Design of a System to Improve Technical Training Equipment Performance

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Abstract

When using automatic bread machines for research and practical exercises in the field of automation and food technology, there is no complete compliance of the obtained results with those in real production conditions, as well as meeting the technological requirements laid down in the normative documents for bread production. In the present work, through the analysis of the technological object - a baking chamber in an automatic bread machine – a precise control system is proposed, replacing the relay controller, which is more commonly used by the manufacturers.

Keywords: Process control, Feedback control, PI-control, Integrating Process, Bread machine

1 Introduction

Automatic bread machines are used in the field of research (Nachev et al., 2016; Trih et al., 2016) as small automatic laboratory devices for examining different indicators of bread quality and reducing electricity consumption.

Indicators that are mainly monitored in test laboratory tests and in production laboratories include: taste, color, odor, crust thickness. The physicochemical parameters to be determined are: mass, volume, humidity of the crumb, total moisture, porosity of the crumb. These indicators are to varying degrees influenced by the regimes of final fermentation and baking. The errors in the modes of preparation, final fermentation and baking have a significant influence on the finished product. The intense mechanical impact of the processing of weak and defective flours gives bread with serious defects in quality. These defects stem from the quality of the raw materials.

The poorly selected regimes of final fermentation and baking strongly influence the quality of the product. Therefore, proper temperature control is required as a basic indicator characterizing the effect of the automatic bread machine operation on a particular operating mode. Another application is in teaching (Hesketh et al., 2001; Dineva et al., 2011) as laboratory facilities for training in technical disciplines. Comparative analyzes of automatic bakeries have been reported (Hamlet et al., 2001), which found that the incorrect application of technological operations and the inaccurate regulation of temperature in bakeries lead to the creation of an environment for the development of pathogens in the resulting bread. It is incomplete to say that inaccurate temperature regulation leads to microbial contamination.

After baking, the bread is sterile with respect to molds and yeasts. Bacterial spores remain viable in the bakery environment of *Bac. subtilis, Bac. mesentericus*. They cause potato disease when stored because their spores are heat resistant. Therefore, the baking temperature indirectly influences the microbiological status of the bread, which is mainly influenced by the microbiological contamination of the raw materials and the manner and conditions of storage of the bread.

From the analysis of the literature, it can be considered necessary to: Improve the technological process of making bread in an automatic bread machine, as close as possible to that used in industrial production. The improvement of the technological process consists in the pre-activation of the yeast, the use of specialized lactic acid starters, the inclusion in the formulation of fats, sugars, which directly affect the firing regimes. Refine the processes of temperature regulation during fermentation and baking.

A method for improving temperature regulation is offered by Nikolova et al. (2017), by combining a relay and PID (proportional-integral-differential) controller.

The purpose of the article is to design a system for improving the performance of an automatic bread machine through a combination of relay and proportional-integral (PI) controller.

2 Material and methods

In the present work were used object approximation methods, basic PI (proportional-integral) control laws, and relay regulators described in (Astrom et al., 2006; Petrov et al., 2017).

The baking chamber of the automatic bread machine Elite BM-001 (E-Elite Bulgaria Ltd.) was used as the control object, with the main characteristics according to the manufacturer: Capacity 450g; Power 480-580W. The object is approximated to a first-order process with a time delay of the type:

[1] $$G(s) = \frac{k_o}{T_o s+1} e^{-\tau_o s}$$

A basic PI (proportional-integral) control law was used:

[2] $$y_{pi} = k_p e(t) + k_i \int_0^{100} e(t)dt$$

where y_{pi} is the calculated impact of the regulator on the object; k_p, k_i - adjustment factors; t - time, s; e - adjustment error.

A basic relay law is used:

[3] $$y_r = \begin{cases} 1, if\ y_o < y_{ref-\delta} \\ 0, if\ y_o > y_{ref+\delta} \end{cases}$$

where y_r is the calculated impact of the regulator on the object; y_0 - value of the regulated parameter; y_{ref} - setpoint of the regulated quantity; δ - hysteresis of the relay controller.

Figure 1 shows a block diagram of a control system with a combination of relay and PID controller. The switching between relay and PID (proportional-integral-derivative) controller is made by means of a comparison block. This block has a Threshold set to a value greater than or equal to k than the setpoint of the setpoint. It is necessary to determine the value of this coefficient, depending on the application of the management system and the specific site.

