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Design for manufacturability and assembly

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ABSTRACT
Design For Manufacturability and Assembly

by
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This report presents a study of the various concepts of design for manufacturability and assembly with some case studies, and examples.

The goal of DFM is reduction of parts and simplifying assembly process. A simple faucet has been studied and attempts have been made at re-designing the same using the techniques of design for manufaturability as postulated by Boothroyd, Dewhurst and Henry Stoll.

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This thesis is dedicated to my family and friends
for their guidance and encouragement

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CHAPTER 1
INTRODUCTION

In today's competitive global market place, it is important for the product designer to understand the implications of decision-making on the manufacturability of a product. While design needs and functional requirements of a product must be met first, no company will survive in today's competitive market by selling an equivalent product at a higher price. A manufacturing system comprises a large number of distinct processes or stages which, individually and collectively, affect the product cost, product quality and productivity of the overall system. The interactions between these various facets of a manufacturing system are complex, and decisions made concerning one aspect have ramifications which extend to the others. **Design For Manufacturability, DFM,** is concerned with comprehending these interactions, and using this knowledge to optimize the manufacturing system with respect to cost, quality and productivity.

Recent experience with modern, flexible manufacturing and formation methods, has demonstrated that product design and manufacturing interact in many ways which extend far beyond just part fabrication. To date the greatest single opportunity for product design improvement using the concept of design has been in the area of assembly. This activity has become widely known as **Design For Assembly, DFA,** and involves minimizing the number of parts to be assembled as well as designing the parts which remain to be easy to assemble.

To help enable product designers and product engineers to consider manufacturability of the product early in the design process, DFM principles, rules, guidelines have been postulated.

The key to any manufacturer's success is to develop a good product that is easily manufactured. Whether a product is produced manually or using automatic equipment, the key to successful production is good design. DFM has been applied by companies in search for the good design that improves manufacturability. Since applying it results in products that can be manufactured at lower cost with high quality, companies are heavily involved with DFM. DFM achieves the low cost and high quality by reducing the product development and manufacturing costs without compromising its quality.

CHAPTER 2

MANUFACTURABILITY

2.1 INTRODUCTION

Manufacturability is the measure of a design's ability to consistently satisfy the product goals profitably. Manufacturability is a function of:

Cost- For competitive design, costs need to be considered as important design parameters, which are included in the specifications alongside the functional requirements. It is unacceptable to provide less than an adequate performance, and equally unacceptable to provide additional unspecified features at extra cost. Costs need to be treated as important design parameters in the same way as the physical and performance parameters, such as loads, speeds, and so on.

Major reductions in production costs can usually be made by reducing the number of parts, particularly by eliminating those which are unnecessary, or by integrating one part with another.

Output quality- Quality is defined as satisfying or exceeding customer expectations. A failure to meet customer expectations may result in direct loss to the customer and will certainly result in dissatisfaction, which in turn means less future sales, that is a reduction in market share, necessitating higher marketing and advertising costs, etc. All this is in addition to direct supplier losses in scrap, rework, inspection, warranty and so on, and is passed right down through the customer/ supplier chain. The financial impact of poor quality is far greater than it appears on the surface.

The goal should be towards achieving highest quality at a minimum cost.

Ease of processing- The number of manufacturing processes needed to assemble a product should be kept to a minimum. Processes that are difficult to control, such as welding, brazing, and those that require separate materials, should be eliminated. Similar operations should be done at the same time in the assembly sequence. For example, all screws should be driven at the same point in the assembly process. Separating manual operations from the automated ones is also a good idea. This lowers safety costs and improves assembly-line flexibility and balance.

Production lead time- In the past, there was no communication between the designer's and the production team. Hence the only time, the production team was associated with the product was after the final design was complete. Hence a lot of time was spent later for planning the production of the same. This amounted to a long production lead time. This lead time could be reduced substantially, by involving the production team during the design stage itself and thereby, certain possible defects could be eliminated in the conceptual stage itself.

Material- Materials play a vital role in the manufacturability of a product. The key is to choose a right material. The choice of material should be such that it eases processing and also should produce the desired quality.

Ease of handling/storage- Design should always take into account the handling/storage operations of a product. The part geometry should be such that it could easily aid in the handling of a product. Also necessary provisions such as slots, projections etc should be provided for proper alignment of the parts during storage.

Output variability- The variance between the finished product and the desired one should be kept to a minimum. Designers, using the concept of design for experiments, and by providing proper tolerances, should ensure minimum variability.

Another means of minimizing output variability is by using the techniques of Geometric Dimensioning And Tolerancing (GD&T). GD&T is a means of specifying engineering design and drawing requirements with respect to actual function and relationship of part features. Further, it is a technique which, properly applied, ensures the most economical and effective production of these features. Thus geometric dimensioning and tolerancing can be considered both an engineering design drawing language and a functional production and inspection technique.

Length of instructions (training)- Ideally, the length of instructions should be small and simple for quick transition of the designed product to production.

Given a process and design, one should estimate the manufacturability.

2.2 MANUFACTURABILITY RELATED COSTS

Various costs affecting the manufacturability of a product are as follows:

1. Preparation

   * Set up (fixturing, resetting, etc.)- Set up costs include cost of designing new fixtures, their fabrication and retooling of the existent work place. Hence drive should be towards developing a modular design so that different product models can be turned in with one common fixture or tools.

   * Training and instructions- Also any new design or technique means, additional training of the personnel which might incur additional costs and time.

2. Processing

   * Number of steps/motions- The number of operations involved in manufacturing a component to the desired geometry should be kept at minimum possible level to minimize the time to complete the required product and thereby reduce the

additional costs of manufacturing. The operator should be able to finish the product in minimum number of steps.

* Tolerance of motion- The specified tolerances should not be intricate, so that high skill and dexterity is not required and also, the complexity of operations should be minimized. Since closer tolerances need specialized equipment and personnel, this results in an increase in the costs, hence the necessity to decrease the tolerance levels.

* Degree of human control (skill)- As mentioned earlier, the degree of human skill should not be too high, since more skill means more money and also the part production should be practicable for any operator to make. Hence the designs should be as simple as possible to aid easier production.

* Time- The time required to manufacture a product should be less, since time and costs are proportional and the more time it takes to manufacture a product, the more it costs. Hence designers to take into account the time taken to manufacture a product.

3. Equipment/Labor

* Break even volume- An increased ease of processing and reduced variability ensures higher

productivity and therefore profit. Hence the break even volume is quickly attained.

* Required complexity or capability- The complexity of operations should be kept as low as possible. Complex operations require extra set ups, such as jigs, fixtures and other work holding equipment. As a result of an increase in the tooling costs, the machining costs, increase substantially.

* Unit rate- Unit rate is a function of productivity. Higher unit rate amounts to lower manufacturability (indirectly). Hence when the productivity goes up, the unit rate comes down.

4. Handling

* Orientation- Z-axis orientation is widely recommended. Vertical orientation, reduces handling time and increases the ease of handling.

* Number of grippers required- Regular geometric shapes, ensure easy gripping as opposed to irregular shapes. Therefore the cost of designing and fabricating additional grippers is reduced.

* Stackability- Good stackability can lead to standardization of containers and shelves. This means, same handlers and storage facilities can be used for different products. Hence it is

recommended for a designer to design parts in regular geometric shapes.

5. Quality

* Cost to maintain- Design using simultaneous engineering, ensures reduction in quality related costs such as costs due to deployment of the quality function and costs to maintain (quality).

* Cost of failure (defects)- The failure of a product occurs as a result of poor or improper designs and/or poor production practices. These failures result in a loss to the customer, because it doesn't serve his purpose for a while. The manufacturer suffers a loss due to rework and customer dissatisfaction.

6. Control

* Good manufacturability ensures reduced production control costs.

* Number of parts- Minimum number of parts means less handling, less work and rework, less material and manufacturing lead time is reduced substantially, thereby improving the manufacturability and reducing the costs.

* Customer waiting time- The customer waiting time should be kept minimum and a satisfied customer always is a healthy customer.

7. Material Blank

* Size- Material procurement should be optimum, to ensure less wastage. Also it is good to design the products conforming to the standard sizes of material blanks available, to reduce the sizing and manufacturing costs.

* Availability- Standard materials that are commonly available in the market should be used to reduce the procurement lead times.

* Properties- The properties of the material chosen should be such that it should be easy to process and also minimum additional operations should be required for better performance of the product.

CHAPTER 3

DESIGN FOR MANUFACTURABILITY

3.1 INTRODUCTION

DFM is the design of products so that:

- Least time and cost is spent in development

  In today's competitive market with short product cycles, it is very important for a manufacturer to be innovative and come up with new products in a short time and with minimum expense.

- Quick and smooth transition to production

  Owing to the above mentioned short product cycles, new products are designed and released in short periods. The transition from design to production should be quick without any hurdles like, new and expensive set-ups, retraining the employees, etc.

- Least time and cost is spent in actual production

  The product should be available in the market before it gets obsolete. Hence least time should be spent in the manufacturing of a product. Further the set-up and preparation costs should be kept low, so that they may not reflect on the final cost of the product.

- Have the desired quality level

  Quality is the key word in any manufacturing concern. Any loss in quality may result in a loss to the manufacturer, since the rework or service costs are more expensive than manufacturing costs, customer dissatisfaction could lead to a loss of customer, thereby losing the market share to a competitor.

