Paper ID: RT:03

Design Construction and Performance Test of an Automatic Tea and Coffee Maker

Bipul Kumar Paul[1], Dr. Mihir Ranjan Halder[2]
[1,2]Khulna University of Engineering & Technology, Khulna 9203, Bangladesh
E-mail: [1]bipul63@gmail.com, [2]drmrhalder@me.kuet.ac.bd

Abstract

Under certain circumstances there are a few hours in life more agreeable than the hour dedicated to the ceremony known as afternoon tea/coffee. This much popular beverage is demandable for all people from rural area to city. Automatic machines for making tea/coffee is still confined to the eminent class cafes and restaurants. It couldn't be reached to the rural area for its higher cost. In this context a low cost automatic tea and coffee maker has been designed and constructed which is capable of making two types of tea and one type of coffee. For controlling the quantity of tea/ coffee making ingredients screw conveyors have been used. The performance of the machine has been tested and found satisfactory results. The cost of the produced machine is Tk 2300.00 but the market price of such machines are found Tk 30,000.00 to Tk 60,000.00. Due to its low cost and simplicity in operation rural people can easily afford and operate it.

Keywords: Ingredients, Temperature Controller, Screw Conveyor, Servo motor, Heating Unit.

1. Introduction

In general usage, automation can be defined as a technology concerned with performing a process by means of programmed commands combined with automatic feedback control to ensure proper execution of the instructions. The resulting system is capable of operating without human being. The retail food industry has started to apply automation to the ordering process. McDonal introduced touch screen ordering and payment systems in many of its restaurants, reducing the need for many cashier employees. The University of Texas at Austin introduced fully automated cafe retail locations.

Various types of automatic coffee maker are available in the market but as they are so much costly, tea sellers of the small tea stalls cannot generally afford them hence its uses are confined in eminent cafés, restaurants, offices etc. [1]

In the present era, automation makes people's life simple by saving the working time and effort. So it is desirable to reach automation in all possible tasks for every level of people. To do so automatic machines should be cost effective, user friendly and simple in design.

In Indian subcontinent majority of the people are lower middle class, naturally they rely on manual tea making process as the automatic machines didn't reach to them due to the higher cost. In this context a low cost automatic tea and coffee maker has been designed and constructed which could be easily reached to them.

The machine has the flexibility of using tea/coffee powder. Any types of powder or premix can be used in this machine. It can be used in small tea stalls, marriage ceremonies, cultural functions, birthday parties, industries, houses, restaurants, cafes etc.

The main objectives of this projects are to design, construct and test performance of a low cost automatic tea and coffee maker which can provide two types of tea and one type of coffee as well as it belongs to self-cleaning function.

2. Theoretical study

Prior to start this project, two different dismantled machines, rice husk separator and material conveying machine were observed very clearly. In the rice husk separator, there was a hopper mounted on a trough containing a screw conveyor. Similarly, in material conveying machine a screw conveyor was used to carry different types of material from one end to another. In both machines the conveying quantity of the rice or material can be controlled by controlling the speed of conveyor shaft and that mechanism is the core concept of this project. Based on this concept the design of the automatic tea and coffee maker had been accomplished. After that the mechanism of a Nescafe Coffee vending machine available in the market was observed. It had also a screw conveyor but the mechanism and design are completely different from this project. It had a canister which can contain 1.2 kg of

coffee powder or premix and also had a boiler which can contain 1.5 liter of water. All the components were installed inside the machine, consequently the machine had to be stopped and opened up for charging new coffee powder when the previous powder is finished. Also it had electronic and programmable devices inside the machine.

3. Design and construction

Required components

As this project was to fabricate a programmable and fully automatic machine, different mechanical and electronic components were required to complete this project. Preliminary, it was decided to make two types of tea and one type of coffee with 5 to 15 seconds time interval. Most of the components were designed in such a way that the size of components selected in a way those would be compatible with each other and the respective materials were selected to provide smooth operation and less costly. The required components of this project are given below:

Hopper: It was mainly cylindrical receptacle of 50mm diameter and 60mm height for containing beverage making ingredients like sugar, coffee powder and tea powder. Stainless steel was used for fabricating this component but food grade plastic (Polyethylene Terephthalate) could be used.

Mixing can: It was a cylindrical box of 75mm diameter and 100mm height made of stainless steel in which all the ingredients including hot water are congregated, mixed up properly and finally passed through the outlet pipe.

Water container: It worked as a cylindrical receptacle of 75mm diameter and 75mm height having a heating unit within water in the container. It could contain 1L of water. Stainless steel was used for this component.

Valve: It was mainly a one way valve of stainless steel used to allow the hot water from the water container to the mixing can at required amount.

Heating element: It was a copper coil used to heat the water in the water container.

