DOI: 10.5604/01.3001.0053.5954

Volume 117 • Issue 1 • March 2023

Journal of Achievements in Materials and Manufacturing Engineering

International Scientific Journal published monthly by the World Academy of Materials and Manufacturing Engineering

Redesign of iron for assembly cost and time reduction using DFA

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ABSTRACT

Purpose: Nowadays, product development is very important to remain competitive in the market, one of which is to reduce the assembly of time and cost design. This article discusses the study of iron products on the market. Based on the problems found in the SMEs of Electronic Services, this iron has many components and complex designs that take time-consuming to assemble. Therefore, the purpose of this article is to redesign the ironing.

Design/methodology/approach: Improvements to the design of iron products are based on the problems present in this product. This problem is obtained by distributing questionnaires to Electronic Services SMEs. The improvements are carried out using the Design for Assembly (DFA) method to evaluate the design with ease of assembly processes.

Findings: This paper attempt to improve the design of ironing products according to the problems obtained from the initial questionnaire, which is to reduce the assembly time and costs using DFA.

Practical implications: The result of these improvements is a reduction in the amount of assembly time and costs and an increase in efficiency. The actual design assembly time is 358.16 to 269.70 seconds on the proposed design. The actual design assembly cost budget is 956.81,- rupiahs, reduced to 720.50, in the proposed design. Then the actual design efficiency of 21.77% increased to 24.74%.

Originality/value: Iron design improvements are based on problems and complaints received from the electronic services SMEs, then analysed using the DFA method. Therefore, the improvements in the design of the ironing product are present in two components, that is the back cover and the handle.

Keywords: Iron, DFA, Assembly time, Assembly cost

Reference to this paper should be given in the following way:

R. Ginting, R. Silalahi, Redesign of iron for assembly cost and time reduction using DFA, Journal of Achievements in Materials and Manufacturing Engineering 117/1 (2023) 15-24.

DOI: https://doi.org/10.5604/01.3001.0053.5954

ANALYSIS AND MODELLING

1. Introduction

Technological developments make manufacturing companies capable of surviving in a competitive market. One is by developing new products with low design time and costs. Product development can be done by improving the attributes or designs of existing products to improve the quality of the product. In order to decrease design time and costs and increase product quality, new products are typically generated by improving the functioning and design of old ones by changing their components and requirements [1]. The manufacturing sector has undergone numerous changes since the first industrial revolution, from design development to shop floor operations. Design for Manufacturing and Design For Assembly/Disassembly address the maintenance of waste, cost reduction, and remanufacturing among these adjustments [2].

In 1987, Boothroyd and Dewhurst conducted a lot of research on assembly boundaries during the design stage to avoid manufacturing and assembly problems during the product development stage [3,4]. The product should be designed using an appropriate economic assembly system to obtain the lowest assembly cost.

DFX techniques have been created recently to help designers in their work. The letter "X" in DFX refers to a stage in the life cycle of the product (such as manufacturing or assembly) or describes the qualities that the product should have. Techniques for effective DFA are well-known and frequently employed in a variety of sizable sectors. DfA promotes cutting costs associated with manufacturing products and offers far more advantages than only speeding up assembly [5,6].

In order to make a product more affordable to create and assemble, DFA plays a vital role in the product's design. Prior to creating a full product model, the major goal of the conceptual DFA technique, as described by the authors, is to decrease assembly time and costs by lowering the number of components. However, the conceptual DFA does not take into account factors of manufacturability, like material selection or the best method for creating components and pieces.

For certain goods, the design phase of product development is a protracted and iterative process. Activities during the design stage can be categorised into four basic phases: problem definition, client needs analysis, conceptual design, embodiment design, and detailed design. The important first phase is the collection and analysis of customer needs, followed by the translation of those requirements into product functions and features, and lastly, the generation and modelling of concepts that satisfy requirements [7].

In this context, the approach proposed in the application of the DFA method takes into account the needs of consumers. In this case, the intended consumers are SMEs of electronic services. Design improvements are based on problems that occur in the product assembly process. Iron is a small tool used to remove wrinkles from cloth. It is also known as a clothes iron, flat iron, or smoothing iron [8]. There are several features in modern electrical ironing, such as thermostats, power cords, wire control, and energy-saving control. Still, sometimes these features are not needed as they will accommodate more parts, thus increasing cost and production time.

The improvements in ironing product design are based on the problems found in this product. This was obtained by distributing a preliminary questionnaire to SMEs of electronic services. So in the assembly process, there are complaints, such as a large number of iron components and the complicated design of the iron. This resulted in a long assembly time.

