

Closed Loop Temperature Control and Auto-Tuning

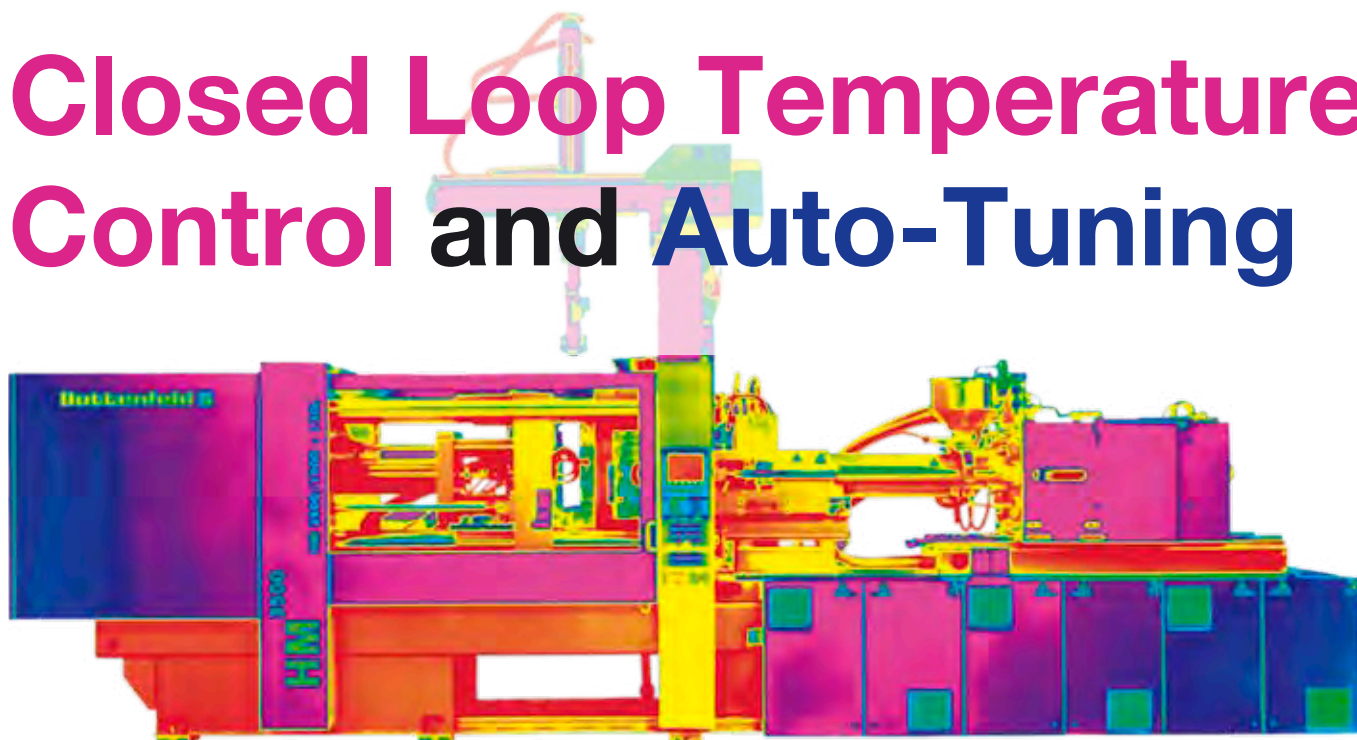


Image source: Battenfeld

In thermal plants, the place where power is introduced is normally not at the same position where the temperature sensor is located. In between these two locations, a heat conduction process usually takes place in a solid body (e.g. a metal block in extruders or injection molding machines). This diffusive heat transferring process results in a minimum-phase system behavior with higher-order delays and high system time constants.

Heating units are usually electrical resistance heaters and are controlled and clocked with semiconductor relays.

Cooling systems are usually designed as forced convection cooling systems with a set approach velocity (fans with impellers) or as evaporation cooling systems. With evaporation cooling systems, the cooling effect is based primarily on a phase transformation (evaporation) while exploiting the high evaporation enthalpy of the cooling medium (usually water).

Whereas heating elements can usually be characterized linearly, cooling systems are generally non-linear due to the complex physical relationships present (turbulent flows, heat transfer over boundary layers, phase transformations, etc.). Additional non-linearities are caused by radiative and free convection heat transfer to the environment.

Due to high system time constants (typically in the minutes range), the availability of efficient auto-tuning procedures for closed loop temperature control takes on special importance in industrial environments.

