International Journal of Innovative Technology and Exploring Engineering (IJITEE)
ISSN: 2278-3075 (Online), Volume-9 Issue-12, October 2020

Industrial Robotic Arm for Chilli Milling Process

R.M.R.D.Abeyrathna, E.M.A.C. Ekanayake, K.S.P. Amaratunga

Abstract: Chilli (Capsicum annuum), one of the essential ingredients in Sri Lankan cuisine, is widely cultivated for producing dried chilli. The narrow conical-shaped chilli pods with wrinkled surface do not support much of the existing common mechanical feeding systems such as augers or bucket conveyorsin the chilli processing plants. Therefore, the objective of this study is to design and develop a robotic arm with a proper grabbing technique to feed chilli into the grinding mill. Furthermore, it is intended to install the developed robotic arm in an industrial level processing plant to test the feasibility of theindustrial application.The industrial robot designed in this study is primarily composed of three parts: the base, the arm and the wrist. These components connect with joints to form a unit. At the end of the wrist, an end-effector, which is a gripper for grasping chilli pods, is located.ATmega328 microcontroller, micro switches and DC motors were used to operate the robotic arm. The feeding rate is automatically controlled using a Hall Effect sensor. The robotic arm grabber was placed on top of the chilli containing trough (2.5m wide, 10.5m long, and 1.25m high) of an industrial level chilli processing plant.When operating, the grabber could grab 1.640±0.128 kg of chilli from the bulk in a single operation. The average time taken for one complete cycle of grabbing chilli, lifting the grabber, turning the arm on to the conveyer and releasing chilli on to the belt conveyor, varies from 20 s and 30 s depending on the height of chilli in the trough. The feeding rate varies from 440.6 kg/h and 218.66 kg/h when chilli is grabbed from the top and the bottom layers respectively. Therefore, this system can be recommended for maximum feeding rate of chilli up to 218.66 kg/h. Capacity can be increased by adding the same mechanism parallel or scaling up the existing system.

Keywords: AT mega328 microcontroller, Stepper motor, Hall Effect sensor, Chilli processing

I. INTRODUCTION

The modern food processing and manufacturing plants are expected to produce more at a lower cost in a sustainable manner that is less dependent on the labor force to meet the growing food demand for the rising population[1]. This has necessitated the use of effective automation systems to automate tasks in the food industry [2]. The characteristic nature of the agricultural produce has made the automation process unique to the particular industry. Hence, site-specific precision management solutions have been identified as the most effective technological solutions given specific circumstances. Robotic is one of the key components in agricultural and industrial automation.The food manufacturing sector has recorded a 25 percent increase in the productivity by employing robotics compared to the work done by human chains even though the speed of execution varies in different food sectors[3]. Numerous studies have been conducted in designing robots for accomplishing the various tasks in the food sector from farm practices to processing and packaging of food products (Sun, 2016).Some of these studies include; designing and developing robots; to perform different farm operations [4, 5, 6, 7] , to harvestcrops [8, 9, 10, 11, 12], and, to automate food processing and packaging tasks [13, 14]. For many years, the researchers have outlined the benefits of automation which offer flexibility to the food processing sector. These studies have further emphasized on the improving efficiency and productivity that industrial robots would offer to the food industry [15, 2, 16]. Chilli (*Capsicum annuum*), one of the essential ingredients in Sri Lankan cuisine, is widely cultivated for producing driedchilli while part of the crop is harvested as green pods. The domestic per capita consumption of dry chilliis estimated 2.32kg per year and the national annual requirement is around 42,634 Mt [17]. Given the importance of the dried chilliin the daily diet, maintaining a continuous production of processed dry chilli is essential to cater to the domestic demand. At present, several chilli processing plants are operating in the country. The common practice in these plants is manual feeding of dried chilli into grinding hoppers as the mechanical handling is restricted by the physical nature of the chilli pod. The narrow conical-shaped chilli pods with wrinkled surface do not support much of the existing common mechanical feeding systems such as augers or bucket conveyors. Moreover, the internal environment of the chilli processing plant is uncomfortable for manual operators due to dispersion of volatile compounds and dust particles generated in chill milling accompanied with an increase of room temperature usually above 42^{0}C. Thus, manual operations are further cumbersome in chilli processing apart. Hence, designing and developing an automated system for chilli feeding is of timely importance.

Revised Manuscript Received on October 30, 2020.

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Therefore, this study aims to design and develop a robotic arm with a proper grabbing technique to feed chilli into the grinding mill. Furthermore, it is intended to install the developed robotic arm in an industrial level processing plant to test the feasibility of theindustrial application.

