4th EDITION

MANUFACTURING PROCESSES

MYRON L. BEGEMAN

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Dedicated to
Hazel, Robert, and Jean

PREFACE

The purpose of this book is to provide for students of engineering a text which will give not only a basic knowledge of the materials and processes to be encountered in industry, but also some training in manufacturing operations. While these operations are often taught in large concerns, the necessary training is not always available for the bulk of the graduates entering small industries.

This book provides a comprehensive survey of manufacturing materials and processes. It can be useful to the practicing engineer and will aid the industrial worker who wishes to review some special phase of metal processing. Each topic is dealt with concisely. Line drawings, rather than photographs, have been used for a clearer visualization of each machine process, and the tables have been chosen carefully for the greatest usefulness and for future reference.

New chapters include Manufacturing Processes, Electroforming and Metal Coating Processes, and Metal Cutting. Chapters which have been rewritten to include much new material are those on Foundry Equipment and Procedures, Press Work, Plastic Molding, Inspection, and Drilling and Boring Machines. In all chapters emphasis has

been placed on recent developments, and the text has been carefully revised to bring it up to date.

My deep appreciation goes to the many people who have contributed illustrative material, as well as helpful suggestions. I wish to especially acknowledge the assistance of Professor J. R. Holmes in preparing the line diagrams, Dr. John Gross in revising the chapter on Heat Treatment, and of colleagues who reviewed sections of the manuscript for accuracy.

Myron Louis Begeman

Austin, Texas
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CHAPTER 1

MANUFACTURING PROCESSES

Since the first use of machine tools there has been a gradual, but steady, trend toward making machines more efficient by combining operations and by transferring more skill to the machine, thus reducing manual labor. To meet these needs, machine tools have become complex both in design and in control. Automatic features have been built into many machines, and some are completely automatic. This technical development has made it possible for industry to attain a high production rate with the accompanying low labor cost which is an essential development for any society wishing to enjoy high living standards.

Along with the development of production machines, the quality in manufacturing has been emphasized. Quality and accuracy in manufacturing operations demand that close dimensional control be maintained to turn out parts which are interchangeable and give the best operating service. For mass production any one of a quantity of parts must fit in a given assembly. A product made of interchangeable parts is quickly assembled, low in cost, and easily serviced. To maintain this dimensional control, appropriate inspection facilities must be provided.

Machine or Process Selection

Product manufacturing requires tools and machines that can produce economically as well as accurately. Economy depends to a large exent on the proper selection of the machine or process for the job that will give a satisfactory finished product. The selection is influenced, in turn, by the quantity of items to be produced. Usually there is one machine best suited for a certain output. In small-lot or jobbing-type manufacture, general-purpose machines such as the lathe, drill press, and planer may prove to be the best type since they are adaptable, have lower initial cost, require less maintenance, and possess the flexibility to meet changing conditions in the shop. However, a special-purpose machine should be considered when large quantities of a standardized product are to be produced. A machine built for one type of work or operation, such as the grinding of a piston or the surfacing of a cylinder head, will do the job well, quickly, and at low cost, requiring only the service of a semi-skilled operator.

Many of the special-purpose machines or tools differ from the usual standard type in that they have built into them some of the skill of the operator. A simple bolt may be produced on either a lathe or an automatic screw machine. The lathe operator must not only know how to make the bolt but must also be sufficiently skilled to operate the machine. On the automatic machine the sequence of operations and movements of tools are controlled by cams and stops, and each item produced is identical with the previous one. This "transfer of skill" into the machine makes possible the use of less skillful operators, but it does require greater skill in supervision and maintenance. Often it is not economical to make a machine completely automatic, as the cost may become prohibitive.

The selection of the best machine or process for a given product requires a knowledge of all possible production methods. Factors that must be considered are volume of production, quality of finished product, and the advantages and limitations of the various types of equipment capable of doing the work. Too much emphasis cannot be given to the fact that production can be by several methods, but usually there is one way that is most economical.

Manufacturing Processes

Most metal products originate as an ingot casting from one of the many ore-reducing or ore-refining processes. Molten metal by these processes is poured into metal or graphite molds to form ingots of convenient size and shape for further processing.

