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AN EFFECTIVE DEVELOPMENT FOR CURVED DECORATIVE SYSTEM

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Abstract. *A novel curved decorative vacuum system is developed in this paper. In order to enhance the efficiency of the curved decorative vacuum system process a programmable controller is applied to being as man and machine interface. The programmable controller also can be a pressure detector and electromagnetic switches. By using a pneumatic component drive, the film material printed with pattern is heated to its softening point. Then the image film in the surface of plastic or metal products can be formed with three-dimensional surface decoration effect by atmospheric pressure. This surface of product will have excellent visual and tactile by using this system. Another advantage is that this design can save much energy because the proposed process in this paper applies the vacuum forming technology to the secondary processing of the curved work.*
Keywords: Programmable controller, Human-machine interface, Pressure detector, Three-dimensional surface decorative effect

1. **Introduction.** Plastic products are easy to be produced, the weight is light, and the appearance is beautiful. Therefore, they are widely used in general household. The application of plastic products [1-3] has been extended to 3C consumer electronics, home appliances, machinery products, building materials, transportation, etc. The beautiful surface of plastic products is one of important purchasing factors for consumers. If it has beautiful appearance, the consumer will have more interesting in this product. Therefore, in order to let the surface of plastic product have beautiful effects, it needs a surface decoration processing technology [4-6]. However, some decoration processing technologies will make a lot of environment pollution problems, such as industrial wastewater, air pollution, and thermal pollution. Considering the environment pollution problems mentioned above, one technology denoted in-mold decoration (IMD) process [7,8] has been developed. This processing is divided into three kinds of technology which are in-mold labeling (IML), in-mold roller (IMR), and in-mold film (IMF). However, IML and IMR are not easy for a curved surface decoration. For example, the cost of IMF process is very high for production. In this paper, one technology denoted vacuum and heating technology which can solve such problems is developed. Because the vacuum and heating technology can directly print the pattern on the surface of the curved surface product, it can reduce the number of operations which can reduce the cost of the mold and save the production time also.

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There is another advantage of the proposed system which can save energy because the production process applies the vacuum forming technology to the secondary processing of the curved work and can reduce some procedures. The development proposed in this paper can not only decorate the surfaces of various materials, but also adopt the functional film coating. It also can increase the benefit value of products. For three dimensional products, it can be modified according to the surface of the concave and convex processing to replace the paint coating or aluminum lacquer coating processing. This technology also denoted a dry coating process which can reduce the volatile of solvents to atmosphere. At the same time, because of its low cost but high quality system, it has a more competitive advantage in the market. In order to enhance the system efficiency, the programmable controller technology is also applied in this system.

The programmable logic controller (PLC) [9] is a digital electronic device with a microprocessor which is a controller that can store data and execute functions. The programmable controller consists of an internal CPU, data memory, digital I/O unit, power module, and analog I/O unit. The functions of programmable logic controller include one computer module which has logic control, sequence control, analog control and serial communication. In this study, the programmable controller is applied in the system which can enhance the efficiency of system.

The rest of this paper is arranged as the following. The second section is system design which describes the detailed algorithm proposed in this paper. The third section is the experimental results. In this section, a test algorithm is applied. Several sets of data are tried in the experiment which can find the best set of parameters. The conclusion is presented in the last section.

2. **System Design.** The system structure of this design is shown in Figure 1, which uses the heating tube with reflective sheet to heat and soften the film. Then it uses the vacuum device technology to put printed pattern to the curved surface directly. Because it only needs to make the fixtures for the product, so it does not need spend much cost for other equipment. Moreover, it can also simplify the production process and shorten the working time. The control architecture of this system [8,9] has an electrical control architecture of the vacuum laminator. The system uses the programmable controller as the major control unit. In the process, the analog current signal is fed back by pressure transmitter and sent to the programmable controller module to detect the vacuum status in the production process. And then, it can control the necessary actions.

