DESIGN FOR MANUFACTURE AND ASSEMBLY (DFMA) ANALYSIS OF BURRING TOOL ASSEMBLY

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Abstract - ***This paper deals with study of Design for Manufacture and Assembly (DFMA) and DFMA analysis of an automotive tool i.e. burring tool assembly designed by an OEM. The method used for DFMA analysis is Boothroyd Dewhurst method. To quantify the factors in the assembly process module of Design for Assembly (DFA) has been implemented which mainly focuses on acquisition phase of the assembly process. Also reengineering of some of the subassemblies has been done on the basis of DFMA guidelines for the easy assembly and manufacturing. Manufacturability of the parts has been checked with Design for Manufacture (DFM) wherever necessary. Design for easy and quantified assembly with suitable manufacturing ways, design for easy maintenance and improved design efficiency are the outcomes of the work.***

Key Words: *Assembly, burring, DFA, DFM, DFMA*

1. INTRODUCTION

In today's economic environment, companies must produce greater product variety, at lower cost, all within a reduced product lifecycle, in order to compete or survive [1]. To reduce product cost most of companies prefer traditional process centric cost cutting tools. But major chunk of product cost is locked during design stage itself. Costs now need to be more fully understood and controlled and even reduced from the earliest stages of product development.

Today companies need product design and development quick, accurate and in suitable way to understand product cost early. DFMA has been around for decades and helped product manufacturers to create world class product with improved quality, lower cost and in shorter design cycles [2]. DFMA is getting used over a wide range of industries including automotive, defence, medical, telecom, etc. A major breakthrough in DFA implementation was made in 1988 when Ford Motor Company reported that DFA had helped them to save billions of dollars on their Taurus line of automobiles [3].

DFMA can be applicable for new product design as well as re-engineering the product. This paper speaks about DFMA for re-engineering the burring tool assembly and work includes following

- Analysis of existing Burring Tool assembly with the help of Design for Assembly (DFA).
- Identification of pockets of improvement.
- Design alterations to improve design efficiency and validation through Design for Assembly (DFA) and Design for Manufacture (DFM).

2. METHODOLOGY

2.1 Design for Manufacture and Assembly

The term "design for manufacture" (or DFM) means the design for ease of manufacture of the collection of parts that will form the product after assembly and "design for assembly" (or DFA) means the design of the product for ease of the assembly, thus "design for manufacture and assembly" (or DFMA) is combination of DFA and DFM. Technically, DFMA is a systematic design procedure to analyze and quantify product design [3].

Any new product development cycle begins with the concepts which arise due to competition in the market, customer's demands, new manufacturing technologies etc. Thus conventionally the bridge from concept development to the final product is built by an organization as shown in Fig -1.

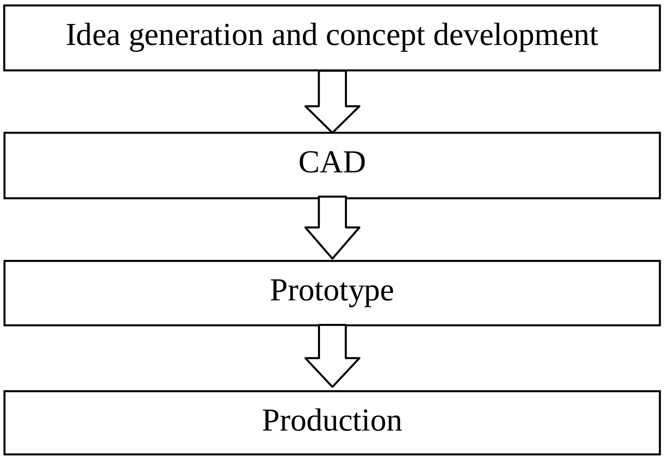

Fig -1: Design stages without DFMA

As shown in Fig. 2, during conventional production cycle product cost and design freedom graph varies as production cycle proceeds.

