Advances in Engineering Design Technology Vol. 5(2) 2023 pp. 1-13 ISSN-2682-5848

NIPES

Advances in Engineering Design Technology

Journal homepage: www.nipesjournals.org.ng

Development and Fabrication of an Upgraded Automatic Whiteboard Cleaning Machine

Loyalty Akpeti , Efe Orumwense, Ukpong Iyeneobong Daniel, Jimoh Hamza, Edegbo Maro Felix
Department of Mechanical Engineering, University of Benin, P.M.B. 1154, Benin City, Nigeria.
Email Address: loyaltyakpeti@gmail.com, efe.orumwense@uniben.edu

ARTICLE INFORMATION

Article history:
Received 20 April 2023
Revised 06 May 2023
Accepted 24 May 2023
Available online 12 June 2023

Keywords:
Whiteboard, Duster, Automatic, Arduino, Cleaner, Board.
https://doi.org/10.5281/zenodo.8029287

ISSN-2682-5821/

ABSTRACT

Over time, traditional blackboards have been gradually replaced by whiteboards in schools and other educational institutions due to the convenience of cleaning. With the increasing popularity of whiteboards with automatic cleaning systems worldwide, an efficient device is expected to completely replace conventional cleaning methods. This study presents the development of a low-cost and effective automatic whiteboard cleaning system using locally sourced materials. Various design factors were considered to surpass the capabilities of existing systems. Our testing and results demonstrate that our design can clean specific areas of the whiteboard, unlike other automatic whiteboard cleaners that clean the entire board at once. The cleaning time recorded was under 19 seconds, and our device leaves zero residue with just a few sweeps of the board. In conclusion, our whiteboard cleaning system is highly efficient and meets market standards with ease.

1. Introduction

Since its inception, the whiteboard has proven to be useful in both professional and non-professional settings. It should come as no surprise that, in comparison to the black and green chalkboards, it offers a number of advantages, making it a popular choice for personal study, business presentations, and knowledge transfer. The dry erase markers used on whiteboards also offer an advantage over the chalks used on blackboards. The inhalation of chalk dust can cause serious health problems, problems that are not caused my dry erase markers [1, 2]. Whiteboards were designed and made with enamel-hard surfaces and melamine in the 1950s and 1960s, based on the level of expertise and resources that were readily available at the time. This was the first-time whiteboards were used, and since then, people all over the world have started using them and black and green chalkboards are being phased out.

Despite the whiteboard's advantages over the black and green chalkboards, they all faced the same problem: "The difficulty and unease in cleaning off what has been written on its surface," specifically between 1950 and 1975. As a result, the porcelain-on-steel whiteboard was introduced. In the years that followed, porcelain became the preferred and most widely used surface material for the production of whiteboards. The substitution of dry-erase markers for wet-erase markers was another limitation addressed during this process. Professionals in the academic, business, and industrial sectors now find it simple to use the whiteboard for daily tasks thanks to modern surface finishes and wipe-clean markers. Whiteboards also support in-person meetings by allowing the focusing of attention, sharing of ideas and summarizing [3]

In today's technologically advanced world, the whiteboard is one of a few manually relevant items that has remained distinctive even as interactive whiteboards are also slowly emerging on the scene [4]. Cleaning the board is always necessary because every letter, number, symbol, or other entity written on it is only temporary. This can be tedious in a fast-paced learning environment or when the need to increase usage speed arises. As a result, reducing the use of manual cleaning techniques and increasing cleaning speed are major strategies for combating this persistent issue. The time and energy aspects are addressed simultaneously in this manner; using an automated system to handle the whiteboard cleaning process is the best way to accomplish these goals. The use of sensors will also increase the efficiency of the automated system [5].

At the moment, automated cleaning techniques are barely used at all, especially in Edo State, Nigeria and the University of Benin where this research project was carried out. The main objective of this project is to provide a standardized and improved automatic whiteboard cleaning system through this project that will clean whiteboards relatively quickly and easily.

