A Study on the Conceptual Design Development of Cleaning Tools for Window Cleaning System

Kyoon-Tai Kim and Young-Hun Jun

***Abstract*—In recent years, both improvements in the outside environment and a clear view have been demanded by the operators of luxury shops located on the 2nd through 5th floors of high rise buildings. However, the conventional window cleaning methods and devices cannot satisfy this demand. For this reason, there is a pressing need to develop a new specialized window cleaning device. A new cleaning tool that addresses these unique window cleaning conditions is needed. In this study, this device has been developed in the form of a wiper and roller-brush type cleaning tool and an all-in-one cleaning tool. Then, the advantages and disadvantages of each tool are compared. Based on this analysis, the size of the all-in-one tool is reduced, and its system becomes simpler as a result. However, the all-in-one tool may leave traces or marks behind, a shortcoming that should be addressed before its commercialization. The analysis shows that all-in-one tool is small and lightweight, but there is a risk of leaving a trace on the window. On the other hand, separate type tool is somewhat larger and heavier, but the cleaning results are clear. Therefore, a separate type tool with excellent cleaning performance is more suitable.**

***Index Terms*—Construction automation, window cleaning, cleaning robot, maintenance, cleaning tool.**

I. Introduction

Since the 1990s, Korea has seen the construction of numerous multi-purpose high-rises. The lower floors of these buildings tend to feature luxury shops such as clinics, hair shops, fitness centers, and banks, all of which put an emphasis on a clean retail environment [1]. Owners or tenant of these luxury shops want to keep both their indoor and outdoor environment clean. However, conventional cleaning methods are difficult to apply to windows on the 2nd through 5th floors. This is because the conventional method is labor intensive and is an advantageous way to clean the entire wall. In other words, it depends substantially on workers hanging from a rope or on a ladder, methods which are cumbersome to apply to windows on the 2nd through 5th floors.

In order to develop an alternative, efforts have been made to come up with a cleaning device for specific windows. As the proposed device is differentiated from existing cleaning devices that clean the entire façade of a building, cleaning tools such as wiper and roller-brush cannot be applied as they are.

The aim of this study is to develop a new window cleaning device for specific window on lower floors of buildings. As it is currently at an early phase, the conceptual design of a cleaning tool is presented in this study. To this end, the cleaning tool of the conventional system is reviewed, and then differences between the conventional method and the newly developed method are analyzed. Next, a combination of cleaning tools is derived. A comparative analysis is performed based on the advantages and disadvantages of the combination of the tools.

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II. Technical Trend of Window Cleaning Tools

A. Conventional Cleaning Tools for Man-Dependent Cleaning Work

As shown in Fig. 1, workers are progressing by using rope for domestic building window cleaning work. There is a wet cleaning method and a dry cleaning method by classifying the cleaning work of windows by the use of detergent and water. For wet cleaning, use detergent and water (see Fig. 1 (a)). The wet cleaning method is the most commonly used method because it is simple, easy and the result is clean. However, detergent water may fall off during cleaning, which may contaminate the road surface, cars parked or running, or the clothes of pedestrians passing by the building, which may result in complaints.

Therefore, in the case of high-rise buildings in urban areas, the cleaning process is carried out by the dry process. The dry cleaning methods use diatomaceous earth and mop (see Fig. 1 (b)). The dry method does not drop pollutants down, but it is difficult and time-consuming to work. Also, because of the high cost, it is not used well except in downtown areas and areas vulnerable to pollutants.

(a) wet cleaning method[2] (b) dry cleaning method [3]
Fig. 1. Window cleaning machine for specific windows.

Since the wet method is commonly used, this study investigated the wet method in more detail. As shown in Fig.

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2, sponge, wiper, blade, rod, hose, nozzle and sucker are used for this man-dependent cleaning work.

The cleaning tool will be described according to the order of the work as follows. First, spray water to a glass with a hose (see Fig. 2 (a)). There is a nozzle at the end of the hose and the hose came from the roof. Sometimes, wet the glass with a sponge dampened with water instead of the spraying water (see Fig. 2 (b)). Next, squeeze the glass with the wiper to remove contaminants from the glass (see Fig. 2 (c)). Sometimes there are stuck contaminants, in which case they are removed using a blade (see Fig. 2 (d)). As one worker carries out cleaning tasks over a wide range, it is common to connect rods to work tools in order to widen the work area (see Fig. 2 (e)). During the cleaning operation such as a water spraying, squeezing, blading, etc., the worker often need to stay in a certain position. It is also often the case that a single worker performs a watch movement to clean the windows of multiple columns. In this case, the worker uses his sucker to support his body, and stays at a specific position to perform the work (see Fig. 2 (f)).

