

ME349

Engineering Design Projects

Design for Disassembly

To optimize a product's end-of-life system, you should consider designing for disassembly. This type of design can also serve to make a product more serviceable for users and aid in maintenance and reparability. Although most products can be disassembled eventually, lengthy disassembly does not make for economic recycling as the cost of disassembly is likely to be much larger than the revenue gained through recycling the parts and materials from the product. It is for this reason that designing products for easy disassembly has increased in popularity enabling more of the product to be recycled economically.

Benefits

Designing for disassembly can have the following benefits:

Facilitate maintenance and repair, thereby reducing costs.

Facilitate part/component re-use, thereby recovering materials and reducing costs.

Assist material recycling, thereby avoiding disposal and handling of waste.

Assist product testing and failure-mode/end-of-life analysis.

Facilitate product take-back and extended producer responsibility, thereby reducing liability and assisting in regulatory compliance.

How Implemented

Certain factors, such as the life span of parts/components, their standardization, maintenance requirements, and instructions for servicing and re-assembly, play a major role in designing for disassembly. In general, designers should attempt to:

Use detachable joints such as snap, screw or bayonet instead of welded, glued or soldered connections.

Use standardized joints so that the product can be dismantled with a few universal tools, e.g., one type and size of screw.

Position joints so that the product does not need to be turned or moved for dismantling.

Indicate on the product how it should be opened non-destructively, e.g., where and how to apply leverage with a screwdriver to open snap connections.

Place parts that are likely to wear out at the same time in close proximity so they can be easily replaced simultaneously.

Indicate on the product which parts must be cleaned or maintained in a specific way, e.g., color-coded lubricating points.

In addition the techniques given above, authors Dowie and Kelly provided the following table of fastening and connection guidelines which may be employed in DFD.

Table of Fastening Guidelines












Guideline	Justification
Minimize the number of fasteners.	Most disassembly time is spent on fastener removal.
Minimize the number of fastener removal tools required.	Changing tools costs time.
Fasteners should be easy to remove.	Saves time during disassembly.
Fastening points should be easy to access.	Awkward movements slow down disassembly process.
Snap fits should be obviously located and able to be opened using standard tools.	Special tools may not be available.
Try to use fasteners of material compatible with the parts being joined.	Allows disassembly operations to be avoided.
If parts cannot be produced of compatible materials, make them easy to disassembly.	The parts must be separated in order to recycle.
Eliminate adhesives unless compatible with material of both parts being joined.	Many adhesives cause contamination of parts for material recycling.
Minimize the number and length of wires and cables used.	Flexible elements are slow to remove, copper contaminates steel in recycling.
Connections can be design to break as an alternative to removing fasteners.	Fracture is a fast disassembly operation.

In general, a product that is designed for easy assembly may also be easily disassembled. However, there do exist some major differences. Below is a table taken from Dowie and Kelly detailing what they refer to as “Do’s and Don’ts” of Design for Disassembly.

Guideline	Don't	Do
Use attachments that are easy to disassemble		
Minimize the number of fasteners		
Use the same fasteners		
Ensure easy access for disassembly		
Use simple standard tools		
Avoid long disassembly paths		
Design for damage free disassembly		
Use the same tools for assembly and disassembly		
Use one disassembly direction to avoid reorientations		
Design for multiple detachments with one operation		

Because the use of plastics is so prevalent in product design the follow table of plastic-to-plastic joint design with respect to disassembly has been included.

Plastic-to-plastic Joint Guidelines (GE 1995)

Type		Disassembly Method	Rating
Mechanical Joints			
Hook		Slipped Loose	○
Snap fit		Snapped Out	○
Press fit		Ripped Out Pressed Out	●
Screw		Unscrewed	●
Screw Insert		Unscrewed Boss Chiseled Off	●
Welded Joints			
Welded – compatible materials		No separation needed	●
Solvent Bonded – compatible materials		No separation needed	●
Welded (with separate welding material)		Cut off welded area	●
Stud welded		Chiseled off Milled away	●
Molded in (insert)		Ripped out Pressed out Drilled out	●
Glue Bonded		Economically not feasible	○

Two areas which may be considered subsets of DFD and which should also be areas of design concern are, Design for the Environment and Design for Recycling.