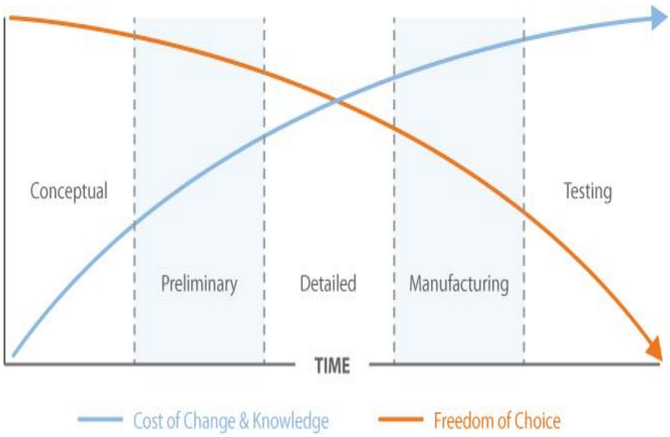

Fig -2: Variation of design cost and freedom of choice during design [4]

Thus any design alteration during production results in loss of time, money and efforts taken. To avoid it, careful consideration of assembly and manufacturing should be early in the design cycle since it is now widely accepted that over 70% of final product costs are determined during design [3].

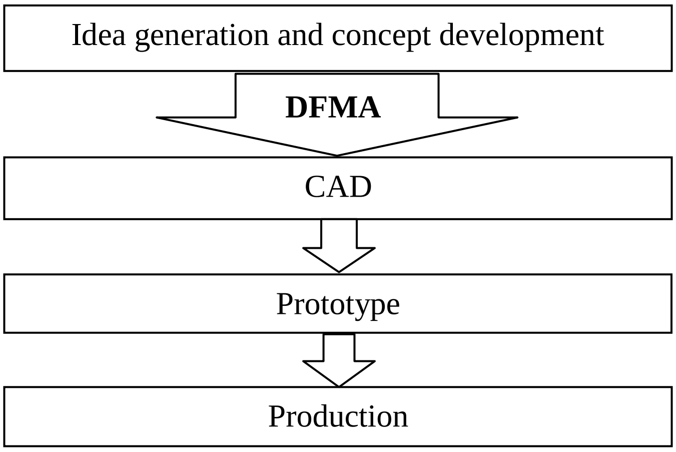

Fig –3: Design stages with integration of DFMA

Fig. 3 shows the place where actually DFMA plays an important role during product design. Introduction of DFMA at early design phase helps to find and resolve manufacturing and assembly concerns.

2.2 DFMA vs. conventional Design Process

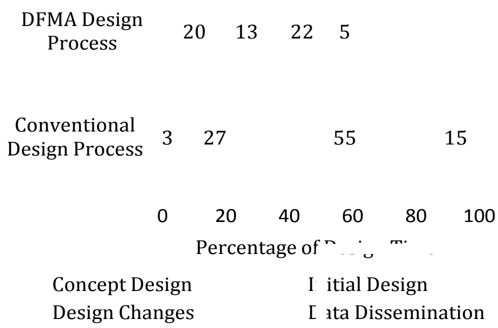

Chart -1: Time spent in different phases of product development [3]

Studies have shown that an increase in time spent during the concept phase of a product's development with DFMA, can shorten product launch time to the market. Fig. 4 shows that DFMA design procedure can result into 40% of time savings.

Apart from manufacturing cost of the parts there are other different cost attributes whose reductions contribute to the total cost reduction. Chart 2 shows such cost reductions other than manufacturing costs after DFMA implementation through an engineering survey.

