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Design for Manufacturability and Design for Assembly

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Abstract: *One of the problems in manufacturing products is the lack of proper communication between product design and manufacturing. If this relationship is not established well between design and product, it always leads to problems in product manufacturing. The issue of obtaining tools to make manufacturing product better, faster, and cheaper has created an intense competition between companies. Excessive long design time of a product will prolong the product development cycle. Moreover, the designers cannot examine the products separately, nor can they spend a lot of time on a manufacturing engineer's engineering idea to find the ways of manufacturing products. An appropriate and strong coherence should be established between human resources, tools, methods, design resources, engineering and manufacturing in a product production process desirable to the customer, designer and manufacturer. Design theories for manufacturing and design for assembling are two very powerful tools for cherishing creativity and innovation, sharing technical knowledge in processes, and reducing design, engineering, and manufacturing loops. Thus, making companies knowledge-based can help manufacturing and complexity of product design. The paper tried to develop products using product design techniques.*

Keywords: *Design, manufacturing, assembly, DFM, DFA, DFX, DFAM*

INTRODUCTION

"A product can be designed in different ways to meet practical, efficiency and other needs. Hence, various organizations with different design ideas and opinions should be founded to meet similar practical needs. Providing a solution for an application depends on how the problem is defined for the designer and the creativity and the designer knowledge. This is because there are so many different ways to solve a problem; thus, the important question is how one can figure out which design is the best solution. Moreover, it is possible that there are other designs better than the designer's knowledge and awareness. Design for manufacturability (DFM) is a tool guiding the designer in selecting the best design and then creates the optimal design, as well as a tool for producing, approving and developing ideas and beliefs. DFM combines information related to the design process of a piece to obtain the maximum advantages and capabilities of the manufacturing method. The construction engineer must have the desired technical knowledge of the advantages and limitations of various construction methods to achieve the best design. Moreover, group members must have similar tools like DFM, design for assembly (DFA), and so on to be familiar with the production of high quality design.

The best example of design is nature design, where various products are created as a whole in a flawless system. In contrast, engineers make different components of a piece and connect them together. Currently, we cannot perform the biological manufacturing processes, but there are many opportunities to invent or train and imitate integrated (non-assembled) designers from the natural world. Nature design is strong and not necessarily difficult and feasible. Nature tries to create a plan compatible with nature. Engineers, on the other hand, traditionally create strong buildings and mechanisms.

The concept of design for manufacturing / design for assembly dates back to the late 1790s when Eli Witney succeeded in accelerating the process of producing rifle butts. Nowadays, the effects of DFM and DFA are abundant in everyday life. For instance, designing equipment with the least number of bolts and nuts, or designing it in the order in which it can be assembled with the least tools, or even designing the side mirrors of the car in such a way that the mirror on the right can be replaced with the left. DFM / DFA effect significantly shows a reduction in the cost of product life cycle, a reduction in the cost of supply and construction, and a reduction in the cost of maintenance.

The primary goal of these theories is to think about manufacturing, assembly, quality, or the production cycle during the design process. This can be realized by working simultaneously in a coordinated engineering environment to avoid further design changes. For instance, if manufacturing and design engineers work separately on the design and construction of the exterior of cars, the engineer produces a simple product or square box, which is cheaper and easier to build. However, no one will buy it because it is lack of beauty. On the other hand, the design engineer creates a beautiful and attractive design that may meet all the needs of the customer, but cannot be manufactured, in which case the product will not sell.

The increase in the competition to reduce costs has made the designers to design their products in the shortest design possible time and with the least resources and costs.

Currently, various theories like DFM, DFA, and design for quality (DFQ), design for life cycle, and coordinated design have been developed to meet the needs of the market.

Design for the various aspects needed in design of a product is called Design for Excellence (DFX), of which the following can be stated:

- DFF = Design for function, which means the piece or product functions properly
- DFC = design for cost, cost or design according to "target price"
- DFD = Design for delivery
- DFQ = design for quality
- DFA = Design for assembly, simple assembly
- DFT = Design for test, the ability to test
- DFR = Design for reparability, simplicity in maintenance.
- DFS = Design for supply chain, supply chain management
- DFD = Design for distribution
- DFH = Design for human factor, human factor
- DFS = Design for style, appearance
- DFS = Design for safety, safety
- DFR = Design for requirement, customer needs
- DFM = Design for manufacturability, the extent, dimensions and design of production line
- DFC = Design for customization, custom product
- DFD = Design for delivery, the time to send the product to the market
- DFU = Design for update, product update
- DFF = Design for the future, future plans
- DFE = Design for environment, product pollution
- DFP = Design for pollution, process pollutions
- DFR = Design for reliability, reliability"(Sanji Mazomdar, 2004)

