# PROCESSES AND MATERIALS OF MANUFACTURE

Fourth Edition

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**Fourth Edition**

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# Preface

Manufacturing is the essential basic strength of any industrialized nation. Although increasingly larger segments of the population may be employed in service industries, it is manufacturing that produces the wealth of the nation.

The objective of this book is to provide engineering and management personnel with a background knowledge of the processes and materials of manufacture as used in modern industry.

The fact that computers now permeate the entire gamut of manufacturing has made it mandatory that this topic be integrated into an early discussion of all manufacturing processes. As examples, the lathe and milling machine are introduced in the traditional manner, but then the text emphasizes the lathe as a turning center and the milling machine as a machining center. To understand how these and other machines are using computer control, terminology such as NC, CNC, and DNC (numerical control, computer numerical control, and direct numerical control) is introduced. This terminology is then used throughout the book.

Modern machine systems are being developed with the ultimate goal of an automatic factory. Some of the essential elements that are included in the development of an automatic factory are probes, both contact and noncontact, automatic tool changing, robot loading and unloading, automatic guided vehicles (AGV), and pallet-shuttle arrangements for workpiece handling. Although the automatic factory has not been achieved as yet, a big step in that direction is flexible manufacturing systems (FMS), now a byword in the machine tool industry.

Even though heavy emphasis has been placed on the integration of the computer into the manufacturing area, basic subjects such as tool geometry, tool life, cutting forces, and metal forming theory have not been neglected.

In addition to questions and problems at the end of each chapter, most chapters have one or more case studies. The case studies are designed to give the student insight into the type of problems actually encountered in an everyday industrial setting. The discussion of a case study in the solutions manual should be viewed as an illustration of one of a number of logical solutions.

The author is indebted to Mr. Raj Kawlra, an engineer with the Advanced Engineering Staff of the General Motors Technical Center, for his many helpful contributions and for checking all the problems.

The author also wishes to acknowledge the work of his colleagues in reviewing the manuscript: Professor Norman Braton, for the chapters on welding, Professor Marvin DeVries, for the remainder of the manuscript, and Professor Harold Steudel, who contributed Chapter 19 on process planning, which is new in this fourth edition.

Acknowledgments are also due to the editor, Mr. Ray Short, for his help in supplying reviews of the manuscript and in obtaining comments from those who have used previous editions of this book.

R. A. L.

# Contents

# 1

# The Manufacturing Engineer

Traditionally, the task of the manufacturing engineer has been to use an engineering design to produce a new part or product. A product starts with an idea for a better part or for a whole new concept, such as an airplane that can take off or land in a vertical direction. Eventually, a particular design approach is selected. After the design has been "frozen" it is turned over to manufacturing. In the past it was said that the design was "thrown over the wall," denoting that there was little if any communication between design engineers and manufacturing engineers. This is no longer the case since each design must be carefully examined for maximum producibility and profit or, in other words, designed for economical manufacture. A big step in the integration of design and manufacture has been brought about by the computer in computer-aided design (CAD), and computer-aided manufacture (CAM) leading to computer-integrated manufacturing (CIM).

After the design is completed and, in many cases, several prototypes have been built and tested, the manufacturing engineer begins the intricate, intellectually demanding job of creating a system that will produce the product. The design must be judged for feasibility of manufacture by several different methods, such as casting, forging, welding, powder metallurgy, machining, or cold forming.

The manufacturing engineer is not only familiar with all the various processes that are available to produce a given product but also with the materials required and their fabricating qualities, such as machinability, formability, castability, and weldability. He or she must be able to give detailed information to the purchasing department concerning the selection of materials, machines, and equipment required and whether some of the components should be purchased or made in house. New equipment, upon arrival, must be properly installed at the desired location and must perform according to specifications.

Many products require special tooling such as jigs, fixtures, dies, templates, and gages. The manufacturing engineer must be able not only to design such special tooling, but also to prepare estimates as to its cost and the cost of each step of production.

As can be seen, manufacturing engineering covers a wide spectrum of specializations that no single person, however talented, could possibly master. This chapter is intended to give a brief overview of some of the important aspects of manufacturing engineering, some of which will be discussed in more detail in the chapters that follow.

Manufacturing engineering can be divided into the following areas of specialization: process planning, tool engineering, work standards engineering, materials handling, facilities planning, and quality control.

## Process Planning

The process planning engineer lays out a logical sequence of manufacturing operations for each component, subassembly, and the final assembly of all subassemblies into a finished product.

Processing, as it is normally called, requires a detailed knowledge of machining processes, forming processes, and assembly processes. It also requires an exhaustive knowledge of the plant capabilities. In other words, the development of the process plan must be based largely on the physical capabilities of existing equipment.

