Research Progress in Mechanical and Manufacturing Engineering Vol. 3 No. 1 (2022) 766-778

RPMME

Homepage: http://publisher.uthm.edu.my/periodicals/index.php/rpmme
e-ISSN : 2773-4765

Design for Manufacturing and Assembly (DFMA) for BBQ Grill Machine

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DOI: https://doi.org/10.30880/rpmme.2022.03.01.081
Received 01 Aug 2021; Accepted 03 Dec 2021; Available online 30 July 2022

Abstract: The research consists of the analysis of three models of barbeque grill (BBQ Grill) using the Design for Manufacturing and Assembly (DFMA) method has been purposed. DFMA is approach to reduce and minimize the time of assembly, cost, and component on the existing product. BBQ Grill has become a common product in our daily life especially for use that usually use the BBQ Grill for family gathering. This product's pricing in the marketplace does not offer consumers an opportunity to acquire it since the price is not reasonable for customers who use it for a brief time. The key for this research is to come up with a barbeque grill (BBQ Grill) which has superlative design efficiency and reduced cost of manufacturing by comparing three barbeque grill BBQ Grill which is Portable Charcoal Grill for Outdoor 18inch (Product 1), Char-Griller Classic Cart Style (Product 2) and Charcoal Kettle Grill with Cart BBQ (Product 3). Manual assembly is determined by remodeling the existing model in SolidWorks 2018 software for all three models. Product 1 which has 18.90% design efficiency compare to Product 2 and Product 3 were 9.87% and 15.54% design efficiency respectively. For the chosen design, Model 1 shows the risen of design efficiency after being a purpose of its new improved design namely Product 1-V2 from 18.90% to 19.64% which increased by 0.74%. There has been 5 modification made to Product 1-V2. The total reduction part is reduced by 4 parts from 47 parts on the original design to 43 parts on the newly improved design. Results from total absorption cost shows that the Product 1 is estimated at RM883.39 for 32 manufactured parts while the Product 1-V2 model costs around RM822.63 for 29 manufactured parts. There were RM 60.76 cost reductions between these two models.

Keywords: DFMA, Barbeque Grill, Design Efficiency

1. Introduction

BBQ Grills have become a popular commodity in our everyday lives, specifically for families that

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use them for picnics or family gatherings. Consumers now expect to have at least one product in their home a BBQ Grill. This product's pricing in the marketplace does not offer consumers an opportunity to acquire it since the price is not reasonable for customers who use it for a brief time.

The alternative, which includes the use of DFMA to build BBQ Grills, is becoming an appealing option for meeting the simple human desire for a high-quality product at a reasonable price. When the component count is decreased by the DFMA process, the BBQ Grill is favored since it lowers the selling price externally. When a concept requires maintenance, it is difficult to assemble, which means it takes longer to fix or maintain. The BBQ Grill will give more advantages to producers and customers in terms of assembly by adopting the DFMA method to make the production process more efficient.

1.1 Literature Review

Design for manufacturing and assembly (DFMA) is the process of developing products with manufacturing in mind so that they can be designed for the least construction cost in the shortest time possible. DFMA efficiency and cost-effectiveness as products can be easily assembled from less standard components. Parts are designed to be easy to produce and in common with other products. To be successful in industries, DFM and DFA have been combined into Design for Manufacturing and Assembly[1]. DFA refers to the process of designing a product for ease of assembly. DFA is only concerned with lowering the cost of product assembly such as minimizes the number of assembly operations [2]. The manual assembly approach is used as a standard work environment while assembly methods are studied and assessed. The manual assembly method can be separated into two different sections [3]. They are handing and insertion.

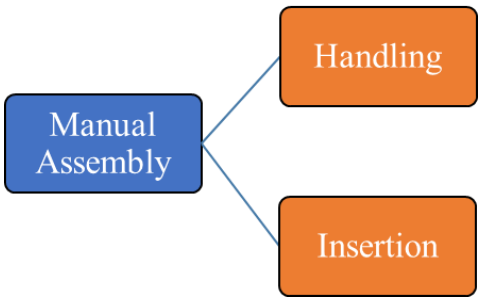


Figure 1.1 Two section of Manual Assembly

Handling involves the acquisition, orientation, and movement of parts. Model parts of end-to-end symmetry and rotational symmetry of the entry axis. Insertion and fastening is a mating part to another part or set of parts. Standardize using similar components, procedures, and practice across all models

DFM is a design approach for making the collection of pieces that will create the product after assembly and optimization of the manufacturing process [4]. DFM is a tool used in the beginning stages of product design to identify the most cost-effective material and method to be utilized in manufacturing.

