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TRANSFER AND HEATING MECHANISMS OF A CURRY PUFF VENDING MACHINE

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ABSTRACT

This paper focuses on the design and development of the transfer and heating mechanisms of a curry puff vending machine. The vending machine contains frozen pre-cooked curry puffs that are packed in containers and require heating process before being dispensed to the consumers. The transfer mechanism transfers the containers containing frozen curry puffs into the microwave by using a slider and brings it out after being heated. In the heating mechanism, the microwave's door is opened and closed by a servo motor through a four bar linkage mechanism and the timer knob is automatically adjusted by a servo motor. The experimental results have shown that the proposed mechanisms have successfully transferred and heated the curry puff for the vending machine application. The main advantage of this system is it allows the curry puffs to be served while it is still hot and fresh to the customers at any time and thus making it tastier.

Keywords: automation, vending machine, transfer mechanism, heating mechanism, hardware.

INTRODUCTION

Vending machines can increase the products sales and companies revenue. It is accessible by the consumers every day for 24 hours and reduces the labour and store rental costs. There are many types of vending machines placed at various places around the world including cafes, schools, hospitals, train stations, airports and hotels.

One of the types of vending machine is the ones that sell hot food and integrated with freezing function and transfer mechanism. In this case, the frozen food that is stored in the cold storage compartment needs to be heated before being dispensed to the consumers. In this vending machine, the food not only can be preserved longer but also can be served hot and tasty to the consumers. One of the products that require the utilization of this kind of vending machine is curry puff. To the best of our knowledge, there is no vending machine with freezing and heating function for selling hot, fresh and tasty curry puff available in Malaysia yet.

Previous vending machine with heating function and cold storage compartment includes the Automatic Hot Food Vending Machine by Smith[1]. The machine is incorporated with a mechanism to control the motion of the heating chamber's door. However, it requires a very high torque motor to tilt the microwave forward in bringing out the food from the heating chamber. Fallen et. al[2] designed the Hot Food and Frozen Food Vending Machine with an easy heating chamber's door motion control mechanism. Nevertheless, the heating chamber has to be internally modified and custom-made. A ram-sleeve mechanism is incorporated in the food vending machine developed by Dunford[3] for smooth transfer mechanism in maintaining the quality of delicate food. Nonetheless, the mechanism might take a long time to perform the process. The food vending machine by designed Knool[4] can heat and transfer the frozen food well, but the conveyor used in transporting the food dishes into and from the oven is relatively complex in design.

Therefore, this paper presents the design and development of transfer and heating mechanisms of a curry puff vending machine. The design is simple and does not take a long time to complete the heating and transfer process. It consists of a slider, gripper, door opening and closing subsystem, automatic timer knob rotation subsystem and external frame. The prototype of the proposed mechanisms have been built and hardware experimental tests have been carried out to evaluated the performance of the system.

SYSTEM DESIGN

Mechanical design

The mechanical design of the transfer and heating mechanisms of the vending machine consists of:

- a slider to transfer the container containing curry puffs to the microwave for heating process and remove it from the microwave after the process.
- a gripper, which is attached to the slider to hold the curry puff container.
- a 4 bar linkage-based door opening and closing mechanism.
- a timer knob rotation mechanism.
- an external frame to support the door opening and closing and the timer knob rotation mechanisms.

In this design, it is assumed that the frozen pre-cooked curry puff has already been transferred from the cold storage to a container. The container is hold by a gripper shown in Figure-1. The gripper is attached to the slider that is placed on a rack and attached to a DC motor through a pulley. A rope is tied to the front and back side of the slider in controlling its forward and backward motion. If the motor rotates clockwise the slider will to move forward towards the microwave and vice versa. Figure-2 shows the mechanical drawing of the complete transfer mechanism from four different views.

The heating subsystem consists of a microwave and an external frame. The external frame supports the

microwave door opening and closing and the timer knob rotation mechanisms. The isometric view of the external frame of the microwave is illustrated in Figure-3 and the side and front views of the frame are illustrated in Figure-4. As can be seen from figure, the door opening and closing mechanism is assembled below the top part of the external frame.