After considering the immediate needs of our environment and the current methods of board cleaning being used, we have been able to itemize the following key issues:

a) Cleaning whiteboards after usage consumes a lot of time while teaching.
b) Energy is expended by the lecturer or student when cleaning manually.
c) Dusters can get stolen or go missing due to carelessness hence rendering the board difficult to clean.
d) Manual cleaning is inconsistent and leaves black residue on the board.

These are the main issues but the above list is by no means all-encompassing. The problems above will serve as our launching pad for this work. Being able to solve them will classify this project as a success. This project aims to design and fabricate an automated whiteboard cleaning system that will be suitable for use in classrooms and other places where whiteboards are regularly used. This project aims to design an automated cleaning mechanism that cleans the entire board automatically with just the push of a button, saving a lot of time and effort.

2.0. Methodology

The design was targeted towards achieving the following: producing a faster and easier way to clean white boards, high cleaning efficiency, availability of locally sourced materials, and cost of the machine.

During the course of this project, three distinct concepts were proposed as analyzed below.

2.1. Concept One: Horizontal Design (Moving Rack)

This concept is called the moving rack horizontal design and it consists of a DC Motor as the prime-mover and a single set of rack and pinion to convert the rotational motion of the DC Motor into linear motion of the duster. When the DC motor rotates, it transfers motion to the pinion. The pinion then moves the rack, and the rack in turn pushes the duster. The duster moves left-to-right across the board cleaning everything in its path.

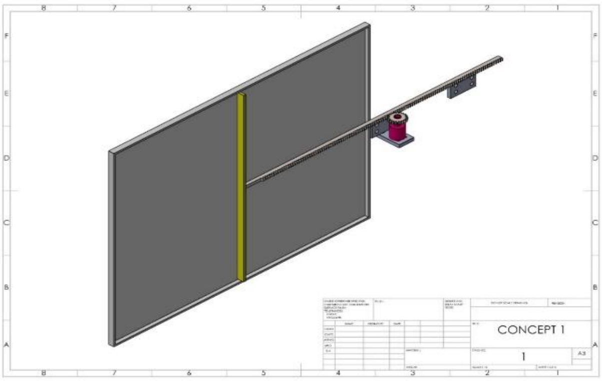


Figure 1 - Concept One: Horizontal Design (Moving Rack)

2.2. Concept two: Horizontal design (fixed rack)

This is what we called the fixed rack horizontal design and it consists of two sets of rack and pinion located at the top and bottom of the board. The pinions are connected with a shaft. The shaft is also connected to the prime-mover, a DC Motor. As the DC Motor spins, the shafts spins, as the shaft spins, the pinions spin, as the pinions spin, they move along the racks thus moving the duster along the board.

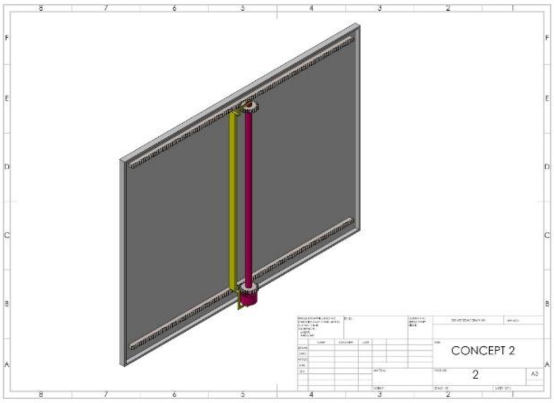


Figure 2 - Concept Two: Horizontal Design (Fixed Rack)

2.3. Concept Three: Vertical Design

This concept is called the vertical design and it is driven by one motor that connects two pulleys with a shaft. The shaft helps to transfer motion from the motor to the pulleys. The pulleys move the belt and the belt moves the duster vertically across the board cleaning it. The duster doesn't cover the entire board, rather it covers a third of the width of the board. There is another motor placed on the duster, which will be responsible for moving the duster from left to right. This way, the duster can pick specific parts of the board to wipe, not having to clean the whole thing while moving.

