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MATHEMATICS

FUZZY LOGIC CONTROL IN HIGH TEMPERATURE FURNACE

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Abstract

This work presents a novel technique to maintain temperature of a furnace using Fuzzy Logic. The furnace temperature has to be controlled and maintained upto 1500 degree Celsius and the purpose of the furnace is to study the characteristics of welding materials at very high temperature. Since the range of temperature above ambient is fairly high and the furnace working area is also large, the phenomenon of maintaining the temperature at the desired value poses many challenges. In this work, Fuzzy Logic Control (FLC) system has been implemented by duly considering the working temperature range, as well as working area. The advent of the control system is, its ability to attain the set temperature at the set time and also to maintain it. A complete study of the furnace, as well as TRIAC based final control element has been done. The choice of membership function is done, so that to minimize steady state errors and also to reach the set temperature at the pre-defined time interval.

Fuzzy Logic uses conventional electronics and instrumentations along with Micro controllers for controlling the furnace temperature. Complete mathematical modeling of the furnace temperature control system based on fuzzy technique delivers a good solution to this work.

Keywords: Pulse width Modulation, Fuzzy logic control, Fuzzy logic

Fuzzy Logic Control

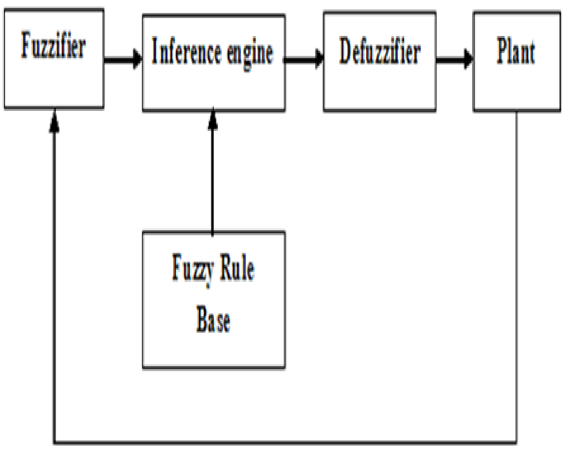
Fuzzy logic is well suited to implementing control rules that can only be expressed verbally, or systems that cannot be modeled with linear differential equations. Rules and membership sets are used to make a decision.

Fuzzy logic based on the way the brain deals with inexact information. Fuzzy systems are structured numerical estimators. Fuzziness describes the ambiguity of an event. A fuzzy logic set is a mathematical way to represent vagueness in the form of membership function which varies from 0 to1 [1], [2]. The basic idea behind FLC is to incorporate the "expert experience" of a human operator in the design of the controller in controlling a process whose input-output relationship is described by a collections of fuzzy control rules (example IF THEN rules) involving linguistic variables rather than a complicated dynamic model.[4].

Fuzzy implementation

The typical architecture of FLC is shown in the block diagram and it has four principle components a fuzzifier, a fuzzy rule base, an inference engine and a defuzzifier. FLC offers several unique features that make it a particularly good choice for control problems like harmonic reduction and power factor control.

It is inherently robust since it does not require precise, noise-free inputs and can be programmed to fail safely if a feedback sensor quits or is destroyed. The output control is a smooth control function despite a wide range of input variations.



Since the FL controller processes user-defined rules governing the target control system, it can be modified and tweaked easily to improve or drastically alter system performance. New sensors can easily be incorporated into the system simply by generating appropriate governing rules.

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FL is not limited to a few feedback inputs and one or two control outputs, nor is it necessary to measure or compute rate-of-change parameters in order for it to be implemented. Any sensor data that provides some indication of a system's actions and reactions is sufficient. This allows the sensors to be inexpensive and imprecise thus keeping the overall system cost and complexity low.

Because of the rule-based operation, any reasonable number of inputs can be processed (1-8 or more) and numerous outputs (1-4 or more) generated, although defining the rule base quickly becomes complex if too many inputs and outputs are chosen for a single implementation since rules defining their interrelations must also be defined. It would be better to break the control system into smaller chunks and use several smaller FL controllers distributed on the system, each with more limited responsibilities.

FL can control nonlinear systems that would be difficult or impossible to model mathematically. This opens doors for control systems that would normally be deemed unfeasible for automation.

The dynamic response and the stability of the FLC is far better than the conventional PI and PID controllers[3],[5].

Thermocouple

Thermocouples are one among the easiest temperature sensors that are widely used in science and industry. They are based on the See back effect that occurs in electrical conductors that experience a temperature gradient along their length.

