Ergonomics in Design for Manufacture and Assembly

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In this section we will cover

Ergonomics in Design for Manufacture and Assembly (DFMA)

An Idea

Product design starts with an idea

In essence, product design starts with an idea, progresses to sketches of parts and assemblies and then to CAD workstation or assembly drawings. These drawings are then passed to manufacturing and assembling engineers who optimize the processes used to produce the final product.

Frequently at this stage manufacturing and assembly problems are encountered with requests made for design changes. Sometimes these changes are large in number and can result in considerable delays in the final product release with a subsequent increase in product lifecycle costs.

DFMA Defined

Improving fabrication and simplifying assembly

DFMA is a set of programs, techniques, tools and methods for improving the fabrication of parts and simplifying the assembly of products.

Ergonomics in DFMA includes the application of sound ergonomics principles as part of the overall DFMA process. DFMA can eliminate potential ergonomic risk factors from the workplace.

DFMA is an important step in the concurrent engineering process because it adds a robust analysis method that all parties can discuss. Without DFMA, early evaluation of design concepts can be "best guess," resulting in opinion-based discussions rather than consensus engineering.

Benefits

DFMA offers significant benefits

DFMA offers significant benefits in design, manufacturing and the end product.

Design

- Improve quality of design
- Encourage dialogue between designers, manufacturing engineers and others who play a part in determining final product costs.

Manufacturing

- Improve ease of manufacturing
- Reduce manufacturing costs
- Greater predictability of product yields
- Reduce maintainability/service efforts and warranty costs

Product

- Simpler and more reliable products
- Develop and launch products in shorter periods of time
- Reduce costs and time to bring product to market

Goals of ergonomics in DFMA

Adding ergonomics to the DFMA process has specific goals that are concurrent with those of the overall DFMA process:

- Minimize ergonomics risk factors
- Minimize assembly time and cost
- Minimize design time and cost
- Maximize product quality (decrease faulty assemblies)
- Maximize process reliability (decrease process failures)
- Maximize product usability (decrease failures in user environment)

Results of published case studies

Boothroyd, Dewhurst and Knight have summarized a number of studies that examined the outcome of the DFMA process. They document a substantial average reduction in a number of the metrics of interest.

Metric	Average Reduction (%)	Number of Studies
Assembly time	61.2	31
Assembly cost	41.4	18
Fixtures/assembly tools	71.0	4
Material cost	48.5	2
Manufacturing cycle time	57.3	6
Product time to market	47.5	4

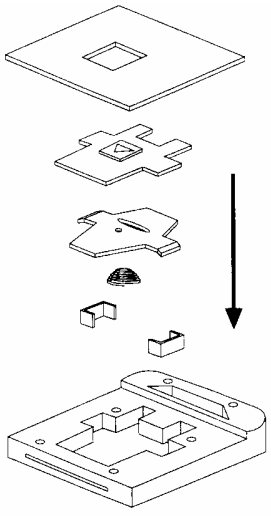
Product Design for Manufacture and Assembly, **Boothroyd, Dewhurst and Knight, Marcel Dekker, New York, NY, 1994.**

Principles: Design for Manufacture and Assembly

Design for Ergonomics and Assembly methodologies are based on the following principles:

PRINCIPLE ➔

Design for a stable base



This is probably the most important concept. Think of an automobile assembly line -- the chassis is the stable base. As it moves along the line, parts and subassemblies are fastened to it in turn. There is no need for reorientation of the entire chassis for each new subassembly.

Strategy ▶ Minimize reorientation of entire assembly

The less an assembler has to move and orient both the original part and parts to be added, the faster and more trouble-free the process will be.

- Reduces number of necessary tools and fixtures
- Reduces final assembly and testing times
- Reduces operator fatigue and improves workplace ergonomics
- Improves quality

Strategy ▶ Make the insertion point easy to see and reach

Utilizing this concept

- Reduces fatigue and repetitive motion problems
- Facilitates proper alignment and fastening of parts/subassemblies
- Decreases assembly time

