J. L. MORRIS

Modern Manufacturing Processes

MODERN MANUFACTURING PROCESSES

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PREFACE

THIS BOOK presents a comprehensive survey of present manufacturing processes. My objective has been to explain each topic in a concrete, understandable manner. Wherever necessary, illustrations have been used to clarify any process or idea that might otherwise be vague to the general reader. The subject matter has been organized for natural continuity; for instance, the processing of metals is discussed in the following order: refining ores, making and refining metals, casting, rolling, hot and cold working, and machining. Such continuity will help the reader to visualize the overall operation and also allow him to understand the inter-relationship of the various steps within the process.

For the advanced reader, such as the practicing engineer or the industrial worker who wishes to study any specific topic exhaustively, adequate references and review questions to supplement his knowledge of the subject are given at the ends of most of the chapters.

The principles and processes of manufacturing are explained at a fundamental level. Some three hundred drawings and photographs have been selected to clarify the text matter, and all were chosen for their utility to the reader. With the same objective in mind, the inclusion of tables has been minimized to those of greatest usefulness for the reader.

Selected visual aids are listed, with their sources, at the ends of most chapters, which relate closely to the subjects discussed. In my own experience I have found such aids very useful adjuncts to visualize any discussion of a particular topic.

I offer my deep appreciation to the many people who have contributed to the contents of this book, both for supplying illustrations and for reviewing sections of the manuscript for accuracy and good organization. Finally, to my wife, Zelda, goes my gratitude for her encouragement and assistance throughout the production of this book.

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THE MANUFACTURING SYNTHESIS: EQUIPMENT, METHODS, AND MATERIALS

What is manufacturing?

Generally, manufacturing is considered to be the repeated production of items, parts, units, or assemblies that have commercially exact size, shape, appearance, and quality. This method of making items or products used in everyday living is claimed to be an outgrowth of American ingenuity and need. Fulfillment of consumer demand by large-scale manufacturing has led to higher wage scales and salaries—higher standards of living resulting therefrom and superior qualities and appearances in the items made.

Nature of manufacturing equipment

Someone has said that the difference between manufacturing and job-shop production is that the latter uses no jigs or fixtures, since only one or a few workpieces, at most, are made. The statement probably concerned metal fabrication, but might befit the nature of most manufacturing and job shop plants. The term "manufacturing" does not necessarily imply that the amount of a single item made be great. However, manufacturing generally involves extensive tooling and high capital outlay. Therefore, if only a small quantity of parts, assemblies, or units were produced, the prorated cost of each would be exorbitantly high. Similarly, the unit costs of parts made by shop methods would be high because of high unit production time and the premium wage rate of the machine operator.

Manufacturing plant operations often begin in job shops. In fact, even today, working models and prototypes of important machines, such as automobiles and airplanes, are originated in this way. Job shops often perform a dual service—regular job-shop work and manufacturing. The latter usually involves general-purpose machines tooled for special-purpose operations. Where repetitive operations seem to warrant the use of special-purpose machines, such as an automatic lathe for the machine shop or a shell-molding machine for the foundry, the plant becomes, in essence, a factory. Machines thus used, and capable of repeating production functions, reduce the unit cost of products so they can be sold at competitive and profit-yielding prices.

General-purpose tools or equipment embody features which enable them to do many processing operations, so they are very useful for general job-shop work where there is little duplication and speed is not too important. The general-purpose drilling machine is typical of such equipment. A drilling machine, although primarily intended to do the simplest kind of drilling operations, may be equipped with a multiple-spindle head and thus be used, with a drilling jig, to drill simultaneously several holes at accurately spaced locations in a workpiece. It is evident that such equipment would be impractical for the making of a single workpiece.

On the other hand, special-purpose machines—made up either of standard machine units or from special units—involve high capital outlay and comparatively long periods of setting up and adjusting. Special-purpose machines are feasible and profitable only when hundreds or thousands of parts are to be made exactly alike, within commercial limits.

Why is manufacturing important in our present economic structure?

Could an American wage earner afford a new automobile every few years if the car sold for twice its current price? The obvious answer justifies mass production and manufacturing in which special tooling, interchangeability, and production-line assembling are practiced. Records show that the hand-fitted, job-shop-built automobile of 1910 was priced as high as $4,000, a figure that often made the vehicle impractical and unattainable at that time. Then, within a decade, manufacturing and continuous-line assembling was realized, along with sharp reductions in cost, by the Ford Motor Company and many other concerns. By this expedient, automobiles were placed on the market at nominal prices, making possible their use by everyone of average means.

