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Online Monitoring of Temperature Using Wireless Module in a Rotating Drum-Applicable to Leather Industries

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Abstract: In order to ensure safe and efficient operation of unit processes, foremost requirement is accurate measurement of process variables, with which quality can be monitored and controlled. Understanding the necessity of online monitoring of process temperature in tanning/dyeing process, the article is focused on wireless measurement of physical parameters involved in wet processing of hides/ skins and monitoring through digital computer for further analysis. It's a challenging task to measure and communicate the process information from a closed rotating drum. Wireless communication is proposed because of its enhanced security, superfast operating speed, and increased mobility. The physical parameters which are predominant in tanning process are temperature, pH, conductivity etc. of the process fluid. It is necessary to carryout dyeing at 65 °C for producing raw to wet blue process. As a first attempt, wireless module for temperature measurement has been developed. The module includes signal transmitter and receiver section. In the transmitter section, the temperature which is measured by an integrated sensor is converted into frequency signal and imposed on a radio frequency signal (career signal) and get transmitted in air. On the other side, receiver section receives the radio frequency signal and converts that into electrical signals to interface with the digital computer for online monitoring. The module is able to receive and control temperature of tanning drum within a distance of 100 meters. Real time experiments on the fabricated model show interesting results for commercialization.

Keywords: Leather tanning, RF transmitter, RF receiver, serial interface, online monitoring, Human-computer interface.

1. Introduction

Unit operations of leather industries includes skin/hide preservation, soaking, unhairing, liming, deliming, bating, pickling, tanning, dyeing, drying. Automation makes the performance of each unit operations efficient. It is necessary to optimize the unit operations for the best production of leather. Among all, the tanning process is the most challenging process which decides the quality of leather. The tanning process provides the physical strength and desired qualities for the processing of leather, so as to consider being the most important unit operation [1-5]. In order to optimize the quality of leather, the process parameters should be measured and monitored to check whether the process is running on the right pathway or not. For online monitoring of the tanning operation, process parameters should be measured, transmitted, received and interfaced to display units. Here the chosen process variable is temperature of the process fluid during the tanning process. For measurement, thermocouple sensor is used. For transmission, wireless communication method is used. The practitioners always focus towards the ease, reliable, optimal and robust things [6]. Wireless communication has gained wide applicability everywhere. In early days, communication was done through wiring with more human intervention and consumption of time. Now the modern era switched the scenario with its quick accessing, online monitoring wireless communication [7]. For monitoring, digital computer is used as display device with embedded software coded to interface the signal data. Considering the industrial requirements, online monitoring module is designed and implemented for testing the operation [8]. To present the proposed work in detail, the state of the art is structured as follows; Process description is stated in Section 2, Section 3 deals with the submodules involved in the wireless measurement system and its hardware setup. Section 4 emphasizes the real time implementation and testing of sensor interfaced wireless module in the rotating drum. The research to be carried out in the future is stated in Section 5. The overall observation and results are concluded in the Section 6.

2. Process Description

The chemical process in process industries is concerned with transforming a range of inputs (raw materials) into those outputs (useful products) that are required by the market. This production process can be carried out in several steps: batch, continuous or semi-continuous (in which certain parts are done continuously and some in batch form). A part of the process may be to mix different materials, emulsify and agitate the mixture to achieve homogeneity. This can be achieved through a rotating drum or blenders or mixers. As the blenders or mixers remain closed and keep on rotating, the measurement of process parameters of the closed system remains a challenge. But precise control of a parameter is important in many process applications. For example, in tanneries most of the leather produced is chrome tanned. This is done to remove hair and non-structured proteins and fats, leaving an essentially pure collagen matrix. The hides are then preserved by impregnation / diffusion with tanning agent. It stabilizes the hide material and imparts basic properties to the hides. So, the hides are processed in a closed rotating drum with chromium ions. During this process to ensure that the hides in the drum are completely processed, workers have to interrupt the process frequently and check the hides by cutting a section or piece of it. This can be prevented by designing a sensor integrated transmitter module, which can be placed inside the drum to measure the process parameters and analyze the process status. This enables online monitoring. In the real process, leather is placed inside the rotating drum of 8 × 8 feet long, capacity of 700-1000 kilogram dipped in chromium ion mixed water solution of 1500-2000 litres. As the drum rotates of the range 3-12 rpm, leather gets mixed up with the process fluid and become a putrescible material which can be further processed to get finished products. Among the process variables, measurement of temperature is the most difficult, since the temperature rise may damage the measuring equipments and it can lead to runaway condition. It is necessary for a measuring module which can handle the harsh enclosed environment and provide the required performance [10].

