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Reducing Product Cost by Implementing DFMA Methodology – Lucas Hull: A Case Study

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ABSTRACT

Design for Manufacture and Assembly (DFMA) consists of two main components which are Design for Assembly (DFA) and Design for Manufacture (DFM). DFMA is an important methodology to review the design for product evaluation. It is very significant in reducing number of parts to be assembled in a product. This can contribute to the reduction of manufacture cost of part, assembly time and material. Therefore to reduce the product cost, DFMA-Lucas Hull methodology is applied by selecting a consumer product which is water nozzle as product case study. The Teamset-Lucas Hull base software is used to evaluate the product. The original design is reviewed; improved and redesigned effort is performed for the product evaluation. The significant result shows the new design of water nozzle is achievable with fewer parts from thirteen (13) to eight (8) parts. Then it will be effected the product cost to be reduced from RM48.26 to RM20.76. This method also eligible to be applied to manufacturing industries in order to improve their design effectiveness.

Keywords: *Design for Manufacture and Assembly (DFMA); Design for Assembly (DFA); Design for Manufacture (DFM); Lucas Hull*

1. INTRODUCTION

Design for Manufacturing and Assembly (DFMA) is a design philosophy that used by designers in reduction in part counts, a reduction in assembly time, or a simplification of subassemblies is desired. The goal of DFA is to ease assembly and the DFA tools helps to ease designers toward assembly issue. The original and the redesign product are produced been compared to show that the new design will contain less part, hence reducing cost, assemble time and operation. The Boothroyd Dewhurst system benefits in reduction in part count. Reducing part count not only saves assembly and manufacturing cost but also can save labor, inventory, floor space, documentation and administration. In addition, the fewer parts the quality of the product will increase because mistake can be avoided. A recent study by Masin [1] reports that DFA methods are essential tools in providing feedback to designers about design′s efficiency from the assembly viewpoint. Several DFA methods are available for the determination of product complexity and easy of assembly. Design for Manufacture and Assembly (DFMA) principles for man established frame work used to design products in

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the modern developed world [2]. Schonberger,R.J. [3] was discusses how Design for manufacture and assembly (DFMA) can help manufacturers get lean with its emphasis on simplifying designs and standardizing parts.

In previous years, Paul Hohnsbeen [4] and Anil M et al. [5] studied the impact using DFMA designs process can shorten or reduce of time production rather than using the traditional construction as illustrated in Figure 1. Adopting early conceptual-stage design collaboration enables to reduce time, effort and risk for clients and designers. Furthermore, the quality, accuracy and completeness of the information the design collaborators produce is better coordinated, more complete, less error prone and formatted for efficient dissemination into the material and component supply chain. Application of Design for Manufacturing (DFM) and Design for Assembly (DFA) methodologies can be beneficial to industries involved in the design and development of products. Improper design decisions are responsible for higher manufacturing cost for a product, Annamalai et al. [6]. However Lu,T and Zhang,Y [7] were study when oil fields become old, the proportion of water in crude oil will get higher and higher. Using a traditional bulk separator to extract the water from crude oil has many disadvantages: e.g. high pressure loss, low separation speed, heavy equipment and sensitive to direction. Caltec Ltd. has developed Wx-12, an innovative separator for the oil and gas industry. The device has been tested on offshore platforms and has shown high performance. Currently however, the manufacturing cost of the device is too high making it unlikely to be accepted by market. Then DFA & DFM methods were applied to Wx-12 in order to make it compact and reduce the manufacturing cost.

Chang and Peterson [8] were discussing various aspects and models of how Boothroyd Dewhurst's Design for Assembly (DFA) methodology can be integrated into product development and design curriculum. The DFA methodology involves a team that includes all the concurrent engineering disciplines and the stakeholders in the success of the product design phase. Manufacturing engineers usually play a vital role in the conceptual design phase. Todić V et al. [9] had explained Boothroyd-Dewhurst DFMA method evaluates the product based on design efficiency. The higher design efficiency, the better the product. Number of parts of the product has significant effect to the design efficiency value. In one year before Sarmetnto et al. [10] had studied that the DFA (Design for Assembly) technique is applied to an automotive fuel intake cover of a currently produced vehicle in order to simplify the current product design. The results from this comparison can be used to bench mark DFA methods so that their weaknesses can be identified and improved, Owensby et al.[11].

