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Designing and Engineering of Automatic Board Cleaner Using CNC Based Mechanism

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Abstract

Report has been written on designing and engineering automatic board cleaner to introduce a new advance mechanism for erasing the board. In previous projects, the mechanism used for erasing the board was failed to achieve its true potential of decreasing erasing time and eventually increasing or optimizing the lecture duration. The reason behind this was if the lecturer had written a small word in a portion of the board, the duster used to erase the whole board, not just that portion. And the mechanism used too were very slow and outdated. These are the areas where we focused to improved. The present demand of the market & customers is always main priority for developing the demand. So, we developed the product using survey analysis, quality function deployment and TOPSIS. And it was run by using updated technology of CNC based 3D printing mechanism.

Index terms: Product design, QFD, TOPSIS, CNC, Arduino UNO.

Introduction

Product design consists in imagining and creating objects meant for mass production. The definition encompasses the physical aspects as well as the functionalities products should possess. In other words, product design as a verb is to create a new product to be sold by a business to its customers. To determine the demand in the market, we first conducted a survey on a questionnaire that we prepared. After analyzing the survey result, we got an idea about the market. Surveying is an important tool to get the voice of the customer. Conversion of market demand or the so-called voice of customers in terms of engineering specifications is done by a process called Quality Function Deployment (QFD). Then followed the material selection process. Among the many processes TOPSIS method was used in this product development for material selection. According to the final design total cost for manufacturing the product was estimated the cost of each component. We begin this product design report from 'Introduction' which gives an introductory discussion about the product to be developed and the process adopted along the way to do that. The following discussion is about the survey questionnaires. Then the survey conducted based on the questionnaires mentioned in QFD is analyzed. There would be an imaginary design of the product. Chapter 'Material Selection' illustrates the process according to which material selection was done. In the final chapter a conclusive discussion was given about the whole process which was followed to develop the product.

Objectives

The traditional method for board cleaning is the manual process. In this modern era, we seek for the technologies that will reduce our effort and ensuring comfort. This product can easily assist to old aged and even disabled people. The other advancements are given below:

1. Easy to install.

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3. Particular place cleaning opportunity.

4. Physical effort not required.

5. The use of AC power supply.

Methodology

Step 1: A group of concepts of a product incorporating with some new features was generated and one of them was selected. Which was an Automatic Board Cleaner.

Step 2: A questionnaire was prepared with the view to get the idea of market needs. A survey was conducted based on this questionnaire.

Step 3: The findings from the survey were analyzed.

Step 4: The voice of the customer was converted into engineering specifications using Quality Function Deployment.

Step 5: Materials needed for each component were selected using TOPSIS.

Step 6: A computer aided design of the product was generated.

Survey Analysis

24. Duster Durability and Expected Life have slightly positive relation. Which is why In questionnaires respondents' demographic characteristics were asked. Whether they prefer automatic board cleaner or use the traditional manual method. We wanted to make the cleaner affordable for everyone and so we have asked some questions about the material. We also wanted some unique functions on our cleaner so that it can gain customer interest and that is why some questions were asked about it. Remembering that each customer is important, we wanted to know about their opinion to the power source we should use. We also wanted to know about their opinion about price and suggestions regarding several questions. From our 315 surveyed people we could see that 85% of total surveyed people were students, 9% were teachers, 1% was engineers, 2% were service holders and 3% were housewives. So, our maximum surveyed people were students.

Qfd (Quality Function Deployment) of our Project

By doing customer survey and discussing among the group members we created our QFD on Automatic Board Cleaner. There are 9 Customer requirements and 10 Engineering specifications. In the Customer Importance column, we rated the Customer Requirements according to the survey we did on the product. It is rated from 1-5. The Co-relation between the 10 Engineering specifications was shown in the "Roof" part of the QFD.

