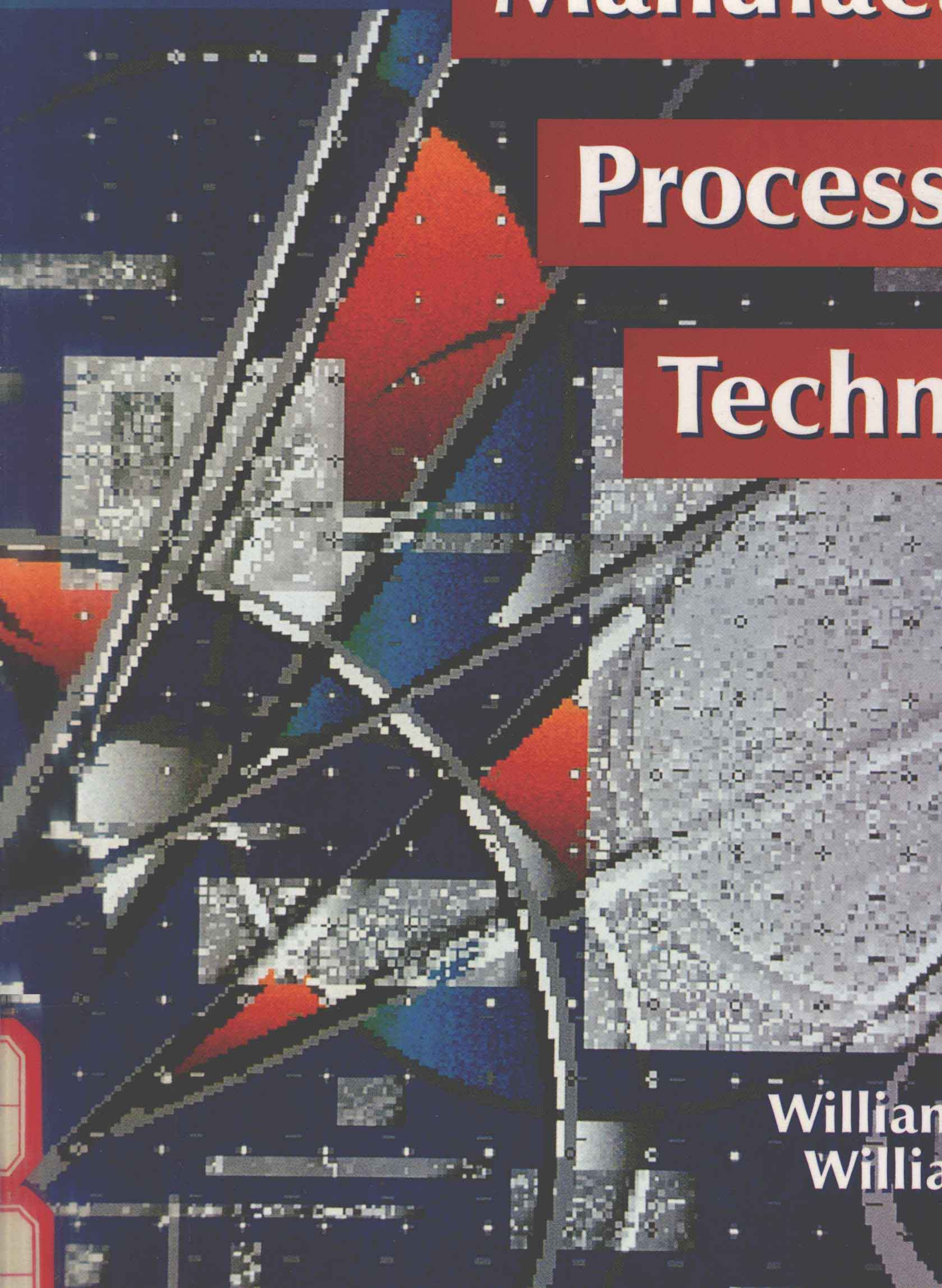
Manufacturing Processes for Technology



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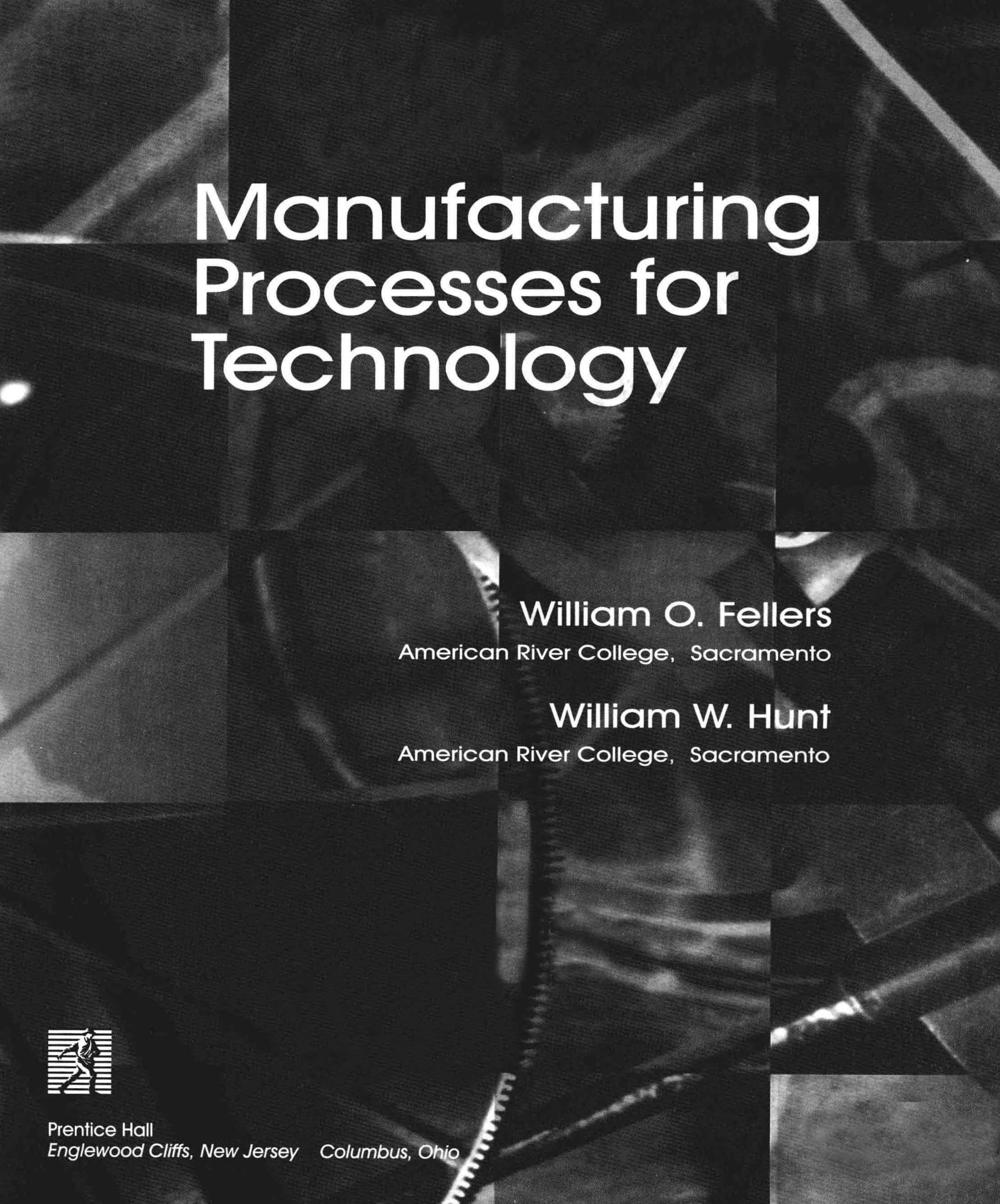

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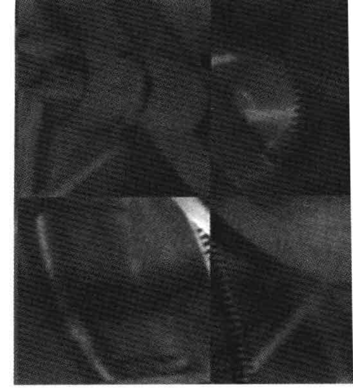

To the Student

Have you ever wondered: "How did they make that? Why did they make it in such a poor way?" Choosing a manufacturing method is part of the design process for nearly everything that is made. Today, that is a complicated choice, but an essential one.