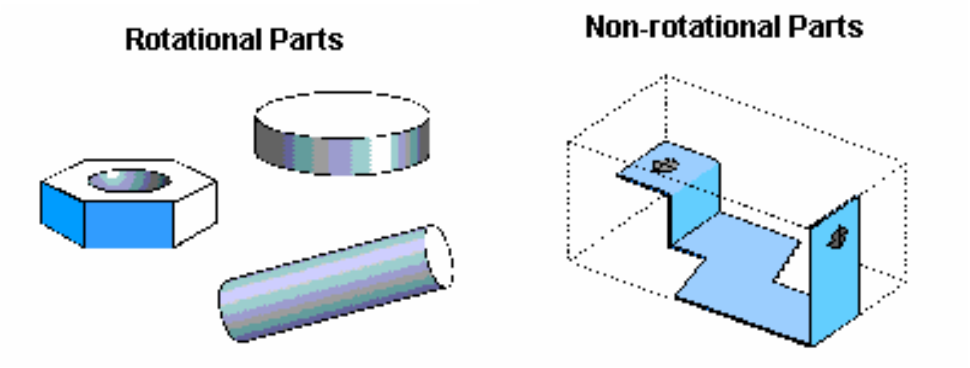
Strategy ▶ Decrease the need for specialized fixtures

Fixtures are devices that hold the part or assembly in a particular orientation so the part can be fastened or inserted securely. A stable base minimizes the need for such fixtures, because it acts as a fixture itself.

PRINCIPLE ➔ *Insertion of parts*

The insertion or parts as part of the assembly process is the next principle.

Strategy ▶ Decrease ambiguity in part/subassembly orientation



First, a review of rotational symmetry. **Alpha symmetry** refers to symmetry about a part's "most repeatable" axis, and is reported as the number of degrees needed to turn an object along this axis before it repeats. For example, a square bar has alpha=90º, a cylinder has alpha=0º (so does a screw, for all practical purposes), and a bar that is rectangular in cross section has alpha=180º. **Beta symmetry** is perpendicular to the alpha axis. It is related to whether the "ends" are identical or not, and whether the part needs to be flipped over before insertion. Values are either 0º (identical ends) or 180º (needs to be flipped).

These affect how a part is oriented before insertion into the larger assembly:

- Lower symmetry values decrease the number of possibilities for incorrect orientation, therefore decreasing manipulation and assembly time.
- At the same time, a part that can only be inserted in a single orientation decreases ambiguity. This, however, requires that the assembler be adept at spatial recognition, and may increase handling time.

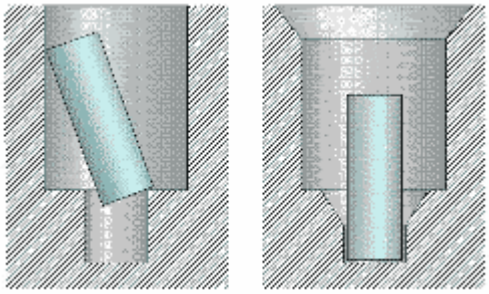
Strategy ▶ Design parts with self-locating features

Make things easier to assemble, and the process will speed up. Advantages:

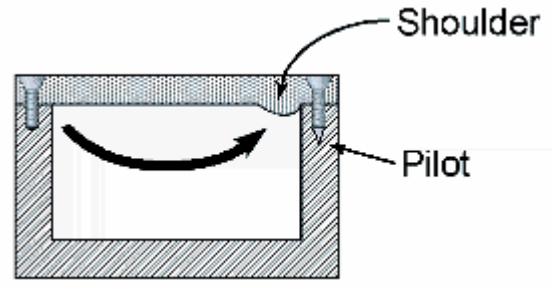
- Reduced assembly tooling
- Reduced operator training

- Reduced operator fatigue and frustration
- Reduces lifetime product cost
- Improves quality

Chamfers help guide the cylinder to its destination.



Addition of a shoulder and a piloted screw make alignment and assembly easier.



Strategy ▶ Fail-safe Assembly

Design components for fail-safe assembly (One Way-Right Way). Three common principles are:

- Design components so that they cannot be assembled incorrectly (use asymmetrical outside surfaces or guides)
- Design components to be fully assembled in one operation (integrate component placement and fastening in one step)
- Design out "false" assembly targets (extra holes or pins)

PRINCIPLE ➔ *Minimize part count and levels of assembly*

Minimizing part count and levels of assembly is an important principle in ergonomics in DFMA. Here are strategies for this principle.

