Lecture #19

ERDM

Prof. John W. Sutherland

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Facilitating Disassembly

- **In our previous discussions about product design we spoke about "hearing" the voice of the environment.**
- **Also examined design for reprocessability.**
- **Most recently, we have looked at the modeling of product disassembly.**
  - **Minimum time / maximum profit**
  - **Partial disassembly**
  - **Reactive disassembly**
- **What about design for disassembly? Guidelines**

Fasteners

- **Fasteners?**
  Screws, bolts, nails, staples, rivets, snaps, latches, adhesives, chemical bonds, welds, solders, etc.

- **What philosophy do we adopt?**
  - **Reversible fastening technologies are preferred for disassembly**
  - **Some advantage to molded in snap fits**
  - **Part breakage may be best way to disassemble**

Benefits of Design for Disassembly

- **Facilitate maintenance and repair - reduce costs**
- **Facilitate part/component re-use - recover materials and reduce costs**
- **Assist material recycling - waste avoidance**
- **Assist product testing and failure-mode/end-of-life analysis**
- **Facilitate product take-back and extended producer responsibility - reduce liability & assist in regulatory compliance**

How to - DFD - General

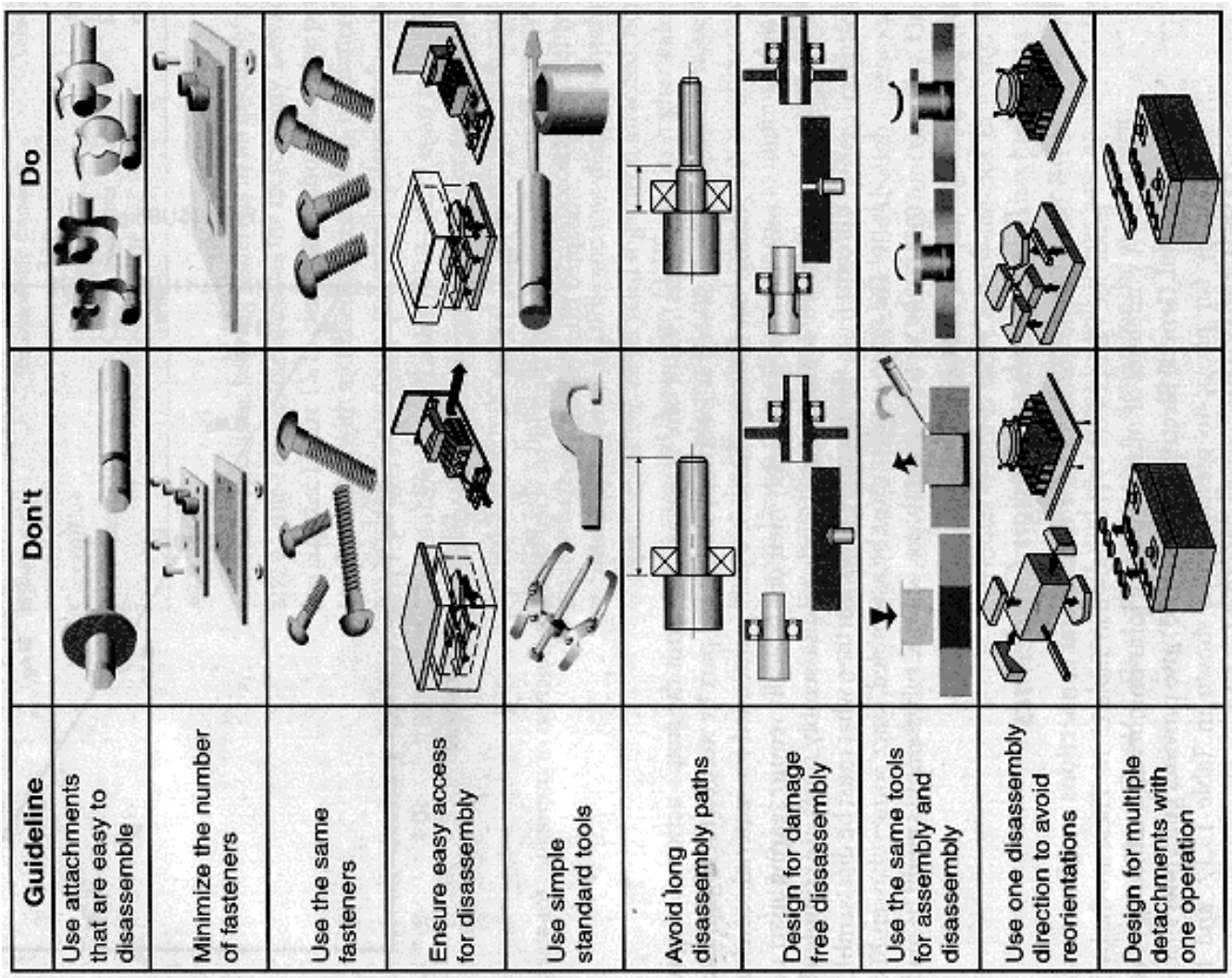
- **Use detachable joints such as snap or screw instead of welded, glued, or soldered connections.**
- **Use standardized joints - product can be dismantled with a few universal tools, e.g., one type and size of screw.**
- **Position joints to avoid turning/moving during dismantling.**
- **Indicate on 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 will 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.**

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 opened using standard tools.	Special tools may not be available.