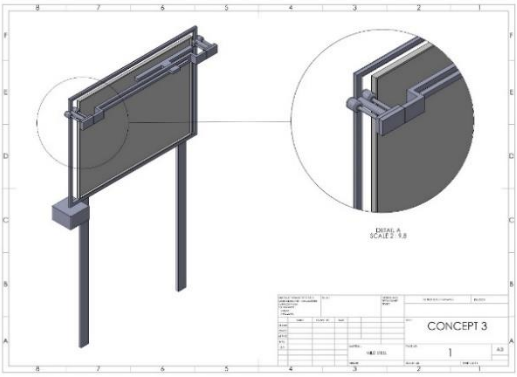


Figure 3 - Concept Three: Vertical Design

2.4. Decision Matrix

Of the three proposed concepts, only one can be used for the prototype. Hence a decision matrix was employed to help us make the choice. We based our decision matrix on five major criteria that we considered to be most important for whatever design we choose. The criteria are:

a) Cost
b) Efficiency
c) Practicality
d) Flexibility
e) Aesthetics

We then assigned each criteria a weight ranging from 1 to 5 with 1 being the least important and 5 being the most important. We discuss the criteria and how each concept was rated below.

a. Cost

Cost was our most important criteria when choosing a concept. Cost was assigned a weight of 5 to signify this. Concept one consists of one motor, one rack and one pinion as its major components. Thus, making it the cheapest of our three concepts. Concept one was assigned a cost rating of 5 for being the cheapest. Concept two consists of one motor, two racks, two pinions and one shaft as its major components. Thus, making it the second cheapest of our three concepts. Concept two was assigned a cost rating of 2 for being the second cheapest. Concept three consists of three motors, four pulleys, four bearings, two belts, and a relay board as its major components. Thus, making it the most expensive of our three concepts. Concept three was assigned a cost rating of 1 for being the most expensive.

b. Efficiency

Efficiency was the second most important criteria when selecting a concept. We assigned it a weight of 4. The efficiency of the concepts is defined as the ability of the design to properly clean all parts of the board. Concepts two and three were given a rating of 5 each for being the most efficient. They have a shaft that presses the duster against the board at all times thus ensuring a smooth clean. Concept one was assigned a value of 2 for being less efficient. It doesn't possess the shaft that the other two concepts have to continuously exert pressure on the duster against the board. The duster is free and could clean less efficiently when the rack is fully extended.

c. Practicality

We defined practicality of our design as the ability of the system to be installed in any classroom. We gave this criterion a weight of 3. Concept one is very impractical because of the way it works. It extends fully to the right of the board at the base of its motion, and this extension cannot be accommodated in most classrooms. Some classrooms have many boards next to each other, so this extension will cover the next board. Other classrooms don't have enough space to the right of their board to accommodate this extension. For these reasons, concept one was given a rating of 1 for practicality. Concepts two and three were given ratings of 5 because they are more practical and don't take up a lot of unnecessary space.

d. Flexibility

We defined flexibility here as the ability of the device to clean specific areas of the board and not just the whole board. Most lecturers like to divide the board when writing so they don't clean the entire thing when they are done, just specific parts. Being able to meet this need is a very important criteria that our design has to have. We gave this criterion a weight of 2. Concepts one and two are not capable of this. They clean the entire board and not specific bits. We gave concepts one and two ratings of 2 for flexibility. Concept three on the other hand is very flexible. The duster in this design is a third of the length of the board and it has a motor to move the duster from left to right. For this flexibility, concept three was given a rating of 5.

e. Aesthetics

Of the five criteria we used, aesthetics was the least important. We gave it a weight of 1. All designs appealed to us aesthetically so all three concepts were given a rating of 5 for aesthetics.

