DESIGN FOR ASSEMBLY: AN APPROACH TO INCREASE DESIGN EFFICIENCY OF ELECTRONICS HOME APPLIANCE

Shah Rima\textsuperscript{a}, Park Hong-Seok\textsuperscript{a}, Lee Gyu-Bong\textsuperscript{b}

\textsuperscript{a}Department of Mechanical and Automotive engineering, University of Ulsan, Daheak-ro 93, Nam-gu, Ulsan 680-749, South Korea
\textsuperscript{b}Korean institute of Industrial Technology, South Korea

Abstract

Innovations lead market. In today's computational and technocrat world, product development needs a prompt respond to accomplish market demands in short time and must be economically sustainable. Since the product design strongly affects the assembly process, it must be taken care at the initial stage which results in improving manufacturing process, saving assembly time and thereby cost. In this paper, an active approach to reduce the number of parts and thereby increasing design efficiency has been taken into consideration. Design for assembly (DFA) approach was applied to facilitate product structure without losing its standardization and functionality of product. Comparative analysis between, current and proposed design of refrigerator components like evaporator fan in freezing compartment and door hinge assembly are described out of the many sub assembly part reduction in total number of parts of refrigerator. Using DFA guidelines, we reduced total number of parts from 328 to 172, thereby leading to increase in design efficiency by more than 25\%. The results obtained from the analysis leads to achieve our required expectations and can be further applied in manufacturing industries in order to improve the design efficiency.

Keywords Design for assembly; standardized parts; manual handling; refrigerator; design efficiency

DOI: 10.2507/26th.daaam.proceedings.122
1. Introduction

In the world of globalization, customer requirements must be able to respond quickly by the product manufacturers with attractive and better quality product. Nowadays industries especially manufacturer trying to cut down their manufacturing cost by regulated and enhanced the assembly method at the same time increase the profit. In order to respond to the market requirements along with competitiveness over other manufacturers, an optimal method must be applied proximately. By evaluating assembly and manufacturing process during early stage of product design, using sophisticated method, well-furnished product can be allocated in the market. Assembly cost plays vital role in the process of manufacturing which mostly ignored during the designing stage. This problem has occurred due to shortening of the lifecycle of product so in the present production environment, specific procedure is necessary to provide product as quickly as possible. To introduce this specific method, following key points must be examined during the early phase of product design: standardized part, self-locating and self-alignment of assembly, use of symmetric/asymmetric parts, top to bottom assembly sequence, which are mentioned in design for assembly. DFA methodology, was introduced by Boothroyd and Dewhurst at University of Massachusetts in 1989 [1] with the goal of simplifying the component design that are good for assembly. Later in 1992, Boothroyd encode the DFA techniques in software [2]. This proposed DFA methodology was widely accepted in diversified manufacturing industries. It implies that it’s not restricted to particular segment but also can be applied to all such products which involve assembly. Later the DFA method was applied in reverse engineering and redesigned by D. Lefever et.al in 1996 [3]. A proposed methodology for optimal assembly sequence was generated by Profesoor Hong-Seok park with the help of knowledge experts in 2000 [4]. Further, DFA was used for product simplification which reduces assembly cost, by Priest J.W et.al in 2001 [5]. In 2010, Masahiro Arakawa used DFA for redesign of Robot (Meduss II) [6]. Based on the assembly point of view, a product design evaluation was proposed by S. Katarina et.al in 2011 [7]. The innovative process design was used for Double gear pumps by C. Opran et.al in 2015 [8]. This diversification of customer requirements and the shortening of product life cycle have created a need for companies to manufacture and develop various types of products in a short-period of time [9] and development of new product is a creative and complex process, which is essentially arduous to improve and organize. Therefore, effective strategies are required to design the product.

In this paper, using selected DFA Methodology parameters, we have tried to reduce the number of parts with simplified design thereby increasing the design efficiency and reducing assembly time. The main goal to focus in the area of electrical home appliances is due to high product demand and ultra-competitive market in terms of time, quality and cost. Out of many Assembly sequential processes, we have focused on refrigerator’s two main compartments; one is freezing compartment in which we targeted evaporator fan assembly and another cabinet compartment in which we focused on hinge assembly. The DFA guidelines proved to be beneficial for achieving goal of this paper which is discussed furthermore in paper.

