Progress in Engineering Application and Technology Vol. 1 No. 1 (2020) 399-408

PEAT

Homepage: http://penerbit.uthm.edu.my/periodicals/index.php/peat
e-ISSN : 0000-0000

Design Improvement of Toner Cartridge Using Design For Assembly Method

Muhammad Alif Haziq bin Nordin[1], **Haffidzudin bin Hehsan**[1*]

[1]Faculty of Engineering Technology
Universiti Tun Hussein Onn Malaysia, 86400 Parit Raja, Batu Pahat, Johor, Malaysia.

*Corresponding Author Designation

DOI: https://doi.org/10.30880/peat.2020.01.01.042
Received 28 September 2020; Accepted 12 November 2020; Available online 02 Month 2020

Abstract: DFMA or known as Design for Manufacture and Assembly, consists of two main components which are Design for Manufacturing and Design for Assembly. To review the design for product evaluation, DFMA is an important methodolgy to be used. Reducing the number of parts to be assembled in a product is very significant. This can contribute to reducing the cost of assembly and assembly time for manufacturer. DFMA methodology is therefore applied to reduce the cost of the product by selecting a consumer product which is a toner cartridge as a case study of the product. The DFA Worksheet table is used for product evaluation and the original product design is reviewed, improved and re-evaluated. The significant result shows the new toner cartridge design is achievable with fewer parts from 32 to 27 parts. This method is also eligible for application to manufacturing industries to improve the effectiveness of their design.

Keywords: DFMA, Design For Manufacture and Assembly, DFA, Design For Assembly

1. Introduction

The manufacturing system consists of a large number of distinct processes which is affect the cost of the product, the quality of the product and the efficiency of the system. Thus, will cause a significant lost in the company's business. DFMA can help to integrate between Design and Engineering production areas in manufacturing and assembly that allow preliminary actions during the development phase to avoid problems and complications during the production phase such as, help designers to develop a product that can be easily manufactured with minimal time, effort and cost during the early design phases [1].

**Corresponding author: haffiz@uthm.edu.my*

The advantages of this method is that the problem of production can be detected at the early stage of the design process. This approach also suggested the best possible way to assemble a component by removing fasteners to other forms of assembly, such as snap fit, press fit and others. Apart from that, this approach often suggested combining parts or eliminating any unwanted components. By implementing this approach, the time of assembly can be reduced and more product can be made. This method also estimated the cost of the product assembling and design efficiency of the product at the early stage of the design, so designers in the manufacturing system can always estimate the efficiency and labor costs of their design before the product is produced [1],[2].

The result of this study would help the manufacturer, especially in the printing device market, in designing product with the requisite data modularization to reduce costs, and at the same time, achieve considerable profit margins. In addition, this work also includes a study of DFMA’s method, its applications, its capability on toner cartridge components including its history. This study also helps students to apply related engineering knowledge in solving issues in the industry.

2. Literature Review and Methods

2.1 Literature Review

Nowadays, designers and manufactures have applied a specific technique such as Boothroyd Dewhurst and many more in their design method. They use this method to ensure that a new product is made up of specifications that are shorter lead time, lower assembly costs, higher production on the market and a high quality product. Product design for manufacturing and assembly can be the key of success to high productivity and cost reduction in all manufacturing industries [3]. In the Boothroyd method, the concept of design for assembly was first designated in the conceptual design phases to ensure that the best design concept can be obtained for materials and processes. The main goal of the concept was evaluated to minimize the manufacturing cost which brings a slight increasing in time usage for the conceptual preliminary design phase [4]. This method which is inside the software can be divided into three stages:

i. Selection of work piece
ii. Selection of process and systems
iii. Assembly of product

2.2 Methods

Design for Assembly (DFA) is a methodology for evaluating part designs and the overall design of an assembly [5]. DFA approach can lead to identify of unnecessary parts in an assembly and to reduce the cost in assembly times. The cost contribution of each part will be evaluated using DFA and the step of simplifying the product concepts by means of part reduction strategies will be implemented. Such approaches include integrating as many features as is economically into one part. The goal by using DFA is to make the product more elegant with fewer parts, which are both functionally effective and easy to assemble. This DFA approach is used to estimate the manual assembly time and the assembly cost of a product by identifying the path to the assembly cost by reducing the number of parts [4]. The methodology of this study were summarized in the flowchart, as shown in Figure 1.