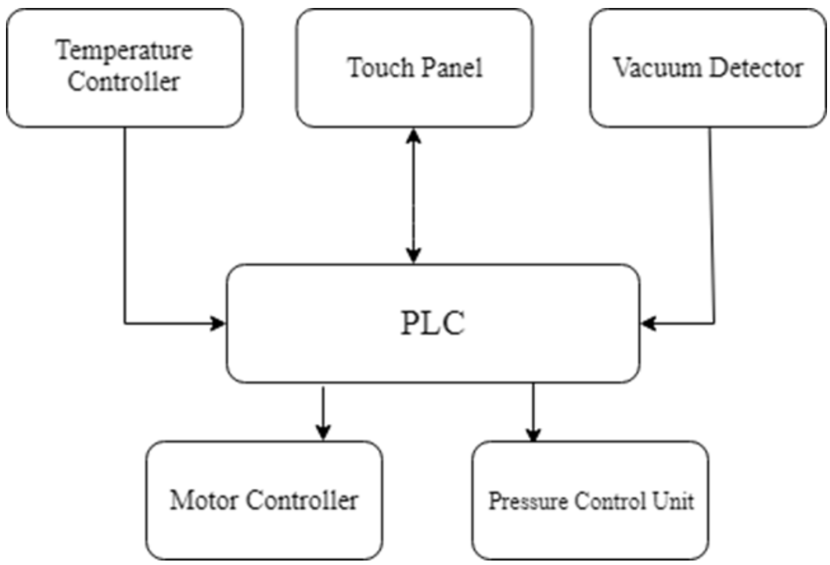

FIGURE 1. The structure of curved decorative vacuum system

The system structure diagram with programmable controller device is shown in Figure 2. The FBS-24MA is the major device of CPU. The digital I/O switch is used to connect the external operation which can control the operation of vacuum motor and the air pressure control unit. The RS-232 port can be connected to the computer for editing the control program and the FBS-CB25 is a communication expansion module. There are two communication ports which are RS-485 denoted port1 and RS-232 denoted port2. The port1 is connected with human-machine interface and can be programmed. The port2 is connected with temperature controller table which also can use the PLC to set the communication parameters and communication protocol. The FBS-6AD is an analog input signal expansion module which connects the pressure transmitter of air pressure control unit.

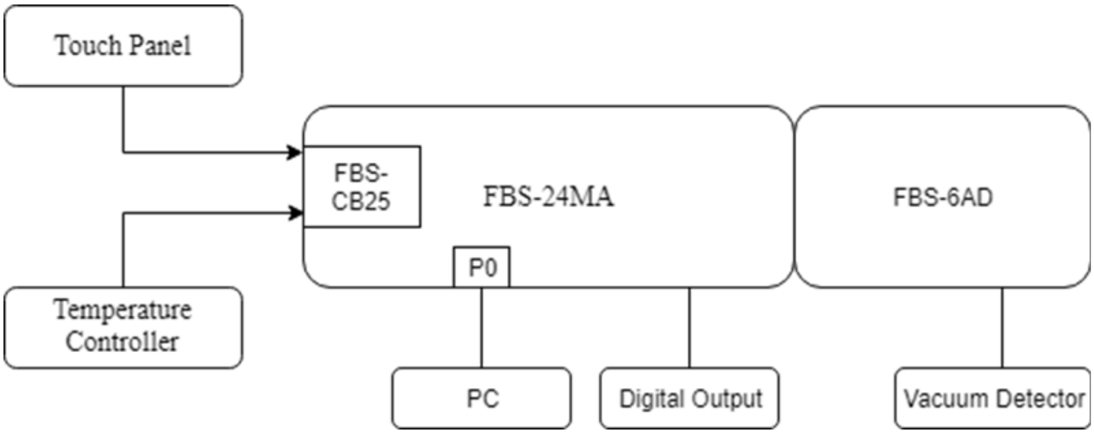

Figure 2. The system structure diagram with programmable controller device

The PLC communicates with the master-slave system architecture. Usually the human-machine interface is the master system, and the PLC is the slave system. In the communication, the human-machine interface initiates the command message, and the PLC is in the passive state. After the PLC receives the instructions of the human-machine interface, and it responds to the human-machine interface according to the instructions. However, the PLC cannot order a command to the human-machine interface because it is in the passive state.