Strategy ▶ Minimize the number of levels of assembly

Some subassembly is good, but don't go overboard. By decreasing the number of assembly levels, you:

- Simplify specifications
- Facilitate the assembly process
- Simplify factory layout

Strategy ▶ Minimize numbers and types of fasteners, cables, etc.

The addition of a single screw to a product doesn't add just the cost of the screw, but also the cost of:

- Having someone align it and screw it in
- Drilling and tapping the hole, and the machinery to do it
- Overhead for inventory, and
- Time and space necessary for the assembly process

The same goes for different types of cables and connectors in electronic equipment, as well as many other examples.

Strategy ▶ Encourage modular, interchangeable assemblies

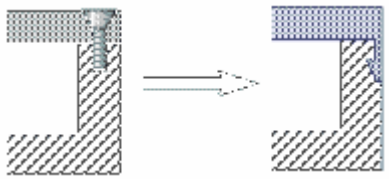
Designing interchangeable parts with specific qualities makes customization easy. Other advantages:

- Reduces final assembly time
- Simplifies inventory
- Facilitates automation
- Reduces post-assembly adjustments
- Improves serviceability

Strategy ▶ Build in self-fastening features

This goes hand-in-hand with reducing the number of fasteners and using special characteristics of the material. Snap-fit items are easily molded from plastics, and fold-over tabs are easily stamped from sheet metal.

This example shows how a snap-fit tab can take the place of a separate screw. Not only does one eliminate the screw, but also time is saved because the tab is self-aligning.



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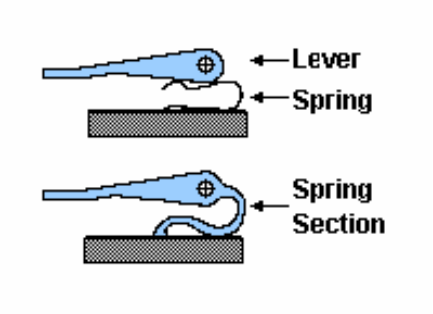
PRINCIPLE ➔ *Use unique characteristics of the material*

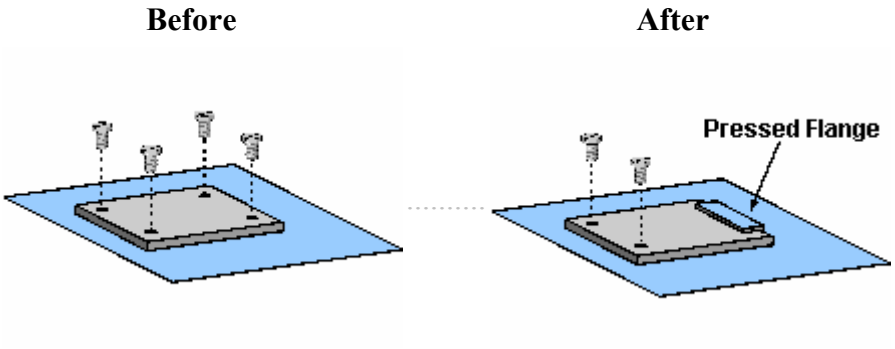
Strategy ▶ Built-in springs

Plastic, being flexible and easily molded, not only uses its unique characteristics, but also can reduce part count by designing a spring as part of another part:



Strategy ▶ Pressed or molded parts

Pressed metal flanges and tabs increase the precision of insertion, and may help reduce part count, too:



Strategy ▶ Injection-molded buttons or signs

A good example of injection-molded buttons is the keys on a computer keyboard. By molding the letters into the keys, they don't wear off like paint or decals would, and the decal application step is eliminated. Decals, however, are desirable where they would not get a lot of wear, because they are less expensive than injection-molded signs.

PRINCIPLE ➔ ***Ergonomics Applications***

Ergonomics principles and applications play a strong role in the DFMA process. Here is a series of strategies that outline specific ergonomics related factors.

