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Motion-based method for estimating time required to attach self-adhesive insulators[☆]

Heungjae Cho [1], Jaeil Park [*]

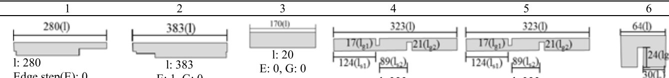
Department of Industrial Engineering, Ajou University, San5 Woncheon-Dong, Yeongtong-Gu, Suwon 443-749, Republic of Korea

HIGHLIGHTS

- This paper presents motion-based time estimation scheme for attaching insulators.
- The scheme has been developed by analyzing the motions of attaching 350 insulators.
- It estimates times by identifying the features of insulators and MODAPTS rules.
- Estimates vary from the actual value by an average of 9.5%.
- It is realistic compared to MTM (13%–18%) and AEM (15%).

GRAPHICAL ABSTRACT

Motion-based time estimation of insulators



No.		1		2		3		4		5		6	
		l: 280 Edge step(E): 0 Groove(G): 0 Hole(H): 0 Folding line(F): 0		l: 383 E: 1, G: 0 H: 0, F: 0		l: 20 E: 0, G: 0 H: 0, F: 0		l: 323 l_{s1}: 124, l_{g1}: 17 l_{s2}: 89, l_{g2}: 21 E: 0, G: 0 H: 2, F: 0		l: 323 l_{s1}: 124, l_{g1}: 17 l_{s2}: 89, l_{g2}: 21 E: 0, G: 0 H: 2, F: 0		l: 64 l_s: 30, l_g: 24 E: 0, G: 1 H: 0, F: 0	
Sub-motion	Representative motion set	MODS											
		MODS	Sum	MODS	Sum	MODS	Sum	MODS	Sum	MODS	Sum	MODS	Sum
Detaching	M3G1G1M(l)	M3G1G1M3.9	8.9	M3G1G1M4.6	9.6	M3G1G1 M3.2	8.2	M3G1G1M4.2	9.2	M3G1G1M4.2	9.2	M3G1G1M2.1	7.1
Putting	M3P2 M3G1M3P2P2	M3G1M3P2P2	11	M3G1M3P2P2	11	M3G1M3P 2P2	11	M3G1M3P2P2	11	M3G1M3P2P2	11	M3P2	5
Rubbing main body	M(l)A2 M(l/2)M(l/2)A 2	M3.9A2	5.9	M3.3M3.3A2 M3.3M3.3A2	8.6 8.6	M3.2A2	5.2	M3.1M3.1A2	8.2	M3.1M3.1A2	8.2	M2.1A2	4.1
Rubbing grooves	M(ls)M((lg)A2							M2.7M0.7A2 M2.4M0.8A2	5.4 5.2	M2.7M0.7A2 M2.4M0.8A2	5.4 5.2	M1.2M1A2	4.2
Rubbing holes	M(ls)M((lg)A2												
Folding	M(ls)G1M((lf) M((lf)A2												
Average Actual time (sec)		2.61		3.72		2.49		4.00		3.99		2.20	
Standard deviation		0.252		0.399		0.366		0.368		0.361		0.216	
Estimated time(sec)		2.96		4.33		2.81		4.13		4.13		2.35	
Difference (%)		0.35(13.4%)		0.61(16.4%)		0.13(12.4%)		0.13(3.2%)		0.14 (3.4%)		0.15(6.8%)	

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ABSTRACT

A self-adhesive insulator is a component of a home appliance that is used to suppress vibration or prevent humidity affecting the internal parts of the appliance. There is a wide range of types and designs available, allowing them to be applied to areas having different shapes. At the design stage, once an insulator design has been developed sufficiently to identify its dimensions and features, the attaching time and baseline cost must be estimated with reasonable accuracy to enable a comparison of vendor quotes. However, the current estimation method is not sufficiently accurate in terms of the baseline cost. This paper presents a motion-based time-estimating scheme with which the time required for the attachment of such insulators can be calculated more accurately. The scheme has been developed by analyzing the motions needed to attach 350 insulators and then designating representative motions and their time values. For this purpose, a modular arrangement of predetermined time standards (MODAPTS) is adopted. Motion-based time-estimation method is useful in terms of simplicity and accuracy. It enables design engineers to estimate the time required for the attachment based only on a drawing of the insulator and a few MODAPTS rules. Estimates made with this method should vary from the actual value by no more than 9.5%.

1. Introduction

In the home appliances industry, ongoing competition has resulted in the need for more effective cost reduction and control.

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[*] Corresponding author. Tel.: +82 31 219 1878; fax: +82 31 219 1610.
E-mail addresses: jipark@ajou.ac.kr, jzp1000@gmail.com (J. Park).

[1] Fax: +82 31 219 1610.

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As a part of this effort, at the design stage, design teams have developed various time-estimation methods that can be used for setting target costs, and have conducted ongoing analysis of the resulting production processes [1]. In particular, the outsourcing of production of components has attracted increased attention as a means of meeting targets. This has resulted in intense collaboration between small- and medium-sized manufacturers.

Most product costs are determined at the design stage [2]. In addition, the assembly cost can be a major element in the overall cost of a product. Therefore, a quick and reliable method of estimating the assembly time is essential. After determining the dimensions and features of components on a drawing, it is necessary to determine the time needed to assemble them without actually making and assembling a physical prototype.

