SEMI-AUTOMATIC TAPPING MACHINE CONTROL USING MICROCONTROLLER

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ABSTRACT

This paper presents a semi-automatic tapping machine development for the manufacturing industry. There are some parts required for screw clamping bolt. The subsidiaries need to order tapping machine importing from foreign country which is expensive. This reason necessary to develop the tapping machine control using microcontroller to facilitate working. In this case, the auxiliary instrument is added on the pedestal drill. Pneumatic system is used to control the displacement distance between the work piece and the drill bits or a thread tap using the distance data from infrared sensor. Microcontroller with infrared sensor to control the drill bits in the range prevent a collision with the work piece base. It setting up a spiral range in work piece using the signals from infrared sensor. After completing work, the drill bits remove from a work piece automatically. Experimental results have shown that the spiral range in the work pieces are accurate for satisfactory to compare with the foreign tapping machine. The accuracy rate of the developed tapping machine in this research is about 4% and 5% for M4 and M9 thread tap. Furthermore, the researchers test the accuracy of infrared distance sensors compare with the ultrasonic distance sensors. The accuracy rate of infrared distance sensors are higher than the ultrasonic distance sensors.

KEYWORDS: Semi-automatic tapping machine, microcontroller, infrared distance sensor, ultrasonic distance sensor

1. Introduction

The growth of Thai manufacturing sector depends massive on its productivity and quality. Therefore stimulate employment to produce the automatic parts. Some parts need to be made the threaded holes for clamping bolt. The factory necessary to order the tapping machine from foreign country which is expensive. Tapping is the method to produce the thread inside the drilling hole on the work piece. In the past uses a hand tapping which is very time consuming process, less accuracy, and higher labor cost. Patel et al [1] reviewed a thread tapping operation and parameterize study. Mali et al [2] reviewed hand tapping is very time consuming process, less accurate and includes higher labor cost, and ultimately leads to less productivity. They propose is developing the pneumatics tapping machine instead of using hand tapping. From the both researches, the hand operated machines should be replaced with the application of automation or semi-automatic machines which utilized to improve productivity. Actually the manufacturing need electronic automation or semi-automatic to facilitate working. Nhivekar and Mudholkar [3] described a design and implement of infrared remote control signal decoder which can be used for various home control applications. They have designed remote controlled fan regulator and ON-OFF power supply switch. The entire system is based on microcontroller that makes the control system smarter and easy to modify for other applications. The microcontroller can be responded this application in categorize different application area such as: consumer electronic products, instrumentation and process control, medical instruments, communication office equipment, multimedia applications, automobiles etc. Shinde et al [4] used the PIC16F1939 microcontroller to control the voltage and display of semi-automatic drilling machine. In this system, the tap is held in the main spindle with the help of collect Chuck/Drill chuck. The spindle gets its drive power from the motor which is controlled by PIC16F1939 microcontroller. GÜVEN et al [5] described the concept of microcontroller base systems to choose the base hardware for applications. Many companies proposed to various microcontroller with different features. Thus, the selection of microcontroller for application is very important. They give the comparison of microcontroller base system. Parai et al [6] described the difficult to choose a particular microcontroller for specific application. Abueejela et al [7] designed and fabricate drilling machine based on PLC to produce holes. The design system was able to run the drilling process autonomously. Yatawara et al [8] designed the automatic rubber tapping using a Raspberry-pi minicomputer board. This board is used to control the horizontal, vertical and depth movements by driving the appropriate motors. The entire system is based on microcontroller that makes the control system smarter and easy to modify for other applications.

From these research mentioned above, the researchers have been to apply the microcontroller with the drilling and tapping machines. The system is based on microcontroller that makes the processes begin a tap cuts a threaded on the inside surface of work piece, create a female surface which functions as a nut. During process, it is necessary to measure the deep of hole to break the drilling process. This step prevents a tap drill through to crash the work base. So, the measured distance of hole is important to stop a drill. The threading process has the several steps and labor intensive. Furthermore, taps and tapping machine problems associated with the tapping process include thread dimensional accuracy, thread form error, and surface roughness of thread form. To facilitate the work of small and medium enterprises (SMEs), this paper have been to try develop the semi-automatic tapping machine controlled by microcontroller. In developing, the pneumatic machine is added on the pedestal drill. The pneumatic machine is used to control of the displacement of drill or thread tap varies according the distance measurement from sensor as detail in section 3 and 4.