Because the system attaches the surface decorative film by atmosphere pressure and vacuum system, another major device of this system is vacuum system. Therefore, the system needs one pressure sensor to detect the air pressure. In this system, the pressure sensor can measure the air pressure range from -100 k-Pa to 100 k-Pa. The air pressure changing signal can be transferred by using two sets of output signals and a set of analog output signals to notify the controller. Then the controller will make proper response and let the control system reach a stable control state quickly. The architecture of pressure sensor system is shown in Figure 3.

Before decorating the products, the system needs to heat and soften the film. The temperature controller is necessary, which can control the temperature for the system. The temperature controller measures temperature by using an electronic device, which can get the signal of temperature change and send the measurement data to the electronic calculator for processing. Then, the output device controls the variation of its temperature within a specific range. After the film material reaches the softening point, the processing platform is raised to the right position, so that the film material is close to the surface of the product, and then remove the thin film material to complete the work processing.

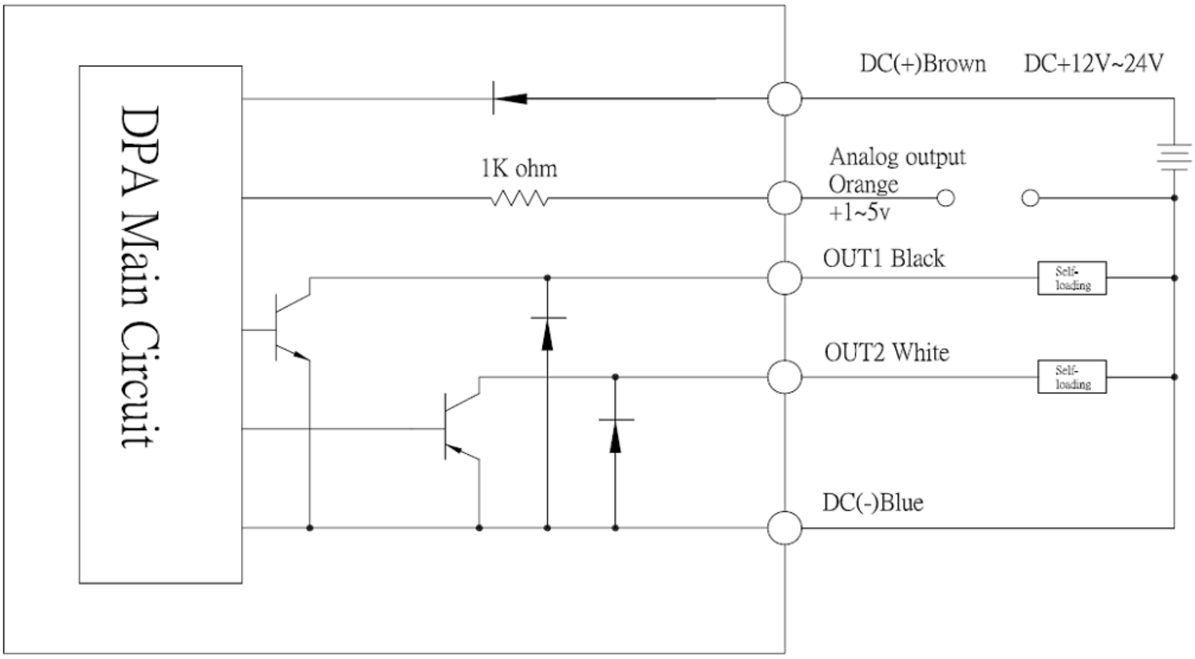

FIGURE 3. Pressure sensor system architecture

3. **Experimental Results.** The flow chart of the experimental process is shown in Figure 4. The operation of the surface decoration vacuum process will follow this procedure. The processing platform is raised to the right position, process the vacuum system to reach the vacuum pressure, let the film material close to the surface of the product, and finally remove the thin film material to complete the working process after the film material reaches the softening point.

