MANUFACTURING ENGINEERING

- Process Planning
- Problem Solving and Continuous Improvement
- Concurrent Engineering and Design for Manufacturability

Manufacturing Engineering Defined

Technical staff function concerned with planning the manufacturing processes for the economic production of high quality products

- Principal role - to engineer the transition of the product from design specification to manufacture of a physical product
- Overall goal - to optimize manufacturing within a particular organization

Manufacturing Engineering Activities

1. *Process planning*
   - Deciding most appropriate processes and their sequence
   - Determining tooling requirements
   - Selecting equipment
   - Estimating costs
2. *Problem solving* and *continuous improvement* - staff support to operating departments
3. *Design for manufacturability* - serve as manufacturability advisors to product designers

Process Planning

Determining the most appropriate manufacturing processes and the sequence in which they should be performed to produce a given part or product specified by design engineering

- If an assembled product, deciding appropriate sequence of assembly steps

- Limitations imposed by available processing equipment and productive capacity of the factory must be considered
- Parts or subassemblies that cannot be made internally must be purchased from external suppliers

Traditional Process Planning

- Traditionally, process planning is accomplished by manufacturing engineers who are knowledgeable in the particular processes used in the factory and are able to read engineering drawings
- Based on their knowledge, skill, and experience, they develop the processing steps in the most logical sequence required to make each part
- Some details are often delegated to specialists, such as tool designers; but manufacturing engineering is responsible

Decisions and Details in Process Planning

- *Processes and sequence* - the process plan should briefly describe all processing steps used on the work unit in the order in which they are performed
- *Equipment selection* - try to develop process plans that utilize existing plant equipment
  - Otherwise, the part must be purchased, or new equipment must be installed in the plant
- *Tools, dies, molds, fixtures,* and *gages* - design is usually delegated to the tool design department, and fabrication is accomplished by the tool room

More Decisions and Details in Process Planning

- *Methods* - include hand and body motions, workplace layout, small tools, hoists for lifting heavy parts, etc.
  - Methods must be specified for manual operations (e.g., assembly) and manual portions of machine cycles (e.g., loading and unloading a production machine)
- *Estimating production costs* - often accomplished by cost estimators with help from the process planner
- *Cutting tools* and *cutting conditions* for machining operations

Process Planning for Parts

- The processes needed to manufacture a given part are determined largely by the material out of which the part is made and the part design itself
  - The material is selected by the product designer based on functional requirements
  - Once the material has been selected, the choice of possible processes is narrowed considerably

Typical Processing Sequence

- A typical processing sequence to fabricate a discrete part consists of:
  1. A basic process
  2. One or more secondary processes
  3. Operations to enhance physical properties
  4. Finishing operations

