Product Design & Development

Design for Manufacturing
Design for Manufacturişnçng (DFM)

• Detail design decisions can have substantial impact on product quality and cost
• Development teams face multiple, and often conflicting, goals
• It is important to have metrics with which to compare alternative designs
• A well-defined method assists the decision-making process
Design for Manufacturing (DFM)

- Customer needs and product specs are hard to link with downstream product development
- Many teams use “design for X” where X means reliability, robustness, environmental impact, manufacturing,...
- Economically successful design is about ensuring high product quality while minimizing manufacturing cost – the goal of DFM
DFM requires a cross-functional team

• One of the most integrative practices in PD

• Inputs to DFM include:
  – sketches, drawings, product specs, design alternatives;
  – detailed understanding of production and assembly processes;
  – estimates of manufacturing costs, production volumes and ramp-up timing.
DFM within Product Development Process

How can we emphasize manufacturing issues throughout the development process?
Design for Manufacturing Example: GM 3.8-liter V6 Engine

Process applied to the intake manifold
ETM 551 Design for Manufacturing

Original intake manifold of cast aluminum

Redesigned intake manifold of molded thermoplastic composite
Overview of the DFM process

1. Estimate manufacturing costs
2. Reduce costs of components
3. Reduce costs of assembly
4. Reduce costs of supporting production
5. Consider impact on other factors
1. Proposed design

2. Estimate manufacturing costs

3. Reduce component costs
4. Reduce assembly costs
5. Reduce supp. Prod. costs

6. Consider impact other factors

7. Recompute manufacturing cost

8. Good enough? (Y/N)
Step 1: Estimate manufacturing cost

MANUFACTURING SYSTEM

- Equipment
- Information
- Tooling
- Raw materials
- Labor
- Purchased components
- Energy
- Supplies
- Services

- Finished goods
- Waste
Understanding Manufacturing

- Manufacturing Cost
  - Components
    - Standard
    - Custom
      - Raw Material
      - Processing
      - Tooling
  - Assembly
    - Labor
    - Equipment and Tooling
  - Overhead
    - Support
    - Indirect Allocation
Estimating manufacturing cost

• Fixed costs versus variable costs
• Estimate the costs of standard components
• Estimate the costs of custom components
• Estimate the cost of assembly
• Estimate the overhead costs
### Variable Cost

<table>
<thead>
<tr>
<th>Item</th>
<th>Description</th>
<th>Cost</th>
</tr>
</thead>
<tbody>
<tr>
<td>Materials</td>
<td>5.7 kg aluminum at $2.25/kg</td>
<td>$12.83</td>
</tr>
<tr>
<td>Processing (casting)</td>
<td>150 units/hr. at $530/hr.</td>
<td>3.53</td>
</tr>
<tr>
<td>Processing (machining)</td>
<td>200 units/hr. at $340/hr.</td>
<td>1.70</td>
</tr>
</tbody>
</table>

### Fixed Cost

<table>
<thead>
<tr>
<th>Item</th>
<th>Description</th>
<th>Cost</th>
</tr>
</thead>
<tbody>
<tr>
<td>Tooling for casting</td>
<td>$160,000/tool at 500K units/tool (lifetime)</td>
<td>0.32</td>
</tr>
<tr>
<td>Machine tools and fixtures</td>
<td>$1,800,000/line at 10M units (lifetime)</td>
<td>0.18</td>
</tr>
</tbody>
</table>

### Total Direct Cost

<table>
<thead>
<tr>
<th>Description</th>
<th>Cost</th>
</tr>
</thead>
<tbody>
<tr>
<td>Overhead charges</td>
<td>$12.09</td>
</tr>
</tbody>
</table>

### Total Unit Cost

**$30.65**

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### Variable Cost

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<thead>
<tr>
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<tbody>
<tr>
<td>Materials (manifold housing)</td>
<td>1.4 kg glass-filled nylon at $2.75/kg</td>
<td>$3.85</td>
</tr>
<tr>
<td>Materials (intake runner insert)</td>
<td>0.3 kg glass-filled nylon at $2.75/kg</td>
<td>0.83</td>
</tr>
<tr>
<td>Molding (manifold housing)</td>
<td>80 units/hr. at $125/hr.</td>
<td>1.56</td>
</tr>
<tr>
<td>Molding (intake runner insert)</td>
<td>100 units/hr. at $110/hr.</td>
<td>1.10</td>
</tr>
</tbody>
</table>

