Design for Manufacture

Mass Production, Assembly & Manufacturing Guidelines

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Mass Production

Prior to about 1840, durables were essentially hand crafted. After 1840, mechanized production techniques gradually spread throughout the manufacturing community. First to take up the production of standardized parts were the armories *(see Design for Maintainability)*, followed by sewing machine makers, and then textile, farm machinery, lock, clock, locomotive and bicycle makers. By the dawn of the 20th century, all the elements were in place to allow Henry Ford to establish his first factory and start production of the model A motor car. Many of his insights and innovations still form the backbone of best practice in volume manufacturing. For example, the production 'line', the delivery of parts to assembly stations, unskilled assembly, and minimization of variants were Ford innovations, achieving huge improvements in throughput while reducing the manual labor required for assembly.

Manufacturing ideals

To fully exploit the techniques of mass production requires the design of products sympathetic to the production process. The production engineer's ideal product is one that…

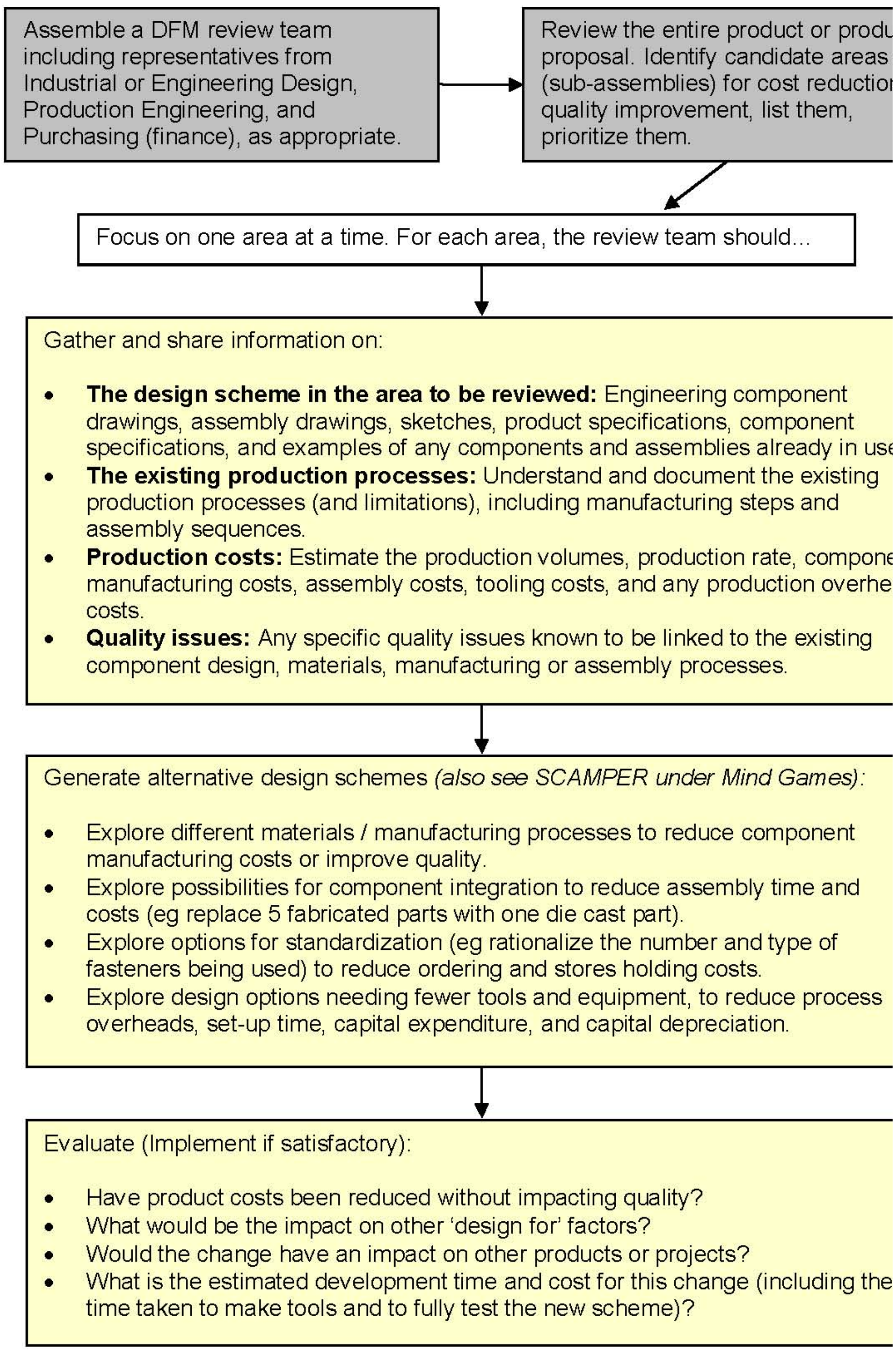
- Employs as few different materials as possible.
- Requires minimum processing of the materials.
- Uses existing machines, tools, jigs and processes, either in house or sub-contracted.
- Complies fully with existing design guidelines.
- Contains the least number of component parts, and uses as many off-the-shelf and standardized parts as possible.
- Is proof against errors in assembly.
- Uses processing and assembly skills already established in the workforce.
- Is fully specified, and testable against specifications.