Screw conveyor: It was a conveying element made of food grade plastic used to convey the ingredients from hoppers to the mixing can at required amount.

Mixing blade: It was used for mixing all the added ingredients at certain amount entered in the mixing can. Stainless steel was used for making this component.

Casing: It was a box of 300mm length, 250mm width and 450mm height which contains all the mechanical and electrical parts used for this machine. Metal sheet was used but plastic could be used for this component.

Arduino: The Arduino UNO was selected for this machine. It is an open-source microcontroller board based on the Microchip ATmega328P microcontroller and developed by Arduino.cc. The board is equipped with sets of digital and analog input/output (I/O) pins that may be interfaced to various expansion boards (shields) and other circuits. The board has 14 digital pins and 6 analog pins.

DC motor: As per the requirement 6V DC motor was selected which could have operation voltage of 3 - 12 V, free-run speed of 11,500 RPM, free-run current of 70 mA, and stall current of 800 mA.

DC gear motor: DC Gearbox Motor was selected in this project which could have a gear ratio of 1:48. It could be powered with 3V DC up to 6V DC.

Servo motor: As per requirement MG996R servomotor was selected. It is a rotary actuator or linear actuator that allows for precise control of angular or linear position. It consists of a suitable motor coupled to a sensor for position feedback. It has maximum stall torque 11 kg/cm at 6V.

Temperature controller: W1209 is a high-precision temperature control module which was selected for this project, it can not only show the temperature, but also according to the current temperature of the relay control, it

can control some of the power equipment through the relay, industrial and DIY it used widely, it comes with a temperature sensor, three buttons for temperature setting and some other functional operation, three digital temperature display, and comes with a program update interface can be used to update.

Motor driver IC: A motor driver is an integrated circuit chip which is usually used to control motors in autonomous robots. Motor driver act as an interface between Arduino and the motors. These ICs are designed to control 2 DC motors simultaneously. L293D motor driver IC was selected for this machine.

Design assumption

For making tea/coffee, according to the preferences of customers, it was needed to mix up appropriate quantity of ingredients like coffee powder or tea powder, sugar and water properly. To do so, it was necessary to control the amount of ingredients passing through the trough by the screw conveyors to the mixing can. In general 3 to 5 gm tea/coffee powder and 4 to 6 gm sugar is needed for making tea/coffee. The dimensions of screw conveyors would be so selected that they serve the appropriate purposes. So for a certain period (5sec) and RPM of gear motors how much ingredients would be accumulated in the mixing can was the design consideration of this project.

Capacity of screw conveyors [2] & [3]:
The Capacity of screw conveyor is determined by

$$Q = 250\pi \times (D_o^2 - D_i^2) \times (p - b) \times i \times Sg \times N \text{ (gm/s)} \quad (1)$$

Where Q = conveying capacity in gm/s

D_o = Outside diameter in m

D_i = inside diameter in m

p = pitch in m

b = flight thickness in m

N = speed of gear motor in rps

Sg = Specific weight of material in N/m^3

i = degree of trough loading

Calculation of screw conveyor capacity for making Heavy Tea:

Dimensions of the screw conveyor

D_o = 10mm = 0.01m

D_i = 8.5mm = 0.0085m

p = 8.5mm = 0.0085m

b = 1.5mm = 0.0015m

N = 255rpm = 4.25rps

i = 0.30

The bulk density of tea powder [12]

$$\rho = 433\ kg/m^3$$

Therefore,

$$Sg = \rho \times g = (433 \times 9.81)\ N/m^3$$

Or, $Sg = 4247.73\ N/m^3$

$$\text{Now, } Q = 250\pi\ (0.01^2 - 0.0085^2) \times (0.0085 - 0.0015) \times 0.3 \times 4247.73 \times 4.25$$

= 0.83 gm/sec

So, total amount of tea powder entering to the mixing can at the duration of five seconds = 5×0.83gm

= 4.15gm

Therefore, for making a cup of heavy tea, 4.15gm tea powder (which is in desired range) is to be supplied to the mixing can by the screw conveyor running 5 seconds at 255 rpm of gear motor. The dimensions of all the screw conveyors and quantity of ingredients are given in Tables 1 and 2.

Table 1. Dimensions of Screw Conveyors

Conveyers	D_o (mm)	D_i (mm)	p (mm)	b (mm)
Tea	10	8.5	8.5	1.5
Coffee	11.5	8.5	8.5	3
Sugar	10.5	8.5	8.5	2

Table 2. Total quantity of ingredients

Conveying Ingredients		N (rpm)	ρ (kg/m^3)	Sg (N/m^3)	Q (gm/sec)	Total Quantity (gm)
Tea (Powdered)	Light Tea	200	433	4247.73	0.65	3.25
	Heavy Tea	255			0.83	4.15
Sugar (Granulated)	Coffee	190	304	6916.05	1.27	6.35
	Light Tea	170			1.14	5.7
	Heavy Tea	120			0.805	4.025
Coffee (Instant)		255	705	2982.24	0.98	3.96

Construction of an Automatic Tea and Coffee Maker

All the components were fabricated with the specified material to fit it properly in its position in the tea/coffee making machine. Then the components were assembled sequentially to serve the operative purposes smoothly as shown in Fig.1.

