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Control and Monitoring Panel for Cookie Tunnel Oven

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Abstract: This paper documents the development and implementation of a control and monitoring dashboard for a tunnel furnace. The results show that implementing this control panel reduced product waste by up to 27%. Implementing this type of system is possible even on manual equipment by following an appropriate methodology and using ad hoc sensors suited to the process being automated.

Keywords: Tunnel oven, automation, frequency converter, temperature sensor.

I. INTRODUCTION

In large-scale cookie production, various ingredients are mixed to form the dough, which is then rolled into sheets and cut into the desired shapes. Once the dough is cut, it is baked in tunnel ovens. These ovens are several meters long, and the temperature is controlled across their different zones [1].

In many companies, ovens operate manually. This forces operators to make manual adjustments based on constant trials of the finished product, which increases operating time and creates inconsistencies in the final product. This work presents the automation process of a line that processes two tons of product per day.

To automate the production line, it is necessary to install and calibrate temperature sensors, control the speed of the oven conveyor belt, and finally install a data visualization system.

A characteristic of tunnel ovens is that cookies enter at one end and emerge baked at the opposite end [2], [3]. Tunnel ovens are divided into multiple zones depending on their length. The final product depends on the oven temperature and the speed of the belt that transports the dough through the oven [3]. In general, the baking process is carried out through trial and error; therefore, measuring temperature and belt speed can improve it, which we take as our working hypothesis [4].

II. PANEL DESIGN

To carry out an appropriate design process, the work followed the flowchart shown in Figure 1. First, the oven operating temperatures were established, as were the conditions at the location where it would operate. Next, to make the best use of the plant's available equipment, an inventory of the oven components was prepared. In a second stage, the electronic components to be used were determined, along with the possible layout inside the control panel. Based on the collected data in the previous stage, electrical connections were designed, and circuits and protections were configured. Finally, the sensors and the data monitor were installed and calibrated.

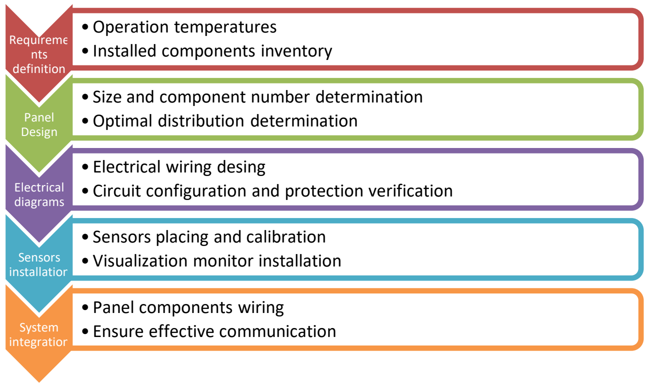

Figure 1. System control and monitoring design diagram. Source: Authors.

The baking line is 45 m long, as shown in Figure 2. The time the cookie spends in the oven is directly related to the conveyor belt's pull speed. This speed, together with the oven temperature, determines the baking of the cookie [5].

Given the company's operating conditions and safety standards, a CAD model was designed using SolidWorks. Based on the designed oven model, the dimensions and locations of the components were calculated. This approach reduced plant visits as much as possible.

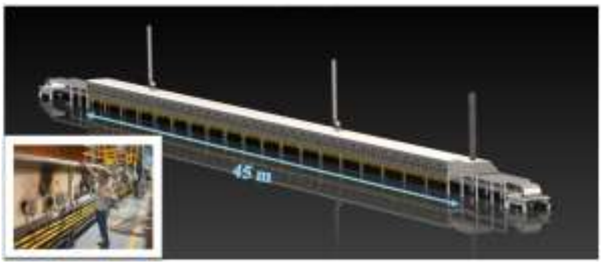

Figure 2. Schematic diagram of the production line oven. The inset shows a section of the oven. Source: Authors.

Figure 3 shows a front view and an isometric view of the designed control panel. This control panel includes two indicators to display the temperature at two points in the oven. It is also possible to adjust the speed of the belt that moves the cookies through the oven. Belt speed, along with oven temperature, is a critical factor in achieving a final product that meets plant requirements.

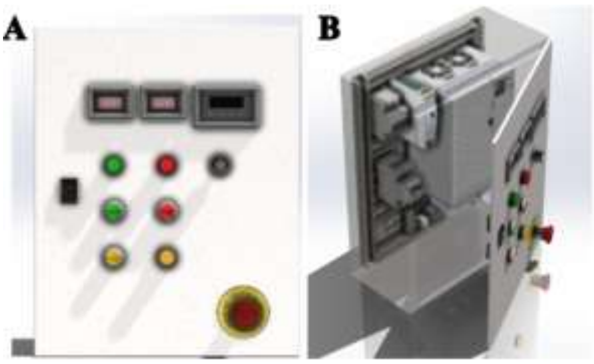

Figure 3. Design of the control and monitoring dashboard. Source: Authors.

