MATERIALS, MANUFACTURING, AND THE STANDARD OF LIVING

Manufacturing is critical to a country's economic welfare and standard of living because the standard of living in any society is determined, primarily, by the goods and services that are available to its people. Manufacturing companies contribute about 20% of the GNP, employ about 18% of the workforce, and account for 40% of the exports of the United States. In most cases, materials are utilized in the form of manufactured goods.

Manufacturing and assembly represent the organized activities that convert raw materials into salable goods. The manufactured goods are typically divided into two classes: **producer goods and consumer goods.** Producer goods are those goods manufactured for other companies to use to manufacture either producer or consumer goods. Consumer goods are those purchased directly by the consumer or the general public. For example, someone has to build the machine tool (a lathe) that produces (using machining processes) the large rolls that are sold to the rolling mill factory to be used to roll the sheets of steel that are then formed (using dies) into body panels of your car.

Similarly, many service industries depend heavily on the use of manufactured products, just as the agricultural industry is heavily dependent on the use of large farming machines for efficient production.

Processes convert materials from one form to another adding value to them. The more efficiently materials can be produced and converted into the desired products that function with the prescribed quality, the greater will be the companies' productivity and the better will be the standard of living of the employees.

The history of man has been linked to his ability to work with tools and materials, beginning with the Stone Age and ranging through the eras of copper and bronze, the Iron Age, and recently the age of steel. While ferrous materials still dominate the manufacturing world, we are entering the age of tailor-made plastics, composite materials, and exotic alloys.

A good example of this progression is shown in Figure 1. The goal of the manufacturer of any product or service is to continually improve. For a given product or service, this improvement process usually follows an S-shaped curve, as shown in Figure 1- a, often called a product life-cycle curve. After the initial invention/creation and development, a period of rapid growth in performance occurs, with relatively few resources required. However, each improvement becomes progressively

more difficult. For a gain, more money and time are required. Finally, the product or service enters the maturity phase, during which additional performance gains become very costly.

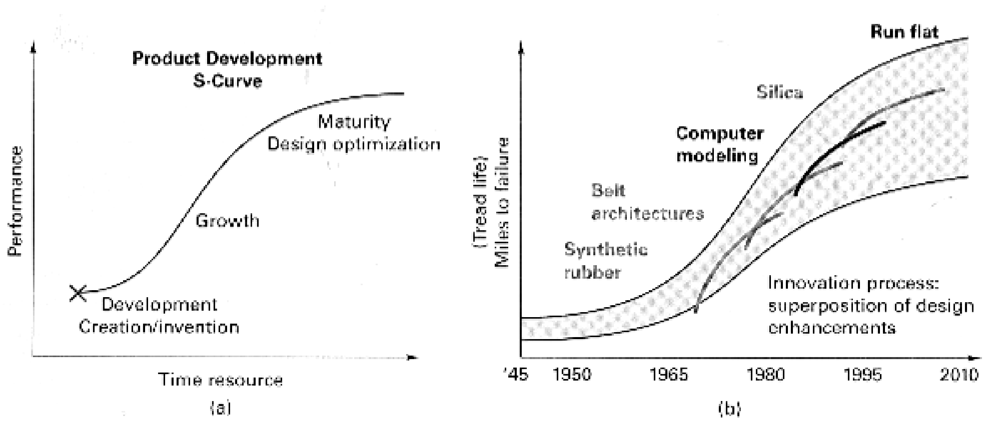

FIGURE 1(a) A product development curve usually has an "S"- shape.
(b) Example of the S-curve for the radial tire. (Courtesy of Bart Thomas, Michelin)

For example, in the automobile tire industry, Figure 1-b shows the evolution of radial tire performance from its birth in 1946 to the present. Growth in performance is actually the superposition of many different improvements in material, processes, and design.
These innovations, known as **sustaining technology**, serve to continually bring more value to the consumer of existing products and services. In general, sustaining manufacturing technology is the backbone of American industry and the ever increasing productivity.

Although materials are no longer used only in their natural state, there is obviously an absolute limit to the amounts of many materials available here on earth. Therefore, as the variety of man-made materials continues to increase, resources must be used efficiently and recycled whenever possible.

