Building Blocks of Automation

Manufacturing systems can generally be classified as fixed (hardware) or flexible (software). These classifications are normally bestowed on both the processing equipment (machine tools, welders, and so on) and the material handling system that integrates the processes. Each process or machine usually consists of dozens of mechanisms that create the required relative motion to complete an activity. These mechanisms include cams, ways and slides, pistons (pneumatic or hydraulic), vibratory devices. push rods, and screw mechanisms. Each of these mechanisms have particular characteristics that allow them to be coupled together to amplify force or speed and create/convert linear or rotary motion. When these mechanisms are mechanically fastened on a base .relative to each other in order to perform a specific task.

An automated manufacturing system consists of a collection of these automatic or semiautomatic machines linked together by an "intra-system" material-handling system. These automated systems have been used to produce machined components, assemblies, electrical components, food products, chemical products, and so on.

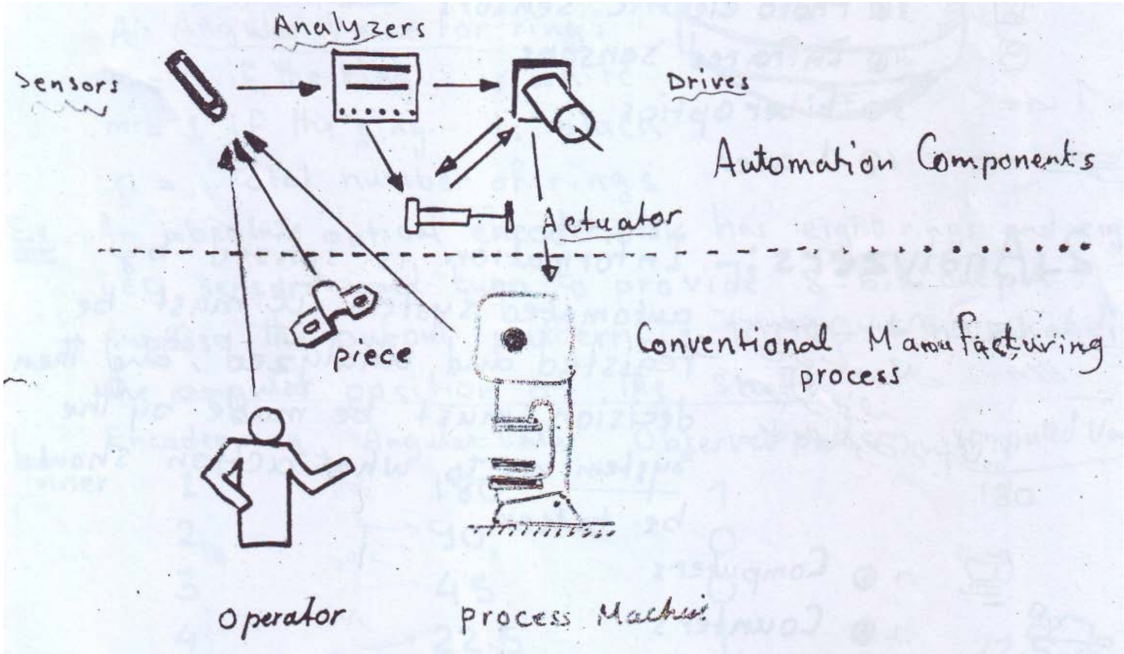
Automation is the process of controlling manufacturing systems to perform repetitive operations with a minimum of human intervention.

The object of automation is to make the best use of available resources, material, money and machines; its goals being the same as in mechanization. The human workers function is limited to machine supervisory control, corrective adjustment, and retooling of the automated machine for product changes.

Flexible automation first appeared in the early 1950s -with the introduction of numerically controlled (NC) machine tools. Later, NC machines evolved into computer numerical control (CNC) machines in which each machine had a small digital computer, usually a microcomputer, as one of its components.

The basic components of automation as primarily belonging to one of the following four classes:

1-Sensors, 2- Analyzers, 3- Actuators and 4- Drives



1-Sensors: - sensors are the first link between the typical automated system and conventional process. Sensor must be classified into following types:

- Manual witches.
- Proximity switches.
- Photo electric sensors.
- Infrared sensors.
- Fiber optics.
- Laser.

2-Analuzers: - information is sensed by automated system it must be registed and analyzed, and then decision must be made by the system as to what action should be taken.

- Computers.
- Counters.
- Timers.
- BC readers.
- Encoders.