2. Methodology

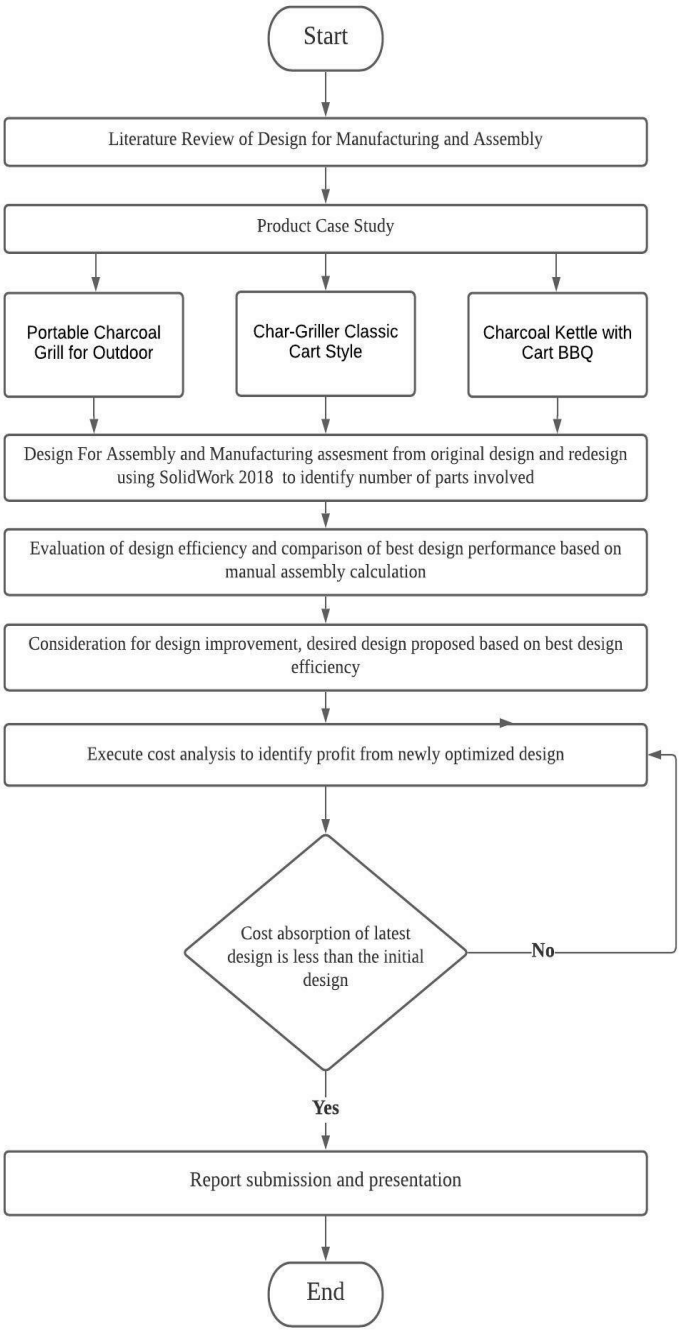


Figure 2.1 Project Flow Chart

2.1 Product Selection for the Case Study

Figure 2.2 Product 1

Table 2.1 Product 1 Specification

SPECIFICATION	DETAILS
Brand	Weber
Model	Portable Charcoal Grill for Outdoor 18 inch
Material	Porcelain, Aluminum, Steel
Dimensions (L x H x W)	18 x 18 x 28 inches

Figure 2.3 Product 2

Table 2.2 Product 2 Specification

SPECIFICATION	DETAILS
Brand	Char-Griller
Model	Classic Cart Style Charcoal Grill
Material	Cast-Iron
Dimensions (L x H x W)	57.3 x 27 x 57.1 inches

Figure 2.4 Product 3

Table 2.3 Product 3 Specification

SPECIFICATION	DETAILS
Brand	Napoleon
Model	Charcoal Kettle Grill with Cart BBQ - 57 cm
Material	Stainless Steel
Dimensions (L x H x W)	113 x 70 x 59 centimeter

2.2 Designs for Assembly Using Manual

Table 2.4 Design for manual assembly worksheet

0	C1	C2	C3	C4	C5	C6	C7	C8	C9
Name of part	Part ID	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)	Total angle of symmetry (α + β), deg (°)	Estimation for theoretical minimum parts
$DE = \frac{3NM}{TM}$							TM		NM

