**REDESIGNING OF ELECTRIC PLUG FOR ASSEMBLY TIME REDUCTION USING DFA**

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Assembly time reduction during product development is an important task to meet the competitiveness in the market. Design for Manufacture and Assembly (DFMA) plays a key role in product development, especially in industries like aerospace, wherein variety in component geometry is more. Design for assembly (DFA) is a systematic procedure to maximize the use of components in the design of a product. Parts count reduction is one of the basic principles of DFA. Many of the companies successfully used this technique for product design improvement. The aim of present work is to propose a new design of electric plug assembly that is better in design efficiency, total assembly time. The analysis is done by using Boothroyd Dewhurst DFA method. There is a reduction in number of parts from 16 to 11 after redesign of electric plug assembly and assembly time is reduced from 87.4 s to 33.9 s. Design efficiency is improved from 36% to 64.89%. Assembly is an important stage in product development and accounts for one third of the labor time. Reducing the number of parts simplify design and enable easier and faster assembly.

***Keywords:*** DFA, redesign, product development, assembly time

1. **Introduction**

Designing For Assembly (DFA) has many benefits in addition to cost of assembly. When a product is simplified it becomes easier to assemble in the factory and to disassemble when maintenance, repair, or disassembly for recycling is required. Simpler assemblies often can be brought to market sooner because of fewer parts to design, procure, inspect, and stock with less probability that a delay will occur. Reducing the number of parts requires fewer engineering and production-control documents, lower inventory levels, reduced need for inspection and quality-control documents, fewer setups, less materials handling, and probably, reduced purchasing workload. DFA should be considered at all stages of the design process. As the design team conceptualizes alternative solutions and the members begin to realize their thoughts on paper, they should give serious consideration to the ease of assembly of the product or sub assembly during production and during field service. As concepts are analysed against selected cost and performance criteria, a systematic analysis of product assembly should be routinely performed. If cost or performance analyses require a concept to be altered or redefined, then the efficiency of assembly of the reconceived design should be analysed before final approval is made. During the detail design parts and assemblies, part features, dimensions and tolerances should be checked to make certain that it reflects the findings and conclusions of the DFA analysis. The analysis of a product design for ease of assembly depends to a large extent on whether the product is to be assembled manually, with special purpose automation, with general purpose automation (robots) or a combination of these.

1. **Literature review**

Douglas D. Lefever and Kristin L. Wood [1] has used a technique for reducing the number of components in assembly. This technique consists of component elimination procedure, component combination analysis and last established a logical approach for abstract component elimination or combination opportunities technique to redesign an auxiliary automobile visor. A.R. Ismail [2] has used DFM and DFA methodology for redesigning a pressure vessel. The existing design of the pressure vessel was modified by incorporating the design for manufacture and assembly requirements. Using DFMA Technique manual assembly efficiency is improved. N. Geren, M. Bayramoglu and U. Esme [3] has studied the design of intensiﬁer used in the prototype of a Water Jet Machining system. P. Suresha  , S. Ramabalanb  and U. Natarajan [4]  has done a research for determining environmental impact sustainability analysis and engineering analysis. A case study using charge alternator pulley is redesigned using DFMA technology. CAD modelling, stress analysis and sustainability analysis of pulley model done for reducing the product cost and minimal impact to the environment. Francis J. Emmatty & S. P. Sarmah [5] has presented a framework for modular product development by integrating function-based modular product architecture, platform-based design and design for manufacture and assembly. It reduces product manufacturing cost and through put time for product development. A case study of a watch mechanism was used by them. Akshay Harlalka C.D.Naiju Mukund nilakantan Janardhan and Izabela Nielsen [6] has used DFMA technique in reducing the time and cost in development of a new product. Food processor was taken as a case study and overall manufacturing cost was reduced. Many DFMA studies claiming significant cost reduction have been published till date. However, very few studies have addressed the consumer durables. No such study has been published on electric plug assembly. In addition, there are not much reported studies which outline the implementation of DFMA on Indian consumer products. The aim of this paper is to demonstrate that assembly time reduction is possible for a product and provide significant cost benefits to the manufacturing company.

