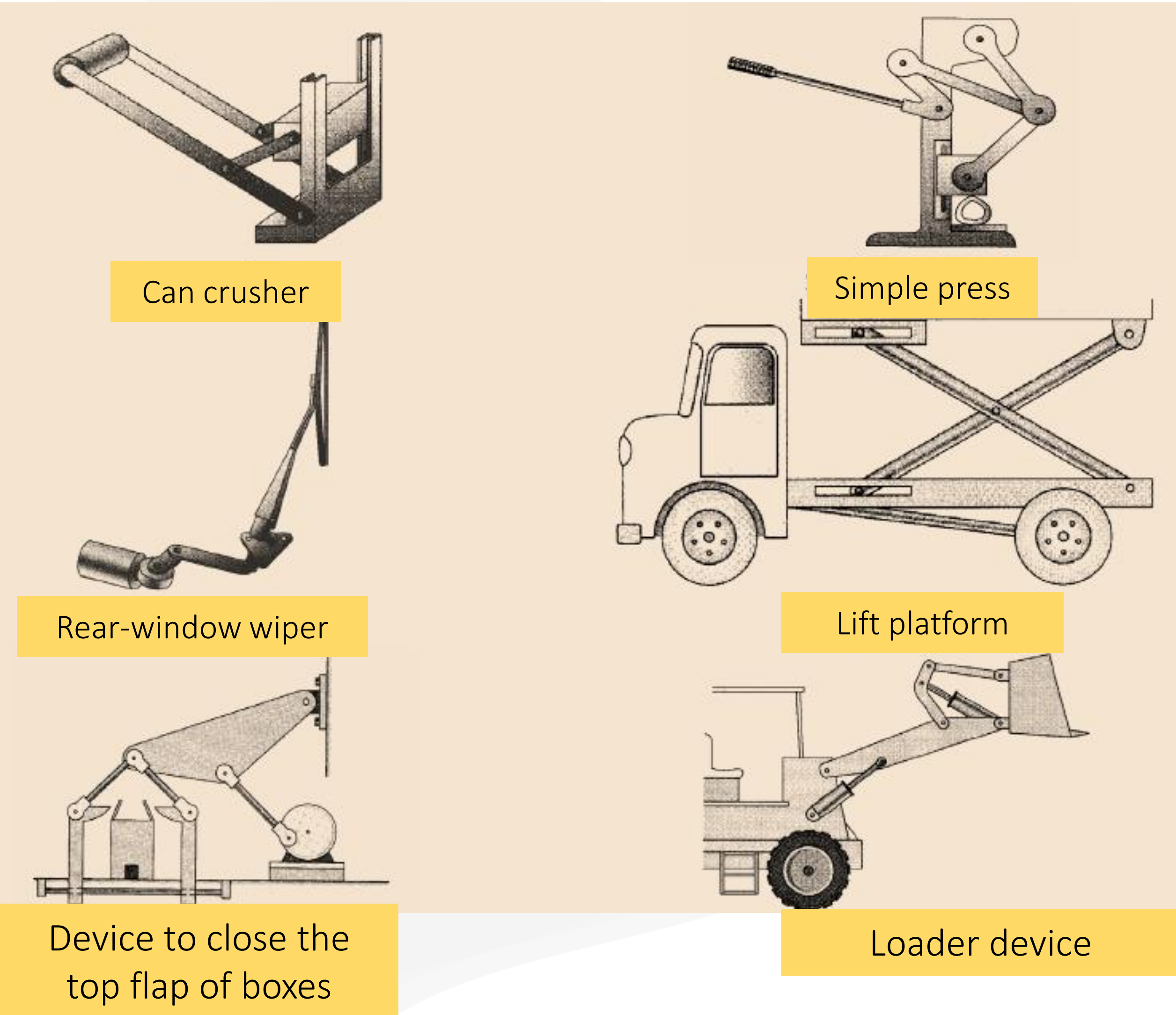
CHAPTER 3:

MECHANICAL SYSTEM: COMPONENTS, DYNAMICS AND MODELING

The motion of mechanical elements can be described in various dimensions as translational, rotational, or a combination of both. The equations governing the motion of mechanical systems are often directly or indirectly formulated from Newton's law of motion.



Types of joint and links

https://youtu.be/Ih8WN8fYGyE

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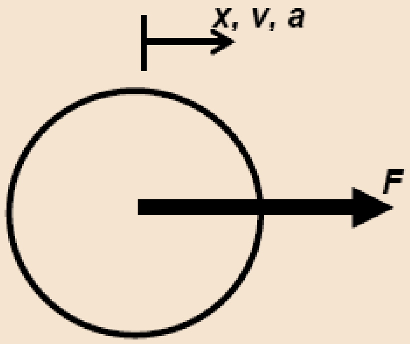
3.2 TRANSLATION OR LINEAR MOTION

If the velocity and acceleration of a body are both zero then the body will be static. When forces act on the body they may cause motion. If the applied forces are balanced, and cancel each other out, the body will not accelerate. If the forces are unbalanced then the body will accelerate. If all of the forces act through the center of mass then the body will only translate. Forces that do not act through the center of mass will also cause rotation to occur.

These state simply that velocity is the first derivative of position, and acceleration is the first derivative of acceleration. Conversely the acceleration can be integrated to find velocity, and the velocity can be integrated to find position. Therefore, if we know the acceleration of a body, we can determine the velocity and position. Finally, when a force is applied to a mass, acceleration can be found by dividing the net force by the mass.



Equations of motion

$$v(t) = \left(\frac{d}{dt}\right) x\,(t)$$

$$a(t) = \left(\frac{d}{dt}\right)^2 x(t) = \left(\frac{d}{dt}\right) v(t), \quad OR$$

$$x(t) = \int v(t)dt = \iint a(t)dt$$

$$v(t) = \int a(t)dt$$

$$a(t) = \frac{F(t)}{M}$$

where,

x, v, a = position , velocity and acceleration

M = mass of the body

F = an applied force

Figure 3.20: Velocity and acceleration of a translating mass [1]

CHAPTER 3:

MECHANICAL SYSTEM: COMPONENTS, DYNAMICS AND MODELING

chapter review questions

1. Differentiate between Machines and Mechanism.

………

………

………

1. Name two types of joints.

………

………

………

1. What is the primary function of linkage?

………

………

………

CHAPTER 3:

MECHANICAL SYSTEM: COMPONENTS, DYNAMICS AND MODELING

chapter review questions (answers)

1. Machines are devices used to alter, transmit, and direct forces to accomplish a specific objective. A chain saw is a familiar machine that directs forces to the chain with the objective of cutting wood. A mechanism is the mechanical portion of a machine that has the function of transferring motion and forces from a power source to an output. It is the heart of a machine.