Design for the Environment (DFE) is a systematic consideration of design issues related to environmental and human health over the life cycle of the product. Below are eight aspects that should be included in design for the environment:

- manufacture without producing hazardous waste
- use of clean technologies
- reduce product chemical emissions
- reduce product energy consumption
- use of non-hazardous recyclable materials
- use of recycled material and reused components
- design for ease of disassembly
- product reuse or recycling at end of life.

Design for Recycling deals with the reclamation of product value from materials at the end of their product life. Below are listed a number of areas associated with Design for Recycling:

Designing for ease of disassembly, to enable the removal of parts without damage.

Designing for ease of purifying, to ensure that the purifying process does not damage the environment.

Designing for ease of testing and classifying, to make it clear as to the condition of parts that can be reused and to enable easy classification of parts through proper markings.

Designing for ease of reconditioning, this supports the reprocessing of parts by providing additional material as well as gripping and adjusting features.

Designing for ease of re-assembly, to provide easy assembly for reconditioned and new parts.

There are a number of benefits of achieving efficient disassembly of products as opposed to recycling a product by shredding, which include:

Components that are of adequate quality can be refurbished or reused.

Metallic parts can be separated easily into categories that increases their recycling value.

Disassembled plastic parts can be easily removed and recycled.

Parts made from other material such as glass or hazardous material can easily be separated and reprocessed.

A key technique for reducing the environmental impact of a product is to reduce the waste stream of the product. When a product reaches the end of its useful life, the waste stream can be greatly reduced by recycling. The first requirement for recyclability of a product is that there must be a demand for the material.

Therefore, one should design with materials that have a high demand such as metals and plastics. With regard to plastics, currently markets exist for HDPE, PET, LDPE, PS, PP and PVC. The designer should examine current plastic recycling figures for demand and usage.

Types of Plastic by Resin		
PET	(PolyethyleneTerephthalate)	(e.g., soda, water bottle, and food containers)
HDPE	(High Density Polyethylene)	(e.g. milk & water jugs, detergent bottles)
PVC	(Vinyl/Polyvinyl Chloride)	(e.g. shampoo and window cleaner bottles)
LDPE	(Low Density Polyethylene)	(e.g. trash bags, 6-pack rings, flexible lids)
PP	(Polypropylene)	(e.g. lids, closure caps, snack food wrap)
PS	(Polystyrene)	(e.g. StyrofoamR, clear brittle cups)

The second major concern of Design for Recycling is a measure of how easy it is to remove the materials from the product. Although most products can be disassembled eventually, lengthy disassembly does not make for economic recycling as the cost of disassembly is likely to be much larger than the revenue gained through recycling the parts and materials from the product. It is for this reason that designing products for easy disassembly has increased in popularity enabling more of the product to be recycled economically.

There are a number of benefits to achieving the efficient disassembly of products.

Components which are of adequate quality can be refurbished or reused.

Metallic parts can be separated easily into categories that increase their recycling value.

Disassembled plastic parts can be easily removed, sorted and recycled.

Parts made from other material such as glass or hazardous material can easily be separated and reprocessed.

A rating system can be applied to help the designer assess the separability and recyclability characteristics of product designs. Examples of such rating systems are given in the following two tables. The examples are taken from the automotive industry, one of the current leaders in Design for Recycling.

Separability Ratings

Rating	Description	Examples
1	May be disassembled easily by manual techniques, less than 1 minute	Pull-apart plastics
2	May be disassembled with effort manually, less than 3 minute	Instrument cluster, radio
3	May be disassembled with effort and some mechanical separation or shredding to separate. The process has been fully proven	Engine, sheet metal, uncorroded screws
4	May be disassembled with effort and some mechanical separation or shredding to separate. The process is under development	Instrument panels, corroded screws, adhesive
5	Cannot be disassembled, no known process for separation	Heated backlight

Recyclability Ratings

Rating	Description	Examples
1	Part is re-manufacturable	Starter motor, alternator
2	Material in a part is recyclable with a clearly defined technology and infrastructure	Most metals, PET, HDPE
3	Material is technically feasible to recycle; infrastructure to support recycling is not available	Most thermoplastics, glass, thermosets
4	Material is technically feasible to recycle with further process or material development required	Armrest, airbag modules, single metal with single thermoset
5	Material is organic; can be used for energy recovery but cannot be recycled	Multithermoplastics, wood products
6	Material is inorganic with no known technology for recycling	Heated glass, fiberglass