Design for Manufacturing and Assembly (DFMA): Redesign of Joystick

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Abstract. Design is the first step in any manufacturing process where the most crucial decisions are made which affect the product's ultimate cost. The researchers used DFMA method in this study to redesign and improve a joystick in order to achieve the goal to decrease the number of parts, handling and insertion time, and improve the design efficiency for a joystick. The main emphasis in this research has been on the design stage of a product development, with a view to accomplishing an optimal design approach for current product. DFMA principles have been used to develop new design ideas and the final design will be evaluated and compared to the current design. In result, the assembly time for redesign then increased by 21 % with a decrease in the assembly time from 294.2s to 232.44s and an improvement in design efficiency by 26.5 % from 20.4 % to 25.8 %.

1. Introduction
The phrase “design for manufacture and assembly” (DFMA) is a combination of DFA and DFM [1]. The word “design for manufacturing” (DFM) implies design for the simple manufacturing of the product set that will complete after assembly and “design for assembly” (DFA) means the design of the product for ease of assembly [1-6]. DFMA method provides the design team with guidelines for simplifying the product structure, the production and assembly costs [2-4]. Other than that, DFMA act as a benchmarking tool to the design team for analyzing the products of competitors and quantifying complexity in production and assembly [1-4,7,8]. Furthermore, DFMA is a standardized procedures developed for support industries to optimize the use of current processes for a component or assembly and to minimize the part count to the minimal [1,8,9,19,22].

2. Research Objectives
The objective of this research to analyze and compare the design efficiency for both current design of joystick and the redesign of joystick. The redesign of the joystick is designed by reduce the number of components in the current product using the DFMA procedure without altering their features.
3. Design for Manufacture and Assembly (DFMA) Joystick

3.1. CAD Drawing
Considering the possible connections between both CAD systems and the DFMA analysis. It is important to analyze the way in which these systems currently work, in particular if the goal is to affect the concept design phase of the new design rather than the altered products[1,10,18,20,21]. Figure 1 shows the Boothroyd-Dewhurst DFMA methodology where the first phase is to design a concept using CAD drawing. Figure 2 below shown the features of current joystick.

3.2. Design for Assembly
Design for assembly (DFA) consideration should be given to all phases of the design process, but in particular to the early stages[11,12,17]. The designer should take into consideration of the ease with the component or subassembly is assembled and planned design alternative option in order for the device to effectively evaluate the efficiency with both design are installed[8,12,13]. The evaluation of component assemblability should be precise and accurate. This method often provides a clearly defined process for assessing projects to assist designers in the evaluation of developments consequent from specific design improvements. This method also serves as a motivational tool for designers. It is possible to study design in both circumstances and to develop design easily and cost-effectively at the conceptual phase[7,12,14,23,24].

The number of the theoretical parts counts depends on how important the joystick's part functions[1,8,15]. Table 1 show the current quantity parts used, handling time, insertion time and assembly time for each component for current joystick. The number 0 indicates that the parts are less importance to the joystick that it can be removed or redesigned and the number 1 implies that the parts are necessary for the function of a joystick [3, 10]. The part can’t be eliminated but can be modified as long as the designers maintains or improves its function to the joystick.
Table 1. Existing part assembly time.

| No | Part Name               | Quantity | Theoretical part count | α | β | Handling Time (second) | Insertion Time (second) | Total Assembly Time |
|----|-------------------------|----------|------------------------|---|---|------------------------|------------------------|---------------------|
| 1  | Base Cover              | 1        | 360                    | 360 | 1.95 | 0                      | 1.95                   | 1.95                |
| 2  | Top Cover               | 1        | 360                    | 360 | 1.95 | 9                      | 10.95                  |                     |
| 3  | Led + Charger Port      | 1        | 0                      | 360 | 2.51 | 6                      | 8.51                   |                     |
| 4  | Led Transparent Cover   | 1        | 360                    | 360 | 2.51 | 1.5                    | 4.01                   |                     |
| 5  | Lighting Bar            | 1        | 360                    | 360 | 2.51 | 4                      | 6.51                   |                     |
| 6  | Lighting Bar Cover      | 1        | 360                    | 360 | 2.51 | 2.5                    | 4.45                   |                     |
| 7  | Electronic Base         | 1        | 360                    | 360 | 2.51 | 1.5                    | 4.01                   |                     |
| 8  | Electronic Parts        | 1        | 360                    | 360 | 2.51 | 6.5                    | 8.51                   |                     |
| 9  | Direction Button        | 2        | 360                    | 0   | 1.8  | 1.5                    | 3.3                    |                     |
| 10 | Control Button          | 4        | 360                    | 180 | 2.1  | 5                      | 28.4                   |                     |
| 11 | Home Button             | 1        | 360                    | 360 | 3.55 | 5                      | 8.55                   |                     |
| 12 | Option and Share Button | 2        | 360                    | 360 | 3.55 | 5                      | 17.1                   |                     |
| 13 | Liners                  | 3        | 360                    | 90  | 2.06 | 1.5                    | 10.68                  |                     |
| 14 | Multi-Touch Button      | 1        | 360                    | 360 | 2.73 | 3.5                    | 6.23                   |                     |
| 15 | Battery Holder          | 1        | 360                    | 360 | 1.95 | 9                      | 10.95                  |                     |
| 16 | Battery                 | 1        | 180                    | 360 | 1.8  | 1.5                    | 3.3                    |                     |
| 17 | Motor                   | 2        | 360                    | 360 | 1.95 | 2.5                    | 8.9                    |                     |
| 18 | Screw                   | 6        | 360                    | 0   | 4.75 | 10                     | 88.5                   |                     |
| 19 | PCB                     | 1        | 360                    | 360 | 1.95 | 7.5                    | 9.45                   |                     |
| 20 | Electrical Sheet        | 1        | 360                    | 360 | 3    | 7.5                    | 10.5                   |                     |
| 21 | Total                   | 38       | 20                     |     |     |                        |                        | 294.15               |

