Software Design of Automatic Vacuum Forming Machine for a Small Food Industry

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Abstract: This paper explains the design and testing of software for control vacuum forming machine. The design and testing is carried out using LabView software which is intended to test the feasibility of the control system before it is implemented on the actual device or vacuum forming machine. The testing arrangement also used an Arduino controller via serial communication protocol to USB in realtime. Moreover, Labview software is integrated with Arduino is capable of rendering remote automation from experiments and using an easy interface. The objective of this study is to make the automation system of thermal vacuum forming machine for small food industrial applications. Therefore, it is suited with the machine design to provide efficient operation automatically. In testing the control for vacuum forming machine software has been running and integrated with Arduino. The result shows that the temperature control can stabilize the heat after 3 minutes of heating. Meanwhile the software of Human Machine Interface monitors and helps an operator to use the machine easily. After this testing phase will be evaluated and implemented on a real machine.

1 INTRODUCTION

The development of the food industry in Indonesia also affects packaging needs (Grün, 2016). Packaging that is incompatible with food products in both form and type will result in product defects, unhygienic food, easy to expire and unattractive in terms of aesthetics. Meanwhile, to order packaging in the form that is tailored to the product to the plastic packaging factory, a high cost is required or must order in large quantities. This causes the UKM in the food sector will find it difficult to be creative in a variety of forms and types of food. Therefore, an automatic UKM scale Vacuum Forming machine with an economical cost is very important.

The Vacuum Thermoforming process is one method for processing sheet plastics into plastic packaging that can later be used to wrap food (Hussain & Safiulla, 2016). This plastic processing utilizes temperature and pressure for its processing. The working principle of the machine is that the stretched plastic sheet is placed under the heating element above the vacuum chamber, the heated plastic sheet is placed on the molding and the pressure will be reduced to help form a better material.

The vacuum thermoforming study has become the focus of several researchers. Film thermoforming for molding Polycarbonate decoration molding is done by (Chen, Huang, Lin, & Chien, 2008). Meanwhile, the product for the microfluidic system is formed using a polymer to reduce the wrinkle due to the thickness of the polymer. In order to optimize the result, Erchiqui adds infra-red during the thermoforming process(Erchiqui, 2017). Furthermore, the vehicle spare part is also used thermoforming method (Balakrishnan & Seidlitz, 2018). As an additional, the thermoforming process for the composite material is presented in the Intelligent Computation in Manufacturing Engineering conference in Naples Italia (Bruns, Bohne, Micke-Camuz, Behrens, & Raatz, 2018). However, for a small type of vacuum forming normally activated manually by an operator. The earlier design of the Vacuum Forming machine for the small food industry has been carried out where the focus of previous research was temperature control on the vacuum forming machine.

This paper focuses on developing software that was previously designed to be simpler than the previous tools. Moreover, it has been equipped with an automatic control system to produce a machine

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that is more economical, efficient. It is expected that after the software implementation, the product can be used to make plastics with various shapes for UKM industry.

2 METHODOLOGY

This paper describes three steps to develop the study namely theoretical base for the plastic forming, components required and the software designed for automatic control.

2.1 Theoretical Thermoforming

The heat transfer during the thermoforming process is considered as the type of radiation. The number of emitted radiation of a black body follows the formula (Ashter, 2014; Selke & Culter, 2015).

$$E = \sigma T^4 \qquad (1)$$

where E, σ dan T are the energy, Boltzman constant= 0.5674×10^{-10} kW/m^2 °C^4 and temperature.

In order to provide the heat, the radiation process uses a specific wavelength. The energy required for generating those wavelengths obey the rule as formulated in (Ashter, 2014; Selke & Culter, 2015).

$$E_{b,\lambda} = C_1 \lambda^{-5} / \left[\exp(C_2 / \lambda T) - 1\right] \qquad (2)$$

where C_1= 3.734 × 105 kW mm^4/m^2, C_2= 1.439 × 104 Kμm and λ is the wavelength (μm).

The heating of the plastic sheet is molded under the specific temperature (between its glass transition and melting temperature). The temperature to form the plastic depends on the material as listed on the table.