CRITERIA	WEIGHT	CONCEPT 1		CONCEPT 2		CONCEPT 3	
		RATING	WEIGHTED SCORE	RATING	WEIGHTED SCORE	RATING	WEIGHTED SCORE
COST	5	5	25	2	10	1	5
EFFICIENCY	4	2	8	5	20	5	20
PRACTICALITY	3	1	3	5	15	5	15
FLEXIBILITY	2	2	4	2	4	5	10
AESTHETICS	1	5	5	5	5	5	5
TOTAL SCORE			45		54		55

Figure 4 - Decision Matrix

2.5. Design Calculations

Our prototype was constructed on a frame for transportation. The eventual machine will be designed to be attached to the wall beneath the board. The height of the "legs" of the frame is **91.44cm**. The top of the frame that houses the board is **107cm x 168cm.** The motors used are **50Watts, 12V** motors. They have a mechanical horsepower of **6hp**. The battery used to power the prototype is **12V, 7Ah.** The pulleys are **6cm** in diameter and the bearings are **5.5cm** in diameter. The belts used are **215cm** in length by measurement. The distance between the belts is **142cm.** The relay switches used are **12V**. Center-to-center distance of the pulleys is **98cm**.

2.5.1. Belt Parameters

b = 12mm, t = 8mm, w/l = 1.06
D_1 = diameter of driving pulley, 60mm
D_2 = Diameter of driven pulley, 60mm.
P_{belt} = 1250kg/m^3
Rotational Speed of driver pulley, N_1 = 319.998rpm
S_s = 3.0MPa
μ = 0.25
Groove angle of pulley = 30° = 2β
Length of belt by calculation,

$$\mathbf{L} = \frac{\pi(D_1+D_2)}{2} + 2C + \left(\frac{(D_1+D_2)^2}{4C}\right) \quad \textbf{[6]}$$

We use a center, C, 980mm.

L = $\frac{\pi(60+60)}{2} + 2\times980 + \left(\frac{(60+60)^2}{4\times980}\right)$ = **2152.169mm = 215.2169cm** (close to the **215cm** obtained via measurement)

A standard belt is then chosen as the nearest match is 2158 mm which is a type **A83 belt.**

2.5.2. Operational Acceleration

$N_s = 319.998RPM$

$$\omega = \frac{2\pi N}{60} = \frac{2\times\pi\times319.998}{60} \quad \textbf{[6]}$$

$\omega = 33.51\ \text{rads}/_{s}$

$$\boldsymbol{\alpha} = \frac{\boldsymbol{\omega}}{\mathbf{t}} = \frac{\mathbf{33.51}}{\mathbf{6}} \quad \textbf{[7]}$$

$\alpha = 5.585\ \text{rads}/_{s^2}$

2.6. Bearing Parameters

The single row deep groove ball bearing was chosen because of its high load carrying capacity and suitability for high running speed. The specific static load rating or capacity C_o is:

$$Co = \frac{1}{5}\times ko\times i\times z\cos\alpha Dw^2 \quad \textbf{[8]}$$

Where:
C_o = Specific Static Load rating or Capacity = 40kN
K_o = Factor depending on the type of bearing = 12.3
D_w = Diameter of the ball
α = Nominal angle of contact = 0
i = Number of rows of the ball in any one bearing = 1
z = Number of balls per row in the groove = 6

$$Ko = \frac{Q\max}{\mathrm{Dw}^2} \quad \textbf{[8]}$$

Qmax = Maximum bearing load.

From the above data, the ball diameter can be calculated

$$Dw = \sqrt{\left(\frac{Co \times 5}{Ko \times i \times z\cos\alpha}\right)} \qquad \textbf{[9]}$$

$$= \sqrt{\left(\frac{40 \times 10^3 \times 5}{12.3 \times 1 \times 6\cos 0}\right)}$$

$$= \sqrt{2710.0271}$$

= 52.06mm

The next available market diameter was **55mm**.

Then the maximum bearing load Q_{max} becomes:

$$Ko = \frac{Qmax}{Dw^2}$$

$Q_{max} = K_o \times D_w^2$

$= 12.3 \times 2710.0271$

= **33333.3333N**

The bearing with identification number 6206, which is has an inner diameter of 25mm and outer diameter of 55mm, was then chosen. The bearing number interpreted as 200 means a light-bearing of the bore that is the inner diameter of 5 × 5 = 25mm. Also, in the selection of this bearing, the radial load of which the bearing can carry was put into consideration. However, for the ball lubrication, grease is used at low and medium speed when the temperature is not over 20°C while oil is used at higher speed. Hence, for this design, grease is regarded as the most satisfactory lubricant, because the temperature rarely exceeds 20°C during operation.