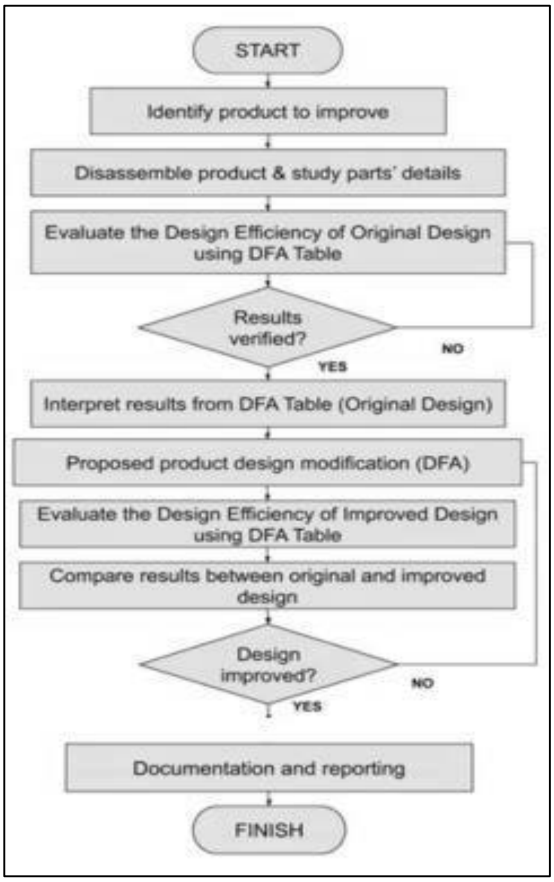

Figure 1: DFA process flowchart

2.3 Materials

The first step in DFMA analysis is gathering the data of the product under study. This step is crucial because DFMA analysis requires a deep understanding about the product. It will be necessary to eliminate or combine a number of parts and to ensure that an efficient product for manufacturing and assembly processes can be obtained. This project will focus on improvement design of a toner cartridge available in the market. The selected model is a New Compatible Cartridge, also known as third party brand. Selection type of product is based on the criteria that the current design of the product can be improved to reduce the cost of production and improving the design efficiency. Figure 2 below show the model of toner cartridge used in this project.

Figure 2: Toner cartridge

3. Results and Discussion

3.1 Results

i. Original product

0	1	2	3	4	5	6	7	8	9
Name of part	Part ID #	# if times the operation is carried out consequtively	two-digit manual handling code	manual handling time per part	two-digit manual insertion code	manual insertion time per part	operation time, sec, (2) x [(4) + (6)]	operation cost, cents, 0.4 x (7)	estimation of theoretical minimum # of parts, 0 or 1
Main Body	1	1	30	1.95	00	1.5	3.45	1.38	1
Toner Sweeper Gear	2	1	10	1.5	30	2	3.5	1.4	1
Cleaning Blade (Small)	3	1	32	2.7	00	1.5	4.2	1.68	1
Screw	4	2	11	1.8	39	8	19.6	7.84	0
Right Cover	5	1	30	1.95	06	5.5	7.45	2.98	1
Stopper Spring (Right Cover)	6	1	05	1.84	30	2	3.84	1.536	0
Connector Gear (Right Cover)	7	1	10	1.5	06	5.5	7	2.8	1
Developer Roller Gear	8	1	10	1.5	06	5.5	7	2.8	1
Developer Roller	9	1	10	1.5	06	5.5	7	2.8	1
Developer Roller Spring	10	1	05	1.84	30	2	3.84	1.536	1
Developer Roller Cover	11	2	11	1.8	30	2	7.6	3.04	0
Screw	12	2	11	1.8	39	8	19.6	7.84	1
Left Cover	13	1	30	1.95	06	5.5	7.45	2.98	1
Stopper Spring (Left Cover)	14	1	05	1.84	30	2	3.84	1.536	0
Toner Releaser Pin	15	1	33	2.51	41	7.5	10.01	4.004	1
Screw	16	1	11	1.8	39	8	9.8	3.92	1
Secondary Body	17	1	30	1.95	19	10	11.95	4.78	1
Computer Chip	18	1	73	9.1	35	7	16.1	6.44	1
Computer Chip Cover	19	1	33	2.51	30	2	4.51	1.804	1
Stopper Spring (PCR)	20	2	05	1.84	41	7.5	18.68	7.472	2
Primary Charger Roller Holder	21	2	72	5.85	41	7.5	26.7	10.68	2
Primary Charger Roller	22	1	00	1.13	30	2	3.13	1.252	1
Cleanig Blade (Medium)	23	1	30	1.95	06	5.5	7.45	2.98	1
Screw	24	2	11	1.8	39	8	19.6	7.84	0
OPC Drum	25	1	10	1.5	06	5.5	7	2.8	1
OPC Drum Gear	26	1	00	1.13	10	4	5.13	2.052	1
OPC Drum Locker	27	1	01	1.43	30	2	3.43	1.372	1
Cover (OPC Drum)	28	1	30	1.95	00	1.5	3.45	1.38	1
Cover Connector (OPC Drum)	29	1	30	1.95	30	2	3.95	1.58	1
Locking Spring (OPC Drum Cover)	30	1	46	6.75	44	8.5	15.25	6.1	0
Right Cover	31	1	35	2.73	19	10	12.73	5.092	1
Screw	32	2	11	1.8	39	8	19.6	7.84	2
						TOTAL	**303.84**	**121.536**	**29**
		Resize					TM	CM	NM
		Reduce						Design Efficiency	
		Eliminate						3 NM/TM	
		Merge						0.28633491	