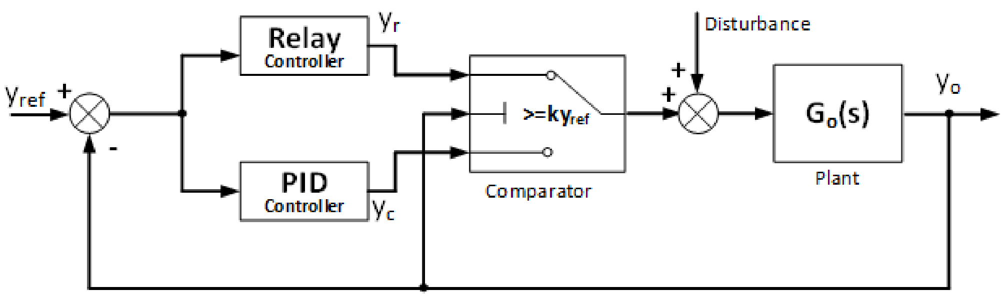

Figure 1 shows an electrical diagram of the control system used.

The system is built from a single-board computer Itead nano (Itead Inc.), type K thermocouple, Analog Output K-Type Thermocouple Amplifier - AD8495 Breakout (Adafruit Industries Inc.), SSR-25DA triac switch the input to which a 10 kΩ resistor is connected. The system controls the heating element of the household bakery. A program has been compiled in the Arduino IDE programming environment that implements the proposed combined control scheme with relay and PI regulators.

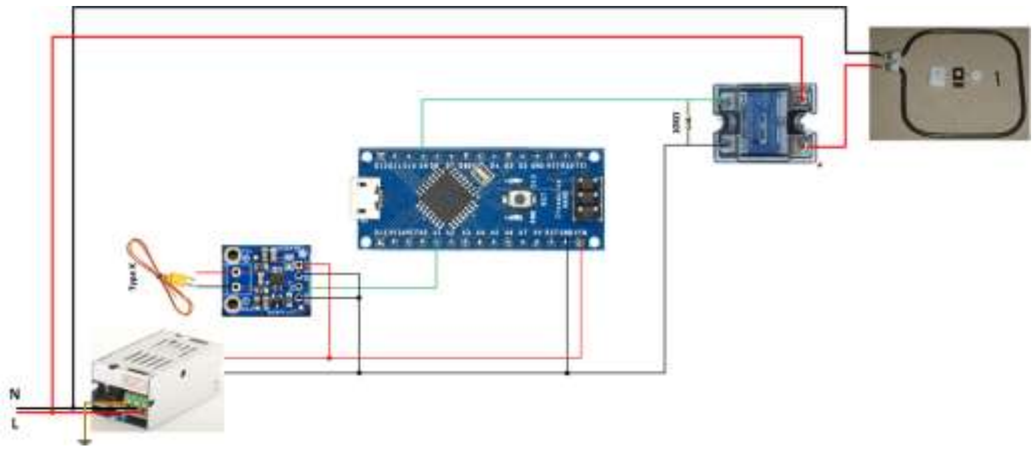

Figure 2. Schematic diagram of the control system used

3 Results and discussion

After approximation according to data obtained with the relay controller, the object is approximated to a first-order process with time delay. The object coefficient, time constant and its delay are determined:

$$[4] \quad W(s) = \frac{1{,}68}{192s+1} e^{-25s}$$

The value of the coefficient k at which the system switches between relay control and PI controller is determined depending on the time taken to reach the reference and the maximum dynamic deviation. In this work, a PI controller was used because the D component of the PID control law had a negative impact on the operation of the control system.

Figure 3 shows the relationships between the value of coefficient k, the time to reach the job, and the maximum dynamic deviation. It can be seen from the figure that at k=0.75 (at 75% of the desired process value), a switching between relay and PI control law can be made, because in this case a fast reaching of the reference is obtained and low values of maximum dynamic deviation.