The door opening and closing mechanism has been built based on four bar linkage mechanism. The calculation of the linkages length is important to ensure that the door can be opened and closed properly. Referring to Figure-5, the values of *a* and *d* can be assumed and the values of *b* and *c* can be determined by considering the 4 bar linkage kinematics.

From Figure-5, A_x and A_y can be found as[5]

$$A_x = a\cos\theta_2, \quad (1)$$

$$A_y = a\sin\theta_2, \quad (2)$$

and the length of *b* and *c* can be obtained using trigonometry[5]

$$b^2 = (B_x - A_x)^2 + (B_y - A_y)^2 \quad (3)$$

$$c^2 = (B_x - d)^2 + B_y{}^2, \quad (4)$$

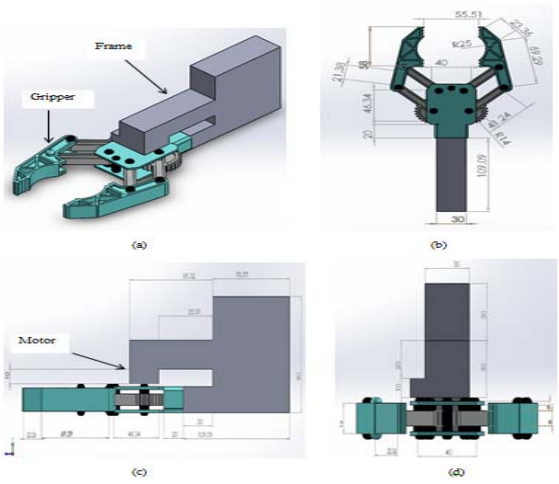


Figure-1. Mechanical drawing of the gripper, (a) isometric view, (b) top view, (c) s.

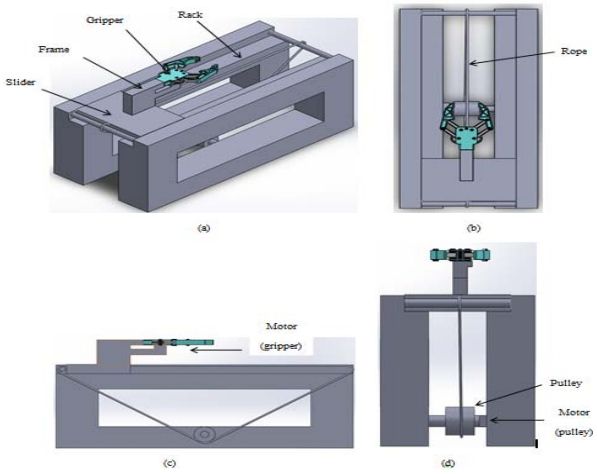


Figure-2. Mechanical drawing of the complete transfer mechanism (a) isometric view (b) top view (c) side view (d) front view.

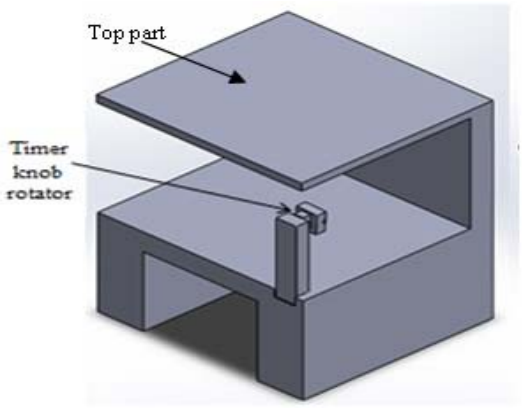


Figure-3. Isometric view of the external frame of the microwave.

