DESIGN IMPROVEMENT OF A PNEUMATIC PISTON USING DESIGN FOR ASSEMBLY (DFA) METHOD, A CASE STUDY

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Abstract - Teknik desain assembly (DFA) sudah lama dan sering digunakan pada industry untuk meningkatkan kualitas, mengurangi biaya, dan memperpendek waktu siklus proses manufaktur dari komponen dan produk. Paper ini bertujuan untuk meningkatkan efisiensi dari piston pneumatic dengan mendesain ulang masing-masing komponen produk dalam hubungannya dengan waktu handling, inserting dan assembling. Dengan kata lain, beberapa modifikasi termasuk sejumlah komponen, pergantian material, dan waktu assembly. Efisiensi dari komponen produk yang dibuat meningkat secara signifikan dari 25,9% ke 67,45%. Efisiensi komponen tersebut meningkat dengan kenaikan hampir 50 % yang menghasilkan sisi ekonomi produk di pasaran.

Keywords: design component, assembly time and product developed, piston pneumatic.

I. Introduction

Many design techniques have been introduced such as design for quality (DFQ), design for competitiveness (DFC), and design for reliability (DFR), however, design for assembly (DFA) or design for manufacturing and assembly (DFMA) is still considered as the best design product technique. One reason is simple components design in manufacturing engineering is market needs, nowadays. Not like previous parts in which they contained many type of materials lead to costly, time consuming in production and complicated assembly line of the parts. Boothroyd and Knight (1993) as pioneers of a technique that is called Design for Manufacture and Assembly formulated the technique by firstly disassembly a camera with the same trademark both USA and Japan made. Result, the camera was made by USA containing a few unnecessary components such as screws and different type of materials leads to less market requirement. Thus, in assembling, inserting of each component needs more times. That was happened due to in manufacturing process, between design engineers, who created the detail drawing in desks, and assembly engineers, creating the assembly plan, worked independently. This process results the final products have many *disadvantages* such as poor characteristics in manufatcuring, assembly, maintenance; long developing period; high cost; and unguaranteed quality. A design for Assembly of a motor drive and its resulted, in which both design engineers and assembly engineers work together formulating of a product, can be seen in figure 1 and 2 respectively [2]. Later, this technique is famous with concurrent engineering. This paper will not be discussed more about it with exception of DFA procedure.

Many authors have been contributing the implementing and developing in different design and products of DFA and/or DFMA technique. All parts assembled using robot has been done. Neural network was applied to insert certain part into base of a product lead to avoiding jam during the assembling steps and fuzzy set method was used to arrange insertions procedure [3]. This method is definitely up to date with current market needs. Furthermore, a new design and model of an old emergency lamp with DFA technique resulted less different type of materials and snaps-on instead of screws and bolts [4]. In calculating the total cost per product, ssoftware help was also provided at UniSA (University of South Australia) computer laboratory.

With obstacle of computer software, this paper only applies the manual ones in order to more understood how the technique works with it. Also, to make use the technique properly what his founder's proposed, the manual procedure is still useful. Pneumatic piston is chosen as a product to implement the DFA procedure. Therefore, the aim of this paper is to show for how DFA works to reach handling, inserting and assembly of each component to make a new simple product (a new pneumatic piston) in higher efficiency. As a result, less time to market and improved quality will be obtained.

II. Methodology

Applying the DFA for manual assembly of a product, general design guidelines divided into 2 parts, namely handling and insertion and fastening [1,2]. In general, for ease of part handling: design parts that have end-to-end symmetry and rotational symmetry of exis insertion; parts that obviously asymmetric are made into symmetric; provide design that is free of jam; allow tangling of the parts and avoid parts components that are hazardous to handler. In conjunction with insertion and fastening: avoid parts that is resistance to insertion otherwise using chamfers; use standardize parts for mass product leads to in lower product cost; provide one axis of datum; design the part is secured as soon as after insertion; part located before release and avoid repositioning of assembly from different position.

Those guidelines were firstly implemented in a motor drive as depicted in Figure 1 and 2. As a result, the author succeded to increase its efficiency by 18.5% with following steps in Table 1 to 3. To develop for automatic assembly, the general design steps have to be mastered.

As shown in the Figure 1, there are 14 parts that must be analysed associating with the guidelines/steps. 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,

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

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.

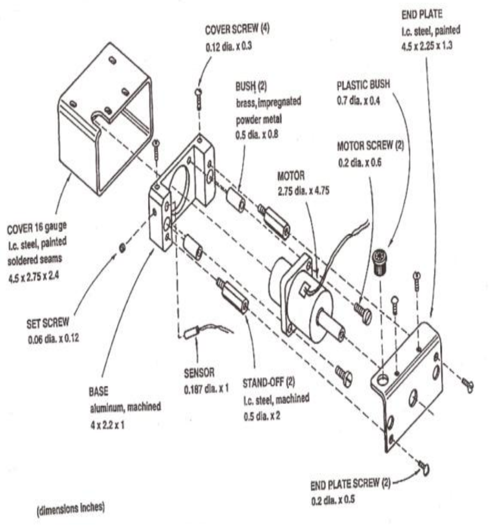


Figure 1. Original design of motor drive assembly (dimensions in inches) [2]

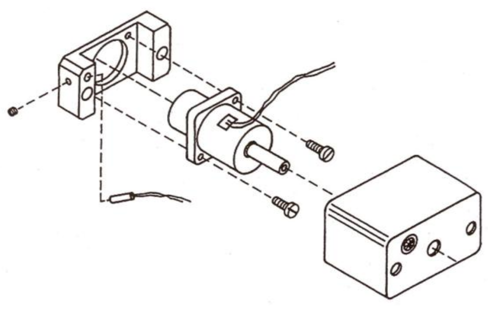


Figure 2. Redesign of motor drive assembly following design for assembly (DFA) analysis [2].