(a) hose and nozzle (b) sponge

(c) wiper (d) blade

(e) rod (f) sucker

Fig. 2. Tools for worker.

B. Conventional Cleaning Tools for Cleaning Device

Window cleaning devices have been developed in Korea and other countries for the entire façade of a building. The shapes of the rail and windowsills are taken into account from the design phase of the building in order to operate a cleaning device. In addition, since the cleaning device is considered from the design phase, the amount of water required for cleaning is considered and incorporated in advance. This means that the cleaning device can easily spray water for the cleaning operation, and then it is mostly squeezed using a wiper. The rail can be stably embedded in the process of construction, and large size and heavy weight of the device does not pose any risk.

As shown in Fig. 3, a cleaning system developed by Hanyang University uses water and wipers for cleaning. This has a water tank within a body of the cleaning device. The water in the tank is sprayed through a nozzle, and the wiper squeezes the water with contaminants, moving along the nozzle in the horizontal direction. In other words, the body sprays water to a glass through the nozzle while moving in the horizontal direction, and the wiper on the body squeeze the glass while moving along the sprayed water.

It also has a suction module and a tank for containing waste water after cleaning. By using this, the suction module recovers the contaminated water and reduces the damage caused by the contaminated water. Since there is no power outlet on the outside of buildings, the system cannot be used electricity. The system therefore has a built-in battery as a power module for drive motors. However, in Hanyang University system, since it always uses water and wipers, it does not need a function to remove dust.

Hanyang University system is designed to divide one floor into two layers and clean it by layer. In other words, it cleans about 1,600 mm at a time, and this cleaning process needs to be done twice to completely clean one floor. Nevertheless the device becomes very large and heavy because it contains the above modules. Also, although there is a suction module, there is no module for receiving water mixed with contaminants. Therefore, the suction function does not work perfectly, and some of the contaminants fall down the window.

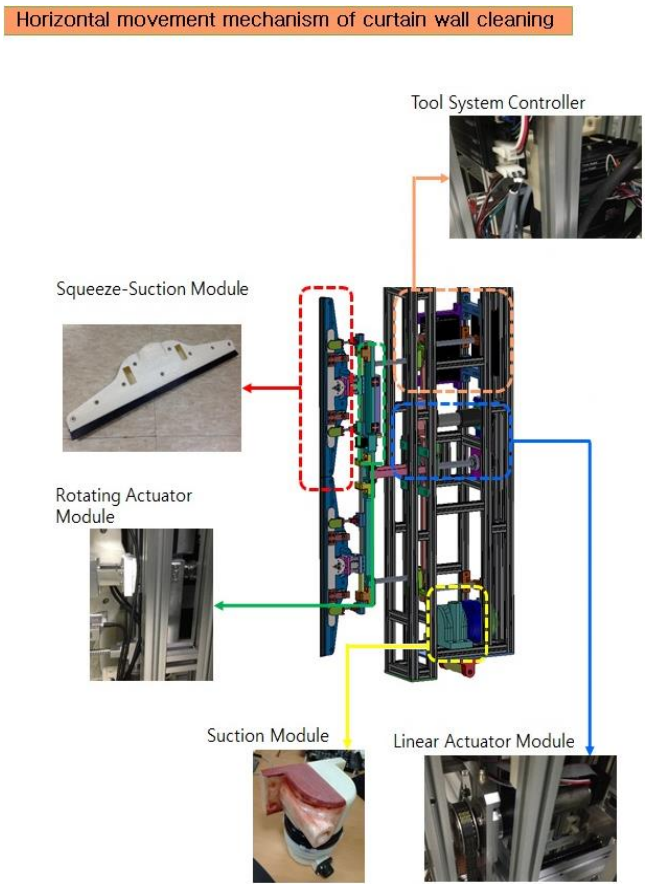

Fig. 3. Window cleaning tools of Hanyang Univ.'s system [4].

On the other hand, Iku's system, as illustrated in Fig. 4, buries pipes and nozzles for cleaning water. In this system, the water is sprayed from the upper part of the building and the wiper squeezes the water, moving downward. In other word, The Iku's system sheds water down from the top of the building and the wiper squeezes down from the top of the building using the water. Therefore, the cleaning device is very simple and small. Since this system uses gravity, it is more advantageous in terms of power aspect and cleaning water supply than Hanyang University system.

