IOP Conf. Series: Materials Science and Engineering **735** (2020) 012031 doi:10.1088/1757-899X/735/1/012031

Design and Implementation of Fixed Length Profile Cutting System Based on Mitsubishi Q Series and CC-Link Field Bus Control

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Abstract. In order to achieve the fixed length cutting of profiles, this paper designs a fixed length cutting system using Mitsubishi Q series PLC as the main controller, Fx series PLC as the slave controller and CC-Link as the field bus. Based on the working principle of the equipment, the paper analyzes the operation process of the cutting system. Based on PLC controller, stepping motor and servo motor, the hardware design of the system is carried out. A mathematical model for calculating the initial remaining length was established and the software was designed. The use indicates that the work intensity of the operator is greatly reduced, the yield is improved, the production cost is reduced, and the application prospect is good.

1. Introduction

Profile fixed length cutting system is an automatic control system that can constantly cut the profiles into set lengths per the custom requirements of the enterprises. A few years ago, profiles cutting required workers using sawing machines or using mechanically fixed flying shears to cut the profiles at a fixed state. These processes make the production efficiency low and require the device to be started and stopped frequently, which affect the stability of the device itself and the power supply. This paper designs a fixed length cutting system based on the profile cutting requirements from Shandong Luxing Steel Pipe Ltd, by using Mitsubishi Q series PLC as the main controller, Fx series PLC as the slave controller and CC-Link as the field bus. This cutting system is for the purpose of improving the yield and reducing the production cost.

2. Structure Design of the Fixed Length Cutting System

The structure of the fixed length cutting system designed in this project is shown in Figure 1.

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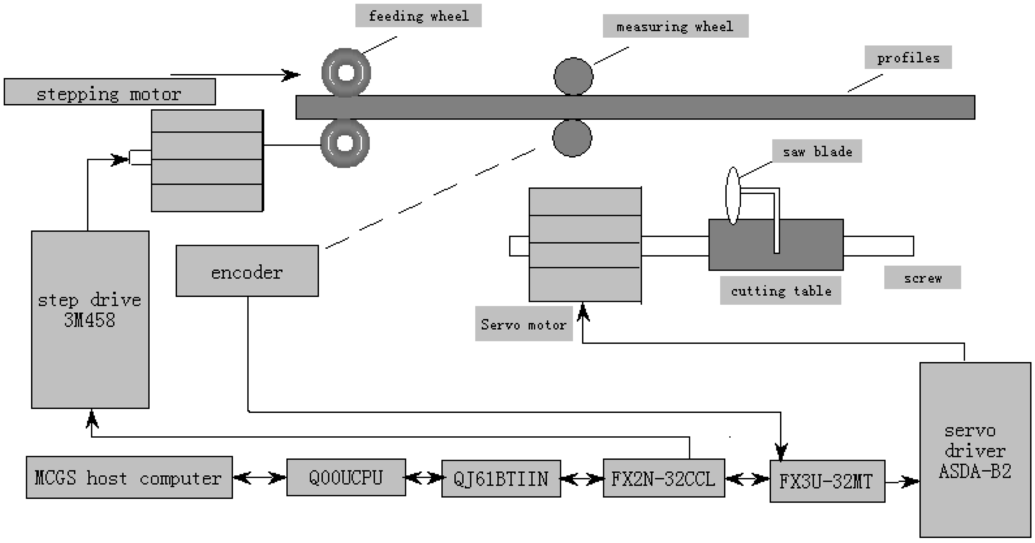

Figure 1. The Structure of the Fixed Length Cutting System

The mechanical structure of the system is mainly composed of servo motor, stepping motor, cutting saw, cutting cylinder and limit switch etc. The electrical control part is mainly composed of Mitsubishi Q series PLC, Mitsubishi Fx series PLC, MCGS touch screen, servo driver, stepping driver and Hengte encoder etc. [1]

According to the working process, the system consists of feeding mechanism, measuring mechanism and cutting mechanism. The feeding mechanism is driven by the stepping motor to push the profile into the cutting mechanism steadily and continuously at a set speed. Them easuring mechanism is powered by the cut profile. When the profile moves forward, it drives the measuring wheel of the encoder to rotate and triggers the encoder to generate pulse, and sends it to the Mitsubishi Fx 3U slave controller in real time. With combining the measurement of the distance traveled by the profile in a circle of rotation, the displacement of the profile is calculated. The cutting mechanism (cutting table) is controlled by the servo motor to make a back-and-forth movement, the hydraulic cylinder coordinates with the rotation and expansion of the saw blade, adjust the speed of the saw blade according to the cutting requirements to achieve the pipe cutting.

