

ME349

Engineering Design Projects

Design for Assembly

Prior to examining a system for DFA you need to have a model, drawing or prototype of the assembly and a suggested assembly sequence.

Definition and Purpose

Design for Assembly is a method of analyzing components / sub-assemblies in order to:

Identify part relevance

- Determining theoretical minimum number of parts
- Minimizing part count/levels of assembly

Identify the assembly process steps

- Use of Structure Charts
- Minimize levels of assembly

Estimate the cost of assembly

- Non-value added process steps
- Part handling
- Part insertion/orientation

The purpose of DFA is to reduce the number of parts, optimize the assembly process and minimize assembly cost.

Basic List of DFA Methods

1. Aim for simplicity.
Minimize part numbers, part variety, and assembly surfaces; simplify assembly sequences, component handling and insertion, for faster and more reliable assembly. Much of this document will pertain to this idea.
2. Standardize.
Standardize on material usage, components, and aim for as much off-the-shelf componentry as possible to allow improved inventory management, reduced tooling, and the benefits of mass production even at low volumes.
3. Rationalize product design.
Standardize on materials, components, and subassemblies throughout product families to increase economies of scale and reduce equipment and tooling costs. Employ modularity to allow variety to be introduced late in the assembly sequence and simplify Just In Time production.

4. Use the widest possible tolerances.

Reduce the tolerance on non-critical components and thus reduce operations, and processing times.

5. Choose materials to suit function and production process.

Avoid choosing materials purely for functional characteristics; material choice must also favor the production process to ensure product reliability.

6. Minimize non-value-adding operations.

The minimization of handling, excessive finishing and inspection will reduce costs and lead-time.

7. Design for process. (Design for Manufacturing)

Take advantage of process capability to reduce unnecessary components or additional processing, such as the porous nature of sintered components for lubricant retention. Design in features and functions to overcome process limitations, such as features to aid mechanical feeding. Avoid unnecessary restriction of processes to allow manufacturing flexibility in process planning.

Assembly Process Assumptions

The operator picks up or retrieves the component/sub-assembly from a container and orients it. This is called “part handling”.

Component/sub-assembly are inserted into a simple fixture. This is called “part insertion”.

Whenever possible, the operator uses one hand.

The operator never picks up one part in each hand, combines them then places them in the fixture. This obscures individual piece assembly.

Any manipulation of assembled parts or change in direction is defined as reorientation.

Any operation to parts already in the fixture is counted as a separate operation. Examples are welding, crimping, etc.

The operator uses simple hand tools, no automation.

Minimizing Part Count and Levels of Assembly

This is probably one of the simplest things to do. Fewer parts mean a faster and more accurate assembly process, and fewer mistakes. It results in:

- Reduced administrative overhead and inventory
- Reduced number of vendors
- Reduced assembly time and savings in material costs
- Simplified factory layout and assembly processes

It can be accomplished by:

- Minimizing numbers and types of fasteners, cables, etc.
- Encouraging modular, interchangeable assemblies
- Building in self-fastening features
- Minimizing the number of levels of assembly

Minimizing 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.

Encouraging 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

Building 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.

Minimizing 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

Using Unique Characteristics of the Material

Plastics may be transparent, translucent, or opaque, and are flexible and can be easily bent, shaped, or molded. Metals can be stamped or pressed into shape. These characteristics allow these materials to be utilized in special ways:

- 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.

- Pressed or molded parts

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

- 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.

Eliminating need for special tools

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? However, Torx drivers are more easily used in automated assembly, and hence the tradeoff continues.

Theoretical Minimum Number of Parts

This guide can help in determining the theoretical minimum number of components.

Question	Yes	No
1) Is the component/sub-assembly used only for fastening or securing other items? If yes, try to eliminate.		
2) Is the component/sub-assembly used only for connecting other items (for example, wiring harnesses, belts, chains)? If yes, try to eliminate.		
3) During operation, does the component move relative to <u>all</u> other parts already assembled? If no, skip question #4		
4) Must the part be made of a different material than, or isolated from <u>all</u> other parts already assembled? Only fundamental reasons concerned with material properties are acceptable. If no, go to question #5		
5) Must the part be separate from all other parts already assembled because of any necessary assembly or disassembly of the other parts would otherwise be impossible? If no to questions #3-5, part is theoretically unnecessary.		
6) If this is a part in a sub-assembly, can any part be combined with another part in the parent assembly?		

