DESIGN OPTIMIZATION ON EVELATOR CAR FOR DOUBLE-DECK SYSTEM

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Abstract:

This study is focused on CE based design processes and design tools DFA and DFMt. After discussing these design tools' structures and criticizing advantages and disadvantages of them, an industrial case study will be illustrated. Some subassemblies of one filling and packaging system have been redesigned with the help of CAD software. Then current and new designs have been compared at the point of assembly time, ease of assembly, part varieties and quantities, required equipment quantities and complexity. In this study, Boothroyd & Dewhurst DFA Method have been chosen for evaluation procedure. Renewed designs were compared according to their part numbers, costs, efficiency and reliability.

Keywords: DOUBLE DECK, ELEVATOR CAR, BOOTHROYD-DEWHURST METHOD, DFMA

1. Introduction

Manufacturing of a product has a lot of steps up to the final product and these steps contain some others. Planning, product design and product development, material selection, management marketing are some of these processes. These processes involve the design process and designers need to use systematic approaches for the great design. For this reason, user involvement has become a widely accepted point of the usable systems [1-4].

The most common purpose of the design and manufacturing works is reducing the cost and time factors. So, reaching to the final product will be easy with the decrease of time and cost. Design and manufacturing phases of a product are related to each other. Optimising these concepts automatically helps to improve the simplicity of the operations [5-7].

Engineering design is a process of developing a system, component, part or process to meet desired needs with a basic meaning. Keeping in mind this main definition and current competitive commercial conditions, the importance of Concurrent Engineering (CE) can be understood better. Beginning from the late '70s, because of improvements in manufacturing and automation systems, Design for Assembly (DFA) and Design for Maintainability (DFMt) have growing importance at design engineering. Both scientific and industrial area, many studies have been done since last 25 years and many articles have been published. The implementations of DFA and DFMt led to enormous benefits including simplification of products, reduction of assembly and manufacturing costs, improvements of quality, reliability and reduction of time to market.

There are great number of methods that provide the desired features on design and manufacturing. Design for manufacturing and assembly method is one of them and it is generally evaluated as using the basis for concurrent engineering. The aim of the usage of the method is reducing the costs of manufacturing and assembly steps, simplifiying the product structure by redesigning it with the fewer parts and ease of manufacturing. The method is the combination of Design for Manufacturing (DFM) and Design for Assembly (DFA) methodologies. DFM means the ease of manufacturing and DFA is the assembly design of the product [8-9].

There are many of published studies on design for assembly application in computer aided engineering [1-9]. Design for assembly (DFA) is a product of the automation endeavors of the late seventies and early eighties when moves toward high levels of automated assembly highlighted deficiencies in current product design with respect to automation capability. There are a number of designs for assembly techniques and evaluative mechanisms [7]. The three best-known and also the most well-documented DFA methods are the Boothroyd Dewhurst System, the Lucas DFA Methodology and the Hitachi Assemblablity Evaluation Method [8,9]. Boothroyd-Dewhurst Method is based on two principles: (a) the application of criteria to each part to determine if it should be separate from all other parts, and (b) estimation of the handling and assembly costs for each part using the appropriate assembly process [10].

The works of the manufacturing and design developments contain every areas of products. Transportation area is also one of the developable areas with the new technologies and elevator industry is essential for especially high rise buildings. Sometimes, conventional systems can not meet the requirements for high rise buildings. Double deck elevators were developed to avoid this negotiation.

An application of double deck elevators will be given with details and the effect of the method on the original and revised designs will be evaluated via the related method and the effect of the method on the revised product will be considered. The enhancement of the revised product will be evaluated depend on the related method criterions.

2. Design for Assembly and Manufacturing

DFA is a systematic method, which analyzes product designs to improve assembly easy and reduce assembly time. DFA method can be also explained by helpful of Design for Manufacturing. The objective of DFM is integration of product design and process planning into one common activity. DFA as a central element of DFM has one important characteristic and it addresses product structure simplification, since the total number of parts in a product is a key indicator of product assembly quality.

