SUMMARY OF AUTOMATION, PRODUCTION SYSTEMS, AND COMPUTER-INTEGRATED MANUFACTURING FOURTH EDITION BY MIKELL P. GROOVER

Guruh Dwi Septano

Graduate Student of Mechanical Engineering Department, Universitas Sriwijaya, Palembang, Indonesia

ABSTRACT

The word manufacturing derives from manus (hand) and factur (make), where the combination means made by hand. The manufacturing operation is concerned with transforming materials into items with greater value; the manufacturing process has adopted the automation system for the production system. Automation refers to mechanical equipment that performs physical tasks without the need for oversight by human workers. An automated system consists of three basic elements: the power to accomplish the system's operation, a program of instructions to direct the process, and a control system to actuate the instructions. The control system causes the process to accomplish its defined function, which performs several manufacturing operations. The controls in an automated system can be either closed-loop or open-loop, using discrete control and programmable logic controller. Sensors and actuators also support the logic controller's role in industrial control systems, which can be used for robotics.

Keywords: Manufacturing, Industrial control, Automation, Logic Control, Control system

1 INTRODUCTION

The manufacturing was accomplished when the word first appeared in English around 1567, defined from two Latin words, i.e., manus (hand) and factus (make), which means made by hand. In those times, the commercial goods were made by hand in small shops, and the goods were relatively simple. As many years passed, factories emerged with many workers at a single site, and much of the work had been organised using machines rather than hand-crafted techniques.

A production system is a collection of people, equipment, and procedures organised to perform a company's manufacturing operations. It consists of two major components, namely facilities and manufacturing support systems, as shown in Figure 1.

Facilities of the production systems consist of manufacturing system, factory and plant layout. And also, the layout of equipment is located. For manufacturing support systems, this section manages production and solves technical or logistics problems.

In ordering materials, moving the work through the factory, ensuring that products meet quality standards, product design and certain business functions are included in the manufacturing support systems. Production system flow will be shown in Figure 1

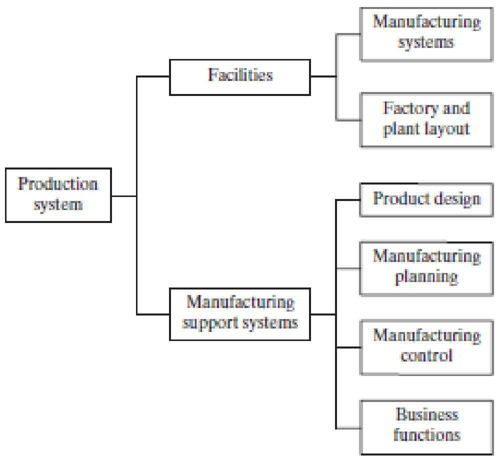

Figure 1 Production system flow

Manufacturing operations are concerned with transforming materials into items of greater value through one or more processing of assembly operations. The key point is that manufacturing

*Corresponding author's email: gd.septano@gmail.com
https://doi.org/10.36706/jmse.v8i2.60

adds value to the material by changing its shape or properties or by combining it with other materials that also have been altered. When iron ore is converted into steel, value is added. When sand is transformed into glass, value is added. When petroleum is refined into plastic, value is added. And when plastic is moulded into the complex geometry of a patio chair, it is made even more valuable. The classification of the manufacturing process is shown in Figure 2.

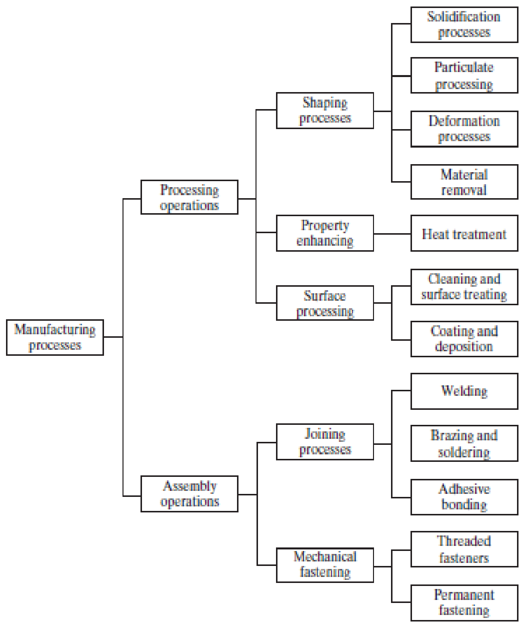

Figure 2 Classification of manufacturing processes

The industry consists of enterprises and organisations that produce and supply goods or services. Industries can be classified as primary, secondary, and tertiary.