Optical Encoder: -

The capability of rapidly scanning a series of bars makes possible additional automation opportunities when light and dark bars are placed in concentric rings on a disk.

$$A = \sum_{i=1}^{n} mi \quad Ai$$

Ai = Angular value for ring i.

mi = 0 if the ring is white.

mi = 1 if the ring is black.

n = total number of rings.

Example: - An absolute optical encoder disk has eight rings and eight LED sensors and turn to provide 8-bit output, suppose the output pattern is 10010110. What is the angular position of the shaft?

	Encoder ring	Angular value	Observed pattern	Computed value
Inner	1	180	1	180
	2	90	0	---
	3	45	0	---
	4	22.5	1	22.5
	5	11.25	0	---
	6	5.625	1	5.625
	7	2.8125	1	2.8125
outer	8	1.40625	0	---
			Total	210.94

3-Actuators: - the real-world condition is sensed and analyzed; something may need to be done about it. Automated systems are closing the loop by taking physical action automatically without operator intervention. [Short, complete motion usually liner].

- Cylinders.
- Solenoids.
- Relay.

4- Drives: - it takes some action upon the process at the command of the computer or other analyzer. Continuous movement typified by rotation.

- Motors.
- DC servo motor.
- Stepper motors.
- Kinematic linkage.
- Walking beams.
- Geneva mechanism.

Example: - the torque speed characteristics of stepping motor drive system are:

L: $T = 200 - 0.05v$.

U: $T = 200 - 0.025v$.

Where T: is in N.m and v is step per second, the motor is loaded by a constant torque of 70 N.m. calculate: -

1- The maximum allowable starting speed?
2- The motor runs at the starting speed during 13 pulses. What is the starting time period?

The max allowable starting speed is determined by L: $70=200 - 0.05*V$; $V = 2600$ step/sec.

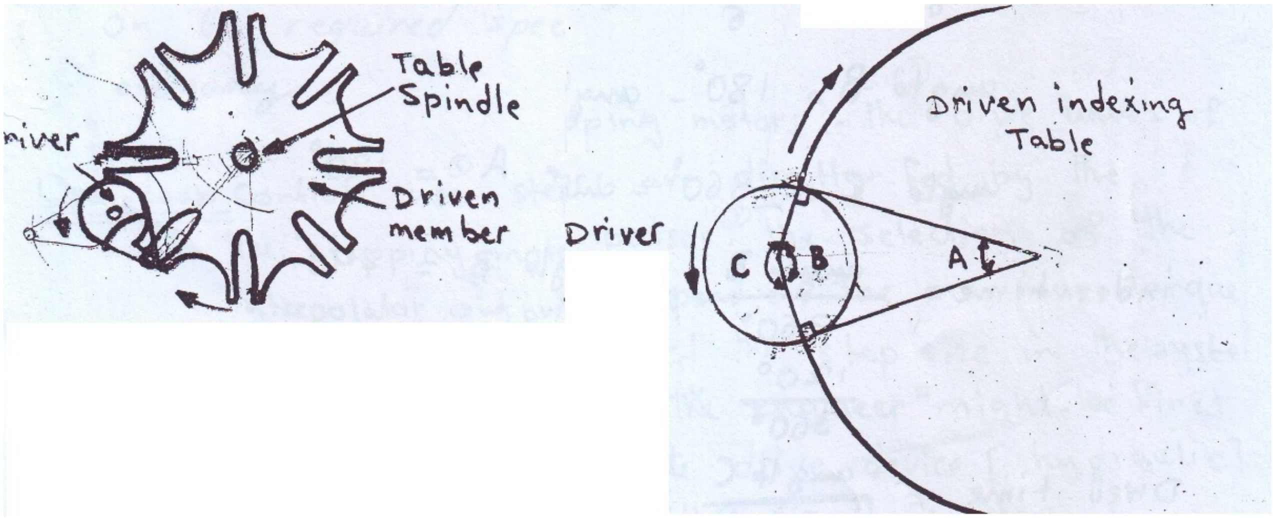
The min speed is determined by U: $70 = 200 - 0.025*V$; $V = 5200$ step/sec.