A review is made of design for assembly (DFA) methods developed over the last fifteen years. It is round that implementation of DFA at the early conceptual stage of design has led to enormous benefits including simplification of products, lower assembly and manufacturing costs, reduced overheads, improved quality and reduced time to market. This integrated structure of DFA and DFM is illustrated in Figure 1 [8,9].

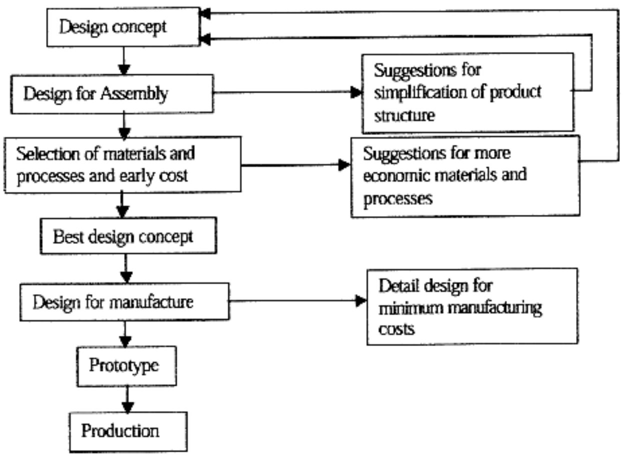


***Fig. 1:** Typical stages in a DFMA procedure*

DFA methodologies were developed to support the designer by generating feedback on the consequences of design decisions on product assembly. The aim is to help the designer to produce an efficient and economic design. The application of DFA guides the designer towards a product with an optimum number of parts that requires simple, cost-effective assembly operations and the most appropriate manufacturing processes and materials for its components [8,9]. A number of different DFA methodologies have been developed recently and there are several quantitative evaluation DFA methods. Three best-known and also the most well-documented DFA methods are Boothroyd & Dewhurst DFA Method, Lucas DFA Method and Hitachi Assemblability Evaluation Method [8,9]. In this study, Boothroyd & Dewhurst DFA Method have been chosen for evaluation procedure. Design implementations can be carried out using either its handbook or its DFA software. This method can be applied to either manual assembly systems, special-purpose assembly systems or robot assembly systems.

The aim of design for assembly (DFA) is to simplify the product so that the cost of assembly is reduced. However, consequences of applying DFA usually include improved quality and reliability, and a reduction in production equipment and part inventory. These secondary benefits often outweigh the cost reductions in assembly. It recognizes the need to analyze both the part design and the whole product for any assembly problems early in the design process. Design for assembly concept may be defined as a process for improving product design for easy and low-cost assembly, focusing on functionality and on assemblability concurrently.

3. Boothroyd Dewhurst Method Approaches

Boothroyd-Dewhurst method is a widely used method of the design for manufacturing and assembly and the objective of the method is minimizing the assembly requirement for existing products. This can be achieved by reducing the number of parts to have assembled for the product. Also, the shape and complexity tried to hold on the minimum. The procedure of Boothroyd-Dewhurst method can be divided into the three steps. The first one is assembly type selection. The assembly type selection stage is determined with the factors such as complexity, shape and tolerance. The next issue is ensuring that the remaining parts are easy to assemble. The last factor is reducing the number of individual parts that must be assembled.

In the Boothroyd-Dewhurst method, the works generally contains the original and re-designed works of a product and they are compared depend on assembly cost, part number, handling time and insertion time factors. The final revised design is expected to have lesser value of the design efficiency coefficient [2,4,10].

The flow of the application is considered depend on the Boothoyd Dewhurst rules [10]. The parts of the new design are considered with their elimination situation. It can be eliminated or there is a combination with another parts of the related assembly.