Here is a brief detail on the Co-relations of the Engineering specifications

- The relation between Weight and Battery Power (in Volt) is slightly negative. That's why it is shown as "-" in the QFD.
- Expected Life and the Battery Power (in Volt) have strongly positive relation. That's why it is denoted with "++" in the QFD.
- The relation between Expected Life and Production Cost is slightly positive. Which is why their relation is denoted with "+" in the QFD.
- Production Cost and the Frame Dimension have slightly positive relation. That's why it is shown as "+" in the QFD.
- The relation between Frame Dimension and Cleaning Time (in secs) is slightly positive. Which is why their relation is denoted with "+" in the QFD.
- Cleaning Time (in secs) and the Frame Material have strongly negative relation. Which is why their relation is denoted with "--" in the QFD.
- Frame Material and Duster size have strongly negative relation. Which is why it is shown as "--" in the QFD.
- The relation between Duster Size and Duster Durability is slightly negative. That's why it is denoted with "-" in the QFD.
- The relation between Noise Level and Duster Durability is slightly negative. That's why their relation is denoted with "-" in the QFD.
- Production Cost and the Battery Power (in Volt) have strongly positive relation. That's why it is denoted with "++" in the QFD.
- Cleaning Time (in secs) and the Production Cost have slightly positive relation. Which is why their relation is denoted with "+" in the QFD.
- The relation between Frame Dimension and Frame Material is strongly positive. Which is why their relation is denoted with "++" in the QFD.
- Production Cost and the Weight have strongly positive relation. That's why it is denoted with "++" in the QFD.
- Frame Material and Production Cost have strongly positive relation. Which is why it is shown as "++" in the QFD.
- The relation between Duster size and Frame Dimension is strongly positive. That's why it is denoted with "++" in the QFD.
- The relation between Noise Level and Frame Material is slightly negative. That's why their relation is denoted with "-" in the QFD.
- Weight and Frame Dimension have slightly positive relation. That's why it is shown as "+" in the QFD.
- Battery Power (in Volt) and Cleaning Time (in secs) have slightly positive relation. Which is why their relation is denoted with "+" in the QFD.
- The relation between Expected Life and Frame Material is slightly negative. Which is why their relation is denoted with "-" in the QFD.
- Duster Size and Production Cost have slightly positive relation. Which is why their relation is denoted with "+" in the QFD.
- Cleaning Time (in secs) and the Weight have slightly positive relation. Which is why their relation is denoted with "+" in the QFD.
- The relation between Production Cost and Duster Durability is slightly positive. That's why it is denoted with "+" in the QFD.
- Frame Material and Weight have strongly positive relation. Which is why it is shown as

"++" in the QFD.their relation is denoted with "+" in the QFD.

- The relation between Weight and Duster Size is slightly positive. That's why it is denoted with "+" in the QFD.
- Battery Power (in Volt) and Noise Level have slightly positive relation. Which is why their relation is denoted with "+" in the QFD.
- Noise Level and Production Cost have slightly positive relation. Which is why their relation is denoted with "+" in the QFD.

  These two symbols what requirements we want from the Selected EngineeringSpecifications.

 Shows that more Battery Power is better, expected lifetime should be longer, Frame Material should be of better quality, Duster Size should be suitable, Longer Duster Durability Etc.

 Shows that Less Weight is better, Production Cost should be lower, Frame Dimension should be suitable, Noise Level should be low, and less Cleaning time is better.**(Figure. 1)**

