Redesign of Pneumatic Piston Using Design for Manufacture and Assembly (DFMA) Technique

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Abstract

Design for Manufacture and Assembly (DFMA) technique has been utilized intensively in industry for many years in order to increase the quality, decrease the cost and shorten the cycle time of a product. This paper is a detail application of the technique in the pneumatic piston product. The redesign effeciency of the product increases significantly from 25.9% to 67.45%.

Keywords: *manufacture and assembly*

1. Introduction

Initially, the tradition manufacturing technique had utilized for many years. The techinque is in where sketches of the parts completed on the CAD (Computer Aided Design) workstation, the design engineers create the detail drawing and assembly engineer create the assembly plan. The workshop makes prototype and gives the feedback, which accords to the sample test, to the design engineers and assembly engineers who will redesign the product, the assembly and the manufacturing process. The same cycle repeats again and again until arriving at competitive design. This process makes the design and manufacturing been performed independently. The designer designs a product and 'tosses it over the wal' to the manufacturer to produce (Boothroyd, Knight and Dewhurst, 2002). The design engineer and the manufacturingengineer works individually and what results is that the final products have many *disadvantages* such as poor characteristics in manufatcuring, assembly, maintenance; long developing period; high cost; and unguaranteed quality.

Currently, the technique has been changed by founder father Dr. Geoffrey Boothroyd and Dr. Peter Dewhurstn who done the research in this new technology at the beginning in the early 1970's. Actually, the 'DFMA' is a trademark of their company. The created and developed the DFMA concept which is used in developing the products of their company using DFMA software system. This software is used to help the design in almost all the industrail fields including circuit boargds (Boothroyd and Knight, 1993), with manual assembly, with robotic assembly and with machining. The University of South Australia in the school of Advanced Manufacturing and Mechanical Engineering has been utilized the software for undergraduate and postgraduate students lessons. Professor Kazem Abhary is the person in charge to consult how to procure and use the DFMA software. The following is a detail of the motor drive how the technology works.

2. "*Golden Criteria*" for Retaining a Component in an Assembly

To start applying the DFMA for assembly a product, pickp up the component that has many attached parts and identify invisible sequences. In other words, each part must be examined as it is added to the product during assembly.

a) During operation of the product, does the part move relative to all other parts already assembled? Only gross motion should be considered-small motions that can be accomodated by integral elastic elements, for example, are not sufficient for a positive answer.
b) About the material, must be part be of a different material than or be isolated from all other parts already assembled? Only fundamental reasons concerned with material properties are acceptable.

c) Must the part be separated from all other parts already assembled because otherwise necessary assembled or disassembly of other separate parts would be impossible.

Other hints to apply the DFMA are:

a) Design or redesign other product starts with concepted design illustrate it with exploded view of the product. Exploded view is the order of disassembly product as dipicted in Figure 1.
b) Do not miss the assembly lines in the exploded view.
c) The 3 golden criterias are not applied for the first component.

Boothroyd et al (2002) redesigned a motor drive and succeded to increase its efficiency by 18.5% as follow steps.

In the Figure 1, there are 14 parts that must be analysed associating with the criterias and the hints. From the Table 1 shown that totals assembly time is 160s with a theoritical minimum time obtained by multiplying the theoritical minimum part count of four by a minimum time of assembly for each part of 3s.

It should be noted that for this analysis standard subassemblies are counted as parts. Thus,

$$Design\ \ Efficiency = \frac{4\,x\,3}{160} = 7.5\% \qquad (1)$$

To improve the design (redesign), bushes are integral to the base, snap-on plastic cover replaces standoff, cover, plastic bush, six screws. Using pilot point screw to fix the base, which redesign to be self-alignment as in Figure 2.