- Product should satisfy the customer

  The ultimate goal of any manufacture is to satisfy the customer, because a satisfied customer brings back more business.

3.2 OBJECTIVES OF DFM

The objectives of DFM are :

- Identify the product concepts that are inherently easy to manufacture.
- To design components for easy manufacturing.
- To integrate product design with process design.

3.3 NEED FOR DFM

There is an emphasis on DFM due to :

- Complex and innovative designs

  To stay competitive, todays manufacturers are producing innovative products with complex features. All these complex features are difficult to manufacture and hence are relatively expensive. But most of these features do not serve the actual purpose to a customer and are just asthetics. DFM is used to simplify the designs and make manufacturing relatively easier.

- Complexity of process equipment

  Complex designs, require complex manufacturing process like expensive fixtures, and specialized manufacturing equipment. The objective of DFM is simplified product design and simple inexpensive production processes.

- Automation

  Owing to the higher labor costs and also due to an increase in the volume of production, more and more companies are adapting to automation. Automated machinery cannot judge the proper orientation of parts and certain difficult operations cannot be performed by machinery. DFM aids in designing the parts for ease of automatic manufacturing and assembly.

- Performance features

  Proper performance of the product is very essential since the main objective is to satisfy a customer. Further the product should be user friendly and should require few instructions to operate.

- Shorter life cycle and variety

  As mentioned earlier, to remain competitive, a manufacturer should come out with a new product in a very short time. Further various options should be given to the customer to suit his needs. DFM aids in developing innovative designs with a wider variety.

- Designers ignorance of manufacturing

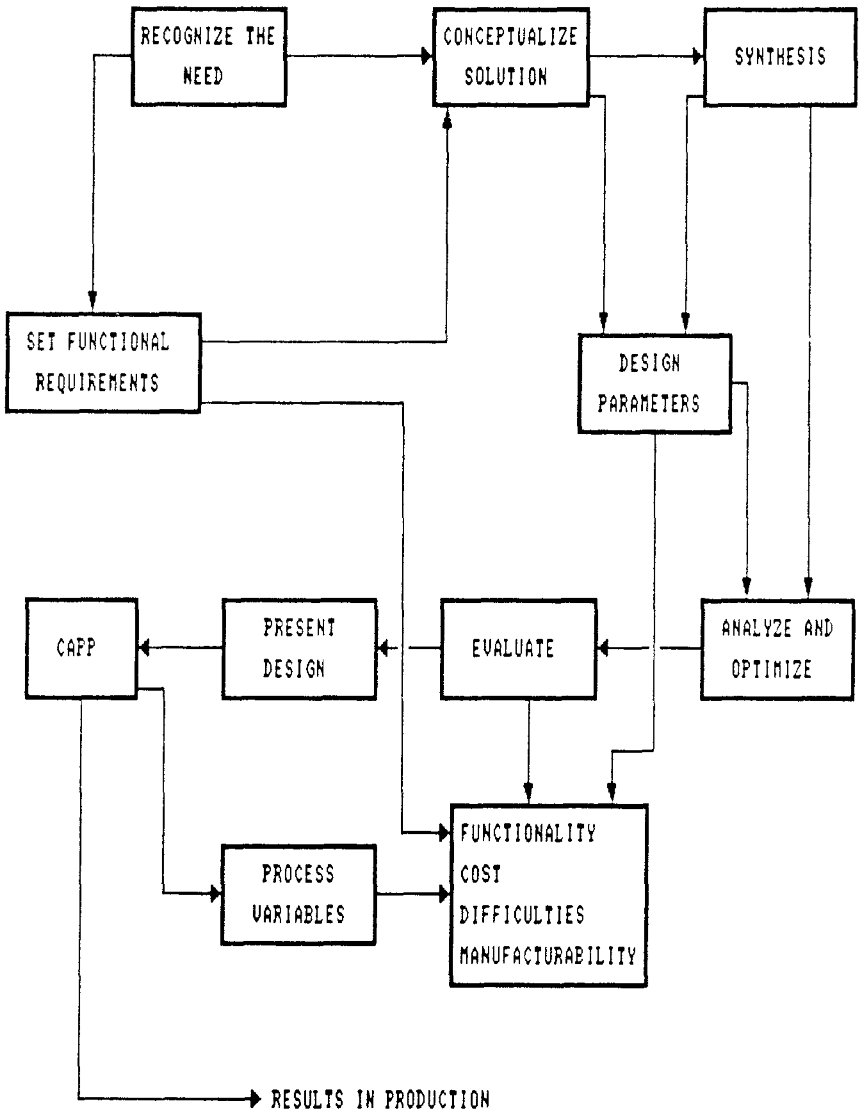
  In a traditional manufacturing environment, designers have been designing products without manufacturing point in view. Further, they have been ignorant about the manufacturing problems. DFM serves in integrating the design and the manufacturing teams.

- Material lost

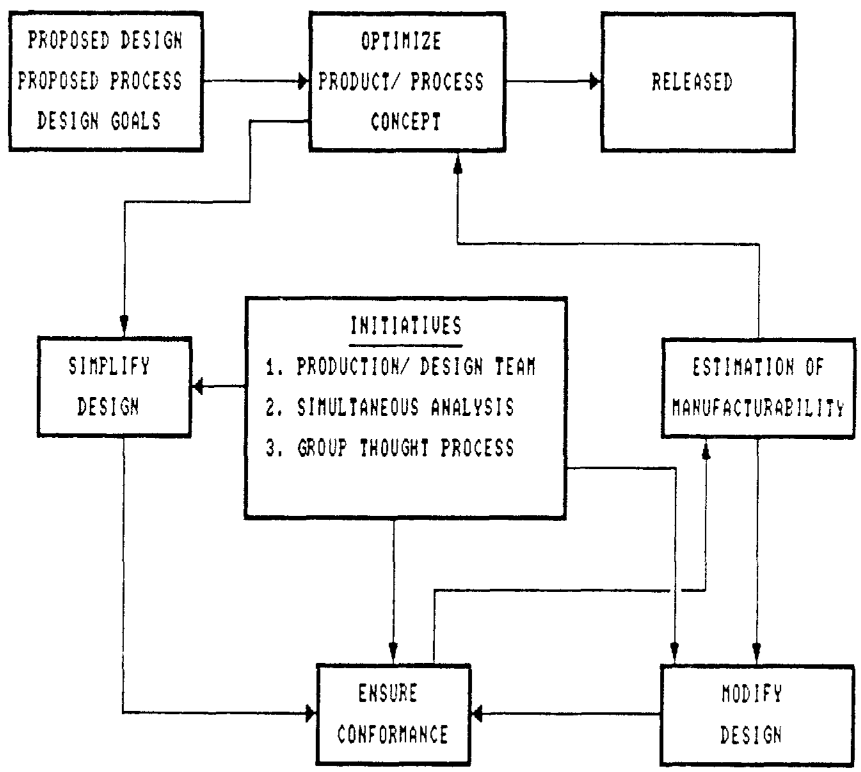
  Complex designs, lead to more wastage of material, due to more manufacturing processes. With a reduction in the total number of parts, which is the objective of DFMA, there is less wastage of material.

All the above factors lead to an increase in the manufacturing cost and effort. DFM could reduce the costs by as much as 70% by modifying the designs.

A traditional design process is as follows:



The ultimate objective of DFM is integration of product design and processing.



3.4 DFM TOOLS

The following are the various tools of DFM :

Design axioms are based on the belief that fundamental principles or axioms of good design exist and that use of axioms to guide and evaluate design decisions, lead to a good design. Design axioms cannot be proven, but must be accepted as general truths because no violation or counter example has ever been observed. The use of design axioms in design is a two step process. The first is to identify the functional requirements (FR's) and constraints. Each functional requirement should be specified such that the FR's are neither redundant nor inconsistent. Once the functional requirements and constraints are specified for a given product or design problem, the second step is to proceed with the design, applying the axioms to each design decision; each decision should be guided by the axioms and must not violate them.

DFM guidelines are systematic and codified statements of good design practice that have been empirically derived from years of design and manufacturing experience. Typically the guidelines are stated as directives that act to both stimulate creativity and show the way to good design for manufacture. If correctly followed, they should result in a product that is inherently easier to manufacture. Various forms of these guidelines are discussed in the proceeding sub section.

DFA method - The design for assembly method was developed by G. Boothroyd and P. Dewhurst while at University of Massachusetts. Based largely on industrial engineering time study methods, the DFA method seeks to minimize the cost of assembly within constraints imposed by other design requirements. This is done by first reducing the number of parts and then ensuring that the remaining parts are easy to assemble. Essentially, the method is a systematic step-by-step implementation of the various principles such as designing with a minimum number of parts, minimizing and if possible, eliminating the use of fasteners, minimizing the assembly directions and making use of gravity and incorporating maximum compliance in the mating parts.

Taguchi method addresses the problems associated with determining robust design by using statistical design of experiment theory. Robust design implies a product designed to perform its intended function, no matter what the circumstances. In other words, robustness is immunity to 'noises' experienced by the system (temperature, viscosity, vibration, wear, tolerances, voltage, age, etc.). In particular, the Taguchi method seeks to identify a robust combination of design parameter values by conducting a series of factorial experiments and/or using other statistical methods. Termed parameter design by Taguchi, this step establishes the mid values for robust regions of the design factors that influences system output. The next step, called tolerance (allowance) design, determines the tolerances or allowable range of variation for each factor. The mid-values and varying ranges of these factors and conditions are considered as noise factors and are arranged in orthogonal tables to determine the magnitude of their influences on the final output characteristic of the system. A narrower allowance will be given to noise factors imparting a large influence on the output.