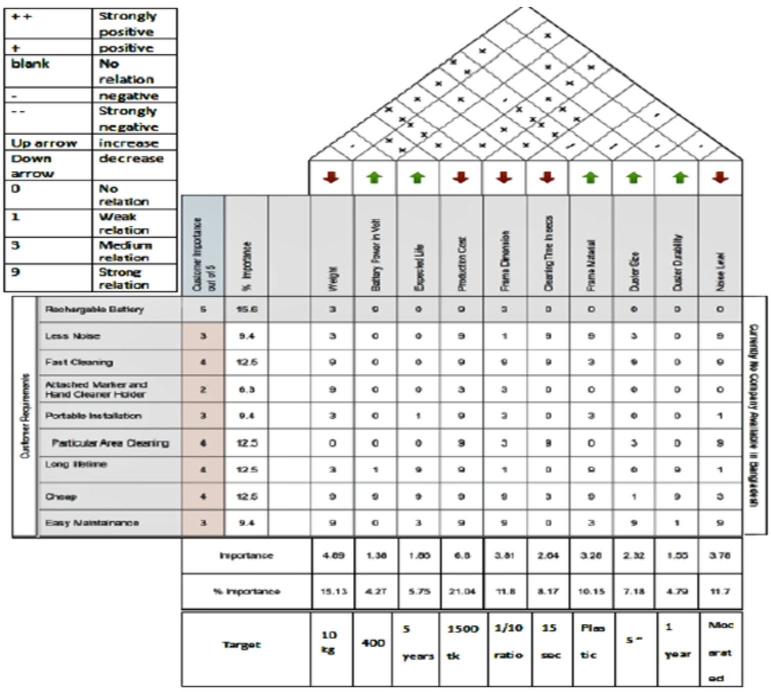

Figure 1. QFD Matrix.

Material Selection Using Topsis (Multi Criteria Decision Making)

Rating Scale: There were 4 criteria selected for weighting in the material selection process.

These criteria are then weighted with respect to the following rating scale.

1. Lightweight: 10 very high – 1 very low

2. Cost: 10 very low – 1 very high

3. Attractive: 10 very high – 1 very low

4. Strength: 10 very high – 1 very low

(Table 1) Then for standardizing, each column of decision matrix is divided by root of sum of square of respective rows. For example: 8.5/ 9.12 =0.93 **(Table 2)** Weighted standardized decision matrix was constructed by multiplying attributes weight to each rating. For example: 8.5*0.93= 7.901 **(Table 3)** Ideal Solution = {7.901,0.420 ,4.270,4.148} Negative Ideal Solution = {0.528,5.548,2.695,3.24} **(Tables 4-6)** From the relative closeness we can see that the highest value is found for steel, so steel would be the best fitted material. **(Figure 2)**

Criteria	Steel	Plastic	Wood
Lightweight	8.5	2.2	2.5
Cost	2	7.3	6
Attractive	7	7	5.5
Strength	6.5	6.8	6

Table 1. Decision Matrix.

Criteria	Steel	Plastic	Wood
Lightweight	0.93	0.24	0.27
Cost	0.21	0.76	0.62
Attractive	0.61	0.61	0.49
Strength	0.58	0.61	0.54

Table 2. Standardize the decision matrix.

Criteria	Steel	Plastic	Wood	
Lightweight	8.5	2.2	2.5	9.12
Cost	2	7.3	6	9.65
Attractive	7	7	5.5	11.32
Strength	6.5	6.8	6	11.16

Table 3. Weighted standardized decision matrix was constructed by multiplying attributes weight to each rating. For example: 8.5*0.93= 7.901.

Criteria	Steel	Plastic	Wood
Lightweight	0	7.373	5.439
Cost	0	5.128	3.3
Attractive	0	0	1.575
Strength	0.378	0	0.908
Si^+=	0.614	3.535	3.350

Table 4. Ideal solution and negative ideal solution were determined.

Criteria	Steel	Plastic	Wood
Lightweight	7.901	0.528	2.462
Cost	0.420	5.548	3.72
Attractive	4.27	4.27	2.695
Strength	3.77	4.148	3.24

Table 5. The separation from ideal solution was determined.

Criteria	Steel	Plastic	Wood
Lightweight	7.373	0	1.934
Cost	5.128	0	1.828
Attractive	1.575	1.575	0
Strength	1.178	0.530	0
Si^- =	3.90	1.450	1.939

Table 6. The separation from negative ideal solution was determined.