2.7. Material Selection

Consideration was given to cost and weight when picking the materials for fabrication. The frame was fabricated using mild steel. Mild steel was readily available and was strong enough to support the entire design. Mild steel is also known for being easy to weld, which was exactly what we needed. The bearings used were stainless steel bearings because of the high corrosion resistance properties of stainless steel. Stainless steel bearings are also known for being low maintenance and not requiring frequent lubrication.

For the duster holder, we opted for wood because it would be lighter than metal which would reduce the load on the motors. HDF Ply board was chosen for the wood because it is light-weight, cheap and readily available in our vicinity. We chose to use copper for our wiring instead of aluminum because of its longer lifespan due to its superior corrosion resistance.

Then for our cleaning material, we chose felt which is the same material that conventional white board dusters use. It is soft and very absorbent which makes it ideal for cleaning off dry erase markers. It is also very easy to clean with just soap and water. For the belts used to transfer motion from the motors to the duster, we chose ethylene propylene diene monomer (EPDM) synthetic rubber belts. They are incredibly heat resistant, flexible and cheap. These traits put them above Polyurethane and Neoprene belts.

2.8. The Prototype

Concept three was chosen with the aid of the decision matrix. The materials needed were identified as outlined in the previous section and then purchased. Then fabrication began.

The frame was the first to be fabricated. Lengths of metal were bought. The metal was cut to the desired measurements and the welded together to the desired shape.

Figure 5 – The Frame

Once the frame was standing, the rest of the materials were attached to it. The board was mounted to the frame. Next the pocket for the battery was fabricated and welded to the back of the frame.

Figure 6 - Board Mounted on the Frame

The driving pulleys were welded to the motors and the motors had pockets fabricated to house them. The driving and driven pulleys were then connected with the belts.

Figure 7 - DC Motor

The driven pulleys were then set up between two bearings each to aid rotation. The bearings are set in a ‘cup’ which was in turn welded to the frame. The cup holds the outside of the bearing firm while allowing the inside rotate freely.

Figure 8 - Driven Pulley and Bearings

Next, a holder was fabricated for the duster. The wood was cut to the required dimensions (1.75ft) and the felt from the dusters we bought was glued to the wood. The duster was then set on the holder and the two induction motors and two wheels were attached to the duster.

Figure 9 - Duster Holder

The duster holder was then fastened to the belts of the device using bolts and nuts. A hole was first punched in the belts as the desired locations in order to give room for the bolts and nuts to be placed. At the sites of the holes, the duster was then fastened. Wheels were then placed at the back of the holder to give the holder freedom to ascend and descend the frame. The wheels are there to make the motion smooth.

Figure 10 - Duster Holder Attached to the Belt

The electrical work and the coding were then done next. The H-bridge relays were built. The aim of this is to reverse the polarity of the motors so the duster can both ascend and descend.

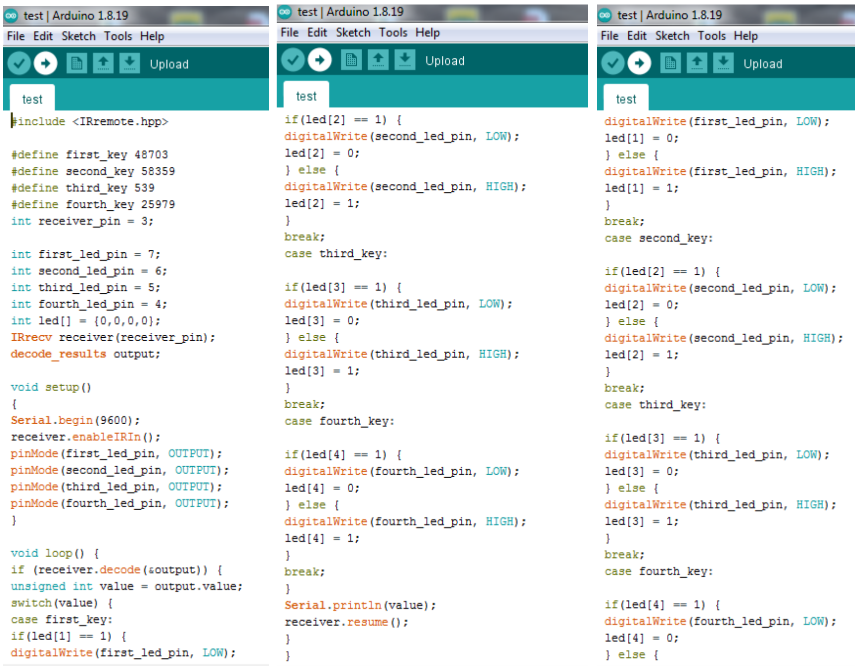
The Arduino code was then done and the board was assembled to enable the system to be operated with the push of a button form a distance. Finishing touches were added to the device, the welded joints were sanded. The belts were tensioned.