In establishing tolerance or allowance range for a particular parameter, Taguchi uses a unique concept defined as a loss function. In this approach, loss is expressed as a cost to either society(customer) or the company that is produced by deviation of the parameter value from the design intent. Because any deviation from the design intent produces a loss, allowance or permissible deviation should be determined based on the magnitude of the cost associated with this loss. The concept of loss and other Taguchi concepts provide valuable insight into quality and the role design plays in determining the quality of a product or the system.

Manufacturing process design rules ensure that parts and products are correctly designed to be produced using a particular production process or method. Design requirements for a given process are often stated in the form of design guidelines and rules of thumb. Typically these guidelines are highly specialized for a particular industry, process implementation, plant, or equipment installation within a plant. Making the designer aware of these process requirements and constraints early in the design process, before concepts are finalized and lines are put irreversible on paper, is a key goal of designs for manufacture.

Design tools that help ensure product/process conformance and enable process-driven design can generally be classified as either process specific or facility specific. Process-specific DFM involves the design of parts to be manufactured using particular methods or processes such as casting, injection molding and stamping. Typically, these tools facilitate systematic application of specialized process knowledge in the form of codified statements of design guidelines and rules. These guidelines and rules are applied to the design of parts, that are to be made using a particular manufacturing process or method. Examples include design for casting, design for injection molding and design for metal stamping. Facility-specific DFM tools facilitate correct design of products intended to be manufactured using highly specialized or unique manufacturing facilities. Such tools, which could be aptly described as "designer toolkits" provide design rules, physical examples and models, various CAD design aids and other specific information about a specialized manufacturing facility in readily usable form to the designer.

Typical applications that could benefit greatly from the designer toolkit approach include such diverse situations as flexible assembly and manufacturing system concepts, design of stampings for production on certain classes of triaxis transfer press lines and design of weldments for production on special flexible welding fixtures or lines.

Computer aided DFM helps simplify the effort and shortens the time required to implement DFM on a daily basis. Computer-aided DFM also enables the design team to consider a multitude of product/process alternatives easily and quickly. "What-if" optimization allows each alternative to be refined and fine tuned. Together these capabilities greatly increase the probability of identifying the most desirable solutions during the early stages of design. When properly implemented and applied, computer aided DFM has the potential to vastly improve the quality of early product/process decisions and thereby enhance the design team's ability to design for effective quality, cost and delivery. Another major benefit of computer aided DFM is the way it fosters team building and the team approach.

Group Technology (GT) is an approach to design and manufacture that seeks to reduce manufacturing system information content by identifying and exploiting the or similarity of parts based on their geometrical shape and/or similarities in their production processes. GT is implemented by utilizing classification and coding systems to identify and understand part similarities and to establish parameters for action.

As a DFM tool, group technology can be used in a variety of ways to produce significant design efficiency and product performance and quality improvements. One of the most rapidly effective of these is the use of group technology to help facilitate significant reduction in designs time and effort. In using a GT system, the design engineer only needs to identify the code that describes the desired part. A search of the GT database reveals whether a similar part already exists. If a similar part is found to exist and this is most often the case, then the designer can simply modify the existing design to design the new part. In essence the GT enables the designer to literally start the design process with a nearly complete design. Group technology can also be effectively used to help control part proliferation and eliminate redundant part designs by facilitating standardization and rationalization approaches. By noting similarities between parts, it is often possible to create standardized parts that can be used interchangeably in a variety of applications and products.

Failure modes and effects analysis is an important design and manufacturing tool intended to help prevent failures and defects from occurring and reaching the customer. It provides the design team with a methodical way of studying the causes and effects of failures before the design is finalized. Similarly it helps the manufacturing engineers identify and correct potential manufacturing and/or process failures. In performing an FMEA, the product and/or production system is examined for all ways failure can occur. For each failure, an estimate is made of its effect on the total system, its seriousness and its occurrence frequency. Corrective actions are then identified to prevent failures.

In FMEA, function is defined as the task that a component, subsystem or product must perform stated in a way that is concise, exact, and easy to understand for all users. Functions are typically actions such as position, support, seal, retain, and lubricate. Failure is defined as an inability of a component/subsystem/system to perform the intended function (design intent). Failure modes are the ways in which a component/subsystem/system could fail to perform its intended functions. Typical failure mode would be fatigue, fracture, excessive deformation, buckling, leakage, fails to open, fails to close and requires excessive force. Asking what could happen to cause loss of function is often an effective way to identify failure modes.

Value analysis provides a systematic approach to evaluating design alternatives that is often very useful and may even point the way to innovative design approaches or ideas. Value engineering utilizes a multidisciplinary team to analyze the functions provided by the product and the cost of each function. Based on results of the analysis, creative ways are sought to eliminate unnecessary features and functions and to achieve required functions at the lowest possible cost while optimizing manufacturability, quality and delivery.

In value engineering, value is defined as a numerical ratio, the ratio of function or performance to the cost. Because cost is a measure of effort, value of a product using this definition is seen to be simply the ratio of output(function or performance) to the input cost commonly used in engineering studies. In a complicated product design or system, every component contribute to both the cost and the performance of the entire system. The ratio of performance, to the cost of each component, indicates the relevant value of each component. Obtaining the maximum performance per unit cost is the basic objective of value engineering. For any expenditure or cost, two kinds of value are received: use(functional) value and esteem(prestige) value. Use value reflects the properties or qualities of a product or system that accomplish the intended work or service. Esteem value is composed of property features or attractiveness that makes ownership of the product desirable.

A value analysis is generally carried out in two phases, the analytical phase and the creative phase. In the analytical phase, the use value and esteem value offered by the product are systematically investigated by a team of experts representing all relevant components of the manufacturing system. Findings generated in the analytical phase are then used by the team in creative phase to define innovative design solutions that maintain the desired balance between use value and esteem value , maximize these values by providing required functions for the lowest cost and eliminate identified waste.

3.4.1 TOOL SELECTION CRITERIA

A number of different methodologies and tools have been discussed above. All these techniques are effective and if properly applied, can produce significant improvements in product quality and performance, manufacturing system productivity and life cycle cost. The following factors should be considered in the selection of the above tools.

Implementation cost and effort- The methodology should be easily implementable simply by creating an awareness through seminars and brief training. It should not require extensive company wide commitment, purchase or development of expensive software or hardware and expensive training. It should not require extensive preparation for use and should be easily implementable.

Training and practice- Extensive training should not be required and should be easy to follow by a layman with relatively less experience and little training. The worker should be able to learn and implement the methodology with ease and simplicity.

Designers effort- Little or no additional designer time and/or effort should be required to make effective use of the methodology. The designer should be able to come up with the design relatively fast, using the group technology techniques or other computer aided techniques.

Management effort- The management effort or expectations should be minimum and it should be easily followed by the lower cadre without the management's effort. Less time should be spent by the management minimum information content in implementing the methodology.

Team approach- The technique should encourage better team approach and good communication among the designers and the manufacturers. Effective product and process planning must be involved.

Stimulate creativity- The methodology should stimulate creativity and innovation in the designers, thereby giving an edge over the competitors. The full potential of the designers should be exposed in using the techniques.

Systematic- The implementation should be systematic and orderly. It should be a step-by-step procedure that ensures that all relevant issues have been covered.

Quantitative- The methodology should be quantitative in nature and more quantified ratings should be generated.

Teaches good practice- Use of the method should ensure that it teaches good practice and formal reliance on the method should diminish with repeated use.

CHAPTER 4
DESIGN FOR ASSEMBLY

The key to successful product DFM is product simplification through design for assembly, DFA. DFA techniques primarily aim to simplify the product structure so that assembly costs are reduced. The elimination of parts as a result of DFA has several secondary benefits more difficult to quantify, such as improved reliability and reduction in inventory and production control costs. DFA derives its name from a recognition of the need to consider assembly problems at the early stages of design.

Design for assembly is basically -

- Design of Parts
- Design of the cell
- Design of operational strategies

DFA is a 3-step method -

- Selecting the assembly method
- Reducing the number of parts
- Simplifying the assembly process

4.1 FACTORS TO BE TAKEN INTO ACCOUNT FOR DESIGN OF PARTS

The following factors are to be considered while designing parts for assembly :

1. Tolerance
2. Allowance
3. Repeatability

4. Geometry

4.1.1 GEOMETRIC DIMENSIONING AND TOLERANCING (GD&T)

GD&T, plays a vital role in all the above factors. As mentioned earlier, GD&T is a means of specifying engineering design and drawing requirements with respect to actual function and relationship of part features. Uniform understanding and interpretation among design, production, and inspection groups are the major objectives of the system.

Although a part has been manufactured within the specified tolerance limits, however at inspection, it is found to be defective and does not match with the mating part. This is as a result of specifying the manufacturing tolerances with respect to different axes or datums. GD&T is a system of building blocks for good drawing practice which provides the means of stating necessary dimensional or tolerance requirements on the drawing, not otherwise covered by implication or standard interpretation. The geometric characteristics that are used as building blocks for geometric dimensioning and tolerancing are in the form of symbols, representing various geometric features such as flatness, straightness, circularity, cylindricity, perpendicularity, angularity, parallelism, etc.