On the other hand, when the building is newly constructed, pipes and nozzles should be embedded on the wall in this system. Therefore, when using this system, the design and construction of buildings becomes very complicated. Besides, because of the freezing of water in the pipes, this system is difficult to use in regions with winter such as Korea.

Both of these types of systems should be considered to attach cleaning devices to the building from the design stage. Also, when building the building, rails, window profiles, etc. should be properly attached for it. It must also be designed to have hidden window profiles or to protrude very slightly. Therefore, there is a concern that architects may avoid these design constraints, construction becomes complicated, and construction costs increase.

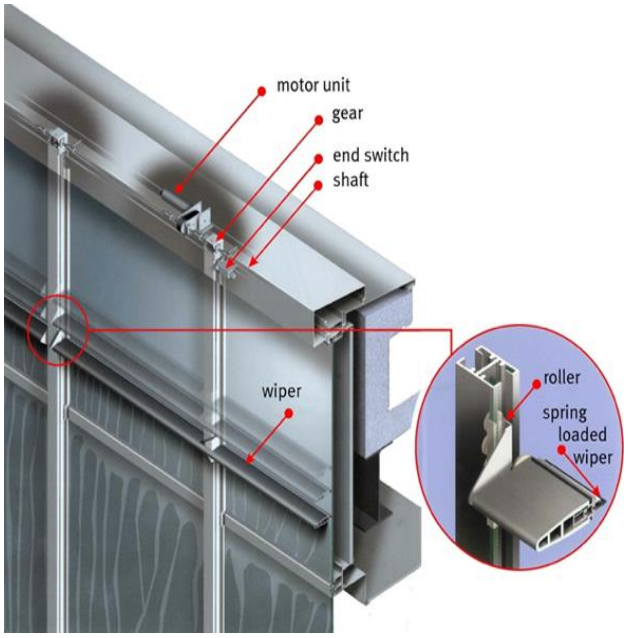

Fig. 4. Window cleaning tools of Iku's system [5].

III. Configuring the Functions and Shape of a Cleaning Tool

A. Configuring the Functions

Kim K. *et al* (2017) defined technical elements and functions required by potential clients through interviews with workers at maintenance specialized companies [6]. Based on the findings, a plan to eliminate water tank and water spraying device is proposed. In other words, the cleaning device to be developed has no tools related with cleaning water. Instead, it uses rainwater to squeeze on a rainy day. Cleaning devices should be cleaned window daily, including non-rain days. Therefore, the device to be developed should have a built-in brush, and on non-rain days, brush off the dust. Thus, the development direction is to use a wiper and a roller-brush.

Two combinations type of a wiper and roller-brush are drawn. The first is named Separate type, a wiper and a roller-brush are installed to a body separately in this type. Therefore, a wiper and a roller-brush are operated separately to perform cleaning work. The second is called All-in-one type, a wiper and roller-brush are combined in a single unit in this type. In this case, as it is a single unit, the wiper and the roller-brush cannot be operated separately. Therefore, not only the brush but also the wiper will rotate throughout the cleaning operation in this type.

B. Separate Type

Fig. 5 illustrates the separate installation concept of a wiper and a roller-brush. When this method is used, either a wiper or a roller-brush are attached on the windows to clean them. More specifically, when it is rainy, only the wiper is moved forward and attached to the window and the wiper is used to squeeze stubborn stains with the rain water on the windows. Therefore, when the squeezing operation by the wiper is finished, the window is cleaned without stain. On the other hand, when it is sunny day, only the roller-brush is moved forward and attached to the window and the cleaning work is done using a roller-brush. Because there is no stain on the windows but is only dust, the roller-brush rotates to clean dust on the windows. In this way, the wiper and the roller-brush play there role in each other, and clean the windows continuously.

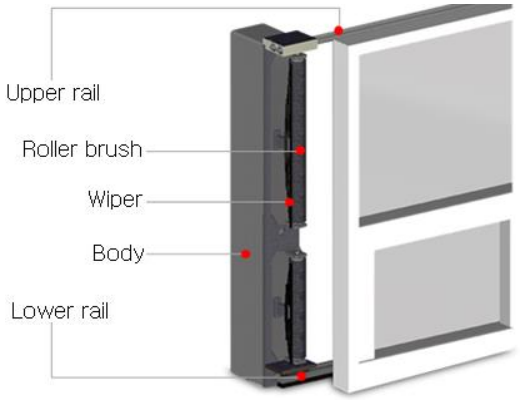

Fig. 5. Separate type cleaning tool [6].

