AN OVER-VIEW OF THE APPLICATIONS OF DFA (DESIGN FOR ASSEMBLY) TECHNIQUES ON AUTOMOBILE COMPONENTS FOR REDUCING ASSEMBLY TIME AND COST

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Abstract. Design for Manufacturing and Assembly (DFMA) techniques are useful for minimizing the cost of products through design and process improvements. DFMA is a combination of Design for Manufacturing (DFM) and Design for Assembly (DFA). This paper focuses case studies on the successful application of DFA techniques on Automobile components and reports the reduction in assembly time and cost of the product successfully achieved by different R&D works carried out by researchers around the World, collected through literature survey. Information available related to the following topics are collected and analyzed: minimize part count, design parts with self-locating features, design parts with self-fastening features, minimize reorientation of parts during assembly, standardization of parts, minimum use of fasteners, modular design, design for a base part to locate other components and design for component symmetry for insertion. The findings reported in this over-view are useful to practicing design engineers.

1. INTRODUCTION

The automobile industry has grown at a faster rate during the last 5 years. It is one of the largest worldwide industries with more than 4 million cars and commercial vehicle produced in India, one of Asia’s largest markets. Competition has increased among industries due to the entry of global players through joint ventures, fully owned units, collaborations with local industries and as a result, economic conditions have changed. This action forces the industries to reduce the prices, which starts straight away from the lower levels of manufacturing supply base. Due to this pressure and constraints on the pricing, various techniques are to be used at the basic design levels of a product. DFMA (Design for Manufacturing and Assembly) is one such technique which reduces the price for a manufactured component. It is a technique which is used by majority of the industries. It enables the company to not only reduce the price but also the time for production with improved quality.

2. STEPS FOLLOWED IN DFMA

DFMA is a combination of DFM (Design for Manufacturing) and DFA (Design for Assembly). “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 assembly [1]. This process was developed by Boothroyd Dewhurst in 1960 in US. There are various processes in the market which increase the productivity of an organization. But DFA stands out to be one of the major processes. It tries to reduce the number of parts by replacing then by a single assembly, which in turn not only reduces the number of parts but also the time of assembly and cost of the product which shoots up the productivity. The Flowchart given below shows the basic steps to be followed in DFMA:
2.1 Guidelines for DFA
Guidelines for DFA are given below:

- Minimizing the part count
- Designing for ease in insertion
- Standardizing the parts
- Designing for the process capabilities
- Awareness about the alternatives for process capabilities
- Making sure there is some free space for handing
- Making sure about pre-positioning
- Ensuring easy testing access
- Providing component structure which is modular
- Differentiating the variants at end processes
- Checking if the material is compatible
- Preferred flow of parts

2.2 The Design efficiency

The design efficiency can be calculated by an index called DFA index. It tells how easily a component can be assembled.

\[
\text{DFA index} = \frac{N_m \times T_a}{T_{ma}} \tag{1}
\]
\[ N_m = \text{Minimum no. of parts (Theoretical)} \]
\[ T_a = \text{Minimum assembly time per part (sec)} \]
\[ T_{ma} = \text{Estimated total assembly time} \]

3. DFA ANALYSIS

The DFA analyses of various automobile parts done were studied and the current progress in the world of DFMA is shown in the following sub section:

3.1 Gear Box

DFA analysis was done on a gearbox by Shete et al. [2]. The gearbox analyzed was a 4-stage gearbox with helical gears and was assembled manually. The DFA index for the existing assembly was found to be 11.73 (as shown in Table 1) and the time for total assembly was found to be 940 seconds. As we know that design efficiency can be improved by analyzing it by DFMA software, the gearbox was then analyzed and the complete gearbox was divided into four sub-assemblies since it reduced the assembly time. After a few changes in the design like use of standard fasteners and reducing the parts, the DFA index was increased drastically and found to be 23.40 (as shown in table 1) and the assembly time was reduced to 630 seconds.