The advantages of using DFX:

"The problem of defect and quality in a product arises from three factors: improper design, improper materials and mistakes in the manufacturing process. For instance, if a product is designed properly but the manufacturing method not, then the product will be defective. Likewise, if the product is not designed properly,

there will be problems with the quality of the product, even if the materials and manufacturing methods are selected well. Such defects are caused by several main and intrinsic factors in the design.
A poor design can lead to several problems in manufacturing plants. This design not only increases the product price, but also reduces the product quality. Common and prevalent design problems are loose parts, noise from collisions or contact of parts, unrecorded components and parts, tight or very tightened parts, missing parts or components, heavy workload, some machine operations, the problems that manufacturing creates, the problems that assembly or connections create, the problems that arise in achieving quality, the problems that assembly or connections create, the problems that arise in achieving quality, the problems related to working conditions in relation to human issues and needs, problems with serviceability and so on. These design problems can be solved in the early stages of design using the best experimental and practical work. The low quality of the product increases the waste and thus the price of the product. Product quality depends on product design. (Boothroyd and Dewhurst, 1987)

Simultaneous engineering and DFM:

"Applying the principles of DFQ and DFR in the earliest stages of design will guarantee product quality during manufacturing, where one can learn and use cost reduction systems and design to manufacturing all the above rules and guidelines.
Simultaneous engineering model proposed in “cost reduction systems and DFM” during design provides a 40% reduction in design time.

What are DFM and DFA?

DFM can be identified by repetition for product design, and considering manufacturing methods. DFM starts with designing on a sheet of paper and knowing the product correctly, efficiency and other product needs.
DFM uses design rules for the best experimental and innovative work to design a piece. The best experimental and practical work for designing are a high quality product, minimizing the number of parts, creating multiple uses in the pieces, minimizing the change in the part, as well as making it easy to check and handle. DFM involves the elimination of the requirements used at the end, with the lowest cost of design, materials and process composition.
DFA is a reduction in the number of complex and large parts by merging these products, which is actually used to reduce the assembly operation of a product.
However, the differences and similarities between these two are listed in the table below:

Table 1: Differences and similarities between DFA and DFM

Similarities	**Differences**	
	DFM	**DFA**
Both refer to lower materials, overhead and workshop costs	Reduces the cost of all manufacturing factors	Only reduces the cost of assembly
Both reduce product development time	Reduces all the complex manufacturing operations	Reduces the number of assembly operations
Both refer to using standard and ready-made parts to reduce costs	Uses standard and ready-made parts	Complex parts are acceptable if they make assembly easier

In the past, product problems used to occur because of poor and improper design. The designers were not aware of the various manufacturing methods and capabilities of the existing manufacturing methods. Thus, products with inappropriate features and characteristics had many parts and components, and therefore multiple assembly operations, which caused poor quality in the part and increased costs.

The technical knowledge of manufacturing must be considered in product design to design a product effectively. The designer must be aware of the process interacts and design. The purpose of DFM, DFA are:

- Limiting design choices to optimize design
- Implementing the generated idea, select the idea and develop and advance the idea
- Minimizing product time and cost
- Reaching high quality product with more reliability
- Simplifying production methods
- Enhancing the strength and competitiveness of the company
- Having a fast and uniform transfer from the design to manufacturing stage
- Minimizing the number of parts and assembly time
- Eliminating, simplifying and standardizing wherever possible. (Mohammad Reza Zarepour 2019)

The purpose of using DFA DFM and practical solutions for using this method:

"Here, one can use the sum of DFA and DFM (DFAM) as one of the solutions to minimize the manufacturing information in the product without destroying the executive tasks and requirements of the product. Moreover, DFAM can be used for a product that has already been produced or is available on the market. Here, the purpose of DFAM is to make the product competitive

In doing so, it is recommended to ask and create each of the questions for the appropriate design:

- **Minimizing the number of components in DFM and DFA**

There is good potential for component integration by meeting the need for manufacturing in component separation. In General Motors, Ford, Chrysler, IBM, GE and other factories, DFM measures and programs in many production lines reduced the total number of parts from 30% to 60%. Minimizing the number of components saves a lot by eliminating assembly, inventory control, storage, inspection and monitoring, transportation, and servicing. According to Hathaway's theory, the ideal product has only one piece. Overall, if a piece needs to be moved, a variety of materials are needed, a different construction is needed, or a regulator is needed, a product with more than one piece is needed.