In the experiment, the vacuum degree is measured by measuring vacuum motor current. The measurement method is to connect the resistor at the motor terminal by 0.02Ω and calculate the motor current by Ohm's law. When the vacuum motor is started, the measured voltage is 500mV by using the oscilloscope. Through the conversion, the maximum starting current is about 25A, and when the vacuum pump reaches a steady state, the voltage is 101mV and the converted current is about 5.05A.

The surface decoration techniques include painting, screen printing, electroplating, hot wheel transfer decoration, in-mold decoration, curved surface decoration and vacuum process. In the experiment, one plastic product is decorated by using the technique proposed in this paper. The images of original product and decorated product are shown in Figure 5. The parameters of the heating temperature, heating time, vacuum degree and vacuum holding time of the experiment are shown in Table 1. Based on the experimental results, there are some defect places in the product of using parameters of No. 1 to No. 5. For example, the products of using parameters of No. 1 and No. 2 are shown in Figures 6 and 7 respectively. The product of using parameters of No. 6 which is shown in Figure 8 is the best one. Therefore, based on the experimental results, the product of using parameters of No. 6 is the most appropriate.

4. **Conclusion.** In this paper, a curved surface decoration system is developed by using vacuum and heating technology. In order to enhance the efficiency of the system a programmable controller is applied. The PLC can be as a man-machine interface, the pressure detector and electromagnetic switches. The experimental results show that the surface of the plastic or metal product can be successfully coated. In order to obtain the better decoration result, some parameters such as the heating temperature, heating time, and the vacuum holding time of the processing are adjusted to obtain the proper one.