After applying the method to the product, there are;

- Lowered part numbers and assembly varieties
- The symmetrical parts and ease of handling. So, design efficiency increases automatically.
- Minimised number of the fault for the assembly of a product

Boothroyd & Dewhurst DFA Method address the problems of to determine the suitable assembly method, to reduce the number of each part that must be assembled, and to get the handling and insertion processes easily [2]. This method has two strong points of consideration. First, one is effort of reducing the number of part since saving the functionality of product. If all answers are NO, then the part can be eliminated or combined with the others [4]. Secondly, this method is based on a system of penalties, which for the particular activity, including part's handling, part's insertion and using these penalties a quantitative judgment options can be established. Using the explanations and tables of handbook, each part in the assembly is compared to its handling and insertion situations.

It is important to quantify the improvements and goals of DFA. Two methods for DFA quantification considered here are the Boothroyd-Dewhurst method and the Lucas method. Boothroyd-Dewhurst Method is based on two principles:

- the application of criteria to each part to determine if it should be separate from all other parts.
- estimation of the handling and assembly costs for each part using the appropriate assembly process.

This method relies on an existing design which is iteratively evaluated and improved. Generally, the process follows these steps:

1. Select an assembly method for each part
2. Analyze the parts for the given assembly methods
3. Refine the design in response to shortcomings identify by the analysis
4. Loop to step 2 until the analysis yields a sufficient design

The values are collected and it is obtained a total assembly time. Then DFA index of assembly is computed. The DFA index of a product is computed with $EM = AM \times (NM \times TM)$ where EM is DFA Index, AM is basic assembly time for each part, NM is theoretical minimum number of parts, and TM is total assembly time. AM can be accepted as 3 s. as generally. Different implementations can be used different basic assembly times. However, it provides an accurate relative comparison between design choices [2,4,10] On the calculations; the number of the each part, manual handling time of the parts, manual insertion times, total operation time, operation cost and the decision that if the part can be eliminated or not are used. Operation cost is a function of operation time (0.4 x operation time). TM is the sum of the operation times, CM is the sum of the operation costs and NM is the total number of the parts that will not be eliminated. Figure 2 shows the relation between the part number and design efficiency. Operation times are calculated with sum of part number times sum of total handling and insertion times. TM, CM and NM are choosen than the related tables. This tables are manual handling and manual insertion tables.

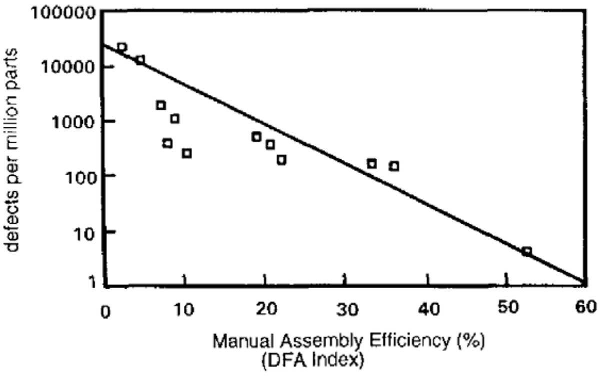
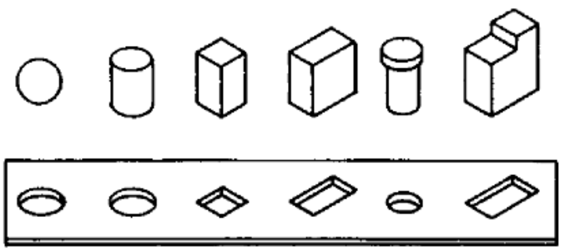


Fig. 2 *Design efficiency relation with part number[10]*

Insertion time can be determined via the assembly difficulties. The table has the angle values for alpha and beta symmetries. Alpha symmetry is rotational symmetry of a part about an axis perpendicular to its axis of insertion and beta symmetry is rotational symmetry of a part about its axis of insertion [10]. Alpha and beta rotational symmetries for part shapes can be determined by using Table 1.

Table 1: *Alpha and beta symmetries determination table [10]*



α	0	180	180	90	360	360
β	0	0	90	180	0	360

Part thickness and shape also have an effect on determining the handling time. Figure 3 show the relation between handling time and part thickness and the effect of part shape to the handling time.

