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INNOVATION IN ACTION: TURNING IDEAS INTO REALITY

Chapter 13
Flexible Sliding Window

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ABSTRACT
Contemporary window designs significantly improve user comfort, safety, and overall convenience, especially for occupants of high-rise buildings. Conventional window systems often present difficulties in terms of limited ventilation and challenging cleaning access, particularly for the elderly, individuals with disabilities, and residents of condominiums. Thus, this project introduces an innovative solution called the Flexible Sliding Window, an automated sliding window that can rotate up to 180°, allowing for easier maintenance and improved airflow. The development process includes several essential stages: conceptualization, 3D modeling using Autodesk Inventor 2016, careful selection of materials like aluminium 6061 and acrylic sheets, machining with computer numerical control (CNC) and traditional machines, and integration of automation elements such as direct current (DC) motors and speed controllers. Prototype testing confirmed that the Flexible Sliding Window functions efficiently and aligns with the intended design criteria. Performance evaluation showed that the system significantly reduces window cleaning time by 3–5 minutes compared to conventional louver-type windows while enabling seamless 180° rotations with controlled speed. Structural analysis conducted through Autodesk Inventor validated the robustness of the design, with aluminium providing excellent strength and corrosion resistance. Project findings revealed that core features, automated operation, complete rotational capability, and user-centered design effectively solve issues related to cleaning and ventilation, offering a reliable and safer alternative. Proposed enhancements for future versions include incorporating rain sensors and utilizing solar power for energy efficiency. This project met its objectives successfully and presents promising potential for use in residential and commercial buildings. The Flexible Sliding Window satisfies modern user demands and demonstrates valuable innovation within the architectural and manufacturing sectors. Future research is encouraged to evaluate long-term functionality, improve child safety features, and explore certification for broader commercialization.

Key Words: automated sliding window; high-rise; design; aluminium; user-centered design

1. INTRODUCTION

Window systems are fundamental components in architectural design, providing access to natural light and ventilation while enhancing energy efficiency and safety and creating a clean, spacious, and visually pleasant environment (Hafez et al., 2023; Kim & Yu, 2018). High-rise buildings, with their challenging window designs, require expert cleaning services involving careful planning, strict safety measures, skilled staff, and reliable equipment to ensure safe and effective maintenance (Shaw, 2022). This issue is significant for the elderly, those with disabilities, and residents of multi-story buildings when access to external window surfaces is limited.

2. LITERATURE REVIEW

Traditional windows, such as louver and casement models, often limit airflow and are challenging to maintain, particularly in high-rise applications. Abdulrahman (2000) stated that modulated louvered windows struggle with reduced airflow at steep angles, wind sensitivity, and complex performance factors. While modern homes increasingly adopt sliding windows for improved access, these systems still lack flexibility and pose safety challenges during maintenance. The concept of rotatable or reversible windows has been proposed in limited architectural applications, primarily in commercial settings. However, many ventilation systems still follow rigid, traditional models and overlook more flexible, user-focused innovations, mainly due to practical challenges like cost, design complexity, and lack of conceptual planning (Seuntjens et al., 2022).

Material selection is another pillar of successful window system development. For high-rise buildings, aluminium alloy 6061 is commonly used because it offers low weight, strong corrosion resistance, and good machinability, with enhanced strength and wear resistance when reinforced (Adediran et al., 2021). A previous study highlighted that the presence of aluminium in aluminium-plastic co-extruded window systems with low-emissivity glazing offers long-term energy efficiency, structural resilience, and climate suitability, making them ideal for sustainable use in high-rise buildings in warm, humid regions (Mo et al., 2024).

3. METHODOLOGY

3.1. Materials

Aluminium is used for the frame (durable and corrosion-resistant), the acrylic board is used as the window panel material (lightweight and easy to maintain), bearings enable 360° rotation, wiring, and locking items are used for the mechanism of sliding automation, and safety lock integration.

3.2. Product development (design)

In developing the Flexible Sliding Window, the design process was carried out first as it directly relates to the subsequent machining process. This process is facilitated using

Autodesk Inventor software to generate 2D and 3D engineering drawings that visualize the selected concept.

3.3. Product development (prototype)

The necessary manufacturing processes were decided from the completed engineering drawing produced by Autodesk Inventor software. Figure 1 illustrates the various processes involved in constructing the Flexible Sliding Window. It starts with measuring the raw materials to match the required specifications from the engineering design. Next, the materials are cut to size using a Power Band Saw machine, ensuring they align with the initial measurements. This is followed by a refining stage, where the edges and surfaces are smoothed and adjusted using a SINO CNC milling machine, Creality Ender 3 S1 Pro 3D Printer and a conventional milling machine to achieve accurate dimensions. Finally, the wiring process is carried out, where all necessary electronic components are connected based on the planned circuit to enable the window's functionality.

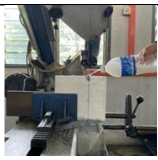
			
Material measurement	Material cutting	Cutting refining	Wiring process

Figure 1: The steps involved in producing the prototype of the Flexible Sliding Window

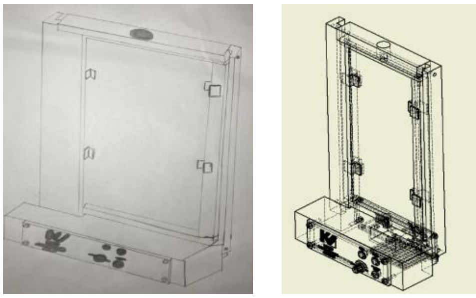
3.4. Product testing

The product testing process was divided into two main parts: (1) evaluating practical performance and (2) analyzing structural strength. The practical performance was evaluated based on its effectiveness in aiding users with window cleaning. The automatic rotation function was activated at both low and high-speed settings to examine the smoothness of operation, system responsiveness, and stability during use.