This research aims to obtain a product design that can minimise the time and cost of the iron assembly.

The organisation of writing this article is divided into six parts. Following this introduction, Section 2 reviews the previous research literature. Section 3 looks in detail at the research methodology. Section 4 implements the proposed framework. Results and discussion are presented in the fifth section. The last section presents a summary of the research findings.

2. Literature review

Boothroyd and Dewhurst created DFA as a technique for accounting for assembly procedures, costs, and time during the product design phase. DfA is a methodology that equips designers with a style of thinking and instructions for creating items favourable to the assembly process. DfA suggests a methodical approach to maximise using the same components and pinpoint the primary assembly-time-problematic solutions. One of the most widely used DfA approaches in industrial practice is the B&D methodology, while others include the Westinghouse, Lucas, and Hitachi-AEM approaches [8-10].

According to Massimo Makovac and Peter Butala, DFA is one of the engineering characteristics that should be considered during design. It has a high priority because of its potential to reduce costs. The final design needs to be a compromise that offers the best overall solution. DFA is generic in nature and can be used in the first stages of development [11].

Wee Soon Chai and Azli Nawawi used this method to reduce the number of components and minimise the cost of a selected product, namely a table fan, by redesigning and analysing it. The analysis was conducted according to the Boothroyd Dewhurst method using the DFA worksheet. As a result, the new table fan design was achieved with fewer components, with assembly run time minimised and assembly cost decreased. The design efficiency of the modified design is increased. Improved design efficiency and greater reductions in installation time and operating costs between the original table fan design and the newly modified design. So that fewer spare parts will provide better operating time and cost [12].

Mohd Nazri Ahmad discovered that Design for Assembly (DFA) is a systematic analysis process to minimise product assembly costs and facilitate assembly by improving product design [13].

N. Hazwani Razak, Muhamad Farizuan Rosli, and M.S.M. Effendi adopted DFA as an industrial tool to reduce assembly costs by optimising the installation process and reducing the number of spare parts. They also redesigned the printer injector product to reduce the number of product components. This is done by evaluating selected assembly parts to reduce parts using the software tool and redesigning the product using the DFA method. With the improvement of the design, the assembly costs were reduced. The DFA method can reduce the cost of assembly, the number of components, and the installation time and is eventually available to determine the complexity of the product and the simplicity of the assembly. Reducing the cost of spare parts has a major impact on the final product cost [14].

Ezpeleta et al. presents a DFA methodology that considers the assembly process of a product during all the activities of its development, using the four most widespread methodologies [9].

DFA seeks to identify concepts for things that are naturally simple to put together and supports the design of simple goods and parts to hold, feed, combine, and put together manually or automatically [15].

Akshay Harlalka et al. established the case study of the DFMA methodology to re-design food processing products in the market. In their paper, various cost reduction opportunities are identified in the design of food processors using DFMA studies, so that design ideas can be developed to reduce the overall production cost of the product [16].

This process ensures that parts are installed at low cost, high speed, and efficiency. Consideration should be given to all stages of the design process, especially in the early stages, which offer many benefits:

- reduce the amount of assembly required for a product,
- minimise the cost of manufacturing operations,
- increase productivity and quality.

3. Methodology

DFA can be applied to new product design as well as product re-engineering. This paper provides details on how DFA can be used to re-engineer iron components.

<u>Design for assembly</u>

Boothroyd argued that design for assembly (DFA) is an approach used to help determine product design and installation methods with optimal time and cost. DFA can also be used to assist designers in improving quality, reduce assembly costs, and measure product design improvements. In general, the DFA application has the following objectives:

- Ascertain the minimum number of components as possible;
- Optimise the assembly capabilities or feasibility of each component;
- Optimize the component and assembly capabilities;
- Improve quality, improve efficiency, and reduce assembly.

According to Boothroyd G., in working on DFA, several steps must be taken, as follows:

- Product identification stage;
- The assembly component selection stage;
- The stage generates alternatives to functions;
- The stage evaluates the component elements in the function;
- Stimulation stage over completion time;
- Expenditure analysis stage;
- Alternative selection stage.

Some important rules when evaluating manual part assembly are to:

- Reduce the number and types of parts;
- Eliminate the need for adjustments;
- Allow some components to be aligned and positioned by themselves;
- Ensure adequate access and vision;
- Ensure ease of use of large quantities of spare parts;
- Minimize reorientation;
- Design a part that cannot be installed properly;
- Maximize part symmetry or make parts that are clearly asymmetric [17].