1. **Methodology**

The first step of the present work is existing assembly design is analysed. Then, each part functionality is recognized. Material used for each part is also recognized. Symmetry of the product design is found based on the Alpha and Beta symmetry. Work sheet analysis is done based on the Boothroyd Dewhurst manual handling and manual insertion coding system. From that total operation time is calculated. Without effecting the functionality, each part has to study based on the criteria wherever elimination or redesign of part is required. Finally design efficiency is measured.

The number for theoretical minimum number of parts represents an ideal situation where separate parts are combined into single part unless, as each part is added to the assembly, one of the following criteria is met:

1. The part moves relative to all other parts already assembled during the normal operating mode of the final product. (small motions which can be accommodated by elastic hinges do not qualify.)
2. The part must be of a different material than, or must be isolated from, all other parts assembled (for insulation, electrical isolation, vibration damping etc.)
3. The part must be separate from all other assembles parts, otherwise the assembly of parts meeting one of the above criteria would be prevented.

Total operation time is the sum of the handling and insertion times multiplied by the number of parts.

An essential ingredient of the DFA method is the use of a measure of the assembly efficiency of a proposed design. In general, the two main factors that influence the assembly time of a product or subassembly are:

1. The total number of parts in a product and the ease of handling.
2. Insertion and fastening of the parts.

The assembly efficiency, Ema is obtained by dividing the theoretical minimum assembly time by the actual assembly time. [7]

**Ema=Nmin ta/tma** (1)

Where

Nmin – theoretical minimum number of parts

ta –basic assembly time for one part

tma- estimated time to complete the assembly of the actual product

**3.1. Effect of part symmetry on handling time:**

One of the principal geometrical design features that affects the time required to grasp and orient a part is its symmetry. Assembly operations always involve at least two component parts the part to be inserted and the part or assembly (receptacle) into which the part is inserted. Orientation involves the proper alignment of the part to be inserted relative to the corresponding receptacle and can always be divide into two distinct operations i) alignment of the axis of the part that corresponds to the axis of insertion ii) rotation of the part about this axis. There are two kinds of symmetry for the part: Alpha symmetry- which depends on the angle through which a part must be rotated about an axis perpendicular to the axis of insertion, to repeat its orientation. Beta symmetry-which depends on the angle through which a part must be rotated about the axis of insertion, to repeat its orientation [7].

1. **Case study**

In the present work electric plug (Anchor, 3 pin Top deluxe) is taken as a case study. Exploded view of the product is shown in Figure 1. Analysis of each part based on the DFA technique is shown in Table 1.

Table. 1. Work sheet analysis for electric plug assembly

|  |  |  |  |  |  |  |  |  |
| --- | --- | --- | --- | --- | --- | --- | --- | --- |
| **Item name** | **No. of items** | **Alpha +Beta** | **Manual handling code** | **Handling time per item, sec** | **Manual insertion code** | **Insertion time per item, sec** | **Total operation time, sec** | **Figures for minimum parts** |
| Top frame | 1 | 360+360 | 30 | 1.95 | 00 | 1.5 | 3.45 | 1 |
| Wire grip screw | 3 | 360+0 | 11 | 1.5 | 00 | 1.5 | 9 | 1 |
| Pin grip screw | 3 | 360+90 | 11 | 1.5 | 09 | 7.5 | 27 | 1 |
| Big pin | 1 | 360+0 | 11 | 1.5 | 00 | 1.5 | 3 | 1 |
| Small pin | 2 | 360+0 | 11 | 1.5 | 00 | 1.5 | 6 | 1 |
| Rubber grip | 1 | 180+180 | 11 | 1.5 | 10 | 4 | 5.5 | 0 |
| Rubber grip screw | 2 | 360+0 | 11 | 1.5 | 06 | 5.5 | 14 | 0 |
| Cord gripper | 1 | 0+360 | 11 | 1.5 | 03 | 3.5 | 5 | 0 |
| Bottom frame | 1 | 360+360 | 30 | 1.95 | 00 | 1.5 | 3.45 | 1 |
| Centre screw | 1 | 360+0 | 11 | 1.5 | 26 | 9.5 | 11 | 0 |
| Total | 16 |  |  |  |  |  | 87.4 |  |

1. **1. Component elimination and redesign of electric plug using DFA technique**