Figure 3: DFA worksheet of original product

Figure 3 shows the breakdown on the operational time and estimated cost of assembly operations of the parts in the toner cartridge. It shows that the total number of parts for the original design product is 32 including fasteners. For the original product design, the overall assembly time is 303.84 seconds or 5 minutes. In addition, the assembly operating cost estimation in Figure 3 indicates that it is approximately 121.54 cents for one product. The total theoretical minimum number of parts have been estimated to be 29 parts with the design efficiency is 0.28633491.

ii. First modified product

For the first modification, the number of screws used in the assembly propocess is proposed to be reduced or eliminated in certain areas. The screws that connect to developer roller cleaning blade and OPC drum cleaning blade are removed and proposed to be set as part secured immediately using snap fit function for the connection between cleaning blade and main body, as well as similarly for cleaning blade in secondary body. At the left and right covers of the main body, the number of screws used was for each side have been proposed to be reduced from two to one for each side of the covers. Next, is the screws used for the cover on each side of developer roller, where the function of the part is to prevent the developer roller from wiggling. The developer roller is made to rotate and the cover is used to protect the roller during rotating process.

0	1	2	3	4	5	6	7	8	9
Name of part	Part ID #	# if times the operation is carried out consequtively	two-digit manual handling code	manual handling time per part	two-digit manual insertion code	manual insertion time per part	operation time, sec, (2) x [(4) + (6)]	operation cost, cents, 0.4 x (7)	estimation of theoretical minimum # of parts, 0 or 1
Main Body	1	1	30	1.95	00	1.5	3.45	1.38	1
Toner Sweeper Gear	2	1	10	1.5	30	2	3.5	1.4	1
Cleaning Blade (Small)	3	1	32	2.7	00	1.5	4.2	1.68	1
Right Cover	5	1	30	1.95	06	5.5	7.45	2.98	1
Connector Gear (Right Cover)	7	1	10	1.5	06	5.5	7	2.8	1
Developer Roller Gear	8	1	10	1.5	06	5.5	7	2.8	1
Developer Roller	9	1	10	1.5	06	5.5	7	2.8	1
Developer Roller Spring	10	1	05	1.84	30	2	3.84	1.536	1
Screw	12	1	11	1.8	39	8	9.8	3.92	1
Left Cover	13	1	30	1.95	06	5.5	7.45	2.98	1
Toner Releaser Pin	15	1	33	2.51	41	7.5	10.01	4.004	1
Screw	16	1	11	1.8	39	8	9.8	3.92	1
Secondary Body	17	1	30	1.95	19	10	11.95	4.78	1
Computer Chip	18	1	73	9.1	35	7	16.1	6.44	1
Computer Chip Cover	19	1	33	2.51	30	2	4.51	1.804	1
Stopper Spring (PCR)	20	2	05	1.84	41	7.5	18.68	7.472	2
Primary Charger Roller Holder	21	2	72	5.85	41	7.5	26.7	10.68	2
Primary Charger Roller	22	1	00	1.13	30	2	3.13	1.252	1
Cleanig Blade (Medium)	23	1	30	1.95	06	5.5	7.45	2.98	1
OPC Drum	25	1	10	1.5	06	5.5	7	2.8	1
OPC Drum Gear	26	1	00	1.13	10	4	5.13	2.052	1
OPC Drum Locker	27	1	01	1.43	30	2	3.43	1.372	1
Cover (OPC Drum)	28	1	30	1.95	00	1.5	3.45	1.38	1
Cover Connector (OPC Drum)	29	1	30	1.95	30	2	3.95	1.58	0
Right Cover	31	1	35	2.73	19	10	12.73	5.092	1
Screw	32	2	11	1.8	39	8	19.6	7.84	1
						TOTAL	**224.31**	**89.724**	**27**
		Resize					TM	CM	NM
		Reduce						Design Efficiency	
		Eliminate						3 NM/TM	
		Merge						0.3611074	