Figure 11 - Finished Design

2.10. Arduino Code

The following is the code used to assign functions to various keys on the remote. 4 keys were needed in total: UP, DOWN, LEFT and RIGHT. We assigned **UP** to button **2, DOWN** to button **8, LEFT** to button **4, RIGHT** to button **6.**

Figure 12 - Remote Control



test | Arduino 1.8.19

```
#include <IRremote.hpp>

#define first_key 48703
#define second_key 58359
#define third_key 539
#define fourth_key 25979
int receiver_pin = 3;

int first_led_pin = 7;
int second_led_pin = 6;
int third_led_pin = 5;
int fourth_led_pin = 4;
int led[] = {0,0,0,0};
IRrecv receiver(receiver_pin);
decode_results output;

void setup()
{
Serial.begin(9600);
receiver.enableIRIn();
pinMode(first_led_pin, OUTPUT);
pinMode(second_led_pin, OUTPUT);
pinMode(third_led_pin, OUTPUT);
pinMode(fourth_led_pin, OUTPUT);
}

void loop() {
if (receiver.decode(&output)) {
unsigned int value = output.value;
switch(value) {
case first_key:
if(led[1] == 1) {
digitalWrite(first_led_pin, LOW);
```

test | Arduino 1.8.19

```
if(led[2] == 1) {
digitalWrite(second_led_pin, LOW);
led[2] = 0;
} else {
digitalWrite(second_led_pin, HIGH);
led[2] = 1;
}
break;
case third_key:

if(led[3] == 1) {
digitalWrite(third_led_pin, LOW);
led[3] = 0;
} else {
digitalWrite(third_led_pin, HIGH);
led[3] = 1;
}
break;
case fourth_key:

if(led[4] == 1) {
digitalWrite(fourth_led_pin, LOW);
led[4] = 0;
} else {
digitalWrite(fourth_led_pin, HIGH);
led[4] = 1;
}
break;
}
Serial.println(value);
receiver.resume();
}
}
```

test | Arduino 1.8.19

```
digitalWrite(first_led_pin, LOW);
led[1] = 0;
} else {
digitalWrite(first_led_pin, HIGH);
led[1] = 1;
}
break;
case second_key:

if(led[2] == 1) {
digitalWrite(second_led_pin, LOW);
led[2] = 0;
} else {
digitalWrite(second_led_pin, HIGH);
led[2] = 1;
}
break;
case third_key:

if(led[3] == 1) {
digitalWrite(third_led_pin, LOW);
led[3] = 0;
} else {
digitalWrite(third_led_pin, HIGH);
led[3] = 1;
}
break;
case fourth_key:

if(led[4] == 1) {
digitalWrite(fourth_led_pin, LOW);
led[4] = 0;
} else {
```

Figure 133 – Arduino Code

3.0. Results And Discussion

The following calculations were performed to first ascertain that our device would be able to clean faster than conventional methods. We spent a week collecting data from two lecture theatres in the University of Benin, namely: Old 1000 LT and LT2. We then were able to determine the average amount of time it would take to clean a board using conventional methods.