It is necessary to answer the following questions to determine if it is possible to remove a piece or set:

1. How is the relationship of the deleted piece to other parts?
2. Is it necessary to make parts using different materials?
3. Does the part need to be moved to repair and service?
4. Is there a need for adjustment and optimization?

The following executive instructions can be used to reduce the number of parts or components:

- The request and the need for a piece must be justified. By asking the above four questions and if the answer is no, then by removing the separate pieces, the product should be redesigned.
- Multipurpose applications should be created in each piece.
- The product features of no value or significance to the customer should be removed.
- Using performance and standard parts in designing.

- **Elimination of mechanical connections in succession**

Avoid using bolt, nuts, and other clamps in the product. It is estimated that it costs about 6 to 10 times as much to tight a screw in a product. The use of fasteners increases financial costs and complicates assembly. IBM used this philosophy to redesign printers: removing a large number of screws and using a suitable clamp connection instead. The design results in a 60% reduction in parts as well as a 70% reduction in assembly time.

- **Minimizing the variables**

The dimensional changes of the part besides the change of characteristics and the similarity are of the main and important defects of the product. Try to use standard parts and avoid using special parts. Dimensional changes in components like bushings or o'rings, nuts, and bolts used in an application should be removed as much as possible. The same size means the same tools for assembling and disassembling. This recipe reduces the parts of the piece and also reduces the number of variations and changes in each section. Thus, the control of the property list and the ability to replace parts is better and easier.

- **Easy service and maintenance capability**

The design of the product should be such that it is easy to disassemble and the part should be visible for inspection and inspection and there should be no obstacle or impact between the adjacent components and no special wrenches and tools are needed for maintenance.

- **Reducing the manufacturing and assembly directions and the possibility of easy inspection**

The assembly movement directions must be minimized for extensions to assemble a product. It is necessary to think about the assembling the parts needed to connect the different parts while designing a product. It is better to use one direction for assembly: the assembly operation in the vertical direction (along the Z axis) is more suitable to help with the assembly operation. One-direction assembly operations minimize component displacement and do not need separate assembly stations. In such cases, it is better to consider the assembly from the point of view of human and ergonomic issues and requirements.
Avoid using components like springs, clamps, and so on which can cause internal entanglements and locks. Eliminate the ones that stop the assembly operation and also cause inconvenience and annoyance to the workers. The location of the parts and the assembly site should be easily accessible to prevent physical fatigue of a worker. The parts should be kept available to the operator. Avoid places where the operator has to bend, get up or walk to get the piece. Use gravity (weight) as a help to move the piece.

- **Provision of easy placement and its arrangement**

When there are more than two parts or components in a product, they can be brought closer together by replacing or arranging. Some guidelines for easy placement and sorting are:

- Making a large list of gentle paths, patches and slopes, and radii for easy placement and assembly
- Providing a feature related to uniform places and similar arrangements if possible
- Preventing obstacles and limitations of the parts involved
- Avoiding using too much force to sort the piece
- The part should be designed to be easy to maintain

- **Design for convenience**

In manufacturing composite parts, without the technical knowledge of manufacturing operations, one cannot make an effective and good design to make the product. Every manufacturing process has its strengths and weaknesses. Product design should consider the benefits of the selected manufacturing process. Design should be as easy as possible, because it will help build and assemble and thus save money. Workers and those dealing with products can easily recognize the simplified design. . (Mohammad Reza Zarepour 2019)

Design evaluation method

"Any design should be evaluated according to increasing quality and meeting customer needs. It is very hard to compare various design options, yet the selection process like PAG analysis and other methods can facilitate the task of choosing the best design. Here, there is a method to select an idea. According to this method, a context is created for selection criteria and design options as shown in Table (1). Each design option is graded on a scale of 1 to 5 for various selection criteria. The weight is determined depending on the importance of the application. Each degree is multiplied by the weight and added together for the final selection. The design that has the highest value is selected as the best design.