Measure of Complexity

Industrial researchers Boothroyd and Dewhurst have developed the following complexity factor. This simple calculation can be used to generate a relative measure of system complexity.

N_p = Total number of parts

N_t = Total number of part types

N_i = Total number of part interfaces (face-face, pin-hole, etc.)

$$\text{Complexity} = \sqrt{N_t + N_p + N_i}$$

Part Handling Characteristics

Part handling characteristics identify design features that help or hinder retrieving a component/sub-assembly and moving it from one location to another. These characteristics include:

Component/sub-assembly symmetry

Alpha symmetry: axis perpendicular to direction of insertion, measured in degrees

Beta symmetry: axis in direction of insertion, measured in degrees.

Geometric Size

Large parts

Require two hands

Require mechanical assistance

Tiny parts

Require tweezers

Require magnification

Component/sub-assembly weight

Part weight > 10 lb

Part weight < 10 lb

OSHA limit = 28 lb

General handling of parts

Require a tool to pickup or assemble

Nest or tangle (can be severe)

Fragile or delicate

Sticky or slippery

Sharp edges or points

Flexible

Part Insertion Characteristics

Part insertion characteristics focus on design features that either help or hinder insertion of a component/subassembly into another part, sub-assembly, or fixture.

Restricted vision

Obstructed access

Alignment features

Resistance to insertion (force greater than applied with one hand)

Stability

Large depth of insertion (> 18")

Severe alignment difficulties (requires multiple movements)

Designing Parts that are Easy to Assemble

Following are some key rules and elements for a successful design. Note that trade-offs are necessary. For example, elements to maximize handling may negatively impact insertion.

Part Handling

Design parts that are easy to handle
Maximize the symmetry of part
Make sure parts are as error proof as possible
Design parts that are “ideal” in terms of size

Part Insertions

Design for uni-directional assembly, preferably down
Design parts that are easy to align and position
Avoid separate fasteners: design the fastening functions into the parts.
Avoid reliance on complex jigs and fixtures; design parts that self-
fixture.
Consider access and visibility for ease of insertion.
Avoid the need for adjustments and reorientations.

Theoretical Part Count

Design for the minimum number of without sacrificing quality.
Commonize the required parts

Designing to a Stable Base

This is probably the most important concept. Consider the example of an automobile assembly line. In the case, the chassis serves as the stable base. As it moves along the assembly line, parts and subassemblies are fastened to it. There is no need for reorientation of the entire chassis when each new subassembly is added.

This aids in:

Minimizing 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 freer the process. It:

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

Making the insertion point easy to see and reach

This is closely related to one of the other major concepts, Z-axis insertion. Utilizing this concept:

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

Z-Axis Insertion of Parts

Z-axis insertion refers to insertion along the line of sight. If the assembler has a good view of the larger assembly as well as the parts to be added, the assembly will be faster and more precise. To further understand this concept, let's look at the affect of part symmetry on part assembly:

First, we will examine a brief review of the principles 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 $\alpha = 90^\circ$, a cylinder has $\alpha = 0^\circ$ (so does a screw, for all practical purposes), and a bar that is rectangular in cross section has $\alpha = 180^\circ$. 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 0° (identical ends) or 180° (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 can increase handling time.

At the same time, remember that while decreasing symmetry will reduce assembly time it may increase the number of components, adding to manufacturing costs. As previously stated, DFM/DFA represents a tradeoff between assembly and manufacture ideals.

Unidirectional Assembly

Unidirectional assembly means assembling a product by adding the parts one by one all from the same direction. During the assembly the base or already assembled part doesn't need to be moved or rotated to allow the other pieces to be attached.

Symmetry is also desirable. If we can achieve the same assembly regardless of the orientation in which the part to be assembled is held, it eliminates the need for adjustments in orientation.

Unidirectional assembly saves time and money during the assembly process because the producer doesn't need to worry about the labor, equipment, or time that is needed to perform the complicated movements used in multi-directional and orientation specific assembly. By avoiding multi-directional assembly the product assembly becomes much more simple, which in return means a faster, cheaper, and easier product development.

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

Decreasing 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.

Non-Value Added Process Steps

Non-value added process steps are extra procedures that could be eliminated with a more efficient design. They are steps that do not increase the value of the product from the customer's perspective. Examples are:

Part reorientation to assist further assembly

Adjustment or manipulation of parts

Secondary securing processes (welding, soldering, adhesive bonding)

In-process quality checks

Reading of instructions

Anything other than adding a part (cleaning, torqueing, etc.)