2. Embedded Systems and Microcontrollers

2.1 Embedded Systems

Nowadays, the electrical and electronic machines are designed using embedded system technology. The computers, mobile phones, tablets, laptops, and digital electronic system are the embedded system. An embedded system consists of hardware and software as shown in Figure 1. The hardware of embedded system includes power supply, central processing unit, memory devices, timers, output circuits, serial communication ports, and system applications. The software used in the embedded system is an instruction set for controlling devices. These programs are primarily written using any programming languages such as C, C++, and Photon. The program is dumped into microprocessors/microcontrollers that are used in the embedded system circuit. There are numerous applications in various fields such as digital electronics, computing network, smart cards, military defense system equipment, research system equipment, and so on.

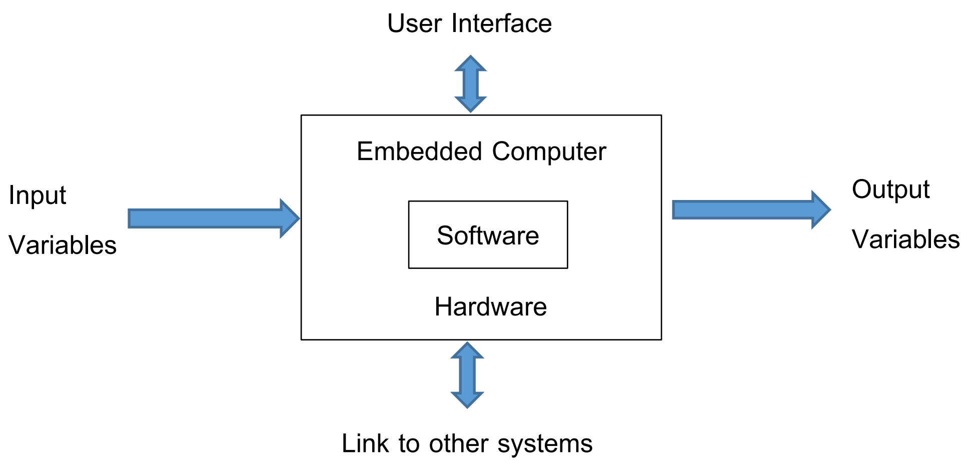

Figure 1 Embedded System

2.2 Microcontrollers

The MCS- 51 is a microcontroller series and uses in the embedded systems. There is a software to develop using Assembly and C language. The feature of the 8051 core is the inclusion of a Boolean processing unit which allows bit-level Boolean logic operations with internal registers, ports, and random access memory (RAM) locations. The 8051 architecture provides many functions, RAM, read only memory (ROM), input/output (I/O) ports, interrupt logic, timer, etc. as shown in Figure 2. Then, the microcontroller can be integrated circuit that contains programmable, input/output peripherals, processor, and memory. The MCS-51 is one of basic type of microcontroller. It is used in this research for some industrial applications which is uses for control devices.