In addition, Defosse [12] in his studies reported that Design for Assembly (DFA) module leads an engineer down a quantifiable path of parts consolidation and assembly simplification. The software methodically guides toward designs that have fewer parts and lower costs. DFA is used as a method to improve the product and will result the cost reduction [13 -15]. By DFA analysis, the minimum number of workstations needed to balance the line that will maintain the production rate (takt time) and precedence constraints is determined. Then the precedence constraints are systematically relaxed in order to generate measures on a component-by- component basis as to the impact it could have on reducing cycle time and improving line balancing performance. These measures, coupled with an understanding of precedence types, are used to identify design improvements to a product, Esterman Jr. et al.[16]. Hardee, C.[17] studies that several softwares have been introduced for the analysis of

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design concepts that leads to the reduction in manufacturing and parts costs in the aeronautical engineering industry. Design for Manufacturing and Assembly (DFMA) is an integrated software suite from Boothroyd Dewhurst, Incorporation, and Wakefield, R.I., that helps engineers ask critical questions about their product designs early in the development process. Design for Assembly (DFA) software guides engineers to simplify a design using questions such as the parts move with respect to one another, or they can be made of the same materials.

Lucas Organization and University of Hull United Kingdom are the two groups behind the development of the Lucas design for assembly (DfMA) method. Lucas DfMA evaluation method takes into consideration the crucial aspects of assemblability and component manufacture [18].

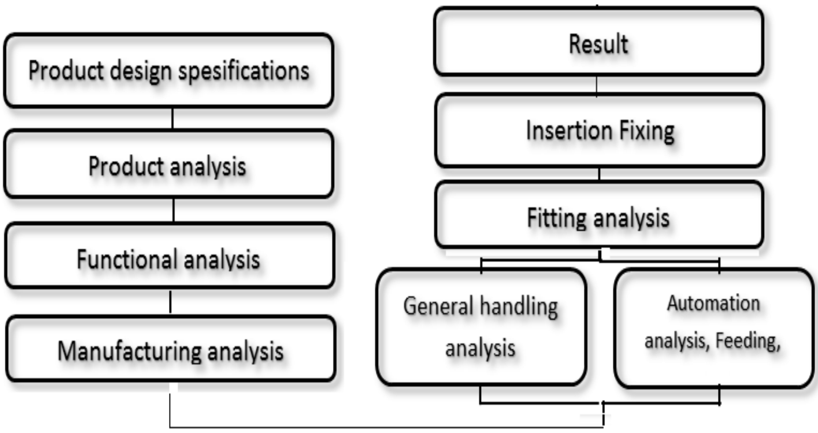

Figure 1: Lucas-Hull DfMA Method [18]

The DFMA procedure can typically be broken down into two stages. Design for assembly is conducted, leading to a simplification of the product structure and economic selection of materials and processes. After iterating the process, the best design concept is taken forward to Design for Manufacture, leading to detailed design of the components for minimum manufacturing costs [18-20]. Developments of the Boothroyd Dewhurst DFA method started in 1977 with funding from the U. S. National Science Foundation and were first introduced in handbook form in 1980. Geoffrey Boothroyd and Peter Dewhurst who founded the Boothroyd-Dewhurst, Inc. (BDI) in 1982 are the first persons doing the research job in this new technology. The Boothroyd Dewhurst method can be used in manual and in software. The manual process can be done by referring to the table which is the manual handling and the manual insertion [21-22].