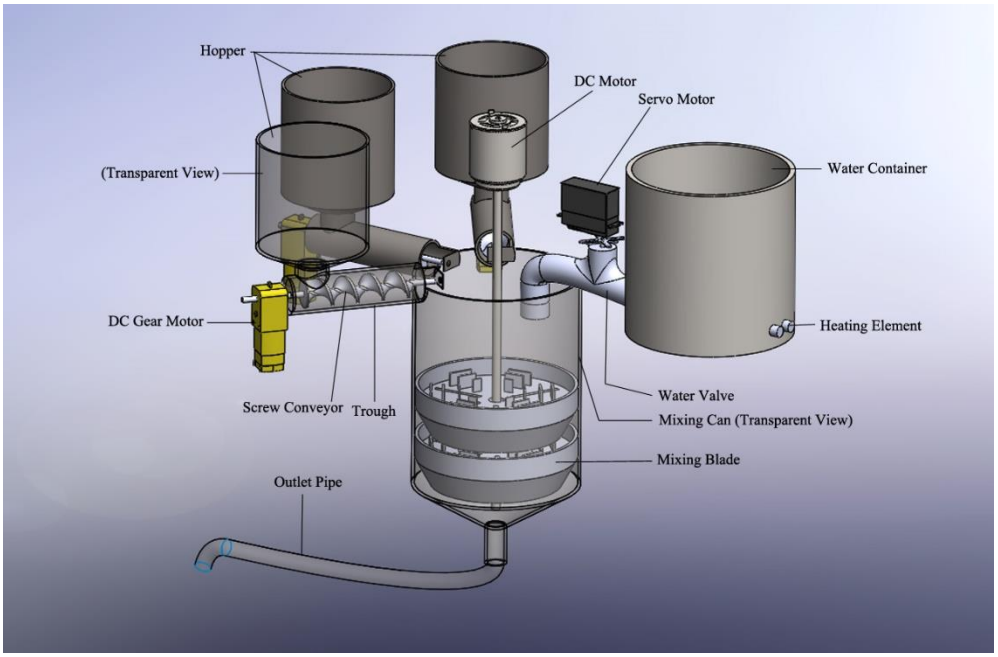

Fig.1. Assembly of Components

Fig.2. Tea and coffee maker after construction

Fig.3. Glasses of heavy tea and light tea

Finally the electronic components were placed in the machine and connected to each other according to the circuit diagram shown in Fig 4.

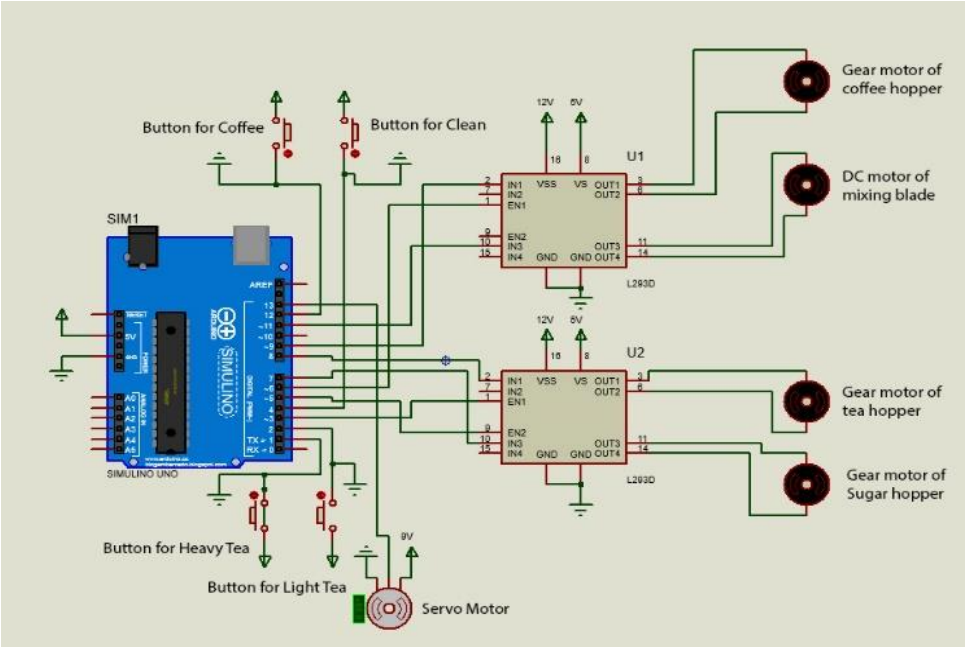

Fig.4. Circuit for controlling motor

4. Results and Discussion

Test Procedure and Working Principle

The test procedure and working principle of the automatic tea and coffee maker are given below:

1. In figure 1 each of the three hoppers were filled with sugar, tea powder and coffee powder. The water container was filled with pure water manually and heated up by putting the switch on of the machine. The temperature of water shown in the display board within the predefined working range was ensured by the temperature controller.