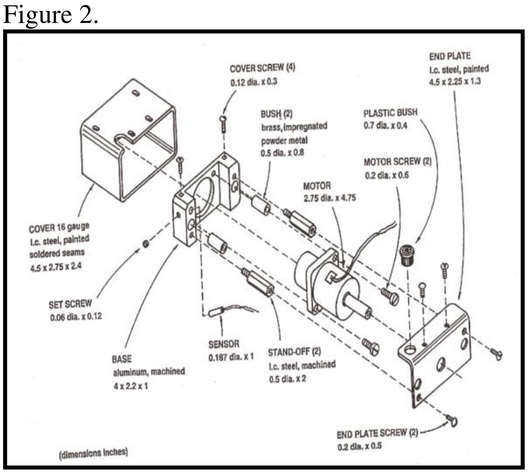

Figure 1. Original design of motor drive assembly (dimensions in inches).

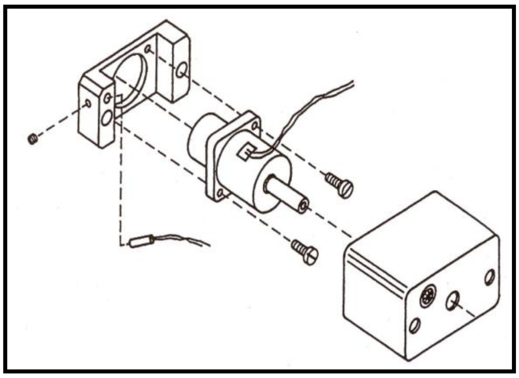

Figure 2. Redesign of motor drive assembly following design for assembly (DFA) analysis.

Table 1. Results of original Design for Assembly (DFA) Analysis for the Motor Drive Assembly.

Item	Number	Theoritical Part Count	Assembly Time (s)	Assembly Cost (cent)*)
Base	1	1	3.5	2.9
Bush	2	0	12.3	10.2
Motor Subassembly	1	1	9.5	7.9
Motor Screw	2	0	21.0	17.5
Sensor Subassembly	1	1	8.5	7.1
Setscrew	1	0	10.6	8.8
Standoff	2	0	16.0	13.3
End plate	1	1	8.4	7.0
End-plate screw	2	0	16.6	13.4
Plastic bush	1	0	3.5	2.9
Thread lead	-	-	5.0	4.2
Reorient	-	-	4.5	3.8
Cover	1	0	9.4	7.9
Cover Screw	4	0	34.2	26.0
TOTALS	19	4	160.0	133.0

Table 2. Results of Redesign for Assembly (DFA) Analysis for the Motor Drive Assembly.

Item	Number	Theoritical Part Count	Assembly Time (s)	Assembly Cost (cent)*)
Base	1	1	3.5	2.9
Motor Subassembly	1	1	4.5	3.8
Motor Screw	2	0	12.0	10.0
Sensor Subassembly	1	1	8.5	7.1
Setscrew	1	0	8.5	7.1
Thread leads	-	-	5.0	4.2
Plastic cover	1	1	4.0	3.3
TOTALS	6	4	46.0	38.4

*)For a labor rate of $30/h

$$Design\ \ Efficiency = \frac{4\,x\,3}{46.0} = 26\% \qquad (2)$$

Clearly, the efficiency increases by 18.5% with application of the technique. In terms of saving from assembly time reduction and parts reduction can be seen in the following table.

Table 3. Original and redesign cost form assembly time and parts.

Original Design		Redesign	
Item	**Cost, $**	**Item**	**Cost, $**
Base (Aluminium)	12.91	Base (nylon)	13.43
Bush (2)	2.40	Base (nylon)	13.43
Motor Screw(2)	0.20	Motor Screw(2)	0.20
Setscrew	0.10	Setscrew	0.10
Standoff(2)	5.19		
Endplate	5.89		
End-plate Screw	0.20		
Plastic bush	0.10		
Cover	8.05	Plastic Cover (include tooling)	8.00
Cover screw (4)	0.40		
Totals	35.44		21.73

Thus, the total saving = saving from assembly time reduction + saving from parts reduction = \$0.95 + \$13.71 = \$14.66

Case Study: Pneumatic Piston

With the same above procedures, pneumatic piston can be redesigned. First, draw the exploded view of a pneumatic piston subassembly is given in the Figure 3. The number of components are redundant, particularly screws in which they are 'enemy' of an engineer and not easy to align. Therefore, by applying DFMA rules for retaining component, redesign product can be obtained (Figure 3b).