4. RESULTS AND DISCUSSION

4.1. Product development (design)

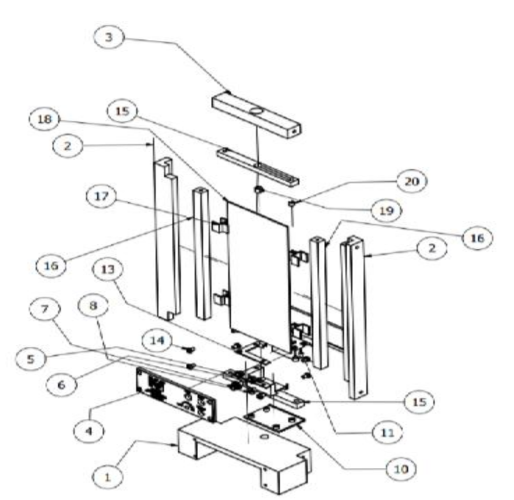
Figure 2 (a) shows an initial drawing that captures the key features of a design concept without detailed information. Based on this product sketch, the technical drawings were later produced using Autodesk Inventor software, as shown in Figure 2 (b). The isometric drawing is created to provide a comprehensive view of the Flexible Sliding Window design. Detailed descriptive information about the shape and structure of the product is presented in Figure 3.



(a) (b)

Figure 2 (a) Idea Drawing (b) Isometric Drawing

Figure 3 displays the view of the Flexible Sliding Window assembly, accompanied by a detailed parts list. This technical drawing outlines the structure and positioning of each individual component, offering a clear guide for the assembly and construction of the prototype. The diagram features 20 labeled components, each marked in the visual layout and listed in the adjacent table. This view is a critical reference during construction, enabling accurate alignment and fitting of all parts.



No	Item (Quantity)
1	Bottom-supported (1)
2	Sliding Support Post (2)
3	Top-supported (1)
4	Controller Holder (1)
5	Forward Button (1)
6	Reverse Button (1)
7	Speed Controller Button (1)
8	12V 3A DC Power Port (1)
9	Controller Holder 2 (1)
10	Controller Holder Clip (1)
11	DC Motor (1)
12	DC Motor Casing (1)
13	DC Motor Support Casing (1)
14	Cross Recessed Pan Head Machine Screw (8)
15	Bracket (2)
16	Vertical Frame (2)
17	Glass Clip (4)
18	Acrylic Plate (1)
19	Rotation Clip (2)
20	Bearing Holder Clip (2)

Figure 3 Parts List of the Flexible Sliding Window

4.2. Product development (prototype)

As shown in Figure 4, the developed prototype offered clear advantages compared to conventional sliding windows, particularly in functionality and user convenience.

	Product Specification Material: Aluminium 6061 Weight: 2.5081 kg Color: Silver Function: Flexible Sliding Window designed to simplify the window glass cleaning process and provide better ventilation for users

Figure 4 Prototype produced with its specification

4.3. Product Testing

The window glass rotated smoothly and functioned well. The result was that cleaning a traditional louver window typically takes 10–15 minutes, while the Flexible Sliding Window reduced the cleaning time by approximately 3–5 minutes. Table 1 summarizes info obtained from the ANSYS Mechanical report. Based on the material analysis, the Flexible Sliding Window is well-suited for real-world use due to its strong, lightweight, and reliable construction. The primary material, aluminium 6061, provides excellent structural integrity with a high yield strength, tensile strength, and stiffness making it resistant to bending, twisting, and environmental stress. Its low density ensures smooth sliding and rotation.

Table 1 Material Selection and Mechanical Properties of Flexible Sliding Window Components

Material	Component(s)	Density (g/cm³)	YS (MPa)	UTS (MPa)	YM (GPa)	SM (GPa)	Remarks
Aluminium 6061	Frame, support structure, screws	2.7	275	310	68.9	25.90	High strength-to-weight ratio, corrosion-resistant
ABS Plastic	Controller holder, buttons	1.06	20	29.6	2.24	0.81	Durable and impact-resistant for electronics
Copper	Motor casing, motor components	8.94	33.3	210	117.5	43.68	Excellent conductivity, structural support
SAN Plastic	Acrylic window plate	1.068	72.3	72.3	3.57	1.29	Transparent, rigid, and easy to maintain

*YS = Yield strength; UTS = Ultimate tensile strength; YM = Young's modulus; SM = Shear Modulus

5. CONCLUSION AND RECOMMENDATIONS

In conclusion, the Flexible Sliding Window project represents a meaningful innovation in addressing everyday challenges faced by occupants of tall buildings, particularly concerning safety, ventilation, and the ease of window maintenance. The system was successfully designed to rotate 180 degrees, allowing for improved cleaning access while incorporating semi-automated components for added convenience. Several enhancements are recommended to increase the product's efficiency and appeal further. These include integrating automatic rain sensors to improve responsiveness during adverse weather and adopting solar energy as a clean and cost-saving power source. With further refinement, this window design holds strong potential to serve as a reliable, efficient, and innovative solution for modern living environments.

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