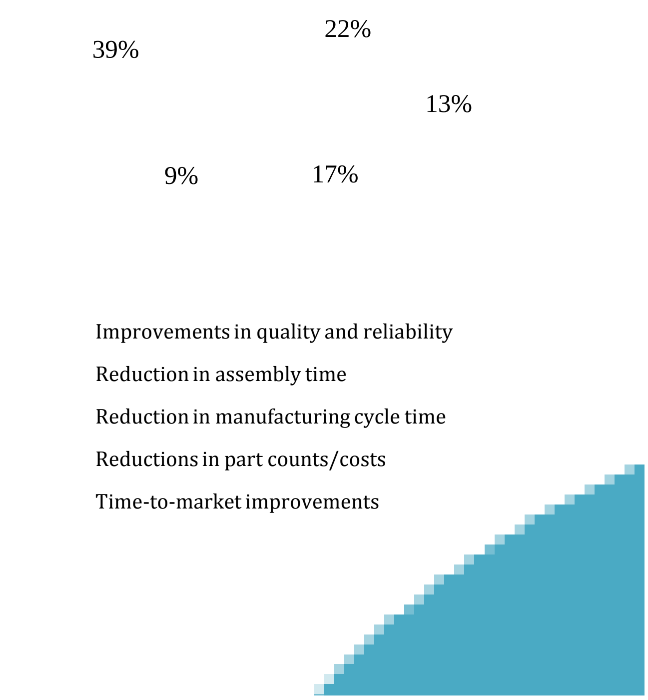

Chart -2: Reductions produced by DFMA [3]

2.3 DFMA working flowchart

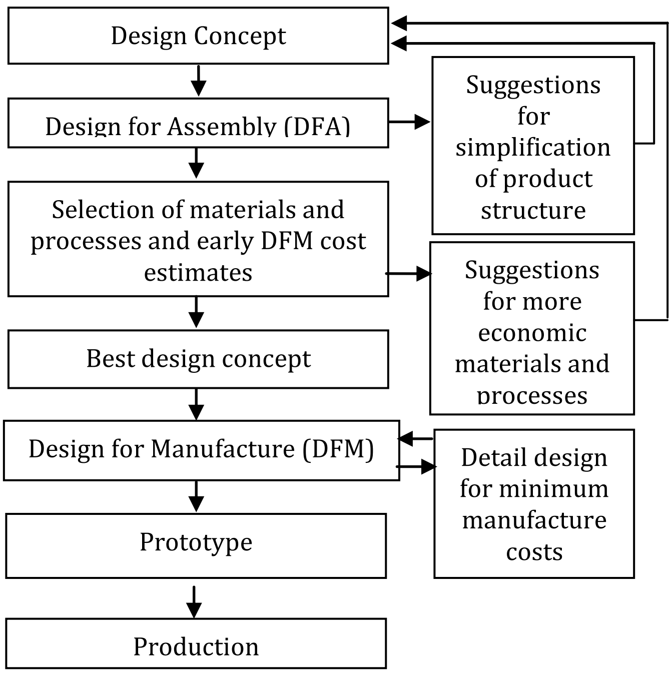

Fig -4: Typical steps taken in a DFMA study using DFMA software [3]

2.4 Burring tool

Burring tool is an automotive tool assembly specially designed for flanging operation of an automobile component. It is being designed by a well reputed OEM, leading in automotive tooling. This paper deals with the study of DFMA analysis applied to the burring tool assembly. Following modules will highlight the methodology of DFMA analysis of burring tool assembly.