Average time taken to clean a 4ft x 8ft board manually = 54s

Ratio of the area of our prototype board to the area of a standard board used in the University of Benin = $\frac{3 \times 4}{4 \times 8} = 0.375$

Time taken to clean a 3ft x 4ft board manually = $0.375 \times 54 = 20.25s$

Time taken for our device to slide top-to-bottom = 6s

Time taken to clean a 3ft x 4ft board with our machine = 6s x 3 = 18s

Percentage time saved = $\frac{20.25 - 18}{20.25} \times 100 = 11.11\%$

Secondly, we performed calculations to find out how long a fully charged battery can be used to power the device in the average University of Benin lecture theatre. We collected date from the two aforementioned lecture theatres over the course of three weeks and determined the average numbers of times a board is cleaned in each of those theatres per week.

Average number of times a week the board is cleaned in Old 1000 LT = 54

Average number of times a week the board is cleaned in LT2 = 51

Battery = 12V, 7Ah

Time to charge with a 12V, 1A charger = $\frac{7\text{Ah}}{1\text{A}} = 7\text{hours}$ **[10]**

Current needed by both motors = 4.2 amps x 2 = 8.4A

Time both motors will run on a fully charged battery = $\frac{7\text{Ah}}{8.4\text{A}} = 0.8333\text{hours} = 50 \text{ minutes}$

Number of times the machine can clean the board on a full battery = $\frac{50 \text{ x } 60}{18} \approx 167 \text{ times}$

At an average of 52.5 cleans per week, number of weeks the machine can last on a full battery = 3.18 weeks $\approx$ 16 school days

Lastly, we determined the torque in our motors.

Time taken to slide top-to-bottom = 6s

Distance from top-to-bottom = 0.98m

Velocity = $\frac{0.98\text{m}}{6\text{s}} = 0.16\text{m/s}$ **[11]**

Radius of the pulley = 0.03m

Revolutions = $\frac{0.16\text{m/s}}{0.03\text{m}} = 5.3333\text{rev/s} = 319.998\text{rev/min}$ **[12]**

Angular velocity = $\frac{2 \text{ x } \pi \text{ x } 319.998}{60} = 33.51\text{rad/s}$ **[13]**

Mechanical Horsepower = 6hp = 6 x 745.7 = 4474.2Watts **[14]**

Torque = $\frac{P}{\omega} = \frac{4474.2}{33.51}$ = 133.52Nm **[15]**

The time taken for the machine to clean (18s) will be slightly more on a 4ft x 8ft board due to the increased length of the shaft and the extra weight. Although there will be an increase, we expect it to still be considerably less than the 54s taken to clean it manually. Thus, the machine will remain efficient even at full scale.

At full scale, and taking losses into consideration, the 16-day battery life of the machine should drop but not so much as to make the 7-hour charging time seem wasted.

4. Conclusion

The design and fabrication of an automatic whiteboard cleaner presented in this research paper aimed to address the challenges and limitations associated with conventional cleaning methods for whiteboards. Through a systematic approach, the development process involved conceptualization, design, fabricating, and testing to achieve a functional and reliable whiteboard cleaning machine.

The automatic whiteboard cleaner offers numerous advantages over conventional cleaning methods. Firstly, it provides convenience and time-saving benefits to users. By automating the cleaning process, users no longer need to spend valuable time manually erasing the whiteboard or using separate cleaning tools. The system efficiently removes dry erase marker ink, erases residual marks, and ensures a fresh and ready-to-use whiteboard surface with minimal user intervention.

The implementation of advanced cleaning mechanisms and technologies contributes to the effectiveness of the automatic whiteboard cleaner. The combination of felt cleaning pads with gentle but efficient motorized movements effectively removes dry erase marker residue. From a maintenance perspective, the automatic whiteboard cleaner offers longevity. The system's removable and washable cleaning pads ensure hygienic operations and cost savings by eliminating the need for disposable wipes or replacement components. Routine maintenance can be easily performed, prolonging the machine's lifespan and ensuring consistent performance.

While the research and development of the automatic whiteboard cleaner have been successful, there are areas for further exploration and improvement. Future iterations could focus on refining the system's autonomous navigation capabilities, incorporating machine learning algorithms to adapt to various whiteboard surfaces, and enhancing edge detection for improved cleaning precision. Additionally, the machine’s wireless capabilities can be improved by adding phone applications to its control options rather than just relying on Arduino remotes.