Surprisingly, no previous study has investigated the reducing product cost by implementing DFMA methodology – Lucas Hull approach. The existing product (water nozzle) has lack in term of part design assembly, many parts, and heavy (use metal instead of plastic). If the product has many parts, the assembly time will be higher. Higher assembly time that means lower design of efficiency. Also, higher assembly time directly means that the assembly cost is higher. The main aim of this paper is to redesign and evaluate of the selected product by DFMA – Lucas Hull method and estimate the product cost. The contribution of this study is obvious as the resulting outcomes can be capitalized as guidelines to simplify the product so that the cost and time of assembly is reduced. Then by applying design for analysis also

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usually to improved quality and reliability, and a reduction in production equipment and part inventory.

2. METHODOLOGY

This research paper starts with a literature review towards the scope of study. The water nozzle is selected as product case study sample as in Figure 2.

Figure 2: Water Nozzle [27]

The case study sample will go through the process of part disassemble, define product function and design critique. Then design will be evaluated by using DFMA-Lucas method. The data are analyzed and parts for modification are proposed. The redesign parts are revaluated using the same method. The results between the original and the improved design are compared. If the design results are improve, will proceed to the sketch and producing the detail drawing. The overall process involved in this study may refer to Figure 2.

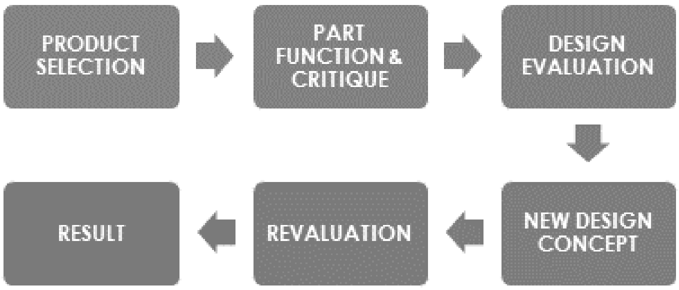

Figure 3: Methodology

The original parts of water nozzle have their self-function, strength and weaknesses. Therefore, this part indicates about the each part of water nozzle function, strength and weakness in an assembly point of view. Product assembly of water nozzle can be referred to Figure 4. Assembly sequence may contributes many aspects of the design can be improved such as screw fastener process and washer. Base on Mohd Ruzi Harun [20] the estimated total assembly time is 100.5 second gained by manual method of boothtroyd-dewhurst. Take

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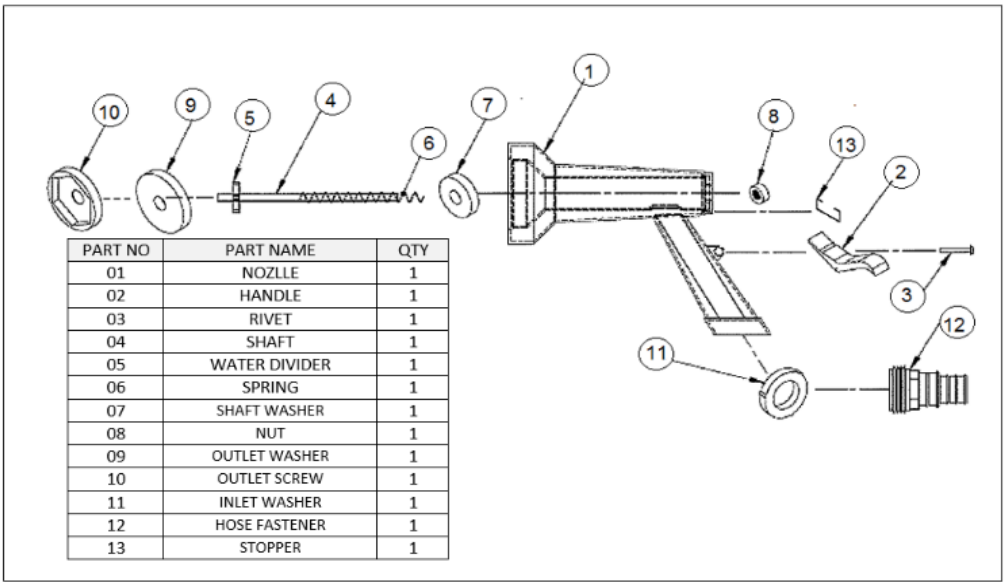
assumption of operator salary RM600 per month and assuming their work hour is eight hours per day.