To ease the analysis and implementation, a small prototype of rotating drum was designed with the specifications mentioned in Table 1.

Table 1. Specification of tank.

Process Parameters	Nominal Values
Height	15 cm
Diameter	14.3 cm
Thickness	1.12 cm
Circumference	45 cm
Volume	2416.19 cm^3
Capacity	3.5 lit
Paint/coating	Powder coating
Motor	Stepper motor
Step angle	1.8^0
Speed of motor	20 rpm
Heater rating	500 Watts
Voltage supply to heater	230 V
Power factor	unity

Fig. 1 shows the prototype of rotating drum which resembles the one used in tanning process.

Fig. 1. Schematic of a setup of rotating drum.

The drum is designed with the withstanding capacity of 100 ^{0}C temperature. In the drum model, stepper motor provides the mechanical force for the drum to rotate up to 20 rpm. Being in rotation, the heat is applied to the process fluid through heating element. The increasing temperature is measured and transmitted for the online monitoring to check the process dynamics. Here water is taken as the process fluid.

3. Wireless Measurement

A minute observation of changes in the leather processing ensures the best quality of finished leather. To analyze and tune the performance of any system, the measurement of process variables should be done [8]. The necessary actions according to the observation are needed for an efficient tanning process. This is possible only with the online monitoring. The older fashion of frequent sampling, testing, analysis, decision making can be replaced through online fast track measurement [9]. This also eliminates the human intervention, easy installation, user-friendly handling. Once the data is measured, it should be further processed to analyze the behaviour of the system to diagnose the problem to design control algorithm to drive the process towards desired performance. For data communication, signals can be either of electromagnetic waves such as radiowave signal, microwave signal, etc. depending upon the application, coverage area, frequency requirement. Wired communication channel and wireless communication channel are two types of communication channels. In older days, communication was done through wired means and acts as a conventional communication. But the recent scenario is engaged with the wireless communication mode due to its extravagant security and fast access ability. Here, the wireless communication is adopted for online measurement of temperature in a tanning process fluid at various time periods. Till now research has not carried out on online measurement of tanning process parameters. The practice of sampling the leather at different stages by the human operators is in practice still for measuring the process parameters like pH of the process fluid, pH of the skin/hide, thickness of the skin/hide, conductivity of the process fluid, etc. The wireless measuring system has been splitted into 5 modules which are: 1. Data acquisition, 2. Data processing, 3. Data conversion, 4. Data correction and 5. Data transmission. The overall block diagram of wireless module is shown in the Fig. 2 below. Here, the PCB design was done using Proteus 8 and the circuit was simulated before fabricating the module. The combined circuit diagram for the measuring system is shown in Figs. 3a and 3b.

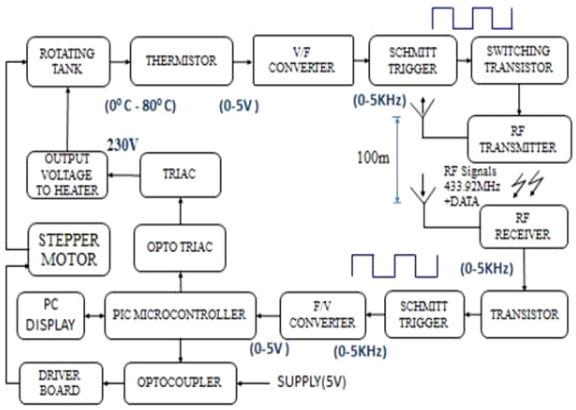

Fig. 2. Block diagram of wireless module for the measurement of temperature in a rotating drum.

