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A Novel Approach to Thermistor Control of Quench Oil Temperature*

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Abstract

This paper concerns the simulation study and mathematical calculation for thermistor control of Quench Oil Temperature using Proteus simulation software. In Industrial processes to impart the proper metallurgical qualities in a metal, heat treated metal parts are quenched in either oil or water. The parts are immersed in a bath of quench oil as soon as they leave the heat treating chamber. The motor driving the re-circulating pump is a series universal motor. The average voltage applied to motor terminals determines its speed of rotation. Since the motor drives the pump, the rotational speed of the motor determines how much oil re-circulates and thereby determines the amount of cooling that takes place. As the motor speeds up, more oil re-circulates, and the oil in the tank tends to cool down. As the motor slows down, less oil re-circulates, and the oil in the tank tends to warm up.

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Keywords: Quench Oil; Pump; Thermistor; Resistance; Temperature.

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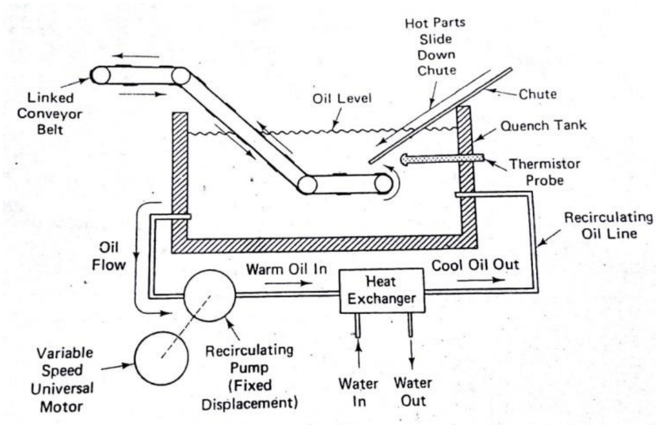
1. Introduction

Very often, heat treated metal parts must be quenched in either oil or water in order to impart the proper metallurgical qualities to the metal. In most such processes, the parts are immersed in a bath of quench oil as soon as they leave the heat treating chamber. Naturally, the temperature of the quench oil as soon as they leave the heat treating chamber. Naturally, the temperature of quench oil tends to rise due to continual dunking of hot metal parts. To accomplish the desired quenching results, the quench oil must be maintained within certain temperature range, this is done by cooling the oil in a heat exchanger. The situation is illustrated in Fig.1. The hot parts slide down a chute into the quench tank, landing on a link belt which catches them on its spurs. The moving belt carries them horizontally through the quench oil and then up and out of the tank. An oil pipe allows oil to flow out of the tank and into fixed displacement re-circulating pump. A fixed displacement pump moves a fixed volume of liquid on each revolution, so the speed of rotation of the pump determines how much oil re-circulates through the cooling system.



°Fig.1 Physical Layout of Quench oil Temperature control

The outlet of the pump feeds into a water cooled heat exchanger. From the heat exchanger, the re-circulating oil passes back into the quench tank.

The motor driving the re-circulating pump is a series universal motor, capable of operating on either ac or dc. In this system, it is operated on ac voltage. The average voltage applied to motor terminals determines its speed of rotation. Since the motor drives the pump, the rotational speed of the motor determines how much oil re-circulates and thereby determines the amount of cooling that takes place. As the motor speeds up, more oil re-circulates, and the oil in the tank tends to cool down. As the motor slows down, less oil re-circulates, and the oil in the tank tends to warm up.

The quench oil temperature is sensed by a thermistor mounted inside a probe, which is protective shield. A thermistor is an ideal temperature transducer for this application because it produces a large response for small temperature changes, and because it suited to the fairly low temperatures encountered in quenching processes (usually less than 200°F).

2. Control Circuit

The thermistor is connected into the control circuitry as shown in Fig.2. The bridge rectifier, in conjunction with the clipping circuit comprised of R1 and ZD1, supplies an approximate square wave across the Q1 circuitry. This square wave has a peak value of 20v and is synchronized with the ac line pulsations, as we have seen before. At that instant the 20v supply appears, the R2-Rth series combination divides it up. The voltage available for driving the base emitter circuit of Q1 depends on just how the R2-Rth voltage divider divides the 20V. If the thermistor resistance is Rth is high, a small voltage will appear across R2, and the base emitter drive will be small. If the thermistor resistance is low, a larger voltage will appear across R2 due to voltage divider action, and the base emitter drive will be large.

The voltage available to drive the base emitter circuit determines the Q1 emitter current, according to (Eq.1)

Where Vr_2 stands for the voltage appearing across resistor R2.

Equation1 is just ohms law applied to the emitter resistor. It shows that an increase in Vr_2 causes an increase in emitter current.

The Q1 collector current is virtually the same as the emitter current. As the diagram shows, the Q1 collector current charges capacitor C1. When C1 charges to the peak point of the UJT, the UJT fires. The resulting current pulse is delivered to the TRIAC gate. The TRIAC then turns on and applies power to motor terminals.