Figure 4: DFA Worksheet of first modification

The result for the first modification of the product is illustrated in Figure 4. It shows the estimated values for total assembly time of 224.31 seconds or 3.73 minutes. The overall assembly expenses estimated was 89.724 cents and the estimated efficiency of design is then 0.361107396. These indicates an improvement in the estimation of total assembly time and total assembly costs in 73.53 seconds and 31.82 cents, respectively, from the original design. The design efficiency value indicates an improvement compare to the original design of 0.64744231. A significant decrease in assembly time and assembly costs, as well as an improvement in design efficiency may have a valuable positive impacts on manufactures in the related industries.

iii. Second modified product

0	1	2	3	4	5	6	7	8	9
Name of part	Part ID #	# if times the operation is carried out consequtively	two-digit manual handling code	manual handling time per part	two-digit manual insertion code	manual insertion time per part	operation time, sec, (2) x [(4) + (6)]	operation cost, cents, 0.4 x (7)	estimation of theoretical minimum # of parts, 0 or 1
Main Body	1	1	30	1.95	00	1.5	3.45	1.38	1
Toner Sweeper Gear	2	1	10	1.5	30	2	3.5	1.4	1
Cleaning Blade (Small)	3	1	32	2.7	00	1.5	4.2	1.68	1
Right Cover	5	1	30	1.95	06	5.5	7.45	2.98	1
Connector Gear (Right Cover)	7	1	10	1.5	06	5.5	7	2.8	1
Developer Roller Gear	8	1	10	1.5	06	5.5	7	2.8	1
Developer Roller	9	1	10	1.5	06	5.5	7	2.8	1
Developer Roller Spring	10	1	05	1.84	30	2	3.84	1.536	1
Screw	12	1	11	1.8	39	8	9.8	3.92	1
Left Cover	13	1	30	1.95	06	5.5	7.45	2.98	1
Toner Releaser Pin	15	1	33	2.51	41	7.5	10.01	4.004	1
Screw	16	1	11	1.8	39	8	9.8	3.92	1
Secondary Body	17	1	30	1.95	19	10	11.95	4.78	1
Computer Chip	18	1	73	9.1	35	7	16.1	6.44	1
Computer Chip Cover	19	1	33	2.51	30	2	4.51	1.804	1
Stopper Spring (PCR)	20	2	05	1.84	41	7.5	18.68	7.472	2
Primary Charger Roller Holder	21	2	72	5.85	41	7.5	26.7	10.68	2
Primary Charger Roller	22	1	00	1.13	30	2	3.13	1.252	1
Cleanig Blade (Medium)	23	1	30	1.95	06	5.5	7.45	2.98	1
OPC Drum	25	1	10	1.5	06	5.5	7	2.8	1
OPC Drum Gear	26	1	00	1.13	10	4	5.13	2.052	1
OPC Drum Locker	27	1	01	1.43	30	2	3.43	1.372	1
Cover (OPC Drum)	28	1	30	1.95	00	1.5	3.45	1.38	1
Right Cover	31	1	35	2.73	19	10	12.73	5.092	1
Screw	32	1	11	1.8	39	8	9.8	3.92	1
						TOTAL	210.56	84.224	27
		Resize					TM	CM	NM
		Reduce						Design Efficiency	
		Eliminate						3 NM/TM	
		Merge						0.38468845	

Figure 5: DFA worksheet of second modification

Further modification, the screws used to connect the right cover and the secondary body habe been reduced to one screw. The cover for OPC drum and the connector for the cover are both have the same purpose, which is, to cover the OPC drum from exposed to the external lights during the printing process. It has been proposed to be combined from two part to one part. This is because with just one part, the OPC drum can be protected from the external lights exposure. Other than that, the computer chip cover and toner releaser pin have been proposed to be resized to a smaller size. However, resizing the parts would have no significant effects on the DFA results and analysis.