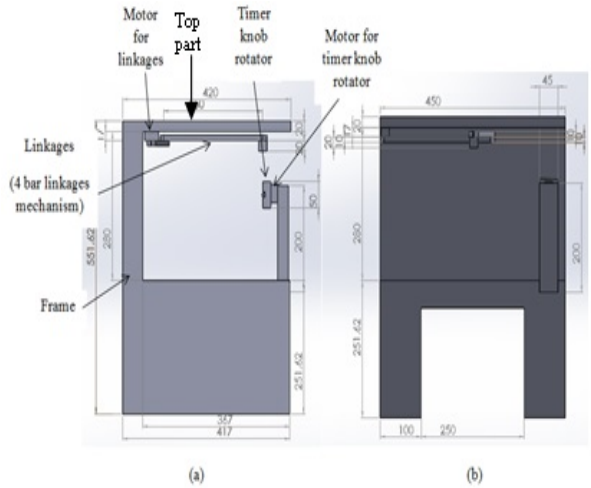


Figure-4. The (a) side view and (b) front view wing of the external frame of the microwave.

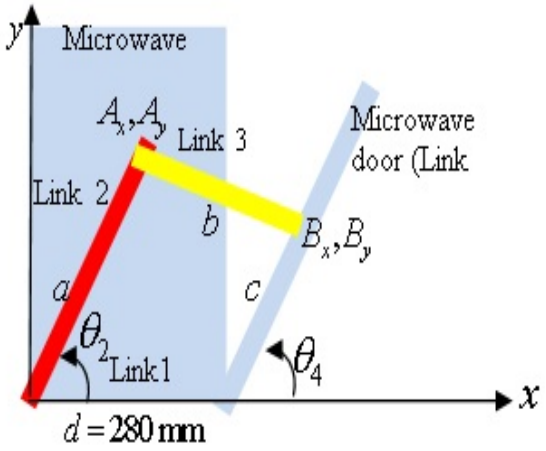


Figure-5. Configuration of four bar mechanism

Where[5]

$$B_x = S - A_y B_y / (A_x - d), \quad (5)$$

$$B_y = \left(-Q \pm \sqrt{Q^2 - 4PR}\right) / 2P \quad (6)$$

$$P = A_y^2 / (A_x - d)^2 + 1, \quad Q = 2A_y(d - S)/(A_x - d), \quad R = (d - S)^2 - c^2, \quad S = (a^2 - b^2 + c^2 - d^2)/(2(A_x - d)) \quad (7)$$

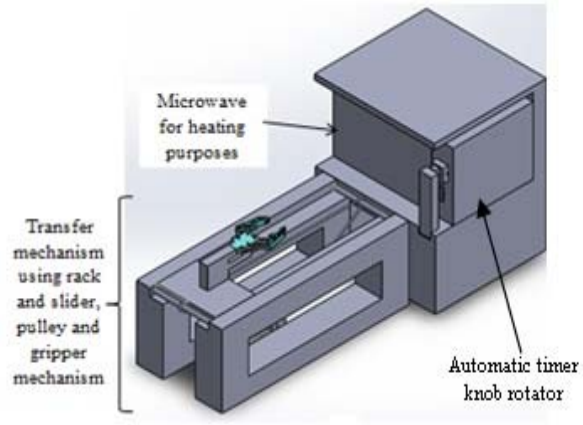
The output angles can be obtained as

$$\theta_4 = \tan^{-1}(B_y / (B_x - d)). \quad (8)$$

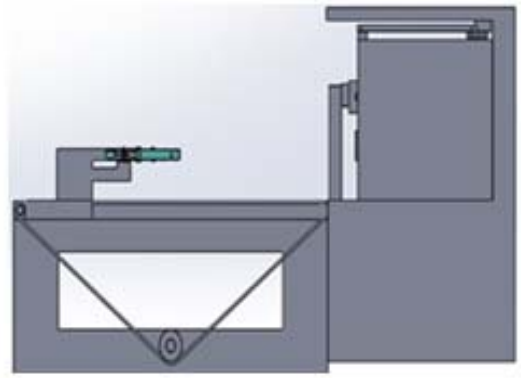
In this work, it is assumed that *d* is equal to the microwave width, where *d*=280 mm, and for simplicity *a* is assigned to 280 mm too. Considering the microwave door is closed, $\theta_4 = 90^\circ$ and therefore, $B_x = d = 280$ mm, and utilizing equation (8) and (4), *c* can be determined as 218.8 mm. It is desired that when the door is opened the maximum value of $\theta_2 = 87^\circ$. Utilizing equation (1)-(3) and the value of θ_2, *b* can be obtained as *b*=270 mm.

