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Design for Manufacturing and Assembly Technique Applicable For a Gearbox

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Abstract: *In traditional manufacturing approach considered as a 'over the wall approach 'and it consist of few steps and they are identification of Customer needs, conceptual design of the product, trial and error developing and testing methods and after the successful testing of the prototype the actual manufacturing of the product will start. Geoffrey Boothroyd stated that almost 30% of the product cost is dedicated to the design stage. Design for Manufacturing and Assembly (DFMA) guidelines helps to optimize the product design and development .DFMA guidelines combines the process and it results in part reduction and cost reduction. This paper presents a guideline which used the concept of Design for Manufacturing and Assembly methodology for specific application on design and manufacturing of gearbox. The main goal of this guideline was to orient the engineers during the gearbox development phase, such that a better gearbox design is achieved. It aims to improve the assembly for easy manufacturing of the gearbox with low cost, high quality and the best optimized condition. A case study is shown to testify the advantages and benefits achieved when the proposed guidelines are used.*

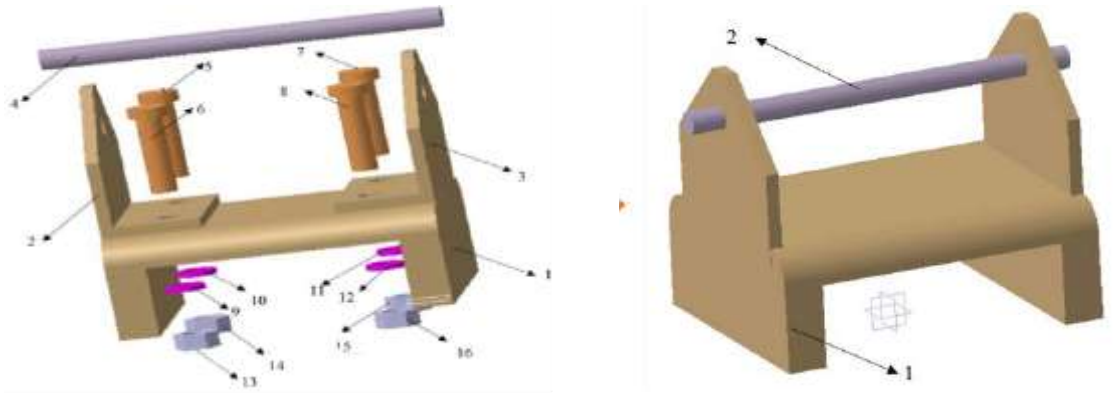
Keyword: *Cost reduction, DFA, DFM, DFMA*

I. Introduction

The objective of the DFMA is to develop a method to study the assemblabilities and manufacturability of the product. Now days every company wants to deliver a product as less cost and less time. This is where DFMA comes into a picture, Design for manufacturing and assembly (DFMA) is a combination of two major aspects i.e., DFA – design for assembly and DFM – design for manufacturing. According to Geoffrey Boothroyd almost 30% of the total cost of the product is involved in the design of the product. [1] DFMA states the methodology for conceptual product design. For theoretical approach designers can use the DFMA guidelines and for analytical purpose DFMA software is also available. This software can be used for investigating every possible process used for manufacturing and assembly. In this study DFMA software is used for the analyses of assembly process and assembly time. A through DFMA analysis gives the categorical approach to each step of the process. This software also rates the costs required for every possible process and creates cost estimation and a process plan. To get the through idea about DFMA and its application an extensive literature review has been carried out. And as described below.

II. Literature Survey

C. D. Naiju et al [2] conducted a study and analysis of a shopping cart design, manufacturing and cost estimation. This cart is widely used in supermarkets, departmental stores and many more places; first priority of this analysis was to reduce the part count of the cart and to reduce the cost. The CAD model of all the parts of the cart was analyzed by using DFMA software as well as Boothroyd Principles. Redesign of the product is manufactured by using a commercially available metallic weave instead of casting the parts. Redesign of some parts causes ease of assembly and elimination of some expensive processes which leads to better and optimized product than the existing one. Observed reduction in assembly time was 3178.82S i.e. 3.89% .Price of the existing product was $327 and the price of the redesigned product was $314.Total reduction in the cost of the modified product is 3.9%.This might seem a small changes but while manufacturing for mass production it causes a lot of difference and end up in a considerable profit margin. [2]G BalaMurali et al [3] states that in manufacturing process 30% of the total time is consumed in only assembly operation compared to all other operations. Hence they have implemented a novel method to the automation of the assembly sequence and that is a combination of AI (Artificial Intelligence) and DFA (Design for Assembly). This method reduces the number of parts i.e., it merges the parts which satisfies DFMA principles because of that manufacturing and assembly cost and its time gets reduced.