One of the fundamental and most important principles of geometric dimensioning and tolerancing is **Maximum Material Condition.** It is a condition in which a feature of size contains the maximum amount of material within the stated limits of size: for example, minimum hole diameter and maximum shaft diameter. Generally, the use of maximum material condition principle permits greater possible tolerance as part feature sizes vary from their calculated maximum material condition limits. It also ensures interchangeability and permits functional gaging techniques. It is one of the principles on which the system of geometric dimensioning and tolerancing is based.

When the maximum material condition is not appropriate, **Regardless Of Feature Size Principle** is used. Unlike maximum material condition, the regardless of feature size principle permits no additional positional, form or orientation tolerance, no matter to which size the related features are produced. The RFS principle is valid only when applied to features of size (a hole, slot, pin, etc., with an axis or center plane).

An alternative to MMC or RFS is the **Least Material Condition.** This is a condition in which a feature of size contains the least amount of material within the stated limits of size: for example, maximum hole diameter and minimum shaft diameter.

4.1.1.1 ADVANTAGES OF GD&T

* First and foremost, its use saves money. It saves money by providing for maximum production tolerances.

* It ensures that design dimensional and tolerance requirements, as they relate to actual function, are specifically stated and thus carried out.

* It adapts to, and assists, computerization techniques in design and manufacture.

* It ensures interchangeability of mating parts at assembly.

* It provides uniformity and convenience in drawing delineation and interpretation, thereby reducing controversy and guesswork.

Aside from these primary reasons, there are others of more general nature

* The intricacies of today's sophisticated engineering design demand new and better ways of accurately and reliably communicating requirements.

* Diversity of product line and manufacture makes considerably more stringent demands of the completeness, uniformity and clarity of drawings.

4.2 TYPES OF ASSEMBLY

There are three types of assembly methods :

1. Manual
2. Automatic
3. Robotic

4.2.1 MANUAL ASSEMBLY

Manual assembly is bench or transfer-line assembly using only simple tools. In manual assembly, the tools are generally inexpensive; manual assembly costs remain relatively constant and independent of the production volume; also, manual assembly methods have great flexibility and adaptability.

4.2.2 AUTOMATIC ASSEMBLY

More than 50% of total production time is spent on the assembly or fastening function. However, mechanical fastening usually represents less than 5% of the total in-place or assembled cost of a product.

When automatic assembly is part of the manufacturing process, the type of fastener or fastening method must not only meet product requirements, but must be compatible with the assembly machinery.

Successful automatic applications are characterized by:

* Dimensional consistency on all components and fasteners. Tolerances required for automatic assembly may exceed those required by the product.
* Stable design that is not changed frequently, or family designs which can be easily programmed.
* Volume production, which one estimate suggests should be at least 300 units per hour or a million units per year.

* Simple components that can be handled easily such as shafts or rods which do not require complex feed mechanisms to orient them correctly.

In selecting fasteners for automatic assembly, the designer should try to standardize fastener size as much as possible. Standardization means fewer assembly stations and lower tooling and re-tooling costs.

Feeding and reliable orientation are generally the most difficult parts of the assembly process. If a fastener can be fed properly, it can be installed.

4.2.3 ROBOTIC ASSEMBLY

Robot assembly can be any of the following:

- One general-purpose robot arm operates at a single workstation
- Two general-purpose robot arms work hand-in-hand at a single station
- A multi-station free-transfer machine with general-purpose robot arms

4.3 FACTORS AFFECTING SELECTION OF TYPE OF ASSEMBLY

- Production volume/shift
- Number of parts in an assembly
- Single part *vs.* a variety of products
- Number of parts required for different styles
- Number of design changes expected during life
- Company's policy on automation

4.3.1 FACTORS AFFECTING THE SELECTION OF MANUAL ASSEMBLY

- Number of parts
- Symmetry of the parts
- Requirement of tools
- Interaction between parts (tangling)
- Part size

4.4 RULES FOR DESIGN OF PARTS

The following rules are to be kept in mind while designing parts :

Avoid projections, holes or slots that could cause tangling. Try to keep the largest hole smaller than the smallest insertion.

Try to make parts symmetrical to avoid the need for extra orienting devices.

If symmetry cannot be achieved, then, exaggerate asymmetry to facilitate orienting.

4.4.1 RULES FOR DESIGN OF MANUAL ASSEMBLY

General design guidelines have been developed that attempt to consolidate manufacturing knowledge and present them to the designer in the form of simple rules to be followed when creating a design. The process of manual assembly can be divided naturally into two separate areas: handling (acquiring, orienting, and moving the parts) and insertion and fastening (mating a part to another part or group of parts). The following rules specifically address each of these ares.

A. Design Guidelines for Part Handling

In general, for ease of part handling, a designer should attempt to:

Design parts that have end-to-end symmetry and rotational symmetry about the axis of insertion. If this cannot be achieved, try to design parts having the maximum possible symmetry (see fig. 4.1).

Design parts that, in those instances in which the part cannot be made symmetric, are obviously asymmetric (see fig. 4.2).

Provide features that will prevent jamming of parts that tend to nest or stack when stored in bulk (see fig. 4.3).

Avoid features that will allow tangling of parts when stored in bulk (see fig. 4.4).

Avoid parts that stick together or are slippery, delicate, flexible, very small or very large, or are hazardous to the handler (i.e., parts that are sharp, splinter easily, etc.).

B. Design guidelines for Insertion and Fastening

For ease of insertion, a designer should:

Design so that there is little or no resistance to insertion and provide chamfers to guide insertion of two mating parts. Generous clearance should be provided, but care must be taken to avoid clearances that will result in a tendency for parts to jam or hang up during insertion (see figure 4.5, 4.6 & 4.7).

Standardize by using common parts, process, and methods across all models and even across product lines to permit the use of higher-volume processes that normally result in lower product costs (see figure 4.8).

Use pyramid assembly-provide for progressive assembly about one axis of reference. In general, it is best to assemble from top (see figure 4.9).

Avoid, where possible, the necessity for holding parts down to maintain their orientation during manipulation of the subassembly or during the placement of another part. If holding down is required, then try to design so that the part is secured as soon as possible after it has been inserted (see figure 4.10).

Design so that a part is located before it is released. A potential source of problems in the placing of a part occurs when, because of design constraints, a part has to be released before it is positively located in the assembly (see figure 4.11).

Consider when common mechanical fasteners are used, the following sequence, which indicates the relative cost of different fastening processes, listed in order of increasing manual assembly cost:

Snap fitting

Plastic bending

Riveting

Screwing

Avoid the need to reposition the partially completed assembly in the fixture.

4.4.2 RULES FOR DESIGN OF AUTOMATIC ASSEMBLY

The important rules for design for automatic assembly differ from those for manual assembly. For manual assembly, the assembly problems are most often associated with part insertion and securing operations. Part handling difficulties will result in an increase in assembly time, but they are not of primary importance. For assembly automation, however, automatic handling of the parts is the principal concern. Automation of the handling process is usually, the most demanding part of an assembly automation task and the cost of automatic handling can change dramatically through small changes in part design. Moreover, the efficiency of an entire assembly automation system is governed to a large extent, by the efficiency with which the individual parts can be automatically handled.

With high speed automatic assembly, the elimination of a part eliminates an entire workstation from the required assembly machine. As well as lowering the machine cost, this will also result in a more efficient machine with reduced stoppages and down-time.

The following rules should be applied to ensure efficient automatic assembly :

- Make parts as simple as possible. This will always make automated orientation easier.
- Avoid the need for re-orientations during assembly.
- Design the product for layer fashion assembly from above. This will lower the cost of the assembly machine workheads and will also make it easier to design the work carriers to resist the insertion forces.
- Avoid the need for high insertion forces, which would increase the cost of the assembly workheads, the work carriers and the machine structure.

4.4.3 RULES FOR DESIGN OF ROBOT ASSEMBLY

Many of the rules for product design for manual assembly and high-speed automatic assembly also apply to product design for robot assembly. However when we weigh the suitability of the of a proposed design for robot assembly, we should carefully consider the need for any special-purpose equipment such as special grippers or special feeders.

The following are some specific rules to follow during product design:

Reduce part count; this is a major strategy for reducing assembly, manufacture, and overhead costs, irrespective of the assembly system to be used.

Include features such as leads, lips, and chamfers to make parts self-aligning in assembly. Because of the relatively poor repeatability of many robot manipulators compared to dedicated workhead mechanisms, this is a vitally important measure to ensure consistent fault-free part insertions.

Ensure that parts that are not secured immediately on insertion are self-locating in the assembly. For multistation robot assembly systems or one-arm single-station systems, this is an essential design rule. Holding down of unsecured parts cannot be carried out by a single robot arm, and so special fixturing is required, which must be activated by the robot controller. This adds significantly to special-purpose tooling and, hence, assembly costs. With a two-arm single-station system, one arm can, in principle, hold down an unsecured part while the other continues the assembly and fastening processes. In practice, this requires one arm to change end-of-arm tooling to a hold-down device; the system then proceeds with 50% efficiency while one arm remains immobile.