Table 2.1. Plastic transition table (Jr., 2007)

Material	Glass Tansition Temperature [°C(°F)]	Melting Temperature [°C(°F)]
Polyethylene (low density)	-110 (-165)	115 (240)
Polytetrafluoroethylene	-97 (-140)	327 (620)
Polyethylene (high density)	-90 (-130)	137 (279)
Polypropylene	-18 (0)	175 (347)
Nylon 6,6	57 (135)	265 (510)
Poly(ethylene terephthalate) (PET)	69 (155)	265 (510)
Poly(vinyl chloride)	87 (190)	212 (415)
Polystyrene	100 (212)	240 (465)
Polycarbonate	150 (300)	265 (510)

2.2 Components

The components used is considered in order to develop the control system. Inputs of the systems.

1. Temperature uses K Type Thermocouple for the feedback system (Figure 2.3).

Figure 2.1 Thermocouple Sensor

2. Limiter switch for marking the position of the tray either maximum or minimum position. (Figure 2.2).

Figure 2.2. Limiter Switch

Futhermore the outputs of the machine are:

3. Heater has a function to create the temperature required for the sheet to be molded. The chosen heater is the tubular type (Figure 2.3)

Figure 2.3 Tubular Heater

4. It uses the dc motor DC (Planetary Geared Motor) to move the tray up and down. The selected type is PG-45ZY45 (Figure 2.4). The electrical specifications are 7.4 (V) with 1 (A) of current.

Figure 2.4 dc motor

5. MD10C is dc motor driver (Figure 2.5) which is designed to drive high current brushed DC motor up to 13Amps continuously. It offers several enhancements over the MD10B such as support for both locked-antiphase and sign-magnitude PWM signal as well as using full solid state components that result in faster response time and eliminate the wear and tear of the mechanical relay.

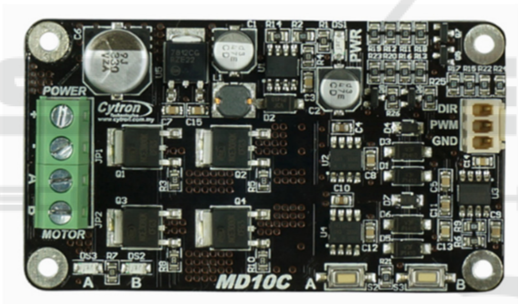

Figure 2.5 MD10C dc motor driver

3 RESULT AND DISCUSSIONS

The development of the software uses interfacing between the micro-controller with the computer (laptop). Using the laptop, an operator can select the the type of plastic sheet material. Furthermore, the selected material will result in the set point of temperature to be maintained.

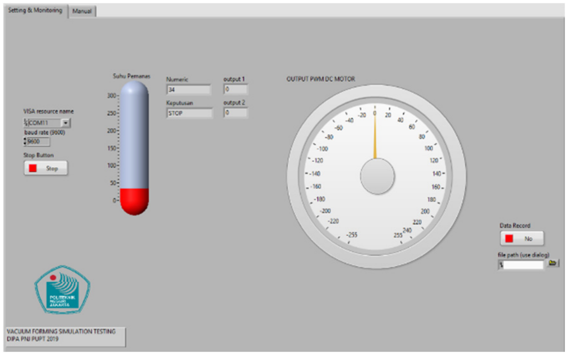

Figure 3.1. Layout of the display monitor

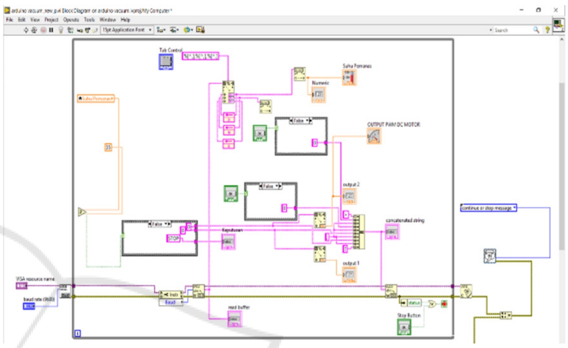

Figure 3.2. The block diagram

4 CONCLUSIONS

The conclusion of this paper is organized as follows:

- The control of temperature achieved with the temperature fluctuates steadily after steady state condition at 100°C for PVC sheet material
- The first movement of the tray to be heated requires around 3 seconds. Later on, heating process needs around 3 minutes before it moves back to the ground to be vacuumed.

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