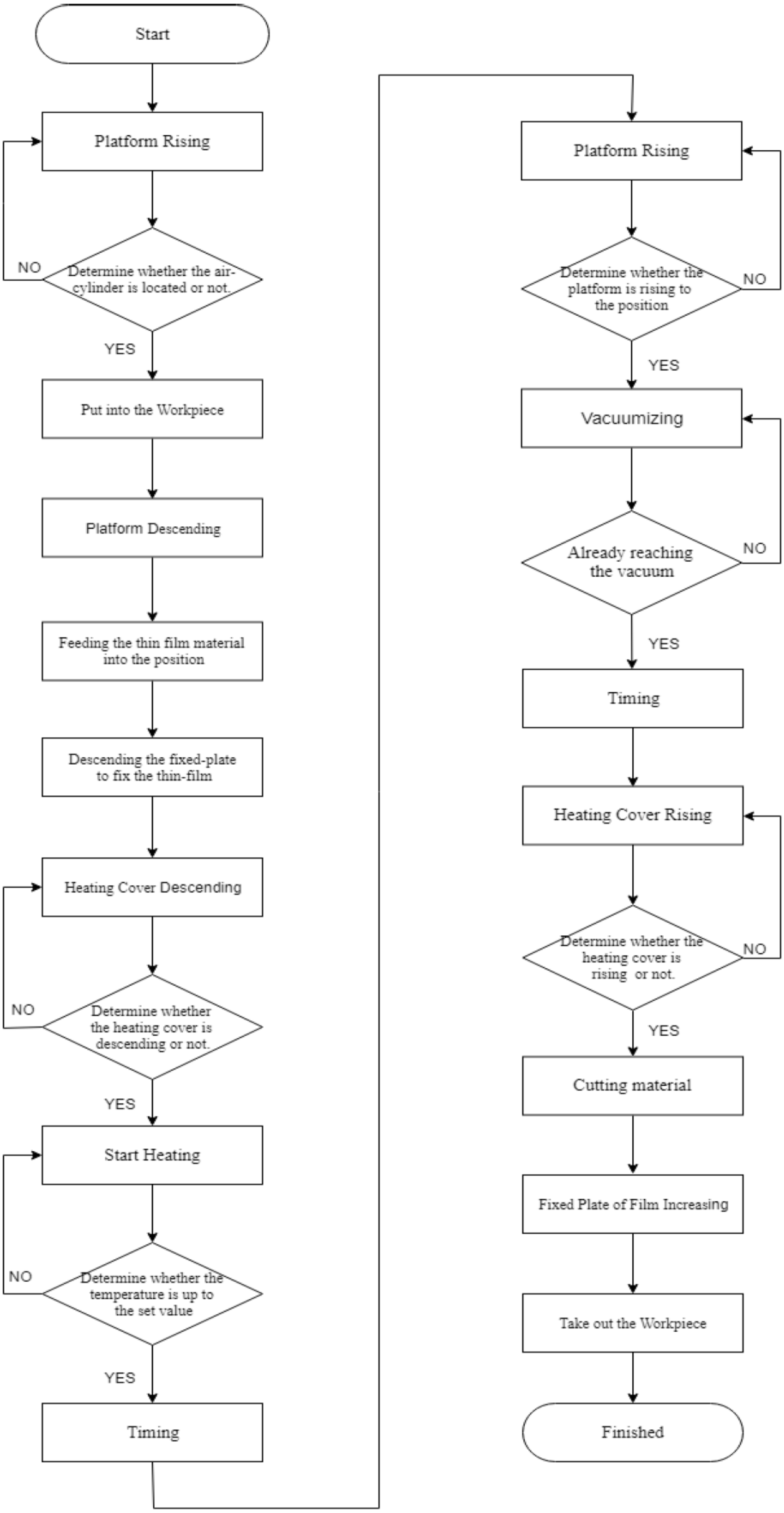

FIGURE 4. The flow chart of control process

FIGURE 5. The images of original product and decorated product

TABLE 1. Experimental parameters

	Heating temperature (°C)	Heating time (sec)	Vacuum degree (torr)	Vacuum holding time (sec)
No. 1	95	50	$9.2 * 100$	15
No. 2	100	60	$9.2 * 100$	20
No. 3	105	65	$9.2 * 100$	20
No. 4	105	65	$9.2 * 100$	15
No. 5	110	70	$9.2 * 100$	15
No. 6	110	70	$9.2 * 100$	20

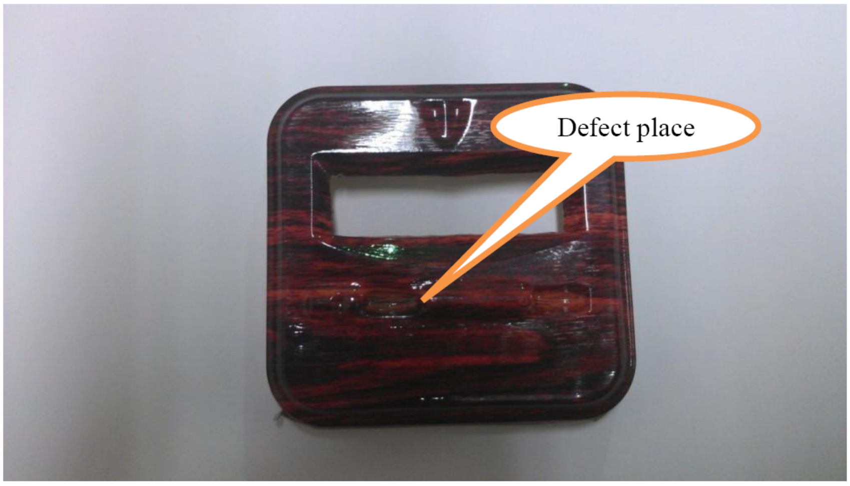

FIGURE 6. Experimental result using parameters of No. 1

Based on the experimental results, the vacuum decoration process is the best processing method. The curved surface decoration vacuum processing machine not only can have the product surface excellent visual and tactile, but also can avoid the pollution problem of the traditional spraying method. In the future, the system may add adaptive control to adjust the parameters automatically.

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Figure 7. Experimental result using parameters of No. 2

Figure 8. Experimental result using parameters of No. 6

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