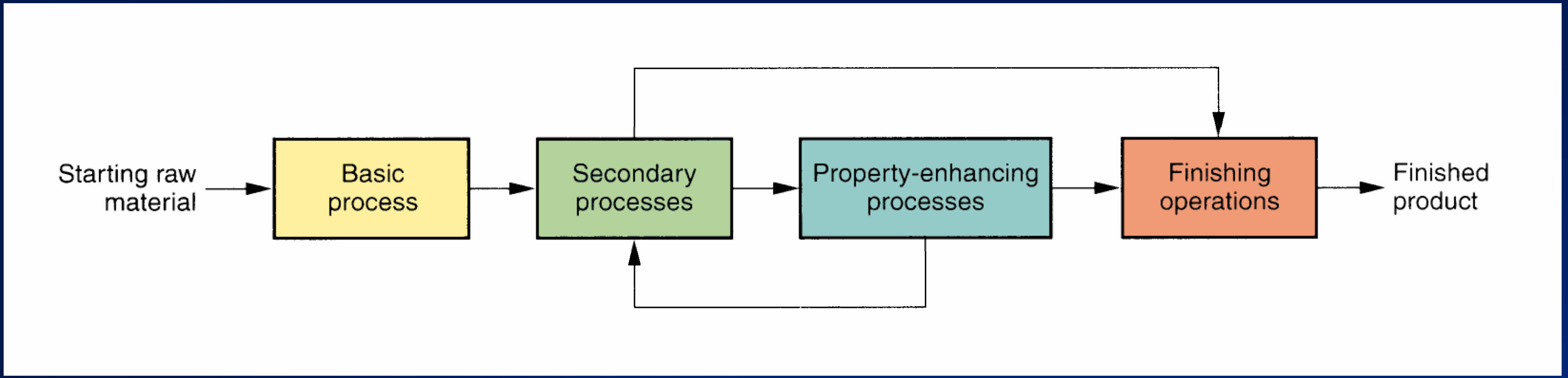

Figure 41.2 - Typical sequence of processes required in part fabrication

Basic and Secondary Operations

- *Basic process* - establishes initial geometry of workpart
  - Examples: metal casting, forging, sheet metal rolling
- In most cases, the starting geometry must be modified or refined by a series of *secondary processes*, which transform the basic shape into the final geometry
  - Examples: machining, stamping

Operations to Enhance Properties and Finishing Operations

- *Operations to enhance properties* - heat treatment operations
  - Treatments to strengthen metal components
  - In many cases, parts do not require these property enhancing steps
- *Finishing operations* - the final operations in the sequence
  - Usually provide a coating on the work surface
  - Examples: electroplating, painting

Examples of Typical Process Sequences

Basic process	Secondary Process(es)	Property enhancing	Finishing operations
Sand casting	Machining	Heat treating	Painting
Rolling sheet	Blanking, bending	(none)	Electroplating
Forging	Machining	(none)	Painting
Extrusion (Al)	Cut to length	(none)	Anodize
Casting of glass	Press, blowing	Annealing	Chem. etch

Process Planning and the Basic Process

- Process planning usually begins after the basic process has provided initial part shape
  - Example: machined parts begin as bar stock or castings or forgings, and the basic processes are often external to the fabricating plant
  - Example: stampings begin as sheet metal coils or strips purchased from the mill
- These are the raw materials supplied from external suppliers for the secondary processes and subsequent operations to be performed in the factory

The Route Sheet

The document that specifies the details of the process plan

- The route sheet is to the process planner what the engineering drawing is to the product designer
- The route sheet should include all manufacturing operations to be performed on the workpart, listed in the order in which they are to be accomplished

Part No: 031393	Part Name: Housing, valve			Rev. 2	Page 1 of 2		
Matl: 416 Stainless		Size: 2.0 dia × 5. long		Planner: MPG		Date: 3/13/XX	
No.	**Operation**	**Dept.**	**Machine**	**Tooling, gages**	**Setup time**	**Cycle time**	
10	Face; rough & finish turn to 1.473 ± 0.003 dia. × 1.250 ± 0.003 length; face shoulder to 0.313 ± 0.002; finish turn to 1.875 ± 0.002 dia.; form 3 grooves at 0.125 width × 0.063 deep.	L	325	G857	1.0 h	8.22 m	
20	Reverse; face to 4.750 ± 0.005 length; finish turn to 1.875 ± 0.002 dia.; drill 1.000 + 0.006, −0.002 dia. axial hole.	L	325		0.5 h	3.10 m	
30	Drill & ream 3 radial holes at 0.375 ± 0.002 dia.	D	114	F511	0.3 h	2.50 m	
40	Mill 0.500 ± 0.004 wide × 0.375 ± 0.003 deep slot.	M	240	F332	0.3 h	1.75 m	
50	Mill 0.750 ± 0.004 wide × 0.375 ± 0.003 deep flat.	M	240	F333	0.3 h	1.60 m	

Figure 41.3 – Typical route sheet for specifying the process plan

Process Planning for Assemblies

- For single stations, the documentation contains a list of the assembly steps in the order in which they must be accomplished
- For assembly line production, process planning consists of *line balancing* - allocating work elements to particular stations along the line
- As with process planning for individual parts, any tools and fixtures needed to accomplish a given assembly task must be decided, and the workplace layout must be designed

Make or Buy Decision

- Inevitably, the question arises whether a given part should be purchased from an outside vendor or made internally
  - It should be noted that virtually all manufacturers purchase their starting materials from suppliers
  - Very few production operations are vertically integrated all the way from raw materials to finished product

Make or Buy Decision (continued)

- Given that a company purchases some of its starting materials, it is reasonable to question whether the company should purchase the parts that would otherwise be made in its own factory
  - The answer to the question is the *make or buy decision*
  - The make versus buy question is probably appropriate to ask for every component used by the company

Make or Buy Example

The quoted part price from a vendor = $8.00 per unit for 1000 units. The same part made in the home factory would cost $9.00. The cost breakdown on the make alternative is as follows:

Unit material cost = $2.25 per unit

Direct labor = $2.00 per unit

Labor overhead at 150% = $3.00 per unit

Equipment fixed cost = $1.75 per unit

Total = $9.00 per unit

Should the component by bought or made in-house?