2.5 Steps involved in DFMA analysis of burring tool assembly

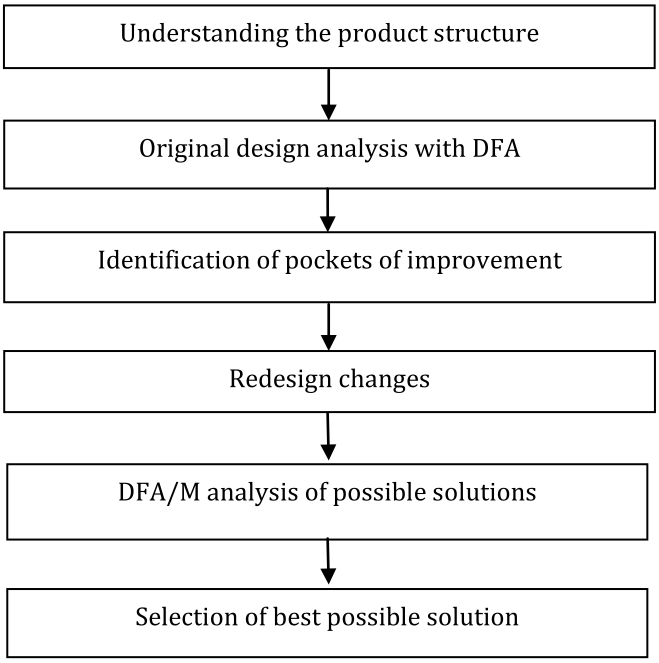

Fig -5: Steps involved in DFMA analysis of burring tool assembly

Fig. 5 shows the major steps involved in the DFMA analysis of Burring tool which has been explained further.

3. ANALYSIS OF EXISTING DESIGN

3.1 Understanding the product structure

Being the first step of the DFMA analysis, existing assembly design was analyzed with DFA analysis. In order to carry out DFA analysis, product structure was completely understood and built in DFA software. For each entry in the product structure, part justification was done. Part justification considers following

- Item weight, function
- Envelope dimensions
- Handling requirements
- Handling, insertion difficulties
- Securing method, etc

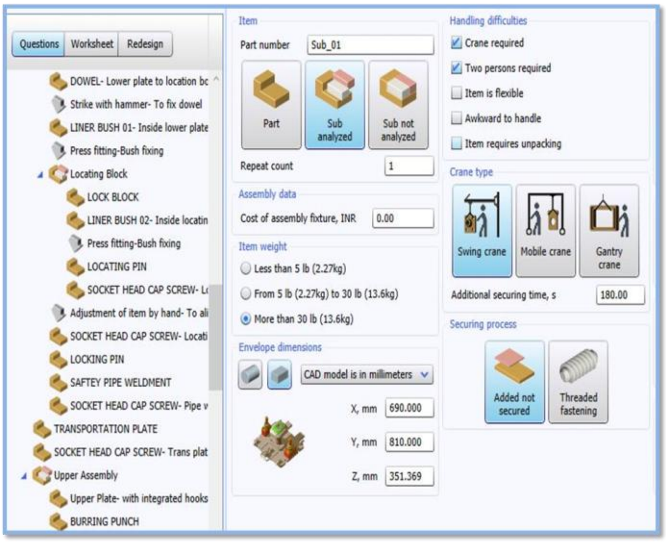

Fig -6: DFA Product Simplification 10.0 software GUI

Thus after successful DFA entries product profile was obtained from DFA software which is as shown in Table 1.

Table -1: Product profile of Burring tool assembly before DFMA

Category	Total Count
Separate operations	96
Analyzed subassemblies	4
Other candidates for elimination	40
Connectors	0
Fasteners	145
Necessary items	30
Total	315

3.2 Assembly time and cost estimation

DFA software gives quick assembly time and cost results at the end of successful DFA entries. The assembly time and cost result estimates for burring tool assembly obtained from DFA software are presented in Chart 3.