Like materials, processes have also increased greatly in the past 50 years, with new processes being developed to handle the new materials more efficiently and with less waste. A good example is the laser, invented around 1960, which now finds many uses in machining, measurement, inspection, heat treating, welding, and more.

New developments in manufacturing technology often account for improvements in productivity. Even when the technology is controlled, the competition often gains access to it, usually quite quickly.

Starting with the product design, materials, labor, and equipment are interactive factors in manufacturing that must be combined properly (integrated) to achieve low cost, superior quality,

and on-time delivery. Figure 2 shows a breakdown of costs for a product (like a car). Typically about 40% of the selling price of a product is the **manufacturing cost**. Because the selling price determines how much the customer is willing to pay, maintaining the profit often depends on reducing manufacturing cost.

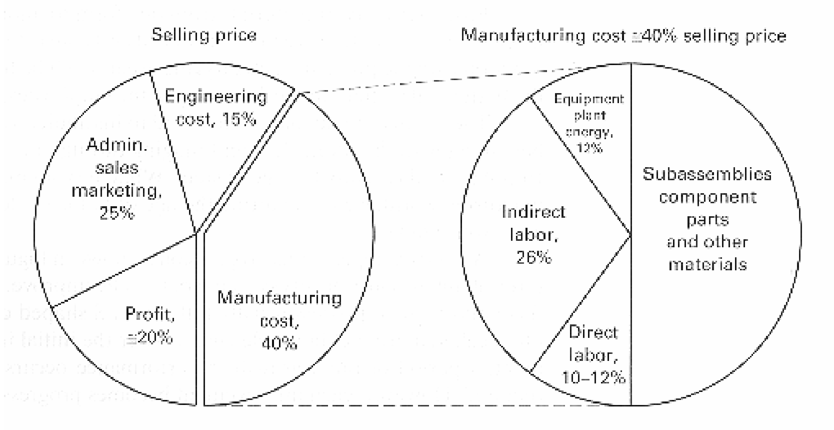

FIGURE 2 Manufacturing cost is the largest part of the selling price, usually around 40%. The largest part of the manufacturing cost is materials, usually 50%.

The internal customers who really make the product are called direct labor. They are usually the targets of automation, but typically they account for only about 10% of the manufacturing cost, even though they are the main element in increasing productivity. A manufacturing strategy is presented that attacks the materials cost, indirect costs, and general administration costs, in addition to labor costs. The materials costs include the cost of storing and handling the materials within the plant. The strategy depends on a new factory design and is called lean production.

MANUFACTURING AND PRODUCTION SYSTEMS

Manufacturing is the economic term for making goods and services available to satisfy human wants. Manufacturing implies creating value by applying useful mental or physical labor. The manufacturing processes are collected together to form a **manufacturing system (MS)**. The manufacturing system is a complex arrangement of physical elements characterized by measurable parameters (Figure 3). The manufacturing system takes inputs and produces products for the external customer.

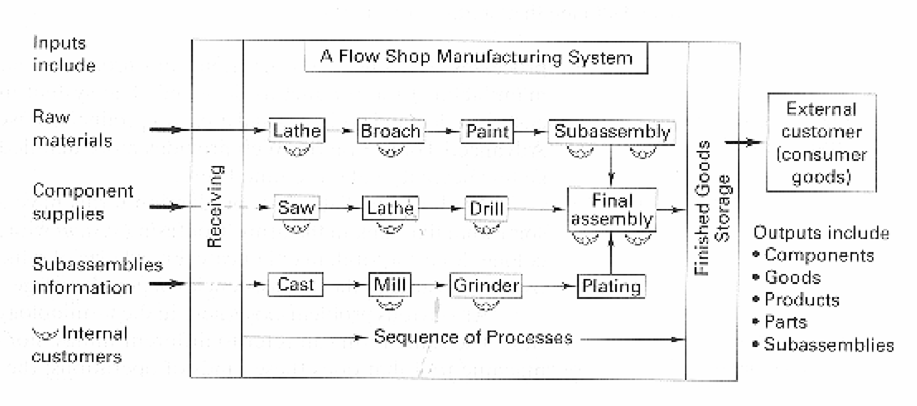

FIGURE 3 The manufacturing system design is composed of machines, tooling, material handling equipment, and people.