Humans have been making useful objects ever since they discovered that they could hold tools. Until about two hundred years ago, most objects were manufactured by hand—in fact, the word "manufacturing" literally translated from Latin means "to make by hand." By today's standards, these objects were crudely made. Parts were not interchangeable. Each part was individually fitted to the others so that the total mechanism worked, at least until something broke. Then, the replacement part had to be made specially to fit.

Today's society could not exist without modern manufacturing and production techniques. Mass production with interchangeable parts is vital to our standard of living. One cannot even imagine the difficulty in making an automobile, a modern tractor used on a farm, or a commercial aircraft if all the parts had to be made by hand. Without modern manufacturing methods, we could not even feed the present population.

The Industrial Revolution brought about two radical changes: the standardization of measurements and the development of manufacturing techniques which allowed interchangeable parts to be mass produced. Before then, workers measured lengths by cubits, hands, or other imprecise gauges. When measurements became standardized, an inch was an inch or a millimetre was the same no matter whose scale was used.

A result of standardization of measurements was the development of interchangeable parts. Using standardized measurements, workers could make parts that would fit similar mechanisms.

With the advent of the steam engine and the resulting portable power source, workers had power available that could run machine tools, make machine tools handle large capacities not possible with human or animal power, and increase production. Workers could make dozens of the same parts at a time and produce them more cheaply than ever before.

The immediate result was that manufactured goods became cheaper, more people could own those goods, and the standard of living rose.

Modern manufacturing is changing continuously. Standards that were adequate a decade ago are not good enough to make the state-of-the-art machines operate properly. Methods of manufacturing will always improve and new materials will change the way that we make things.

Look around. How many products can you list that have become obsolete in your lifetime? We have gone from the vacuum tube to the transistor to the integrated circuit even before some of the old vacuum tubes have burned out. In cameras, we have progressed from black-and-white film to color film to instant prints to filmless electronic-imaging cameras in less than half a lifetime. Thirty years ago, classroom exams were mimeographed, or simply written on the chalkboard. Now, photocopier machines are the standard. As late as 1975, engineers used slide rules, which now are as obsolete as the abacus. Electric typewriters hailed as state of the art are antiques compared to the modern computer and word processing systems. This latter invention is one for which the authors of this text are truly grateful.

This text is as up-to-date as the authors could make it, yet even the newest manufacturing techniques described in this text might be replaced before you finish this course. Please consider this text only a starting point. *It is the responsibility of each engineer and technician to keep current with new technologies in his/her field!* Professionals should read technical journals and trade magazines in their field and join technical societies. These societies publish magazines and books and offer workshops, to keep their members current. The era when a person could learn a skill and be set for life ended long ago. One must keep up-to-date!

Societies, as well as individuals, must keep up with change. The United States of America is the only major industrial country that does not use the metric system exclusively. Eventually, the United States and American industry will have to join the rest of the world in this standardization of measurement. Therefore, at the request of many industries, we have included some metric system examples and problems in this book. This is a good time to master the metric system if you have not already done so. You are going to need it.

The format for this text is as follows: a concept is introduced, discussed, and followed immediately by questions and exercises. Get in the habit of answering the questions and working the exercises as you come to them. They have been designed to help you master a block of material before building on it with new concepts. Don't wait until test time to do the work, or the course will get ahead of you.

Above all, stick with it! It takes hard work to master these new concepts and organize all of this material, but you need them in order to be ready to take your place in today's industry.

Good luck in the course.