Guideline	Justification
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 designed to break as an alternative to removing fasteners.	Fracture is a fast disassembly operation.

DFD -- Do's & Don'ts (Dowie & Kelly)



Plastic-to-Plastic Joint Guidelines (GE 1995)

Type		Disassembly Method	Rating
Mechanical Joints			
Hook		Slipped Loose	O
Snap fit		Snapped Out	O
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	O

Next Steps -- Separability Example

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. Process under development	Instrument panels, corroded screws, adhesive
5	Cannot be disassembled, no known process for separation	Heated backlight

Next Steps -- Recyclability Example

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

Fasteners & Tools

	Fastener	Disassembly Tools	Problems in Disassembly
Discrete Fastener	screws	screwdriver	corrosion, damage, accessibility
	nuts and bolts	screwdriver, ratchet, wrench, Allen key	accessibility, corrosion, damage, missing parts
	spring toggle bolts	screwdriver, pliers	accessibility, corrosion
	nails	pliers, hammers, or hacksaw	corrosion, accessibility
	rivets	chisel, hammers, grinders, punches and blow torches	difficult, permanent connection, corrosion, accessibility
	staples	staple pliers, flat tipped screw driver	accessibility, corrosion
	clips	manual, pliers	accessibility
	retaining rings	ring pliers	accessibility
	snap-type fasteners	pliers, screwdrivers, punches	accessibility, corrosion
	quick release fasteners	screwdriver	accessibility, corrosion

Integral Attachments	cantilever hook	screwdriver, punches, pliers	accessibility, difficult - multiple latches
Energy Bonding	welding	chisels, hammer, blow torches, and grinders	difficult, permanent connection, through cutting - but part damage
Others	seaming	cutters, shears, hacksaw	difficult, permanent connection - through cutting - part damage
	crimping	vice, pliers, punches, hammers, hacksaw	difficult, part damage
	zippers	manual, pliers	wedging of parts
	Velcro	manual, pliers	accessibility, multiple joints, dirt, contamination
	tape	manual	difficult to remove, if too sticky or tape degraded, or if tape tears too easily, dirt

Joint Comparison -Discrete Fasteners

Stage	Issues
Design	High Joint Efficiencies, R = 1, localized stress concentrations, allow relative motion, fastener spacing, shear and tension joint loads, fastener weight
Manufacturing	no chemical or microstructural changes, cost per fastener installation
Assembly	join similar and dissimilar materials, hole alignments, tolerance accumulations
Operation/ Service	aids product service, corrosion-entry source, damage tolerance
Disassembly	good for non-destructive or semi-destructive disassembly, often time consuming

Joint Comparison - Integral Attach.

Stage	Issues
Design	Tailorable joint efficiencies, R > 1, elastic assembly deformation and local friction forces, macroscale material interference
Manufacturing	secondary operations for manufacturing of non-net shape components
Assembly	low insertion forces, join similar and dissimilar materials
Operation/ Service	high pull-out resistance, vibration and loosing resistance, compressive deflection concerns, improved service
Disassembly	good for non-destructive disassembly

Joint Comparison- Adhesive Bonding

Stage	Issues
Design	Low Joint Efficiencies, R < 1, large bearing joint/ bond areas, uniform stress distributions, damping of shock loads, smooth joint contours, adhesive and cohesive failure
Manufacturing	careful surface preparation and process control, chemical changes to adhesive
Assembly	join similar & dissimilar materials and different component shapes, measurable cure times
Operation/ Service	thermal and corrosion sealing, structure service difficulties, resistance to cyclic loads, operating environment concerns
Disassembly	only destructive disassembly

Joint Comparison - Energy Bonding

Stage	Issues
Design	Low Joint Efficiencies, R < 1, thermal or electrical conductivity in bond area and length, bonding region
Manufacturing	phase change at joint interface, careful surface preparation and process control
Assembly	join similar materials, application of external energy source to joint, application of external pressure during joint formation
Operation/ Service	creep and brittle failure modes, services and disassembly problems
Disassembly	only destructive disassembly