Temperature regulation with B&R systems

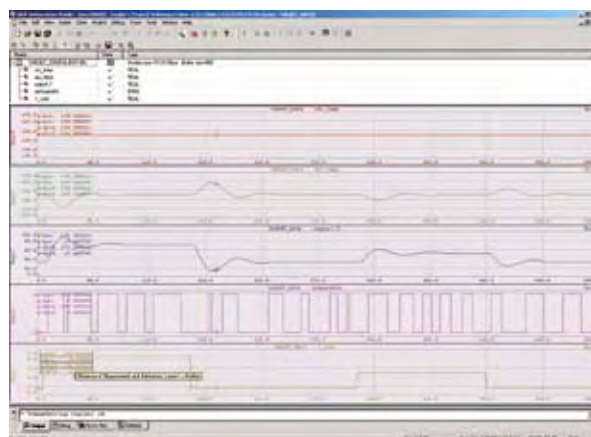
B&R temperature controllers with integrated auto-tuning procedures do not use any special hardware. Instead, they are included as a powerful software library on any B&R target system with an I/O configuration tailored to any application for temperature measurement and regulating devices.

The most important advantages of this approach when compared to using spe-

cial hardware to regulate temperature are as follows:

- Flexibility due to the modular hardware configuration
- An additional engineering tool does not need to be used.
- Communication with temperature regulating hardware does not require configuration or programming.
- Complete integration in Automation Studio (B&R's engineering tool) with powerful diagnostic features
- Cost savings

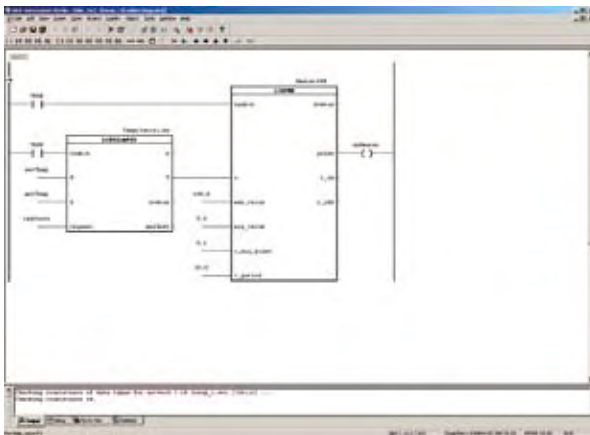
Control operations can be visualized using the trace function.



Auto-tuning

Procedures for having regulators tune themselves (auto-tuning) are extremely important on a practical level so that a simple push of a button is enough to adapt control loops to changes in production conditions such as the operating point, tools, etc.

Of special importance are auto-tuning procedures for minimizing commissioning times for temperature regulation loops since they often have high system time constants such as lag times and dead times, i.e. manually determining controller settings and the subsequent optimizations can take a great deal of time.



Programming is done using prefabricated function blocks.

B&R's auto-tuning procedures are model-based: In the first step, the plant is excited by a sequence of controller outputs; the plant's response to this is measured. Mathematical system parameters of the plant are determined by correlating the excitation and response signals. In the second step, optimized regulator settings are determined depending on the desired characteristics (disturbance rejection or tracking controller, overshoot, etc.).

Different tuning procedures such as frequency-domain closed-loop and open-loop time-domain methods are available. The tuning procedures are optimized with regard to tuning times, adapt automatically to the configured operating point, and enable synchronized tuning of several zones.

Software library with powerful function blocks

The following functionalities (among others) are implemented using function blocks in the library:

- Temperature control algorithms with integrated auto-tuning procedures for controlling one or two opposite actuators (heating and/or cooling).
- Modulation methods for controlling switching actuators (pulse width modulation and pulse frequency modulation).
- Linearization of actuators such as valves, etc.
- Simulation of thermal controlled systems

can't fall below the minimum value. This method has proven to be very effective for controlling evaporation cooling systems.

The simulation function block can be used to test the application software regardless of whether actual machines or systems are available. This significantly shortens machine and system commissioning times.

Advantages for the customer

This concept results in the following advantages for machine and system manufacturers as well as end customers:

- Increased product quality due to high control performance
- Increased machine productivity with low settling times and short tuning times
- Reduced work when creating the application software through the use of powerful function blocks
- Shorter commissioning times using efficient auto-tuning procedures
- Powerful diagnostic capabilities thanks to complete integration in Automation Studio

In the software development phase, special attention was placed on the simple operation and usability of function blocks (e.g. fewer parameters in the function block interfaces).

Pulse frequency modulation is a modulation method with a fixed pulse duration and a varying pause duration that

The Author:



"B&R's closed loop temperature control allows the user to preserve maximum flexibility, while simultaneously reducing engineering effort. The result: you save time and money."

Dr. Robert Kicking is the specialist for the areas of print media and closed loop control technology at B&R in Eggelsberg.