Nomenclature

<table>
<thead>
<tr>
<th>DFA</th>
<th>Design for assembly</th>
</tr>
</thead>
<tbody>
<tr>
<td>B &amp; D</td>
<td>Boothroyd and Dewhurts</td>
</tr>
<tr>
<td>$N_m$</td>
<td>Theoretical minimum number of parts</td>
</tr>
<tr>
<td>$t_a$</td>
<td>Basic assembly time for one part</td>
</tr>
<tr>
<td>$t_{ma}$</td>
<td>Estimated time to complete assembly of the product</td>
</tr>
<tr>
<td>$t_m$</td>
<td>Total number of parts</td>
</tr>
</tbody>
</table>

2. Project overview

2.1. Design for assembly

DFA principles and guidelines were developed to assist the designer by establishing feedback on the consequences of design decisions of product assembly with the aim to guide the designer to create an economic and efficient product structure. M.Andreasen.S. kahler and T.Lund blame this limited consideration for assembly during design on lack of time or deficient time planning, lack of realization as to the importance of assembly, lack of knowledge of design oriented assembly, the habit of saying “they usually work it out in production”, and/or organizational problems which restrict a fruitful co-operation between employee from various functional areas [3].Modern assembly process needs to be applied to analyse, criticize and remake the existing product designs, although researches have shown that the decision during the design stage determine 70% of the product costs, for
the decisions made during the production correspond to only 20% of these costs[10]. Therefore, the inclusion and integration of product life cycle activities into the product development process have received much attention over the last two decades, especially at the detailed design phase.

DFA is a systematic analysis process primarily intended to reduce the assembly cost of a product and production time by simplifying the product design [11]. DFA can be strongly advantageous if applied during the initial phase of the product design since it will be beneficial in manufacturing process and reduce the assembly time and production cost. Boothroyds Dewhurt’s DFA methodology allows the designers to rate assemblability of their product designs quantitatively [12] and it is highly used in the industries.

2.2. Approach

We have implemented B&D DFA approach, using six basic principles; Reduce part handling, Easier handling of parts, introduction of high level of assembly mean top-down assembly sequence, reduction of non-value added assembly, Easy insertion assembly and self-avoidance assembly. It is mainly depending on analysis of product assemblability through numerical parameter calculations. This paper depicts the analysis and calculation of current and re-designed component’s design efficiency through short-listed Principals of B&D DFA manual method. In order to minimize the number of parts and simplify the design for components B&D guidelines were used as described in fig.1. In this assembly analysis process total assembly score will be counted in terms of design efficiency. Once the appropriate score have been achieved it will move forward to assembly line process else it has to be modified by Design team. Designed structure should be analysed by process analysis team before the implementation of design to product form.

2.3. Design improvement using DFA

We tried to modify and redesign some components of the refrigerator using DFA guidelines. The Fig.2 shows the refrigerator and its different compartment which was dissamble and ressemble by us to understand the comfortness of assembly, assembly time and ease of handling and insertion ratio.

Fig. 1. Concept of the DFA analysis

Fig. 2. A Case study of refrigerator’s freezer compartment
Current design of the selected compartment and redesign of the assembly of freezer compartment, evaporator fan with motor, hinge assembly and door assembly has been shown in fig.3 simultaneously. After experimental data and design evaluation we redesign the component with different geometry, angle, reducing number of parts and handling position. In this paper, we represent a brief overview of the some of components out of whole design of the refrigerator which reduces about half of the actual design for some part of the component or one forth parts for rest of components. The current design data collection was based on the actual product review, engineering drawing and assembly process. After that, modified design of the current parts of refrigerator proposed on based on B&D DFA guideline in order to minimize the total number of parts count, easy insertion of the assembly and reduce the complexity of assembly process. Then, the design efficiency of the current and redesign both were calculated. If the design efficiency of new component does not achieve B&D ideal value than redesign component will be repeated else the component will be proposed.