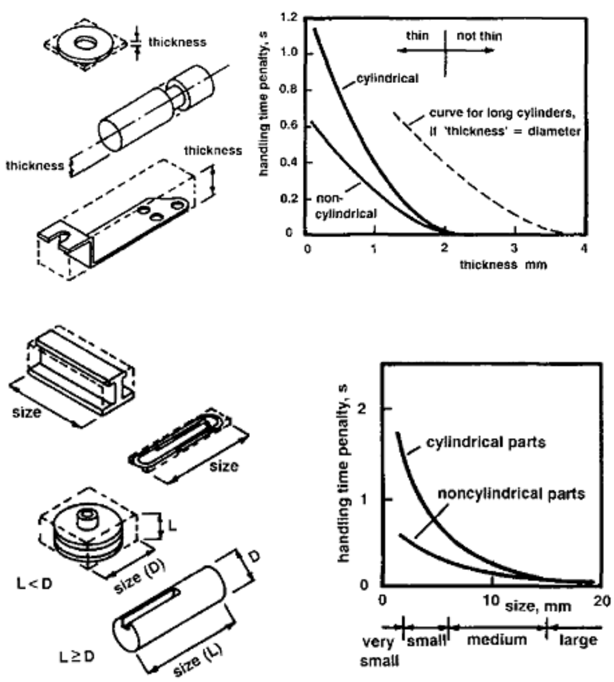


Fig. 3 *Effect of part thickness and part size on the handling time*

This method contains the improvement with the part considerations on elimination possibility of the parts and combinations between the parts.

It's obviously seen that the assembly becomes easier with the new design. By changing the assembly, efficiency of the design is considered and the improvement of the new design is given in percentage.

4. Double Deck Elevators

Reducing the space required by elevators in high-rise buildings is the use of mutlideck or double deck elevators. Here the upper and lower decks of each elevator are loaded simultaneously with passengers destined for the odd-numbered floors entering the lower deck and those for the even-numbered floors entering the upper deck [11]. There are many advantages to using double-deck elevators, among which are the following: (1) more passenger-handling space per hoistway, (2) fewer double-deck elevator are required, (3) up-peak operation is optimized.

Double deck elevators are the systems that designed with two elevator cars and one car is attached on top of the other on the whole system. Both cabs are connected to a single carcass and a drive system together. The lower deck and the upper deck serve two adjacent floors and it allows the passengers on two consecutive floors to be able to use the elevator simultaneously. During a trip, the two decks are arranged to serve odd and even floors. The passengers at the even and odd floors use the related deck to reach to the destination that they want. Double deck elevator systems require escalators or stairs for the transportation of the passengers from ground floor to the upper floor. A view of a common double deck system can be seen in Figure 4.

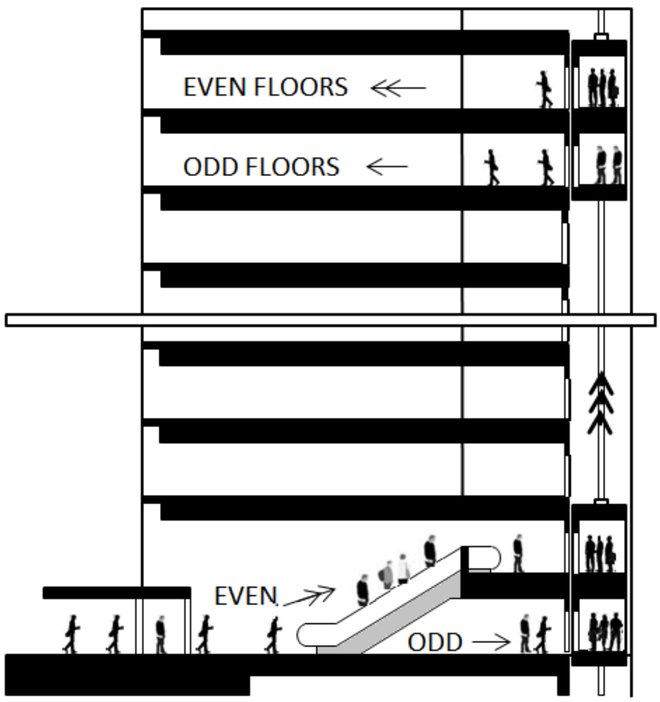


Fig.4 *Sectional rendering of double deck elevators*

Double deck elevators are the systems that two elevator cars are attached one on top of the another (see Figure 5). The main concept of the product development is needed to be explained depend on the related design first and the properties of product development concept will be associated with design for manufacturing and assembly method. The sequential and concurrent approaches are also needed to be determined.