Design parts so that they can all be gripped and inserted using the same robot gripper. One major cause of inefficiency with robot assembly systems arises from the need for gripper or tool changes. Even with rapid gripper or tool change systems, each change in a special gripper and then back to the standard gripper is approximately equal to two assembly operations. Note that the use of screw fasteners always results in the need for tool changes since robot wrists can seldom rotate more than one revolution.

Design products so that they can be assembled in a layer fashion from directly above (Z-axis assembly). This ensures that the simplest, least costly, and most reliable four-degree-of-freedom robot arms can accomplish the assembly tasks. It also simplifies the design of the special-purpose work fixture.

Avoid the need for reorienting the partial assembly or manipulating previously assembled parts. These operations increase the robot assembly cycle time without adding value to the assembly. Moreover, if the partial assembly has to be turned to a different resting aspect during the assembly process, this will usually result in increased work-fixture cost and the need to use a more expensive six-degree-of-freedom robot arm.

Design parts that can be easily handled from bulk. To achieve this goal, avoid parts that, nest or tangle in bulk, are flexible, have thin tapered edges that can overlap or shingle when moving along a conveyor or feed track, are delicate or fragile to an extent that recirculation in a feeder can cause damage, are sticky or magnetic so that a force comparable to the weight of the part is required for separation, are abrasive and will wear the surfaces of automatic handling systems and are light so that air resistance will create conveying problems.

If parts are to be presented using automatic feeders, ensure that they can be oriented using simple tooling.

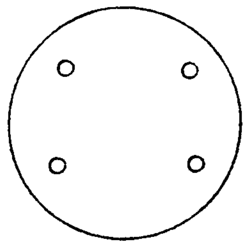
If parts are to be presented using automatic feeders, ensure that they can be delivered in an orientation from which they can be gripped and inserted without any manipulation.

If parts are to be presented in magazines or part trays, ensure that they have a stable resting aspect from which they can be gripped and inserted without any manipulation by the robot.

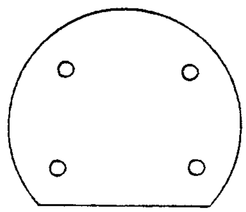
Asymmetrical

Symmetrical

Figure 4.1 Provide symmetry at both ends.

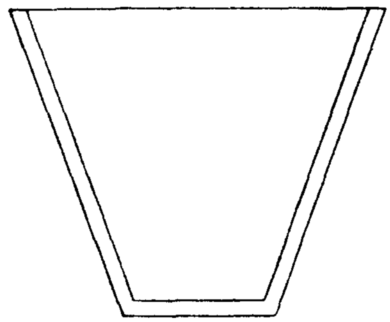


Slightly asymmetrical

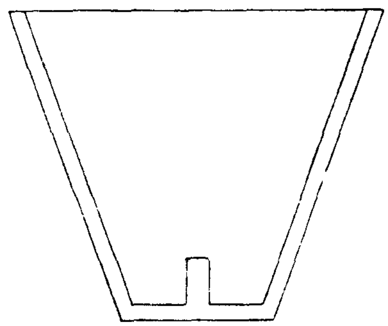


Pronounced asymmetrical.

Figure 4.2 Exaggerate symmetry.

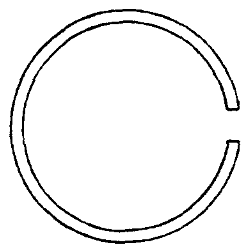


Will jam

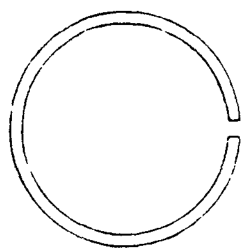


Cannot jam

Figure 4.3 Projection to prevent part from jamming.



Will tangle



Cannot tangle

Figure 4.4 Provide features to prevent entangling.

Part jams across corners

Part cannot jam

Figure 4.5 Incorrect geometry can allow part jam during insertion.

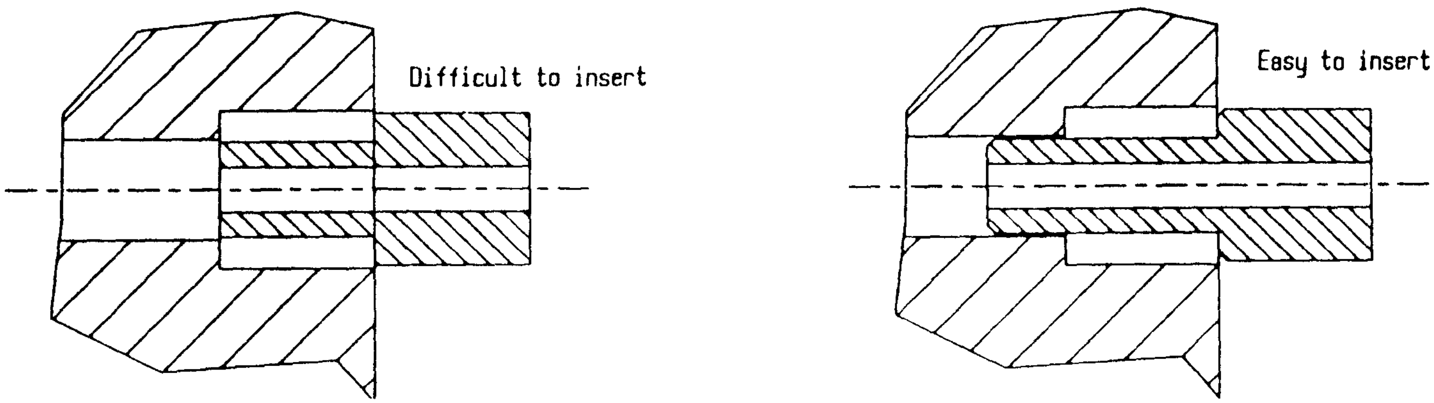
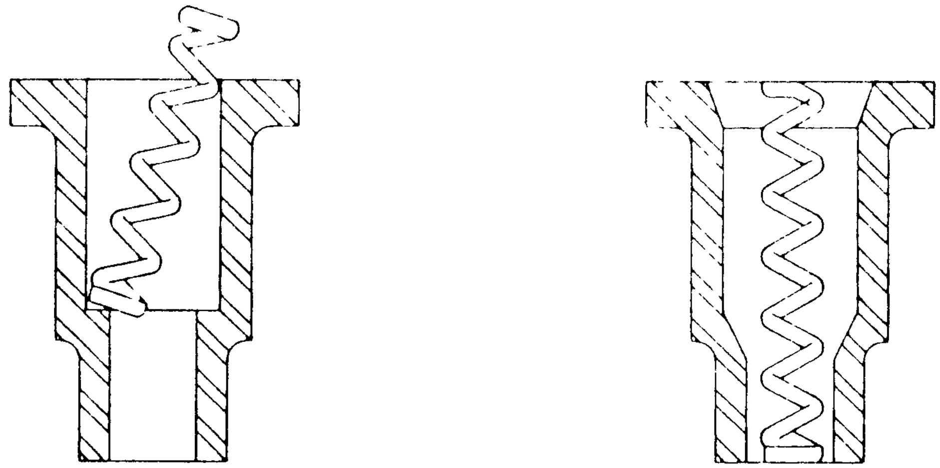


Figure 4.6 Design for ease of insertion.



Part can hang up Part falls into place

Figure 4.7 Provision of chamfers to allow easy insertion.

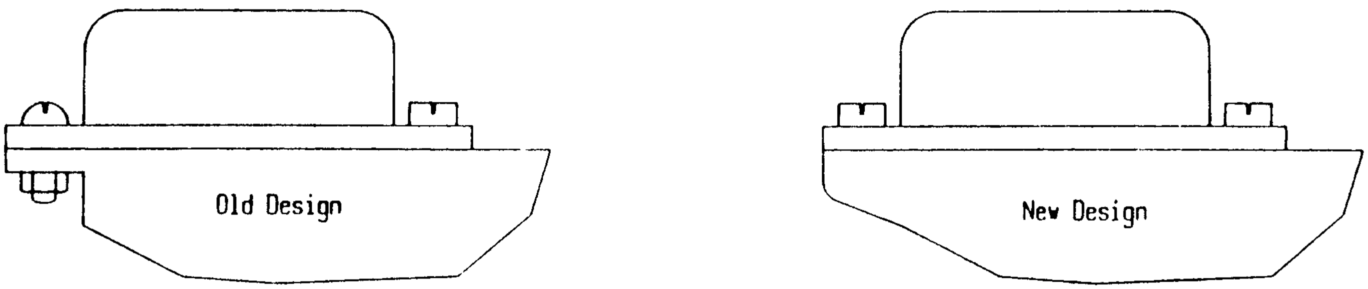


Figure 4.8 Standardize parts.

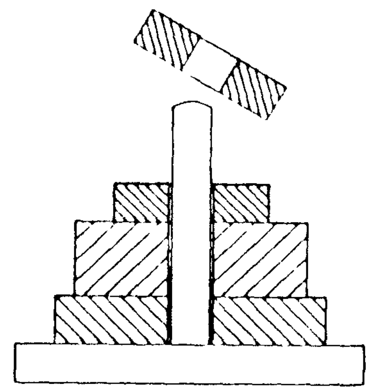


Figure 4.9 Single axis pyramid assembly.