Figure 5 shows the result obtained from the second modification. The second modification result shows a total assembly time of 210.56 seconds with 84.224 cents of assembly costs, having a design efficiency of 0.38468845. This result shows that further modification would provide further improvement on total assembly time, reduce the assembly costs, as well as an improvement in the design efficiency of the product.

3.2 Discussions

Upon evaluating the toner cartridge for redesigning purposes, certain modifications have been applied to the product design. The modifications were made not to effect the main function of the parts and the product itself. The toner cartridge concept was redesigned according to the principles of DFMA method as follows:

i. Prevent from eliminated of base part.

ii. Reducing and eliminating of fasteners or connectors.
iii. Cost and time reduction by changing the type of material and manufacture process.

Modifications on the original products was introduced, whereby, the number of screws were reduced or eliminated, and snap fit securing method has been used in certain areas of the parts. Table 1 shows the summary of results obtained from the DFA worksheets analysis between the original product, first modification and second modification.

Table 1: Comparison of assembly operation time, cost and design efficiency

Item	Original Product	First Modification	Second Modification
Number of parts	32	29	27
Assembly operation time, seconds	303.84	224.31	210.56
Assembly operation cost, cents	121.54	89.724	84.224
Design efficiency	0.28633491	0.3611074	0.38468845

For the first modification the cumulative number of parts have been reduced from 32 parts to 29 parts. In the second modification, the cumulative number of parts hav been further reduced to 27 parts. Referring to Table 1, it stated that the original product assembly operation time is achieved with 303.84 seconds. Then, with 224.31 seconds or equivalent to 3.74 minutes, the first modification assembly operation time is reached. Next, with 210.56 seconds, the second modification assembly operation time is obtained. This indicates that further modification have significantly reduced the assembly operating time from 303.84 seconds (5.1 minutes) to 210.56 seconds (3.5 minutes).

Table 1 also shows that the assembly operation costs have been reduced form 121.54 cents to 89.724 cents in first modification, and further reduced to 84.224 cents in the second modification. Meanwhile, the design efficiency value has been improved from 0.28633491 in the original product to 0.3611074, while for the second modification, the design efficiency has been further improved to 0.38468845.

The objectives of this project have been achieved by eliminating the screws used at the cleaning blade screws and reducing the number of screws used on both sides of the main body cover, in order to reduce the assembly operation time and assembly operation costs. Besides that, the stopper spring that attached to the right and left of the main body cover has also been removed. Similarly, the locking spring mechanism at the OPC drum cover have been removed. In adddition, the developer roller covers has also been eliminated due to the low level of part feature or function.

Eliminated spring and reduced screws can be seen in Figures 6. It shows that sides of the main body cover used two screws to assemble them, and this has been been reduced to one screw for each side of the cover. Figure 7 shows the cleaning blade inside the main body. The screws that connect the cleaning blade and the main body has been eliminated, where the secured method has been changed from screws tight might to snap fit secured method. In addition, the developer roller cover has been eliminated (as seen in Figure 7) due to the low function of the part is low, and removing the developer roller cover will not effect the function of the product. In addition, referring to Figure 8, the OPC drum cover and the cover connector can be proposed to be redesigned to be one part. This would further reducing the number of parts for the product and assembly operation time, and subsequently will further reduce the total assembly costs of the product. Figure 9 illustrates the snap fit secured method that been applied at the cleaning blade that connected to the main body.

In the second modification of the product, Figure 12 shows the location of the screws on the secondary body left cover. One of the screws has been eliminated. In the secondary body, it contains a cleaning blade and have the same function as the cleaning blade in the main body (as shown in Figure

10 and 11). The screws that connect the cleaning blade to the secondary body have been eliminated and the method of connection has been changed to snap fit secured method. In addition, referring to Figure 8, the OPC drum cover and the cover connector can be proposed to be redesigned to be one part. This would further reducing the number of parts for the product and assembly operation time, and subsequently will further reduce the total assembly costs of the product.

