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Improving The Design of Body Temperature Scanner Using Design for Manufacturing and Assembly (DFMA)

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Abstract: Every industry needs to manufacture low cost, high quality and quicker time on the market. Design for Manufacturing and Assembly (DFMA) is a method that can be used to reduce or redesign many products in the manufacturing sector. The benefit of DFMA is that it can reduce the manufacture cost. The major purpose of this study is to propose a new design of body temperature scanner. Besides that, the manufacture cost, assembly time and design efficiency are analysing in order to support the modifications. The analysed were carried out by disassembling the body temperature scanner, the operation of each component and 3D modelling using SolidWork software and, lastly, the DFMA design guidelines are used to create a new design. The selection criteria for a successful design are based on the cost of manufacture and the time of assembly. Finally, the design chosen has been proven to meet all the relevant requirements by improving in the operation cost, operation time and design efficiency. The existing product design efficiency is 43.90 % and the new design is 78.20 %. The operation time for new design also improving from 68.29 s per unit to 34.51 s per unit. In this study, the overall operation cost reduction is RM13.51 per unit which is RM27.31 reduce to RM13.80, the percentage reduction is 45.50 %

Keywords: Design for Manufacturing and Assembly, DFA, Body temperature Scanner, Reduce Cost

1. Introduction

Design for Manufacturing and Assembly (DFMA) is one design process that focuses on developing a product which ease to manufacture and assembly. DFMA is used to identify, and eliminate waste or inefficiency in product design. DFMA combines two methodologies: Design for Manufacture, which refers to the design of pieces that will create a product for ease of manufacture, and Design for Assembly, which refers to the design of the product for simplicity of assembly. This design process was presented by Peter Dewhurst [1] and Geoffrey Boothroyd. Therefore, when designing a new product,

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DFMA will be utilized at the beginning phase of the venture configuration to characterize the prerequisites that the item will satisfy. DFMA can also help to incorporate between production areas (Manufacturing and Assembly) and Engineering and design that allowing preliminary actions during the development phase to avoid problems and by simplifying the design of any product that will make it more efficiently in manufacture and assemble. Basically, the designers could use DFMA as a direction in operation. The early designing stages to develop a product might be easily be manufactured with cost, effort and minimum time. All factors may be counted the2 final output of product to avoid any problem.

1.1 Design for Manufacturing and Assembly (DFMA)

DFMA is a method of planning that focuses on direct assembly and joint execution and it is also used as a benchmarking tool for comparing things to competitors, as well as a cost-cutting tool for switching providers. This concept will be streamlined to the greatest extent possible in order to make it more efficient and simpler to create and prepare. Time will be shortened or minimized as a result of a lower cost. DFMA has traditionally been used in the design industry, such as automotive and consumer items, where high-quality goods must be produced in large quantities in a timely way. The DFMA approach combines two methods of Design for Manufacture (DFM) and Design for Assembly (DFA) [2].

1.2 Design for Manufacturing (DFM)

Design for Manufacturing (DFM) is the general engineering practice of designing goods in such a way that they are easy to manufacture. DFM is a way to design a part, segment, or goods to the simplicity of installation with the ultimate goal to improve the item for a lower price. Besides, DFM has been the issues expected to be resolved at the planning stage, which is the most economical place to address them. Furthermore, DFM will allow concerns to be rectified at the planning stage, which is the most cost-effective time to do so. Although the principle is found in practically all engineering disciplines, how it is implemented varies greatly depending on the manufacturing technique [3].

1.3 Design for Assembly

Design for Assembly is a systematic analysis process for primarily intended to reduce the assembly cost of a product by simplifying the product design. DFA is a tool for the industry to minimize the assembly cost by optimizing the assembly process and reducing the number of parts [4]. This process will make sure that the part has been assembled with high speed, low cost, and productivity DFA became prominent as new products were designed with automated assembling in mind. In the event, it was found that DFA could show significant savings for manual as well as for automated assembling and was therefore even more useful than had at first been thought. Applying DFA reduced not only assembling costs but often showed even greater savings in materials and overheads [5].

1.4 Body Temperature Scanner

A body temperature scanner or infrared thermometer deduces temperature from a fraction of the thermal radiation emitted by the object being measured, also known as black-body radiation. Because a laser is used to help aim the thermometer, they are also known as laser thermometers, non-contact thermometers, or temperature guns, which refer to the device's capacity to monitor temperature from a distance. The temperature of an object may often be determined within a specific range of its actual temperature by knowing the amount of infrared energy emitted by the object and its emissivity. The term "thermal radiation thermometers" refers to a group of devices that includes infrared thermometers [6]

2. Materials and Methods

As DFMA methodology, the DFA Manual Analysis approach was chosen to study the selected product. Therefore, the method of manual DFA analysis determined by Boothroyd and Dewhurst is practical to be tested.