3. System Working Process Analysis

3.1. System Working Process

The system is controlled by the MCGS touch screen of the host computer. When the equipment is powered on, parameters such as profile feeding speed, profile cutting length, acceleration of cutting table and profile thickness are set on the start-upinterface. The profile starts moving after the equipment is started up, FX3U PLC receives the pulse transmitted by the encoder, calculates the displacement of the profile, compares it with the initial remaining length, to determines the start time of the cutting table. When all the requirements are met, the cutting table starts accelerating according to the set acceleration. When the speed is the same as the profile’s speed, the profile length at the front meets the cutting requirements. At this time, the motor of the saw starts and the saw starts cutting profile. After the cutting is finished, the cutting table returns to the datum point and waits for the next instruction. A completed cutting process is finished. [2]

3.2. Working Process of Cutting Table and Saw

From the working process analysis above, when the profile displacement does not reach the initial remaining length, the cutting table waits at the datum point [3]. When the initial remaining length is reached, the cutting table completes a cutting process through the process of "waiting--approaching--synchronizing & executing the cutting--forward deceleration to stop--reverse acceleration--reverse deceleration--return to the datum point to wait for the next cutting” [2]. The change of the motion speed pulse of the cutting table is shown in Figure 2.

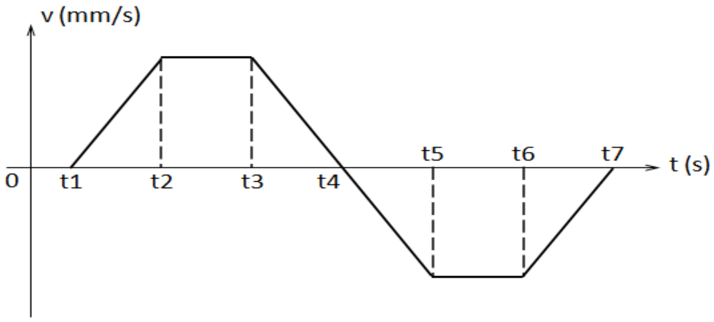

Figure 2. Chart of the Pulse Change

Waiting section 0-t1: start the control system through the touch screen, the profile is pushed forward continuously, and the cutting table is in the waiting section at the starting position.

Forward pursuit section t1-t2: when the profile’s displacement is equal to the initial remaining length, Mitsubishi Fx3U slave controller sends tracking signal to the servo driver through the high-speed output outlet. The cutting table accelerates from 0 and reaches the set speed according to the set acceleration time; the set speed is equal to the profile’s speed.

Cutting section t2-t3: the Mitsubishi Fx 3U slave controller sends pulses to the servo driver at a fixed frequency, the cutting table moves forward at a constant speed, the hydraulic cylinder of the cutting equipment extends, the sawing blade moves down and starts cutting until completed.

Positive deceleration section t3-t4: after receiving the cutting completed signal, the hydraulic cylinder retracts and the saw blade is reset. Fx series PLC sets the deceleration time to reduce the sending of pulse until the sending pulse is reduced to zero.

Return to the datum point section t4-t5: the Mitsubishi Fx 3U slave controller sends pulses to the servo driver at a fixed frequency to control the cutting table to move toward the datum point. The cutting table accelerates and then moves with a constant speed and then decelerates until the speed reaches zero and the cutting table returns to the datum point at the same time.

4. The design of the System Hardware

4.1. Selection and Design of the Controllers

The system is designed to be able to complete the speed and length measurement of the profile, establish tracking motion curve, precisely control the operation of the servo motor, allow human-machine interaction, and meet the extensibility of the equipment’s function at later stages. After comprehensive considerations, Mitsubishi series PLC is selected as the main controller, Mitsubishi Fx 3U series PLC is selected as the controller [4], the connection and the communication between the two controllers is achieved through the CC-Link communication method. Cc-link is an open field bus developed by Mitsubishi Corporation [5], which is based on Mitsubishi PLC and other automatic control systems. It has the advantages of fast communication speed and convenient connection. [6]The input/output terminals of the controller are allocated as shown in Table 1.

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Table 1. The Input/Output Terminals of the controller

F_X3U Input		
Terminal	Label	Function
X0	Encoder	Encoder input pulse port
X1	Encoder	Encoder input pulse port
X2	SB1	Start Button
X3	SB2	Stop Button
X4	SQ1	Saw blade limit switch
X5	SQ2	Datum point limit switch
X6	FR1	Saw blade motor thermal protection
F_X3U Output		
Terminal	Label	Function
Y0	CW	Servo pulse input
Y1	CCW	Servo Direction
Y2	PLS-	Step-by-step pulse
Y3	DIR-	Step-by-step Direction
Y4	KM1	Saw motor control coil
Y5	Electromagnetic Valve	Control electromagnetic valve

4.2. Selection and Design of Servo System

The servo system is used to move the cutting table. The servo driver receives the pulse [7] sent by the Mitsubishi Fx3U slave controller’s high-speed pulse port to control the operation of the servo motor [8]. This system selects Delta servo driver and Delta ASDA-B2 servo motor that adapt the servo driver [9].