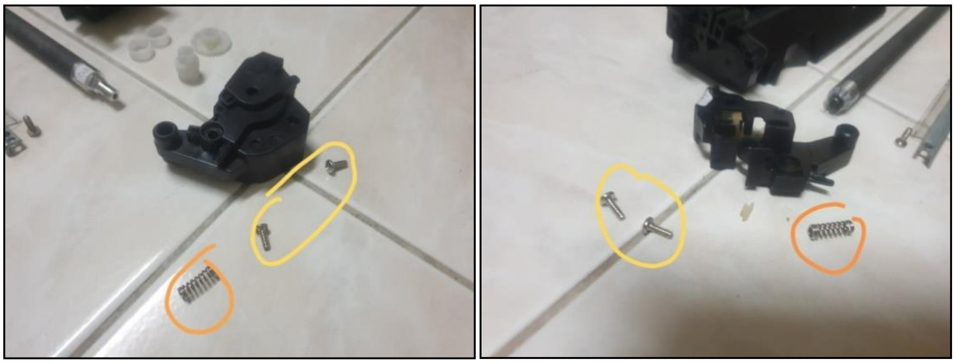

Figure 6: Eliminated spring and reduced screws

Figure 7: Eliminated cleaning blade screws and developer roller cover

Figure 8: Eliminated locking spring and combined OPC drum cover

Figure 9: Eliminated cleaning blade screws

Figure 10: Main body right cover screws location

Figure 11: Main body left cover screws location

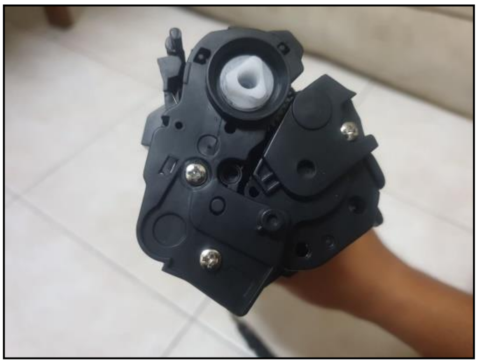

Figure 12: Secondary body left cover screws location

4. Conclusion

Based on the study conducted, the conclusion follows can be made where the DFA method is very useful in analyzing the present toner cartridge designs. This method also aims to improve productivity and assembly operation costs for the product. The comparison between design performance and assembly costs before and after progress indicates that the use of this method has greatly contributed to the purposes. It can also be concluded that reducing the number of parts will increases the design efficiency and thus decreases the total assembly operation costs. The result from this study show that DFA method is very useful in reducing costs of production as well as the total number of parts.

4.1 Recommendation

This study should be continued as various changes and related areas can be explored in this study. This study is only theoretical measurement and performance improvement of the product, and further analysis can be carried out in order to assess the output of an improved design. The manufacturing costs for each item are another factors to be considered as this study only provide the costs of the assembled parts. For the material and mold costs or processes to be produced for each component, cost measurement can be further developed. The main concern in developing a product is whether the improvement in materials and processes would raise the total costs of the end product. This study can also be furthered with various DFA methods and the most effective methods of improving the design of the product can be compared. The results obtained from various methods can be compared and the most suitable method for analyzing the productcan be justified.

Acknowledgement

The authors would like to thank the Faculty of Engineering Technology, Universiti Tun Hussein Onn Malaysia for its support.

References

[1] Barbosa, G. F., & Carvalho, J. (2014). Guideline tool based on design for manufacturing and assembly (DFMA) *Journal of the Brazilian Society of Mechanical Sciences and Engineering*, *36*(3), 605–614. https://doi.org/10.1007/s40430-013-0103-1

[2] Othman, M. S. Bin. (2010). Design for Assembly and Application Using Boothroyd Dewhurst Method. (April).

[3] Henry W. Stoll. “Product Design Methods and Practices”

[4] Ć, G. M. J. Č. I., & Sadu, N. (2014). *Projektovanje za izradu i montažu u okviru projektovanja za izvrsnost : prilazi , metode i metodologije*. *63*, 233–242.

[5] G. Boothroyd. “Design for Assembly- The Key to Design for Manufacture.” Department of Industrial & Manufacturing Engineering, University of Rhode Island, Kingston