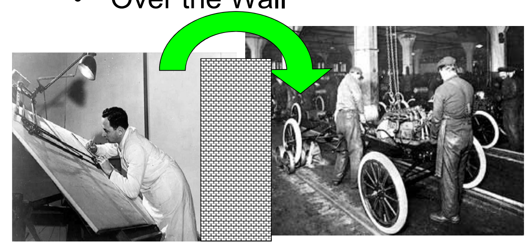
Mech 328
Mechanical Engineering Design Project

DFM: General Issues in the Manufacturing of a Design

Manufacturing/Build Issues:

- “Over the Wall”



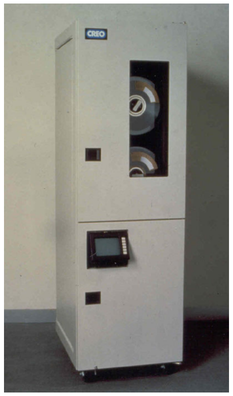
Over the Wall

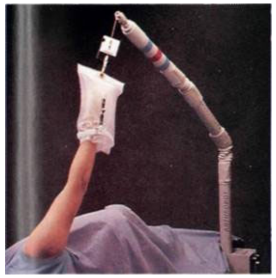
- A design is “finished” (e.g. functional prototype or on-paper design) then “thrown over the wall” to Manufacturing to work out how to actually produce it cost effectively.
- Advantages
  – Don’t get bogged in details/constraints; get something to work
  – Focus on function first before worrying about manufacturability may waste fewer resources
  – Experts focus solely on their own area – well-defined responsibilities
  - Clarity on responsibility- clear cut-offs between groupsand hand-offs

Over the Wall

- Disadvantages:
  – **Slower to market**
  – **Re-engineering often req’d** for manufacturing, cost, regulatory and service issues
  – **Long communication chain** (delays, risk of misinterpreting)
  – **Changes may not maintain design intent** (conflicting requirements resolved with bias favouring the maker of changes)
  – **As-builts don’t match specification** documentation making service and upgrades a potential nightmare
  – **Wasted resources** (time, effort)

Over the Wall





Concurrent Engineering

- Simultaneous launch of effort in all departments
- Manufacturing/construction, regulatory, service, product end-of-life issues considered during initial design (people included in the list of stakeholders; needs assessed; requirements and ECs include consideration of manufacturing, installations, service, disposal)
- Start work with incomplete information e.g. begin tooling design for a part that is not yet fully designed
- Feedback between designers, manufacturing/contractors, marketing, distribution and service helps to ensure that the overall profitability of the result is maximized.

Concurrent Engineering

- Benefit: Overall reduction in time to market/completion with a viable product/installation; capitalize on "window of opportunity"/benefit of early implementation.
- *"First to Market" critical for market position and profitability in new product markets
  - #1 market position is making money
  - #2 market position is breaking even (me too)
  - #3 market position is losing money
- Downsides: inefficiencies; slack times; danger of running fast in the wrong direction; high burn-rate – easier to make fatal mistake
    - *Source: Amos Michelson former CEO Creo products

Part Count

- Every additional part requires
  - Validation
  - Unique part number
  - Inventory space
  - Supplier management
  - Tooling
  - Procedures
  - Handling during manufacture and service
  - Alternate sources identified, etc.
- And adds
  - potential failures
  - requirements for interface
  - contributions to tolerance stack-up
  - can be installed correctly…etc.

Parts : Off-the-Shelf vs. Custom-made

- Advantages
  - Low cost due to economies of scale
  - Multiple sources
  - Low lead times possible
  - Engineering risk low
  - Installation tools and practices familiar to many
- Disadvantages
  - Required performance may not be available
  - Dependency on suppliers
  - Limited ability to optimize: may pay for unnecessary features
  - Customer can source own replacement parts and possibly own service
  - Require knowledge of standard parts
  - Profit on part-making lost

Parts : Off-the-Shelf vs. Custom-made

- Advantages of Custom-made
  - Total control over features (optimize)
  - May increase profitability
    - Cost reduction
    - Replacement parts and service business
    - Retain profit on making of the part
- Disadvantages
  - Development and production cost (money, time, effort)
  - Full risk of design and manufacturing (no part application history)
  - May be single source if special technology req'd (availability and bandwidth)
  - managing the making of the part may be outside of expertise

Buy vs. Make: Summary

- In most cases it is very difficult to beat off-the-shelf parts on performance/cost, so it is often best to begin with using them in a design and refining for cost later, unless cost is of very high importance
- Designer needs an "encyclopedic knowledge" of available parts in order to work efficiently

Options for Making Parts

- Sometimes you have no choice but to make it.
- Options include making it yourself (in-house) or have it made (contract out):

Make Parts In-house

- Advantages:
  - Total control of quality, cost, proprietary information (core technology)
  - Optimization possible
  - Talent, skills stay inside company
  - Shorter and more secure communication path
- Disadvantages:
  - Investment in workforce, equipment and supplies may not be core to company (distraction of resources, capital)
  - Design constrained by in-house capability

Contract Out

- Advantages
  - Lower investment in equipment (focus on core business)
  - Multiple sources (can "Wal-Mart" suppliers)
  - Access to expertise, capability not available in-house
  - Costs are very evident
- Disadvantages
  - Risk of information leaks (know-how, production plans)
  - Risk with less control (how is their business doing?)
  - Loyalty risk
  - Contractor retains some profit
  - Changes somewhat more difficult to communicate and implement (contractual obligations)

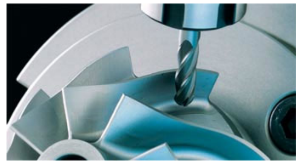
Contract Out: Qualifying Suppliers

- Qualify = ensure supplier is able to deliver what is needed and when
- Typically have to visit site to inspect capabilities, be able to randomly sample regular operation
- Written contract is almost worthless if you can't trust your supplier to deliver when you need your parts.