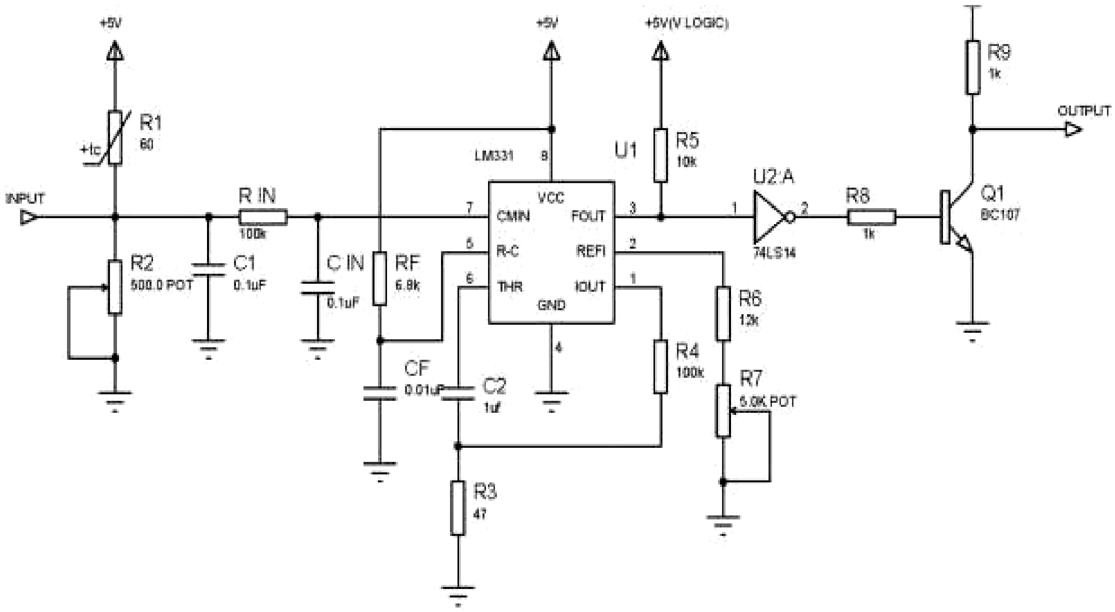

Fig. 3 (a). Transmitter circuit of measuring system.

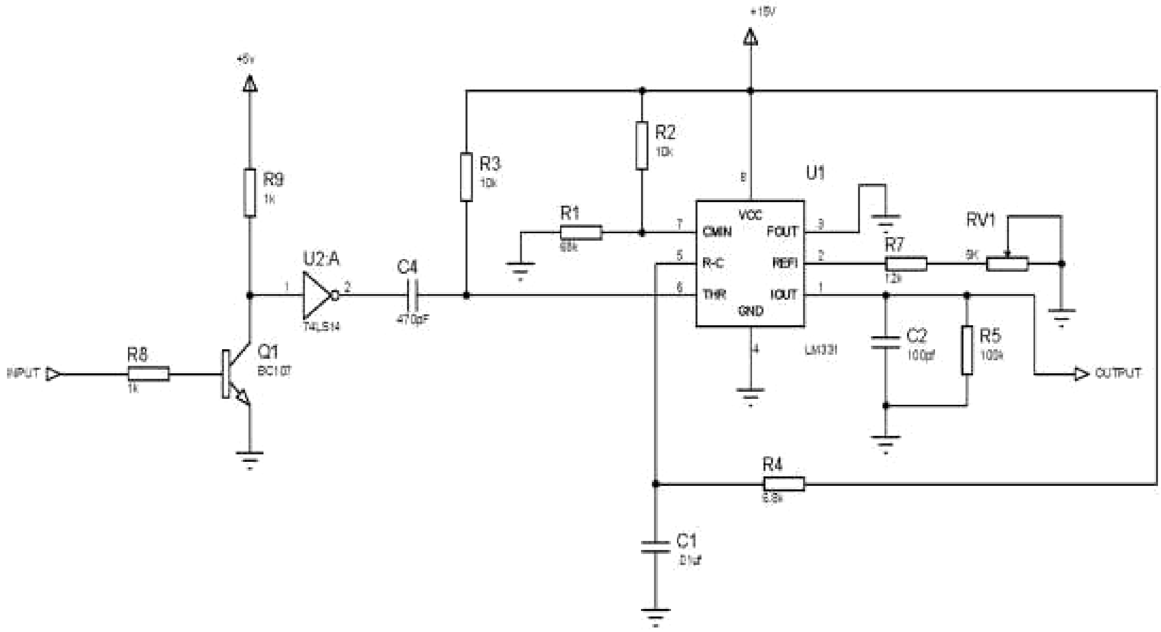

Fig. 3 (b). Receiver circuit of measuring system.

