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Design for Manufacturing and Assembly (DFMA) for Handheld Corded Electrical Drill

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Abstract: Design for Manufacture and Assembly (DFMA) is an industry tool that helps to reduce assembling costs by improving the assembly process and minimising the number of parts. The hand-held corded electrical drill was chosen as the case study sample in this work. The key for this research is to come up with a new design efficiency and reduced cost of manufacture by comparing the new model and the original model. To improve the design and lower the cost of the Hand-held corded electrical drill, the Boothroyd Dewhurst DFA manual method and DFMA software is used. The CAD models are generated using the Solidworks software, which is then examined using the Boothroyd Dewhurst DFMA software application. According to the findings of this study, assembly time per product reduce from 523.47 seconds to 482.19 seconds when using the software analysis while using DFA manual method the assembly time per product part is reduce from 532.47 second to 472,19 second. The DFMA result demonstrates that the cost per product is reduced from RM113.78 to RM103.69. As a result, it has been demonstrated that the Boothroyd Dewhurst DFA manual method and DFMA software method approach was capable of improving the design in terms of design efficiency, product assembly time, and cost reduction. This strategy can be used in the manufacturing business to improve design effectiveness and estimate the cost of production for newly design product.

Keywords: DFMA, DFA, DFM

1. Introduction

DFM and DFA are typically integrated with Design for Manufacturing and Assembly. Design for Manufacturing (DFM) is a tool that focuses on lowering production costs and shortening time to market while maintaining the good quality of the product. Design for Assembly (DFA) is method for utilizing components in a product's design. DFMA also a method for systematically examining suggested designs from the standpoint of assembly processes [1]. To get the most out of DFMA, the method should be started early in the design process as possible and within a concurrent engineering collaborative context [2]. Reducing the number of individual pieces in a product is one way to cut costs by using design for manufacturing and assembly techniques early on in the design process.

The introduction should describe general information on the subject matter area of study. It is usually arranged in such a manner to gradually bring to focus the specific motivations of the current

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study, the research questions, the problem statements, the hypotheses, the objectives, as well as the expected outcome.

1.1 Design for assembly (DFA)

During the design process, DFA considers and resolves potential difficulties that may arise during the assembly process, ensuring that the part is assembled in a timely manner and at a minimal cost and high output [3]. Design for assembly (DFA) is a type of design model in which the engineer employs a variety of methods such as analyzing, estimating, planning, and simulating to take into account all factors that will have an impact on a product's assembly process throughout the entire design process and revise the assembly constructions to ensure that the final product's characteristics and functions are satisfied, at the same time reduce the cost as much as possible

1.2 Design for manufacture (DFM)

Design for manufacture (DFM) has three main goals:

i. Improve the quality of new products while they are being manufactured in areas such as design, technology, manufacturing, assembly, service, and several others.

ii. Reduce the cost of design, technology, manufacture, shipping, technical support, disposal, and other expenses.

iii. Shorten the developing time and increase productivity include the time of design, manufacturing preparing and repeatedly calculation.

1.3 Electric hand drill

A drill is a tool used to produce holes or drive a screw. It has a chuck that holds a bit, either a drill or a driver. Several powered drills have a hammer function. A power drill is equipment that utilizes an electric motor to drill a hole in wood, plastic, or metal using a replacement drill bit.

Figure 1: Protech handheld corded electrical drill

2. Methods

In this study, the design for manufacture and assembly DFMA method that will be use is Boothroyd Dewhurst analysis. The study will conduct by using Boothroyd Dewhurst manual analysis and by using Boothroyd Dewhurst DFA and DFM software analysis.

2.1 DFA manual method

After dissembling and analyses the hand drill, the assembly evaluation using Boothroyd Dewhurst can be proceed. The DFA approach, grading scheme for manual handling procedure, is a standardized arrangement of certain characteristics to improve complexity level operation. The characteristics of the parts can significantly affect the manual handling time:

a) Size
b) Weight
c) Thickness
d) Flexibility
e) Necessity for using grasping tools
f) Necessity for using one hands
g) Necessity for using two hands
h) Necessity for optical magnification

2.2 DFA using software

The initial step after beginning the DFA program is to specify the Product Structure. DFA's Product Structure is the same as a BOM or parts list. It contains a list of all of the product's components, subassemblies, and operations. On the left side of the DFA software's Structure Chart, the Product Structure is built and maintained. This is where you'll find the components and operations list. Insert the component list into the Structure Chart to begin the analysis. Component lists may be imported from Excel or other spreadsheets into the DFA tool, which cuts down on data entry time.

