Design of a Fully Automatic Ironing Machine

Haotian Jiang*

ZJU-UIUC Institute, Zhejiang University, Jiaxing, Zhejiang, China

* Corresponding Author Email: haotianj.20@intl.zju.edu.cn

Abstract. This paper represents a design of an automatic ironing machine, whose motion is controlled by two stepper motors and two servo motors. The computer-aided design figure will be introduced first, to express the basic structure and show the movement process of the automatic ironing machine to achieve the goal of ironing a cloth. Next, the control methods of servo motors and stepper motors are represented as well as the way to optimize the algorithm, where the objective is to make the motion adapt to the structure of the machine. Then, since some parts of the machine are made by 3D printing, there are some problems in the actual production process, and some solutions to those problems are going to be introduced. Finally, the results are discussed, with a focus on both the advantages and disadvantages of this machine and further improvement.

Keywords: Automatic; Ironing machine; Servo motor.

1. Introduction

Traditional manual ironing is time-consuming and labor-intensive, and there is a risk of being scalded. The automatic ironing machines on the market use the method of steam ironing, which hang up clothes and generate steam to pass over the surface of cloth to iron. Here comes the question that it is hard to maintain the temperature between upper steam and lower steam, which would affect the ironing quality. The influence of temperature during ironing process can increase the rate of wrinkle healing roughly by from 6% to 21%. With an increase in temperature, the rate of wrinkle recovery will increase somewhat [1]. Compared with traditional ironing machine, the fully automatic ironing machine could solve the problem by imitating manual ironing to move up and down. A dual control system called "water level control" and "pressure control" is used to operate the steam generator. [2]. Much of the work of fully automatic ironing machine is on modeling and control, such as CAD modeling, servo motor control, and stepper motor control. The purpose of fully automatic ironing machine is to free labor and obtain high quality ironing at the same time.

In literature there is a work accomplished by Fan Wu et al. on the correlation between temperature and ironing efficiency and quality [1]. Stefano Bracco et al. design a control system of the steam generator [2]. Other works concentrate on the body structure and control system. A variety of control systems have been developed, which have different effect of motors and precision to meet different requirements. Some examples of these include a PID controller with friction compensation [3, 4], a robotic arm controlled based on Arduino [5, 6], stepper motor's position control [7-9], servo motor's control system [4, 10], the strength and thermal expansion of 3D-printing part [11-14], and the optimization for the control system [15]. Each strategy has its own advantages and disadvantages. Here, a fully automatic ironing machines is presented with CAD modeling, stepper motor control and servo motor control system.

2. CAD Design

2.1. Static Structure

The basic structure of the fully automatic ironing machine is shown in Fig. 1 and Fig. 2. Because the machine's structure is left- and right-symmetrical, only the half of it will be discussed. 1 on the top is a stepper motor while 2 is a belt which is connected to the servo motor with belt pulley. 3, 11 and 9 altogether form the steam generation and transportation system. 9 is a water tank with the ability of storing 1.5L water. 3 is a spray with several holes on one of its sides to release high temperature steam to iron the cloth. 11 is a heat retaining tube that connects spray and water tank. 4 is a board to support the cloth in order to create normal force, on which the spray will press the cloth. 10 is a part which is connected to the board to hang the cloth. 5 is aluminum bar and 7 is 3D-printed foot for the machine to stand on the floor. At the bottom, there is a servo motor 6, which is also connected to the belt by a connection part 8.

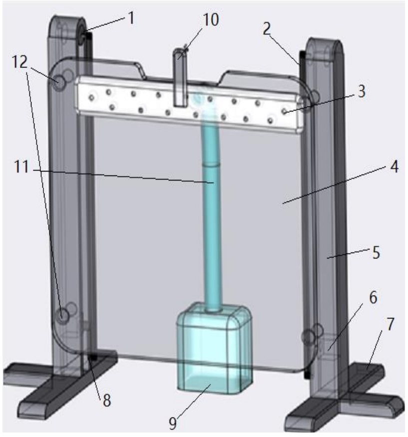

Fig 1. The back view of CAD modeling of the machine.

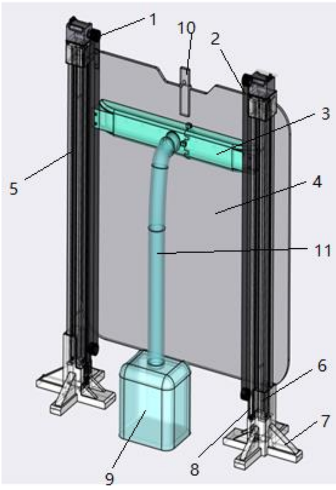

Fig 2. The front view of CAD modeling of the machine.