2.1 Methods

The manual review of the DFA is normally carried out in five stages of:

i. Disassembled component and description of parts.
ii. Evaluation of the assembly process (Boothroyd Dewhurst Method)
iii. Definition and improvement of the parts proposed.
iv. Re-evaluation of modified parts (Boothroyd Dewhurst Method)
v. Evaluation of original and improved parts

2.2 Product part details

The body temperature scanner is chosen as the product chosen for this research. The complexity of the design and the number of components has an impact on the prices of the product. The first step is to disassemble the body temperature scanner into parts. Upon disassembly, the component consists of 9 or more main parts. Table 1 shows the body temperature scanner parts name and the quantity of the parts.

Table 1: Parts detail

Part no.	Part name	Quantity
1	Casing	2
2	Power button	1
3	LCD backlit display cover	1
4	Speaker cover	1
5	Button section	3
6	Infrared sensor	1
7	Battery compartment	1
8	Fastener	4
9	Roller shaft	1

2.3 Assembly process evaluation (Boothroyd Dewhurst)

The evaluation of the assembly using the Boothroyd method will be carried out in this study were, first, the use of the DFA worksheet table as shown in Figure 2. The evaluation procedure for the DFA Worksheet can be described as:

i. Description of the parts and the quantity:

As described in Figure 1, the dimensions and number of the components are measured in this DFA worksheet

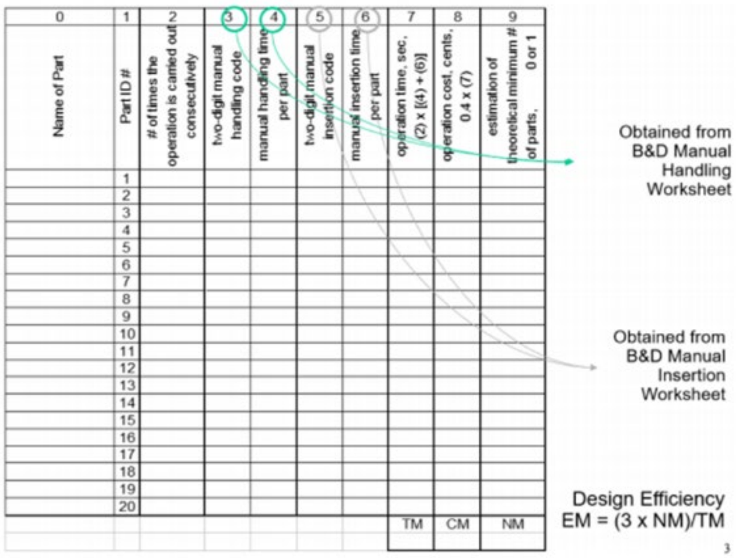


Figure 1: Manual DFA worksheet

ii. The determine of the effect of part symmetry of each part:

As an essential factor for the assembly process, part of symmetry on handling is vital. There are two kinds of equality that are alpha symmetry and beta symmetry. Figure 2 shows the rotation of the alpha symmetry, where rotated about an axis perpendicular to the rotation axis. Meanwhile, beta symmetry rotation is on the axis of insertion, as shown in Figure 3.

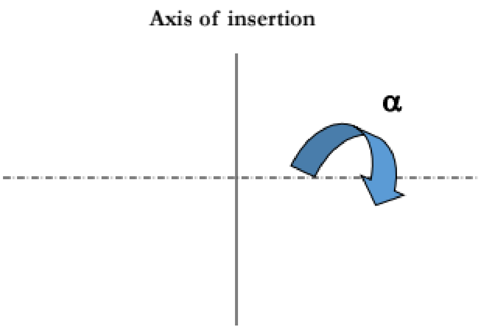


Figure 2: Alpha symmetry rotation

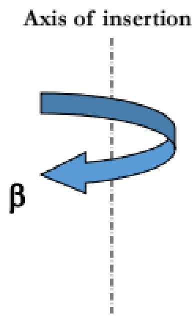
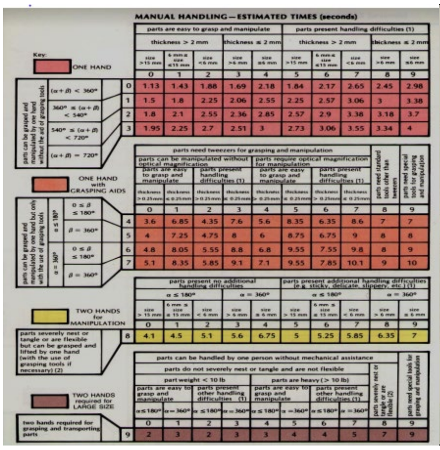