Machines and labor

The introduction of special-purpose manufacturing machines produced a wave of feeling among workmen and labor organizations that jobs would disappear. In short-term consideration, such a feeling was well-founded and has in some instances occurred. Speaking in a long-term sense, however, two significant advantages have accrued to the workmen out of mechanization. Although the installation and use of one automatic machine might have displaced ten workmen, over a long period of time the machine made possible merchandise of lower cost, an advantage that was passed on to the displaced workmen, making their dollar worth more. In the meantime, the displaced persons were employed in other areas of the plant or they found work elsewhere and, because of their increased purchasing power, their demands became greater which, in turn, required more production from the automatic machine that originally initiated the economic cycle. Production history reveals thousands of cases that are in nature and effect similar to the example given. American industry is based on machines and automatic manipulations rather than hand production, the latter system tending to persist in the European countries, although their production backgrounds are much older. This fact will account, certainly in part, for the lower living standards in such countries as Russia, Greece, Italy, Spain, among others.

Production machines are not subject to whims, moods, or temperaments as are human beings. If a machine is properly designed, installed, and serviced, it will produce parts of good, uniform quality faithfully and continuously. The advantages of machine-made parts are higher quality and more uniform appearance, whereas most hand-made parts vary in these features, and, as a result, fail to lend themselves to rapid assembling into final units. Of course, hand work must be used in the control, tooling, and adjustment of automatic machines, or in production where some individual touches of artistry are required. Such items as pottery, paintings, and carvings are frequently made entirely by hand.

Interchangeability—its influence on production economy

Manufacturing, where developed to commercial perfection, employs the principle of *interchangeability.* In effect, interchangeability means that any one of several thousand parts selected at random will fit and function satisfactorily with any one of several thousand mating parts both in assembly and in subsequent use. Such production perfection requires rigorous inspecting and gaging. Although made on a precision machine, such parts will vary slightly in size and shape, depending on the degree of precision of the machine used, the skill of the operator, the uniformity of raw material, and possibly other factors. To achieve successful interchangeability, many types of gages are employed during and after shaping a part to assure its suitability for use. In this way loss of labor is avoided both during production and from misfits at the point of assembly. One of the most common gages used for dimensional inspection is the GO and NOT GO gage, the two features usually being combined into one instrument. For example, when a snap gage is brought into gaging position, if the workpiece enters the GO gage and will not enter the NOT GO gage it is small enough but not too large to fulfill its intended purpose satisfactorily. A gage of this type will serve to sort workpieces into satisfactory and unsatisfactory groups.

The amount of variation, plus or minus, away from the ideal size, depends on the design engineer's judgment and on the class of fit he has selected.[1] Parts made for earth-processing equipment, such as farm implements and road graders, require much less precision for their fitted functional parts, in contrast to the close clearances demanded for Diesel-engine fuel-pump pistons and cylinders, antifriction bearings, and other similar parts. Closely fitted parts are much more expensive to produce than loosely fitted ones and, therefore, close fitting should not be specified by the designer unless it is really necessary.

[1] American Standards Association, B4.1-1947, *Limits and Fits for Engineering and Manufacturing.*

Manufacturing and interchangeability are companion systems that have made American manufacturing the industrial giant that it is today. Several advantages result from such production. First, for machine assembly, such as an automobile or tractor, the interchangeable component parts flow to specified points along a continuous production line and are there used at random, their installation requiring no individual attention or fitting. Second, repair or replacement parts are cataloged and stored in bins at the factory or in the local distributor's plant, so that machine repair work is rapid and economical.

The principle of interchangeability also applies to sub-assembly units, which when joined compose the final assembly. Such an effect is frequently attained by the efficient use of jigs and fixtures to hold and support the several component parts in proper relationship until they are permanently secured together. This method of assembly is possible only through the quantity production of interchangeable parts. Sub-assembly and final assembly are common in the automotive, aircraft, electrical, and many other industries.

Purpose of the job shop

The primary purpose of a job shop is usually to make a single item or to make the necessary parts to repair a single machine. Mass assembling is never practiced in a job shop, but limited interchangeability is possible for some stock items, such as standard drills and reamers, cap screws, nuts, antifriction bearings, bushings, and other items that are usually purchased from a supplier. Since the cost of jigs and fixtures cannot be justified, these tools are seldom employed in job shops.

Standards for manufactured products

Quality, shape, size and other features of many ordinary items made vary considerably among the many producing concerns. In keeping with the American spirit of making interchangeable parts, many professional societies and other sponsoring agencies have frequently pooled their resources and efforts toward the standardization of shapes, dimensions, and qualities of such common and elemental items as gears, cap screws, drawing symbols, cutting tools, etc. Most testing procedures are standardized. The use of standards is not always compulsory unless details excerpted from them are used in specifications, purchase orders, or work orders. The purposes of these standards are to avoid confusion in definition and terminology, misunderstanding in applying and supplying, and to provide a basis from which elemental parts may be made and thus achieve the greatest advantages from interchangeability.

