International Research Journal of Engineering and Technology (IRJET) e-ISSN: 2395-0056
Volume: 07 Issue: 04 | Apr 2020 www.irjet.net p-ISSN: 2395-0072

Low-Cost Temperature and Flow Control in Coffee Bean Roaster Machine

Pary Aakash K[1], Vimal E[2]

[1]*Pary Aakash K, Dept. of Instrumentation and Control Systems Engineering, PSG college of technology, Coimbatore, Tamilnadu, India.*
[2]*Asst. Prof. Vimal E, Dept. of Instrumentation and Control Systems Engineering, PSG college of technology, Coimbatore, Tamilnadu, India.*

Abstract - *In this buzzing world, everyone is busy with their day-to-day activities. Sometimes they miss their important works and duties. But the love for coffee and its taste remains the same despite the age, time, and duties. Coffee is one of the most preferred and consumed hot beverages across the world. Though the taste of coffee is different in various parts of the world, the shop which provides the same taste all the time is the most crowded and preferred. The way at which the coffee bean roasted changes the taste of the coffee. The coffee bean roaster machine used by most of the industries are manual type machines. These types of machines are highly prone to man-made errors. Manual control over the temperature is carried out which may result in an error so that the roasting profile of the coffee bean may be altered and also the taste factor. Moreover, in manual control, there will be a reduction in the quality and quantity of the coffee. So, it is necessary to automate the control of temperature and protect the coffee beans from being burnt by designing a suitable low-cost control system.*

Key Words: **Coffee bean, Roaster machine, control system, pneumatic control valve, bypass system, temperature control.**

1.INTRODUCTION

The taste of the coffee depends on several factors like the nature of milk, water to be added, sugar quantity, heating time, and many. But these factors play a role in the taste only under 20%, which is so less and it will not affect the taste of the coffee to the maximum. The remaining 80% depends on the nature of the coffee bean. The way at which the coffee bean roasted changes the taste of the coffee. A large roasting period results in well-burnt beans, which gives the denser taste. [1]Most roasters have specialized names for their favored roasts and there's little or no industry standardization. This can cause some confusion when you're buying, but generally, roasts fall under one among four color categories — light, medium, medium-dark, and dark. Many consumers assume that the strong, rich flavor of darker roasts indicates a better level of caffeine, but the reality is that light roasts have a rather higher concentration. The perfect roast may be a personal choice that's sometimes influenced by national preference or geographic location. Within the four-color categories, you're likely to seek out common roasts as listed below. It's a good idea to ask before you buy. There is often a world of difference between roasts. In the early days, people used manual methods to roast coffee beans using traditional methods. But after the industrial boon, machines were introduced to roast the coffee beans to reduce the wastage of coffee beans. One such machine is the Coffee bean roaster machine. Such machines are nowadays used in many places to roast coffee beans. One of the notable industries is the Sree Annapoorna Sree Gowrishankar restaurant located in Coimbatore which is famous for its coffee. They use the manual coffee bean roaster machine for their coffee production. Many small scale coffee powder making industries in Ooty and Nilgiris use such small coffee bean roaster machines.

1.1 Justification of the project

Roasting causes chemical changes to require place because the beans are rapidly delivered to very high temperatures. It takes years of coaching to become an expert roaster with the power to "read" the beans and make decisions with split-second timing. The difference between perfectly roasted coffee and a ruined batch is often a matter of seconds. Light brown in color, this roast is usually preferred for milder coffee varieties. There will be no oil on the surface of those beans because they're not roasted long enough for the oils to interrupt through to the surface Medium roast is medium brown in color with a stronger flavor and a non-oily surface. It's often mentioned because of the American roast because it's generally preferred within us. Medium-dark roasts Rich, dark color, this roast has some oil on the surface and with a small bittersweet aftertaste. Dark roast produces shiny black beans with an oily surface and a pronounced bitterness. The darker the roast, the less acidity is going to be found within the coffee beverage. All these different roasts depend on the temperature at which the beans are roasted. hence temperature control plays a major role in the taste of the coffee. Any product's quality and quantity will play a key role in the success of the product. The taste of the coffee depends on the roasting process it undergoes. The temperature of the roasting process is a critical component. If it is not controlled, the product will lose its value. To err is human. So, to remove such errors proper controlling unit is necessary.

2. SYSTEM DESCRIPTION

The coffee bean roaster machine as shown in fig -1, used by the industry as of now is manual type. The machine has a huge drum of 5kg capacity which is used to hold the coffee

beans for roasting. A funnel is connected to the drum for bean inlet. The drum is connected with the inductance motor for constant rotation. A mechanical lift is used for pushing the beans outside the drum after roasting. A cylinder with rotary vane is used to spread the beans uniformly to avoid attachment of beans due to heat.