The entire company is often referred to as the enterprise or the production system. The production services the manufacturing system, as shown in Figure 4. In this text, a production system will refer to the total company and will include within it the manufacturing system. The production system includes the manufacturing system plus all the other functional areas of the plant for information, design, analysis, and control. These subsystems are connected by various means to each other to produce either goods or services or both.

Goods refer to material things. **Services** are nonmaterial things that we buy to satisfy our needs. Service production systems include transportation, banking, finance, savings and loan, insurance, utilities, health care, education, communication, entertainment, sporting events, and so forth. They are useful labors that do not directly produce a product. Manufacturing has the responsibility for designing processes (sequences of operations and processes) and systems to create (make or manufacture) the product as designed. The system must exhibit flexibility to meet customer demand (volumes and mixes of products) as well as changes in product design.

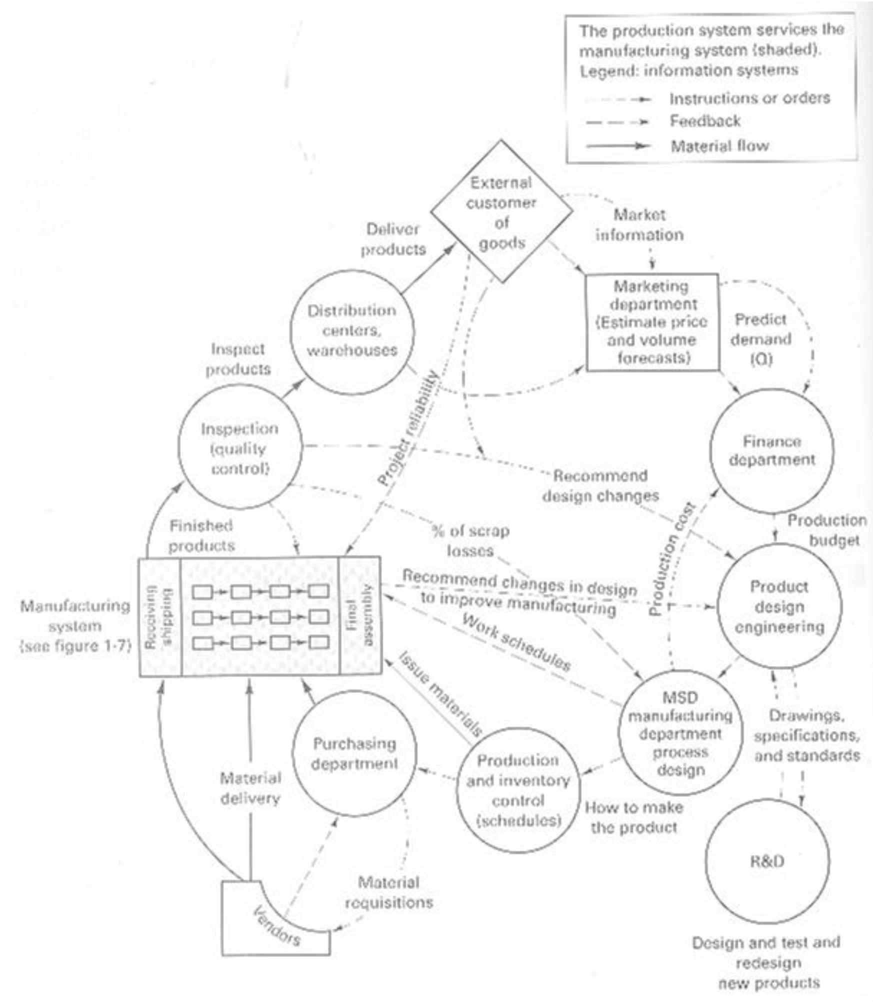

FIGURE 4 The production system includes and services the manufacturing system. The functional departments are connected by formal and informal information systems, designed to service the manufacturing that produces the goods.