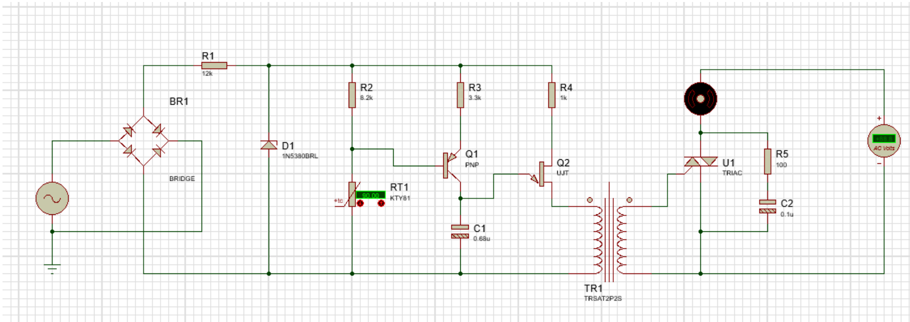


Fig.2 Control Circuit

$$Ie = \frac{Vr_2 - 0.6\text{ v}}{3.3\text{ k}\Omega} \qquad \textit{(Eq1)}$$

To summarize the behavior of this circuit, the greater the voltage across R2, the greater the charging current to C1. If the C1 charging current is greater, the UJT will fire sooner in the half cycle, and the power delivered to the motor will be greater. This causes the motor and pump to spin faster.

If the voltage across R2 is small, the Q1 collector current will charge slowly. This causes late firing of the UJT, TRIAC and reduced motor speed. An increase in oil temperature results in a lowering of the thermistor resistance Rth, due to the thermistor's negative temperature coefficient. Lowering the Rth causes an increase in Vr_2 by voltage divider action. As we have seen, an increase in Vr_2 causes the pump to run faster. This recirculates more oil through the heat exchanger and tends to drive the temperature back down.

The thermistor characteristic is such that at 140°F, Rth=30kΩ, so

$$\frac{V_{r2}}{20V} = \frac{R2}{R2 + Rth} = \frac{8.2k\Omega}{8.2k\Omega + 30k\Omega}$$

$$Vr2 = 4.3V$$

The emitter current is given by Eq.1

$$I_E = \frac{4.3V - 0.6V}{3.3k\Omega} = 1.12mA$$

Therefore IC, the capacitor charging current, equals 1.12mA also. Assuming that the UJT has a standoff ratio η equal to 0.64, the UJT peak voltage is given by

$$Vp = (0.64)(20V) + 0.6V = 13.4V$$

Therefore the capacitor must charge to 13.4V to fire the UJT and TRIAC. The time required to do this can be found from

$$\frac{\Delta V}{\Delta t} = \frac{I}{C}$$

This expresses the voltage buildup rate for a capacitor. Rearranging, we obtain

$$\Delta t = \frac{C}{I}(\Delta V) = \frac{(0.68\mu F)(13.4V)}{1.12mA} = 8.14ms$$

Therefore the UJT should fire at about 8.14ms after the start of the cycle. This time can be expressed as angle by saying that

$$\frac{\theta}{360^{\circ}} = \frac{8.14ms}{16.67ms}$$

Where 16.67msec is the period of the 60 Hz AC line. Thus the firing delay angle is calculated as 176° when the oil temperature is 140°F.

Table 1. Resistance or Temperature verses Revolution

Resistance –R2(k ohm)	Temperature °F	Revolution Time (ms)
8.2	140	8.14
20	160	6.85
30	180	3.28
40	200	1.55

The above table depicts the different values of resistances, Temperature and the corresponding time taken by the motor to spin.

3. Results and Discussions

Fig.3 below shows the waveform across the supply and load. This particular circuit is designed to start recirculation when the tank oil reaches 140°F. Below 140°F the motor does not run at all. Above 140°F the UJT and TRIAC start firing and motor begins running. Therefore for temperature of exactly 140°F, the TRIAC should be on the verge of firing. This is equivalent to saying that the firing delay angle should be 180°. When the temperature is 140°F then any slight increase in temperature beyond that point will reduce the firing delay angle to less than 180°. And cause the motor and pump to start running. Any further temperature rise from this point will cause the firing delay angle to be reduced, and consequently, the motor and pump begin to run faster. The pump is then able to hold the oil temperature close to 140°F

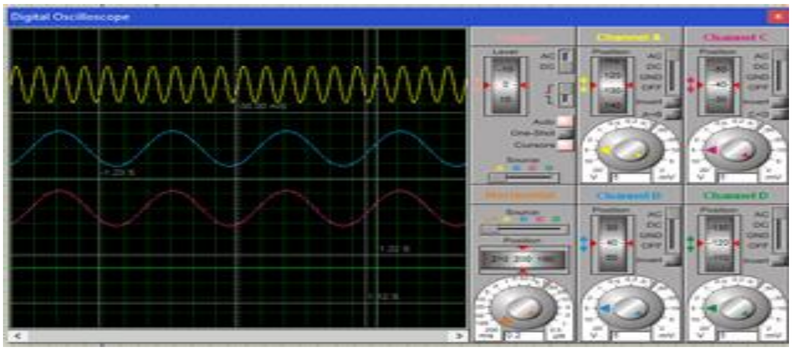


Fig.3 Waveform across Supply and Load

From Table1 it is observed that as the resistance and temperature increases the time taken by motor to spin decreases.

Conclusion

The proposed paper gives the better understanding and results for the designed circuit of thermistor controlled quenching process. Further it is desired for some reason to have a variable temperature set point, the R2 resistor could be replaced by a potentiometer, which concludes that as the pot resistance is increased, the temperature set point will be lowered and as the pot resistance is decreased, the temperature set point will be raised. Thus the designed circuit varies as temperature and resistance varies and motor is controlled.

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Biography

Mohammed Afzal is a research Student pursuing Electronics and Instrumentation Engineering from Muffakham Jah college of Engineering and Technology, Hyderabad, INDIA 2016. His research area of interests includes Digital Electronic, Logic Design, Linear Integrated circuits for control, automation of various process and iot embedded systems for smart home and wireless controlled devices.

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