2. A sliding joint and this is called PRISMATIC in some fields of engineering such as robotics. The pin joints allow rotation of one part relative to another. These are so called REVOLUTE joints in others areas of engineering..

3. A linkage is a mechanism where rigid parts are connected together to form a chain. One part is designated the frame because it serves as the frame of reference for the motion of all other parts. The frame is typically a part that exhibits no motion.

CHAPTER 4

AUTOMATION SENSORY DEVICES

CHAPTER 4:
AUTOMATION SENSORY DEVICES

4.1 GENERAL CHARACTERISTIC OF SENSOR

The sensor is a component that notifies the guard of the processor's state continually or at the conclusion of each movement.

A sensor is a device that generates a proportionate output signal such as electrical, mechanical magnetic in response to exposure to a physical phenomenon such as temperature, displacement, force.

Sensors can used to detect situation, control a process and operation. Sensors that stop the robot operation where employees into the work area while the robot are operating.

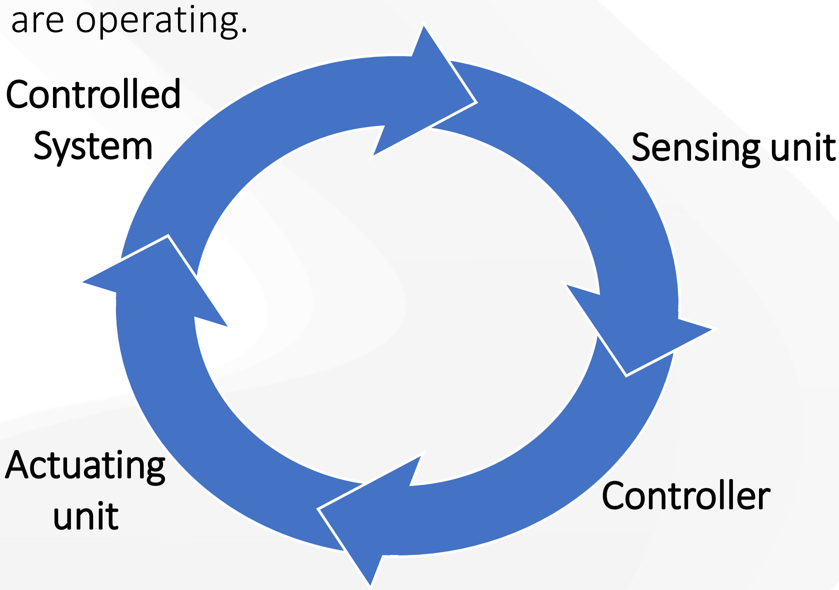


Figure 4.1: A typical control system

4.1.1 CLASSIFICATION OF SENSOR

Generally, sensors can be classified into 2 group:

Internal state sensors - device being used to measure the position, velocity and acceleration of the robot joint and/or end-effector. These devices are potentiometer, tachometers, resolvers, differential transformers, optical encoders and accelerometer.

External state sensors – device being used to monitor the relationship between the robot kinematics and/or dynamics with its task, surrounding, or the object being manipulated. These devices are proximity sensors, tactile sensor, limits switch, range sensor and miscellaneous sensors.

4.1.2 SENSOR GENERALITIES

In modern technology, sensor has develop into more sophisticated function. Here are some of the sensors generalities.

Transducers. Sensors that convert nonelectrical signals into electrical energy.

Contact sensors (limit switches). Switches designed to be turned ON or OFF by an object exerting pressure on a lever or roller that operates the switch.

Noncontact sensors. Devices that sense through changes in pressure, temperature, or electromagnetic field.

Proximity sensors. Devices that sense the presence of a nearby object by inductance, capacitance, light reflection, or eddy currents.

Range sensors. Devices such as laser-interferometric gauges that provide a precise distance measurement.

Tactile sensors. Devices that rely on touch to detect the presence of an object; strain gauges can be used as tactile sensors.

Displacement sensors. Provide the exact location of a gripper or manipulator. Resistive sensors are often used—usually wire-wound resistors with a slider contact. As force is applied to the slider arm, it changes the circuit resistance.

Speed sensors. Devices such as tachometers that detect the motor shaft speed.

Torque sensors. Measure the turning effort required to rotate a mass through an angle.

Vision sensors. Enable a robot to see an object and generate adjustments suitable for object manipulation; include dissectors, flying-spot scanners, vidicons, orthicons, plumbicons, and charge-coupled devices.

4.1.3 SENSOR CHARACTERISTICS

Each sensor have different characteristic, so they can works as requirement by the manufacturer. Here is some of the sensos characteristics

Range - Difference between the maximum and minimum value of the sensed parameter.

Precision - Ability to reproduce repeatedly with a given accuracy.

Sensitivity - Ratio of change in output to a unit change of the input.

Error - Is the difference between a measure value and the true input value.

Accuracy - This is the maximum difference between the indicated and actual reading.

Resolution - Used for systems that step through readings. This is the smallest increment that the sensor can detect.

Repeatability - When a single sensor condition is made and repeated, there will be a small variation for that particular reading.

Linearity - In a linear sensor the input phenomenon has a linear relationship with the output signal.

Dynamic Response - The frequency range for regular operation of the sensor.

Environmental - Sensors all have some limitations over factors such as temperature, humidity, dirt/oil, corrosives and pressures.

Calibration - When manufactured or installed, many sensors will need some calibration to determine or set the relationship between the input phenomena, and output.

Cost - Generally more precision costs more. Some sensors are very inexpensive.

4.2 TYPES OF SENSOR

There many types of sensor in the market out there. Here are some of the sensor we commonly used.

i. Linear and Angular (rotational) Sensors – Potentiometer, Capacitive Sensor, Inductive Sensor (LVDT, Resolvers), Optical Encoder, Optical Proximity Sensors, Optical Photoelectric Sensor

ii. Distance , Velocity and Acceleration Sensors – Range sensor, Tachogenerator (Tachometer), Rotary Encoders, Sagnac Interferometer, Micromechanical Angular Velocity (Gyroscopes), Triangle sensors, Time-of-Fight Sensors, Laser-Range Radar, Laser Interferometric Distance meter, Laser-Doppler Velocimeter.

iii. Contact Sensors – Piezoresistive, Capacitive Tactile sensors, Strain gauge sensors, Limits switch.

4.2.1 LINEAR AND ANGULAR SENSORS

Linear and angular (rotational) position sensors are two of the most fundamental of all measurements used in a typical mechatronics system.

By far the most common motions in mechanical systems are linear translation along a fixed axis and angular rotation about a fixed axis.