The design for the manual assembly worksheet shown in Table 2.3 is an example. In general, this worksheet worked in tandem with the Manual Handling and Manual Insertion. Based on Table 2.3, there is column for C1 to C9 which function differently.

a) C1 is the column in which the part ID number for each part is placed.

b) C2 is a column in which the parts count the number of repeated operations involved.

c) C3 is a manual handling code column. In order to get the two-digit code, this had to refer to the manual handling table. To get the first digit, the table should be read from the top to the bottom sequence, then from left to right for the second digit. Depending on appropriate characteristics, the digits had to be selected wisely.

d) C4 is the manual handling time column per part. The value we got from the C3 value will be placed in this column.

e) C5 is a manual insertion code column. In order to get the two-digit code, this had to refer to the manual insertion table. To get the first digit, the table should be read from the top to the bottom sequence, then from left to right for the second digit. Depending on appropriate characteristics, the digits had to be selected wisely.

f) C6 is a column for the handling time of insertion per part. The value we got from the C5 value will be

placed in this column.

g) C7 is the column for operation time calculation. The value can be obtained by adding C4 and C6. Then the added value will be multiple by the value of C2.

h) C8 is the column for total angle of symmetry. The formula of (α + β), deg (º) can be completed by referring at Figure 3.5.

i) C9 is the column for the estimation value for theoretical minimum parts. The value can be determined by two numbers only which are '1' and '0'. '0' value is for the fastener and other than fastener is valued '1'.

j) Design efficiency formula can be completed by taking the total C7 and C9 values as TM and NM.

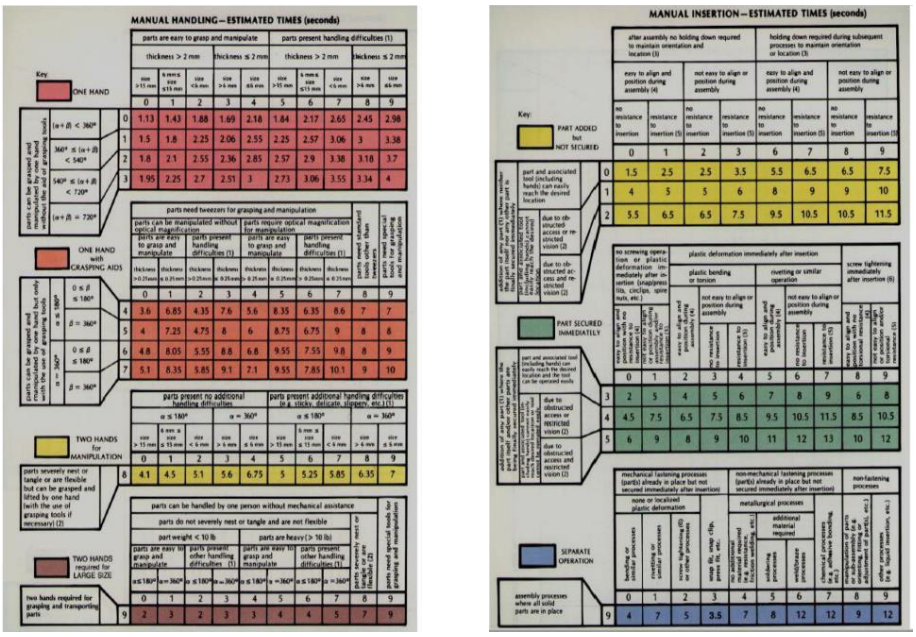
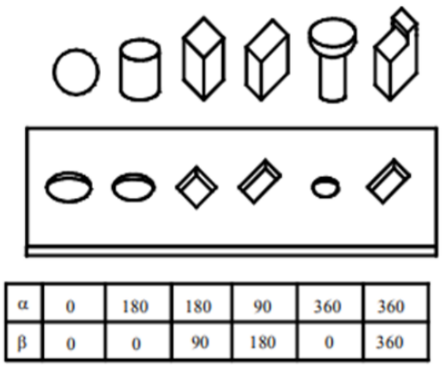


Figure 2.5 The original classification system for the features section affecting manual handling time.