Therefore, the length of the 4 bar linkage in this design is set as *a*=*d*=280 mm, *b*=270 mm and *c*= 218.8 mm.

The transfer mechanism is placed exactly in front of the microwave as shown in Figure-6 so that the curry puff can be transferred into and from it. The microwave is placed inside the external frame and the linkages are attached to the microwave's door. An automatic timer knob rotator with a servo motor is placed in front of the microwave's timer knob as illustrated in Figure-6.



(a)



(b)

Figure-6. Complete integrated mechanical drawing of the transfer and heating mechanism of the curry puff vending machine (a) isometric view and (b) side view.

ELECTRICAL DESIGN

The main electrical components of the vending machine include the microcontroller, motors, and limit switches. Arduino microcontroller board is utilized in controlling the whole operation of the transfer and heating mechanisms of the curry puff vending machine.

Three servomotors and one DC motor are used in this work. The DC motor is incorporated into the design to control the forward and backward motion of the slider during the transfer process. A servomotor, denoted as Servo motor 1 acts as the actuator for the gripping mechanism. It is attached directly to the gripper's gear to open and close the gripper. Two servo motors, namely Servo motor 2 and Servo motor 3 are utilized for the microwave door opening and closing mechanism and timer knob rotation mechanism respectively. The servomotors however, has limitation in which they can only rotate for 180° in clockwise or anti clockwise direction, compared to the DC motors, in which it can rotate 360°.

The limit switch detects whether the slider has reached the end of the rack. The slider will press the limit switch installed at the end of the rack, causing the electrical circuit to break and stops the DC motor from rotating. Another limit switch is also used as an emergency button for safety precaution in case of any accidents.

PROTOTYPE OF THE TRANSFER AND HEATING MECHANISMS OF THE CURRY PUFF VENDING MACHINE

The prototype of the complete transfer and heating mechanisms of the curry puff vending machine is illustrated as in Figure-7. The external frame and the rack are built from wood, the gripper has been fabricated using 3D printer and Perspex is used in constructing the linkages for the door opening and closing mechanism. The gripper for carrying the curry puff container is shown as in Figure-8. The size of the gripper should be designed according to the size of the curry puff container. Servo motor 1 is attached directly to the gripper's gear as depicted in the figure. Figure-9 shows the position of the slider that is initially away from the microwave before the heating process. The figure also illustrates the position of the slider at the other end of the rack while transferring the curry puff container into the microwave. Figure-10 shows the microwave door when it is opened and closed by Servo motor 2 through the utilization of four bar linkage mechanism concept. The timer knob rotation mechanism can be seen in Figure-11. A linkage from the external frame is fixed to Servo motor 3 and the timer knob will be turned by the servo motor according to the desired heating duration.

OPERATIONAL STEP

In this work, it is assumed that the gripper is already holding the container containing curry puff from the storage compartment. The transfer mechanism starts with the slider attached to the gripper moves forward towards the opened microwave. The slider will stop moving once it hits the limit switch installed in front of the microwave. Then, Servo motor 1 will rotate to open the gripper and place the curry puff container on the microwave's plate. Next, the DC motor turns in the opposite direction to move the slider back to its original position until it hits the limit switch installed at the other end of the rack. After that, Servo motor 2 rotates the four bar linkage mechanism to close the microwave door to start the heating process. Servo motor 3 then turns the timer knob to heat the curry puff according to the desired heating duration. The microwave door will be opened again and finally the slider and gripper will pick up the heated curry puff to be transferred to the dispenser. This complete transfer and heating process repeats every time the customers purchase the curry puff from the vending machine.