3.1. Data Acquisition Module

Data acquisition acts as a backbone for any measurement system. As the name says, it is acquiring data (process variable) from the physical system which is under observation. This module includes the sensing element which senses the actual process parameter with negligible error for further processing of data. In this module, temperature sensor of negative temperature coefficient called Thermistor is used to measure the temperature ranges from 0-225 °C. Here the reason behind choosing thermistor is to provide significantly large change of resistance for capturing the changes in temperature accurately. The added properties of thermistors are high resolution, low cost, high speed of response. For the varying temperature range, the thermistor is calibrated to change its resistance from 1 KΩ to 10 KΩ Thermistor is highly heat sensitive compared with the other sensors. As thermistor is made up of sintered semiconductors, care to be taken in deciding the type of semiconductor [7] which is the main part in sensing the temperature. Manganese oxides of metals such as nickel, cobalt, bismuth, copper, iron, and titanium can be used in thermistor. The semiconductor material used here is Bismuth oxide as it has got excellent optical and electrical properties. Every metal oxide material has its own properties which suits the temperature measurement range. For high temperature applications, titanium oxide can be utilized.

3.3. Data Processing Module

After the acquisition of process parameter data from the physical system, processing of acquired data is needed. In the present system potential divider of range 0-10 V is used to provide the corresponding electrical signal for the changes in temperature. The electrical signal is further converted by V/F converter (LM331) into the frequency of the range 0-10 KHZ which acts as the modulating signal. Schmitt trigger is used to provide pure square wave.

3.3. Data Conversion Module

After the data gets processed in the form to be suitable for further analysis and communication, it should be converted as per the requirement. Data conversion includes A/D conversion, D/A conversion, converting the signal into wireless frequency. For data conversion RF transmitter and receiver modules are designed here.

3.3.1. RF Transmitter Module

Any signal to be analyzed needs an efficient transmission with high signal to noise ratio. Here the transmission is done using radio frequency signal. Based on the requirement, the distance coverage of transmission is limited to 400/200 foot outdoor/ indoor operations. The processed modulating signal is superimposed on a carrier signal of UHF band (433.92 MHz) and gets transmitted in air for further communication through antenna. A magnetic field is induced by antenna which oscillates at the above said frequency and can be felt around 100 m as per the design. The transmitter output is up to 8 mW at 433.92 MHz with a range of approximately 400 foot (open area) outdoors. In indoors, the range is approximately 200 foot, and will go through most walls.

3.3.2. RF Receiver Module

In the receiver module, the radio frequency receiver (RF Receiver) receives the signal carried by the carrier wave of frequency 433.92MHz and fed to the further data processing components where switching transistor is used to amplify the signal voltage and Schmitt trigger generated pure square pulse. Frequency to voltage converter is used to generate the corresponding analog voltage.

3.4. Data Correction Module

The control action needed to maintain the desired performance of the system is possible through data manipulation module. Using PIC micro controller, PID algorithm is coded in such a way to track the set point temperature. As the process reaches set point, supply to the heater element becomes off and the temperature is maintained in the set point. The power electronics circuit includes TRIAC and opto coupler serves the best for providing isolation and power supply to the heater.

3.5. Data Presentation Module

As the receiver receives the transmitted signal and further processing has been done. The final stage is the online monitoring. It can be possible through display units such as LCD or LED**,** software such as Visual basics (for designing the preferred display screen), Proteus for monitoring the simulated response of the circuit. Here Visual basic software is used to present the data with its controlling actions. For interfacing the data with the digital computer, a serial interface (RS232) can be used.

4. Implementation and Testing

The temperature process was used for testing. A step change in input voltage (from 0.5 V to 3.5 V) was given when the bath temperature was recorded to rise from 29 C to 42 C. The transfer function of the process was evaluated by reaction curve method. It was found that the transfer function $G_P = \frac{1.5e^{-3s}}{65s+1}$ where time constants are in s. A PID controller was tuned with values as: proportional constant, K_C=0.06, integral and derivative constants are $\tau_I = 40$, $\tau_D = 10$ respectively. Fig. 4 shows the complete module of online monitoring system using the prototype. It was tested by increasing the temperature of the process fluid which is chosen as water here. The Figs. 5 and 6 show the profile of measured process temperature. As the temperature exceeds its maximum value, control signals are sent through PIC microcontroller by programmed PID controller to maintain the temperature in the desired level.