II. METHODOLOGY

The industrial robot designed in this study to feed chilli pods into the grinding millis primarily composed of three parts; the base, the arm and the wrist. These components connect with joints to form a unit. At the end of the wrist, anend-effector, which is a gripper for grasping chilli pods,is located.

As shown in Fig. 1, the gripper was designed in such a way that the “finger-like structure” facilitatesgrabbing of chilli pods. This finger grabber avoids most of the difficulties faced in the manual grasping of chilli pods due to their specific physical characteristics while maintaining the feeding rate of chilli to the grinding mill. A pneumatic piston was located in the grabber and it is used to grab chilli from the bulk.An air pump was used to supply compressed air to the pneumatic piston.A two-way solenoid valve was used to control the airflow to the pneumatic piston. The air pump and the solenoid valve operate according to the signals generated from an electronic control system.When the air pump and solenoid valve are turned on, the fingers grab chilli. Once the grabber moves and comes to the required position to release the grabbed bulk of chilli pods, the air is released by the solenoid valve. Then the fingers automatically open due to the tension of the springs.

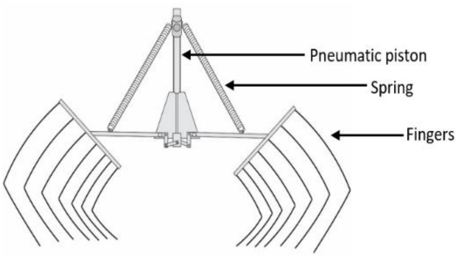

Fig.1: Grabbing mechanism

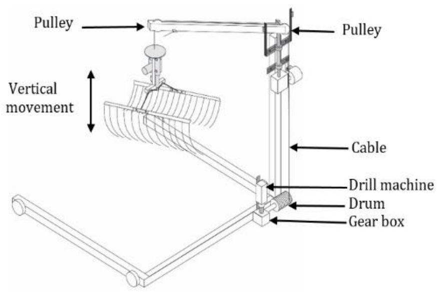

Fig. 2: Vertical moving mechanism

Once the grabber grabs chilli from the bulk, a vertical movement mechanism was operated to move the grabber upwards. Fig.2 shows the vertical movement of the arm and the components used to control the vertical movement. The vertical position of the shaft was facilitated by two bearings.

Then the left-right moving mechanism is operated. **Error! Reference source not found.** shows the schematic diagram of the Left-Right moving mechanism.Left-Right movement of the arm was controlled by 12 V DC motor and gearbox (warm and wheel, ratio 30:1) and the direction of the movement was controlled by changing the direction of the motor rotation.

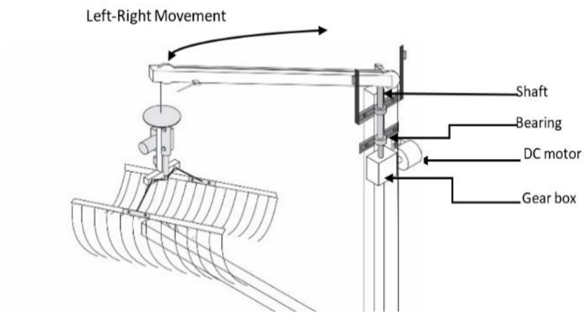

Fig. 3: Left-Right movement mechanism

Fig. 4 shows the arrangement of the limiting switches which control the grabbing mechanism and vertical and left-right movements of the robotic arm. Limiting switches are normally in “open state”. Switch 2 controls the operations of the grabber.Switch 2 is turned into “close state” by releasing the tensionof cable when the grabber touches chilli and a digital signal is sent to the microcontroller to stop the downward movement. Then, the grabber operates as mentioned earlier. Once the grabber collects chilli and moves vertically, Switch 1 is turned into “close state” when the plate in the grabber touches the switch. Then, it sends a digital signal to a microcontroller and stops the upward movement. Switch 3 and switch 4control the direction of left-right movement of the horizontal arm by sending of digital signals to the microcontroller.

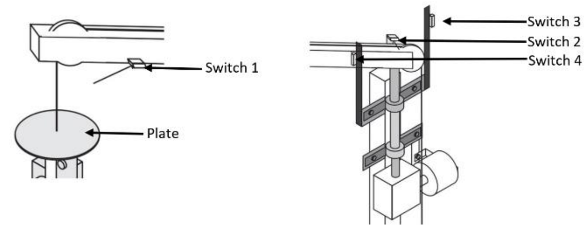

Fig. 4: Arrangement of the limiting switches

12 V DC supply was used to supply current to the electronic control panel and the DC motors. ATmega328 microcontroller was used as the main controlling unit and the decision-maker. Microcontroller makes decisions according to digital signals from the limiting switches. Rotating direction of the motor can turn by changing the polarity of the supply voltage to the motor. Four relays were used to change the polarity of the supply voltage and control the power supply (H Bridge). Figure 6 shows the schematic diagram of the DC motor control circuit. State of the relay was changed according to the signals from the microcontroller.