2.2. Motion Structure

The main transmission structure in the fully automatic ironing machine is the belt. Each belt connects two motors, servo motor on the bottom and stepper motor on the top. Between the belt and servo motor, there is a part 8. One side of 8 is connected to the servo motor while another side is connected to the belt through belt pulley. The spray is also fixed on the belt.

2.3. Analysis of Motion

The function of stepper motor is to control the spray moving up and down. Since spray is fixed on the belt, its motion is in synchronism with the belt. The lower servo motor changes the input to the change of angular motion. The part 8 is used to amplifier the angular motion. Suppose the spray is on the top initially and the servo motor locates at its initial position. Turn on the machine, the stepper motor will start to rotate and the belt will carry the spray to move down, at which time the servo motor will not work which means that the spray adds a pressure on the cloth to iron. When the spray reaches the bottom position, the stepper motor stops and servo motor receives a input signal to rotate. The servo motor will rotate to a specific angle and the spray will leave the surface of cloth in case when spray moves up, the friction force between the spray and cloth will wrinkle the cloth. After the former step, the servo motor stops and stpper motor rotates back to lift the spray. When the spray reaches top position, servo motor rotates back and the spray will add pressure on cloth renewedly. Then the fully automatic ironing machine will repeat the cycle until it reaches the set-up time.

This new-designed motion solves the problem that other automatic ironing machines lack the function to press the cloth. Since other automatic ironing machines on the market would meet the problem that how to maintain the upper steam and lower steam at the same temperature, the fully automatic ironing machine's spray could move up and down, which can maintain the temperature of out coming steam as well as the quality of ironing. The function of servo motor at the bottom is to add pressure when the spray moves down and leave the cloth in case to bring the cloth up when the spray moves up. To guarantee the synchronism, the four motors, one stepper motor and one servo motor on each side will receive the same input from Arduino.

3. Stepper Motor Control

The desired motion of stepper motor is to simulate the movement of hands in manual ironing process. Thus, the time for spray to move down should be longer than the time to move up. Here, the moving down time is set to 10 seconds and moving up time is 5 seconds. Assume the fully automatic ironing machine is designed for cloth that is not longer than 1 meter and the radius of stepper motors belt pulley is 1.6 centimeters. According to calculation, it takes gear pulley to rotate 10 revolutions to achieve 1 meter. The Arduino code and connection graph are shown in Fig. 3 and Fig. 4.

```
#define VCC 2
#define PLS 3
#define DIR 4
#define ENA 5
void setup() {
  pinMode(VCC, OUTPUT);
  pinMode(PLS, OUTPUT);
  pinMode(DIR, OUTPUT);
  pinMode(ENA, OUTPUT);
}
void loop() {
  digitalWrite(VCC, HIGH);
  digitalWrite(ENA, HIGH);
  digitalWrite(DIR, HIGH);
  //define 1 rerevolution is 1600 steps
  //rotate forward for 10 seconds and 10 revolutions
  for(int x=0; x<1600*10; x++){
    digitalWrite(PLS, LOW);
    delayMicroseconds(625/2);
    digitalWrite(PLS, HIGH);
    delayMicroseconds(625/2);
  }
  delay(3000);   //stop 3s
  digitalWrite(DIR, LOW);    //rotate back
  //rotate back for 5 seconds and 10 revolutions
  for(int x=0; x<1600*10; x++){
    digitalWrite(PLS, LOW);
    delayMicroseconds(625/4);
    digitalWrite(PLS, HIGH);
    delayMicroseconds(625/4);
  }
  delay(3000);   //stop 3s
}
```

Fig 3. Arduino code for stepper motor.

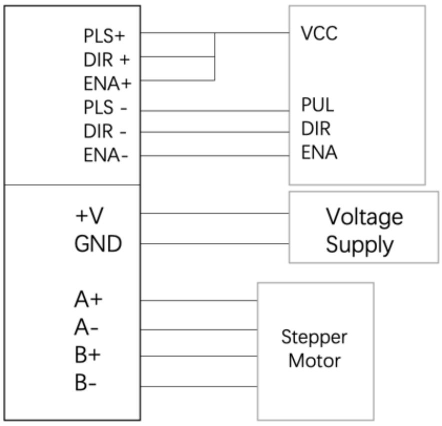

Fig 4. Connection graph for stepper motor.