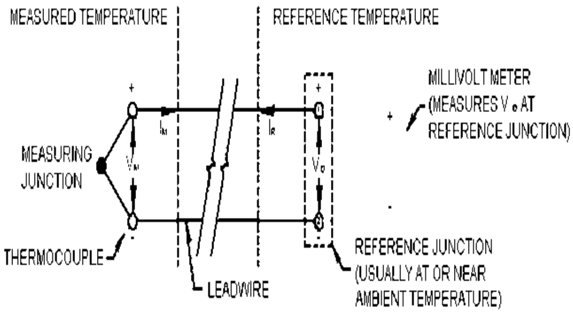
A thermocouple is a junction between two different metals that produces a voltage related to a temperature difference. Thermocouples are widely used type of temperature sensor and can also be used to convert heat into electric power. They are cheap and interchangeable, have standard connectors, and can measure a wide range of temperatures. The main limitation is accuracy; System errors of less than one Kelvin (K) can be difficult to achieve [5].

Thermocouples for practical measurement of temperature are made up of specific alloys, which in combination have a predictable and repeatable relationship between temperature and voltage.

Thermocouples are standardized against a reference temperature of 0 degree Celsius. practical instruments use electronic methods of cold-junction compensation to adjust for varying temperature at the instrument terminals.

Electronic instruments can also compensate the varying characteristics of the thermocouples and to improve the precision and accuracy of measurements

In our project we need to measure the temperature of about 1400°C to 1500°C.Type C Thermocouples have positive Tungsten 5%Rhenium wires and negative Tungsten 26%Rhenium wires. These alloys have inherently poor oxidation resistance and therefore recommended for use in vacuum, hydrogen or inert gases. The maximum operating temperature for this alloy is 2760°C.[5]



Nature of furnace

A induction furnace is an electrical furnace in which the heat is applied by induction heating of a conductive medium (usually a metal) in a crucible placed in a water-cooled alternating current solenoid coil.

The advantage of the induction furnace is a clean, energy-efficient and well-controllable melting process compared to most other means of metal melting. Most modern foundries use this type of furnace and now also more iron foundries are replacing cupolas with induction furnaces to melt cast iron, as the former emit lots of dust and other pollutants. Induction furnace capacities range from less than one kilogram to one hundred tonnes capacity, and are used to melt iron and steel, copper, aluminum, and precious metals.

The one major drawback to induction furnace usage in a foundry is the lack of refining capacity; charge materials must be clean of oxidation products and of a known composition, and some alloying elements may be lost due to oxidation (and must be re-added to the melt).

Operating frequencies range from utility frequency (50 or 60 Hz) to 400 kHz or higher, usually depending on the material being melted, the capacity (volume) of the furnace and the melting speed required. [9].

Generally the smaller the volume of the melts the higher the frequency of the furnace used; this is due to the skin depth which is a measure of the distance an alternating current can penetrate beneath the surface of a conductor.

For the same conductivity the higher frequencies have a shallow skin depth - that is less penetration into the melt. Lower frequencies can generate stirring or turbulence in the metal.A preheated 1-tonne furnace melting iron can melt cold charge to tapping readiness within an hour.

An operating induction furnace usually emits a hum or whine (due to magnetostriction), the pitch of which can be used by operators to identify whether the furnace is operating correctly, or at what power level. [9].

ADC

The AD574A is a complete 12-bit successive-approximation analog-to-digital converter with 3-state output buffer circuitry for direct interface to an 8- or 16-bit microprocessor bus. A high precision voltage reference and clock are included on-chip, and the circuit guarantees full-rated performance without external circuitry or clock signals.

The AD574A design is implemented using Analog Devices' Bipolar/I2L process, and integrates all analog and digital functions on one chip. Offset, linearity and scaling errors are minimized by active laser trimming of thin-film resistors at the wafer stage. The voltage reference uses an implanted buried Zener for low noise and low drift. On the digital side, I2L logic is used for the successive-approximation register, control circuitry and 3-state output buffers.

The AD574A is available in six different grades. The AD574AJ, K, and L grades are specified for operation over the 0 C to +70 C temperature ranges.

Operation

The AD574A is a complete 12-bit A/D converter which requires no external components to provide the complete successive approximation analog-to-digital conversion function. A block diagram of the AD574A is given below.

Microcontroller AT89C51

Features

- Compatible with MCS-51™ Products
- 4K Bytes of In-System Reprogrammable Flash Memory
- Fully Static Operation: 0 Hz to 24 MHz
- Three-level Program Memory Lock
- 128 x 8-bit Internal RAM
- 32 Programmable I/O Lines
- Two16-bit Timer/Counters
- Six Interrupt Sources

The AT89C51 is a low-power, high-performance CMOS 8-bit microcomputer with 4Kbytes of Flash programmable and erasable read only memory (PEROM). The device is manufactured using Atmel's high-density nonvolatile memory technology and is compatible with the industry-standard MCS-51 instruction set and pin out. The on-chip Flash allows the program memory to be reprogrammed in-system or by a conventional nonvolatile memory programmer. By combining a versatile 8-bit CPU with Flash on a monolithic chip, the Atmel AT89C51 is a powerful microcomputer, which provides a highly flexible and cost-effective solution to many embedded control applications.