MANUFACTURING SYSTEMS

A collection of operations and processes used to obtain a desired product(s) or component(s) is called a **manufacturing system**. The manufacturing system is therefore the design or arrangement of the manufacturing processes in the factory. Control of a system applies to overall control of the whole, not merely of the individual processes or equipment. The entire manufacturing system must be controlled in order to schedule and control the factory-all its inputs, inventory levels, product quality, output rates, and so forth.

MANUFACTURING PROCESSES

A manufacturing process converts unfinished materials to finished products, often using machines or machine tools. For example, injection molding, die casting, progressive stamping, milling, arc welding, painting, assembling, testing, pasteurizing, homogenizing, and annealing are commonly

called processes or manufacturing processes. The term process can also refer to a sequence of steps, processes, or operations for production of goods and services, as shown in Figure 5, which shows the processes to manufacture an Olympic-type medal.

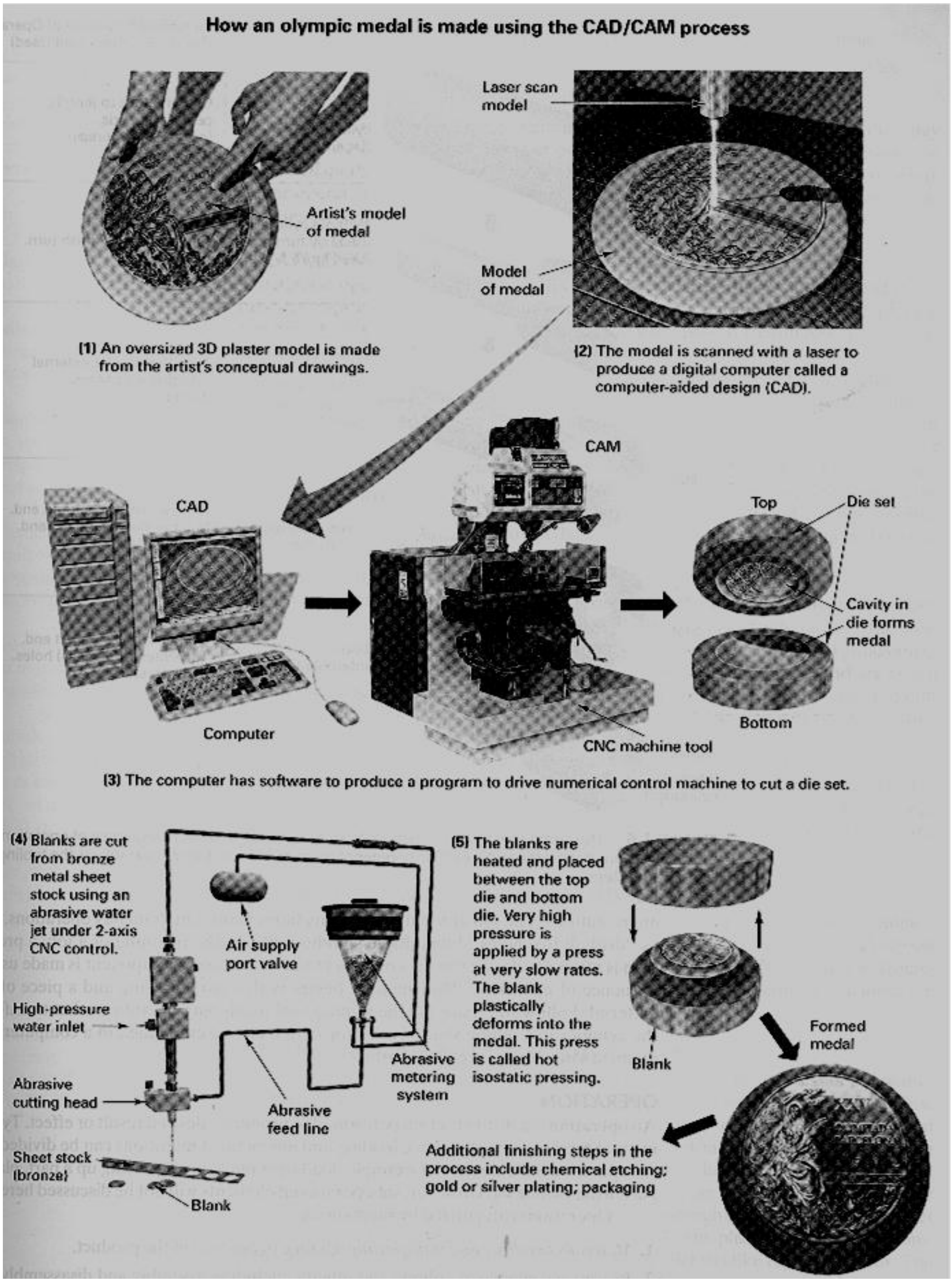

FIGURE 5 The manufacturing process for making Olympic medals has many steps or operations beginning with design and including die making.

A machine tool is an assembly of related mechanisms on a frame or bed that together produce a desired result. Generally, motors, controls, and auxiliary devices are included. Cutting tools and work-holding devices are considered separately.

A machine tool may do a single process (e.g., cutoff saw) or multiple processes, or it may

manufacture an entire component. Machine sizes vary from a tabletop drill press to a 1000-ton forging press.

JOB AND STATION