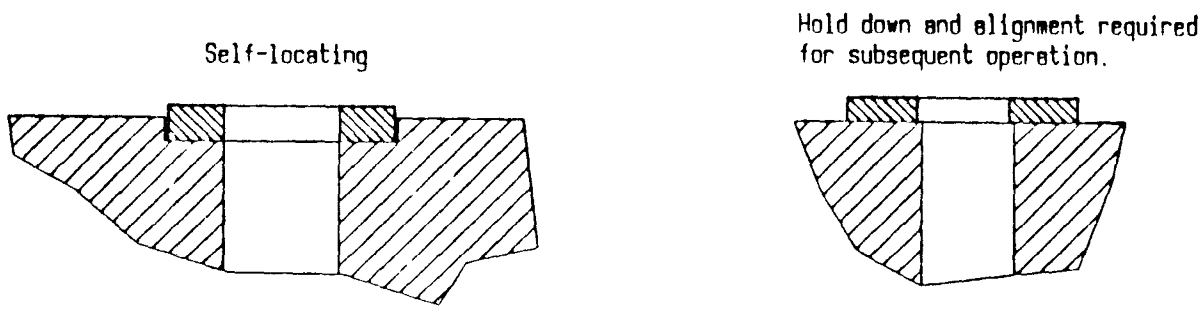
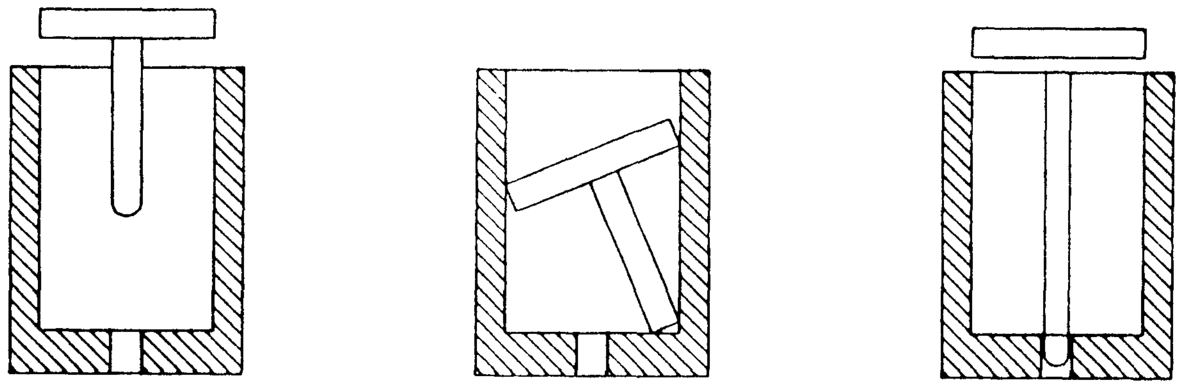


Figure 4.10 Provision of self locating features.



Part must be released before it is located.

Part located before released.

Figure 4.11 Design to aid insertion.

4.5 STOLL'S RULES FOR DFM

1. Minimize the total number of parts : Fewer parts means less of everything. that is needed to manufacture a product. This includes engineering time, drawings, production control records, inventory, number of purchase orders, number of items to inspect and type of inspections to be done, the amount of complexity of part production equipment, and facilities, assembly and training. Hence a part that is eliminated costs, nothing to make, assemble, move, handle, orient, store, purchase, inspect and service. It never jams or interferes with automation. However part reduction should not exceed the point of diminishing return where further part elimination adds cost and complexity because the remaining parts are too heavy, or too complicated to make and assemble, or are too unmanageable in other ways. Perhaps the best way to eliminate parts is to identify a design concept which requires few parts. Integral design or combination of two or more parts into one is another approach. Besides the advantages given above, integral design reduces the amount of interfacing information, decreases the weight and complexity. One piece structures have no fasteners or joints, and fewer points of stress concentration.

2. Develop modular design : A module is a self-contained component with a standard interface to other components of a system. Modular design offers the ability to standardize

diversity because it allows a product to be customized by using different combinations of standard components. Modular design resists obsolescence and shortens the redesign cycle. Change is provided via a few, new, or improved modules. Cost and ease of service and repair are enhanced because a defective module can be quickly replaced by a good one. Most importantly, modular design simplifies final assembly because there are fewer parts to assemble and each module can be fully checked prior to installation. On the downside, modular design can add cost and complexity because of extra fittings and interconnections required. Therefore modular design should not be used unless its advantages are needed.

3. Use standard components : A stock item is always less expensive than a custom made item. Standard items require little or no lead time and are reliable because characteristics and weaknesses are well known. They can be ordered in any quantity at any time. They are usually easy to repair and replacements are easier to find. Use of standardized components, puts the burden on the supplier and makes the supplier do more.

4. Design parts to be multi-functional: Combine function wherever possible. For example, design a product to act both as a spring and a structural member. An electronic chassis can be made to act as an electrical ground, a heat sink and a structural member. Less obvious combinations of functions

might involve guiding, aligning and/or selffixturing features to a part to aid in assembly, or providing a reflective surface or recognizable feature to facilitate vision inspection.

5. Design parts for multi-use: Many parts can be designed for multi-use. For example, the same mounting plate can be designed to mount a variety of components. Similarly, a spacer can also serve as an axle, lever, standoff, etc. One approach involves sorting all parts (or a statistical sample) manufactured or purchased by the company into two groups consisting of:

* parts which are unique to a particular product or model.
* parts which are generally needed in all products and/or models.

Each group is then divided into categories of similar parts. Multi-use parts are then created standardizing similar parts. Once developed, the family of standard parts should be used wherever possible in existing products and used exclusively in new product designs. Also, manufacturing processes and tooling based on a composite part containing all design features found in a particular part family should be developed. Individual parts can then be obtained by skipping some steps and features in the manufacturing process.

6. Design parts for ease of fabrication: This principle requires that all individual parts be designed using the least costly material that just satisfies functional requirements (including style and appearance) and such that both material waste and cycle time are minimized. This then requires that the most suitable fabrication process available be used to make each part and that the part be properly designed for the chosen process. Use of near-net shape processes are preferred whenever possible. Like wise secondary processing (finish machining, painting, etc) should be avoided whenever possible. Secondary processes can be avoided by specifying tolerances and surface finishes carefully and then selecting primary processes (precision casting, P/M, etc.) which meet requirements. Also material alternatives which avoid painting, plating, buffing etc., should be considered. This principle is based upon the recognition that higher material and/or unit process cost can be accepted if it leads to lower overall production cost.

7. Avoid separate fasteners: In automation applications, separate fasteners are difficult to feed, tend to jam, require monitoring for presence and torque, and require costly fixturing, parts feeders and extra stations. Even in manual assembly, the cost of driving a screw can be six to ten times the cost of the screw. One of the easiest ways to do is to eliminate separate fasteners in assembly by using

tabs or snap-fits. If fasteners must be used, cost as well as quality risks can be significantly reduced by minimizing the number, size and variations used, and by using standard fasteners whenever possible. Screws that are too short or too long, separate washers, tapped holes, and round and flat heads (not good for vacuum pickup) should be avoided. Conversely captured washers should be used for reduced part placement risk and improved blow feeding. Self-tapping/forming/locking fasteners are preferred as are screws with dog or cone (chamfered) point for improved placement success. Also screw heads designed to reduce cam-out problems, bit wear and fastener damage should be used. For vacuum pick-up, use screw heads having flat vertical sides.

8. Minimize the number of assembly directions: All parts should be assembled from one direction. Extra directions mean wasted time and motion as well as more transfer stations, inspection stations and fixture nests. This in turn leads to increased cost and increased wear and tear on equipment due to added weight and inertia load, and increased reliability and quality risks. The best possible assembly is when all parts are added in a top-down fashion to create a z-axis stack. Multi-motion insertion should be avoided. Ideally the product should resemble a z-axis club sandwich with all parts positively located as they are added.

9. Maximize tolerance or compliance: Because parts are not always identical and perfectly made, misalignment and tolerance stack-up can produce excessive assembly force, leading to sporadic automation failures and/or product unreliability. Major factors affecting rigid part mating include part geometry (accuracy, consistency), stiffness of assembly tool, stiffness of jigs and fixtures holding the parts and friction between the parts. To guard against this, compliance must be built into both the product and production process. Methods for providing compliance include highly accurate (consistent) parts, use of worn-in production equipment, remote center compliance, selective compliance in assembly tool, tactile sensing, vision systems, designed-in compliance features and external effects. Although a variety of combinations of these approaches are commonly used, experience has shown that the simplest solution consists of a combination of acceptable (consistent) quality parts, designed-in compliance features, accurate (rigid) base components and selective compliance in the assembly tool.

Designed-in compliance features include the use of generous tapers or chamfers for easy insertion, use of leads and other guiding features, and use of generous radii whenever possible. A clever trick, if possible, is to design one of the components, perhaps the largest, to act both as the part base (part to which other parts are added) and as the assembly fixture (avoid need for a special fixture to hold the assembly). In any case, the part base should be made as stable and rigid as possible to improve accurate insertion and simplify handling. If fixturing is required, 'fixture-friendly' features such as accurate location points, generous tapers, and other guiding features which provide easy compliance between base part and fixture should be provided.