a. Existing Topology **b.** Modified topology

Fig 1. Machine Frame Model. [3]

Boothroyd et al. [4] states that before the adoption of DFMA, design engineers would typically work irrespective of manufacturing and assembly process, the objective of DFMA is to reduce cost in the overall life of a product. There are number of approaches available on how this can be achieved. Most notably, authors were a pioneer in formalizing such an approach. They provide criteria's upon which each part must be examined. And it is focused on part count reduction in increasing product Assemblability .However; every manufacturing system will require the development of its own tailored tool. The authors concluded that no improvements in operation can make a plant fully competitive if the product design is defective. Design for Manufacture and Assembly can be the key to high productivity in all manufacturing industries. Claudio Favia [5], discussed "A multi-objective design approach to include material, manufacturing and assembly costs in the early design phase." and states that Conceptual design is a crucial activity in the product development process. The design freedom must consider a tradeoff analysis among several aspects such as assembly, manufacturing, and costs. To create feasible design options for multi-objective design approach is the main intension. The approach is based on the concept of the analysis of product modules and the theory of Multi Criteria Decision Making (MCDM) approach. The main intension of this work is to define a multi-objective design approach which aims to have a comprehensive analysis of the manufacturing aspects (including assembly, materials, processes, costs and times).

H.Tasalloti et al [6] states that for adoption of Concurrent Engineering (CE) in design of welded structures, a new model is proposed that integrates the Design for Manufacturing and Assembly (DFMA) with Product Data Management (PDM) system. This product data management (PDM) system is integrated with DFMA as a database of welding processes, materials, consumables, standard and guidelines as well as for storing and tracking changes in weldments design [6] The proposed approach in this paper is also useful in coordination with CAD applications and manufacturers Product Data Management (PDM) software to increase the quality of a design of a weldments. And since this PDM it enhances the decision making as its use by designers require only minimum welding and metallurgy knowledge. Zhenmin et.al[7]states that design for manufacturing and assembly (DFMA) in prefabricated building design ,and it combines with parametric design of Building Information Modeling(BIM) to develop the concept of DFMA oriented parametric design. Authors have also stated that how to create a prefabricated building information model for construction and its precast components information models for manufacturing, which have good manufacturability and Assemblability so as to avoid the manufacture and assembly problems in later stages and improvement the one time success rate of design. In comparison with the traditional manufacturing process this newly developed model is more manufacturable and assemblable.WankhadeNiteshPrakash et al [8] have used DFMA to re-design a ball valve fluid flow control valve and optimized its design to ensure reduced number of parts, safety, and reliability. Early consideration of manufacturing issue also shorten product development time, minimize cost and ensure smooth transition into production for quick time to market. Therefore optimum design, low cost and good quality with quick delivery was outcome of this research work. Total no of parts present in the existing design are 23 and after application of DFMA principles the part count is 6.This results in cost reduction. Observed changes in assembly time is from 145 sec to 45 sec .i.e. 68% reduction.

AkshayHarlalkaa [9] suggests that significance of implementation of DFMA on an Indian consumer product (in-market food processor). DFMA is considered as an effective cost reduction technique. While studying existing design author notices that there is lot of opportunities where DFMA principles can be applied so that cost of the product can be reduced. In accordance to DFMA principles Design objectives were proposed. As a result there was a significant improvement in product architecture, assembly time & design efficiency. This

paper concludes that, by using DFMA principles an increase in DFA index is from 15.99 to 19.93 overall costs saving if 0.25 USD (INR 16.79) and reduction of 108.49 sec in total assembly time was achieved. [9]

MohdNazri [10] stated that significance of the DFMA is to reduce the total part count. This analysis contributes to the reduction to the manufacturing cost, Assembly time and material, hence author conducted analysis of the water nozzle as a case study, and used Lucas-Hull methodology. The original design is reviewed, analyzed and redesigned. By the analysis author concluded that redesigned assembly is consisting of fewer parts 13 to 8, and total reduction in cost is almost 40%. This cost reduction will results in to the profit margin. As per the study of literature survey of DFMA, for methodology development the subassemblies of the gearbox are studied. First the assembly sequence of the gearbox is predicated in the CAD atmosphere. The generated random sequence is then assessed by the DFA, and after satisfying these criteria the new assembly sequence will be generated with reduced no of assembly levels. Gearbox a case study

