Design of A Window Cleaning Device and Its Operating Mechanism

Kyoon-Tai Kim and Young-Hun Jun

***Abstract*—Recently, demand has been increasing for a cleaning device that can be used for specific window(s) on a specific floor. However, the conventional cleaning devices that have been developed are for cleaning the entire façade, making them inappropriate to meet the demand for partial cleaning. In addition, the different cleaning target means that the conventional devices cannot be used, as their forms and operating mechanism present a limitation. The purpose of this study is to develop a design of cleaning device and its operating mechanism in order to clean specific windows occasionally. In this study, two methods are derived, and a comparative analysis of the two was performed. The window-height device is evaluated to have more advantages in cleaning windows individually.**

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

I. Introduction

An increased interest in building aesthetics has led to a rise in building maintenance for cleaning purposes [1], and to cope with this trend, diverse types of cleaning devices have been developed. The devices developed to maintain a clean façade thus far target the entire façade of a building. Most of these devices are expensive and should be considered from the design stage of the building and should be installed in advance in the construction stage.

As such, they do not provide a satisfactory solution for clients on lower floors who want to clean their windows on a regular basis to keep a higher level of cleanliness. In addition, large, expensive equipment is used in most cases, and it is almost impossible to apply it to conventional buildings. For this reason, it is necessary to develop a cleaning device that can be attached on a specific window on a specific floor [2]. The cleaning tool attached to this cleaning device (wiper, roller brush) must avoid obstacles such as a profile; for this reason, it is very important to design a cleaning device and tool that can be operated effectively.

The objective of this study is to design the concept of a cleaning device and its operating mechanism to ensure that it performs effective cleaning. To accomplish this, the limitations of the conventional cleaning devices are examined, and the target windows are set. In addition, the functions demanded by potential clients are researched, and the technical elements are defined to implement these. Next, a conceptual design of a cleaning tool is drawn, and the operating mechanism is defined depending on the method. Finally, a comparative analysis is conducted to identify the advantages and disadvantages of the two methods.

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II. Conventional Window Cleaning Device and Operating Mechanism

Conventionally, window cleaning devices were developed to clean the entire façade. For this to work, the motions of a cleaning device must be taken into account from the building façade design phase. For example, to ensure a cleaning device can be applied, the windowsills or profiles must have no protruding parts. In addition, as a cleaning device must move to another floor after finishing cleaning the windows on one floor, a device that enables the device to move vertically must be embedded at the design phase. However, there are not many architects who like to be constrained by architectural design due to maintenance equipment. Therefore, it is not easy to apply a conventional cleaning device to the design of a new building unless the owner has a firm will. An example of a conventional window cleaning device developed by Hanyang University is shown in Fig. 1.

Besides, most of the existing buildings in Korea were designed and constructed without considering that kind of window cleaning systems. Therefore, it is almost impossible to install and operate the cleaning devices in existing buildings those can be installed and operated only on specially designed buildings.

Fig. 1. A window cleaning device developed by Hanyang Univ. [3].

The existing buildings to be cleaned in this study are designed without considering the attachment of window cleaning devices. As illustrated in Fig. 2, in many conventional buildings vertical profiles are arranged between

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glasses. If the protruding length of the vertical window profiles are small enough, it can be ignored or passed in a very simple way. However, most window frames are too large to be ignored. Therefore, a new window cleaning device and method that can avoid the obstacles is needed

Fig. 3. Examples of windows in existing buildings.

III. Form and Driving Mechanism of the New Cleaning Device

A. Required Functions

Kim K. *et al* (2017) defined technical elements in order to implement the functions demanded by potential clients through interviews with practitioners in maintenance-specialized companies [4]. Table I indicates the obstacle avoidance-related parts.

TABLE I: Functions Demanded by Clients and Technical Elements [4]

Functions demanded by clients	Technical elements	Definition
Cleaning the windows between the 2nd and 5th floors	Window cleaning efficiency	-Minimization of uncleaned area
Cleaning project type windows with a profiles	Avoidance motion mechanism	- Avoidance of obstacles including profile (prevention of productivity deterioration, prevention of contamination at a stop)
Minimize load on window frames	Weight reduction	- Water tank exclusion - Cleaning using rainwater
Easy to remove stained dust and squeezed marks	Cleaning method	-Using a brush or wiper

Potential customers first wanted a device that could efficiently clean the windows on floors 2-5. And to minimize the uncleaned area due to the tolerance of the cleaning device. In order to clean multiple windows with a single device, it was hoped that the function of avoiding profiles in the windows of existing buildings would be implemented. They also said that the device should be light in order to avoid heavy load on the exterior walls and window frames of buildings. Finally, in order to remove stuck dust, the wiper should be squeegeed and a method of removing the dust at all times is necessary.