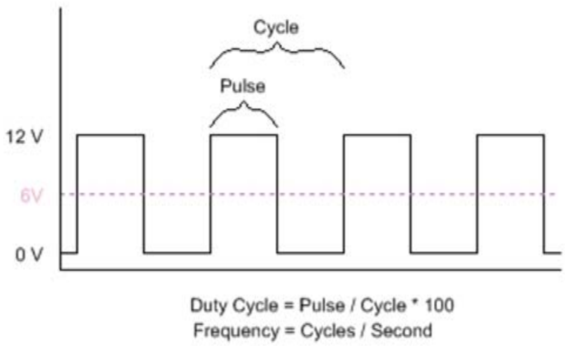
The AT89C51 provides the following standard features: 4K bytes of Flash, 128 bytes of RAM, 32 I/O lines, two 16-bit timer/counters, a five vector two-level interrupt architecture, a full duplex serial port, on-chip oscillator and clock circuitry. In addition, the AT89C51 is designed with static logic for operation down to zero frequency and supports two software selectable power saving modes. The Idle Mode stops the CPU while allowing the RAM, timer/counters, serial port and interrupt system to continue functioning. The Power-down Mode saves the RAM contents but freezes the oscillator disabling all other chip functions until the next hardware reset.

PWM technique

PWM or Pulse Width Modulation refers to the concept of rapidly pulsing the digital signal of a wire to simulate a varying voltage on the wire. This method is commonly used for driving motors, heaters, or lights in varying intensities or speeds.

A few terms are associated with PWM:

- Period - how long each complete pulse cycle takes
- Frequency - how often the pulses are generated. This value is typically specified in Hz (cycles per second).
- Duty Cycle - refers to the amount of time in the period that the pulse is active or high.
- Duty Cycle is typically specified as a percentage of the full period.

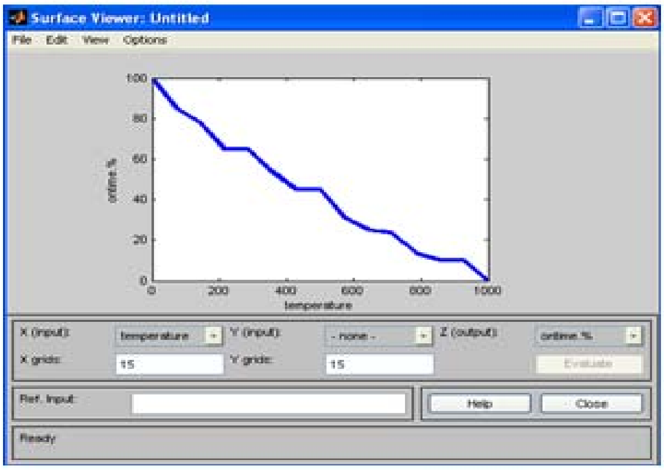


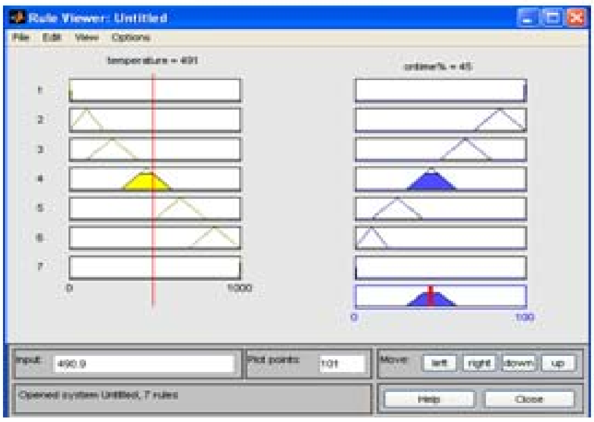
PWM duty cycle

A simple method of obtaining the characteristics of the PWM signal is to split the analogue signal into a number of discrete segments equal to the length of the PWM period. Then, the PWM cycle for this period can be set equal to the average of the analogue signal over this same interval.

Experimental Result Fuzzy Rules

Furnace Temperature	TRIAC ON Time %
If cold	Then 100% on time
If cool	Then 80% on time
If low	Then 60% on time
If warm	Then 45% on time
If hot	Then 30% on time
If very hot	Then 10% on time
If set temp	Then 0% on time





Conclusion

Fuzzy Logic Control (FLC) in high temperature furnace for material characterization was designed for temperature control. The performance of the FLC based system was evaluated and compared with the traditional PID controller.

In earlier PID controller was tuned by stepwise determining the control parameters. FLC was tuned with a ramp function to determine the membership function of input and output domains. The FLC perform superior to the PID controller, showing faster transient response and less overshoot and oscillation. But it had some steady state errors. This was caused by the coarse tuning and small size of fuzzy set.

Future scope

Fuzzy logic control gives various advantages over the presently used PID control. But, fuzzy logic control introduce steady state error in the system which can be improved by training membership function and increase number of membership function. Now the new control like neuro fuzzy can be employed for the above application with which high degree of accuracy system handling error and stability can be achieved.

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