Manufacturing processes used in the working of metals may be classified as follows:

1. Processes used primarily to change the shape of metals:

(*a*) Casting.
(*b*) Forging.
(*c*) Extruding.
(*d*) Rolling.
(*e*) Drawing.
(*f*) Squeezing.
(*g*) Crushing.
(*h*) Piercing.
(*i*) Swaging.
(*j*) Bending.
(*k*) Shearing.
(*l*) Spinning.
(*m*) Stretch forming.
(*n*) Roll forming.
(*o*) Torch cutting.
(*p*) Electroforming.
(*q*) Powder metal forming.

In this group of processes material is changed into its primary form for some selected part. In certain cases the parts are suitably finished for commercial use, as in metal spinning, cold rolling of shafting, die casting, stretch forming of sheet metal, and drawing wire. In other cases, neither the dimensions nor the surface finish are satisfactory for the final product, and further work on the part is necessary. It should be noted that the last two processes, electroforming and the forming of powder metal parts, do not originate as a casting. Electroformed parts are produced by electrolytic deposition of metal onto a conductive preformed pattern. Metal is supplied from the electrolyte and a bar of pure metal which acts as an anode. Parts of controlled thickness, having high precision, can be made by this process. The method used in the production of powder metal parts is essentially a pressing operation. Metal powders are placed in a metal mold and compacted under great pressure. Most powder metal products also require a heating operation to assist in bonding the particles together.

2. Processes used for machining parts to planned dimensions:

(*a*) Turning.
(*b*) Planing.
(*c*) Shaping.
(*d*) Drilling.
(*e*) Boring.
(*f*) Reaming.
(*g*) Sawing.
(*h*) Broaching.
(*i*) Milling.
(*j*) Grinding.
(*k*) Hobbing.
(*l*) Routing.

In these secondary operations which are necessary for many products requiring close dimensional accuracy, metal is removed from the parts in small chips. Such operations are performed on machine tools which include the various power-driven machines used for the cutting of metal. All of these operate on either a reciprocating or

a rotary-type principle: either the tool or the work reciprocates or rotates, as indicated in Figure 1. The planer is an excellent example of a reciprocating machine since the work reciprocates past the tool, which is held in a stationary position. In other machines, such as

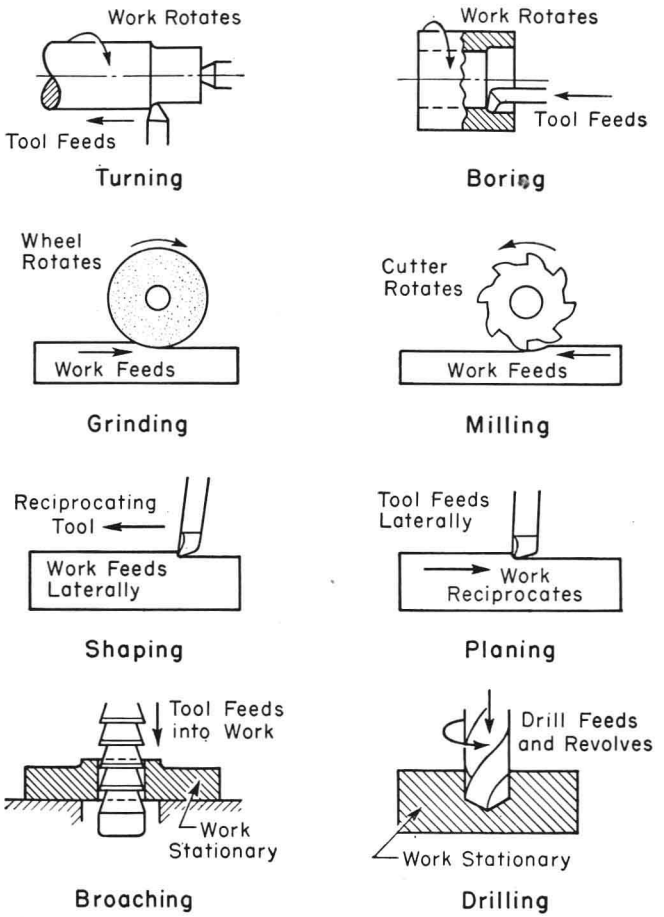

Fig. 1. Basic processes used for machining parts to planned dimensions.

the shaper, the work is stationary and the tool reciprocating. Rotary machines are exemplified by the lathe, which has the work rotating and the tool stationary. In the drill press it is the tool that is rotating.