Make or Buy Example - continued

- Although the vendor's quote seems to favor the buy decision, consider the possible effect on the factory if the quote is accepted
  - Equipment fixed cost is an allocated cost based on an investment that has already been made
  - If the equipment is rendered idle by a decision to buy the part, then the fixed cost of $1.75 continues even if the equipment is not in use
  - The overhead cost of $3.00 consists of factory floor space, indirect labor, and other costs that will also continue even if the part is bought

Make or Buy Example - continued

- By this reasoning, the decision to purchase might cost the company as much as \$8.00 + \$1.75 + \$3.00 = \$12.75 per unit if it results in idle time in the factory on the machine that would have been used to make the part
- On the other hand, if the equipment can be used to produce other components for which the internal prices are less than the corresponding external quotes, then a buy decision makes good economic sense

Computer-Aided Process Planning (CAPP)

- During the last several decades, there has been considerable interest in automating the process planning function by computer systems
- Shop people knowledgeable in manufacturing processes are gradually retiring
- An alternative approach to process planning is needed, and CAPP systems provide this alternative

CAPP Systems

- Computer-aided process planning systems are designed around either of two approaches:
  1. Retrieval systems
  2. Generative systems

Retrieval CAPP Systems

- Also known as *variant CAPP systems*
- Based on GT and parts classification and coding
- A standard process plan is stored in computer files for each part code number
  - The standard plans are based on current part routings in use in the factory, or on an ideal plan prepared for each family
  - For each new part, the standard plan is edited if modifications are needed

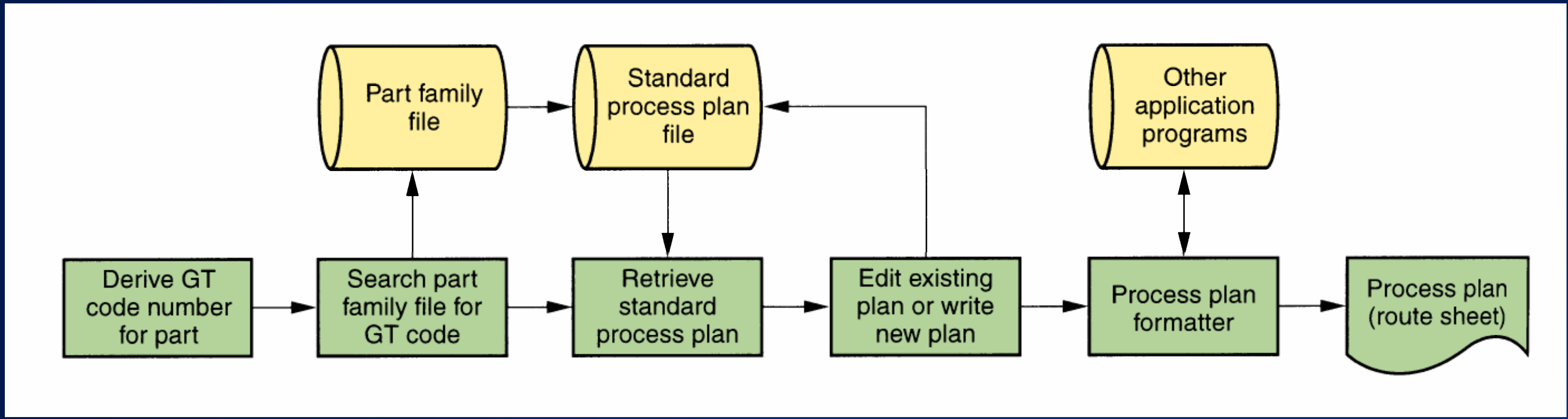

Figure 41.4 Operation of a retrieval type computer-aided process planning system

Retrieval CAPP Systems - continued

- If the file does not contain a standard process plan for the given code number, the user may search the file for a similar code number
  - By editing the existing process plan, or starting from scratch, the user develops a new process plan, which becomes the standard plan for the new part code
- Final step is the process plan formatter
  - The formatter may call other application programs: determining cutting conditions, calculating standard times, or computing cost estimates