Gravity is an extremely useful external effect which not only assists compliance, but also costs nothing. In addition to assisting with insertion, gravity is useful for feeding parts and for ejecting finished and defective product. The vibration insertion process, VIP, consists of nominally locating the part using a robot, vibrating the base until the part lines up and then inserting the part upon alignment. This technique is widely used in electronic assembly.

10. Minimize handling requirements: Position is the sum of location (x, y, z) and orientation (A, B, C). Position costs money. Therefore, parts should be designed to make position easy to achieve and the production process should maintain position once it is achieved. The number of orientations required during production equates with increased equipment expense, greater quality risk, slower feed rates and slower cycle times. To assist in orientation, parts should be made as symmetrical as possible. If polarity is important, then an existing asymmetry should be accentuated, or a very

obvious asymmetry should be designed in, or a clear identifying mark provided. Orientation can also be assisted by designing in features which guide and locate parts in the proper position. Parts should also be designed to avoid tangling, nesting and shingling in vibratory part feeders.

To facilitate robotic part handling, provide a large, flat, smooth top surface for vacuum pick-up, or provide an inner hole for spearing, or provide a cylindrical surface or other feature of sufficient length for gripper pick up. Since parts usually come off production line properly oriented, this orientation should be preserved by using magazines, tube feeders, part strips, etc. Palletized trays and kitting are methods for supplying properly oriented parts to the assembly line. For ease of handling, avoid flexible components. Use rigid gaskets where possible; use external connector to eliminate lead wires; use a circuit board in place of a cable; etc.

Design in features which facilitate product and component packaging. Use standard outer package dimensions for machine feeding and storing, design packing adequately to protect and ensure quality at all stages of handling, and design packaging for easy handling.

4.5.1 MODULAR DESIGN

Sub-assemblies are designed such that they can be interchangeably used. This is done when a customer demands a variety of products.

The advantages of modular design are :

- Reduce production lead time
- Reduce work in process inventory
- Reduce development cost
- Reduce serviceability
- Economics of scale

4.5.2 PART REMOVAL

The following factors affect part removal in design for assembly :

1. Parts need to have relative motion from all its mating parts.
2. Parts need to be of a different material than that of the mating part.
3. Whether assembly or disassembly would not be possible.

4.5.3 AVOID FASTENERS

Fasteners are a major obstacle to efficient assembly. The cost of driving a screw can be two to three times the cost of the screw and they often cause jamming. Fasteners often are defective because :

- Bad slot head
- Metallic defects
- Shank lengths are wrong
- Wrong shank diameters
- Bad thread

- Fasteners cannot be detected by outgoing quality control

There are many alternative methods for fastening. These can fall into two general categories: permanent (weldments, adhesives, etc.) or temporary (screws, circlips, etc.). In addition, a method that can fit either category is the use of snap-in devices which achieve assembly and retain attachment by utilizing the elastic properties of the component or the device itself. The use of adhesives is increasing as they generally cost less, with reduced weight, minimum component distortion and further the appearance is not affected.

It is important that designers are aware of the methods of assembly to be adopted for their process. Manual operators have the advantage of feel intuition and judgement, and can thus accomplish assembly operations which are very difficult, or in some cases impossible, for a robot or automated assembly work station.

CHAPTER 5

REDESIGN OF A WATER FAUCET

5.1 Introduction

The highlight of the proposed design is the reduction in the total number of parts, in meeting the functional requirements, while also keeping the manufacturability in view. A conventional faucet has only one outlet incorporating the use of fasteners to hold the parts together, and also those with two outlets, have many intricate parts and fasteners, thereby making it difficult for automatic assembly and also expensive for manual assembly. The redesigned faucet has a single control knob for both the outlets and also the need for fasteners is totally eliminated by providing the threads on the ball shank which itself is a part of the assembly.

5.2 An Axiomatic Approach To Design

In this approach, a small set of global principles, or axioms, are hypothesized. These axioms constitute guidelines or decision rules which can be applied to decisions made throughout the synthesis of a manufacturing system and if correctly followed, lead to decisions which maximize the productivity of the total manufacturing system, in all cases. By definition, an axiom must be applicable to the full range of manufacturing decisions. Design axioms cannot be proven, but must be accepted as general truths because no violation or counter-example has ever been observed. The fundamental axioms are as follows:

* Axiom 1: In a good design, the independence of functional requirements is maintained.

* Axiom 2: Among the designs that satisfy Axiom 1, the best design is the one that has the minimum information content.

These two axioms imply that specification of more functional requirements than necessary, results in over-design whereas specification of insufficient functional requirements must be evaluated with within specified tolerances.

Design corollaries are immediate or easily drawn consequences of the design axioms. In contrast to the design axioms, corollaries may pertain to the entire manufacturing system, or may concern only a part of the manufacturing system. Some of these are:

- Decouple or separate parts or aspects of a solution if functional requirements are coupled or become coupled in the design of products and processes.
- Integrate functional requirements into a single physical part or solution if they can be independently satisfied in the proposed solution.
- Minimize the number of functional requirements and constraints.

- Use standardized or interchangeable parts whenever possible.
- Make use of symmetry to reduce the information content.
- Conserve materials and energy.
- A part should be a continuum if energy conduction is important.

5.2.1 DESIGN PARAMETERS CONSIDERED :

1. DP1: Diameter of the inlet holes, of the ball.
2. DP2: Diameter of the casing holes to which the inlet pipes are attached.
3. DP3: Area / geometry of the slot in the ball thru' which the water flows into the outlet pipe of the faucet.
4. DP4: Movement of the ball relative to the base.
5. DP5: Packing material used.
6. DP6: Amount of packing used.
7. DP7: Fastening Method to be used for securing the ball to the handle.

Design Equations:

FR1= A14DP4

FR2= A21DP1 + A22DP2 + A23DP3 + A24DP4

FR3= A33DP3 + A36DP6 + A35DP5 + A37DP7

The Design Matrix:

$$
\begin{bmatrix}
0 & 0 & 0 & A14 & 0 & 0 & 0 \\
A21 & A22 & A23 & A24 & 0 & 0 & 0 \\
0 & 0 & A33 & 0 & A35 & A36 & A37
\end{bmatrix}
\begin{bmatrix}
DP1 \\ DP2 \\ DP3 \\ DP4 \\ DP5 \\ DP6 \\ DP7
\end{bmatrix}
$$

5.3 BILL OF MATERIALS:

Base - 1 unit

Ball - 1 unit

Cap - 1 unit

Handle - 1 unit

Cam - 1 unit

Packing - 1 unit

5.4 EXPLANATION OF THE WORKING OF THE FAUCET DESIGN

The resting position of the handle will be vertically straight up positioned at the middle. This will shut off the water flow. Therefore, one can only move the handle down and/or to the sides.

Moving the handle down will only control the water flow. The further down the higher the pressure. This is so because the holes in the ball in the resting position are located right above the holes in the base preventing any flow of water. As we move the handle down the holes on the ball will align themselves with the stationary holes in the base until coming all the way down corresponding to maximum pressure. At this position the water will be warm since the handle is positioned on the middle allowing both hot and cold water to go through with the same volume rate of outflow. At this position both (left and right) bottom halves of the holes located in the ball match the upper halves of the holes in the base. In other words, this will not be a full matching.

In summary, the movement of the handle straight up and down will control the volume rate outflow while maintaining the temperature of the water constant (warm)

Now, to control the temperature of the water we move the handle to the left to obtain hot water or to the right to get cold water. The more we move to the left the hotter the water gets. Similarly the more we move the handle to the right, the colder the water. This is so because the holes in the ball at the middle position only match partially with the holes in the base. If we turn the handle let us say to the left, the left hole in the ball will completely match the left hole in the base (the hot water one) and at the same time the right hole in the ball will be situated above the hole in the base, therefore, no cold water will be permitted to go through. This will result in getting the highest temperature for the water flow. The same analysis holds for the cold water. Thus by moving the handle to left we will get hot water, at the middle we get warm water and at the right we get cold water. It is assumed that the pipe on the left side is carrying hot water and the pipe on the right side is carrying cold water. This handle is designed to be highly sensitive. Small movements in the handle will result in the desired volume or temperature changes. If the user notices a leak from under the handle, just remove handle and tighten adjusting cap until water no longer leaks.

The cam and packing will prevent any leaks by putting a sealing pressure on the ball. However, the more you tighten it the harder it gets to move the handle.

This faucet will be very easy to assemble because the assembler only has to vertically drop the ball into the base. Then, place the cam and packing onto the ball. Then screw the cap into the base. Finally, snap fit the handle into knob which is attached to the ball. Very simple and smooth movements which will result in high product Manufacturability. Also there will be a groove in the back of the ball (opposite to the front outflowing hole) and a corresponding projection on the base. This feature will permit the user to move the handle down by approximately 30 degrees and to the sides by 20 degrees on each side. This feature will control the user's limit in the movement of the handle.