In the early design stages, the designer has to determine the type of assembly method to reach the best product. Then the design should be in the scope of the capabilities and benefits of the selected assembly method. Decisions are made for an assembly method based on cost, total number of parts in the product, production speed, and so on. For instance, if the annual production volume of the product is only 1000, it is preferable that the assembly be done in the traditional way, whereas the choice of automatic equipment can be the best choice for the production volume of several million pieces per year. . (INS-17418-1 2018)

Table 2: Evaluation of design ideas

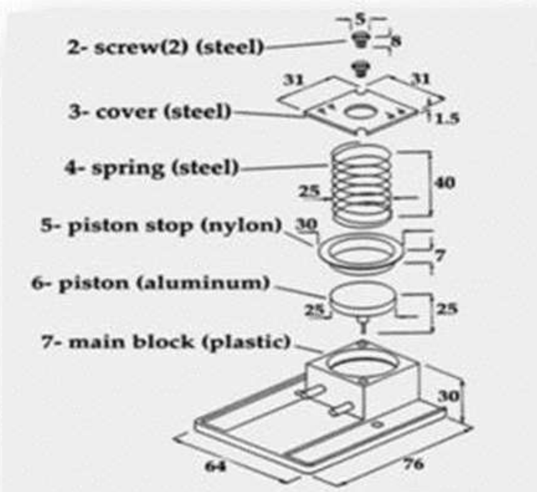
Factors	Weight percentage	Design A	Design B	Design C
Weight	15	3	4	3
Cost	20	4	5	3
Implementation	10	3	4	3
Reliability	5	2	4	3
Sound	5	3	3	4
Assembly time	15	3	5	3
Strength and durability	7	3	4	3
Number of parts	10	2	4	3
Aesthetics	5	2	4	4
Ease of service	8	2	5	3
Total	100	2.92	4.38	3.1

DFMA implementation sample:

"Reducing the manufacturing cost of a product during design can be done by considering the share of each of the following topics:

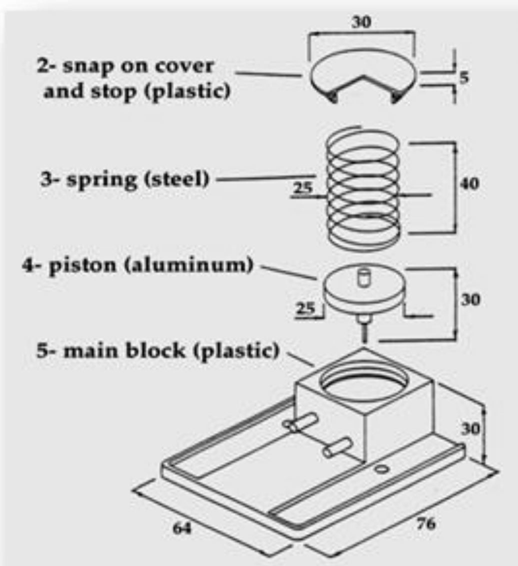
1. Removal
2. Simplification
3. Standardization

Please see the figure below. This is a pneumatic pump before applying DFMA principles or design for assemblability. . (Seyed Hadi Mohaghegh 2019)

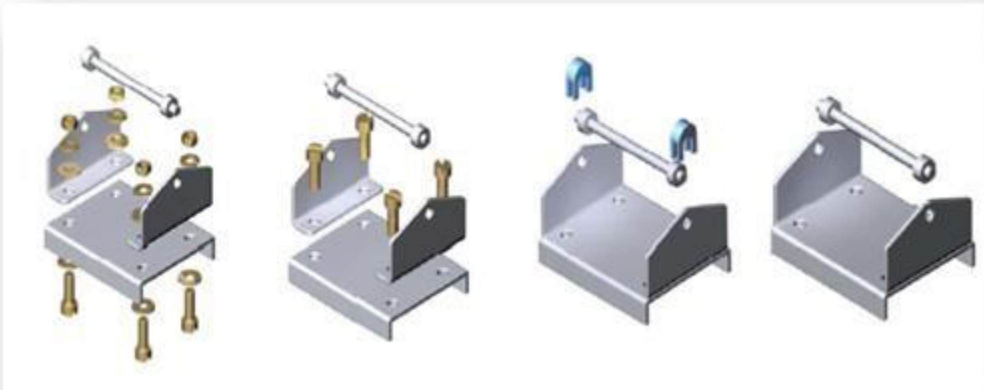


Pneumatic Piston Sub-Assembly
(dimensions in mm)

The figure below shows the same pump after DFMA



One can see an example in the figure below that shows the changes made in the design from left to right to understand the significance of using DFMA:



As is seen, the last piece on the right is the same modified one as the first piece on the left and has the same use, except that its quality has increased and its manufacturing cost has reduced, with all the advantages stated above expressed for the pneumatic pump. ."(Kota, 2008)

Conclusion

DFAM should be used in the early stages of the product development process, when there is a strong disagreement over product costs in decision making, or when the best opportunity is for product development components. When a product design is completed or the part is in production, it is very late to use DFAM. Any change in design at the next stage will effectively increase the product price. DFAM can be used to develop and advance existing products to gain more profit and increase market competitiveness. DFAM helps make the final design less time consuming compared to traditional product design methods.

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