Primary industries cultivate and exploit natural resources, such as agriculture and mining. Secondary industries convert the output of the primary sectors into products. Manufacturing is the principal activity in this category, but the secondary industries also include construction and power utilities. Tertiary industries constitute the service sector of the economy.

Production operations in the process and discrete product industries can be divided into continuous and batch production. Continuous production occurs when the production equipment is used exclusively for the given product, and the output of the product is uninterrupted. In the process industries, continuous production means that the process is carried out on a continuous stream of material, with no interruptions in the output flow. Batch production occurs when the materials are processed infinite amounts or quantities. The finite amount or quantity of material is called a batch in both the process and discrete manufacturing industries. Batch production is discontinuous because there are interruptions in production between batches. Reasons for using batch production include (1) differences in work units between batches necessitate changes in methods, tooling, and equipment to accommodate the part differences; (2) the capacity of the equipment limits the amount or quantity of material that can be processed at one time; and (3) the production rate of the equipment is greater than the demand rate for the parts or products, and is, therefore, makes sense to share the equipment among multiple parts or products.

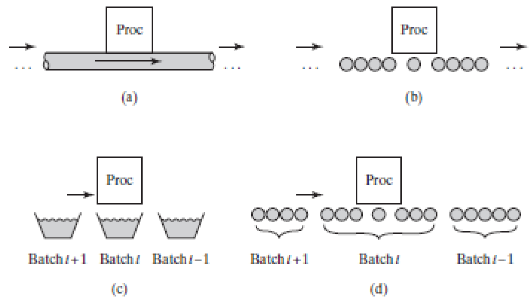

Figure 3 Batch production in the process and discrete manufacturing industries

Figure 3 is depicted the differences in batch production between the process and discrete manufacturing industries, where (a) continuous production in the process industries, (b) continuous production in the discrete manufacturing industries, (c) batch production in the process industries, and (d) batch production in the discrete manufacturing industries.

2 DISCUSSIONS

Every industry and manufacturing process should have an automation system for the production system. Automation refers to mechanised equipment that performs physical tasks without the need for oversight by a human worker. An automated system consists of three basic elements: (1) power to accomplish the process and operate the system, (2) a program of instructions to direct the process, and (3) a control system to actuate the instructions. The relationship among these elements is illustrated in Figure 4. All systems that qualify as automated include these three basic elements in one form or another. They are present in the three basic types of automated manufacturing systems: fixed, programmable, and flexible.

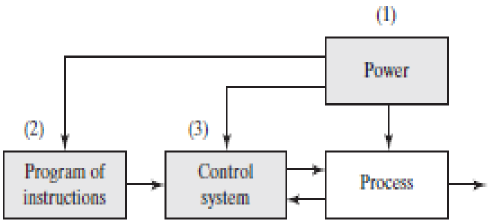

Figure 4 Elements of an automated system: (1) power, (2) program of instructions, and (3) control systems.

Power is also required for the following material handling functions: Loading and unloading the work unit, Material transport between operations. The automation power is used to; controller unit, power to actuate the control signals, data acquisition, and information processing. A program of instructions defines the actions performed by an automated process. Whether the manufacturing operation involves low, medium, or high production, each part or product requires one or more processing steps unique to that part or product. These processing steps are performed during a work cycle.

Work cycle programs are usually much more complicated than the furnace example described. Following are five categories of work cycle programs, arranged in approximate order of increasing complexity and allowing for more than one process parameter in the program; Set-point control, Logic control, Sequence control, Interactive program, and Intelligent program.

The Control system of the automated system executes the program of instructions. The control system causes the process to accomplish its defined function, which is to perform some manufacturing operation. The controls in an automated system can be either closed-loop or open loop. A closed-loop control system, also known as a feedback control system, is when the output variable is compared with an input parameter. Any difference between the two is used to drive the output to agree with the input. All the control will work as industrial control manufacturing process. Industrial control is defined here as the automatic regulation of unit operations and their associated equipment and the integration and coordination of the unit operations in the larger production system. In the context of this book, the term unit operations usually refer to the manufacturing process.

However, the term can also be applied to material handling and other industrial equipment. Industries and their production operations were divided into two basic categories: (1) process industries and (2) discrete manufacturing industries. Process industries perform their production operations on materials because they tend to be liquids, gases, powders, and similar materials. In contrast, discrete manufacturing industries perform their operations on quantities of materials. After all, the materials tend to be discrete parts and products. The kinds of unit operations performed on the materials are different in the two industry categories.