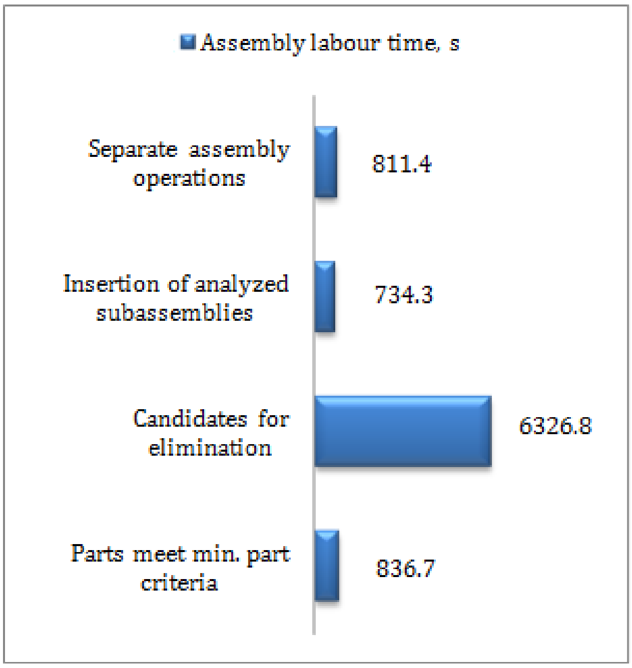

Chart -3: Assembly labour time of existing Burring tool assembly

Total assembly process time (s) = 8709.26
Total assembly process cost (INR) = 239.38

3.3 Design efficiency (DFA Index)

Design efficiency is measured in terms of DFA index. It is a ratio of process time for an ideal product assembly to the process time for an actual product assembly. [5] DFA index is expressed as percentage using formula given by equation (1)

$$\text{DFA Index [3]} = 100 \times \frac{\{T1 + T2 \times (N_{min} - 1)\}}{Ta} \quad (1)$$

Where,

T1 = Ideal assembly process time for handling and inserting the first necessary item in the product.

T2 = Ideal assembly process time for handling and inserting each subsequent necessary item in the product.

Nmin = Theoretical minimum item count

Ta = Actual assembly process time for the product

All the values mentioned above are calculated by the software based on the justification of part entries done in DFA software.

DFA index is calculated in DFA software on successful entries.

DFA index for existing Burring tool assembly = 2.68

For the improved product design designers aim to maximise DFA index.

4. REDESIGN CHANGES

On the basis of DFA software redesign suggestions and DFMA guidelines, design alterations were identified to improve design efficiency. It has been verified with the DFMA software that plain sailing changes in product design can improve design efficiency considerably. Following were the altered designs of Burring tool assembly.

4.1 Standardization of fasteners

As per DFMA guidelines fasteners are most redundant part of the assembly and standardization of fasteners can save major chunk of assembly process cost. In burring tool assembly 40% part count are of fasteners. Table 2 presents the summary of fasteners used in the burring tool assembly.

Table -2: Summary of fasteners used in Burring tool assembly before DFMA

	Grub screw	Socket head cap screw	Dowel pins
Types of standard screws	03	06	05
Total count	12	102	26

Standardization of fasteners made assembly easy for maintenance and reduced secondary assembly processes resulting into reduced assembly time and cost as shown in Table 3.

Table -3: Reductions by standardization of fasteners

	Before	After	% reductions
Separate operations	96	76	21
Total assembly process time (s)	8709	8449	3
Assembly cost (INR)	239	233	2.5

4.2 Lifting hooks redesign

Lifting hooks were amongst the strong candidates of elimination. It counts 8 individual parts, 16 fasteners and 8 separate operations in product structure. Redesign of lifting hooks integration into the lower plate reduces the excess assembly time and cost keeping functionality same. Table 4 shows that integration of lifting hooks into lower plate reduces assembly process time by 12.5 percent and assembly cost by 11 percent.

Table -4: Outcomes of lifting hooks redesign

	Before	After	% reductions
Parts and unanalyzed subs.	215	191	11
Separate operations	76	68	10.5
Total assembly process time (s)	8449	7388	12.5
Assembly cost (INR)	233	207	11

4.3 Guide post redesign

To ensure required gap between lower & upper subassembly in operational condition, set of two limit blocks has been used in combination with guide posts which maintain relation between upper & lower subassembly on press with precision guiding. Guide post subassembly along with limit blocks needs 12 fasteners and 8 separate operations for assembly. Redesign of guide post after DFMA reduces part count by 7 percent and separate operations by 12 percent which results into 6 percent of total assembly process cost as shown in Table 5.