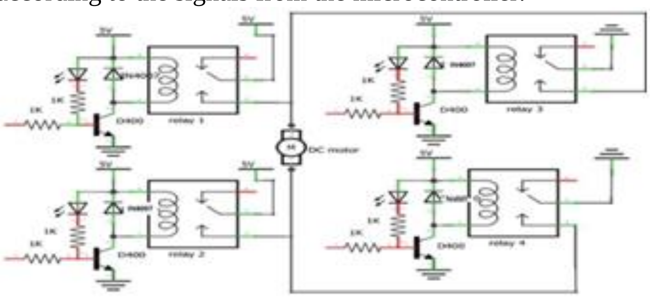

Figure 5: DC motor control circuit

Retrieval Number: 100.1/ijitee.L79321091220
DOI: 10.35940/ijitee.L7932.1091220
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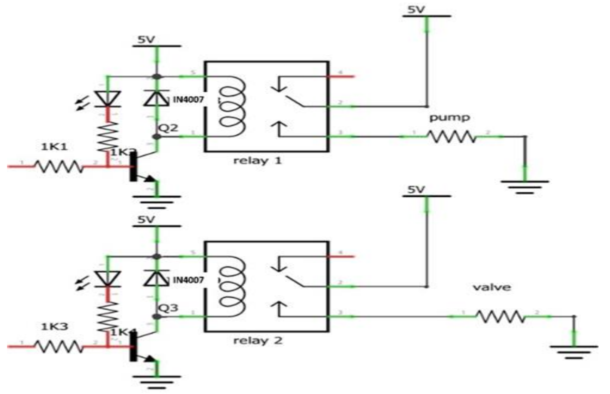

Figure 6: Air pump control circuit and pneumatic piston valve control circuit

Figure 6 shows the air pump and the pneumatic piston control circuit the pneumatic piston help to the movement of the grabber, the air pump compresses the air into the pneumatic piston and the valve release the air from the piston.

Figure 7: Testing the robotic arm at the industry level

Figure 7 shows the testing procedure that was done at the industry level. Hall Effect sensor was used to measure the current taken by the mill. Current taken by the mill is high when the motor of the mill is overloaded. Atmega328 microcontroller was used to measure the analog signal from the Hall Effect sensor. According to that analog read, a digital signal was sent to the electronic control panel through Bluetooth module. Bluetooth module in the electronic control panel receives the digital signal and operate the robotic arm accordingly. When the motor of the mill is overloaded, it stops the feeding in the same manner.The microcontroller used to make decisions according to digital signals from the limiting switches and ATmega328 microcontroller at the mill. Programming language C was used to write the program for the microcontroller.

III. RESULT AND DISCUSSION

The time consumption for downward movement to reach the top layer of the bin was 1.6 seconds and it took 8 seconds to reach the bottom layer of the bin. The time consumption for grab chilli and upward movement from the top layer of the bin was 1.8 seconds. Time consumption for grab chilli and upward movement from the bottom layer of the bin was 9 seconds. Time consumption to the horizontal movement and release chilli was 5 seconds. The total time duration for one cycle of feeding mechanism was calculated from the bottom layer of the bin and top layer of the bin. It took 27 seconds to grab chilli from the bottom layer of the bin and release chilli to the rotating belt which carries chilli to the mill. It took 20 seconds to grab chilli from the top layer of the bin and release. Ten readings were taken to calculate the weight of chilli feed in one cycle. The average weight of chilli grabbed in one cycle was 1.640 ± 0.128 kg. There was only ± 0.128 kg deviation in the tested 10 cycles of feeding. The rate of feeding was calculated according to the observed values of grabbing chilli and it was 440.6 kg/hour from the top layer and it was 218.66 kg/hour from the bottom layers.

IV. CONCLUSION

The study attempted to design and develop a robotic arm to feed chilli in to chilli grinding mill with the intention of overcoming the inherent difficulties associated with the manual operation and limitations associated with manual operations due to physical nature of chilli pods. The developed automated chilli feeding mechanism was successfully installed and operated at the industrial level. According to the overall performance evaluation, it was found that the developed system could be effectively used in the industrial milling of chilli with a feeding rate of 440.6 kg/hour and 218.66 kg/h from the top layers andbottom layers respectively. Therefore, this system can be recommended for maximum feeding rate of chilli up to 218.66 kg/h. Capacity can be increased by adding the same mechanism parallel or scaling up the existing system.

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Retrieval Number: 100.1/ijitee.L79321091220
DOI: 10.35940/ijitee.L7932.1091220
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