PART NO	PART NAME	QTY
01	NOZLLE	1
02	HANDLE	1
03	RIVET	1
04	SHAFT	1
05	WATER DIVIDER	1
06	SPRING	1
07	SHAFT WASHER	1
08	NUT	1
09	OUTLET WASHER	1
10	OUTLET SCREW	1
11	INLET WASHER	1
12	HOSE FASTENER	1
13	STOPPER	1

Figure 4: Water Nozzle

Product tree structure illustrate the level of assembly for the product where the number of level will determine the efficiency of product assembly. In order to minimize product assembly time, number of level should be less. The product tree structure for water nozzle is shown in Figure 5 which indicates three levels of assembly.

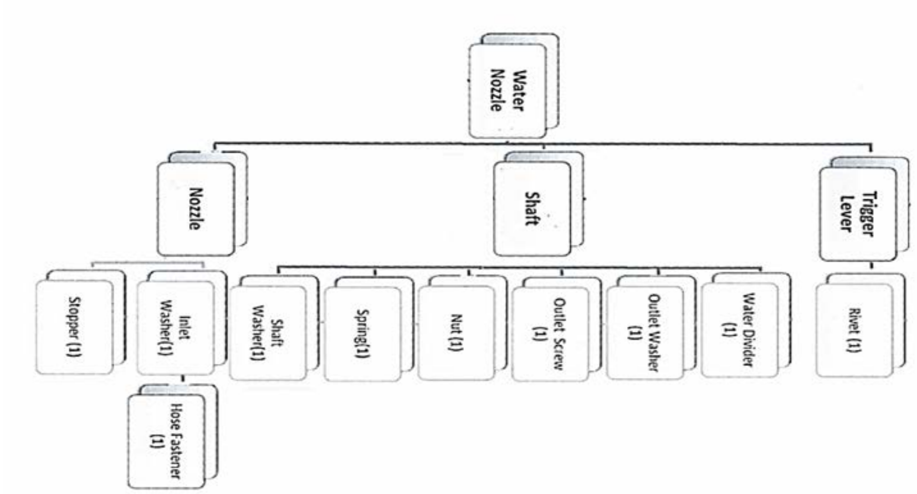


Figure 5: Product tree structure

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Table 1 shows the part critique for each part of water nozzle. This is crucial to identified in early process of redesign. By this process part that potential to be eliminated or combined will be highlighted. These effort will become useful during the evaluation of the product by using Teamset software.

Table 1: Part function and critique

Part No.	Part Name	Function	Critique
01	Nozzle	As base to transmit the pressure of water	Theoretically necessary part since this is the base part. Handle can be designed to Finger Grip
02	Trigger Lever	Retract the shaft to control the water flow	Theoretically necessary part since this is the moving part
03	Rivet	As a hinge and joint the trigger lever	Theoretically not necessary
04	Shaft	Connection between valve, spring, shaft washer and nut	Theoretically necessary part because it must be separate for reason of assembly
05	Water control valve	Control the water flow through the outlet screw	Can be combine with the shaft
06	Spring	Retract the shaft to initial condition	Theoretically necessary as mechanism to retract the shaft to initial condition
07	Shaft washer	Prevent leaking	Theoretically necessary part since this
08	Nut	Connect to the shaft and as a stopper during release operation	Combine with the nozzle
09	Outlet washer	Prevent leaking at outlet area	Suggested to eliminate
10	Outlet screw	Increase water concentration	Can be eliminated
11	Inlet washer	Prevent leaking at the connection of nozzle and hose fastener	Combine with nozzle
12	Hose fastener	Connect the nozzle and pipe hose	Combine with nozzle
13	Stopper	Hold the compression of spring during clamping	Combine with nozzle

The concept selection is the process of evaluating concepts with respect to customer needs and other criteria, comparing the relative strengths and weaknesses of the concept and selecting one or more concept for further investigation or development [21]. All the design concept prior to redesign the product as in Figure 6.

