

CHAPTER 1

Introduction to DeGarmo's Materials and Processes in Manufacturing

Review Questions

1. The availability and cost of manufactured products are an important part of our cost of living and the real wealth of the nation. Thus, reducing the cost of producer and consumer goods improves the productivity while holding down inflation, thereby improving the general standard of living.
2. This is true if you consider that everyone who uses the output from a process, including all the intermediate steps, is a customer. The operator of the next process is the user and customer of the proceeding process. In fact, some companies identify two customers, the external customer who buys the finished product and the internal customer, who builds the product one - i.e., the people who work in the manufacturing system.
3. Job shop - an injection mold manufacturing shop, the shop at a large university that produces research equipment and apparatus. Job shops are capable of producing products with great variety, typically employing highly skilled workers.

Flow shop – automobile assembly. Flow shops are usually laid out so that specific products pass through a series of operations with no backflow. The product range is limited, production volume is large and labor skill is lower than in job shops.

Project shop – diesel-electric locomotive production facility. The end product is very large and so many machines, tools and people come to the product to produce it at a relatively fixed location.

The Subway sandwich shop would be a flow shop.

4. In the context of manufacturing, a manufacturing system is a collection of men, machine tools, and material-moving systems, collected together to accomplish specific manufacturing or fabrication sequences, resulting in components or end products. The manufacturing system is backed up by and supported by the production system, which includes functions like control of quality, inventory, production, and manpower, as well as scheduling, planning and the like. Within the manufacturing system, there will be machine tools, which can perform jobs or
5. No. The cutting tool is the implement that does the cutting. It contains the cutting edge and is used in the machine tool. The machine tool drives the cutting tool through the work material.
6. The basic manufacturing processes are: casting or molding, forming, (heat) treating, metal removal, finishing, joining (welding), assembly, and inspection.

7. Casting could be used, provided the material can be melted and poured in the appropriate process. By casting, the desired shaped in final or near-final form, could be obtained. This greatly reduces the necessity for machining the hard-to-machine metal. Less machining is needed when the raw material shape is close to the finished part size and shape (called near net shape casting). The part could also be made in simpler segments and assembled or joined.
8. The wax pattern is melted and removed as a liquid. Any remaining wax is then vaporized when the mold is heated in preparation for the pour.
9. A relief-image is the cavity in the die that the work material is deformed into when the die is pressed into the workpiece. Material on the workpiece moving into the cavity, “concave,” of the die results in the raised, “convex,” part of the medal surface.
10. Trains stop at the station to load and unload people and materials. In an assembly line, products stop at stations to take on materials or have operations performed on them.
11. False. Storage is very expensive because time costs the company money. It is expensive to keep track of stored materials, to put them into storage, to get them back from storage, to damage them as a result of excessive handling, and so on. More importantly, storage usually adds no value - very few items appreciate on the shelf.
12. For the simple, conventional paper clip, forming processes are first used to make and coat wire, which is then cut to length and formed in three bending operations.
13. Tools are used to hold, cut, shape, or form the unfinished product. Common hand tools include the saw, hammer, screwdriver, chisel, punch, sandpaper, drill, clamp, file, torch, and grindstone. Basically, machines are mechanized versions of such hand tools and are called cutting tools. Some examples of tools for cutting are drill bits, reamers, single-point turning tools, milling cutters, saw blades, broaches, and grinding wheels. Noncutting tools for forming include extrusion dies, punches, and molds. Tools also include workholders, jigs, and fixtures. These tools and cutting tools are generally referred to as the tooling, which usually must be considered (purchased) separate from machine tools.
14. Inefficient is a relative term here. If we can eliminate machining, we can save the time and the money. Machining processes are generally those which give the part its final size, shape, and surface finish and add value to the part. Because they do not produce the shape and size in bulk, but rather by localized action they may not be as efficient as forming and casting processes. Cutting tool and workholding tooling expenses may also be reduced, since the same tool can work on many different products.
15. Figure 1-1 and figure 1-16 both show life cycle progressions. For an audiocassette tape, it went to a commodity product, and is now in decline as CD's are taking over. We will know that it is in severe decline when the new autos no longer offer cassette players.

16. The cost to manufacture a typical manufactured product is 20% - 30% of the selling price. For the mass produced product at the lower end of this range the manufacturing cost is \$0.20. These 20 cents includes material and processing costs. Processing includes assembly in addition to producing the components. Since the blade cost involves forming the edge in a material it is probably the highest cost part of the razor.

So, with 20 cents to cover materials, processing and assembly, and the blade the most expensive individual part an estimate of 2-3 cents is reasonable for the production of the high precision (in terms of edge) blade.

The same kind of reasoning can be used with manufacturing cost being 40% of selling cost as suggested in Problems 1 and 2.

17. Packaging is used to protect the product from the environment, to protect the product during shipping and to hold fixed numbers of products for sale.