An important element of the DFA method is the use of a measure of the DFA index, or "assembly efficiency," of the proposed design. The DFA index is a number obtained by dividing the theoretical minimum assembly time by the actual assembly time. The equation to calculate the DFA (E_{ma}) index is as follows:

$$E_{ma} = \frac{N_{min} \times T_a}{T_{ma}} \quad (1)$$

where

N_{min}: theoretical minimum amount,

T_a: basic assembly time for one part, calculated by $T_a = \frac{T_{ma}}{T_m}$,

T_{ma}: estimated time to complete product assembly,

T_m: number of components [18].

This paper is carried out according to the process flow diagram as shown in Figure 1, where the work begins by understanding the terms and principles of the DFA methodology that will be used to facilitate product assembly. [19,20].

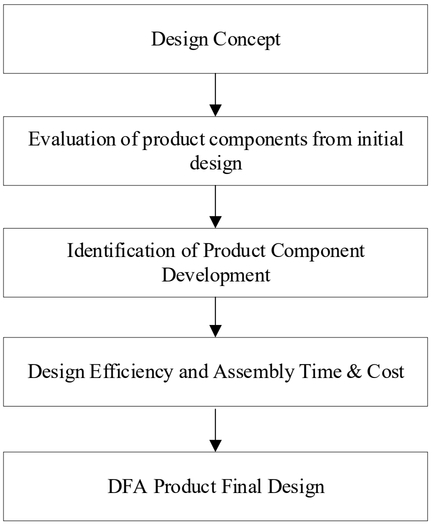


Fig. 1. Research methodology flow

4. Result

4.1. Design concept

In the current design of the product, the ironing product components are 26 units with 12 types of components. Product assembly work elements are 26 activities with a total assembly time. The initial design of the product and the specifications of the iron components are depicted in Table 1.

4.2. Evaluation of product components

The improvement design is based on the assembly problems found by Electronics Services SMEs. An assembly process can be developed by simplifying or reducing the number of components, standardizing materials, uniformity of materials used, and designing products that facilitate assembly. Table 1 shows the product components developed for the Philips HI 115 clothes iron product.

Problems were found by surveying owners and workers of Electronic Service SMEs. Identifying customer needs is important so that problems in the market can be overcome. The product component specifications selected to be developed will depend on what is technically and economically feasible and on what the customer is complaining about [21].

The customer survey was conducted on the entire population of 15 people. The questionnaire distributed was an open questionnaire with the following questions:

- In your opinion, what are the problems in the Iron product assembly process?
- In your opinion, what components will be the critical components in Iron products?

From the customer survey conducted, the following are the requirements and limitations, which are customer needs that must be included when conceptualizing product improvements.

- Product design should reduce the number of ironing parts,
- The complexity of the assembly process can be reduced,
- Design of some complex ironing components,
- Some parts that are the priority for repair are the back cover, handle section, cables and sole plate.

An assembly process can be developed by simplifying or reducing the number of components, standardizing materials, uniformity of materials used, designs that facilitate assembly. The product constituent components developed for the Philips HI 115 clothes iron product can be seen in Table 2.

4.3. Identification of product component development

Some principles that must be met in designing to improve the assembly process include the following: the simplification and reduction of the number of components, standardising and the use of components with uniform materials, design to facilitate handling and component orientation; minimising flexible and interdependent components, design for convenience. The assembly uses simple movement patterns and minimises the number of assembly axes. It is designed for combined and efficient fasteners and modular product design for assembly [22]. Based on these principles, design improvements are made using the Design for Assembly (DFA) method. Design improvements with DFA can be made through component development, combining or eliminating unnecessary components [2]. The identification of product component development can be seen in Table 3.