There are several type of sensor that can be used to determine the position like potentiometer, optical encoder, Linear Variable Differential Transformer (LVDT) & etc.

Position measurement is often required in feedback loops. The position sensors produce an electrical output that is proportional to the displacement they experience. There are contact type sensors such as strain gauge, LVDT, RVDT, tachometer, etc. The noncontact type includes encoders, hall effect, capacitance, inductance, and interferometer type.

i. Potentiometer (by resistive)

Potentiometer transducers can be used to measure both linear and angular displacement. It a very common transducer in the industrial environment.

One of the simplest and least expensive ways to measure rotational is using a variable resistor called a *potentiometer* or *rheostat*.

A potentiometer is a passive electronic component. Potentiometers work by varying the position of a sliding contact across a uniform resistance. Figure 4.1 shown in a potentiometer, the entire input voltage is applied across the whole length of the resistor, and the output voltage is the voltage drop between the fixed and sliding contact.

A potentiometer has the two terminals of the input source fixed to the end of the resistor. To adjust the output voltage the sliding contact gets moved along the resistor on the output side. Figure 4.3, Figure 4.4 and Figure 4.5 different types of potentiometer [5].

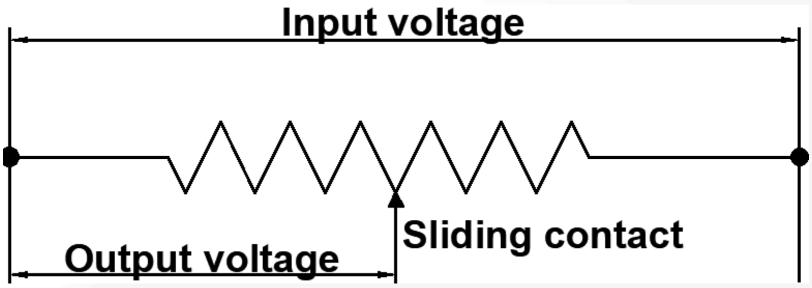


Figure 4.2: Output voltage is the voltage drop between the fixed and sliding contact

Figure 4.3: Angular potentiometer

Figure 4.4: Linear potentiometer

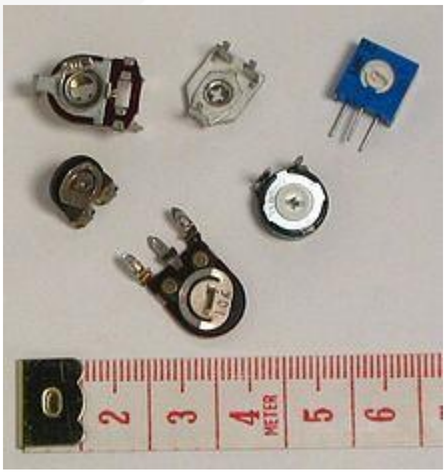


Figure 4.5: PCB mount trimmer potentiometer

ii. Capacitive sensor

Capacitance can be used to measure proximity or linear motions on the order of millimeters.

Capacitance is an electrical property which is created by applying an electrical charge to two conductive objects with a gap between them.

A simple demonstration is two parallel conductive plates of the same profile with a gap between them and a charge applied to them. Figure 4.6, Figure 4.7 and Figure 4.8 shown different types of capacitive sensors [6].

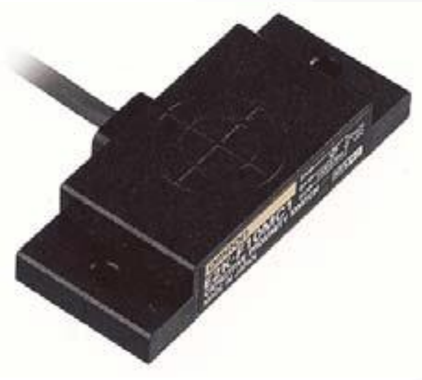


Figure 4.6: Flat mounted Capacitive sensor. Used for detecting panels of glass. Range=10mm +/- 10%

Figure 4.7: Panel Mounted Capacitive sensor. Can detect wood, plastic and metal. Range 3mm-25mm

Figure 4.8: Panel mounted Capacitive sensor. Used for detecting panels of metal. Range 3mm-8mm +/- 10%.

iii. Optical Rotary Encoder

Optical Rotary encoders, also called rotary shaft encoders or rotary shaft-angle encoders, are electromechanical transducers that convert shaft rotation into output pulses, which can be counted to measure shaft revolutions or shaft angle.

There are two main types: absolute and incremental (relative). The output of absolute encoders indicates the current position of the shaft, making them angle transducers.

Optical encoder allows linear or rotational displacement to be converted directly into digital form without using an analog-to-digital converter. Simplest type of optical encoder is the optical-slotted vane rotary switch. Figure 4.9, Figure 4.10 and Figure 4.11 shown different types of optical rotary encoder [7].

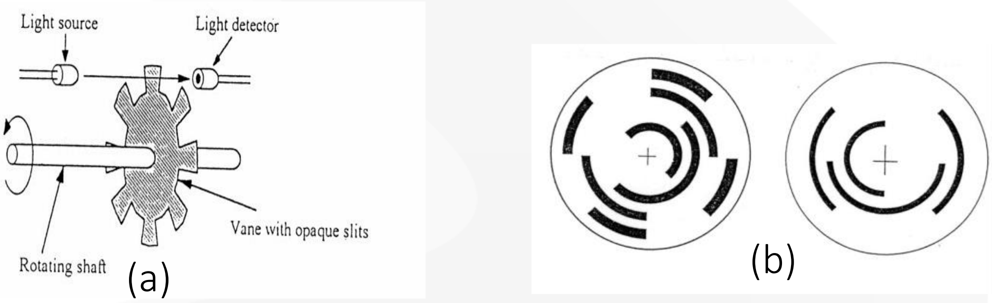


Figure 4.9: (a) Optical-slotted vane rotary (b) Optical Encoder disk

Figure 4.10: Inner parts of Optical Rotary Encoder

Figure 4.11: Examples of Optical Rotary Encoder

iv. Inductive Sensor (LVDT)

The linear variable differential transformer (LVDT) (also called just a differential transformer) is a type of electrical transformer used for measuring linear displacement (position). A counterpart to this device that is used for measuring rotary displacement is called a rotary variable differential transformer (RVDT).