Cleaning devices that satisfy the conditions indicated in Table I can be divided into two types: the window-height device and the lower-height device. The window-height device cleans the entire glass surface with a cleaning tool of the same size as the glass. The lower-height device, on the other hand, has a cleaning tool smaller than glass. It cleans the entire glass surface by repeatedly performing the cleaning motions from the surface.

B. Window-Height Cleaning Tool

This cleaning device cleans the window as a whole using a tool (wiper or roller brush) as shown in Fig. 3.

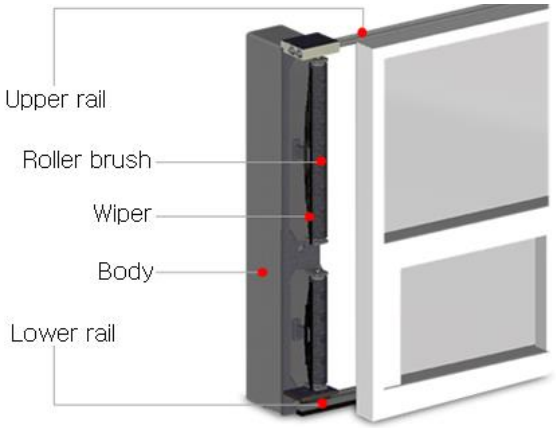

Fig. 3. Window-height cleaning tool [4].

Before cleaning, the cleaning tool is on the body side, and the body is on the window frame position. Describing the driving mechanism of this design, first, as the body begins to move toward the glass, the cleaning tool moves to adhere to the glass. Next, the cleaning device cleans the entire window at the same time with the cleaning tool (wiper or roller brush) from the starting position to profile. Then, when approaching the obstacle to some extent, the body stops and the cleaning tool moves toward the body so as not to catch on the protrusion. If the cleaning tool moves sufficiently, the body begins to move and pass through obstacles. After it completely passes the obstacle, the body stops again and moves to adhere to the glass again, and keeps cleaning. The operation method can be diagramed as shown in Fig. 4.

When using a window-height cleaning tool, the obstacles avoiding technique and the minimization technique of uncleaned area conflict with each other. For example, when the wiper attached to the cleaning machine encounters protrusions while it is squeezed to clean the glass, it should avoid the obstacle. However, if the cleaning machine stops for a while to avoid it, it leaves some marks and traces of its own on another window where there is no protruding part. In addition, it performs the stop and the driving modes repeatedly, deteriorating the cleaning efficiency. To address this weakness, the motion to avoid an obstacle should be started at a substantial distance from an obstacle, which results in a larger uncleaned area around the protruding part of the window (see Fig. 5). Therefore, an obstacle avoidance

mechanism should be developed to minimise the uncleaned area without compromising the efficiency of the cleaning work [5].

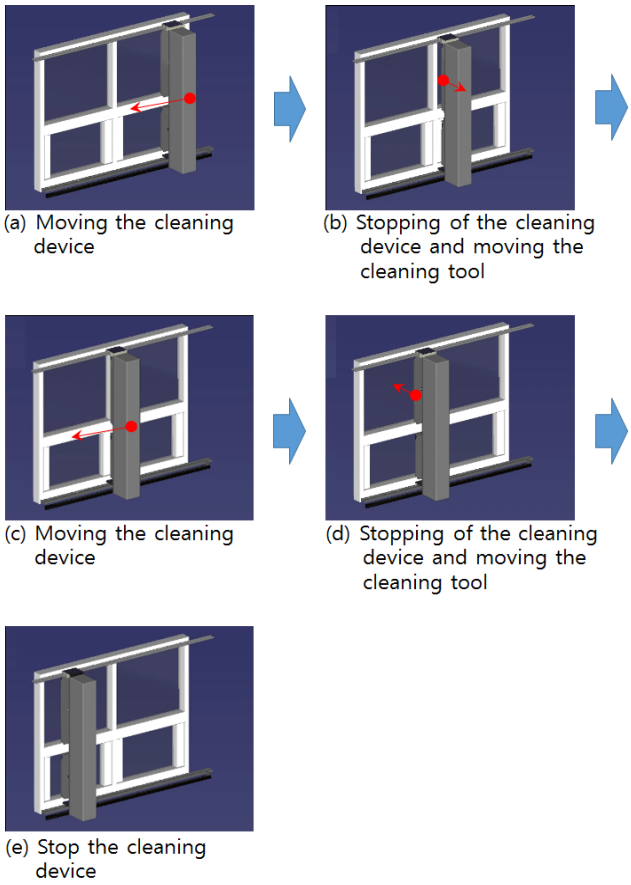

Fig. 4. Window-height cleaning tool.