III. DFMA overview

Design for manufacturing and Assembly is a combination of two aspects and these aspects are Design for manufacturing and Design for assembly. The Design for assembly guidelines are as stated below [12]

- Minimize number of parts
- Design for Ease of Handling
- Design for Ease of Insertion
- Standardize parts
- Design for current process capabilities
- Maintain awareness of alternative process capabilities
- Watch for free handling space
- Make sure of pre-positioning
- Ensure easy access for testing
- Provide modular component structure
- Differentiate variants at the end of process
- Check material compatibility
- Prefer flow parts instead of single parts

Industry always tries to learn new methods and procedures that may help then reduce the overall expenditure of the manufacturing process hence they intend to believe in continuous learning process. In order to reduce the expenses increasing the productivity is an important step one of the aspect to increase the productivity is application of six sigma.

The DFMA can run activities in a parallel form at the same time while task sequencing. It also allows us the use of simulation techniques and co-working of different teams such as design team, production team, sales and marketing team, finance team etc. This underlines the factors affecting project failures and allows us to eliminate the causes. It also makes it possible to eliminate those factors. The procedure for application of DFMA is as follows.

Step 1 - product information.
- Functional analysis.
- Identify parts that can be standardized.
- Determine part count efficiencies.

Step 2 - Determine your practical part count.
Step 3 - Identify quality (mistake proofing) opportunities.
Step 4 - Identify handling (grasp and orientation) opportunities.
Step 5 - Identify insertion (locate and secure) opportunities.
Step 6 - Identify opportunities to reduce secondary operations.
Step 7 - Analyze data for new design.

Efficiency of the design is calculated by DFA index,

DFA index = $\frac{N_{min} * t_a}{t_{ma}}$ …… (1)

N_{min} is a theoretical minimum no of parts,
t_a is the basic assembly time for one part, and
t_{ma} is the essential time to complete the assembly of the actual product.

DFMA software is developed by Boothroyd Inc. This software optimizes the manufacturing and assembly process. It is one of the most important software used by designer to decide the optimum design, manufacturing process. DFMA is used for acquiring the high manufacturability level of a product. Designer goes through a lot of experiences while designing any product the mistaken decisions , misinterpreted data , improvement opportunities or just a really nice ideas are developed while product design and development areas. The integral

part of the DFMA is that the teamwork between different teams in the industry. This all factors of application of DFMA can be validated from the gearbox analysis in next segment.

IV. Analysis Of The Existing Design

The gearbox under consideration is a 4 stage gearbox containing helical gears. The existing design of a gearbox contains 4 stages. With a parallel shafts and a vertical offset. The input rpm provided to the gearbox is 1390 and the output required is 1.17 RPM. The frame of this gearbox is MFO225-L1-71P4. The four gears stages are designed accordingly. The existing assembly process used for this gearbox is manual assembly process. Since this is a manual assembly process there is a scope for lean manufacturing as well as the application of design for assembly guidelines. The gearbox housing of this gearbox is made up of 3 parts. The assembly process can be divided into the different subassembly procedure The DFA analysis of the existing gearbox is as follows

Table 1 – DFA Analysis Of Existing Design

Entries Including Repeats	
Parts meet minimum criteria	30
Parts are candidates for elimination	53
Analyzed subassemblies	5
Separate assembly operations	0
Total entries	88
Assembly labor time, s	
Parts meet minimum part criteria	297.52
Parts are candidate for elimination	622.15
Insertion of analysed subassemblies	17.70
Separate ssembly operation	0
Total assembly labor time	937.37
Design Efficiency	
DFA index	11.73

V. Suggestions For The Improvement In The Design Efficiency

In order to improve the design efficiency of the gearbox. The gearbox is analysed in the DFMA software. For the ease of assemblabilities of the gearbox the entire assembly is mainly divided in to 4 subassemblies, as it is easy to assembly the subassemblies and it also reduces the total assembly time and the DFA index. Fasteners usually cost 5% of the total assembly cost. It is beneficial if designer is using the standard fasteners in the assembly as it reduces the no of parts, fewer orders to the vendors, less inventory cost, less documentation and the total reduction in the cost. After the changes the new design consists of lesser no of parts and lesser assembly time. The DFA index of the updated design is also increased. The DFA of the updated design is as follows