C. All-in-One Type

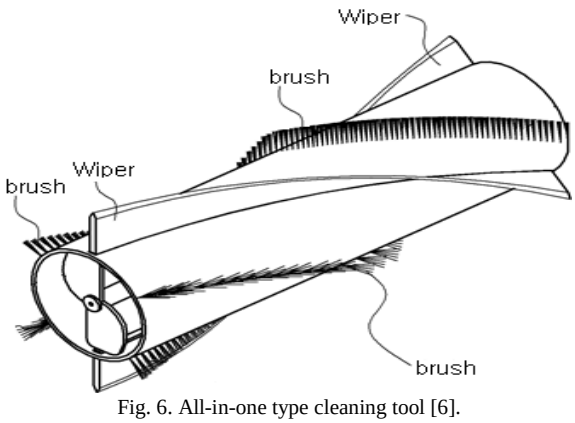

Fig. 6. All-in-one type cleaning tool [6].

Fig. 6 shows the concept of an All-in-one type. It operates regardless of weather conditions because the wiper and roller brush combine to form one cleaning tool. Specifically, it dusts on sunny days because there is no water on the windows, while it squeezes water on rainy days to clean the stain off. In this study, it is assumed that the wiper and roller-brush are fixed to simplify the cleaning tool. If the wipers or roller-brush can move in the forward and backward directions, the cleaning tool can become very complex.

IV. Analysis of Advantages and Disadvantages of the Two Types

The separate type has a dedicated tool for sunny days and rainy days. Therefore, it is possible to use the tool which is most suitable for the environmental condition, and the cleaning result is expected to be good. In other word, proper cleaning process can be performed and leaves no stains or traces behind in this type. On the other hand, both of tools must be attached to the body of the cleaning device. And the body must contain modules for controlling both of tools. Therefore, the size of the body may become larger and heavier. As such, when the body is large, the device may obscure the view or damage the aesthetics of the building. When the body is heavy, the load on the window frame or the wall increases.

The all-in-one type cleaning tool is small and light, which puts a smaller load on the fixed parts (upper and lower parts of the windowsills and the rail). The system is also simple and easy to control. On the other hand, the brush can leave traces, on a rainy day and the wiper can cause noise on a sunny day. When the cleaning tool is worn out and needs to be replaced, the maintenance cost may increase due to the replacement of the integral tool.

TABLE I: Comparison of Advantages and Disadvantages of the Two Types

	Separate type	All-in-one
Advantages	No stains, marks, or traces left because it uses the suitable tool considering weather conditions Minimization of noise Low prices for individual tools Use tools optimized by weather	Simple system and mechanism Small in tool size Light weight Easy to control its load Easy to change the tool A small body is enough to operate one tool
Disadvantages	Complex system and mechanism Large cleaning tool Heavy weight Difficult to control Each tool has a different method of replacement Since two tools must be operated, the body size is relatively large.	Stains, marks and traces left after squeezing water Noise caused by the wiper on sunny days The price of the tool is expensive Tool is consumed by unnecessary contact

The advantages and disadvantages of the two types are analyzed in Table I. From a comparison between the two derived in this study, the separate type cleaning tool has more advantages than the all-in-one type one. This is because the separate type is expected to have a better cleaning result and make less noise which occupants don't like than the all-in-one type.

In this study, it is assumed that the wiper and the roller-brush are fixed in the all-in-one type. However, if the wiper or rotating brush is not fixed, the analysis in Table I may be somewhat different. For example, in Fig. 6, a vane-type rotating plate is shown inside the cylindrical center axis. This rotating plate functions to push out the wiper. When the rotating plate is rotated and moved to a position where the wiper is not pushed, the wiper is inserted into the cylinder by the spring. However, as described above, this kind of all-in-one type tool capable of being rotate in such manner has a disadvantage that the apparatus becomes very complicated and delicate. Therefore, all-in-one type that can be changed is excluded from the analysis.

V. Results

In recent years, luxury shops have been interested in maintaining the cleanliness of both their indoor and outdoor environments. To satisfy this need, devices that can perform window cleaning occasionally have been developed. However, as there has been no system developed that does not require the selection of a cleaning tool, its composition has not been reviewed. For this reason, a wiper and a roller-brush are selected as cleaning tools, and two combinations of the two components are presented: Separate type and All-in-one type. Based on the comparison between the two types, the all-in-one type is concerned to produce less satisfactory cleaning results because of the stains, marks and traces it leaves behind. In addition, this type may cause noise, which may make the tenant uncomfortable. Therefore, despite the limitations of heavy weight and complexity of the system, the Separate type was considered to be more suitable. The findings of this research will be used as fundamental data for developing a cleaning device.

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