Table -5: Reductions of guide post subassembly after DFMA

	Before	After	% reductions
Parts and unanalyzed subs.	191	177	7
Separate operations	68	60	12
Total assembly process time (s)	7388	6883.5	7
Assembly cost (INR)	207	194.5	6

4.4 Lower cap redesign

Complex cast and machined part then drilling and threading at the bottom of casted cavity was the problem statement of manufacturing the lower cap. Redesign solution of DFM came up with the combined lower cap and burring die eliminating two grub screws with saving their drilling and threading cost. DFM software gives systematic cost breakdown of manufacturing cost in terms of material, setup, process and tooling which helps to select best suitable manufacturing way. Table 6 shows the DFM cost breakdown of lower cap redesign.

Table -6: DFM cost breakdown for original and redesigned lower cap

Cost (INR)	Lower cap before DFMA	Lower cap after DFMA
Material	14315.50	3378.46
Setup	632.25	1164.93
Process	6845.89	2005.69
Tooling	600.00	3098.41
Rejects	374.75	121.34
Total	22768.39	9768.83
% savings	57.09	

4. RESULT

After complete DFMA analysis DFA and DFM software create system generated result which can be exported in various formats.

DFA software allows comparing maximum 5 product profiles. Table 7 represents system generated result of burring tool assembly before DFMA and after DFMA in terms of part count, assembly process time and design efficiency i.e. DFA index.

Table -7: Burring tool assembly result

	Burring tool assembly before DFMA	Burring tool assembly after DFMA
Entries including repeats		
Parts meet minimum part criteria	30	30
Parts are candidates for elimination	185	147
Analysed subassemblies	4	4
Separate assembly operations	96	60
Total entries	**315**	**241**
Assembly labour time, s		
Parts meet minimum part criteria	836.70	836.70
Parts are candidates for elimination	6326.83	4857.95
Analysed subassemblies	734.33	734.33
Separate assembly operations	811.40	454.60
Total assembly labour time	**8709.26**	**6883.58**
Design efficiency		
DFA Index	**2.68**	**3.39**

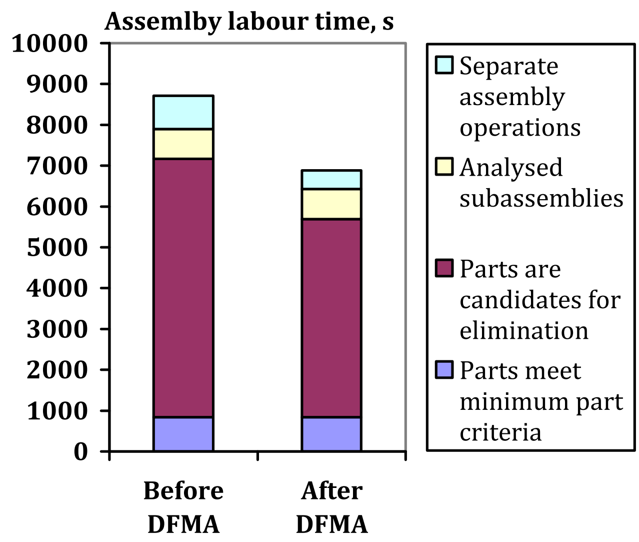

Chart -4: Assembly process time of burring tool assembly

5. CONCLUSION

Study of DFMA was studied and applied successfully on burring tool assembly for its design and assembly analysis. DFMA approach carries the potential to reduce the cost of design and development of burring tool assembly. Bottom-line issues of manufacturing and technology were taken into consideration at the design stage itself. In order to optimize the analysis information collection and proceedings were carried out with sittings of respective cross functional team. Results of DFMA have proven that it truly supports the concurrent engineering. The objectives were ensured with the most favourable quality, reliability, lifecycle, cost, and customer satisfaction. Total 23.5% of cost reduction was achieved resulting into the reduction of 21% assembly process time. The assembly design efficiency was improved by 26.5% after successful DFMA analysis. Implementation of DFMA at the early stages of product design in new product development (NPD) can come out with the more surprising results.

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BIOGRAPHIES

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