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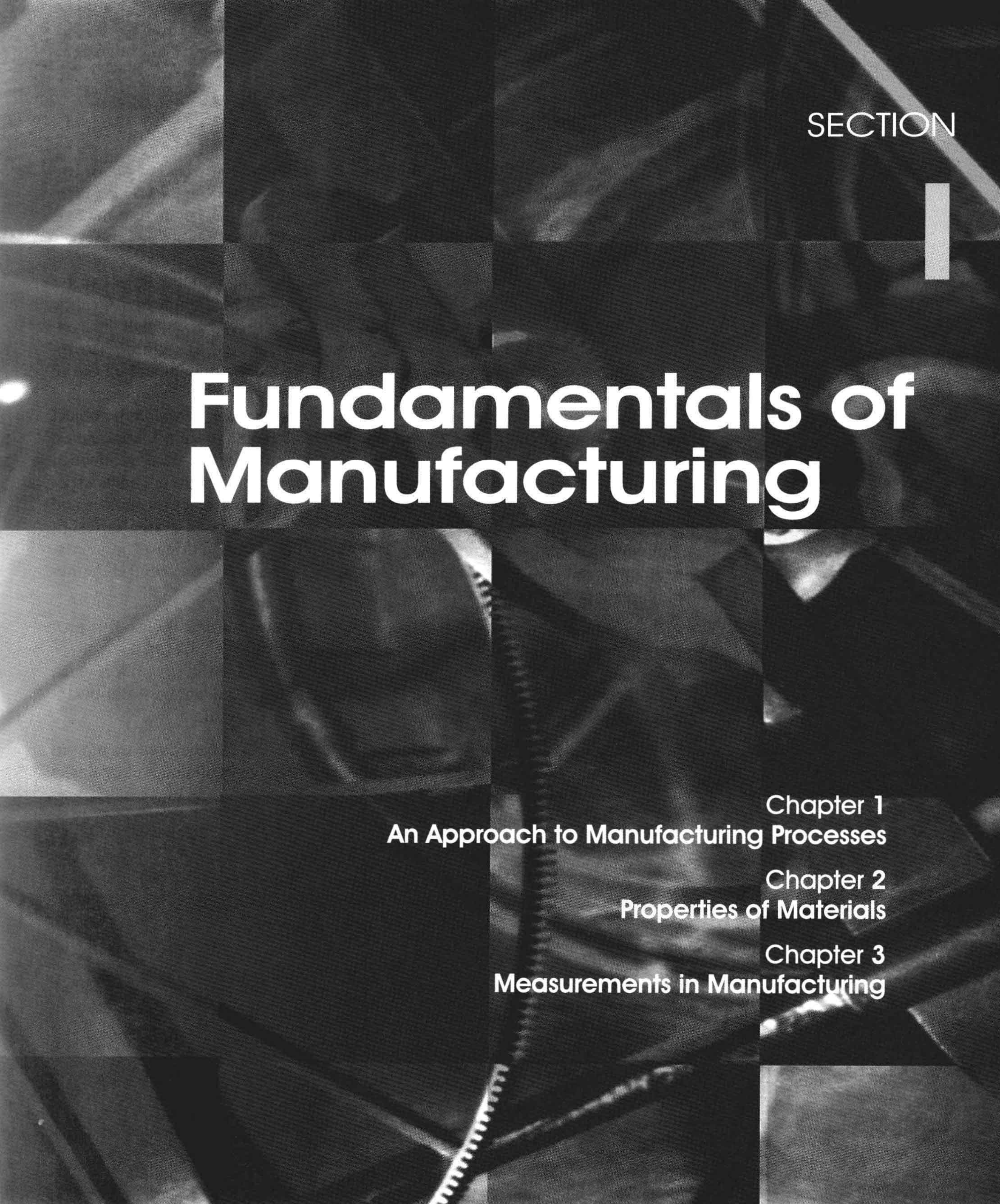

SECTION

I

Fundamentals of Manufacturing

Chapter 1
An Approach to Manufacturing Processes

Chapter 2
Properties of Materials

Chapter 3
Measurements in Manufacturing

INTRODUCTION

Look around you. How many things do you see that you wear, sit on, or use that were made by someone? We rarely use "found objects." Therefore, *someone had to make* nearly everything that we use, and they had to make it in some manner. How those things were made, the **manufacturing processes,** is what this book is all about.

Specifically, this book examines the processes by which things can be made. We know that they can be made rapidly, with acceptably high quality, at a cost low enough to be affordable, and with an acceptably small environmental impact if we are wise enough in our choice of manufacturing processes. We can make wise choices only if we clearly understand all of the available options in manufacturing and their consequences.