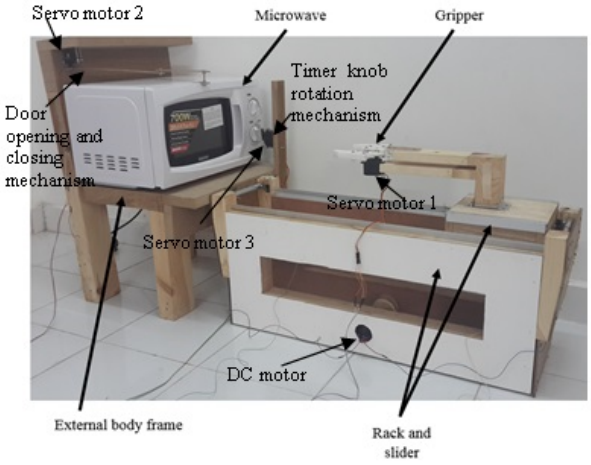


Figure-7. Prototype of the transfer and heating mechanism of the curry puff vending machine.

Figure-8. Gripper holding the curry puff container.

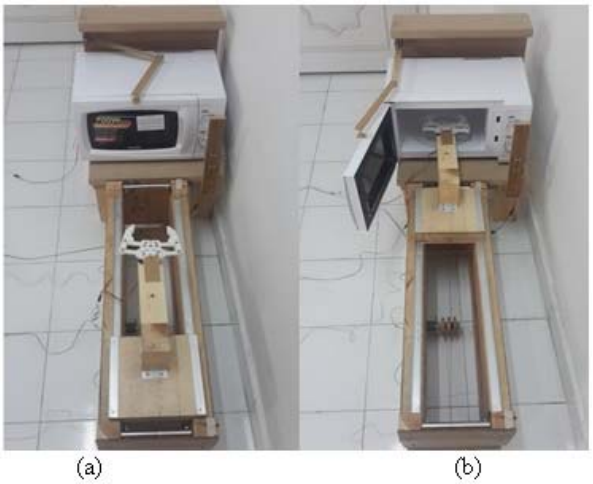


Figure-9. Slider when it is (a) initially away from the microwave before the heating process (b) at the other end of the rack while inserting the curry puff container into the microwave.

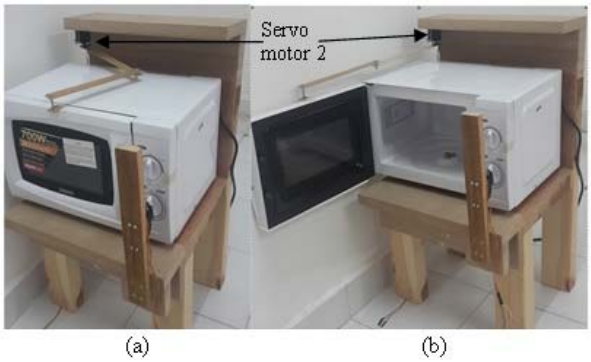


Figure-10. The position of microwave door when it is completely (a) opened and (b) closed.

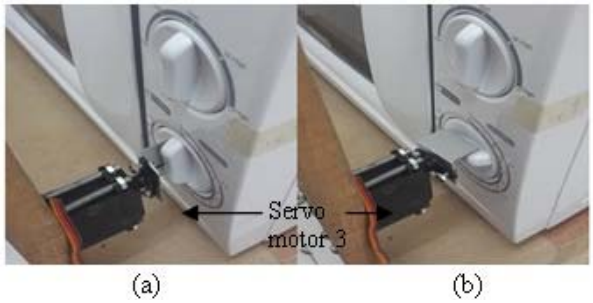


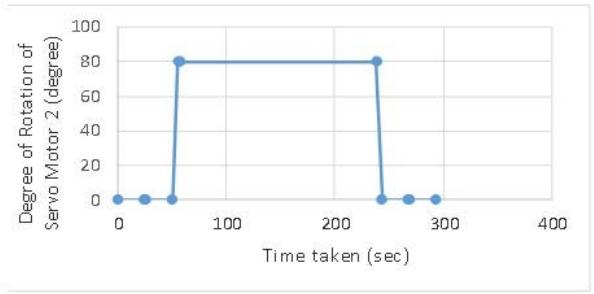
Figure-11. Timer knob rotating mechanism (a) before and (b) after rotating the knob.