Fig. 4 shows the open loop response of the system, as the heat through the filament increases there is increase in the temperature of the liquid inside the tank. It can be visualized from the graph, the temperature can be raised up to 65 C. The set point is given as 40 C. Once the temperature reaches the set point value, controller will send the signal to stop heating thereby temperature of the liquid gets into the desired value.

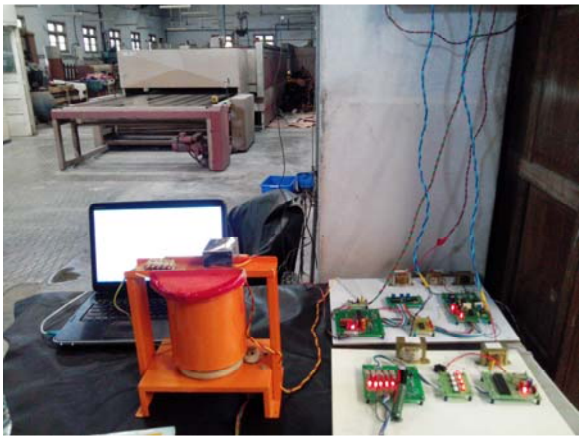

Fig. 4. Online temperature monitoring module.

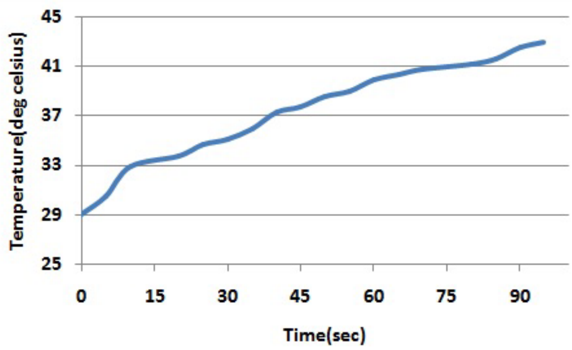

Fig. 5. Open loop response of the system.

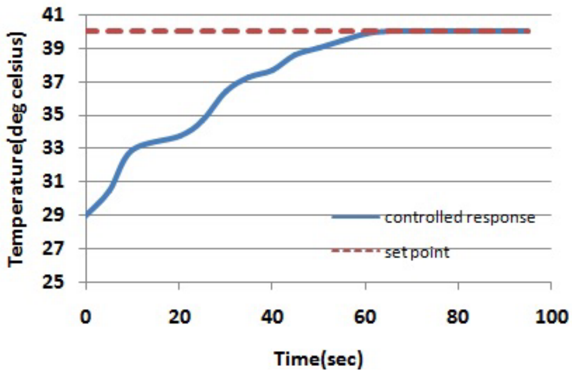

Fig. 6. Closed loop response of the system.

5. Future Scope

The next phase is to develop wireless module for measuring pH level of process fluid and the animal skin of more rotating drums as a multi process. It is not that much easy to measure the pH level of fluid as well as skin simultaneously. For that it is necessary to model the tanning process to capture the process dynamics at different operating conditions and differentiate the measurements of every rotating drum. It is proposed to use the heuristic method to monitor the process variables. Transmitter module should be developed individually for all the drums to transmit the measuring data parallel. Once the receiver receives the transmitted signal, corresponding signals of each drum should be identified and analyzed through heuristic method. Each transmitter module will transmit the corresponding frequency signals using different radio frequency signals as career signal in order to distinguish the measurement among several drums. Receiver will receive all the signals and demodulate the signals and interface with the digital computer.

6. Conclusion

A prototype resembling rotating drum used in tanning process was kept under observation with the working fluid operates at a maximum of 80 ºC. Using Thermocouple, the working temperature was measured and transmitted using RF transmitter through UHF band. A complete module for reception was developed for receiving the RF transmitted signal and monitored through personal computer using the interfacing port RS232 and display software coded using Visual basic. The temperature inside the drum was controlled using PID controller which is implemented via coded PIC microcontroller. The testing shows the successful and accurate monitoring of the process variable (temperature) at different time periods. Online monitoring module is rarely implemented for a closed rotating drum in the leather industries.

Acknowledgement

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