The design of any object limits the choice of processes by which the object can be manufactured. The designer must bear this fact in mind. Sometimes, the converse is also true: The design may be limited by the small number of manufacturing processes available to the engineer or designer. This is especially true in small industries with limited facilities. So the design choices and the manufacturing-process choices are integral parts of a single design process. In this book, the primary focus is on the manufacturing-process considerations, viewed as one part of the design process. The two central themes in this book are as follows:

1. For a given *object,* what manufacturing processes could be used to produce it?
2. For a given *manufacturing process,* what are the conditions under which this would be a wise choice to use? Further, the advantages and disadvantages of using that process must also be considered.

Answering these two questions may seem to be a tall order, but let us start by developing a conceptual framework so that the information will be easier to organize and understand.

Chapter 1

An Approach to Manufacturing Processes

CLASSIFICATION OF PRODUCTION TASKS

What tools would you expect to find in a mechanic's toolbox? Perhaps there would be a hammer, some wrenches, several screwdrivers, tin snips, propane torch, micrometers, and maybe even a flashlight. Why does a mechanic or machinist need so many different tools? They're needed because there are so many different jobs to be done. The same is true in manufacturing. The manufacture of any single item, whether it's a simple screw or a jet aircraft, requires many different operations or jobs during its production. To study all of the possible methods of manufacturing may seem to be an overwhelming task. Fortunately, nearly all **manufacturing processes** can be divided into just six categories:

1. Material removal
2. Material addition
3. Change of form
4. Change of condition
5. Material joining
6. Finishing

A full section in this book is devoted to each of these operations, and most of these sections are further divided into separate chapters. For instance, material joining is divided into chapters on adhesives, welding, and mechanical or other forms of joining. Entire courses are often offered in each of these manufacturing operations. The purpose of this text is to provide a brief introduction to each of the concepts. Although more detailed explanations of these categories appear later in this book, a brief description of them is in order here.

Material Removal

Material removal includes any process by which a part or piece of a material is severed or separated from another section of the same material. This includes the use of such hand tools as saws, chisels, and snips, as well as mechanically driven tools such as lathes, drills, planes, shapers, and grinders. Mechanical, chemical, electrical, thermal, optical, hydraulic, and other methods can also be used to remove material. These techniques are discussed in Section II.

Material Addition

Material addition involves all methods by which a piece of stock can be increased in volume or weight.

(**Stock** is any material still in the form and shape in which it comes from the supplier.) These methods include electroplating, dipping, metallizing, electroforming, spraying, and vacuum deposition. Many of these processes are quite sophisticated technologically and require highly skilled personnel to perform them. Section III covers these methods.

Change of Form

Change of form includes the methods by which the shape of a piece of material is altered. Such processes as rolling, forging, bending, and many others are discussed in Section IV.

Change of Condition

Often, the internal structure of metal and other parts can be altered to provide the qualities required in the final product. Steels in particular can be hardened or softened significantly by heat treatments. The mechanical properties of other metals can be altered somewhat by forging and cold rolling. The characteristics of glass can be changed by chemical or thermal means. Any alteration of the properties of a material is considered to be a **change of condition.** Although it is necessary to study the properties and mechanics of materials in separate courses to understand completely the processes that result in a change of condition, the more important concepts of this subject are covered in Section V.

Material Joining

The method by which two or more parts are held together is called **material joining,** which includes, but is not limited to, such methods as welding, riveting, gluing, bolting, and pinning. The number of these methods that are available may be surprising. Section VI discusses this vast array of methods.

Finishing

When a machined product comes right out of the mold or off the machine, the surface it has at that point is not usually suitable for further use. At that point, it is unattractive, probably would not be salable, and might not even perform its intended function very well. It is therefore necessary that a "finish" be applied to the part. **Finishing** can involve anything from painting the part to plating it. Finishes are covered in Section VII.