4. Servo Motor Control

Servo motor serves to rotate an angle so that the spray can move up without touching the cloth. And the motion cycle analyzed before is to firstly wait for the spray moving down until a position, then the servo motor rotates to a specific angle and stop, waiting for the spray moving back to the original position and then rotates back.

To achieve the function, Fig. 5 shows the Arduino circuit and code. The stop time and moving time can be adjusted according to the need. In the example, the moving time is 3 seconds each, and it takes 10 seconds for spray to move down and 5 seconds to move up.

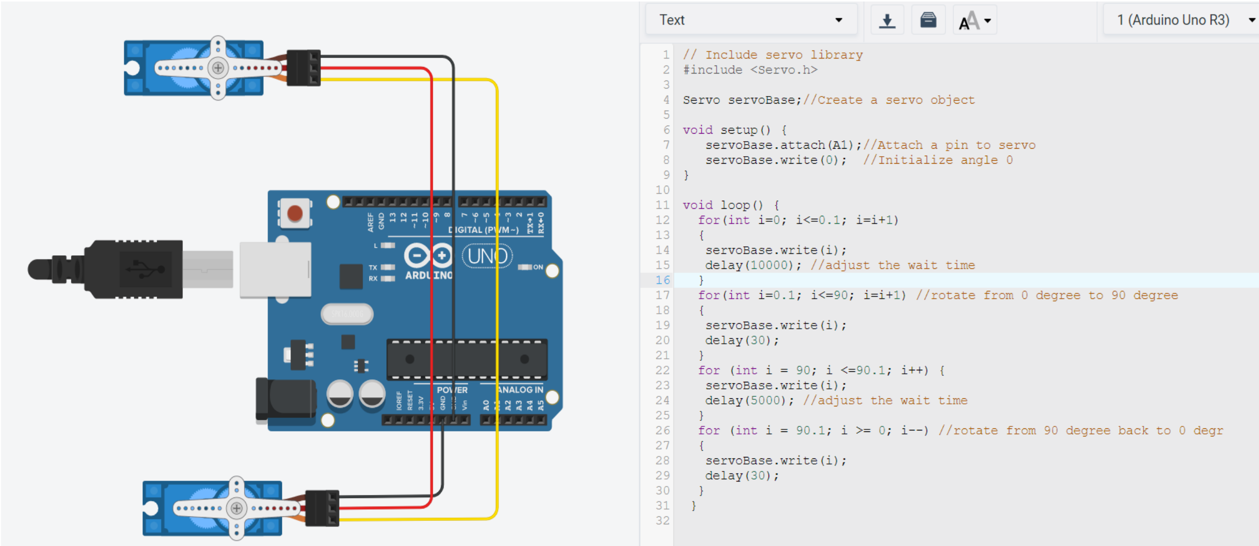

Fig 5. Arduino circuit and code for servo motor in Tinkercad.

5. 3D-Printing Optimization

In the real manufacturing process, some problems occur. The intensity of part 8 is not strong enough to resist the tension in belt and the gravity of spray. Part 13 in Fig. 6 is then introduced to solve the problem. Part 13 provides a vertical force to part 8, so that the tension force locates between part 13 and servo motor. In this way, both part 13 and the servo motor provides forces to resist the tension in belt, which will increase the stability of the structure.

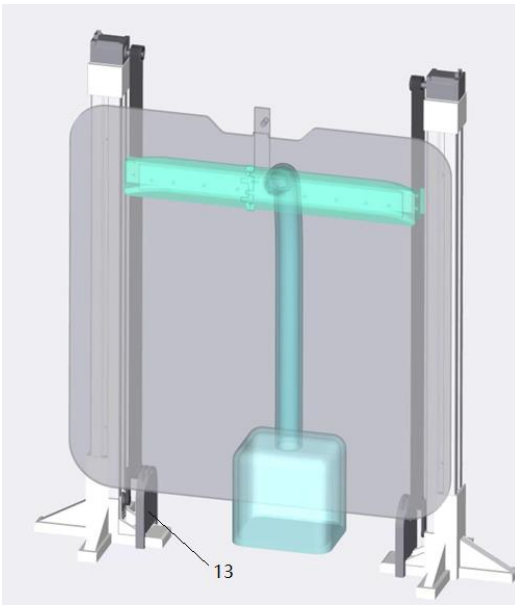

Fig 6. Introduction of part 13.

Part 8 is also made by 3D printing. In what direction and by what method it is printed also matters. Since it is printed by PLA method, how it is placed to print will affect the structure strength of it. The direction it is placed to print should be adjusted according to the force direction it will receive. Fig. 7 shows a failure of part 8.