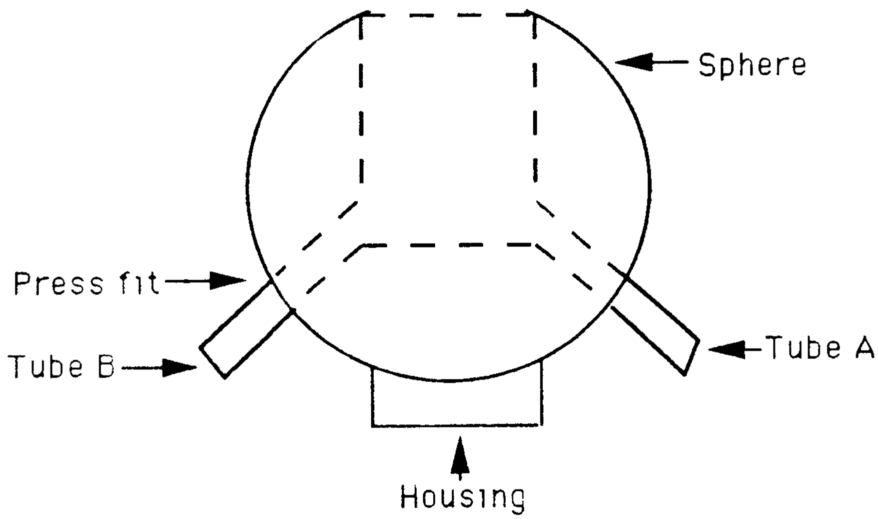


Figure 5.1 Sphere-Tube assembly

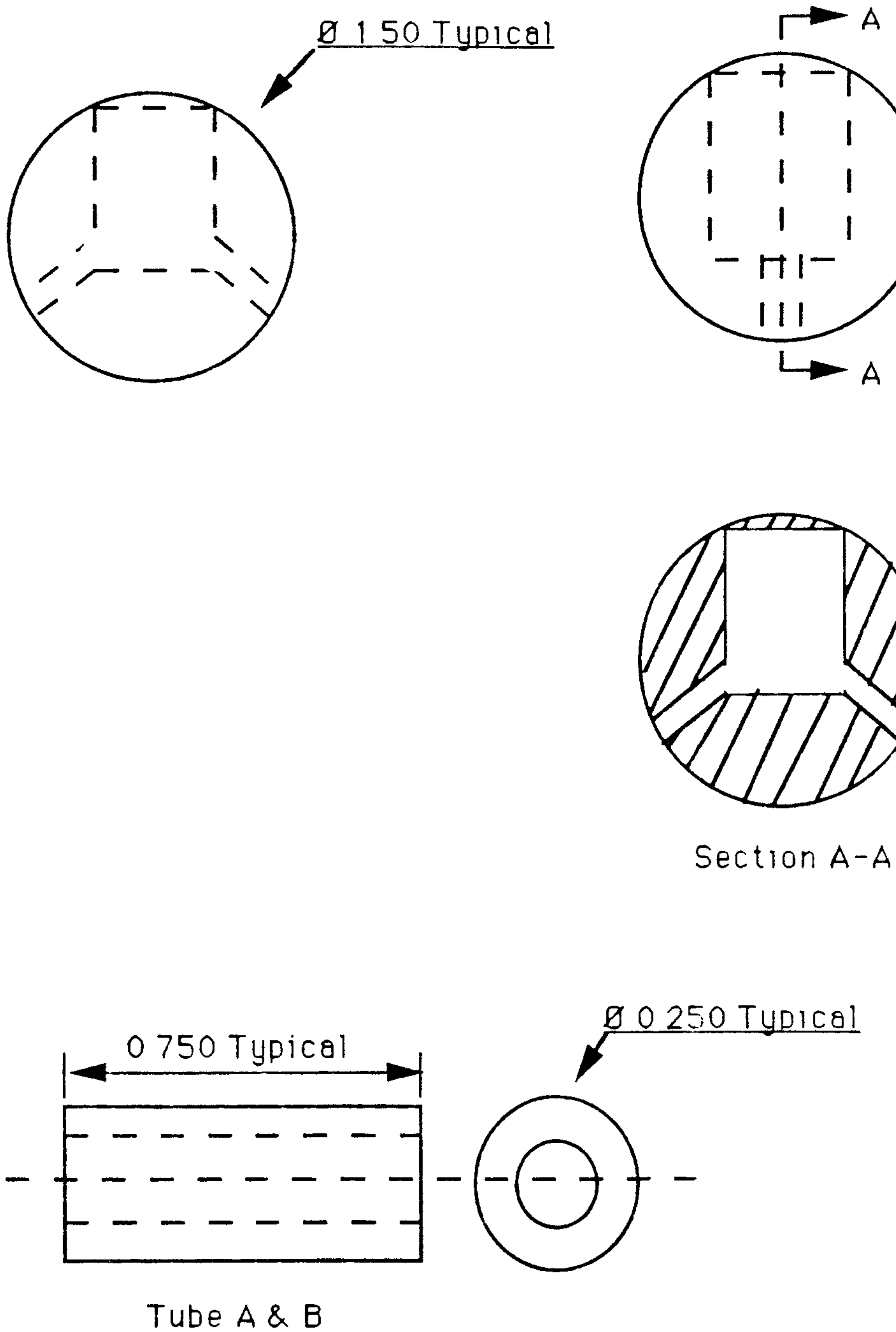


Figure 5.2 Details of sphere-tube assembly

5.5 FACTORS TO TEST THE DESIGN AND MANUFACTURABILITY OF THE PRODUCT

5.5.1 LIST OF FACTORS USED IN TESTING THE DESIGN

* Accomplishment of the desired quality level by completely satisfying the functional requirements without violating any design constraints.

* (Least) Time and cost spent in the production of the faucet.

* Ease of processing and assembling.

* Quick and smooth transition from the design stage to the production stage.

* The amount of resources (time and money) spent in the development of the faucet.

* Achieve a high design efficiency. (highly manufacturable).

* Reduction of production lead time.

*(Min) Number of problems encountered during manufacturing.

5.5.2 LIST OF FACTORS USED IN TESTING THE MANUFACTURING QUALITY OF THE PRODUCT

* Satisfy the customer needs and perceptions of quality.

* Output variability.

* Lasting of the faucet without any failures or deviations from the intended purpose (functional requirements).

* How many times the faucet fails during a set period of time. Compare this number with other faucets' design.

* Ease of handling and usage (smoothness).

* Material doesn't get altered with time.

* The total loss to the manufacturer and to the customer due to functional variation and/or failure.
* Number of complaints from users.
* Satisfaction of the functional requirements set for the faucet without violating any constraints.
* Ease of replacing and of repairing parts if needed be.

5.6 CHARACTERISTICS AND ADVANTAGES OF THE PROPOSED DESIGN

The following are the Characteristics / Advantages of the proposed design.

a) Number of parts: In the proposed design of the Faucet, a single control device (a knob) controls the flow of both the hot and cold water, there by eliminating the need for two separate outlet pipes and knobs. This feature makes it possible to control the temperature of the outflowing water. Also the need for separate fasteners to secure the ball and the control knob is eliminated by providing threads on the ball shank.

b) Leak prevention: A special Cam and Packing arrangement provides leak proofing.

c) Control device sensitivity: control is established by the relative positions of the two apertures in the ball with the inlet pipes of the casing. Because of the geometry of the ball, the required matching between the ball and the casing can be accomplished by very small movements of the knob.

d) Manufacturability:

i) The ball is a polymer and therefore lends itself to injection moulding. Thus there is an increased ease of manufacturing the most critical component of the faucet.

ii) As regards the assembly of the various components, the following are the advantages.

* All assembly is done in the vertical direction and therefore the design is consistent with the principles of DFA, (Ease of assembly)

* The ball is secured / fastened to the control knob by providing threads on the shank portion of the ball and in the knob. Thus the screws/bolts are eliminated, there by avoiding many quality problems.

e) Lastly this design adds to the asthetics of the faucet .

The above characteristics confirm the soundness of the proposed design and the associated advantages.

CHAPTER 6
DISCUSSION AND CONCLUSION

DFA and DFM techniques can be applied for products assembled manually or automatically or manufactured by specific techniques, such as machining, die-casting or injection molding. These techniques can play a major role in reducing costs and increasing productivity.

Different case studies illustrate that products can indeed be designed for manufacture. Numerous business benefits can be derived from doing so. Yet DFM cannot operate in isolation; it needs to be conceived and implemented as part of a broad strategy including sound product planning and operational management. Everybody in an organization need to recognize that design is too important to be left to designers alone. All designs and manufacturing engineers need to be trained in DFM.

DFM and DFA techniques can easily be used with automated assembly because of their similar goals. Used properly, DFM, DFA and automated assembly lower the cost of producing a product and increase its reliability. The key to achieving these goals is to produce designs with fewer, simpler parts and such designs , often lend themselves to automated assembly.

The number of parts in a product is typically proportional to the cost of assembling that product. Such parts as fasteners, clips and washers may be small in size, but they often account for the majority of the assembly cost. Hence the objective should be towards minimizing the use of fasteners, etc., if possible, totally avoiding them.

DFM is a relatively new way of looking at a very old problem. The importance of manufacturability in product design has been recognized. Design for manufacturability is a large subject spanning many disciplines and points of view. DFM is recognized as the key to simultaneously minimizing manufacturing cost, assuring product quality and realizing the productivity increase promised by the advanced manufacturing technology.

The trend towards design for manufacture and assembly has advanced swiftly in the past few years. Design for manufacture represents a new awareness of the importance of the design as the first manufacturing step. It recognizes that a company cannot meet quality and cost objectives with isolated design and manufacturing engineering operations. To be competitive in today's market place requires a single engineering effort from concept to production. The essence of DFM approach is therefore the integration of product design and process planning into one common activity.

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