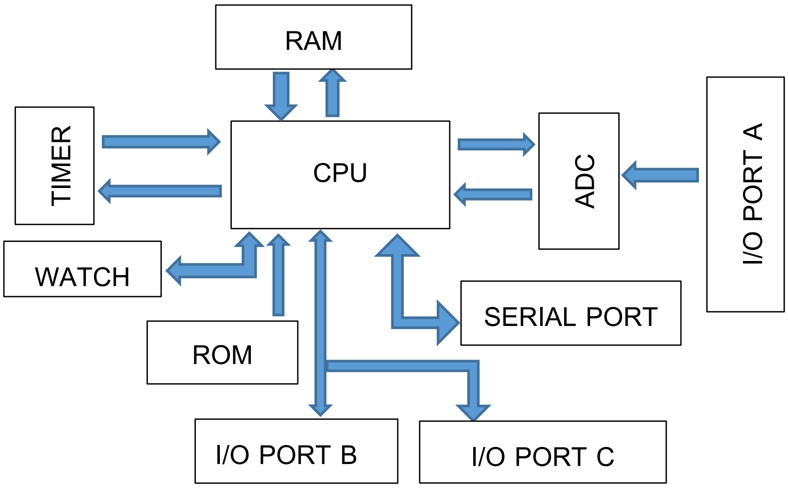

Figure 2 Microcontroller Components

3. Design of Control System for Semi-Automatic Tapping Machine

3.1 Control System

Figure 3 is a block diagram for the control system which is divided into three parts. The first part is the input switches and sensor. There are eight switches: S1 uses for sending the command to forward the rotation of motor, S2 uses for sending the command to reverse the rotation of motor, S3 is the increasing distance switch, S4 is the reducing distance switch, S5 is the drilling mode switch, S6 is the tapping mode switch, S7 is the manual switch, and S8 is the stopping switch, respectively. The infrared sensor uses to measure the deep of hole in work piece which is controlled by MCS-51 microcontroller. The second part is the measurement system which uses the infrared sensor. MCS-51 receives the distance values from distance sensor and the command form the control switch. It computes the signal to control the devices and sending the distance values to LCD display. These actions corresponding to the operation of working. The last part is the Opto relays which are the isolation between the control circuits and drive circuits. The relay 1 and 2 are used to send the command signals to the K1 magnetic contactor for the forward rotation of motor and the K2 magnetic contactor for the reverse rotation of motor. Relay 3 and 4 are used to send the command signals to the C1 solenoid to move the forward cylinder and the C2 solenoid to move the reverse cylinder.