18. Assembly of a binder type paper clip involves putting the formed wire handles in to the spring steel binder part of the clip. Assembly of bicycle wheels involves putting spokes into the wheel and hub.

If the ingredients of the club sandwich are all in their finished state then they can be assembled. If processing is necessary as in slicing as turkey, the entire process is more than just assembly.

19. The physical elements of a manufacturing system are the machine tools, the tooling like workholding devices, material handling equipment, inspection equipment and people who actually produce the products. Manufacturing systems are characterized by measurable parameters (throughput time, cycle time, defect rates, production rates, number of direct laborers, annual production volumes, etc.). Machine tools are characterized by the size of the workpiece that can be processed or the spindle speeds they can be run at. Tools like dies for sheet metal forming are characterized by their size and weight. Inspection devices have measurement resolution limits. Measurable parameters extend past machine specifications to higher level (involving more than one aspect of part production) descriptions of the process such as production rates. The manufacturing system is more than the physical elements. Support and control systems, along with the physical elements, are combined in the manufacturing system.

20. The manufacturing engineer is responsible for selecting or designing and overseeing operation of the manufacturing processes. In the sense of immediate contact with processes the manufacturing engineer is often the center of “making the product”. However, the decisions made by part and product designers and materials engineers have large influences on the kind of processes that can be used to make the part. How the part can be made is constrained by part design and materials used. So, all individuals who make decisions that determine manufacturing process choice should be involved in figuring out how to make the part.

21. In Figure 1-8, the lines connecting the processes represent possible paths as material moves through the shop – from machine-to-machine or operation-to-operation.

22. This is really a discussion question to get the students to be aware of all the things involved in characterizing a process technology. The extrusion process results when the pressure applied to a material exceeds its flow strength. Sufficient energy must be applied to overcome friction, so lubrication is very important. The tooling is generally very expensive. A single die may cost \$5000 and setup time can be long. The process usually produces 10 to 25 surface feet per minute of material. The critical process parameters are temperature and pressure, the material being extruded, lubrication, and extrusion rate. Some metals cannot be extruded very well. The process is constrained by the power available and the size of the billets --i.e. the standard process is not continuous. The process operates reliably but users should always be aware of the high pressures involved in upsetting the materials. Operator skills are not critical and the process is semiautomatic. The process can do a wide variety of parts with constant cross section, depending only on the die design. It is hard to do hollow extrusions. Extrusion as a process is typically good to a tolerance of about 0.001 or 0.002 inches.

23. It is almost impossible to fabricate a low-cost item that is poorly designed and do it in an economical way. It must be designed so that it is easy to produce if it is going to be inexpensive (i.e. it has producibility). Thus, this statement is true.

24. The times, temperatures and quenchants used in heat-treating a metal part are often considered to be proprietary.

25. The rolls produce many feet of sheet metal that end up in many cars, so the fixed costs (like the rolls) are spread out over many sheets (feet) of metal. Thus the cost of sheet metal per car may be 50 to 100 dollars before the metal is formed into fenders and door panels.

26. Insurance, health, entertainment, sporting events, transportation, lodging, banking, communications, education, etc. are examples of service industries -- anything bought or sold in trade that cannot be dropped on your foot. Service industries worry about productivity, quality, and economic output just as much as manufacturing industries.

27. The difference is that the MPS has a manufacturing system embedded in the production system and the manufacturing system produces goods by adding value to materials via processes to create finished products. This manufacturing system always includes a service system to help "deliver" the goods to the customer. Almost all of the methods developed by engineers to run the manufacturing system apply to the service systems.

28. Disassembling it adds costs and value - you want the cuts of meat, not the whole animal. You are adding value to the cow when you are raising it and feeding it, so it becomes more valuable in the market. You add cost, not value when you ship the cow to the market.

29. Powder manufacture often involves the solidification of minute droplets of liquid material, and hence assumes aspects of casting. Shapes are produced by compaction or pressing, which has many aspects of forming. Finally, the particles are fused together

through the sintering operation, thereby assuming aspects of a joining or assembly process.

30. The selling price is determined by the marketplace and what the customer will pay. The best way to improve profit is to reduce manufacturing costs per unit. This can be difficult to do when the price keeps going up.

31. The manufacturing cost for an assembled product, e.g., a car, is made up of materials (raw materials, cutting tools, purchased parts and components and their storage and handling), direct labor, indirect labor (people who work in the manufacturing system but don't work directly on the product – the car), and energy and depreciation (machines and tooling).

32. Product lifecycle is composed of startup, rapid growth, maturation, commodity or decline.

33. To use the concepts presented in Figure 1-18 the type of components and required production rates have to be specified. If we assume two 8-hour shifts and 250 working days per year, then:

$$\text{Production rate of 16,000 parts/year} = (16,000 \text{ parts/year}) / (250 \text{ days} \times 16 \text{ hours/day}) = 4 \text{ parts/hour.}$$

The lower part of Figure 1-18 shows that for part variety of 10 and 4 parts per hour production rate there is significant overlap of the system possibilities of 1) flexible manufacturing system, 2) manned and 3) unmanned cells, 4) CNC equipped job shop.