Table 1.
Iron component specification

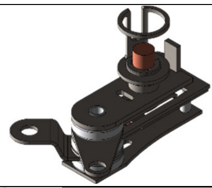
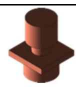
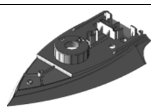
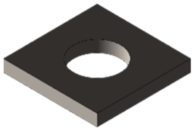
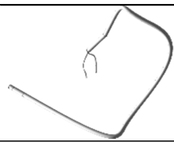
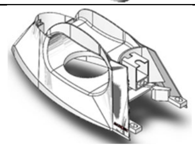
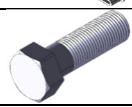
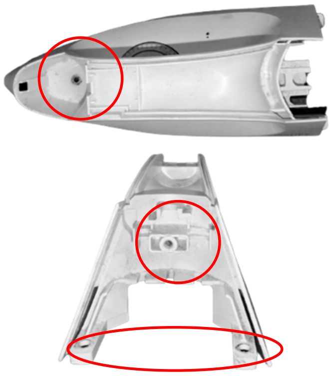
No	Component	Amount	Material	Picture
1.	Soleplate and thermostat	1	Steel	 
2.	Temperature light	1	Glass	
3.	Dial connection	1	Steel	
4.	U-metal gasket	1	Steel	
5.	Valve	1	Steel	
6.	Cowling	1	Plastic	
7.	Bracket	3	Steel	
8.	Electrical flex and connection	1	Thermoplasti c	
9.	Handle section	1	Plastic	
10.	Temperature dial	1	Plastic	
11.	Back cover	1	Plastic	
12.	Bolt	13	Steel	

Table 2.
Problem identification of product components

No	Component	Illustration	Component function	Assembly problem
1.	Back cover		Cover the back of iron	Bolt hole is too deep
2.	Handle section		As part of the iron handle	Using too many fasteners as of takes time to assembly

4.4. Design efficiency and assembly time and cost

Design efficiency describes the comparison between the estimated assembly time of the redesigned product and the ideal time of the previous product's assembly. The ideal time is obtained, assuming each component is easy to operate and assemble. The assembly time used is cycle time. The assembly time for the current design can be seen in Figure 2.

- Current product design:
  The calculation of the initial design efficiency is known as the number of components (NM), which is 26 units, and the total manual installation time (TM) is 358,16 seconds. Therefore, using the formula (1), the initial design efficiency value is 21,77%.
- The proposed product design:
  The calculation of the design efficiency as a result of the design shows that the number of components (NM) is 22 units and the total manual assembly time (TM) is 269,7 seconds. Therefore, using the formula (1), the initial design efficiency value is 24,74%.

  Based on recommendations for design improvements, a DFA worksheet will be created to see a comparison of activity elements, assembly time, and assembly cost after the repair. The assembly time for the current design can be seen in Figure 3.

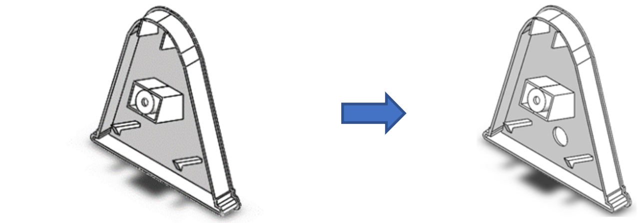
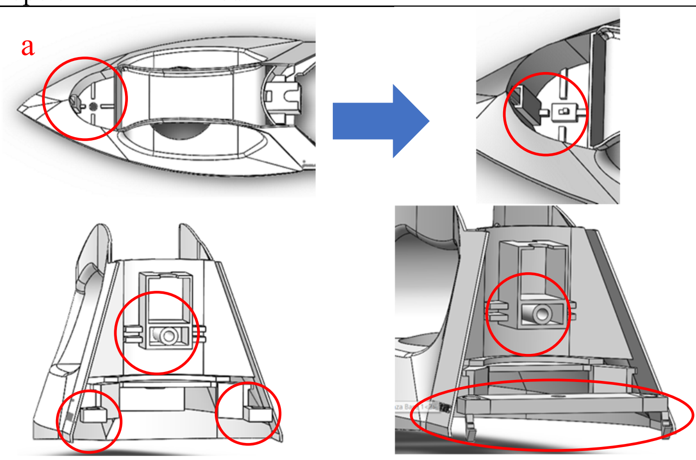
  The assembly cost required to install each unit of the Philips HI 115 iron is derived from the estimated salaries of the Philips HI 115 operator, with a total workforce of 1.