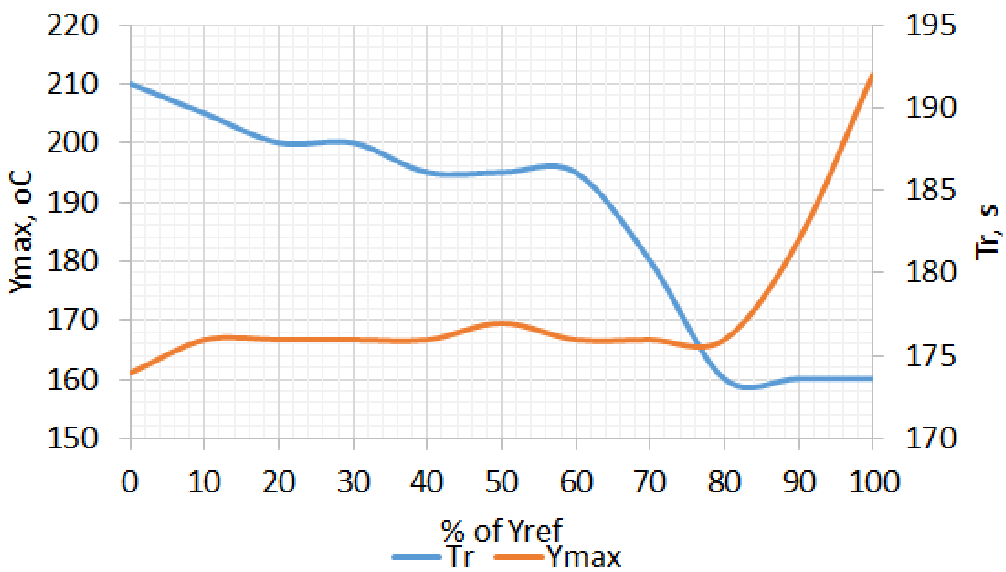

Figure 3. Relationship between k (% of Yref) and time to reach the reference temperature and maximum dynamic deviation from the set point

Figure 4 shows the performance of the proposed combined controller. The PI controller settings are kp = 1.69 and ki = 0.006125. The coefficient k = 0.75, therefore the switching between relay and PI controller is at a temperature of 131.5°C. The graph shows that there is an improvement in the operation of the site using a combined controller.

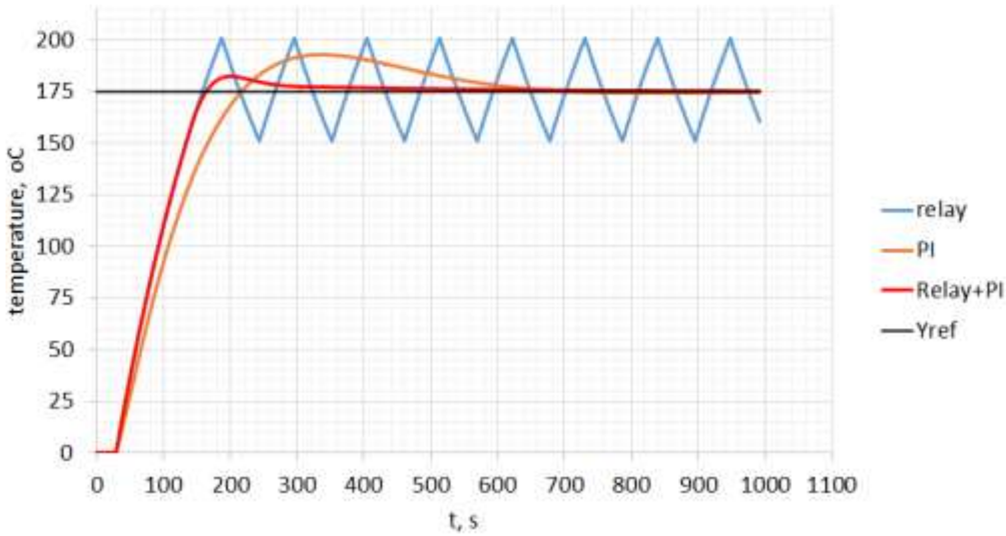

Figure 4. Operation of temperature regulators for an automatic bread machine

Table 1 presents parameters of system responses when working with different regulators. The presented temperature control system for bread baking in an automatic machine has its advantages and disadvantages. By using a relay controller, the setpoint is reached faster than the PID controller. The PID controller, for its part, precisely regulates the temperature, but reaches the set point much slower.

Table 1. Parameters of system responses when working with different regulators

Regulator	T_r, s	Y_{max}, oC	T_s, s
Relay	160	201	-
PI	220	192	690
Relay+PI	160	182	630
T_r-time to reach reference; Y_{max}-maximal temperature value; T_s-settling time			

The presented temperature control system for bread baking in an automatic machine has its advantages and disadvantages. By using a relay controller, the setpoint is reached faster than the PID controller. The PID controller, for its part, precisely regulates the temperature, but reaches the set point much slower.

In the system under consideration, it was found that the use of a PID controller containing the D (derivative) component was not appropriate. Here, its major drawback is that it exacerbates interference, leading to higher levels of overregulation. It may be recommended to use a PI regulation law when using the method of combining regulators.

Nikolova et al. (2017) make such recommendations, which indicate that with such a combination between a relay and a PID controller, the D component may have a negative impact on the effective operation of the control system. This statement is true of the management system considered here.

4 Conclusion

In this work, software and hardware tools have been adapted to improve the performance of an automatic bread machine, which can be used to meet the requirements set out in the regulatory documents.

From the measurements, calculations and analyzes made, the authors believe that:

- ✓ It is necessary to generalize the methodology for determining the value of coefficient k, which switches between relay control and PID control. This question remains unresolved;
- ✓ The use of a control law containing a differential component when combining relay and PID controllers is strictly dependent on the control object and the interference available.

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