4.3. Selection and Design of Stepping Motor and Encoder

The stepping motor drives the feeding wheel to rotate, and the profile is returned to the cutting mechanism at a constant speed. Meanwhile [10], the friction force generated by the forward moving profile drives the speed measuring wheel to rotate, triggering the encoder to send pulse to Fx3U slave controller to calculate the displacement of the profile [11]. In this system, HETKJ Hengte HTK4808 incremental encoder is selected, the encoder sends out 1000 pulses in one complete speed wheel rotation.

The electrical schematic diagram of the system is shown in Figure 3.

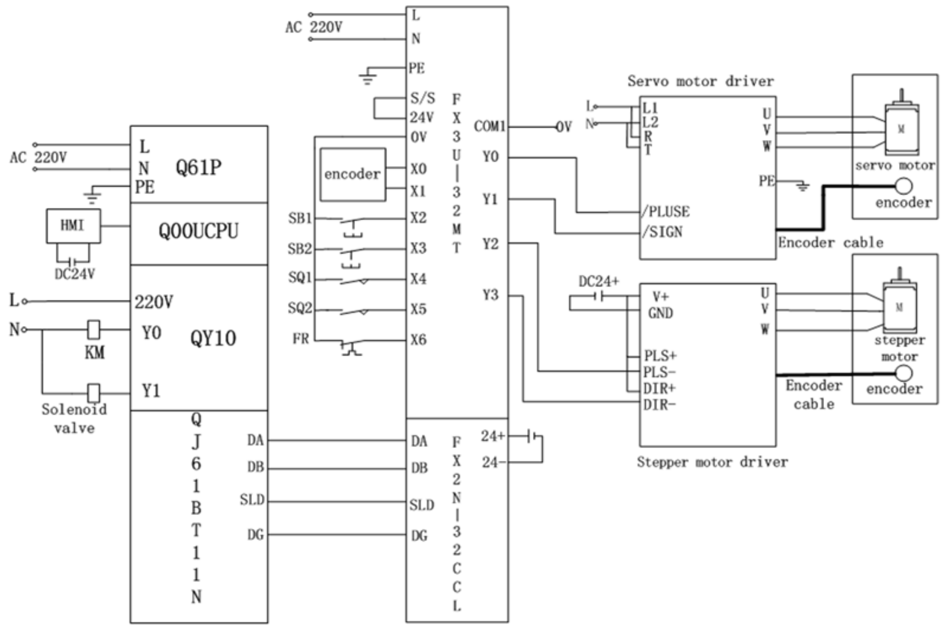

Figure 3. The Electrical Schematic Diagram of the System

4.4. Host Computer Selection and Interface Design

In order to understand the real-time data of the profile cutting system directly and to facilitate the setting of relevant parameters such as profile cutting length and acceleration of the cutting table, MCGS touch screen is selected for the host computer [12]. The touch screen is connected to PLC serial port of Mitsubishi Q series main station through RS232 module to complete data exchange [13]. Host computer interface design shows profile speed, profile cutting length, chasing acceleration, profile thickness and other settings; it also has start and stop control buttons. The interface is shown in Figure 4.

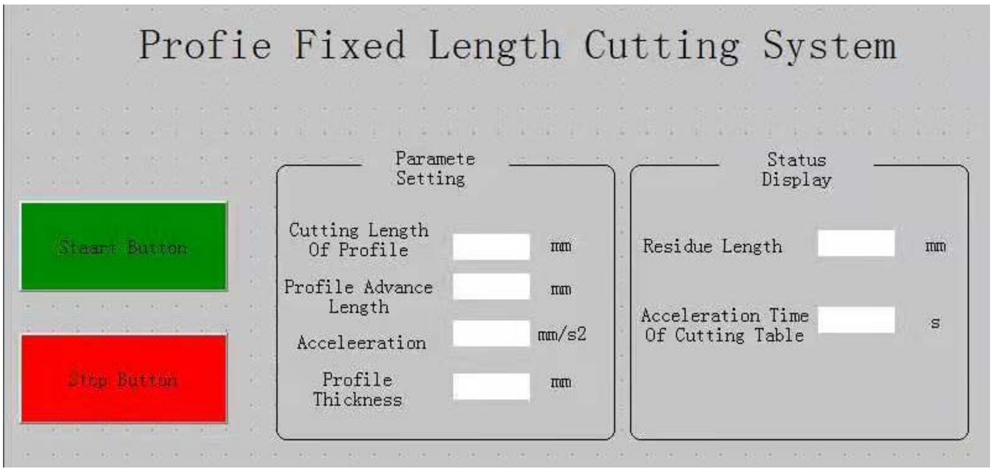

Figure 4. Interaction Simulation Interface

5. Software Design

5.1. Calculation of Initial Remaining Length

To complete the cutting process, the key point is to determine when to start the cutting table [14]. The design takes the forward displacement of the front end of the profile from the Datum point as the reference, the cutting table began to accelerate to chase when the profile displacement reached the initial remaining length. Once the cutting table's speed and the profile's speed are equal, the profile's length at the front of the saw blade is S0, which is the length set on the interface.