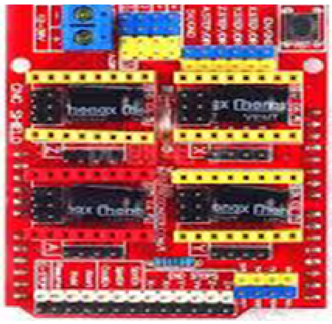

Figure 2: CNC Shield.

Criteria	Steel	Plastic	Wood
Si^+	0.614	3.535	3.350
Si^-	3.90	1.450	1.939
Si^++Si^-	4.514	4.985	5.289
Si^-/(Si^++Si^-)	3.90/4.514	1.450/4.985	1.939/5.289
	0.86	0.29	0.36

Table 7. Relative closeness to ideal solution was determined.

Used Elements

For manufacturing our desired products, we needed -

1. Stepper motor (2 pieces, Nema 17)

2. Arduino UNO R3 44

3. CNC Shield

4. Male to Female wires

5. Driver 4988

6. Wood for wooden frame

7. Pulleys (6)

8. Pipe (Stainless Steel 2 piece, 10 feet per)

8. Pipe (Aluminum 2-piece, 5 ft per)

9. Timing belt, sewing belt

10. Bearings, hooks, screws

11. USB extended table

12. Duster

13. Color detector sensor **(Figure 3)**

Basic Structure of Bec Logic

First, we have researched about this type of mechanism. As this can be done by the principle of 3d printing mechanism so we bought our electrical parts according to our need. But there is no exact work like ours. So, we needed to modify something as our need.

The system run by an Arduino which was controlled through giving direction using GRBL, a universal G code sender by CNC principle.

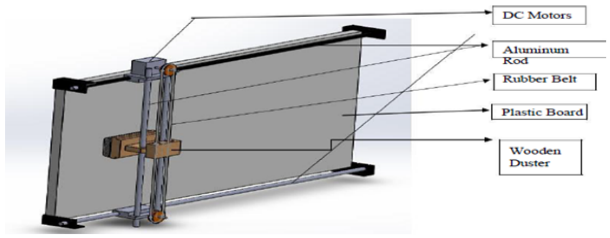

Figure 3*:* CAD Design on Solid works.

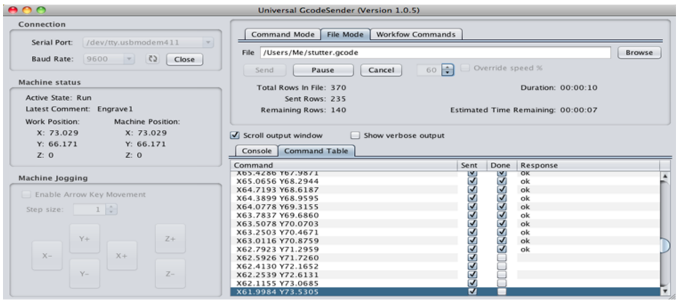

Figure 4*:*

• For X axis movement **(Figure 4)**

Electrical component

As we need to clean particular spot, so we needed x axis movement. For this we have used 2 stepper motors as our classroom board is huge and one motor cannot move the whole attachment.

Wooden Component

To move the whole attachment, we needed that can move the duster and the whole component. So, we have made two component which goes through the SS pipes and stays in position with the aluminum pipe.

• For Y axis movement **(Figure 5)**

Electronic Component

For y axis movement we have used one stepper motor as the load was smaller compare to the x axis movement.

Wooden Component:

To hold the servo motor, we have used a wooden block which goes through the aluminum pipe and goes up and down.

- For all this movement we have used timing belt and hooks was applied at the moving wooden blocksto hold the belt.
- To hold and rotate the belt pulley was attached at the motors and at the opposite sides another pulley was attached via screws.
- For the main part “cleaning”, the duster was attached at the servo motor.