35. The total cost for a quantity of goods is composed of the fixed costs and the variable costs. You as an engineer working for the company are part of the fixed cost - your salary is the same regardless of how many items your company produced this year. The variable costs are based on what goes into each item made, so the direct labor and materials (including the subassemblies) make up the bulk of the direct cost. Another obvious fixed cost in manufacturing is a die for a forming machine. The die may cost \$100,000, so you would need to make a million parts on it to bring its unit cost down to \$.10 per part. In manufacturing, this is part of the economy of scale first brought to the masses by Henry Ford in 1913.

Problems

1. a)

$$\% \text{ Direct labor} = [(\text{labor cost}) / (\text{manufacturing cost})] 100\%$$

$$\text{labor cost} = (20 \text{ hours}) (\$50/\text{hour}) = \$1000$$

$$\text{manufacturing cost} = \text{assumed } 40\% \text{ of selling price} = (0.40) (\$26,000) = \$10,400$$

$$\text{Direct labor} = (1000 / 10400) 100\% = 9.6\%$$

b)

$$\text{Production rate} = 50 \text{ trucks per hour assuming an 8-hour day with no breaks}$$

2. How would a bumper have to be redesigned to provide the equivalent strength? What other components would have to be redesigned? What additional or different processing equipment, including finishing equipment, would be needed? Would the aluminum bumper satisfy the safety requirements (5 mph crash test) needed by the car? What are the costs savings produced by this change?

3. Historically, many companies designed their products and then "threw the designs over the wall" to the manufacturing/industrial engineers who then had the job of figuring out how to make it. This often resulted in products that couldn't be reasonably built and it also locked out many manufacturing alternatives. Getting the manufacturing and industrial engineers together with the design engineers during the design phase of product development (including the suppliers) has become the concurrent way of doing business in the global world of manufacturing.

4. The university is an example of a service job shop and shows that value can be added by service processes and operations --the student enters engineering worth the minimum wage and graduates worth \$20 to \$30/hour. In the university job shop, the professors are the machine tool operators, the students are the workpieces, courses are the processes, tests are the inspections, books are the tooling, and department heads are the foremen. This question calls for the student to imagine himself as a product being processed by his university. Let us assume he spends 1 hour in class and 2 hours in preparation for the class for each 3 credit hour course during each of 8 semesters of 15 weeks and 10 hours are spent getting ready for the final exam. Over 4 years, let's assume the student takes 50 courses (about 6 per semester), so he spends $50 \times 3 \times 15 \times 3 + 50 \times 10 = 7250$ hours adding value (knowledge) to raise his market value upon graduation. The total number of available hours for adding value during the four years would be $364 \text{ days} \times 16 \text{ hours per day} \times 4 \text{ years} = 23294$ hours. (You could use 24 hours in this calculation instead of 16 since sleeping and eating are just part of the process of living and going to school.) So $7250/23294$ is about 31 percent which is a very high value for "value adding" in a process.

5. Comparing the university to the factory is an interesting exercise. Many have stated the student is the customer but that is wrong. The student is the product - comes in as a HS grad - the raw material, and is passed through many value adding processes (called courses) which convert him from a burger-flipper to a civil engineer (\$6/hr to \$46/hr). The customer here is industry who is "buying " the product but not paying the manufacturer directly. The industry/gov. may be buying research which may pay for the student but this is usually grad students. The machine tools are of course the courses that do the processing, so the profs are machine tool operators. A lively discussion will ensue in your class when you discuss this prob. and ask what is the throughput time (4 years??), the cycle time (a quarter or semester), the methods of inspection and quality control (should we sample the class with the next exam and then give everyone the grade that the sample gets?) and so forth. And of course, what is the design of the academic manufacturing system (a job shop?).

6. The sequence of steps will differ with the particular type of sandwich. Various students should have different answers.

7. The manufacturing system in Figure 1-4 generates about 40% of the total cost to run the business.

8.

1. Select one of the items from the list and discuss the materials or materials advances that enabled its creation.
2. For the same item selected in Part 1, discuss the manufacturing processes, or process advances, that enabled its creation.
3. If new items were to be added to the list over the next 10 to 20 years, what do you think they would be?
4. For items suggested in part 3, what materials or process advances would have been instrumental in their development and use?

Case Study: Famous Manufacturing Engineers

This is effectively a somewhat open-ended library or web search, designed to give students a feel for the history of the profession and the people who have made the type of contributions that have been significant. We suggest that you assign each student a name to research (ours is just a starter list) and have them give a one-minute thumbnail sketch of the person and a one-page bio as a handout to the class.