Lecture 19
Design for Manufacture
Design for Assembly

DFM

- Design’s decisions will have significant impact on the costs associated with the manufacture of the product
  - Piece part costs
  - Cost of quality
    - yield
    - process precision
  - Set-up costs
  - Labor content
  - Throughput
  - Flexibility
Design for Manufacture

• Broad term applied to a variety of tool, guidelines, and methods to ensure
  – Low cost parts
    • Piece parts are built using the lowest cost process possible
    • Design dimensions/tolerances are specified with thought.
  – Low cost assembly
    • DFA
  – Low cost processes
    • Processes are designed to target the critical to function characteristics

Tradeoffs

• Piece part simplicity vs. assembly time
• Variety vs. integrality
• Manufacturability vs. performance
DFM Iteration

• Process selection
  – material requirements
  – volumes
  – tolerances
  – part complexity
  – setup costs
  – expertise

• Design for the process
  • ensure that the product can be made with the process
  • exploit some of the benefits of the process

• General Design Guidelines
  • Reduce part count
  • DFA

DFM Support Processes

• Simultaneous Engineering / Cross-functional teams
• Design for Manufacturing Reviews
• DFM Guidelines
• DFM Metrics
• Simulation software
**Simultaneous Engineering / Cross-functional teams**

- Simultaneously design the product and the process
- Prevents *over-the-wall design*
- Cross-functional teams continually evaluate each others work and have input on the whole product/process design

**DFM Reviews**

- Formal reviews where experts are brought in to evaluate the manufacturability of the product
- Formalized gate
- Problems
  - Often not taken seriously
  - “we never can get design to make changes, we’ll just wait until we get it to make it manufacturable”
**DFM Guidelines**

- Formalized lists of guidelines for a specific manufacturing process
- Developed by manufacturing to generate rules for design to follow
- Can be either computer based or book based
- Heuristics rather than quantitative
- Problems
  - Just sit on the desk - never used

**Design for Adhesives**

Worse → Better
Design for Assembly

- Reduce assembly time by
  - Integral parts
  - Remove fasteners
  - Minimize assembly time
Minimize part count through integral parts

• Identify
  – parts that can be made of the same material
  – parts that don’t move relative to each other
  – parts that do move but can use
    • integral joints
    • flexures
• Problems
  – Reduce modularization
  – Increase complexity
• Benefits
  – Reduced assembly
  – Reduced tolerance stack-ups

Minimize assembly time

• Easy to get part
  – parts don’t tangle
• Easy to orient part
  – symmetrical or very unsymmetrical parts
• Easy to assemble parts
  – self aligning
  – lead-in chamfers
Minimize fasteners

- **Options**
  - Press fits
  - Adhesives
  - Snap-fits
  - Integral parts
- **Problems**
  - Fasteners are stronger
  - Fasteners can be used to locate parts
  - Temperature insensitive
  - Less sensitive to part variation

DFM metrics

- Quantitative evaluations that are used to put a metric on the manufacturability of a product.
- The goal is to improve the metrics through design changes
- Examples
  - Boothroyd and Dewhurst's complexity
  - Yield
  - # of manuf. Rule violations
Boothroyd and Dewhurst Complexity factor

- Total number of parts $N_p$
- Total number of part types $N_T$
- Total number of interfaces $N_i$

$$\text{Complexity} = \sqrt{N_T + N_P + N_i}$$

Yield

- Calculation of the number of parts that will not pass inspection.
- Ways to calculate
  - Models of the product
  - Statistical correlation with historical data
Yield based on Model

• Use historical data to determine the product characteristics that are highly correlated with yield problems
• SMT example
  – Process technology
  – Number of parts
  – Number of interconnects
  – Volume
  – ....
Simulation software

- Used to simulate the “as built” state of a product
- Examples
  - Mold flow (injection molding)
  - CNC simulations
- Problems
  - Don’t give guidance on the changes
  - Time consuming

Collect the DFM guidelines and review
**Fixtured vs. Determinate Assembly**

<table>
<thead>
<tr>
<th></th>
<th>Fixtured</th>
<th>Determinate</th>
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</thead>
<tbody>
<tr>
<td>Location</td>
<td>Fixtures</td>
<td>Precision holes</td>
</tr>
<tr>
<td>Flexibility of fixture</td>
<td>Low</td>
<td>High</td>
</tr>
<tr>
<td>Precision requirements</td>
<td>Low</td>
<td>High</td>
</tr>
<tr>
<td>Ability to rework</td>
<td>Low</td>
<td>High</td>
</tr>
<tr>
<td>Assembly Time</td>
<td>High</td>
<td>Low</td>
</tr>
</tbody>
</table>
Sub-assemblies

• Build ups
  – Parts (bulkheads, doors, etc) are built up of many parts that are assembled in dedicated fixtures

• Monolithic
  – parts are machined out of a large
    • forging, or
    • billet
  – to make a single piece

Monolithic vs. build up

<table>
<thead>
<tr>
<th></th>
<th>Monolithic</th>
<th>Build up</th>
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</thead>
<tbody>
<tr>
<td>Near net shape forging</td>
<td>High</td>
<td>Low</td>
</tr>
<tr>
<td>Billet</td>
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<td>flexible</td>
</tr>
<tr>
<td>Cycle time</td>
<td>High</td>
<td>Low</td>
</tr>
<tr>
<td>Ability to increase throughput</td>
<td>Low</td>
<td>Low/med</td>
</tr>
<tr>
<td>Crack resistance</td>
<td>Med</td>
<td>Med.</td>
</tr>
<tr>
<td>&quot;Quality&quot;</td>
<td>High/med</td>
<td>High</td>
</tr>
</tbody>
</table>
Lecture 20:

- VARIATION RISK MANAGEMENT, THE ROLE OF QUALITY

- No readings