The best known AC inductive sensor is the *linear variable differential transformer*, or LVDT. The LVDT is a tube with a plunger, the displacement of the plunger being the variable to be measured (Fig. 4.12) [8]. The tube is wrapped with at least two coils, an excitation coil and a pickup coil. An AC current (typically 1 kHz) is passed through the excitation coil, and an AC signal is detected from the pickup coil and compared in magnitude and in phase (0 or 180°) to the excitation current. Support electronics are needed for the demodulation, which is called synchronous detection. The plunger carries a ferromagnetic slug, which enhances the magnetic coupling from the excitation coil to the pickup coil. Depending on the position of the slug within the pickup coil, the detected signal may be zero (when the ferrite slug is centered in the pickup coil), or increasing in amplitude in one or the other phase, depending on displacement of the slug (Fig.4.13) [8].

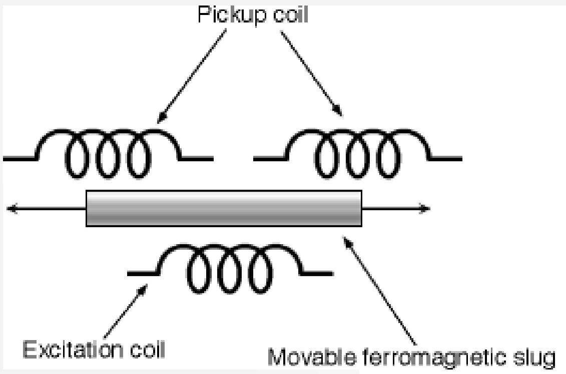


Figure 4.12: Operating principles of an LVDT

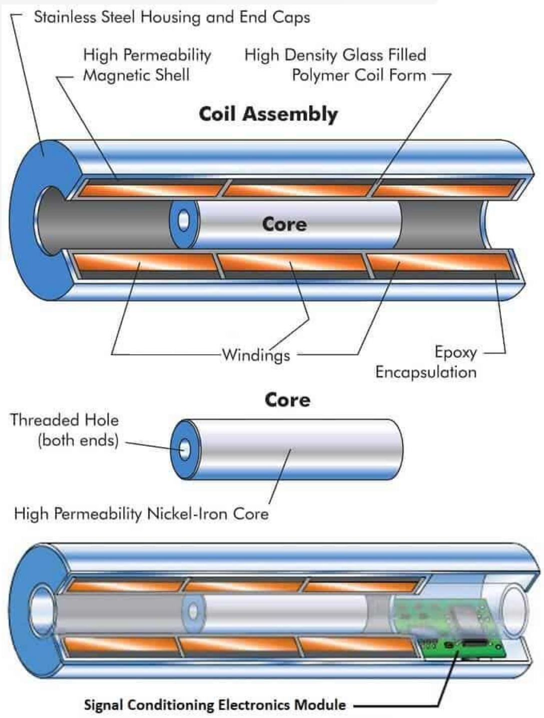


Figure 4.13: Operating principles of an LVDT

v. Optical Photoelectrical Sensor

Optical sensing techniques primarily rely on modulating the properties of an optical frequency electromagnetic wave. In the case of optical sensors, the measurand directly modulates the properties of the electromagnetic wave.

Optical sensors require both a light source (emitter) and detector. Emitters will produce light beams in the visible and invisible spectrums using LEDs and laser diodes. Optical proximity sensors detecting the number of infra-red from the object pass through. The amount of reflected light or wave will determine the presence of the or position of the object. Detectors are typically built with photodiodes or phototransistors. The emitter and detector are positioned so that an object will block or reflect a beam when present. A basic optical sensor is shown in Fig. 4.14 and Fig. 4.15 [9].

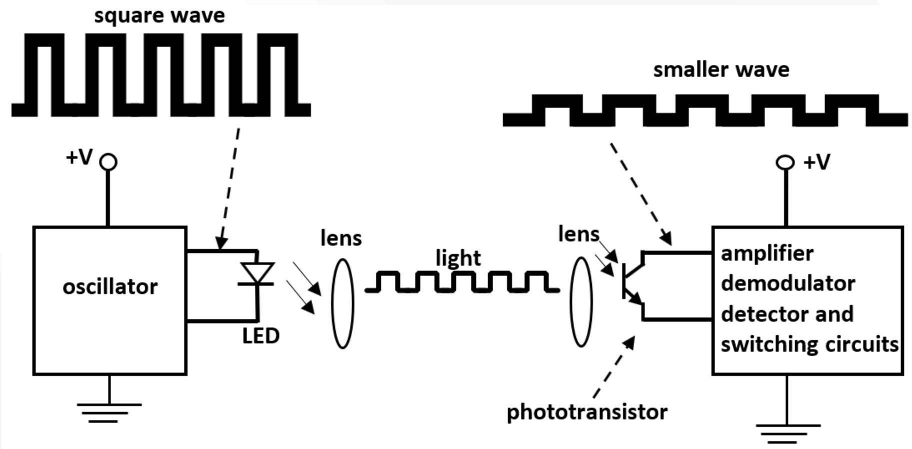


Figure 4.14: A Basic Optical Sensor

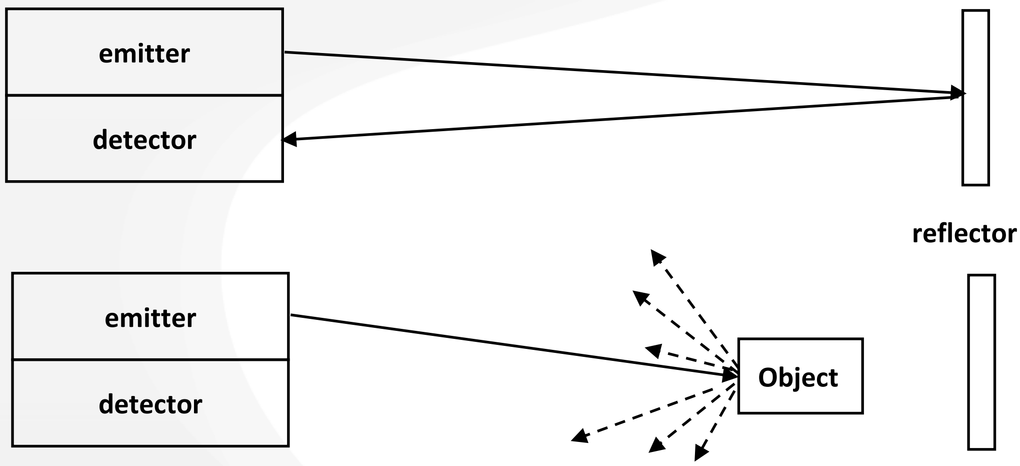


Figure 4.15: The reflector is constructed with polarized screen oriented at 90 deg. Angles

vi. Optical Proximity Sensor

Consist of a light source (LED) and light detector (phototransistor)
Modulation of signal to minimize ambient lighting conditions.
Various models: 12-30V DC, 24-240V AC, power.