Because the conveyor belt speed is a critical variable in the cookie-baking control process, belt speed control was included.

The oven conveyor belt uses a 15 HP motor for movement; therefore, that power rating must be considered in the speed control. A variable frequency drive (GA500, Yaskawa) was used for speed control. The steps required to configure the drive are shown schematically in Figure 4.

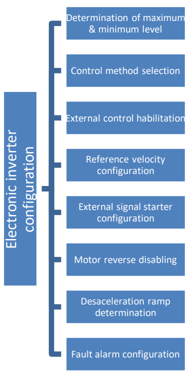

Figure 4. Variable frequency drive configuration for conveyor belt speed control. Source: Authors.

Once the drive terminal configuration was completed, integrated tests of the control circuit and its actuation were conducted to evaluate its performance under various expected operating conditions.

III. RESULTS

Figure 5 shows the designed control panel. The figure shows the temperature indicators, the belt speed display, and the start, stop, and alarm reset buttons.

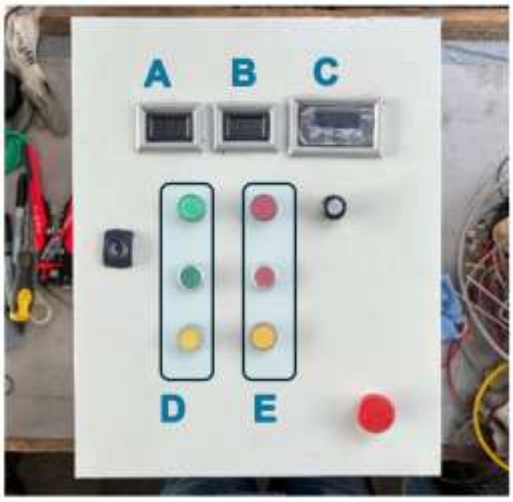

Figure 5. Final control panel. A) Inlet temperature, B) Outlet temperature, C) Belt speed, D), and E) Start, stop, and alarm reset buttons. Source: Authors.

The control panel was installed at the oven inlet. This location was determined considering operators' opinions and the company's safety criteria.

After installing the control panel, integrated tests of the control circuit and its actuation were conducted to evaluate its performance under various expected operating conditions. These tests validated proper system operation and ensured component compatibility between electrical and electronic elements.

To objectively evaluate the savings achieved through the development of the control panel, cookie production must be measured over time. Table 1 shows the cookie production data for the oven under study.

Table I. Cookie Production Data for the Oven Under Study. Source: Authors.

Time	Cookie Units	Weight (kg)
1 min	7,560	13.61
4 min	30,240	54.43

8 min	60,480	108.86
12 min	90,720	163.29
30 min	226,800	408.24
1 h	453,600	816.48
8 h	3,628,800	6531.84
24 h	10,886,400	19595.52

After each temperature or speed adjustment in the oven, wait at least 4 minutes to determine whether the product meets the quality parameters or if a new adjustment is needed. Therefore, an estimated 54 kg of product is lost per adjustment. In addition, the oven operators must walk along the 45 meters of the oven to check temperatures. This represents an additional waste of approximately 163 kg of product.

Figure 6 shows the dashboard during plant operation and during product manufacturing. An emergency stop button and temperature indicators were included in both oven sections.

Figure 6. Control panel in full operation. A), B) Temperature monitors, C) Speed, D), E) Start, stop, and alarm reset, F) Belt speed control, G) Emergency stop. Source: Authors.

IV. CONCLUSION

Based on the design and implementation of the semi-automatic control and monitoring dashboard for oven number two, the objectives set for this project were achieved. Integrating the different monitoring and control devices significantly improved operational efficiency, reduced production time, and minimized product losses, thereby confirming the established hypothesis.

As a result of these improvements, the number of trials required to adjust the oven was reduced, resulting in 268 kg less product waste per trial. Considering that three trials were previously required on average, implementing the control panel yielded approximately 800 kg of cookies per adjustment, representing a 27% optimization in the line's production.

The semi-automatic control and monitoring dashboard proved to be an effective solution for optimizing the baking process, improving system stability, and reducing product waste. This project lays the groundwork for future improvements, such as fully automating thermal control and expanding the system to other ovens within the plant.

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