Fig -1: Coffee bean roaster machine

The motor and the lift are controlled by using a PLC controller. An RTD is used to measure the drum temperature which is used only for indication. The drum is preheated before filling it out with beans up to 60°C. After that, the beans are filled. LPG is used as a fuel that is fed to the burner through a manual control valve. An ignitor is used to lit the fuel. The temperature is raised to 180°C by manually adjusting the control valve. The temperature is maintained at 180°C until the required bean color is achieved.

2.1 Specifications of the components in the Actual System

- Pipe size : 1 inch (diameter)
- Gas type : LPG
- Maximum operating pressure : 5 bar
- Maximum operating temperature of gas valve : 150°C
- Drum size : 5 Kg
- Cylinder capacity : 14.7 Kg
- Temperature sensor : RTD Pt-100
- PLC : Selec Controller
- Motor : 1ϕ induction motor

3. PROPOSED SOLUTION

Automatic temperature control in the case of a coffee bean roaster is controlling the flow of gas fuel for the burner so that that the amount of heat exposure can be controlled which is direct control of temperature. A closed-loop control system has to be designed for gas control. Since the gas is flammable electrical control valves are not allowed. Hence pneumatic operated valves must be used. For maintaining the temperature between 175°C and 185°C, ON-OFF control action with offset can be used. Proportional control valves are not used because of the high cost. Since this type of machine is used in small scale industries, a cost-effective solution is mostly preferred. So a pneumatic ON-OFF flow control valve is used with a bypass valve connected across with a manual control valve to guarantee a minimal gas flow all the time. If not used then every time the ignition process and flame detection process has to be carried out. The air supply to the pneumatic control valve is actuated by using an electrical solenoid valve which is connected with the compressor supply line. The signal from RTD is signal conditioned and given to the controller. The controller here can be of three types, PLC controller, or a built-in Schmitt trigger circuitry which acts as an ON-OFF controller, or a microcontroller. Hence a closed-loop gas control system is designed and an P&I diagram shown in fig 2 is used to illustrate the design.

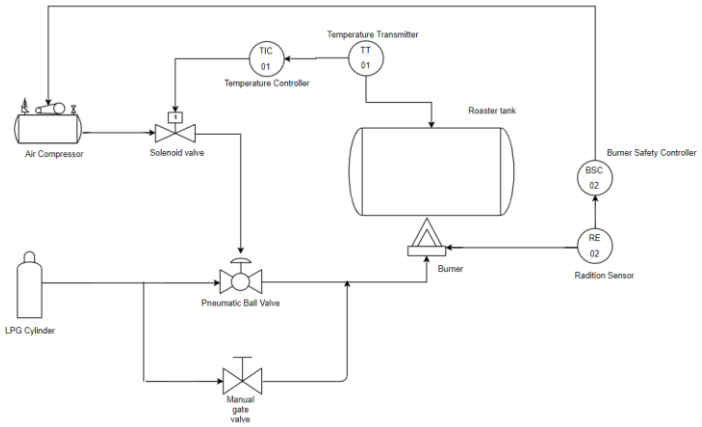

Fig -2: P&I Diagram for temperature control

4. HARDWARE DESCRIPTION

After the block diagram design, selecting suitable hardware that meets the requirement is must and important. The components have to be selected by taking cost, range, accuracy, and all other specifications into consideration. The following section lists out the selected components that meet the requirements to the maximum.

4.1 Pneumatic ball valve

A pneumatic ball valve as shown in fig -3 is a flow control valve that controls the fluid flow with the help of a rotating ball inside the cavity. This type of valve is actuated by a pneumatic signal. Once the pneumatic signal is fed to the valve it actuated the diaphragm inside the valve which changes its shape so that it rotates the ball inside the cavity. The position of the ball dictates the flow of fluid. The most used type is normally closed.

Fig -3: Pneumatic ball valve

Specifications:

• Pipe size	: 1 inch (diameter)
• Type	: Single/Double acting
• Pressure (ON)	: greater than 15 psi
• Actuator	: Solenoid driven
• Cost	: Rs. 6000
• Fluid type	: Both flammable and inflammable

4.2 Solenoid actuator

The linear solenoid works on an equivalent basic principle because the electromechanical relay has seen within the previous tutorial and a bit like relays, they will even be switched and controlled using transistors or MOSFET. A Linear Solenoid is an electromagnetic device that converts electricity into a mechanical pushing or pulling force or motion. The linear solenoid consists of an electrical coil wound around a cylindrical tube with a ferromagnetic actuator or plunger that is free to move or slide IN and OUT of the body of the coil. Solenoids can be utilized to electrically control doors and latches, valves, move and operate robots limbs and actuate switches just by energizing its coil. Fig 4 shos the solenoid actuator that can be connected with the pneumatic ball valve to control the pneumatic sugnal.