In the current market we can buy 3 types of optical proximity sensor. There 3 operational modes for optical proximity sensor. They are:

i. Through Beam is suitable for long range (20m) and the alignment is critical (Fig. 4.16) [10].
ii. Retro-reflective is suitable for mid range (1-3m), is popular and cheap (Fig. 4.17) [10].
iii. Diffuse-reflective is suitable for low range (12-300mm) is cheap and easy to use (Fig. 4.18) [10].

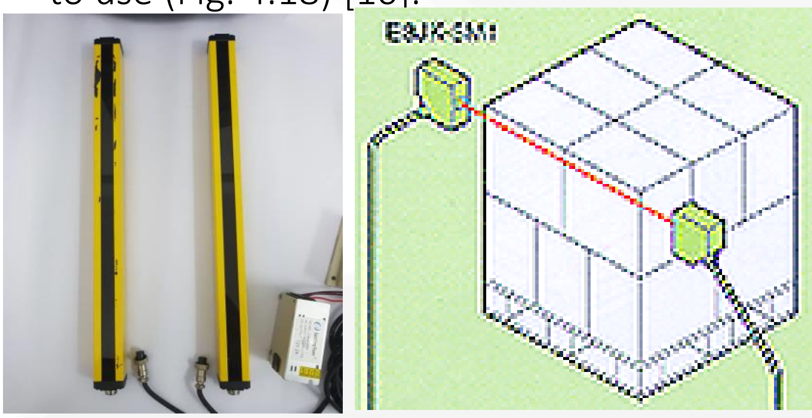


Figure 4.16: Through Beam Optical Proximity Sensor

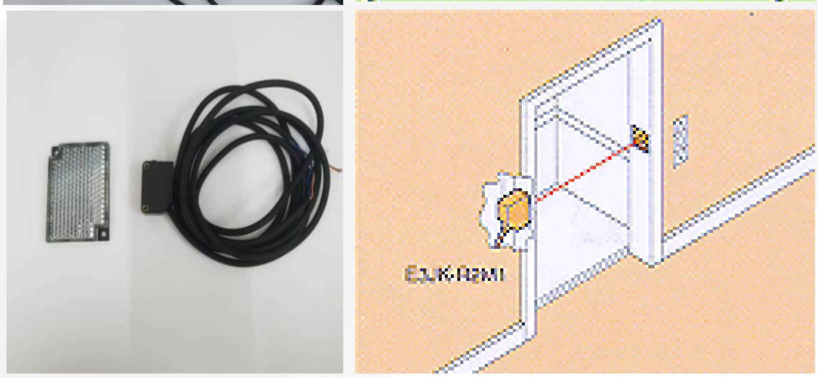


Figure 4.17: Retro-reflective Optical Proximity Sensor

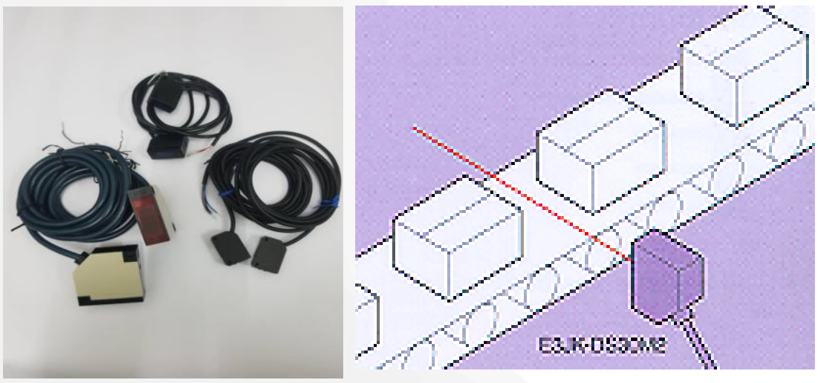


Figure 4.18: Diffuse-reflective Optical Proximity Sensor

CHAPTER 5

AUTOMATION SENSORY DEVICES II

CHAPTER 5:

AUTOMATION SENSORY DEVICES II

5.1 Distance, Velocity and Acceleration Sensor

Distance Measuring Sensors - Range sensors are used to measure the distance from a reference point to an object. A number of technologies have been applied to develop these sensors, the most prominent being light/optics, computer vision, microwave, and ultrasonic. Range sensors may be of contact or noncontact types.

Velocity sensing is used to provide velocity feedback to the motor controller which help stabilize the behavior of the joint, especially at low speed. A DC generator can be used but most system use a position sensor then compute velocity as the change in position over time.

Acceleration relating to motion is an important section of kinematic quantities: position, velocity, acceleration, and jerk. Each one of these quantities has a linear relationship with the neighboring ones. That is, all the kinematic quantities can be derived from a single quantity.

i. Range Sensor

Is a non contact sensor. It detect object presence by measuaring the object location from the sensor location with accurancy. Example: Inductive sensor (Fig. 5.1), distancesensor (Fig. 5.2), *Tellurometers,* dan *Interferometric.*

Figure 5.1: Inductive sensor as Range sensor that can measuaring the object location from the sensor location with accurancy

Figure 5.2: Subway brand device can measure distance of 100 meter

ii. Tachogenerator (Tachometer)

A tachometer (revolution-counter, rev-counter, RPM gauge) is an device measuring the rotation speed of a shaft or disk. Tachometer usually displays the revolutions per minute (RPM) on a calibrated analogue dial, but digital displays are increasingly common (Fig. 5.3).

Measurement of rotary speed using a DC generator. Essentially a motor running in reverse. Used to be common to have these attached to motors to enable direct analog feedback. Much less common now with digital control (use incremental encoder). Figure 5.4, Figure 5.5 shown Digital Tachnometer [17].

Figure 5.3: Tachogenerator for large industrial plant (GE)

Figure 5.4: Mini Tachometer for measurement of rpm of shaft or blade

Figure 5.5: Wireless Tachometer for bicycle, for measurement of rotational velocity and speed

iii. Sagnac Interferometer

The Sagnac effect (also called Sagnac interference), named after French physicist Georges Sagnac, is a phenomenon encountered in interferometry that is elicited by rotation. Sagnac interferometer used to measure rotation rates Figure 5.6 and Figure 5.7 showing Sagnac interferometer [11][12].

A beam of light is split and the two beams are made to follow a trajectory in opposite directions. To act as a ring the trajectory must enclose an area. On return to the point of entry the light is allowed to exit the apparatus in such a way that an interference pattern is obtained.