Figure 3: Beta symmetry rotation

iii. Manual Worksheet Evaluation Handling:

Using the handling symmetries, α and β, and the information of the parts in, the two-digit handling code and the time taken for manual handling of each piece are obtained by manual handling, as shown in Figure 4 and 5.



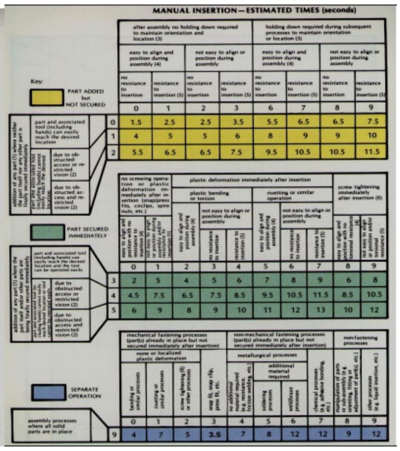


Figure 4: Manual handling worksheet **Figure 5: Manual insertion worksheet**

iv. Evaluation of the manual insertion worksheet:

Manual insertion worksheet assessment showed when Figure 6 also uses the handling symmetries, α and β, and the parts described to achieve two-digit manual insertion and time taken for each part during insertion.

v. Time of operation and cost calculation:

The operation time can be determined by the quantity of the part multiplied by the amount of manual handling and the time of insertion taken for each part. For the cost of operation, a scale of 0.4 is used to quantify the efficiency of the design. The cost of operation can be measured as 0.4 multiplied by the times of operation before each component.

vi. Estimation of theoretical minimum parts:

For the value of the calculation for potential minimum pieces. There are rules to be followed at this point, such as:

• Does the part move relative to all other assembled parts during the operation of the product?

• Does the element component have to be different from the pieces already assembled?

• The part must be separated from all the parts already assembled?

3. Results and Discussion

This section focuses mainly on the results of the review of the data. This section aims to improve the study's goal by reducing the number of parts and making a better-quality product than the original design. These analyses will be carried out via the DFA Manual.

3.1 Manual DFA analysis on original design

Table 2 below shows the analysis of the original design of a body temperature scanner. The study has been done using DFA table. The table will generate the operation time, operation cost and design efficiency on the original design

Table 2: DFA table analysis on original design of body temperature scanner

	c1	c2	c3	c4	c5	c6	c7	c8	c9
Name of Assembly	Part I.D Number	No. of operations carried out consecutively	Manual handling code	Manual handling time per part	Manual insertion code	Manual insertion time per part	Operation time C2(C4 + C6)	Operation cost 0.4C7	Estimation for theoretical minimum parts
Casing	1	2	30	1.95	00	1.5	6.9	2.76	2
Power button	2	1	33	2.51	01	2.5	5.01	2.0	1
LCD backlit display cover	3	1	24	2.85	30	2.0	4.85	1.94	1
Speaker cover	4	1	10	1.5	00	1.5	3.0	1.2	1
Button section	5	3	00	1.13	00	1.5	7.89	3.16	3
Infrared sensor	6	1	34	3.0	30	2.0	5.0	2.0	1
Battery compartment	7	1	23	2.36	01	2.5	4.86	1.94	1
Fastener	8	4	70	5.1	00	1.5	26.4	10.56	0
Roller shaft	9	1	02	1.88	01	2.5	4.38	1.75	0
Total							TM=68.29	CM=27.31	NM=10