2. Then when a switch was pressed as per the requirements for making certain types of tea or coffee, two screw conveyors (If switch is pressed for making tea, the conveyors attached to tea powder hopper and sugar hopper will be rotated. If switch is pressed for making coffee, the sugar hopper conveyor and coffee powder hopper conveyor will be rotated) were started rotating by DC gear motor at a certain speed for a certain period according to the program.

3. As a result, the required amount of sugar and tea/coffee powder were passed from the hoppers through the trough to the mixing can. Then the gear motors were stopped. Immediately after that, the servo motor was started to rotate to a certain angle then the hot water entered to the mixing can.

4. In the meantime, the DC motor along with the mixing blade was started to rotate. Consequently, the powder, sugar and water were mixed up in the mixing can and passed through the outlet pipe into the cup. After certain duration, the servo and DC motor were stopped.

5. It was found to take 12 seconds to complete one cycle of operation which was supposed to take 5 to 15 seconds as per design assumption. This processes were repeated for making different types of tea and coffee.

Test Data

Different quantity of ingredients were found for different types of beverages during performance test. The mean value of quantity were taken from 20 data in different span of time are presented in the Tables 3 and 4.

Table 3. Quantity of different ingredients

Type	Average Tea (gm)	Average Coffee (gm)	Average Sugar (gm)
Light Tea	3.05		5.26
Heavy Tea	3.91		3.8
Coffee		3.47	5.92

Table 4. Quantity of water

Type	Rotation (degree)	Duration (sec)	Water(ml)
Light Tea	180	7	85
Heavy Tea	160	7	63
Coffee	170	7	80
Cleaning	180	5	85

Results

From the test it was found some variations in test data and theoretically calculated data. The variations are shown in the Tables 5 and 6.

Table 5. Variation between Theoretical Data and Test Data for Tea

Type	Tea (gm)		Deviation (%)	Sugar (gm)		Deviation (%)
	Th	Test		Th	Test	
Light Tea	3.25	3.05	-6.1	5.7	5.26	-7.72
Heavy Tea	4.15	3.91	-5.8	4.025	3.8	-4.84

Table 6. Variation between Theoretical Data and Test Data for Coffee

Type	Coffee (gm)		Deviation (%)	Sugar (gm)		Deviation (%)
	Th	Test		Th	Test	
Coffee	3.96	3.47	-12.4	6.35	5.92	-6.77

Discussion

The test results showed some variations between the theoretical data and test data. The test data was found always less than the theoretical required data. This deviation was occurred due to slower rotation of motors attached to the conveyors than the rotation set by the program. The rotations that were set in the program for each of the motors were the rotations in no load conditions of the motors. That's why, when the ingredients were passed through the conveyors the rotation of the motors got slower than the programmed rotations consequently less of the ingredients were passed to the mixing can which made slight deviation from the theoretical value.

Cost Analysis

The cost of automatic tea/coffee makers that are available in Bangladeshi market is around Tk 30,000.00 to Tk 60,000.00. But the manufacturing cost of this project was only Tk 2300.00. Therefore, it can be said that this project is so much cost effective hence rural people can afford this easily.

5. Conclusion

In this project, an automatic tea and coffee maker which is susceptible to make two types of tea and one type of coffee within very short time has been designed and fabricated. Its performance has been tested for several times and found satisfactory results. No disorder was found during the operation of the machine but the machine was found to supply the ingredients 4.84 to 12.4% less than the designed expected values. The taste was found more or less ok but can be improved. The screw conveyors used in this project have some advantages because the quantity of ingredients can easily be controlled with them. Due to its simplicity it is very easy to repair or change any components if damages. The cost of this machine is about Tk 2300.00 so it can be reached to the rural area for its low cost to serve the function of automation.

6. References

[1] A. Parulekar, A. Shinde, S. Rath, P. Shriyan, T. Raut, A.V. Bhonsale, "Design and Development of Mini Tea and Coffee Machine", IJERT, Vol. 5, pp. 453-455, 2016.

[2] https://www.bechtel-wuppertal.com/media/1859/calculations-screw-conveyor-bechtel.pdf.

[3] A. Spivakovsky and V. Dyachkov, "Conveyors and Related Equipment", Peace Publishers, p. 274, 1995.