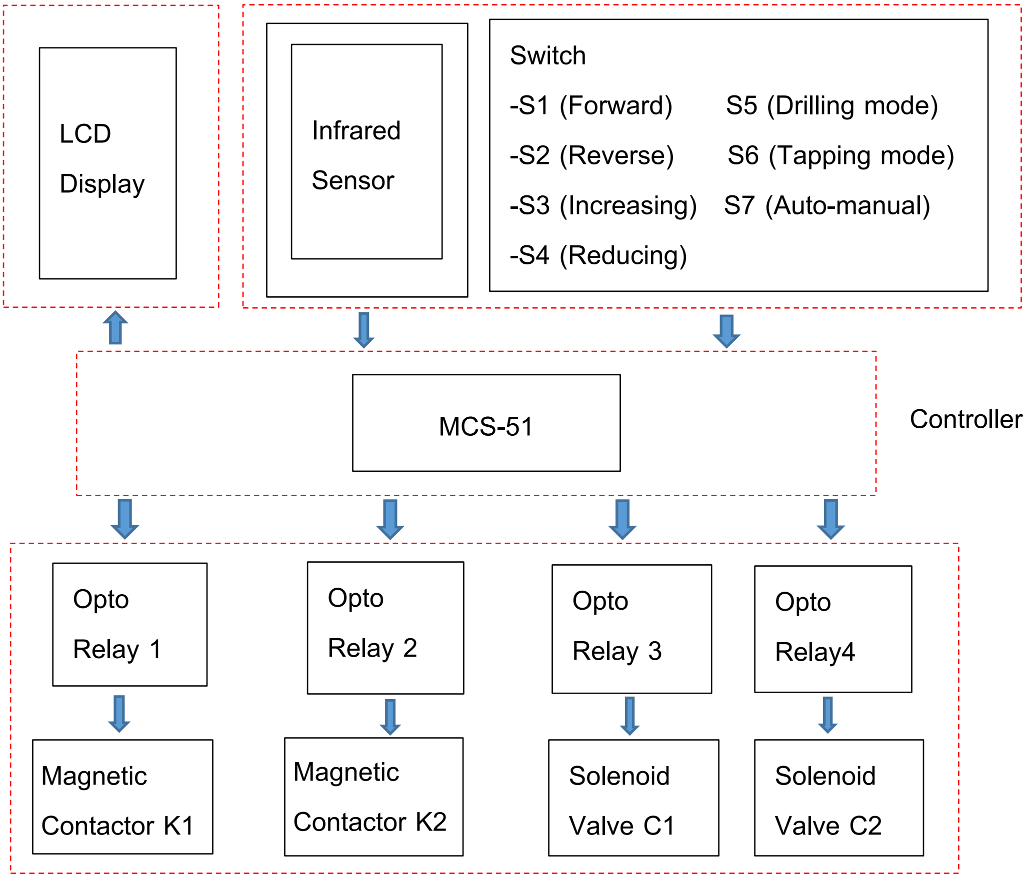

Figure 3 Control Block diagram

3.2 Control Circuits

Figure 4 shows the control circuits of semi-automatic tapping machine. From a circuit diagram the K1 and K2 connect the P0.0 and P0.1 of MCS-51 via isolation circuit. The solenoid valves C1 and C2 connect the P0.2 and P0.3 of MCS-51 via isolation circuit. An infrared sensor connects directly P0.4 of MCS-51. The program of semi-automatic tapping machine divided into two modes: drilling mode and tapping mode. Drilling mode uses a switch S5 on the drill and the infrared sensor to measure the distance operation. The sensor sends a distance signal to microcontroller and shows on LCD display. Microcontroller sets the deep value of hole and in order to the Opto relay 1. The Opto relay 1 connects to a magnetic contactor K1 and on the forward rotation motor. Simultaneously, the MCS-51 in order to the Opto relay 3 for controlling pneumatic cylinder. The tap drill cut a thread on the inside of work piece until fits the set value, the Opto relay 4 on and stop the process.