Standards covering manufactured products may be found in any good engineering library. The following is a list of standards that covers a few of the ordinary and varied kinds of production items.

A87.1-1941. *Building Code Requirements for Steel Joint Construction.*

B18.6-1947. *Slotted and Recessed Head Screws.*

Z38.8.3-1947. *Photographic Processing; Manipulation of Films and Plates, Practices for.*

B4.1-1947. *Limits and Fits for Engineering and Manufacturing.*

B16.1-1949. *Ferrous Plugs, Bushings, and Locknuts, with Pipe Threads.*

Z21.11-1948. *Gas Space Heaters, Approval Requirements for.*

B.7-1949. *Nomenclature, Definitions, and Letter Symbols for Screw Threads.*

Z10.7-1950. *Letter Symbols for Aeronautical Sciences.*

The production plan

An efficient production plan consists of the procurement of raw materials and supplies, scheduling of materials to appropriate points in the processing plant, actual processing, scheduling to the assembly line, and storing or shipping the end product. Unless production is planned with care, stocks will accumulate in unwieldy quantities at certain points in the plant, while other divisions may be delayed by shortages of perhaps small but important items.

The production plan may or may not include the actual product design, depending on the policy of the particular concern. Three personalities and their staffs are mutually responsible for the design of satisfactory parts after the management has decided to manufacture a product.

It is the responsibility of the design engineer to select appropriate materials, calculate sections, and strengths, and decide from what class of raw or semifinished materials the component parts should be made. He usually encounters two problems. First, will the item (to be made from a selected material, and of a given mass and shape) function properly for a reasonable period of time? Second, as conceived on the drawing board, can the item be made and marketed competitively and profitably? With these two questions paramount in his mind, the designer must use well-considered judgment in selecting from the materials and processes available to him. In the matter of materials, should plain carbon steel, alloy steel, aluminum, brass, or plastic be used? In the matter of processes, should manufacturing be done by casting, welding, or machining? From the standpoint of raw materials, should parts be made from castings, forgings, plates, standard shapes and bar stock, or other materials? His final judgment will be influenced by the labor skills and types of machines which are available and by proximity to necessary supplies. For example, if machine bases were to be manufactured in a plant having welding skills and equipment, and if a source for favorably priced rolled-steel shapes and plates were near the plant, the units could be advantageously made from steel and weld-fabricated. On the other hand, if the plant's principal interest was the production of gray iron castings, then the design should probably reflect the most effective use of foundry castings.

Usually a model and/or prototype of the product is prepared before its actual production. Then the item can be studied in its true perspective and revised where necessary to improve its final form.

If eye appeal or beauty are to be a feature of the product, an artist specializing in product design should be consulted during the drawing stage and at the completion of the model. For instance, plumbing fixtures and household appliances, among others, require collaboration between the design engineer and artist throughout the design stage for best effect. Before styling and mechanical design are completed, the plant production superintendent should be consulted to examine the drawings to determine whether such design and styling are suited to his manufacturing facilities. If this step is overlooked, prohibitive tooling costs may result later, as well as disagreements with the production division, so that the designer's work is wasted.

Satisfactory and profitable manufacturing can be achieved only after all or most features of a product are agreed upon by management, including sales, from production through final assembling. One or more prototypes should have been tested and revised when necesary. The ultimate test, of course, will be applied by the operator or owner of the product, whose unanticipated uses are often quite dissimilar to those imposed during factory testing routines. For this reason, most reliable manufacturers stand ready to make even major adjustments and replacements to a product after it has been purchased by the user.

Starting the production program

A production program is usually initiated upon release of work orders by management which, in turn, set in motion the procurement of raw materials and process scheduling. Simultaneously, the production department scrutinizes its facilities both as to space available and processing machines capable of maintaining the quality and quantity standards required. Any necessary equipment which must be ordered should be scheduled so that its installation, adjustment, and use will not cause a delay in production. The number of machine units required will depend on anticipated output and the policy set by management with respect to capital outlay. Occasionally, such a policy, if stubbornly restrictive, will act as a real hindrance to effective and smooth plant output, although reluctance to buy new equipment seldom exists in management if well-founded reasons for such procurement can be supported.

Questions

1. What is manufacturing?
2. How does manufacturing differ from job-shop work?
3. Explain what is meant by "general-purpose machine tools"; "special-purpose machine tools"?
4. How can the use of machines lead to a higher standard of living?
5. What is "interchangeability," and how is it related to manufacturing?
6. Explain the term "standard."