The design and fabrication of an automatic whiteboard cleaner represents a significant advancement in the field of whiteboard maintenance. This innovative solution offers enhanced convenience, improved user experience, efficient cleaning performance, and sustainability. The automatic whiteboard cleaner has the capacity to transform educational institutions, corporate environments, and various other settings where whiteboards are widely used in Nigeria. As further research and development continue, this technology has the potential to evolve and adapt to meet the evolving needs of users, contributing to a more productive and organized classroom/workspace.

In summary, we were able to achieve our objectives:

a) Our device cleans faster than a person cleaning using conventional means.
b) Manpower was saved because the device is almost fully automated, only the push of a button is required and sliding of the duster is required.
c) The entire device can be fixed to the wall above and under the board to prevent theft.
d) The duster applies enough pressure on the board to ensure no residue is left behind after cleaning.

References

[1] Suresh, M., Meenakumari, D. R., Raghavendran, D. P., Gowrishankar, V., Karthikeyan, P., Surendar, V., Prashant, N. K. (2018). Design and Development of Automatic Whiteboard Cleaner for Effective Cleaning Mechanism using Arduino. *International Journal of Innovative Research in Electrical, Electronics, Instrumentation and Control Engineering*.

[2] C.Betcher and M.Lee, (Camberwell Victoria, 3124, Australia, by ACER Press, 2009). The Interactive Whiteboard Revolution.

[3] Gormish, M., Erol, B., Van Olst, D. G., Li, T., & Mariotti, A. (2011). Whiteboard sharing: capture, process, and print or email. Paper presented at the Imaging and Printing in a Web 2.0 World II.

[4] Odiase P.O., and Okoli G.C. (2016). “Electro-Mechanical Based Automated Whiteboard Wiper” FUOYE Journal of Engineering and Technology. Vol. 1, Issue 1, Sept., 2016

[5] Onochie, U. P., Obilikpa, S. C., Onwurah, C., Kwasi-Effah, C. C., Itabor, N. A., & Damisah, L. E. (2021). Design, Modelling, Simulation, Fabrication and Performance Evaluation of a Portable Foot Operated Dispenser. *NIPES Journal of Science and Technology Research*, *3*(4).245-258

[6] B. Chougule, P. Mathur, Automated Motorized Sensing Whiteboard, IJARET, 2014, vol. 5, issue 3, pp. 155-163.

[7] Khurmi, R. & Gupta, J., 2005. *A Textbook of Machine Design.* 14th ed. New Delhi: Eurasia Publishing House (PVT.) Ltd.

[8] Unuareokpa, O. J., Madu, J. C., Edo-Taiwo, S. A., Peters, S. D., & Kwasi-Effah, C. C. (2022). Design and Fabrication Of A Shell And Tube Heat Exchanger For Laboratory Experiments. *Int. J. Renew. Energ & Environ Vol*, *3*(1), 34-53.

[9] Palmgren, A., 1945. *Ball and Roller Bearing Engineering.* 2nd ed. Sweden: SKF Industries.

[10] Budynas, R. G. & Nisbett, J. K., 2015. *Shigley's Mechanical Engineering Design.* 10th ed. s.l.:McGraw-Hill Education.

[10] Bird, J., 2003. *Electrical Circuit Theory and Technology.* Revised 2nd ed. s.l.:Newnes.

[11] Resnick, R. & Walker, J., 2004. *Fundamentals of Physics.* 7 ed. s.l.:Wiley.

[12] Kelly, S. G., 2012. *Mechanical Vibrations: Theory and Applications.* s.l.:Cengage Learning.

[13] Hibbeler, R. C., 2009. *Engineering Mechanics.* Upper Saddle River, New Jersey: Pearson Prentice Hall.

[14] Avallone, E., Baumeister, T. & Sadegh, A., 2006. *Marks' Standard Handbook for Mechanical Engineers.* 11th ed. s.l.:McGraw-Hill.