EXPERIMENTAL RESULTS

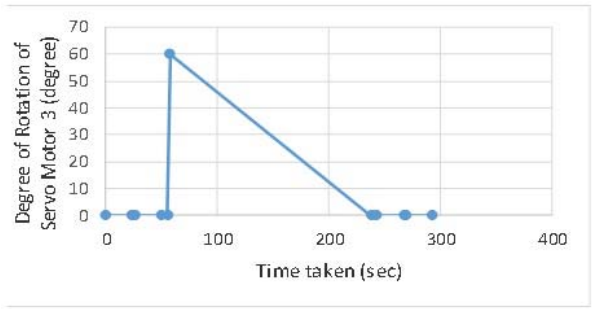
Experiments have been conducted to evaluate the effectiveness of the proposed mechanism. The overall motion for all motors is shown in Figure-12. From Figure-12 (a) and (b) it can be seen that from 0 s to 24.3 s, the DC motor rotates 2500° to transfer the slider to the opened microwave. Then, the motor stops for 1.8 seconds, while Servo motor 1 opens the gripper to place the curry puff container. From 26.4 s until 31.7 s, the DC motor reverses and the slider slides back to its original position.

After the slider had returned to its initial position, Servo motor 2 rotates 80° to open the microwave door and then, Servo motor 3 turns 60° to adjust the heating time on the timer knob as can be observed in Figures 12 (c) and (d) respectively. After the heating process has completed at 238.1 s, Servo motor 2 rotates in the opposite direction to open the door as depicted in Figure 12 (c). Figure-12 (a) shows that the slider then moves forward to the microwave door and then it halt for 1.8 s while Servo motor 1 actuates the gripper to pick up the curry puff container. Lastly, the DC motor rotates 2500° in the opposite direction for the dispensing process.

The experiments have been repeated for the 10 times and it has been found the average total time taken for the proposed mechanisms to complete the transfer and heating operation for one cycle is 293.6 s. The success rate is 100%, where the mechanism has successfully and smoothly completed the task for every trial. Therefore, it can be seen that the proposed system is successful in transferring and heating the curry puff for vending machine application.



(a)



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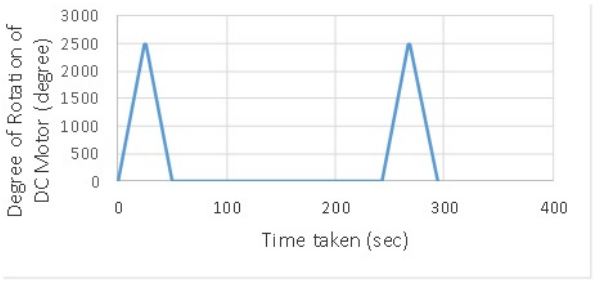
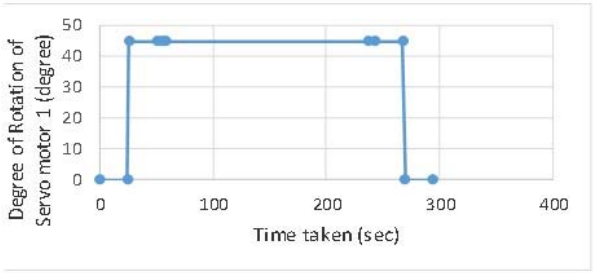


(c)



(d)

Figure-12. Motion of (a) DC Motor (b) Servo motor 1 (c) Servo motor 2 and (d) Servo motor 3 during 1 cycle of transfer and heating process.

CONCLUSIONS

The transfer and heating mechanisms for a curry puff vending machine is presented is this paper. The

mechanisms consist of a slider, gripper, door opening and closing mechanism, automatic timer knob rotation subsystem and external frame. The experimental results show that the proposed system has successfully performed the desired task. The average time taken for the proposed system to carry out the heat and transfer process is 296.8 s and the success rate in 10 trials is 100%. Future works involves the improvement in the motors speed and integration of the mechanism with the automatic storage, dispenser and user interface subsystems.

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