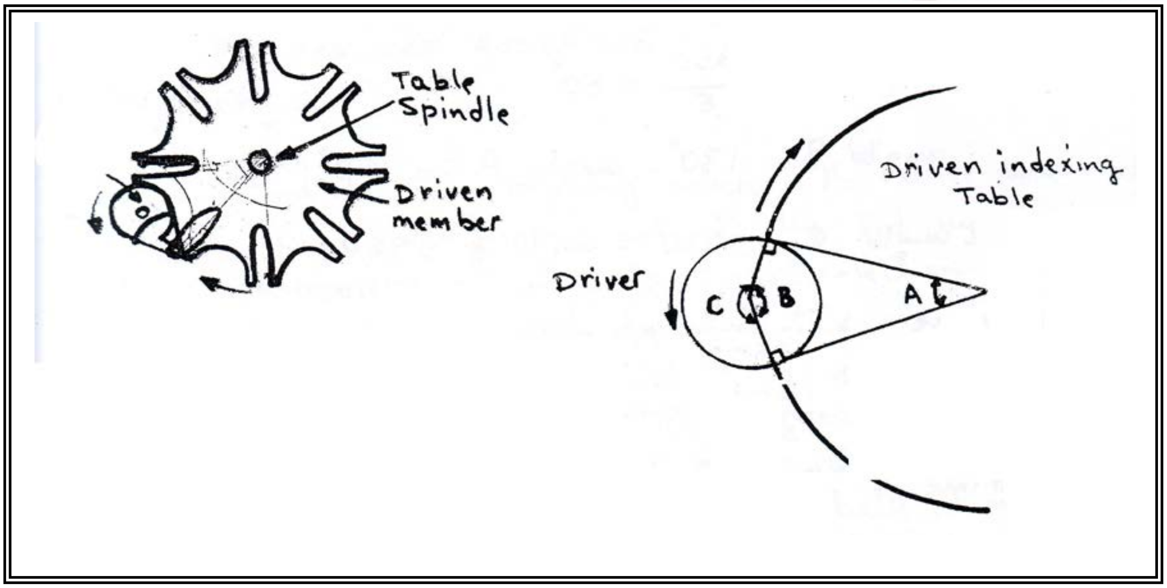
During the starting period the frequency is 2600 p.p.

$$t = \frac{13}{2600} = 5ms$$

Geneva mechanism:-

A Geneva mechanism is used to drive an indexing intermittently or used for low – and high speed machinery. There are two wheels driver and the driven indexing table. The actual driven force is delivered by a pin on the driver which slide in an arc-shaped slot in the driven indexing table. The driver rotates continuously. The driver rotates continuously. This allows the use of constant velocity motors without having to deal specifically with indexing table acceleration and deceleration problems. It has widespread use where a spindle, turret, or worktable must be indexed.





$$angle\ A + angle\ B = 180°$$

$$angle\ B + angle\ C = 360°$$

$$Index\ time = \frac{angle\ B}{360°} * \frac{1}{driver\ (r.p.m)} \qquad (minutes)$$

$$Dwell\ time = \frac{angle\ C}{360°} * \frac{1}{driver\ (r.p.m)} \qquad (minutes)$$

$$Cycle\ time = Index\ time + Dwell\ time$$

<u>Case study</u> :(Indexing table calculations)

An indexing table driven by a Geneva mechanism has six stations and a driver speed of 12 r.p.m calculate: a-index time, b- dwell time, and c-ideal production rate/hr.?

$$angle\ A = \frac{360}{6} = 60°$$

$$angle\ B = 180° - angle\ A = 120°$$

$$angle\ C = 360° - angle\ B = 240°$$

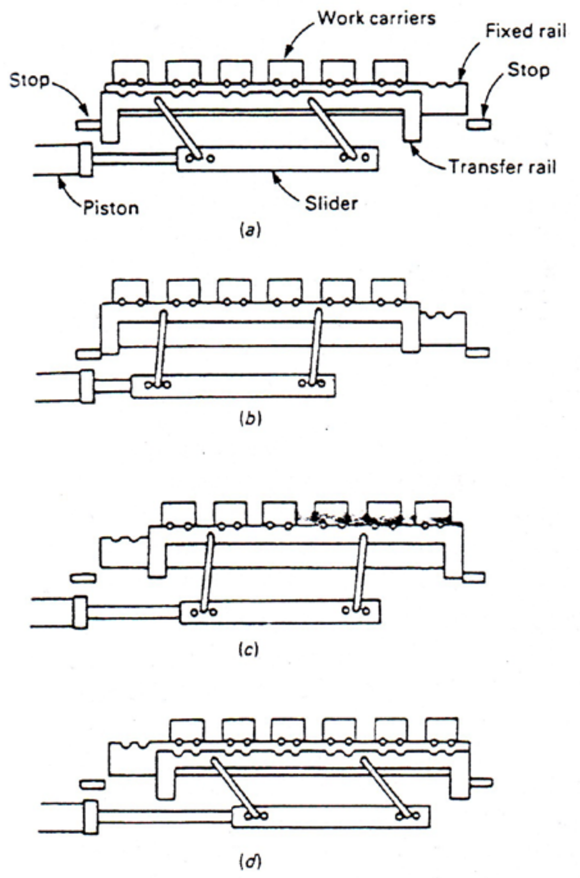
$$Index\ time = \frac{angle\ B}{360°} * \frac{1}{driver\ (r.p.m)} = \frac{120°}{360°} * \frac{1}{12} * 60\ sec/\min = 1.67\ sec$$