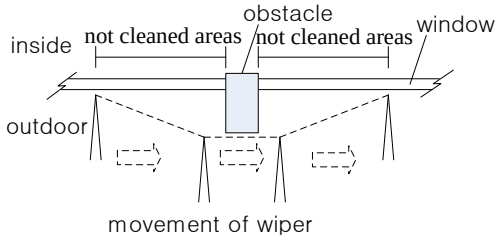

Fig. 5. Existing ways to avoid an obstacle [5]

C. Lower-Height Cleaning Tool

The lower-height cleaning tool can be illustrated as shown in Fig. 6.

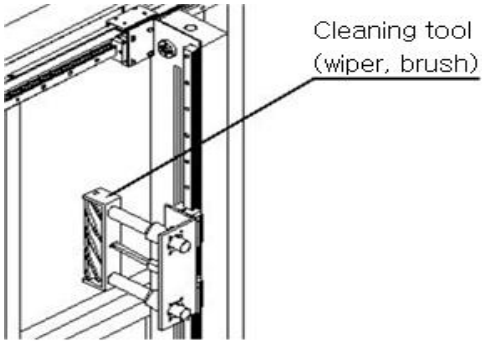

Fig. 6. Cleaning tool smaller than window-height [4].

Before cleaning, the lower-height cleaning tool is also on the body side, and the body is on the window frame position. This cleaning tools starts cleaning from the upper part of the window. When it meets a profile, the body stops and the cleaning tool moves toward the body to the point where the cleaning tool is not blocked by an obstacle. If the cleaning tool moves sufficiently, the body passes by the obstacle completely, and the cleaning tool closes to the glass and keeps cleaning. Once the process finishes cleaning to the end, the tools moves downward. The body moves in reverse and keeps cleaning in the same fashion described above. This process will repeat until the cleaning tool reaches the bottom of the window and the cleaning operation is completed. Therefore, in the case of the lower-height cleaning tool, the position changing movement and the obstacle avoiding movement are repeatedly used. The operating mechanism can be illustrated as shown in Fig. 7.

IV. Analysis of Advantages and Disadvantages of the Two Devices

The window-height cleaning tool can perform window cleaning through a single process, and leaves no horizontal stains or traces behind. Also, since the cleaning tool does not need to move to the top and bottom of the window, the control of the body and tool are simple.

On the other hand, there is a possibility that the cleaning tool will become heavy and a higher load will be applied to the fixing part such as the rail. Also, a mechanism for avoiding the protrusion should be well developed and if there is not the mechanism, there is the possibility of leaving vertical marks and traces. In addition, since the wiper and the roller brush must be individually controlled, there is a limitation in that the mechanisms and controls in the body are complicated.

The lower-height cleaning tool can be small and light in weight. This can result in a reduced load on the fixed part such as the rails and upper and lower parts of the windowsills. Also, since no special obstacle avoidance mechanism is required, the operation mechanism can be simplified.

However, the use of this tool has the disadvantage of requiring repeated cleaning operations, changing direction and cleaning motion, which can leave traces of residue and complicate cleaning paths. Also, the cleaning path is complicated and the efficiency may vary depending on how the cleaning path is set.

The advantages and disadvantages of the two device types are shown in Table II. From a comparison between the two types derived in this study, the window-height cleaning tool has more advantages than the lower-height one.

This is because the window-height cleaning tool is likely to be clean, even if the weight of the window is heavy. Also, the lower-height one may cause noise, which is likely to be disturbed by the occupants.