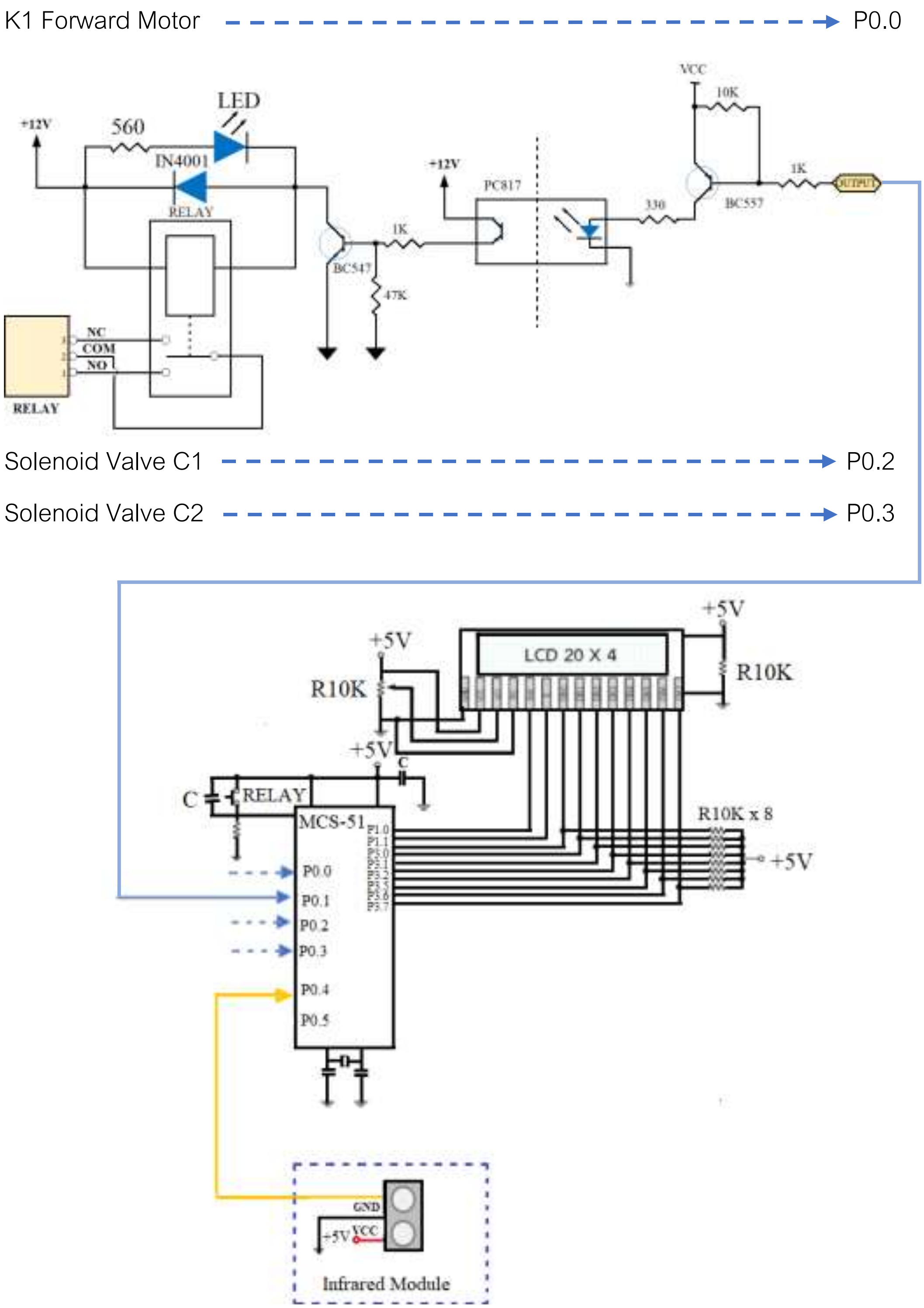

Figure 4 Control circuits and interfacing

Tapping mode uses switch S1 create a female surface inside of hole. The infrared sensor measures the deep of hole and send the deep signal to microcontroller and shows on the LCD display. Opto relay 1 connect to the magnetic contactor K1 and on the forward rotation motor. Simultaneously, MCS-51 in order to Opto relay 3 for controlling pneumatic cylinder. A tap creates female surface until fits the set value, the reverse rotation motor on. Opto relay 2 and 4 on, a tap falls out of the work piece.

3.3 Installation of Control Devices and Sensor

Infrared sensor and control devices are installed with the shaft support spindle of drill bit as shown in Figure 5. When adjusted a feed handle wheel at drill head, the infrared sensor will be moved up and down follows the shaft support spindle. The distance signal from a sensor is sent to microcontroller. The pneumatic cylinder is installed at the top of spindle. It can be pushed the spindle and infrared sensor move down to the work piece.

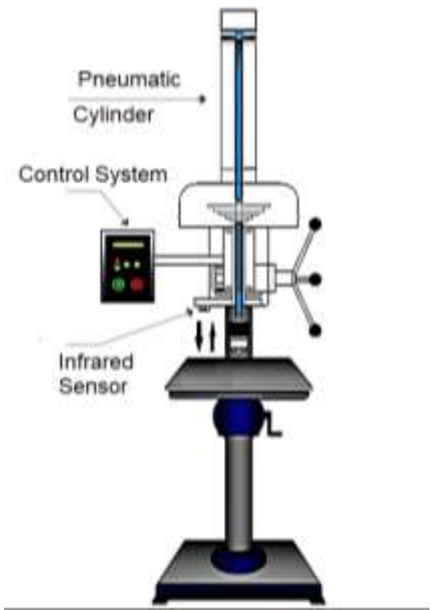

Figure 5 Installation of sensor and control devices

4. Implementation and Results

4.1 Tapping Stage

This section is the testing for tapping, and more particularly to control circuits including sensor operations. In drilling step, begin setting value, and move the drill bit to a surface of work piece. It have distance 20 mm. and need to cut into the inside surface of work piece 40 mm. Then, necessary to set the range operation 60 mm. (not less than 40 mm. for the GP2Y0A41SK0F infrared sensor which has measuring distance: 4 to 30 cm.). Hole creating, will plus the required deep (distance) of hole which is 20 mm. as shown in Figure 6. Press the drilling mode switch S5, the control system will operate automatically. After the system has finished working, perform inspection with standard tools and check the error. The next step, set the range operation 60 mm. which consists of the distance plus the tapping depth 40 mm. as shown in Figure 7. Press the tapping mode switch S6, the control system will tapping automatically. After the system has finished working, perform inspection using the bolts to the end of the spiral and measure the remainder thread length of the bolt. The error values will be getting to analysis as shown in Figure 8, Table 1 and 2.