Strategy ▶ Ease of Handling

Design parts for ease of handling. Avoid components that are sharp, too small, or slippery; also, care should be taken to minimize the opportunity for parts to nest or **tangle while in storage.** If parts are easier to handle and accurately locate, assemblers will experience less fatigue and frustration. In addition, it:

- Enables automatic assembly and/or feeding techniques
- Simplifies the assembly process
- Reduces tangling and nesting of parts
- Reduces total assembly time

Strategy ▶ Correct tool/Eliminate need for special tools

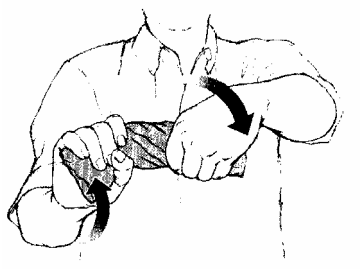
Choose the correct tool according to how it will be used so that a safe posture is maintained during the assembly process.

Specialized tools and machines often need specialized training. In many cases, these tools may be necessary, but their use often increases handling time because the tool must be picked up and manipulated before it is used.

A classic example is the Torx driver, used for automobile headlight adjustment among other things. These come in several sizes that can be easily confused. Why not use a simple Phillips screwdriver instead?

Strategy ▶ Avoid 'washrag' postures

Avoid 'washrag' postures - bent wrist and pinch grip postures associated with the development of cumulative trauma disorders (CTDs).

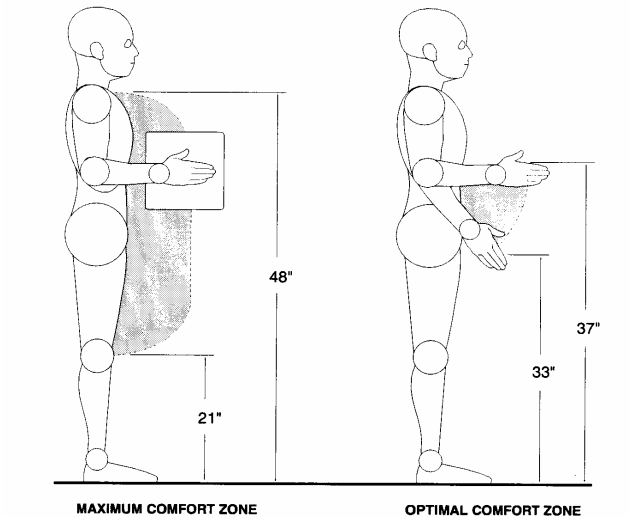


Strategy ▶ Eliminate mechanical pressure

Eliminate unnecessary mechanical pressure on tissues.

Strategy ▶ Comfort zone

Keep it in the comfort zone — design the work area to fit the individual, instead of forcing an individual to fit a work area.

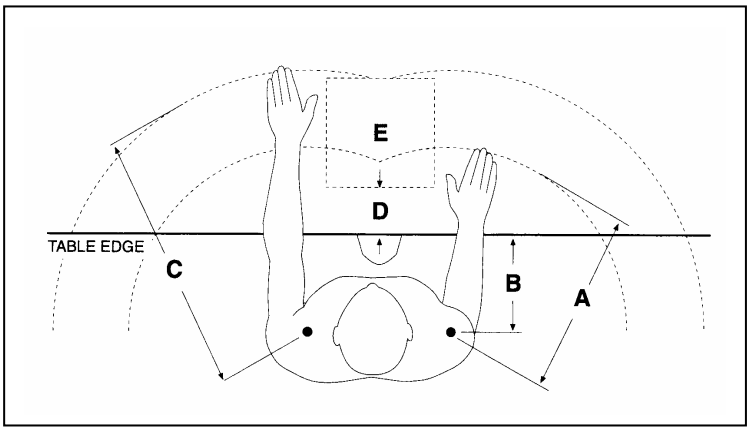


Strategy ▶ Reach and see access

Design for access so that a product and its parts are easy to reach and see. The four rules for access are:

- Provide clearance for the operator's hands, tools, and testing fixtures
- Design so that mating surfaces are visible
- Avoid designs that require fasteners at the rear of the assembly
- Design for accessibility during assembly and future maintenance

Reach Guidelines



Primary Work Area	Horizontal Range	
A	Normal Reach Radius	Max = 15"
B	Sitting/Standing Distance	Max = 9"
C	Extending Reach Radius	Max = 22"
D	Work Distance	Ideal = 4"
E	Optimum Work Area	10 by 10"

Adapted from: Ron Garrett, Instructor, Michigan Virtual Automotive College, (www.engineer.gvsu.edu/vac) and Product Design for Ergonomics in Assembly, Humantech.