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

Item	Number	Theoritical Part Count	Assembly Time (seconds)	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

III. Results and Discussion

From the above table indicates that the longest assembly time (34 second) is on cover screw followed by motor screw (21s). As far as engineers concern, screws are the 'enemy' for them due to a long time technique to insert and assembly a part to the base lead to highest cost. Therefore, in DFA procedure, the component contains screws must be focused on eliminating them as depicted in Table 2. In Table 2, assembly time for motor screw decreases from 21 seconds, as shown in Table 1, to 12 seconds and total efficiency rises from 7.5% to 26%. This means labor cost will be cheaper.

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

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

From Figure 1 figures out the number of component are 19 and become 6 components after applying the method as depicted in Figure 2.

Case Study

With the same procedure, design of a pneumatic piston in Figure 3 can be reduced in terms of number of parts leading to increasing efficiency as shown in Table 3 and 4. To achieve that, two screws, cover steel and piston stop were combined into single screw plastic cover as shown in Table 4. The design efficiency becomes:

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

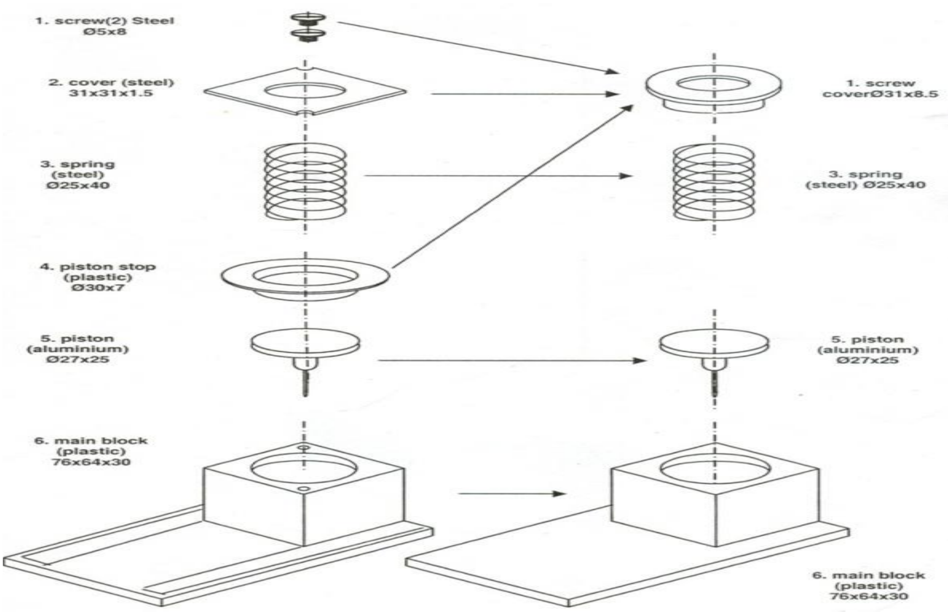
While, redesign efficiency becomes

$$Design\ \ Efficiency\ = \frac{4\ x\ 3}{17.79} = 67.45\%$$

To see the complete procedure how to eliminate unnecessary parts and improve the efficiency, Table 4 and 5 are its guide.

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



a. b.

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

IV. Conclusions

Although, many other techiniques have been proposed, for example, design for quality (DFQ), design for competitiveness (DFC) and design for reliability (DFR), it is shown DFA is still a choice to increase design efficiency leading to competitiveness product globally. The efficiency of the piston rises almost double compare with the original design. The method can be applied for all design products in order to reach market shortly. The most important things are the economical side in which the cost is cheap.

References

[1] Boothroyd, G., Knight, W., and Dewhurst, P., 2002, *Product Design For manufacture and Assembly*, 2nd Edition, Marcel Dekker, Inc.

[2] Boothroyd, G. and Knight, W., 1993, *Manufacturing À La Carte: Efficiency: Design for assembly*, *IEEE Spectrum*. pp. 51-53.

[3] Son, C., 2001, *A neural/fuzzy optimal process model for robotic part assembly*, International Journal of Machine Tools and Manufacture 41, page 1783-1794.

[4] Mustofa dan Naharuddin, 2009, *Redesign of Emergency Lamp Using Design for Manufacture and Assembly (DFMA) Technique*, Media Eksakta, Jurnal Matematika dan Sains, Vol. 5, No.1, hal 001-005.

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

Name of parts	Part number	Σ Parts	Retaining Criterion			α	β	α + β	Handling code	Handling time (s)	Insertion code	Insertion time (s)	Assembly time (s)
			Move Y/N	Material Y/N	Separate Y/N								
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 DFA analysis (results of redesign for manual assembly)

Name of parts	Part number	Quantity of parts	Retaining Criterion			α	β	α+β	Handling code	Handling time (s)	Insertion code	Insertion time (s)	Assembly time (s)
			Move Y/N	Material Y/N	Separate Y/N								
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 cover (plastic)	1	1	No	No	Yes	360	0	360	10	1,5	01	2,5	4
Totals		4											17.79