Most production engineers and managers appreciate that capturing new markets requires innovation, and innovation sometimes brings unfamiliar materials and processes. However, a design that departs radically from its ancestors is going to need considerable investment in the production phase, and it is unwise to present a radical design without some prior consultation with the people you expect to turn it into volume product.

DFM Process

The primary goal of any commercial enterprise is profit. Profit margin may be improved either by reducing product cost, or by increasing revenue from product sales. Product costs may be reduced by changes to manufacturing processes that lead to reduced labor costs (component manufacture and assembly time), reduced materials costs, or reduced capital outlay and depreciation. Revenue may be increased either by increasing retail price (without loss of sales volume) or by increasing the number of units sold, both approaches requiring an improvement in the product's perceived value, this value being largely related to product quality. The practice of reducing costs while holding or improving quality is central to design for manufacture, and must be performed down at the detailed (component) level.

The flow chart below offers a sequence of events for Design for Manufacture:



Design for Manufacture -Guidelines

- Consider the whole manufacturing cycle, including suppliers' activities, materials handling and stores functions, the manufacturing and assembly shop, workforce skills, and the means of product distribution.

- Know your market – select the minimum product standards that will meet the needs of the specified market. Domestic kettles don't need to be ruggedized.

- Work with the production engineers. Bring them into the design loop early – 80% of the product cost is determined by the first 20% of design effort. Hold regular design reviews.

- Select materials and processes appropriate to the anticipated production volume. Processes such as injection molding and die casting are suitable for high volumes. Sheet fabrication, investment casting, vacuum forming and sand casting are intermediate volume processes. Machining from solid and composite fabrication are low volume unless fully automated.

- Keep it simple. Using more components means longer assembly times, higher manufacturing and assembly costs, and a higher risk of product failure.

- Use standard commodity parts or items from a preferred parts list rather than designing custom components.

- Design parts with tolerances appropriate to the manufacturing processes to be performed.

- Where surface finish is not critical, don't exclude the use of standard parts by specifying exotic finishes.

- Integration. If the production volumes can carry the tooling cost, consider integrating several discrete components into a single molding or casting to reduce the number of processing steps.

- Avoid stacking tolerances – design from a common datum where possible. Calculate the overall tolerance accumulation on assemblies and verify that the parts will still fit together and work properly at the extremes of tolerance accumulation.

- Avoid small threaded holes if possible to reduce tool breakages and material scrap. Specify through holes in preference to blind holes.

- In molded components, consider material flow, cooling, and risk of distortions due to inconsistent wall thickness.

Design for Assembly

- Adopt a modular approach where possible. This simplifies assembly, improves maintainability, and can reduce the risk of assembly-induced damage.
- Design for assembly by hand. Minimize the requirement for assembly tools.
- Avoid the use of different ‘handed’ versions of components (left-hand, right-hand). Try to design around a single universal configuration. If separate left and right-hand versions are essential, make them visibly different (by color coding, for example) to reduce assembly errors.
- Design components for ease of handling and orientation, whether assembled by hand or by machine. Where automated or robotic assembly is required, source components in bandolier or cartridge form.
- Design for one-move assembly. Avoid assembly techniques requiring difficult maneuvering of components to reach their mating positions. The easiest assembly is where all components can be assembled from one side without having to rotate or invert.
- Where a component is a blind fit (not wholly visible during assembly), add mating guides for the component and for any fasteners and assembly tools. Consider the use of captive fasteners.
- Incorporate polarizing features on components to prevent wrong orientation during assembly. Use locating pins or unique fastening patterns.
- Chamfer all lead-ins on male-female mating parts. Avoid sharp edges on components.
- Design so as to allow visual confirmation that the product has been correctly assembled.
- Design robustness into parts to be assembled to reduce the risk of assembly-induced failures. Avoid delicate or fragile components if possible; otherwise pre-mount them to improve robustness in handling.
- Trade off joining processes against the likely need for future maintenance – adhesive assembly can be quick and low cost, but reduces maintainability.
- Minimize the number of different fasteners used – standardize for ease of assembly and maintenance.

LINKS and RESOURCES

- Engineering talk website: www.engineeringtalk.com/index.html
- Engineer's Edge: www.engineersedge.com/design_guidelines.htm
- DRM Associates: www.npd-solutions.com/dfmguidelines.html
- SME (Society of Manufacturing Engineers): www.sme.org