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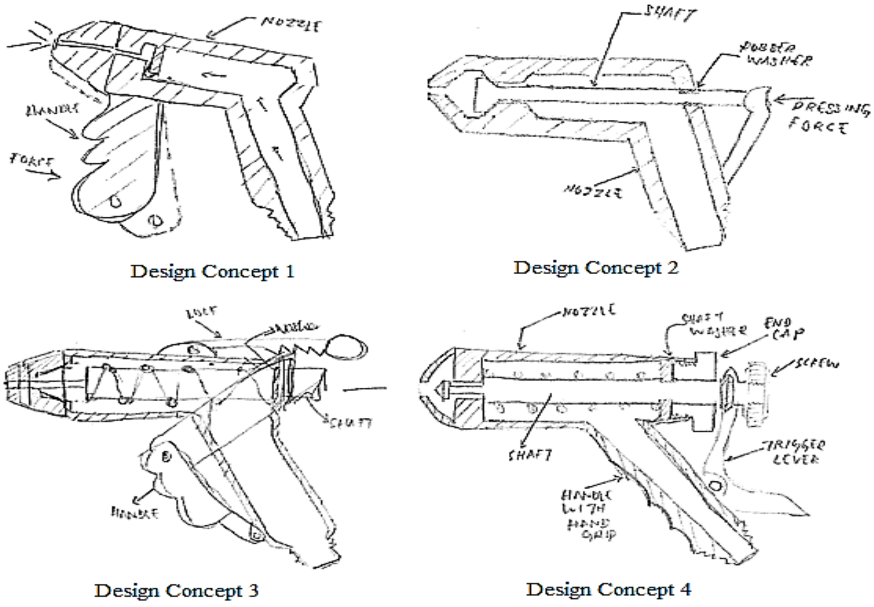

Figure 6: Design concept

From the result gained in design concept selection which are screening and scoring method. The design concept 4 is selected as improved design shown in Table 2.

Table 2: Summarized Result of Design Selection

Design concept	1	2	3	4
		Concept screening		
Net score	4	3	5	7
Rank	3	4	2	1
Continued	No	No	Yes	Yes
		Concept scoring		
Total score	-	-	6.55	7.55
Rank	-	-	2	1
Concept selected				4

The assembly drawing of selected design concept is shown in Figure 7. The new design of water nozzle consists of eight (8) parts instead of thirteen (13) part for previous or original design. Then the list of part for new design which are nozzle/body, trigger lever, rivet, shaft, spring, washer, endcap and screw.

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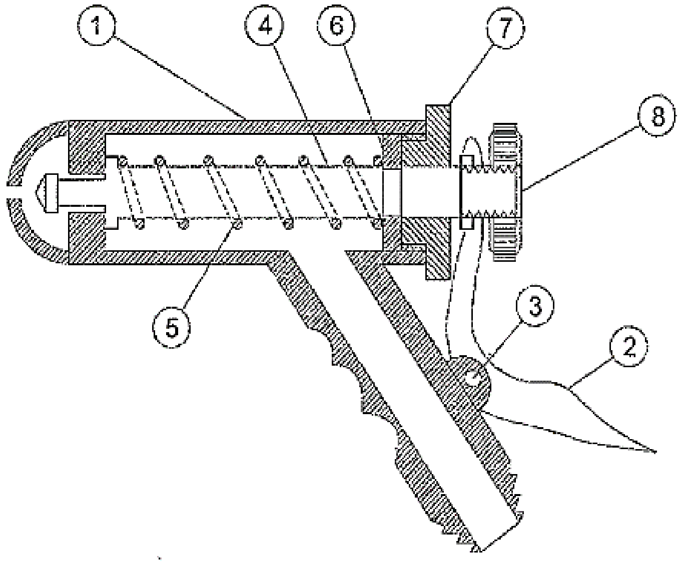

List of Part		
No.	Part Name	Qty
1	Nozzle	1
2	Trigger Liver	1
3	Rivet	1
4	Shaft	1
5	Spring	1
6	Washer	1
7	End Cap	1
8	Screw	1

Note:
- Shaft washer is designed to be self located.
- Handle is designed with hand grip.