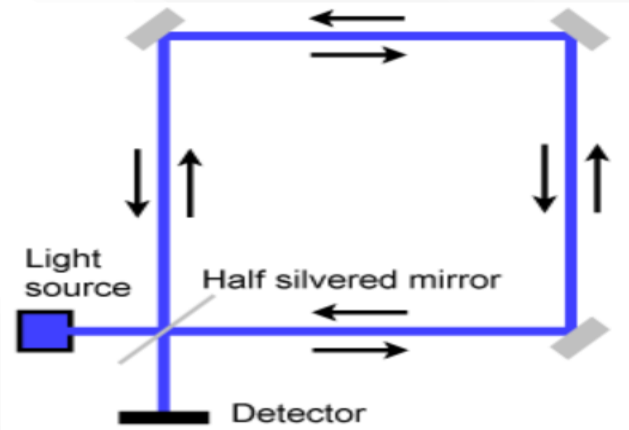


Figure 5.6: Sagnac Interferometer

Figure 5.7:Sagnac interferometer from www.laboratorysci.com

iv. Micromechanical Angular Velocity (Gyroscopes)

Structural arrangement of silicon which records centrifugal acceleration and thus angular speed.

Use strain-gauge bridges and/or piezo structure to record deformations. Multiple component elements to calibrate other accelerations. Figure 5.8 shown structural for micromechanical angular velocity (Silicon Gyroscopes). Figure 5.9 shown MEMS gyroscope TL725D [14] .

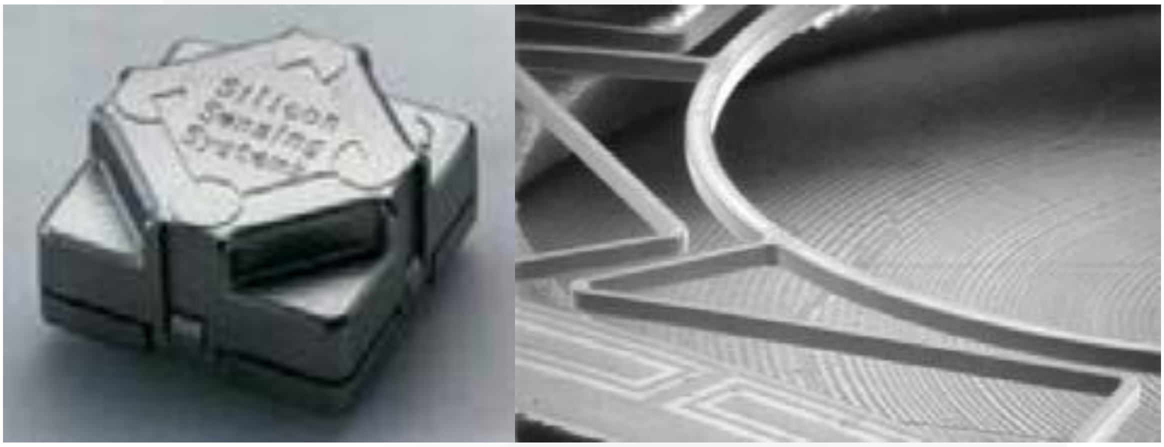


Figure 5.8: Examples of micromechanical angular velocity (Silicon Gyroscopes).

Figure 5.9: MEMS gyroscope TL725D

v. Laser Interferometric Distance Meter

Laser interferometers are capable of measuring incremental linear motions with resolution on the order of nanometers. In an interferometer, collimated laser light passes through a beam-splitter, sending the light energy on two different paths (Fig. 5.10)[17].

One path is directly reflected to the detector, such as an optical sensing array, giving a flight path of fixed length. The other path reflects back to the detector from a retroreflector (mirror) attached to the target to be measured.

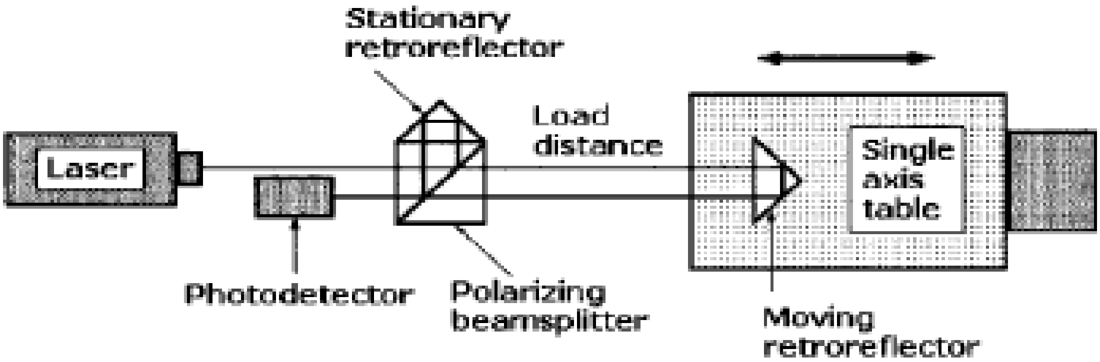


Figure 5.10: Diagram of a laser interferometer for position feedback that combines high resolution

vi. Laser-Doppler Velocimeter

Laser Doppler velocimetry (LDV) , also known as laser Doppler anemometry (LDA), is the technique of using the Doppler shift in a laser beam to measure the velocity in transparent or semi-transparent fluid flows, or the linear or vibratory motion of opaque, reflecting, surfaces (Figure 5.11)[17].

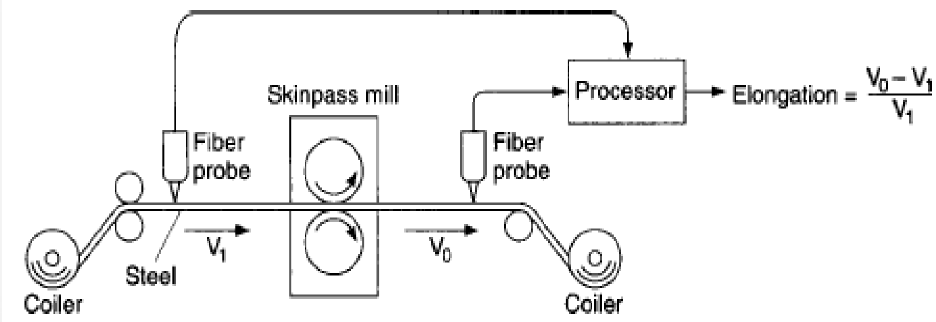


Figure 5.11: Fiber-optic Doppler velocimeter at a rolling mill controls pressure by measuring inputs speeds

5.2 CONTACT SENSOR

Contact Sensor (Force and Pressure) generally measured indirectly through deflection of an alternate surface.

i. Piezoresistive

Piezoresistive materials that generate changes in resistance when deformed.

In a piezoresistive sensor, the magnitude of a mechanical displacement is measured by the amount of stress it induces in a mechanical member.