Generative CAPP Systems

- Rather than retrieving and editing existing plans from a data base, the process plan is created using systematic procedures that might be applied by a human planner
- In a fully generative CAPP system, the process sequence is planned without human assistance and without predefined standard plans
- Designing a generative CAPP system is a problem in *expert systems* - computer programs capable of solving complex problems that normally require a human with years of education and experience

Components of an Expert system for a Generative CAPP System

- *Knowledge base* - the technical knowledge of manufacturing and logic used by process planners must be captured and coded in a computer program
- *Computer-compatible part description* - the description must contain all the pertinent data needed to plan the process sequence
- *Inference engine* - the algorithm that applies the planning logic and process knowledge contained in the knowledge base to a given part description

Benefits of CAPP

- Process rationalization and standardization – CAPP leads to more logical and consistent process plans than when traditional process planning is used
- Increased productivity of process planners
- Reduced lead time to prepare process plans
- Improved legibility over manually written route sheets
- CAPP programs can be interfaced with other application programs, such as cost estimating, work standards, and others

Problem Solving

- Problems arise in manufacturing that require technical staff support beyond what is normally available in the line organization of the production departments
  - Providing this technical support is one of the responsibilities of manufacturing engineering
  - The problems are usually specific to the particular technologies of the processes performed in the operating departments and engineering expertise is often required to solve them

Continuous Improvement

Constantly searching for and implementing ways to reduce cost, improve quality, and increase productivity in manufacturing

- Called *kaizen* by the Japanese
- Accomplished one project at a time
- May involve a project team whose membership includes people from other departments such as product design, quality engineering, and production control

Typical Continuous Improvement Project Areas

- Cost reduction
- Quality improvement
- Productivity improvement
- Setup time reduction
- Cycle time reduction
- Manufacturing lead time reduction
- Improvement of product design to increase performance and customer appeal

Design Engineering and Manufacturability

- Much of the process planning function is pre-empted by decisions made in product design
  - Decisions on material, part geometry, tolerances, and other design features limit the manufacturing processes that can be used
- The manufacturing engineer must act as an advisor to the design engineer in matters of manufacturability because manufacturability matters, not only to the production departments but to the design engineer

How Design Affects Process Planning – Example

- If the product engineer designs an aluminum sand casting with features that can be achieved only by machining,
  - Then the process planner must specify sand casting followed by the necessary machining operations
  - The manufacturing engineer might advise the designer that a plastic molded part would be superior

Design for Manufacturing and Assembly (DFM/A)

An approach to product design which systematically includes considerations of manufacturability and assemblability in the design

- DFM/A includes:
  - Organizational changes
  - Design principles and guidelines

Organizational Changes in DFM/A

- To implement DFM/A, a company must make changes in its organizational structure to provide closer interaction and better communication between design and manufacturing personnel
  - Often done by forming project teams consisting of product designers, manufacturing engineers, and other specialties to design a product
  - In some companies, design engineers must spend some career time in manufacturing to learn about the problems encountered in making things

DFM/A Principles and Guidelines

- DFM/A includes principles and guidelines that indicate how to design a given product for maximum manufacturability
- Many of these principles and guidelines are universal
  - Rules of thumb that can be applied to nearly any product design situation
- In addition, DFM/A includes principles that are specific to given manufacturing process

Benefits Typically Cited for DFM/A

- Shorter time to bring the product to market
- Smoother transition into production
- Fewer components in the final product
- Easier assembly
- Lower costs of production
- Higher product quality
- Greater customer satisfaction

Traditional Approach to Launch a New Product

An approach to product design that tends to separate design and manufacturing engineering

- Product design develops the new design, sometimes with small regard for the manufacturing capabilities possessed by the company
- There is little interaction between design engineers and manufacturing engineers who might provide advice on DFM/A

Concurrent Engineering

An approach to product design in which companies attempt to reduce elapsed time required to bring a product to market by integrating design engineering, manufacturing engineering, and other functions

- Also known as *simultaneous engineering*
- Manufacturing engineering becomes involved early in the product development cycle
- In addition, other functions are also involved, such as field service, quality engineering, manufacturing departments, vendors supplying critical components, and in some cases customers

Concurrent Engineering (continued)