Figure 7. Selected Design Concept

3. RESULTS AND DISCUSSION

Design for Assembly (DFA) is a tool for the industry to minimize the assembly cost by optimizing the assembly process and reducing the number of parts [28]. The total number of part is reduced from 13 to 8 parts. Design efficiency is increased by 8.7% from original to improved design. Whereas total cost of assembly is decreased from 63.5% to 45.3% respectively. The detail comparison result of DFA analysis as shown in Table 3. The number of 'A' parts means components that are critical or essential because of it relates to the function of the product which are reduced from 3 to 2 parts. Then handling score was improved from 14.2 to 8.5 and handling ratio also decreased from 4.7 to 4.3. The labor time was decrease from 51.7 second to 28.3 second.

Table 3: Comparison result of DFA

Part Name	Original Design	New Design
Number of Parts	13	8
Number of A Parts	3	2
Handling Score	14.2	8.5
Handling Ratio	4.7	4.3
Total Assembly Labor Time (sec)	51.7	28.3
Design Efficiency (%)	23	25
Total Cost (RM)	28.64	10.46

The Design for Assembly (DFA) efficiency was increased from 23% to 25%. Its shows that the new design is much better than original. Furthermore it will affect the cost of assembly to be reduced from RM28.64 to RM10.46. Refer to Table 4 shows the improvement between original and new design of water nozzle. Production time for original is 51.7s and 28.3s for new design. Total reduction of production, handling and assembly time are 45%, 40% and 47% respectively.

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Table 4: Improvement result

Part Name	Original Design	New Design	Improvement
Production Time (s)	51.7	28.3	45%
Handling Time (s)	14.2	8.5	40%
Assembly Time (s)	37.5	19.8	47%

In DFM or manufacturing analysis shows the reduction of manufacturing cost by 47.6% as in Table 5. The main factor contributes to reduction of manufacturing cost is less number of parts and material changing.

Table 5: Comparison of Manufacturing Cost

Part Name	Original	New Design
Number of Parts	13	8
Number of A Parts	2	2
Total Cost of Manufacturer	19.62	10.30

The comparison result data by DFA and DFM or manufacturing Analysis (MA) are shown in Figure 8 and Figure 9.