A stress-sensitive resistor (called a piezoresistor) located strategically on the mechanical member experiences a change of resistance as a result of the applied stress. Figure 5.12 shown sample of piezoresistive element [14]. Figure 5.13 shown Honeywell piezeresistive pressure sensor transmitter [15].

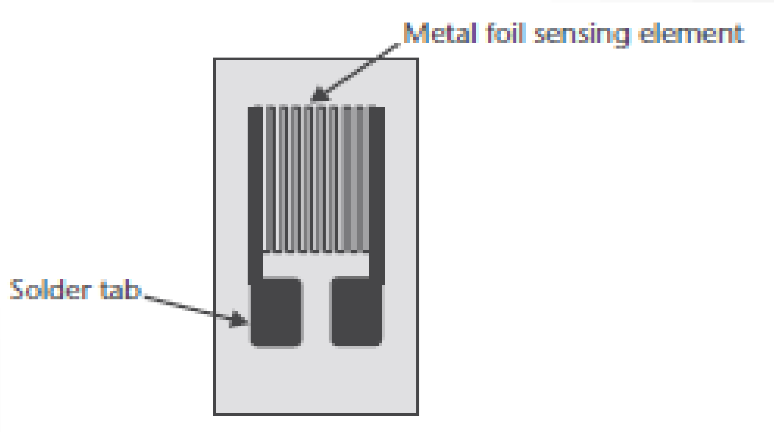


Figure 5.12: Sample of piezoresistive element

Figure 5.13: Honeywell Piezoresistive pressure sensor transmitter

ii. Capacitive Tactile Sensor

A transducer that uses capacitance variation can be used to measure force.

The force is directed onto a membrane whose elastic deflection is detected by a capacitance variation.

A highly sensitive force transducer can be constructed because the capacitive transducer senses very small deflections accurately. An electronic circuit converts the capacitance variations into DC-voltage variations. Figure 5.14 shown force applied at parallel plate design [17]. Figure 5.15 Capacitive sensor can be found in todays tablet.

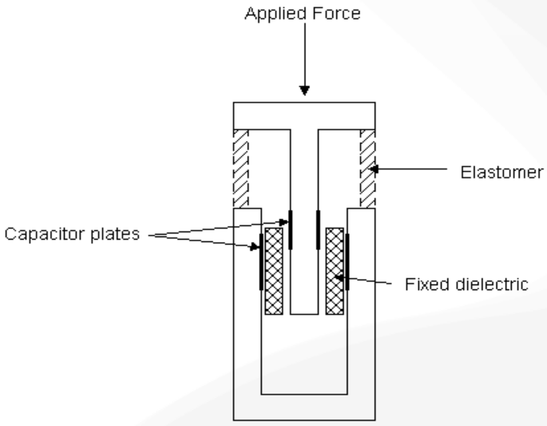


Figure 5.14: Force applied at the parallel plate design

Figure 5.15: Capacitive tactile sensor can be found in todays tablet

iii. Optical Tactile Sensor II

Force applied will change the amount of light reflected to the receiver. In the reflective touch sensor below, the distance between the reflector and the plane of source and the detector is the variable. The intensity of the received light is a function of distance, and hence the applied force (Fig. 5.16) [17].

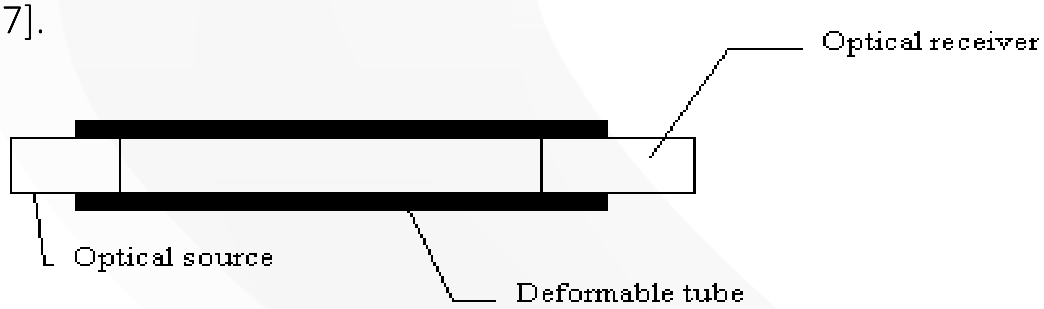


Figure 5.16: Examples of Optical Tactile sensor

iv. Strain Gauge Sensor

The strain gauge load cell consists of a structure that elastically deforms when subjected to a force and a strain gauge network that produces an electrical signal proportional to this deformation (Fig. 5.17) [17].

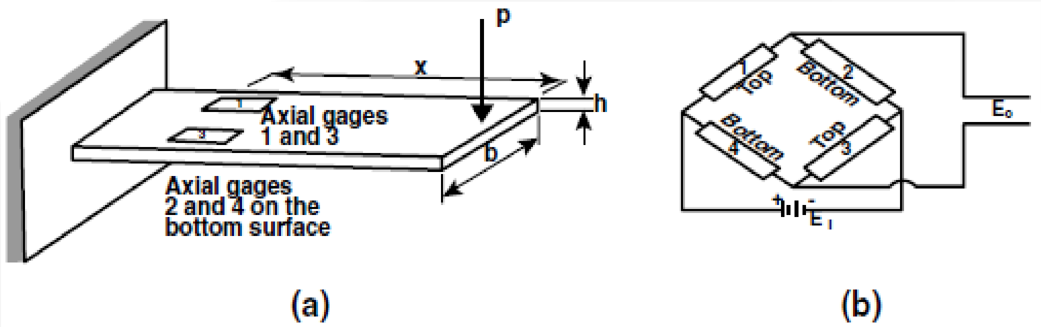


Figure 5.17: Beam-type load cells; (a) a selection of beam-type load cells (elastic element with strain gauges) and (b) gauge position in the Wheatstone bridge

Figure 5.18: Laboratory strain gauge available in 6mm, 10mm and 20mm long

v. Limit Switch

A standard limit switch used in industrial applications is an electromechanical device that consists of a mechanical actuator linked to a series of electrical contacts. Limit switch use the mechanical movement of the actuator plunger to control or change the electrical switches state.