Other Issues…

Complexity of Geometry

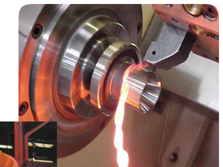
- More features often = higher development and production cost, higher risk, higher service cost, but can reduce assembly cost if part is replacing multiple other parts



Materials Choice

Typically constrains processing

- Machining:
  - e.g. cutting speeds for 1018 steel, 316 stainless and 6061 aluminum are 90, 45 and 200 SFPM respectively (HSS cutter)
- Welding: alloying elements, HAZ
- Forming: ductility
- Finishing requirements: protective coatings



Raw Materials

- Availability
  - Preferred sizes, grades, form

  processing
- At low production volumes with high complexity material costs can become insignificant
- Lowest cost material is not necessarily best - consider processing costs, joining, need for finishing (plating?), life, reliability, etc.
- Economies of scale – don't apply in small

Where to Find Process Descriptions

- Talk to the folks who do it!
- MECH 392☺
- References: Machinery's Handbook, Knovel
- Equipment manufacturer sites
- *E-funda, Eng-tips, Practical Machinist, CNC Zone, American Machinist*
- Engineering and trade magazines: *Machine Design, Design News*
- *https://www.sheldonbrown.com/bridgestone/1994/index.htm*
- **Youtube**

Processing

Wider variety of processes = increased cost + risk due to wider variety of equipment, skill-sets and increased time

Machining Costs

- Very volume dependent
  - Small volume and high variety = High cost/part
  - Large volume and low variety = low cost/part
- Compare relative costs by number and variety of size, location orientation of features, relative machinability of material, size , measure the amount of chips removed.

Design Issues Affecting Assembly and Installation of Parts

- Part Fit
- Tool Access
- Complexity of Assembly
- Assembly Processes required
- Size (handling)

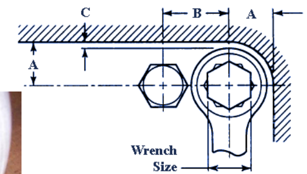
Assembly

- Part Fit
  - Larger tolerances on interfacing features make assembly easier but are constrained by performance requirements

(may be need for adjustment to optimize performance; can assembly be put together yet be not meet requirement?)

Assembly

- Assembly Tool Access
- Assembly Sequence



- See Machinery's Handbook (e-books, UBC Library)

Assembly

- Assembly Tool Access
  – Requires familiarity with tools used for assembly/disassembly
  – Reduce requirement with fewer parts
  – Solid modeling makes this much easier to evaluate prior to build

Assembly

- Complexity
  – Increase in Assembly Complexity = increase in:
    - assembly time
    - risk of error
    - constraint of access for assembling and servicing
    - part inventory, tracking costs

  – Higher complexity justified by increase in performance needed to meet a requirement or overall reduction cost

Assembly

- DFMA
  – Minimize the number and the variation in fasteners and other small components
  – Assemble from one side or top using gravity
  – Minimize re-orientation, tools, possible incorrect installation, etc.
- Evaluate complex parts vs. complex assemblies

Assembly Conditions

- Field assembly site conditions (outside, in the rain?)
- Handling: assembly sequence (e.g. press fit supports, tool access, routing of wiring)

Assembly

- Size

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Installation

Service

- In the field servicing can be difficult if:
  - Parts are large or heavy or extremely small
  - Many tools or supplies are required
  - Special equipment is required
  - Assemblies can be adjusted out of spec
  - Diagnostic features absent
- This may be ok if your customer is willing to pay for service and you are making money (Finning, Heidelberg Druckmaschine)

- Cost of replacing faulty part during initial assembly $
- Cost of replacing before shipping $$$
- Cost of replacing after shipping $$$$$

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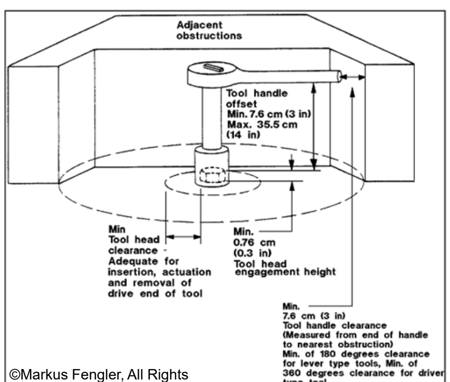
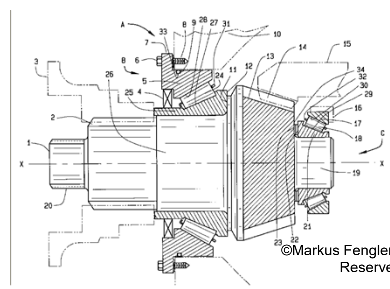
Service

- Service tool access and service personnel sightlines



Design Issues Affecting **Service**

- Disassembly possible without damage
- Sometimes damage can't be avoided:
  - Design for in-the-field replacement



EoL

- Don't forget End of Life costs!
  - E.g. a more expensive material should be selected if doing so reduces cost of decommissioning, disposal or recycling and net costs are reduced

DFx: Impact on Overall Cost is Important

- Don't blindly reduce costs in one area while overlooking costs added in other areas
  - a lower cost material may require higher finishing costs
  - a lower cost component may increase warranty costs
  - a higher cost production process may be much faster, more reliable, more accurate, etc. thereby saving money in the long term

Summary:

- In very general terms, the best design often consists of a minimal number of mostly standard parts, is easy to assemble and disassemble quickly, easy to transport, install and service and (more recently) is easy to decommission for recovery and recycling.