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”

- 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
Who does Process Planning?

- Traditionally, process planning is accomplished by manufacturing engineers who are familiar with the particular processes 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 has overall responsibility.

Details in Process Planning

- Interpretation of design drawings
  - The part or product design must be analyzed to begin the process planning procedure.
    - Starting materials
    - Dimensions
    - Tolerances
  - Processes and sequence
    - The process plan should briefly describe all processing steps used to produce the work unit and the order in which they will be performed.
More Details in Process Planning

- **Equipment selection**
  - The process planner attempts 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 of special tooling is usually delegated to the tool design group, and fabrication is accomplished by the tool room

More Details in Process Planning

- **Methods analysis**
  - Hand and body motions, workplace layout, small tools, hoists for lifting heavy parts
  - Methods must be specified for manual operations (e.g., assembly) and manual portions of machine cycles (e.g., loading and unloading a production machine)
- **Work standards**
  - Time standards set by work measurement techniques
- **Cutting tools and cutting conditions for machining operations**
Process Planning for Parts

- 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
**Typical Processing Sequence**

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

- **Secondary processes**
  - 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
Property Enhancement 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

<table>
<thead>
<tr>
<th>Basic process</th>
<th>Secondary Process(es)</th>
<th>Property enhancing</th>
<th>Finishing operations</th>
</tr>
</thead>
<tbody>
<tr>
<td>Sand casting</td>
<td>Machining</td>
<td>Heat treating</td>
<td>Painting</td>
</tr>
<tr>
<td>Rolling sheet</td>
<td>Blanking, bending</td>
<td>(none)</td>
<td>Plating</td>
</tr>
<tr>
<td>Forging</td>
<td>Machining</td>
<td>(none)</td>
<td>Painting</td>
</tr>
<tr>
<td>Extrusion (Al)</td>
<td>Cut to length</td>
<td>(none)</td>
<td>Anodizing</td>
</tr>
<tr>
<td>Casting of glass</td>
<td>Press, blowing</td>
<td>Annealing</td>
<td>Chem. etch</td>
</tr>
</tbody>
</table>

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Process Planning: 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 these 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 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
- Route sheet should include all manufacturing operations to be performed on the workpart, listed in the order in which they are to be performed
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
  - 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 or all of its starting materials
  - Shouldn’t we 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

Given: The quoted part price from a vendor = $20.00 per unit for 100 units. The same part made in the home factory would cost $28.00. Cost breakdown on the make alternative is as follows:

- Unit material cost = $8.00 per unit
- Direct labor = $6.00 per unit
- Labor overhead at 150% = $9.00 per unit
- Equipment fixed cost = $5.00 per unit

Total = $28.00 per unit

- Should the component be 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 of $5.00 is an allocated cost based on an investment that has already been made
  - If equipment is idled by a buy decision, then the fixed cost continues even if the equipment is not in use
- Overhead cost of $9.00 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 $20.00 + $5.00 + $9.00 = $34.00 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

- 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 computer-aided process planning (CAPP) provides this alternative.
Benefits of CAPP

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

CAPP Systems

Computer-aided process planning systems are designed around either of two approaches:

1. Retrieval systems
2. Generative systems
Retrieval CAPP Systems

- Based on group technology 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
- Also known as variant CAPP systems

Retrieval CAPP System

Operation of a retrieval type computer-aided process planning system

New part begins

1. Search part family file for part code number
2. Search standard process plan
3. Use standard process plan to create new job
4. Compare plan with existing standard
5. Edit plan as necessary
6. Use plan to create job

Preparation stage

Automation

Computer-aided process planning

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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 an existing process plan, or starting from scratch, the user develops a new process plan that becomes the standard plan for the new part code
- Final step is the process plan formatter
  - Formatter may call other application programs: determining cutting conditions, calculating standard times, or computing cost estimates

Generative CAPP Systems

Rather than retrieving and editing an existing plan 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

- **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.

Product Development: Two Approaches

Comparison of:

(a) traditional product development cycle,

(b) product development using concurrent engineering.
Traditional Approach to Launch a 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 producibility

Concurrent Engineering

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

- 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, and in some cases customers
Concurrent Engineering

- 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

Design for Manufacturing and Assembly

- Estimated that 70% of the life cycle cost of a product is determined by basic decisions made during product design
  - Decisions include material for each part, part geometry, tolerances, how parts are organized into subassemblies, and assembly methods
  - Once these decisions are made, the ability to reduce manufacturing cost of the product is limited
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
  - It is important for the manufacturing engineer to have an opportunity to advise the design engineer as the product design is evolving

Design for Manufacturing and Assembly

“An approach to product design that systematically includes considerations of manufacturability and assembleability in the design”

- DFM/A includes:
  - Organizational changes
  - Design principles and guidelines that should be implemented during product design
Organizational Changes in DFM/A

To implement DFM/A, a company must make organizational changes to provide closer interaction between design and manufacturing personnel

- Often done by forming design project teams consisting of product designers, manufacturing engineers, and other specialties
- 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 processes
Examples of DFM/A Principles

- Minimize number of components in the product
- Use standard commercially available components wherever possible
- Use common parts across product lines
- Design parts with tolerances that are within process capability
- Design product for foolproof assembly
- Use modular design
- Shape parts and products for ease of packaging
- Eliminate or reduce adjustments

Other Product Design Objectives

- Design for quality
  - Principles and procedures to ensure that the highest possible quality is designed into the product
- Design for product cost
  - Efforts to specifically identify how design decisions affect product costs and to develop ways to reduce cost through design
- Design for life cycle
  - Gives consideration to costs associated with reliability, maintainability, serviceability, etc., which may be a significant portion of the total cost of the product
Advanced Manufacturing Planning

- Emphasizes planning for the future
  - Distinct from process planning because it is concerned with products being contemplated in the company’s long-term plans rather than products currently being designed and released
- Advanced manufacturing planning attempts to forecast the new products that will be introduced in the two to 10 year future
  - And to determine what production resources will be needed to make those future products

Activities in Advanced Manufacturing Planning

1. New technology evaluation
   - Decisions required whether to develop new processes for future products in-house or purchase from vendors
2. Investment project management
   - Investments required for new process technologies must be planned and managed
3. Facilities planning
   - New plants may be needed to produce new products
4. Manufacturing research and development
   - To develop the new process technologies
Advanced Manufacturing Planning