3.2 Assembly Cost and Design Efficiency of Original Design

From Table 2, the original body temperature scanner consists of 9 main parts. The analysis started by listing all the components and parts and arranges it correctly in sequences order. After that, the sequences data acts as input to be inserting on the DFA table thus the result can be generated. The operation time per unit is 68.29 second and the operation cost per unit is RM 27.31. The design efficiency can be calculated by using equation 1 below

$$Design\ efficiency = (3s\ NM\ /\ TM)\ x\ 100.00\ \%\ Eq.\ 1$$

$$= ((3 \times 10) / 68.29) \times 100.00\ \%$$

$$= 43.90\ \%$$

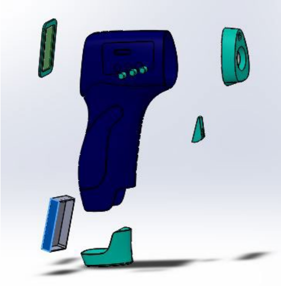
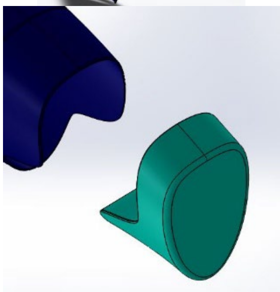
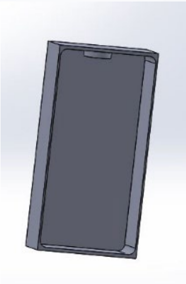
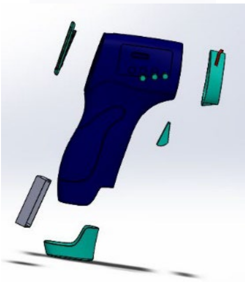
TM = total operation time

NM = theoretical minimum number of part

3.3 Design Modification of Electric Oven

Modifications are usually performed on the original parts without modifying their features. It is done to reduce the number of components, time and expense of the assembly process. The efficiency of the design can be improved by removing the unnecessary part. The assembly process is more straightforward, as it is considered a modern design approach by designing the modification. A few changes to the design were obtained from the analysis, which can be applied if manufacturing costs are reducing significantly. Table 3 below shows the modification suggestion for body temperature scanner.

Table 3: The modification suggestion for body temperature scanner

Parts	New design
	Reduce the number of main parts from 9 parts to 6 parts.
	Reduce the diameter of casing from 2 mm to 1 mm.
	Reduced the number of roller shaft to assemble battery cover and the casing. Use snap fit method to assemble the parts.
	Reduced the diameter for battery compartment from 3 mm to 1 mm
	Reduced the number of fasteners by using snap fit method to assemble all parts.

3.4 Manual DFA analysis on redesign body temperature scanner

Table 4 below shows the analysis of the redesign of a body temperature scanner. The study has been done using DFA table. The table will generate the operation time, operation cost and design efficiency on the redesign body temperature scanner.

Table 4: DFA table analysis on redesign body temperature scanner

	c1	c2	c3	c4	c5	c6	c7	c8	c9
Name of Assembly	Part I.D Number	No. of operations carried out consecutively	Manual handling code	Manual handling time per part	Manual insertion code	Manual insertion time per part	Operation time C2(C4 + C6)	Operation cost 0.4C7	Estimation for theoretical minimum parts
Casing	1	2	30	1.95	00	1.5	6.9	2.76	2
Power button	2	1	33	2.51	01	2.5	5.01	2.0	1
LCD backlit display cover	3	1	24	2.85	30	2.0	4.85	1.94	1
Button section	5	3	00	1.13	00	1.5	7.89	3.16	3
Infrared sensor	6	1	34	3.0	30	2.0	5.0	2.0	1
Battery compartment	7	1	23	2.36	01	2.5	4.86	1.94	1
Total							TM=34.51	CM=13.8	NM=9

3.5 Assembly cand design efficiency of modified body temperature scanner

From Table 2, the redesign body temperature scanner consists of 9 main parts. The analysis started by listing all the components and parts and arranges it correctly in sequences order. After that, the sequences data acts as input to be inserting on the DFA table thus the result can be generated. The operation time per unit is 34.51 second and the operation cost per unit is RM 13.80. The design efficiency can be calculated by using equation 2 below.

$$Design\ efficiency = (3s\ NM\ /\ TM)\ x\ 100.00\ \%\ Eq.\ 2$$

$$= ((3 \text{ x } 9) / 34.51) \text{ x } 100.00\ \%$$

$$= 78.20\ \%$$

TM = total operation time

NM = theoretical minimum number of part

The results and discussion section presents data and analysis of the study. This section can be organized based on the stated objectives, the chronological timeline, different case groupings, different experimental configurations, or any logical order as deemed appropriate.