Fig -4: Solenoid actuator

Specifications:

• Pipe size	: 1/2 inch (diameter)
• Type	: Electrical actuated, NC
• Supply	: 24V DC
• Pressure	: 5-9 bar
• Cost	: Rs. 2000
• Fluid type	: Not for flammable gases, Air

4.3 Thermistor

A thermistor shown in fig 5 may be a thermally sensitive resistor that exhibits a particular and predictable change in resistance proportional to small changes in blood heat. How much its resistance will change depends upon its unique composition. Thermistors are a part of a bigger group of passive components. And unlike their active component counterparts, passive devices are incapable of providing power gain, or amplification to a circuit.

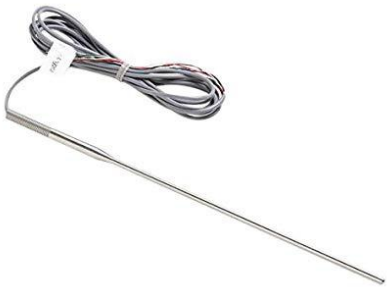

Fig -5: Thermistor

5. CONTROLLER DESCRIPTION

For the controller part, there are three different strategies. They are,

- Analog circuit design
- PLC ladder logic
- Micro-controller based

Based on the requirement and availability any of the ones can be used. If the PLC used in the industries has free I/O parts then PLC ladder logic can be used to act as a controller. If there are no free I/O parts then analog circuit design or microcontroller can be used.

5.1 Analog circuit design

The resistance change from the thermistor is converted into an electrical signal by using a Wheatstone bridge circuit. This is then signal conditioned and given to a Schmitt trigger which acts as an ON-OFF controller.

Stage 1:

The temperature range: 175°C -185°C
The resistance of thermistor for the given temperature range: 2454Ω - 2984Ω
Voltage range to be maintained: -1 V to 2.5 V

Fig 6 shows the bridge circuit that has been designed for the thermistor it function in a linear range.

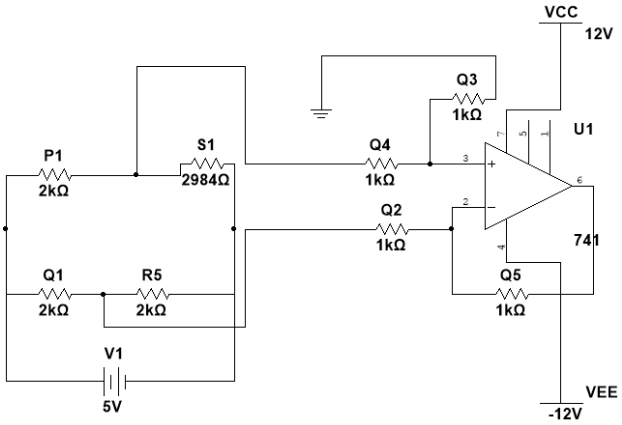

Fig -6: Bridge circuit for thermistor

Stage 2:

A signal conditioning circuit shown in fig 7 is designed which is used to fed input to the controller part.

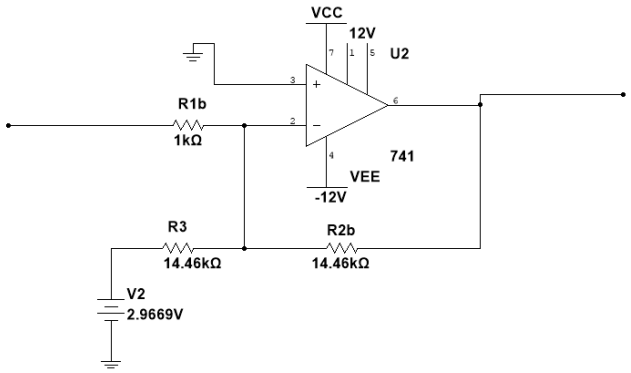

Fig -7: Signal conditioning circuit

Stage 3:

The Schmitt trigger shown in Fig 8 acts as an On-Off controller with the hysteresis of 3V. It produces high output when the voltage reaches 2.5 V as it indicates a temperature of 175°C and it produces low output when the voltage reaches -1V as it indicates a temperature of 185°C. The voltage and temperature vary inversely because the thermistor is of negative temperature coefficient type. This on-off signal is given to the electrical solenoid actuator which the intern controls the pneumatic ball valve. Thus controlling the flow of gas which intern controls the roasting temperature. Hence a closed loop is achieved.