In the classical manufacturing system, a **job** is the total of the work or duties a worker performs. A station is a location or area where a production worker performs tasks or his job.

A job is a group of related operations and tasks performed at one station or series of stations in cells. For example, the job at a final assembly station may consist of four tasks:

1. Attach carburetor.
2. Connect gas line.
3. Connect vacuum line.
4. Connect accelerator rod.

The job of a turret lathe (a semiautomatic machine) operator may include the following operations and tasks: load, start, index and stop, unload, inspect. The operator's job may also include setting up the machine (i.e., getting ready for manufacturing). Other machine operations include drilling, reaming, facing, turning, chamfering, and knurling. The operator can run more than one machine or service at more than one station.

The terms job and station have been carried over to unmanned machines. A job is a group of related operations generally performed at one station, and a station is a position or location in a machine (or process) where specific operations are performed. A simple machine may have only one station.

Complex machines can be composed of many stations. The job at a station often includes many simultaneous operations, such as "drill all five holes" by multiple spindle drills. In the planning of a job, a process plan is often developed (by the engineer) to describe how a component is made using a sequence of operation. The engineer begins with a part drawing and a piece of raw material.

Follow in Figure 6 the sequence of machining operations that transforms the cylinder in a pinion shaft. This information can be embedded in a computer program, in a machine tool called a lathe.