$$Dwell\ time = \frac{angle\ C}{360°} * \frac{1}{driver\ (r.p.m)} = \frac{240°}{360°} * \frac{1}{12} * 60\ sec/\min = 3.33\ sec$$

$$Cycle\ time = Index\ time + Dwell\ time = 1.67 + 3.33 = 5\ sec$$

$$Production\ rate = \frac{1}{5} * 3600\frac{sec}{hr} = 720\ pcs\ per\ hour$$

***<u>Walking Beam:</u>* -** is a reasonably simple device used for to intermittent transfer of parts to stations laid out in a linear manner. The power drive for the walking beam is typically a pneumatic or hydraulic two-stroke piston. The walking beam is illustrated in Fig (4). The piston provides the horizontal as well as the vertical drive for the system. As such, the driver stroke of the piston must be greater than the distance that the transfer rail and par travel. The action, as seen in the fig, begins by withdrawing the piston. The transfer rail moves backward until the rail makes contact with the back stop. The rail is then driven up by the walking beams until the rail falls to rest on the forward rest. The piston then drives the transfer rail forward until the forward stop is impacted. The forward stop inhibits the forward movement of the transfer rail, driving it back off the beams.



ECONOMICS OF AUTOMATION

The key to any production system is to utilize those components that produce the required quality part at the minimum cost. This cost is determined by a number of factors that go into the design of the system.

There are many ways to justify the use of automation in manufacturing. Although some industry projects are automated for a variety of reasons, including to increase: safety, to improve the work environment, to increase quality, and so on, the basis for virtually all automation applications is the economic advantage that it brings. In this section, we discuss one of the three of the most popular project economic-analysis methods. They are the ***playback period***, the ***before-tax cash-flow analysis***, and the ***after-tax cash-flow and analysis***.

Payback period: - is used to estimate the number of years required to recover an initial equipment investment. Payback may be the most widely used procedure in industry to cost justifies projects. A commonly used indication of an acceptable project is to have a payback period (N) less than 1.5 years. That is, any equipment that is used in industry must pay for itself within 1.5 years of installation. Although the period for payback varies throughout industry, 1.5 years seems to be the most common meter used.

The playback period, N, can be defined as

$$N = CO / Sa$$

Where:

Co = initial investment

Sa = annual savings

Example

A machine shop currently employs 5 machine operators. 3 material handlers, and uses 10 conventional machine tools. Based on a shop modernization study, 6 of the 10 machine tools can be replaced by 2 machining centers. After the system is implemented, only 2 machine operators are needed. However, an NC programmer will have to be hired. Some of the loading/unloading work can also be done by 2 pick-and-place robots. It is suggested that an automated material-handling system also should be implemented. The material-handling system will replace the 2 material handlers. After a simulation study is conducted, it is shown that the new system can increase production by 50%. We are interested to know whether the project is cost justifiable to implement. All equipment costs include installation. The cost data are

Operator rate (including overhead): $30,000/year

NC programmer rate (including overhead): $40,000/year

NC machine cost: $70.000 and $100,000, respectively

Estimated salvage value of 6 existing machines: $60.000

Robot cost: $50.000

Automated material-handling system cost: $50.000

Additional annual maintenance cost: $40,000/year

Solution:

CO = NC machine cost - salvage value of existing machines + robot's cost + automated material-handling-system cost

= $70,000 + $100,000 - $60,000 + $50,000 + $50,000 = $210,000

Sa = labor savings - programmer cost - maintenance cost

= \$30,000 x (3 + 2) - \$40.000 - \$40.000 = \$70,000

N = \$210.000 / \$70.000 = 3 years