2.3 DFM using software

DFM software can calculate how much it should cost for a lot of different manufacturing processes and materials. In DFM, a custom operation can be added to figure out how much the supplier will spend on overhead and how much they will earn per part. People who want to make a custom DFM operation will have to choose how much they want to pay for overhead and how much they want to make. The total cost of making the part can be thought of as the total “price” of the part.

3. Results and Discussion

The purpose of this study is to investigate the design efficiency of the handheld corded electrical drill by using Boothroyd Dewhurst method. Then redesign the original model by eliminating and decreasing the number of parts without effect the quality and function of the product.

3.1 Results of DFA using manual method

The table 1 and Table 2 show the analysis of the original and modified design of handheld corded electrical drill. The table below will generate the total operation time for assembly, total theoretical minimum part and the design efficiency.

Table 1: DFA manual analysis for original model.

0	A2	A3	A4	A5	A6	A7	A8	A9
Name of part	No of operations carried out consecutively	Manual handling code	Manual handling time per part	Manual insertion code	Manual insertion time per part	Operation time A2(A4+A6)	Total angle of symmetry (α + β), deg (°)	Estimation for theoretical minimum parts
Casing A	1	30	1.95	00	1.5	3.45	720	1
Chuck Shaft	1	19	3.38	54	10	13.38	360	1
Chuck interior	1	18	3	37	9	12	360	1
Chuck bevel gear	1	18	3	37	9	12	360	1
Chuck jaw	3	84	6.75	57	13	59.25	360	3
Chuck external sleeve	1	19	3.38	37	10	13.38	360	1
Ball Bearing (6201VVCMPS2S)	1	09	2.98	06	5.5	8.48	180	1
Helix Gear	1	09	2.98	06	5.5	8.48	180	1
Retaining ring	1	43	7.6	01	2.5	10.2	180	1
Ball Bearing (606-2Z-GBT-276-94)	1	09	2.98	06	5.5	8.48	180	1
Armature assembly	1	39	4	06	5.5	9.5	720	1
Armature fan	1	09	2.98	06	5.5	8.48	360	1
Stator	1	01	1.43	06	5.5	13.86	720	1
Ball Bearing (608VVMC2EPS2L)	1	09	2.98	06	5.5	8.48	180	1
Ball Bearing (626VVMC2ERPS2S)	1	09	2.98	06	5.5	8.48	180	1
Brush housing	2	02	1.88	09	7.7	19.16	270	2
Brush spring	2	00	1.13	06	5.5	13.26	180	2

Table 1: DFA manual analysis for original model (cont.)

0	A2	A3	A4	A5	A6	A7	A8	A9
Name of part	No of operations carried out consecutively	Manual handling code	Manual handling time per part	Manual insertion code	Manual insertion time per part	Operation time A2(A4+A6)	Total angle of symmetry (α + β), deg (°)	Estimation for theoretical minimum parts
Carbon brush	2	00	1.13	01	2.5	7.26	180	2
Reversing Switch casing	1	30	1.95	26	9.5	11.45	720	1
Reversing lever switch	1	30	1.95	26	9.5	11.45	720	1
Copper plate	2	02	1.88	09	7.7	19.16	180	2
spring	1	09	2.98	06	5.5	16.9	180	1
Reversing switch connector	2	02	1.88	09	7.7	19.16	270	2
Reversing switch upper panel	1	30	1.95	26	9.5	11.45	720	1
Reversing switch lower panel	1	30	1.95	26	9.5	11.45	720	1
Trigger housing	1	43	7.6	01	2.5	10.2	720	1
Speed knob	1	13	2.25	19	9	11.25	360	1
Trigger side plate	2	30	1.95	26	9.5	22.9	720	2
Coil	1	09	2.98	06	5.5	8.48	180	1
Push button	1	14	2.85	13	6	8.85	360	1
Tapping screwd4x6	2	11	1.8	49	10.5	24.6	360	0
Cable holder	1	00	1.13	02	2.25	3.38	270	1
Casing b	1	30	1.95	00	1.5	3.45	720	1
Tapping screw D4x20	7	11	1.8	49	10.5	86.1	360	0
Design Efficiency =3NM/TM						TM		NM
3(39)/517.47=0.2261(22.61%)						517.47		39