Real View of The Automatic Board Cleaner(Figure 5)

Time Analysis

The board of a classroom was used for this project which has a dimension of width 120 inch and length 70inch. It takes about 85 secs for whole board cleaning in the manual process. If we take data from the paper mentioned in reference [3], it takes 5.975 sec time on average for cleaning a 6-inch-wide and 10-inch-long board. So, it will take approximately 61 secs time to clean our specified board. While our proposed product will take only 14 secs to wipe out the full board. So, it does not only shorten the duration of physical cleaning, but also an upgrade of the previous rack and pinion based cleaner.This was

Figure 5: Moving Wooden Part.

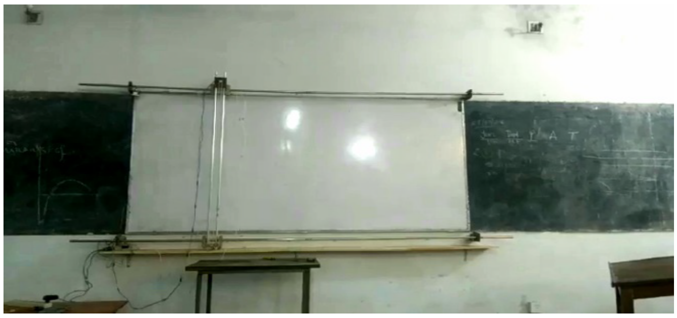

Figure 6: Final Product.

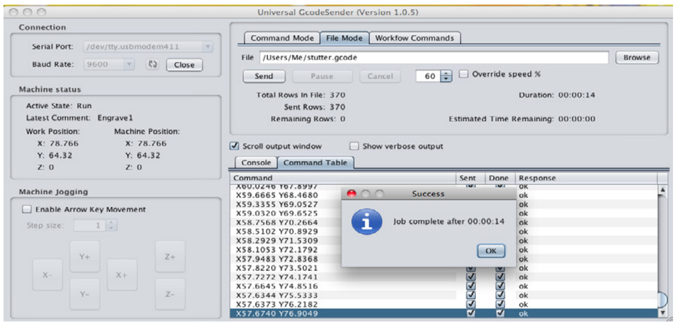

Figure 7:

the scenario of full board cleaning. **(Figures 6,7)** But while only a word or a sentence is written on the board, to clean that specimen, rack and pinion-based cleaner would take again full 61 secs as it must cover the whole board for cleaning. While this proposed cleaner will directly go to the written position and cleans the area. Here it takes only a single digit seconds time to clean that. Here is the ultimate optimization done.

Result and Discussion

The newly designed and fabricated board cleaner takes only 14 seconds to wipe out the whole board. Whereas it used to take 85 seconds to do so manually. So, it indicates the system is more than 6 times faster than the traditional one. It also faster than the previous suggested models where it is more than 4 times faster than the rack and pinion type cleaner in term of full board cleaning. But it is optimized in the way that when it is needed to wipe just only few words, it does not need to wipe out the full board like previous improvisations. So, here it changes the game by doing it way more quicker.

Future Scope

Although our intentions were to introduce a product containing features as much as possible and as innovative as possible, there is much room left for improvement. For example, we used wooden attachment to hold the duster, but a 3D printed holding attachment would be precise and lightweight. As a result, the movement would be smooth and fast. So, using the precise measurement may give us opportunity for the need of only two motors for the entire product where in our product we had to use three stepper motors to deal with the friction and other factors that hampered the horizontal movement of the core of the cleaner.

Conclusion

In this report the whole process which was followed to develop the product is discussed. Which includes the processes of surveying conversion of the survey results to the quantifiable engineering specifications, selection of material for each component, designing a computer aided design with specific dimensions and finally estimating the whole cost to build up the automatic board cleaner. All these processes were done to fulfill our objectives of introducing an automatic board cleaner the study of the survey work help to identify the voice of customers according to their preference cost & maintenance. The QFD form helps to identify the correlation between engineering specifications each other. The present demand of the market & customers is always main priority for developing the demand. All the processes will necessary as it will cause less changing during the development of the product.

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