There are differences in the types of actuators and sensors used in the two industry categories at the device level, simply because the processes and equipment are different. In the process industries, the devices are used mostly for the control loops in chemical, thermal, or similar processing operations. In contrast, in discrete manufacturing, the devices control the mechanical actions of machines. At level 2, the difference is that unit operations are controlled in the process industries, and machines are controlled in discrete manufacturing operations. At level 3, the difference is between the control of interconnected unit processing operations and interconnected machines. At the upper levels (plant and enterprise), the control issues are similar, allowing for the products and processes are different.

Industrial control systems used in the process industries tend to emphasise the control of continuous variables and parameters. By contrast, the manufacturing industries produce discrete parts and products, and their controllers emphasise discrete variables and parameters. Just as there are two basic types of variables and parameters that characterise production operations, there are also two basic types of control: (1) continuous control, in which the variables and parameters are continuous and analog; and (2) discrete control, in which the variables and parameters are discrete, mostly binary discrete. Most operations in the process and discrete manufacturing industries include both continuous and discrete variables and parameters.

Consequently, many industrial controllers are designed to receive, operate on, and transmit both types of signals and data. Chapter 6 covers the various types of signals and data in industrial control systems and how the data are converted for use by digital computers

In continuous control, the usual objective is to maintain the value of an output variable at the desired level, similar to the operation of a feedback control system. Most continuous processes in the practical world consist of many separate feedback loops, all of which must be controlled and coordinated to maintain the output variable at the desired value. There are several ways to achieve the control objective in a continuous process-control system. In the following paragraphs, the most prominent categories are surveyed.

In discrete control, the parameters and variables of the system are changed at discrete moments in time, and the changes involve variables and parameters that are also discrete, typically binary (ON/OFF). The changes are defined in advance by employing a program of instructions, for example, a work cycle program. The changes are executed either because the system's state has changed or because a certain amount of time has elapsed. These two cases can be distinguished as (1) event-driven changes or (2) time-driven changes.

The control computer must collect data from and transmit signals to implement automation and process control. In Section 5.1.2, process variables and parameters as continuous or discrete, with several subcategories in the discrete class. The digital computer operates on digital (binary) data, whereas at least some data from the physical process are continuous and analog. Accommodations for this difference must be made in the computer–process interface.

A sensor is a device that converts a physical stimulus or variable of interest (such as temperature, force, pressure, or displacement) into a more convenient form (usually an electrical quantity such as voltage) to measure the stimulus. The conversion process quantifies the variable to be interpreted as a numerical value. Sensors can be classified in various ways, the most relevant of which for this discussion is by the category of stimulus or physical variable measured, as presented in Table 1.

Table 1 Categories of sensor and Physical Variables

Category	Examples of physical variables
Mechanical	Position (displacement, linear and angular), velocity, acceleration, force, torque, pressure, stress, strain, mass, density
Electrical	Voltage, current, charge, resistance, conductivity, capacitance
Thermal	Temperature, heat, heat flow, thermal conductivity, specific heat
Radiation	Type of radiation (e.g., gamma-ray, X-ray, visible light), intensity, wavelength
Magnetic	Magnetic field, flux, conductivity, permeability
Chemical	Component identities, concentration, pH levels, presence of toxic in gradients, pollutants

Besides the sensor, in industrial control systems, an actuator is a hardware device that converts a controller command signal into a change in a physical parameter. The change in the physical parameter is usually mechanical, such as a position or velocity change. An actuator is a transducer because it changes one type of physical quantity, such as electric current, into another type of physical quantity, such as the rotational speed of an electric motor. The controller command signal is usually low level, so an actuator may also require an amplifier to sufficiently strengthen the signal to drive the actuator.

Most actuators can be classified into one of three categories, according to the type of amplifier: (1) electric, (2) hydraulic, and (3) pneumatic. Electric actuators are most common; they include electric motors of various kinds, solenoids, and electromechanical relays. Electric actuators can be either linear (output is linear displacement) or rotational (output is angular displacement). Hydraulic actuators use hydraulic fluid to amplify the control command signal. The available devices provide either linear or rotational motion. Hydraulic actuators are often specified when large forces are required. Pneumatic actuators use compressed air (typically "shop air" in the factory) as the driving power. Again, both linear and rotational pneumatic actuators are available. Because of the relatively low air pressures involved, these actuators are usually limited to relatively low-force applications compared with hydraulic actuators.