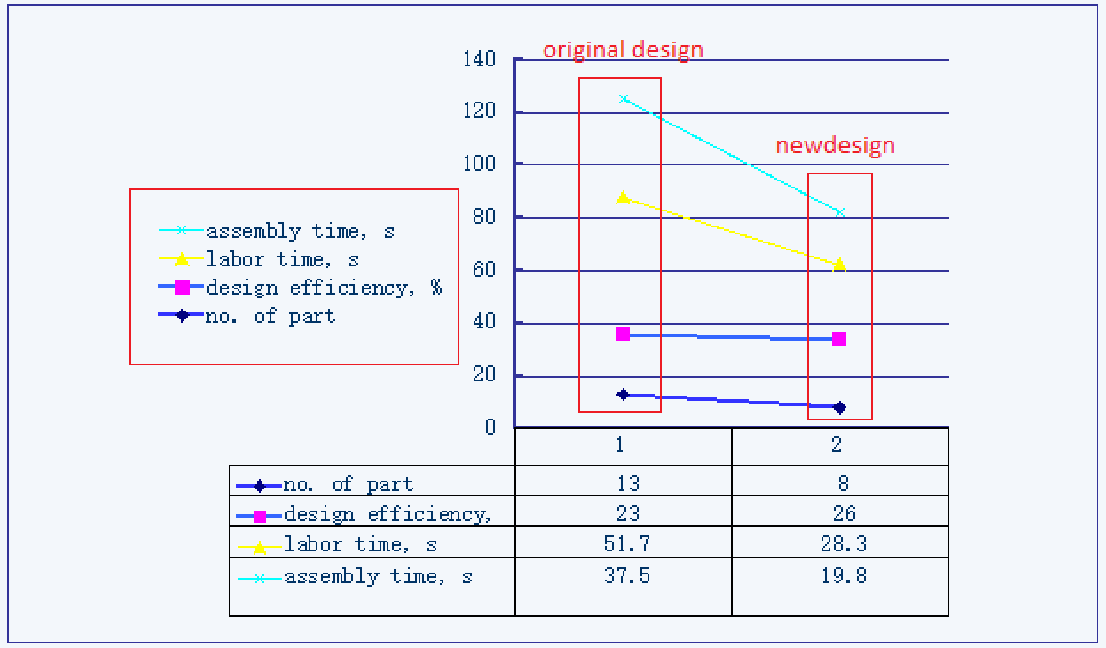

Figure 8: DFA result comparison

Figure 9 shows the cost of DFA and DFM for original design and improved design. Manufacturing and assembly cost for original design are RM19.62 and RM28.64 respectively. Whereas, manufacturing and assembly cost for new design are RM10.30 and RM10.46 respectively. Therefore, the total cost of original design and new design are RM48.26 and RM 20.76. It means that the saving cost is about 60% comparing between original design and new design of water nozzle.

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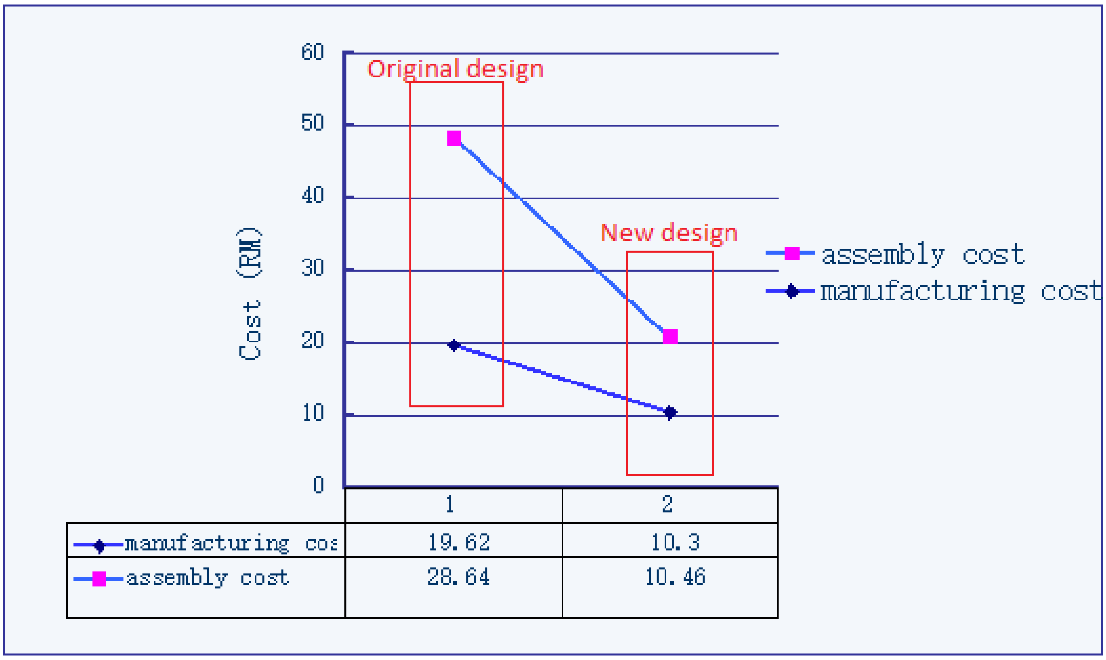

Figure 9: Cost of manufacture and assembly

4. CONCLUSION

The improvement of product design by using DFMA-Lucas Hull method able to produce significant result upon manufacturing cost and assembly cost. The total cost of product is reduced from RM 48.26 to 20.76. It will give significant effect to company whereby reducing production cost will increase the profit margin.

Important conclusions have been obtained and are summarized as follows:

DFMA - Lucas Hull methods is powerful tool reduce the total cost of part.
Percentage of part count reduction is 38.5% from 13 parts to 8 parts.

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