Reduction of End-of-Life Impacts Through Design for Disassembly (DfD)

**Introduction**

- Achieving product sustainability and lowest total cost of ownership (TCO) requires integrating all aspects of Design for X in green life-cycle engineering design.
- Existing green DfX approaches mainly focus on materials, manufacturing, and assembly, and the use phases.
- End-of-Life (EoL) phase is often overlooked or neglected due to lack of data and/or high degree of complexity/uncertainty.
- Integrating EoL aspects in the design phase can facilitate a more complete LCA and LCC analysis.
- Most common design approach for reducing EoL impacts is Design for Disassembly (DfD).

**End-of-Life Pathways**

- Need to identify the appropriate EoL pathway(s) as part of the design process.
- Generally better to: reuse ⇒ remfg. ⇒ recycle.
- Challenges:
  - Generally, product A ≠ product Aasw (contaminated, damaged, worn, etc.).
  - Current EoL infrastructure not well regulated; no standardization.
- Many recycling processes have yet to be developed and current ones improved.

**DfD Guidelines**

**DfD Design Goals**

- Factors affecting the disassembly process
  - Guides to improve disassembly
  - Design for assembly
  - Product assembly
  - Materials
  - Process and tooling requirements
  - Number of joints and connections
  - Characteristics of the components for disassembly
- Disassembly conditions
  - Good accessibility (low weight, low height, visibility, etc.)
  - Not necessary: pressure, other adhesives
  - Design for automated disassembly
  - Evaluate the need for specialized disassembly procedures
  - Design with simple and standard tools

**DfD Design Rules for Metals**

- Recycled products are easier to recycle than plated ones.
- Low alloy metals are more recyclable than high alloy steels.
- Most cast irons are easily recycled.
- Aluminum alloys, steel, and magnesium alloys are readily separated and recycled from shredder outputs.
- Contamination of zinc or steel with copper, iron, lead, aluminum reduces recyclability.
- Contamination of aluminum with zinc, steel, chromium, zinc, lead, copper or magnesium reduces recyclability.
- Contamination of steel with zinc, steel, lead, or cadmium reduces recyclability.

**Summary & Future Work**

- End-of-Life considerations can be equally, if not more important when conducting LCA and LCC analyses.
- DfD has emerged as a key discipline in the DfX field for product sustainability and lowest total cost of ownership.
- DfD practices can be adopted through a series of relatively simple guidelines and understanding of the EoL system.
- Full DfD implementation with DMA, etc. can be achieved using liaison graphs and the liaison intensity.

**Future work:**

- Develop systematic strategies for choosing preferred EoL pathway.
- Integrate DfD design guidelines and EoL system in DfD model.
- Developing and customizing more advance engineering attributes for the liaison intensity.
- Developing and modeling non-conventional liaisons such as material additive processes (e.g. thin film deposition, coatings) and surface finishes.
- Full integration of DMA and DfD with multi-objective analysis.