$$\text{Assembly cost} = \text{Cost/second x assembly time} \quad (2)$$

No.	Assembly Work Elements	Assembly Time (s)
1	Combines the soleplate and thermostat with the E1 nut	15,10
2	Combines the soleplate and thermostat with the E2 nut	14,67
3	Combines the soleplate and thermostat with the E3 nut	15,67
4	Combines the soleplate and valve	15,10
5	Combines the soleplate and thermostat with the temperature light	11,79
6	Combines the soleplate and thermostat with the dial connection	13,10
7	Combines the soleplate and U-Metal Gasket become assembly 5	22,71
8	Combines assembly 5 with the soleplate cover	24,02
9	Fasten assembly 5 and soleplate cover with D1 nuts	18,13
10	Fasten assembly 5 and soleplate cover with D2 nuts	10,26
11	Fasten assembly 5 and soleplate cover with D3 nuts to assembly 4	10,48
12	Combining electrical flex & connection with vertical cord lift to become an electrical flex & connection set	9,39
13	Joins assembly 4 with bracket 1	7,86
14	Joins assembly 4 with bracket 2	7,86
15	Joins assembly 4 with bracket 3	7,86
16	Combining assembly 4 with the electrical flex & connection set	17,47
17	Fastening with nut C1	20,09
18	Fastening with nut C2	20,22
19	Fastening with nut C3 become assembly 2	19,78
20	Combining handle selection with temperature dial into assembly 3	9,39
21	Combining assembly 2 with assembly 3	13,10
22	Combining assembly 2 and assembly 3 with nut B1	10,26
23	Combining assembly 2 and assembly 3 with nut B2	10,48
24	Combining assembly 2 and assembly 3 with nut B3 to become assembly 1	10,48
25	Combining assembly 1 with the back cover	7,86
26	Fasten assembly 1 and back cover with nut A to finish iron	15,03
	Total	**358,16**

Fig. 2. Assembly elements current design

Table 3.
Identification of product component development

No	Component	Illustration	Improvement
1.	Back Cover		 On the back cover component, the bolt hole is shortened to facilitate the placement. Then also added a hole in the back cover component to facilitate the movement of the cable. Then, the lifting part of the vertical rope can be eliminated.
2.	Handle Section	 	 In the section of handle A, the bolt is replaced with a sliding switch to facilitate the removal or assembly of the casing. In part B, the height is added to make it easy to place the beans. In section C the concept of the bolt is replaced using Snap-fit. Snap-fit used is catches [23].

No.	Assembly Work Elements	Assembly Time (s)
1	Combines the soleplate and thermostat with the E1 nut	13,1
2	Combines the soleplate and thermostat with the E2 nut	12,67
3	Combines the soleplate and thermostat with the E3 nut	12,67
4	Combines the soleplate and valve	13,1
5	Combines the soleplate and thermostat with the temperature light	11,79
6	Combines the soleplate and thermostat with the dial connection	13,1
7	Combines the soleplate and U-Metal Gasket become assembly 5	22,71
8	Combines assembly 5 with the soleplate cover	15,17
9	Fasten assembly 5 and soleplate cover with D1 nuts	18,13
10	Fasten assembly 5 and soleplate cover with D2 nuts	10,26
11	Fasten assembly 5 and soleplate cover with D3 nuts to assembly 4	10,48
12	Joins assembly 4 with bracket 1	7,86
13	Joins assembly 4 with bracket 2	7,86
14	Joins assembly 4 with bracket 3	7,86
15	Combining assembly 4 with the electrical flex & connection set	6,37
16	Fastening with nut C1	20,09
17	Fastening with nut C2	19,22
18	Fastening with nut C3 become assembly 2	18,78
19	Combining handle selection with temperature dial into assembly 3	9,39
20	Combining assembly 2 with assembly 3	3,39
21	Combining assembly 2 and assembly 3 with nut B3 to become assembly 1	10,04
22	Combining assembly 1 and back cover with nut A to finish iron	5,66
Total		**269,7**

Fig. 3. Assembly elements proposed design

- Current product design
  The calculation of the known assembly cost of the number of components (NM) is 26 units, and the total manual installation time (TM) is 358.16 seconds. Using formula (2), the assembly cost is 956,81 rupiahs.
- The proposed product design
  The calculation of the assembly cost is known as the number of components (NM), which is 22 units, and the total manual assembly time (TM) is 269.7 seconds. As a result of that, using the formula (2), the assembly cost is 720,51 rupiahs.

4.5. DFA product design

The selection of the best design can be carried out by comparing the level of design efficiency and also the assembly costs of the current design to the proposed design.

The recapitulation of improvements in design efficiency and assembly as presented in Table 4.

Table 4.
Comparison of design efficiency, time and assembly cost

Design	Parts number	Assembly time, s	Assembly cost, R_p	Efficiency, %
Current design	26	358.16	956.81	21.77
Proposed	22	269.70	720.50	24.77

Further discussion of Table 4 is presented in the next section. Based on the table above, it can be seen that the improved design has higher design efficiency, lower installation time, and lower installation cost (Fig. 4).