Table 2: DFA manual analysis for modified design

	A2	A3	A4	A5	A6	A7	A8	A9
Name of part	No of operations carried out consecutively	Manual handling code	Manual handling time per part	Manual insertion code	Manual insertion time per part	Operation time A2(A4+A6)	Total angle of symmetry (α + β), deg (°)	Estimation for theoretical minimum parts
Casing A	1	30	1.95	00	1.5	3.45	720	0
Chuck Shaft	1	19	3.38	54	10	13.38	360	1
Chuck interior	1	18	3	37	9	12	360	1
Chuck bevel gear	1	18	3	37	9	12	360	1
Chuck jaw	3	84	6.75	57	13	59.25	360	3
Chuck external Sleeve	1	19	3.38	37	10	13.38	360	1
Ball Bearing (6201VVCMPS2S)	1	09	2.98	06	5.5	8.48	180	1
Helix Gear	1	09	2.98	06	5.5	8.48	180	1
Retaining ring	1	43	7.6	01	2.5	10.2	180	1
Ball Bearing (606-2Z-GBT-276-94)	1	09	2.98	06	5.5	8.48	180	1
Armature assembly	1	39	4	06	5.5	9.5	720	1
Armature fan	1	09	2.98	06	5.5	8.48	360	1
Stator	2	01	1.43	06	5.5	13.86	720	2
Ball Bearing (608VVMC2EPS2L)	1	09	2.98	06	5.5	8.48	180	1
Ball Bearing (626VVMC2ERPS2S)	1	09	2.98	06	5.5	8.48	180	1
Brush housing	2	02	1.88	09	7.7	19.16	270	2

Table 2: DFA manual analysis for modified design (cont.)

	A2	A3	A4	A5	A6	A7	A8	A9
Name of part	No of operations carried out consecutively	Manual handling code	Manual handling time per part	Manual insertion code	Manual insertion time per part	Operation time A2(A4+A6)	Total angle of symmetry (α + β), deg (°)	Estimation for theoretical minimum parts
Brush spring	2	00	1.13	06	5.5	13.26	180	2
Carbon brush	2	00	1.13	01	2.5	7.26	180	2
Reversing Switch casing	1	30	1.95	26	9.5	11.45	720	1
Reversing lever switch	1	30	1.95	26	9.5	11.45	720	1
Copper plate	2	02	1.88	09	7.7	19.16	180	1
spring	1	09	2.98	06	5.5	16.9	180	1
Reversing switch connector	2	02	1.88	09	7.7	19.16	270	2
Reversing switch upper panel	1	30	1.95	26	9.5	11.45	720	1
Reversing switch lower panel	1	30	1.95	26	9.5	11.45	720	1
Trigger housing	1	43	7.6	01	2.5	10.2	720	1
Speed knob	1	13	2.25	19	9	11.25	360	1
Trigger side plate	2	30	1.95	26	9.5	22.9	720	1
Coil	1	09	2.98	06	5.5	8.48	180	1
Push button	1	14	2.85	13	6	8.85	360	1
Casing b	1	30	1.95	00	1.5	3.45	720	1
Tapping screw D4x20	5	11	1.8	49	10.5	61.5	360	0
	Design Efficiency =3NM/TM 3(39)/456.76=0.2364(23.64%)					TM 456.76		NM 39

The time for assembly for original model is 517.47 second then it reduces to 456.76 second for the modified design 50.28 second time reduction for the assembly. While the design efficiency is also increase by 1.03% from 22.61 form the original model.

3.2 DFA using software

Table 3 shows the analysis result for the original and modified model of handheld corded electrical drill.

Table 3: Result for DFA analysis using software

		Original	Modified
Per production data	Entries (including repeats)	48	43
	Number of different entries	42	40
	Total assembly labour time (sec)	532.47	482.19
	Weight	1.93	1.78
Per production cost	Labour cost	11.18	10.26
	Manufacture piece part cost	79.42	72.58
	Manufacture tooling cost	23.19	20.86
	Total cost	**113.78**	**103.69**

3.3 DFM using software

Table 4 and table 5 display the material use and cost for the production for each component using the DFM software for the original model and modified model. Base on the Table 4 the total cost for manufacture the part for the electric drill for the modified design is less than cost for original design due to material change for the product.