3.3. Design Efficiency
A measurement of the proposed design's DFA index or “assembly efficiency” shall be a fundamental element of the DFA method. Two key factors which impact product assembly costs or sub-assembly are (1) number of part and (2) the ease of handling, insertion, and fastening of the parts[1,10]. The estimation of the DFA index equation are as the equation (1) below.

\[
DE = \frac{\text{Theoretical Part Count} \times 3 \text{ s}}{\text{Total Assembly Time (s)}}
\]

\[
DE = \frac{(20 \times 3 \text{ s})}{(294.15 \text{ s})}
\]

\[
DE = 0.2039 \text{ @ 20.4%}
\]

The joystick's current design efficiency is 20.4 %, based on the above calculation. For further development design of joystick efficiency need to be more effective than the initial design efficiency.

3.4. Design for Manufacturing
DFM is a method to design a set of parts that form the product after assembly easily [1]. It is systematic approach for maximizing the productivity of the component design through manufacturing processes. The material and manufacturing process are defined in this stages to enhance the design of the joystick [7-8]. Table 2 shows the material and manufacturing process that the current joystick used for each part.
Table 2. Existing Design for Manufacturing.

| No | Part Name              | Material    | Process        |
|----|------------------------|-------------|----------------|
| 1  | Base Cover             | ABS         | Injection Molding |
| 2  | Top Cover              | ABS         | Injection Molding |
| 4  | Led Transparent Cover  | Acrylic     | Machining      |
| 5  | Lighting Bar           | PyraSied Xtreme Acrylic | Machining |
| 6  | Lighting Bar Cover     | ABS         | Injection Molding |
| 7  | Electronic Base        | ABS         | Injection Molding |
| 9  | Direction Button       | ABS         | Injection Molding |
| 10 | Control Button         | ABS         | Injection Molding |
| 11 | Home Button            | ABS         | Injection Molding |
| 12 | Option and Share Button| ABS         | Injection Molding |
| 13 | Liners                 | ABS         | Injection Molding |
| 14 | Multi-Touch Button     | ABS         | Injection Molding |
| 15 | Battery Holder         | ABS         | Injection Molding |
| 18 | Screw                  | Aluminium Alloy | Machining |

4. Result and Discussion

In order to determine which parts where removed, reduce or combined for better design efficiency, the current design of the joystick will go through numbers of times assembly and disassembly processes. Next, to determine which part has bigger potential to be removed or combined, each part will be analyzed and to reduce the number of screw the base cover are being modified and the design before and after redesign were shown in Table 3 below and the current battery holder was replaced by the built-in battery holder.

Table 3. Existing Design for Manufacturing.

| Original design | Redesign |
|-----------------|----------|
| Screw Hole      | Snap-fit |
| Base Cover (Snap-fit) |         |
| Battery Holder  |          |
The process to achieve the goal to minimize manufacturing time and remove fasteners, the snap-fit is designed on the cover to reducing the number of parts so that, the time required for assembly has been reduced. Thus, the joystick design efficiency will be improved. The next modification is to redesign the battery holder. The current design of battery holder were separated to the cover in fact it can be designed to be one part. This situation were adverse because the controller's overall weight will increase, additional assembly time is needed, and the battery holder also consumes space. Therefore, the battery holder was combined with the cover to reduce the overall joystick part count. Table 4 shows the difference between the current design and the improved design of the joystick with respect to part quantity, handling time, insertion times, manufacturing time and design efficiency.

![Table 4. Existing Design for Manufacturing.](image)

| Part Quantity         | Existing Design | Redesign | Differences | Improvement |
|-----------------------|-----------------|----------|-------------|-------------|
| Handling Time (s)     | 50.08           | 45.62    | 4.46        | 8.9%        |
| Insertion Time (s)    | 90.5            | 77.5     | 13          | 14.36%      |
| Assembly Time (s)     | 294.2           | 232.44   | 61.76       | 21%         |
| Design Efficiency     | 20.4%           | 25.8%    | 5.4%        | 26.5%       |

From Table 4 the design efficiency improves by 26.5%, due to the removal of 5 parts during the redesign stage. Based on the calculation, the result shows that the insertion time is decreased to more than 10s compared to handling time with 4.46 s. A total time of 61.76s is reduced for the total assembly time. Therefore, the redesign is capable of reducing the total production time and reducing costs by listing fewer parts than current design.

5. Conclusion
It is obvious that DFMA program have a massive influence in a competitive engineering environment when implemented correctly. This paper initiated the study and redesign of joystick through the implementation of the design for manufacturing and assembly (DFMA) method [25,26]. Ultimately, after the redesign process, the design efficiency for joystick, total part count and assembly times was improved. The design efficiency for joystick was increase from 20.4% to 25.8%. Unfortunately, this isn't the best possible design for the joystick, for further enhancements or advanced technologies for joystick, there is a lot of improvement can be made [27]. In addition, the electronic component holder currently in use can be merge with the cover to reduce total part count number and the space is quite limited.

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