For this industrial era, the industry used numerical control. Numerical control (NC) is a form of programmable automation in which the mechanical actions of a machine tool or other equipment are controlled by a program containing coded alphanumeric data. The alphanumeric data represent relative positions between a work head and a work part and other instructions needed to operate the machine. The work head is a cutting tool or other processing apparatus, and the work part is the object being processed. When the current job is completed, the instructions can be changed to process a new job. Changing the program makes NC suitable for low and medium production. Writing new programs is much easier than making major alterations in the processing equipment. Numerical control can be applied to a wide variety of processes. The applications are divided into (1) machine tool applications, such as drilling, milling, turning, and other metalworking, and (2) other applications, such as assembly, rapid prototyping, and inspection. The common operating feature of NC in all of these applications is control of the work head movement relative to the work part. An NC system consists of three basic components: (1) a part program of instructions, (2) a machine control unit, and (3) processing equipment. The general relationship among the three components is illustrated in Figure 5.

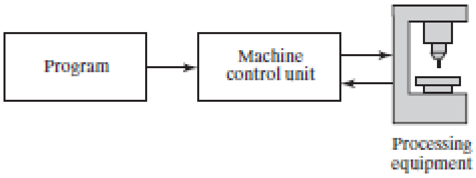

Figure 5 Basic components of an NC system.

The machine control unit (MCU) is a micro-computer and related control hardware that stores the program of instructions and executes it by converting each command into mechanical actions of the processing equipment, one command at a time. The related hardware of the MCU includes components to interface with the processing equipment and feedback control elements. The MCU also includes one or more reading devices for entering part programs into memory. Software residing in the MCU includes control system software, calculation algorithms, and translation software to convert the NC part program into a usable format for the MCU. Because the MCU is a computer, the term computer numerical control (CNC) is used to distinguish this type of NC from its technological ancestors based entirely on hardwired electronics. Today, virtually all new MCUs are based on computer technology. The configuration of the CNC machine control unit is shown in Figure 6.

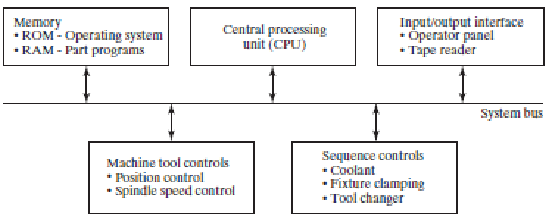

Figure 6 Configuration of CNC machine control unit.

A robotics system can motorise all This CNC. An industrial robot is defined as "an automatically controlled, reprogrammable, and multipurpose manipulator programmable in three or more axes, which may be either fixed in place or mobile for use in industrial automation applications".

It is a general-purpose machine possessing certain anthropomorphic characteristics, the most obvious is its mechanical arm. Other human-like characteristics are the robot's capabilities to respond to sensory inputs, communicate with other machines, and make decisions. These capabilities permit robots to perform a variety of industrial tasks. The development of robotics technology followed the development of numerical control (Historical Note 8.1), and the two technologies are quite similar. They both involve coordinated control of multiple axes (the axes are called joints in robotics), and they both use dedicated digital computers as controllers. Whereas NC (numerical control) machines are designed to perform specific processes (e.g., machining, sheet metal hole punching, and thermal cutting), robots are designed for a wider variety of tasks. Typical production applications of industrial robots include spot welding, material transfer, machine loading, spray painting, and assembly.

The arm or manipulator of an industrial robot consists of a series of joints and links. Robot anatomy is concerned with the types and sizes of these joints and links and other aspects of the manipulator's physical construction. The robot's anatomy affects its capabilities and the tasks for which it is best suited. A robot's joint, or axis as it is also called in robotics, is similar to a joint in the human body: It provides relative motion between two body parts.

Robots are often classified according to the total number of axes they possess. Connected to each joint are two links, an input link and an output link. Links are the rigid components of the robot manipulator. The purpose of the joint is to provide controlled relative movement between the input link and the output link.

Nearly all industrial robots have mechanical joints classified into five types: two types that provide translational motion and three types that provide rotary motion; 1—linear joint (type L joint). The relative movement between the input link and the output link is a translational telescoping motion, with the axes of the two links being parallel. 2. Orthogonal joint (type O joint). This is also a translational sliding motion, but the input and output links are perpendicular. 3. Rotational joint (type R joint). This type provides relative rotational motion, with the axis of rotation perpendicular to the axes of the input and output links. 4. Twisting joint (type T joint). This joint also involves rotary motion, but the axis of rotation is parallel to the axes of the two links. 5. Revolving joint (type V joint, V from the "v" in revolving). In this joint type, the axis of the input link is parallel to the joint's axis of rotation, and the axis of the output link is perpendicular to the axis of rotation.