Table 4: Total of DFM concurrent costing for modified model

No	Name of part	Material	Quantity	Price part cost (RM)	Total cost (RM)
1	Chuck Shaft	Stainless steel	1	5.38	5.38
2	Chuck interior	Stainless steel	1	4.33	4.33
3	Chuck external sleeve	Carbon steel	1	2.89	2.89
4	Chuck bevel gear	Stainless steel	1	3.75	3.75
5	Chuck jaw	Stainless steel	3	2.31	6.93
6	Reversing switch	High Density Poly Ethylene (HDPE)	1	1.08	1.08
7	Speed knob	High Density Poly Ethylene (HDPE)	1	0.77	0.77
8	Helix Gear	High Density Poly Ethylene (HDPE)	1	8.35	8.35
9	Stator	High Density Poly Ethylene (HDPE)	1	9.25	9.25
10	Split Casing	High Density Poly Ethylene (HDPE)	2	6.70	13.40

Table 4: Total of DFM concurrent costing for modified model

No	Name of part	Material	Quantity	Price part cost (RM)	Total cost (RM)
11	Brush housing	High Density Poly Ethylene (HDPE)	2	1.58	3.16
12	Reversing switch casing	High Density Poly Ethylene (HDPE)	1	1.28	1.28
13	Reversing switch upper panel	High Density Poly Ethylene (HDPE)	1	0.98	0.98
14	Copper plate	Copper	2	0.32	0.64
15	Reversing switch connector	High Density Poly Ethylene (HDPE)	2	0.97	1.94
16	Reversing switch lower panel	High Density Poly Ethylene (HDPE)	1	1.81	1.81
17	Trigger housing	High Density Poly Ethylene (HDPE)	1	1.81	1.81
18	Trigger side plate	High Density Poly Ethylene (HDPE)	2	0.88	1.76
19	Push button	High Density Poly Ethylene (HDPE)	1	0.31	0.31
20	Armature Fan	High Density Poly Ethylene (HDPE)	1	1.50	1.50
21	Armature Assembly	Stainless steel	1	10.79	10.79
22	Cable holder	High Density Poly Ethylene (HDPE)	1	0.25	0.25
Total			29	65.70	79.42

Table 5: Total of DFM concurrent costing for modified model

No	Name of part	Material	Quantit y	Price part cost (RM)	Total cost (RM)
1	Chuck Shaft	Carbon steel	1	4.46	4.46
2	Chuck interior	Carbon steel	1	3.84	3.84
3	Chuck external sleeve	Carbon steel	1	2.89	2.89
4	Chuck bevel gear	Carbon steel	1	3.75	3.75
5	Chuck jaw	High Density Poly Ethylene (HDPE)	3	1.89	5.67

Table 5: Total of DFM concurrent costing for modified model (cont.)

No	Name of part	Material	Quantity	Price part cost (RM)	Total cost (RM)
6	Reversing switch	High Density Poly Ethylene (HDPE)	1	1.08	1.08
7	Speed knob	High Density Poly Ethylene (HDPE)	1	0.77	0.77
8	Helix Gear	Cast iron	1	6.28	6.28
9	Stator	Plain carbon steel	1	9.25	9.25
10	Split Casing	High Density Poly Ethylene (HDPE)	2	4.59	9.18
11	Brush housing	High Density Poly Ethylene (HDPE)	2	1.58	3.16
12	Reversing switch casing	High Density Poly Ethylene (HDPE)	1	1.10	1.10
13	Reversing switch upper panel	High Density Poly Ethylene (HDPE)	1	0.98	0.98
14	Copper plate	Copper	2	0.32	0.64
15	Reversing switch connector	High Density Poly Ethylene (HDPE)	2	0.97	1.94
16	Reversing switch lower panel	High Density Poly Ethylene (HDPE)	1	1.81	1.81
17	Trigger housing	High Density Poly Ethylene (HDPE)	1	1.63	1.63
18	Trigger side plate	High Density Poly Ethylene (HDPE)	2	0.88	1.76
19	Push button	High Density Poly Ethylene (HDPE)	1	0.31	0.31
20	Armature Fan	High Density Poly Ethylene (HDPE)	1	1.50	1.50
21	Armature Assembly	Stainless steel	1	10.79	10.79
Total			28	60.36	72.58

4. Conclusion

The result comparison between manual and software DFA, the differences is significantly low. When using manual method, the time reduction for assembly time between original design and modified is 50.28 second. The time reduction when using software is 60.68 second. For design efficiency of original model is 22.61% and the new modified model is 23.64% it increases 1.03%. The result for DFA index for modified model when using software analysis is 20.2% which is increase 1% from 19.2%. Base form results of DFA manual and software analysis, both result software and manual increase 1%

design efficiency the different between the result is total time assembly, theoretical number of part and DFA index. Both result show improvement in assembly time by reducing the time for assembly more than 50 second.

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