### Fixed Cost

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</tr>
</thead>
<tbody>
<tr>
<td>Mold tooling (manifold housing)</td>
<td>$350,000/tool at 1.5M units/tool</td>
<td>0.23</td>
</tr>
<tr>
<td>Mold tooling (intake runner insert)</td>
<td>$150,000/tool at 1.5M units/tool</td>
<td>0.10</td>
</tr>
</tbody>
</table>

### Total Direct Cost

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<thead>
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<th>Description</th>
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</tr>
</thead>
<tbody>
<tr>
<td>Overhead charges</td>
<td>$3.36</td>
</tr>
</tbody>
</table>

### Total Unit Cost

**$13.66**
Step 2: Reduce Cost of Components

- Understand the process constraints
- Redesign the components to eliminate processing steps
- Choose the appropriate economic scale for the part process
- Standardize components and processes
- “Black-box” component procurement
Step 3: Reduce cost of assembly

- Design for assembly (DFA) is a subset of DFM
- Keeping score

\[
DFA\ index = \frac{(Theoretically\ minimum\ number\ of\ parts) \times (3\ seconds)}{(Estimated\ total\ assembly\ time)}
\]

- Ask of each part in a candidate design:
  1. Does the part need to move relative to the rest of the device?
  2. Does it need to be of a different material because of fundamental physical properties?
  3. Does it need to be separated from the rest of the device to allow for assembly, access, or repair?
- Parts satisfying one or more of the questions should theoretically be separate.
Reduce cost of assembly (cont)

• Integrate parts
  – Integrated parts do not have to be assembled
  – Integrated parts are often less expensive to fabricate than the separate parts they replace
  – Integrated parts allow for the geometrical dimensions and tolerances to be more precisely controlled
Reduce cost of assembly (cont)

- Maximize ease of assembly
  - Part is inserted from the top of the assembly
  - Part is self-aligning
  - Part does not need to be oriented
  - Part requires only one hand for assembly
  - Part requires no tools
  - Part is assembled in a single, linear movement
  - Part is secured immediately upon insertion
Reduce cost of assembly (cont)

• Consider customer assembly
  – Look into it if purchasing and handling by the customer are substantially easier
  – Substantial challenge to design a product to be assembled by the most inept customers, many of whom will ignore directions
Design for Assembly Rules

Example set of DFA guidelines from a computer manufacturer:

1. Minimize parts count.
2. Encourage modular assembly.
3. Stack assemblies.
4. Eliminate adjustments.
5. Eliminate cables.
6. Use self-fastening parts.
7. Use self-locating parts.
8. Eliminate reorientation.
9. Facilitate parts handling.
10. Specify standard parts.
Design for Assembly

• Key ideas of DFA:
  – Minimize parts count
  – Maximize the ease of handling parts
  – Maximize the ease of inserting parts

• Benefits of DFA
  – Lower labor costs
  – Other indirect benefits

• Popular software developed by Boothroyd and Dewhurst.
  – [http://www.dfma.com](http://www.dfma.com)
To Compute Assembly Time

\[ \text{Assembly Time} = \text{Handling Time} + \text{Insertion Time} \]
Step 4: Reduce cost of supporting production

- Minimize systemic complexity
- Error proofing
Step 5: Consider impact of DFM decisions on other factors

• Impact of DFM on development time
  – Reduction of $1 on each manifold would be worth $1 million in annual cost savings, but would not be worth a six-month delay in the project

• Impact of DFM on development cost
  – If properly integrated in product development, extra cost is meaningless
Impact of DFM decisions on other factors (cont)

• Impact of DFM on product quality
  – Usually DFM results in improved serviceability, ease of disassembly, and recycling
  – Can cause adverse effects in product reliability and robustness

• Impact of DFM on external factors
  – Component reuse
  – Life cycle cost
Summary

• DFM begins with the concept development phase and system-level design phase
• DFM utilizes estimates of manufacturing cost to guide and prioritize cost reduction efforts
• DFM practice involves making decisions in the absence of detailed data