Set C as the initial remaining length and V0 as the speed of the profile. When C meets the starting conditions, the cutting table accelerates from zero with acceleration a, and the profile continues to be pushed forward with V0. The two speeds are equal after time t, the mathematical model is shown in Figure 5.

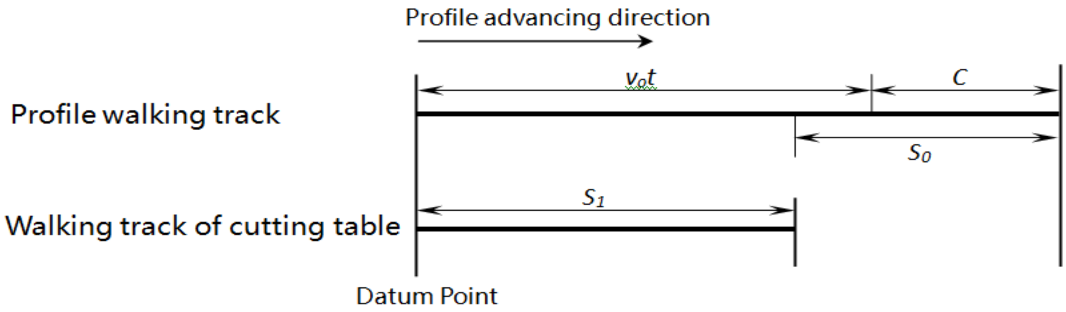

Figure 5. Mathematical Mode for Initial Remaining Length Calculation

At this point

$$t = \frac{V_0}{a}$$

The distance traveled by the cutting table

$$S1 = \frac{V_0^2}{2a}$$

According to the above formula, the Initial remaining length can be obtained.

$$C = S_0 + S_1 - V_0 t = S_0 - \frac{V0^2}{2a} \quad [15]$$

5.2. System Flowchart

According to the control requirements, the work flow of cutting table and saw blade is shown in Figure 6.

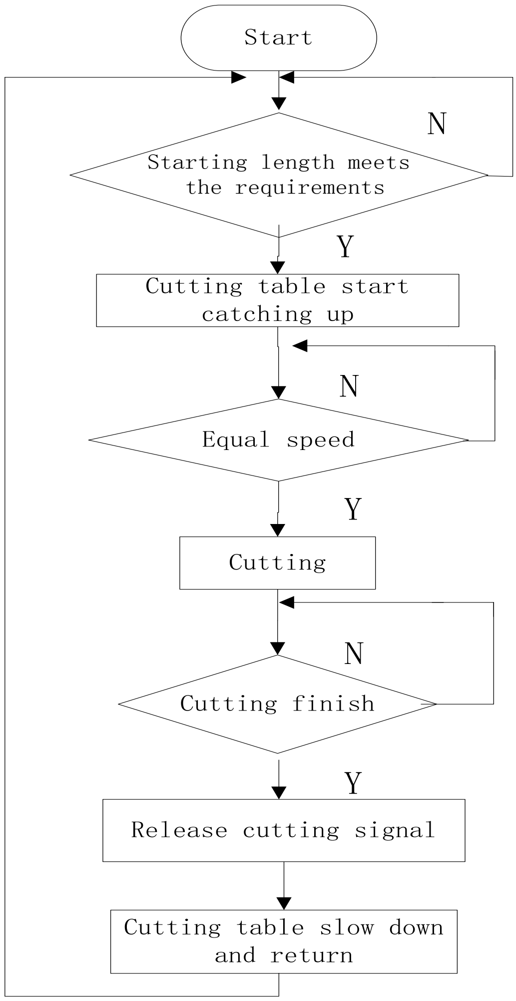

Figure 6. The Work Flow of Cutting Table and Saw Blade

6. Conclusion

The system adopts Mitsubishi Q series PLC as the main station and Mitsubishi Fx3U series PLC as the slave station, the stations are connected by Mitsubishi cc-link field bus. An automatic fixed-length profile cutting production line is established with stepping motor feeding and servo motor driving cutting table. The results show that the system is intelligent and easy to maintain, which greatly reduces the work intensity of the operators, improves the yield and reduces the production cost.

7. References

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