TOOL OR PROCESS SELECTION

Once a decision has been made as to which operation classification is to be used, several other questions must be asked. Suppose that a piece of stock must be cut to start making a part. Which tool should be used? Would a pocket knife do the job, or would a saw, torch, or perhaps a set of shears be required? Can steel, wood, rubber, and ceramic be cut with the same tool? To determine the proper tool with which to remove the material, the following questions must be answered:

1. What are the physical properties of the material being cut, formed, or shaped, and what are the properties of the tools being used?
2. Does the tool or process selected have the precision required for the product?
3. Does the tool or process selected meet the required production rate of the job?
4. Is the tool or process economical? In other words, is the per-unit cost of the process low enough to do the job profitably?
5. Does the selected tool or process meet the social or environmental requirements, and are the resulting environmental costs small enough to justify using the process?
6. Will the tool or process be available when it is needed?
7. Is a trained operator required for the process? If so, will one be available when needed?

Questions 6 and 7 are not covered in this text, but they must be considered in actual industrial situations. With regard to Question 6, many small industrial plants do not have and cannot afford many of the tools, production facilities, or high-technology methods currently available. Further, small job runs may preclude the investment of large sums of money to obtain a high-production-rate machine. Therefore, the manufacturing engineer must often "work with the tools at hand." Simply put, to complete a contract, a small company may find it cheaper to hire a machinist to produce the few parts needed using the lathes and milling machines currently in the shop than to buy the latest computer-aided, robotics-controlled equipment.

As for Question 7, many manufacturing processes require specially trained, often licensed personnel to perform them. It would be futile for a manufacturing engineer to specify, for instance, "heliarc welding" if there was no one available who knew how to do it. In large companies, or if the contract is sufficiently large, a management decision might be to hire a qualified heliarc welder to do the job. On the other hand, management might tell the engineer to figure out some other way to do the job.

What if a wise choice cannot be found among the processes and tools that are available? Then the choice may be between obtaining the part from a subcontractor or vendor or devising a new manufacturing process to do the job. Why not risk the latter? Often the best engineering is innovative and cannot be found in a "cookbook."

EXAMPLE OF PROCESS SELECTION

To illustrate a method of selecting a manufacturing process, let us look at a specific example and examine the options available. Suppose that we needed to produce a 1-inch-wide wood chisel for a specific job. Further let us assume, for purposes of argument, that we were on an isolated island and the only tools and materials available were hand tools in a toolbox. We examine the questions posed earlier with respect to this task. The shape of the chisel is approximately as illustrated in Figure 1–1.

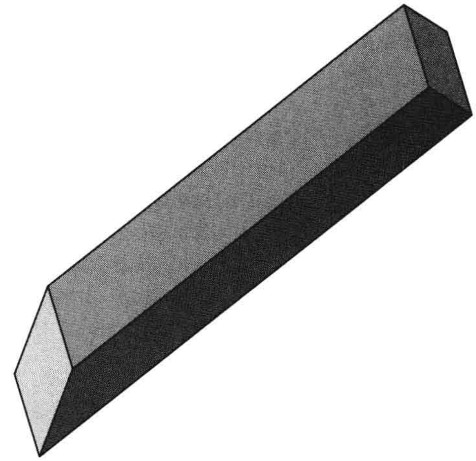

Figure 1–1. Wood chisel.

1. What are the physical properties of the material and the properties of the tools? Here the choice is very limited. Perhaps the only material from which the chisel can be made is an old file. But files are very brittle and cannot be cut with other ordinary hand tools. In this case the file would have to be annealed by heating it to a red heat in a fire and allowing it to cool slowly in air. The file could then be cut with a hacksaw, drilled with a hand drill, or filed with another file. The edge could be put on the tool with an abrasive stone.

2. Does the tool or process have the precision required for the product? The precision here would be limited by the skill of the worker. Because this job doesn't require any mating parts, the requirement for precision is not very high.

3. Does the tool or process selected meet the required rate of the job? Production of a tool by hand would be a very slow process. But since only one is needed, the production requirement could be met.

4. Is the tool or process economical? In a word, *no!* However, considering other alternatives, such as importing a chisel from another part of the world and paying shipping charges, it might be cheaper to make the tool than to order it.

5. Does the selected tool or process meet the social or environmental requirements? The production of a tool, such as a chisel, by hand produces few environmental consequences. The smoke and fumes from the annealing fire would seem to be the major pollutants. The shavings and filings from cutting and shaping the tool would not be excessive.

6 and **7.** Will the tools and operators be available? This is a case in which the process is determined by the tools available, not the other way around. If the required whetstone is not available for sharpening the