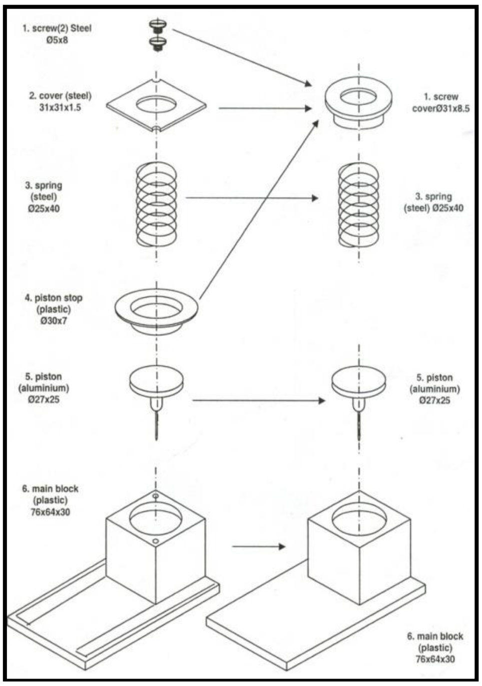

Figure 3. Pneumatic piston (a) original design; (b) redesign.

a b

From the figure as can be seen that the number of components are reduced from 6 components to 4 components in which piston stop is eliminated, screw and cover are combined to be screw cover in plastic material. To see how this technique works, look at the table 4. Where,

$$Design\ \ Efficiency = \frac{4\,x\,3}{46.25} = 25.9\% \qquad (3)$$

While, redesign efficiency becomes

$$Design\ \ Efficiency = \frac{4\,x\,3}{17.79} = 67.45\% \qquad (4)$$

as shown in the Table 5.

Table 4. Pneumatic piston DFMA analysis (results of original design for manual assembly).

Name of parts	Part number	Σ Parts	Retaining Criterion Move Y/N	Material Y/N	Separate Y/N	α	β	α+β	Handling code	Handling time (s)	Insertion code	Insertion time (s)	Assembly time (s)
Main block (plastic)	6	1	-	-	-	360	360	720	30	1,95	0	1,5	3,45
Piston (aluminium)	5	1	Y	-	-	360	0	360	10	1,5	20	5,5	7
Piston stop (plastic)	4	1	N	N	Y	360	0	360	10	1,5	0	1,5	3
Spring (steel)	3	1	Y	-		180	0	180	5	1,84	0	1,5	3,34
Cover (steel)	2	1	N	N	N	180	360	540	23	2,36	9	7,5	9,86
Screw (steel)	1	2	N	N	N	360	0	360	11	1,8	39	8	9.8x2=19.6
Totals		7											46,25

Table 5 Pneumatic piston DFMA analysis (results of redesign for manual assembly)

Name of parts	Part number	Quantity of parts	Retaining Criterion Move Y/N	Material Y/N	Separate Y/N	α	β	α+β	Handling code	Handling time (s)	Insertion code	Insertion time (s)	Assembly time (s)
Main block (plastic)	6	1	-	-	-	360	360	720	30	1,95	00	1,5	3,45
Piston (aluminium)	5	1	Yes	-	-	360	0	360	10	1,5	20	5,5	7
Spring (steel)	3	1	Yes	-		180	0	180	5	1,84	00	1,5	3,34
Piston stop+cover+screws=Screw	1	1	No	No	Yes	360	0	360	10	1,5	01	2,5	4

cover (plastic)		
Totals	4	17.79

From the Figure 3 shown as well that screws, cover and piston stop are combined into one single screw cover. It leads to reduce assembly times. In addition to that, cover material has been changed from steel to plastic. Thus, the part can be cheaper to manufacture and easily to assembly.

3. Conclusions

It is shown the power of DFMA to redesign the product in order to increase its efficiency leading to competitiveness product globally. The piston effeciency rises by 41.5% that is almost double compare with the original design. This is manual redesign technique. Later, it will show how to use the automatic technique using DFMA software to compare with manual ones.

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