Robot controllers can be classified into four categories: (1) limited-sequence control, (2) playback with point-to-point control, (3) playback with continuous path control, and (4) intelligent control. The robot has many applications for industrial robots that are used in a wide field of applications in industry. Most of the current applications are in manufacturing. The applications can usually be classified into one of the following categories: (1) material handling, (2) processing operations, and (3) assembly and inspection.

A robot must be programmed to perform a motion cycle to accomplish useful work. A robot program can be defined as a path in space to be followed by the manipulator, combined with peripheral actions that support the work cycle. Examples of peripheral actions include opening and closing a gripper, performing logical decision making, and communicating with other pieces of equipment in the cell. A robot is programmed by entering the programming commands into its controller memory. Different robots use different methods of entering the commands. In the case of limited-sequence robots, programming is accomplished by setting limit switches and mechanical stops to control the endpoints of its motions. A sequencing device regulates the sequence in which the motions occur. This device determines how each joint is actuated to form the complete motion cycle. Setting the sequencer's stops and switches and wiring is more akin to a manual setup than programming. Today, nearly all industrial robots have digital computers as controllers and compatible storage devices as memory units. For these robots, three programming methods can be distinguished: (1) lead through programming, (2) computer-like robot programming languages, and (3) offline programming.

We know there are discrete control and programmable logic controllers in industrial control. Discrete process control systems deal with parameters and variables that are discrete and that change values at discrete moments in time. The parameters and variables are typically binary; they can have either two possible values, 1 or 0. The values mean ON or OFF, true or false, object present or not present, high voltage value or low voltage value, and so on, depending on the application. The binary variables in discrete process control are associated with input signals to the controller and output signals from the controller. Input signals are generated by binary sensors, such as limit switches and photosensors, interfacing with the process. The controller generates output signals to operate the process in response to the input signals and time. These output signals turn on and off switches, motors, valves, and other binary actuators related to the process—interpreting their 0 and 1 values. The controller's purpose is to coordinate the various actions of the physical system, such as transferring parts into a work holder, feeding a machining work head, and so on. Discrete process control can be divided into two categories: (1) logic control, which is concerned with event-driven changes in the system, and (2) sequence control, which is concerned with time-driven changes in the system.1 Both control types are referred to as switching systems because they switch their output values on and off in response to changes in events or time.

A programmable logic controller (PLC) is a microcomputer-based controller that uses stored instructions in programmable memory to implement logic, sequencing, timing, counting, and arithmetic functions through digital or analog input/output (I/O) modules for controlling machines and processes. PLC applications are found in both the process industries and discrete manufacturing. Examples of applications in process industries include chemical processing, paper mill operations, and food production. PLCs are primarily associated with discrete manufacturing industries to control individual machines, machine cells, transfer lines, material handling equipment, and automated storage systems. The basic components are as follows: (1) processor, (2) memory unit, (3) power supply, and (4) I/O module. These components are housed in a suitable cabinet designed for the industrial environment. In addition, there is a programming device that can be disconnected from the PLC when not required [1]. A schematic diagram of a PLC is presented in Figure 7

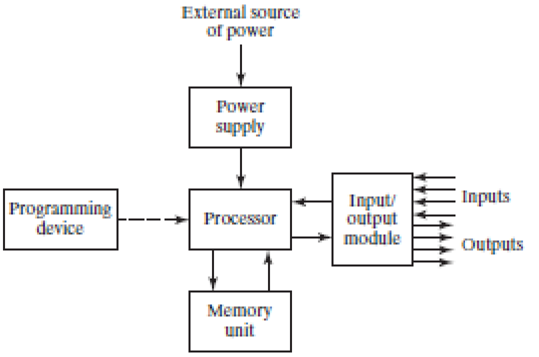

Figure 7 Component of PLC

The industrial revolution 4.0 era is a phase of change. The manufacturing industry uses the internet for all activities in digital form. One of the challenges in industrial revolution 4.0 for the manufacturing industry is monitoring and evaluating product quality. Product Quality Assurance (PQA) systems are used to ensure the production process from raw materials until becoming a product [2] [3].

REFERENCES

[1] Groover M P 2014 *Automation, Production Systems, and Computer-Integrated Manufacturing*

[2] Illes B, Tamas P, Dobos P and Skapinyecz 2017 New Challenges for Quality Assurance of Manufacturing Processes *Solid State Phenom.* **261** 481–6

[3] Daniel D E, Koerner R M and Carson D A 1995 *Quality Assurance and Quality Control for Waste Containment Facilities.* (Cincinnati, Ohio, USA)