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

Figure 2.6 The original classification system for the features section affecting manual handling time

Basic equations apply to the DFA worksheet:

$Operation\ time, T_0 = N_0[T_h T_i]$

Where,

N_o = *Number of operation*

T_h = *Manual time handling per part (sec)*

T_i = *Manual time insertion per part (sec)*

$Total\ manual\ assembly\ time, TM = T_t + T_s$

Where,

T_t = *Total handling time (sec)*

T_s = *Total insertion time (sec)*

$Design\ effieciency, DE = \frac{3NM}{TM}$

Where,

NM = Theoretical minimum number of part

TM = Total manual assembly time (sec)

2.3 Absorption Cost

Table 2.5 Absorption cost analysis

Steps	Notes	Unit Cost, RM
1. Define unit	Portable Charcoal Grill for Outdoor 18 inch	
2. Determine no of units.		
3. Calculate the direct cost	-	
Material Cost:		
Other:	-	
Total direct cost:	-	
4. Calculate indirect cost	-	
Fasteners:		
Utilities:		
Other:	-	
Total indirect cost	-	
5. Calculate overhead cost	-	

Overhead cost:	Total indirect cost / Total Number of units	
Total overhead cost		
6. Calculate the unit cost		
.From step 3	-	
From step 4	-	
From step 5	-	
Total Cost	-	

Absorption costing, also referred to as complete absorption costing, is a management interested that every product should bear its total cost, be it fixed or variable cost and leave something towards profits towards return on investment [5]. Direct and indirect expenses, such as direct materials, direct labor, rent, and insurance, are paid for using this approach. Absorption costs also require fixed overhead charges as part of the expense of the product. Many of the expenses involved with the manufacturing of the product include wages for workers who are physically involved in the production of the product, raw materials used in the production of the product, and other operating costs such as the utility charges that are used in production.

3. Result and Discussion

3.1 Comparison manual insertion between Product 1, Product 2, Product 3.

Table 3.1 DFA comparison between Product 1, Product 2 and Product 3

	Product 1	**Product 2**	**Product 3**
Total manual assembly time, TM	237.99	668.03	443.97
Theoretical number of parts, NM	15	22	23
Design Efficiency	18.90%	9.87%	15.54%

Based on the data in Table 3.1 above, the entire assembly time by three designs Product 1, Product 2, and Product 3 is 237.99, 668.03, and 443.97 respectively. Product 1 has a shorter total manual assembly time and a theoretical number of parts by 237.99 and 15 parts.

It has been shown that the less the theoretical number of parts, NM, the shorter the overall manual assembly time, TM. As a result, Product 1 has the highest design efficiency than the other two products.

3.2 Design Improvement of BBQ Grill

Table 3.2 Improved Product 1 from original Product 1

Original Product 1	Improved Product 1
	

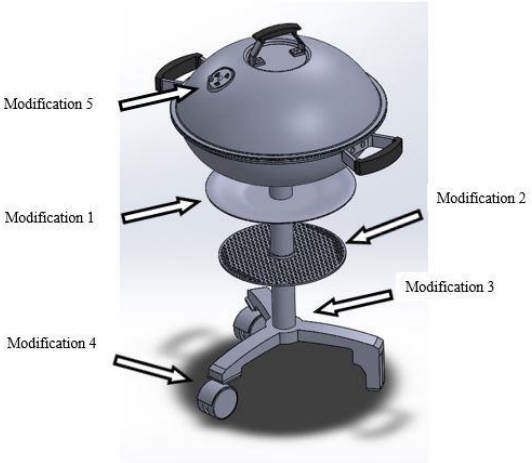


Figure 3.1 Product 1: Portable Charcoal Grill for Outdoor 18 inch -V2 points of modifications

Figure 3.1 shows five modification from Product 1: Portable Charcoal Grill for Outdoor 18inch to the Product 1: Portable Charcoal Grill for Outdoor 18 inch-V2 which is consist of redesign the ash filter, change and redesign base rack, reduce four legs to the one legs with bigger diameter, change and reduce the size of the wheel and merge the smoke vent with top lid.

Table 3.3 Design improvement for Portable Charcoal Grill for Outdoor

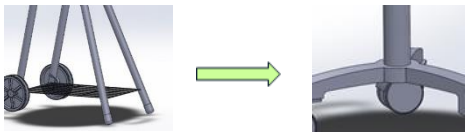
No	Modification	Figure	Justification
1	Change the type joint of ash filter from original to single axis joint		Redesign the ash filter to reduce the assembly time and allow of higher-volume processes.
2	Change the base rack model from rectangle to circular model		The redesign of the base rank system can reduce the time of assembly with single axis joint and reduce the raw material use in production.
3	Modify the uses of legs from four legs to one leg with a larger diameter		The elimination the four legs can reduce the raw material used and cost in production. Make the assembly more easier and reduce the assembly time.
4	Change and reduce the size of the wheel.		To reduce the raw material use and raw material production cost on the wheel.
5	Merge and combine the smoke vent with the top lid.		To reduce the number of part and assembly time to become much simpler.

