Some details on Design for Manufacture and Assembly

1. Recognized as one of the most common and effective methodologies for reducing product cost

2. The basic techniques are mostly a collection of common sense rules that lead engineers to streamline designs, combine several parts into one piece, reduce the number of fasteners and commonize materials.

3. Three words: Simplify, simplify, simplify

4. The key to successful DFMA is to get designers to think about how parts will be manufactured and how products will be assembled early in the design phase
   » Designers must learn about manufacturing and assembly methods
   » Concurrent engineering to get design engineers and manufacturing engineers working together early in the design process.
Machined Part Design Guidelines (Product Design, Otto & Wood)

(a) Design holes to the shape of tool. If Hole is to be tapped, provide space for it.

(b) Use standard dimensions.

(c) Do not design impossible to machine hollows or overhangs.

(d) Avoid long narrow holes.
Machined Part Design Guidelines (Product Design, Otto & Wood)

Don’t

Impossible

Radius smaller than 1/4"

Design for reasonable internal pockets radii.

(e)

Do

Use 1/4 - 1/2” radius

(f) Avoid thin walls that break when machining.

Don’t

Thin wall

(g) Avoid drilling inclined faces.

Do

(h) Place holes away from corners and edges.
Machined Part Design Guidelines (Product Design, Otto & Wood)
Sheet-formed Part Design Guidelines

(Product Design, Otto & Wood)

Design for ease of blanking:
- \( W = 0.040'' \) min for materials thinner than 0.047'' – wider if possible.
- \( W_1 \geq \) material thickness; wider if possible.
- \( L = 5W \) maximum depth; less if possible.
- \( L_1 = 5W \) maximum length; less if possible.

Tolerance in a pierced hole is only attained for 25% of its length. Hole must not be smaller than thickness of blank.

**Don’t**
- Avoid sharp corners, or the material will tear.

**Do**
- Shear and form operations should have a minimum height \((h)\) of 2 1/2 the blank thickness.

Position holes away from bends.
Sheet-formed Part Design Guidelines
(*Product Design, Otto & Wood*)

(a) Don’t

On Paper

What will happen

Web

Bulge

Ear

A narrow web will cause bulging. Provide an ear in the blank or include the hole as a notch.

(b) Don’t

Tear

Do

Offset bends.

(c) Don’t

(d) Do

If $D \geq 2t$, a cutout is needed to bend flange.

Use separated straight flanges when possible.
Design for Assembly Guidelines
(Product Design, Otto & Wood)

a) Minimize part count by incorporating multiple functions into single parts.

b) Modularize multiple parts into single sub-assemblies.

c) Design open enclosures to permit assembly in open space, not in confined spaces. Never bury important components.

e) Standardized to reduce part variety.
Tolerance Design

• Drawings of components or assemblies are incomplete without tolerances on all dimensions

• Only a fraction of the tolerances actually affect the function

• Don’t specify unnecessarily tight tolerances for noncritical dimensions (unnecessary cost)

*The Mechanical Design Process, David Ullman*
Tolerance vs. Manufacturing Process

Tighter tolerance = Higher cost
Example: Motorola DFM

Motorola (winner of the 1988 National Quality Award) defines Design for Manufacturability (DFM) as a method for creating robust product designs that will be insensitive to long-term dynamic variation in the processes and materials used in manufacturing.

The six steps in Motorola's DFM method are:

1. Identify the physical and functional requirements of the end product which are necessary to satisfy the requirements of:
   - Customer's intended use of the product;
   - Foreseeable misuse of the product;
   - Environment in which the product is used;
   - End of life disposal of the product, and
   - Regulatory agencies and applicable standards.
The six steps in Motorola's DFM method (continued):

2. Identify the **characteristics** of the components and assemblies of the product which are key to meeting the end-product requirements. (Critical to quality - CTQ)

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**Example from Cincinnati Machine**

- It is crucial that the supplier and Cincinnati Machine understand and agree on which features are critical to quality so that special care is taken during process design and manufacturing.

- These Key Control Characteristics must be listed on the KCC form.

- Normally, Cincinnati Machine Engineering would provide a list of product KCC’s and the Supplier would add process KCC’s to create the final list.

- The list of KCC’s drives the Gage R&R and Process Capability effort during process prove-out.

- By policy, all KCC features must be manufactured on stable and capable processes to manage risk. Inspection alone is not an adequate control.
The six steps in Motorola's DFM method (continued):

3. For each key characteristic, determine whether it is controlled by the piece part, the assembly process, or a combination of both.

4. For each key characteristic, determine the target value which minimizes the effects of variation in that characteristic on the successful outcome, and determine the maximum allowable range of that characteristic which can be tolerated by the design.

5. For each key characteristic, determine the variation which can be expected in that characteristic based on the known capability of the process selected to produce it.
**Process Potential Index (\(C_p\))**

A measure of the ability of a process to satisfy specifications. \(C_p\) is the ratio of the specification tolerance spread to the actual process spread.

\[
C_p = \frac{USL - LSL}{6\sigma}
\]

**Process Capability Index (\(C_{pk}\))**

An indication of how much a process mean can shift and still meet the specification limits. \(C_{pk}\) is the distance from the center of the distribution to the closest specification limit, measured in units of standard deviation.

\[
C_{pk} = \text{MIN} \left( \frac{\bar{x} - LSL}{3\sigma}, \frac{USL - \bar{x}}{3\sigma} \right)
\]

Ref: 6 Sigma presentation, Cincinnati Machine, ME471, Dr. Kremer
The six steps in Motorola's DFM method (continued):

6. Calculate design margin (design tolerance divided by process capability). If the design margin is not greater than 2, evaluate the characteristic using a concurrent engineering approach and modify product or process design to attain the required design margin.

   »This is equivalent to a Cp=2 in 6 sigma

Results

In the late 1980s, Motorola pioneered the use of DFMA and reduced part count for a vehicle-mounted remote radio from 217 to 97, realizing an 87% reduction in direct cost.