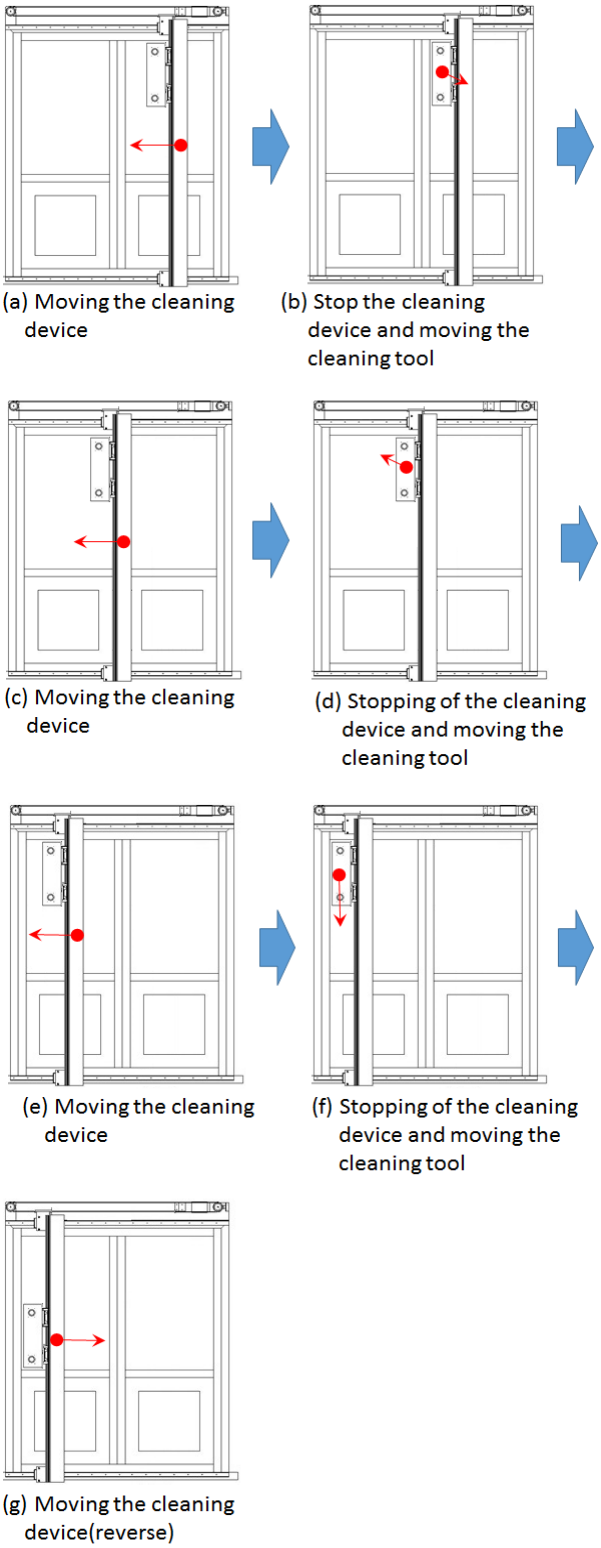

Fig. 7. Operating mechanism of a cleaning device smaller than window.

V. Results

Conventional window cleaning devices have been designed to clean the entire façade of a building. As such, there has been a pressing need to develop a cleaning device to clean some specific windows at a certain floor frequently. As this type of system has not yet been developed, an effective cleaning tool shape and operating mechanism for this type of approach have not yet been reviewed. For this reason, the conceptual shapes that enable a cleaning tool and device to perform cleaning effectively were designed, and its operating mechanisms were presented in this study. From a comparison between the two derived in this study, the window-height cleaning tool has more advantages than the lower-height one. Because this method has the disadvantage of heavy weight, but the cleaning result is expected to be good. In addition, it is less likely to generate noise, which is a cause of discomfort to occupants. The findings of this study will be utilized as fundamental data for the development of a window cleaning device in the future.

TABLE II: Analysis of Advantages and Disadvantages of the Two Devices

	Window-height	Lower-height
Advantages	- Fast cleaning speed - Done through a single process - No horizontal stains and marks left behind - Simple path of a cleaning tool operating mechanism - No operating mechanism needed to move the cleaning tool up and down	- Small in size - Light in weight - Less load on the fixed part - No vertical marks and traces
Disadvantages	- Heavy cleaning tool - Higher load on the fixed parts - Leaves vertical marks and traces if there is no avoiding mechanism	- Slow cleaning speed - Repetition of cleaning motion - change direction and cleaning motion - Might leave stains and marks behind - Complicated cleaning path - Operating mechanism needed to move the cleaning tool up and down - Possibility of unnecessary noise and friction

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