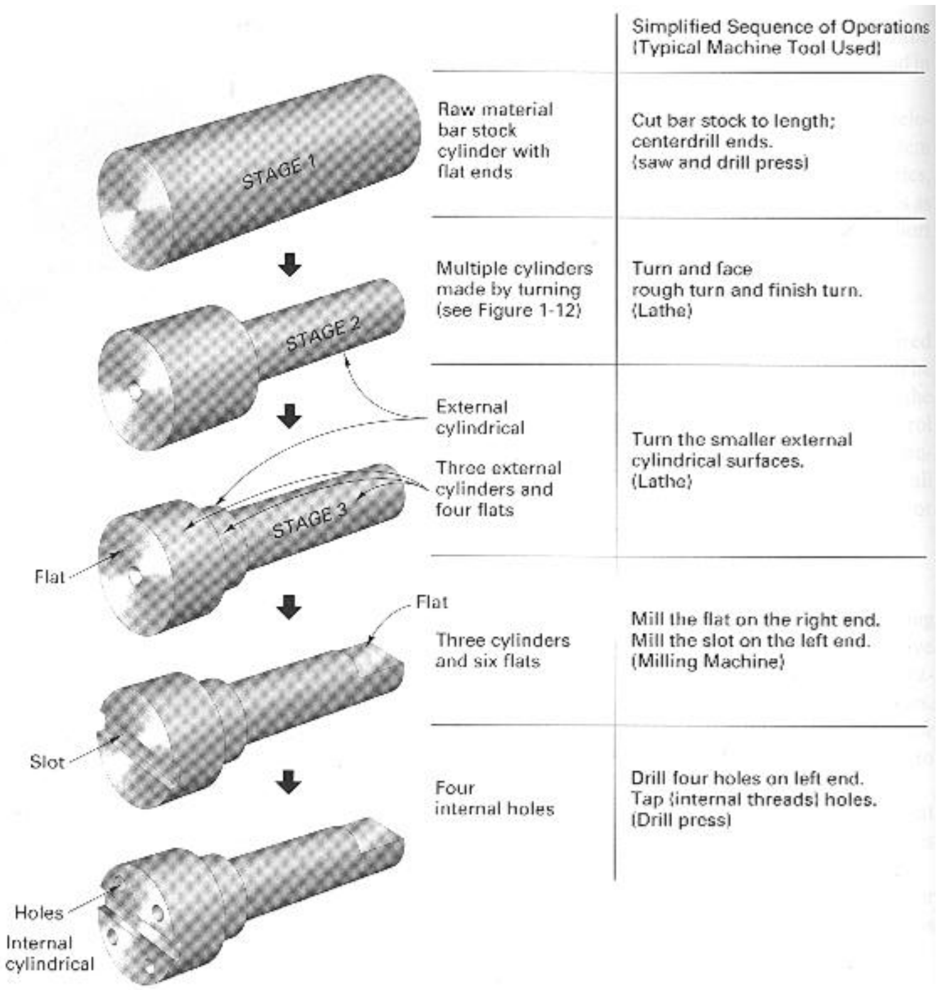

FIGURE 6 The component called a pinion shaft is manufactured by a "sequence of operations" to produce various geometric surfaces. The engineer figures out the sequence and selects the tooling to perform the steps.

OPERATION

An operation is a distinct action performed to produce a desired result or effect. Typical manual machine operations are loading and unloading. Operations can be divided into sub operational elements. For example, loading is made up of picking up a part, placing part in jig, closing jig. However, sub-operational elements will not be discussed here.

Operations categorized by function are:

1. *Materials handling and transporting:* change in position of the product.
2. *Processing:* change in volume and quality, including assembly and disassembly; can include packaging.
3. *Packaging:* special processing; may be temporary or permanent for shipping.
4. *Inspecting and testing:* comparison to .the standard or check of process behavior
5. *Storing:* time lapses without further operations.

These basic operations may occur more than once in some processes, or they may sometimes be omitted. *Remember, it is the manufacturing processes that change the value and quality of the materials.* Defective processes produce poor quality or scrap. Other operations may be necessary but do not, in general, add value, whereas operations performed by machines that do material processing usually do add value.

ROLES OF ENGINEERS IN MANUFACTURING

Many engineers have as their function the designing of products. The products are brought into reality through the processing or fabrication of materials. In this context designers are a key factor in the material selection and manufacturing procedure.

A design engineer, better than any other person, should know what the design is to accomplish, what assumptions can be made about service loads and requirements, what service environment the product must withstand, and what appearance the final product is to have. To meet these requirements, the material(s) to be used must be selected and specified.

Manufacturing engineers select and coordinate specific processes and equipment to be used or supervise and manage their use. Some design special tooling is used so that standard machines can be utilized in producing specific products. These engineers must have a broad knowledge of manufacturing processes and material behavior so that desired operations can be done effectively and efficiently without overloading or damaging machines and without adversely affecting the materials being processed. Although it is not obvious, the most hostile environment the material may ever encounter in its lifetime is the processing environment.

Industrial and lean engineers are responsible for manufacturing systems design (or layout) of factories. They must take into account the interrelationships of the factory design and the properties of the materials that the machines are going to process as well as the interreaction of the materials and processes. The choice of machines and equipment used in manufacturing and their arrangement in the factory are key design tasks.

Materials engineers devote their major efforts to developing new and better materials. They, too, must be concerned with how these materials can be processed and with the effects that the processing will have on the properties of the materials. Although their roles may be quite different, it is apparent that a large proportion of engineers must concern themselves with the interrelationships of materials and manufacturing processes.