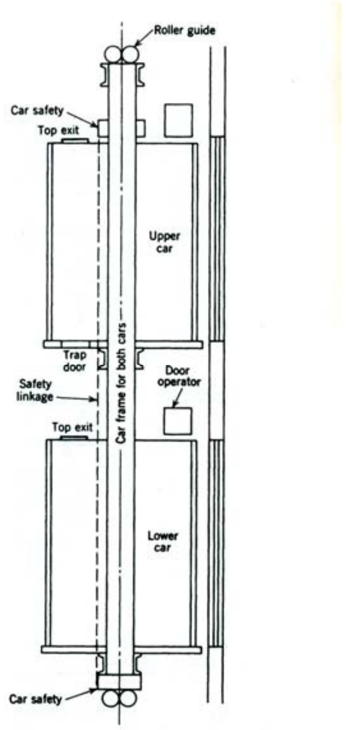


Fig.5 *Double-decked elevator car [11]*

5. Application on Double Deck Elevator Car

In this work, a double deck elevator car will be determined depend on the Boothroyd-Dewhurst method and the factors of the design for the original and revised designs will be compared. Figure 5 shows the original design of the double deck. The thickness of the ground of the cabs are 3 mm. The other sheets have the 1.5 mm. Design of the original double deck car can be seen in Figure 6.

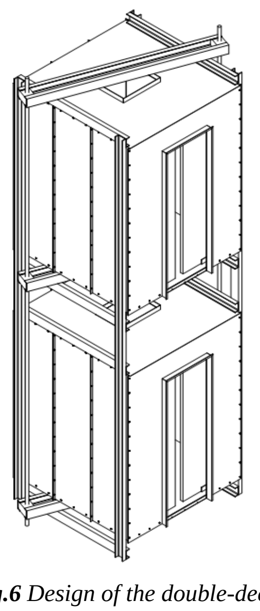


Fig.6 *Design of the double-deck elevator car*

The sheet part is inserted in the chassis. The number of fasteners is reduced significantly at the revised design. All the fastener parts are groups and a bolt needs washer and nut to complete the assembly. So, one part of fastener causes three parts to the design. Also, Table 2 shows the modular sheet number at the original design. It is significantly reduced by the support elements. There is just 12 parts support element for the double deck added to the design for reducing the side sheet number. The other parts have the same value in both designs. Total mass of the revised deck is almost the half of the mass of the original design. So, the same functional product is designed with the half mass for the whole design. This is one of the benefits of the related method.

Part number of the new design is less than the half of the original design. The original one was with fastener design and there were too many parts on the car. So, the cost and assembly time were higher. The revised car was designed to reduce the number of parts and so the cost became lower at the new design and efficiency factor becomes higher [12-15]. The first one has 1188 parts. There are 26 different kind of parts and total time of manual handling and manual insertions is 8701,6 seconds. For the revised design, the number different kind of parts is 27 but there are totally 572 parts in the whole system for the double deck. Total time for handling and insertion is 4444,88.

6. Conclusions

Elevator car design for the double deck systems is the subject of the study. Design for manufacturing and assembly methods are considered for the design. Original and revised elevator cars are evaluated by using Boothroyd- Dewhurst methodology. Design efficiency factor is calculated and the values of design efficiency for both designs are compared. Number of parts at the original car is tried to be halved. An analyze model and the calculations are given and the compare of the systems is shown in tables. Total assembly cost is an important factor on manufacturing as total assembly time.

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