The first step of the DFMA analysis is existing assembly design is analysed with DFA analysis. Each part function is studied. Generally, maximum design efficiency improvement results from a reduction in the number of parts. To identify a part for elimination, there is a need to check whether the part satisfies the minimum part criteria. Any part not meeting the criteria is a part for elimination. The redesign steps were identified during the analysis are a) Integration of cord gripper to bottom frame, b) replacement of centre screw with transition fit joint, c) elimination of rubber grip and screws and redesign and d) redesign of pin grip screw. Redesign steps a, b and c are the most significant redesign changes as these are eliminated the need for a separate part altogether. Because of minimum number of parts separate manufacturing, documentation, inventory control and quality control strategy not required. In -fact eliminating a part in the design itself reduces the production cost. Redesign a part purely to reduce assembly time.

1. Integration of cord gripper to bottom frame: In the existing design of the electric plug, the cord gripper and bottom frame are separate parts. The cord gripper did not meet the minimum part criteria and is eliminated. To accommodate this bottom frame is redesigned.
2. Replacement of centre screw with transition fit joint: Transition fit joints provide many advantages over threaded joints. Threaded joints take more assembly time and material cost is increased because of separate screws. In electric plug assembly while fastening the centre screw to bottom frame obstructed the part and restricted the vision. By replacing this centre screw with a fit saves the assembly time, cost and improves the easiness of assembly.
3. Elimination of rubber grip and screws and redesign: Main function of this rubber grip is to provide guidance to the card. In the original design it is taking major assembly time. Eliminating the rubber grip and screws based on the minimum part criteria it is integrated with the top frame.
4. Redesign of pin grip screw: Orientation of the pin grip screw is consuming more time during assembly. Based on the concept of part symmetry on handling time pin grip screw is redesigned. Eliminated the square seating into circular seating. While assembling more concentration and care is not required. In turn it reduces operation time from 27 sec to 9 sec.

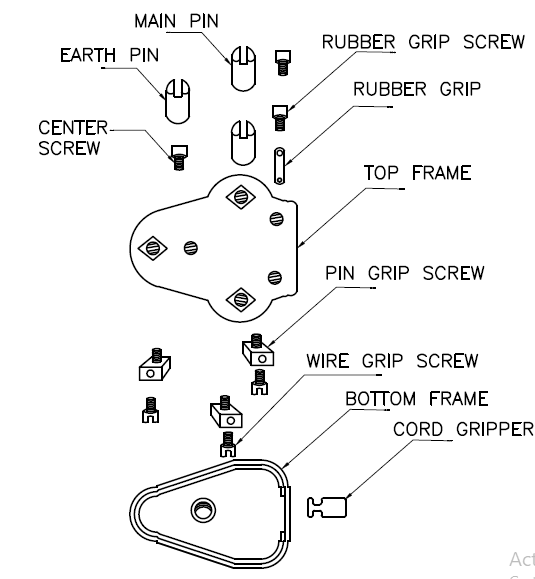


Fig. 1. Exploded view of Electric plug assembly

ta = 2 sec (basic assembly - handling and insertion time for one part and can be taken as 2sec on average). The original design consists of Nmin=16 parts and estimated assembly time is tma=87.4 sec. Then design efficiency from equation (1) obtained as 36%. After implementing DFA analysis minimum number of parts are reduced to Nmin=11 parts and estimated assembly time is tma=33.9 sec. Finally design efficiency is improved to 64.89%. Further, prototype has to be prepared by using Rapid Prototyping Technique (RPT) and results has to verify.

Table. 2. Redesign of electric plug assembly

|  |  |  |
| --- | --- | --- |
| Name of the part | Before DFA | After DFA |
| Bottom frame |  |  |
| Top frame |  |  |
| Pin grip screw |  |  |

1. **Conclusion**

This paper illustrates the various DFA considerations in the design of existing product used in the Indian market. The DFA approach is essential to reduce the assembly time of product development. For improving the design and assembly of the electric plug product is presented in detail. Using DFA methodology assembly efficiency can be improved from 36% to 64.89%. Because of reducing the assembly time production cost can be reduced. In turn profitability of the industry can be increased. Moreover, electrical products like electric plug are manufactured on a large scale and the cumulative time and cost savings to the company can be more significant. DFA methodology in connection with design for environment is more powerful tool to reduce the cost of the product.

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