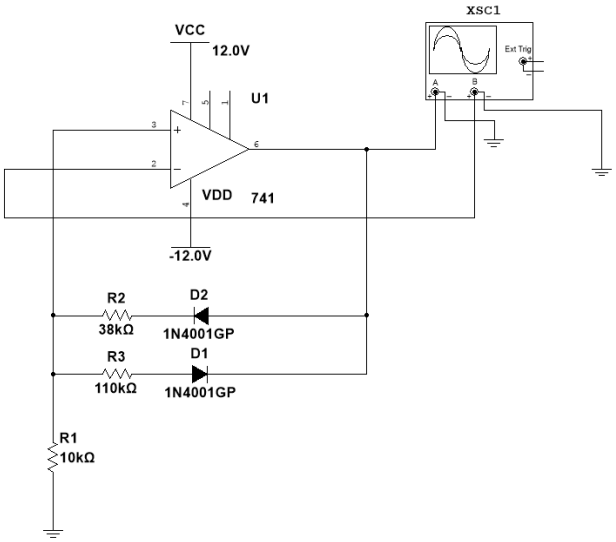

Fig -8: Schmitt trigger as the ON-OFF controller

Stage 4:

Multisim software is used to test the designed circuit. All the three stages are combined and the circuit is being simulated in multisim. Fig 9 shows the simulated output in multisim.

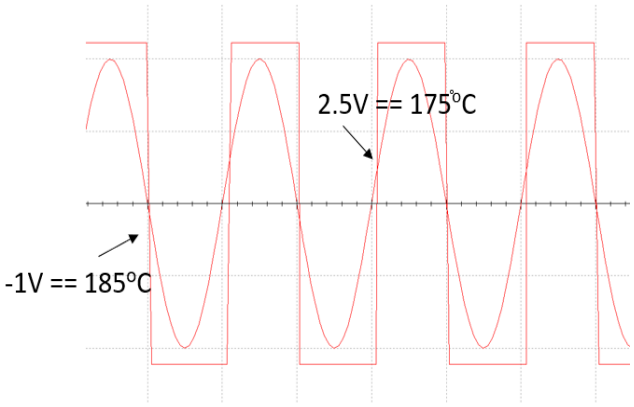

Fig -9: Multisim simulation output

5.2 PLC ladder logic design

SELPRO software is used for designing PLC ladder logic. Window comparator block is used which acts as an ON-OFF controller whose hysteresis can also be adjusted. This block replaces the entire analog circuit designed. Fig 10 shows the hysteresis block which imitates the same functionality as of the on off controller in analog circuit design.

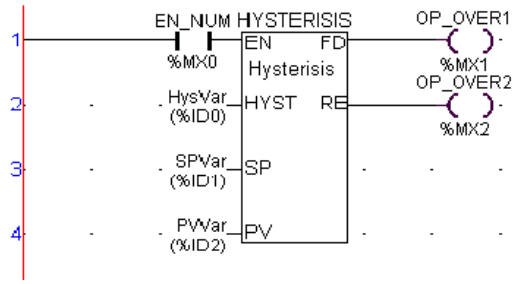

Fig -10: PLC ladder logic

5.3 Microcontroller based design

The 8051 microcontrollers are used where the control action is fed as code. It has two inputs one is the input from the thermistor and the other is the desired temperature that has to be maintained. One output that sends either high or low output. This method may not be suiable for most of the applications due to its nature and properties. Mostly PLC and analog circuit design is preferred. Fig 11 shows the simple block diagram of how micro controller can act as a temperature controller in coffee bean roaster machine.

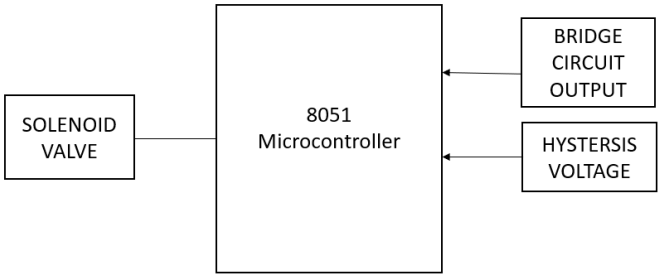

Fig -11: Microcontroller based design

6. CONCLUSION

Thus, low-cost temperature control in a coffee bean roaster machine is achieved by using a bypass valve system that ensures a continuous supply of LPG gas to the burner. A solenoid valve acts as an actuator to the pneumatic ball valve to ensure there is no electrical contact with the LPG gas line. Three different controllers are also designed for controlling the temperature inside the drum. The controller can be chosen based on the components available in the industry and the cost. PLC is the most preferable controller because the machine has already PLC installed in it. The ports in the existing PLC can be used to achieve the necessary operation. In addition to that image processing can also be used to ensure the roast quality by color recognition and make the system entirely a human-less machine. Hence a low-cost solution is achieved for changing a manual coffee bean roaster to an automatic coffee bean roaster machine.

REFERENCES

[1] Dr. Alfonso J. Kinglow Ph.D., "The Complete Coffee book," 2013, pp. 60 - 61.