Table 3.4 DFM Costing comparison of Product 1-V2

	Product 1	**Product 1-V2**
Design Efficiency	18.90%	19.64%
DFM Costing (RM)	868.29	807.48

By compared the data obtained, 4 parts have been reduced to be 43 parts from the initial 47 parts of product 1. As a result, the design efficiency, DE, increased from 18.90 percent on the original product to 19.64 percent on the modified product. Reducing the number of parts has an impact on the product's DFM costs. Product 1 was originally priced at RM868.29 but has been reduced to RM807.48, a savings of RM60.81.

3.3 Absorption Costing for both Product 1 and Product 1-V2

Absorption cost or which is commonly known as the “Cost plus approach” is made for both model Portable Charcoal Grill for Outdoor 18 inch and newly improved model Portable Charcoal Grill for Outdoor 18 inch -V2. The total absorption cost of the product is calculated by adding the direct cost, indirect cost,

and overhead cost.

Table 3.5 Total absorption cost comparison

Portable Charcoal Grill for Outdoor 18inch	Portable Charcoal Grill for Outdoor 18inch-V2
RM 883.39	RM 822.63

Table 3.5 shows the total absorption cost for both model Portable Charcoal Grill for Outdoor 18inch and redesigned model Portable Charcoal Grill for Outdoor 18inch V2. There were RM 60.76 cost reductions between these two models.

4. Conclusion

The DFMA analysis, as well as the cost analysis, were completed satisfactorily. Three models, Portable Charcoal Grill for Outdoor 18inch, Char-Griller Classic Cart Style, and Charcoal Kettle Grill with Cart BBQ, were manually inspected for 47, 125, and 91 components, respectively. The results revealed that the Portable Charcoal Grill for Outdoor 18inch has a highest design efficiency level of 9.03 percent than the Char-Griller Classic Cart Style, and 3.36 percent than Charcoal Kettle Grill with Cart BBQ thus it was decided to undertake a revised model. Only 32 of the 47 original items were engaged in the Design for Manufacturing (DFM) concurrent costing evaluation. All items that were not computed using DFM software were acquired from the supplier and were not included in the production process in terms of DFM. This procedure aids in the identification and material selection processes required to improve the newly redesigned product. Based on the findings, the manufacturing procedure for the Portable Charcoal Grill for Outdoor 18inch model was casting, machined/cut from stock, welding, injection mold, and joining.

The number of parts in the Portable Charcoal Grill for Outdoor 18inch-V2 model has been reduced from 47 to 43. The materials used to create the redesign were also mostly stainless steel and aluminium. In contrast, the concurrent costing model of the Portable Charcoal Grill for Outdoor 18inch-V2 requires only 29 parts from the original product where 32 parts. The manufacturing process also the same as the original product were casting, machined/cut from stock, welding, injection mold, and joining.

In cost analysis, the result shows that the total cost per product of Portable Charcoal Grill for Outdoor 18inch-V2 is RM 822.63 while the original product of Portable Charcoal Grill for Outdoor 18inch is RM 883.39. As an outcome, the newly designed model is RM 60.76 cheaper than the previous Portable Charcoal Grill for Outdoor 18inch.

Following that, one of the most significant issues that must be addressed is the question of sustainability. In this study, three aspects of sustainability are examined: the environment, the economy, and society. In terms of economics, it will improve the company's profit and shorten the manufacturing route's time. With respect to the environment redesigning the barbeque grill will have no negative impact because it is digital and completely utilizes software. It also can minimize the amount of raw material used during manufacture. Lastly, the impact on society will enhance the quality of life for companies, industries, and labor, as well as boost the efficiency with which the barbecue grill is manufactured.

Furthermore, due to the Covid-19 pandemic, the laboratory session could not be completed, and the software data could not be recorded. Only data from manual calculations have been collected.
As a recommendation to improvise the conducted research it is highly recommended as following:

i. The DFMA study performed on a barbeque grill may be combined with the Finite Element Analysis (FEA) analysis to get more precise and trustworthy data.

ii. It is also strongly advised to utilize cost analysis software such as "Clarity Software" and "Cost Management Software."

Acknowledgement

The author would like to give thanks to Universiti Tun Hussein Onn Malaysia (UTHM) for supporting these research activities.

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