Currently, there are two main types of time-estimation techniques: product-based and process-based. Among the product-based time-estimation techniques, the original design for assembly (DFA) method and its variations for manual assembly have been widely adopted [3]. Among the process-based time-estimation techniques, the modular arrangement of predetermined time standards (MODAPTS), a type of time and motion study, is applied to determine the actual time needed to complete assembly [4]. In both methods, the goal is to design assembly lines that make assembly as easy as possible so that products can be rolled off in high volumes.

Home appliances such as refrigerators, air conditioners, and washing machines all go through a manufacturing process known as "final assembly" whereby components are put together by hand to prepare the product for delivery. New components may incur different assembly operations, which can cause the time required for assembly on the line to differ. Among these, self-adhesive insulators, which are used to suppress vibration and block moisture, are designed with different forms and methods of attachment according to the requirements of the customers. For example, the front module of an air conditioner incorporates 39 insulators among its 93 parts, that is, the insulators account for 41% of the total. The cap module of a refrigerator contains 10 insulators among its 16 parts, such that the insulators account for 62% of the total.

The conventional DFA method has been widely used as a time-estimation method in the design phase. The DFA estimates the total handling and insertion time based on tables that relate the assembly time to design factors that influence the gripping, orientation, and insertion of parts [5]. Although the DFA is able to calculate accurate assembly times for general parts, the time estimates for handling adhesive insulators range from 5 to 7 s depending on their sizes, while those for insertion vary between 5.5 and 6.5 s depending on the holding down required and their ease of alignment [6]. These estimates are far from realistic, however, because the insulators used in industry are much more varied in their sizes and shapes.

The MODAPTS system is used to analyze the way work is performed by quantifying the amount of time required to perform an assembly operation [7]. It is accurate enough to be used for setting labor rates in industry. However, the method is not easy for design engineers to apply because it incurs tedious manual processing requiring hours of effort.

In the home appliances industry, the attachment time is that time needed to attach a self-adhesive insulator. It must be estimated from a drawing in terms of product assembly time. The current time-estimation method is based on times that are directly proportional to the area of the baseline insulator. No consideration is given to the actual shape and size of the insulator. As such, the method is very easy but inaccurate. For a given size, for example, a time estimate can be determined by identifying the size of an insulator as given by the following equation: attaching time (s) $= 1.2 + 0.0000888 \times A$, where $A =$ area of insulator (length $\times$ width). This method is easy to use because it needs only the size of the insulator, but the average difference between an estimate made with this method and the actual data can be as much as 30% because it does not consider the shape of the insulator.

In this paper, as an alternative, we propose an easy and accurate time estimation model based on the time relationship between the motions involved in attaching an insulator and the size and shape of that insulator. For this purpose, we recorded videos of the attaching of 350 different-shaped insulators of the types used in refrigerators, air conditioners, and washing machines, and then analyzed the motions used to attach them in an actual physical factory layout using MODAPTS.

This study aims to contribute to a practical means of estimating the time required for attaching self-adhesive insulators at the design stage. The remainder of the paper is organized as follows. Section 2 describes the review of the related literature. Section 3 presents MODAPTS in detail. Section 4 presents the proposed time-estimation method and its validation. Section 5 summarizes the results obtained for an actual industrial case. Section 6 discusses the case results and some issues arising from the development of the proposed method. Finally, Section 7 summarizes the advantages and limitations identified by these studies.

2. Literature review

The most widely used method for estimating the time required for assembly at the design stage is the Boothroyd–Dewhurst DFA Method, the Hitachi Assembly Evaluation Method, the Lucas DFA Method, and the Fujitsu Productivity Evaluation System. The first such evaluation method was developed by Hitachi and was called the Assembly Evaluation Method (AEM) [8].

The Hitachi Assembly Evaluation Method (AEM) was developed as a design evaluation method for evaluating the assemblability of products and their component parts. It rates assemblies according to the ease with which they can be automatically assembled based on the principle of an assemblability evaluation score called a "point-loss standard". The AEM was then extended to make it more practical in terms of cost estimation capability. The accuracy of the extended assemblability evaluation claims to be within 15% for parts. This means that AEM can be applied to a wide variety of products with a degree of accuracy that is sufficient for practical purposes [9].

DFA has been used to enhance the ease of assembly by identifying those aspects of assembly that are relatively difficult during the product development phase. The DFA method, like the AEM method, was originally provided as a table that related the assembly time to design factors influencing parts gripping, orientation, and insertion [10]. It assesses the difficulty of handling and insertion. The levels of difficulty in handling are determined by checking whether there are any barriers to an operative gripping a part and then moving it to a specific location. The assembly time for each component is then obtained by adding the handling time for that part to its insertion time [11].

The Lucas DFA evaluation is based on three indices that provide a relative measure of assembly difficulty. The following three analyses are performed in three sequential stages: functional, feeding (or handling), and fitting analyses [12]. In the analyses, the feeding/handling and fitting ratios are used as measures of performance to indicate the effectiveness of the design quality with respect to assembly [13]. When making estimates for self-adhesive parts, however, Lucas DFA provides only one score, which is 0.5. It does not attempt to make any allowance for the different sizes and features of the insulators for accurate time estimation.

Unlike the previous three methods, the Fujitsu Productivity Evaluation System allows designers to select parts similar to those