Fig 7. A failure of part 8.

6. Arduino Optimization

The biggest problem of the whole control system is about the synchronism. Since the code uses time to control the movement of two motors, it would be better and more accurate to apply a position sensor on the spray to control the input of both stepper motor and servo motor, which will make the movement more accurate and durable. When using Arduino to control more than two motors, there comes the problem of insufficient current. The solution is to connect an external power supply with a constant current power source. Also, adding a capacitor to the circuit could avoid the problem of sudden electric current when turning on and off the switch. It would also be better to add code for the stepper motor to move with a positive acceleration first and negative acceleration when the spray nearly reaches ending position.

7. Conclusion

The fully automatic ironing machine introduced in the article is a basic designed that can realize some basic functions. There is a long way to go to put the machine into commercial use. Some optimizations include the Arduino program, the steam-generating and steam-transporting system and, safety problems and the intelligent control system. More modes to different materials of clothes will widen the range of application of the machine. And there should be another method to tell the machine when to stop instead of a setting time. However, the fully automatic ironing machine gives a theoretical solution to solve the drawbacks of manual ironing and existing ironing machine in the market and an example to combine the advantages of manual ironing and existing ironing machine together.

References

[1] Wu, Fan, Shuai Tong Liang, and Xue Mei Ding. Study on the mechanism of woven cotton fabric during steam ironing. Key Engineering Materials, 2016, Vol. 671: 179-185.

[2] Bracco, Stefano, and Carlo Cravero. Dynamic simulation of a steam generator for ironing machines. Energy conversion and management, 2014, 84: 13-19.

[3] Maung, Myo Maung, Maung Maung Latt, and Chaw Myat Nwe. DC motor angular position control using PID controller with friction compensation. International journal of scientific and research publications, 2018, 8(11): 149.

[4] Aguilar-Acevedo, Francisco, and Vignaud Granados Alejo. Using open-source platform for trajectory control of DC motors. IEEE International Autumn Meeting on Power Electronics and Computing (ROPEC), 2013: 1-5.

[5] Bhargava, Ankur, and Anjani Kumar. Arduino controlled robotic arm. International conference of Electronics, Communication and Aerospace Technology (ICECA), 2017, vol. 2: 376-380.

[6] Mohammed Ali H, Hashim Y, Alaadden Al-Sakkal G. Design and implementation of Arduino based robotic arm. International Journal of Electrical and Computer Engineering. 2022, 12(2): 1411.

[7] Adrian-Augustin PO, Emil-Daniel MA. Control technique for unipolar and bipolar step motor using Arduino and LabVIEW. International Scientific Technical Conference Alternating Current Electric Drives (ACED) 2021, 18: 1-5.

[8] Ahmed EQ, Aljazaery IA, Al-zubidi AF, ALRikabi HT. Design and implementation control system for a self-balancing robot based on internet of things by using Arduino microcontroller. Periodicals of Engineering and Natural Sciences (PEN), 2021, 9(3): 409-417.

[9] Parmar SJ, Zala MS, Thaker IS, Solanki KM. Design and Development of Stepper Motor Position Control using Arduino Mega 2560. International Journal of Science Technology and Engineering, 2017, 3(09).

[10] Sadun AS, Jalani J, Sukor JA, Pahat B. A comparative study on the position control method of dc servo motor with position feedback by using arduino. InProceedings of Engineering Technology International Conference, 2015: 10-11.

[11] Ansari AA, Kamil M. Effect of print speed and extrusion temperature on properties of 3D printed PLA using fused deposition modeling process. Materials Today: Proceedings, 2021, 45: 5462-5468.

[12] Abeykoon C, Sri-Amphorn P, Fernando A. Optimization of fused deposition modeling parameters for improved PLA and ABS 3D printed structures. International Journal of Lightweight Materials and Manufacture, 2020, 3(3): 284-297.

[13] Yao T, Deng Z, Zhang K, Li S. A method to predict the ultimate tensile strength of 3D printing polylactic acid (PLA) materials with different printing orientations. Composites Part B: Engineering, 2019, 163: 393-402.

[14] Rădulescu B, Mihalache AM, Hrițuc A, Rădulescu M, Slătineanu L, Munteanu A, Dodun O, Nagîț G. Thermal Expansion of Plastics Used for 3D Printing. Polymers, 2022, 14(15): 3061.

[15] Narayanavaram B, Reddy EM, Rashmi MR. Arduino based automation of agriculture a step towards modernization of agriculture. International Conference on Electronics, Communication and Aerospace Technology (ICECA), 2020, 4: 1184-1189.