Figure 5.19: An example of Limit Switch

CHAPTER 4 & 5:

AUTOMATION SENSORY DEVICES

QUESTION:

1. Describe meaning of sensors?

2. Explain the function of sensors?

3. List THREE (3) types of internal sensors and THREE (3) types of external sensors.

4. What is the differences between contact sensors and noncontact sensors by giving samples for each type sensors.

5. Explain how the vision sensors works?

6. Define the following term for sensors.
   i. Range
   ii. Sensitivity
   iii. Error
   iv. Dynamic Response
   v. Resolution

7. Explain the working principles for the following sensors.
   i. Potentiometer
   ii. Capacitive sensors
   iii. Optical encoder
   iv. Linear Variable Differential Transformer (LVDT)
   v. Optical Photoelectric Sensors

8. Named FOUR (4) types of sensors for used in angular position measurement.

9. Gives THREE (3) operational mode for Optical proximity sensor.

10. Explain the working principles for Tachogenerator

CHAPTER 4 & 5:

AUTOMATION SENSORY DEVICES

QUESTION:

11. Explain how the velocity sensors work and named three examples of velocity sensors
12. Explain the working principles for rotary encoders.
13. Explain the working principles for Sagnac Interferometer.
14. Explain about the Laser-Doppler Velocimeter that commonly used in electronic industries.
15. Explain how the strain gauge works.
16. Mention desirable characteristics of strain gauge.
17. What are the points to be considered for selecting sensors.
18. Explain the concept of contact sensors and named THREE (3) types of contact sensors.

CHAPTER 4 & 5:

AUTOMATION SENSORY DEVICES

ANSWER:

1. Describe meaning of sensors?
Sensor is a component that notifies the guard of the processor's state continually or at the conclusion of each movement.

2. Explain the function of sensors?
Sensors can used to detect situation, control a process and operation. Sensors that stop the robot operation where employees into the work area while the robot are operating.

3. List THREE (3) types of internal sensors and THREE (3) types of external sensors.
Internal sensor – potentiometer, tachometer and optical encoder
External sensor – limit switch, proximity sensor, range sensor, tactile sensor.

4. What is the differences between contact sensors and noncontact sensors by giving samples for each type sensors.
Contact sensors (limit switches). Switches designed to be turned ON or OFF by an object exerting pressure on a lever or roller that operates the switch.
Noncontact sensors (optical encoder). Devices that sense through changes in pressure, temperature, or electromagnetic field.

5. Explain how the vision sensors works?
Enable a robot to see an object and generate adjustments suitable for object manipulation; include dissectors, flying-spot scanners, vidicons, orthicons, plumbicons, and charge-coupled devices.

6. Define the following term for sensors.
   i. Range
   Difference between the maximum and minimum value of the sensed parameter

   ii. Sensitivity
   Ratio of change in output to a unit change of the input

   iii. Error
   Is the difference between a measured value and the true input value

   iv. Dynamic Response
   The frequency range for regular operation of the sensor

   v. Resolution
   This is the smallest increment that the sensor can detect; this may also be incorporated into the accuracy value

CHAPTER 4 & 5:

AUTOMATION SENSORY DEVICES

ANSWER:

7. Explain the working principles for the following sensors.
i. Potentiometer
Potentiometer sensors can be used to measure both linear and angular displacement. It a very common transducer in the industrial environment

ii. Capacitive sensors
Capacitance is an electrical property which is created by applying an electrical charge to two conductive objects with a gap between them

iii. Optical encoder
Optical encoder allows linear or rotational displacement to be converted directly into digital form without using an analog-to-digital converter.

iv. Linear Variable Differential Transformer (LVDT)
The linear variable differential transformer (LVDT) is a type of electrical transformer used for measuring linear displacement (position).

v. Optical Photoelectric Sensors
Optical sensing techniques primarily rely on modulating the properties of an optical frequency electromagnetic wave. In the case of optical sensors, the measurand directly modulates the properties of the electromagnetic wave.

8. Named FOUR (4) types of sensors for used in angular position measurement.
- Potentiometer
-Capacitive sensor
-Optical Encoder
-Inductive Sensor and Resolvers

9. Gives THREE (3) operational mode for Optical proximity sensor.
-Through beam
-Retro-reflective
-Diffuse-reflective

10. Explain the working principles for Tachogenerator.
A tachometer (revolution-counter, rev-counter, RPM gauge) is an device measuring the rotation speed of a shaft or disk. Tachometer usually displays the revolutions per minute (RPM) on a calibrated analogue dial, but digital displays are increasingly common.

11. Explain how the velocity sensors work and named three examples of velocity sensors.
Sensors devices such as tachometers that detect the motor shaft speed. Examples of velocity sensors are tachometer, rotary encoder, laser-doppler velocimeter.

12. Explain the working principles for rotary encoders.
Rotary encoders, also called rotary shaft encoders or rotary shaft-angle encoders, are electromechanical transducers that convert shaft rotation into output pulses, which can be counted to measure shaft revolutions or shaft angle.

CHAPTER 4 & 5:

AUTOMATION SENSORY DEVICES

ANSWER:

13. Explain the working principles for Sagnac Interferometer.
Sagnac Interferometer is a phenomenon encountered in interferometry that is elicited by rotation. A beam of light is split and the two beams are made to follow a trajectory in opposite directions. To act as a ring the trajectory must enclose an area. On return to the point of entry the light is allowed to exit the apparatus in such a way that an interference pattern is obtained.

14. Explain about the Laser-Doppler Velocimeter that commonly used in electronic industries.
Laser Doppler velocimetry (LDV) , also known as laser Doppler anemometry (LDA), is the technique of using the Doppler shift in a laser beam to measure the velocity in transparent or semi-transparent fluid flows, or the linear or vibratory motion of opaque, reflecting, surfaces.

15. Explain how the strain gauge works.
The strain gauge load cell consists of a structure that elastically deforms when subjected to a force and a strain gauge network that produces an electrical signal proportional to this deformation.

16. Mention desirable characteristics of strain gauge.
The characteristics of a strain gauge are mainly defined by the gauge dimensions, resistance, gauge factor, temperature coefficient, resistivity, and thermal stability. Gauge dimensions and shape are very important in choosing a right type of strain gauge for a given application. Gauge resistance is defined as the electrical resistance measured between two metal tabs or leads. Gauge factor or strain sensitivity is defined as the ratio of ($\Delta R/R$) and the strain ε.

17. What are the points to be considered for selecting sensors.
Range - Difference between the maximum and minimum value of the sensed parameter.
Precision - Ability to reproduce repeatedly with a given accuracy.
Sensitivity - Ratio of change in output to a unit change of the input.
Error - Is the difference between a measure value and the true input value.
Accuracy - This is the maximum difference between the indicated and actual reading.

18. Explain the concept of contact sensors and named THREE (3) types of contact sensors
Contact sensors (limit switches). Switches designed to be turned ON or OFF by an object exerting pressure on a lever or roller that operates the switch. Examples of contact sensor are limit switch, tactile sensor and capacitive sensor.

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