3.6 Discussion

The relation between the original design and the improved design would be distinguished according to the discussion for this project. As previously mentioned, guidelines for the DFMA technique, assembly can be quick when the number of parts is reduced and this modified design can assist the assembly process. In addition, manual analysis of Boothroyd Dewhurst DFA have been used to evaluate both the original design and the improved design to obtain design efficiency. The original design of the body temperature scanner with operation time per unit is 68.29 s and the operation cost per unit is RM27.31 had the design efficiency of 43.90 %. Whereas, the modified design body temperature scanner with 78.20 % efficiency will reduce the cost and time of operation with RM13.80 and 34.51s respectively. Figure 6 below shows chart performance of body temperature scanner.

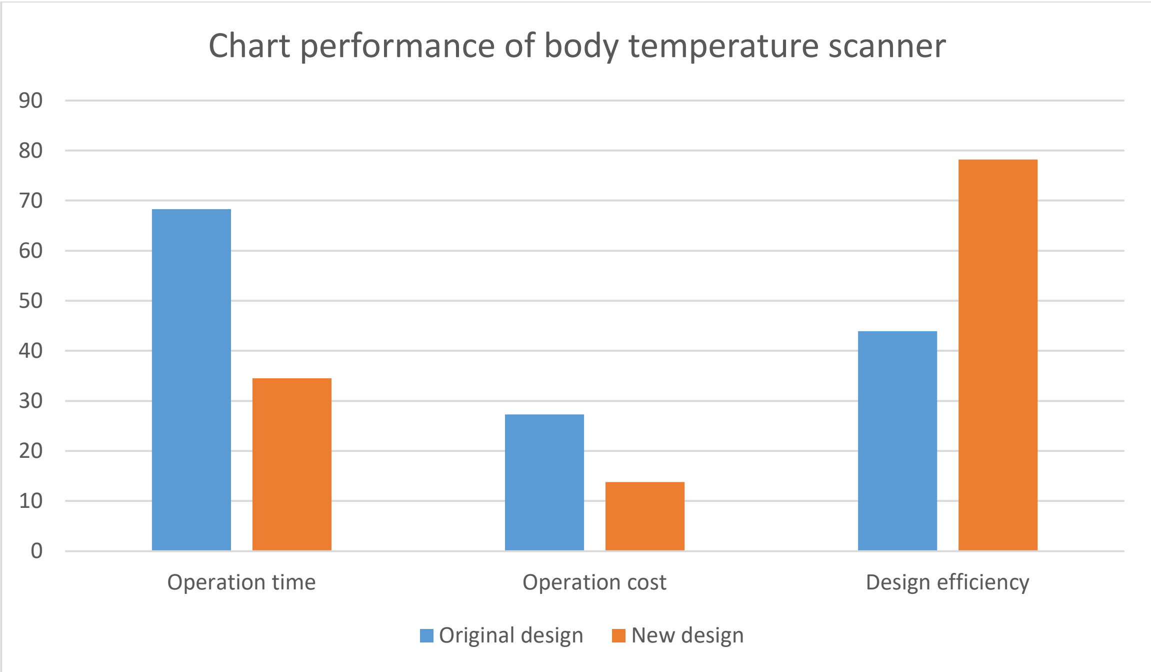


Figure 6: Chart performance of body temperature scanner

4. Conclusion

The research's primary purpose is to evaluate the current product and develop the design of the body temperature scanner using the Design for Manufacturing Assembly process. The factors needed in this research include improving the quality of the product chosen, reducing the number of components and parts, and reducing the cost of the product. The DFA table is used in this research by contrasting the original and redesigned findings. Overall, this product is much better than the original design due to cost and time savings of 45.50 %. The operation cost for the original design is RM13.51 while the operation cost for the improvement design is RM13.80. This shows that the operation cost for design improvement is much lower with the difference in operation cost of the two is RM13.51. As a result, the data reveals that the redesign has a lower cost than the initial version. Finally, the design efficiency of the original and revised products is 43.9 percent and 78.2 percent, respectively.

4.1 Recommendation

For the recommendation, there are some improvements can be done in order to optimize the design of body temperature scanner. Even though the DFMA is the improve method that cutting down the cost of manufacturing assembly in the industry and the purpose of the analysis is to compare products with relative design performance. Therefore, there are still spaces to improve.

First, the aspect that can be improved is speed. One of the aspects of DFMA in construction is the significantly reduced programmed on-site through the use of prefabricated elements. For the improved design, the speed of designing can be done much faster if eliminate or change any unnecessary according to customer needs. Next, assembly cost can be reducing to the minimum value. The DFMA is a method that using fewer parts. By doing that, it decreasing the amount of labor required, and reducing the number of unique parts, DFMA can significantly lower the cost of assembly. To make sure the DFMA is running with efficiently, the knowledgeable labor is crucial need.

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