- All of these functions can contribute to a product design that performs well functionally, and is also manufacturable, assembleable, inspectable, testable, serviceable, maintainable, free of defects, and safe
  - All viewpoints have been combined to design a product of high quality that will deliver customer satisfaction
- Through early involvement of all interested parties, the total product development cycle time is reduced

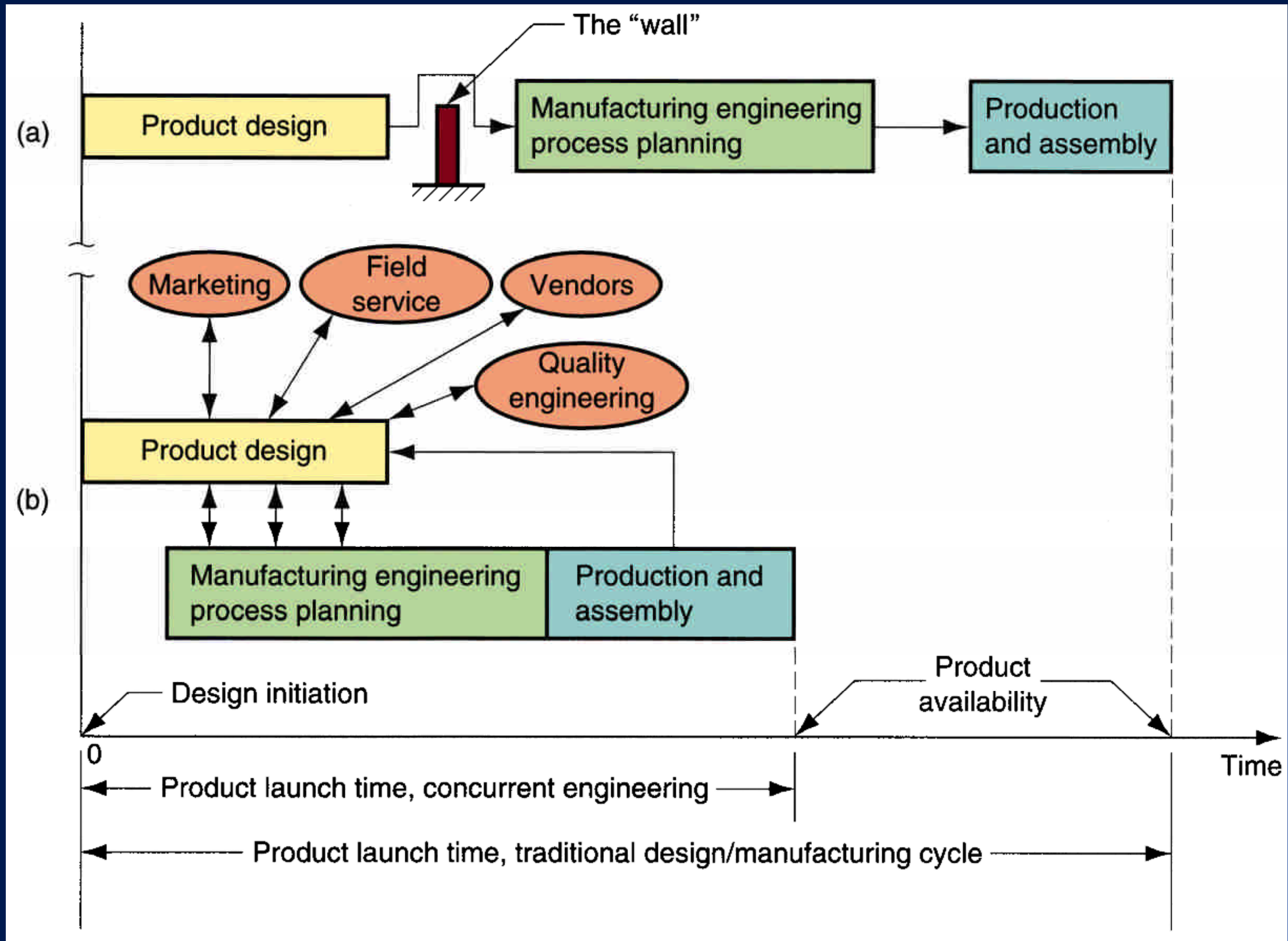

Figure 41.5 – Comparison of: (1) traditional product development cycle, (b) product development using concurrent engineering