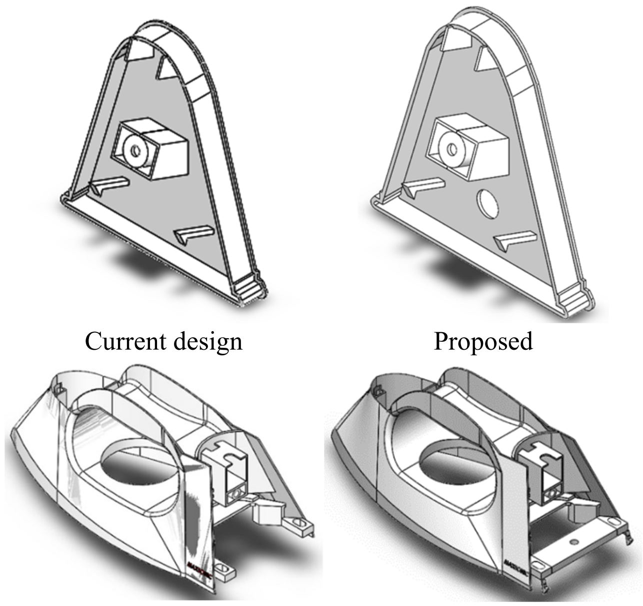


Fig. 4. Proposed final design

5. Discussion

In this paper, the improvement of the ironing design is based on problems and complaints received from the iron installation operator. This paper develops the design improvements to two components, namely the back cover and the handle part. The back cover component is enhanced by changing the size of the bolthole and adding holes to the components to facilitate the movement of the cable so that the vertical cord lift part can be eliminated. The components of the handle part are replaced with a bolt with a sliding switch to facilitate the assembly process so that one bolt component can be removed, and two bolts are replaced using the snap-fit concept.

As shown in Table 4, a comparison of assembly times, installation costs, and design efficiencies between current products and modified products is presented. The total number of spare parts has been reduced from 26 for current products to 22 for modified products. This indicates a complete reduction compared to the current production of 4 parts for the modified product.

Meanwhile, the assembly time was reduced from 358.16 seconds to 269.70 seconds for the modified product. These results indicate the percentage reduction in the operating time of the assembly between the proposed design and the actual design. This also indicates that the product improvement design has a shorter assembly time and will save more time than the current design. Furthermore, the estimated reduction in assembly costs is from 956.81 to 720.50 rupiahs. This resulted in a decrease of 24.7%.

Based on the assessment of the results, it can be seen that the assembly costs of the proposed product design are cheaper than the current ones. From the time and cost of assembly results, it can be seen that the assembly costs of the proposed product design are cheaper than the current ones. The time and cost of assembly are reduced since the proposed has fewer parts, and the difficulties during the assembly process are reduced.

Based on the results of the observations with the questionnaire, the proposed design has met the problems found and answered the objectives of the study to reduce the time and cost of assembly.

In addition, calculating the design efficiency parameters, time, and cost of the assembly were to find out if the proposed design could provide improvements. The effectiveness of the design is a measure of design efficiency. The more efficient the design, the better the design. Design efficiency for product development is calculated based on the theory of the number of spare parts, the time it takes to assemble spare parts, and the number of parts [7]. The time and cost of assembly are influenced by the parts or components that compose each iron product.

In contrast to the time and cost of assembly, design efficiency indicates improvements in product design. Based on Table 4, design efficiency has increased from 21.77% to 24.77% for the proposed design. The design efficiency of the proposed design is better than the current one, which indicates fewer redundant parts and complications during the assembly processing than the current one.

Some of the advantages of the DFA method in terms of improving the iron design applied in this study are as follows:

- Simplify the fabrication and assembly;

- Reduce rework;
- Improve serviceability;
- Reduction in the budget;
- Optimize the number and types of spare parts;
- Minimize the reorientation during assembly;
- Eliminate the need for adjustment;
- Easily adjusted;
- Diminish the number of tools required [24].

6. Conclusions

DFA improvement was made on the back cover and grip parts by changing the size of the bolthole and adding holes to the components for easy cable movement, thereby eliminating the lifting part of the vertical cable. The handle component is replaced with a bolt with a sliding switch to simplify the assembly process, and the bolt is replaced with the concept of a snap fit. As a result of iron design improvements, the decrease in assembly time decreased from 358.16 to 269.7 seconds, the costs decreased from 956.81- to 720,50- rupiahs and increased the design efficiency from 21.77% to 24.47%.

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