Figure 6 Drilling value setting

Figure 7 Value setting and tapping

Figure 8 Thread depth inspections

Table 1 Testing results (thread tap 4 mm. size)

No.	Spiral hole depth setting (mm.)	Thread depth (mm.)	Error value (%)	Voltage supply (V)	Current supply (A)	Active current (A)
1	20	19	5	380	1.06	1.19
2	20	19	5	380	1.06	1.16
3	20	20	0	380	1.06	1.17
4	20	19	5	380	1.06	1.14
5	20	19	5	380	1.06	1.17
Average error			4			

Table 2 Testing results (thread tap 9 mm. size)

No.	Spiral hole depth setting (mm.)	Thread depth (mm.)	Error value (%)	Voltage supply (V)	Current supply (A)	Active current (A)
1	20	19	5	380	1.06	1.37
2	20	19	5	380	1.06	1.41
3	20	20	0	380	1.06	1.40
4	20	19	5	380	1.06	1.39
5	20	18	10	380	1.06	1.42
Average error			5			

4.2 Comparative results

The experimental results of semi-automatic tapping machine for pre investigation were compare between the infrared sensor and ultrasonic sensor as shown in Table 3 and 4. From the experiments, it found that the error value of infrared sensor is less than ultrasonic sensor. The accuracy rate of the developed tapping machine using infrared sensor in this research is about 3% for M 4 drill bit, 3.5% for M 9 drill bit, 4% for M 4 thread tap, and 5% for M 9 thread tap. In the case of Ultrasonic sensor, the accuracy rate is about 4.5% for M 4 drill bit, 5% for M 9 drill bit, 6% for M 4 thread tap, and 7% for M 9 thread tap, respectively.

Table 3 Comparative results

No.	Infrared Sensor				Ultrasonic Sensor			
	drill bit 4 mm. size				thread tap 4 mm. size			
	Drill hole depth setting (mm.)	Drill hole depth (mm.)	Spiral hole depth setting (mm.)	Thread depth (mm.)	Drill hole depth setting (mm.)	Drill hole depth (mm.)	Spiral hole depth setting (mm.)	Thread depth (mm.)
1	40	39	20	19	40	38	20	19
2	40	39	20	19	40	39	20	19
3	40	38	20	20	40	38	20	18

Table 3 Comparative results (continued)

No.	Infrared Sensor				Ultrasonic Sensor			
	drill bit 4 mm. size				thread tap 4 mm. size			
	Drill hole depth setting (mm.)	Drill hole depth (mm.)	Spiral hole depth setting (mm.)	Thread depth (mm.)	Drill hole depth setting (mm.)	Drill hole depth (mm.)	Spiral hole depth setting (mm.)	Thread depth (mm.)
4	40	39	20	19	40	38	20	19
5	40	39	20	19	40	38	20	19
	Average error	3%	Average error	4%	Average error	4.5%	Average error	6%

Table 4 Comparative results

No.	Infrared Sensor				Ultrasonic Sensor			
	drill bit 9 mm. size				thread tap 9 mm. size			
	Drill hole depth setting (mm.)	Drill hole depth (mm.)	Spiral hole depth setting (mm.)	Thread depth (mm.)	Drill hole depth setting (mm.)	Drill hole depth (mm.)	Spiral hole depth setting (mm.)	Thread depth (mm.)
1	40	39	20	19	40	38	20	18
2	40	39	20	19	40	39	20	19
3	40	38	20	20	40	38	20	19
4	40	39	20	19	40	37	20	19
5	40	38	20	18	40	38	20	18
	Average error	3.5%	Average error	5%	Average error	5%	Average error	7%

5 Conclusions

In this paper, the researchers are mainly concerned with the study of tapping working. However, the tapping machine is expensive. The relatively high price of a tapping machine compare with a pedestal drill. This point lead to develop the semi-automatic tapping machine. The pneumatic cylinder installs add on the top of pedestal drill, and uses the infrared sensor to detect the distance and the depth of work piece. The control system uses MCS-51 microcontroller with distance data to control the range in drilling and tapping. In developing of semi-automatic tapping machine, measuring the distance and depth of the holes in the work piece is very important. The researchers necessary to test the working of infrared distance sensor with the other sensor. Accuracy rate of drilling is about 3% and 3.5% for M4 and M9 drill bits, 4% and 5% for M4 and M9 thread tap, respectively. The accuracy comparison results found the infrared sensor has ability slightly higher than ultrasonic sensor.

This research focuses on building a tapping machine from a pedestal drill, and develop control system program. The tapping machine necessary to use three phase induction motor, because it uses a lot of electric power to drill and thread. Furthermore, the ultrasonic wavelengths greater than infrared wavelengths. This reason, ultrasonic measurements are lower ability measuring when compare with infrared distance sensor.

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