**Table 1. DFA analysis of a gear box [2]**

| Entries Including Repeats | Original Design | Re-Design | Saving s |
|---------------------------|-----------------|-----------|----------|
| 1. Parts meet minimum criteria | 30              | 19        | 11       |
| 2. Parts are candidates for elimination | 53              | 41        | 12       |
| 3. Analyzed subassemblies | 5               | 4         | 1        |
| 4. Separate assembly operations | 0              | 0         | 0        |
| 5. Total entries | 88              | 64        | 24       |

| Assembly labor time, s |        |        |          |
|------------------------|--------|--------|----------|
| 1. Parts meet minimum part criteria | 297.5  | 185.88 | 111.64   |
| 2. Parts are candidate for elimination | 622.1  | 415.95 | 206.15   |
| 3. Insertion of analysed subassemblies | 17.7   | 28.16  | -10.46   |
| 4. Separate assembly operation | 0      | 0      | 0        |
| 5. Total assembly labor time, s | 937.3  | 629.99 | 307.38   |

| Design Efficiency |        |        |          |
|-------------------|--------|--------|----------|
| 1. DFA index      | 11.7   | 23.40  | 11.67    |

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3.2 Bumper middle pole assembly

A DFMA analysis was done on a middle pole assembly of a bumper by Beijing Automotive Technology Center [3]. Middle pole’s main function is to provide points for mounting front grill and compound horn. Apart from this it also has to have sufficient stiffness to withstand impact force while closing of the bonnet cover.

The original design had many fasteners and number of parts. DFA was applied and the count of bolts and fasteners were reduced and the time for assembly was reduced from 552 seconds to 131 seconds. The DFA index was augmented by 70%.

Table 2. DFA Analysis of middle pole Assembly [3]

| Sl. No | Item            | Original Design | Re-Design | Savings |
|-------|-----------------|-----------------|-----------|---------|
| 1     | Parts           | 30              | 10        | 20      |
| 2     | Fasteners       | 20              | 6         | 14      |
| 3     | Actual Time, s  | 552 s           | 131 s     | 421 s   |
| 4     | Manufacturing Costs ₹ | ₹ 432.31 | ₹301.94     | ₹130.38 |
3.3 Instrument Panel

Peter Dewhurst [4] conducted DFA analysis on the instrumental panel of a model truck to reduce the cost of manufacturing and assembly. The original design had a total of 482 steps in assembly and a total of 123 fasteners and the total time for assembly was 3780 sec which on applying DFA was reduced to 121 steps in assembly, 23 fasteners and the time was reduced to 894 sec. The original design had a major of 4 injection molding structures which in proposed design was brought down to 2 injection moldings structures. A noticeable change was witnessed in the total cost.

| Sl. No | Item / processes       | Original Design | Re-Design | Savings |
|--------|------------------------|----------------|-----------|---------|
| 1      | Assembly steps         | 482            | 121       | 361     |
| 2.     | Fasteners              | 123            | 23        | 100     |
| 3.     | Items for elimination  | 173            | 39        | 134     |
| 4.     | Assemble               | 130            | 15        | 115     |
| 5.     | Time, s                | 3780 s         | 894 s     | 2886 s  |
| 6.     | Cost/IP                | ₹ 3149.14      | ₹ 608.12  | ₹ 2541.02 |

Figure 3. Comparison between Original and Re-design of bumper middle pole assembly
3.4 Jump Seat

Richard F. Johnson carried out DFA analysis on a jump seat. Jump seat is a seat which can be folded up and is mostly used in cars, taxis, busses and airplanes. The DFA analysis was done by “Magna Seating Group” with the aim of reducing the materials, sub-assemblies and tooling costs. On performing DFA analysis on the original design the number of separate parts was found to be 105 which were made up of 4 different types of materials. There were 6 major subassemblies and the total assembly time as found to be 1440 sec. which on Redesigning the part count was reduced to 19, the sub-assemblies were brought down to 5 and the total assembly time was found to be 258 seconds.