Most important to the success of the plan is the logical integrity of the sequence steps. Most of us have purchased equipment that requires assembly. If we faithfully follow the steps outlined for the assembly, the process proceeds well; but if a step is skipped, we have to retrace our steps to find where we deviated from the proper sequence.

Similarly, every mass-produced part has its own process sheet. This sheet is developed by process planning engineering and establishes the rules for the production of the part. Once these sheets are finalized, any deviation creates significant problems.

The master process sheet (Fig. 1-1) shows the sequence of operations for a given part, the machines used, the tooling required, and the setup and cycle time. More detailed process sheets are used to give exact information on the fixtures, tools, and gages required. Today the information on process sheets is often stored in computer memory and used in management information systems so that an entire process, or even a factory, can be simulated by means of mathematical models. Simulation techniques are useful in determining the relationships between system parameters such as production rate, number of modules, and module types. A *module* is a device that performs a process on a part at a *station* or a group of stations. *Station* refers to the physical location where a part normally stops either to have an operation performed on it or to wait for clearance to proceed to the next station.

Process engineering is not an academic subject, nor can it be taught effectively in a classroom situation. Much of the basics can be learned from process texts such as this, but to be effective the text must be accompanied by manufacturing experience.

## Tool Engineering

*Tools* in the world of manufacturing refer to a vast array of standard and specially designed devices used to perform specific work tasks. Tools are used in forming flat

| | | |
|---|---|---|
| 12-4-73<br>Form No. X-1 | Master Process Sheet | Page of pages |
| Written by J. B<br>Date 1/4/73 | Order no. 19278-B<br>Date 2/1/73 Pcs. req'd. 50 | Dwg. No. 15620<br>Patt. No. 3567 |
| Enters assembly at stage 15 | D-56 Loader | Part name Rope Drum |
| Material condition Gray Iron Casting<br>190 BHN - Bore cored 1" dia. | Rough weight 153# | Finish weight |

| Oper. no | Description | Set-up hrs | Cycle hrs | Mach. no. |
|---|---|---|---|---|
| 10 | Turn O.D. of body and rims. Face inside rims, face hub and rim on one side - 2AW&S turret lathe. | .50 | .70 | M6-41 |
| 20 | Rough, semi-finish, and finish bore 1.500/1.501 hole, face hub and rim on other end - 2AW&S turret lathe. | .80 | .27 | M6-41 |
| 30 | Cut 3/8 keyway and finish push broach - Davis keyseater and hand arbor press | .25 | .17 | M4-53 |
| 40 | Drill and tap (1) 1/2" pipe tap hole 2-Spindle upright drill press. | .30 | .17 | M3-45 |
| 50 | Groove - 20" Engine lathe | .50 | .30 | M4-46 |
| 60 | Rotary file - Bench | | .21 | |

| Oper. no. | Tool Description | | Speed RPM | Feed IPM | Tool no. |
|---|---|---|---|---|---|
| 50 | 1-special taper shank arbor with drive key | | | | T-205 |
| | 1-Forged H.S.S. grooving tool | | 35 | | T-206 |
| 40 | 1-1/2 pipe tap and driver | | | | |
| | 1-23/32 H.S.T.S. drill | | | | |
| | 1-Type K, drill press vise | | | | |
| 30 | 1-Finish push broach | | | | T-204 |
| | 1-1-1/2 die × 3/8 slot locating bush | | | | T-203 |
| | 1-3/8 standard keyway cutter | | | | |
| 20 | 1-1.500 setting ring | | | | |
| | 1-dial bore gage | rough | 249 | .011 | |
| | | semi fin | 249 | .011 | |
| | 1-set of (3) 9X blocks to fin. 1.500 | fin | 189 | .011 | T-202 |
| | 1-special 1-1/4" Davis bar with pilot bush | | | | T-202 |
| | 1-1-3/8 dia. core drill straight shank | | 249 | .027 | |
| | 1-stub boring bar to start core drill | | 249 | .011 | |
| | 1-set soft jaws, external grip | | | | |
| 10 | 2-90 L.H. Offset tools, type B | body | 134 | .011 | |
| | 2-90 R.H. Offset tools, type B | rim | 187 | .011 | |
| | 1-special offset round nose tool | hub | 101 | .011 | |
| | 1-set of hard coarse jaws, internal grip | | | | |

**Figure 1-1** Master process sheet for a small manufacturing organization. (Courtesy of the Society of Manufacturing Engineers.)

sheets into automobile fenders or airplanes fuselages. Tools are used in holding two or more pieces of metal together in the proper relationship so that they can be welded. Tools are used in producing the finish on cylinder blocks as they advance through a giant transfer line (which itself is a tool). These are only a few examples of the tools that must be designed and used by the tool engineer.

Standard tools, such as drills, reamers, taps, counterbores, dial gages for size