3. Results and analysis

From the experimental design analysis of the refrigerator, the minimum parts of the door assembly were reduced to 29 which in original are 38. Apart from that Freezing compartment parts in are originally 69 which is reduced to 54 and refrigerating assembly parts is reduced from 328 to 110. In designing new product, it depicts that the concept in making new component is more focused on the body of that part and its joining method. After examination of the feeding and the fitting analysis, the actual component utilize high ratio than modified component which entails the cost of the assembly of current product’s is higher than modified. Design efficiency for the product development is calculated on the base of the theoretical number of parts, time taken to assemble the parts and total parts count of the component. Table 1, depicts the design efficiency of the current and redesigned evaporator fan with motor used in freezer compartment and table 2, represents the overall design efficiency of the current and redesigned parts of the refrigerator to be assembled.

3.1 Calculation

(A) Design Efficiency of the current evaporator fan with motor’s design

\[ E_{ma} = N_{min} \times \left( \frac{t_a}{t_{ma}} \right) \]

Where, \( t_a = t_{ma}/t_m \)

\[ = [10 \times (11.52/196)] \times 100 \]

\[ = 58\% \]

<table>
<thead>
<tr>
<th>Refrigerator Design</th>
<th>Number of parts</th>
<th>Total operation time (second)</th>
<th>Minimum parts count</th>
<th>Design Efficiency (%)</th>
</tr>
</thead>
<tbody>
<tr>
<td>Current</td>
<td>17</td>
<td>196</td>
<td>10</td>
<td>58</td>
</tr>
<tr>
<td>Proposed</td>
<td>9</td>
<td>103</td>
<td>7</td>
<td>78</td>
</tr>
</tbody>
</table>

Table 1. Design efficiency of evaporator fan with motor
Table 2. Design efficiency for assembly of refrigerator

<table>
<thead>
<tr>
<th>Refrigerator Design</th>
<th>Number of parts</th>
<th>Total operation time (second)</th>
<th>Minimum parts count</th>
<th>Design Efficiency (%)</th>
</tr>
</thead>
<tbody>
<tr>
<td>Current</td>
<td>328</td>
<td>2847</td>
<td>126</td>
<td>38</td>
</tr>
<tr>
<td>Proposed</td>
<td>172</td>
<td>1450</td>
<td>110</td>
<td>63.9</td>
</tr>
</tbody>
</table>

Design Efficiency of the Re-designed evaporator fan with motor’s design

\[
E_{ma} = N_{\text{min}} \times \left( \frac{t_{a}}{t_{\text{ma}}} \right)
\]

\[
= [7 \times (11.44/103)] \times 100
\]

= 78%

(B) Calculation of current refrigerator’s Design efficiency

\[
E_{ma} = N_{\text{min}} \times \left( \frac{t_{a}}{t_{\text{ma}}} \right)
\]

(Where, \(t_{a} = t_{\text{ma}}/t_{\text{ma}}\))

\[
= [126 \times (8.67/2847)] \times 100
\]

= 38%

Calculation of modified refrigerator’s Design efficiency

\[
E_{ma} = N_{\text{min}} \times \left( \frac{t_{a}}{t_{\text{ma}}} \right)
\]

\[
= [110 \times (8.43/1450)] \times 100
\]

= 63.9%

4. Conclusion

In spite of the primary contribution of method which simplifies the product structure and reduces the assembly time we proved that if DFA structure is applied in early stage of the product design, it seeks an ergonomics improvement at work site and at assembly line. The result represent that the total number of counts are being reduced with feasible approach to integrated DFA analysis and design efficiency of the product increased by 25% compared to current product. The application of DFA is not limited to specific production process. It can be applied to many different fields of the assembly line process and workstations for new product development. The cost cutting and ease of assembly by reducing time is achieved which benefits the industrial sector and is also effective in re-engineering of product development.

Further study areas are improving the manual handling of subassembly assembly process of the refrigerator. This area is not restricted with only to electrical home appliances but it’s a general for all the manufacturing industries where assembly is their main constraint especially manual handling process.

5. Acknowledgement

This work was supported by University of Ulsan.

6. References


[12] Dr. A. Chang, Dr. W. Peterson, Using design for assembly methodology to improve product development and design learning at MSU, American society for engineering education, ss(2012).