| Sl. No | Item               | Original Design | Re-Design | Savings |
|-------|--------------------|-----------------|-----------|---------|
| 1     | Parts              | 105             | 19        | 86      |
| 2     | Sub- assembles     | 6               | 5         | 1       |
| 3     | Actual Time,s      | 1440 s          | 258 s     | 1182 s  |

Table 4 DFA analysis of a Jump Seat

Figure 5. Comparison between Original and Re-design of a Jump Seat
3.5 Diesel Engine

Carla and Marcelo [6] performed the DFMA analysis on the cylindrical block of diesel Engine. Casings were not there in the cylinder block; open refrigeration system incorporated and it is connected directly to the gear box. When the analysis was done, the bearing cover bores were found to have potential for elimination. The number of parts found before DFMA analysis were 29, the assembly time was found to be 381 sec and a DFA index was 0.23. The non-pass bored and milling the assembly were found to be unnecessary and apart from this the block painting and the serial number plate of the engine were eliminated. After the re-design, the minimum number of parts was 29 and the assembly time was found to be 301 and DFA index was 0.29. This resulted in a reduction of price by 0.41%.

Table 5. DFA analysis of Diesel engine (cylindrical block) [6]

| Sl. No | Item               | Original Design | Re-Design | Savings |
|-------|--------------------|-----------------|-----------|---------|
| 1     | Parts              | 29              | 29        | 0       |
| 2.    | Operation time, s  | 381             | 301       | 80      |
| 3.    | DFA                | 0.23            | 0.29      | 0.06    |

![Figure 6. Comparison between Original and Re-design of cylindrical block](image)

3.6 Burring Tool

It is designed for performing flanging operation in components used in automobiles. It is an automotive tool assembly. Nilesh and Rajesh[7] have done the DFMA analysis on burring tool. The product was completely studied and the CAD model was fed into the DFA software to analyse the tool. The total part number was found to be 315 with a assembly time of 8709.26 seconds and the DFA index was found to be 2.68. On applying DFA, few redesign changes were implemented like standardization of fasteners, redesigning of lifting hooks, guide post and lower cap. The part number was reduced to 241, the assembly time was reduced to 6883.58 sec and DFA index was brought down to 3.39. The cost was reduced to 23.5% by applying DFMA.
Table 6. DFA analysis of Burring Tool [7]

| Entries Including Repeats | Original Design | Re-Design | Savings |
|----------------------------|-----------------|-----------|---------|
| 1. Parts meet minimum criteria | 30              | 30        | 0       |
| 2. Parts for elimination     | 185             | 147       | 38      |
| 3. Analyzed subassemblies   | 4               | 4         | 0       |
| 4. Separate assembly         | 96              | 60        | 36      |
| 5. Total entries             | 315             | 241       | 74      |

**Assembly labor**

|                          | Original Design | Re-Design | Savings |
|--------------------------|-----------------|-----------|---------|
| 1. Parts meet minimum criteria | 836.70          | 836.70    | 0 S     |
| 2. Parts for elimination  | 6326.83         | 4857.95   | 1468.88 S |
| 3. Insertion of analysed subassemblies | 734.33         | 734.33    | 0 S     |
| 4. Separate assembly operation | 811.40          | 454.60    | 356.8   |
| 5. Total assembly labor time | 8709.26         | 6883.58   | 1825.68 S |

**Design Efficiency**

|                          | Original Design | Re-Design | Savings |
|--------------------------|-----------------|-----------|---------|
| 1. DFA index             | 2.6             | 3.3       | 0.7     |
| 2. Re-Design             | 8              | 9         | 1       |

Figure 7. Comparison between Original and Re-design of Burring Tool
4.0 Summary
An overview of applications of DFA analysis of various automobile components is presented in this paper. DFA has a great potential to reduce the price of the component and the time for assembling the product. It follows a basic rule of eliminating all those parts which do not contribute to product’s functionality and properties. It has been shown through many examples that DFA provides a concrete support for reducing the assembly time. It is evident in many cases that the design efficiency can be improved substantially by applying DFA concept. While developing a new product, if DFA is applied at the early stages of design it can yield much better results. Therefore it can be inferred that DFA can be a great asset to product development and design process.

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