Table 2 – DFA Analysis of Improved Design

Entries including repeats	
Parts meet minimum part criteria	19
Parts are candidates for elimination	41
Analyzed subassemblies	4
Separate assembly operation	0
Total entries	64
Assembly labor time, s	
Parts meet minimum part criteria	185.88
Parts are candidates for elimination	415.95
Insertion of analyzed subassemblies	28.16
Separate assembly operation	0
Total entries	629.99
Design efficiency	
DFA index	23.40

VI. Graphical comparison

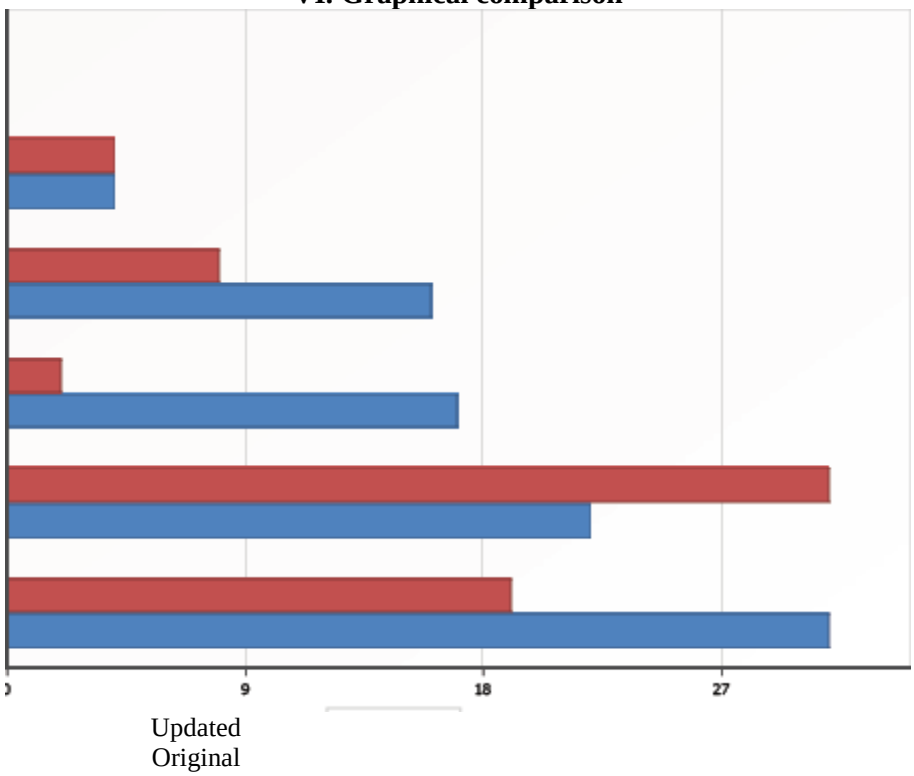


Fig 2.Graphical Comparison

VII. Advantages

Today products are becoming more complex, and also the requirement of the products is increasing as population is increasing. There is an aggressive competition in market hence it is important to satisfy wide range of variations in user population. Through DFMA it is possible to produce competitively priced, high performance product at a minimal cost. The advantages of applying DFMA during product design are as follows.

- DFMA not only reduces the manufacturing cost of the product but it helps to reduce the time to market and quality of the product.
- DFMA provides a systematic procedure for analyzing a proposed design from the point of view of assembly and manufacture.
- Any reduction in the number of parts reduces the cost as well as the inventory.
- DFMA tools encouraged the dialogue between the designer and manufacturing engineer during the early stages of design

VIII. Conclusion

This paper presents a customized specific tool for DFMA application in Gearbox manufacturing. After the analysis it is observed that, there are considerable changes in the assembly process, which can reduce total part count of the gearbox, as a result there is a reduction in total assembly time. Earlier the total assembly time was 940 seconds and after DFMA application the improved assembly time is 630 seconds, it is observed that there is 32% decrease in the assembly time.The efficiency of the design is indicated by the DFA index. The DFA index of existing assemblies is 11.73 and for the improved assembly it is 23.40. Being a specific and customized tool for any industry ,the DFMA guidelines can help in identification and orientation of the solutions for manufacturing and assembly problems, and mostly for difficulties identified before production .Hence it can be concluded that, DFMA technique plays a vital role in a product design and development process.

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Conflict of interest The authors declare that there is no conflict of interests regarding the publication of this paper.

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