Many of the machine tools can do a variety of machining operations, and all are capable of producing parts having close dimensional tolerance. The important factor is that the advantages and

limitations of each be known so that an intelligent selection of the right machine can be made.

3. Processes used primarily to obtain a surface finish:

(*a*) Polishing.
(*b*) Abrasive belt grinding.
(*c*) Barrel tumbling.
(*d*) Electroplating.
(*e*) Honing.
(*f*) Lapping.
(*g*) Superfinishing.
(*h*) Metal spraying.
(*i*) Inorganic coatings.
(*j*) Parkerizing.
(*k*) Anodizing.
(*l*) Sheradizing.

In this group there are processes that cause little change in dimension and result primarily in giving the surface finish. Other processes, such as grinding, remove some metal and bring the part to a preplanned dimension in addition to giving it a good finish. In the processes such as honing, lapping, and polishing it is a matter of fitting and removing small scratches with little change in dimension. Superfinishing is also a surface-improving process which removes undesirable fragmented metal, leaving a base of solid crystalline metal. Plating and similar processes, used to obtain corrosion-resisting surfaces or just to give a better appearance, do not change dimensions materially.

4. Processes used in joining parts or materials:

(*a*) Welding.
(*b*) Soldering.
(*c*) Brazing.
(*d*) Sintering.
(*e*) Pressing.
(*f*) Riveting.
(*g*) Screw fastening.
(*h*) Adhesive joining.

Welding is the fusion or uniting of metal parts by heat. Soldering and brazing operations are similar except that the parts are joined by introducing a different metal between the two in a molten state. Sintering applies to the bonding of metallic particles by the application of heat. Structural adhesives in the form of powders, liquids, solids, and tapes are widely used in the joining of metals, wood, glass, cloth, and plastics.

5. Processes which change the physical properties of metals:

(*a*) Heat treatment.
(*b*) Hot working.
(*c*) Cold working.
(*d*) Shot peening.

Heat treating includes a number of processes which result in changing the properties and structure of metals. Although both hot and cold working of metals are primarily processes for changing the shape of metals, these processes have considerable influence on

both the structure and the properties of the metal being worked upon. Shot peening renders many small parts, such as springs, resistant to fatigue failure.

Engineering Materials

In the design and manufacture of a product it is essential that the material as well as the process be understood. Materials differ widely in physical properties, machinability characteristics, methods of forming, and possible service life. The designer should consider these facts in selecting an economical material and a process which are best suited to the product.

Few metals used in industry exist as elements in nature. The natural compounds used, such as oxides, sulfides, or carbonates, must undergo a separating or refining operation before they can be further processed. Once separated, they must have an atomic structure which is stable at ordinary temperatures over a prolonged period. In metal working, iron is perhaps the most important natural element. Iron has little commercial use in its pure state, but when combined with other elements into various alloys it becomes the leading engineering metal. The nonferrous metals, including copper, tin, zinc, nickel, magnesium, aluminum, lead, and others, all play an important part in our economy, and each has specific properties and uses.

Further descriptions of the common engineering materials and their processing will appear in the following chapters, with particular emphasis given to their advantages and limitations.

Automation

Automation is a word, coined by the automotive industry, to indicate the application of automatic control to the operation of various basic machines. The control may include one machine or a series of machines, whatever is necessary to complete a series of operations in making a product. It may include loading the machines, transferring the product from one machine to another, inspection, and final ejection of the product from the machine. It has been defined in broad terms as ". . . manufacturing, processing or performing of services as automatically as economics permit or demand."[1]

Generally speaking, almost any machine or process can be made automatic. The extent to which this idea is carried out depends entirely on the economics of the situation. In one case a machine

[1] R. W. Bolz, "Automation to Date," address given at Michigan State University.